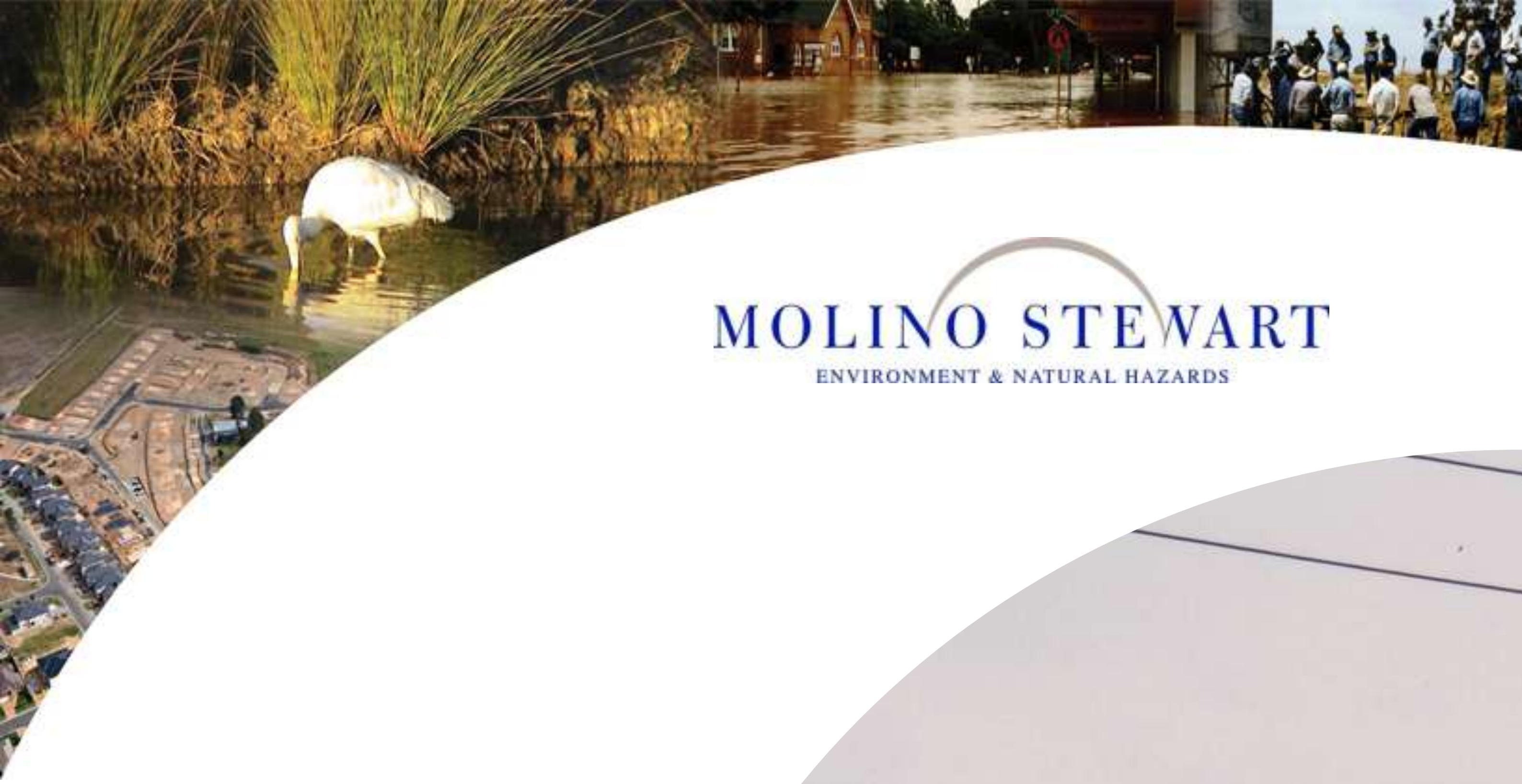

Hawkesbury-Nepean Flood Damages Assessment

Addendum Report: Answers to Recent Questions

Hawkesbury-Nepean Flood Damages Assessment

ADDENDUM REPORT

for

Infrastructure NSW

by

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SEPTEMBER 2012

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 ANSWERS TO RECENT QUESTIONS

1.1 HAS FLOODING CONSTRAINED DEVELOPMENTS IN RECENT YEARS?

Answer: Yes

It is estimated that approximately 8,000 residential lots and 60ha of commercial and industrial land have not been developed above the 1 in 100 planning level within the floodplain due to flooding constraints.

In the past 20 years, flooding has been a significant planning issue in the Hawkesbury Nepean Valley. In some cases it has acted as a constraint to development and resulted in developers downsizing their proposals and other developments being unable to proceed as flooding issues have not been resolved.

This has been the case primarily with greenfield (new) developments, however, within the Valley there have been a considerable number of infill developments that have occurred. This is where larger single dwelling blocks are subdivided and the existing residence demolished for multiple town house style dwellings.

Previous studies, undertaken by Molino Stewart, show that this infilling has had a considerable impact on the populations within flood prone areas, increasing the population at risk of flooding and potentially creating evacuation traffic that is beyond the capacity of the designated evacuation routes.

- Molino Stewart is aware of the following developments that have been affected by flooding constraints:
  Vermont Living at Pitt Town was initially proposed as 1,235 residential lots in 2003 but the final approval in 2008 was for 943 lots.
- The North Bligh Park development has not been able to get rezoning. It was originally proposed to be 1,000 residential lots in 2006 but was then downsized to 700 lots in 2010.
- Landowners with land in the Penrith Riverside Precinct between the M4 and Jamison Road want their land redeveloped. If it weren't for flooding constraints it may yield in excess of 700 lots.
- The Richmond Riverview Estate has not proceeded, it is proposed to be 1,000 lots
- The Penrith Lakes Urban Release has not proceeded. In 2005 it proposed up to 4,900 residential lots plus 60ha of commercial and industrial land.
- The Phoenix Developments medium density development at Emu Plains has not proceeded. It is proposed to be 66 lots.

This represents a total of approximately 8,000 residential lots and 60ha of commercial and industrial land that have not been developed above the 1 in 100 planning level within the floodplain due to flooding constraints.

- There are a number of other developments that are currently in the planning phase where it is likely that flooding constraints will be a significant factor in their design, these are:
  The Penrith Panthers Redevelopment, with a proposed 891 residential properties as well as approximately 50ha of commercial development, with an estimated parking space for 5,000 vehicles to service entertainment and commercial development.
- The Riverstone West Industrial Development, which has 10,800 proposed parking spaces associated with the commercial and industrial developments proposed across more than 100ha.
- The Schofields Precinct Development, which has proposed approximately 1,680 residential lots that can be affected by flooding, and parking space for approximately 2,500 vehicles in the expanded Nirimba Education Precinct.
- The Marsden Park Development, which has proposed approximately 6,000 potentially flood affected lots.

This represents more than 8,500 residential lots and over 150ha of commercial and industrial land above the 1 in 100 planning level.

These developments only represent those that Molino Stewart is aware of and there may be other proposed developments which have been affected by flooding constraints.

1.2 CAN EXISTING INFRASTRCTURE MITIGATE FLOODS?

Answer : Yes, but it is very limited

1.2.1 Warragamba Dam

The current capacity of Warragamba Dam is 2,031,000 ML (mega litres), of which 795,000 ML or 39% is above the crest of the main spillway and held back by the dam's radial gates and drum gate. This compares to the 2,800,000 ML of mitigation airspace which would be provided by raising the dam wall by 23m.

The volume of the 1867 flood as it flows through Warragamba Dam is estimated to be between about 2,200,000 ML and 2,600,000 ML. A probable maximum flood would exceed 6,000,000 ML at the dam.

The question has been asked whether some, or all, of this storage above the spillway crest could be converted to flood mitigation airspace.

a) Permanent conversion of all space above spillway to mitigation

There are a number of issues with permanently reducing the current full supply level and converting all of this to flood mitigation air space:

- The full supply level would need to be lowered 12m which would reduce Sydney's main water supply storage's volume by 39%
- The flood mitigation air space would only accommodate 36% of the volume of an 1867 flood (approximately 1 in 200 chance per year). The remaining water would still have 90% of the volume of a 1 in 100 chance per year flood.
- The flood mitigation air space would only accommodate 13% of the volume of a probable maximum flood (1 in 100,000 chance per year). The remaining water would still have 185% of the volume of the 1867 flood.
- Even the 1961 flood, which is the largest in living memory and had about a 1 in 40 chance of occurrence per year, had a volume in excess of 1,100,000 Ml and would have also exceeded the available airspace above the spillway. In fact, the dam was only 83% full at the beginning of this flood and it still reached almost 15m AHD at Windsor

Therefore, in an event like the flood on record (1867), permanently draining the dam to the spillway level would not provide sufficient mitigation capacity to prevent widespread flooding and mass evacuations but would have a significant impact on Sydney's long term water supply security.

b) Temporary conversion of all space above spillway to mitigation

To overcome the issue of permanently depleting the water supply, it has been asked whether the storage could be held full until flooding is forecast. Then the water above the spillway would be drained in advance of the coming flood so that water supply storage could be converted to flood mitigation capacity in response to a flood warning. This also has a number of issues which make it impractical, such as:

- If the gates are opened up completely the initial release would have a similar flow rate to the peak of a 1 in 100 chance per year design flood event and which would quickly cause significant flooding downstream.
- If it were able to maintain this peak spillway discharge rate, the water above the spillway would require a minimum of 17 hours to discharge. However as the dam drains, the discharge would decrease, increasing the time taken to drain.
- If a constant release rate of 3,000 m^3/s were maintained (the same as the peak release rate of the formerly proposed mitigation dam), the dam would take approximately 73 hours (3 days) to drain to the spillway level. This release rate would still result in some flood impacts, such as the closure of Windsor and

Richmond Bridges and the flooding of some low lying agricultural land.

- These release rates and times assume that there is no inflow into the dam while the water is being released. In other words, this water would have to be released before any significant rain began falling if flood mitigation capacity were to be created.
- Given the above times, to convert 795,000ML of supply storage to flood mitigation capacity, the dam would have to begin draining between one and three days before any significant rainfall began.
- Forecast rainfall generally cannot be relied upon for accurate flood forecasting.

Pre-releasing water from the dam based on such a forecast would definitely cause significant downstream flooding but may result in loss of water supply if the forecast flooding does not eventuate.

The provision of permanent flood mitigation airspace has several advantages over temporary flood mitigation airspace:

- There is a guaranteed flood mitigation capacity which does not require a pre-release strategy for its creation
- The amount of flood mitigation which is available is not dependent on accurate rainfall and flood forecasting
- It slows the rise of the flood downstream giving more time for emergency planning and evacuation whereas creating temporary flood mitigation airspace actually accelerates the flood rise and gives less time for downstream responses
- Downstream peak flood levels will be reduced for the same amount of mitigation storage because with permanent mitigation capacity the flood waters can be released slowly after the flood whereas with temporary mitigation capacity the flood waters need to be released quickly before the flood
- The temporary conversion of water supply storage to flood mitigation capacity runs the risk of losing water supply should forecast rainfall and runoff exceed actual runoff.

c) Temporary conversion of some space above spillway to mitigation

It is understood that the Sydney Catchment Authority is investigating whether its current gate operating procedures could be modified to provide some flood mitigation.

This was previously investigated in 1997 and it is understood that it would only have a significant benefit in smaller floods such as a 1 in 5 chance per year event and no real benefit in floods above about the 1 in 50 chance per year flood. It also would carry two risks:

- Downstream flooding will occur more quickly as water is released from the dam sooner and faster than otherwise would be the case. This means that there will probably be less time available for emergency response.
- If the forecast rainfall does not eventuate then the storage may be less than full at the end of the event and some of the water supply lost

1.2.2 Penrith Lakes

It has also been suggested that the Penrith Lakes Scheme would mitigate flood levels. It should be noted that the flood modelling undertaken in both the 1995 and 1997 EIS's and the subsequent modelling that has been used in this study have incorporated some design of a completed Penrith Lakes Scheme.

During a flood, the following sequence will occur at the Penrith Lakes Scheme:

- Prior to the flood, the Lakes are likely to be already filled to their maximum operating level because of the rainfall that would be needed to saturate catchments to the extent needed for flooding to occur
- Once floodwaters in the Nepean River have reached approximately the 1 in 20 chance per year flood level, water will begin spilling into the Lakes through a series of weirs that connect each lake to the river. This will reduce the flow rate within the river.
- Water within the Lakes will cascade through the system using a set of internal weirs.
- Once the lakes have been filled to the weir level, the weirs will become

submerged and the flow into the lakes will cause no further reduction in river flows.

In a 1 in 100 Year flood, it can be seen in Figure 1 that the lakes have little effect on the flood hydrograph, almost no effect on the peak flow rate and would reduce the flood volume below the lakes by approximately 36,000 Ml or around 2% of the total volume.

As already stated, the flood modelling to date has included a configuration of Penrith Lakes and although the final configuration may change, it is unlikely to make a significant difference to the model results.

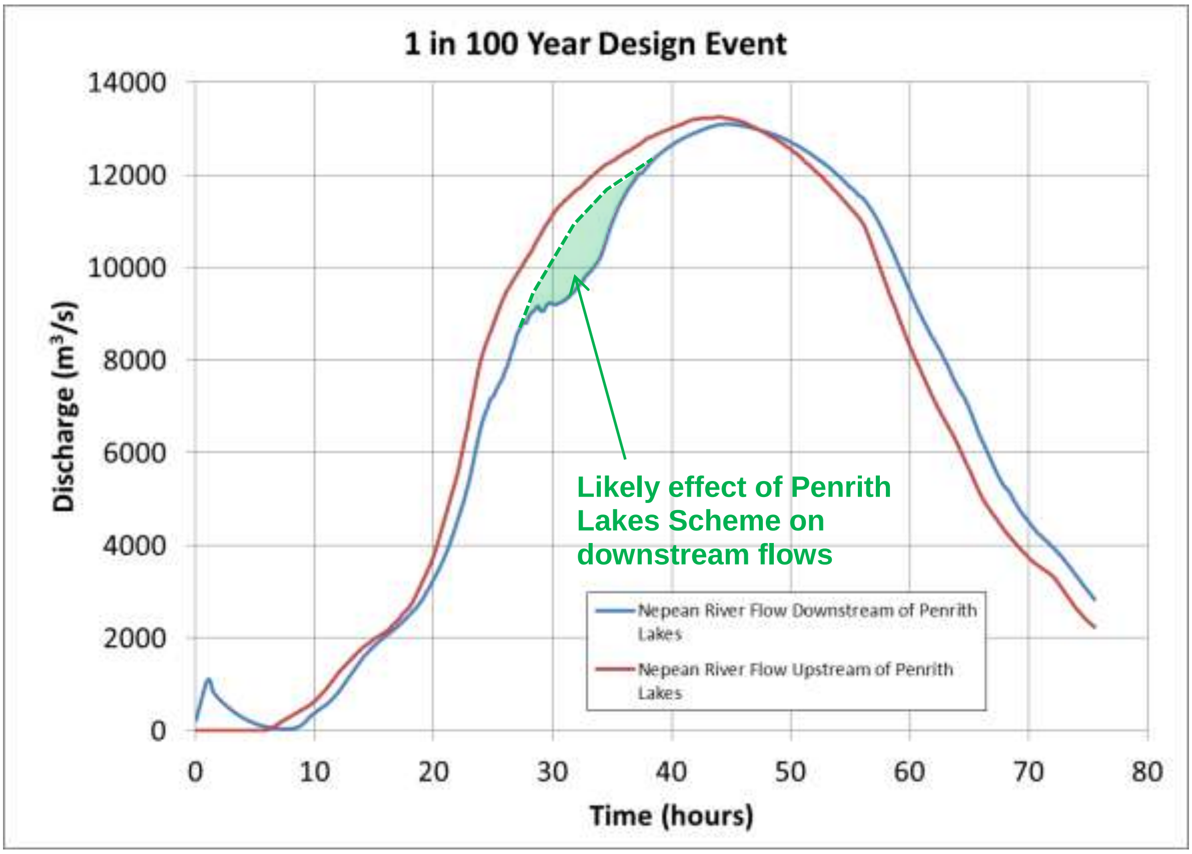

Figure 1 Likely Effect of the Penrith Lakes Scheme on Downstream Flow

1.3 TO WHAT EXTENT DID THE OPERATION OF WIVENHOE DAM CONTRIBUTE TO FLOODING IN THE 2011 BRISBANE FLOOD

Answer: According to expert retained by the Qld Flood Commission of Inquiry – it did not contribute significantly.

Mark Babister, Managing Director of WMAwater, was commissioned by the Queensland Flood Commission of Inquiry to prepare a review of hydraulic modelling of the Brisbane River and to use the available modelling to determine answers to some of the inquiry's questions. This included:
To what extent the January 2011 floods were caused by releases from Somerset and Wivenhoe Dams?

- To what extent did the releases from these dams coincide or avoid peak flows from Bremer River and Lockyer Creek (tributaries to the Brisbane River)?
- Had the levels in these dams been reduced to 75% of the full supply level (FSL) prior to the floods, what impact would this have had on flooding?
- What effect would the implementation of different release strategies have had on flooding?

Wivenhoe Dam is built and operated as both a water supply dam and a flood mitigation dam.
It has a water supply storage of 1,165,238ML and a flood mitigation airspace of 1,450,000ML. It controls 52% of the Brisbane River Catchment Area.

The study found that the flow from releases of Wivenhoe accounted for approximately 59% of the total flood volume. Additionally, the study showed that the bulk of the releases from Wivenhoe occurred prior to the upper tributary peak flows, however, further downstream the flow from the Wivenhoe releases occurred almost simultaneously with the Bremer River flows. The study also noted that had the tributaries been empty, then the flood would have been attenuated as the release from Wivenhoe would back up the Bremer River and then drain slowly downstream to Brisbane.

The study then looked at alternative scenarios, including pre-release water to reducing the reservoir to 75% of its water supply capacity prior to the flood. It also investigated alterations to the gate operations (i.e. releasing more water earlier during the flood). However due to time constraints the combined effect of reducing the full supply level and altering the gate operations was not looked at. The study showed that if either of these scenarios were enacted, it would have resulted in reductions in flood levels at Brisbane of between 0.3 and 0.4 metres.

However, the above results need to be placed into the context of the information that would have been available at the time of the releases. The modelled changes in gate operations which reduced the flood levels would require anticipation of the incoming flood magnitude and timing. This would have required relying on forecast rainfall to determine what the future inflows to the dam would be. Forecast rainfall data is not as reliable for flood forecasting as fallen rain. The rainfall which was being forecast at the time when early release would have had to take place was significantly less than the rain which eventually fell. Even if the dam operators were to have operated to an early release set of operating rules, they probably would not have released the amount of water necessary to create a 0.3m reduction in downstream flooding.

If the storage volume of the dam had been reduced to 75% of its maximum storage prior to the event and the forecast rain had not eventuated, then the city's water supply security could have been compromised. The dam's volume dropped from 100% in 2001 to 15% in 2007. If the dam were less than 85% full in 2001 due to prelease of water in anticipation of a flood which did not eventuate, a repeat of the drought between 2001 and 2007 would have emptied the main water supply for Brisbane.

1.4 CAN EVERYBODY EVACUATE FROM THE HAWKESBURY NEPEAN VALLEY?

Answer: No

The SES categorises flooding in the Hawkesbury Nepean into two levels.

- A Level 1 is where the flood is not expected to exceed 15 m AHD at the Windsor Bridge gauge (about 1 in 40 chance per year). In such a flood it is expected that the response operation is within the normal capabilities of the regional SES and local disaster planning.
- A Level 2 flood is any flood that is forecast to exceed 15m at Windsor (1961 flood or bigger) and it will require state level arrangements in the planning and operation of the response.

The SES has developed a plan for the evacuation of affected areas in a Level 2 flood. The plan utilises all of the available data and current modelling practices and designates the evacuation routes for each population centre and nominates forecast flood heights which would trigger evacuation. These heights are set in order to maximise the chances of all people being able to evacuate, without the need to evacuate people unnecessarily nor having to rescue people because there is insufficient time to evacuate.

These evacuation routes direct the evacuees out of the flood waters and towards the M4 and M7 Motorways. Evacuees will be expected to find accommodation outside of the floodplain if they are able, otherwise they will be directed to a regional evacuation centre that will be established at the Sydney Olympic Park site at Homebush.

The NSW Government received expert advice in 2011 that there are significant road capacity constraints to evacuating the Valley in a Level 2 flood in accordance with the SES Plan. At the current level of development, with no infrastructure improvements, it is estimated that approximately 22,000 people would not have time to evacuate in an extreme flood.

In summary, the following road upgrades would be required to be able to complete evacuation in time:

- Duplication of the existing evacuation route for Windsor
- A secondary evacuation route for Bligh Park and Windsor Downs
- Drainage improvements to Vincent and Northern Road for Richmond evacuation traffic
- Upgrade the M4 or Great Western Highway to prevent queuing for Penrith and Richmond evacuation traffic
- Raise section of Great Western Highway to allow Emu Plains to fully evacuate

In addition, some areas would have to commence evacuating much earlier than the SES currently plans.

1.5 WILL RELEASES FROM A FLOOD MITIGATION DAM MAKE LOW LEVEL FLOODING DAMAGES WORSE?

Answer: No

Any flood mitigation arrangement at Warragamba Dam or elsewhere in the catchment would work on the principal of converting high volume flows over a short period to low volume flows over a much longer period. The total volume of floodwaters passing any one point in the catchment will not change.

An added flood mitigation function at Warragamba Dam would be operated on the following principles:

- A flood mitigation airspace would be provided above full supply level by increasing the height of the dam wall
- Ungated outlets would be provided in the raised dam wall.
- As rainfall begins and water flows into the dam, the inflow rate would exceed the outflow through the outlets because their cross section area would be less than that of the river

- As the water level rises (due to the difference between inflows and outflows) the outflow rate progressively increases but will reach a peak rate which is governed by the size of the outlets
- The mitigation airspace would gradually fill until the flood inflow rate drops back to the peak outflow rate
- The outflow rate would then exceed the inflow rate until the level upstream of the dam gradually drops back to full supply level over a period of several days

Essentially, the mitigation dam does not 'store' any water, it is merely acting as a bottle neck, slowing down the release and letting the inflows back up behind it. This means that upstream of the dam the water level is periodically raised above the current full supply level for a period of several days and downstream of the dam, there will be releases of flood waters for the same extended period of time.

The duration of upstream flooding and downstream releases will be dependent on the size and number of outlets in the dam wall. The less outlet capacity, the longer it will take for the flood mitigation storage to drain but the smaller the downstream flood peaks will be. However, the less the outlet capacity, the higher the dam wall needs to be raised because more of the flood volume will build up behind the dam wall up to the peak of the flood.

In the 1995 EIS, the March 1978 flood (1 in 30 chance per year) was discussed as a way of explaining this concept. Figure 2 shows the dam inflows, the release from the dam under the current arrangement and the hypothetical release from the proposed mitigation dam. It can be seen that the current arrangement matches fairly closely to the dam inflows, with a slight attenuation of the size and timing of the peak as the water spreads over the large surface area of the lake. The mitigation dam in contrast would release a small amount early, and then a larger volume after the majority of the inflows have occurred.

The mitigation effect can be clearly demonstrated here. A visual assessment of the three curves shows that the area underneath (the volume of water) is equal. Examining the current dam releases, the majority (67%) of the flow occurs in a two day period between the start of day two and day four. Whereas examining the mitigation dam releases shows that the majority of the flow is spread across 5 days and the maximum two days of releasing only represents 41% of the total volume. It is this "spreading" of the releases that mitigates the flooding downstream.

It should be noted that a mitigation dam does not increase the frequency of small floods. It reduces the frequency of high flood levels being reached and increases the duration that the large floods remain at the lower flood levels.

This means that it will not increase direct tangible losses to agriculture and low lying roads because the damage to these is done when the flood waters first come through and is not highly dependent on duration. What the extended duration of these larger floods will mean is that it will take longer for the low lying roads to be reopened and for agricultural land to be reused but this needs to be compared to the roads and agricultural land which will not be flooded and suffer damage but otherwise would have been had it not been for flood mitigation. Overall flood mitigation will reduce agricultural and road damages in all floods except the very smallest events in which case it will have no impact or benefit.

Of course it will significantly reduce impacts on residential and business premises in the larger floods. Table 1 compares the reductions in the number of premises with above floor flooding with the number of extra days that Windsor Bridge would be flooded in a couple of large floods. Thousands of premises will directly benefit from mitigation but Windsor Bridge will be closed for 10 days instead of 5 days.

The proposed 3,000 m^3/s outflow from the mitigation dam would be enough to keep water levels at Richmond and Windsor Bridges high enough that they would be closed. The 1995 EIS calculated the number of days for each of the design events that the flow at Windsor would be enough to close the three bridges under both the current and mitigation dams. The mitigation dam generally doubled the amount of time that the bridges were closed in each significant flood event but will reduce the chance of the bridges being closed at all in some of the smaller events.

Using the flow duration curve from the EIS, the current dam would result in the Richmond and Windsor Bridges being closed 1.4 days on average each year, while under the mitigation dam, the bridges would be closed 2.1 days on average each year.

The increased duration of the large floods will increase the length of time that there are freshwater inputs into the brackish estuary downstream of Windsor in these events. This is likely to have an impact on the aquatic ecology of the estuary which may then have an impact on the commercial and recreation fisheries within the estuary.

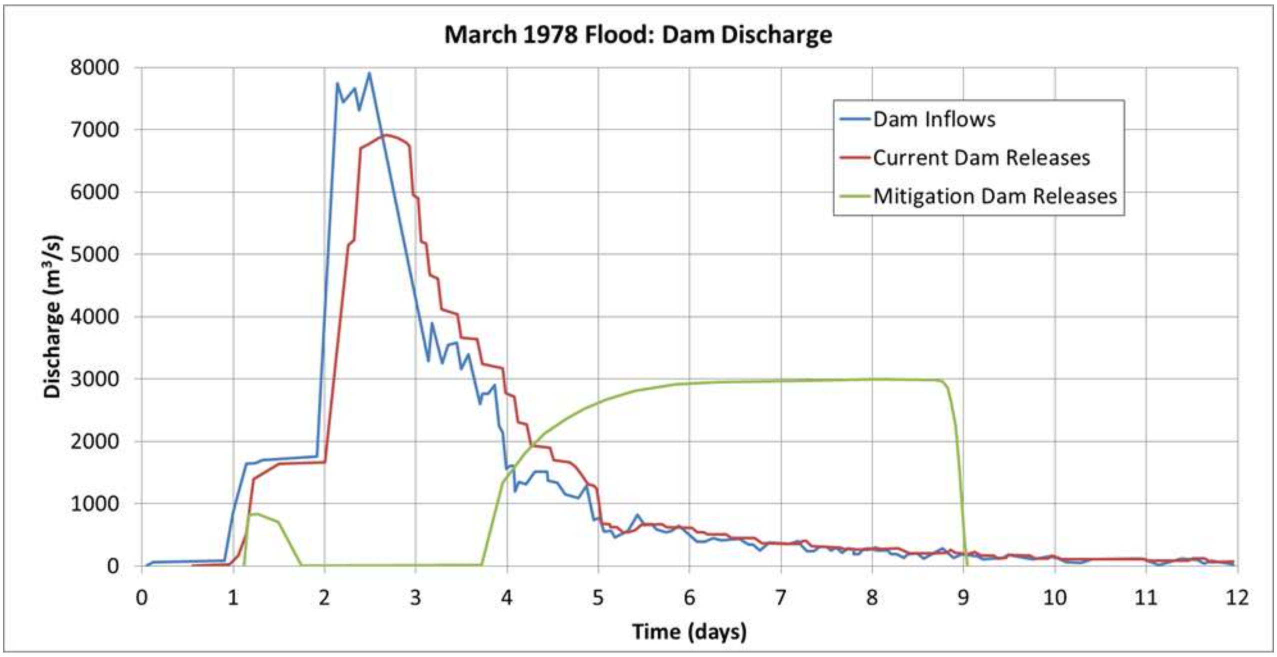

Figure 2 March 1978 Flood Hydrograph

Table 1 Reduction in Damages Compared to Low Level Flooding

Flood chance of occurrence per year	Reduction in number of flooded residential buildings because of mitigation dam	Reduction in number of flooded business buildings because of mitigation dam[1]	Days of Low Level Flooding[2]	
			Without mitigation	With mitigation
1 in 100	3,715	39	5	10
1 in 200	6,416	124	5	10

[1] Based upon 1988 level of development, since then more than 100% increase in commercial floor space below the PMF

[2] Discharge at Windsor Bridge greater than 1,000m^3/s

1.6 WHAT IMPACT WILL MITIGATION HAVE ON AREAS UPSTREAM OF THE DAM?

Figure 3 shows the dam water levels for the March 1978 flood (about 1 in 30 chance per year). With the current dam, the water is essentially released at a rate similar to that which flows into the dam. Therefore the water level within the dam generally does not go up, except during the peak inflows when the releases cannot quite match the inflow. Were the mitigation dam in place, the dam water level would increase by approximately 11 metres, as the water is stored within the dam and then slowly drained out.

The 1995 EIS conservatively estimated that there would be permanent environmental damage if the area upstream of the dam were inundated for a week or more. Figure 3 shows that there might be some damage from this flood for areas up to around 117m AHD, less than a metre above the current full supply level. Examination of the total time series in the 1995 EIS showed that approximately 2 m above the current full supply level would be damaged by the flood mitigation dam in a PMF event. This translates to 24 km^2 of vegetation. In an event of the same magnitude as a 1 in 200 chance per year flood (similar to the 1867 flood) the damaged area would be approximately 10km^2. Table 2 shows a comparison of the area upstream that has increased inundation compared to the area downstream that has decreased inundation as a result of the mitigation dam.

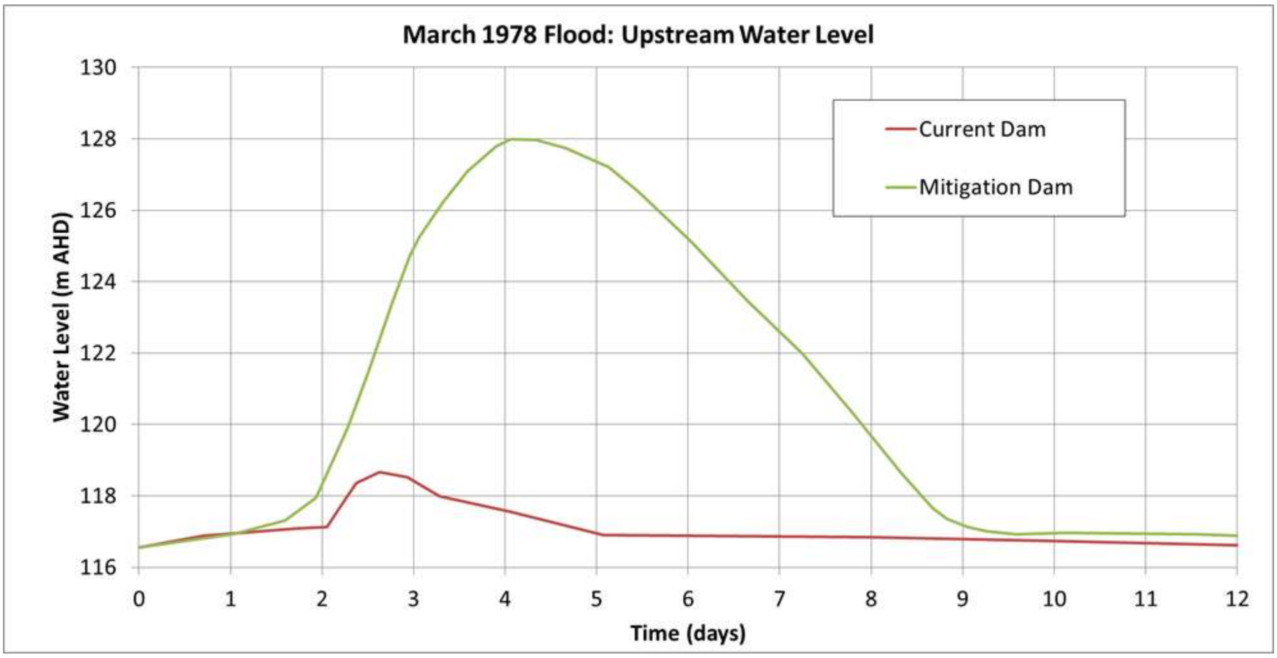

Figure 3 March 1978 Flood, Upstream Water Levels

Table 2 Comparison of Flooded Areas (upstream and downstream)

Average Recurrence Interval	**Additional Flooded Area Upstream of the Dam (km^2)**	**Reduction in Flooded Area Downstream of the Dam (km^2)**
5	6	42
10	8	45
20	13	36
50	19	35
100	22	64
200	25	73
500	26	70
1000	43	67
PMF	46	42

1.7 WHAT IMPACT DOES THE WARRAGAMBA CATCHMENT HAVE ON FLOODING IN THE HAWKESBURY-NEPEAN VALLEY?

Each flood is different and flood peaks and their timing at any particular location will depend on the temporal and spatial distribution of rainfall over the catchment. The catchment above Warragamba Dam accounts for more than 80% of the total catchment above Penrith. By the time the river reaches Windsor, the Warragamba Catchment accounts for about 70% of the total catchment at Windsor. This reduces to about 50% of the total catchment above Brooklyn but flooding is not significant this far down the river system.

1.8 WHAT IMPACT WILL FUTURE RAINFALL PATTERNS PREDICTED AS PART OF CLIMATE CHANGE (MOSTLY COASTAL) HAVE ON THE RISK OF FLOODING IN THE HNV?

The impacts of climate change on future flood risks are unknown.

In 2005 the CSIRO produced a series of reports detailing the likely effects of climate change in NSW. The study found that by 2030:

- The annual rainfall is likely to decline.
- The runoff from rainfall, and stream flows will be reduced.
- Extreme rainfall events are likely to become more intense.

Specific to the Hawkesbury Nepean catchment, the study found that the intensity of extreme rainfall could change between -3% and +12%.

In 2007 the then NSW Department of Environment and Climate Change released a guide for ‘Practical Considerations of Climate Change’. Utilising Figure 1 of this report and the worst case scenario (increased intensity of 12%) it can be calculated that by 2030, an event with a 1 in 100 Year chance of occurrence will have a similar magnitude to the current 1 in 200 Year event. The implications of this are:

- The 1 in 100 Year event may be as high as 26.9 in Penrith (0.9 m higher than what is currently planned for)
- The 1 in 100 Year event may be as high as 18.6 in Windsor (1.4 m higher than what is currently planned for)

Contrary to this, the range includes negative values and the best case scenario in terms of flooding could decrease the magnitude of the 1 in 100 Year event. It should be noted that the NSW Office of Environment and Heritage is currently working to update these estimates through its NSW and ACT Regional Climate Model (NARCliM) project.

Section 4.2 of the Practical Considerations of Climate Change developed a number of strategies for dealing with future development with respect to climate change these are outlined in Table 3.

Table 3 DECC Proposed Strategies for development under climate change

DECC Proposed Strategies	**Associated Risk**
Strategy 1: Do not develop where the risk is unacceptable	No risk, no cost but no development
Strategy 2: Set minimum fill and floor levels to allow for high scenario climate change	Low risk to property, low risk to life, high cost
Strategy 3: Set minimum fill and floor levels based upon existing situation and accept additional flood risk	High risk to life, high risk to property, low cost
Strategy 4: Provide additional protection for homes (floor levels greater than high climate change scenario) but allow surrounding land to be more regularly inundated (no requirement to fill for existing situation)	Low risk to property, high risk to life, moderate cost
Strategy 5: Fill based upon existing situation but increase protection of houses (floor levels greater than high climate change scenario)	Low risk to property, high risk to life (less than Strategy 4), moderate cost (higher than Strategy 4)
Strategy 6: Fill based upon existing situation, increased protection of houses, levee or other flood protection device to low climate change scenario to reduce frequency of inundation	Low risk to property, high risk to life (less than Strategy 5), high cost
Strategy 7: Fill and floor level based upon existing conditions, levee or other flood protection device to high climate change scenario	Low risk to property, low risk to life, high cost (higher than Strategy 6)