7.7 Hydrology

This section assesses hydrology impacts of and on the project. The assessment is supported by a detailed study of the potential impacts of the project on hydrology, including local and regional flooding, which is presented in the Hydrology working paper (Volume 4 – working paper 8). The Director General's requirements for hydrology and flooding have been addressed (as detailed in **Table 7-53** below) as well as the requirements detailed in Part 3 of Schedule 2 of the *Environmental Planning and Assessment Regulation 2000*.

Table 7-53 Director General's requirements - hydrology

Director General's requirements	Where addressed
The EIS must address the following specific matters: **Soils, Sediments and Water –** including but not limited to:	
• erosion and sediment impacts on the Hawkesbury River during construction/ operation; including an assessment of water quality; mitigation measures to prevent water pollution; details of the proposed storm water management measures for the containment of pollutants; and waste handling.	Section 7.6
• justification for the proposed flood immunity and an assessment of the flooding impacts and characteristics to and from the project, including consideration of changes to rainfall frequency and/or intensity as a result of climate change.	Section 7.7.3
• the potential impacts on flow velocities and directions, and impacts on bed and bank stability as a result of removal of the existing bridge and relocation of a new bridge downstream.	Section 7.7.3 & 7.7.4

7.7.1 Guidelines and methodology

The results of previous hydrological and hydraulic modelling were used to provide information on the existing environment. An appropriate level of additional modelling for assessing impacts for the EIS was then undertaken to identify the potential flooding impacts of the project at a regional and property level, for events up to and including the probable maximum flood. The potential bed and bank scour effects of the project were also examined.

The data used in the assessment of existing conditions and the potential impacts of the project included:

- Land use and property (sourced from Land and Property Information and Hawkesbury City Council).
- Digital terrain data derived from airborne laser survey (sourced from Hawkesbury City Council).
- Water level data for the Hawkesbury River at Windsor (sourced from Manly Hydraulic Laboratory).
- Flooding data from previous studies, including the Warragamba Flood Mitigation Dam Environmental Impact Statement Flood Study (Webb McKeown and Associates, 1994).
- Surveyed building floor levels in vicinity of the project.

- Dataset of the location of residential structures and estimated ground levels at structures in the Hawkesbury Local Government Area used in the *Draft Hawkesbury Floodplain Risk Management Study and Plan* (Hawkesbury City Council, 2012).

The study area for the project included the length of the Hawkesbury River from Freemans Reach to Wilberforce, as well as the floodplain area up to six kilometres in width. The floodplain areas predominantly comprise agricultural and rural land uses, as well as urban development within and around the townships of Freemans Reach, Wilberforce and Windsor.

The guidelines and policies considered in the assessment of hydrology and flooding impacts included:

- NSW Flood Prone Land Policy.
- NSW Floodplain Development Manual (DIPNR, 2005).
- Floodplain Risk Management Guideline - Practical Consideration of Climate Change (DECC, 2007).
- NSW Policy and Guidelines for Aquatic Habitat Management and Fish Conservation (DPI, 1999).

Building impact assessment

Information on the location and ground level height of buildings with the Hawkesbury River floodplain was obtained from the Hawkesbury City Council and is the same data that was used in the recent *Draft Hawkesbury Floodplain Risk Management Study and Plan* (Hawkesbury City Council, 2012). This data was used to identify potential buildings that would be at risk of increased flooding due to the project. There are limitations to the data set namely:

- The location of buildings was based on cadastre with reference to the garbage collection dataset for land occupancy, rather than survey of individual properties.
- The ground level data has been obtained from Airbourne Laser Survey (ALS) and ground levels between measured points are interpolated, which may not be an accurate reflection of actual ground level between two points.
- The ALS ground level data for each lot that contains a building may not accurately reflect the actual ground floor level of the building. This is because the ALS ground level data for each lot may not be taken where the building is located on a lot. For example on a lot that has a slope, the ground level data may be from the lowest point of the lot, rather than the highest point where buildings are often located.
- The data may not accurately reflect the floor level of a building as a building may be raised or located on an earth mound, a feature common of many of the buildings in the floodplain. An example of the difference between the ALS data and actual floor level (from a conventional survey) is 27 Wilberforce Road, at the corner of Wilberforce Road and Freemans Reach Road. The ALS data for this property is 10.23 metres AHD, where the survey data is 12.99 metres AHD.

- The data was prepared to assess damages to residential dwellings, which may be located on either a residential lot or associated with a commercial land use. Thus buildings that are large sheds and associated offices used for agricultural activities such as turf farming and horticulture are not explicitly captured in the data. Land use for each identified building was based on Council's zoning and broad assumptions were applied for assessment of potential damages, for example where a property is located in an agricultural zone the land use was classified as residential to reflect that dwellings are often associated with this land use. Commercial zones that are also used for residential dwellings were classified as commercial and therefore potential residential impacts may be understated.

To address these limitations in the flood study dataset, RMS undertook additional survey of actual floor levels of buildings near and immediately upstream of the project. These buildings were generally in the 5 year ARI floodplain. The assessment of flooding impacts was undertaken using both the flood study data and the additional RMS floor level survey data and the results of both assessments are presented in the EIS and associated working paper.

7.7.2 Existing environment

Overview

The Hawkesbury River is part of the greater Hawkesbury-Nepean River, which is the largest river system in the Sydney region. The Hawkesbury-Nepean River has a total catchment area of around 22,000 square kilometres, extending from Goulburn in the Southern Tablelands to the ocean at Broken Bay, incorporating the vast estuarine areas of Pittwater on Sydney's northern beaches and Brisbane Waters on the Central Coast. The catchment area includes large areas of natural bushland and mix of land uses, including agricultural, rural, urban residential, and commercial and industrial development. The major urban centres of Richmond and Penrith are located on the river upstream of Windsor.

The Hawkesbury-Nepean River system, in particular its upper catchment tributaries, incorporates several major water storage dams, which provide the primary water supply source for Sydney. The largest of these dams is Warragamba Dam (or Lake Burragorang), which is located at the confluence of the Coxs, Wollondilly and Nattai rivers around 20 kilometres upstream of Penrith. The main Hawkesbury-Nepean river channel is known as the Nepean River between Warragamba Dam and the confluence of the Grose River at Yarramundi, and the Hawkesbury River between the Grose River and Broken Bay.

Large floods in the Hawkesbury-Nepean River system inundate floodplain areas on both sides of the river downstream of Penrith, and particularly along the reach between Yarramundi and Wilberforce. Flooding is amplified in this reach as discharge to the Broken Bay estuary is restricted by the capacity of gorges downstream of Wilberforce. The township of Windsor is located on the banks of this reach. Much of the township of Windsor is built on a ridge above the river, although the existing Windsor bridge and the floodplain north of the river is at a lower elevation and has been subject to inundation during a number of major floods. Inundation of the existing bridge can last for several days.

The Hawkesbury River at Windsor is subject to tidal influences without saline intrusion. The channel is cut in silt-rich sands, which form fairly cohesive banks with inset sandy deposits of post-settlement alluvium. Between Freemans Reach and Wilberforce, the river channel has large meanders with the floodplain being up to six kilometres wide. Hawkesbury River has been classified by the Fisheries division of the NSW Department of Primary Industries as 'Key Fish Habitat'.

Flooding

Flooding of the Hawkesbury River at Windsor is influenced by flows from upstream tributaries (including upper catchment tributaries) as well as inflows from South Creek and constriction of flows through downstream gorges (located downstream of Wilberforce/Sackville). Information on peak flow levels at various locations upstream and downstream of Windsor bridge based on previous flood modelling studies is provided in **Table 7-54**. The peak flow values presented for Sackville represent the combined flow in the river channel and on the floodplain at Windsor, while the data for the remaining locations represent flow levels within the river. These data indicate a significant distribution of flow over the floodplain during large flood events. In the modelled 100 year average recurrence interval (ARI) event, for example, there was 6,200 m^3/s through the bridge at Windsor compared with 10,800 m^3/s combined flow.

Table 7-54 Modelled estimates of existing peak flood flows near Windsor bridge

Location	Peak flow for modelled flood events (m^3/s)			
	5 year ARI	20 year ARI	100 year ARI	PMF[1]
6.2 km upstream	3,790	7,140	8,310	8,420
3.5 km upstream	3,750	6,610	7,660	7,800
Windsor bridge	3,650	5,440	6,250	6,690
Sackville[2]	3,680	6,260	10,800	32,000

1. Probable maximum flood. 2. Represents combined flow of river and floodplain.

Flood inundation maps for the five, 10, 20, 50 and 100 year ARI events and the probable maximum flood are presented in Volume 4 – Working paper 8. These maps show inundation of low lying floodplain areas around Windsor, including the Bridge Street, Wilberforce Road and Freemans Reach Road approach routes to the existing Windsor bridge for the five year ARI event.

The ten highest flood levels recorded at Windsor bridge since 1857 are listed in **Table 7-55**. Modelled estimates of peak water levels along the Hawkesbury River and floodplain in the vicinity of Windsor, based on the results of previous flood studies, are presented in **Table 7-56**. These data show that peak flood levels at Windsor bridge are 11.1 metres Australian Height Datum (AHD) and 17.2 metres AHD for the five year and 100 year ARI events respectively. The existing Windsor bridge has a height of seven metres and is overtopped by about four metres and 10 metres for the five year and 100 year ARI events respectively.

Table 7-55 Top 10 highest flood levels recorded at Windsor

Year	Month	Flood level (metres)
1867	June	19.7
1864	June	15.1
1961	November	15.0
1964	June	14.8
1900	July	14.5
1978	March	14.5
1870	April	14.1
1956	February	13.8
1879	September	13.6
1990	August	13.5

Table 7-56 Existing conditions - Modelled estimates of peak water levels along the Hawkesbury River

Location	Peak water levels (m AHD) for modelled flood events			
	5 year ARI	20 year ARI	100 year ARI	PMF
River locations – upstream of project				
Downstream of Penrith Weir	19.24	22.07	25.26	30.97
Devlin Road, Castlereagh	13.77	17.34	20.1	28.92
Yarramundi	13.04	16.12	18.22	25.98
North Richmond	12.43	15.11	17.52	25.64
Hibberts Lane	11.63	13.74	17.31	25.53
Windsor Bridge	11.04	13.61	17.29	25.54
River locations – downstream of project				
South Creek Junction	10.99	13.6	17.28	25.53
Wilberforce	10.75	13.53	17.23	25.51
Sackville	7.78	10.06	13.14	22.39
Floodplain locations – upstream of project				
Agnes Banks	13.01	14.53	18.18	25.96
Richmond	16.09	16.19	17.31	25.56
Bakers Lagoon, Richmond	11.24	13.68	17.35	25.57

Emergency management

Floods in the Hawkesbury-Nepean River are classified in the Hawkesbury Nepean Flood Emergency Sub Plan (HNFESP) as either Level 1 (when the water level at Windsor is less than 15 metres AHD) or Level 2 (for floods greater than 15 metres). State Emergency Services (SES) manages evacuation during a Level 2 flood in accordance with measures provided in the HNFESP. The plan covers the area between Wallacia to downstream of Spencer. Flood evacuation routes used in this plan are for areas on the south side of the Hawkesbury River. Windsor's evacuation routes include recently constructed Windsor flood evacuation bridge (centreline height 17.8 metres AHD) over South Creek and Windsor Road at South Creek (closed at 13.5 metres AHD). The HNFESP notes that the stream gauge at Windsor (reference 212426) is used for emergency planning. This gauge is located around 50 metres upstream of the existing bridge.

Emergency management for Level 1 floods is addressed in the Hawkesbury City Local Flood Plan (a sub-plan of the Hawkesbury City Local Disaster Plan). The Plan notes that the council closes and re-opens its own roads as does RMS (Subsections 3.13.2 and 3.13.3). This plan does include a traffic management plan for flooding for Wilberforce Road and Freemans Reach Road.

Windsor bridge flood immunity

Access to Windsor from areas north of the Hawkesbury River (such as Wilberforce and Freemans Reach townships) during floods is limited by the level of the existing Windsor bridge and low lying sections of Freemans Reach Road and Wilberforce Road. Levels along Freemans Reach Road vary between 9.6 and 12.8 metres AHD with the low point at the intersection with Wilberforce Road and a second low point of 10 metres AHD around two kilometres from the intersection with Wilberforce Road. Levels along Wilberforce Road vary between 8.4 to 10.8 metres AHD between Windsor bridge and where the road crosses Buttsworth Creek. Levels are based on Airborne Laser Survey data. Additionally Wilberforce Road is potentially inundated due to local catchment runoff surcharging culverts at Buttsworth Creek. The existing bridge is around 1.4 metres lower than the low point on Wilberforce Road and 2.6 metres lower than the low point on Freemans Reach Road. Between 1987 and 2011 there have been eight events for which water levels were higher than the level of the existing bridge. The average duration of these events was 43 hours.

Flood affected properties

Existing flood risk to residential dwellings in the Hawkesbury LGA is addressed in the *Draft Floodplain Risk Management Study and Plan* (Hawksbury City Council, 2012). Property data used in this study was provided through Hawkesbury City Council for use in this EIS to estimate impacts from the project. This is supplemented for properties close to the project for which floor levels were surveyed. Additionally a wider assessment has been done to consider potential impacts to land use other than residential dwellings.

The preliminary estimates of existing regional property and land use impacts anticipated under four modelled events are presented in **Table 7-57** and **Table 7-58** respectively. These estimates show that the main land uses impacted by flooding are horticulture and grazing. Urban areas account for only 10 per cent of the inundated area in a 100 year ARI event.

Table 7-57 Existing conditions - Estimate of number of lots inundated

Location	Number of lots inundated for modelled flood events			
	5 year ARI	20 year ARI	100 year ARI	PMF[1]
Northern floodplain	270	310	470	620
Richmond floodplain south of the river up to the railway	170	230	390	1100
Southern floodplain from South Creek to Wilberforce	260	350	570	690

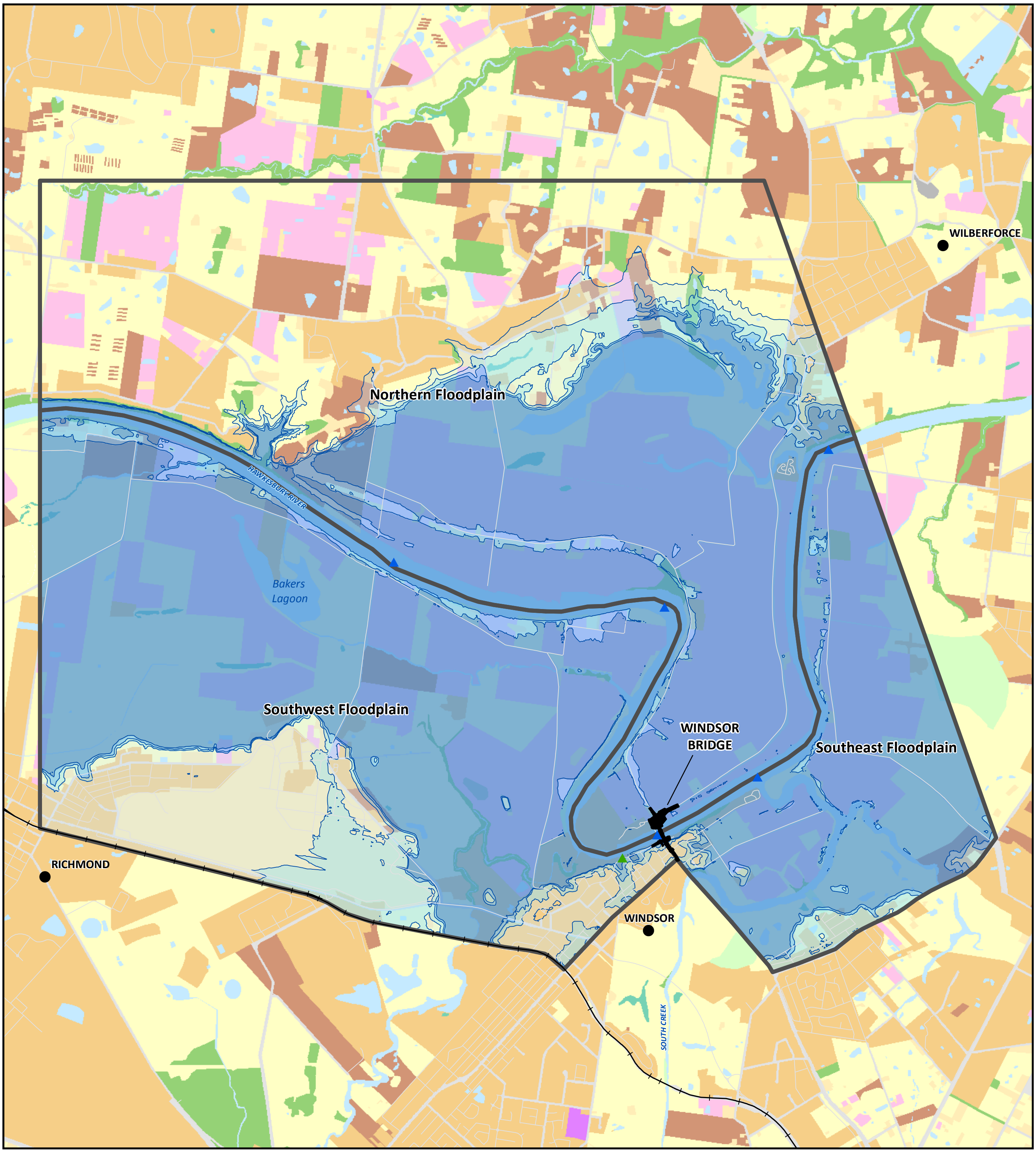
1. Probable maximum flood.

Table 7-58 Existing conditions - Preliminary estimate of land use impacts

Land use type	Area impacted for modelled flood events (ha)			
	5 year ARI	20 year ARI	100 year ARI	PMF[1]
Northern floodplain				
Grazing	200	230	300	350
Horticulture - Orchards & vegetables	240	250	250	250
Horticulture - Turf farming	540	570	580	600
Intensive animal production	0	30	50	60
Urban	70	80	120	170
Vegetated areas & water features	240	250	250	260
Richmond floodplain south of the river up to the railway				
Grazing	640	670	680	700
Horticulture - Orchards & vegetables	150	160	170	170
Horticulture - Turf farming	410	420	420	420
Intensive animal production	50	50	50	50
Urban	110	120	160	300
Vegetated areas & water features	160	160	160	160
Defence	10	10	90	260
Mining & quarrying	3	4	4	4
Southern floodplain from South Creek to Wilberforce				
Grazing	470	490	500	510
Horticulture - Cropping & vegetables	30	30	30	30
Horticulture - Turf farming	270	270	270	270
Intensive animal production	10	20	20	30
Urban	50	70	120	140
Native forest & waterways	140	140	140	140

1. Probable maximum flood.

Figure 7-37 | Land use and approximate extent of inundation



Indicative only – subject to detailed design

LEGEND

- 5 year ARI
- 20 year ARI
- 100 year ARI
- PMF
- Water level gauge station
- Model location
- Road
- Railway

Land use

- Conservation Area
- Cropping
- Grazing
- Horticulture
- Intensive Animal Production
- Mining & Quarrying
- Power Generation
- River & Drainage System
- Special Category
- Transport & Other Corridors
- Tree & Shrub Cover
- Urban
- Wetland

GDA 1994 | MGA Zone 56

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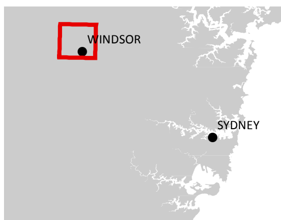
Kilometres



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In addition to buildings from the data provided through Hawkesbury City Council, RMS surveyed floor levels for properties near the bridge and within the upstream floodplain that are potentially impacted by the project. The location, floor level and estimated depth of existing flooding at these buildings are provided in **Table 7-59**.

Of the buildings where additional survey of floor levels was undertaken by RMS:

- Twenty four buildings on twelve properties are estimated to experience above floor inundation in a 5 year ARI event.
- Thirty-four buildings on sixteen properties are estimated to experience above floor inundation in a 20 year ARI event.
- Thirty-five buildings on sixteen properties are estimated to experience above floor inundation in a 100 year ARI event.

Estimated inundation of other properties from the Hawkesbury City Council database for existing conditions include:

- Three buildings experience above floor inundation in a 5 year ARI event.
- 130 buildings experience above floor inundation in a 20 year ARI event.
- 699 buildings experience above floor inundation in a 100 year ARI event.

It is noted these are a subset of potentially inundated properties considered in the Floodplain Risk Management Study which accounted for properties in the whole Hawkesbury LGA.

Table 7-59 Estimated depth of overfloor inundation for existing conditions

Property Address	Surveyed Floor Level (mAHD)	Estimated Existing Flood Depth above surveyed floor level (m)			
		5 year ARI	20 year ARI	100 year ARI	PMF
1 Thompson Square	14.03	-	-	3.26	11.51
5 Freemans Reach Road	13.12	-	0.49	4.16	12.41
5 Freemans Reach Road	13.47	-	0.14	3.81	12.06
5 Freemans Reach Road	11.52	-	2.09	5.76	14.01
27 Wilberforce Road	12.99	-	0.62	4.29	12.54
27 Wilberforce Road	11.17	-	2.44	6.11	14.36
33 Wilberforce Road	10.34	0.69	3.27	6.94	15.19
33 Wilberforce Road	10.97	0.06	2.64	6.31	14.56
33 Wilberforce Road	11.67	-	1.94	5.61	13.86
1A Wilberforce Road	10.88	0.18	2.74	6.41	14.66
1A Wilberforce Road	10.86	0.20	2.76	6.43	14.68
1A Wilberforce Road	10.88	0.18	2.74	6.41	14.66
1A Wilberforce Road	10.86	0.20	2.76	6.43	14.68
23 Wilberforce Road	11.11	-	2.51	6.18	14.43
23 Wilberforce Road	10.93	0.13	2.69	6.36	14.61
98 Cordners Lane	11.69	-	1.96	5.61	13.85
124 Cornwallis Road	10.51	0.74	3.15	6.79	15.03
124 Cornwallis Road	9.42	1.83	4.24	7.88	16.12
295 Freemans Reach Road	11.22	0.05	2.44	6.08	14.32
295 Freemans Reach Road	11.09	0.18	2.57	6.21	14.45
295 Freemans Reach Road	10.92	0.35	2.74	6.38	14.62
295 Freemans Reach Road	11.01	0.26	2.65	6.29	14.53
1 Gow Lane	9.23	2.09	4.44	8.07	16.31
1 Gow Lane	9.36	1.96	4.31	7.94	16.18
332 Cornwallis Road	11.42	0.07	2.27	5.89	14.13
332 Cornwallis Road	11.17	0.33	2.53	6.14	14.38
362 Cornwallis Road	11.63	-	2.07	5.68	13.92
156 Freemans Reach Road	10.81	0.35	2.83	6.49	14.73
238 Freemans Reach Road	10.69	0.43	2.94	6.60	14.84
238 Freemans Reach Road	11.53	-	2.10	5.76	14.00
238 Freemans Reach Road	10.19	0.93	3.44	7.10	15.34
238 Freemans Reach Road	10.21	0.91	3.42	7.08	15.32
490 Freemans Reach Road	11.19	0.33	2.51	6.12	14.36
521 Freemans Reach Road	11.16	0.39	2.54	6.15	14.39
521 Freemans Reach Road	10.88	0.67	2.82	6.43	14.67

7.7.3 Construction and demolition impacts

Potential impacts of flooding on the project

It is possible that a flood could occur during the construction or demolition period, which could have adverse effects on work activities and increase the risk of soil and sediment erosion. The impacts and associated environmental management measures for soil and sediment erosion are presented in **Section 7.6**. The occurrence of high river flows during construction or demolition could result in erosion of bed and bank material if the proposed scour protection measures have not yet been constructed.

Before the demolition of the existing bridge is completed, it could fail during a flood event causing damage to the new bridge. While the existing bridge is in poor condition, the new bridge would open by 2015 and the existing bridge is extremely unlikely to fail in the next three years.

Potential impacts of the project on flooding

The presence of construction infrastructure and equipment in the river (such as barges and temporary platforms) and the period when two bridges are present (whether partially constructed, demolished or complete) has the potential to increase flooding at properties upstream of the project. The increase in flood levels when both bridges are present (and complete) is estimated to be around 0.18 metres (that is 0.06 metres above the estimated increase with the replacement bridge alone) in a five year ARI event. The period between opening the new bridge and completing the demolition of the existing bridge would be about four months.

During the construction of the new bridge, increased flooding would be negligible until the launching of the new bridge commences. As the bridge is gradually launched across the river, the potential impact of flooding upstream would increase. It would take about 12 months to launch the bridge and complete finishing works before the opening of the new bridge.

Flood impacts would be greatest for properties that are near the bridge (see further information on property impacts below).

7.7.4 Operational impacts

Changes in flow distribution near Windsor

The predicted changes in peak flow volumes within the Hawkesbury River as a result of the project are presented in **Table 7-60**. The flows are representative of flow for a width of around 250 metres over the main river channel and thus do not include flow that is within the floodplains. For the project the change in flow is minor with a small reduction in the peak flow in the river (less than one per cent) in a 100 year ARI event. Peak flows reduce due to attenuation of floods when water levels increase and due to some redistribution of water onto the floodplains.

Table 7-60 Modelled estimates of changes in peak flow as a result of the project

Location upstream of Windsor bridge	Change in peak flow for modelled flood events - m^3/s and (percent change in flow compared to existing conditions)			
	5 year ARI	20 year ARI	100 year ARI	PMF[1]
6.2 km upstream	-10 (<1%)	-20 (<1%)	0	-120 (-1.5%)
3.5 km upstream	-10 (<1%)	-60 (<1%)	-50 (<1%)	-90 (-1.2%)
At Windsor bridge	-10 (<1%)	-140 (-2.5%)	-60 (-1%)	-20 (<1%)

1. Probable maximum flood.

Changes in peak water levels

The project would potentially increase flood levels on the Hawkesbury River floodplain, as the new bridge and approach road modifications would obstruct the movement of floodwaters to a greater extent than the existing bridge and approach roads.

The predicted changes in peak water levels as a result of the project are shown in **Table 7-61**. These predictions indicate that the effect of the project on flood water levels would be minor and would be greatest for the five year ARI event.

In the five year ARI flood event, the peak water level in the channel would increase by 0.12 metres just upstream of the project. The increase in water levels would decrease with distance upstream, with water level increases of 0.06 metres at North Richmond and 0.03 metres at Devlin Road, Castlereagh. Flood water levels on the Hawkesbury River floodplain would also increase upstream of the project, with an increase of 0.11 metres at Bakers Lagoon and 0.04 metres at Agnes Banks. In contrast, flood water levels downstream of the project and on the South Creek floodplain would decrease in the five year ARI event.

For the 20 year ARI event, there would be a very minor increase in peak water levels within the channel upstream of the project, with an increase of 0.03 metres just upstream of the bridge and 0.01 metres at Devlin Road. There would also be a very minor increase in peak water levels within the channel downstream of the project. On the floodplains, there would be a minor increase in water levels at Bakers Lagoon and a very minor increase around South Creek.

The model predictions for the 100 year ARI and PMF events indicate that the effects of the project on flood behaviour and peak flood levels during extreme flood events would be negligible.

Table 7-61 Change in peak flood level as a result of the project

Location	Change in peak water levels (m AHD) for modelled flood events			
	5 year ARI	20 year ARI	100 year ARI	PMF
River locations – upstream of project				
Penrith Weir	Nil	Nil	Nil	Nil
Devlin Road, Castlereagh	0.03	0.01	Nil	Nil
Yarramundi	0.04	0.01	Nil	Nil
North Richmond	0.06	0.01	Nil	Nil
Hibberts Lane	0.09	0.02	Nil	Nil
Windsor Bridge	0.12	0.03	0.01	-
River locations – downstream of project				
South Creek Junction	-0.02	0.01	Nil	Nil
Wilberforce	-0.02	0.01	Nil	Nil
Sackville	-0.02	0.01	Nil	Nil
Floodplain locations – upstream of project				
Agnes Banks	0.04	Nil	Nil	Nil
Richmond	Nil	Nil	Nil	Nil
Bakers Lagoon, Richmond	0.11	0.02	Nil	Nil

Property impacts

An assessment of the potential flood impacts to properties upstream of the project has been undertaken using the model results, ALS data over the floodplain and cadastre. Flood levels downstream of the project (in the southeast zone) are not considered as flood levels slightly reduce due to the project in the five year ARI event and have only a minor increase in a 20 year ARI event (up to 0.01m which is considered within the range of model accuracy) and no change in a 100 year ARI event.

The assessment indicates that one additional lot would experience flooding in a five year ARI in the southwest zone due to the project and up to 359 lots (in the northern and southwest zones) would be expected to experience an increase in a five year ARI flood depth due to the project. The increase of flood depths would be five percent (for example 0.05 metre increase in depth above an existing flood depth of one metre) for 200 of the lots, an additional 103 lots are estimated to have an increase up to ten percent and an additional 51 lots an estimated increase up to 15 percent. The distribution of increases to depths for various land use are presented in **Table 7-62**.

The assessment indicates that one additional lot would experience flooding in a 20 year ARI in the southwest zone due to the project and up to 581 lots (in the northern and southwest zones) would experience an increase in a 20 year ARI flood depth due to the project. For all lots potentially subject to an increase in inundation depth, the percent increase of flood depths above the existing flood depths would be less than five percent.

The majority of the area subject to inundation is used for agricultural purposes, refer to **Table 7-62**. Agricultural damage is usually quantified by considering both the depth of inundation and time of inundation, and the following are suggested criteria for damage (Read Sturgess & Associates, 2000):

- Grain and vegetable crops are expected to be lost when the flood depth is between 0 and 0.15 metres, no matter how long the land is flooded for;
- Pasture, vines and orchards are damaged when the inundation time is greater than 7 days and/or the depth of flooding is greater than 0.15 metres.
- Significant livestock losses occur when the depth of flooding is greater than 0.15 metres and/or the inundation time is greater than 7 days.

Table 7-62 Potential impacts to average flood depths on properties between Richmond and Wilberforce – 5 year ARI event

Land use groupings	Existing Conditions	Replacement Bridge	
	Average depth (metres)	Average depth (metres)	Increase in average depth (metres)
Northern Floodplain			
Grazing	2.95	2.99	0.04
Horticulture	2.15	2.21	0.06
Horticulture - turf	3.06	3.11	0.05
Intensive Animal Production	1.83	1.88	0.05
Other	4.48	4.53	0.05
Urban	3.81	3.85	0.04
South West Floodplain			
Grazing	3.79	3.86	0.07
Horticulture	2.03	2.09	0.07
Horticulture - turf	3.75	3.82	0.08
Intensive Animal Production	3.22	3.29	0.06
Other	6.19	6.28	0.09
Special Category	3.88	3.94	0.06
Urban	2.03	2.06	0.03

While the average flood impacts over the wider floodplain due to the project are minor, there would be a small number of properties that would be impacted by a higher level of flooding. Properties most vulnerable to impacts would be those located immediately upstream of the replacement bridge. Increases in flood levels would potentially result in increased flood damage costs and other impacts associated with flooding.

Higher flood damage costs and other impacts occur when commercial and residential premises are flooded. Data from the recent Draft Hawkesbury Flood Risk Management Study was used to assess the magnitude of potential impacts from increased flooding due to the project. As described in **Section 7.7.2**, the data used to predict the increase in flood levels at buildings had limitations and uncertainties. It provides an indication of likely impacts to residential properties. Results presented assume residential buildings have floor levels at the ground levels of the properties.

Potential impacts to residential buildings between Richmond and Wilberforce

Flood afflux (increase in water depths) of buildings located upstream of Windsor bridge, and on the northern floodplain, was assessed from the preliminary mapping prepared for this EIS, surveyed floor levels undertaken by RMS and buildings identified from the HCC dataset used in the FRMS. Identification of existing flood impacted properties does not represent a replication of flood assessment undertaken for the FRMS, nor does it accurately identify overfloor inundation for properties other than surveyed by RMS, as survey of floor levels was not undertaken when developing this dataset for the FRMS. It provides an indication of likely impacts to residential properties. Impacts to properties may include increased flood damages, impacts on the safety of residents and impacts to property access.

Buildings with an estimated increase in flooding of less than 0.01 metre due to the project are not included in this assessment as this increase is considered negligible and beyond the accuracy of the modelling used to determine afflux. Properties subject to flooding greater than one metre for existing conditions are not included in this assessment as the increase in flood depths is minor compared with existing flood inundation.

Table 7-63 shows the existing flood depths and estimated increase in flood levels for buildings with surveyed floor levels. The increase to flood depths is shown for the five, 20 and 100 year ARI events. Results for the PMF are not provided as there is negligible increase in flood levels for this event. These results indicate that:

- In a five year ARI event one additional residential dwellings would be experience over floor flooding (23 Wilberforce Road) due to the project and 25 buildings would experience increased flooding levels greater than 0.01 metre. Of these 25 buildings, three buildings have an existing over floor flooding of greater than one metre. Average increase in flood levels due to the project for the other 22 buildings would be 0.10 metre, with the largest increase in water depth of 0.12 metre. There would be 15 buildings with an increase in flood levels due to the project of greater than 25 percent, two of which are generally subject to low levels of flooding in the existing conditions (less than 0.1 metre). These two buildings would be at most risk of increased flood damage from increases in flood levels due to the project.
- In a 20 year ARI event there would be no additional buildings experiencing over floor flooding due to the project. Thirty four (34) buildings would experience increases in flood levels due to the project of greater than 0.01 metre however, 31 properties have an existing depth of inundation greater than one metre. The average increase in flood levels for the three properties that have increase greater than 0.01 metre and an existing depth less than one metre is 0.03 metre.
- In a 100 year ARI event there are negligible changes to flood levels at buildings due to the project.

Estimated afflux for buildings other than those surveyed, was assessed using the HCC dataset. As noted previously this data assumes residential buildings have floor levels at the ground levels of the properties. The predicted impacts for the different flodd events include:

- In a five year ARI event there would be no additional residential dwellings would be experience over floor flooding due to the project. Three residential dwellings would experience increases in flood levels of greater than 0.01 metre due to the project and of these, one dwelling has an existing depth of inundation greater than 1 metre. The increase in flood levels at these buildings due to the project would be 0.11 metre.
- In a 20 year ARI event there would be four additional residential dwellings that would experience over floor flooding due to the project. One hundred and thirty (134) residential dwellings would experience increases in flood levels greater than 0.01 metre due to the project, however 45 properties have an existing depth of flooding greater than one metre. Average increase in flood levels due to the project for the other 89 properties would be 0.02 metre with the highest experiencing an increase of 0.03 metre.
- In a 100 year ARI event there would be negligible changes to flood levels at properties due to the project.

Table 7-63 Increase to over floor inundation for buildings near Windsor Bridge

Property Address	Surveyed Floor Level (metres AHD)	Estimated Flood Depth above surveyed floor level (metres)			Estimated Increase in Flood Depths (metres)		
		5 year ARI	20 year ARI	100 year ARI	5 year ARI	20 year ARI	100 year ARI
1 Thompson Square	14.03	-	-	3.26	-	-	0.01
5 Freemans Reach Road	13.12	-	0.49	4.16	-	0.03	0.01
5 Freemans Reach Road	13.47	-	0.14	3.81	-	0.03	0.01
5 Freemans Reach Road	11.52	-	2.09	5.76	-	0.03	0.01
27 Wilberforce Road	12.99	-	0.62	4.29	-	0.03	0.01
27 Wilberforce Road	11.17	-	2.44	6.11	-	0.03	0.01
33 Wilberforce Road	10.34	0.69	3.27	6.94	0.11	0.03	0.01
33 Wilberforce Road	10.97	0.06	2.64	6.31	0.11	0.03	0.01
33 Wilberforce Road	11.67	-	1.94	5.61	-	0.03	0.01
1A Wilberforce Road	10.88	0.18	2.74	6.41	0.12	0.03	0.01
1A Wilberforce Road	10.86	0.20	2.76	6.43	0.12	0.03	0.01
1A Wilberforce Road	10.88	0.18	2.74	6.41	0.12	0.03	0.01
1A Wilberforce Road	10.86	0.20	2.76	6.43	0.12	0.03	0.01
23 Wilberforce Road	11.11	-	2.51	6.18	0.12	0.03	0.01
23 Wilberforce Road	10.93	0.13	2.69	6.36	0.12	0.03	0.01
98 Cordners Lane	11.69	-	1.96	5.61	-	0.02	<0.01
124 Cornwallis Road	10.51	0.74	3.15	6.79	0.11	0.02	<0.01
124 Cornwallis Road	9.42	1.83	4.24	7.88	0.11	0.02	<0.01
295 Freemans Reach Road	11.22	0.05	2.44	6.08	0.11	0.02	<0.01
295 Freemans Reach Road	11.09	0.18	2.57	6.21	0.11	0.02	<0.01
295 Freemans Reach Road	10.92	0.35	2.74	6.38	0.11	0.02	<0.01
295 Freemans Reach Road	11.01	0.26	2.65	6.29	0.11	0.02	<0.01
1 Gow Lane	9.23	2.09	4.44	8.07	0.11	0.02	<0.01
1 Gow Lane	9.36	1.96	4.31	7.94	0.11	0.02	<0.01
332 Cornwallis Road	11.42	0.07	2.27	5.89	0.10	0.02	<0.01
332 Cornwallis Road	11.17	0.33	2.53	6.14	0.10	0.02	<0.01
362 Cornwallis Road	11.63	-	2.07	5.68	-	0.02	<0.01
156 Freemans Reach Road	10.81	0.35	2.83	6.49	0.08	0.02	<0.01
238 Freemans Reach Road	10.69	0.43	2.94	6.60	0.07	0.02	<0.01
238 Freemans Reach Road	11.53	-	2.10	5.76	-	0.02	<0.01
238 Freemans Reach Road	10.19	0.93	3.44	7.10	0.07	0.02	<0.01
238 Freemans Reach Road	10.21	0.91	3.42	7.08	0.07	0.02	<0.01
490 Freemans Reach Road	11.19	0.33	2.51	6.12	0.10	0.02	<0.01
521 Freemans Reach Road	11.16	0.39	2.54	6.15	0.10	0.02	<0.01
521 Freemans Reach Road	10.88	0.67	2.82	6.43	0.10	0.02	<0.01

Climate change

The *Practical Consideration of Climate Change, Floodplain Risk Management Guideline* (DECCW, 2007) provides a range of predicted climate change impacts for various regions. Within the Sydney Metropolitan region the likely change in extreme rainfall is estimated to be between -3 and +12 per cent up to 2030 and -7 and +10 per cent up to 2070. These changes are applied to all frequency events and various duration events (greater than one day). The *Floodplain Risk Management Study* reported that peak flood levels are highly sensitive to increases in rainfall. A ten percent increase in rainfall results in an increase of 0.9m in peak flood level in a 100 year ARI at Windsor. Alternatively the current 100 year ARI flood would occur more frequently and would become around a 60 to 70 year ARI event with a 10% increase in rainfall. Therefore the bridge would be overtopped in more frequent events, likely subject to higher velocities, potentially greater depths of scour and increased depth of inundation. The replacement bridge would be designed to be overtopped and to withstand scouring of the piers and abutments up to 2000 year ARI event. As a result it would be unlikely to be affected by changes in rainfall and flooding events.

Coastal sea level rise produced by DECCW (as part of the *NSW Sea Level Rise Policy Statement* (DECCW, 2009)) has been assumed to be applicable to the township of Windsor. These projections are sea level rise of 40cm by 2050 and sea level rise of 90cm by 2100. The *Draft Hawkesbury Floodplain Risk Management Study* reported that sea level rises produce no significant increases in peak flood levels for the majority of the floodplain.

Other potential risks due to climate change are identified and addressed in the Climate change section (see **Section 8.4**) and are further discussed in Chapter 11 (Ecologically Sustainable Development).

Scour protection

Flooding of the Hawkesbury River has the potential to cause bed and bank scour, including scour around bridge abutments and piers. Scour may also occur due to local turbulence generated at bridge abutments and piers under normal flow (non-flood) conditions. On the southern bank of the river there is an existing retaining wall, gabions and vegetated fill where the former wharf was located. This area would be potentially impacted by increased velocities as a result of turbulence generated by the abutments and piers of the replacement bridge.

The need to prevent bed and bank scour has been addressed in project design (see **Section 5.2.7**). These design measures would provide bed and bank scour protection for both frequent and large flood events. The project also includes filling the existing low area between the northern abutments of the existing bridge and proposed replacement bridge to limit opportunities for generation of turbulence and scour.

Flood immunity

The bridge would connect Bridge Street in Windsor to Wilberforce Road and Freemans Reach Road. The project would have a minimum road level of RL 9.8 metres AHD (2.8m higher than the existing bridge). This would result in the replacement bridge being a similar height to the lowest level of Freemans Reach Road and higher than around 60 per cent of Wilberforce Road, from the bridge to Wilberforce.

The level of the replacement bridge would be optimal as it would provide a connection to the existing roads while improving the flood immunity for the crossing. A higher level would not improve regional access during floods as the northern roads would be inundated before the bridge is overtopped. Additionally extensive road works on the northern bank would be required to transition to the existing road profiles and such earthworks would inhibit the passage of floods. Having the bridge at a lower level, that is a lower flood immunity, would limit access across the river during floods as Freemans Reach Road would be accessible when the bridge is closed. This is similar to the current conditions.

The increased height of the new bridge would result in a decrease in the frequency of the river crossing closures. Using historical flood level data from 1987 to 2011 the number and length of bridge closures for the existing bridge and new bridge was estimated. If the new bridge had been in place, the number of bridge closures would have been three instead of eight and the average duration of closures would have decreased from 43 hours to 19.5 hours.

Changes in flow direction

As only a concept design of the project was available at the assessment stage, no detailed modelling of potential impacts on flow direction was undertaken. However as the existing alignment of the river banks would remain unchanged and the replacement bridge would be inundated in floods greater than the three year ARI event, the impacts on flow direction for most flood events would be negligible. The key flood events that would require more detailed assessment would be flood events around the three year ARI, namely when the replacement bridge would be partially submerged. As the replacement bridge has a slight slope from south to north, some additional flood waters may be forced to the north during partial submergence of the bridge. This may have a localised impact, however it would not be expected to be significant as the volume of water would be relatively small and the landuse is predominately agricultural. Once the detailed design of the replacement bridge is further advanced, an assessment of potential changes in flow direction would be undertaken.

[11] recorded water levels at Windsor gauge (MHL stream gauge 212426)

7.7.5 Environmental management measures

Construction measures

The potential impacts of flooding on the construction and demolition phases of the project, as well as the impacts of construction and demolition activities on flooding, can be reduced to acceptable levels with the application of standard construction site management procedures. Procedures to minimise flooding impacts during construction would include (but would not be limited to) the following:

- The extent of obstructions within the river will be minimised as far as practicable at all times during construction and demolition.
- The time between completion of construction of the replacement bridge and demolition of the existing bridge will be minimised as far as practicable.
- Construction infrastructure and equipment will be removed from the river channel and floodplain in the event of a forecast flood to minimise both the risk of damage to infrastructure/equipment and the risk of flood impacts on properties.
- Appropriate procedures to manage the effects of flooding during construction, and minimise any associated adverse environmental impacts to the greatest extent practicable, will be incorporated into a construction environmental management plan and emergency response plan (to be prepared and approved before the start of construction). The emergency response plan would include procedures to ensure adequate warning of floods is obtained and that appropriate emergency response procedures are implemented in a timely manner
- Suitable scour protection would be provided to protect the bridge abutments, piers and banks during construction.

Environmental management measures to minimise potential water quality and erosion impacts from flooding during construction are detailed in **Section 7.6**.

Operational measures

Property impacts

The following environmental management measures will be implemented to minimise impacts from flooding:

- Flood impact mitigation requirements and options for buildings potentially impacted by the project will be investigated during detailed design in consultation with the landholders. Appropriate measures will be identified, developed and implemented, as required, to minimise impacts on the building structure, building access and business opportunities.
- During the detailed design of the new bridge, detailed flood modelling will be undertaken on the final design of the project to identify any additional impacts. This will include collecting survey data at potentially impacted properties with buildings upstream of the bridge. Where impacts are identified, appropriate measures will be identified, developed and implemented, as required, to minimise impacts on the building structures, building accesses and business opportunities.
- Suitable scour protection would be provided to protect the bridge abutments, piers and banks during operation.