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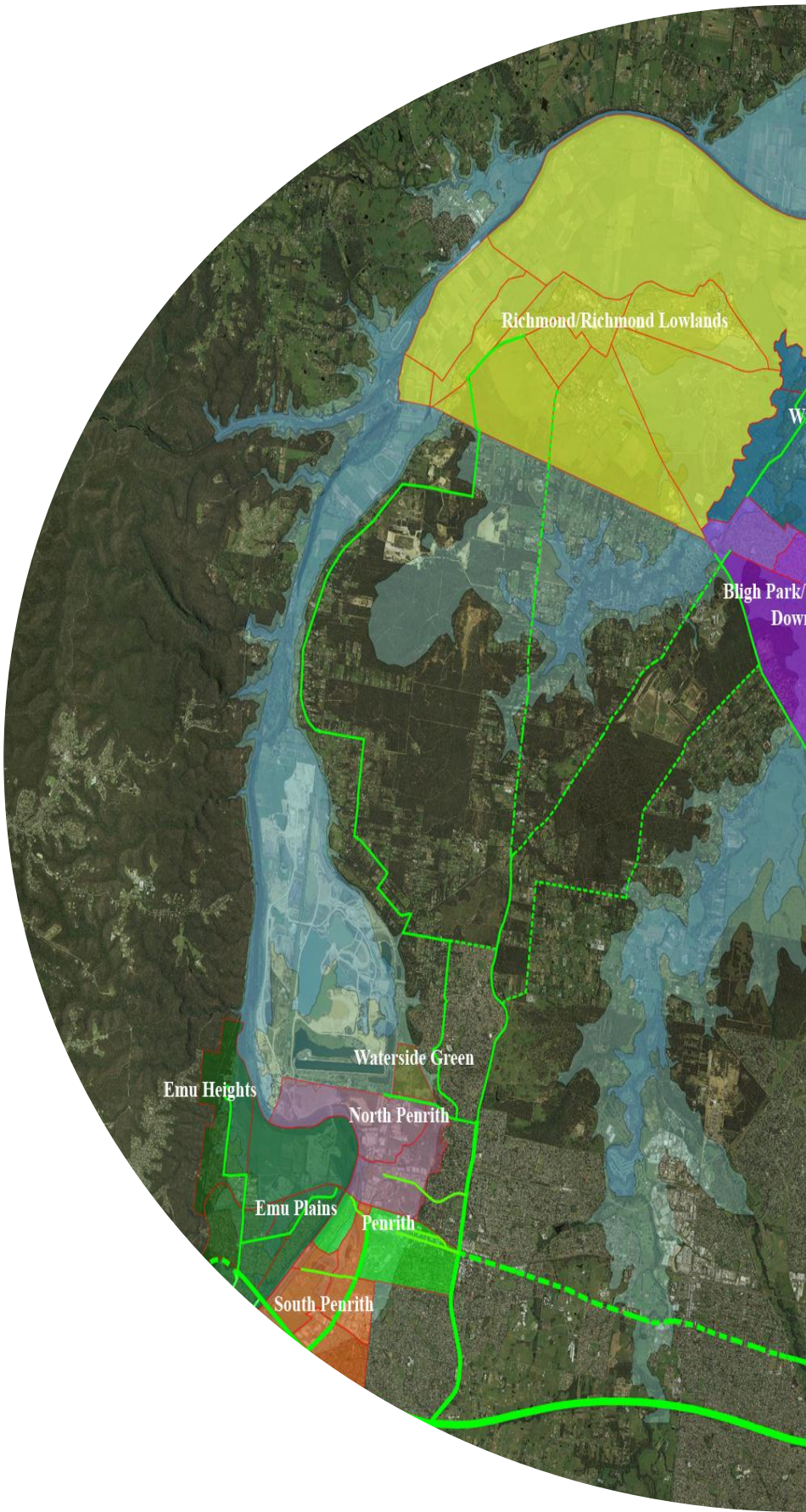

NSW Department of Planning

North West Sector Flood Evacuation Analysis

Final Report

North West Sector Flood Evacuation Analysis

FINAL REPORT

for

NSW Department of Planning

by

Molino Stewart Pty Ltd
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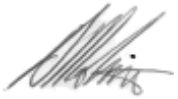
Name	Steven Molino 
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EXECUTIVE SUMMARY

Background

This report investigates flood evacuation for the Hawkesbury Nepean Valley so that informed decisions can be made about the future development of Penrith Lakes and the provision of flood evacuation infrastructure.

The convergence of evacuation traffic across the regional road network, the potential to send some traffic along alternative routes and the risk of traffic from one new development taking route capacity from another new development has meant that a whole of Valley investigation is warranted.

Modelling Methodology

A coarse regional flood evacuation model has been set up in Microsoft Excel using one dimensional hydraulic modelling in the Windsor and Richmond areas and two dimensional hydraulic modelling in the Penrith area to estimate the times at which evacuation routes are cut by flooding. A flood rising as fast as a 72 hour PMF has been used in the modelling which is consistent with what is used by the State Emergency Service (SES) for its flood evacuation planning. It should be noted that smaller floods could rise this fast and some floods might rise faster.

The evacuation routes and triggers were taken from the SES's Hawkesbury Nepean Flood Emergency State Plan which has most evacuation traffic heading to the Homebush Olympic Precinct via the M4 or M7 motorways.

The NSW SES Evacuation Timeline Model has been used to estimate how much time is required for people to evacuate along any particular route. This takes into account the time necessary for the SES to decide to evacuate and mobilise personnel, the time required for people to receive, accept and act upon the warning, and the time needed for evacuation traffic to travel along the evacuation routes, taking into account the likely adverse driving conditions and the potential for delays due to accidents or incidents.

A critical variable in the modelling is the number of vehicles which need to evacuate and this will be a function of the number of residential, commercial and industrial premises which are occupied at the time an evacuation is called. While census data provides some indication of the number of dwellings and their vehicles, it provides no indication of commercial premises and vehicles. Furthermore, the census data is reported by collector district (CD) and CD boundaries do not necessarily coincide with the flood extent nor the SES's operational subsectors which will determine the sequencing of evacuation.

The SES has commissioned Geoscience Australia (GA) to use its NEXIS database to estimate the potential number of flooded residential, commercial and industrial premises which fall within each operational subsector. We have multiplied the residential dwelling numbers by 1.8 and the business premises by 2.0 to estimate an upper bound number of vehicles which will need to evacuate from each subsector.

Future Development

In addition to possible development at Penrith Lakes, there are other greenfield and infill developments proposed for the floodplain. While none of those will be constructed below the current flood planning level (at or above the 1 in 100 per year flood level), there is potential for many thousands of dwellings and commercial developments in areas which would need to be evacuated in larger events.

Estimates of future development in Hawkesbury local government area (LGA) were derived from the draft Hawkesbury City Residential Land Strategy and discussions with Hawkesbury City Council and the Department of Planning. In Penrith LGA they were taken from the Penrith City Population and Household Forecasts, development proposal documents by Penrith Panthers and Landcom and discussions with Penrith City Council and the Department of Planning. Documents describing plans for the North West Growth Sector and discussions with the Department of

Planning were used to identify future development in Blacktown LGA.

Evacuation modelling was undertaken for expected development in the years 2010, 2020, 2030 and 2040.

Council engineers from Penrith, Blacktown and Hawkesbury LGAs and the Roads and Traffic Authority advised on proposed and potential future road developments.

Results

2010

The investigations showed that there is likely to be considerably more evacuation traffic today than has been allowed for in the current SES Plan and previous analyses for development proposals including Penrith Lakes. This is partly because of ongoing residential infill development and also some greenfield developments since data collection upon which the SES Plan is based. Another contributing factor is the fact that the SES had not previously accounted for the inevitable traffic from commercial and industrial premises.

Following the current SES plan on the current road network, about 10,500 vehicles of about 48,000 would not have enough time to evacuate. There is insufficient road capacity for much of Windsor to evacuate and Richmond and Bligh Park evacuation traffic may block traffic evacuating from Penrith onto The Northern Road. Emu Plains does not have enough time for all of its development to evacuate.

Another significant problem is the capacity of the M4 motorway and its on ramps. There is one on ramp at Emu Plains and one at Mulgoa Road yet at both locations there are two lanes of traffic needing to enter. At The Northern Road there are potentially three lanes trying to merge into one.

Some of the above problems can be overcome by triggering evacuations in some locations earlier. This increases the risk that places will be evacuated and then flooding not reach levels which impact on buildings.

The following works (or similar) are needed to deal with existing problems.

- Windsor can only be fully evacuated if the evacuation route to Windsor Road is widened to two lanes from the west side of Jim Anderson Bridge to the Bandon Road Windsor Road intersection.
- Roadworks on Eighth Ave and suburban streets through to Oakhurst would allow all of Bligh Park and Windsor Downs traffic to evacuate along Richmond Road and free up a lane on The Northern Road.
- The Emu Plains evacuation route along the Great Western Highway and Russell St would have to be raised by up to 1m.

Even with all of these measures there would be insufficient capacity on the M4 Motorway and an additional lane heading to Homebush is needed. This could be done by widening the Motorway or reducing the risk of local flooding along the length of the Great Western Highway from The Northern Road to Homebush.

2020

Additional measures will be needed to manage further projected urban development by 2020.

If the Windsor evacuation route is widened as recommended above there would be sufficient capacity for project infill development to evacuate.

The proposed Riverstone West Industrial precinct would have to be evacuated along the soon to be upgraded Hamilton St, McCulloch St and Alex Ave to the M7 at Sunnyholt Road. At Sunnyholt Rd the traffic would have to wait up to 2.5 hours for the Windsor evacuation traffic to clear.

An extra lane for evacuation would have to be provided out of Richmond to cope with the expected infill development. This would most cost effectively be achieved by upgrading Londonderry Rd. Even so up to 600 vehicles could queue for up to an hour during an evacuation likely to take 19 hours.

A little over 800 dwellings could be evacuated from Penrith Lakes provided that:

- All Bligh Park and Windsor Downs traffic has been directed to the M7 via Richmond Rd or an alternative
- Andrews Road has an additional eastbound lane
- Penrith Lakes traffic is allowed to use a contraflow lane on the Northern Road
- Richmond and Waterside Green traffic are sent along an upgraded Great Western Highway
- Traffic from Landcom's Penrith North development queues in local streets until Penrith Lakes and Waterside Green have evacuated
- Some Penrith traffic queues in local streets

The evacuation of Penrith Panthers and surrounding areas will have to be brought forward by about 3.5 hours to provide sufficient time for this development to evacuate. This will increase the risk that a flood cutting the evacuation route will not eventuate let alone one which does not flood the premises.

2030

Further infill development at Windsor could be accommodated by the duplicated route but Riverstone West Industrial Traffic may have to queue for up to 14 hours.

Similarly, additional traffic caused by infill development at Richmond would have to queue for up to 2.5 hours in an evacuation which could take as long as 26 hours.

Additional development could only be accommodated at Penrith Lakes if it were evacuated earlier than currently planned or engineering works (road raising or levees) could be used to delay the road being cut by floodwaters.

Further infill development in Penrith and Jamisontown will result in more traffic having to queue in local streets for hours.

Any new development at Emu Plains would require the evacuation route to be raised further or the evacuation to commence earlier.

2040

There are no projected developments beyond 2030 that would impact on regional flood evacuation routes.

Sensitivity Testing

The revised estimates of current evacuation traffic are so much larger than previous estimates and the scale of new development so significant that the outcomes are not particularly sensitive to varying assumptions about rates of traffic generation for existing developments.

The range of regional evacuation traffic estimates has little impact on the cost of infrastructure required to support a development at Penrith Lakes.

However, future infill development capacity in Penrith, Richmond and Windsor is extremely sensitive to estimates of current evacuation traffic.

Suggested Improvements

Our review suggests that the following needs to be done to improve flood evacuation in the Hawkesbury Nepean Valley.

2010

- Commence evacuation as early as practical based on road cut of triggers in Mulgrave, McGraths Hill, Bligh Park, Windsor Downs, Richmond, Waterside Green, Jamisontown Penrith and Emu Heights
- Double the planned number of doorknockers in Windsor and Waterside Green
- Provide an additional evacuation lane from Windsor at a cost of about $9.5m
- Provide an alternative crossing of South Creek for Bligh Park and Windsor Downs at a cost of about $30m
- Make drainage improvements to allow Richmond evacuates bypass Mt Pleasant at a cost of about $0.5m

- Raise a low section of the Great Western Highway at a cost of about $12.5m to enable all of Emu Plains to evacuate
- Provide an additional east bound lane on the M4 or upgrade creek crossings on the Great western Highway to prevent gridlock on The Northern Road

2020

- Direct Riverstone West industrial traffic along Spine road that is upgraded as part of the Riverstone precinct development
- Commence evacuation of traffic onto Mulgoa Road earlier if additional development takes place in its catchment
- Upgrade Londonderry Road at a cost of about $5m to provide a second evacuation lane out of Richmond if future development exceeds the evacuation capacity of Castlereagh Road.
- Provide an extra lane on Andrews Road for Penrith Lakes evacuees
- Provide an additional lane east from the Northern Road to Homebush to prevent gridlock on The Northern Road.

2030

- Expect longer merging queues of evacuation traffic from Penrith, Jamisontown, Richmond and Riverstone West
- Undertake further works to keep Andrews Road open longer if more than 800 lots are proposed in Penrith Lakes

All of the above are suggested measures only and are based on current SES evacuation planning and evacuation modelling. The length of queues and the timing of some works would be sensitive to actual existing evacuation traffic which estimated with certainty from the available data.

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1 INTRODUCTION

1.1 BACKGROUND

The Penrith Lakes Development Corporation (PLDC) was established as a consortium of extractive resource companies. About 30 years ago it reached an agreement with the NSW Government that the member companies would extract sand and gravel from the floodplain north of Penrith and as part of the quarry rehabilitation create a network of recreational lakes and regional parkland. Part of the site was also to be set aside for urban development.

The first stage of the rehabilitation involved the creation of the Regatta Lake and Penrith Whitewater Stadium for the Sydney 2000 Olympics.

About a decade ago work began on amending the Sydney Regional Environmental Plan No 11 – Penrith Lakes Scheme to reflect the proposed final form of development of the rehabilitated quarry and to ensure that appropriate planning controls were applied.

A key issue which was identified during the REP process was the need for safe evacuation of the proposed recreational and urban areas. The scale of the proposed urban development which involved nearly 5,000 residential lots as well as large industrial and commercial precincts meant that significant investment in road infrastructure would be needed if everyone was to be evacuated the way in which the NSW State Emergency Service (SES) was planning.

While the PLDC was investigating alternative urban development and evacuation arrangements, the ownership of member companies changed and the commitment to urban development as part of the quarry rehabilitation was reviewed.

PLDC is now contemplating a smaller scale of urban development which will nevertheless require adequate evacuation infrastructure. A Government Task Force has been established to investigate the future of the Penrith Lakes including the need for evacuation infrastructure.

1.2 THE EVACUATION PROBLEM

1.2.1 A Regional Issue

The SES classifies flooding in the Hawkesbury-Nepean Valley as either a Level 1 flood or a Level 2 flood according to the degree of severity. The levels are defined as follows;

“A Level 1 flood is defined as one in which the water level of the Hawkesbury-Nepean River is not expected to exceed 15.0 metres on the Windsor Bridge gauge. For such a flood the operation is within the scope of normal arrangements detailed in the respective SES Region and Local Flood Plans and the respective District and Local DISPLAN’s. Additional high level planning is not required.

A Level 2 flood is defined as one in which the water level of the Hawkesbury-Nepean River is expected to exceed 15.0 metres on the Windsor Bridge gauge. In such a flood the operation will be beyond the scope of the respective SES Region and Local Flood Plans and the respective District and Local DISPLAN’s. Additional planning in the form of State level arrangements is needed. (SES, 2005)”

The NSW State Emergency Service (SES) has a plan for the evacuation of the Hawkesbury Nepean Valley during Level 2 floods (NSW State Emergency Service 2005). The evacuation plan has been based on the results of evacuation modelling undertaken by the SES using a model which it has developed (Opper, 2004).

It utilises estimates of:

- advanced flood warning available from the Bureau of Meteorology;
- the rate of rise of floodwaters suggested by hydraulic models;

- the number of vehicles which will need to be used for evacuation;
- the time needed for the SES to disseminate warnings via door knocking of all properties which need to be evacuated;
- the rate at which vehicles will be able to travel along the evacuation routes; and
- delays due to evacuee response and traffic contingencies

The plan designates evacuation routes for each population centre and nominates forecast flood heights which trigger evacuation to maximise the chances of all people being able to evacuate without the need to evacuate people unnecessarily.

The NSW SES estimated that there could be about 60,000 people who would have to be evacuated from the Hawkesbury Nepean Valley in an extreme flood along several regional evacuation routes (SES 2005). While many of these people would have to evacuate if their houses or businesses are forecast to be flooded, many others will need to evacuate because floodwaters would cut off their access and isolate them for several days. In some locations, including major towns such as Richmond and Windsor, these isolated communities could become completely overwhelmed if floodwaters continue to rise.

Figure 1 shows the maximum extent of possible flooding in the Hawkesbury Nepean and the general directions of flood evacuation

1.2.2 Penrith Lakes

Were the issue of evacuation confined to Penrith Lakes alone it would be challenging but not particularly expensive to address. However, evacuation of Penrith Lakes will be triggered by Level 2 floods which will require the evacuation of parts of Penrith, Emu Plains and Leonay at the same time and there will be the need for some sharing of evacuation routes.

To further add to the complexity of the issue, areas further north including Agnes Banks, Richmond, Bligh Park, Windsor Downs and Windsor may need to evacuate at the same time as Penrith Lakes and some of that traffic is also likely to share evacuation routes with the Penrith Lakes evacuation traffic.

The aforementioned locations, and others on the floodplain, are also being investigated for future urban development. Due to significant amounts of infill development in Richmond and Windsor since the original SES vehicle estimates were calculated for the region, the capacity of the current SES evacuation routes to adequately serve their purpose has also come into question.

The development of Penrith Lakes would create additional evacuation traffic which, in converging with existing flood evacuation traffic, could cause sufficient congestion to prevent some people from being able to escape from the rising floodwaters unless additional infrastructure is provided.

The flooding can be so widespread, and the number of routes available out of the floodplain so limited, that development at one location may have implications for the safety of evacuees from another location many kilometres away and therefore may affect the cost or feasibility of that other development if additional infrastructure is needed to manage the flood risk.

So it is with Penrith Lakes. Depending on what route is chosen for Penrith Lakes evacuation, the scale of the development and the evacuation infrastructure provided, it could have implications for new developments at Emu Plains, Leonay, Windsor, Bligh Park, Richmond and the North West Growth Centre including Vineyard, Riverstone West, Schofields and Colebee.

By the same token, there may also be opportunities for some of these developments to share evacuation infrastructure costs with Penrith Lakes, making it more cost effective all around. These new developments will also require the upgrading of road infrastructure to manage daily traffic. Some of these road upgrades alone will provide additional flood evacuation capacity while others may need

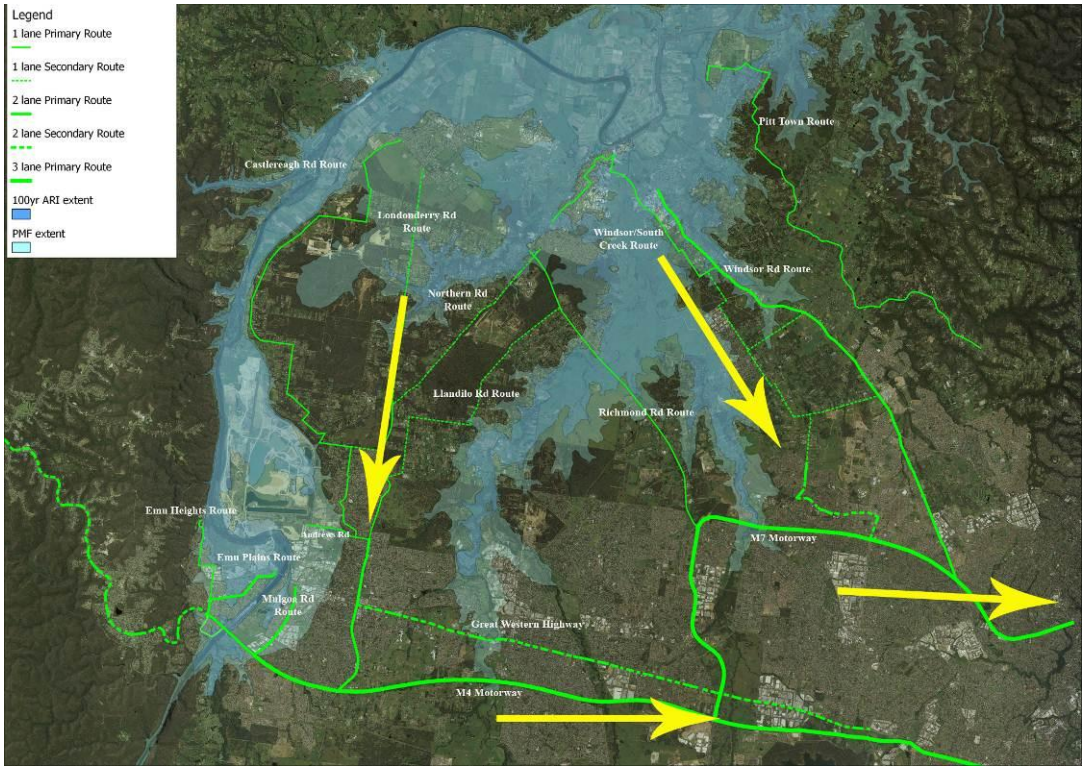


Figure 1: Hawkesbury Nepean PMF and evacuation direction

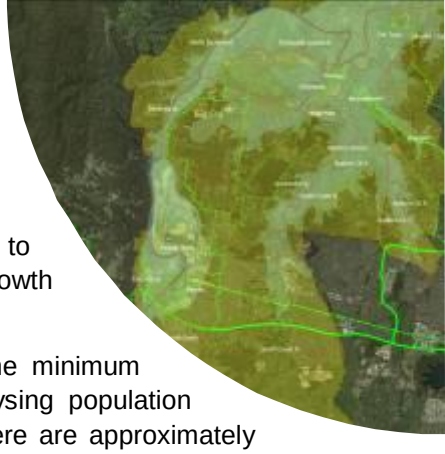
some additional expenditure for them to be able to function as evacuation routes

1.3 THIS REPORT

Given the complexity of the regional development and flood evacuation issues and challenges and opportunities which they present, The Department of Planning commissioned Molino Stewart Pty Ltd to investigate the evacuation infrastructure needs of the Hawkesbury Nepean Valley for future development scenarios in 2020, 2030 and 2040 compared to the existing evacuation infrastructure and that which is required to meet the needs set out in the current SES Hawkesbury Nepean Flood Emergency Sub Plan (SES 2005).

While the evacuation needs of Penrith Lakes has been a catalyst for this report, it is hoped that it will assist in the integration of flood evacuation planning into the development of the whole of the North West Sector.

It has been prepared in consultation with the Department of Planning, State Emergency Service, Roads and Traffic Authority, Penrith City Council and Hawkesbury City Council.



2 METHODOLOGY

2.1 OVERVIEW

In simple terms, the method which was adopted was to compare the time needed to evacuate the flood affected population with the time available to evacuate this population and determine whether there would be a time surplus or a time deficit. If there was a time deficit, options for upgrading road infrastructure were identified which would enable everyone to evacuate in sufficient time.

To do this the following information was needed:

- The population which needs to evacuate
- The number of vehicles which would be using the roads
- The changes in population and vehicle numbers over time
- The locations from which they will be evacuating
- The evacuation routes which will be available
- Planned upgrades to evacuation routes
- The time taken to evacuate
- The time available to evacuate

The means by which the above list of information was acquired or estimated is set out in the following subsections. This is followed by an explanation of how the information was then used and what assumptions were made in modelling evacuation traffic.

2.2 POPULATION ESTIMATES

The SES Hawkesbury Nepean Flood Emergency Sub Plan uses evacuation estimates based on 2001 ABS Census data. There have significant changes between 2001 and 2006, the year of the latest ABS Census. There is also expected to be further population growth over coming decades

Collector Districts are the minimum available scale for analysing population and vehicle counts. There are approximately 170 Collector Districts in the North West Sector at risk of either partial or complete inundation during a PMF event.

The most up to date population counts are provided in the 2006 ABS Basic Community Profile Data which was used as a starting point for population estimates. This data also provides a count of occupied residential dwellings on census night. However these numbers do not provide the full picture.

The census population count does not include those people who were overseas on census night nor those who failed to complete census forms. Furthermore, the dwellings which were unoccupied on census night may be occupied when an evacuation takes place. For these reasons the census data could underestimate the population which needs to be evacuated.

Also there have been changes in dwelling numbers and population since 2006. For example, urban consolidation has been taking place in Richmond and Windsor in particular as well as rural residential dwellings having been built.

The ABS publishes an estimated resident population (ERP) every six months which takes into account the population which has been missed on census night as well birth and death data and migration data.

For those Collector Districts fully contained within the floodplain, the residential population needs to be evacuated in its entirety. For Collector Districts which are only partially located within the PMF extent, a method is needed to estimate the proportion of the population which would need to evacuate.

2.2.1 Geoscience Australia

The SES commissioned Geoscience Australia (GA) to provide it with an estimate of the number of residential dwellings and population,

as well as the number of commercial and industrial buildings, within the floodplain which would need to be evacuated. They also estimated the value of the buildings.

GA used the National Exposure Information System (NEXIS) to provide these estimates for 2010. NEXIS makes use of:

- The Geocoded National Address File (G-NAF®) for spatial locations of known addresses supplied by Pitney Bowes MapInfo Australia Pty Ltd
- The Property Cadastre for cadastral parcel size and location supplied by Pitney Bowes MapInfo Australia Pty Ltd
- Geoscience Australia's National Mapping 25k homestead data
- The ABS 2006 census datasets for population, residential data and unoccupied dwellings
- The ABS ERP for June 2009
- Reed Construction Data provides information on construction activity and building costs across Australia

These estimates were presented by SES subsector which is the most meaningful geographic unit for evacuation planning because these are the areas which will be managed as an entity. Not all subsector and census collector district boundaries coincide.

It should be noted that not all of the addresses which are generated by this method will have buildings on them (i.e. some may be undeveloped blocks at this stage) and others may have vacant buildings. In this sense they may slightly overestimate the number of buildings which will require evacuation.

2.2.2 Molino Stewart

In the Penrith, Richmond and Windsor areas there are clusters of collector districts which are almost entirely coincident with a cluster of subsectors and are wholly within the floodplain. This allowed alternative methods of dwelling and business estimates to be used to check the reliability of the NEXIS results. Two methods were used.

One used census data and council development records and provided a comparison of dwelling and vehicle numbers but could only be used where clusters of collector districts coincided with clusters of sub sectors that were fully within the floodplain.

The second method used Council rating data and could be used for any subsector which was fully within the floodplain and provided a comparison of dwelling and business estimates.

a) Census Data Method

This method estimated residential building numbers using:

- 2006 census collector district data for the number of occupied and unoccupied dwellings
- Hawkesbury City Council and Penrith City Council data for the number of new lots created since 2006

This method may underestimate the number of residential properties which need to be evacuated in 2010 because it does not include vacant blocks which have been built upon since 2006 nor does it count each dwelling where new multi-unit developments are constructed on a single lot.

It will count new lots which have been created by the consolidation of multiple lots but this error is expected to be small.

Where collector districts fell partially within SES subsectors and the flood affected areas, we used visual estimates of percentage coverage using air photography to estimate the proportion of a collector district which may have to evacuate.

The ABS does not count commercial and industrial properties so an alternative method for estimating these premises was needed.

One source of information was work done by the Australian National University (ANU) in 1988. This counted the number of commercial and industrial businesses (including multiple businesses in the same building) as part of the flood damage estimation work for the upgrade of Warragamba Dam (Sydney Water, 1995).

Although this data is over 20 years old, the numbers of businesses is not likely to have changed significantly in the established urban areas.

As part of another research project (Molino Stewart, in progress), we mapped the areas of new commercial and industrial development since 1988 and were able to quantify the areas of greenfields commercial and industrial development.

b) Council Rating Data Method

Hawkesbury City Council and Penrith City Council were able to compare the SES subsector boundaries with their property rating databases and count the number of residential, commercial and industrial properties within each sub-sector. The counts will include unoccupied buildings but will not include vacant lots which are able to be developed.

It should be noted that the Council's rating database counts the number of properties pay rates. Many buildings, particularly commercial and industrial buildings may have a single owner but many tenants. Therefore this method can significantly underestimate the number of businesses. However, it can be compared to the number of commercial and industrial buildings (as opposed to addresses) estimated by the NEXIS data.

2.3 VEHICLE ESTIMATES

2.3.1 Residential

The ABS provides data on vehicle counts for residential dwellings by listing whether there was 0, 1, 2, 3 or 4 or more vehicles at a dwelling. This is available for all collector districts for 2006. We assumed that those which reported 4 or more vehicles only had four. The number of dwellings in this category was small so this would have not introduced a significant error in estimates.

About 5% of households did not report the number of vehicles on their census form therefore we have assumed that there are 5% more residential vehicles than reported in the ABS data. From this we calculated an average number of vehicles per dwelling for Richmond and Windsor which both have train stations, and the other areas which are more remote from public transport.

As a lower bound estimate of residential vehicles these vehicle ownership ratios were applied to the Molino Stewart estimate of residential building numbers. As an upper bound estimate a ratio of 1.8 vehicles per dwelling was applied to the NEXIS dwelling estimates[1].

2.3.2 Commercial and Industrial

During an evacuation there are likely to be vehicles which need to evacuate from business premises.

The ABS does not count commercial and industrial vehicles so a method for estimating these vehicles was needed.

It is more difficult to estimate how many commercial vehicles need to evacuate because:

- many of the vehicles at the commercial premises will belong to people who live locally and are already counted in the residential vehicles;
- many commercial vehicles are on the road during working hours and away from the site out of hours so may not need to evacuate; and
- the time when all of the residential vehicles are at home is likely to be when most of the commercial vehicles are not e.g. at night.

The Hawkesbury Social Atlas (Hawkesbury City Council, 2009) suggests that about three quarters of businesses in the LGA have less than 5 staff and two thirds have incomes of less than $100,000 which suggests these businesses have no more than two staff.

[1] A check of the 2006 census data suggests that in Penrith local government area there is an average of 1.65 vehicles per dwelling. In fact for the whole of the Sydney Metropolitan area only Camden (1.87) and the Hills Shire (1.94) have vehicle ratios equal to or exceeding 1.8.

The assumption was made that it would be reasonable to add two more vehicles to the residential evacuation numbers for each commercial property to get an estimate of the maximum number of vehicles likely to have to evacuate.

This was used as a multiplier to the NEXIS estimate of business premises as an upper bound estimate and to the Council rating method count as a lower bound estimate.

2.4 PROJECTED GROWTH

We used Department of Planning, Penrith City Council and Hawkesbury City Council publications along with discussions with relevant town planners from each organisation to get a sense of the size, location and timing of future development on the floodplain. This included residential, commercial and industrial development.

Figure 2:Future Urban Development shows the general areas of expected future urban development and population growth. It is expected that all new residential, commercial and industrial development will be built above the 1 in 100 flood level. The extent of this level and the PMF are also shown in **Error! Reference source not found.**

2.4.1 Hawkesbury

According to the Draft Hawkesbury Residential Strategy of 2010, The Department of Planning has allocated an additional 5,000 dwellings for the LGA by 2030 as part of its North West Metropolitan Strategy although Council suggests that 5,000 – 6,000 dwellings might be possible. We have assumed 5,000.

Approximately 1,000 of these dwelling would be located on release areas in Pitt Town. Although Pitt Town needs to evacuate, it does not use the routes which are part of this evacuation.

Approximately 800 of the remaining 4,000 allocated dwellings had already been constructed from 2006 until 2010. Hawkesbury City Council has indicated that approximately 450 of these are located in areas which would not contribute to regional evacuation traffic, while approximately 350 will.

Of the 3,200 lots still to be developed, Council estimates that perhaps 700 of those would be outside of the areas of interest.

According to Hawkesbury City Council, about half of the remaining 2,500 dwellings could be created through multi-unit housing or construction on vacant land where it is already permissible within the current zonings.

The Department of Planning has advised that its current policy is not to approve new residential subdivisions east of the Hawkesbury River below the PMF level.

We have therefore assumed that only a further 1,250 new lots of those allocated to the region would occur within the Richmond and Windsor areas. Based on advice from Council, we have assumed approximately 75% would be developed in Richmond while the remaining 25% would be developed in Windsor by 2030.

2.4.2 Penrith

Penrith has been flagged for regional city status by the Department of Planning as part of its Metropolitan Strategy, entitled City of Cities. The population is expected to grow by approximately 36,000 people by 2031 with an additional 25,000 new dwellings and the creation of 40,000 new employment opportunities throughout the LGA. The CBD is expected to accommodate 10,000 additional residents and provide 10,000 new jobs.

Population and dwellings estimates for 2010 were acquired from Penrith City Council documents. The Penrith City Local Area Profile for 2010 provided detailed maps of future urban release areas flagged for development together with the number of dwellings, jobs and resident population planned for each release area. These areas are expected to house the majority of the projected new dwellings allocated to the LGA. The remaining development is expected to be infill development of existing urban areas.

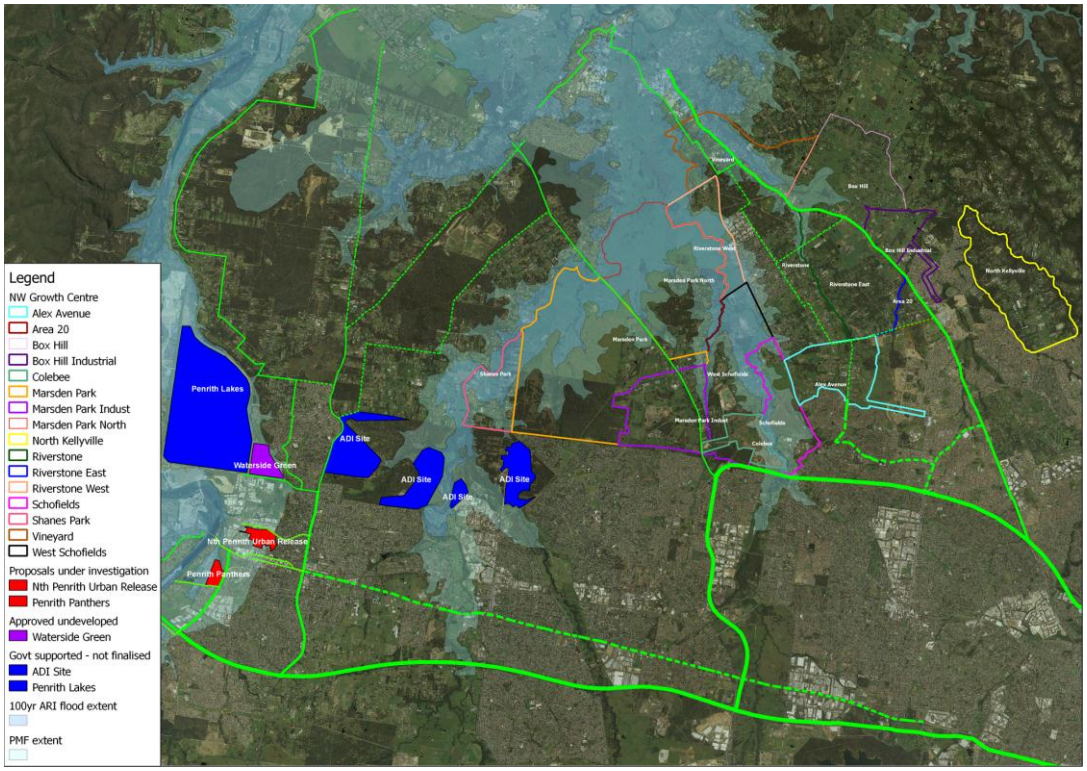


Figure 2: Future Urban Development

The Penrith City Population and Household Forecasts (PCC, 2010) provided forecast population and dwelling estimates for each suburban area within the LGA over 5 years intervals from 2006-2031

The population and dwellings for both existing and future growth scenarios in the Penrith LGA were in included in the evacuation modelling on the basis of their location. All areas within the PMF or isolated for an extended period during a PMF event were included in the modelling.

Determining which areas would be included was undertaken through GIS analysis with release areas being overlayed by the PMF. Where a release areas was located partially inside the PMF, a percentage of the relevant population and dwellings counts was calculated based on the percentage of area to fall inside. Infill development was determined from information on Population and Household Forecasts for each individual suburb located on Penrith City Councils website. The forecast

figures from suburbs either fully or partially located within he PMF were included in the analysis.

2.4.3 North West Growth Centre

The North West Growth Centre covers an area roughly bounded by South Creek and the M7 to the west and south, existing suburbs to the east and an area which straddles Windsor road along the north east.

The area has been divided into 16 precincts as shown in

Figure 2:Future Urban Development and has a projected population increase of 200,000 people by 2031. Of the sixteen precinct plans, 10 had already been released for development at the time of writing.

When completed, the North West Growth Centre development is expected to contain

60,000 – 70,000 new residential dwellings together with commercial and industrial premises in designated precincts.

Precincts which were included in the evacuation analysis were determined by the PMF extent and whether or not the controlled evacuation of the individual precinct would utilise regional evacuation routes. If a precinct was located outside the PMF or was likely to only require localised evacuation, it was excluded from further evacuation analysis.

Estimated total dwellings numbers and jobs for each precinct were available from the Department of Planning and were used as the basis for evacuation modelling unless more detailed design information was available for approved industrial and commercial areas. The expected percentage completion of the relevant precincts at each of the time intervals of this project were obtained through discussion with the Department's North West Growth Centre Team.

2.4.4 Traffic Estimates

Using the estimated size and timing of future development in each part of the floodplain as outlined in the preceding subsections, we estimated by eye what percentage of the precinct which was above the 1 in 100 flood level was within the PMF extent and used that proportion of the future growth as our estimated number of dwellings and workers which would need to be evacuated.

We assumed that there would be 1.8 vehicles for each new dwelling and 1 vehicle for each new employee. The exception to this was the Riverstone West Industrial Area where we already had concept design information which estimated the number of car parking spaces to be provided.

2.5 EVACUATION PLANS AND ROUTES

This section sets out the way in which the SES has planned warning and evacuation to take place and how that has been reflected in the evacuation modelling.

2.5.1 Forecasting Flood Severity

The river gauge relevant to flood forecasting around Penrith is the Victoria Bridge Gauge and for the Richmond/Windsor area if the Windsor Bridge Gauge. The Bureau of Meteorology will report flood forecasts in relation to these gauges and update its forecasts hourly, however it takes about four hours for the models to be run and the outputs interpreted.

The Bureau has advised that in an extreme flood (1 in 100 AEP or greater) its modelling should be able to forecast flood heights at Penrith (based on rainfall records) at least seven hours in advance with a confidence level greater than 95%. The timing of such a forecast is called the Quantitative Precipitation Forecast (QPF) Limit and is the minimum time (in advance) that the flood height can be forecast with a high level of certainty. This forecasting is not simply forecasting the peak height but any particular height being reached or exceeded. A QPF limit of seven hours has been assumed in all of the evacuation planning and modelling around Penrith. The Bureau has also advised that it could provide at least nine hours warning at Windsor, so a nine hour QPF limit has been used for the Richmond-Windsor area when analysing regional evacuation traffic.

Forecast rainfall can be used to make flood height forecasts at any time but the further in advance the forecast is made the greater the risk that the forecast flood height will not eventuate or that it will be reached faster than that predicted.

2.5.2 Mobilisation

The SES's preferred approach for flood preparation throughout the State is to mobilise personnel after the QPF limit is reached. That is, emergency services personnel (SES, police, fire brigade etc) are mobilised under the SES command after sufficient rain has fallen

for the Bureau of Meteorology to confidently forecast that the evacuation critical flood height will be exceeded.

However, there are many places in NSW, and in the Hawkesbury Nepean Valley in particular, where development has occurred in the past without a proper understanding of flooding or flood evacuation logistics such that mobilising emergency services after the QPF limit is reached would result in insufficient time for evacuation. It has been estimated that if emergency services personnel were mobilised for the Hawkesbury Nepean Valley after the QPF limit was reached then there would only be sufficient time for subsequent warning dissemination to, and evacuation of, a few thousand homes.

In light of the long planning history of Penrith Lakes, which preceded the most recent developments in flood evacuation logistics developed by the SES, it was agreed several years ago to consider an evacuation strategy where the emergency service personnel are mobilised prior to the QPF Limit and the warning is disseminated soon after the QPF Limit.

This methodology, and an allowance of six hours for mobilisation, has been assumed in all evacuation planning and modelling in this report. There are risks and costs inherent in taking such an approach as discussed in later sections. The SES stressed at the time that this should not be seen as setting a precedent for developing evacuation strategies elsewhere in the Valley or the State.

The ability to sensitivity test the impact of mobilising after the QPF limit has been included in the model to assist with decision making about any future developments.

2.5.3 Evacuation Plan Overview

During a Level 2 flood the SES will activate its emergency response evacuation plan. This makes provision for those on the floodplain to evacuate along predetermined evacuation road routes as shown in Figure 3.

The overall evacuation plan works on the following principles:

- Evacuate homes and businesses only after the QPF limit is reached
- Commence evacuation as early as is practicable after the QPF limit is reached
- The majority of evacuees will be able to self-evacuate by vehicle.
- Door-knocking by volunteers will identify any evacuees who need assistance and buses or other vehicles will have to be provided for their evacuation.
- Completely evacuate any locality which can be overwhelmed or isolated by floodwaters before its evacuation route is cut
- Direct all such evacuees to the Homebush sports precinct for processing and temporary accommodation if they are unable to find alternative accommodation outside of the floodplain themselves
- Where a locality which can be flooded has access to an evacuation route which generally rises and the locality will not become isolated, only evacuate those buildings which are immediately threatened by the floodwaters and accommodate evacuees locally if practical, otherwise direct them to Homebush
- Use designated evacuation routes which have a low probability of being cut by localised flooding (i.e. flash flooding in a local catchment rather than by flooding from the Hawkesbury Nepean River).
- Secondary evacuation routes are used should localised flooding, breakdown, accidents or other contingencies block the primary evacuation routes.

The SES has advised that although the above principles underpin the plan, there is some flexibility to adapt to changing circumstances.

In particular, several existing communities in the Hawkesbury Nepean Valley need to have evacuation commenced before the QPF limit due to the number of existing residences and

current evacuation routes. If it is found that there are other existing population centres where this would be necessary to evacuate everyone then the SES will adjust its plan accordingly.

The Hawkesbury Nepean Flood Emergency Sub Plan also identifies secondary evacuation centres in case Homebush is not able to be used or does not have sufficient capacity to meet the demand.

2.5.4 Evacuation Routes

There are four main areas which need to be evacuated and are the focus of this investigation. Recommended routes for each are as follows:

- **Penrith/Emu Plains:** evacuated onto the Great Western Highway (GWH) or M4 and directed east to Homebush
- **Richmond:** directed south to the (GWH) or M4 and then east to Homebush
- **McGraths Hill/Windsor/Riverstone:** directed south east to the M7 and then east along the M7 and M2 and then south to Homebush or alternatively on non-tolled roads to Homebush.
- **Bligh Park/Windsor Downs:** sent south east to the M7 and then east along the M7 and M2 and then south to Homebush or alternatively on non-tolled roads to Homebush. This occurs until south creek cuts the route to the M7 after which they are directed south to the M4 or GWH then east to Homebush

Other locations do get evacuated but they do not have to immediately use the regional evacuation routes that these four main areas use and so have been excluded from these investigations. The excluded areas encompass:

- Wallacia
- North Richmond
- Pitt Town
- Wilberforce
- Rural areas north of Windsor

It was assumed for investigation purposes that evacuation would take place according to the SES plan along the nominated evacuation routes. The route descriptions are provided in more detail in Chapter 3.

2.5.5 Evacuation Triggers

A Level 2 flood is defined as one in which the water level of the Hawkesbury-Nepean River is expected to exceed 15.0 metres on the Windsor Bridge gauge. Level 2 flood operations designate a different level of flood emergency management arrangements because the scale of operations requires coordination at a State level.

While a 15.0 metre gauge reading is not in itself an evacuation trigger, a flood expected to reach exceed that height will require a scale of evacuation that is best managed at a state level.

The evacuation trigger for each area is based on the estimated time required to evacuate and the gauge level at which its evacuation route is likely to be cut. Where evacuation traffic from more than one location share an evacuation route, evacuation may need to be triggered earlier to avoid traffic arriving at any one time exceeding the capacity of the route.

The way in which these times and triggers are estimated is discussed further in Section 2.6.

a) Richmond/Windsor

Richmond, McGraths Hill, Windsor, Bligh Park and Windsor Downs can be isolated then overwhelmed by floodwaters.

Some isolated rural properties or peri urban areas such as south west Riverstone, Marsden Park, West Schofields and Colebee may need to be evacuated earlier because they can be isolated by local creek flooding before being affected by flooding from the River. The numbers of properties in these areas is currently small.

The SES may choose to delay the evacuation of Richmond because its evacuation route gets

cut at a higher level than the other areas. We have assumed for the purposes of modelling that its evacuation will be triggered at the same time as Windsor.

There is very little slope on the flood surface in the Richmond/Windsor floodplain and the gauge level at Windsor is almost the same as the flood level in all of the surrounding areas.

b) Penrith/Emu Plains

The areas of Emu Plains, Emu Heights and Leonay fall within Emu Plains Sector boundary. Parts of these suburbs are at risk of inundation. Emu Heights and Leonay have the potential to become isolated for extended periods of time during a level 2 flood. The SES may therefore choose to evacuate all properties including those located above the PMF.

These suburbs are subject to varying evacuation triggers, all of which result in evacuation traffic converging onto the M4 on-ramp at Russell Street. There is only limited available information in the Hawkesbury Nepean Flood Sub Plan on the triggers associated with evacuation from this sector. As a result two dimensional flood modelling was analysed in the program WaterRide to ascertain relative road route triggers and cut off times.

Similarly, on the eastern side of the Nepean River, the properties between Peach Tree Creek and the River and Boundary Creek and the River need to be evacuated well in advance of water threatening them because the floodwaters from the River will flow back up these creeks and cut off evacuation routes early in a flood.

During earlier investigations into Penrith Lakes, the SES decided that it would commence a Level 2 evacuation in Penrith Lakes if the Bureau advised that a 1 in 100 level would be exceeded at Penrith Bridge Gauge. This was based on the assumption that there would be residential development at Penrith Lakes affected by a 1 in 100 flood.

There is a significant slope on the flood surface through this stretch of River. For example, in a 1 in 100 flood peak the gauge reading just upstream of Victoria Bridge (Great Western Highway) would be 26.3m AHD but less than 3km upstream at the M4 Motorway Bridge at Regentville the level would be 28.1m AHD. Similarly, immediately downstream of Victoria Bridge, less than 100 metres from the gauge, the level would be 25.7m AHD. Further downstream, where the River would first overflow into the Penrith Lakes Scheme, the level would be 23.4m AHD.

Penrith Lakes flooding is further complicated by the fact that the floodwaters will enter the lakes through a series of weirs. These will attenuate floods which will mean that a 1 in 100 flood level in the lakes will be reached some time after it is reached in the River and this will add to the time taken for the floodwaters to travel from the gauge to the weir.

These significant differences in levels and timings have been considered in ascertaining the relative timings of evacuation triggers for each locality.

For this study a two dimensional RMA-2 flood model of the 72 hour PMF displayed in WaterRIDE was used for the analysis. This has some significant differences in flood behaviour, particularly downstream of Victoria Bridge, than flood modelling which was available for previous evacuation analyses of Penrith Lakes (Molino Stewart, 2005).

2.5.6 Warning Dissemination

While the SES intends to use multiple means of warning dissemination, including mass broadcasting of warning messages, the evacuation planning requires that sufficient time be allowed for every building to be door-knocked.

The SES intends to use volunteers working in pairs. From field exercises it is estimated that each pair of volunteers will take an average of five minutes to warn each household by door-knocking.

It was assumed for planning purposes that the time taken to warn business premises would

be one minute for each employee and that all premises (residential and business) would need to be door-knocked irrespective of the time of day, as it is never possible to assume that a building is unoccupied.

Preliminary analyses indicated that too few doorknockers may not generate evacuation traffic quickly enough to fully utilise the road capacity. We have therefore estimated for each area the number of pairs of door-knockers that would provide an optimal match between traffic generation rates and road capacities.

2.6 EVACUATION MODELLING

Evacuation modelling was undertaken using an Excel spreadsheet which represented each of the main population centres, the evacuation routes and the convergence of evacuation traffic.

The SES Timeline Evacuation Model (Opper 2004) was used to calculate the time required for evacuation and this was compared to the time available for evacuation.

The following subsections explain the assumptions used in the evacuation timeline model.

2.6.1 Warning Acceptance Factor

It was assumed that evacuees might take some time to accept the warning message. SES experience in other floods suggests that while some people accept the warning immediately others need some sort of visual cue to make them respond. Recent field surveys (Molino Stewart, 2005, 2007 & 2009) indicate that many people seek verification of warning information from a second source such as the radio or internet.

For planning purposes the SES assumes all residents and employees need a maximum of two hours as a warning acceptance factor (WAF). The SES evacuation modelling generally assumes that this warning acceptance factor diminishes to zero by the time the last person is warned as there would be sufficient visual cues for people to take the warning seriously. An average WAF of one hour was therefore used for all areas.

2.6.2 Warning Lag Factor

After accepting the warning it will take evacuees some time to organise themselves, their possessions and their property before leaving their premises. A one hour warning lag factor (WLF) has been incorporated in the evacuation planning for such an allowance. Surveys of occupants affected by flooding on the NSW North Coast (Molino Stewart 2005 & 2009) indicate that residents spent between 10 minutes and 48 hours to organise themselves before leaving the property. Most took 1-2 hours. Businesses on the other hand spent considerably more time with most taking 4-6 hours to pack and leave.

One hundred and five respondents in Maitland estimated how long it took them to prepare for evacuation, of which 94 were residences and 11 were businesses. The minimum preparation time was 10 minutes for both residences and businesses and the maximum time was 48 hours for a residence. The maximum time recorded for businesses was 36 hours. On average, residents took a little over five hours to prepare for evacuation and businesses took nearly 12 hours (Molino Stewart, 2007).

2.6.3 Road Capacity

A two lane rural road under normal driving conditions can carry about 1,200 vehicles per hour per lane. For modelling, it was assumed that the internal 'feeder' roads and external evacuation routes would each have an average capacity of 600 vehicles per hour per lane. This is consistent with the SES evacuation model which was developed in consultation with Roads and Traffic Authority engineers, consulting traffic engineers and international experts on emergency evacuation. This reduction in road carrying capacity has been assumed to account for the likely adverse weather conditions which are likely to be prevailing at the time of evacuation

and the potential lack of street lighting and traffic signals due to power failure.

A 600 vehicle per hour flow equates to vehicles travelling at about 10km/hr two car spaces apart or 20km/hr seven car spaces apart.

All routes were assumed to have one lane dedicated to emergency service vehicles entering or leaving the area.

With the exception of The Northern Road south of Andrews Road, it was assumed that no contraflow traffic would be used for evacuation traffic. That means all evacuation traffic (other than one lane on The Northern Road) would be driving on the correct side of the road.

It was assumed that residents who are outside the development when the warning is first issued will return within the first couple of hours, and that once a vehicle leaves the area it will not return.

A further assumption was that the State Government, on advice from the SES, would declare a state of emergency or a public holiday and close schools and government offices to reduce the demand for travel and free up road capacity for evacuation.

2.6.4 Traffic Safety Factor

It was recognised that apart from the Nepean River rising to cut evacuation routes, flooding as a result of local rainfall could also cause route closure. It was therefore assumed that all evacuation routes would be constructed, or reconstructed, to a standard which would ensure they had less than a 1 in 500 chance per year of being cut due to runoff from local catchments.

The model acknowledges that rarer local flood events could block evacuation routes temporarily as could fallen trees and powerlines, vehicle collisions or other incidents. To account for these possibilities the SES use traffic safety factors (TSF), as shown in Table 1 when planning its evacuation strategies.

Table 1: SES Evacuation Traffic Safety Factors

Base Travel Time (hours)	**Traffic Safety Factor (hours)**	**Total Travel Time (hours)**
1 to 3	1	2 to 4
4 to 6	1.5	5.5 to 7.5
7 to 9	2	9 to 11
10 to 12	2.5	12.5 to 14.5
13 to 15	3	16.5 to 18.5
16	3.5	19.5

2.6.5 Required Evacuation Time

The model assumes that emergency service personnel are mobilised and the first premises can be doorknocked as soon as the QPF limit is reached for the evacuation trigger level.

The time required for evacuation is therefore:

ET=WAF+WLF+BTT+TSF

Where:

ET = evacuation time

WAF = warning acceptance factor (1hr)

WLF = warning lag factor (1hr)

BTT = base travel time (number of vehicles divided by number of lanes divided by 600)

TSF = traffic safety factor (as per Table 1)

2.6.6 Available evacuation time

The SES evacuation modelling of the Hawkesbury Nepean Valley is based on evacuating ahead of a flood rising as fast as a 72hr probable maximum flood (PMF). Floods which are more common than a PMF could rise this fast and it is also possible for extreme floods to rise faster than this.

For this analysis the modelled 72hr PMF was used to estimate rates of flood rise. It averages about 0.5m per hour on the rising limb of the

flood stage hydrograph in the early stages of the flood.

The available evacuation time will therefore be the amount of advanced warning that the Bureau of Meteorology can give ahead of the evacuation trigger point being reached plus the time it takes for a 72hr PMF to rise from the trigger level to cut off the evacuation route or flood the premises (whichever comes first). In some places the trigger level will be the level of the road or the premises and so it will simply be the amount of advanced warning given by the Bureau.

2.6.7 Evacuation traffic convergence

Where evacuation traffic travelling along different routes converges at an intersection, and the combined traffic flows exceed the road capacity, then it was assumed that certain traffic streams would be given priority while others queued until there was sufficient capacity for another traffic stream to use the road.

For analysis purposes is has been assumed that traffic which would first be overwhelmed by rising floodwaters would be given priority and the other traffic would queue.

Another important consideration in estimating the degree of traffic convergence is the relative timing of evacuation triggers in the Penrith Emu Plains area compared with the Richmond/Windsor Area.

The one dimensional flood model of the Hawkesbury Nepean River has been run with design floods which produce the same probability peak at all points along the river. For example the design 1 in 100 event results in a 1 in 100 peak at Penrith and a 1 in 100 peak at Windsor. Real floods will not necessarily behave like this. For example the 1867 event had about a 1 in 180 chance of occurrence at Penrith and a 1 in 220 chance of occurrence at Windsor. It very much depends on the relative timing and location of the rainfall which produces the flood.

There are three factors which can influence the relative timings of evacuation from the two parts of the floodplain.

Firstly, at Windsor 14m AHD which has about a 1 in 20 chance of being exceeded while the critical level of 25.4m AHD at Penrith has a 1 in 100 chance of being exceeded. In other words, for a flood with the same probability along the river the critical level at Windsor is passed earlier in the flood rise at that location than at Penrith. Therefore the Richmond, Bligh Park and Windsor evacuation is called earlier in the flood.

Secondly, the Bureau of Meteorology expects that it will be able to confidently forecast critical levels at Windsor nine hours in advance but at Penrith only seven hours in advance. The SES is likely to trigger evacuation as soon as the Bureau is confident critical levels will be exceeded

Were the rain to be distributed as per the design PMF then flood levels of a given probability would be reached at Penrith before they are at Richmond or Windsor. However, should the Grose and Colo Rivers peak before major flows come down the Nepean River, then Richmond and Windsor trigger levels could be reached in advance of those at Penrith.

Previous investigations (Molino Stewart 2005) indicate that it would be reasonable to assume that 14m AHD at Windsor could be reached at any time from four hours before to seven hours after 26.3m AHD is reached at Penrith (the trigger level for Penrith Lakes evacuation) although conceivably it could happen outside of those times too.

For the purpose of analysis, the worst case was assumed: that the Penrith Lakes and Waterside Green evacuation traffic would converge at the intersection of The Northern Road and Andrews Road. This is a credible scenario. The relative timing of other traffic from the Penrith region was based on the timing of evacuation triggers being reached in a flood rising as fast as the 72 hour PMF. For the downstream areas of the Valley, it was assumed that a forecast of 14m AHD at Windsor Bridge would be the evacuation

trigger for all areas around Richmond and Windsor and back up along South Creek. It was assumed that if the SES wished to delay the evacuation of any of those areas then this would simply be reflected in a longer time for mobilisation for that particularly locality. This is how it has been set up in the model.

2.7 ROAD UPGRADE OPTIONS

As urban development increases in the floodplain and surrounding areas, it is anticipated that road infrastructure will be upgraded to cater for day to day traffic. Much of this road infrastructure would be able to be used for flood evacuation. Some may need some additional modifications to be incorporated into the upgrades to make them more suited to flood evacuation (e.g. raising of low spots, improved creek crossing or sealed shoulders).

The need to cater for flood evacuation may require these roadworks to be brought forward from their otherwise expected construction date.

Other roads, which are not planned for upgrade may need to be improved to cater for flood evacuation.

Through discussions with the Roads and Traffic Authority, Department of Planning, Penrith Council, Blacktown Council and Hawkesbury Council we identified what roadworks are planned, their design details and their likely timing.

Where the evacuation modelling revealed that existing or planned roadworks would need further modification we identified modification options and civil engineering firm J Wyndham Prince provided rough cost estimates for the additional roadworks.

2.8 LIMITATIONS

The method which has been used has relied on four sets of modelling which introduce several limitations to the results which must be recognised and understood. Furthermore, assumptions have had to be made to estimate the number of vehicles which will evacuation now and in the future.

2.8.1 Flood Modelling

While computer based flood models can give fairly accurate estimates of flood levels and rates of rise for a given set of inflows, the inflows at various points and times in an actual event can vary considerably from those which have been assumed for modelling purposes.

In particularly, rates of rise may be faster or slower than assumed in models and the relative flood peaks and timings at different points along the river may vary considerably.

We have been conservative by assuming that any event that triggers evacuation will rise as fast as a 72 hour PMF irrespective of the final peak it reaches. This is conceivable and is consistent with the approach which has been taken by the SES in all of its evacuation planning for the Valley. It is also conceivable that floods could rise faster than this. For example a 24 hour PMF could rise at almost three times this rate in some parts of the Valley.

We have also assumed that the relative timings of evacuation triggers being reached around Penrith and Richmond/Windsor will result in Penrith Lakes, Richmond and Bligh Park traffic all arriving at the Andrews Road/Richmond Road intersection. This is a conceivable scenario. It is also conceivable that either traffic streams begins arriving before the other in which case any problems caused by traffic convergence would be lessened.

2.8.2 Flood Forecasting

During an actual flood the Bureau of Meteorology will use its own rainfall and runoff modelling to forecast future flood heights and timings. We have assumed, based on advice from the Bureau, that it will be able to forecast the Level at Penrith at least 7 hours in advance and at Windsor at least 9 hours in advance.

While it expressed a 95% confidence in achieving these times, it might not, in which case there will be less time for evacuation. If they are able to provide reliable forecasts further in advance then more time would be available for evacuation than has been assumed.

2.8.3 Evacuation Modelling

The SES Evacuation Timeline Model makes assumptions about the time it takes for various steps in the warning and evacuation process to take place. While these assumptions are reasonable, and a sound basis for testing the ability to evacuate an area, they are assumptions and in a real event more or less time may be taken for any or all of the steps.

The greatest risk in terms of evacuation planning is that evacuees are simply unwilling to leave their premises (particularly homes) until it is too late to safely evacuate by car, or will not evacuate at all. Even if everyone decides to evacuate, if they all do so a soon as the first warning is broadcast considerable traffic congestion and queuing would ensue although it should be able to dissipate in the time allowed for staged evacuation in the model. Should they all leave well after they are expected to then many may not be able to get out in time.

2.8.4 Evacuation Traffic Modelling

The evacuation traffic model is a spreadsheet and not a specialised traffic model. As such, it makes some simplifying assumptions about traffic flow and behaviour. It has also been necessary to assume whole subsectors will be evacuated when a particular trigger is forecast to be reached. In a real event the SES may decide to wait and see how quickly the River is actually rising and what the Bureau forecasts are and they may choose to delay evacuation or only evacuate those who are immediately threatened.

The evacuation traffic modelling also assumes that no evacuating vehicles will make return trips and that the routes will all be free of general background traffic. If either of these assumptions prove to be incorrect in an actual evacuation then evacuation route capacity will be reduced considerably.

2.8.5 Vehicle estimates

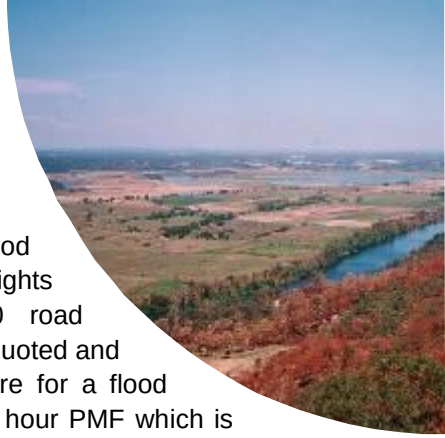
The only count of actual vehicles in the Valley is taken every five years during the Census. This is not a complete count as it only includes vehicles at residential properties, not everyone answers the question on motor vehicles and if there are more than five vehicles at one household those extra vehicles are not counted.

Furthermore, there is growth in population between census dates and car ownership ratios are not static. Assumptions need to be made about population growth and vehicle ownership.

Estimating the number of vehicles evacuating from commercial and industrial properties requires assumptions to be made about the number of vehicles at each of these premises but there is not real way of knowing whether these are correct.

Finally, it has been assumed that all of the estimated residential, commercial and industrial vehicles will need to evacuate when an evacuation is called. If the evacuation is called outside of business hours then there is likely to be little commercial or industrial vehicular traffic. If it is called during business hours then many residents may be away from the floodplain and some commercial vehicles away from their premises. They might all return before subsequently evacuating.

The assumptions made regarding the number of evacuating vehicles therefore represents a worst case if the number of vehicles in the floodplain has not been underestimated.



3 EVACUATION ROUTE DETAILS

This section explains in detail the evacuation routes assumed for each sector and subsector, the time and gauge level which has been assumed as an evacuation trigger and the timer and gauge level at which the evacuation route(s) is cut.

3.1 SES PLANNING

3.1.1 SES sector/subsectors

The NSW SES has divided potentially flood affected areas into 29 emergency response sectors, which are controlled by the six local SES offices in the region. Flood response is managed on a sector by sector basis. The majority of sectors located on the floodplain contain two or more subsectors.. We estimated the number of vehicles which would need to evacuate from each sector/subsector in the years 2010, 2020, 2030 and 2040.

3.1.2 Evacuation Routes

Figure 3 shows the primary and secondary evacuation routes together with their designated population centres as determined by the NSW SES Hawkesbury Nepean Flood Emergency Sub Plan (2005). Locations affected by flooding are serviced by several primary evacuation routes some of which converge with each other. Some locations also have secondary evacuation routes which may be utilised by the evacuees and/or the SES during the event, particularly if there are incidents causing delays on the primary route.

Routes vary in capacity from single lane roads to three lane Motorways. This affects the time taken for evacuation along each route as well as the capability for regional traffic to merge.

We analysed the current evacuation routes in the figure and investigated potential changes in the evacuation route structure and capacity for the years 2020, 2030 and 2040.

In this Section, the flood levels at which road heights are cut are for 2010 road conditions. The timings quoted and relative gauge heights are for a flood rising as quickly as a 72 hour PMF which is the event the SES uses as the basis of its evacuation planning. Floods triggering evacuation could rise more slowly than this but there is also a small chance that they could rise more quickly. Evacuation will be triggered if the SES believes that there is a real risk of an area becoming inundated, evacuation may need to take place well in advance of that occurring if routes are cut early in a flood.

All heights are reported in metres above Australian Height Datum (AHD) which is approximately mean sea level. Gauge heights referred to are just upstream of Victoria Bridge at Penrith for the Penrith and Emu Plains areas and Windsor Bridge for the Richmond and Windsor areas.

3.2 EMU PLAINS

Traffic from Emu Plains, Leonay and Emu Heights all travel along separate single lane evacuation routes until they turn onto the same M4 on ramp at Russell Street as shown in **Error! Reference source not found.**.

a) Emu Heights

Traffic evacuating from Emu Heights, Emu Plains North and Emu Plains West subsectors would travel

- south along Wedmore Road
- east on Old Bathurst Road
- south on Russell Street
- east onto the M4 Motorway on ramp at Russell Street

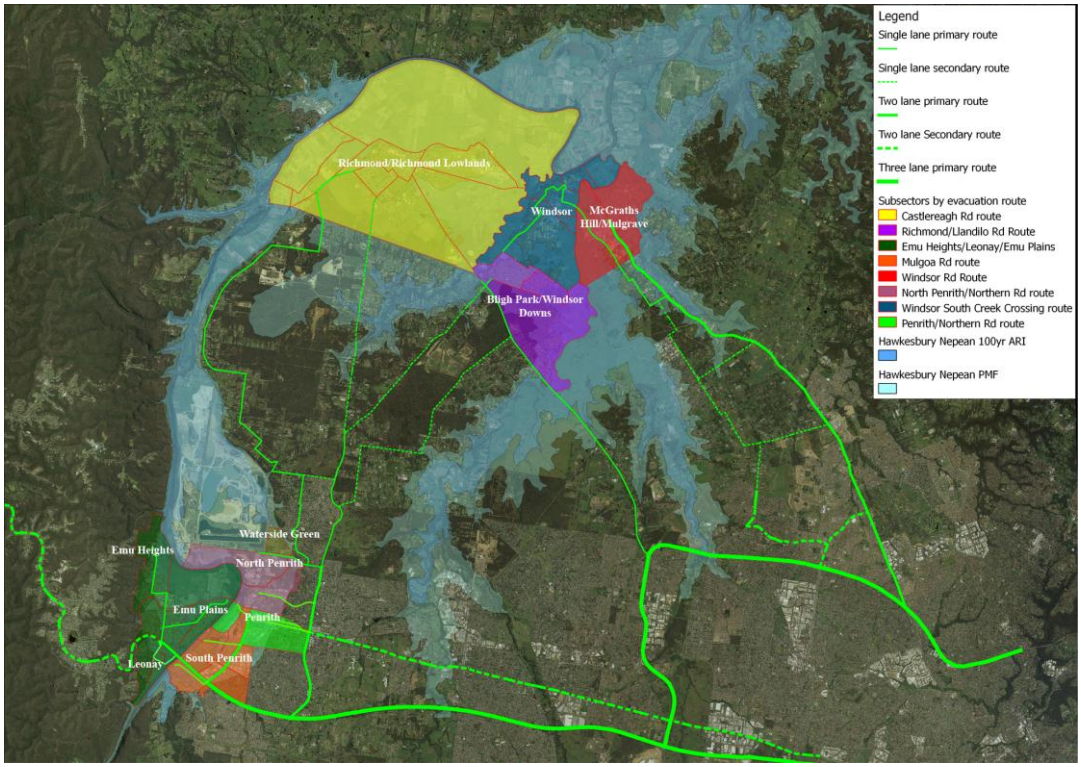


Figure 3: Hawkesbury Nepean Evacuation Routes

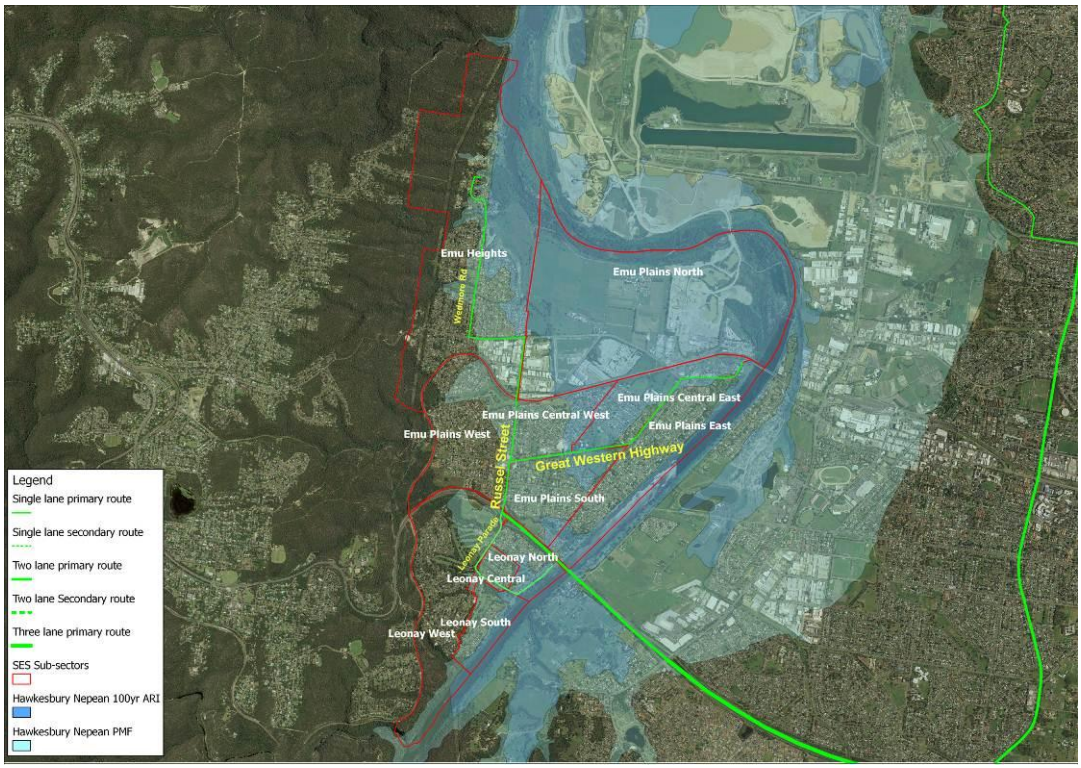


Figure 4: Emu Plains, Emu Heights and Leonay Evacuation Routes

This stream of traffic would be the first to commence evacuation from the area during a significant flood event. Sections of Emu Heights become isolated when the route is cut at Wedmore Road close to Alma Crescent at a local height of 20.4m which corresponds to a gauge height of 23.8m at Victoria Bridge in a flood rising as fast as a 72 hour PMF.

This route is a single lane all of the way to the M4. The M4 itself has two eastbound lanes at this location.

b) Leonay

Leonay North, Leonay Central and Leonay South subsector traffic would be the next to commence evacuation and would travel

- south along Nepean Street
- west along Buring Avenue
- north along Leonay Parade
- east onto the M4 Motorway on ramp at Russel Street

This route would be cut at Buring Avenue close to Nepean Street at a local height of 26.9m corresponding to a gauge height of about 24.4m.

The entire suburb of Leonay including Leonay West subsector would become isolated after Russell Street is cut at a height of 32.9m. Even though no houses in the Leonay West subsector would flood, they could be isolated for a considerable time so the SES intends to evacuate the subsector if it is forecast this level will be exceeded.

This route is a single lane all of the way to the M4.

c) Emu Plains

The final stream of evacuation traffic from the area would include the subsectors of Emu Plains Central West, Emu Plains Central East, Emu Plains East and Emu Plains South. This stream would travel

- west on the Great Western Highway
- south on Russel Street
- east onto the M4 Motorway on ramp at Russell Street.

These subsectors would become isolated after the Great Western Highway is cut close to Lawson Street at a height of 25.5m which corresponds to a gauge height at Victoria Bridge of 25.7m.

This route is a single lane all of the way to the M4.

3.3 PENRITH

The area around Penrith contains a number of relatively short evacuation routes all of which are expected to take evacuation traffic to the M4 as shown in **Error! Reference source not found.**.

3.3.1 Penrith North

Both the North Penrith A and North Penrith B subsectors would evacuate

- North east along Coreen Ave
- south along The Northern Road
- east onto the M4 on ramp

North Penrith A is cut off by rising floodwaters at Castlereagh Road close to Boundary Creek at a height of 22.3m before North Penrith B is cut at Coreen Avenue close to Castlereagh Road at a height of 23.9m. For modelling purposes we assumed Penrith North A would require earlier evacuation than Penrith North B.

This route is two lanes all of the way to The Northern Road. The Northern Road has two southbound lanes and the SES has previously indicated that it would be willing to accept a third, contra-flow lane, on the Northern Road if necessary.

There is only a single lane on ramp from The Northern Road to the M4 but the motorway has three eastbound lanes at this point.

3.3.2 Penrith

The Peach Tree Creek West subsector is a small group of houses between Peach Tree Creek and the River just south of Victoria Bridge which would evacuate:

- north along Nepean Avenue
- east onto the Great Western Highway
- south onto The Northern Road
- east onto the M4 on ramp

This subsector would require early evacuation because the Great Western Highway would be cut close to Ladbury Avenue at a height of 20.3m and a gauge height of 22.1m.

For modelling purposes we assumed that the primary route of evacuation from the Penrith subsector would involve travelling

- east along the Great Western Highway or High Street
- south onto the Northern Road
- east onto the M4 on ramp.

Two lanes would be available to The Northern Road.

Alternative routes exist further south. These include Derby Street and Jamison Road which can each carry two lanes of traffic. We have assumed for modelling purposes that the industrial areas of Jamisontown East and the residential areas of Jamisontown South will evacuate along these routes rather than head downhill towards Mulgoa Road which bisects these sectors.

It was assumed that the flood would cut off all alternative routes at approximately 27.2m corresponding to a gauge height of 27.4m at Victoria Bridge. This is probably conservative.

3.3.3 Penrith South

Three streams of traffic would evacuate along Mulgoa Road during a PMF event.

The first of these streams to commence evacuation would be the Regentville subsector. This evacuation route involves travelling

- east along Factory Road
- north along Mulgoa Road
- east onto the M4 on ramp

It is assumed that the entire subsector would require evacuation prior to Factory Road being cut at a height of 25.3m corresponding to a gauge height of 23.2m at Victoria Bridge. Most of the houses in the subsector are east of the low point on Factory Road so this is a simplifying assumption.

Factory Road provides a single lane and Mulgoa Road has two lanes available for evacuation heading north.

Jamisontown West and Peach Tree Creek South subsectors need to evacuate:

- north along Tench Avenue
- east on Jamison Road
- south along Mulgoa Road
- east onto the M4 on ramp

This route is expected to be cut at Jamison Road close to Anakai Drive at a height of 22.7m corresponding to a gauge height of 23.6m at Victoria Bridge.

The final stream to evacuate along Mulgoa Road would include the Peach Tree Creek East subsector and the western parts of Jamisontown East (residential) and Jamisontown South (commercial/industrial) subsectors. This evacuation route would involve travelling

- south onto Mulgoa Road
- east onto the M4 on ramp.

The evacuation route would be cut along Mulgoa Road close to Blakie Road at a height of 27.1m and a gauge height of 27.1m at Victoria Bridge.

Each of the feeder roads has a single lane out but there are two lanes heading south on Mulgoa Road. These and the two north bound lanes on Mulgoa road would all need to use the single lane on ramp at the M4.

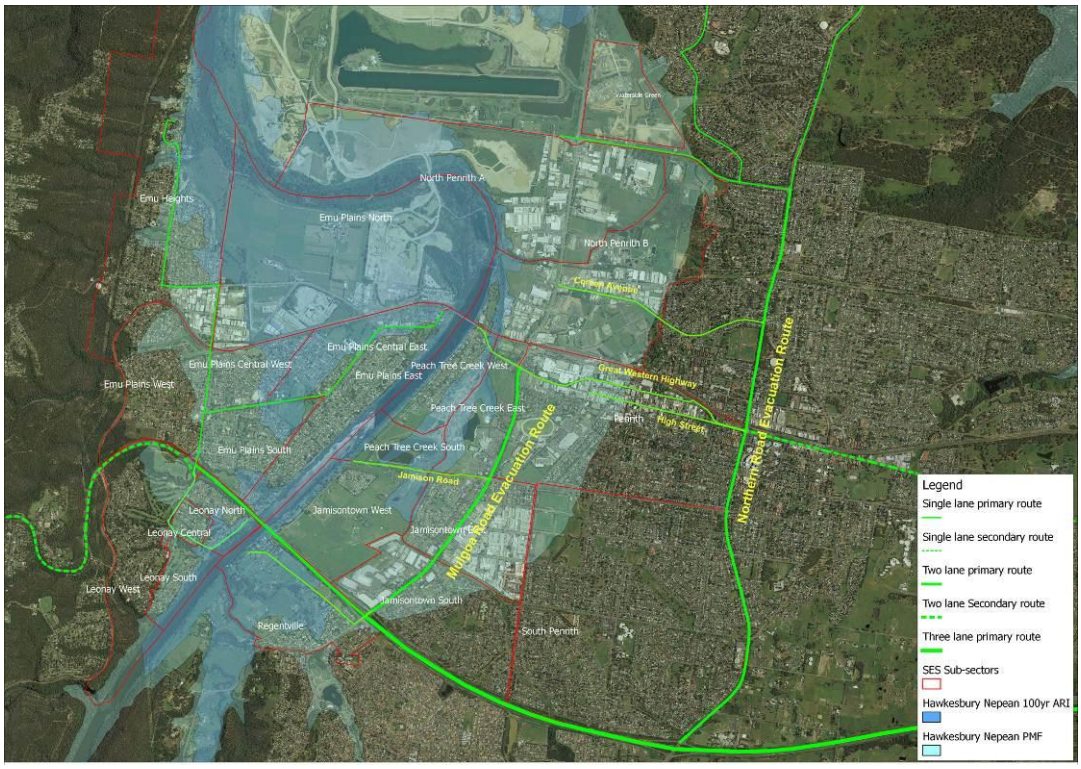


Figure 5: North Penrith, Penrith and South Penrith Evacuation Route

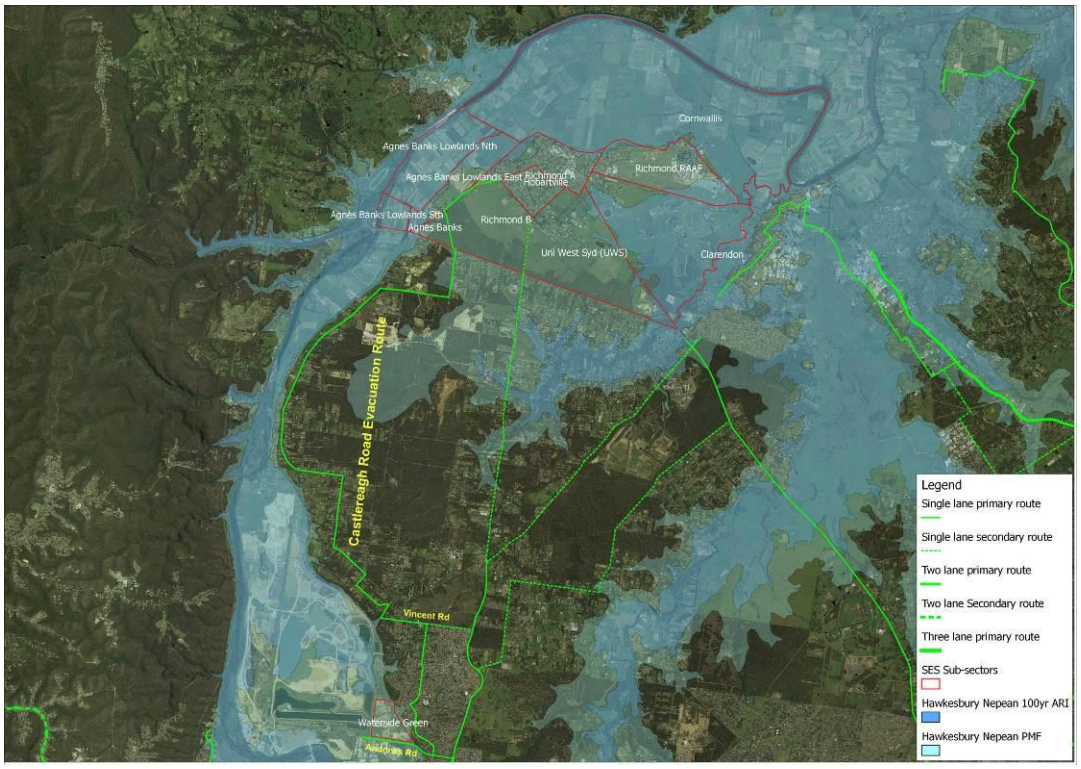


Figure 6: Richmond/Richmond Lowlands Evacuation Route

3.4 RICHMOND

The entire Richmond/Richmond Lowlands sector would evacuate along the Castlereagh Road route. This would include traffic from subsectors Richmond A, Richmond B, Hobartville, Cornwallis, Richmond RAAF Base, Clarendon, University of Western Sydney, Agnes Banks, Agnes Banks Lowlands South, Agnes Banks Lowlands East and Agnes Banks Lowlands North as shown in Figure 6 The primary evacuation route for these sectors would involve travelling:

- south on Castlereagh Road
- east along the Agnes banks detour (The Driftway, Jockbet Rd and Wiltshire Rd)
- south along Castlereagh Road
- east along Hinxman Road
- south along Sheredan Road
- east onto east Wilchard Road
- south onto Church Street
- east onto Church Lane
- south onto Cranebrook Road
- east onto Vincent Road
- south onto Grays Lane
- east onto Hindmarsh Street
- south onto Laycock Street
- south onto Greygums Road
- east onto Andrews Road
- south onto the Northern Road
- east onto the M4

The evacuation route is cut along Castlereagh Road, close to the Driftway at a height of 20.2m corresponding to a gauge height at Windsor Bridge of 20.1m.

Under the current evacuation arrangements, the Castlereagh Road route converges with Waterside Green evacuation route on Andrews Road, east of Greygums Road.

Two alternative evacuation routes exist for Richmond/Richmond Lowlands subsectors. The main alternative would be to evacuate traffic south along Londonderry Road and then onto the Northern Road. This route is cut approximately four hours prior to the primary route at a road height of 18m and Windsor Bridge gauge height of 17.9m.

The second alternative route involves diverting traffic east along the full length of Vincent Road and then onto the Northern Road, bypassing the streets of Mt Pleasant. This alternative route contains low points which under present conditions could be subject to localised flooding.

3.5 MCGRATHS HILL/MULGRAVE

McGraths Hill and Mulgrave subsectors have only one designated primary evacuation route as shown in

Figure 7:South Creek and Windsor Road Evacuation R.

This would involve travelling

- south east along Windsor Road
- south east along Old Windsor Road
- east onto the M7/M2 Motorway on ramp

This route would be cut at a number of points on Windsor Road between Curtis Road Mulgrave and Park Road Vineyard at a height of 13.5m and a Windsor Bridge gauge height of 13.4m.

Two streams of evacuation traffic could utilise this route, with one stream from Mulgrave subsector and one stream from McGraths Hill travelling along the allocated two lanes.

a) Windsor/South Windsor

The primary evacuation route for the South Windsor, Windsor East, Windsor Central and North Windsor subsectors, as shown in

Figure 7:South Creek and Windsor Road Evacuation R would involve travelling

- north east along Macquarie Street
- north west onto Argyle Street

- north east along Cox Street through the gated railway level crossing
- north east along Moses Street
- south east onto Tebbutt Street
- north east along George Street
- south east onto Christie Street
- north east along Macquarie Street
- south onto Day Street
- south east along the South Creek Crossing
- south east along Railway Road South
- north east along Level Crossing Road
- south east along Wallace Road
- north east onto Bandon Road
- south east along Windsor Road
- south east along Old Windsor Road
- east onto the M7/M2 on ramp

This route is expected to be cut at the South Creek Crossing (Jim Anderson Bridge) at 17.3m and a gauge height at Windsor Bridge of 17.3m.

There are several alternative routes for Windsor traffic south of Bandon Road. These alternative routes include several entrance points onto Windsor Road south of its intersection with Bandon Road.

The alternative evacuations routes would involve travelling

- south east along O'Connell Street
- south west onto Victoria Street
- south east onto Hamilton Street
- south west onto Garfield Road to Windsor Road)

If Garfield Road cannot be used the traffic can continue:

- south east along McCulloch Street
- north east onto Park Road
- south east along Boundary Road
- east onto Schofields Road to Windsor Road

If Garfield Road cannot be used the traffic can continue:

- south onto Hambledon Road
- east onto the Quakers Hill Parkway
- south onto Sunnyholt Road (alternative option – north east to Windsor Road)
- east onto the M7 Motorway on ramp

The alternative routes are all located above the PMF flood level, with the exception of the Garfield Road alternative and the section of O'Connell Street closest to Bandon Road. Bandon Road, Garfield Road and Schofields Road can each be potentially cut by localised flooding.

b) Bligh Park/Windsor Downs

The evacuation of Bligh Park West subsector, and Bligh Park East subsector as shown in

Figure 8:Bligh Park/Windsor Downs Evacuation Route. have a primary route which goes:

- south along Thorley Street via the gated road
- south east along Richmond Road
- East onto the M7 Motorway on ramp

Windsor Downs sector would also travel south east along Richmond Road to the M7.

This route is expected to be cut at 14.1m at the Richmond Road South Creek crossing with a gauge height at Windsor Bridge of 14.1m.

Apart from a section of Richmond Road approaching the M7, this route provides a single evacuation lane and a single lane on ramp to the M7.

The Secondary route for these vehicles would involve turning off Richmond road and travelling:

- south west on Llandilo Road
- west on Fourth Avenue
- south onto Terrybrook Road
- west along Ninth Avenue

- south onto the Northern Road

The secondary route would be cut at a height of 17.3m and a gauge height at Windsor Bridge of 17.3m.

This route has a single evacuation lane all the way to the Andrews Road intersection with The Northern Road.

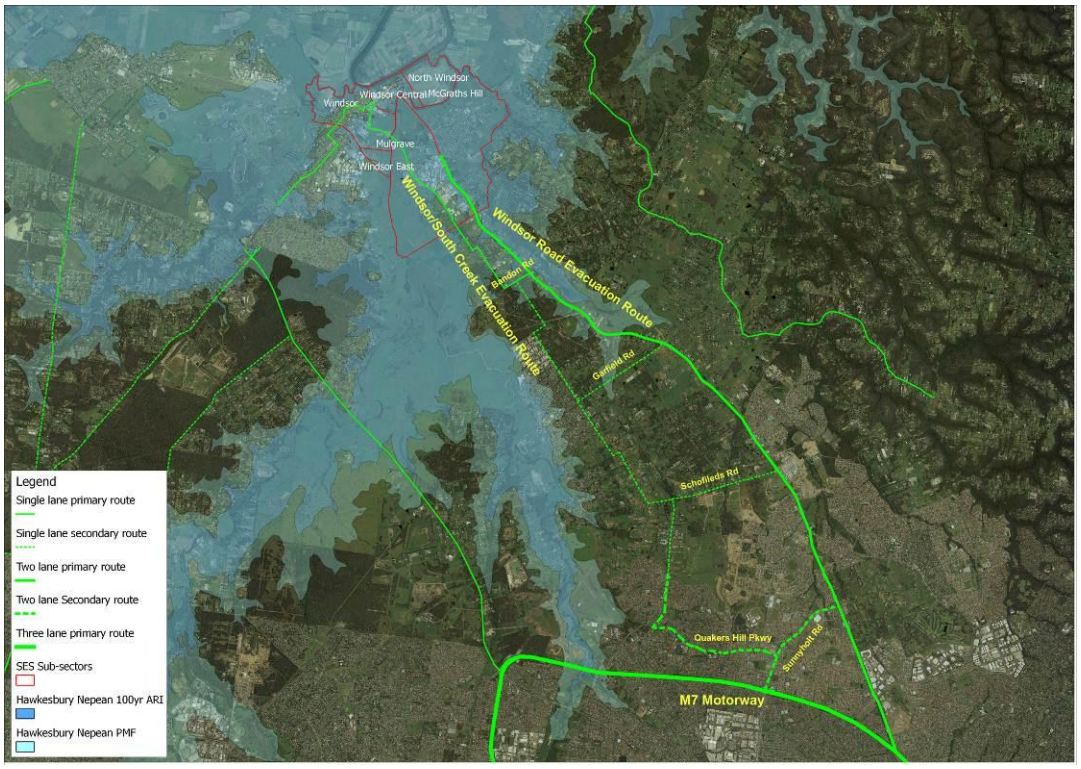


Figure 7: South Creek and Windsor Road Evacuation Route

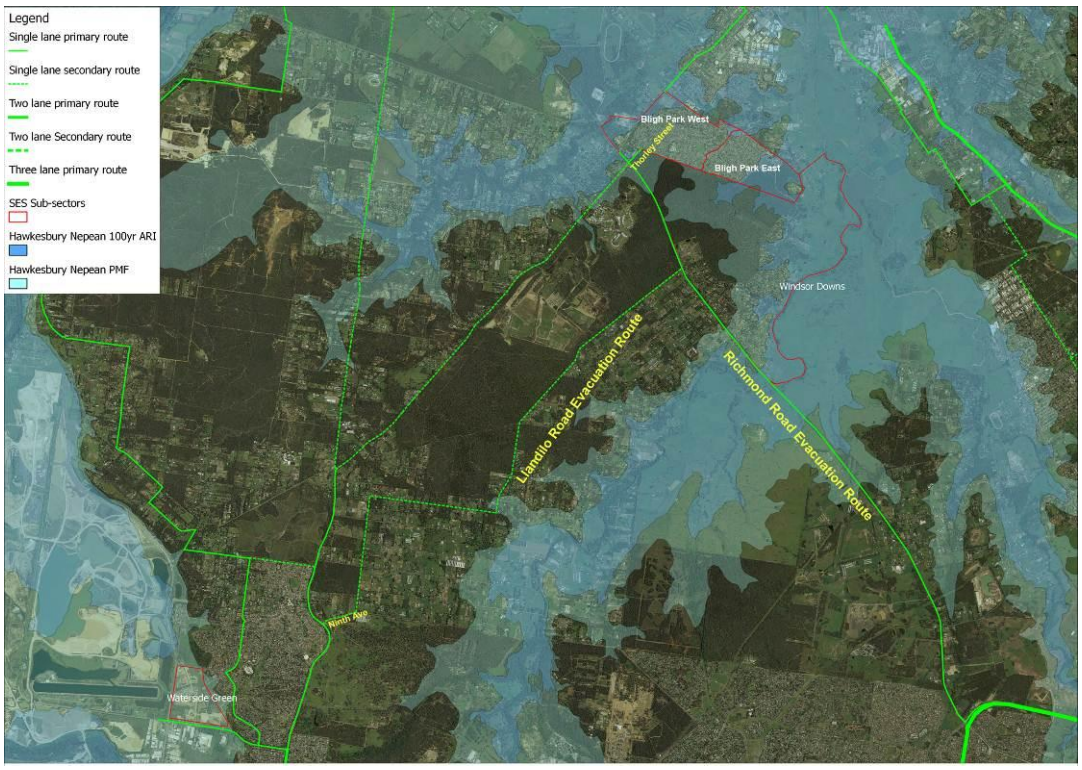
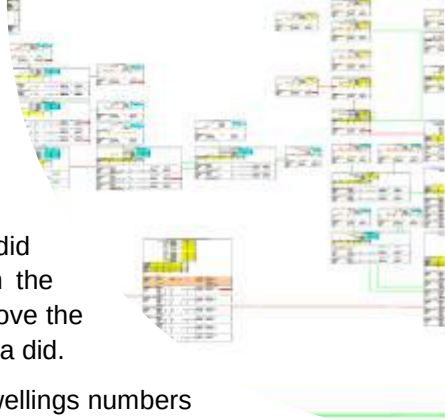


Figure 8: Bligh Park/Windsor Downs Evacuation Route



4 MODEL INPUT RESULTS

This chapter sets out the results of investigations into the number of properties which may be affected by flooding, the number of vehicles which may need to evacuate and the possible evacuation infrastructure available now and in the future.

4.1 AFFECTED PROPERTIES

4.1.1 2010

Table 3 summarises the number of potentially flood affected residential and commercial properties in each subsector as estimated by Geoscience Australia. These estimates are compared with estimates derived by the other two methods.

The NEXIS residential dwellings data and the Council rating data correlate well in some subsectors, while they are significantly different in others. There are significant differences in:

Jamisontown East, NEXIS data estimates 1,411 dwellings below the PMF which is, exactly 1,000 dwellings more than the Council estimates (411) for the same subsector.

Windsor/South Windsor subsector NEXIS data is also significantly higher than the council estimates with a total of 3,621 dwellings, resulting in more than 840 residential dwellings or 30% difference between the NEXIS and the council data.

Richmond NEXIS data has an additional 1,041 dwellings or 34% more than Council data

Bligh Park has an extra 644 dwellings or 26% more

Emu Plains has 244 more dwellings or a 12% increase..

In some places council estimates were significantly higher than NEXIS counts but these can be attributed to the fact that the council ratings database did not exclude areas within the subsector which were above the PMF while the NEXIS data did.

The NEXIS residential dwellings numbers are also significantly higher than the latest Census data, when including additional lots created between 2006 and 2010. The results in Table 3 show differences of 19% or 789 dwellings for Richmond, 14% or 445 dwellings for Windsor/South Windsor, 15% or 395 dwellings for Bligh Park Windsor Downs and 13% or 264 dwellings for Emu Plains. The ABS dwelling numbers are however generally higher than those from council.

When making these comparisons it should be borne in mind that the three datasets are not estimating exactly the same things. Nexis calculates residential addresses, ABS counts residential dwellings and the council counts ratable residential properties. The latter will count dual occupancies and strata titled dwellings as single residential properties where the other two methods will count them as multiple addresses or dwellings,

The number of vehicles generated by commercial and industrial development will not be a function of the number of buildings but rather the number of businesses occupying the premises. This can be significantly different as demonstrated in Table 2. The NEXIS counts for commercial/industrial buildings correlates well when compared to council estimates but it is clear from the NEXIS data that on average each building has several businesses.

Modelling was undertaken using NEXIS data which was also assumed to be an upper bound and council data was assumed to represent a lower bound.

4.1.2 Future

Figure 9 shows locations of proposed and approved developments on or adjacent to the Hawkesbury Nepean floodplain within the North West Metropolitan Strategy. This includes a number of North West Growth Centre precincts. summarises the expected

population and development growth in these precincts for the years 2020, 2030 and 2040.

Some of these proposed developments however would not be subject to flooding during a PMF event.

In the North West Growth Centre the precincts of Alex Avenue, Riverstone East, Area 20, Box Hill Industrial and North Kellyville would not be flooded in areas subject to built development. In addition, one of the ADI development sites is not located on the floodplain and would not require evacuation during an event.

Other localities where growth is expected and the number of additional premises for each decade is summarised in Table 5

Table 2: 2010 NEXIS commercial and industrial buildings and addresses by SES sector

Sector	**2010 NEXIS commercial & industrial buildings**	**2010 NEXIS commercial & industrial addresses**
Emu Plains	195	573
Penrith	342	2,519
North Penrith	253	826
Richmond	212	807
Richmond Lowlands	0	0
Bligh Park	1	5
Windsor Downs	0	0
Windsor	330	946
McGraths Hill	173	423

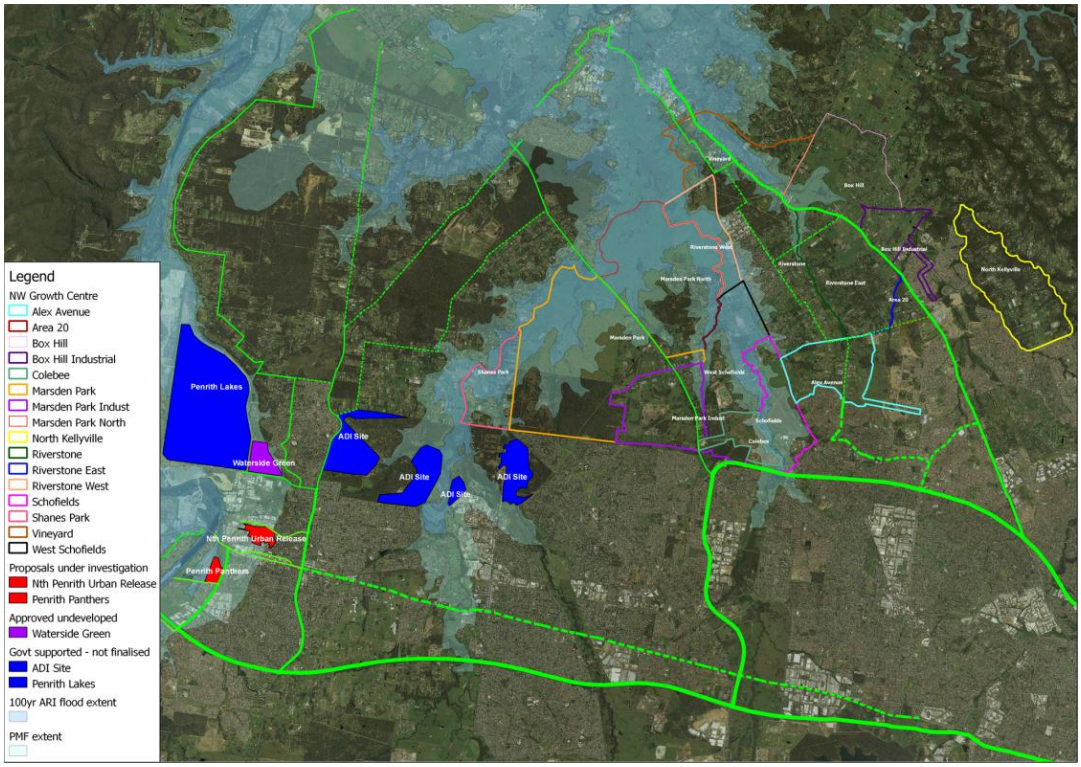


Figure 9: Approved and proposed developments

Table 3: 2010 Residential dwelling and commercial/industrial property estimates

Sector	Subsector	Residential dwellings			Commercial and Industrial buildings	
		2010 NEXIS	2010 Council Estimates	2006 ABS Census private occupied and unoccupied dwellings + additional lots 2010	2010 NEXIS	2010 Council Estimates
Emu Plains	*Emu Heights*	613	1129[1]	2,082[2]	44	45
	Emu Plains Central East	308	276		41	49
	Emu Plains Central West	442	408		0	1
	Emu Plains East	826	684		0	9
	Emu Plains South	528	470		0	0
	Emu Plains West	242	909[1]	NA	0	0
	Emu Plains North	0	22	NA	110	134
	Leonay Central	73	88	NA	0	0
	Leonay North	183	177	NA	0	0
	Leonay South	108	117	NA	0	1
	Leonay West	533	517[1]	NA	0	0
Penrith South	*Regentville*	288	308	NA	1	0
Penrith	*Jamisontown East*	1411	411	NA	135	156
	Jamisontown South	332	969[1]	NA	24	25
	Jamisontown West	52	27	NA	1	0
	Peach Tree Creek East	35	19	NA	2	0
	Peach Tree Creek South	11	2	NA	0	0
	Peach Tree Creek West	245	197	NA	2	0
	Penrith	1012	1379[1]	NA	178	422[1]

Sector	Subsector	Residential dwellings			Commercial and Industrial buildings	
		2010 NEXIS	2010 Council Estimates	2006 ABS Census private occupied and unoccupied dwellings + additional lots 2010	2010 NEXIS	2010 Council Estimates
Penrith North	*North Penrith A*	0	17	NA	384	144
	North Penrith B	0	14	NA	442	130
Richmond	*Richmond A*	2,083	1,203	3313	183	161
	Richmond B	0	0		0	0
	Richmond RAAF	495	381		59	36
	Clarendon	113	50		0	2
	Uni Western Sydney	0	0		0	0
	Agnes Banks	121	123		0	0
	Hobartville	1,123	1,070		10	2
Richmond Lowlands	*Agnes Banks Lowlands East*	29	32		0	0
	Agnes BanksLowlands Nth	30	34		0	0
	Agnes Banks Lowlands Sth	8	10		0	0
	Cornwallis	100	158		0	0
Windsor Downs	*Windsor Downs*	402	NA	366	0	0
Bligh Park	*Bligh Park East*	1,189	831	2,325	1	0
	Bligh Park West	1,495	1,209		0	4
Windsor	*South Windsor*	2,758	2,044	2,369	171	201
	North Windsor	0	12		0	0
	Windsor	475	405		63	93

Sector	*Subsector*	Residential dwellings			Commercial and Industrial buildings	
		2010 NEXIS	2010 Council Estimates	2006 ABS Census private occupied and unoccupied dwellings + additional lots 2010	2010 NEXIS	2010 Council Estimates
	Windsor Central	263	202		96	126
	Windsor East	125	118		0	0
McGraths Hill	*Mulgrave*	41	59	123	169	167
	McGraths Hill	1,005	946	863	4	1

[1] these estimates include buildings within the sector but above the PMF which the SES plans to evacuate because of isolation

[2] these estimates are taken from PCC data, which does not include additional lots since 2006.

N.A. – not available or council data includes properties outside PMF that do not need to be evacuated

Table 4: Estimated Population and Job capacity for NWGC Precincts

Precinct	Estimated Population		Estimated Job Capacity	Estimated rate of development			Assumed Evacuation
				2020	2030	2040	
Alex Avenue	18,000		-	-	-	-	N/A
Area 20	28,000		-	-	-	-	N/A
Box Hill	-		-	20%	30%	50%	Locally
Box Hill Industrial	Employment Land		-	-	-	-	N/A
Colebee	2,800		-	9%	10%	-	If new road to Richmond Road is high enough then this should ensure this is no longer isolated and therefore can evacuate locally. Otherwise will need to evacuate onto Richmond Rd and M7
Marsden Park	30,800	PAP	-	20%	30%	50%	Locally
		Phase 4	-	0%	0%	100%	
Marsden Park Industrial	3,200		10,000	50%	50%	0%	Locally
Marsden Park North	11,200		-	0%	0%	100%	Locally
North Kellyville	12,600		729	-	-	-	N/A
Riverstone	27,000		-	20%	30%	30%	N/A
Riverstone East	16,800		-	0%	30%	30%	Locally although controls would be needed to ensure that it did not interfere with McCulloch or Windsor Rd routes

Precinct	Estimated Population	Estimated Job Capacity	Estimated rate of development			Assumed Evacuation
			2020	2030	2040	
Riverstone West	Employment Land	12,000	50%	50%	0%	Bandon Rd/ Windsor Rd is currently proposed but this would converge with Windsor/South Windsor traffic. Alternatively use the upgraded McCulloch/Alex Ave route
Schofields	14,000	-	50%	30%	20%	Is isolated between creek and rail line. New Schofields Rd extension would prevent isolation and therefore may be able to only evacuate locally. Controls would be needed to ensure that it did not interfere with Alex Ave evacuation route
Shanes Park	1,400	-	0%	0%	30%	Local
Vineyard	7,000	-	0%	0%	30%	Bandon Rd and Windsor Rd but will be above 1 in 100 level which is the cut off for evacuations from other locations along this road so may be able to simply evacuate along these roads when the others have finished evacuating
West Schofields	5,600	-	0%	30%	30%	Is isolated between creeks. New Schofields Rd extension would prevent isolation and therefore may be able to only evacuate locally. Controls would be needed to ensure that it did not interfere with Alex Av evacuation route or Richmond evacuation route.

Table 5: Additional dwellings estimates for residential areas on the floodplain

Growth Area	Additional premises	
	2010 - 2020	2010 - 2030
Penrith	861	3,542
Emu Plains	89	178
Emu Heights	0	22
Jamisontown	86	208
Regentville	25	55
Leonay	10	14
Penrith Lakes	557	2300*
Bligh Park/Windsor Downs	0	0
Windsor/South Windsor	156	313
Mulgrave	0	0
McGraths Hill	0	0
Richmond	469	938

- assumed maximum development at Penrith Lakes

4.2 VEHICLE ESTIMATES

4.2.1 2010

As discussed in the preceding section, Census data, upon which previous SES estimates were based, do not appear to be a reliable estimate of the number of dwellings. By implication one could expect that the census is also under estimating the number of vehicles.

Table 6 compares, for each sector which is fully within the PMF and clusters of collector districts and subsectors cover the same area, the:

- SES evacuation traffic estimates based on 2001 Census data which have previously been used by SES in evacuation planning;
- Vehicle estimates derived by applying current Census vehicle ownership rates to Council estimates of premises; and
- Vehicle estimates derived by applying 1.8 vehicles per residential building and two vehicles per business address to Geosciences Australia's NEXIS building data.

The two current estimates are considerably higher than the original SES modelling for a few reasons.

Firstly, there has been considerable development, particularly urban consolidation in the Hawkesbury LGA, since 2001.

Secondly, the earlier SES data did not account for traffic from commercial and industrial developments. The SES recognised, during its review of the earlier proposals for the Penrith Lakes Scheme, that such traffic could be substantial and needs to be accounted for in evacuation planning.

Thirdly, the other methodologies attempt to include residential properties which did not complete census forms, vacant blocks and unoccupied buildings which may be developed and occupied when an evacuation is called.

Finally, a vehicle ownership rate of 1.8 vehicles per residential property has been applied to the Geoscience Australia residential property estimates, which is slightly higher than past and current vehicle ownership rates for the region.

It should be noted that previous work by the SES focussed on estimating vehicles in the Hawkesbury LGA where risks were correctly perceived to be greater.

Table 6: Evacuation vehicle estimates

Population Centre	**Original SES Vehicle Estimates**	**2010 vehicle estimates based on council rated buildings x 1.66 vehicles/ dwelling (lower limit estimate) + 2 vehicles per business**	**2010 vehicle estimates based on NEXIS x 1.8 vehicles/ dwelling (upper limit estimate) + 2 vehicles per business**
Richmond	4,478	6,695	8,998
Windsor/ South Windsor	4,594	6,508	8,410
Bligh Park/ Windsor Downs	3,782	4,064	5,565
Emu Plains	NA	4,295	5,029

* NA – not available

It should be noted that none of the data sets, NEXIS, Council or ABS show any residential or business premises in the University of Western Sydney (UWS) and Richmond B subsectors. While a check of Richmond B subsector confirms that it is unpopulated, it is known that UWS generates noticeable traffic. It should therefore be noted that all methods may be underestimating the traffic from this subsector.

4.2.2 Future

A multiplier of 1.8 vehicles per dwelling was applied to all future development. This number had previously been agreed between the SES, Department of Planning, PCC and Department of Environment Climate Change and Water as a likely upper limit of ownership given that most of the new urban development will be near public transport, there has been a gradual growth in the number of vehicles per dwelling and there is projected to be a gradual decline in the number of people per dwelling.

Future Evacuation Infrastructure

Figure 10 shows both approved and proposed road upgrades in the North West Metropolitan Region, which could potentially affect the current evacuation routes and their capacity.

A brief discussion of their status as explained by Penrith, Hawkesbury and Blacktown councils and the RTA follows.

a) Bandon Road

This is to widened to two lanes and a low spot raised to pass a 1 in 500 local rainfall event. This is to be done as part of the Riverstone West Industrial precinct which has been rezoned but the developer has struck financial difficulties as a result of the global financial crisis and the timing of this work is unknown.

b) Hamilton Street to Alex Avenue

These roads will be widened to an 11m wide dual carriageway with a lane for car parking along their entire length. This width would accommodate two evacuation lanes providing there are no narrowings along the route. This work will be done as part of the Riverstone precinct development which has been rezoned and is likely to occur by 2020.

c) Garfield Road

The future upgrading of this road will depend very much on decisions which are made about closing the level crossing at Riverstone. Several options are being investigated for Garfield Rd or alternative crossing points. Planning decision possibly within next 5 years. Whatever option is chosen it is unlikely that Garfield Rd will be raised where it crosses Eastern Creek.

d) Schofields Road

The plan is to upgrade this to a four lane road and extend it so that it links Richmond Road and Windsor Road. The RTA wants to finalise an alignment by the end of 2011 but apart from some funds from Landcom at the Windsor Road end, there is no funding commitment from government or developers.

This will prevent areas between Eastern Creek and the Richmond Rail line getting isolated by floodwaters. If built high enough it would also prevent areas between Bells Creek and Eastern Creek being isolated by flooding. This would reduce the need to evacuate these areas in events smaller than a 1 in 100 flood.

e) Burdekin Road

There are plans for this is to be extended across the Richmond Rail line to Richmond Road. As with the Schofields Road extension, this could reduce risk of areas between Bells Creek and the rail line getting isolated but there are no funds committed and this is likely to be a Council road.

f) Nirimba Roads

New roads may be built as part of the Nirimba land development to connect the Burdekin Road Extension with Quakers Hill Parkway.

g) Colebee Road

A new access road is likely to be built from Richmond Road into Colebee when it is developed. If built at an appropriate level this could reduce the need to evacuate this area in events smaller than the 1 in 100 flood.

h) Richmond Road

This will be upgraded to a four lane road between the M7 and the eastern end of the South Creek floodplain using developer contributions as Marsden Park and surrounding areas are developed. Unless there were new urban development west of South Creek there would be no traffic justification for upgrading Richmond Rd in that direction.

i) Castlereagh Freeway

There is a road reserve for a motorway extension from the M7 at Richmond Road to Yarramundi Bridge. While this would connect Castlereagh Rd, Londonderry Rd, The Northern Rd and Llandilo Rd to the M7, and could be built to provide flood free access, there are not plans for this to be built in the foreseeable future.

j) Stoney Creek Road

Council plans to upgrade this road which connects Richmond Road west of South Creek to urban areas to the east of South Creek. The length of this road which is in the floodplain would make it an expensive means of improving flood free access across south Creek.

k) Thorley Street Extension

This is currently being raised to 17.3m AHD to provide more time for Bligh Park traffic to evacuate.

l) George Street, Northern Road intersection

Currently the intersection of George St with Richmond Rd and the Northern Rd with Richmond Rd at Bligh Park are offset by a couple of hundred metres. The RTA plans to realign these roads to create a single intersection beyond 2020.

This may provide an opportunity to raise this section of road which is a low point and provide some additional time for Bligh Park or South Windsor to evacuate.

m) ADI Roads

Development of the ADI site at St Mary's will see construction of a new road across the upper end of South Creek which will be connected to The Northern Road which itself will be widened to two lanes south to Andrews Road form this intersection. This may provide an alternative high level access across South Creek.

n) Eighth Avenue

This is not shown on the map as it does not currently appear in any plans. The RTA has suggested however that if a high level crossing of South Creek is being considered, the current Eighth Ave crossing may be worth looking at. Once the Marsden Park area is developed there is likely to be justification for a link road through here.

o) Werrington Arterial

Penrith City Council is suggesting a road connecting the Great Western Highway and the M4. This would provide access from the Highway to the Motorway before evacuation has to cross the low point on the Highway at South Creek.

p) Jane Street Extension

Penrith City Council is suggesting that Jane Street Penrith be extended to overpass Mulgoa Road and connect directly to the Victoria Bridge. This would provide an alternative evacuation route for Emu Plains.

q) Nepean Street Extension

Penrith City Council is suggesting an extension of Nepean St south to Jamison St which would give the people along Nepean St more time to

evacuate. This could have a lockable gate like the Thorley St extension to prevent its use as a through road at other times.

r) M4 Motorway

The RTA suggested that the M4 may reach capacity by 2020 and one solution would be to add an extra one or two lanes in each direction. This would provide additional flood evacuation capacity if the additional lanes extended as far west as South Creek and additional on ramps were provided west of this point.

There are no specific plans or funding available for this upgrade at this time.

s) M7 Motorway

In October 2010, toll operator Transurban announced an agreement with the NSW State Government to permit it to build additional on and off ramps and additional east bound lanes on two sections of the motorway. It has not been possible at the time of writing to find any details of where these additional lanes and ramps will be to be able to assess what benefit, if any, they would have for flood evacuation.

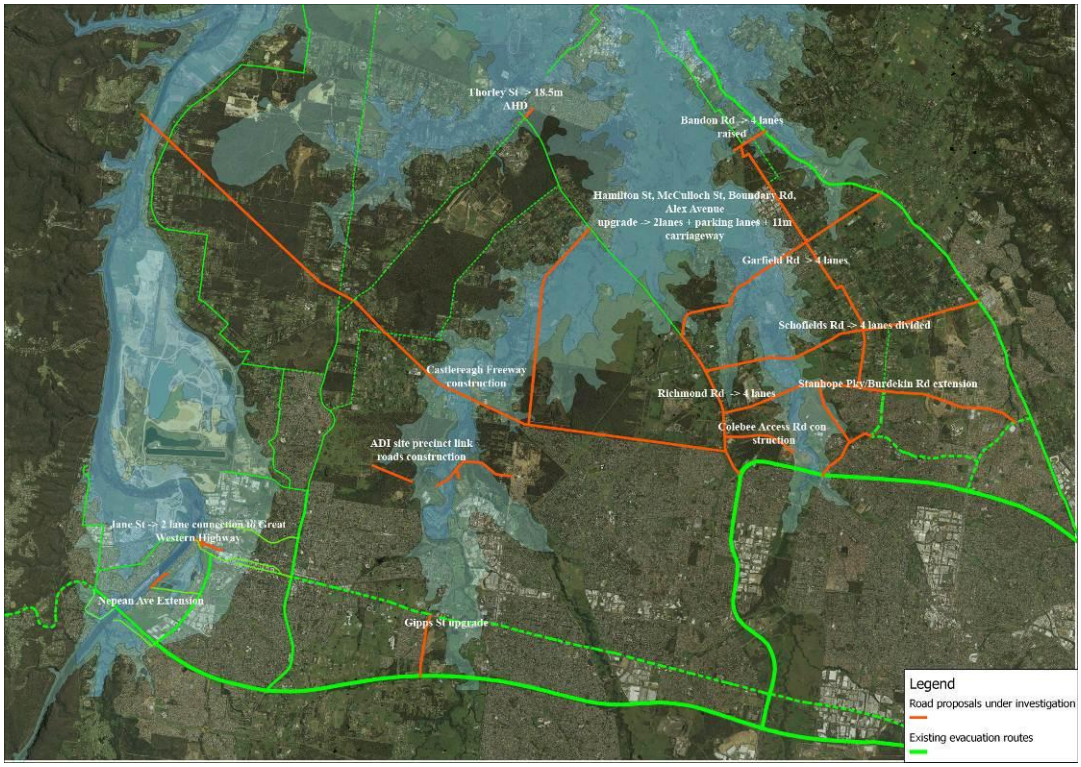
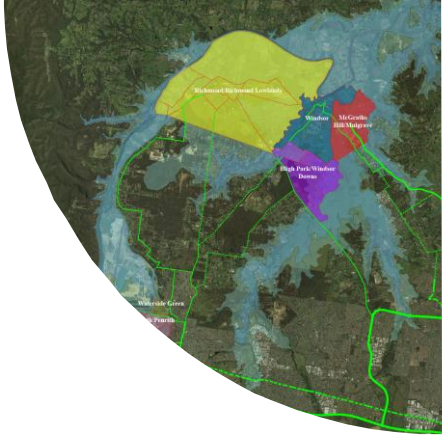


Figure 10: Future road proposals



5 EVACUATION MODEL FINDINGS

This Chapter reports on the results of the evacuation modelling using the information which is set out in Chapter 4.

Model results are reported for the years 2010, 2020, 2030 and 2040 with some options and sensitivity analyses investigated and reported on.

The modelling was done using an Excel spreadsheet which was given a layout which roughly reflected the layout of the evacuating subsectors and the evacuation routes. Calculation cells were set up for each source subsector or sector as appropriate as well as at points where evacuation routes converge.

To further assist in understanding the results from the model, arrows were used to connect calculation cells in the model. Each arrow represented a lane of traffic and direction of flow between each point. Furthermore, using the results from the calculation cells, each arrow was colour coded with green arrows representing lanes which had spare capacity and red representing those lanes operating at capacity. Also, where calculations indicated that not all traffic would have time to get past that point within the floodplain before critical flood levels were reached, the cell showing the number of vehicles failing to evacuate in time was coloured red.

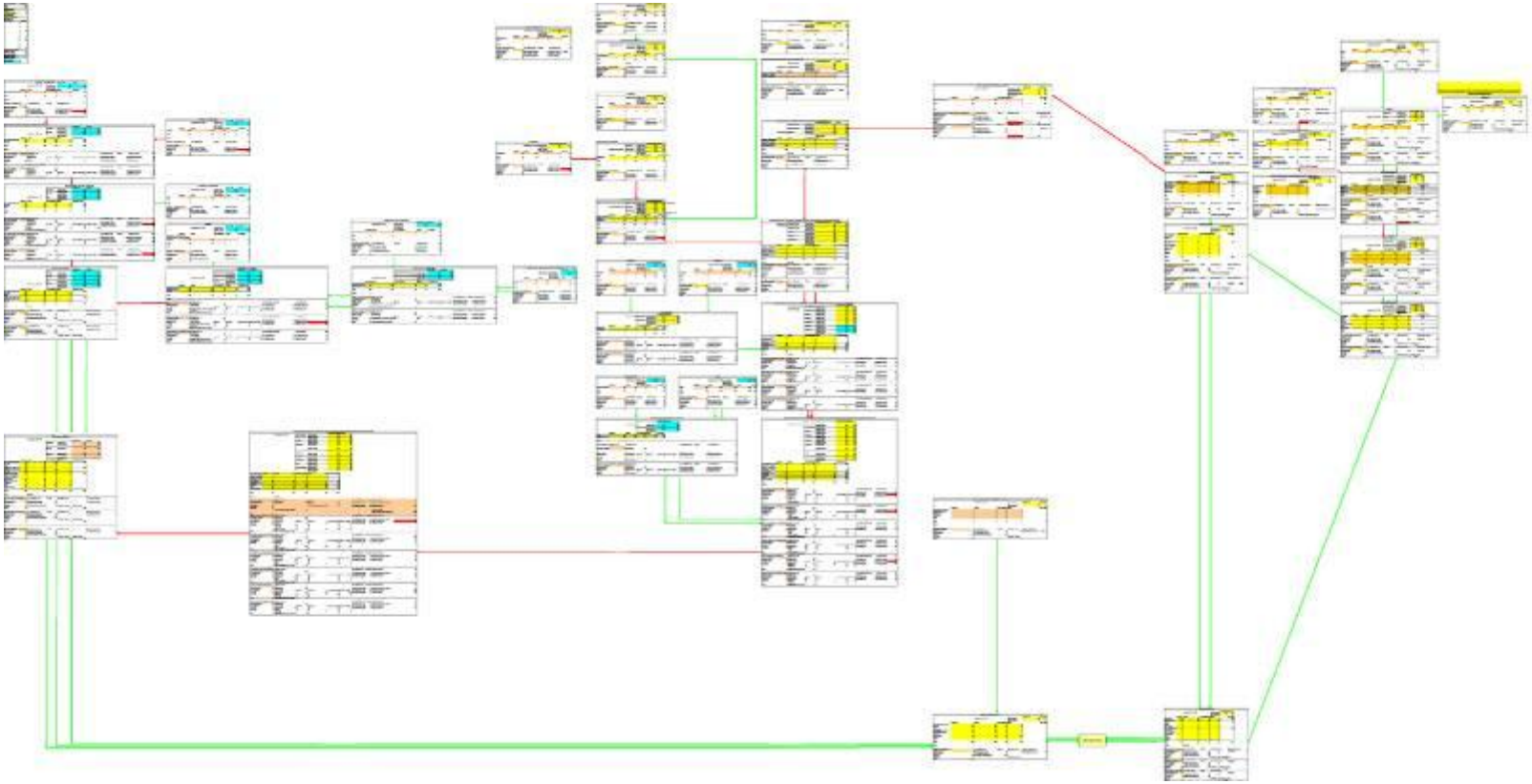


Figure 11: 2010 NEXIS North West Sector Evacuation Model

Figure 11 shows a small scale view of the model for the 2010 scenario using Geoscience Australia data to illustrate the layout and colour coding. Appendices A - C show the details for each sector for each modelled year.

5.1 2010 DEVELOPMENT

5.1.1 Relative timings

Current evacuation route triggers and route cut off times were extracted from the Hawkesbury Nepean Flood Sub Plan where they were available. In the case of Penrith LGA there was insufficient detail so they were each estimated using WaterRIDE as explained in Section 2.5.5. All times were reported relative to the Windsor or Penrith gauge height which would cause the level of interest to be reached at the location of interest in a flood rising as fast as a 72 hour PMF. As advised by the Sydney Catchment Authority (map sent by Maheswaran Selvaratnam), the relevant gauge at Penrith is located a short distance upstream of Victoria Bridge on the Eastern bank.

While the SES prefers to delay mobilisation until after it is confident evacuation will be necessary, the significant increase in vehicle numbers will make this impractical over most of the floodplain. The modelling has therefore generally assumed that mobilisation will be completed prior to the evacuation trigger level being reached even if the current sub-plan suggests a later mobilisation.

It is also noted in Section 2.6 that it has been assumed that any future Penrith Lakes traffic will arrive at The Northern Road and Andrews Road intersection at the same time as Richmond and Bligh Park traffic. While this gives the worst case scenario for evacuation of Penrith Lakes, it does not necessarily give the worst case scenario for evacuation of other areas around Penrith, the timing of which we have calculated relative to Penrith Lakes.

Our assumption that Regentville will evacuate before Factory Road is cut by floodwaters may underestimate the amount of traffic trying to converge at the Mulgoa Road on ramp to the M4.

5.1.2 Overview

Once the evacuation analysis had been completed, evacuation times were compared across regional evacuation routes and these are summarised in Table 7.

This analysis included only existing SES evacuation routes as they are shown in the Hawkesbury Nepean Flood Sub-Plan (NSW SES, 2005) and described in discussions with the SES. This scenario did not include any alterations or upgrades and represented the current evacuation infrastructure at the time the analysis was undertaken.

The calculated surplus times available were based on SES mobilisation being completed before trigger levels were reached for each location in the entire floodplain, except the Bligh Park/Windsor Downs area which was assigned decide and mobilisation time of 3.5 hours based on the SES expectation of evacuating 900 vehicles along Richmond Road before rising flood waters would cut off the route at the South Creek crossing. As explained elsewhere, the SES had not planned to complete mobilisation at all locations prior to evacuation trigger levels.

The evacuation time trigger and limit for each route was based on each stream's physical constraints at 2010.

From Table 7 the number of vehicles requiring evacuation along regional evacuation routes would be approximately 49,943, based on 2010 NEXIS data and the upper limit of vehicles per premises.

From the modelling it is estimated that approximately 37,249 of these vehicles would evacuate safely while 12,693 would remain stranded on the floodplain, cut off by rising flood waters. This could be caused by one or both of two causes:

- the evacuation capacity of a particular route is insufficient for everyone to get out; and/or
- the added time required to evacuate due to convergences of two or more routes means that traffic has to queue until after its evacuation route is cut.

The table also summarises the amount of time traffic from each sector has to queue whether this results in failure to evacuate or not.

The following subsections report the results in detail for each subsector or sector as is relevant.

5.1.3 Emu Heights/Emu Plains/Leonay

During a significant flood event, Emu Heights, Emu Plains and Leonay would each send a single lane stream of evacuation traffic to the M4 on ramp at Russell Street. The evacuation trigger levels for each stream were assumed to be the same as the evacuation cut off levels for each and therefore evacuation would be triggered seven hours before each was cut off.

Emu Heights would be the first area to evacuate, seven hours before the gauge height of 23.8m is exceeded at Victoria Bridge. Approximately 279 vehicles or 15% of Emu Heights traffic would be unable to evacuate before this route was cut by rising flood waters.

Leonay traffic would be the next area to evacuate, seven hours before the gauge height of 24.4m is exceeded at Victoria Bridge. In the absence of traffic from nearby sectors, the entire population of Leonay could evacuate with approximately 1.3 hours of surplus time available. This includes all houses above PMF in Leonay West subsector which the SES intends to evacuate because they would be isolated by floodwaters with no road access if the water rose high enough.

Under current conditions however there would be a convergence of Emu Heights and Leonay streams of traffic at the roundabout leading onto the single on ramp lane onto the M4. This convergence would result in vehicles from one or other stream queuing for 2.7 hours of vehicle movement.

As Emu Heights would commence evacuation prior to Leonay, we have assumed for modelling purposes that it would be given priority thus reducing the available time for Leonay's evacuation traffic. So although Leonay on its own would 1.3 hours more time that it needs to evacuate, when it queues for 2.7 hours to let Emu Heights traffic go it would have a deficit of 1.4 hours, with approximately 829 vehicles or 51% of the population unable to evacuate before the route is cut.

There remains the potential to give the areas of Leonay below the PMF priority, thus evacuating everyone at least above the flood waters.

Emu Plains traffic would commence evacuation seven hours before the gauge height of 25.7m is exceeded at Victoria Bridge. This stream would not commence traffic movement until after Emu Heights and Leonay traffic complete evacuating. Emu Plains traffic would therefore not converge with either of these two routes under current conditions However, approximately 2,193 vehicles or 55% of the total number of evacuation vehicles would be unable to evacuate from the subsector prior to the route being cut locally by floodwaters.

It should be noted that our evacuation modelling only includes houses below the PMF in Emu Plains West subsector. The SES plans to evacuate even those above the PMF in this subsector but that would simply increase the number of vehicles which would not be able to evacuate. There is an alternative road access for people in Emu Plains West via the Old Bathurst Road so it is less critical for them to evacuate than it is for those in Leonay who are above the PMF.

Table 7: Evacuation Capacity summary

Sector	Subsectors	Vehicles needing to evacuate	Vehicles able to evacuate	Vehicles unable to evacuate	Queuing times (hrs)	Reasons for failure to evacuate or queuing
Emu Plains	Emu Heights, Emu Plains North, Emu Plains West	2,479	2,100	379	0	Route cut @ 13.5 hrs
	Emu Plains Central East, Emu Plains Central West, Emu Plains East, Emu Plains South	3,993	1,800	2,193	0	Route cut @ 19.25 hrs
	Leonay Central, Leonay North, Leonay South, Leonay West	1,615	785	829	2.7	Convergence with Emu Heights traffic @ M4 on ramp East of Russel St
Penrith	Jamisontown West, Peach Tree Ck South	117	117	0	0.2	Convergence with Regentville traffic @ M4 on ramp
	Jamisontown East, Peach Tree Ck East, Jamisontown South	3,243	2,100	1,143	1.9	Merging traffic from 2 lanes on Mulgoa Rd to 1 lane @ M4 on ramp
Penrith South	Regentville	524	524	0	0	-
Richmond	Agnes Banks, Agnes Banks Lowlands East, Agnes Banks Lowlands Nth, Agnes Banks Lowlands Sth, Clarendon, Cornwallis, Hobartville, Richmond A, Richmond B Richmond RAAF UWS	8,998	8,700	298	0.5	Convergence with Waterside Green traffic @ Andrews Rd intersection with Greygums Rd
Richmond Lowlands						
Bligh Park	Bligh Park East,	5,565	4,692	873	-	Primary Route

Sector	Subsectors	Vehicles needing to evacuate	Vehicles able to evacuate	Vehicles unable to evacuate	Queuing times (hrs)	Reasons for failure to evacuate or queuing
Windsor Downs	Bligh Park West, Windsor Downs					cut @ 16.1 hrs then Secondary Route cut @ 22.6 hrs
Penrith North	Cranebrook (Waterside Green)	1,422	600	822	-	Route cut @ 20 hrs
	Penrith North A	768	768	0	0.2	Convergence with Peach Tree Creek traffic @ M4 on ramp
	Penrith North B	884	884	0	-	-
Penrith	Penrith, Jamisontown South	6,809	5,489	1,320	6.3	Single lane on ramp to M4 creating queuing
	Peach Tree Creek West	445	445	0	-	-
Windsor	South Windsor, Windsor, Windsor Central, Windsor East	8,410	6,000	2,410	-	Route cut @ 22.5 hrs
McGraths Hill	McGraths Hill	1,863	1,863	0	-	-
	Mulgrave	866	300	566	0.9	Convergence with Windsor traffic @ Windsor Rd intersection with Bandon Rd
TOTAL		48,001	37,167	10,833		

a) Penrith South

The Mulgoa Road evacuation route would provide for three streams of evacuation traffic to the M4 on ramp. The evacuation trigger levels for each stream were assumed to be the same as the evacuation cut off levels for each and therefore evacuation would be triggered seven hours before each was cut off.

Regentville would be the first stream to evacuate, seven hours before the gauge height of 23.2m is exceeded at Victoria Bridge. There would be enough capacity on this route to evacuate all 524 vehicles onto the M4 on ramp with approximately 3.1 hours of surplus time available. Note that the model makes the conservative assumption that the whole subsector of Regentville must evacuate before the lowest point on Factory Rd is cut by floodwaters but the majority of houses can evacuate after this time.

Jamisontown West and Peach Tree Creek South subsectors would be the next stream to evacuate seven hours before the gauge height of 23.7m is exceeded at Victoria Bridge. This stream would have sufficient capacity to evacuate the entire 117 vehicles with a 3.8 hour surplus.

Under current conditions, a slight convergence would occur at the M4 on ramp between the Regentville and Jamisontown West/PeachTree Creek South streams of traffic, contributing an 0.2 hours of traffic queuing. There would still however be more than enough surplus time to evacuate both streams completely.

Traffic evacuating from Jamisontown East, Jamisontown South and Peach Tree Creek East would evacuate seven hours before the gauge height of 27.1m is exceeded at Victoria Bridge. This traffic would evacuate along the two designated evacuation lanes of Mulgoa Road without converging with either Regentville or Jamisontown West/Peach Tree Creek South streams of traffic (note that if the majority of Regentville evacuates later than we have assumed it might converge with these other traffic streams).

Two evacuation lanes would provide a surplus time of 1.3 hours, allowing the entire stream to evacuate prior to rising flood waters. However the two Mulgoa Road lanes of traffic merge into one at the M4 Motorway on ramp. This merging would result in a deficit of 1.9 hours with approximately 1,143 vehicles or 35% forced to queue back into rising flood waters.

b) Penrith

In the Penrith area the evacuation trigger levels for all but one stream were assumed to be the same as the evacuation cut off levels for each and therefore evacuation would be triggered seven hours before each was cut off.

Peach Tree Creek West is expected to commence evacuation seven hours before the gauge height of 22.1m is exceeded at Victoria Bridge. Results from the modelling indicate that Peach Tree Creek West is expected to evacuate its entire 445 vehicles along the Great Western Highway with 3.3 hours of surplus time available.

Two streams of traffic would evacuate Penrith North. Under the current scenario, the subsector of Penrith North A is expected to commence evacuation seven hours before the gauge height of 23.1m is exceeded at Victoria Bridge and would complete evacuation prior to the commencement of evacuation from Penrith North B. North Penrith B would not require evacuation until seven hours before the gauge height of 24.8m is exceeded at Victoria Bridge. Both streams would evacuate safely with surplus times of 2.7 and 2.5 hours respectively.

There is the potential that evacuation traffic from the Penrith North A would converge with the Peach Tree Creek West stream of traffic at on the Northern Road south of the Great Western Highway. However, there are two lanes available on the Northern Road at this point and so neither stream would interfere with the evacuation of the other at this point. However they would converge at the M4 on ramp. This convergence would only produce 0.2 hours of traffic queuing and would not interfere with the safe evacuation of either stream nor the Penrith North B traffic.

These three streams of traffic are expected to complete evacuation prior to the

commencement of Penrith traffic resulting in no convergence between these early evacuees and later ones.

We have assumed that two streams of Penrith traffic would evacuate along either the Great Western Highway or High Street and then onto the Northern Road. These streams would commence evacuation seven hours before the gauge height of 25.9m is exceeded at Victoria Bridge. For the Penrith streams, the evacuation trigger gauge height of 25.9m is 1.5m less than the cut off height of 27.4m.

The two lane capacity would allow the entire stream of 6,809 vehicles from Penrith to evacuate safely with a surplus time available of 4.1 hours.

However there is potential for this traffic to converge with traffic travelling on the Northern Road from further north. Even if it does not, these two lanes must converge into a single lane on ramp at the M4. This would result in 6.3 hours of queuing and a 2.2 hour evacuation time deficit for one of these streams resulting in about 1,320 vehicles not getting on the M4 before the internal roads around Penrith are cut. These vehicles may be able to queue above the PMF level.

c) Richmond

Under current conditions there would be only one stream of evacuation traffic from Richmond travelling along the primary route of Castlereagh Road. For modelling purposes it has been assumed that evacuation will commence nine hours before the gauge height of 14.1m is exceeded at Windsor Bridge. The SES Plan expresses a preference to delay this evacuation if possible but with the revised traffic volumes there is not enough time available to delay evacuation.

The modelling suggested there would be 1 hour of surplus time available to evacuate all 8,998 vehicles prior to the route being cut upstream of The Driftway at 20.1m.

From this point the route would remain convergence free until the intersection of Greygums Road with Andrews Road. Andrews Road carries traffic from Waterside Green at this location.

d) Waterside Green

Waterside Green was assigned the SES estimate of 1,422 vehicles as stated in the Penrith Lakes report (Molino Stewart, 2005). It was assumed that Waterside Green could only evacuate at a rate of 300 vehicles/hr as dictated by the number of doorknocking teams the SES could provide the area (Molino Stewart, 2005).

In the absence of other information, it was assumed that the internal roads in Waterside green would be cut when floodwaters reached 25.9m which is the current cut off level for Andrews Road. If this is the case, then traffic from Waterside Green would not have enough time to evacuate onto Andrews Road prior to this route being cut by rising flood waters. Modelling for Waterside Green resulted in an evacuation time deficit of 2.7 hours with 822 or 58% of the total vehicles unable to evacuate in time.

It should be noted that previous analyses which have included Waterside Green (Molino Stewart 2005) have assumed that Andrews Road would be cut 5.8 hours after the 1 in 100 level would be reached at the Victoria Bridge gauge. This analysis suggests that it will be cut 1.5 hours before that level is reached which is why the evacuation model shows that less than half of this traffic will be able to get out.

This has arisen because of two significant differences between the hydraulic model provided by PCC and the previous model which was available.

Firstly, the current model estimates the 1 in 100 flood level is 26.3m at Victoria Bridge compared to the previous estimate of 25.4m. This means that there is nearly two hours less warning time.

The second difference is more significant and that is that the time it takes floodwaters to travel from Victoria Bridge to Andrews Road is much less because the hydraulic connection along Boundary Creek and other topographic

features is much more open than previously modelled.

e) Andrews Road

Assuming the traffic from both Waterside Green and Richmond are arriving at the same time, it is expected that the convergence between the two streams onto the single lane at Andrews Road would result in approximately 298 vehicles from the Richmond stream having to queue for 0.5 hours after the route is cut at Andrews Road. We have assumed Waterside Green traffic would receive priority because of the earlier cut off time under a worst case scenario.

The length of road above the PMF between the cut off point close to The Driftway and the convergence point on Andrews Road would mean that the 298 vehicles from Richmond would not be forced to queue back into the rising floodwaters.

The model therefore assumed that Andrews Road would contribute a single stream of evacuation traffic to the Northern Road being the combined total of all Richmond traffic and that proportion of Waterside Green traffic which could evacuate in time.

f) Bligh Park and Windsor Downs

A stream of traffic is expected to leave Bligh Park West and Bligh Park East subsectors immediately followed by a stream of traffic from Windsor Downs sector.

Their evacuation trigger is a forecast gauge height of 14.1m at Windsor Bridge. They are expected to travel along Richmond Road until rising flood waters cut the road at South Creek when it reaches 14.1m.

The SES currently plans to delay evacuation of these subsectors such that only 900 vehicles or approximately 16 % of the population would be able to travel along this primary evacuation route before it is cut.

At which time the remaining 4,665 vehicles or 84% of the total vehicles would begin travelling down the alternative Llandilo Road route.

Under current conditions, the number of vehicles travelling along the alternative route would be above capacity with a time deficit of 2.3 hours meaning that approximately 1,389 or 25% of the total number of vehicles would be unable to evacuate on either primary or secondary routes.

The number of vehicles which would be able to evacuate could be increased if evacuation of these subsectors is commenced nine hours before the cut of level is reached. That is, evacuation is not delayed and an additional 2,100 vehicles are sent along Richmond Road before it is cut.

This stream of traffic is expected to occupy one lane of traffic on the Northern Road from Ninth Avenue south to the M4 motorway for several hours.

g) The Northern Road

The preceding discussion indicates that there are several streams of traffic which are expected to use the Northern Road as their primary evacuation route to the M4.

The modelling suggests that Penrith North A, Penrith North B and Peach Tree Creek West traffic is likely to use the road early, not interfere significantly with each other and have gone well traffic from the larger population centres needs to use the Northern Road.

However, both the Richmond traffic and the Bligh Park & Windsor Downs traffic will be using the Northern Road simultaneously as may the Waterside Green Traffic.

South of Andrews Road there are two south bound lanes on the Northern Road so it would be able to accommodate the stream of traffic from Andrews Road on one lane and the stream from Llandilo Road on the other all the way to the M4. But as mentioned previously, there is only a single lane entry onto the M4 so these two traffic streams would need to converge at this point and about 3,300 vehicles would have to queue with maximum queuing times of 5.5 hours.

The Northern Road evacuation route may also have to carry Penrith evacuation traffic at the same time. This could be contributing a further

two lanes of traffic, all of which would have to queue if only two south bound lanes on The Northern Road were used for evacuation. Modelling suggests that there could be an overlap of 12.3 hours between the Richmond and the Penrith streams of traffic.

In the past the SES has been willing to accept a contra flow lane on The Northern Road which would provide a third evacuation lane south. This would mean only one lane of the four traffic streams arriving at this intersection would have to queue rather than two. However, this would simply send three lanes of traffic down to the single lane on ramp at the M4.

An alternative would be to divert the Bligh Park/ Windsor Downs traffic and the Richmond/Waterside Green traffic from The Northern Road onto the Great Western Highway as alternative route east. The risk with this is that there are many low points along the Highway which may be cut by localised flooding. Theses risks are unknown at many of these points.

The impacts of these traffic streams from various locations merging on the Northern Road or the M4 on ramp have not be included in the analysis of potential for vehicles not being able to evacuate as summarised in Table 7.

h) M4 Motorway

The M4 is proposed as a main evacuation route to Homebush but it does present some problems. The first is the fact that there is only a single lane on at Emu Plains, Mulgoa Road and the Northern Road but two or more streams of evacuation traffic needing to enter at those points.

However, if all of these streams were able to access the M4, then the M4 itself would present capacity issues.

From Emu Plains to Mulgoa Road the M4 has two lanes and then it increases to three lanes all the way to Homebush.

If only one lane of the M4 takes the Emu Plains/ Emu Heights/ Leonay traffic it would be occupied with evacuation traffic from 8.5 hours into the flood to 19.3 hours into the flood. During this period Mulgoa Road would be feeding Jamistown West, Jamisontown East, Peach Tree Creek South, Peach Tree Creek East and Regentville traffic onto the M4 from 7.3 to 9.7 hours into the flood. Also Peach Tree Creek West, followed by Penrith North A, followed by Penrith North B traffic would use a lane from the Northern Road east from 5.5 hours into the flood to 13.7 hours into the flood. In other words, all three lanes will be used for some period simultaneously during this time so if an extra lane were provided at the Emu Plains on ramp, traffic from Mulgoa Road or The Northern Road would have to queue to allow the traffic from further west to use two lanes.

Furthermore, by increasing the number of lanes entering at Emu Plains, more traffic will be able to evacuate from further west and will therefore occupy these lanes for longer.

As it is Penrith traffic is likely to be arriving from 15 hours to 28.8 hours into the flood, Richmond traffic from 16.5 hours to 35.5 hours and Bligh Park Traffic from 18 hours to 23.5 hours, all of which would partly overlap with just one lane of traffic from west of the River. If a second lane came from west of the river, the extended travel time would then coincide with the rest of the Mulgoa Road traffic which needs to use the M4 from 20 hours to 26.9 hours.

It is clear from the above that the simultaneous arrival of traffic from the three feeder roads will take up all lane capacity on the motorway and providing additional on-ramp capacity would simply transfer the convergence bottle necks from the bottom of the on-ramps to the top of the on-ramps at Mulgoa Road and The Northern Road.

It should also be noted that Holroyd City Council has advised that it studies show that the M4 would be cut by localised flooding at two locations in its LGA. It only has flood mapping for the 1% flood and the PMF but the Clay Cliff Creek and A'Becketts Creek crossings would be cut by the PMF but not by the 1% flood. The SES prefers that its

evacuation routes be immune from localised flooding up to the 0.2% event.

i) Mulgrave and McGraths Hill

The subsectors of Mulgrave and McGraths Hill would evacuate along two streams of traffic taking up both lanes of Windsor Road. These two streams are expected to commence evacuation at the same time, approximately nine hours before the gauge height of 14.10m is exceeded at Windsor Bridge. As the evacuation route is cut at a gauge height of approximately 13.4m, the trigger time is later than the cut off time for these two streams of traffic.

Modelling the current scenario resulted in surplus times of 2.7 hours for Mulgrave and 1 hour for McGraths Hill. This would enable the entire population of both subsectors to evacuate safely.

j) Windsor/South Windsor

The population centre of Windsor and South Windsor is expected to evacuate via internal roads leading to a single lane on the recently completed South Creek Crossing. This stream is expected to commence evacuation approximately nine hours before the gauge height of 14.1m is exceeded at Windsor Bridge. The evacuation trigger for this route would be issued at a gauge height 3.2m less than the cut off gauge height of 17.3m.

The modelling suggests that there is nowhere near enough time to evacuate all of these people. There would be 2,410 vehicles or 29% of the total unable to evacuate.

k) Windsor Road

Assuming that the trigger to evacuate for Windsor is the same as that for McGraths Hill and Mulgrave, then those vehicles from Windsor which were able to evacuate would then converge with one lane of traffic on the Windsor Road route from either the Mulgrave or McGraths Hills subsector streams.

As the McGraths Hill and Mulgrave streams of evacuation traffic would arrive at the Bandon Road intersection prior to the Windsor South Creek Crossing traffic, it has been assumed that they would be expected to receive priority, meaning that 866 vehicles from Windsor would need to queue until the Mulgrave traffic had passed. This would result in a hours with a further 566 vehicles from Windsor being unable to evacuate.

The alternative routes for Windsor traffic along either Garfield Road or Schofields Road would create the same convergence with one stream of Windsor Road traffic, however these alternatives potentially provide a longer stretch of road suitably long enough to queue above the PMF.

It was assumed that under current 2010 development/road conditions that areas within Vineyard, Riverstone, Schofields, Box Hill and surrounding areas which are below the PMF would only need to evacuate locally and were not added to regional evacuation routes.

l) M7 Motorway

The M7 motorway will be taking traffic from McGraths Hill, Mulgrave, Windsor, South Windsor, Bligh Park and Windsor Downs. All of this traffic will be evacuating simultaneously.

Each of the motorway on ramps are only one lane, there are three potential entry points and the motorway has three lanes. Under the current scenario the M7 Motorway does not present a capacity problem.

5.1.4 Necessary Improvements

Further modelling was undertaken to identify what changes to the evacuation strategy and road infrastructure would be necessary to enable all of the existing traffic to evacuate in time. The following discusses that for each sector.

a) Windsor/South Windsor

Two evacuation lanes are required to get all of this traffic out in time. Generally the internal roads within Windsor can carry two lanes of traffic with the exception of the emergency

level crossing at Cox St which would have to be widened by one lane.

The Jim Anderson Bridge which crosses South Creek is currently designed to carry one lane of traffic in each direction. It does have reasonably wide shoulders and it would be theoretically possible to carry two evacuation streams and one incoming emergency service vehicle stream. The only other alternative to increasing the evacuation capacity by a lane in this location would be to widen the bridge which would come at a substantial cost.

On the eastern side of South Creek all the roads along this evacuation route (approx 4.5km) would have to be widened to carry an additional evacuation lane. This might be possible by providing a wide sealed road shoulder as none of these roads are currently kerbed and guttered.

It would also require the widening of the emergency level crossing at Groves Ave and the level crossing at Level Crossing Road.

This would provide either 4 hours surplus time for Windsor to evacuate or capacity for about another 2,400 vehicles to evacuate from Windsor in the future. The surplus time could be used to delay the evacuation of Windsor and assign it an evacuation trigger of 16.2m rather than the current 14.2m.

b) Mulgrave/McGraths Hill

The two lanes evacuating from Windsor will need to use both lanes of Windsor Road and so it will be important that these two streams of traffic have finished evacuating before Windsor begins evacuating.

This can be achieved by one of two ways. Either evacuation of Windsor can be delayed by up to 4 hours as previously described or by evacuating Mulgrave and McGraths Hill earlier than currently planned.

If the current evacuation trigger of 14.2m is maintained for Windsor, then the evacuation trigger for Mulgrave would have to be lowered to 13.1m and for McGraths Hill 12.2m.

c) Bligh Park/Windsor Downs

Rather than delay the evacuation of Bligh Park and Windsor Downs as is currently planned and only get 900 vehicles out along Richmond Road, it would be possible to use a 14.1m evacuation trigger and get 3,000 vehicles out along this route.

This would leave 2,565 vehicles which would have to travel down Llandilo Road and The Northern Road to the M4.

Given the capacity issues with merging traffic on The Northern Road and the M4, it would be preferable if there were another means of getting this traffic onto the M7.

One option which has previously been investigated is raising Richmond Road where it crosses South Creek. This is an expensive option because the floodplain is wide at this location and would need to be raised over a distance of 1-2 km depending on the height it needs to be raised to.

The RTA has advised that it is not in favour of upgrading this section of Richmond Road as it would not provide any benefits outside of a major flood (Ian Neuhaus pers. comm.). The RTA has advised however, that there would be regional traffic benefits in upgrading Eighth Avenue where it crosses South Creek further to the south.

Evacuation traffic could travel down Llandilo Road but turn left onto Eighth Avenue and through Willmot, Shalvey, Bidwill and Hassall Grove to Richmond Road and the M7. Some upgrades of culverts along the route may be necessary to reduce the risk of localised flooding.

If the 14.1m trigger is maintained for evacuating these areas and this route is used, then Eighth Ave may not need to be raised at all. If sections of the road are raised then evacuation of Bligh Park and Windsor Downs could be delayed.

d) Waterside Green

There are four ways in which the evacuation deficit at Waterside Green could be managed. Two are operational and two are structural.

Operationally, the SES could simply commence the evacuation earlier. For this to work a forecast flood level of 24.9m at Victoria Bridge rather than 26.3m would need to be used. This could result in evacuating in a flood which does not eventually inundate Waterside Green.

The other operational option is to provide more door knockers to Waterside Green so that they have a better opportunity to evacuate at 600 vehicles per hour rather than the currently assumed 300.

Raising Andrews Road and internal roads within Waterside Green to 26.6m would provide sufficient time for evacuation. This might not be physically possible.

An alternative structural option which has been suggested by PCC is to construct a levee along the east bank of the Nepean River near Boundary Creek. This would increase the time it takes for floodwaters to get from the River to Andrews Road. The downside of this is that it would most likely increase flood levels in Emu Plains unless compensating adjustments can be made to the overflow weirs from the River to Penrith Lakes.

e) Richmond

There is enough time to evacuate the Richmond traffic if an evacuation trigger of 14.1m is used. However, the current route through Mt Pleasant means that this stream of traffic will converge with Waterside Green traffic at Andrews Rd and some of it will need to queue to give Waterside Green traffic to get out in time.

If any of the aforementioned options are chosen to get more people out of Waterside Green then the convergence with Richmond traffic is likely to increase.

This can be avoided if minor improvements are made to Vincent Road and The Northern Road to reduce the risk of them being cut by localised flooding. If these changes are made, Richmond traffic can be sent along this route and not meet up with Waterside Green traffic until the intersection with Andrews Road. At this point there would be two lanes available for the two traffic streams.

f) Penrith North and Peach Tree Creek West

All of these subsectors have sufficient time to evacuate and will all be gone long before other traffic needs to use The Northern Road. No further adjustments would need to be made to accommodate these subsectors.

g) Penrith

The current challenge for Penrith evacuation traffic is the risk of wanting to use two lanes of Andrews Road at the same time as traffic from Richmond and Bligh Park.

Sending Bligh Park traffic along Richmond Road to the M7 removes part of this problem but improving the evacuation of Waterside Green takes up some of the capacity created.

One way of mitigating this problem would be to evacuate the lowest parts of Penrith based on a trigger level of 22.1m as opposed to the 25.9m currently proposed. This would bring evacuation 10 hours forward and allow half of the Penrith Population to leave before Richmond traffic arrives. It may result in many people evacuating in an event which does not eventually inundate their premises. However, many of these premises are commercial and industrial and it might be more practical to do so than if they were residential.

The other half could evacuate after the Waterside Green traffic has passed. Their evacuation trigger would still need to be an hour earlier than currently proposed.

It should be noted that trying to finely juggle arrival and departure times of traffic from different parts of the floodplain will have significant practical difficulties.

Firstly, the relative timing of traffic arriving from Richmond and Penrith may vary widely depending on the temporal and spatial distribution of rainfall.

Secondly, while Waterside Green's evacuation timing will be somewhat in sync with that of Penrith, their relative timings will depend

largely on what options are chosen to get more people out of Waterside Green.

The final consideration here is that currently the two lanes on The Northern Road converge into a single lane on ramp at the M4 and two lanes of the M4 would be carrying evacuation traffic from further west. Without providing an extra lane to take The Northern Road traffic east, all of these adjustments to evacuation timings get undone by the need to queue at the M4.

This can only be overcome by either adding an extra lane to the M4 from The Northern Road to Homebush or sending Richmond, and possibly Waterside Green, traffic along the Great Western Highway. The first would be a significant expense but would benefit daily traffic flows (Ian Neuhaus pers. Comm.). The second would have risks of the route being cut by localised flooding at many locations, some of which might not be able to be overcome by improved creek crossings but would actually provide two additional evacuation lanes rather than one.

h) Mulgoa Road

The main problem at Mulgoa Road is that two lanes merge into one and evacuees from the developments along the western side of Mulgoa Road will be queuing longer than the road will be open for them. It might be possible to raise some of the low points along the road to provide more time for evacuation. More time is likely to be gained if evacuation is commenced two hours earlier. As with other locations, this approach increases the risk that evacuated properties will not eventually be flooded.

i) Emu Plains/ Emu Heights/ Leonay

Evacuating Emu Heights three hours earlier than currently planned would not only give the people in Emu Heights enough time to get out but it would also reduce the convergence with Leonay traffic so that all of this sector could evacuate too.

Emu Plains cannot be evacuated much earlier as it would begin to converge with Leonay traffic on the single lane on ramp. Emu Plains therefore needs to be given more time to evacuate. The entire length of its evacuation route would have to be raised at least 1m higher than its current lowest point.

PCC has suggested that an extension of Jane Street in Penrith to link up with the Victoria Bridge would provide Emu Plains with a route which is less prone to flooding or at least a second lane out. The problem with this solution is that it will direct traffic to The Northern Road which is already at capacity.

5.2 2020 DEVELOPMENT

The projected increases in evacuation traffic on regional evacuation routes in 2020 would mainly arise from:

- Infill development in Richmond Windsor
- Partial development (50%) of Riverstone West industrial estate
- Landcom's Penrith North development
- Penrith Panthers redevelopment
- Partial (25%) development of Penrith Lakes

The impacts of these developments on evacuation was assessed, assuming that measures had been taken to overcome the evacuation deficiencies identified for 2010 evacuation traffic.

5.2.1 Windsor and Riverstone West

The additional development in Windsor can be evacuated if there are two evacuation lanes leading to Windsor Road.

Some of the Riverstone West industrial area traffic would also be able to use Bandon Road to Windsor Road but nearly 1,500 vehicles (about 30% of the development) would not be able to evacuate along this route. However, it would be possible for all of the Riverstone West traffic to be diverted along Hamilton St, McCulloch St and Boundary Rd which are

being upgraded as part of the Riverstone residential development in the next few years.

This route option is not without some constraints. To evacuate all of Riverstone West there needs to be two lanes available for evacuation traffic. While the upgrade would make these roads wide enough for this, current speed restriction devices at schools on Hamilton Ave and roundabouts at intersections along the route would constrict traffic to a single lane unless these were reconfigured.

A second problem is that these two lanes would lead to the M7 at Sunnyholt Road which has a single on-ramp which will be used by one of the lanes of evacuation traffic using Windsor Rd. This means that one lane of evacuation traffic from Riverstone West would have to queue for up to an hour and a quarter and the second would have to queue for up to two and a half hours.

5.2.2 Richmond

The evacuation route from Richmond only has sufficient capacity to accommodate 300 of the additional 845 vehicles which will need to evacuate. Londonderry road which is nominated as a secondary evacuation route could be used to take the additional traffic but may require upgrades in some sections to reduce the risk of local flooding.

Londonderry Rd could be used in one of two ways. It could be used as a second evacuation lane and virtually halve the time it takes to evacuate Richmond or it could be used simply to take the additional traffic which does not have enough time to evacuate along Castlereagh Rd. In either case the two routes would converge at The Northern Road intersection with Vincent Road.

If it is used as an overflow lane then about 545 vehicles would have to queue at this intersection for up to an hour. If both lanes are used as a primary evacuation route then The Northern Road would have to have a second southbound lane, or a wide sealed shoulder constructed along the 3.5km from Vincent Rd to Andrews Rd.

Providing this second lane on the Northern Road would allow two lanes of Richmond traffic to evacuate along the full length of The Northern Road. This however, would have significant implications for other evacuation traffic as set out in the following.

5.2.3 Waterside Green

The analysis for 2010 traffic has assumed Waterside Green is fully developed although that is not yet the case. The 2020 scenario therefore does not increase the amount of traffic evacuating from here.

However, were Richmond to use two lanes of The Northern Road to evacuate, Waterside Green traffic would have to use a contraflow lane on The Northern Road to head south. This is not preferred by the SES but is acceptable.

When this traffic has to merge with that from Penrith, it would be necessary for both lanes of Richmond traffic to travel east on the Great Western Highway to avoid unmanageable merging at the M4 on ramp.

If Richmond were to only use one lane of the Northern Road it would still have to turn onto the Great Western Highway but there would be sufficient capacity for evacuation traffic from Waterside Green.

5.2.4 Penrith Lakes

If it is assumed there are only about 560 new lots developed at Penrith Lakes by 2020 then the resulting 1,000 vehicles would have sufficient time to evacuate along Andrews Road at its current level.

The problem for Penrith Lakes will be merging with other evacuation traffic which can only be overcome if:

- Andrews Rd is widened to two lanes so that it can evacuate at the same time as Waterside Green;
- Penrith Lakes uses a contraflow lane on The Northern Road;

- Richmond is restricted to a single evacuation; and
- Both Richmond and Waterside Green evacuate along the Great Western Highway

5.2.5 Penrith North

It was assumed that North Penrith B subsector would include 1,000 new dwellings (1,800 vehicles) as part of the North Penrith Landcom urban release area by 2020.

Modelling suggests that there would be insufficient time for all of this development to evacuate before Coreen St is cut by floodwaters. But access from this development onto Coreen St is east of the low point, there are other access routes out of the development and all new buildings will be built well above the 1 in 100 flood level.

This means that there will be sufficient time for it to evacuate but its evacuation will no longer be completed before other evacuation traffic needs to use The Northern Road. Rather, it will have the potential to block evacuation traffic from further North unless the new residential development in Penrith North is queued in local streets west of the Northern Road.

5.2.6 Penrith Panthers

There is enough time for the extra 1,800 vehicles to evacuate from the proposed Penrith Panthers development onto the two lanes of Mulgoa Road but there is a bottle neck where these converge into one lane at the M4. This can only be overcome by commencing evacuation of Penrith Panthers about 3.5 hours earlier than if there were two lanes available on the M4. Add this to the need to commence evacuation of the current developments in this area 2.5 hours earlier than otherwise and the whole areas is starting to evacuate 6 hours earlier.

5.3 2030 DEVELOPMENT

Further increases in regional flood evacuation traffic would mainly be caused by:

- Further infill development in Richmond and Windsor
- Infill development in Penrith, Jamisontown and Emu Plains
- Completion of Riverstone West Industrial precinct
- Completion of Penrith Lakes

5.3.1 Windsor and Riverstone West

The earlier duplication of the evacuation route from Windsor would ensure that there would be sufficient capacity to handle the projected 2030 infill growth.

However, nearly 8,400 of the expected 10,800 vehicles from the Riverstone West development would have to evacuate along two lanes on Hamilton St. This would result in about 4,200 vehicles queuing for up to 7 hours at Sunnyholt Rd and another 4,200 queuing for up to 14 hours.

5.3.2 Richmond

Nearly 1,400 vehicles would have to use a second lane out of Richmond. These would queue for up to 2.5 hours at The Northern Road's intersection with Vincent Road. Evacuation of Richmond would take nearly 26 hours.

5.3.3 Penrith Lakes

An additional 5.4 hours would be needed to get all 2,300 dwellings evacuated from Penrith Lakes. This could be achieved by evacuating 5.4 hours earlier, raising Andrews Rd and Castlereagh Road by a couple of metres or using a levee or similar to delay floodwaters reaching the evacuation route.

5.3.4 Penrith and Jamisontown

Infill development in these areas would simply increase the amount of traffic trying to reach The Northern Road and M4. Since these routes would already be at capacity, it would be necessary to queue additional traffic from the infill in the streets west of The Northern Road

5.3.5 Emu Plains

The only way in which any additional traffic could be evacuated from Emu Plains would be to raise the Great Western Highway and Russell street higher to provide more time for evacuation or commence evacuation earlier.

5.4 2040 DEVELOPMENT

Only projects for the North West Growth Centre were available for 2040 and since all of the areas which would use the regional evacuation routes would be fully developed by 2030, the model was not run for the 2040 scenario.

5.5 SENSITIVITY TESTING

Penrith and Hawkesbury City Council rating data were used to estimate a lower bound number of residential properties and these were multiplied by an average of 1.66 vehicles per dwelling to get a lower bound estimate of residential vehicles.

Where council data extended beyond the PMF we used the NEXIS data.

The NEXIS data counted both the number of commercial/industrial buildings and the number of the commercial/industrial addresses. The latter are significantly greater than the former because many buildings have more than one business in them. The council data on the other hand only counts the number of rateable premises which corresponds closely to the number of buildings. Therefore, if the NEXIS estimate of buildings and the Council estimate of commercial industrial premises were similar, the NEXIS data estimates of business addresses were used. If however, the Council's database suggested that there were significantly less commercial and industrial buildings then the NEXIS number of addresses was reduced proportionally.

The results are summarised in Table 8. When compared with the corresponding results in Table 7 it is clear that the size of the evacuation problem much less but this does not generally diminish the need to upgrade evacuation at key locations.

For example, even using these lower bound figures it is apparent that there is insufficient road capacity to evacuate everyone from Emu Heights, Emu Plains and Leonay. The difference between the two analyses is simply that less people are unable to evacuate but it shows that close to 2,000 would be trapped without changes to the evacuation routes or plans.

Along Mulgoa Road there would be less capacity issues with traffic merging on the M4 on ramp. This location is clearly sensitive to the assumed existing population feeding onto this road and it is noted that this includes a subsector where the NEXIS estimate of residential dwellings was exactly 1,000 more than the Council estimate. This warrants closer investigation, particularly in light of the Penrith Panthers rezoning/redevelopment which is currently under consideration.

Similarly, there would be more capacity for growth in Richmond is there is less existing traffic but roadworks would be needed to divert the Richmond traffic off Andrews Road were Penrith Lakes to proceed. In other words, the roadworks may be able to be delayed rather than avoided.

While there would be less local capacity issues for Bligh Park and Windsor Downs, their convergence with other traffic on the Northern Road will still create problems and therefore we would still recommend road upgrades to ensure this traffic could use Richmond Road as an evacuation route for the duration of the flood.

If there is less traffic evacuating from Penrith then there is less likely to be a problem with these two lanes converging on the M4 on ramp but it will still be necessary to provide an additional eastbound lane to take the Richmond traffic.

Likewise at Windsor, the lower bound estimates suggest less people will be trapped but two evacuation lanes will still be required to get all of the existing population out in time.

None of these population estimates will affect the number of new dwelling which can be constructed at Penrith Lakes because this will need a dedicated evacuation lane in any case and the number than can get out on this will be dictated by the timing of evacuation triggers and cut offs within the development and along Andrews Road.

Table 8: Lower Bound Evacuation Capacity Summary

Sector	Subsectors	Vehicles needing to evacuate	Vehicles able to evacuate	Vehicles unable to evacuate	Queuing times (hrs)	Reasons for failure to evacuate or queuing
Emu Plains	Emu Heights, Emu Plains North, Emu Plains West	2,359	2,100	259	0	Route cut @ 13.5 hrs
	Emu Plains Central East, Emu Plains Central West, Emu Plains East, Emu Plains South	3,257	2,100	1,157	0	Route cut @ 19.25 hrs
	Leonay Central, Leonay North, Leonay South, Leonay West	1,494	906	589	2.5	Convergence with Emu Heights traffic @M4 on ramp
Penrith	Jamisontown West, Peach Tree Ck South	48	48	0	0.1	Convergence with Regentville traffic @ M4 on ramp
	Jamisontown East, Peach Tree Ck East.Jamisontown South	872	872	0	0	-
Penrith South	Regentville	478	478	0	0	-
Richmond	Agnes Banks, Agnes Banks Lowlands East, Agnes Banks Lowlands Nth, Agnes Banks Lowlands Sth, Clarendon, Cornwallis, Hobartville, Richmond A, Richmond B Richmond RAAF UWS	6,695	6,695	0	0	-
Richmond Lowlands						
Bligh Park	Bligh Park East,	4,064	4,064	0	0	-

Sector	Subsectors	Vehicles needing to evacuate	Vehicles able to evacuate	Vehicles unable to evacuate	Queuing times (hrs)	Reasons for failure to evacuate or queuing
Windsor Downs	Bligh Park West, Windsor Downs					
Penrith North	Cranebrook (Waterside Green)	1,422	600	822	0	Route cut @ 20 hrs
	Penrith North A	796	796	0	0	-
	Penrith North B	907	907	0	0	-
Penrith	Penrith, Jamisontown South	6,621	6,621	0	5.3	
	Peach Tree Creek West	327	327	0	0	-
Windsor	South Windsor, Windsor, Windsor Central, Windsor East	6,508	6,300	208	0	Route cut @ 22.5 hrs
McGraths Hill	McGraths Hill	1,572	1,572	0	-	-
	Mulgrave	890	0	890	1.48	Convergence with Windsor traffic @ Windsor Rd intersection with Bandon Rd
TOTAL		38,310	34,386	3,925		

6 EVACUATION UPGRADES

Table 9, Table 10 and Table 11 outline the road upgrades required to satisfy SES evacuation criteria based on existing vehicles modelled for 2010, as well as future projections for 2020 and 2030 respectively. The cost estimates have been developed by engineering firm J Wyndham Prince based on Molino Stewart's advice on required upgrades.

The need for these upgrades has been based on the application of the SES evacuation timeline model to major population centres using regional evacuation routes as nominated by the SES. The 2010 evacuation numbers have been derived from data provided by Geoscience Australia resulting in vehicle estimates 15% to 30% higher in some areas than suggested by other available data,.

The cost estimates do not allow for property acquisition, reconfigured property access or relocation of services and have been derived by applying broad unit rates to a desk top review of aerial photos of the routes. These are approximations and in some cases exclude specific components of the works which could only be estimated through a more detailed investigation.

These cost estimates should only be used to get a generally indication of cost magnitudes.

6.1 2010 UPGRADES

Table 9: Evacuation route upgrades required based on data modelled for 2010

Population Centre	**Works Required**	**Estimated costs $m**	**Other improvements/comments**
Mulgrave	Nil	Nil	Evacuation must be commenced earlier than currently planned
McGraths Hill	Nil	Nil	Evacuation must be commenced earlier than currently planned
Windsor and South Windsor	Duplication of the evacuation route from Windsor including: • using existing parking lanes or second lanes where they exist through South Windsor and Windsor • adding 2nd lane to emergency level crossings at Cox St and Groves Ave • running two east bound lanes on the Jim Anderson Bridge without widening the bridge • constructing an extra east bound lane along the primary evacuation route from Groves Ave to Windsor Rd	9.5	Doubling the number of doorknocking personnel. Some of these costs might be saved if the section of Bandon Road is not duplicated but rather its low point is raised and the second stream of evacuation traffic is sent along the secondary evacuation route on Hamilton St Riverstone – <u>not costed</u>

Population Centre	Works Required	Estimated costs $m	Other improvements/comments
Bligh Park & Windsor Downs	Nil for the safe evacuation of these areas, however their convergence with Richmond and Penrith traffic on The Northern Road will create long queues unless this traffic is diverted. Our recommendation: Further roadworks including a secondary evacuation route for Bligh Park and Windsor Downs traffic which goes along Llandilo Rd, Second Ave, Eight Ave, Palmyra Rd, Luxford Rd, Rooty Hill Rd Nth, Richmond Rd to M7 which may require • raising some sections of Second and Eighth Ave • lifting the bridge over South Creek at Eighth Ave • raising a floodway on Palmyra Ave • improving flood conveyance at two creek crossings on Luxford Rd	Nil 30	Evacuation must be commenced earlier than currently planned
Richmond	Drainage improvements to Vincent Rd and The Northern Rd near their intersection so that Richmond traffic does not impede evacuation of Waterside Green	0.5	Evacuation must be commenced earlier than currently planned
Waterside Green	Nil	Nil	Evacuation must be commenced earlier than currently planned and the number of doorknocking personnel doubled
Richmond/ Penrith/ Waterside Green	To overcome significant queuing where these four traffic streams converge on The Northern Road it will be necessary to either provide a fourth east bound lane on M4 as far as Homebush OR	320m (plus cost of extra lane on 2km overpass at Parramatta – Auburn)	Assumes all current drainage under M4 can pass 1 in 500 flood. This option will provide 1 extra lane only but provides benefit for daily traffic

Population Centre	Works Required	Estimated costs $m	Other improvements/comments
	Upgrade up to 17 creek crossings along Great Western Highway between Kingswood and Penrith to pass 1 in 500 flood	Impossible to estimate without flood information for each of the creeks which is only available for some but could cost a few hundred million	This option will provide 2 extra lanes suitable for flood evacuation which provides for future growth but provides no benefit for daily traffic
Jamisontown	Nil	Nil	Evacuation must be commenced earlier than currently planned
Penrith	Nil	Nil	Evacuation must be commenced earlier than currently planned
Emu Heights	Nil	Nil	Evacuation must be commenced earlier than currently planned
Emu Plains	1.2km low section of the Great Western Hwy raised by up to 1m to allow Emu Plains to fully evacuate	12.5	
Leonay	Nil	Nil	
TOTAL		**>$372.5 MILLION**	

6.2 2020 UPGRADES

Table 10: Evacuation route upgrades required based on data modelled for 2020

Population Centre	**Works Required**	**Estimated costs $m**	**Other improvements/comments**
Windsor/ Mulgrave/ McGraths Hill	Nil	Nil	
Riverstone West (industrial)	Nil	Nil	Assuming that Hamilton St etc have been upgraded to one lane plus parking lane with no traffic calming devices as part of the Riverstone residential development, expect traffic queues before entering M7 at Sunnyholt Rd
Penrith Panthers Development	Nil	Nil	Commence evacuation even earlier than 2010
Jamisontown	Nil	Nil	Commence evacuation even earlier than 2010
Penrith infill and Landcom's Penrith North	Nil	Nil	Expect evacuation traffic to queue for several hours before it can use The Northern Rd as its evacuation route
Richmond infill	Upgrade Londonderry Rd to be flood free in local flood events up to 1 in 500 so it can be part of the primary evacuation route for Richmond	5	Assumed 10 new flood crossings using twin 2.1x9 RCBC – some traffic will still require queuing

Population Centre	Works Required	Estimated costs $m	Other improvements/comments
Penrith Lakes	Limit of 800 lots • Extra eastbound lane on Andrews Rd • Upgrade Eighth Ave, Palmyra Rd, Luxford Rd secondary evacuation route for Bligh Park if not already done so for 2010 traffic above Upgrade Great Western Hwy creek crossings if not already done so above for 2010 traffic – but might not need extra lane on M4	5 30 (not included in total) Impossible to estimate without flood information for each of the creeks which is only available for some but could cost a few hundred million	Extra lane on Andrews Rd is fully attributable to Penrith Lakes development and has previously been part of that development
Total		**>$5**	**Arguably only $5million attributable to Penrith Lakes but also arguable that GWH upgrade is too**

6.3 2030 UPGRADES

Table 11: Evacuation route upgrades required based on data modelled for 2030

Population Centre	**Works Required**	**Estimated costs $m**	**Other improvements/comments**
Penrith	Nil	Nil	Longer merging queues for traffic than in 2020
Jamisontown	Nil	Nil	Longer merging queues for traffic than in 2020
Richmond	Nil	Nil	Longer merging queues for traffic than in 2020
Windsor infill	Nil	Nil	
Riverstone West (industrial)	Nil	Nil	Longer merging queues for traffic than in 2020
Emu Plains	Further raising of the Great Western Hwy	Not costed	
Penrith Lakes	Raise Andrews Rd and Castlereagh Rd or construct Boundary Creek levee or leave earlier or combination	not costed because all are attributable to the developer and will depend on what combination is chosen	Assumed 2,300 lots total
Total		**Not yet costed**	

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APPENDIX A – 2010 – EXISTING SES PLAN AND NEXIS DATA

APPENDIX B – 2020 – REVISED EVACUATION PLAN AND COUNCIL ADVISED ADDITIONAL DEVELOPMENT

APPENDIX C – 2030 – REVISED EVACUATION PLAN AND COUNCIL ADVISED ADDITIONAL DEVELOPMENT