SUNSHINE COAST REGIONAL COUNCIL STORM TIDE MANAGEMENT

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Abstract

The former Caloundra City Council (now part of the Sunshine Coast Regional Council), in conjunction with Connell Wagner, has completed a number of storm tide studies of the Caloundra coastal area. From these studies Council has developed a comprehensive understanding of the impacts associated with a significant storm tide event. State of the art techniques including stochastic analyses and 3D hydrodynamic modelling were employed to analyse historical events, quantify the likelihood of various storm tide magnitudes and predict the hazard posed to people, infrastructure and the environment. The assessment considered the impacts of climate change in terms of weather system intensity, frequency and mean sea level rise. Results from the study were used to develop Storm Tide Emergency Management Procedures in consultation with Council's Flood Management Officers and the Local Disaster Management Group (LDMG). These procedures provide a link between the numerical predictions of the studies and practical management measures to be employed by the local authority.

Key Words: Storm tide, emergency management, climate change, mean sea level rise, Monte Carlo

Introduction

The former Caloundra City Council has recently been amalgamated with Maroochy and Noosa Shire Councils to form the Sunshine Coast Regional Council. It was the second largest municipality by area (1,107km^2) on the Sunshine Coast. The Local Growth Management Strategy for the former Caloundra City Council projects that by 2026 the region will have a population of 162,500 requiring an additional 34,750 new dwellings to accommodate the increase in population. Due to its scenic coastal location and proximity to Brisbane, Caloundra and its environs are a popular tourist location. To accommodate the swell in population over the holiday season, the coastline offers a myriad of holiday accommodation styles.

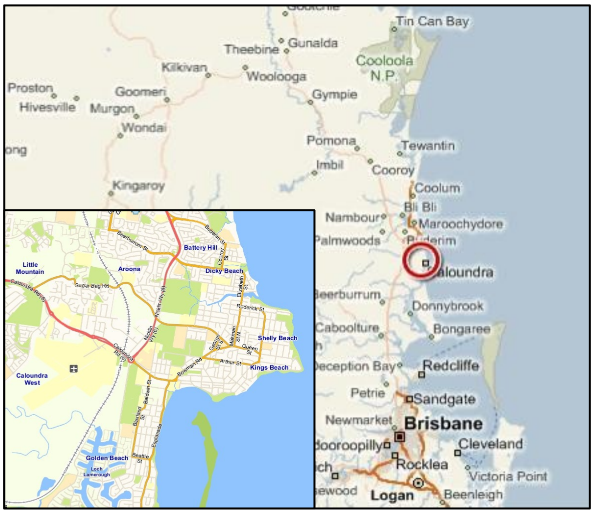

Figure 1 – Location Map

In 2003, the former Caloundra City Council commissioned a study to assess the risk of storm tide and gain an appreciation of potentially affected areas. Council required an understanding of the flood risk associated with storm tide for the purposes of development control and emergency planning, now and into the future. The study was funded through the Commonwealth and State Governments Natural Disaster Risk Management Studies Program and administered by the Department of Emergency Services. Numerical models (a wind-model, hydrodynamic model and wave-model) in addition to statistical analyses were used to derive offshore storm tide levels. The resulting “Counter Disaster Planning Report/Development Report” provided areas of inundation associated with the storm tide predictions and made recommendations to Council for planning restrictions.

A key recommendation of this study was an assessment of the joint probability of a storm tide event and freshwater flood event. Thus, the “Caloundra City Council Joint Probability Study – Storm Tide and Freshwater Flooding” was instigated. The joint probability study employed statistical methods only to analyse stream flow and tide gauge data and provide an assessment of the appropriate tide condition to apply when analysing a freshwater flood event.

Recently, the study was extended further to develop Emergency Management Procedures for the predictions from the earlier studies. Connell Wagner has worked closely with Council’s various stakeholders to provide a mapping set and associated procedures to apply in the event of the Bureau of Meteorology issuing a storm tide warning.

Figure 2 – Bribie Island (Photograph by Greg McKean)

This paper discusses the various studies undertaken, the methods employed to predict storm tide levels and the management tools Council has developed to manage storm tide now and into the future.

Storm Tide Level Predictions

Storm surges are associated with cyclonic or severe low pressure systems (east coast lows) located offshore from the study area. A change in pressure (no wind stress) over the ocean of 1 hPa leads to an increase in the local sea level of approximately 1 cm (CSIRO, 2007). As the weather system moves across the coastline the combination of extreme winds and an increase in sea level produce a surge in sea level greater than the predicted astronomical tide. The coinciding of these elements is what is known as a storm surge and in combination with normal tidal motions and wave setup produce a storm tide. The storm tide study combined statistical analyses of historic data and hydrodynamic modelling to provide an assessment of impacts due to both cyclonic and non-cyclonic storm surge on the Sunshine Coast.

An analysis of historic cyclone events was undertaken to define a number of parameters that could be used to describe a cyclone event. Each parameter was assigned a finite range of values based on the historic events. 36 “basic” storms were then described by each combination of the parameters. These basic storms were simulated using a hydrodynamic model (Delft 3D) and time series of the tide levels were extracted at the locations of interest. A Monte Carlo simulation was then used to randomly select a parameter value and simulate a large number of cyclones (over a period of 5000 years) in support of extreme event analysis. Time series of the resulting tide levels were interpolated from the basic storm dataset. For non-cyclonic events a statistical analysis of historic data combined with hydrodynamic wave modelling was used to provide predictions. Both assessments provided design storm tide level predictions at the coast.

Wave setup (the increase in water level resulting from wave activity on the shoreline) was calculated and included with tide and storm surge to provide storm tide levels. One dimensional hydraulic modelling (MIKE 11) was used to consider the inland progression of a storm tide along the major river/creek systems. This was used to assess depth and inundation of storm tides along the shoreline and inland. Recommendations for planning restrictions were presented to Council. These included:

- the adoption of the 100 year ARI storm tide level as the limit of development
- an allowance for wave runup for coastal sites
- the addition of a 0.5m freeboard to determine floor levels (to allow for uncertainty in predictions including mean sea level rise associated with Climate Change)

The inundation mapping was used to undertake a hazard assessment which considered risk to people, infrastructure and the environment. The hazard assessment considered the likelihood and consequence of a design storm tide event and categorised the hazard according to the velocity and depth of inundation predictions.

The study considered a climate change impact of 0.2m mean sea level rise over 50 years based on CSIRO research at the time. According to the predictions made in the 2003 study, this had the impact of increasing the hazard rating for most properties.

Joint Probability Assessment – Storm Tide and Freshwater Flooding

A key recommendation of the storm tide study was a joint probability assessment to consider the storm tide level that should be applied when assessing a significant freshwater flood event. The study involved a complex statistical assessment of freshwater flow records and tide gauge records.

Initially, separate assessments were made of the probability distribution of the freshwater flow and tide level gauge data. In addition, significant tide anomaly events (the increase due to storm surge) were tabulated by considering the measured tide levels and the astronomical tide cycle. The relative statistical independence of the freshwater events and the tide anomalies was demonstrated. Extreme value analysis was applied to the freshwater flow records, the derived tide anomaly and the measured peak water levels individually to obtain probability distributions for each component based on the measured data.

The next step was to consider the tide anomaly that occurred at the time of each significant freshwater flow event, that is, the "concurrent tide anomaly". Extreme value analysis was applied to this subset of tide anomaly data (or partial series) and a probability distribution obtained.

The final step was to apply a joint probability analysis to the freshwater flow annual maxima series and the concurrent tide anomaly partial series based on their individual analyses. Joint exceedance contours were derived presenting the infinite combinations of freshwater flow Average Recurrence Interval (ARI) events and tide anomalies that could together produce a combined floodplain event with a particular ARI. These contours were then related to concurrent tailwater levels rather than tide anomalies.

It is important to consider that the relationship derived was for the freshwater flow event and tide level measured at the gauge. Thus, simply knowing the likelihood of joint occurrence flow and storm tide events does not on its own answer the question of what combination of boundary conditions to use for estuarine flood modelling in order to obtain design water levels corresponding to a given risk throughout the floodplain. In order to make this assessment it was necessary to know how the freshwater and ocean boundary conditions combined to generate water levels within the estuary. Hydraulic models of the Mooloolah River, developed and run by Sinclair Knight Merz (SKM), and of the Maroochy River, developed and run by the Department of Main Roads (DMR), were used for this purpose.

Combining the results of this model with the joint probability statistics allowed design water levels within the estuary to be evaluated. These results could then be interpreted to define appropriate combined boundary conditions for a design run(s) which obtained these design water levels.

Discussion of Two Methodologies

An interesting outcome of the studies was the comparison between the water level predictions provided by the two studies. The storm surge study used numerical models (a wind-model, hydrodynamic model and wave-model) in addition to statistical analyses to derive offshore storm tide levels, with and without wave setup. The objective was an assessment of storm tide risk on coastal areas.

The joint probability study used statistical methods only to analyse tide gauge data. The objective of this study was to determine the appropriate tide boundary to apply to a freshwater study to obtain the design levels within the watercourse.

The two methods were found to agree reasonably well. The joint probability study referenced the storm tide prediction without wave setup because it was interested in the interaction between a freshwater event and storm tide event within the estuary. Generally, wave set-up does not propagate very far upstream in estuaries. It is considered that most of the wave energy dissipates in the surfzone and in the near shore zone. This is based on Professor Peter Nielsen.s research at Brunswick Heads (Dunn, 2000) and circumstantial evidence from the storm tide data gathered at the Mooloolaba Jetty. However, wave flooding (setup, run-up, overtopping) and beach erosion can have a significant impact on flood levels in the near shore and low-level areas.

The Implication of Climate Change

The science of climate change is complex with innumerable national and international climate models being developed to describe different aspects and impacts. The Queensland Climate Change Centre of Excellence website (CSIRO sourced) states the following in terms of level of confidence in projections of Queensland’s climate:

Table 1 Queensland Climate Change Centre of Excellence Projections

Level of confidence in prediction	**Prediction**
Very high	Higher temperatures and changes in extreme temperatures **Global sea level rise** Declining soil moisture
High	Direction of rainfall change (decreasing) Increasing potential evaporation (actual depends on many factors) **Increasing storm surge heights/risk along the east coast of Queensland** I**ncreasing tropical cyclone intensity** Increasing temperatures at the regional scale, including extremes

Adopting the Precautionary Principle, it is important that Local Government plans for the climate change predicted impacts despite uncertainty surrounding the predictions.

According to the “Climate Change in Australia – Technical Report” (CSIRO, 2007) global sea level rise is projected by the IPCC to be 18-59cm by 2100, with a possible additional contribution from ice sheets of 10 to 20cm. Storm surge and wave models have predicted an increase of the 100 year ARI storm tide events to be 0.45m on the Sunshine Coast with the change dominated by the sea level rise. Stochastic models have also suggested a 10% increase in tropical cyclone intensity and frequency.

The storm tide study undertaken in 2003 considered a climate change impact of 0.2m sea level rise over 50 years. This was based on CSIRO research at the time which suggested that there was no evidence that cyclone intensity is significantly worsened under enhanced greenhouse conditions. The predictions have since developed as discussed above. It is important that planners therefore consider the underlying assumptions associated with development studies in light of ongoing climate change research. In this instance, the statistical assessment used to define the design storm tide levels may require revisiting if the results are to be used to make long term future projections.

Practical Application – Emergency Management Procedures

The storm tide studies provided storm tide predictions and constraints on development control. A further objective was the translation of this technical data into practical management tools in the event of a significant storm tide warning. Connell Wagner in conjunction with Council's Flood Management Officers and the Local Disaster Management Group (LDMG), developed a mapping product to assist LDMG officers, providing potential evacuation zones for a given warning range, preferred evacuation routes, evacuation centre availability and capacity. These procedures provide a link between the numerical predictions of the studies and practical management measures to be employed by the local authority in accordance with Government guidelines and recommendations.

A key reference for the study was the National Storm Tide Mapping Model, an output of a Queensland Department of Emergency Services study undertaken in 2001. The mapping model describes the general process to be employed in producing the mapping and detail such as the mapping colours to be adopted to ensure consistency nationally. The procedures developed also needed to conform to Council's Local Plan and the Bureau of Meteorology's "Tropical Cyclone Storm Tide Warning-Response System" document. The previous storm tide study was referenced to ensure that assuming a storm tide forecast at the coast could be directly related to potential zones of inundation inland.

The initial step was to contour the ALS data into 0.5 metre bands starting from HAT to the next even 0.5 metre (Zone 1) and then increasing in 0.5 metre intervals. Figure 3a illustrates the resulting raw zones. Although these zones are in accordance with the guidelines the final mapping required further refinement to render them usable in an emergency situation. The next stage therefore involved manually rationalising the "raw" zones into refined evacuation zones (Figure 3b). The rationalisation considered:

- property elevation
- manageability of evacuation zones
- placement and capacity of evacuation centres
- access routes (low points) versus overland flow paths

It was decided by the study group that placing zone boundaries between adjacent properties was acceptable as it reduced the number of affected properties within a zone and allowed for more accurate zone representation. It is understood that the Bureau of Meteorology only issues a receding warning (a decline in the issued storm tide height) during an event. This implies that residents will not become trapped on their properties. Accordingly, zones were not required to be set by the lowest reach of an egress route.

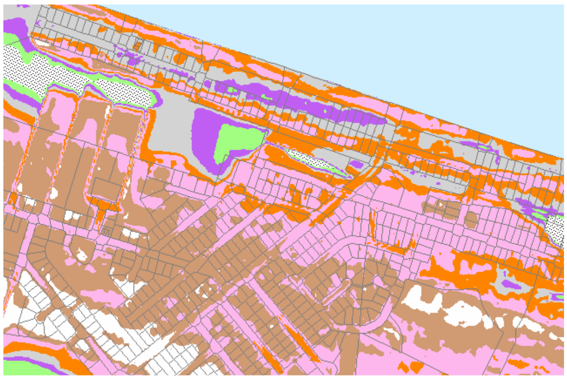

Figure 3a - Raw contour zones

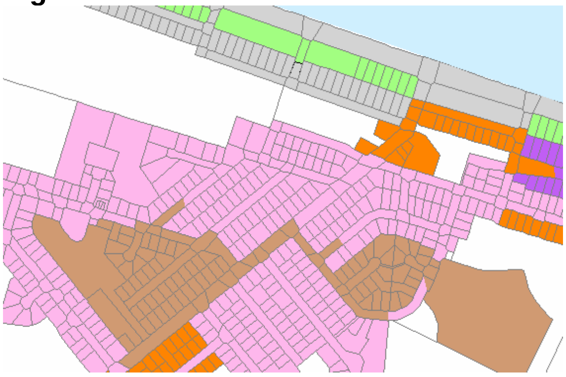

Figure 3b - Refined zones

A series of workshops were held with the Caloundra City Council and members of the Local Disaster Management Group to confirm the practicality of the zoning. In addition, suitable routes for evacuation were developed collaboratively using census data, road closure levels, evacuation centre capacities and their respective zones. The local knowledge of the collective group was vital to the success of the project. At the final workshop, the zoning was "tested" by the group by working through a "simulated" event.

To assist in understanding the magnitude of event associated with the evacuation of a particular zone, a reference to an ARI was made. In Caloundra, storm tides higher than Zone 3 represent events with a greater than 10,000 year ARI. It is important to understand however that the evacuation zones are related to the 0.5m topographic contours and not a particular ARI event.

The output of the study was:

- an emergency mapping set relating a Bureau of Meteorology storm tide warning to evacuation zones
- tabulated information based on census data to describe the number of evacuees and emergency centre capacity for each evacuation zone
- a procedural flow chart conforming to Council's emergency management reference documents providing a simplified interpretation of the steps to be followed (refer Figure 4)

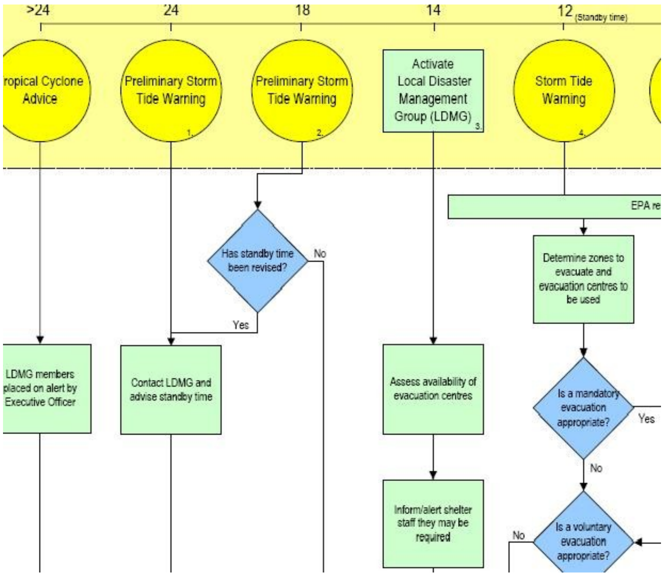

Figure 4 – Example of flow chart emergency management procedures

There are a number of studies that would further add value to the emergency management process, including:

- a traffic study to consider the evacuation routes available capacity in the event of an emergency
- a property survey to refine the occupants required to be evacuated (building type, no storeys etc)
- identification/documentation of special needs groups and their specific requirements

Conclusion

The former Caloundra City Council (now part of the Sunshine Coast Regional Council) has undertaken detailed studies of storm tide risk within the Caloundra Coastal area. The studies have provided:

- design storm tide level predictions
- mapped extents of inundation for given storm tide events
- recommendations for development control planning (including an allowance for Mean Sea Level Rise, as presented in the Caloundra City Storm Tide Study Development Report)
- recommendations for tide boundary conditions to be applied to studies of inland river/creek systems
- emergency management reference mapping and procedures in the event of a Storm Tide warning being issued by the Bureau of Meteorology

Uncertainty surrounds the science of climate change and the predictions with regard to storm tide intensity and mean sea level rise. These impacts potentially affect the design storm predictions that have been made based on statistical analyses. However, the emergency management procedures developed are independent of the probability of a storm tide event and therefore provide Council with a tool to manage the impacts into the future.

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