CHAPTER **THREE** - SUSCEPTIBILITY OF THE BUILT ENVIRONMENT

Two hundred years of European settlement has established infrastructure which has coped with climate extremes. Plenty of life remains in major infrastructure such as the Snowy Hydro Scheme (construction began 1949), the Eildon Weir (1951), the West Gate Bridge (1968) and the Thompson Dam (1976).

However, much of our social and economic activity now depends on infrastructure which was built for a climate that will be subject to significant change. Current construction must respond to present and future needs, and present and future climate conditions.

If the Eureka Tower in Melbourne lasts as long as the Royal Exhibition Building (1880) has already, it will have to deal with the climate of the year 2144. Major infrastructure decisions will need to take into account future climate, even as we struggle to understand exactly what that climate will be at the end of its life. Future uncertainty can be addressed by deliberately shortening time horizons - building something to last for a shorter length of time, knowing it can be replaced relatively easily in the future. However, this is not always an efficient option. Another option might be to plan and build infrastructure which can be easily retrofitted as conditions change, as this could provide efficiencies.

All our cities, and all our rural infrastructure networks, are challenged by climate change eventualities.

If the Eureka Tower in Melbourne lasts as long as the Royal Exhibition Building (1880) has already, it will have to deal with the climate of the year 2144.

Extreme events that impact on our built environment are a part of life in Victoria. Such events have always happened, and always will. What is at issue is the increased intensity of these events as the climate changes.

3.1 Extreme weather events and our infrastructure

Direct Impacts

On the night of 13 January 2011, residents of Halls Gap were warned that they might be cut off by rising flood waters.[99] Almost 300 mm of rain hit the town in the space of three days,[100] triggering widespread landslides through the world-famous Grampians National Park. Kilometres of road and many vehicle and pedestrian bridges were laid to waste.[101] Major rainstorms in the area sparked a trail of devastation across much of the north-west of the state (see Chapter Four).

Severe rainstorms also cause havoc in cities.

In Melbourne on 6 March 2010, roofs collapsed, houses were flooded, trains failed to run, and 100,000 houses in the city lost power. The insurance bill was calculated to be over $1 billion – essentially the same as the Black Saturday bushfires.[102] All this was caused by 26 mm of rain and hail falling in less than an hour.[103]

An event of this intensity is considered a one-in-ten-year storm – put another way, it has a 10% chance of occurring every year. A similar storm occurred in Melbourne in February 2011 and resulted in insurance claims of $384 million.

Storm-induced erosion and king tides are already causing damage to our built environment. The Seaspray Surf Life Saving Club in West Gippsland is built on coastal dunes and, following storms in 2007, is being relocated to prevent it from toppling into the ocean.[104] In Fairhaven on the Surf Coast, a beach access ramp has been destroyed. It is suggested this is a harbinger of worse things to come.

Heatwaves, another extreme weather event, cause extensive damage to physical infrastructure. In late January 2009, temperatures spiked over 43 degrees on three consecutive days in Melbourne. Across the other side of the continent, Perth has undergone eight heatwave events since November 2011 (BoM) and that city experienced a record of consecutive days in excess of 30 degrees in the summer of 2010/11.

The strain on the electricity system in Melbourne in 2009 due to the record demand for cooling was exacerbated by a heat-related explosion that crippled two 500 kV power lines just north of Melbourne at South Morang. Power was cut for several hours to over 500,000 people, equivalent to 10% of the state. At the same time, across the state, train tracks were buckling and roads were melting.

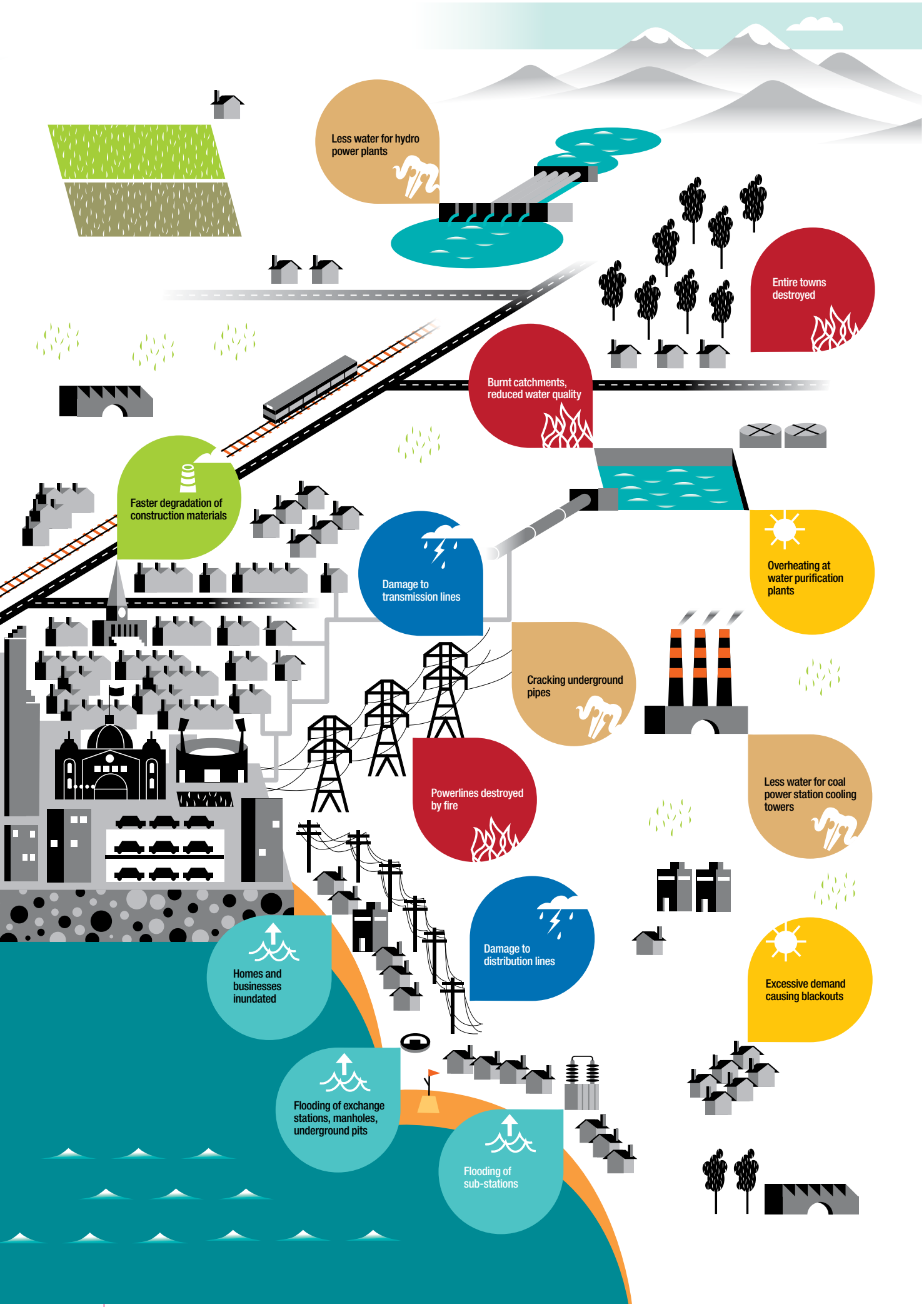
Extreme events that impact on our built environment are a part of life in Victoria. Such events have always happened, and always will. What is at issue is the increased intensity of these events as the climate changes.

Beyond the extreme weather events we are also told to expect gradual changes, such as sea-level rise, rising temperatures and elevating CO_2 levels - beyond IPCC projections - bringing a range of new threats (Figure 22).

As a community, we will have to develop new ways of thinking about managing our urban environments and service infrastructure. Such challenges require serious consideration in all sectors of government, business and society generally. Our thinking and action will need to be collaborative and constructive.

Such challenges require serious consideration in all sectors of government, business and society generally.

Figure 22:
Direct impacts of climate change on infrastructure.[105]
CfES developed infographic.

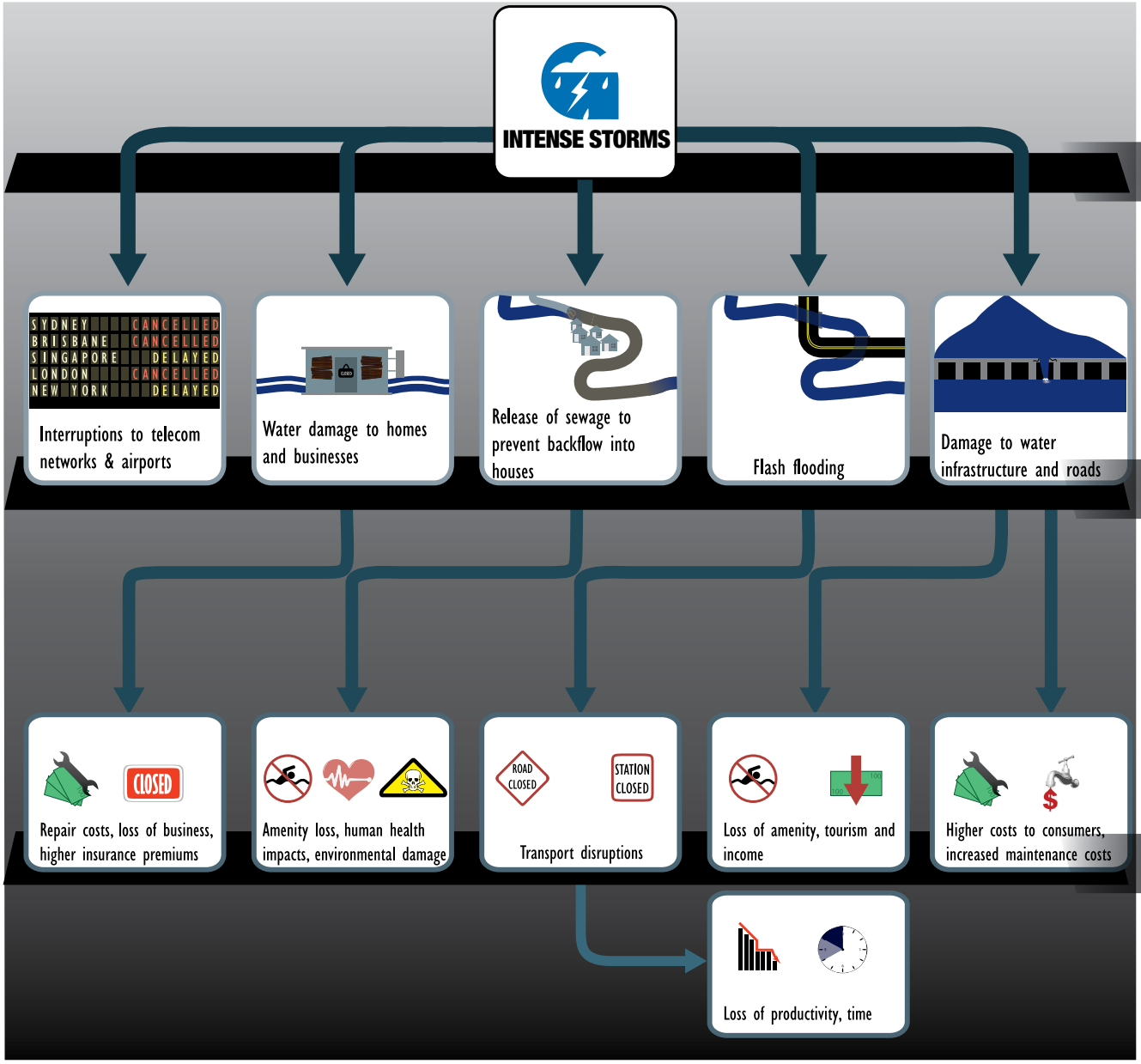

Less water for hydro power plants
Entire towns destroyed
Burnt catchments, reduced water quality
Faster degradation of construction materials
Damage to transmission lines
Overheating at water purification plants
Cracking underground pipes
Powerlines destroyed by fire
Less water for coal power station cooling towers
Damage to distribution lines
Excessive demand causing blackouts
Homes and businesses inundated
Flooding of exchange stations, manholes, underground pits
Flooding of sub-stations

It is not just the owner of the buckled train line who bears a cost; so will the stranded commuters.

Cascading impacts

Disruptions of the kind described above will have socio-economic impacts that affect many more people than just those who own damaged property (Figures 23A-C). It is not just the owner of the buckled train line who bears a cost; so will the stranded commuters. When heavy rain damages drainage infrastructure and causes flooding over roads, businesses are affected by disrupted logistics and supply chains, especially when relying on "just-in-time" delivery of goods.[106] This is because our society has evolved with a dependence on the *function* of the built environment and its service infrastructure.

Figure 23_A: **Cascading Impacts.** CfES developed infographic.[108]



Critical infrastructure functions are increasingly inter-dependent, as well as being intimately linked to our social and economic structures.[107] Assessment of the economic damage of these cascading impacts is imprecise. The imprecision of financial evaluation does not diminish the cascading impacts and their importance.

Figure 23_B: **Cascading Impacts.** CfES developed infographic.[108]

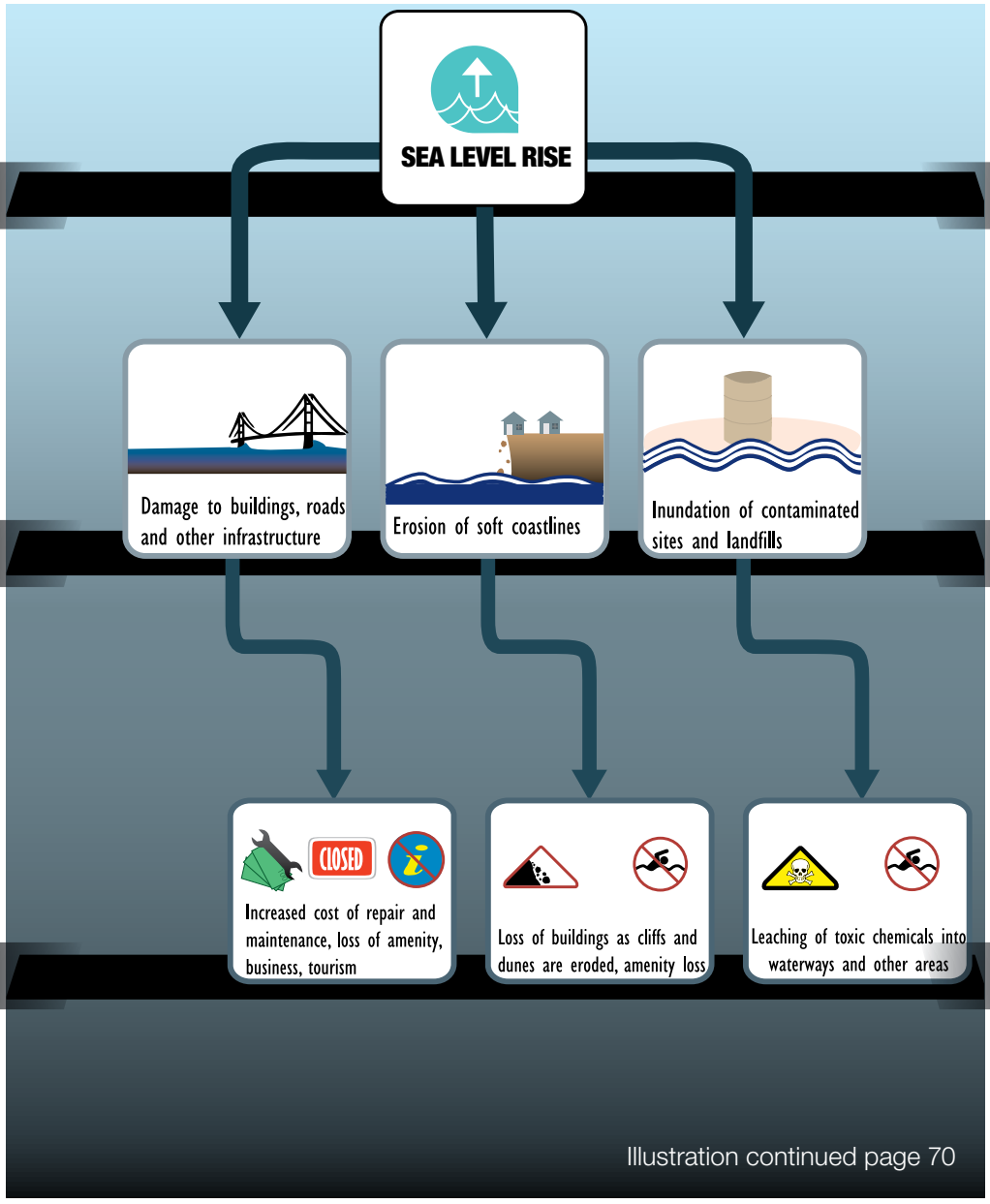


Illustration continued page 70

Costs of disruption of infrastructure by extreme heat[109]	
16 January 2007	$501 million
29-30 January 2009	$800 million

Figure 23_C: **Cascading Impacts.** CfES developed infographic.[108]

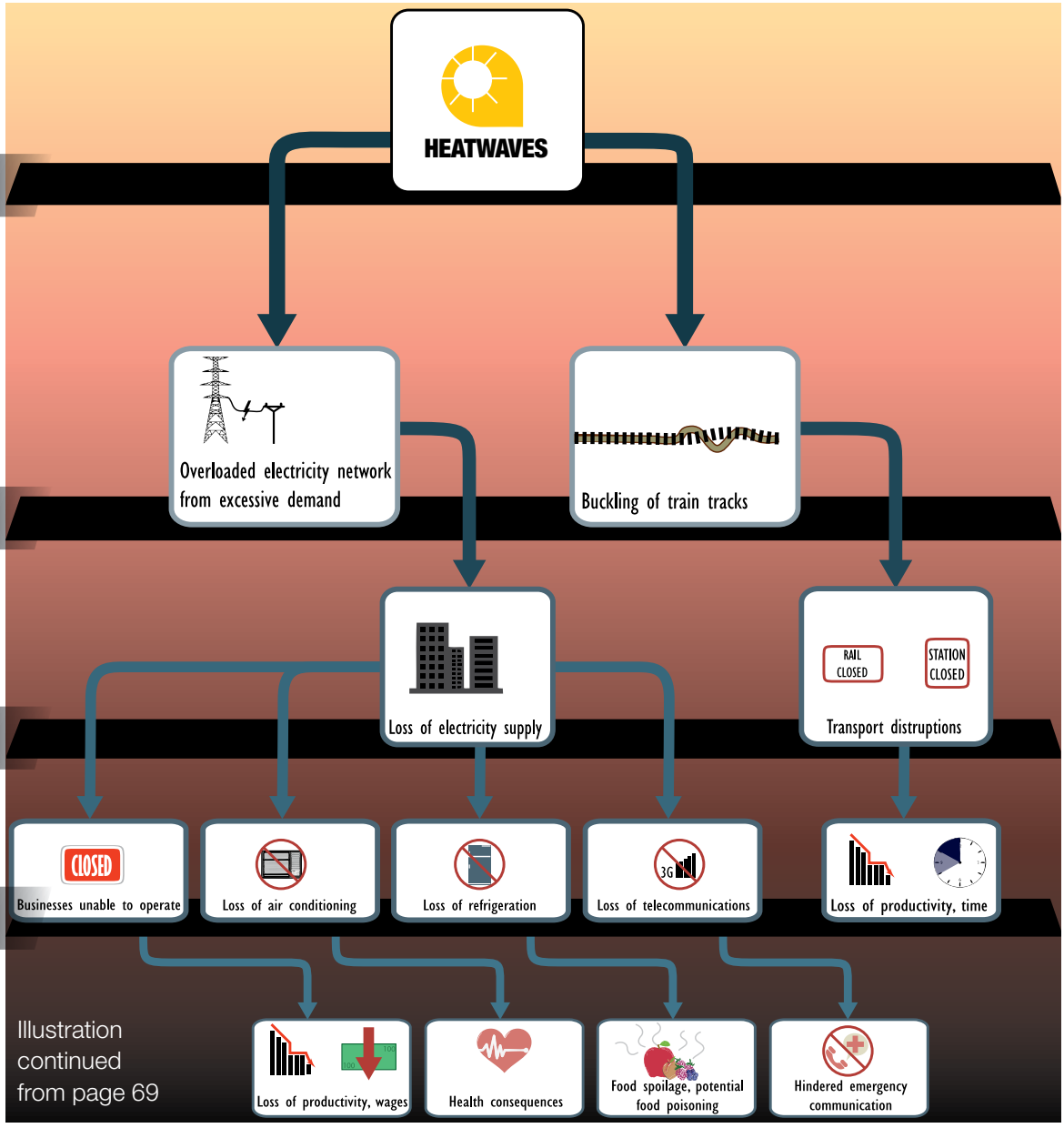


Illustration continued from page 69

One infrastructure impact of the 2011 floods through northern Victoria was the breaking of the Dimboola weir by a swollen Wimmera River. The weir, previously needed for water storage purposes, has been superseded by the Wimmera-Mallee pipeline and there is little incentive to repair it for water management purposes.

For the townspeople, however, the presence of water in the river has a strong link to recreation, tourism and socio-economic outcomes. Tourists “come in droves” when there is water in the river – “it’s like a magnet”

(Rodney Lehmann, Dimboola Rowing Club President).

In particular, the Dimboola Regatta is a major event in the local calendar, and it was threatened by the absence of a weir to keep the water level high enough.

Hindmarsh Shire Council is now working to quantify the value of the regatta for the town, so that the full societal costs of the broken weir can be brought to light.

Local management of natural resources is often complex and this impacts on effective decision-making. The Dimboola Weir is owned by GWM Water (the local water authority). Decisions about how to operate the weir (e.g. adjusting water heights in the river) are made by the Wimmera Catchment Management Authority. The actual operation of the weir is undertaken by the Hindmarsh Shire Council. Importantly, though, it is the whole town and surrounding area that shares the socio-economic benefits of the weir and the ‘costs’ of its absence.

For all organisations, it is generally considered advisable to integrate climate change impacts into existing risk management frameworks, whether that is a physical risk or a purely financial risk such as that faced by investors.[112]

3.2 Climate change and the future of Victorian infrastructure

Who is Responsible?

The Dimboola Weir experience demonstrates that responsibility for dealing with the impacts of climate change on the built environment is the responsibility of a wide variety of people, not just the owners of property and infrastructure.

Stakeholders in any piece of infrastructure can include all levels of government, regulatory authorities, the insurance industry, engineers, lawyers, banks and lending institutions and others. Community members are also expressing their interest in local adaptation strategies and are insisting on being included in discussions and the development of solutions.

State and Federal Parliaments have a critical role, ensuring that the legislative framework governing our built environment is capable of allowing, and even promoting, the necessary innovation for adaptation actions.

The business sector is also key to adaptation. A recent review of global business attitudes found that 90% of businesses surveyed had been impacted by climate events in the past three years.[110] The survey noted that, in response, approximately one third of businesses are taking a range of actions to address the coming impacts of climate change.

Adapting to climate change is also seen by some businesses as presenting opportunities, for example through providing products or services that would help others adapt. Specifically relating to infrastructure, 38% of businesses see adaptation as primarily an opportunity to climate-proof physical assets.[111]

For all organisations, it is generally considered advisable to integrate climate change impacts into existing risk management frameworks, whether that is a physical risk or a purely financial risk such as that faced by investors.[112]

Flexibility and Efficiency

Difficult decisions lie ahead, with much complexity to consider. Figure 24 shows how decisions about infrastructure made today should consider a very different, future climate.

Uncertainty in the impacts of climate change, as in every other area where complex decisions are made, is an incentive for innovation and creativity.

In defence strategies such as the Defence White Paper,[114] we do not pick one possible future scenario and plan for only that scenario. We do not assume that one particular country or terrorist group will be the only threat in the future, ignoring the possibility of others. Nor should we do so in the face of the uncertainties attending climate change. Interestingly, critical infrastructure planning for terrorist attacks on Sydney is now being deployed for climate change sea-level inundation eventualities.[115]

The UK Environment Agency developed the Thames Estuary 2100 project to deal with sea-level rise in London.[116] This long-term risk management plan incorporates climate change projections in the design of a system of barriers to prevent flooding across London. Rather than assuming a specific increase in ocean levels, the planners have designed major infrastructure that is adaptable across a range of projected sea-level rise possibilities.

When adapting, it can be tempting to choose a particular future climate scenario and make the best decision under that scenario (referred to as an "optimal" decision). However, it is becoming increasingly important to re-think how we plan for climate change. Focussing on "optimal" outcomes could lead to maladaptation - misguided investments and infrastructure that is inadequate for mid-century climate conditions - if decisions are based on a specific climate future that does not eventuate.

"Robust" decisions - those that are least sensitive to future climate conditions, or that will be good decisions regardless of the extent of future changes in climate - make more sense strategically when faced with an uncertain future.[117]

Focussing on "optimal" outcomes could lead to maladaptation - misguided investments and infrastructure that is inadequate for mid-century climate conditions...

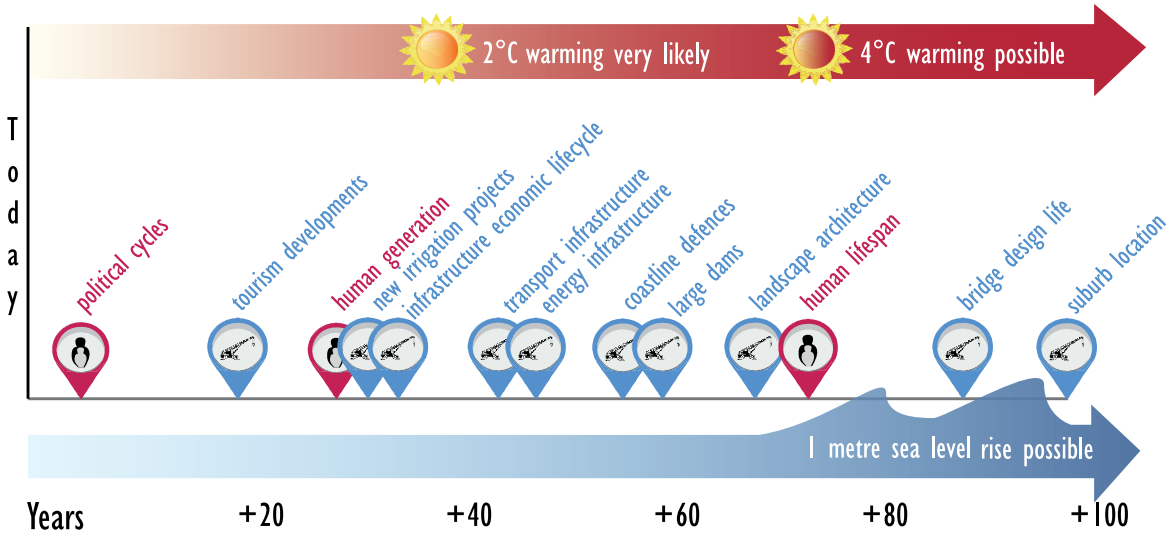


Figure 24:
Adapted by CfES from CSIRO.[113]

Photo: Elizabeth St in flood, March 2010 (from: http://www.flickr.com/photos/gemmajones/4446963060/)

3.3 Responding to the challenge

No-regret strategies

Recent developments such as green roofs and green walls (where vegetation is grown on a surface through a special soil-type substrate) also reduce electricity demand by providing insulation. Additionally, green roofs help reduce the urban heat island effect found in large cities (see Chapter 6). Perhaps their most valuable co-benefit, from the perspective of reducing the impacts to infrastructure, is their ability to capture rainfall, helping to reduce the amount of stormwater running into drains during heavy downpours, thus ameliorating the risk of flash flooding.[118]

Another method for combating flash flooding in heavily urbanised areas is the use of permeable pavement. Currently, hard surfaces like concrete, bitumen and other paved areas prevent rain from soaking through to the soil beneath, and instead funnel water towards drains. When drains overflow, there is nowhere else for the water to go, resulting in flash flooding.

Elizabeth Street in central Melbourne is built along an old creek bed and is often flooded during major rain events – most recently in 2010. It is the lowest point in the Melbourne CBD and largely surrounded by extensive areas of impervious surfaces. The City of Melbourne is in the process of implementing porous surfaces to reduce the damage caused by heavy rain. This work will be beneficial in today's climate, and will continue to provide benefits in the future, as rainfall intensities are projected to increase by 30% by 2030.[119]

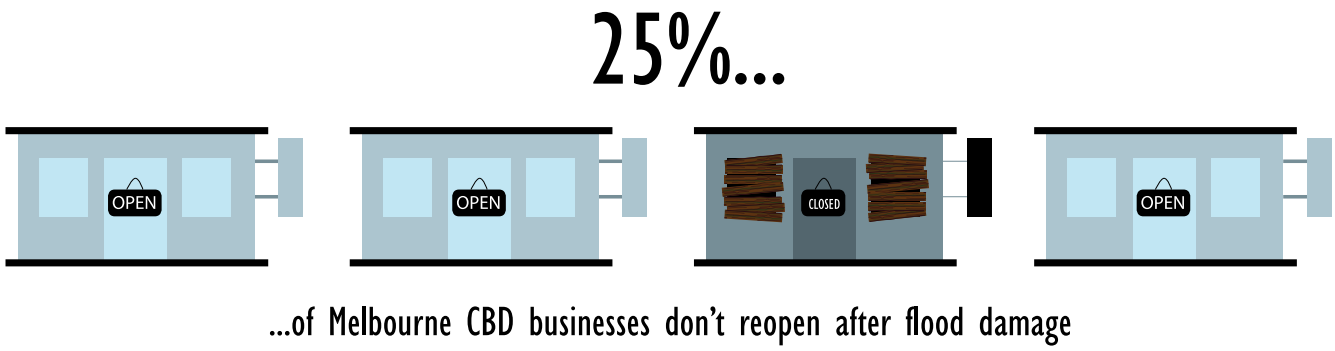


Figure 25:
Closed Businesses.
CfES developed infographic.[120]

Better design and insulation of buildings reduces the cost of heating and cooling, and thus can help reduce the strain on the electricity grid during times of peak demand. Innovative new buildings in Melbourne such as the City of Melbourne's "Council House 2" and the award-winning Pixel Building both make use of "night-time purging" - a system whereby the warm air that has collected in the building during the day is vented to the night sky.[121] In Council House 2, this system alone reduces the building's daytime cooling requirements by 20%.[122] Existing buildings can also be retrofitted for improved energy performance.

The Green Building Council of Australia and the Australian Green Infrastructure Council are both developing energy rating tools to help owners of buildings and other infrastructure reduce electricity demand.

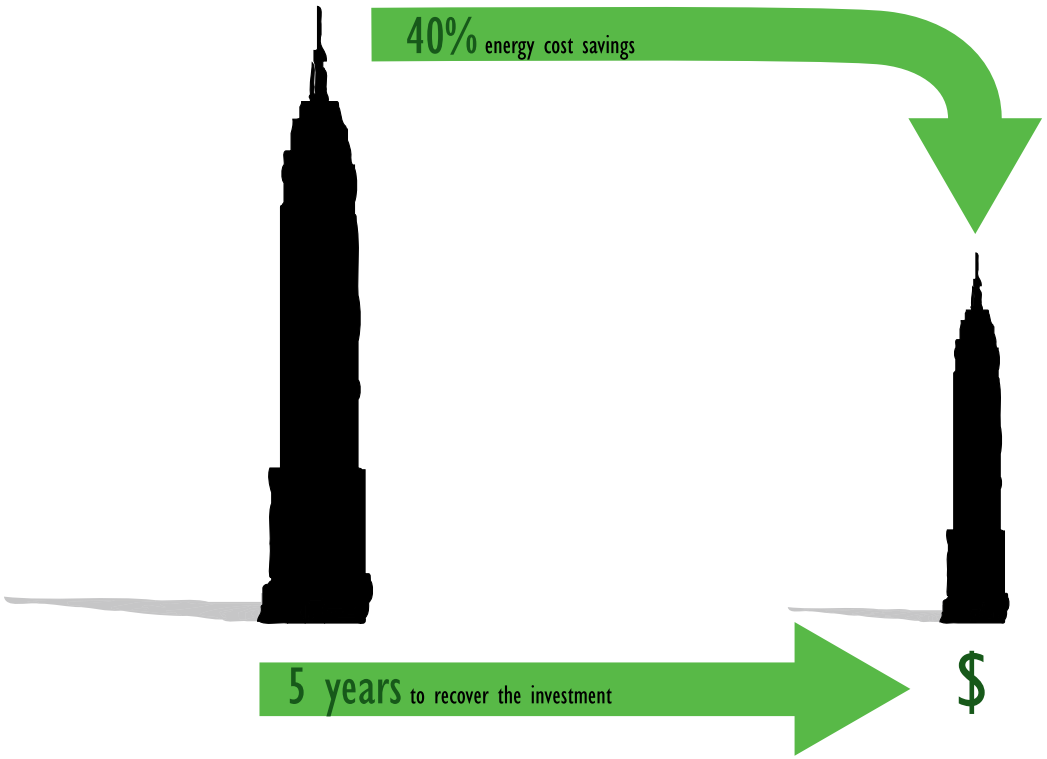


Figure 26: Empire State Building retrofit.[123]

Safety-margin strategies

Where certain events can be anticipated, it is often beneficial to address them pre-emptively at the design stage, rather than to try to retro-fit or upgrade later.

HafenCity is a new suburb in the port area of Hamburg, Germany. Until recently, the site was essentially a disused port, but now it is home to 126 hectares of homes, businesses and public spaces. The developers designed the entire water-front suburb for resilience against significant sea level rise. Living, working and transport areas are elevated to avoid storm surges. Certain areas are explicitly designed to accommodate flooding, but in such a way that the operation of the suburb is largely unaffected.[124]

Even where coastal defences or infrastructure is built, it is important to take adequate account of the scale of events these structures will need to withstand. The effect of Hurricane Katrina on New Orleans stands as an example of what can go wrong when man-made defences fail - vast tracts of the city were flooded and damaged, several hundred people died, and critical infrastructure such as electricity and water were disrupted. The longer-term impacts also must not be forgotten: on-going post-traumatic stress disorder, environmental damage and health problems from leaked oil, petrol and other chemicals, and regional economic impacts.

Photo: "Last House Standing" after Hurricane Ike, Source http://news.blogs.cnn.com/2011/07/26/owners-of-last-house-standing-part-of-peninsulas-comeback.

In 2008, Hurricane Ike devastated Cuba, Haiti and the USA's Gulf of Mexico coast. In the town of Gilchrist, Texas, the scene was one of utter devastation, with the exception of a single house (see photo). Built in the wake of Hurricane Rita, the "Last House Standing" was explicitly designed to withstand the future events it was likely to face. The higher construction standard may be moderately more expensive, but has meant this house survived where none others did.

Coastal risks

Some issues confronting coastal communities in relation to sea level rise are similar to those faced by communities living in peri-urban areas where the risk of bushfires is increasing. Both involve establishing the built environment in locations where natural hazards exist and where these hazards are projected to become worse with climate change.

In our state the *Victorian Coastal Strategy 2008* sets out the policy and strategic direction for responding to coastal hazard risks in the context of climate change. The strategy identifies the need to:

> *Plan for sea-level rise of not less than 0.8 metres by 2100, and allow for the combined effects of tides, storm surges, coastal processes and local conditions such as topography and geology when assessing risks and impacts associated with climate change.*

In recognition of the long-term impacts of possible sea level rise, the State Planning Policy Framework of the *Victoria Planning Provisions* and local planning schemes reflect the Victorian Coastal Strategy, and the policy applies to non-urban land, greenfield land and development beyond existing settlements in coastal areas.

With regard to development proposals in existing settlements and urban zoned areas. The State Planning Policy Framework specifies:

> *In planning for possible sea level rise, an increase of 0.2 metres over current 1 in 100 year flood levels by 2040 may be used for new development in close proximity to existing development (urban infill).*[125]

The Commonwealth funded the *Climate Change Risks to Australia's Coast: a first pass national assessment* and the *Climate Change Risks to Coastal Buildings and Infrastructure - A Supplement to the First Pass National Assessment* and produced maps which the Department of Climate Change and Energy Efficiency describe as showing "low-lying vulnerable areas for a low (0.5m), medium (0.8m) and high (1.1m) sea level rise scenario, for the period around 2100". This was done "to help understand the potential impacts and risk to society" and "help communicate the risks of climate change."

The Australian Government has adopted a view that there are significant benefits for governments, businesses and communities in considering the adoption of a nationally consistent sea-level rise planning benchmark,[vi] but a level has not been determined.

One difficulty of dealing with sea-level rise is that there is no one-size-fits-all solution. Outcomes in a given place depend heavily on local peculiarities. Flood mitigation infrastructure may not be suitable for all areas for reasons of cost and geography.[126] The issues are complex, requiring continuing careful consideration at all levels of government.

One difficulty of dealing with sea-level rise is that there is no one-size-fits-all solution.

Soft strategies

Not all approaches to deal with the impacts of climate change on the built environment necessarily require construction-based solutions. There are many "soft" strategies that, in the right situations, can also provide flexible and robust pathways to change.

In Britain, organisations that manage major infrastructure are required by the UK *Climate Change Act* to develop plans to deal with the impacts of climate change. The list of organisations includes gas and electricity generators and suppliers, road and rail networks, ports, airports, water authorities and economic regulators (similar to our Essential Services Commission).[127] By requiring these plans, the UK is encouraging genuine long-term thinking and planning from organisations that control major infrastructure, with a view to ensuring future resilience to climate impacts.

vi Australian Government response to the House of Representatives report—Managing our coastal zone in a changing climate

Similarly, insurance schemes provide incentives to appropriately consider future increased risks, but they are unlikely to be a panacea – as risks increase, so will insurance premiums, potentially making coverage unaffordable for many.

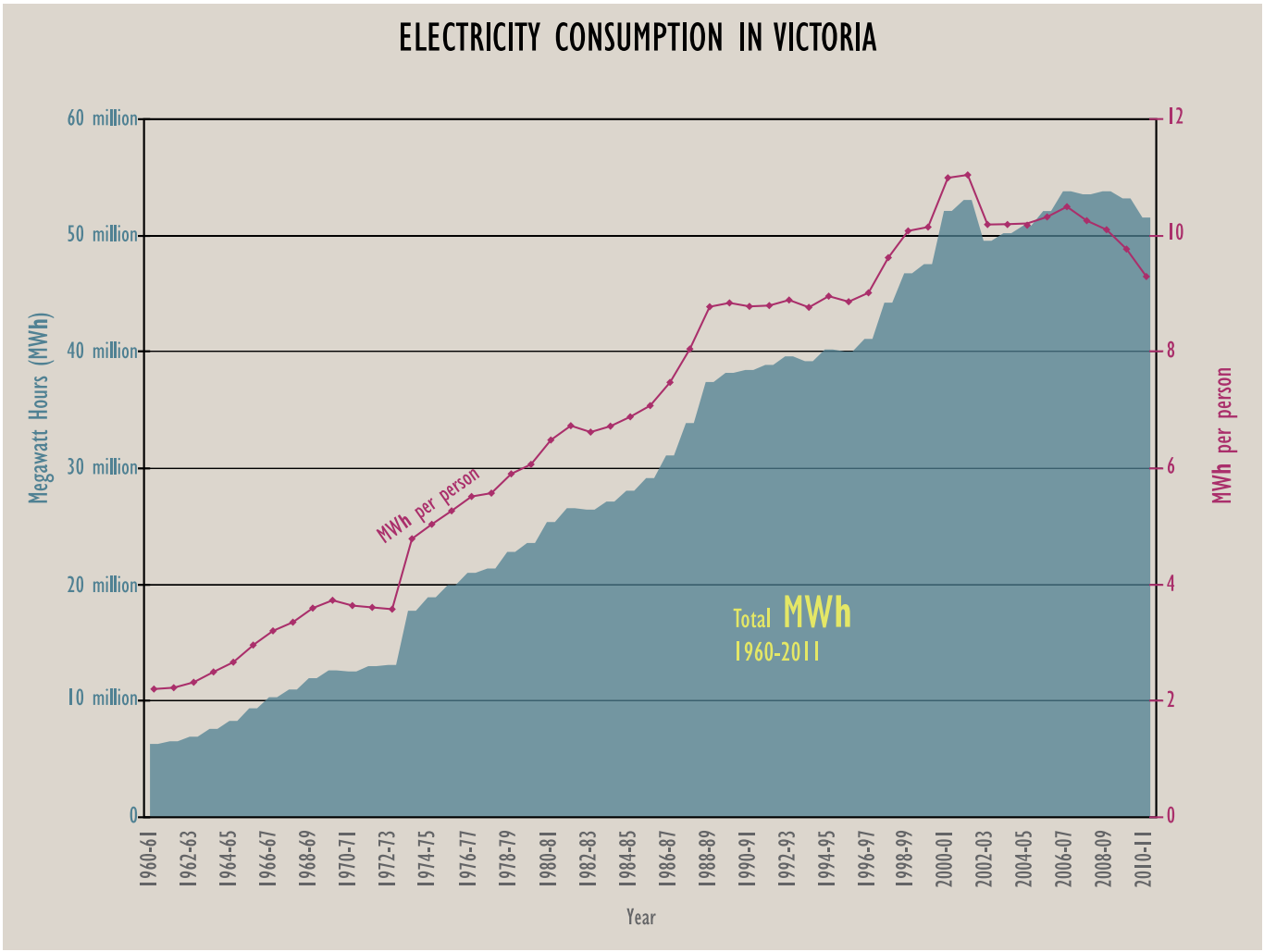
Early warning systems can also be effective at minimising loss and disruption from a wide range of extreme events - from heatwaves and bushfires to floods and storms. Providing information and notifications can help reduce the cascading losses from infrastructure failure.

Reducing maximum demand for energy

One particularly important "soft strategy" (mitigation/adaptation) is managing how much electricity we use.

Our electricity consumption has increased almost ten-fold in the last 50 years (Figure 27). Factoring in population growth, the average person today still uses about five times as much electricity as a person in the 1960s.

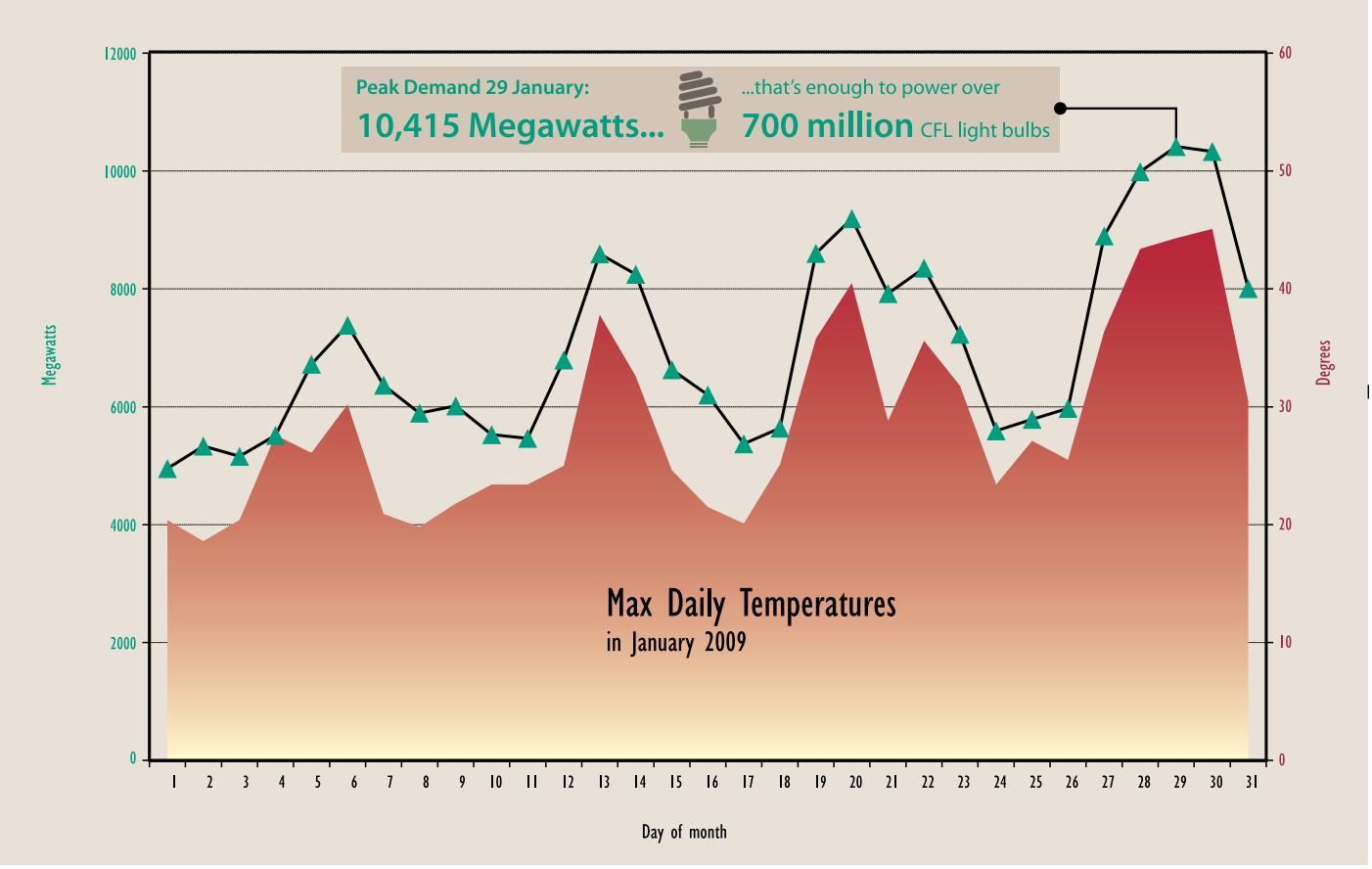
Figure 27: Electricity consumption in Victoria.
CfES developed infographic.[128]



Air conditioners provide an illustration of maladaptation. While keeping us cool, they are increasing our emissions of greenhouse gases (Figures 28-29). Further, by placing extra strain on electricity supplies, particularly when the weather is hot, air conditioners also necessitate additional construction of infrastructure.

For every $1500 air conditioner unit installed, approximately $7000 needs to be spent on network upgrades – a cost that is shared across all users, regardless of air conditioner ownership.[129]

Figure 28:
The influence of daily temperature on electricity demand.
Temperature data available from BoM[131]; electricity data available from Australian Energy Market Operator.[132]



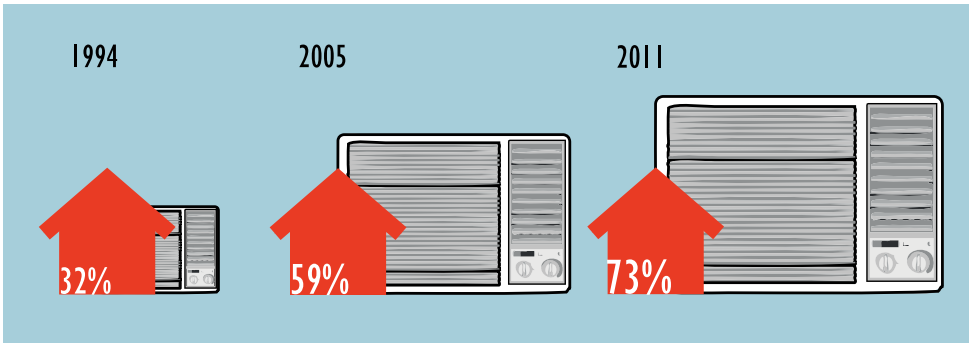


Figure 29:
Ownership of air conditioners.
Australian Bureau of Statistics data CfES developed infographic.[130]

When consumers have access to real-time price information through smart meters and a tiered pricing system for peak and non-peak consumption, they will be able to make informed choices about their electricity use.

How much electricity we use is directly linked to the possibility of black-outs during heatwaves. Summer maximum demand in Victoria was projected to increase by 2-3% per year,[133] although there is now recognition that, for a variety of reasons, maximum demand may now not be rising that quickly. Hot days and higher temperatures lead to higher electricity demand, with daily maximum demand tied very closely to daily maximum temperatures.

With sufficient planning, some of the social consequences of blackouts could be minimised (see Chapter Six), even as the physical limitations of critical infrastructure cannot always be avoided (e.g. over-heating of machinery in water treatment plants).[134]

The construction of additional electricity infrastructure (generation capacity, transmission lines, distribution networks) will continue to be deployed to combat rising maximum demand – this can potentially include distributed generation from renewable energy resources. The construction of this infrastructure is a key factor behind rises in electricity bills over the past decade. Higher infrastructure costs mean higher costs for consumers.

Without building more infrastructure, is it possible to avoid blackouts simply by managing summer maximum demand? Demand management may be a higher-risk strategy than building more or bigger cables, but it is much cheaper and potentially has other benefits including mitigation - reduced carbon emissions. The Commonwealth Energy White Paper (2012) urges adoption of this sort of strategy.

When consumers have access to real-time price information through smart meters and a tiered pricing system for peak and non-peak consumption, they will be able to make informed choices about their electricity use. Where price increases are used to decrease demand (or to shift demand to other times), equity issues need to be addressed so that the impact of heatwaves is not felt disproportionately by low-income households or those with unavoidable high daytime energy needs.[135]

Arrangements have been made between electricity retailers and some large consumers of electricity. Under the agreements, the large users agree to shut down at times of peak demand to protect the network, in exchange for cheaper electricity at other times. A small number of users can release enough electricity to constitute the difference between a system under strain and a system unable to cope. Such schemes could also be extended to residential customers.

The existing regulatory framework for electricity enables the expansion of the generation network without any consideration of reducing demand[137] - despite the options available for demand-side management. On the back of public backlash over rising electricity prices, the last two years have seen a major shift in thinking in the energy sector on these regulations, which currently represent a barrier to effective adaptation. Competing interests between the various players in the energy sector has also been identified as hampering adaptation efforts.[138]

Since the Australian Energy Regulator (AER) called for changes to the price-setting rules to reduce the incentive to build more energy infrastructure,[139] the Australian Energy Market Commission (AEMC) has been investigating ways in which demand management can be made more effective. The final AEMC report finds ample scope for improvement in demand management in the grid, and this coincides with a change to the National Electricity Rules that gives greater power to the AER to control network investment.[140]

Given the additional benefits of reduced demand (i.e. cost savings and lower greenhouse gas emissions), these are welcome developments.

Considering change

Flexibility and robustness manifest themselves in a variety of ways depending on the setting. There is no one-size-fits-all approach to ensuring our complex built environment, in all its diversity, is resilient to impending changes.

What are we prepared to pay to protect? What are we prepared to give up? The realities of climate change have changed the status quo. As a community, we now must work for change. The examples outlined in this chapter raise compelling questions for consideration.

Flexibility and robustness manifest themselves in a variety of ways depending on the setting.

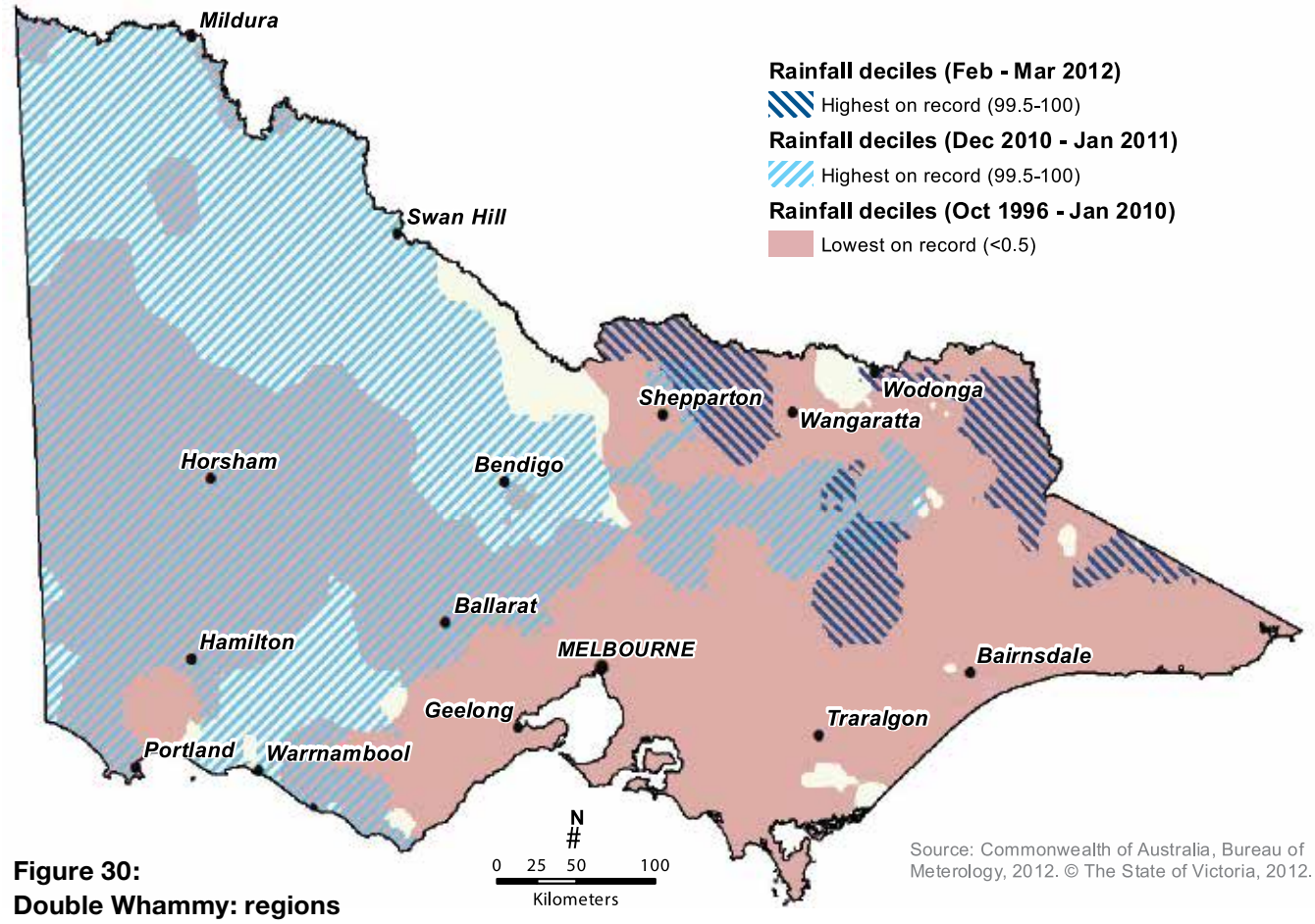
CHAPTER **FOUR** - DROUGHT, FLOOD AND CLIMATE CHANGE

This chapter does not explore inland water systems, urban water issues or the ecosystem services they provide. Those matters will be addressed in the *Biodiversity and Land Foundation Paper* and *Water Foundation Paper*

In February 2011, many people in northwest Victoria - coming out of a protracted drought and surrounded by floodwaters in towns and farms - were asking themselves whether the drought and floods were the direct consequence of climate change (see Figure 30).[141]

Victorians across the state were considering this question too - particularly in the light of the flooding in southern Queensland which took lives as well as property, prompted a Federal Government levy on the public to pay for the damage, and challenged insurance company policies and sympathies.

Australian climate scientists have been considering this same question.



Source: Commonwealth of Australia, Bureau of Meterology, 2012. © The State of Victoria, 2012.

Figure 30: Double Whammy: regions of Victoria impacted by the Millennium Drought (1996-2010) and the floods of Dec 2010 – Jan 2011 and Feb-Mar 2012. Source BoM data, map developed by Department of Sustainability and Environment for CfES.

The relationship between climate change, weather and extreme events is being examined around the world. Researchers in the UK have linked the millennium floods in England and Wales to anthropogenic climate change. There, flooding impacted 10,000 properties.[142]

As Victoria, NSW and Queensland experienced record breaking rains in March 2012, the question continues to be asked.

In the case of drought, lower rainfall and reduced runoff in the south-east of Australia is in part due to natural variability as well as to human-induced climate change.[143]

However, CSIRO's modelling[144] shows that the greenhouse gases we emit into the atmosphere are contributing to the atmospheric conditions necessary to increase temperatures and reduce rainfall.[vii]

In terms of the recent flooding, the connection to anthropogenic climate change is more complex - it is difficult to attribute specific events to just climate change.

This is because each particular flood event is due to a combination of factors that operate over both short and long periods. Additionally a wide range of extreme events is a normal occurrence even in a stable climate.[145]

What CSIRO can tell us is that recent flood events do reflect natural climate variability, but that the magnitude of such events over the longer term may increase with climate change.[146]

"It is expected that long-term climate change will result in greater climate variability with more intense extreme events than in the past."

CSIRO[147]

Scientists reporting to the Intergovernmental Panel on Climate Change confidently state that human actions contribute to the "intensification of extreme precipitation at the global scale".[148]

As extreme drought and flood events become more frequent and severe, elevated levels of distress will be felt by Victorians across the State.

vii For a detailed description of these atmospheric drivers, see DPI's ClimateDogs: http://www.dpi.vic.gov.au/agriculture/farming-management/weather-climate/understanding-weather-and-climate/climatedogs

4.1 Climate change and a hotter, drier Victoria

Our principal scientific agencies – CSIRO and BoM – demonstrate through evidence and modelling that the extremes we have seen recently are going to become more normal as drought and flood events become more frequent and extreme.

Victoria has a history of drought.

However, the recent drought, the "Big Dry" or the "Millennium Drought" was Victoria's longest and driest ever. It lasted the greatest number of years, 14 in all, compared to 10 years and seven years for the other major droughts since records began (Figure 31).[149] It was also the driest, in that it did not have a single wet month; whereas the WWII drought had nine wet months during the 10 year drought.[150]

The Millennium Drought resulted in a reduction to Victoria's average rainfall of around 15%.[151]

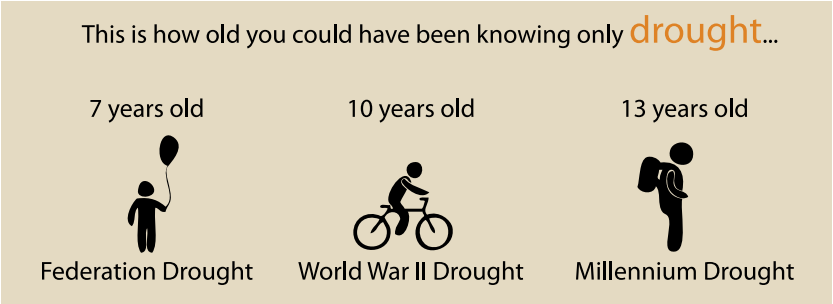


Figure 31: Knowing only drought. CfES developed infographic[152]

Most of Victoria experienced the lowest observed rainfall on record during this period (Figure 32).

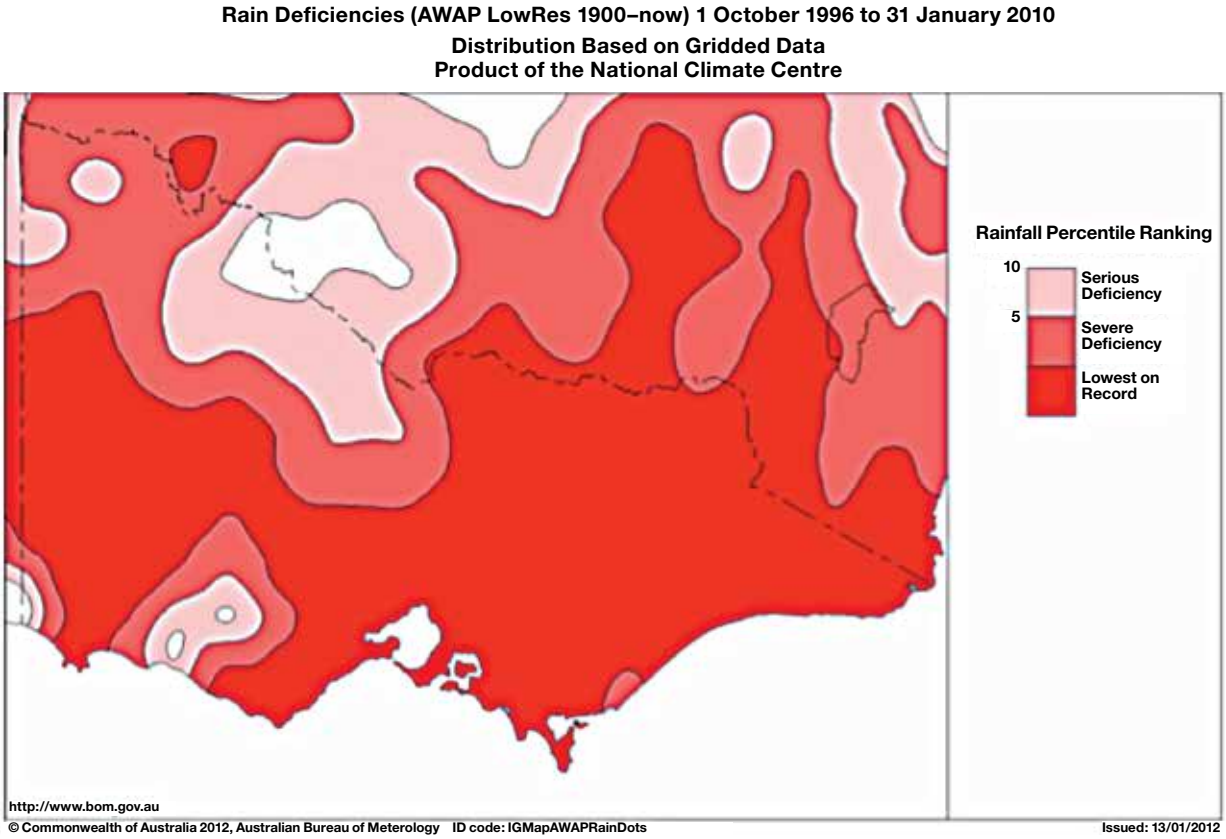


Figure 32: Rain deficiencies during Millennium Drought. Source BoM.

NB: Rainfall decile 1 means that the observed totals fall in the lowest 10% of historical totals for this length of period.

Importantly, projections indicate more extremely hot years and extremely dry years for Victoria in the future.[153] CSIRO projects that the extent and frequency of droughts in Victoria may more than double by 2050.[154] This will have serious impacts on Victorian landscapes and communities.

Direct Impacts of Drought

Natural environment

Self evidently reduced rainfall results in reduced water availability in rivers and streams on the surface, as well as groundwater storages. However, it also reduces the amount of moisture in the soil as natural evaporation is not replaced through rainfall.

Soil erosion and nutrient loss impact on the ability of plants to thrive, resulting in failing crops for farmers, and fewer sources of food and shelter for wildlife. Fish, platypus and other aquatic wildlife have less water in which to live, and the quality of the water that remains is reduced. This degraded habitat impacts on the ability to reproduce and survive.

Increased dryness also creates the conditions for more severe bushfires.

Agricultural productivity

Warmer and drier conditions will have a range of impacts, including lower crop quality, increased risk of disease and pests, and reduced yields.[155] Decreasing rainfall, increasing carbon dioxide levels and higher temperatures could decrease overall wheat quality in western Victoria by 34% by 2050.[156]

Grazing industries (including livestock and dairy) will suffer from a decline in forage quality, thermal stress on livestock, and increased pests, diseases and weeds.

Urban water supply

Under drought conditions, water storages are not refilled, putting pressure on water supply for cities and towns as well as rural areas.

Regionally, for three consecutive seasons between 2006 and 2009, water was pumped from the Waranga Basin, near Rushworth and Tatura, below the normal off-take level, to supply water for irrigation. This had only occurred twice before, during extreme drought in 1926 and 2003.[157]

As a result of record low inflows in 2006 and 2007, water entitlement holders on the Latrobe River System faced supply shortfalls. Gippsland Water, power generators and the Latrobe River irrigators were all looking to source additional water to cope with the impact of the unprecedented low inflows.[158]

Goulburn Valley Water's Sunday Creek system supplies the towns of Kilmore, Broadford, Wandong, Heathcote Junction and the surrounding area. During 2007 and 2008, Goulburn Valley Water resorted to carting water from Seymour to supply Broadford, resulting in costs of more than $2.5 million.[159]

Water restrictions try to limit the consumption of water in urban areas to make existing storages last longer. In Victoria, permanent water saving rules came into place in 2005, mainly targeting outdoor uses. From September 2006 to September 2010, at least 200 towns were under water restrictions at any one time - up to over 450 towns at one stage.[160] Ballarat, for example, was subject to the harshest restrictions (Stage 4, which bans outdoor water use entirely) for almost three years.[161]

Indirect Impacts of Drought

Water scarcity and its consequences for agriculture, biodiversity, ecosystems and human settlements are clear. Not so apparent, however, are the flow-on effects of drought and their social and environmental implications.

Rural economic instability

Impacts on agricultural productivity means reduced revenue for farmers which can lead to community-wide financial hardship.

A 2008 study conducted by Department of Primary Industries, investigated the link between rainfall variability and agricultural production. The study found that variability of annual rainfall over the years on grain farms does have a medium to strong impact on the variability of farm business profit and cereal production, especially wheat production.[162]

A 2011 study of the Wimmera-Mallee region supports this finding, as it showed a close relationship between growing season rainfall and wheat production (see Figure 33).

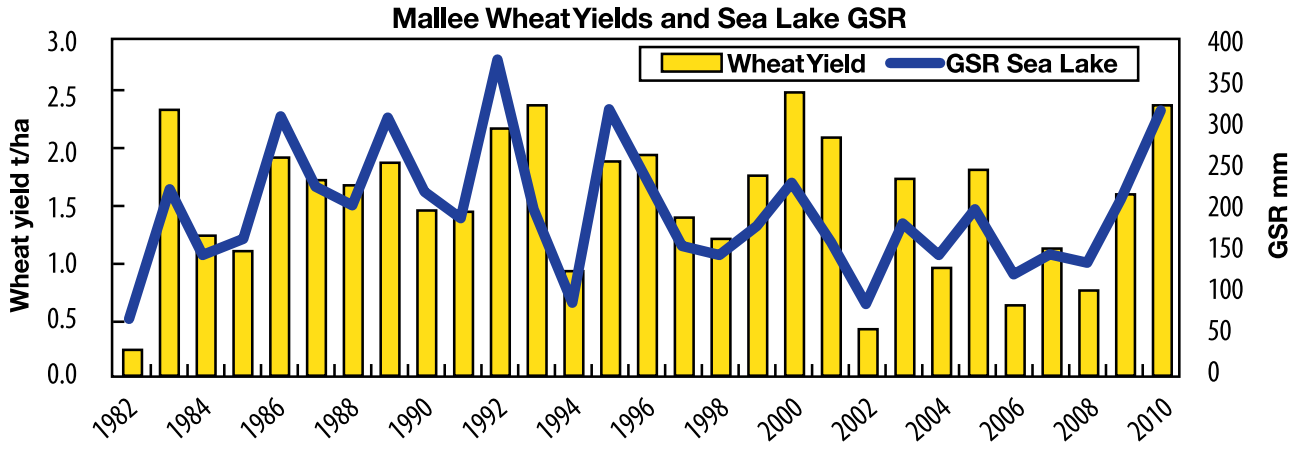


Figure 33:
Mallee annual wheat yield and growing season rainfall for Sea Lake.[163]

Financial hardship is more common in drought affected areas.

The study further found that farmers in the region also experienced increased ratios of debt to equity as a result of greater borrowings required to cover cash deficits during the dry years.[164] This is no surprise to farming communitites.

Financial hardship is more common in drought affected areas. A recent study found 47% of farmers living in a drought-affected area were experiencing financial hardship, whereas only 25% of farmers who had not experienced drought in the last three years were in the same situation.[165]

During drought, farmers also fare worse than their community neighbours. A study by the Australian Institute for Family Studies (2008) revealed that a much higher percentage of farmers were in financial hardship than people who are employed but not in agriculture.[166]

Australia is not the only country whose agricultural industries are experiencing record-breaking droughts due to climate change. In 2011, a drought in Texas resulted in record $5.2 billion in agricultural losses, making it the USA's most costly drought on record.[167]

Buying the essentials

Lost productivity in the agricultural sector has impacts on everyone through an increase in food prices, which can hit families on a tight budget the hardest.

In the two years from September 2005 to September 2007, food prices in Australia increased at *twice* the rate of the Consumer Price Index.[168]

In 2007, the ANZ Bank identified the drought as a primary contributor to these soaring food prices, where the average Australian grocery bill rose 12%.[169] The availability and affordability of nutritious food is critical to maintaining a healthy society and food independence. More frequent and severe drought is likely to make it harder to get local, affordable food.

These increases in prices of essential commodities affect everyone; however those on lower incomes are more likely to struggle as food and water take up more of their weekly budget.[170] These burdens are in addition to the potential rises in energy costs outlined in the preceding chapter.

This raises concerns over fair and equal access to the basics which become less affordable for society's most vulnerable groups.

Reduced amenity and recreation

Water restrictions reduce the health and vitality of home gardens and public spaces. These parks and green spaces are valued by the public for urban amenity, such as recreation, youth development, and social capital.[171]

In particular, reduced water availability for sporting fields and other spaces reduces opportunity for physical activity and social cohesion such as community convergence, local identity and pride, and economic activity are all effected.[172]

As discussed in the previous chapter, Dimboola Rowing Club was unable to hold its annual regatta due to lack of water in Lake Dimboola in 2010, which impacted on local tourism, social networks and recreation in the town. Lake Wendouree suffered similarly, as well as countless footy grounds, cricket grounds, and other sporting and recreation spaces across Victoria. This reduction in recreational and community capacity is difficult to measure, but there is little doubt it will worsen under a drier climate.

Mental illness and depression

Australia's National Rural Health Alliance points to the presence of a causal relationship between drought-related trauma and individuals at-risk in agricultural communities.

A 2007 report by the *Australian Institute for Health and Welfare* showed that 15-24 year-old males in regional areas are 1.5–1.8 times more likely to commit suicide than their urban counterparts. The incidence is up to six times higher in very remote areas, due to a number of factors including unemployment, lack of access to mental health services, and migration of peers to urban areas.[173]

According to a 2011 report by the *Climate Institute* - financial strain, landscape degradation and a dwindling rural population are all factors that raise the risk of suicide among older, male farmers, and all are set to increase under climate change scenarios.[174]

Australia has relatively high carbon emissions compared to other industrialised economies because of our high reliance on coal.[179]

Cascading Impacts of Drought

Although we cannot be certain of the intensity and frequency of future droughts, social and economic studies provide insights into the longer-term and ongoing challenges of a hotter, drier Victoria.

Decline of rural communities

Drought areas have been associated with lower employment rates.

Since 1996, entry of young persons into farming in Australia has continued at low levels following a sharp decline in the 70s and 80s.[175] As older farmers exit the industry, fewer young farmers are taking over. Remote areas, such as the Mallee and Wimmera, where agriculture will need to adjust to climactic change, are in decline and becoming increasingly isolated from health and community services, and educational and economic opportunities.[176]

Rural communities often depend on farming and farm income to drive other economic and social aspects of their community, and productivity downturns mean less economic activity, fewer jobs, and fewer people in towns. Although drought cannot be directly attributed to migration from rural areas at this time it is an additional pressure on towns already experiencing decline and isolation.[177]

Energy, water and carbon emissions

Water availability has a close relationship with another important aspect of our lives – energy. Stationary energy is a significant water user, consuming about 4% of non-agricultural water.[178] Higher water prices mean that energy could become more expensive as costs to supply energy to power stations increases.

New water supply infrastructure requires substantial amounts of energy. Desalination plants, pumps for pipelines and water recycling stations all require significant resources of energy.

This poses a critical feedback loop where rising energy costs compound the expense of water supply which in turn puts additional pressure on the price of energy.

The consequences are not only economic.

In order to adapt to a drier climate which is being driven by human emissions, we will need to generate more water for human and natural uses to compensate for lower rainfall. However, the energy needed to produce this water actually *uses* lots of water and emits greenhouse gases that are driving the drier climate in the first place.[179]

Restrictions and water efficiency measures would appear to be a preferable alternative to more infrastructure which drives up prices, emissions, and water use simultaneously.

4.2 Climate change and an increase in more extreme rainfall events

In stark contrast to 1997-2009, 2010 was the fifth wettest year on record in Victoria and the summer of 2010-11 was the wettest in Victoria since records began, with several rivers experiencing the largest or second largest flood ever recorded.[180]

The rainfall in early 2012 was also record breaking, with the highest observed rainfall at many points across the state. The north-east in particular was affected (see Figure 35). CSIRO tells us that a warming climate is likely to result in more extreme rainfall events and this could potentially result in more severe flooding.[181]

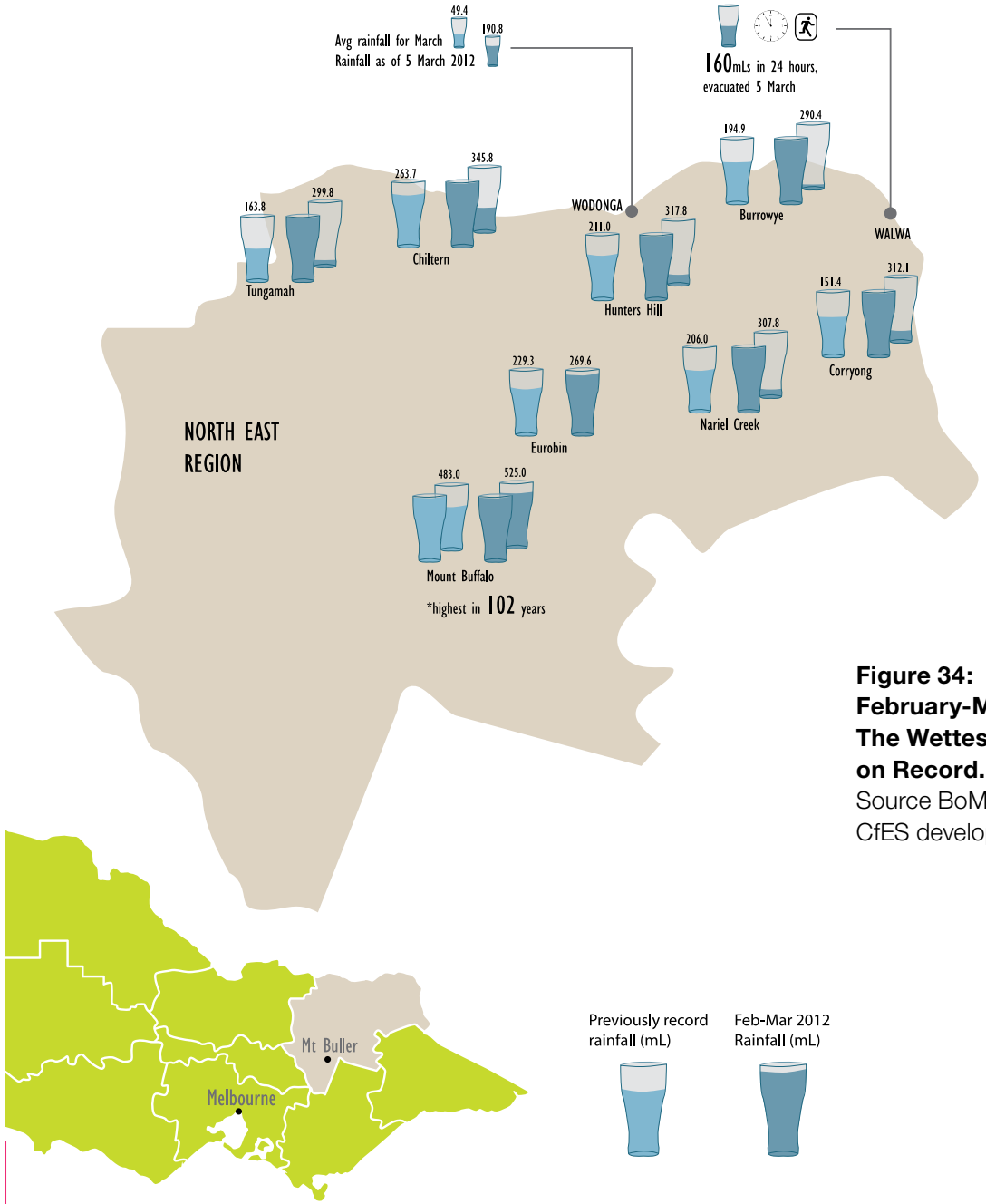


Figure 34: February-March 2012: The Wettest 7-day Period on Record.
Source BoM.
CfES developed infographic.

Victoria and the La Niña Event

The wet summers we have experienced recently are partly due to the close relationship between the La Niña weather phenomenon and rainfall in Australia, and a potential connection between the strength of La Niña and changes to sea surface temperatures.[182]

Australia is more likely to get flooding during strong La Niña events because of the unseasonably heavy rains that accompany La Niña. The flooding events of 1950, 1974, 2010-11 and 2012 all occurred in a strong La Niña period.[183]

Although La Niña is a naturally occurring event, there is now evidence to suggest that it may be strengthened by the rising sea surface temperatures associated with climate change.[184] If this is the case, it is no coincidence that ocean temperatures around Australia were warmer in 2010-11 than for any previous La Niña event.[185]

Recent Flood Reviews

Two critical reviews of the 2010-11 floods have recently been released in Queensland and Victoria - the *Queensland Floods Commission of Inquiry Final Report.* March 2012 and the *Review of the 2010-11 Flood Warnings and Response* (Comrie Review), December 2011.

The Environment and Natural Resources Committee of the Victorian Parliament tabled its report on matters relating to flood mitigation infrastructure in Victoria on 29 August 2012.

Comrie Review and the Queensland Floods Inquiry

The Queensland Floods Inquiry's terms of reference extended beyond flood warnings and response, however its findings on the subject are consistent with those in the Comrie Review.

Recommendations in both reports include improving the understanding of roles and responsibilities of various agencies, as well as clarifying what directive powers emergency management staff (such as State Emergency Service) have during the emergency, and better overall communications.

The Comrie Review recommendations broadly support the Victorian Government's Green Paper on emergency management, *Towards a More Disaster Resilient and Safer Victoria*, and the companion document, *Victoria Prepared: An Action Plan.*

As the Queensland Flood Inquiry had broader terms of reference, some additional detail is provided below.

Emphasis on mapping

The Queensland Flood Inquiry had a particular and consistent emphasis on mapping as a highly desirable and effective flood management and planning tool. It gave numerous examples of councils who already use maps extensively, such as Brisbane and Ipswich, which make available, free of charge, property-scale flood reports to the public. This was considered best practice, and the Comrie Review recommended that all flood mapping commissioned or adopted by government be made available to the public, together with guidance on interpretation.

This emphasis on the role of quality mapping informing robust decision-making and better preparedness was also expressed in the Victorian Bushfires Royal Commission into the Black Saturday fires (see Chapter Five).

Support for buy-backs

The Queensland Government does not currently operate a state administered buy-back program for properties at high risk of flooding, although some properties were acquired through joint State/ Commonwealth programs on an ad hoc basis.

The Queensland Flood Inquiry recommends that councils consider implementing property buy-back programs as part of a broader floodplain management strategy (Recommendation 11.1). The Land Swap program and Grantham Development Scheme were used as exemplars in the Review due to the social cohesion benefits of relocating an entire community rather than individuals.

Performance of private insurers

The Comrie Review includes an analysis of the response times of each of the eight major insurance providers involved for assessing claims, making payments, and responding to appeals.

The Queensland Flood Inquiry received a limited number of responses from the public around insurance issues, potentially due to the necessary preoccupation of policy-holders with recovering from the effects of the floods, and their potential disinclination to re-live their experience through making submissions or providing evidence to the inquiry.[186]

Impacts of Flood in Victoria

Commodity prices

According to ABARES, the impact of the 2010-11 floods on Australia's agricultural production and exports was roughly $2.3 billion.[187]

The flooded regions of Victoria accounted for around 19% of Australian milk production, 3% of vegetable production, and 13% of fruit production.[188] Flooding here and elsewhere in the country caused a sudden surge in food prices, particularly for fruits and vegetables from the affected areas. Melbourne shoppers felt the shock of flooding in the Gascoyne region of Western Australia in the price of mangoes, and the flooding in Queensland in the prices of zucchini and bananas (see Figure 35).

The flooded regions of Victoria accounted for around 19%of Australian milk production, 3% of vegetable production, and 13% of fruit production.[188]

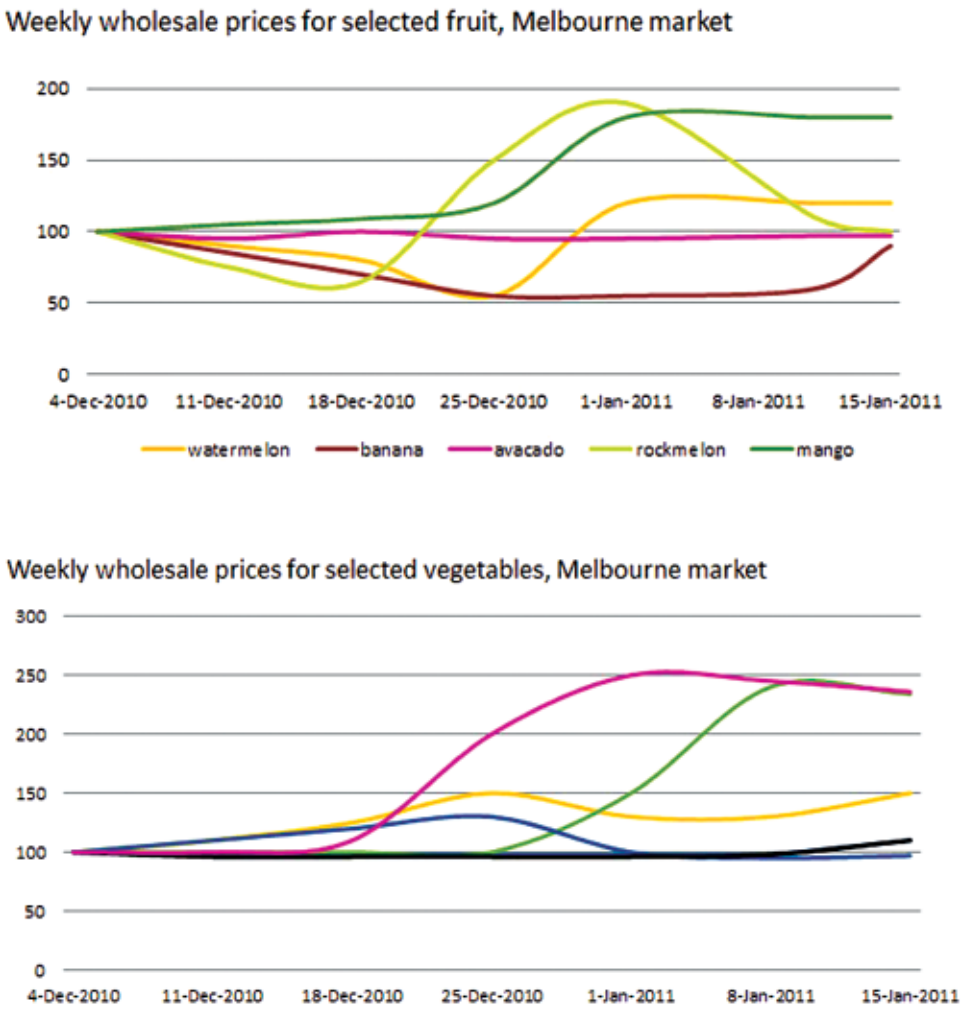


Figure 35:
Weekly wholesale fruit and vegetables prices, Melbourne market.
Source ABARES 2011.

Scarcity of supply was not only due to flood damaged crops, but also due to flood damaged infrastructure, such as rail and roads, which producers rely on to get their food to market.

Wheat prices also soared due to reduced supply, with winter wheat jumping to a two-year high.[189] The Australian cotton industry experienced 894,000 tonnes of projected losses driving up the price of cotton.[190] Australian sugar production in 2010–11 was 3.6 million tonnes, the lowest since 1991-92.[191]

High prices were welcome for some producers, who had managed to get their crops harvested in time and benefit from a bumper year. However the financial benefits for some are anticipated to be nowhere near enough to offset the overall economic fallout from the year's La Niña weather events, estimated at $6 billion.[192]

Scarcity of supply was not only due to flood damaged crops, but also due to flood damaged infrastructure, such as rail and roads, which producers rely on to get their food to market. These logistical delays can also serve to drive up prices, as commodities are trapped in production zones and out of reach of consumers. Fortunately, where transportation issues drive up prices, eventually the commodities are delivered and markets stabilise.[193]

Financial Hardship and the Limits of Private Insurance

Many families and communities are trying to manage the risk of climate events through private insurance coverage. The recent floods in Queensland and Victoria exposed some serious gaps in flood insurance measures.

The *Queensland Floods Commission of Inquiry* 2012 (see boxed text page 95-96) considered the role of the eight major insurance companies. Accepted claims far outnumbered declined claims, with roughly 73% of claims accepted and only 27% of claims declined.[194] However, the Commission's terms of reference "did not extend to what has emerged as the major complaint: the fact that many people thought they were insured for flood, but have found that the wording of their policies actually excludes their claims".[195]

The *Natural Disaster Insurance Review* 2011 addressed this issue.[196] The *Review* included the announcement of a new policy requiring all home insurance policies to include flood cover. The *Review* found that many Australians were "under-covered" in relation to flooding as current policies allow buyers to opt out of this type of cover, while they are not able to opt out of coverage for similar events - such as bushfire, storm and earthquake.

The new measures attempt to remove inequalities between providers by providing a standard definition of flood that applies to all insurance companies.

Cost of Natural Disasters - Victoria

The cost and expenditure relating to natural disasters is significant and wide reaching. The majority of cost analysis and data on the cost of disasters comes from the insurance industry, however using this data

as a basis of analysis is narrow as most identified costs refer to insured losses, which only includes a fraction of total costs of each event. Insured loss is usually associated with a small range of property and assets from 25-35% for severe fires and storms and only 10% for floods.

In order to provide a relatively standardised and comparative assessment of the cost of natural disasters to government, the figures presented below are based on information and data available from Australian Government Disaster Assist on funds provided in the recovery/relief cycle of a disaster. These amounts stem from payments made under the Australian Government Disaster Recovery Payment.

Figure 36: Cost of Natural Disasters Victoria 2009/12.[197]

Costs Victoria 2009-2012 (Recovery/Relief)		
Disaster/Event	**Disaster Assist payments**	**Insurance council estimates**
Victoria Severe Storms and Floods commencing 26 February 2012 (4,010 claims North/Central)	$4,560,600	$418,670,000
Victoria Severe Weather Melbounre 25 December 2011 (North/Central)	Not disclosed	$680,724,000
Victoria Storms and Flash Flooding 18 December 2011 (North/Central)	Not disclosed	
Victoria Storms 9-10 November 2011 (North/Central)	Not disclosed	$122,465,000
Gippsland Flood July and August 2011 (North/Gippsland		
Victoria Floods 22-23 March 2011 (North/Gippsland)	Not disclosed	
Victorian Floods February 2011 (North/Central/East)		
Australian Government Disaster Recovery Payment (34,309 claims)	$39,521,000	
Disaster Income Recovery Subsidy (1421 claims)	$2,320,190	
Victorian Floods January 2011 (North/Central/East)		
Australian Government Disaster Recovery Payment (34,309 claims)	$39,521,000	$122,465,000
Disaster Income Recovery Subsidy (1421 claims)	$2,320,190	
Victorian Floods September 2010 (North/Central/East)	Not disclosed	
2009 Victorian Bushfires January-February		$1,100,000,000
Recovery Assistance Package	$465,000,000	
Individual Assistance	$82,000,000	
Income Recovery Subsidy for Employers	Not disclosed	
Assistance for Funeral/Memorial and Related Costs	$850,000	
Caring for our Country Bushfire Recovery Program	$10,500,000	
Total disclosed payments	**$646,592,980**	**$2,444,324,000**

Cost per-capita

1999/2001 – $23
2009/2012 – $118

Figure 37:
Cost of Natural Disasters Victoria per-capita.
CfES developed infographic.[198]

As the scientific evidence linking climate change to extreme events is mounting and the likelihood of increased frequency and severity of bushfires, drought and floods is increasing, analysis of the rising costs of relief and recovery tells a compelling story (Figures 36-37).

The critical issues to note here are that although the figures are considerable – $3.1 billion for the events from January 2009 to February 2012 – they are incomplete costs. The insured loss figures are associated with approximately 25-35% of property and assets damaged or lost in severe fires and 10% for floods.

The costs per capita to finance disaster recovery have risen from $23 to $118 in the past decade. However, this figure is narrow and does not incorporate the loss of social and environmental services.

In May 2012 Queensland's biggest insurer Suncorp announced that the cost of premiums would rise dramatically and that it would no longer offer new flood policies in the towns of Roma and Emerald until levees were built. The Local Government Association of Queensland has responded by calling on the large insurers to contribute to the cost of flood mitigation works to take the pressure off governments.[199]

This is an example of the emerging tensions as industry, government and communities tackle the increased frequency and severity of extreme events.

In the following chapter we will consider the risk of bushfire in more detail but it is critical to note that these figures further emphasise the point that will be made in the bushfire chapter – that it is critical to focus more energy and resources on preparedness as our exposure to extreme events increases in a time of climate change.

Former Federal Attorney-General Robert McClelland has described how little Australia spends on disaster prevention as "absolutely shameful", compared with the billions spent on national security and the cost of recovery.[200]

Former Federal Attorney-General Robert McClelland has described how little Australia spends on disaster prevention as "absolutely shameful", compared with the billions spent on national security and the cost of recovery.[200]

CHAPTER **FIVE** - BUSHFIRES

5.1 Bushfires in the landscape

During the Black Saturday bushfires one hundred and seventy three people died. Over 2,000 homes were destroyed and 430,000 hectares burnt.

Our recent history

During the Black Saturday bushfires one hundred and seventy three people died. Over 2,000 homes were destroyed and 430,000 hectares burnt. In addition, in the week preceding the fires, three hundred and seventy four people had their deaths hastened by the extreme heat events which reduced human resilience and turned a broad swathe of the environment into a tinderbox.

These personal tragedies and impacts are extreme, even given our history of exposure to bushfire events.

The Victorian Bushfires Royal Commission, 2009 (VBCR) led to a set of extensive recommendations and triggered major changes in how bushfire responses are planned and response managed. There were also changes introduced to strengthen the consideration of bushfire at different stages of the land use planning process and to better integrate the planning and building systems.

It is important to consider how these events and the phenomena of climate change are linked - to learn from those tragic events. CSIRO *State of the Climate* 2012 builds on the bushfire exposure knowledge in its *State of the Climate* 2010. We are now armed with two authoritative outlines of the climate science as it applies to us in this region. We have also seen in Chapter One of this paper, that notwithstanding the diversion of La Niña events we can only, realistically, expect the trend of increased temperatures to continue, persistent dry spells to test us, and bushfire vulnerability to continue and elevate (Figure 39).

The planet is warming, the climate is changing and Australia is vulnerable. Events that were once worst-case scenarios will become more likely. Governments will face the challenge of identifying areas and factors of extreme risk – both now and in the future - and adapt policy and practical responses to address these risks.

In the wake of the 2009 fires we, as a community, need to better reconcile human reactions and lifestyle choices with developing methods of dealing with forest ecological and climatic patterns. Long term retreat or transition options can be very sensitive matters for communities who might see these approaches as threatening their traditions and choices. Although future projected risks can be hard to visualise, the consequences, for example, of relocation a town, are not.