Modelling of combined storm-tide and riverine flooding under sea-level rise: the case of Busselton, WA

Summary

A modelling study of combined storm-tide and riverine flooding was carried out for the Busselton area of Western Australia. The results suggest that, under current conditions, the combination of riverine flooding with storm-tide inundation has little effect on inundation extent compared to storm-tide only scenarios. However, under future sea-level rise of 0.9 m or more, the combined impact becomes more evident.

Understanding the reality of flood risk now and in the future is an important first step in coastal management under sea-level rise. The importance of this study is that it explored the combined effects of both marine inundation (resulting from tropical cyclone, storm-tide, sea-level rise), and riverine flooding (resulting from upper catchment rainfall) to understand the full extent of potential flooding on local infrastructure and communities.

Keywords

Coincidence flooding, ANUGA, inundation modelling, Busselton

Background

Western Australia's (WA) coastline is particularly vulnerable to the impacts of storm-tide, mainly because of the close proximity of the urban environment to the coast and, generally, the low relief of the coastal plain. There have been numerous storm-tide events in the historical records of the region. The effects of changing climatic patterns, along with changing behaviour of cyclones and rising sea levels, may lead to increased storm-tide inundation in the future. Three government agencies — Geoscience Australia, the Western Australian Department of Planning and the Western Australian Planning Commission — partnered in a pilot project to understand the potential inundation extent from a Tropical Cyclone (TC) storm-tide event (similar to TC Alby which occurred in 1978) when the event is combined with riverine flooding. This study was conducted for the area of Busselton, using ANUGA, a hydrodynamic modelling tool developed by the Australian National University and Geoscience Australia.

TC Alby was one of the most intense cyclones on record to impact the southern reaches of the west coast of WA. There were two advantages of using TC Alby as the baseline event for this study. First, observed water levels at the Busselton Jetty could be used to validate the modelling results. Second, people could see, on the basis of their own experiences of living through a TC, that the modelled inundation aligned well with reality and this helps to build their confidence in the results from the project.

Methodology and data

The project had four major steps:

1. Input datasets such as bathymetry, topography elevation and river hydrographs were collected for the study area. Figure 1 shows the major rivers and locations of hydrographs in the study area.
2. A storm-tide model for TC Alby was developed using the two-dimensional storm modelling platform GCOM2D, which simulated the actual and worst case scenario (where the storm track and timing were changed to direct maximum winds over Busselton with a coincident spring tide). Then a storm-tide model was developed and calibrated by comparing the modelling results to the Busselton Jetty tide gauge observations during TC Alby.
3. The outputs from the storm-tide model were used to determine the maximum inundation extents (including depths and momentum) reached during the simulations. Riverine flood was modelled using the hydrographs for the rivers and drains of interest (Figure 1). Once both storm-tide and riverine flood models were found to be performing satisfactorily, the timing of the riverine flooding was altered so that it coincided with the storm-tide.
4. Finally the models were run to investigate the impact of various climate change scenarios.

Inundation extents were investigated for eleven separate cases as shown in Table 1. The base case was TC Alby alone, without any riverine flood (the case which was used to calibrate and validate the models). Then, a series of progressively more severe events were modelled: coincident timing of TC Alby and spring tide, followed by riverine flooding of different Annual Recurrence Intervals (ARI), and finally three sea-level rise scenarios: 0.4 m, 0.9 m and 1.1 m.

Results

In total, eleven scenarios were modelled over the Busselton to Dunsborough region (Table 1 and Figure 2). A significant increase in inundation extent was found in the case (B1) where the actual TC Alby track was changed in the model to pass directly over Busselton and to coincide with spring tide. This highlights the importance of storm trajectory and tidal condition.

As expected, inundation extents increased as sea levels increased. In these cases, inundated areas such as Busselton Jetty experience higher water velocities and therefore an increase in the destructive potential of the storm event.

Interestingly, under current sea levels, the combination of riverine flooding with storm-tide inundation was found to have relatively little impact on inundation extent as compared to the equivalent storm-tide only scenarios (e.g. B5 vs. B1 scenarios). This is mainly because the effects of coincident riverine flood are largely confined to an increase in the water levels within the estuaries. However, additional inundation occurs when the Vasse Diversion Drain spills over. Therefore, the study concluded that in the event of coincident storm-tide, sea-level rise and riverine flooding, the effect of the riverine flooding will be greatly reduced if overtopping of the Vasse Diversion Drain can be prevented above the Busselton Bypass.

Limitations of this study

The results are based on several regional-scale models (hydrodynamic and data models) and therefore the results apply only at the regional scale. Due to sea floor (bathymetric) and land surface (topographic) changes since 1978, direct model validation was not possible. However, the regional storm model (GCOM2D) results showed a good match to the Busselton Jetty tide-gauge recordings of the TC Alby storm-tide water levels (Figure 3).

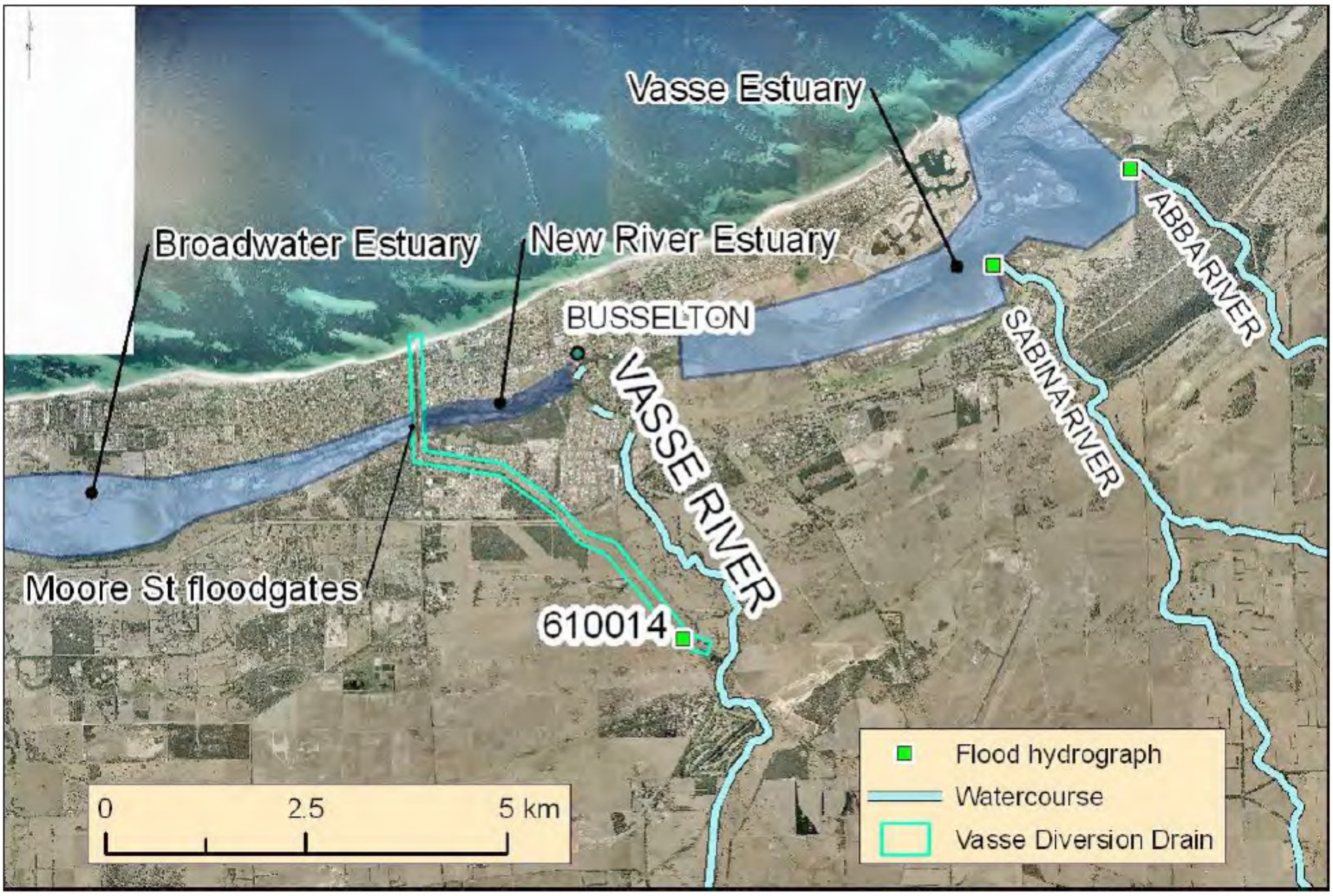

Figure 1: Location of the Busselton Hydrographs and water courses. Source: © Geoscience Australia.

Table 1: Storm-tide and flood modelling scenarios. Source: © Geoscience Australia.

ID	Type	Sea-Level	Riverine Flood
B0	Base Case (Validation against TC Alby)	Current	None
B1	Worst Case (TC Alby, track and time shift)	Current	None
B2	Worst Case + SLR	+ 0.4 m	None
B3	Worst Case + SLR	+ 0.9 m	None
B4	Worst Case + SLR	+ 1.1 m	None
B5	Worst Case + Coincident Flooding	Current	25 year ARI
B6	Worst Case + Coincident Flooding	Current	100 year ARI
B7	Worst Case + Coincident Flooding + SLR	+ 0.9 m	25 year ARI
B8	Worst Case + Coincident Flooding + SLR	+ 0.4 m	100 year ARI
B9	Worst Case + Coincident Flooding + SLR	+ 0.9 m	100 year ARI
B10	Worst Case + Coincident Flooding + SLR	+ 1.1 m	100 year ARI

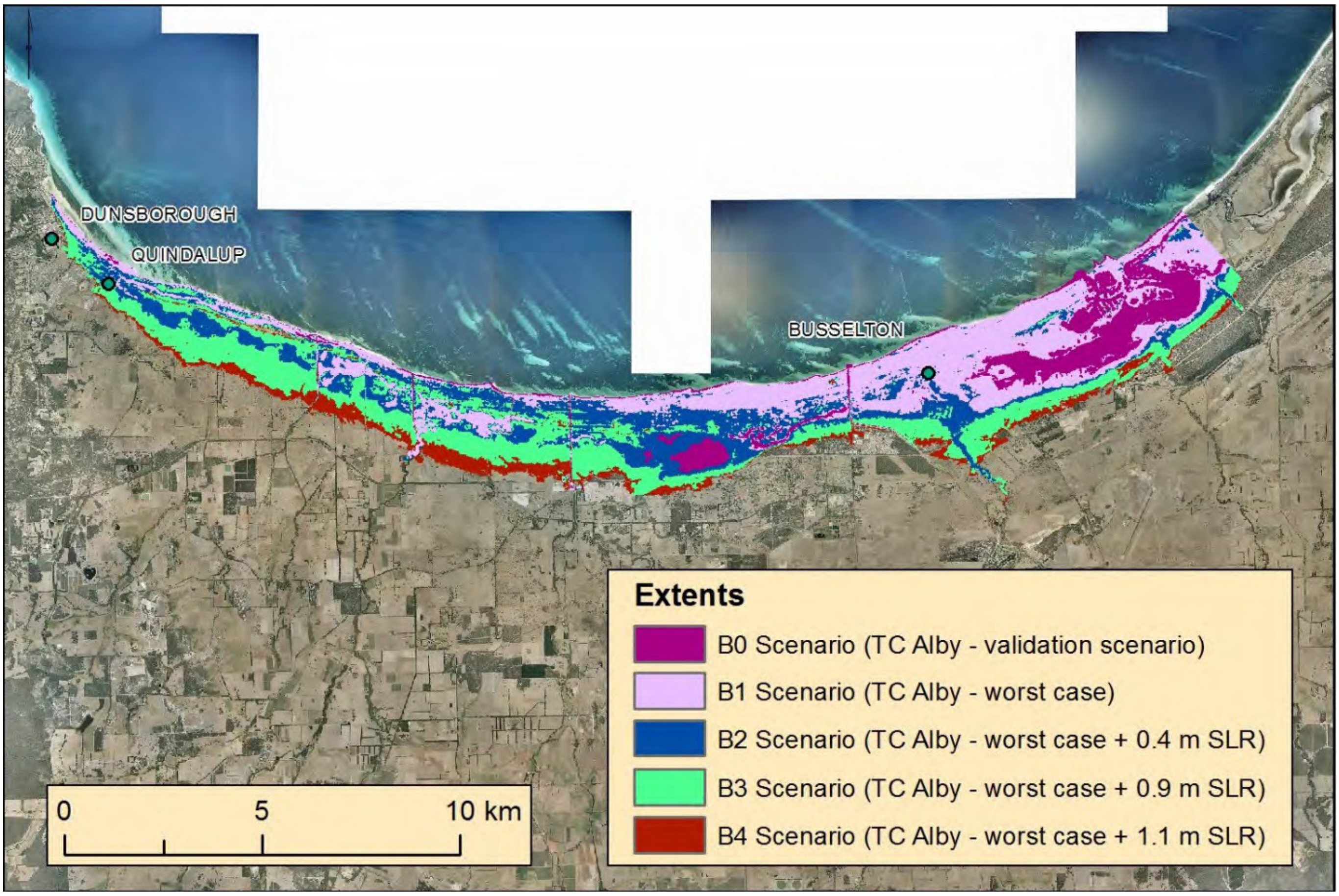

Figure 2: *Inundation extents under different cases. Validation (B0), TC Alby worst case (B1) and worst case plus sea-level rise (B2 to B4) scenario inundation extents. Source: © Geoscience Australia.*

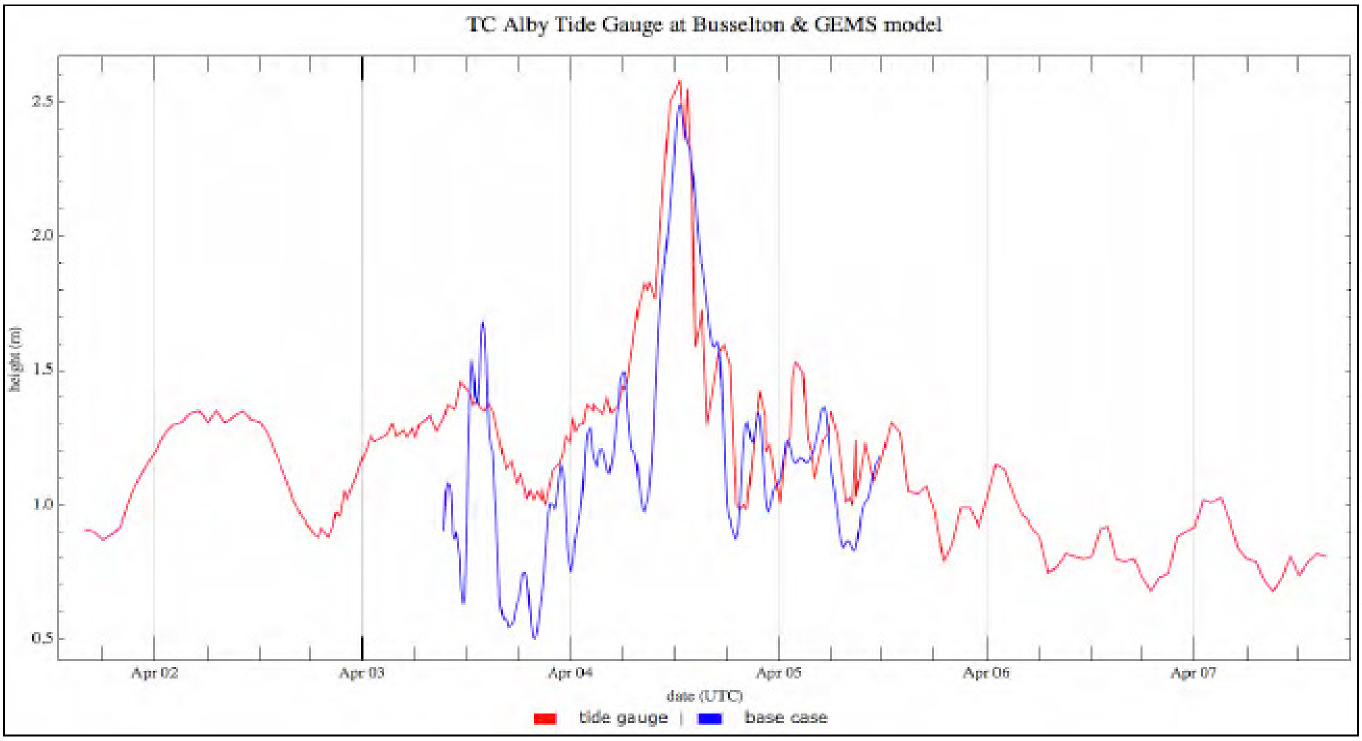

Figure 3: *TC Alby observations at the Busselton Jetty and the GEMS modelling results. Source: © Geoscience Australia.*

Further reading

Martin, S., D. Moore, and M. Hazelwood, 2014: Coastal inundation modelling for Busselton, Western Australia, under current and future climate. Record 2014/03. Geoscience Australia: Canberra. Accessed 15 June 2017. [Available online at: https://www.planning.wa.gov.au/dop_pub_pdf/busselton_inundation_reduced.pdf].

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