



Department of
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Office of Water

Hawkesbury-Nepean Valley Flood Management Review Stage One

Summary Report

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Hawkesbury-Nepean Valley Flood Management Review Stage One — Summary Report

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Cover image: Penrith Weir and fishway on the Nepean River, Penrith

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Executive summary

The Hawkesbury-Nepean Valley Flood Management Review (the Review) commenced in early 2013, in response to the NSW Government's adoption of *The State Infrastructure Strategy 2012-2032* and ongoing community concerns about flood risk. The Summary Report presents the key findings of the first stage of the Review and the outlines the next steps for improved flood risk management in the Hawkesbury-Nepean Valley.

An Interagency Committee was established to undertake Stage One of the Review, comprising representatives of the Office of Water, Sydney Catchment Authority, Office of Environment and Heritage, Department of Finance and Services, NSW Treasury, the NSW State Emergency Service, Department of Premier and Cabinet, the Department of Planning and Infrastructure and the Department of Trade and Investment.

The scope of the Review has been broad, as required by its terms of reference. Stage One of the Review evaluated the adequacy and effectiveness the current flood management arrangements in the Hawkesbury-Nepean Valley. The focus was to identify the key issues, gaps and potential solutions for more detailed investigation and cost benefit analysis in Stage Two.

The Stage One Review adopted a strategic approach that explored all feasible flood mitigation options with the potential to reduce flood risk to life and property. The Review considered that flood mitigation covers the full range of measures to reduce flood risk, including governance arrangements, policy settings, planning, community education and infrastructure. The overarching objective of the Review was to develop a package of options to ensure the Hawkesbury-Nepean Valley is strategically managed so the community is more resilient to flood risk. This aligns with Goal 28 of the NSW 2021 Plan which aims to '*ensure NSW is ready to deal with major emergencies and natural disasters*'.

Albeit an infrequent event, a severe flood in the Hawkesbury-Nepean Valley would lead to economic, social and other impacts of State significance. There is no simple solution or single infrastructure option that can address all of the flood risk in the Hawkesbury-Nepean Valley. This risk will continue to increase with projected population growth unless flood mitigation options are adopted. However, the Review found it is possible to reduce and manage the risks through a combination of flood prevention, preparedness, response and recovery.

While infrastructure options can reduce but not eliminate the risk to life and property, effective evacuation is the only measure that can guarantee to reduce the risk to life, as the potential for widespread flooding will continue for extreme rare but large flood events. Evacuation of the Valley in a flood event needs to be supported by an adequate regional road network and community education and awareness. Previous community surveys conducted by the State Emergency Service indicate that less than 10 per cent of people have a plan for what to do in a flood and about 20 per cent of people are unlikely to evacuate when directed to do so.

Enhancements of the road network are needed to meet the evacuation requirements of any future population growth in the Valley. Several potential options have been identified for road augmentation, including upgrading the M4 motorway or the Great Western Highway. These would need to be confirmed within the context of regional road network planning.

Further detailed investigation is required to support a more integrated and coordinated approach to reduce overall flood risk in the Valley. The Review has identified a need for enhanced community education on flood risk and response. A risk-based framework that considers the full range of potential flood events should be adopted, encompassing planning systems, flood

mitigation infrastructure and emergency response. More consistent flood modelling, data and information are also required for use across the region.

The Review considered all practical flood mitigation infrastructure options to reduce peak flood inflows, drain floodwaters from the basin more quickly, or protect people and property within the floodplain. The options included:

- levees
- downstream diversion channels
- dredging of the river
- raising Warragamba Dam
- changing the operation of current Warragamba Dam.

Preliminary analysis indicates that raising Warragamba Dam wall by 15 to 23 metres would provide the greatest overall reduction in flood frequency and peak height, compared to dredging or diversion channels. The downstream options were found to be of a similar cost to raising the Dam wall but only providing limited mitigation benefit. Levees were found to only provide limited local protection due to the extreme depth of flooding in the Valley.

The option to raise Warragamba Dam wall will reduce flood frequency and peak height but will not eliminate the flood risk from the Hawkesbury-Nepean Valley. Controlled releases of temporarily stored floodwaters from the Dam after a flood event could also extend minor downstream flooding for up to several weeks, potentially resulting in longer inundation of low lying bridges and roads. Raising the dam will be costly and could take ten years to complete. Raising the dam wall will also have a number of environmental impacts, including temporary inundation of upstream National Park and World Heritage areas in large flood events.

The next stage of the Review will undertake a more detailed cost benefit analysis of specific flood mitigation and road infrastructure options, and progress the priority actions identified in this Summary Report to reduce flood risk in the short and longer term.

Contents

Executive summary.....	i
Contents	iii
The Review	1
Background.....	1
Terms of Reference	3
Flooding in the Hawkesbury-Nepean Valley.....	4
Unique nature of the floodplain.....	4
Historic flooding in the Hawkesbury-Nepean Valley	6
Current management of floods in the Hawkesbury-Nepean Valley.....	7
Review Approach.....	9
Review Investigations	11
Review Findings.....	13
Strategy A – Enhance flood mitigation infrastructure	14
Strategy B – Enhance flood evacuation capacity of transport infrastructure	16
Strategy C – Establish governance arrangements that support more integrated and effective management of flood risk.	17
Strategy D – Collection of post-event flood data and intelligence.	17
Strategy E – Improve recovery planning.....	18
Strategy F – Improve emergency management, planning and implementation.....	18
Strategy G – Improve community education on flood risk and response.	19
Strategy H – Improve accessibility of flood risk information.	19
Strategy I – Improve flood modelling framework and tools.	20
Strategy J – Improve consideration of flood risk in land use planning.....	20
Conclusion and next steps	22

The Review

Background

In 2012, Infrastructure NSW (INSW) proposed a range of specific infrastructure investments and reforms over a 20-year period. In its 'First Things First – The State Infrastructure Strategy 2012-2032' report, INSW recommended the need for a review of flood mitigation options for the Hawkesbury-Nepean Valley as a high priority for NSW Government consideration.

At the same time, community awareness of flooding issues, and the potential role of dams in mitigating the effects of floods, was raised by significant flood events in south-east Queensland, Victoria, and at various locations across NSW.

Following its review of the INSW recommendations, the NSW Government released its State Infrastructure Strategy in December 2012 identifying the State's infrastructure delivery and reform priorities over the next five years. One of the key projects in the strategy was a review of major flood mitigation options available in the Hawkesbury-Nepean Valley, including options for raising Warragamba Dam wall and road upgrades.

In response to these issues, in December 2012 the NSW Government commissioned the Hawkesbury-Nepean Valley Flood Management Review (the Review). The Review is being conducted in a staged approach:

- **Stage One** outlined in this Summary Report, is an assessment of the current status of flood management, land use planning and emergency response for the Hawkesbury-Nepean Valley, and short-lists flood mitigation options to be investigated in Stage Two.
- **Stage Two** of the Review will progress the identified priority actions and will undertake a detailed cost benefit analysis of the short-listed mitigation options from Stage One. This would detail and determine whether there are viable flood mitigation strategies that can improve on existing floodplain management in the Valley.

An Interagency Committee was established to undertake Stage One of the Review, comprising representatives of the Office of Water, Sydney Catchment Authority, Office of Environment and Heritage, Department of Finance and Services, NSW Treasury, the NSW State Emergency Service, Department of Premier and Cabinet, the Department of Planning and Infrastructure and the Department of Trade and Investment.

The study area for the Review was defined the Hawkesbury-Nepean Valley floodplain as the riverine floodplain of the main river from Warragamba Dam to Brooklyn Bridge with consideration of the entire catchment for calculating inundation of the floodplain. This covers the two most populated floodplains in the Hawkesbury-Nepean catchment, namely the Penrith floodplain and the Richmond-Windsor floodplain, in the rapidly growing western Sydney region. The sub-catchments and location of major towns are shown in Figure 1.

The Review did not examine flooding upstream of Warragamba Dam and in the Nepean River upstream of Wallacia, nor localised flash flooding from smaller intense storm events. These areas do not have the potential regional impacts of flooding of the Penrith and Richmond-Windsor floodplains.

This Summary Report presents the key findings and proposed next steps arising from Stage One of the Review. Further details of the Review findings can be found in the Review Report.



Figure 1: Sub-catchments of the Hawkesbury-Nepean Valley

Terms of Reference

The terms of reference for Stage One of the Review were:

- Describe current management arrangements in relation to flood mitigation in the Hawkesbury-Nepean Valley and evaluate their adequacy and effectiveness. Flood mitigation includes flood emergency planning and response, land use planning and structural measures for Warragamba Dam and downstream of Warragamba Dam.
- Consider what factors have changed since the current management arrangements were put in place and, in particular, to consider the influence of the Sydney North West and South West Growth Centres on the changing risk profile within the Valley.
- Collate current information and flood modelling to assist the Review, and scope any additional modelling required.
- Describe the management options that have previously been examined to further mitigating the impacts of flooding in the Valley, and review whether any of these options need re-assessment.
- Explore all options to improve flood mitigation strategies and processes in the Valley, including but not limited to:
 - assessment of current flood evacuation routes and whether upgrades are required
 - assessment of the appropriateness of current urban planning policies
 - consideration of current governance arrangements for flood planning and response
 - assessment of whether changes to the operation and configuration of key processes of water infrastructure, such as Warragamba Dam, are required.

Flooding in the Hawkesbury-Nepean Valley

Unique nature of the floodplain

The natural characteristics of the Hawkesbury-Nepean Valley make it particularly susceptible to significant flood risk. The combination of the large upstream catchments and narrow downstream sandstone gorges results in floodwaters backing up behind these natural ‘choke points’. Floodwaters rise rapidly causing significant flooding both in terms of area and depth as shown in Figure 2. This ‘bathtub effect’ is different to other coastal floodplains and river valleys where the Valley progressively widens as the river approaches the river mouth.

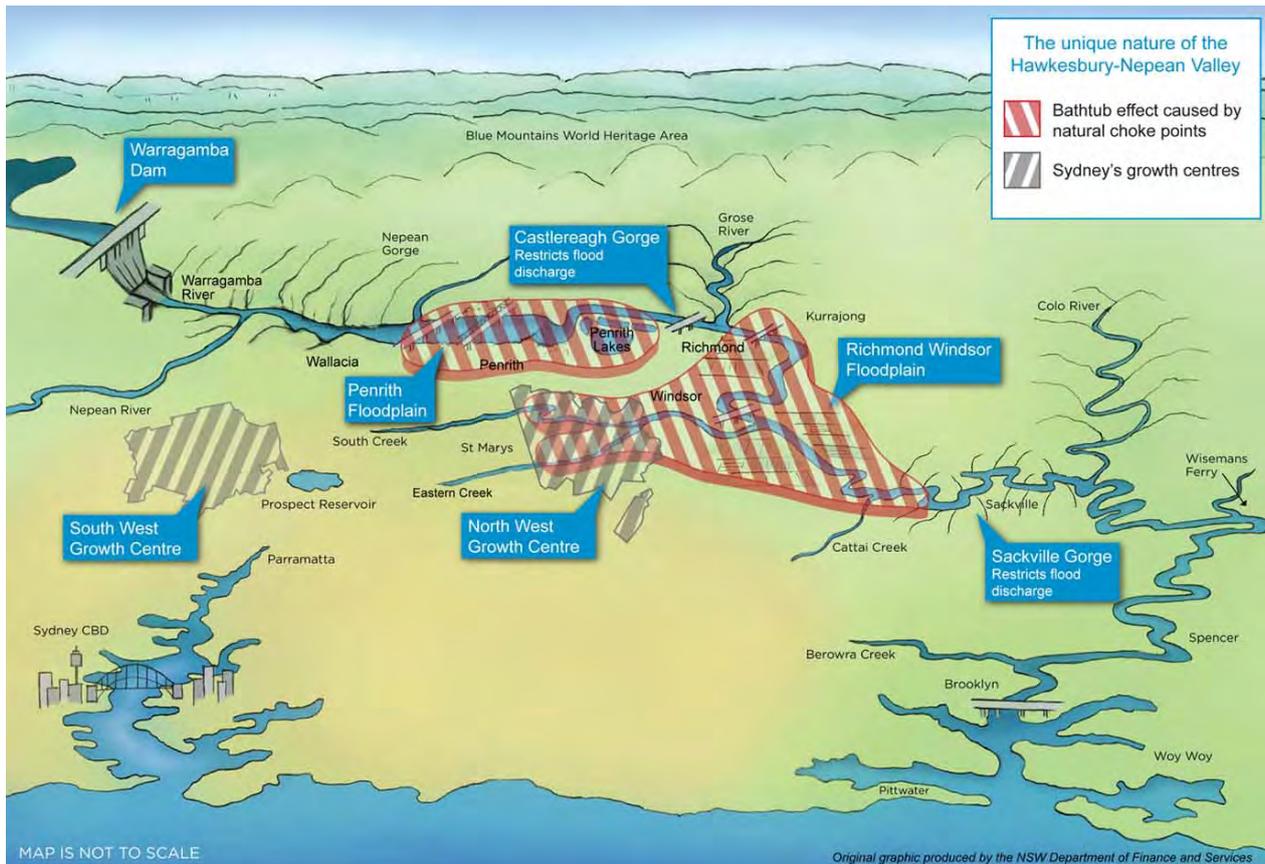


Figure 2: The two main floodplains in the Hawkesbury-Nepean Valley

For significant flood events, the flows coming into the Hawkesbury-Nepean River and its tributaries are much higher than the flows that can flow out of the Castlereagh gorge between Penrith and Richmond, and the 100 kilometre long Sackville gorge between Sackville and about Brooklyn. This causes the ‘bathtub effect’ and floodwaters spill out of the main river and flood the Valley. The towns affected by flooding are Penrith and Emu Plains in the upper floodplain, Richmond, North Richmond, Windsor, McGraths Hill, Bligh Park, Pitt Town and Wilberforce in the lower floodplain, together with a number of small communities along the Sackville gorge down to Spencer.

Hydrologists describe floods in terms of their chance of certain level of flood occurring in any year. Floods occur randomly, and the chance of a flood occurring in any year is not affected by floods that have previously occurred. Therefore a 1 in 100 chance year flood has a one per cent chance of occurring each and every year. Previous flood events do not make this flood more or less likely to occur.

The worst flood that could conceivably occur is referred to as the Probable Maximum Flood (PMF). It is the PMF that defines the extent of the floodplain and the potential area to be evacuated. Management of risks from flooding, including danger to personal safety, needs to consider all floods up to the PMF although such an event is extremely rare.

The combined effect of these ‘bathtubs’ and ‘gorges’ is that during heavy rain flood water enters the floodplain much faster than it can escape, and so water levels rise quickly on the floodplain. Flood levels on the Hawkesbury-Nepean floodplain can rise at a rate of half a metre an hour for several hours, and can even rise at over one metre per hour for shorter periods. At these rates of rise of floodwaters, a house on the lower areas of the floodplain could be submerged in six hours or less.

Another effect of the ‘bathtubs’ and ‘gorges’ is that the depth of floodwaters can get much deeper than most other floodplains in NSW, or even Australia. Figure 3 shows a comparison of the differences in flood levels and flood risk between the Hawkesbury River at Windsor and two other typical floodplains in NSW. In floodplains such as those in Lismore, on the NSW north coast and Nyngan, in inland NSW, the difference between a 1 in 100 chance per year flood is about two to three metres. At Windsor, in the Hawkesbury-Nepean floodplain, this difference in flood level is about nine metres.

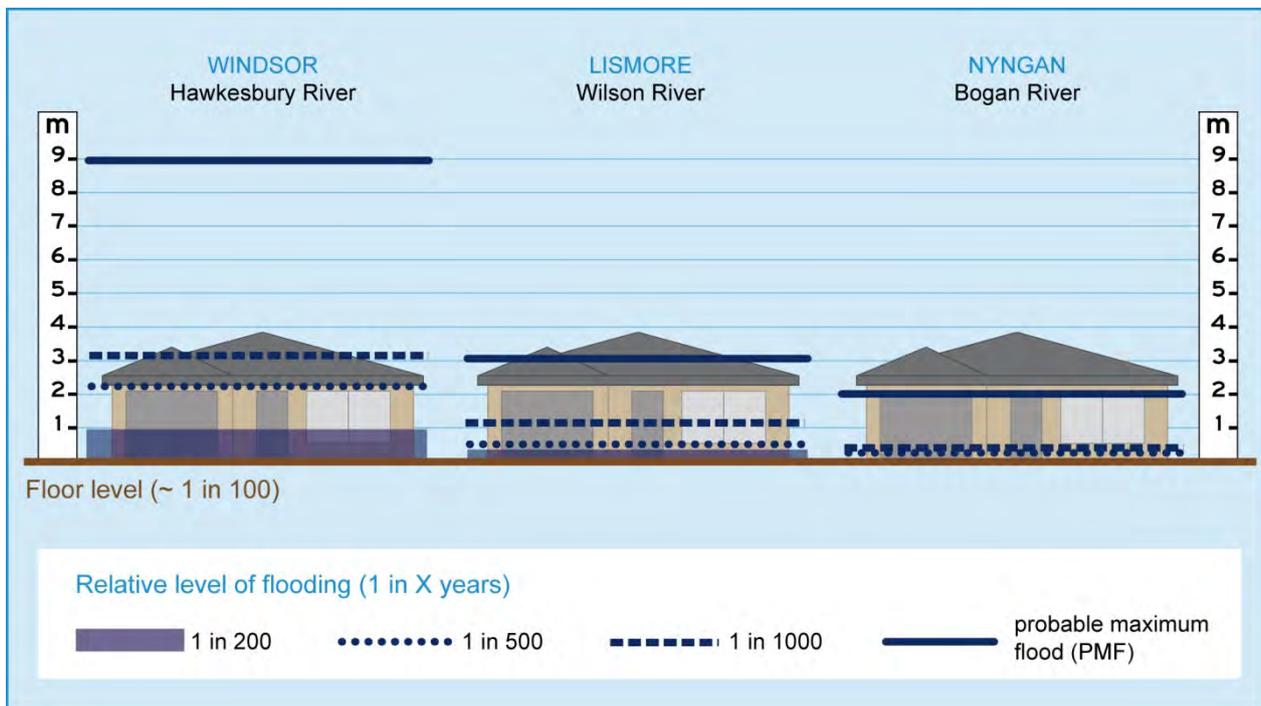


Figure 3: Comparison of the differences in flood levels and flood risk between the Hawkesbury River at Windsor and other floodplains

The population of the Hawkesbury-Nepean Valley is larger than many other coastal catchments in NSW, and is continuing to grow. An estimated 73,000 people are currently living in areas prone to flooding from the Hawkesbury-Nepean River.

The floodplain is also in the heart of the Western Sydney region, one of Australia’s largest and most diverse economies with an annual gross regional product of about \$95.6 billion in 2010-11. Large flood events could impact the entire NSW economy by affecting transportation routes and utilities outside the flooded area.

The Metropolitan Strategy for Sydney, currently being prepared, will set out the framework for Sydney's growth to 2031. The draft Strategy sets out a projected population increase in the Metropolitan West subregion (most of which is located in the Hawkesbury-Nepean Valley) of 89,000 by 2031, with a target of at least 39,000 new homes and 37,000 new jobs. Many of these homes and areas of employment are located in the Hawkesbury-Nepean floodplain, which encompasses large parts of the North West Growth Centre.

Historic flooding in the Hawkesbury-Nepean Valley

The Hawkesbury-Nepean Valley has a long history of flooding. The largest flood on record in the Valley occurred in 1867 when the river level reached 19.7 metres above mean sea level (referred to Australian Height Datum or AHD) at Windsor. Overall, this flood has been estimated to be around a 1 in 200 to 1 in 500 chance per year flood.

Analysis of sediments within the Nepean gorge shows that prior to European settlement at least one flood reached or exceeded the level of a flood with about a 1 in 1,000 chance per year. Such a flood would about 20 metres above mean sea level at Windsor. Table 1 shows the recorded and modelled flood levels in the Hawkesbury-Nepean Valley and an estimate of the 'size' of the historical flood in terms of 'chance per year'.

Chance per year	Penrith (m AHD)	Windsor (m AHD)	Previous occurrence(s)
1 in 5	20.1	11.1	1992, 1986, 1975, 1956, 1952 and 11 other times
1 in 30	23.9	13.3-14.5	1990, 1978, 1964, 1956 and 12 other times (8 times from 1806-1819)
1 in 40	24.4	15.0	1961, 1799
1 in 100	26.0	17.2	No record
1 in 200	26.9	19.7	1867
1 in 500	27.6	20.3	At least once before 1788
1 in 1,000	28.5	21.7	No record
probable maximum flood	32.1	26.4	No record

Table 1: Recorded and modelled flood events in the Hawkesbury-Nepean River Valley

Each flood event in the Hawkesbury-Nepean is different due to the different amounts of rainfall and different timing of rainfall across the catchment. The contribution of each subcatchment to flooding in Hawkesbury-Nepean Valley varies for every flood event.

Minor to moderate flood events can occur from localised rainfall downstream of Warragamba River, but due to its large catchment the Warragamba River is the largest contributor for major flood events on the Penrith and Richmond-Windsor floodplains (see Figure 1). Analysis of available records for the 1867 flood suggests that the Warragamba River and possibly the Grose River were the principal sources of floodwater in this event, with relatively small contribution from the upper Nepean River.

Between late 2011 and early 2012 New South Wales experienced broad scale and prolonged flooding, with the State Emergency Service declaring approximately 80 per cent of the State as flood affected. During this wet period the Hawkesbury-Nepean Valley experienced minor 1 in 3

year flooding in March 2012, with Warragamba Dam spilling for the first time in 14 years. A minor flood of similar size occurred in June 2013. These recent events, although relatively minor, caused considerable downstream disruption. Flood evacuation warnings were issued for low lying areas, including caravan parks along the Hawkesbury River from Windsor to Sackville. Yarramundi Bridge was closed, as were the Sackville, Lower Portland, Webbs Creek and Wisemans Ferry ferries.

Current management of floods in the Hawkesbury-Nepean Valley

Management of the flood risk in the Hawkesbury-Nepean Valley includes **prevention** or mitigating the impact of flood, planning and **preparedness** for flooding, as well as **response** to and **recovery** from floods. Figure 4 illustrates how flood risk is managed in the Hawkesbury-Nepean Valley which involves local, state and Australian government agencies. Responsibilities for flood risk management in NSW are identified in a range of specific legislation and in the *NSW Flood Prone Land Policy* and NSW Government’s 2005 *Floodplain Development Manual – the management of flood liable land*.

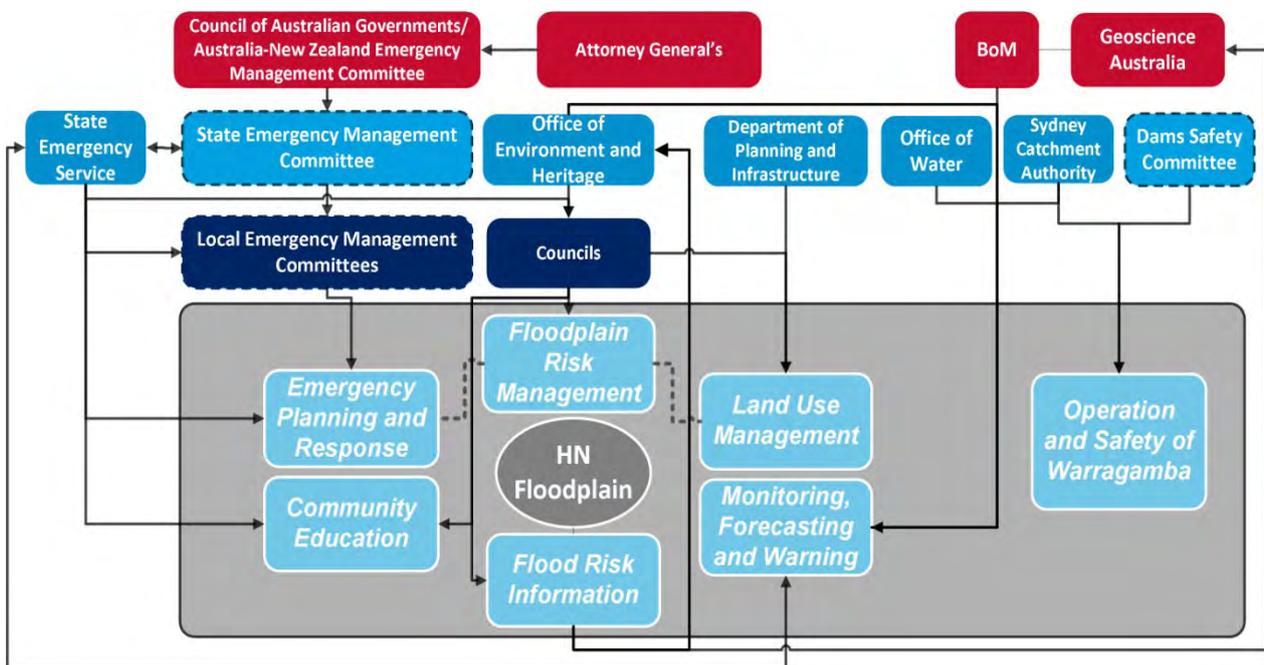


Figure 4: Current flood risk management arrangements in the Hawkesbury-Nepean Valley

Prevention involves regulatory and physical measures to ensure that emergencies are prevented, or reduced in incidence or severity. Prevention not only involves large scale flood mitigation options such as those relating to Warragamba Dam or downstream of the Dam, but also flood emergency planning and response, land use planning and community flood awareness.

Local government is primarily responsible for local prevention activities through developing and implementing floodplain risk management plans and informing the community about flood risk. Local government’s role also includes land use planning to manage flood risk in new and existing areas, and local flood mitigation works to reduce risk to existing development where warranted.

The NSW Government provides councils with technical support from flood risk management experts in the Office of Environment and Heritage and financial assistance through the State Floodplain Management Program managed by the Office of Environment and Heritage.

The NSW Office of Water is the key government agency for the management of the State's surface water and groundwater resources. Its functions include the development of research and policy to manage the use of water between towns, users and the environment. The NSW Office of Water is also responsible for monitoring the quantity, quality and health of water ecosystems, including the Hawkesbury-Nepean catchment.

The Office of Water, Office of Environment and Heritage, Sydney Catchment Authority and Sydney Water manage river level gauges that are essential to warning the community about a flood threat in the Hawkesbury-Nepean Valley. These agencies must report the gauge information to the Commonwealth Bureau of Meteorology. While these agencies currently maintain these gauges, there is no regulatory requirement for them to do so for flood information purposes.

The Department of Planning and Infrastructure provides guidance on consideration of flood constraints in strategic planning instruments and leads regional and subregional planning processes. This includes the development of the draft Metropolitan Strategy for Sydney which provides the framework for Sydney's growth to 2031.

Local councils and the NSW State Emergency Service have roles in educating the community about flood risk and how to respond to a flood threat.

Preparedness involves arrangements or plans to ensure the resources and services needed to cope with the effects of an emergency can be efficiently mobilised and deployed. The State Emergency Service is responsible for emergency management planning for floods and for implementing these plans, including the Hawkesbury-Nepean Flood Emergency Sub Plan 2013. These plans identify roles and responsibilities during a flood emergency. They are developed in conjunction with other relevant areas of state and local government and are approved by the State Emergency Management Committee. The Hawkesbury-Nepean Flood Emergency Sub Plan 2013 is the only state level Sub Plan to the NSW Emergency Management Plan developed due to the unique flood risk in the Hawkesbury-Nepean Valley.

Response refers to actions taken in anticipation of, during, and immediately after an emergency, to ensure that its effects are minimised and that people affected are given immediate relief and support. The State Emergency Service is also responsible for these flood response or combat activities including coordinating support from functional areas, local government and other agencies in response to flood, as well as coordination of welfare of affected communities. The State Emergency Operations Controller works with the State Emergency Service to coordinate response.

The Sydney Catchment Authority operates Warragamba Dam to protect the safety of the dam and Sydney's water supply, and provides advice and information to the State Emergency Service and Bureau of Meteorology on the status of Warragamba Dam and the Sydney Catchment Authority's flood gauges. The Sydney Catchment Authority is a water supply authority that operates and maintains major dams in the Hawkesbury-Nepean catchment, including Warragamba Dam in accordance with dam safety requirements.

Recovery after major floods in the Valley is addressed through the Hawkesbury-Nepean Flood Emergency Sub Plan 2013 which includes arrangements to form a Region Recovery Committee during or following a flood event. This Committee would develop a Recovery Action Plan and coordinate the activities of agencies responsible for delivering services and assist affected communities to restore normal activities and functions.

Review Approach

The Review adopted a holistic approach that explored all options with the potential for reducing flood risk to life and property in the Hawkesbury-Nepean Valley.

The overall aim of the Review was to ensure:

The Hawkesbury-Nepean Valley is strategically managed so the community is more resilient to flood risk.

This is consistent with Goal 28 of the NSW Government's 10-year strategic business plan (known as NSW 2021), which states: *Ensure NSW is ready to deal with major emergencies and natural disasters.*

The Review determined that the following three outcomes are required to support this aim:

- *keeping the community safe* – the risk to life, property and infrastructure within existing development in the Hawkesbury-Nepean Valley is managed strategically
- *community awareness* – an informed community that understands the risks of living with floods in the Hawkesbury-Nepean Valley
- *sustainable future growth* – future growth and development in the Hawkesbury-Nepean Valley is strategically managed considering the flood risk

Figure 5 illustrates the guiding principles and key inputs to the aims and desired outcomes of the Review. In particular, the 'National Disaster Resilience Statement' released by the Council of Australian Governments (COAG) in 2009, and the subsequent 2011 *National Strategy for Disaster Resilience* identified the important roles of government in helping communities to prepare for, respond to, and recover from natural disasters such as severe floods. These roles were applied by the Review specifically in relation to flood risk management, as follows:

- *preparing for extreme events* – supporting individuals and communities to prepare for extreme flood events
- *emergency response* – ensuring the most effective, well-coordinated response from our emergency services and volunteers when disaster hits
- *informing the community on flood response* – having clear and effective education systems so people understand what options are available and the best course of action in responding to a hazard as it approaches
- *informing the community on flood hazard/risk* – having effective arrangements in place to inform people about how to assess risks and reduce their exposure and vulnerability to hazards
- *land use planning* – developing and implementing effective, risk-based land management and planning arrangements
- *recovery and learning* – working in a swift, compassionate and pragmatic way to help communities recover from devastation and to learn, innovate, and adapt in the aftermath of disastrous events.

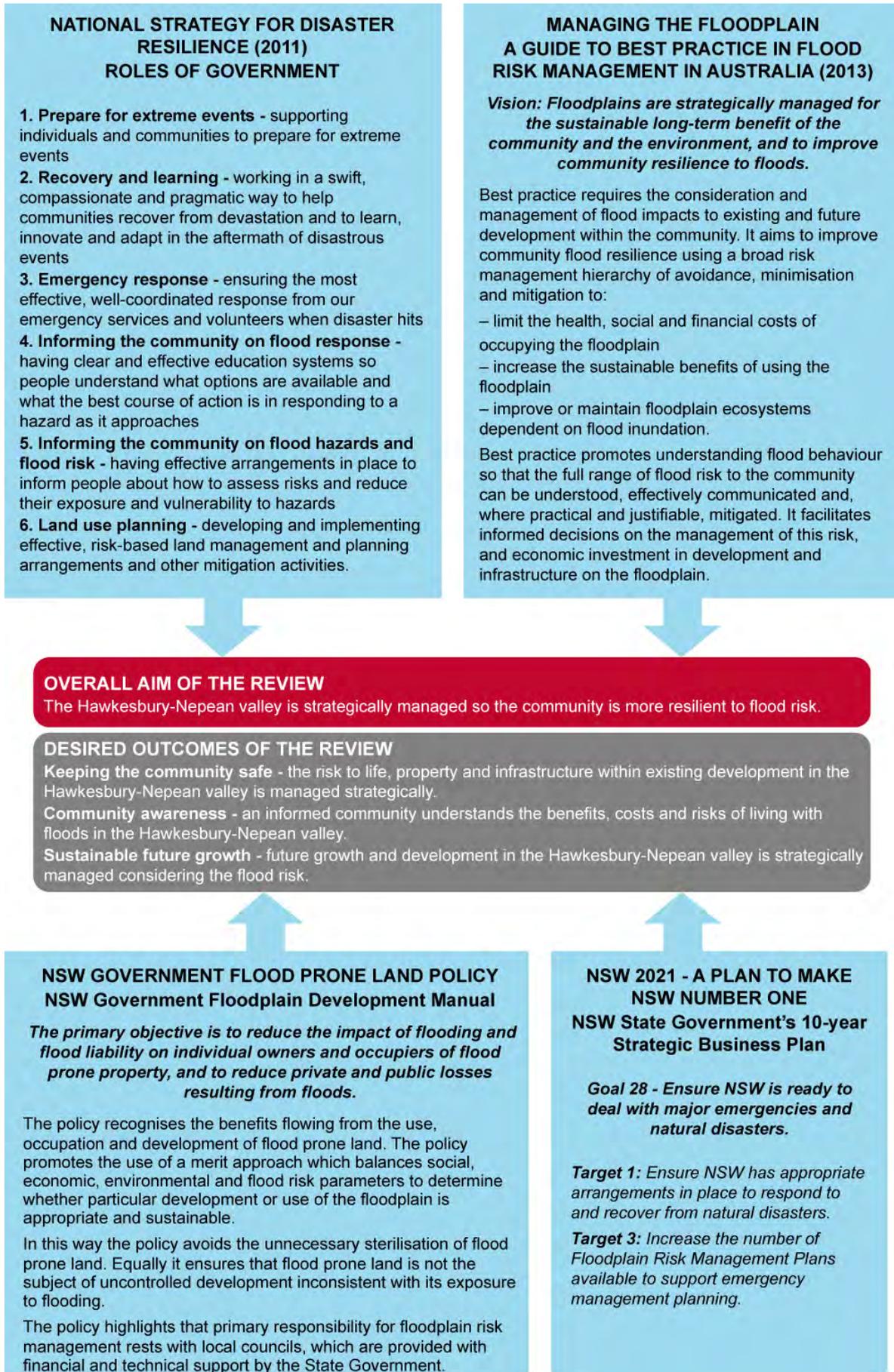


Figure 5: Guiding principles and key inputs to Review aims and desired outcomes

The Review adopted the guiding principles for the roles of government in disaster resilience and best practice in flood risk management shown in Figure 5, to assess the adequacy and effectiveness of existing flood management arrangements including infrastructure, non-infrastructure and governance solutions to identified issues or problems.

Specialist working groups were established to examine the major elements of flood management: flood emergency planning and response, flood mitigation, land use planning, flood damage assessment and flood modelling and monitoring. The roles of these working groups included identifying, assessing and evaluating the adequacy and effectiveness of the current situation and undertaking a gap analysis to identify the most important issues or problems requiring improvement.

Review Investigations

The Review had the benefit of extensive previous investigations into flood mitigation options for the Hawkesbury-Nepean Valley, including those from the *1995 Proposed Warragamba Flood Mitigation Dam Environmental Impact Statement*, the *1997 Achieving a Hawkesbury-Nepean Floodplain Management Strategy*, and the *2012 Hawkesbury City Council Floodplain Risk Management Study and Plan*. A key component of Stage One of the Review was to review, verify and update the information from these previous investigations using the most up-to-date information.

New investigations undertaken or commenced for the Stage One Review included:

- A review of the flood hydrology of Warragamba Dam and the downstream catchment using the latest developments in flood estimation
- An expert review of all the proposed and any new flood mitigation infrastructure for the Valley
- An engineering feasibility assessment of short-listed flood mitigation infrastructure for the Valley
- Updated flood damage assessment that estimates the population requiring evacuation and flood damage from large floods in the Hawkesbury-Nepean Valley
- A review of the flood planning and emergency response governance in the Valley.

The **regional flood estimates** for the catchment downstream of Warragamba Dam was remodelled by specialist flood hydrology consultants. The model estimated the area inundated under a range of floods up to the probable maximum flood with the current Warragamba Dam and range of short-listed mitigation options. This was the first complete revision of regional flood estimates since late 1980s. This new modelling found that floods at the current default planning level (1 in 100 year chance of occurring) and the possible maximum flood are largely consistent with previous estimates as presented in Table 1. Further work is required to peer review these new estimates and then to integrate the new estimates into regional and local flood planning.

A large range of **flood mitigation infrastructure options** have previously been proposed and examined for the Hawkesbury-Nepean Valley. All of these options were identified and reviewed as part of Stage One of the Review. No feasible new flood mitigation options for the Valley were identified.

A short-list of flood mitigation options were developed based on either the potential for significant flood mitigation or had a certain level of support from stakeholders. Pre-feasibility designs for constructing these mitigation options were developed, and these designs were used to estimate their order of magnitude costs as well as their likely effectiveness on reducing flood levels in the Valley.

The overall finding was that raising Warragamba Dam is the most effective at reducing regional flood damages across the Valley, primarily due to the large volume of floodwater that can be temporarily stored and released in a controlled manner. The investigation indicated that since Warragamba Dam was modified with an auxiliary spillway in 2002 it may be possible to provide similar flood mitigation benefits as the 23 metre raising proposed in 1995 with a lower raising of the dam wall, but detailed engineering and environmental investigations will be required to optimise any raising of Warragamba Dam.

Other options, such as changing the operation of the current Warragamba Dam or excavation of downstream diversion channels, were found to provide less or in some cases negligible flood mitigation benefits and most had significant financial costs and environmental impacts.

However, these large-scale flood mitigation options only reduce the chance of large floods occurring, and modelling has indicated that large scale evacuation will still be required for extreme floods. In addition, smaller floods that cause low-lying bridges to be cut and flooding of semi-rural land can be caused by local downstream rainfall will not be mitigated.

An **updated flood damages assessment**, undertaken by specialist floodplain management consultants, was commenced as part of Stage One of the Review. Only preliminary results were available for inclusion in Stage One of the Review. Initial results have found that there have been significant increases in the number of people that will require evacuation since the previous assessment was undertaken in the 1990s. This, combined with general low level community flood awareness and rapidly rising and deep floodwaters, creates a significant risk to life during extreme flood events. The updated flood damages assessment will inform the cost benefit analysis work in Stage 2 of the Review.

Review Findings

The Review developed ten potential strategies for further consideration to improve flood risk management in the Hawkesbury-Nepean Valley. These ten strategies have been grouped under three major categories:

Infrastructure – which includes works that can be built to mitigate floods

- Strategy A. Enhance flood mitigation infrastructure
- Strategy B. Enhance flood evacuation capacity of transport infrastructure

Governance – which includes measures that can reduce the impacts of floods through improved preparation and management

- Strategy C. Establish governance arrangements that support more integrated and effective management of flood risk
- Strategy D. Collection of post-event data and flood intelligence
- Strategy E. Improve flood recovery planning

Non-infrastructure – which includes measures for better flood emergency response and planning, land use planning and flood modelling

- Strategy F. Improve emergency management, planning and implementation
- Strategy G. Improve community education of flood risk and response
- Strategy H. Improve accessibility of flood risk information
- Strategy I. Improve flood modelling framework and tools
- Strategy J. Improve consideration of flood risk in land use planning

Figure 6 shows how each of these strategies have been linked back to the overall aims and desired outcomes of the Review as well as the roles of government as outlined in the *2011 National Strategy for Disaster Resilience*.

A summary of each of the strategies and the proposed next steps are presented below.

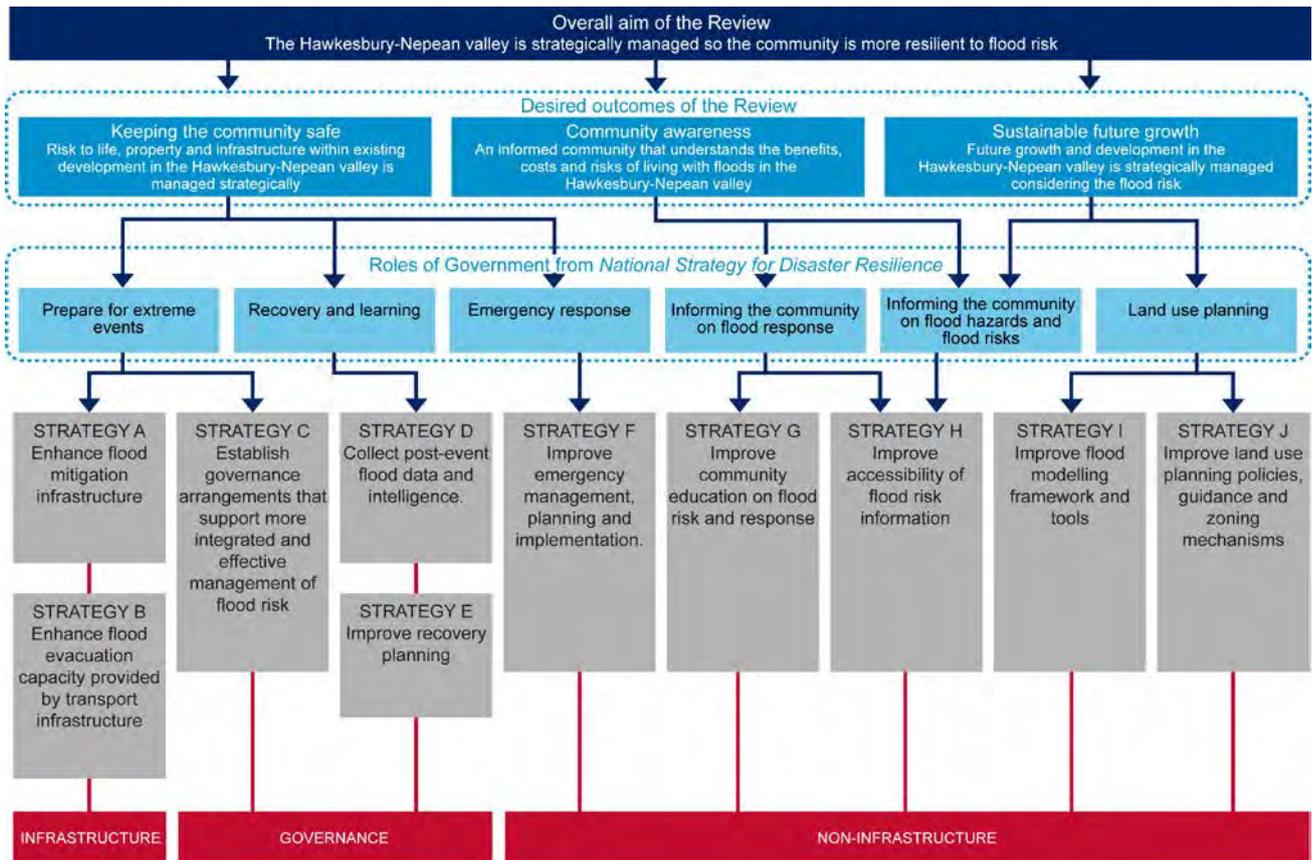


Figure 6: Structure of the Review Findings

Strategy A – Enhance flood mitigation infrastructure

The Review found that flood mitigation infrastructure can reduce, but not eliminate, the risk of flooding by lowering flood levels of particular sized flood event. The Review considered a number of flood mitigation options to hold back floodwaters or drain floodwaters from the basin more quickly. The options included:

- levees;
- downstream diversion channels
- dredging of the river
- raising Warragamba Dam
- changing the operation of current Warragamba Dam.

The Review found while the presence of Warragamba Dam and the Upper Nepean dams provide some flood mitigation, they are not designed or operated as flood mitigation dams, and there is currently no significant flood mitigation infrastructure in the Hawkesbury-Nepean Valley.

The Review considered two options for raising Warragamba Dam, by 23 and 15 metres. The Review found both options for raising Warragamba Dam had the most potential to reduce flood risk at both the Penrith and the Richmond-Windsor floodplains over other water infrastructure options. Raising of Warragamba Dam would not eliminate the need to evacuate as the floodplains will still be inundated in extreme floods, but raising the dam would delay the flood peak, allowing for evacuations to occur with more certainty and fewer false alarms.

The contribution of each subcatchment to flooding at Windsor is different for each flood event. This means that, even with a raised Warragamba Dam, significant flooding at Windsor could occur from localised rainfall from the Nepean, Grose and Colo rivers catchments downstream of Warragamba Dam.

Whilst flood mitigation dams reduce the frequency of major flood events by temporarily storing flood waters, after a flood event these waters must be released to recover the airspace for future mitigation events. The effect of such controlled releases could extend minor flooding for up to several weeks, resulting in inundation of low lying bridges and roads.

Due to time constraints the Review only assessed the flood mitigation potential of raising of the Warragamba Dam wall crest by 15 and 23 metres. Pre-feasibility construction costs and reduction of flood levels have been calculated. However, economic, environmental and social costs and benefits have not been included at this stage. Detailed cost benefit analysis will be conducted for the options for the raising of Warragamba Dam in Stage Two of the Review.

The Review also assessed the potential for changing the operation of Warragamba Dam at its current configuration to provide for flood mitigation. Options examined different ways to create airspace to capture a portion of incoming floodwaters, by reducing the full supply level of the dam, 'pre-releasing' water if major flood inflow are expected based on forecast rainfall, or 'surcharging' the dam level during floods using the dam's gates.

The Review concluded that only minor floods, below levels where significant damages occur, could be mitigated using the current dam unless its role as the main water supply to Sydney was compromised. It was also concluded that 'pre-releasing' of water from the dam prior to a flood was limited due to the inaccuracies in rainfall forecasts beyond three days, and the potential to increase or prolong downstream flooding.

'Surcharging' the water level in the dam by raising the radial gates to follow the rising water levels during flood events is practised by State Water for a number of their dams. The Review found that there could be significant risks of adopting this approach for Warragamba Dam. The small number of radial gates on the dam increases the risk of gate failure, which could result in increased downstream flooding and the potential loss of large amounts of water from the dam.

Reducing the full supply level of Warragamba dam provides only a reduction in minor flooding and needs to be assessed against the impacts on Sydney's water supply. The Review considered lowering the full storage level by two, five and twelve metres, and concluded that the two metre lowering had minimal flood mitigation benefits, and the twelve metre lowering would have significant impacts on Sydney's water supply.

Stage Two of the Review will further analyse surcharging the gates and reducing the full supply level for the mitigation of smaller floods, including the operational risks and the impact on Sydney's water supply.

Downstream flood mitigation options aim to increase the rate at which floodwater can drain away from the floodplain. The Review assessed a broad range of these options, and estimated direct construction costs and flood mitigation benefits for a short-list of options. The options assessed were:

- a diversion channel from the Hawkesbury River at Wilberforce to Currency Creek, which then discharges into then Hawkesbury River at Sackville
- a diversion channel on the Hawkesbury River from Sackville to the Cumberland Reach

- a diversion channel on the Hawkesbury River from Sackville to Leets Vale
- dredging of the Hawkesbury River from Windsor to Wisemans Ferry.

The diversion channel from Sackville to Leets Vale was calculated to have a construction only cost of more than five billion dollars and as such was not considered feasible. The Currency Creek diversion channel and dredging of the Hawkesbury River have similar costs to raising Warragamba Dam when land acquisition and environmental costs were included, but had less than half the benefits in terms of flood mitigation at Windsor and negligible benefits at Penrith. The Sackville to Cumberland Reach diversion channel was considerably cheaper but had minimal impact on flooding at Windsor. The Review agreed that for comparison purposes a more complete costing and environmental assessment of the Currency Creek diversion channel and dredging of the Hawkesbury River should be completed in Stage Two.

Strategy B – Enhance flood evacuation capacity of transport infrastructure

The Review found that large numbers of people need to be evacuated from the Hawkesbury-Nepean Valley during large flood events. The undulating nature of the floodplain leads to roads being progressively cut and the formation of isolated flood islands as flood levels rise which can be totally covered with floodwater if levels continue to rise.

Evacuation modelling undertaken for the Windsor township has identified that a number of intersections on local roads may create previously unknown bottlenecks during flood evacuation. More comprehensive modelling of this type is required to determine the extent of this problem across the floodplain, and what opportunities exist to address such bottlenecks through cost effective modifications such as signage, local traffic lights, and merging lanes.

The overall evacuation timeframe is determined by the rate of rise of the floodwaters, the capacity of the main evacuation routes from the Valley, and the flood levels at which these routes get cut. Raising Warragamba Dam would reduce the likelihood and frequency of extreme flood events, and may increase the certainty of calling an evacuation, but would have limited impact in the total number of people that will need to be evacuated in extreme flood events.

Several potential options have been identified for road augmentation, including upgrading the M4 motorway or the Great Western Highway to prevent queuing for Penrith and Richmond evacuation traffic. These would need to be confirmed within the context of regional road network planning. Transport for NSW will be included in Stage Two of the Review to conduct an assessment of the regional road network and its evacuation capacity.

The interaction between the various options for raising Warragamba Dam and providing adequate flood evacuation capacity for the growing population in the Valley is complex, and requires a more integrated approach to flood management and evacuation planning. Stage Two of the Review will include evacuation modelling and test exercises together with an investigation of the regional road network to identify potential upgrades to the network to increase evacuation capacity for future population growth.

Strategy C – Establish governance arrangements that support more integrated and effective management of flood risk.

The Review has identified several opportunities to improve the existing governance framework for flood risk management. Some of these issues apply across NSW, or would be most effectively addressed through enhancements of broader, state-wide governance arrangements, while others are specific to the Hawkesbury-Nepean Valley.

The management of flood risk in the Hawkesbury-Nepean Valley involves a number of agencies, local councils and other stakeholders. Governance arrangements for flood planning, preparation and response need to encourage and facilitate effective coordination and cooperation between these organisations.

Effective flood risk management requires an integrated approach to land use planning, flood mitigation, infrastructure and flood evacuation, all of which must be linked to contemporary, catchment-scale flood information and modelling. While these issues are typically addressed through local floodplain risk management plans prepared by local councils, the high number of councils within the Hawkesbury-Nepean floodplain has precluded a truly integrated approach.

Improved governance arrangements are needed to undertake and maintain catchment-based flood modelling, mitigation and evacuation capacity studies and plans for a range of development scenarios and timeframes across the Valley, and to ensure linkages between these elements.

The lack of an effective governance framework for undertaking catchment-scale flood and evacuation modelling, as well as collating information on flood mitigation infrastructure and evacuation capacity has resulted in the lack of contemporary and accessible data to inform statutory land use planning.

In the past, regional land use plans have often only included general flood-related statements, rather than detailed consideration of the hazard and implications for growth. As a result these plans have not adequately considered the cumulative impact of ongoing development and the associated risks to evacuation capacity.

Stage Two of the Review will develop the best model of governance to achieve a more integrated and coordinated approach to the planning of land use, infrastructure, flood evacuation and flood modelling across the Hawkesbury-Nepean Valley. The potential model will create linkages between agencies and groups dealing with broader state-wide flood risk management arrangements.

Strategy D – Collection of post-event flood data and intelligence.

Lessons from rare flood events can provide critical insights to inform future response and management efforts. Councils and state government agencies, including the Office of Environment and Heritage and the State Emergency Service, all undertake post-event studies of flood incidents, including collection of data and information on flood behaviour and incident management.

There is no strategic, governance framework for coordinating data collection and related activities and, for continuous improvement through collection, access and provision of post-event data collection.

Clarifying the governance arrangements for flood management in the Hawkesbury-Nepean Valley should include coordination of post flood data collection. This would also enable timely, quantitative inputs to emergency management plans.

The benefits of improved collection and use of post-event data and intelligence are not limited to the Hawkesbury-Nepean Valley. A State-wide solution to this issue is necessary. Not learning the lessons from large flood events is likely to lead to suboptimal flood response and management in future, increasing risks to life and property.

Strategy E – Improve recovery planning.

The Review found that a severe flood in the Hawkesbury-Nepean Valley would lead to economic, social and other impacts of state significance. Community recovery from such a flood would be prolonged and highly complex to coordinate. Current flood recovery strategies and arrangements may not adequately reflect the impacts of major flood events in the Hawkesbury-Nepean Valley.

High-level principles for recovery planning are provided in the 2010 NSW Recovery Plan. However this plan does not provide the level of detail required for recovery activities in the Hawkesbury-Nepean Valley, such as critical ‘hotspot’ locations likely to require special attention.

The potential scale and duration of the flooding impacts within the Hawkesbury-Nepean Valley warrants the development of a specific *Hawkesbury-Nepean Flood Recovery Sub Plan*, incorporating strategies and arrangements for recovery from severe floods, and providing the transitional support from response operations under the *Hawkesbury-Nepean Flood Recovery Sub Plan* to the full spectrum of recovery activities.

The prompt restoration of utility service infrastructure, such as electricity and gas transmission systems, water and wastewater treatment and reticulation infrastructure, as well as essential health and other community infrastructure is clearly a critical aspect of planning the recovery from a major flood event in the Hawkesbury-Nepean Valley.

Stage Two of the Review will also look at the adequacy of current infrastructure reconstruction arrangements and how to ensure that infrastructure restoration efforts following a major flood event are supported by coordinated and effective governance, funding and planning frameworks.

Strategy F – Improve emergency management, planning and implementation.

The emergency response to a severe flood in the Hawkesbury-Nepean Valley is a resource intensive and complex operation. The Review found it is therefore critical that the NSW State Emergency Service has the capacity to plan for, respond to, and manage the full range of floods in the Hawkesbury-Nepean Valley.

There are three specific areas of risk with the potential to adversely impact on effectiveness of the flood emergency planning and response management arrangements:

1. the nature and timing of flood emergency evacuation decision making;
2. community response to decisions to implement flood evacuation; and

3. cumulative impact of population growth and the consequential demand on emergency services and evacuation infrastructure, beyond available capacity.

Options to address these risks include:

- a review of the flood emergency subplan for the Hawkesbury-Nepean Valley.
- capability assessment of the State Emergency Service to ensure they have adequate resources and expertise to effectively manage and prepare for flood incidents in the Hawkesbury-Nepean Valley.
- the development of a flood recovery plan for the Hawkesbury-Nepean Valley, as outlined in *Strategy E*.

Stage Two of the Review will further assess these options.

Strategy G – Improve community education on flood risk and response.

It is important to have clear and effective education systems so the community is aware of flood risks, understands what options are available to them, and what the best course of action is in responding to flood incidents. Community surveys in the Hawkesbury-Nepean Valley have revealed that there is a lack of community awareness of the flood risk in the Hawkesbury-Nepean Valley, 20 per cent of the population is unlikely to evacuate when directed to do so.

The Review found that there is a clear need to provide more information and education on the flood risk in the Hawkesbury-Nepean Valley to the affected communities.

The NSW State Emergency Service and local councils each have a role in community education. Local councils provide information on flood risk and management to owners and purchasers. The State Emergency Service educates the community through its FloodSafe programs on how to prepare for and respond to a flood threat, focussing on public safety and property protection.

Failure to deliver education programs will result in a community that is not primed to respond in a timely way to flood warnings with the result that evacuation may fail and result in a rescue operation. Experience has shown that in the absence of a sustained community education program, community awareness can rapidly decay between events.

A key task for Stage Two will be to increase community awareness in the Hawkesbury-Nepean Valley of flood risk, and to identify appropriate measures to ensure awareness is maintained in the future.

Strategy H – Improve accessibility of flood risk information.

The Review found that the community has no single source of information on flood risk in the Hawkesbury-Nepean Valley. Local government has a key role in informing the community about flood risk. However, the availability and format of information available to the community varies within the Valley, and across NSW and Australia. Data ownership and licensing issues can also inhibit the collection, availability and dissemination of flood information.

The development of an appropriate standard and mechanism to provide flood information to the community, insurers and government, with appropriate links to flood education, will enable improvements in understanding, managing and responding to the flood risk. This is likely to lead

to more informed investment decisions on the floodplain and improved pricing of flood insurance. The provision and accessibility of information will be further considered in Stage Two of the Review.

Strategy I – Improve flood modelling framework and tools.

The Review found that planning of land use, urban development, infrastructure and flood evacuation is not supported by a comprehensive and integrated flood modelling framework.

Computer modelling of flood events provides an essential basis for many other aspects of flood management. The planning of land use, emergency response, flood evacuation and recovery all rely fundamentally on an ability to predict the levels and behaviour of floods of various magnitudes or frequencies. A comprehensive and integrated regional flood model and flood modelling framework is required to support appropriate planning of land use, flood mitigation, emergency response, and flood evacuation in the Hawkesbury-Nepean Valley.

Local councils, as the principal managers of flood prone land, have relied on and continue to rely on flood modelling developed in the 1990s for their flood mapping and land use planning and emergency management decisions.

As part of the Review the Sydney Catchment Authority engaged specialist floodplain management consultants to develop an updated flood model of the main Hawkesbury-Nepean River channel based on the latest developments in flood estimation. This flood model was used to assess likely effectiveness of large scale flood mitigations on reducing flood levels in the Valley. The results of this model are subject to review, but do not indicate significant changes in flood levels in a 1 in 100 chance per year flood or the probable maximum flood.

The Review assessed the updated flood model and determined that the this new flood model would provide an excellent basis for a new regional flood model of the main river between from Warragamba Dam to Broken Bay. The new flood model could form the basis of a revised Hawkesbury-Nepean River Flood Study, the results of which could be used by local councils and other stakeholders for flood mapping, flood hazard definition, strategic land use planning, setting of flood planning levels and emergency response management.

Stage Two will progress the establishment of a regional, accessible flood model for the main river channel, supported by a framework that facilitates flood modelling at various scales and by different organisations.

Strategy J – Improve consideration of flood risk in land use planning.

Land use planning and development control are critical elements in minimising the impacts of floods on the community. The Review found that there is currently no effective state-level policy for land use planning in relation to natural hazards, including flooding. This gap results in land use planning authorities applying different principles in their flood-related functions, different risk management approaches in land use planning, different levels of response to flood management and risk assessment and potentially different land use planning requirements and development assessment regimens.

There is currently no NSW land use planning guideline relating to flood prone land, resulting in a lack of clear principles to guide land use planning and development assessment in these areas.

These matters are particularly critical in the Hawkesbury-Nepean floodplain, where land use planning and development consent are the responsibility of six local councils, with the Department of Planning and Infrastructure also having a role within the North-West and South-West Growth Centres. This can result in a range of different approaches to flood risk and land use planning.

The issues relating to the effectiveness and consistency in land use planning and development control could be addressed through the development of a NSW Planning Policy relating to relevant natural hazards that would apply to all levels of land use planning in NSW. Such a policy would provide principles and guidance relating to strategic, statutory and development assessment matters relating to all flood prone land.

The proposed reforms to the NSW planning review provide for an opportunity to develop strategic planning instruments to address flood risk management issues in the Hawkesbury-Nepean Valley.

The draft Metropolitan Strategy for Sydney sets the framework for Sydney's growth and prosperity to 2031. It includes objectives policies and actions to achieve five outcomes - balanced growth, a liveable city, productivity and prosperity, healthy and resilient environment, accessibility and connectivity.

Regional and subregional land use planning provides critical opportunities to integrate consistent considerations of flood risk to inform growth options, implications and evacuation capacity issues. There needs to be clear, consistent and detailed consideration of flood risk and evacuation capacity.

The draft Metropolitan Strategy sets out for the first time an objective to '*Build Resilience to Natural Hazards*'. Although this objective focuses on matters broader than flooding, the risk associated with flooding in the Hawkesbury-Nepean Valley is recognised. Management of the flood risk in the Hawkesbury-Nepean Valley would benefit from a strategic approach to land use planning. Better use of the State's proposed new planning regime for flood risk management will be considered in Stage Two.

Conclusion and next steps

The Review found that there is no simple or single solution that can completely address all of the flood risk in the Hawkesbury-Nepean Valley. The Review has identified that infrastructure options can reduce, but not eliminate, the flood risk in the Valley. Evacuation is the only mitigation measure that can guarantee to reduce risk to life, and detailed investigation is required to support an integrated approach to reduce overall flood risk in the Valley.

The Review has developed ten strategies to improve flood risk management in the Hawkesbury-Nepean Valley, and has identified a suite of more detailed investigations and cost benefit analyses to be addressed in Stage Two of the Review.

The NSW Government will establish a dedicated Task Force, headed by an independent Chairperson, to lead the Review as it progresses to the next stage. The Task Force will include representatives from relevant Government agencies and will coordinate flood management and knowledge for the Hawkesbury-Nepean Valley.

The Task Force's main responsibility will be to coordinate and oversee the implementation of Stage Two Review for improved flood management in the Hawkesbury-Nepean Valley and building better community preparedness and resilience to flood events.

The Task Force will undertake the following actions as a priority, with a focus on community awareness and emergency preparedness:

- review the Hawkesbury-Nepean Flood Emergency Sub Plan and other relevant emergency plans to ensure they include the most up-to-date information and data (from *Strategy F*)
- enhance community education programs and further investigating community attitudes and responses to flood risk (from *Strategy G*)
- develop an effective evacuation modelling tool to enable completion of an integrated traffic evacuation plan for the floodplain (from *Strategy B*)
- identify any minor road and intersection improvements that could assist in flood evacuation in the short term (from *Strategy B*)
- review key local and state government planning instruments and guidance to minimise the risks associated with ongoing infill and greenfield development (from *Strategy J*)
- investigate alternative gate operation procedures and reduction of the full supply level by up to five metres for Warragamba Dam. This could help reduce the frequency and impact of small floods. Water supply impacts would need to be fully considered (from *Strategy A*).

The next stage will also involve a detailed assessment of the infrastructure flood mitigation options identified by the review in relation to economic and social impacts, associated costs and time frames. These actions will focus on longer term planning and will include Warragamba Dam wall raising and regional road infrastructure upgrade considerations. They are:

- identifying major regional road and intersection improvements that would assist with evacuation and undertaking cost benefit analysis of the selected options (from *Strategy B*)
- revising the regional emergency management plan to include consideration of the implications of the scenario of more widespread flooding in the Greater Sydney region (from *Strategy F*)
- commencing development of a state-wide planning policy addressing floods and other natural hazards (from *Strategy J*)

- developing a flood recovery plan which includes consideration of reconstruction of essential infrastructure following a major flood (from *Strategy E*)
- undertaking detailed cost benefit analysis of optimising Warragamba Dam for flood mitigation and water supply, including consideration of upstream and downstream impacts (from *Strategy A*)
- seeking an agreed approach and consistent use of flood modelling and monitoring data for the region (from *Strategy H and I*).
- developing governance reforms to create an enduring and effective whole of government response to flood risks (from *Strategies C and D*)

The Task Force will consult with key stakeholders including local government, the insurance industry, water authorities, the Floodplain Management Association and the community as appropriate.