

Bow Bowing Bunbury Curran (BBBC) Creek Strategic Floodplain Risk Management Study and Plan – Ingleburn CBD (Summary)



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1. Introduction

Campbelltown City Council at its Ordinary meeting on 9 April 2019 resolved to endorse a planning proposal to increase the residential density of the Ingleburn Central business district in alignment with Ingleburn precinct plan within the Glenfield to Macarthur Urban renewal corridor strategy.

NSW Government department of Planning Industry & Environment issued the Gateway Determination on 09 March 2020 and required to address the Flooding in Ingleburn CBD prior to Public exhibition.

1(d). Prepare a summary of the Bow Bowling Bunbury Curran Creek Catchment Flood Management Study to identify the flooding risk, behaviour, vulnerability (H1-H6 classification) and impact/risk to life associated with development in the Ingleburn CBD;

1(e). Prepare a summary of the Flood Management Plan for the Ingleburn CBD which nominates:

- i.Options to mitigate the impact of flooding in the Ingleburn CBD as a result of the proposed development; and
- ii.Proposed management options such as through the preparation of detailed design controls and measures to mitigate the flooding risk to property and life.

The Bow Bowling Bunbury Curran (BBBC) Creek Strategic Floodplain risk Management study and plan (Final Draft) was prepared by Molino Stewart Pty Ltd for Campbelltown City Council dated January 2019. The report was adopted by Council in Council meeting dated 12 February 2019.

2. Flood behaviour

When assessing flood damages the actual flood depths, without any filtering applied were compared with building floor level estimates to determine whether a building was likely to experience above floor flooding. When assessing the risk to pedestrian vehicle or building stability, the hazard were used.

a. Overland flooding

In Ingleburn at the Southern end, two overland flow paths run parallel to each other from Euroka Street to Ingleburn Road in a south – east to north - west direction. These affect several properties, however mostly in rare events (i.e. from the 0.2% AEP).

A significant overland flow path runs from south - east to north - west direction through Ingleburn CBD. This starts from south - west of the CBD, downstream of the culvert under Cumberland Street, on Redfern Creek. Here, Redfern Creek exceeds the culvert capacity from the 5% AEP event, resulting in floodwaters affecting residential and commercial properties north and south of Norfolk Street, and continuing downstream towards the CBD through properties on Carlisle St, Albert St, Oxford Rd and Ingleburn St. The overland flow path re-joins Redfern Creek once this exits the CBD culvert system, northwest of the crossroad between Macquarie Rd and Ingleburn St.

At the eastern end of Ingleburn CBD, an overland flow path runs from Oxford Rd in a north-west direction towards Koala Walk Reserve, where it joins Koala Walk Drain. The path causes above floor flooding from the 20% AEP in four buildings in Oxford Rd.

Results of the Flood Studies show that flooding in the BBBC Creek catchment is characterised by a quick rate of rise and short-duration. The rate of rise and duration of flooding increase slightly as one moves down the catchment. The hydrograph extracted for Ingleburn CBD (as in image below) shows a significantly different behaviour, which is typical of overland flash flooding where flood depths are shallower and the flood durations are much shorter.

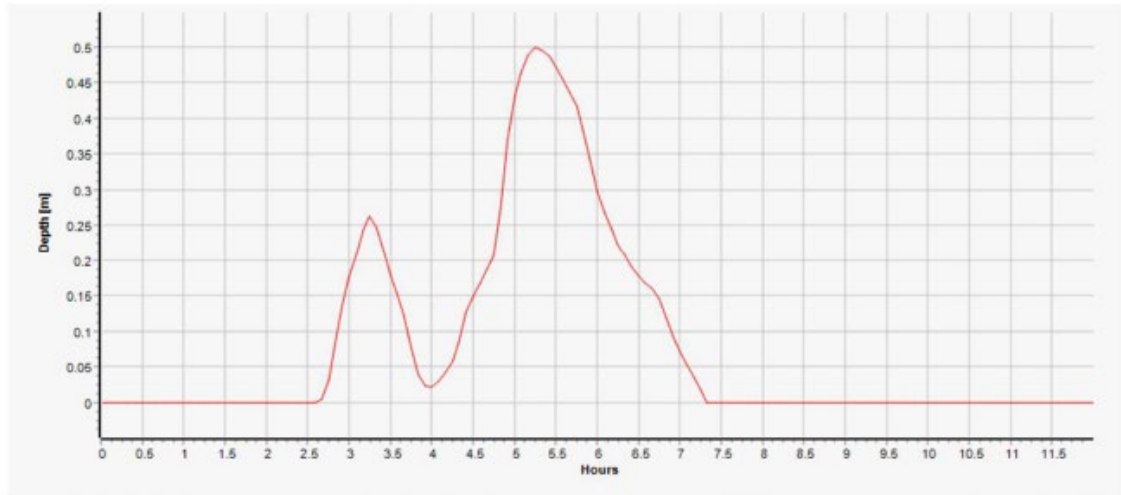


Figure 18. 1% AEP hydrograph: overland flooding in Ingleburn CBD (Macquarie Rd and Boots Ln)

Floodwaters are conveyed towards and through Ingleburn CBD by two main flow paths:

Redfern Creek, running in a NW direction and approaching Ingleburn CBD through Cumberland Rd and Norfolk St; and

A flow path along Koala Walk drain from Kingfisher Reserve, entering the northern end of the CBD across Carlisle St and Macquarie Rd.

- i. 20% AEP: The area experiences overland flooding and high hazard levels from the 20% AEP event. Modelling suggests that in a 20% AEP flood, 15 residential buildings may experience above floor flooding. More than 50 residential buildings would be isolated by flooding in the 20% AEP event.
- ii. 1% AEP: In a 1 % AEP flood about 37 residential buildings may experience above floor flooding. Flooding as deep as 0.8m may be experienced in roadways.
- iii. PMF: About 100 single-storey residential buildings may experience above floor flooding in a PMF more than 0.5m deep. Of these, the model shows that 71 are located in low flood islands and 12 would be exposed to flood hazards which may affect their structural stability.

3. Flood risk mapping

Floodplain according to its hydraulic function can be divided in 3 categories as per NSW Floodplain development manual (2005),

Floodways: Areas conveying a significant proportion of the flood flow and where even partial blocking would cause a significant redistribution of flood flow or a significant increase in flood levels. Criteria

adopted by council to categorise an area as Floodway is part of the BBBC extent of flood-prone land that is not classified as either Flood Fringe or Flood Storage.

Flood storage areas: Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas. Criteria adopted by Council is: A part of the BBBC extent of flood-prone land that is not classified as Flood Fringe, and: If the land use is classified as "drainage": Depth (D) $\leq$ 2m and Flow Velocity (V) $\leq$ (-0.3D+0.8) OR D $\geq$ 2m, and V $\leq$ 0.2m/s If land use is classified as "urban": V $\leq$ 0.2 m/s

Flood Fringe - The remaining area of land affected by flooding, after floodway and flood storage areas have been defined. Development (e.g., filling) in flood fringe areas would not have any significant effect on the pattern of flood flows and/or flood levels. Criteria adopted by Council V $\leq$ 0.2m/s, and V $\leq$ (-40D = 6)

4. Flood Hazard

The classification includes six categories, ranging from H1 (no restrictions), to H6 (not suitable for people, vehicles or buildings). These six hazard categories are shown in Figure below. The provisional hazard categorisation should be used in conjunction with the following factors to determine true hazard categories

- Extent of flood;
- Effective warning time;
- Flood preparedness;
- Rate of rise of floodwaters;
- Duration of flooding;
- Evacuation problems;
- Effective flood access; and
- Type of development.

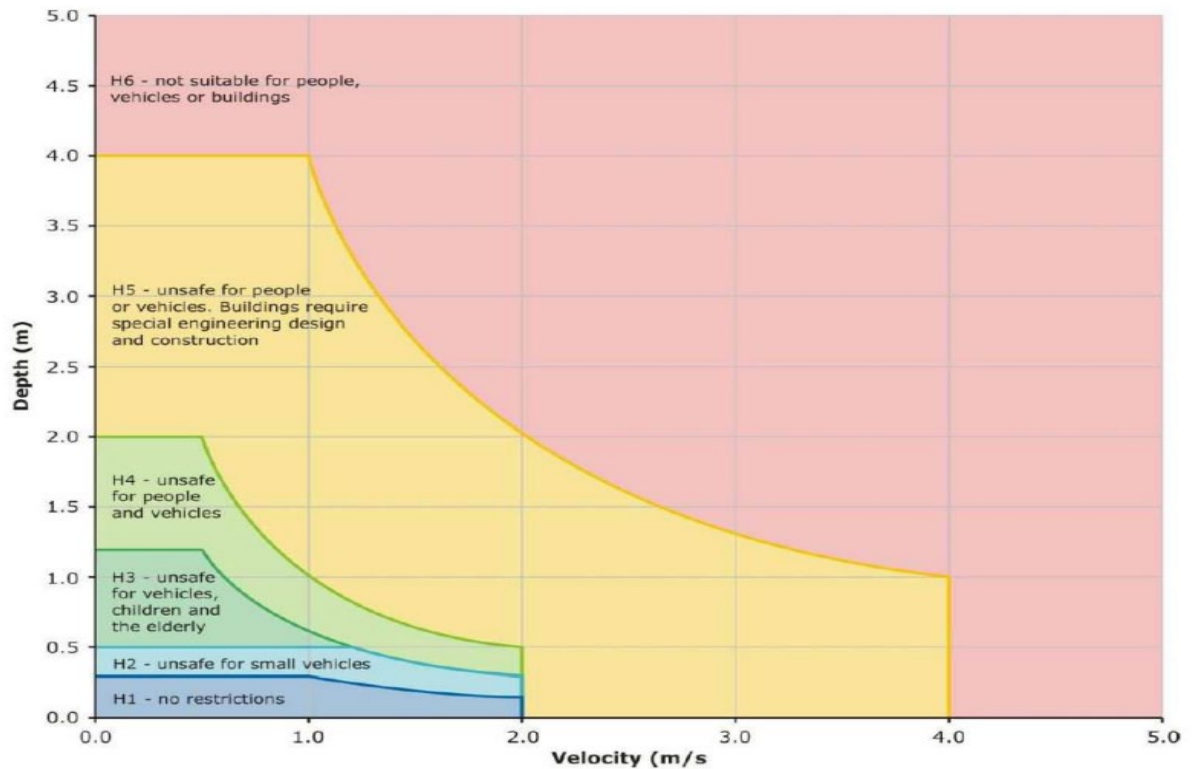


Figure 22. Provisional Flood Hazard Categories (AIDR, 2017)

5. Flood Damage

Table 16. Estimates of infrastructure and intangible damages

Event	Total residential and non-residential damages \$m	Infrastructure Damages \$m	Intangible Damages \$m	TOTAL \$m
20% AEP	\$127.9	\$19.2	\$32.0	\$179
5% AEP	\$207.6	\$31.1	\$51.9	\$291
2% AEP	\$223.5	\$33.5	\$55.9	\$313
1% AEP	\$266.3	\$39.9	\$66.6	\$373
0.2% AEP	\$411.4	\$61.7	\$102.9	\$576
0.1% AEP	\$510.0	\$76.5	\$127.5	\$714
PMF	\$3,128.1	\$469.2	\$782.0	\$4,379
AAD total \$m	\$39.2	\$5.9	\$9.8	\$54.9
AAD per affected building \$	\$31,749.0	\$4,762	\$7,937	\$44,449

Tables above and one below (BBBC Creek Catchment not just the Ingleburn CBD) shows that no buildings are completely surrounded by floodwaters classified as H6, and the number of buildings surrounded by floodwaters classified as H5 is relatively small. Nonetheless, the risk posed to the structural integrity of these buildings should be considered when planning the emergency response

strategy. Please note table below represent the entire BBBC Creek Catchment not just the Ingleburn CBD.

PMF event	Flood Hazard = H5	Flood Hazard = H6
Buildings touched by highly hazardous floodwaters	3,215	207
Buildings completely surrounded by highly hazardous floodwaters	200	none

Risk to people was assessed using the NSW OEH's guideline "Flood Emergency Response Planning Classification of Communities Floodplain Risk Management Guideline" (DECC, 2007b).

Table 18 below summarises the number of buildings that in the PMF would be isolated in low and high flood islands. It is noted that 367 of the residential buildings isolated on some of the high flood islands were not included in the original property database because they were clear of the estimated PMF extent.

The flood islands which are isolated by the 20% AEP flood event are: (3 properties extracted below from list are only for Ingleburn CBD).

- Ingleburn commercial area bounded by Ingleburn Rd, Cambridge St, Carlisle St and Norfolk St;
- Houses Carlisle Ingleburn; between St and Cambridge Macquarie St, Rd
- Townhouses between Macquarie Rd and the railway Ingleburn;

Table 18. Number of buildings on flood islands (PMF)

	Residential	Non-Residential
High Flood Island	1,448	145
Low Flood Island	757	616

Many of these properties are only isolated by H1 flooding in the 20% AEP event but by higher hazard flooding in less frequent events. It should be noted that in most instances flood islands are isolated for a short duration, which in the PMF ranges between about 2 hours (in the upper catchment) and 5 hours (in the lower catchment).

6. Flood response

NSW SES holds that the evacuation is the preferred response for floodplain communities where this can safely be achieved, late evacuation through flood water may be a recipe for disaster and it might be safer to remain inside the building, though sheltering in place has a number of direct and indirect risks associated with it. Evacuating prior to flooding is therefore much preferred where current hydro-meteorological monitoring systems, communication systems, road infrastructure and expected community behaviours do not allow this, the SES advocates improvements to those so that evacuation can proceed safely.

a. Proposed Evacuation Centres

The NSW SES has advised that a Local Flood Plan covering Campbelltown LGA is currently under preparation. In the process of drafting the LFP, the NSW SES has identified three possible flood evacuation centres within the LGA. These are:

- Campbelltown Catholic Club, located in 20-22 Camden Rd, Campbelltown;
- West Leagues Club, located in 10 Old Leumeah Rd, Leumeah; and
- Ingleburn RSL Club, located at 70 Chester Rd, Ingleburn.

Proposed Evacuation Centre	Frequency of Flooding	Flood Island?	Road access
Ingleburn RSL Club 70 Chester Rd, Ingleburn	The building is surrounded by very low hazard floodwaters (H1) in every event from the 20% AEP to the PMF. Floodwaters do not enter the building in any event. The car park is not flood affected.	The building itself may be considered a high flood island, but is surrounded by very low hazard floodwaters	All access roads are cut from the 5% AEP event, however: - The 20% AEP event cuts Chester Rd south east bound towards Warbler Ave. - The 20% AEP event cuts Lorikeet Ave. - The 20% AEP event cuts Wagtail Cres.

7. Flood hotspot mitigation

In Ingleburn CBD there are 189 residential buildings and numerous commercial buildings satisfying the flood hotspot criteria. It should be noted that some of the commercial buildings host multiple tenancies. Given the proximity of residential and non-residential buildings in this area, these would benefit from the same flood risk mitigation measures. As such, the cost benefit analysis of the shortlisted flood modification options as discussed in following sections considers residential as well as commercial buildings.

8. Flood risk mitigation

Across the BBBC flood prone area there are locations where clusters of assets are impacted by flooding. These locations are herein named as "hotspots" and may benefit from local flood risk mitigation options. There are also additional scattered assets across the whole catchment which have unacceptable risks and may benefit from catchment-wide mitigation options as listed below:

- Blockage reduction – reducing the standard blockage scenarios for pits, pipes, bridges, culverts across the catchment, sensitivity test undertaken revealed there was no significant difference, hence this was not further investigated.
- Pipe capacity upgrade - Where above floor flooding (AFF) was caused only by rarer events (i.e. 1 % AEP event or rarer), upgrading pipe capacity was deemed unlikely to resolve those flood risks and this was not investigated further as an option.
- Property modification – removing building from areas which floods, ensuring floor levels are at a level with a low probability of flooding, constructing with flood compatible materials

- Modification to existing developments – voluntary house purchase, voluntary house raise, renovation with flood compatible building materials.
- Modification to future developments – strategic planning to move inappropriate development away from high flood risk areas, development controls to ensure development, redevelopment or renovation reduces flood risks to an acceptable level for each property which can include, among the measures, requirements for minimum floor levels and building material compatibility.

Flood risk mitigation measures fall into following three categories:

- Flood modification;
- Property modification;
- Response modification.

a. Flood Modification

The influence of partial blockage of the stormwater system on the 1 % AEP flood level was first assessed. Results showed that a slight reduction of the 1% AEP flood level could be achieved if there was no blockage in any part of the system. However, even without considering the significant technical challenges that achieving a no-blockage scenario would present, the 1 % AEP level would generally be reduced by a negligible amount (less than 0.1 m overall). As such blockage reduction, even if it were practically achievable, would not be an effective option for Ingleburn CBD. The analysis identified 31 residential buildings which may benefit from an increase in flow conveyance by augmenting the existing underground pipe capacity with larger pipes, additional pipes or an open channel. The stormwater system around these buildings operates at full capacity from the 20% AEP event, when many of these buildings begin to experience AFF.

Increasing outflows from this area is an option that was deemed worth investigating further. In a 1 % event, about 58m³/s is flowing into the CBD but the culverts that carry flow beneath the CBD have sufficient capacity to convey only 18m³/s (assuming no culvert blockage). This could be addressed by a conveyance of at least 40m³/s in addition to what is currently flowing through the existing pipes.

Several configurations of flood modification options to increase outflows from the Ingleburn CBD area were considered and tested with the hydraulic model. The set of flood modification options that produced the most significant flood level reductions throughout the Ingleburn CBD (as in picture below) included the following upgrades to the storm water system:

- Filling the existing open channel downstream of Cumberland Rd and replacing it with two new 2.1 m wide by 1.5m high culverts, as well as a new 3m wide by 2.7m high culvert that connects into the existing trunk drainage line. This culvert would continue along Norfolk St up to Ingleburn Rd;
- A new 3.6m wide by 3m high culvert to then convey flows to the open channel downstream of Macquarie Rd;
- A new 3.6m wide by 1.5m high culvert introduced along Ingleburn Rd upstream of Norfolk St which would be charged by several new 3.8m² grated inlets.

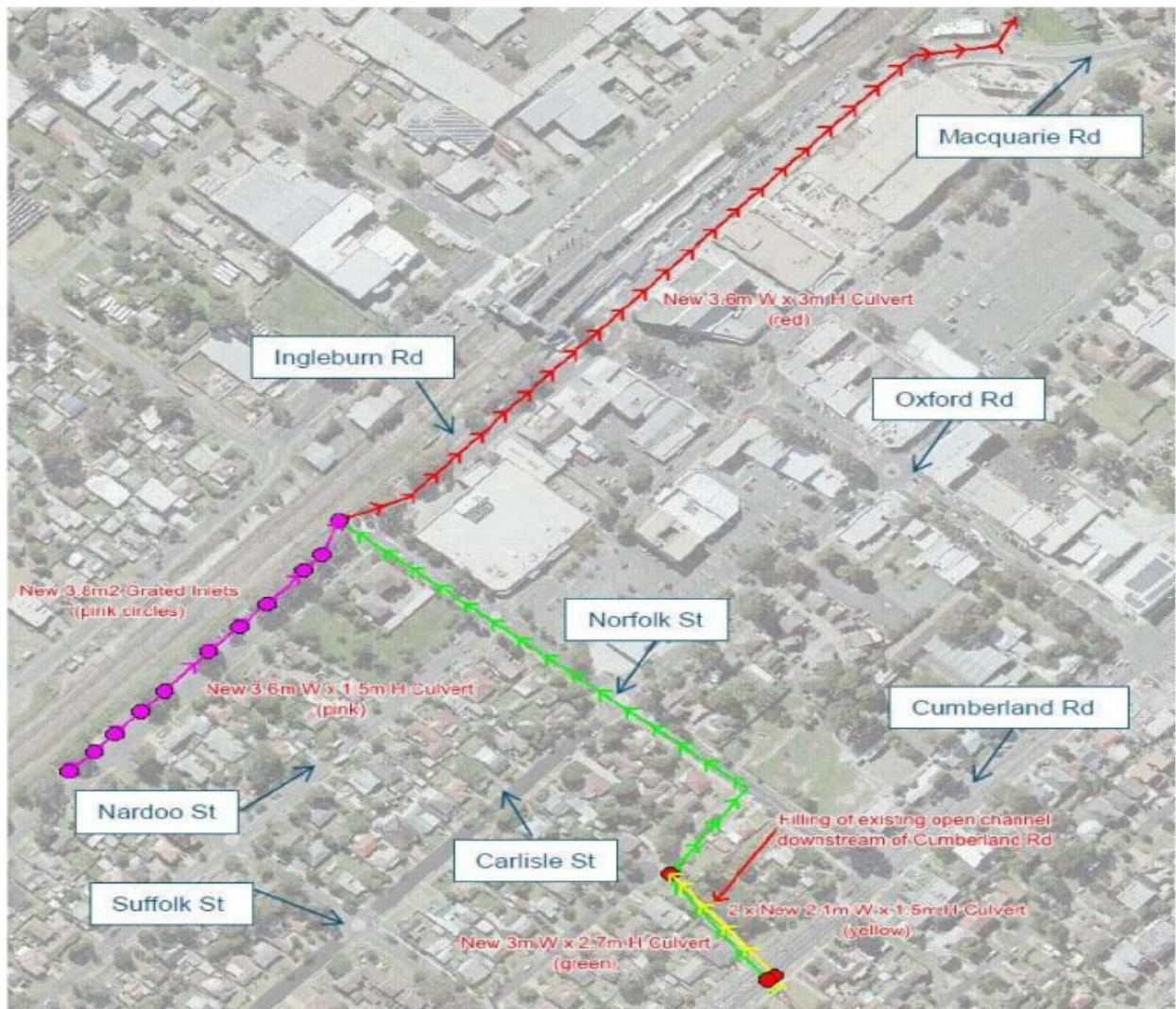


Figure 33. Layout and details of flood modification options in Ingleburn CBD

b. Property modification

This provides an opportunity to further reduce risk to property and life by doing one or more of the following:

- Designing a new CBD layout with buildings outside of the highest flood risk areas;
- Redeveloping some of the flood affected buildings. Building redevelopment could incorporate:
 - Car parking at ground level through which overland flows could pass;
 - Buildings with elevated ground floor slabs under which overland flows would pass;
 - Buildings with sealable ground floors to prevent entry of floodwaters;
 - Buildings with ground floor uses and materials which are compatible with occasional flooding.

There are also areas immediately adjacent to the CBD which are significantly affected by flooding. These includes low-rise buildings along Macquarie Rd north east of the CBD. That land is currently zoned for medium density which would permit townhouses to be constructed similar to those closer to the CBD on Macquarie Road. Although many of these dwellings would experience reduced flood

levels if the proposed flood modification options were put in place, a better flood risk outcome may be possible if all of these blocks (including the existing townhouses) were zoned for high density residential which would allow private open space to be made available for overland flows and ensure no dwellings were at ground level. It is noted that the Glenfield to Macarthur Urban Renewal Corridor Land use and Infrastructure Summary (NSW Govt, 2015) identifies this area as potential high rise development of seven storeys or more as in figure below.

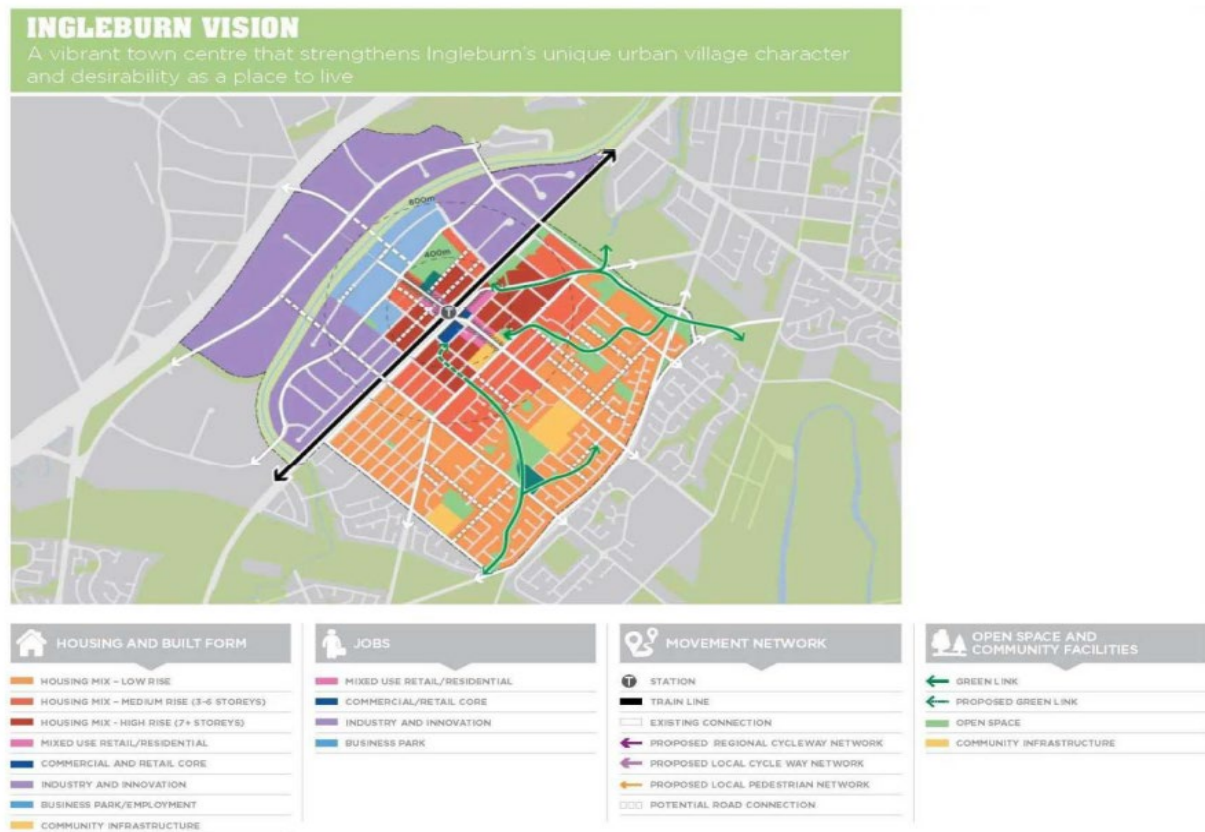


Figure 34. Ingleburn Precinct from Glenfield to Macarthur Urban Renewal Strategy

c. Response modification

The rezoning and redevelopment of Ingleburn CBD to replace existing low rise buildings with high rise buildings and implementation of flood modification measures could completely change the risk profile of this flood hotspot. Response modification measures need to adapt to the changing risk profile taking into account the rapid rate of rise and short duration of flooding in this area.

9. Evaluation of flood risk mitigation options

In light of the preceding analysis, the following local food risk reduction options were evaluated in detail:

a. Flood modification

A cost-benefit analysis was undertaken for the shortlisted flood modification options as discussed in section 8 (a) above to assess if these would be economically worthwhile. Table below shows a summary of the results.

Total Option Costs	\$13.487M
Total Option Benefits	\$23.486M
Benefit/Cost Ratio	1.74

The benefit/cost analysis showed that flood modification at this location would be economically worthwhile, having a benefit to cost ratio of 1.74. In terms of social and environmental costs, the shortlisted flood modification option would cause some inconvenience during construction and maintenance operations. For instance, closing Norfolk St and Ingleburn Rd would have significant impact on the local traffic flows during construction. However, these impacts would be temporary and would be further reduced if the construction works were undertaken as part of the CBD redevelopment. However, the following feasibility issues were identified:

- Major Service's assets exist along the alignment of Ingleburn Road in the vicinity of stormwater upgrades.
- Of particular note are sewer mains present along Norfolk Street and Ingleburn Road ranging in size from 225mm to 450mm.
- Given the relatively large size of the proposed culverts it is likely that conflicts with existing services will arise.

For these reasons, it is recommended that the culvert amplification option proceed to detailed design.

b. Property modification

As part of the rezoning and redevelopment of Ingleburn CBD:

- Relocating buildings outside high hazard zones; redeveloping some of the flood-affected properties to reduce their exposure to floodwaters.
- Rezoning the land containing the low-rise buildings along Macquarie Rd north east of the CBD from medium to high density residential to allow the construction of less vulnerable buildings.
- Use locality-specific development controls throughout the area to reduce risk to property.

The redevelopment of Ingleburn CBD as part of the Glenfield to MacArthur Urban Renewal Corridor Strategy (NSW Govt., 2015) provides an additional opportunity to reduce flood risk through property modification measures. The advantage of addressing flood risk with property modification as part of redevelopment to high rise buildings is that the associated costs are distributed across many property owners, making the benefit to cost ratio much greater than it would be in low rise dwellings.

In this location, property modification measures could be used in combination with flood modification in a number of different ways. For instance, property modification could be used to manage residual risks after the recommended flood modification option has been implemented.

Alternatively, property modification under the Glenfield to Macarthur Urban Renewal Corridor could be used as the main way to reduce flood risks in Ingleburn CBD. This could be achieved with more substantial investments in the design and construction of a CBD that is less vulnerable to flood damage. In this scenario, flood modification would be used to manage residual risks and would require smaller investments.

From a theoretical perspective, in Ingleburn CBD, any combinations of flood modification and property modification could be used to reduce risks to the same extent, and each of them would have different economic and social costs. A cost/benefit analysis of the all possible combinations is not practical; however the following observations can be made to inform Council's preferred approach:

- If property modification were used as the main risk reduction measure, this would come at a significant economic and social cost for the community. For instance, building to a higher FPL would have higher construction costs. Similarly, more stringent development controls may become a deterrent for developers. In addition to this, a floor level that is significantly raised over ground level may not be suitable or ideal for commercial uses (e.g. retail).
- On the other hand, if flood modification were used as the main risk reduction measure, property modification could have less stringent requirements and there would be more flexibility in the design and construction of the CBD. For instance, building to a lower FPL, or in an area that, because of flood modification, is now above the FPL, would be less onerous to developers and would allow to create spaces at the ground floor that are suitable for a larger number of commercial uses. In addition to this, the cost of flood modification could be partly reduced via developer's contributions, which would become a more viable option in a context in which development controls are less stringent.

Regardless of the preferred approach to flood risk reduction in Ingleburn CBD, it is recommended that Council work with the NSW Department of Planning and Environment to ensure that flood risk is acknowledged and addressed as part of the redevelopment. This could be achieved through locality-specific development controls to complement flood modification measures and reduce risk to property and life.

c. Response modification

Considers the adoption of locality specific development controls to improve flood response outcomes.

10. Flood mitigation

a. Strategic planning and potential redevelopment

Ingleburn has considerable flood risks for both residential and non-residential buildings and urban renewal provides a real opportunity to provide significant flood mitigation benefits.

b. Development controls

There are opportunities to make flood risk management through planning controls more robust, consistent, unambiguous and easier to follow. This would require a significant reworking of both the CDCP 2015 and its accompanying engineering guide. It is recommended that Council undertake such a review and rewrite, taking into account the recommendations in the preceding section.

c. Voluntary house raising

Report recommends there are no houses that satisfies the cost benefit criteria for this option hence no further investigation is required into voluntary house raising for flood mitigation.

d. Voluntary purchase

No properties have been identified by the modelling where there is a significant risk to life in events more frequent than the PMF. Finally, no buildings have been identified which are in floodway or causing a significant blockage to floodway. For these reasons it is recommended that voluntary purchase not be considered as an option for flood mitigation.

11. Flood response

a. Flood warning

The Bureau will provide severe weather warnings for the area generally and may warn of the chance of flash flooding. This, followed by the commencement of heavy rain is the only warnings which the area would currently get that flooding may be about to occur and there would be no indication as to how severe it might get.

Council could choose to install its own flash flood warning system in the catchment and the Bureau provides councils with guidance to do that. The long narrow shape of the catchment means that outside of the main channel of Bow Bowing / Sunbury Curran Creek there would be less than 30 minutes between the commencement of rainfall and the commencement of flooding in the streets or along the side creeks. At the northern end of Sunbury Curran Creek it may be possible to get a few hours warning. However, the northern end of the floodplain is not where most of the risk to property and risk to people occurs. A council operated catchment wide flood warning system is not seen as a practical response modification option.

b. Emergency response plans

The NSW SES is the lead agency for response to flood events and accordingly has a local flood emergency response plan for Campbelltown LGA. The information in this study provides the NSW SES to complete Volume 2 with the most up to date flood information and make any necessary amendments to Volume 1 in light of that information and changes to their response strategies. Businesses and households can also develop their own flood emergency response plans which are specific to their own circumstances to reduce the direct and indirect impacts of flooding on them. The NSW SES has produced templates to assist with this task and the information in this floodplain risk management study can also assist in the regard. Some property owners and occupiers may need to obtain more specific local flood data from Council.

c. Community Education

While flooding will come up quickly in the study area, the flood depths and velocities in most residential areas are such that they do not pose a significant risk to people who stay indoors even in events exceeding the 1 % AEP flood. There are some areas where risks are higher and these are highlighted in the hotspots in Section 3 and Section 10.

The NSW SES has flood education initiatives throughout NSW including campaigns advising people not to drive, walk or ride through floodwaters. The NSW SES stance is also to prefer evacuation in advance of a flood to get people out of the floodplain. However, it does acknowledge that where it is unsafe to evacuate it is better for people to remain in buildings. In most areas in the BBBC Creek catchment flooding is more hazardous in the streets than it is where buildings are situated across the full range of floods.

Because of short warning times and more hazardous flooding in streets it is neither safe nor practical to try and evacuate people from buildings in the BBBC Creek catchment during a flood. The short duration of the flooding, which varies between about two hours in the upper catchment and 5 hours in the lower catchment, also means that people will not be isolated in buildings for long.

It is recommended that the appropriate flood response throughout the BBBC Creek catchment is for people to shelter within buildings, preferably above the reach of floodwaters. It is recommended that Council work with the NSW SES to reach consensus on that approach and develop and implement a community education strategy to encourage that response.

There are several ways in which Council can assist people to respond appropriately:

- Strategic planning and development controls which minimises the chance of above floor flooding in buildings will make people safer within buildings and discourage them to exit the building during a flood;
- Encouraging people with single storey homes which have a significant risk from above floor flooding to add a second storey would also give people place to take refuge and discourage leaving buildings;
- Working with the NSW SES to encourage the preparation of household and business flood emergency response plans using NSW SES tools and templates;
- Provide information in community languages and through existing community networks to maximise the number of people reached. It is recommended that all of the above be investigated in consultation with the NSW SES as part of an ongoing community flood response and education strategy.

12. Recommendations for flood risk mitigation

The recommended measures for Ingleburn CBD floodplain risk management are summarised below:

- A detailed investigation of Floodplain risk management study and plan (FRMSP) for Ingleburn locality, funded by a combination of Council funds and State and Federal government grants
- Ingleburn CBD stormwater system upgrade with initial cost of \$13.4m and benefit to cost ratio of 1.74 funded by combination of Council funds, State and local government grants or Developer's \$7.11 contributions. This is subject to detailed Engineering investigations, design and costings, locating underground services may affect feasibility and/or cost. In terms of social and environmental costs, this flood modification and mitigation option would cause some inconvenience during construction and maintenance operations. However, these impacts would be temporary and would be further reduced if the construction works are undertaken as part of the CBD redevelopment.

a. Ingleburn Stormwater system upgrades

The Ingleburn CBD is understood to be one of the worst affected areas in the Campbelltown LGA with respect to overland flows. Flows from the upper catchment, near Wood Park, transverse an overland flow path towards Cumberland Road at Norfolk Street. Flows then follow Norfolk St overland to Ingleburn Road where they inundate the Ingleburn CBD area. This option seeks to upgrade the capacity of a number of existing stormwater system elements and construct new stormwater elements to convey flows within the subsurface pipe network as much as possible, before discharging back into an existing open concrete channel near Macquarie Road (refer Figure below).

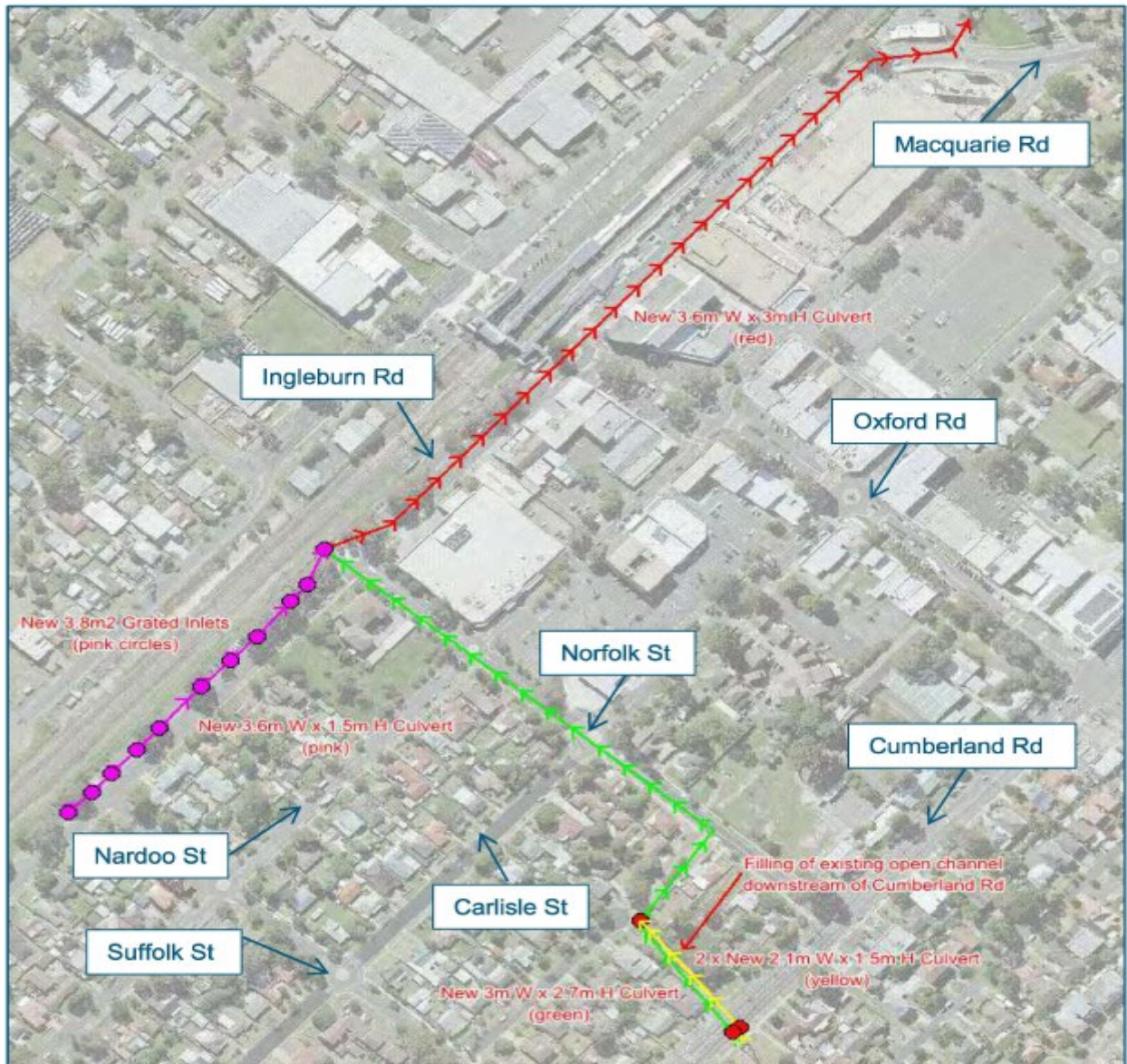


Figure 8: Option 2 Schematised Overview

Major services assets exist along the alignment of Ingleburn Road in the vicinity of the proposed stormwater upgrades. Noteworthy services present include:

- A telecommunications services duct is present parallel to Ingleburn Road at the Macquarie Road intersection.
- A Jemena Gas 0150mm, 1050kPa secondary main runs along Ingleburn Road between Norfolk Street and Oxford Road. A further 50mm 210 kPa network main runs along Norfolk Street between Cumberland Road and Ingleburn Road.
- NBN assets exist along Ingleburn Road between Norfolk Street and Oxford Road and between Suffolk Street and Norfolk Street. NBN assets also exist along Norfolk Street between Ingleburn Road and Cumberland Road. NBN assets generally follow a similar alignment to the proposed stormwater upgrades.
- A Nextgen services duct cuts across Norfolk Street at Nardoo Street and then continues along to Ingleburn Road after Oxford Road.
- An Optus fibre optic asset exists along the same alignment as the Nextgen services duct.

- A 100mm CICL Sydney Water Corporation main exists along Ingleburn Road between Norfolk Street, becoming a 150mm CICL between Norfolk Street and Oxford Road. A 100mm Ductile Iron Cement (mortar) Lined (DICL) water main exists along Norfolk Street between Nardoo Street and Cumberland Road.
- A 450mm VC Sydney water sewer main traverse across Norfolk Street at Palmer Street. 225mm and 300mm VC sewer mains exist on Norfolk Street between Carlisle Street and Nardoo St and Nardoo St and Ingleburn Road respectively. A further 225mm VC sewer main exists on Ingleburn Road between Oxford Road and Macquarie Road.
- Multiple Endeavour Energy assets exist along the proposed alignment of stormwater upgrades for Ingleburn.

b. Concept design of stormwater system upgrade

This predominantly involves two main tasks, demolition of the existing open concrete channel and replacement with culverts, and installation of proposed new culvert lines. The open channel north of Cumberland Road near Norfolk Street (refer Figure 10) is to be demolished, replaced with 3 new reinforced concrete box culverts and backfilled to match the surrounding surface levels. Two of the proposed culverts will be 2.1 m (W) x 1.5m (H) with the third being 3m (W) x 2.7m (H). Demolition of the existing open concrete channel would require breaking out of the concrete and ground excavations of over 2m to adequately fit the proposed box culvert sizes. A typical section of the proposed box culverts replacing the existing open concrete channel is presented in Figure below. Upstream of the open concrete channel Cumberland Road would be saw cut and excavated, and the existing culverts underneath demolished and replaced.



Figure 10: Existing Open Concrete Stormwater Channel Between Cumberland Road and Palmer Street (to be Culverted)

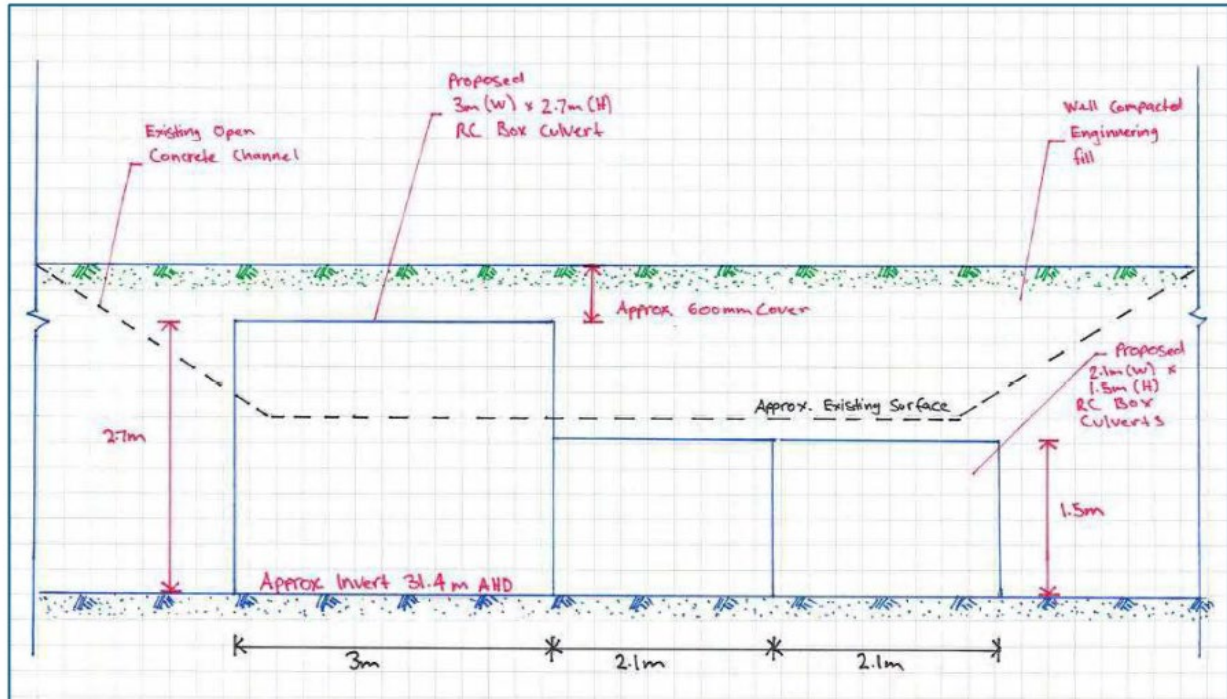


Figure 11: Cross Section of Proposed Culverts Replacing Concrete Channel (Looking Downstream)

The 3m (W) x 2.7m (H) culvert is to continue downstream along Norfolk Street to the intersection with Ingleburn Road where it would connect to a new 3.6m (W) x 3m (H) culvert. This culvert will continue north east along Ingleburn Road to the intersection with Macquarie Road where it will discharge to an open concrete channel. A new 3.6m (W) x 1.5m (H) culvert will also be construction along Ingleburn Road from Suffolk Street to Norfolk Street along with eleven (11) 3.8m² grated inlet pits.

All Culverts would be assumed to be Class 2A reinforced concrete box culverts capable of being subject to loads associated with up to 2m of fill above the culvert unit, link or base slab (depending on the orientation and configuration) and road vehicle loadings in accordance with AS5100.2. Culverts would require excavation of a trench with a width having a minimum of 150mm between the culvert walls and trench walls (including any shoring equipment). Installation of the culverts would require a bedding layer of a minimum depth of 150mm, side zones of a minimum width of 150mm and an overlay zone of a minimum depth of 150mm. All bedding zone, side zone and overlay zone material would be select engineering fill in accordance with AS1597.2-2013.

- Owing to the size of the proposed box culverts and their alignments, large excavations along busy roads will be required, resulting in lane closures and traffic diversions necessitating extensive traffic management.
- As the proposed culverts are relatively large and are proposed along the alignment of a number of existing services assets it is likely that construction of the culverts will require the realigning of some existing services. It is not possible at this stage to determine which services and at which locations this may be the case, without further detailed services survey.
- No alternative approaches are deemed necessary at this stage for consideration with respect to recommended option.

The following further investigations/data are considered to be required prior to any further design development:

- Detailed services survey with the location and invert of all relevant services assets along the alignment of the proposed stormwater network upgrades.
- Detailed topographic survey of the existing open concrete channel from just upstream of Cumberland Road, through to Palmer Street.
- Geotechnical investigations below the existing concrete channel to determine the soil characteristics beneath the proposed new box culverts. Further geotechnical investigations to determine the soil characteristics where new stormwater lines are proposed.

c. Health and safety considerations

The following health and safety considerations have been identified for the proposed Option 2:

The existing open concrete channel is to be demolished, excavated deeper to maintain long profile grade, and replaced with several culverts and backfilled to match the surrounding ground levels. As a result there will be a local increase in surface levels (when compared to the existing open channel) by up to approximately 1.5m. Without installation of proper drainage infrastructure (i.e. pits) this has the potential to result in a localised increase in flood levels to the adjacent properties, due to water ponding.

d. Operation and maintenance considerations

The following operation and maintenance considerations have been identified for preferred option:

- Construction of eleven 3.8m² grated inlets along the proposed new 3.6m(W) X 1.5m(H) on Ingleburn Road would require routine maintenance to remove debris and reduce the risk of blockages.
- New culverts would also increase effort to inspect.

e. Cost

The estimated costs for the implementation of proposed flood mitigation option are presented in Table below. In preparing the cost estimate below following key assumptions have been made:

- No excavation into rock;
- No services relocation; and
- Class 2A reinforced concrete box culverts are sufficient.

Table 5: Option 2 Estimated Capital Costs

Items	Costs
Preliminaries	\$420,000
Clearing & Demolition	\$175,140
Earthworks	\$2,044,352
Stormwater Drainage	\$6,756,386
Road Pavements	\$368,437
Concrete Works	\$19,076
Landscaping	\$16,505
Subtotal	\$9,799,896
Contingency and Administration	\$3,636,762
TOTAL	\$13,436,659

Table 6: Option 2 Estimated Whole of Life Costs

Items	Rate (\$/Period)	Total Present Value (at Rate of 7%)
Routine Cleaning of grated Inlet Pits (i.e. once every 5 years)	\$11,000 every 5 years	\$26,395
Routine Inspection and Cleaning of stormwater culverts (i.e. once every 5 years)	\$5,000 every 5 years	\$11,998
Subtotal		\$38,393
Contingency (30%)		\$11,518
TOTAL		\$49,911

13. Summary and recommendation

As summarised in table below the total annual average damages for Ingleburn CBD without improvements are \$27.694m, the damages are estimated to reduce significantly to \$4.208m with the proposed Stormwater upgrade works. The proposed works are estimated to cost \$13.436m and provide benefit to cost ratio of 1.74 making it the most cost effective option to be further investigated (need to undertake detailed survey, services search and detailed design for proposed concept design).

Option Number (Appendix E)	Description		Cost of Flood Modification										Benefit/Cost Ratio
			Residential Annual Average Damages (including indirect)	Residential Annual Average Damages (including infrastructure and intangible damages)	Non Residential Annual Average Damages (direct and indirect)	Non Residential Annual Average Damages (including infrastructure and intangible damages)	Total Annual Average Damages (including infrastructure and intangible damages)	Total Annual Average Damages (net present value)	Capital Costs	Whole of Life Costs (net present value)	Total Option Cost (net present value)	Option Benefits (as reduction of damages)	
2	Ingleburn CBD Stormwater Upgrades	Current Condition	\$299,084	\$418,718	\$1,134,372	\$1,588,120	\$2,006,838	\$27,694,364	na	na	na		
		With Flood Modification	\$145,802	\$204,123	\$72,031	\$100,843	\$304,966	\$4,208,530	\$13,436,659	\$49,911	\$13,486,570	\$23,485,835	1.74

The benefit/cost analysis shows that flood modification at Ingleburn CBD would be economically worthwhile, having a benefit to cost ratio of 1.74. In terms of social and environmental costs, the

shortlisted flood modification option would cause some inconvenience during construction and ongoing maintenance operations. For instance, closing Norfolk St and Ingleburn Rd would impact on the local traffic flows during construction. However, these impacts would be temporary and would be further reduced if the construction works were undertaken as part of the CBD redevelopment.