Natural Hazard Risk in Perth, Western Australia

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Geoscience Australia

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Cities Project Perth

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ABBREVIATIONS AND ACRONYMS

ABS	Australian Bureau of Statistics
ACRES	Australian Centre for Remote Sensing
AEP	annual exceedance probability
AHD	Australian height datum
ARI	average recurrence interval
AWS	automatic weather stations
BOM	Bureau of Meteorology
BTE	Bureau of Transport Economics
CD	census district
CDF	cumulative distribution function
COAG	Council of Australian Governments
DEM	digital elevation model
DLI	Department of Land Information
DCLM	Department of Conservation and Land Management
DMAP	Disaster Mitigation Australia Package
DPI	Department for Planning and Infrastructure (WA)
EMA	Emergency Management Australia
FCB	functional classification of buildings
FDI	fire danger index
FESA	Fire and Emergency Services Authority (WA)
GA	Geoscience Australia
GIS	geographic information system
GSS	General Social Survey
HAT	highest astronomical tide
HEC-RAS	Hydraulic Engineering Center – river analysis system (US Army Corps of Engineers)
IDRO	Insurance Disaster Response Organisation
IFD	intensity–frequency–duration (rainfall curves)
IOCI	Indian Ocean climate initiative
IPCC	Intergovernmental Panel on Climate Change
LAT	lowest astronomical tide
LGA	local government areas
MSLP	mean sea level pressure
PMF	probable maximum flood
PMP	probable maximum precipitation
PML	probable maximum loss
POT	peaks over threshold
SCPT	seismic cone penetrometer test
SEIFA	Socioeconomic Index For Areas (ABS)
SEMC	State Emergency Management Committee (WA)
SLIP	Shared Land Information Platform
SLWS	severe local wind storms
SWSZ	southwest seismic zone
TIN	triangulated irregular network
UTM	Universal Transverse Mercator
WALIS	Western Australian Land Information System
WAPC	Western Australian Planning Commission
WMO	World Meteorological Organization
WRC	Water and Rivers Commission (WA), now part of the Department of the Environment

EXECUTIVE SUMMARY

Cities Project Perth is a natural hazard risk assessment study of a major Australian capital city by Geoscience Australia (GA) and its Federal, State and Local collaborators. Cities Project Perth has produced authoritative knowledge on the risks from sudden-onset natural hazards in Australia's fourth largest city and the capital of the state of Western Australia (WA).

Cities Project Perth is the most recent multi-hazard risk assessment undertaken by GA and collaborating agencies (notably the Bureau of Meteorology (BOM) and local governments), following earlier studies of the Queensland cities of Cairns (Granger et al., 1999), Mackay (Middelmann and Granger, editors, 2000), Gladstone (Granger and Michael-Leiba, editors, 2001) and South-East Queensland (Granger and Hayne, editors, 2001). GA also published the single-hazard report *Earthquake Risk in Newcastle and Lake Macquarie*, New South Wales (Dhu and Jones, editors, 2002).

This study is aimed at estimating the impact on the Perth community of several sudden-onset natural hazards. The natural hazards considered are both meteorological and terrestrial in origin. The hazards investigated most comprehensively are riverine floods in the Swan and Canning Rivers, severe winds in metropolitan Perth, and earthquakes in the Perth region. Some socio-economic factors affecting the capacity of the citizens of Perth to recover from natural disaster events have been analysed and the WA data compared with data from other Australian states. Additionally, new estimates of earthquake hazard have been made in a zone of radius around 200 km from Perth, extending east into the central Wheatbelt. The susceptibility of the southwest WA coastline to sea level rise from climate change has also been investigated. A commentary on the tsunami risk to WA coastline communities is also included.

This report aims to improve our understanding of the future costs to Perth for earthquakes through direct calculation of earthquake risk. The report also provides estimates of hazard for floods and severe winds that, with additional work on loss estimation, would provide quantitative information on the costs of these two hazards also.

Such new information on natural hazard risk to Perth provides input into the decision making processes by WA and local government community, planning and emergency management agencies with regard to setting priorities in:

- prevention, planning response and recovery (PPRR);
- risk management of the natural hazards against each other, for example floods against severe winds;
- applying resources in the most cost effective way in Perth to reduce the impacts of natural hazards, prioritised against other parts of WA; and
- applying resources to risk management of natural hazards, against applying resources to other 'all hazard' events that affect communities.

The key findings and recommendations are summarised below.

Severe wind hazard

- The severe wind hazard calculated in this report for Perth Airport is in close agreement with the wind hazard for Perth in the Australian wind loadings standard (Standards Australia, 2002). The standard places Perth in Region A, the lowest hazard region of four in Australia. However, the historical record from the automatic weather station (AWS) at Perth Airport was the sole dataset used in calculations for the wind loadings standard. This airport is some 20 km inland. Winds from the western quadrant, the strongest in Perth, are reduced in intensity in

their path from the coast inland, and return period wind speeds in the standard are most applicable to Perth sites some kilometres inland.

- In this report, the data from eight stations in the Perth region were used, along with spatial modelling of the effects of topography, terrain roughness and shielding on the incoming winds, thus producing a much more comprehensive and broad-based knowledge of wind hazard across the metropolitan area. Our statistical analysis of the AWS data, the model of decrease in wind speed from the coast, and the modelling of terrain, shielding and topographic factors across Perth have revealed a richness in wind hazard across Perth.
- Across metropolitan Perth, severe wind hazard varies considerably. Localised areas of Perth with measurably higher hazard than the wind loadings standard lie:
  - in a band several kilometres wide along the coastline, with a near-shore coastal strip a few hundred metres wide having the greatest hazard;
  - in a north–south band several kilometres wide running along the top of the Darling Scarp; and
  - on exposed shores of the lower reaches of the Swan River, extending inland approximately as far as the Kwinana Freeway.
- The reader needs to be aware that variability in wind speed, wind turbulence, incoming wind direction, and the ability of the models themselves to describe accurately the physical characteristics of the wind, all add variability to the wind hazard at any place and for any particular wind event. The variability in the behaviour of buildings and other structures, due to variability in construction strength and orientation to the wind, will also add variability to damage for any specific event.

Recommendations

Use the wind hazard maps:

- **to review, improve and complement the design and construction guidelines for severe winds set by state and local governments;**
- **as a source of information for response planning and response;**
- **as a basis for further research on severe wind risk in Perth; and**
- **as an aid to bushfire risk assessment at the Perth urban/rural interface.**

Use the wind hazard multipliers for topography, terrain roughness and shielding:

- **to review, improve and complement the design and construction guidelines for severe winds set by state and local governments;**
- **as a reference for design engineers and the construction industry;**
- **as a basis for further research on severe wind risk in Perth; and**
- **as an aid to bushfire risk assessment at the Perth urban/rural interface.**

Flood hazard

The key results follow.

- There are six major catchments in the study area that contribute flow to the Swan River, of which the Avon catchment is by far the largest. Not surprisingly, the hydrologic estimation of flows showed that the Avon River was by far the most dominant flow contributor to the Swan River. Simulations showed that another significant source of flow is from the tributaries, particularly the Canning and Southern Rivers.
- The season of the tidal cycle was found to influence flood flows marginally, with water levels slightly higher in winter. As expected, the variation in water levels decreased with distance upstream from the Port of Fremantle.
- Eight flood scenarios were modelled for the Swan River and its tributaries ranging from AEPs of 10% to 0.05% (return periods of approximately 10 years to 2,000 years). Previously, only

the 1% AEP scenario had been mapped using a less complex steady flow model. The new model provides emergency managers and planners with important new hazard information for scenarios with a large range of return periods. The unsteady flow model and the stream levels predicted by the modelled events are now held by government agencies in WA, including the DOE and BOM.

- Perth has experienced a lengthy dry period in the past 40 years. Only two major flows have occurred, in 1983 and 1987, since all the streamflow gauging stations at the outer boundaries of the model became operational. Therefore, when more data become available, the unsteady flow model should be recalibrated as far as possible.
- Water levels in this study were found to be lower than those modelled previously for the 1% AEP flood event. The variation in water levels can be explained by the differing methodology of this model and the earlier DOE model. The model differences are best explained by the inclusion of the tributaries, followed by the use of an unsteady flow model rather than a steady flow model, in the Cities Project Perth model. The current lack of data has resulted in the model results being inconclusive and, therefore, the availability of the new model, on its own, does not warrant a complete replacement of current procedures on 1% floodplain mapping. This report provides recommendations that will help reconcile the two models and reduce uncertainties in flood hazard estimates.

Recommendations

- **Further data are acquired and applied to refine, revise and recalibrate the unsteady flow model for flooding in the Swan and Canning Rivers.**
- **Systematic data are collected during future major flood events.**
- **The model for river flooding in the Swan and Canning Rivers is reviewed after each major event.**
- **Until adequate data are available to further refine and calibrate the unsteady flow model, the Department of Environment's 1% AEP floodplain mapping should continue to be used as the basis for ensuring that future development has adequate flood protection.**

Earthquake risk

The earthquake risk to Perth discussed in Chapter 5 can be summarised by the following results.

- Overall, the estimates of earthquake hazard on rock foundation in Perth and in southwest WA are similar to those in the current and draft Australian earthquake loading standards. These results have come from a comprehensive update of the earthquake hazard in Perth and in southwest WA. The reader is referred to Chapter 5 for a comparison of the earthquake hazard calculated in this report and the hazard described in the current and draft earthquake loadings standards.
- The earthquake risk to Perth has been aggregated across the metropolitan area and illustrated by a risk curve or probable maximum loss (PML) curve in Chapter 5. Loss is expressed as a percentage of the total value of all buildings and their contents in the study region.
- The results of this study suggest that, on average, greater metropolitan Perth will suffer an estimated economic loss of around 0.04% per year.
- About three-quarters of the earthquake risk in the study region is from events that have annual probabilities of occurrence of 0.004 or less (return periods of 250 years or more). This suggests that about three-quarters of the risk to metropolitan Perth is from rare events with major or, in extreme cases, catastrophic impacts. The long-term nature of earthquake risk to Perth and regional communities to the east indicates that the risk is likely to be realised very rarely. These earthquake events will have relatively high consequences. This provides a motivational challenge for emergency managers to remain vigilant and for appropriate risk treatments such as adequate insurance to remain in place.

- The earthquake risk to Perth varies spatially across the study region. A gradual reduction in risk occurs across metropolitan Perth in a southwesterly direction as distance from the southwest seismic zone (SWSZ) increases. The effect of the higher earthquake hazard in the Wheatbelt region can thereby be discerned.
- Most of the annualised risk for building usage type is for the residential types (almost 90%) with the next most common being commercial. This is mainly because residential buildings make up the overwhelming majority of buildings in the study area, and comprise the majority of the total estimated value of all buildings in the study area.
- The unique capital city profile of Perth has also influenced the results in that the residential building stock is predominantly unreinforced double brick construction with a much smaller proportion of framed timber construction. Unreinforced masonry is significantly more vulnerable than framed timber construction.
- The locations of earthquakes that create most of the risk to metropolitan Perth show a split distribution. About half of the earthquake risk in metropolitan Perth is due to moderate to strong earthquakes (magnitudes in the range about 5 to 6.5) that could occur with epicentres at distances of less than 30 km from Perth. Estimates of earthquake risk in Perth are sensitive to model assumptions of the rate of occurrence of earthquakes for these close-in earthquakes, because historic seismicity has been low in and around Perth.

  The second significant contribution to earthquake risk in Perth comes from large earthquakes that could occur at the western margin of the SWSZ (60–90 km from Perth), where the earthquake activity is higher than it is in Perth.
- The area of elevated hazard in the Wheatbelt is considerably more extensive than identified in the current earthquake loadings standard. This area is wider in an east-west direction, extends further northward and is generally located closer to Perth.

Recommendations

Use the earthquake hazard maps for metropolitan Perth and the Perth region:
- **to review, improve and complement the design and construction guidelines for earthquakes set by state and local governments;**
- **as a source of information for response planning and response.**

Enforce the compliance with current earthquake loading standards for all new structures.

Promote the importance of adequate insurance against earthquakes for householders, small business operators and corporations.

Protect facilities such as police, SES, fire and ambulance stations and hospitals, which provide essential services following any earthquake event. These facilities could be examined by suitably qualified engineers on a site-by-site basis to assess their performance under earthquake loadings. This recommendation is pertinent for SWSZ communities.

Indicators of social resilience for recovery

The indicators ‘household financial capacity’, ‘community and social networks’ and ‘distance to services’, explored in Chapter 6, show that Perth households and the broader community have many characteristics that will favourably influence the recovery process following a natural hazard event. However, these indicators are only three of many influencing recovery.

- The majority of households in metropolitan Perth have good economic resources, relative to the rest of Australia. Twenty-nine of 30 Local Government Areas (LGA) in the Perth Statistical Division rank in the top 50% of Australian LGAs in the ABS Index for Economic Resources (ABS, 2004a). Of these 29 LGAs, 22 rank in the top 25% nationally. Therefore, in the event of any natural disaster that has direct and widespread effects on residences, the community has

many households that can draw on their economic resources to assist their recovery. However, it must be noted that there are some areas, or clusters, of households within suburbs that may experience difficulties in the recovery process due to limited financial capacity.

- The strong community network in WA is indicated by results from the General Social Survey (GSS) (ABS, 2004b). This strong network suggests that, for many in Perth, recovery may involve a strong utilisation of friends, family, neighbours and informal organisations, such as community groups or sporting clubs. Almost all WA participants in the GSS indicated that they could ask someone outside of their home for assistance in times of need, including a health, legal or financial professional, charity or religious organisation. This information may assist recovery managers in tailoring programs and services for people in the Perth community.
- People in some outer suburban areas may have further to travel to access major services than those living more centrally. These major services, whether they are medical, welfare, social or cultural, can be important factors in influencing the recovery of these outer communities. This information may assist recovery managers in understanding some access/transport issues for people living in this part of the Perth metropolitan community.

Recommendations

We recommend that relevant WA government agencies and local governments participate in national research in social vulnerability models as they apply to all sudden-onset hazards.

Potential impact on the southwest WA coast from sea level rise due to climate change

Key findings follow.

- It is highly likely that coastal erosion will have a significant impact on coasts around the globe, including Australian coasts, over the next century.
- Three sections of the Fremantle to Hillarys coastline appear to be susceptible to coastal erosion: Port/South Beach; Swanbourne to Floreat Beach; and the Pinaroo Point area. The hazard decreases from south to north, primarily due to the northward net longshore drift.
- Given a sea level rise of 18 cm over the next 50 years, and 48 cm over the next 100 years, Swanbourne beach is likely to erode approximately 40–50 m and 100–130 m respectively.
- The impact of modelled recession at Swanbourne Beach is not significant due to a lack of overlying infrastructure. Similar erosion at the other vulnerable localities would have a much greater impact.
- The majority of the Mandurah to Fremantle coastline does not appear to be susceptible to coastal erosion over the next century, despite the fact that the Tamala Limestone is preserved below sea level across the majority of the area. This is due to the fact that this sector has been the primary depositional province for the Swan coast over the last 8,000 years.
- The Bunbury to Mandurah coastline is the section of Swan coast that appears to be most susceptible to coastal erosion over the next century. This is because the Tamala Limestone is preserved below sea level, this sector is not well sheltered from offshore swell, and this location is at the southern end of the net northward littoral conveyor that operates along the Swan Coast.
- The Hillarys to Yanchep coastline does not appear to be susceptible to erosion over the next century as Tamala Limestone is preserved above sea level along the majority of the coast, and the beaches are well sheltered by three lines of offshore reefs.
- The Cape Naturaliste to Bunbury area may be impacted by coastal erosion associated with long-term sea level rise. With increasing development of coastal urban infrastructure, this sector is an important focus for quantitative coastal erosion modelling in southern Western Australia.

Recommendations

To improve decision making and reduce uncertainties about the potential for future coastal erosion due to sea level rise:

- **Undertake a Bruun Rule calculation as a preliminary methodology in planning for coastal recession due to sea level rise.**
- **Focus future research on the Bunbury to Mandurah coastline, the Cape Naturaliste to Bunbury coastline, and the Port/South beach area of Fremantle.**
- **Improve data availability, particularly sector specific wave data and more detailed subsurface data.**
- **Improve the sophistication of current models to allow for calculation in areas where the nearshore/offshore includes competent substrate.**

Bushfire risk assessment

- Historic records indicate that bushfires have caused major impacts in southwest WA. Climate change may also modify the frequency and intensity of these events in future decades. A bushfire threat analysis is currently being undertaken by government agencies such as FESA and the WA Department of Conservation and Land Management. Bushfire risk at the Perth urban/rural interface could be compared more systematically with other natural hazard risks assessed in Cities Project Perth if similar methods and measurables are developed across all of the risk assessments.

Recommendations

Align the bushfire threat analysis currently being undertaken by WA government agencies with the hazard, exposure, vulnerability and loss assessment methodologies and databases of Cities Project Perth in order to develop a systematic and consistent set of information on the risks from the major sudden-onset natural hazards in Perth.

Spatial databases and risk assessment models

- More than a dozen major spatial databases and risk assessment models, including the flood hazard model and comprehensive building and building footprint databases, digital elevation models and GIS hazard maps, were developed in Cities Project Perth. The Western Australian Land Information System (WALIS) and the Department of Land Information (DLI) have played leading coordination roles in ensuring that the Cities Project Perth databases will be added to, maintained and made available by the appropriate WA Government agencies. These databases will be reviewed for possible inclusion in the WA Shared Land Information Platform (SLIP).

Recommendations

WALIS and DLI have played leading coordination roles in ensuring that the Cities Project Perth databases will be added to, maintained and made available by the appropriate WA government agencies. These databases will be reviewed for possible inclusion in the WA Shared Land Information Platform (SLIP).

Where to from here?

In this chapter we have suggested risk management options that could reduce natural hazard risks in Perth based on the results of the research in Cities Project Perth. Most of the suggested options are aimed at the key public and private sector agencies who are responsible for emergency management, land use planning and information management in WA. Some of these risk management options include recommendations for additional research and additional data gathering.

It is now largely the task of the WA partners in Cities Project Perth, and the people and organisations with whom they work, to implement decisions based on the new information made available.

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