Debris Control Structures – What they are and why we need them.

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In the floods of 1998, a lot of the damage to properties was done by overland flows. Some were in excess of the stormwater conveyance capacity, ….. and some weren't.

In multiple cases debris blockage at inlets to pipes, culverts and even within channels massively reduced the conveyance capacity, sending flows through houses.

In April this year, Wollongong Council engaged Optimal Stormwater to review the first 15 priority sites within their two worst hit catchments, to assess what, could be done to prevent major system blockages in the future.

The solution for each location depended on a number of things including: hydraulic impact, structural integrity when being smashed by rocks and trees during a 100yr event, size, height, design, catch points, location, buildability, and ongoing access for maintenance.

Whilst it's nice to standardise on a design and repeat its use (for ease of ongoing operation), the very different stormwater scenarios and site conditions meant that a wide variety of site specific solutions were proposed. The concept designs were discussed and reviewed between the consultant and Council. Detail design will take place shortly, and construction will follow that.

This paper provides a valuable insight into all the constraints taken into account when considering control of waterborne debris during large events, which without control has been demonstrated to cause massive potential problems. Readers will be afforded a common-sense checklist of when and where problems can be expected, and a range of site specific options for consideration to control and minimise Council's ongoing risk in this area.

Wollongong Council is leading the field in debris control devices and other stormwater managers will be able to learn from their experience.

Introduction

One of the major things that leads to flooding, is the blockage or restriction of the inlet to a stormwater conveyance like a pipe, culvert or channel. Whilst the conveyance may have had sufficient capacity to handle the storm, it wasn't the water flow rate or volume that caused the problem, but rather…… what was being transported by the water.

Flooding caused by blocked gully pits is reasonably common, and more nuisance than anything else, but when pipes or culverts block, this is completely different.

Once the "minor" drainage system is disabled, the water will build up and find a new way to continue on its natural path towards the sea. In some cases, there are "major" systems, overland flow routes that are designed to take the excess flow above a Q20, but in some cases there are not. In cases where there is no overland flow route, and the pipes are sized for a Q100, but what happens if this pipe blocks? Massive damage bills and high risks to residents is what results.

In previous flooding incidents, Wollongong Council noted that many of their major conveyance inlets had suffered some degree of blockage, massively decreasing their capacity.

In an effort to dramatically reduce the current risks, Optimal Stormwater was engaged to review 15 system inlet locations, and determine what options were possible at each site, come up with a recommended option, model that option in TUFLOW; ballpark cost the options, and recommend a way forward for each site.

This paper looks at the background to this work, the investigations, the modelling and the outcomes. Why did the system block? What blocked it? Where did it come from? What physical controls and/or maintenance works are necessary to reduce the potential for blockage? How will they be structurally designed, built and maintained?

And most importantly, what can other Councils learn about blockage prevention, based on the experience and actions to date of Wollongong Council

2 Background

The Wollongong area has a long history of flooding. The combination of its coastal location and its vicinity to the Illawarra Escarpment to the west produce regular large intensity storm events of varying short durations. This in turn can generate flash flooding, and these high velocity flows have the capability to lift and carry large objects such as boulders, uproot trees and on several occasions move cars.

From Wollongong City Council's records, there have been over 30 serious, severe or very severe classified floods within the Wollongong City Council area in the last 50 years. There have also been 3 extreme floods during this 50 year period, the most recent in 1998.

Given the circumstances outlined above, Council has been diligently undertaking flood mitigation measures throughout the Council municipality, and have undertaken many flood investigations, flood models, and have produced many recommendations reports and plans.

In December 2010 Wollongong City Council prepared a Flood Risk Management Study and Plan for the Fairy Creek and Cabbage Tree Creek catchments. As part of the Flood Risk Management Study and Plan, investigations were undertaken using available flood event data and computer simulated modelling.

The study found that there were several critical locations within the catchment where flooding effects where worsened due to blockages of culverts or pipelines. The study found that choking and blockage played a significant role in the property damage caused by flooding.

As part of the rectification works, Optimal Stormwater in conjunction with Wollongong City Council investigated 15 system inlet choke points throughout the catchment and designed debris control structures which would reduce the potential for the blockage of culverts and pipelines without having an major upstream flooding effect themselves.

This paper outlines the common issues found at each of the 15 locations, key design constraints, and discusses the solutions for some locations. It is hoped that the experience and information in this paper, will be of relevance to the majority of the industry, when they go down a similar path to Wollongong Council.

3 Existing Site Conditions

In order to fully grasp the current situation at the 15 locations, Optimal Stormwater undertook detailed site specific investigations. Site specific information was then gathered and analysed. From the analysis it was determined that whilst there were some site specific issues, there were many common issues which presented at all the sites. The issues common to the majority of the 15 investigated sites included:

- potential for large debris through weak and dead trees,
- rocks and boulders,
- illegal dumping,
- large levels of organic growth within creeks and channels, and
- channel constrictions in some of the locations (due to building up to the top of bank level)
- about half had difficult access for construction and maintenance.
- Inspections require 2 people due to WHS working in slippery creeks and channels.

One of the most common aspects visible at all of the sites visited was the level of potential debris present. Most of the sites were downstream of areas with steep catchments and medium dense vegetated banks. These banks commonly had dead or weak trees with overhanging branches extending into the channel. During larger velocity flood events these overhanging branches or the whole tree itself could end up coming down the line, potentially blocking the inlet structures and causing flooding upstream. A majority of the sites also had evidence of fallen branches and uprooted trees from previous floods which had not been carried all the way to the inlets yet.


Another potential issue is large rocks and boulders. Given that the catchment upstream of most of the inlets is very steep and beginning at the peak of the Illawarra Escarpment, velocities can get very fast moving and this presents a powerful erosive force. This creates the potential for the flows to transport very large and/or heavy items found in the upper reaches of the catchment. Although there was no evidence of it during the site visits undertaken, Council advised that there had previously been vehicles carried during the flood events. There was, however, evidence of illegal dumping at several locations. Although the items were small in the majority of cases, there was evidence of larger items, in one location a couch and shopping trolley had been dumped that would easily have blocked under the next bridge downstream.


It was also observed that the majority of the sites had large levels of organic growth around the inlet structures or not too far upstream. This vegetation causes another potential catch point for the debris, but also encourages deposition of sediment. This sediment builds up over time, more vegetation grows through the sediment, and this cycle causes channel constriction and potentially blockage of the inlet structures.

It is understandable, and acceptable, that Council cannot maintain the entire catchment all the time, so this issue of potential debris and organic growth needed to be taken into account when designing suitable debris control structures. Over 60% of the entire creek length throughout the LGA are within private property and are the responsibility of the owners to maintain. Maintenance alone is not enough. The specific site conditions and potential velocities and type of potential debris also needed to be taken into account to ensure that a site specific solution was found. In some instances, the Debris Control structures could be enhanced to provide additional pollution control, but this was at a minority of sites.

4 Design Solutions

Maintainability

Besides designing a solution which would increase the potential for the inlet structures to convey as much flow as possible, the other key design factor was maintainability. The design solution needed to be easy to inspect and easily maintainable to ensure the proper working condition which maximises the effectiveness of the solution. In many cases, residents will be able to alert Council to the need for maintenance, so solutions that are easy to see, have this advantage.

Bollards

For all but one of the sites it was proposed to construct a solution that incorporated bollards spaced dependant on the inlet structure as part of the solution. Along with the maintainability issue discussed above, the bollards were selected for two specific reasons.

The first reason was strength. Medium to large concrete filled bollards have a high tolerable strength to fast moving forces either distributed or point loads. They are commonly used to prevent cars doing ram raids on shops, so withstanding trees and shopping trolleys won't be an issue. Other options looked at included crash barriers, energy dissipaters, bars, mesh, and trash racks, but these were generally not considered as viable solutions based on either strength or effectiveness.

The second reason for the selection of bollards was the bollards did not restrain the low flows or even medium flows through the system. Those flows simply flow past the bollards, which means that there will be a very low potential of blockage of the bollards during these small events.

The bollards were designed to be constructed with different spacing dependant on the configuration of the inlet structure. For example, the spacing of the bollards for 900mm diameter piped outlet would be approximately 600mm centre to centre between the bollards. This spacing allows smaller debris to flow past the bollards and through the inlet structure, thus reducing the amount of debris build-up around the bollards and greatly reducing the potential for blockage of the inlet.

Each site required different layouts and configurations, and used bollards of different heights, diameters and spacings. At sites with particularly hard access, the bollards were angled across the channel to encourage the debris to one side of the bank for ease of maintenance, and increase the area of bollards so they were not limited by the perpendicular cross section of the conveyance. Additionally, sites with a much greater potential for large debris to flow down the channel have strengthened bollards to withstand the additional forces of both impact, and the pressure head from being blocked.

The use of bollards reduces the potential for blocking of the inlet structures by creating an upstream capturing zone. If the area in front of the bollards can be widened or deepened, then this reduces the velocity, and therefore the force on the bollards, and delays their potential for blockage.

There was a minor change to the flooding profile due to the bollards, but generally only for the larger events. In large events when the pipe or culvert capacity is exceeded, the bollards have no impact. For larger events in channels, they do have an impact, but Tuflow modelling suggests it is minor and acceptable for all the sites looked at.

Access

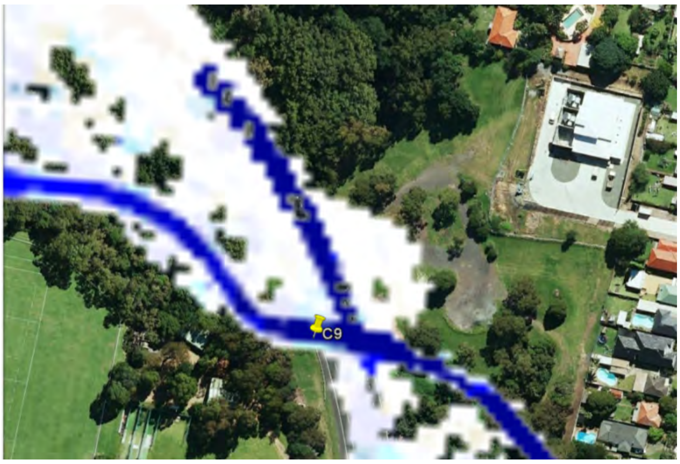
Because maintenance of Debris Control Structures is not required as frequently as say gross pollutant traps, it is generally not required to have a formal concrete driveway, but a stabilised access using crushed rock or road base is generally a good idea. In some cases, a simple grassed access route will be acceptable if the ground is solid and not on too much of a slope.

Sites that have poor access or no access need to at least have a route for a people to get to the inlet. In the worst case, workers may need to go in with jackhammers for rocks, or grinders for cars, or chainsaws for trees, and cut things into pieces that can be manually carried out.

5 Hydraulic Assessment

Flood modelling of Fairy and Cabbage Tree Creeks has previously been undertaken as part of the Flood Risk Management Study and Plan. Wollongong City Council made available the reports and modelling, which fed into the modelling as part of this project.

To determine the effects of the Debris Control Structures on the existing flooding profile and conditions, the existing model was used as a base, and was modified where required. Through liaison with Council, the blocking factors which were previously assumed for the inlet structures were remodelled, and full blockage was assumed at the location of the Debris Control Structures. In general, the modelling noted that there would be some minor hydraulic impact from these structures, but in all cases, the benefits of keeping the stormwater system operational, massively outweighed any small hydraulic impact.



6 Typical Construction Costs

Each site would require clean-up of the existing vegetation. There would also likely be some regrading works for access paths, as well as the installation/construction of the bollards and concrete plinths.

Added to this are miscellaneous costs such as environmental controls, approvals, design and supervision, site rehabilitation, etc. It is estimated that these works will typically cost around $50,000 to $150,000 per site.

Two sites of the 15 require expenditure in excess of $500,000. Once designs have been agreed and completed, Council can prioritise the works, and add these to their works program in coming years.

7 Summary: Things to take away from this paper

The following are a list of useful things that the audience should note, which are highly likely to be relevant for most sites, at every Council.

- Many options exist, but appropriately designed and installed upstream bollards were very cost effective for most sites, and a part of almost every solution.
- Bars, grates, grills, racks or anything else that could block to the top, and then not allow flow to reach the inlet, only increased the risk, and was not considered further.
- Bollard spacing at 2/3^{rds} of the conveyance aperture width
- Bollard heights are dependent on velocity and the expected debris types. These typically range from 50% to 100% of the conveyance aperture height. Bollards taller than 100% generally started to cause unacceptable upstream impacts in their own right when fully blocked.
- Vehicle access to an area in front of the Debris Control Structure/solution should be possible. But it does not necessarily need to be a formal concrete driveway.
- Introducing an area of wider flowpath can aid in reducing the velocity and causing deposition of debris upstream of the inlet
- Excavation of a “deposition zone” can allow for coarse sediment to build up in a controlled area for ease of removal later. If not addressed, sediment build up can decrease the capacity within pipes and culverts, but it can also encourage vegetative growth in and around inlets, that when left unchecked can allow the vegetation to provide a “point of purchase” for large debris to get caught on. Hence sediment control is also important for some sites.
- Benching was recommended on most sites to remove vertical walls going into circular pipes that add to the risk of sticks and wood catching across the pipe inlet or headwall.

- If using bollards try for a minimum of triple the conveyance width. I.e. for a 1200mm pipe, the bollards should seek to cover a width of 3.6m or more.
- Upstream detention basins or detention structures can aid the functionality of the Debris Control Structures, by reducing the size and load of debris coming through.
- When doing the site inspection/audits, beware slippery rocks, snakes, spiders, etc. Work in pairs.
- Look for designs that can solve multiple problems, or increase the scope of the project to address multiple issues. In most stormwater systems, water quality, quantity and flooding are all interrelated.
- For most sites, a significant reduction in risk would result if 2 qualified people with chainsaws walked upstream for a few hundred meters, and cut any large dead trees within the flow path, into pieces that were small enough to enter the inlet without problems. Alternatively, chop up into smaller pieces and remove from the flow path altogether. This preventative maintenance is relatively cheap and easy, and should ideally be done on a yearly basis upstream of inlets that have open creeks and steep catchments.
- During this risk reduction work, boulders, mattresses, pallets, cars, galvanised sheeting or any other anthropogenic items that could cause problems can be identified, and action taken, but the largest problem for blockages is trees and large branches.
- Vegetation clearing (especially overgrown macrophytes) and removal of deposited sediment from within creeks and channels upstream of inlets, will reduce the flow velocity, and encourage large items to drop out before the Debris Control Structures.
- Energy dissipaters can have a dual function of debris control as well reducing the erosive force of the water, but beware of the maintenance difficulty this could create. As part of this project we noted that blockage on the debris control structures would raise the water level and thereby reduce velocity and achieve similar outcomes, but in a solution that was easier to engineer and easier to maintain.
- Talk to the residents. They commonly have lots of local knowledge not necessarily held by Council. They are always very keen to know what works are being considered, and how it might impact them, but they proved incredibly helpful and cooperative …. Once advised that we were looking to solve blockage and flooding problems.
- Council should be prepared to send a ranger to houses which are noted to be illegally dumping palm fronds (which aid inlet blocking), and also grass clippings, leaves etc., that will definitely cause pollution in subsequent rain events.
- In all cases the option to upgrade the conveyance capacity (i.e. install a larger pipe) was considered to be too expensive. Council also advised, that increasing this capacity would (in most cases) just move the problem downstream, by changing the flow regime and flooding people further down the catchment
- At concept stage, there was no stakeholder interaction with state government departments such as the RTA, although some solutions were proposed on their lands.

Given that in each case, the solution would reduce the risk of their roads flooding, Council expects a positive response from these stakeholders.

- Access, Access, Access. Consider people, machinery and trucks.
- Maintenance, Maintenance, Maintenance. Stable access for people and vehicles is a must for every site. If it can’t be maintained, don’t consider building it. (Council, 2010)

Location T1 – Hinkler Avenue Reserve

The site is located in Fairy Meadow, and is bounded by both industrial and residential buildings. The outlet structure is made up of three 1500mm box culverts which run perpendicularly under Memorial Drive. The catchment area channelling into the outlet structure is relatively large and the surrounding topography very flat, and as such, blocking of the culverts will cause flooding of surrounding properties. The existing condition of the site is relatively poor. The site has signs of large sediment deposits as well as relatively dense vegetation growth and even evidence of dumping, with several shopping trolleys and even a couch dumped at the site.

There is a pedestrian bridge which is located approximately 12 metres upstream of the culverts. The pedestrian bridge has a deck span of 8m which would allow free flow, and is not seen to be a constriction. At the time of the site visit, a depth to underside of the pedestrian bridge was not measurable as there was a significant build-up of sediments, debris and vegetation. But these can be reasonably easily removed.

Figure 1 - Upstream pedestrian bridge with sedimentation, vegetation and illegal dumping.

Figure 2 - Downstream culvert, under a major RTA road.

Given that the surrounding area and channel are relatively flat, the velocity of the flows is not as high as they are in the upper catchment. Having said this, the potential for larger debris is increased given the ease of accessibility to site. Given this fact, it was proposed to construct 150mm diameter concrete filled galvanised steel bollards approximately 1m high, 1m apart and 1m upstream of the existing triple 1500mm x 1500mm culverts. This will ensure that the bollards can withstand the force applied by larger debris and if it's small enough to get through the bollards, it should also be able to go through the culverts.

The channel itself is relatively consistent in its geometry, then actually widens following the pedestrian bridge, creating an area for potential velocity reduction and debris deposition. This area assists in capturing the sediments and debris as the carrying velocity reduces and the larger and heavier debris is 'dropped' prior to the bollards.

The location of the site and its accessibility is of great benefit even though its location has contributed to its potential for large debris through illegal dumping. The open location allows for ease of access for maintenance vehicles and allows for excellent visual inspection of the potential debris build-up. Visual inspection can be undertaken from the pedestrian bridge or even from the

Memorial Drive shoulder. The site is easily accessible either via Memorial Drive or Florence Street to the north, so buildability is relatively straight forward as is the maintenance access.

Modelling of the proposed bollards shows they have had no impact to the hydraulic conditions at the site. During low flow events, the flows simply pass between the bollards which are equally spaced across the channel. This is also the case in medium (20 year) events. The bollards reducing the channel cross sectional area by approximately 1.5%, which has a very minimal upstream effect in larger events (50 and 100 year). It was assumed, however, for the models that the channel was blocked across the face of the bollards in the larger events. This had a minor local effect around the bollards, but given the blockage was upstream of the culverts, and the culverts remained unblocked, the flooding was massively improved.

The sections below show the proposed improvements for this location.

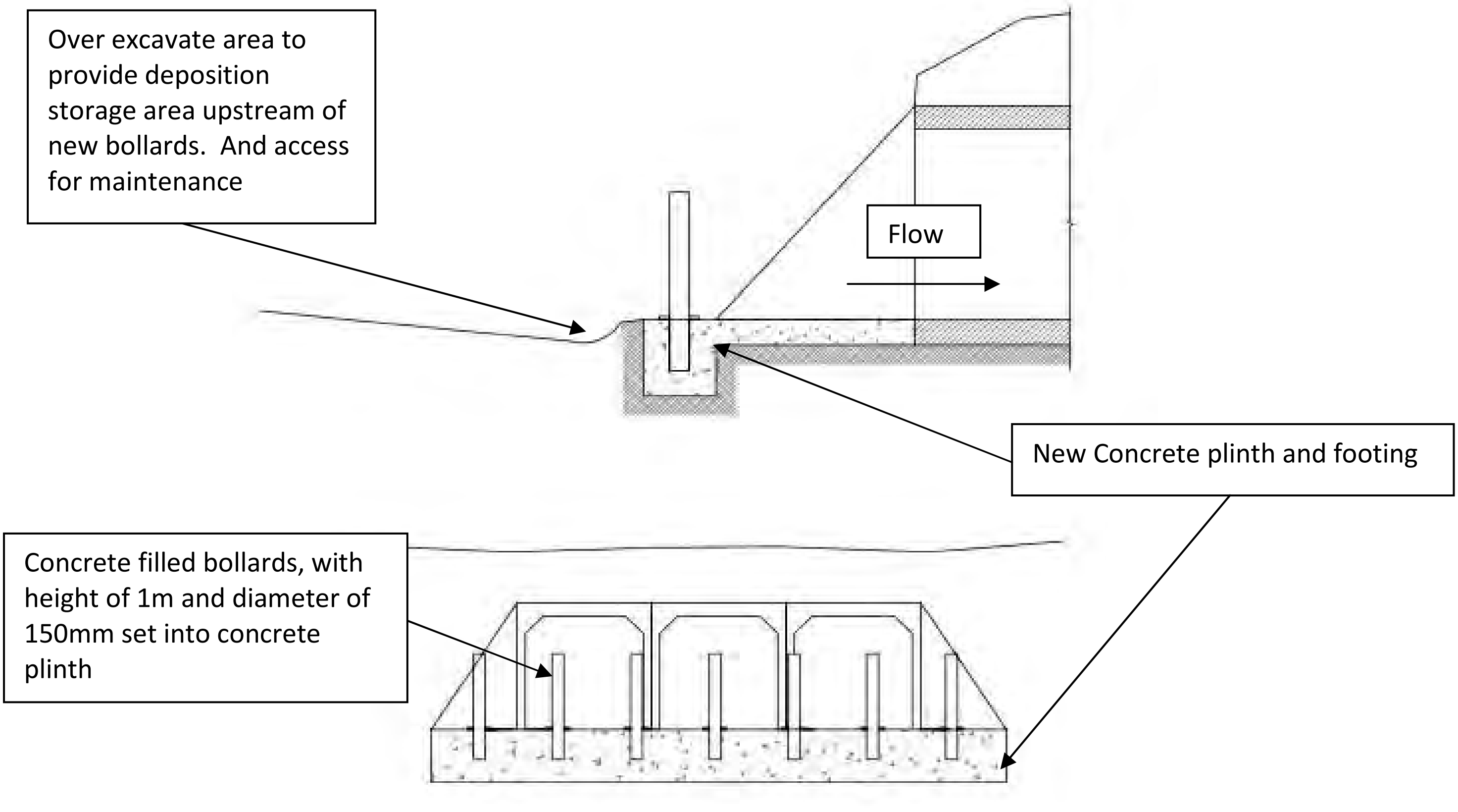


Figure 3 – Cross Sections of proposed works

Location F2 – Kooloobong Park, Cosgrove Avenue

The site is located in Keiraville, and is located in a deep valley at the base of a steep catchment. There are residential properties located in the vicinity of the inlet structure, although they are significantly elevated, and should not be within the flood impact zone. There is potential of flood impacts on properties downstream of the outlet structure should overtopping occur, with houses and solid fences built directly in the overland flow path.

The outlet structure is made up of a single 1050mm pipe which proceeds to run in an easterly direction towards the University of Wollongong. The area directly upstream of the inlet structure is vegetated, and there is evidence of deposition of large debris including large boulders and uprooted trees.

Figure 4 - Upstream the valley/creek area contains rolls of fencing wire and plenty of large dead trees.

Figure 5 - Downstream the inlet structure

There is also evidence of planting new trees in the upstream reaches of the flow path. This has the potential to cause issues as these trees are susceptible to uprooting and can cause blockages. Given the steepness of the upstream catchment, there is a large potential for these young newly planted trees to be uprooted and carried. There is evidence of large trees and boulders which have been moved by previous flows. It is proposed to remove the wire from around the newly planted trees and remove any older weaker or dead trees which will cause blockages.

The site currently acts as a detention basin with the boundary to the neighbouring property acting as a headwall of sorts. Given the potential extreme velocities and the depth of the outlet pipe in relation to the neighbouring properties, it is proposed to further formalise this ‘basin’ effect. It is proposed to extend the existing 1050mm pipe upstream approximately 2m (to create an area for access to maintain) and then create a 6m wide x 6m long x 2m deep area upstream of the extended pipe. It is then proposed to install Reno mattresses and gabion walls (or similar) along the ground and walls respectively. This will give structural support to the walls and ground. It is proposed to install bollards at 0.7m centres along the upstream face of the gabion wall across the channel. This will capture large debris which would otherwise gather at the face of the inlet structure. The bollards have been spaced at 0.7m intervals to capture debris which is larger than the width of the pipe, but will allow smaller particles to pass through both the bollards and pipe.

Relocation of the inlet structure will allow for a maintenance access to be constructed as well as giving room to raise the headwall above the inlet pipe, effectively creating not just control of large debris, but also creation of a formal detention basin.

Modelling in Tuflow shows the proposed bollards have had no impact to the hydraulic conditions at the site. During low flow events, the flows simply pass between the bollards which are equally spaced across the channel. This is also the case in medium (20 year) events. The solution has effectively increased the cross sectional area for the flow and improved the storage capacity. This, in turn, will improve the current flooding issues in the area.

The sections below show the proposed improvements for this location.

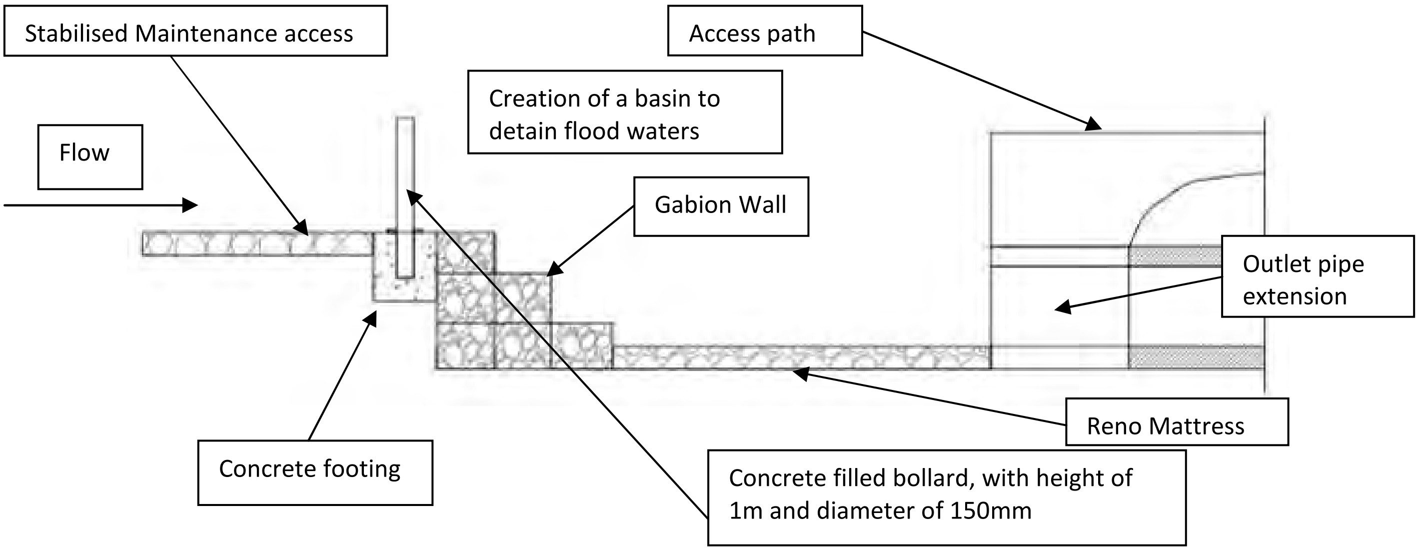


Figure 6 – Cross Section of proposed works

Location C8 – Cabbage Tree Lane Reserve, 53-71 Cabbage Tree Lane

The site is located in Fairy Meadow, and is bounded by an open space. There are residential properties located downstream of the inlet structure. The inlet structure is made up of a single 1800mm pipe which proceeds to run beneath Cabbage Tree Lane. The catchment area channelling into the inlet structure is relatively large. The topography is and any pipe blockage will flood properties. The area directly upstream of the inlet has some vegetation build-up which has caused sediment deposition and growth. Also noted at the site was undercutting of large tree and a dumped bicycle just waiting to block over the inlet.

The area immediately upstream of the site is relatively flat and the overland flow path is relatively wide, meaning the velocities are lowest at this point, however there is still evidence of scour along the creek line and its surrounds. There is a potential for illegal dumping in the area, and as such it is proposed to install concrete filled bollards to prevent potential destruction of the debris control structure.

This particular site has multiple issues: existing ongoing erosion, illegal dumping, high inlet blockage potential because of its configuration, it's very close to the road and neighbour, there are high risk services exposed just upstream.

Figure 7 – Inlet structure

Figure 8 – Evidence of scour and debris within channel

Given the abovementioned issues for this site, a redesign of the existing area is proposed. It is proposed to extend the existing inlet structure approximately 20m upstream, past the exposed and undermined service pipelines so these can be backfilled over, and protected.

In addition to the relocation of the inlet, a new 6m inlet plinth can be created, with 900mm high bollards at 1m centres, the creek will be slightly realigned and a wetland will be created to reduce the flow velocities and allow deposition of the larger debris before the new inlet.

Only at this site, the bollards could alternatively be swapped for a wider style trash-rack, to add some pollution control potential as well.

It is proposed to create and maintenance access path on the southern side of the site. This will require a connection from Cabbage Tree Lane, as well and some minor regrading. This path will allow for easy access for maintenance as well as visual inspection of the site.

The plan below shows the proposed improvements for this location.

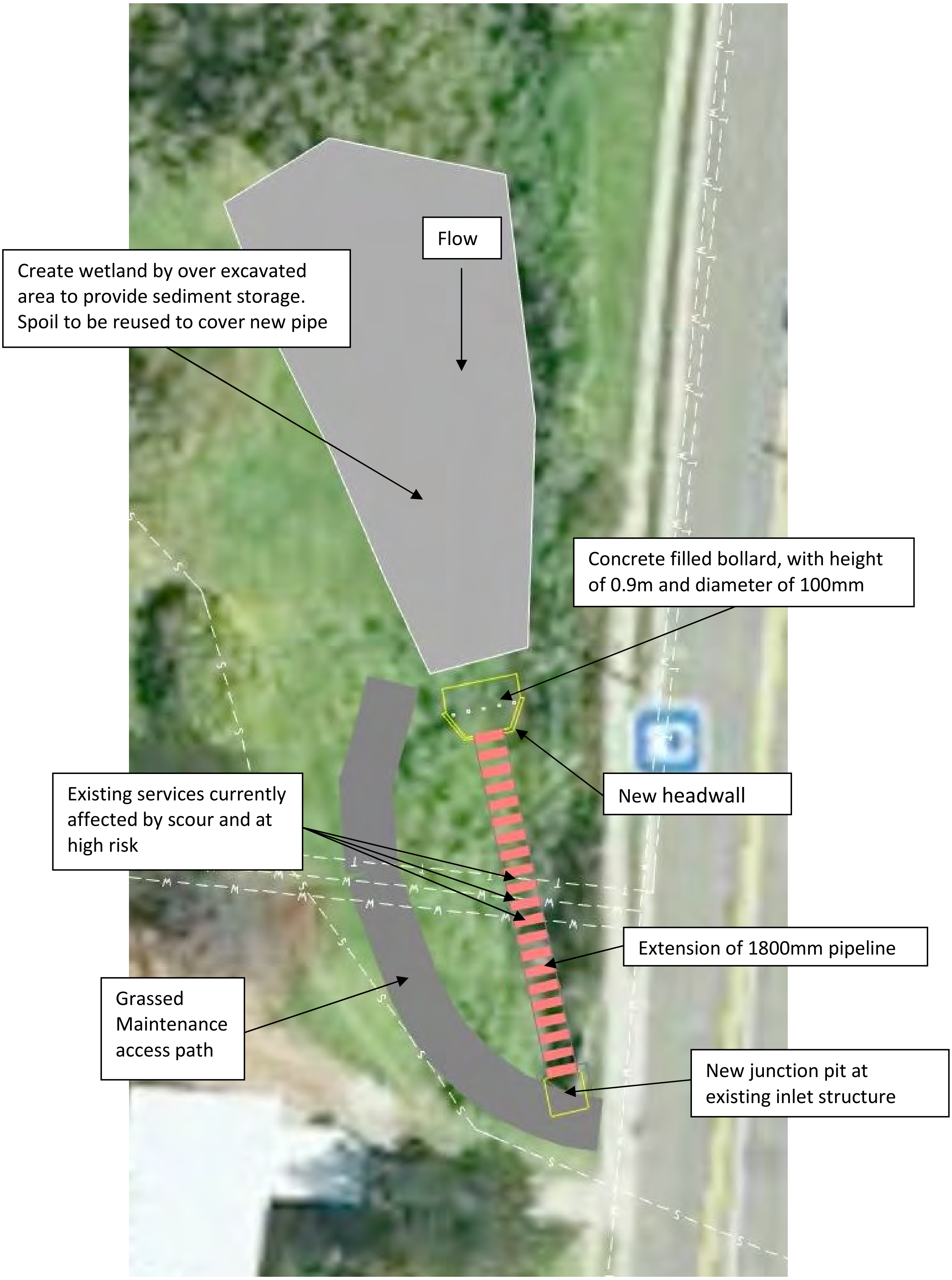


Figure 9 – Plan view of proposed works

Site Designation	Site Inspection Key Points	Existing Hydraulic Risk	Proposed Solution	Proposed Access and Maintenance	Priority
T1 – Hinkler Avenue Reserve, Fairy Meadow	• Significant amount of vegetation growth • Rubbish dumping • Great potential for large debris given evidence of dumping • Constriction point upstream • Area relatively flat • Site is reasonably accessible	• High risk to neighbouring properties given the existing condition of the site, and the shallowness of the creek bed	• Mass vegetation clean up • Removal of upstream constriction • Installation of bollards or trash rack • This will also give a good visual of any built up debris which may block the outlet	• Proposed access path from Florence Street along the existing walkway • Minor grading works to create an access over sewer access chamber • 6 monthly review and/or clean-up • Clean up following storm events	High
T2 – Smith Street, Fairy Meadow	• Vegetation build-up • Constriction under bridge deck • Area relatively flat • Site is reasonably accessible	• Risk to neighbouring properties given the existing condition of the site • Depth of creek bed reduces the risk.	• Mass vegetation clean up • Removal of upstream constriction • Installation of bollards or trash rack structure	• Proposed access path from Smith Street along the existing walkway • 6 monthly review and/or clean-up • Clean up following storm events	High
C1 – Rose Parade Reserve, Balgownie	• Vegetation-build-up • Constriction under bridge deck • Area relatively flat • Site is reasonably accessible	• Currently, there is a minor flooding risk to neighbouring properties both upstream and downstream • The deep flooding is contained within the reserve • Access to site is the overland flow path	• Vegetation clean-up • Excavate upstream beneath bridge • Install bollards • Strengthen northern bank	• Proposed access path from Wellington Drive along the existing walkway • 6 monthly review and/or clean-up • Clean up following storm events	Medium
C2 – Downstream of Brokers Rd Detention Basin, Balgownie	• Some vegetation build-up • Constriction of creek prior to bridge • Area relatively flat • Site has excellent access	• Site is in an area of high flood risk • Both upstream and downstream residential properties have the	• Vegetation clean up • Widening of creek • Installation of bollards • Bank stabilisation	• Proposed access path from Chalmers Street • 6 monthly review and/or clean-up • Clean up following storm	High

Site Designation	Site Inspection Key Points	Existing Hydraulic Risk	Proposed Solution	Proposed Access and Maintenance	Priority
		potential to be effected		events	
C3 – Foothills Road Bridge, Balgownie	• Northern creek bank has gabion • Some vegetation build-up downstream • Constriction of creek downstream of bridge • Area relatively flat • Site has excellent access	• Site is in an area of high flood risk • Both upstream and downstream residential properties have the potential to be effected	• Vegetation clean up • Stabilisation of banks beneath bridge • Installation of bollards	• Proposed access path from Foothills Rd • 6 monthly review and/or clean-up • Clean up following storm events	Low
C4 – RMS Culvert No. 8, Mount Pleasant	• Site looks to have been recently cleared of vegetation • Upstream catchment very steep • No flooding risk to upstream residential properties • Currently no site access	• Overtopping of freeway is the prominent risk • No residential properties will be effected upstream	• Installation of bollards • Removal of larger debris and weaker trees • Stabilisation of banks • Create access off freeway	• Proposed access path from M1/Mount Ousley Road • 6 monthly review and/or clean-up • Clean up following storm events	Medium
C7 – Sunninghill Circuit Reserve, Mount Ousley	• Vegetation build-up • Creek channel constriction • Site flanked by residential properties • Constrained site access	• Both upstream and downstream residents are effected • The upstream residents have a lower risk than the downstream residents	• Vegetation clean out • Stabilisation of southern bank • Installation of bollards • Creation of access point (stairs)	• Access point from Parkview Grove • 3 monthly clean-up • Clean up following storm events	Medium
C8 – Cabbage Tree Lane Reserve, Fairy Meadow	• Some vegetation and debris build-up • Scouring and undermining of existing services upstream of outlet • Relatively flat, potential for flooding of downstream properties • Creek alignment and outlet location should be reviewed • Site has excellent access	• Overtopping of Cabbage Tree Lane is the prominent risk • No residential properties will be effected upstream • There is potential for residential properties to be effected downstream	• Relocation of existing outlet structure further upstream • Support for existing services • Creation of wetland • Installation of bollards • Installation of access	• Proposed access path from Cabbage Tree Lane • 6 monthly review • Clean up following storm events	Medium

Site Designation	Site Inspection Key Points	Existing Hydraulic Risk	Proposed Solution	Proposed Access and Maintenance	Priority
C9 – Mt Ousley Road, Keiraville	• Significant vegetation build-up • High probability of debris blockage given existing upstream conditions • Relatively flat, although flooding of university is not probable, more potential for water sheeting over freeway • Currently no access, however, site is accessible	• Overtopping of freeway is the prominent risk • No residential properties will be effected upstream • High potential for blockage due to pipe size and amount of debris upstream • Major consequences to blockage, flooding of freeway	• Removal of vegetation and extensive clean-up of upstream area, removing or reducing the size of debris • Installation of bollards • Creation of access path	• Proposed access path from Freeway • 6 monthly review and/or clean-up • Clean up following storm events	High
C10 – Collaery Avenue, Fairy Meadow	• Significant vegetation build-up • No consistent flows, no creek • Small catchment flowing in storm events • Very low potential for large debris to block outlet • Excellent site access	• Very small catchment flowing to the site • Existing fence acts as a barrier • No creek line running through site, only a overland flow path	• Removal of vegetation • Installation of bollards	• 6 monthly review and/or clean-up • Clean up following storm events	Low
F1 – Robsons Road, Keiraville	• Some vegetation build-up • Large potential for debris from weak trees in vicinity of outlet • Low risk of flooding of residential properties given the height of their floor levels • More potential for overtopping and flooding of downstream sites • Excellent site access	• Site acts as a detention basin • Site is an overland flow path, with no creek running through the site	• Removal of vegetation and dead/weak trees • Installation of bollards • Creation of access path	• Proposed access path from Robsons Road • 6 monthly review and/or clean-up • Clean up following storm events	Medium
F2 – Kooloobong Park,	• Sediment and vegetation build-up • Great potential for	• Site acts as a detention basin given	• Removal of vegetation and	• Proposed access path from Cosgrove	High

Site Designation	Site Inspection Key Points	Existing Hydraulic Risk	Proposed Solution	Proposed Access and Maintenance	Priority
Keiraville	large debris to block outlet given outlet size and catchment grading • Low probability of flooding of existing residential properties, however downstream site has all the risk • Site access is difficult	the surrounding grading • Inlet structure is undersized given the potential flows • High potential for overland flow through private property	dead/weak trees • Extend existing 1050 diameter pipe • Reno mattress and gabions • Installation of bollards • Creation of access path from Cosgrove Avenue along neighbouring property boundary	Avenue along neighbouring property boundary • 6 monthly review and/or clean-up • Clean up following storm events	
F3 – College Place Park, Gwynneville	• Vegetation build-up • Evidence of previous cleaning • Creek was not flowing, with stagnant water visible • Area flat, with residential properties very close by, potential for flooding • Upstream culverts restrict debris size flowing from upstream catchment • Excellent site access	• Area is flat and any blockage of culverts will result in localised flooding and effect surrounding residents • Upstream culverts limit the potential for large debris to enter the channel from upstream • Any blockage at downstream culvert will flood the upstream houses	• Removal of vegetation • Stabilisation of southern bank • Installation of plinth and trash rack • Driveway into trash rack • Continue to clean out creek with long reach excavator to maintain capacity and minimise velocity	• Proposed access path from College Place • Monthly review • Clean up 1-3 monthly and after storm events	High
F4 – Cedar Park, Keiraville	• Significant sediment and vegetation build-up • Flood detention structure in place • Good site access	• Site not covered by existing modelling. • Downstream properties most at risk.	• Removal of sediments and vegetation from upstream of the existing inlet pit. • Removal of vegetation	• Access path already exists • Slight regrading works to allow for easier access to site • 6 monthly review and/or clean-up • Clean upstream	Medium

Site Designation	Site Inspection Key Points	Existing Hydraulic Risk	Proposed Solution	Proposed Access and Maintenance	Priority
			within the downstream channel to increase flow capacity	every 5 years	
F6 – Cnr Gipps Rd & Allen St, Mount Keira	• Significant vegetation build-up • Existing service pipelines have evidence of scour and undermining • No residential risk from upstream flooding, downstream properties most at risk • No existing site access	• Site not covered by existing modelling. • Downstream residential properties are at significant risk if inlet blocks	• Removal of vegetation • Installation of bollards • Creation of access path • Use existing creek alignment and protect existing 500mm water line • Remove vegetation from beneath other service lines to ensure no blockages	• Proposed access path from Gipps Road • 6 monthly review and/or clean-up • Clean up following storm events	High

8 Bibliography

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