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North Arm Cove Stormwater Management Strategy

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Synopsis: This document outlines a stormwater management plan for North Arm Cove including consideration of the existing village and potential future development areas.

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1 Introduction

North Arm Cove village is located on the northern shore of Port Stephens. The village currently comprises 280 developed residential lots, with an additional 157 undeveloped lots located adjacent to the existing village area. The rural zoning of the undeveloped lots currently prevents property owners from erecting dwellings or other structures on these lots. Rezoning of these undeveloped lots would be required prior to further residential development proceeding.

Stormwater management planning in North Arm Cove has historically been limited, resulting in ad-hoc and ultimately ineffective management of stormwater in many areas. Future development of the rural lots has the potential to exacerbate current stormwater management issues.

Great Lakes Council is committed to protecting the Port Stephens estuary that receives runoff from the North Arm Cove village. A key component of this is a commitment to manage the load of gross pollutants, sediments, nutrients and other stormwater pollutants generated from existing development. Any future development would require developers to comply with Council's DCP requirements for stormwater management. Currently these requirements are outlined in DCP 54.

This report outlines a Stormwater Management Plan (SMP) for North Arm Cove village. The SMP outlines a range of actions that are considered to be appropriate for mitigating current stormwater management issues and avoiding potential additional issues associated with further development.

The SMP discusses a range of short term and long term actions. The short term actions focus on improving the management of stormwater quality and quantity in the existing village. Issues identified by the community indicate that improvement of stormwater drainage and the integrity of the drainage system should be a key focus of the short term actions. The long term actions focus on improving the planning of stormwater quality and quantity management systems as a component of any potential future development in the undeveloped lots. Long term actions also include improvement of stormwater quality at key central locations in the existing North Arm Cove village.

The investigations, strategy and actions are outlined in the SMP as follows:

Section 2 provides a background review of key catchment characteristics in North Arm Cove and how these influence the management of stormwater.

Section 3 summarises the key stormwater management issues that have been identified by the community and Council in North Arm Cove. The issues include village wide issues that are commonly observed across the study area, and site specific issues at particular locations.

Section 4 outlines a range of short term actions that are recommended for consideration to assist with resolving present key stormwater management issues identified within North Arm Cove.

Section 5 outlines a range of long term actions that are recommended for consideration if future development were to proceed in existing rural-zoned lots in North Arm Cove.

Section 6 outlines a stormwater management schedule listing the recommended options and associated preliminary budgetary estimates for each.

Appendices summarise the technical modelling approaches followed to evaluate stormwater quality and flooding in the study area.

2 Catchment Characteristics

2.1 Overview

To achieve effective management of stormwater it is important to gain a good appreciation of the physical characteristics of the catchment area that produces the stormwater runoff. Key catchment characteristics that typically influence stormwater management include existing urban infrastructure, terrain, drainage, soils, groundwater, ephemeral creeks, vegetation and receiving environments. These key catchment characteristics are described below along with how these characteristics impact on opportunities for improved management of stormwater in North Arm Cove.

2.2 Urban Infrastructure

Development in North Arm Cove has proceeded with limited consideration of stormwater management. Where stormwater management infrastructure has been provided, this has typically been constructed to alleviate localised stormwater drainage issues. The stormwater drainage system has therefore been progressively constructed in an ad-hoc manner, with the implications of individual localised drainage solutions on downslope properties and infrastructure not thoroughly considered.

Existing urban infrastructure that significantly influences stormwater management in North Arm Cove includes roads, table drains, driveway crossings, informal diversion structures, piped drainage systems, open channels and private dwellings. Some of the key influences of the existing urban infrastructure in North Arm Cove on stormwater management include:

- Private properties and structures block natural overland flow paths;
- Steep unsealed village roads and fire trails generate soil erosion;
- Piped driveway crossings block and re-direct stormwater in some locations;
- Roads aligned along contours function like dam embankments;
- Road cross-fall is insufficient in some areas leading to concentrated overland flow across roads;
- Table drains concentrate stormwater forming pathways for organic debris to be conveyed to piped drainage system inlets causing blockage and unintended flow diversions;
- Informal bunds and other structures divert flow from one property to another;
- Some constructed drainage lines are underutilised; and
- Hazardous conditions exist for the community adjacent to drainage system inlets and along constructed channels.

The influence of existing urban infrastructure on stormwater management is discussed further in Section 3.

2.3 Terrain and Drainage

The terrain in North Arm Cove is dominated by Baromee Hill which peaks at around 56m AHD. Gradients of around 15 to 20% are common along the Port Stephens shoreline up to the Baromee Hill ridge line. Gentler gradients occur along the ridge line and in southern parts of the study area. Figure 2-1 depicts the variation in gradient across the study area.

North Arm Cove village terrain also provides significant challenges to stormwater management. Many of the drainage pathways within the study area are ill-defined and have been significantly altered by the construction of roads and other infrastructure. Construction of roads has altered drainage pathways and concentrated stormwater flows in many parts of the village area. This has resulted in localised blockages and flow constrictions in some areas leading to uncontrolled overland flows through private properties.

The steep gradients also provide a considerable constraint for stormwater quality management. Gradients of 1 to 4% are typically suitable for a range of stormwater quality/quantity management measures. Gradients in the 4 to 7% range are less suited, but may have potential where localised regrading is able to reduce gradients. Gradients above 7% are a significant constraint for the implementation of stormwater management measures. Given that the majority of existing residential development in the study area occurs in areas where the gradient exceeds 7%, the provision of stormwater management measures in these areas may be unfeasible. Centralised locations in lower gently grading areas near the foreshore are likely to be most suitable for positioning stormwater management measures.

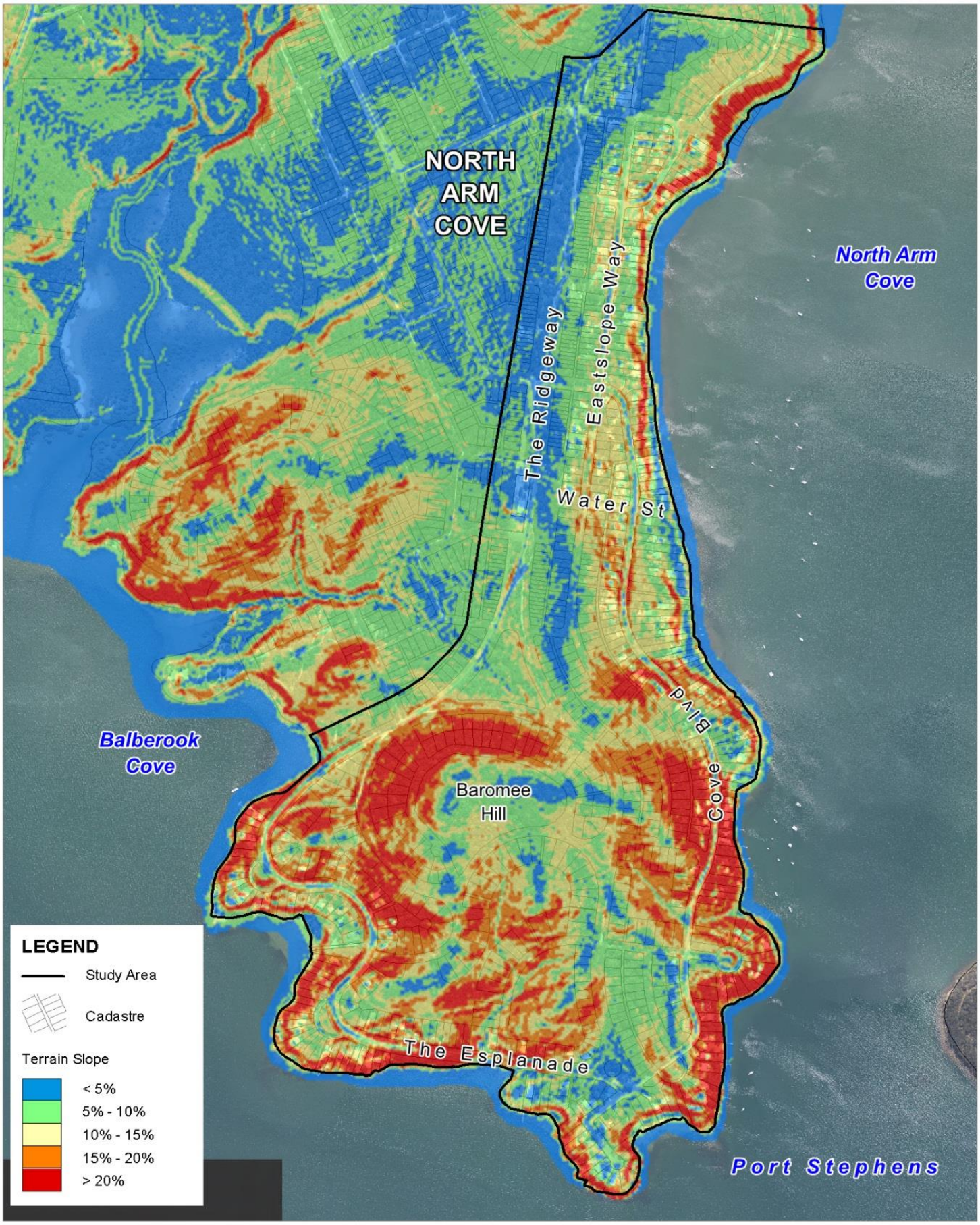
2.4 Soils

The soil landscapes occurring within the study area are summarised below and shown on Figure 2-2. The soil landscape summaries were derived from Murphy (1995).

Soils in North Arm Cove are dominated by the residual North Arm Cove soil landscape which is found across the entire study area. These soils typically occur with undulating to rolling hills with gradients of less than 15%. The upper soil layer is typically 0.1 to 0.5m deep and is usually highly permeable. Subsoil layers are typically 0.5 to 1.5m deep and exhibit low permeability. North Arm Cove soils present a high erosion hazard for concentrated and non-concentrated flows and are prone to seasonal waterlogging in lower slope areas.

Within North Arm Cove, small pockets of River Road and Gan Gan soil landscapes may also be present. The se soil landscapes exhibit a high erosion risk. They are characterised by a shallow depth of topsoil which is often lost through erosion, exposing a hard setting layer with low permeability. Gan Gan soils in particular pose a severe constraint due to their sodic and highly dispersive nature. Dispersible soils are structurally unstable in water and easily spilt into constituent particles and when discharged into receiving waterways can result in high turbidity levels.

Previous site investigations by Council have located bedrock at depths of less than 1m along Water Street. Residents have also indicated that soils are shallow throughout many properties. Soils in this area were also found to have experienced considerable erosion. Shallow soil depths form a key constraint to the provision of a range of stormwater management systems in this area. Considerate design would be required to avoid concentrating stormwater discharges into areas



Title:

North Arm Cove Terrain

Figure: **2-1**

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Approx. Scale

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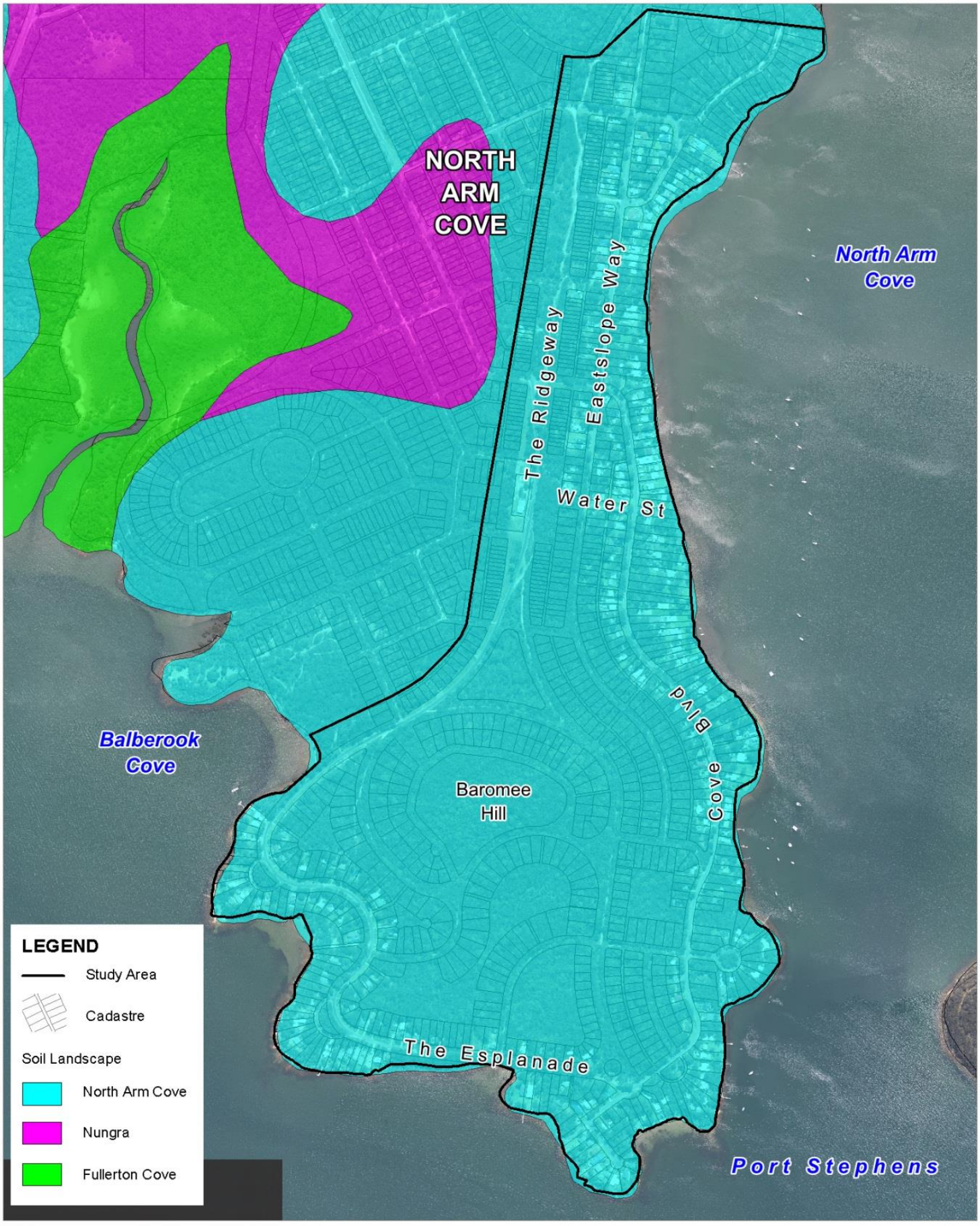

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North Arm Cove Soil Landscapes

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2.5 Groundwater

Steep site terrain, shallow bedrock and coarse grained weathered/fractured rock soil layers in North Arm Cove are likely to be leading to rapid recharge of the shallow groundwater following rainfall. This shallow groundwater appears to be flowing along the highly permeable soil / low permeability soil or soil / bedrock interface prior to resurfacing as interflow downslope, or draining to deeper groundwater through joints in the bedrock.

The shallow groundwater flow direction appears to be strongly influenced by the construction of roads along the contours in some areas. It appears that the road formation of Cove Boulevard is functioning like a dam in places, restricting the flow of shallow groundwater in a direction towards North Arm Cove. Shallow ground water potentially is backing up behind the road pavement prior to resurfacing and flowing across the road. Residents have suggested that water continues to seep from grass on the upslope side of roadways for several days after conclusion of wet weather.

2.6 Overland Flow Paths and Ephemeral Creeks

North Arm Cove village includes a number of ephemeral creeks that, in their original state would have conveyed surface runoff from naturally vegetated areas into Port Stephens. Creeks are often the receiving environment where development impacts are first observed. Such impacts include increased frequency of elevated discharges and larger volumes of runoff due to rise in impervious areas of future development. Associated risks to water quality include increased potential for erosion and sediment transfer capacity, as well as potential for stormwater to convey pollutants into natural creeks and other receiving environments.

Many of the creeks in North Arm Cove have been modified where they pass through the existing village. Contours suggest that some creeks have been filled in and piped drainage systems constructed. Other creeks appear to have been filled in, with stormwater now flowing overland through developed properties. Some creeks have also been re-directed to constructed channels that now divert stormwater along alternative flow paths.

Creeks in the elevated undeveloped areas in North Arm Cove have been less impacted. The main impacts in undeveloped areas are associated with fire trails that cross the creeks blocking natural flow paths and contributing elevated loads of eroded sediment to these creeks.

The main overland flow paths and ephemeral creeks are shown in Figure 2-3.

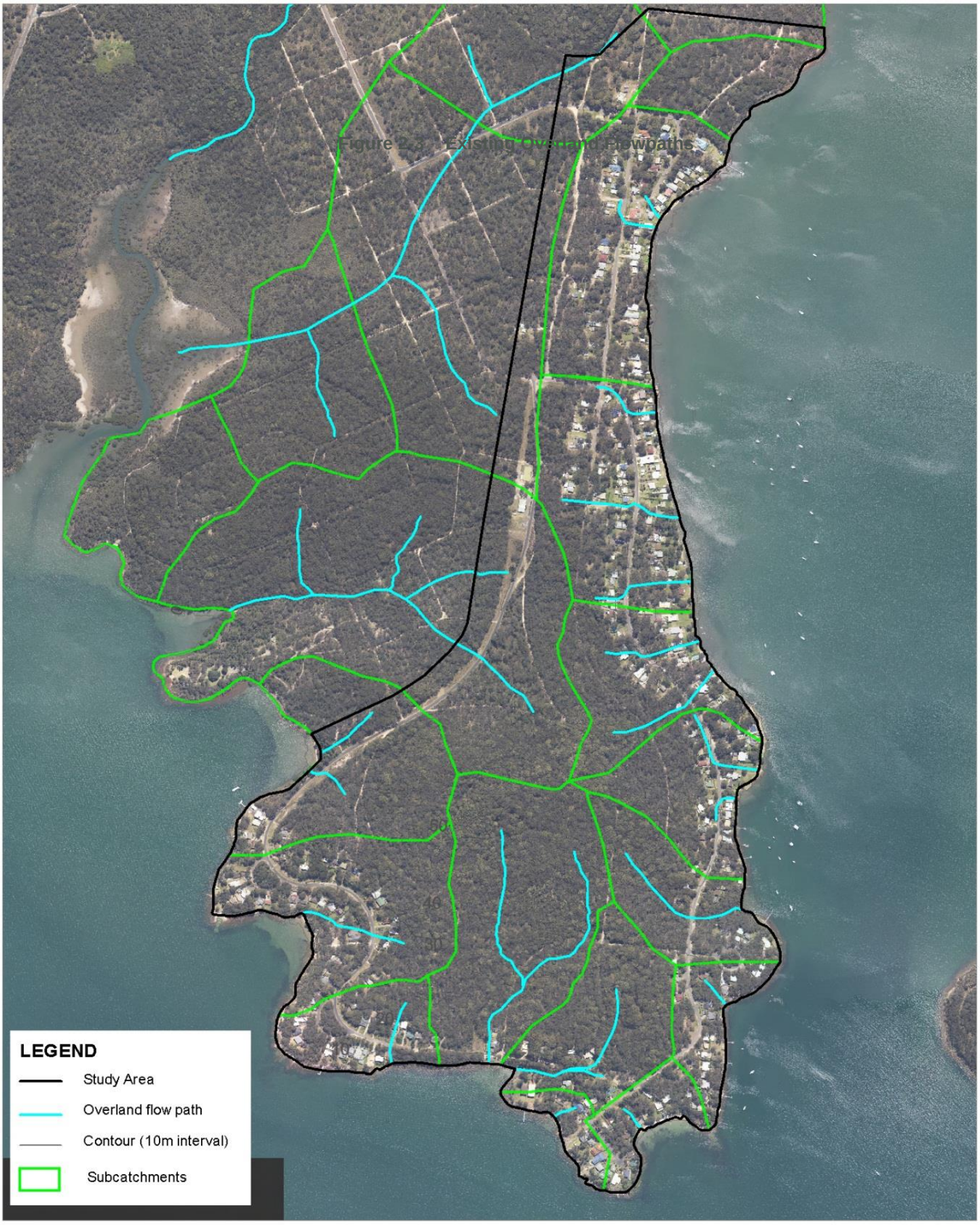

Figure 2-3 Existing Overland Flowpaths

Title:

Existing Overland Flow Paths

Figure: 2-3

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2.7 Receiving Environments

The Port Stephens estuary is the key receiving environment for stormwater runoff from North Arm Cove. The Port Stephens estuary contains diverse ecosystems that form the foundation of the coastal food chain. The estuary provides important habitats for a variety of marine and terrestrial plants and animals. Estuarine water quality is typically controlled by tidal flows and inputs from diffuse and point sources within the catchment. When compared to coastal lakes and lagoons, more efficient tidal flushing of estuaries assists with maintaining superior water quality. Although, reduced flushing of embayment areas (e.g. North Arm Cove) along the estuary can often result in comparatively lower water quality in those areas.

The northern parts of North Arm Cove are designated as Sanctuary Zones within the Port Stephens – Great Lakes Marine Park. Sanctuary Zones are areas within marine parks that are afforded the highest level of protection for habitats, animals and plants, and ecological processes. Any new development discharging water into Sanctuary Zones is required to have minimal impact on existing water quality.

In terms of water quality, larger water bodies such as the Port Stephens Estuary will generally be more detrimentally affected by turbidity (the presence of fine sediments) as opposed to coarse sediments. Preventing erosion should be a focus of stormwater management in North Arm Cove, with a goal to limit the discharge of fine particles into North Arm Cove. Designation of parts of the Cove as “Sanctuary Zones” also highlights the importance of controlling soil erosion within the North Arm Cove catchments.

North Arm Cove also includes a number of areas that have been designated as priority oyster aquaculture areas within the Oyster Industry Sustainable Aquaculture Strategy (NSW DPI, 2006). A number of these areas are currently actively managed for oyster aquaculture and would be susceptible to impacts from poor quality stormwater from existing and future development in North Arm Cove. The eastern side of the site drains to an embayment in North Arm Cove where oyster aquaculture currently occurs. The Oyster Industry Sustainable Aquaculture Strategy (NSW DPI, 2006) outlines that changes to the concentrations/levels of suspended solids (turbidity) have the greatest potential to impact on the healthy growth of oysters. Heavy metals and pH also strongly influence the health of oysters.

2.8 Future Development

Any future upslope development has the potential to exacerbate the existing issues under current drainage conditions. Increased impervious areas and flow diversions associated with further development could contribute to similar problems (to those currently occurring) arising at other locations across the study area.

3 Stormwater Management Issues

3.1 Overview

Existing stormwater management issues in North Arm Cove were identified following a review of Council's records, a drop-in session with the community and additional site inspections.

3.2 Site Specific Community Observations

Site specific stormwater management issues highlighted by community members in the drop-in session and in correspondence to Council are summarised in Table 3-1.

Table 3-1 Site Specific Community Observed Stormwater Management Issues

Location		Description
Street No.	Street Name	
-	Merriwa Boulevard	Erosion of the unsealed section of Merriwa Boulevard.
42	Eastslope Way	Stormwater observed to overtop the road near the intersection of Merriwa Boulevard and Eastslope Way and flow overland through 42 Eastslope Way during high rainfall events.
-	Water Street	Poor quality stormwater observed to flow down Water St from upper catchment areas.
-	Water Street	Stormwater flows fast down Water St.
-	Water Street	Water pools to a high depth around pit inlet on corner of Water St and Cove Boulevard.
-	Water Street	Open channel rock lining has dislodged and been deposited into the bay.
4	Cove Boulevard	Runoff from the road flows down, and has scoured parts of the driveway.
10	Cove Boulevard	Overland flow observed across the roadway and down the driveway. Observed scouring of driveway after rainfall events. Pit inlet across from property frequently blocked with organic debris.
34	Cove Boulevard	Stormwater observed to overtop the road in front of property. Mud and debris observed to wash into property.
44-54	Cove Boulevard	Road side drainage on upslope side of roadway is poorly defined and flow observed across the road and into properties.
70-72	Cove Boulevard	Overland flow through property. Pit inlet across from property regularly blocked with organic debris.
80-84	Cove Boulevard	Runoff from road flows overland into properties.
102-106	Cove Boulevard	Turbid stormwater flows overland across properties.
108-110	Cove Boulevard	Stormwater overtops open channel. Blockage to pipe crossings under driveways.
49	Point Circuit	Observed scouring of driveway after rainfall events.
33	The Esplanade	Overland flow through property. Erosion observed within property boundary and along roadway.

	Location	Description
91	Promontory Way	Runoff from road flows down driveway and overland across properties. Observed scouring of driveway.
131	Promontory Way	Culvert discharging runoff directly onto a property. Council is not believed to have a drainage easement through.

3.3 Village Observations

3.3.1 Community Safety

A number of existing stormwater pit inlet openings across the study area are too deep and would exceed standards introduced to restrict access to drainage systems by children. Four pit inlets were identified with openings ranging between 0.6m and 0.9m. During large rainfall events, the depth of stormwater able to pond around the pit inlets would be hazardous and particularly dangerous for children.

Figure 3-1 Example of hazardous pit inlet opening

Steep rock-lined open channels convey concentrated stormwater runoff through existing development at two locations in the existing North Arm Cove village. Flow velocity along these channels during large rainfall events would be significant and hazardous for the community. The velocity is sufficient to displace rock lining parts of the channels. Transport of the channel rock lining into foreshore areas frequently used by residents for recreational purposes (e.g. swimming) has been identified as a safety issue that is considered by the community to be particularly hazardous to small children.

3.3.2 Unsealed Roads

Unsealed fire trails traverse the undeveloped, upper catchment areas. The main streets within North Arm Cove are predominantly sealed, however some unsealed sections remain. The study area includes a number of unsealed roads that are susceptible to elevated erosion. Unsealed roads that are aligned steeply across the contours have a particularly high potential for erosion.

Erosion rills have typically formed along the steeper unsealed roads resulting in runoff becoming increasingly concentrated at these locations. Left unmitigated, deeper gullies form resulting in the roads becoming difficult to traffic which has implications for access particularly by the Rural Fire Service. During stormwater runoff events, eroded soil particles and gravels, entrained in stormwater settle in/near drainage structures or are discharged directly to the Cove in large

volume. Unsealed roads aligned along the contours and in gently grading areas are less susceptible to erosion.

Figure 3-2 highlights the different conditions of fire trails in the area when trails are aligned along contours (shallow gradients) or aligned across the contours (steep gradients).

Figure 3-2 Unsealed Fire Trails - aligned along contours (L) and across contours (R)

3.3.3 Surface Erosion

Erosion of catchment surfaces has resulted in sediment being conveyed along natural and formed drainage flow paths. Finer sediments that do not readily settle or are re-entrained in the flow are being drained through properties and along driveways prior to discharge into Port Stephens. Discharge of these finer sediments into North Arm Cove increases turbidity in the estuary.

The community has indicated that sediment and erosion controls in some residential dwelling construction sites are inadequate with sediment laden runoff being observed from a number of sites. This is believed to constitute a significant gap in Council's audit processes.

3.3.4 Table Drains

Shallow table drains (swales) are located adjacent to most sealed roads in North Arm Cove. These table drains have been formed to convey stormwater runoff adjacent to the roads during minor runoff events. The table drains are typically provided along the high side of each road or on both sides when roads are aligned across contours.

The size and shape of the table drains varies significantly throughout North Arm Cove and in some areas a defined table drain is missing resulting in stormwater flowing along the edge of the road. Some locations have appropriate cross fall to encourage drainage to upslope table drains. In other locations, the cross fall is conducive to stormwater flowing across the road (e.g. parts of Eastslope Way and Cove Boulevard).

The current condition of table drains across the site is highly variable. Table drains are lined alternatively with concrete, maintained grass, heavy vegetation, rocks or bedrock.

3.3.5 Driveway Crossings

Driveway crossings typically form the key controls and consequently points of weakness, for flow along the table drains. A number of driveway crossings in North Arm Cove grade directly up from the edge of the road to achieve access into properties located on the steeper high side of the road.

This has resulted in a number of driveways functioning like small dams and diversions, significantly impeding the flow of stormwater. Stormwater backs up behind the driveway crossings at a number of locations, and spills across the road into properties located on the low side of the road. An example driveway is shown in Figure 3-3.

Figure 3-3 Example of Elevated Driveway Crossing

The size of pipe crossings under driveways was also observed to vary significantly. At a number of locations the pipe crossing invert is elevated above the adjacent table drain resulting in shallow ponding of stormwater on the high side of the driveway. This appears to have occurred mainly as a result of poor construction control. However, over excavation of the drains during maintenance has in places caused stagnant water to pool behind driveways encouraging mosquito breeding habitat.

3.3.6 Organic Debris

Organic debris comprising tree branches, sticks and leaves are present in significant quantities throughout the study area due to the large proportion of remnant vegetation (Eucalyptus, Corymbria and Allocasuarina spp.) across the village. Debris material has tended to accumulate in table drains and around drainage inlets leading to significant capacity reductions. Debris load is recognised as a function of normal seasonal cycles as well as droughts and wet periods.

Stormwater conveys organic debris along flow paths where it becomes trapped and accumulates at flow constriction locations. Blockage to table drains, piped driveway crossings, pit inlets, pipes and culverts prevents the efficient flow of stormwater. This has resulted in stormwater being re-directed overland across roadways and into private properties at specific locations.

3.4 Site Observations

3.4.1 Site 1 – Eastslope Way between Merriwa Boulevard and Casuarina Park

This site includes sections of Merriwa Boulevard and Eastslope Way. The key stormwater management issues for this site are shown on and discussed below and shown on Figure 3-16.

At this site, Merriwa Boulevard is currently unsealed. The section of road is steep for a regularly trafficked unsealed road and this is contributing to erosion of the road surface. Vegetated table

drains direct surface runoff to the stormwater pit located on the corner of Eastslope Way and Merriwa Boulevard. The existing pit inlet opening height exceeds standards developed to ensure safety to the community and current arrangements are considered to be particularly hazardous for children.

Surface flow that exceeds the capacity of the pit overtops Merriwa Boulevard near the intersection with Eastslope Way and is conveyed south along a table drain formed on the high side of Eastslope Way. Drainage along the table drain is currently impeded by driveway crossings that are elevated above the adjacent road level. This has resulted in stormwater backing up behind driveways during significant runoff events, prior to overtopping Eastslope Way and draining through downslope properties. The community has advised that the impacts have been concentrated in 42 Eastslope Way and adjacent properties.

The existing drainage infrastructure in place across from Casuarina Park is significant, with multiple pit inlets and pipes. The current configuration of driveway crossings upslope of this drainage system minimises the volume of stormwater that drains to this system. A 900mm diameter pipe discharges stormwater from this drainage line into Casuarina Park.

3.4.2 Site 2a – 10 Cove Boulevard

This site occupies a section of Cove Boulevard north of Water Street. It includes a drainage line that discharges stormwater runoff into North Arm Cove through 10 Cove Boulevard. The key stormwater management issues for this site are shown on Figure 3-17 and discussed below.

Construction of a driveway associated with a new dwelling in the property opposite 10 Cove Boulevard has limited the stormwater flowing to a new stormwater inlet. The drainage inlet is connected to a piped drainage system through 10 Cove Boulevard. The pipe within 10 Cove Boulevard has been inspected by Council. The pipe is butt jointed which enables water to seep in through gaps at the joints. Recent CCTV inspection by GLC has confirmed that the pipe was not blocked, broken or excessively deflected at the time of this inspection.

The constructed driveway causes stormwater to back up the table drain effectively diverting most flows across the road. Smaller flows conveyed within the table drain upslope of the driveway are able to drain through the driveway crossing, but even modest flows are re-directed across the road. Re-directed stormwater flows down a relatively steep unsealed driveway in 10 Cove Boulevard. The owner has indicated that the driveway has been scoured by uncontrolled stormwater, necessitating reconstruction of the driveway on several occasions. Overland flow through this property then drains into North Arm Cove.

Figure 3-4 New Drainage Inlet Opposite 10 Cove Boulevard

3.4.3 Site 2b – Water Street

Water Street forms a key drainage flow path to North Arm Cove. The drainage system along Water Street has recently been reconstructed including formation of partially concrete lined table drains, new driveway crossings, new culverts and rock lined open channels. Residents have reported an improvement in drainage along the upper half of Water Street since the completion of the new drainage works. Examples of the new works in the upper half of Water Street are shown in Figure 3-5.

Figure 3-5 New Works in Upper Water Street

The main issue with the new works in the upper section is that the steep table drains are likely to require regular inspections to ensure that the integrity of the concrete lining is maintained and the drains are not eroded over time. Runoff from an existing unsealed track upslope of the new works also contributes elevated levels of sediment discharged into North Arm Cove.

The inlet opening to the piped drainage system under Cove Boulevard exceeds standards developed to ensure safety to the community. In particular, the current situation is considered to be ***extremely*** hazardous for children.

Figure 3-6 Drainage Inlet near Cove Boulevard / Water Street Intersection

The lower section of the drainage system along Water Street below Cove Boulevard comprises three sections of new rock-lined channel separated by culverts under Water Street and a driveway crossing. Site observations indicate that the rock lining has been placed unevenly and may be insufficiently sized for the flow velocities along the channel. The lower section of the channel below the driveway crossing appears to have been constructed with a face angle that is too steep to maintain stability of the rock lining. Combined with the small rock size, this has resulted in parts of the channel rock lining collapsing and the liner protecting the bare channel sides also dropping into the channel (refer Figure 3-8). The banks in this lower area are now highly susceptible to erosion from stormwater and tidal movements and eroded sections of the channel are suspected of encroaching on the adjacent private property.

Rock lining dislodged and discharged into the foreshore area is considered hazardous by the community who use this area for launching dinghies and for children to swim. The community has suggested that the concentrated stormwater discharge has seriously impacted on sea grasses in the area.

Figure 3-7 Upper and Middle Open Channel Reaches (looking upslope)

Figure 3-8 Lower Reach - undercutting of rock lining

Site 2c – 49 Cove Boulevard to Water Street. A number of residents have observed runoff discharging across the road near the existing road crest in front of 49 Cove Boulevard. Residents have also indicated that seepage continues across the road for several days after conclusion of significant wet weather. The runoff then drains into properties on the low side of Cove Boulevard causing nuisance to residents in these lots. There is currently no table drain or other drainage system on the high side of Cove Boulevard to intercept this runoff before it overtops the road. The adverse road cross fall also leads to runoff being directed into the low side lots.

It appears that the construction of Cove Boulevard at this location is functioning similarly to a dam, restricting the flow of shallow groundwater in a direction towards North Arm Cove. Shallow ground water is potentially backing up behind the road pavement prior to resurfacing and flowing across the road. Driveways are also regarded as preferential paths for runoff and the longer term seepage. This shallow seepage groundwater continues to flow slowly down the slope for several days after rain. The road pavement has deteriorated at this location, providing further evidence that sub-surface water potentially may be weakening the pavement.

Figure 3-9 Existing Road Condition Near 49 Cove Boulevard

3.4.4 Site 3a – 70 Cove Boulevard

An existing drainage structure is located at a low point on the high side of the road opposite 70 Cove Boulevard. This drainage structure appears to be in poor condition and the size of the opening exceeds standards and is considered to be ***extremely*** hazardous to the community. The pit discharges to a 900mm diameter concrete pipe that drains into 70 Cove Boulevard adjacent to the boundary and conveys runoff to North Arm Cove. Unfortunately, the 900mm diameter pipe reduces to a 500mm diameter uPVC pipe at a drainage pit located within 70 Cove Boulevard. This pipe is located of 70 Cove.

The drainage line transition from a 900mm to 500mm diameter pipe creates a potential choke point in this system, where larger debris able to enter the pipe through the existing large inlet (refer Figure 3-10) potentially can become blocked at the inlet to the 500mm diameter pipe. Ensuring large debris does not enter the 900mm diameter pipe is important for maintaining the integrity of this system. The pipe size reduction also encourages system overflows based on downstream capacity alone.

Residents have recorded that the pit inlet across from 70 Cove Boulevard can become blocked with organic debris during rainfall events. When the pit inlet becomes blocked, or the capacity of the downslope drainage system is exceeded, stormwater over tops the road and drains overland through 70 Cove Boulevard.

Figure 3-10 Drainage Inlet Opposite 70 Cove Boulevard

3.4.5 Site 3b – 80-84 Cove Boulevard

An existing significant natural overland flow path discharges through 79 Cove Boulevard and onwards into the Cove Boulevard Road reserve. The catchment for this overland flow path is shown in Figure 3-19. Currently there is no table drain or other drainage system to intercept this flow on the high side of the road. This results in the overland flow spilling across Cove Boulevard. Residents have observed stormwater overtopping the road crest at this location, and draining into 80-84 Cove Boulevard on the low side of the road damaging driveways and causing nuisance to the owners.

3.4.6 Site 3c - 102-110 Cove Boulevard

Drainage in this area is primarily influenced by table drains located on the high side of the road. These table drains have been constructed to convey stormwater runoff to an existing drainage pit opposite 108 Cove Boulevard. This drainage pit is connected to a pipe that conveys stormwater across Cove Boulevard and discharges into a steep rock lined channel aligned along the southern boundary of 108 Cove Boulevard. The existing drainage pit inlet opening exceeds standards and would be hazardous for the community. The rock-lined channel is steep and would also be hazardous to the community. The rock lining is collapsing in areas and the channel actively eroding due to high velocity flows. Rocks are also being dislodged and conveyed by fast flowing stormwater into North Arm Cove. The current condition of the drainage pit and rock lined channel is shown in Figure 3-11.

Figure 3-11 Drainage Inlet Opposite 108 Cove Boulevard and Rock Lined Channel

Video footage taken by residents during the March 2013 event shows that a significant proportion of runoff draining from the north overtopped the road opposite 104 Cove Boulevard and drained overland through this lot prior to reaching the drainage pit opposite 108 Cove Boulevard. The overland flow was highly turbid. Residents also observed runoff draining from the south spilling across the road near 99 Cove Boulevard and draining overland towards 110 Cove Boulevard.

The drainage pit opposite 108 Cove Boulevard is not located at the natural low point which is closer to 104 Cove Boulevard. Whilst the table drains have been graded to force the low point to 108 Cove Boulevard, during high runoff events the existing piped driveway crossings impede these flows. Runoff backs up behind the driveway crossings and then overtops the road opposite 104 Cove Boulevard prior to draining overland through this lot.

Stormwater runoff from the north is significantly impeded during large events by the existing driveway access to 99 Cove Boulevard. Runoff backs up behind the driveway prior to overtopping

the road in front of 110 Cove Boulevard. A temporary sand bag barrier and raised bitumen bund have been formed along the low side of the road in front of 110 Cove Boulevard to divert overland flow away from this property towards the steep rock lined channel along the boundary of 108 Cove Boulevard.

3.4.1 Site 4a – 33 The Esplanade

The residential development within 33 The Esplanade has resulted in an ephemeral watercourse being filled and the land regrading/landscaping. Whilst the ephemeral watercourse has been filled in, the property remains a key overland flow path for runoff draining along the remaining ephemeral watercourse tributaries located upstream of the property. Preliminary flooding extents for the 100 year ARI event are shown in Figure 3-22.

The recent significant runoff event in March 2013 resulted in high velocity and deep overland flow through the property causing damage to the landscaped areas. The property owner advised that some of the damaged landscaping areas were replaced with harder concrete lined sections to reduce damage occurring in future events (refer Figure 3-12).

A concrete lined causeway is located at the end of The Esplanade adjacent to the site (refer Figure 3-12). The community has identified potential hazardous conditions during large rainfall events associated with flow over this causeway. There is potential that the depth and velocity of stormwater discharging to the foreshore will be a safety hazard, especially to young children as the site provides public access to the waterfront. Similar hazards are likely to exist within the property upslope of the causeway.

Figure 3-12 Existing Concrete Lined Overland Flowpath and Causeway at 33 The Esplanade

It is considered that similar overland flow events are likely to occur on a relatively regular basis. We understand that the dwelling on this site was recently constructed and that there is currently no

intention to modify the use of the land. It will be important that any strategy developed for this land recognises the existing flooding potential, and potential for this to be exacerbated if the catchment upstream is modified. It will be important that flooding risks for this property are registered on a planning certificate for the property to ensure that future purchasers are aware of the risk.

3.4.2 Site 4b – 51 The Esplanade

The Esplanade is a narrow unsealed road with a deep table drain formed on the northern side of the road at this site. An earth lined swale along the southern side of the road conveys stormwater into the remnant waterway. Culverts connect the table drain to the swale.

A significantly large undeveloped catchment drains along a flow path that crosses the driveway access to 51 The Esplanade. The property owner has advised this has resulted in regular stormwater damage to the driveway and nuisance due to the driveway access to the property being impeded by the overland flows. Only very small flows are capable of being conveyed under the driveway through a 375mm diameter pipe into an adjacent table drain.

Figure 3-13 Northern Table Drain and Driveway Access to 51 The Esplanade

The existing table drain and culverts located on the northern side of The Esplanade adjacent to the property are not currently functioning efficiently. Stormwater overtopping the driveway access would currently primarily flow across The Esplanade into the drainage swale on the southern side. A high proportion of the overland flow would currently bypass the existing table drain.

The drainage culverts discharging from this table drain are not aligned well and would be hydraulically inefficient at conveying stormwater to the swale on the opposite side of the road. Any changes to the drainage that would increase flows to the table drain would require consideration of modifications to the table drain grading and culvert alignments to improve the hydraulics.

The table drain is currently relatively deep and level between culverts which has led to accumulation of organic debris, ponding of stormwater and associated creation of mosquito breeding habitat.

3.4.3 Site 5a – 91 Promontory Way

An existing drainage pit is located at a low point on the high side of the road opposite 91 Promontory Way. A second pit is located on the low side of Promontory Way. The low side of Promontory Way has a raised roadside kerb that directs runoff down along the road to the low side pit; this can be seen in Figure 3-14. The two pits discharge into a 525mm diameter concrete pipe that drains between 91 and 93 Promontory Way conveying runoff into Port Stephens.

The residents at 91 Promontory Way have advised Council that there are continuing issues with the drainage at this location. Residents have reported that during any rain event runoff washes parts of their gravel driveway away. During a recent large storm this drainage issue resulted in internally flooding of their garage. The raised kerb on the low side of Promontory Way stops at the boundary between 89 and 91 and appears to result in runoff from the road draining onto the residents driveway, a flow path from the road through to the residents driveway can be seen in Figure 3-14. This combined with excess water overflowing from the drainage pit and flowing through 91 Promontory Way has resulting in scouring of the driveway.

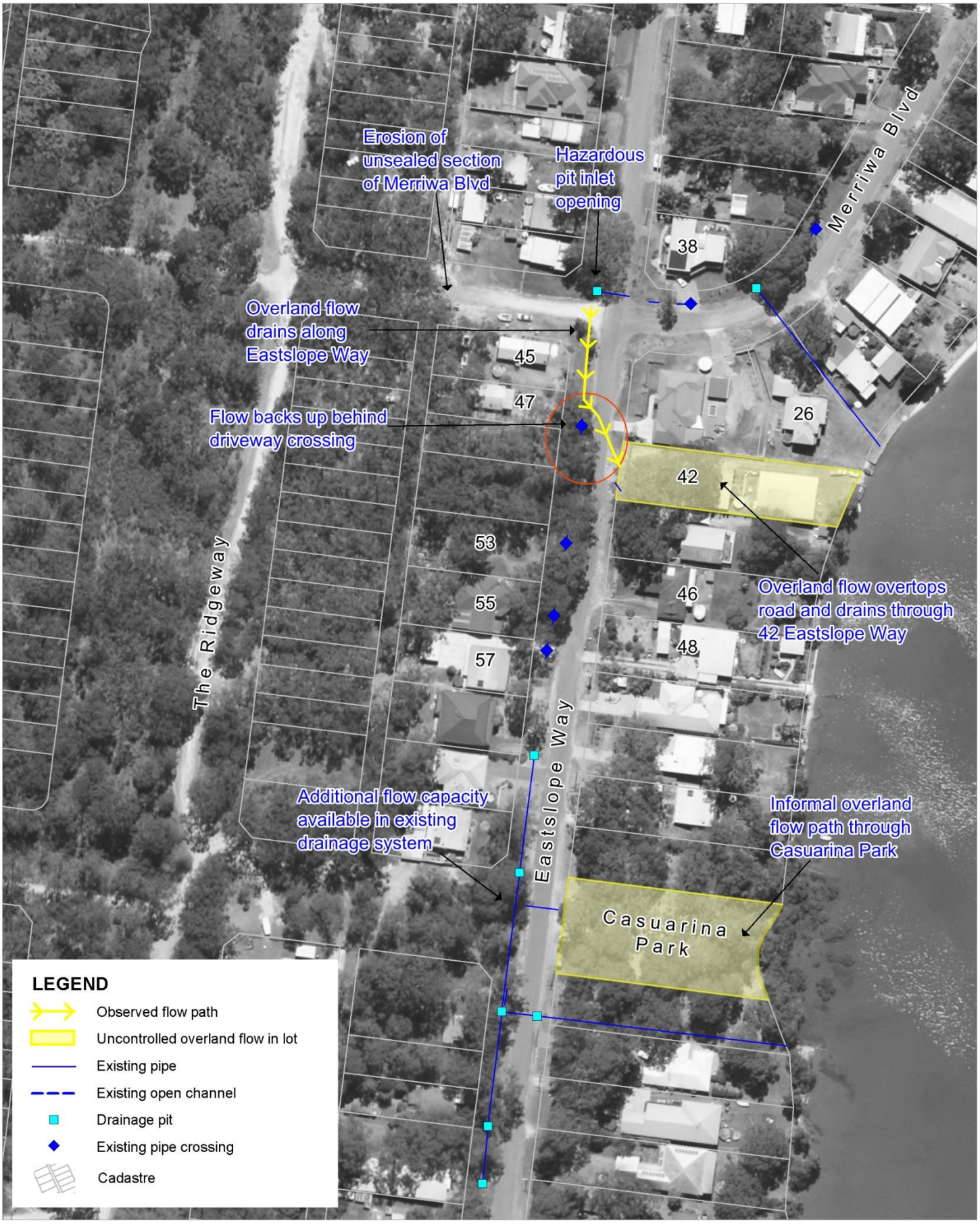
Figure 3-14 Raised Roadside Kerb and Resulting Overland Flow Path at 91 Promontory Way

Figure 3-15 Scouring of Driveway at 91 Promontory Way as a result of Stormwater Runoff

3.4.4 Site 5b – 131 Promontory Way

A stormwater drainage pit located on the high side of the road opposite 131 Promontory Way is diverting stormwater runoff under the road and discharging directly onto the currently vacant lot. This issue has not been raised as a problem in the past as the lot is vacant and does not have any buildings on it. However, development of the lot is being considered and a request for Council to address the issue has been made. No existing drainage easement is believed to be held by Council to drain runoff through 131 Promontory Way. There is also no defined overland flow path through the lot.

Additionally, runoff from the low side of the road appears to have previously been draining down driveways towards resident's houses. As a result, some driveways have small speed-bump style kerbs across the entrance to their driveways to direct the water down along the road. This results in most of the runoff draining through 131 Promontory Way.



Title:
Site 1 - Existing Stormwater Management Issues

Figure: **3-16**

Rev: **A**

N

0 m 37.5 m 75 m

Approx. Scale

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Title:

Sites 2a, 2b and 2c - Existing Stormwater Management Issues

Figure: **3-17**

Rev: **A**

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Approx. Scale

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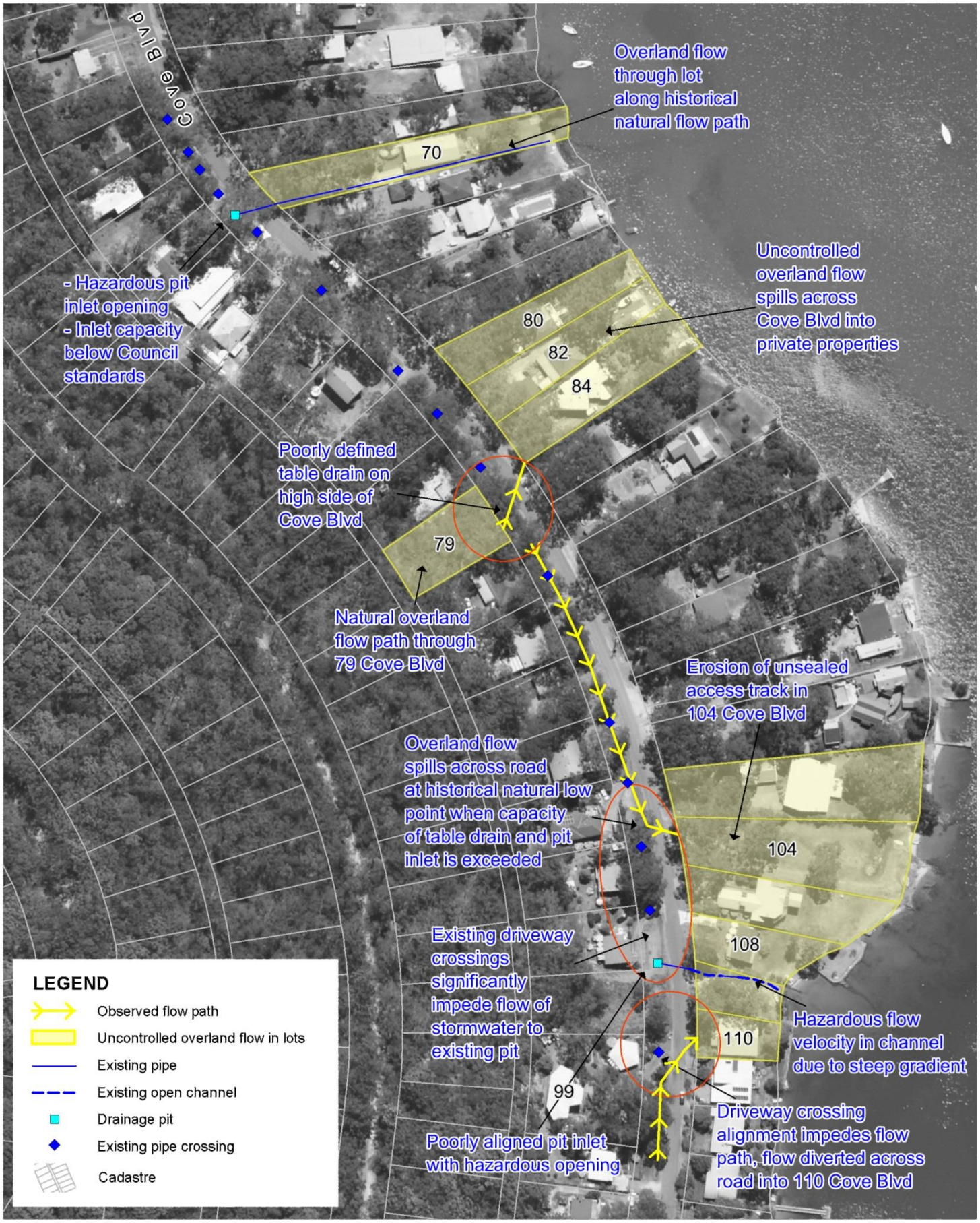

Title:

Sites 3a, 3b and 3c - Existing Stormwater Management Issues

Figure: **3-18**

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Approx. Scale

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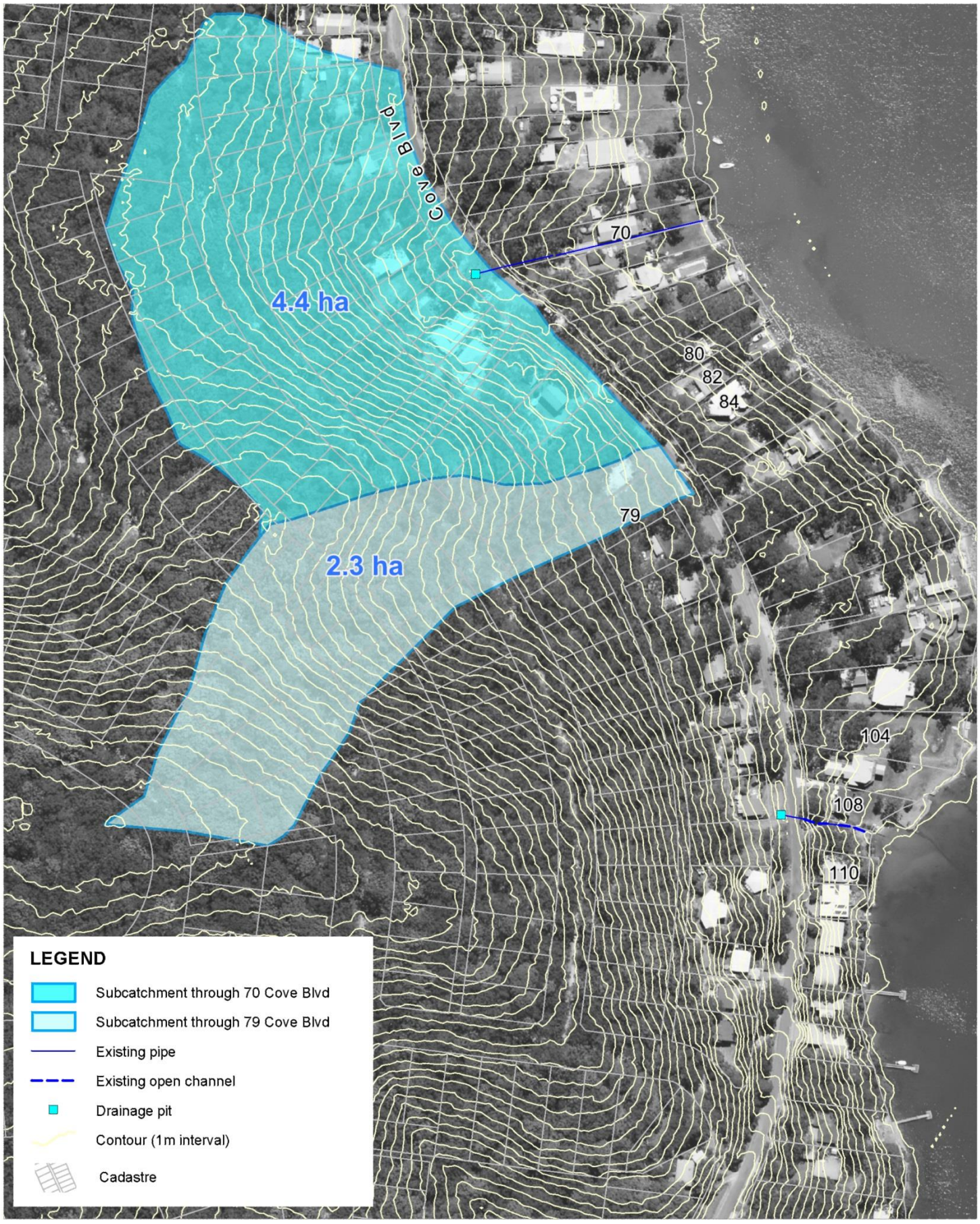

Title:

Overland Flow Catchment Through 79 Cove Blvd

Figure: **3-19**

Rev: **A**

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0 50 100m

Approx. Scale

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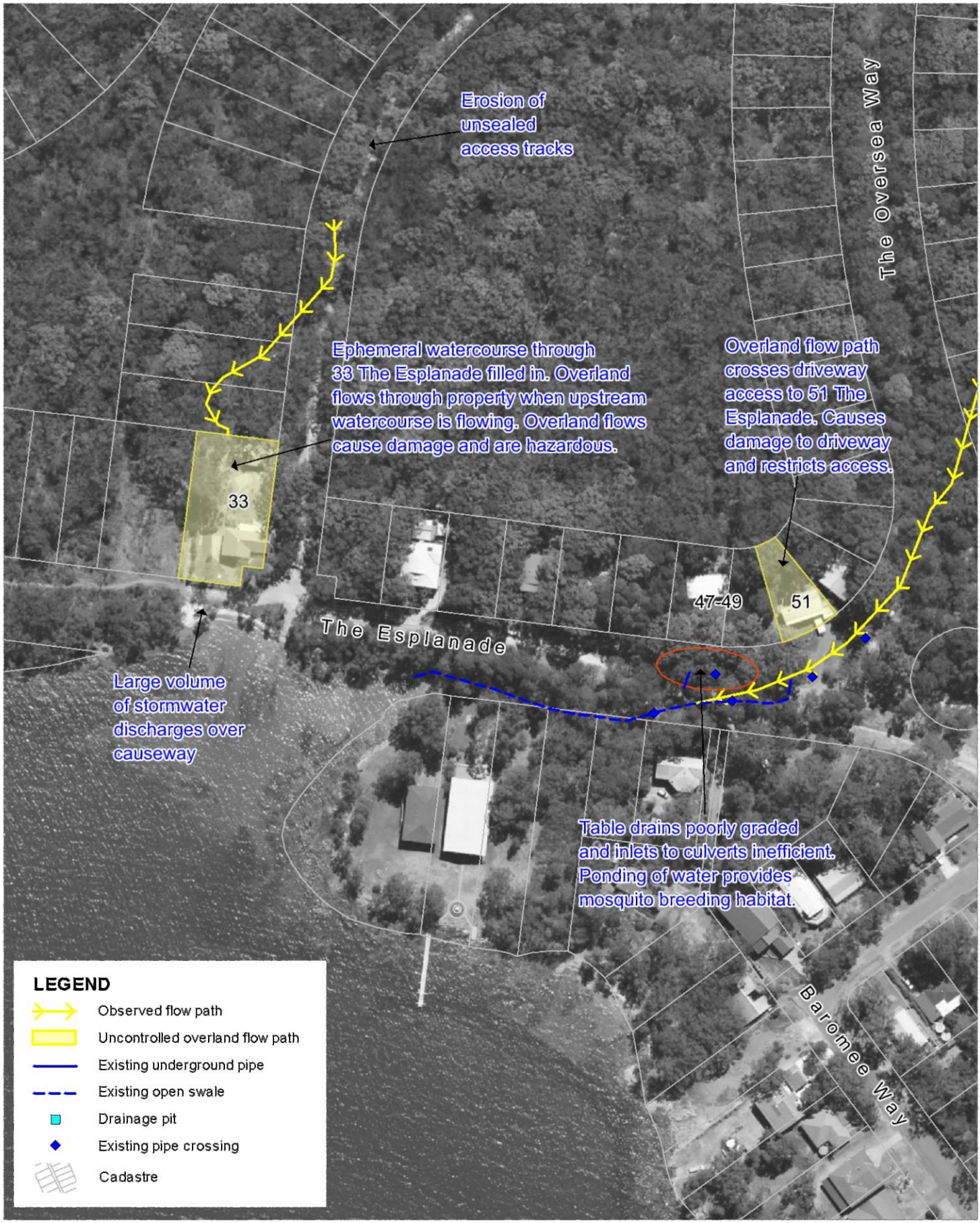

Title:

Sites 4a and 4b - Existing Stormwater Management Issues

Figure: **3-20**

Rev: **A**

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0 m 37.5 m 75 m

Approx. Scale

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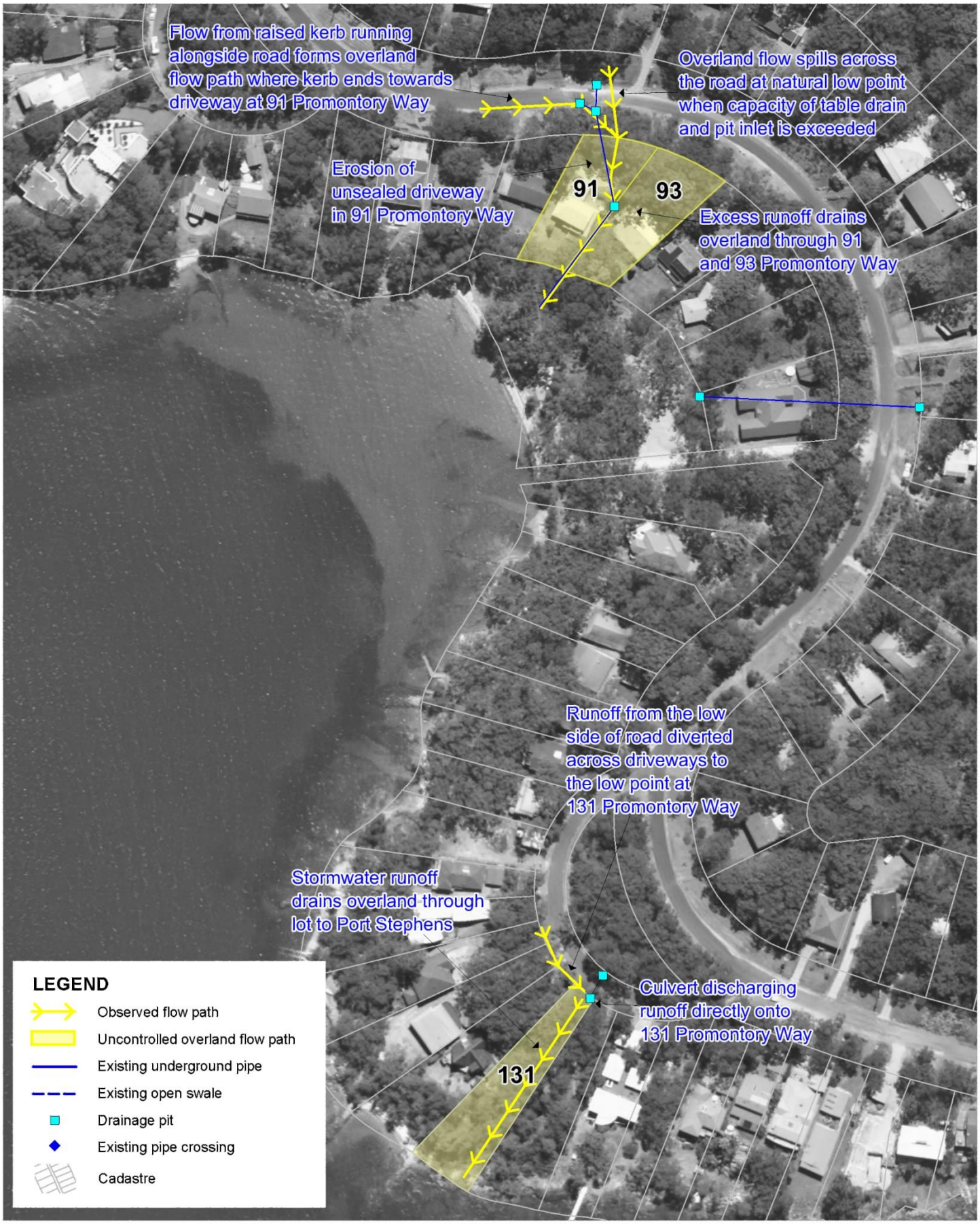

Title:

Sites 5a and 5b - Existing Stormwater Management Issues

Figure: **3-21**

Rev: **A**

N

0 m 37.5 m 75 m

Approx. Scale

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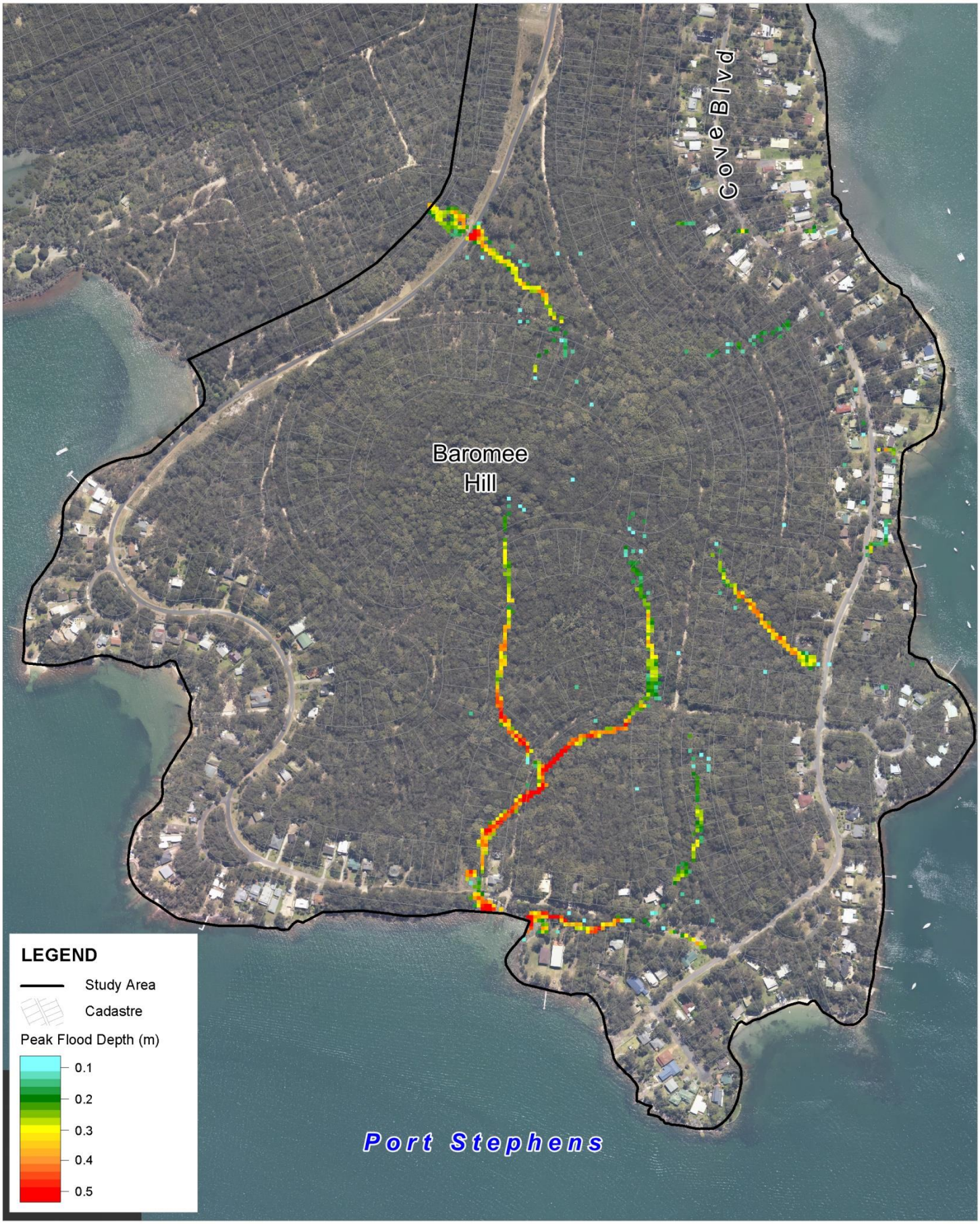

Title:

Preliminary 100 Year ARI Flooding Extents

Figure: 3-22

Rev: A

N

0 125 250m

Approx. Scale

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4 Short Term Actions

4.1 Overview

The North Arm Cove Stormwater Management Plan comprises two main components, short term actions and a long term actions. The short term actions include recommended measures to address existing stormwater management issues within North Arm Cove. The long term actions include measures for consideration if development were to proceed in undeveloped areas of North Arm Cove.

The short term stormwater management actions for North Arm Cove are discussed below and the long term actions are discussed in Section 5. The short term actions are described below under the following broad categories:

- ***Village actions*** – Actions to address stormwater management issues that are widely distributed throughout existing development in North Arm Cove. A number of these actions will require further targeted investigations to confirm all locations where intervention will be beneficial. The village actions include a range of structural and non-structural measures.
- ***Site actions*** – Actions to address stormwater management issues at specific high priority sites identified by the community, Council and BMT WBM. Concepts have been developed for each of these sites for consideration.

Individual actions within each of these categories are discussed in the following sections.

4.2 Village Actions

4.2.1 Community Liaison and Education

It is recommended that Council prepares and distributes concise information to the community describing existing stormwater and flooding behaviour within North Arm Cove and identifying the key risks. This information could be conveyed in the form of a fact sheet (or series of fact sheets) or a web page. This information should also outline the community's responsibilities in avoiding exacerbating existing stormwater and flooding issues and how the community can increase their preparedness for flooding. It is recommended that the community education initially focuses on the following key issues:

- Ensuring the safety of the community (particularly children and less mobile residents) during significant wet weather events where overland flows, high velocity open drain flows and large drainage inlets increase hazards for the community.
- A plan and description of the existing drainage system in North Arm Cove that outlines how the system currently functions, the current limitations and higher hazard areas.
- Information on any new initiatives where the community can assist in improving management of stormwater within the village (e.g. monitoring and clearing debris in table drains, monitoring of stormwater drainage infrastructure blockages).
- Confirm with private property owners their responsibility to accept runoff that naturally flows onto their land or accumulates within natural topographical depressions without redirecting these flows to adjacent property owners by means of drainage swales or bunds. Highlight that

unapproved drainage works whilst temporarily solving one problem may exacerbate problems for adjacent or downslope residents. Such diversions may also attract civil litigation.

- Provide advice on how individual property owners can improve the management of stormwater within their existing lots (e.g. diverting flow from driveways to pervious vegetated areas; rain gardens to treat paved area runoff; and overflow from rainwater tanks).
- Ensure the community is aware of the need to gain approval from Council for the construction of driveway crossings, drains or any other works within the public land. Outline the problems caused particularly by poorly constructed (from a drainage perspective) driveway crossings.

4.2.2 Reduce Erosion of Unsealed Roads

Steep unsealed fire trails in undeveloped areas should be regraded to remove deep rills and provide one way crossfall. It is recommended that low contour banks ('whoa boys') be aligned across the road to direct runoff laterally into tailout drains that discharge into the existing bushland.

The design, spacing and location of the 'whoa boys' and tailout drains should be confirmed from the Unsealed Roads Manual published by ARRB. Guidelines published by the NSW Rural Fire Service should also be utilised and the NSW RFS consulted with to confirm appropriate intervention actions. An example arrangement for a 'whoa boy' is shown in Figure 4-1.

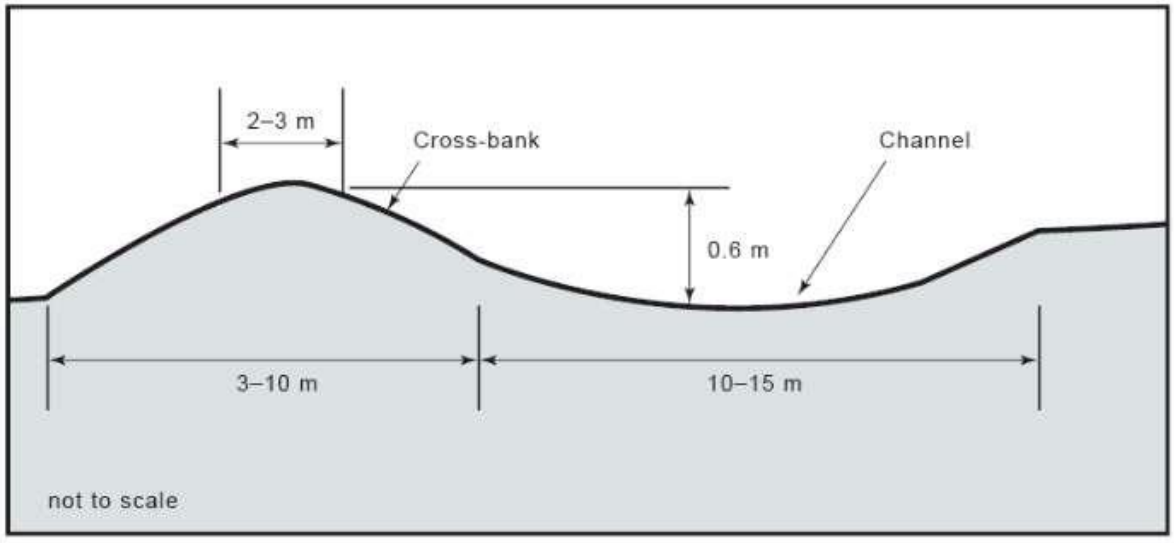


Figure 4-1 Example 'Whoa Boy' (Diversions Berm) (OEH, 2012)

Intervention actions are recommended in Section 4.3 to reduce erosion along specific section of unsealed roads in the developed areas.

4.2.3 Improved Sediment and Erosion Control for Construction Sites

The community has raised concerns with the lack of erosion and sediment controls provided in some building sites in North Arm Cove that has resulted in sediment being conveyed through the drainage system into North Arm Cove.

It is strongly recommended that Council increase surveillance of building sites to ensure that builders are complying with Council's sediment and erosion control requirements for construction sites. It is further recommended that builders be required to erect a sign at the road boundary of

the building site advising the community to contact Council in the case of any concerns with the erosion and sediment control practices at the site.

4.2.4 Drainage Pipe Inspections

It is recommended that Council consider completing CCTV inspections of all larger drainage pipes and culverts that discharge into North Arm Cove to ensure that the pipes are not blocked, damaged or out of alignment. A priority drainage line for inspection is the system through 70 Cove Boulevard.

4.2.5 Drainage Pit Inlet Inspections

It is recommended that Council inspect each public drainage pit inlet and confirm whether the inlets comply with current Council and/or Australian Standards as well as a general public safety context. Where inlets do not comply, it is recommended that the inlets be modified to ensure they are compliant. Inlets not complying on safety grounds should be a high priority for upgrade.

It is considered that in advance of construction works to modify the pits, the height of openings to minor drainage systems should be limited to 0.15m to prevent children from entering the pits. This could be achieved by retrofitting horizontal bars across the openings. It is recommended that Council consider replacing concrete pit covers with hinged grates to increase the drainage inlet capacity and improve access and maintainability.

Specific locations identified in the preparation of this plan where drainage inlets are recommended to be modified are described in Section 4.3. Note that other pits throughout the village may also require modification to improve safety.

4.2.6 Improve Maintenance of Table Drains

Heavily vegetated road sides throughout North Arm Cove produces significant leaf and branch drop into table drains. Build-up of this organic debris over time combined with irregular maintenance often results in drainage inlets blocking rapidly when runoff events occur. This has led to elevated, concentrated and uncontrolled overland flows occurring downslope of these inlets thus increasing flows through private properties. The following actions are recommended to reduce the potential for the inlets to become blocked and subsequently reduce the frequency of uncontrolled overland flows through private properties:

- Community Green Waste Bins - Provision of community green waste bins along the roads is recommended to assist with the removal of organic debris from table drains. Key locations for bins should be adjacent to the debris barriers near key drainage inlets, but outside of potential overland flow paths. It is recommended that Council engage with the community to identify people who can assist with monitoring and occasionally clearing organic debris loads from the swales and debris barriers.
- Debris Barriers – It is recommended that vertical log debris barriers be positioned within existing table drains immediately upslope of major drainage inlets to intercept organic debris. A debris barrier concept sketch is presented in Figure 4-2. The locations of the debris barriers should be co-ordinated with locations of community green waste bins.

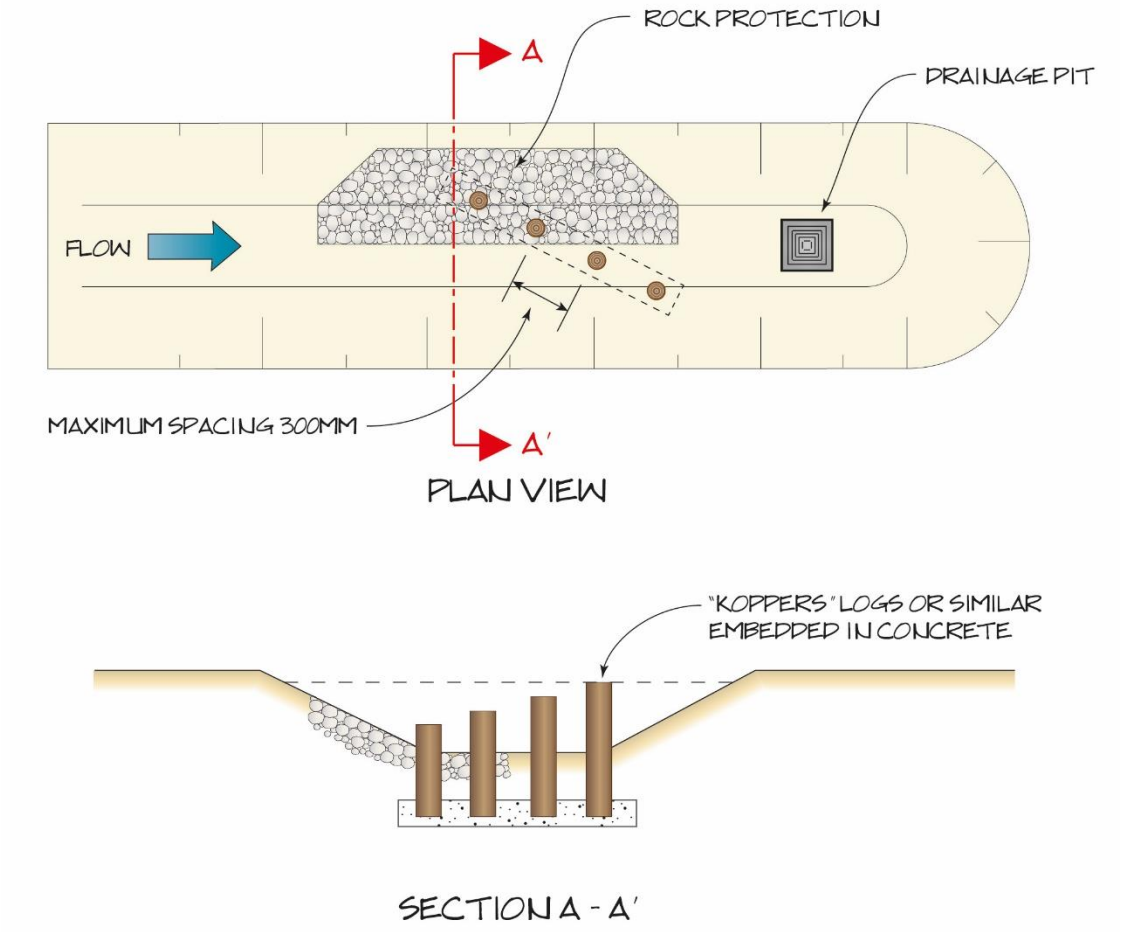


Figure 4-2 Debris Barrier Concept Sketch – Plan and Section A-A

- Table Drain Modification – Machinery clearing of table drains in North Arm Cove has resulted in drains becoming progressively deeper with steeper side slopes in some areas. It is recommended that Council investigate and trial options to stabilise the base of the table drains to reduce weed growth, prevent over excavation during maintenance and reduce maintenance requirements. Rationalisation of the size of the table drains should also be undertaken at this stage to minimise the width and depth of table drains. Council has previously lined the base of table drains in parts of Forster to prevent over clearing during maintenance and a similar approach may be effective here. The base of newly constructed drains in Water Street have also been stabilised with concrete. It is recommended that Council monitor how these drains perform in the short term.

4.2.7 Driveway Crossing Audit

Consultation with the community and site observations across the study area has identified that a number of driveway crossings and private lot access driveways appear not to comply with Council's current driveway crossing policy and standards. A number of driveway crossings providing access to properties on the upslope side of the road have been observed to significantly impede flow along the table drains and at times, re-direct flow across the road. It is recommended that Council complete an audit of driveway crossings to confirm the locations of non-complying driveway

crossings where the crossing adversely interferes with stormwater flows. Non-complying crossings should be individually assessed to confirm if any modification is required to improve stormwater flows.

Driveway crossings at sites where it has been identified that stormwater flows have been impeded resulting in nuisance flooding for adjacent properties are discussed in Section 4.3.

4.2.8 Update Stormwater Assets Register

A number of drainage structures within North Arm Cove have been surveyed in the preparation of this plan. It is recommended that Council complete field investigations, survey and condition assessments for all public stormwater management assets (including table drains) in North Arm Cove.

This information should be utilised to update Council's current stormwater assets register and associated GIS data to ensure that it is current and can be utilised effectively for asset management purposes.

4.3 Site Actions

4.3.1 Site 1 – Eastslope Way between Merriwa Boulevard and Casuarina Park

The recommended site actions for Site 1 are shown on Figure 4-3 and described in further detail below.

Sealing of the steep section of Merriwa Boulevard between The Ridgeway and Eastslope Way is recommended to reduce erosion and improve runoff quality. A stabilised table drain should be formed along the northern side of the road to direct runoff to the existing drainage pit. Provision of one-way crossfall on the new sealed section road should assist to reduce scouring of the road edge that is currently occurring adjacent to this road.

It is recommended that the existing drainage pit at the intersection of Merriwa Boulevard and Eastslope Way be modified. The existing pit has an inlet opening height that exceeds standard requirements. It is recommended that height of the inlet be reduced, the size of the pit increased and a hinged grate added to compensate for the likely loss of capacity associated with reducing the inlet height. Debris barriers are recommended to be considered adjacent to the pit to intercept vegetation and other large debris.

When the capacity of the drainage pit at the Merriwa Boulevard and Eastslope Way intersection is exceeded, overland flow drains to the south along Eastslope Way. It appears that the original intention of the drainage system in this area was for overland flow to be conveyed along the western side of Eastslope Way to drainage pits located further south.

The integrity of this system has been compromised by constructed driveway crossings that significantly impede flow along the table drain. As a result, runoff during significant events currently backs up behind a driveway crossing at 47 Eastslope Way prior to overtopping the road and draining through properties on the downslope side of the road. The network of pits and pipes located further south along Eastslope Way and through Casuarina Park are therefore oversized for the stormwater that currently drains to these locations.

The stormwater management actions for this site aim to contain overland flow within the road reserve of Eastslope Way prior to discharge into North Arm Cove through Casuarina Park. Improving conveyance along the table drain on the upslope side of Eastslope Way to direct overland flow into the existing underutilised drainage network across from Casuarina Park was considered.

It is recommended that the unsealed driveway crossing at 47 Eastslope Way be lowered to initially improve drainage to the south along Eastslope Way. As a number of driveway crossings between 53 Eastslope Way and the existing piped drainage system near Casuarina Park significantly impede flow, the realisation of this option relies on reconstruction of multiple paved driveways to ensure the current issue is not simply relocated downslope. This option was considered but would be more costly for Council to fund all the associated works. The recommended action involves construction of kerb and gutter on the downslope side of Eastslope Way with provision for new vehicle crossings. The kerb and gutter would only function during larger events similar to the March 2013 event to direct overland flows away from private property on the eastern side of Eastslope Way.

The recommended actions would direct overland flows away from private lots to the Casuarina Park public reserve. A level spreader is recommended to distribute runoff as sheet flow through the park during high flow periods. A level spreader would reduce potential scouring that would otherwise result from concentrated flow.

Formation of a confined major flow path through Casuarina Park was considered. At this stage, it is considered the costs of that option are likely to exceed the benefits to the community. Stabilisation of the overland flow path through Casuarina Park would involve planting appropriate vegetation to assist in managing erosion and sedimentation issues.

Provision of a grassed pre-treatment swale/basin and biofiltration basin in Casuarina Park is recommended to manage stormwater quality from the upslope catchment prior to discharge into North Arm Cove. The location of these measures should be co-ordinated with any improvements to the park access and improved boat ramp facilities. The existing two drainage outlets would be connected to the grassed pre-treatment swale and flows up to the peak 3 month ARI flow diverted to the swale. The swale would filter out coarse sediment and organic debris prior to discharge into the biofiltration basin. Drainage and overland flows would bypass the treatment facilities for events where flows exceed the 3 month ARI flow. Preliminary MUSIC modelling has been completed for this catchment to size the grassed swale and biofiltration basin (refer Appendix B). The preliminary footprint of these measures is shown on Figure 4-3.

4.3.2 Site 2a – 10 Cove Boulevard

The recommended site actions for Site 2a are shown on Figure 4-4 and described in further detail below.

Currently the flow of stormwater to the pit located across from 10 Cove Boulevard is impeded by a new concrete driveway at 3 Cove Boulevard. Stormwater backs up behind the concrete driveway and is diverted across the road into 10 Cove Boulevard scouring the driveway.

Preliminary hydrologic and hydraulic calculations have been completed for the existing pit located opposite 10 Cove Boulevard. It is estimated that this pit currently has sufficient capacity to capture

runoff from the 10 year ARI event, but the driveway construction currently impedes the flow of stormwater to this pit.

Construction of a new drainage pit on the high side of the driveway is recommended to capture runoff backing up behind the driveway. This drainage pit would need to be connected by a new pipe across Cove Boulevard to an existing pit adjacent to the10 Cove Boulevard.

During major events, the overland flow path is concentrated down the driveway of 10 Cove Boulevard. To prevent flooding through private property, conveyance of overland flow along the road carriageway to Water Street was considered. However, increasing the volume of stormwater directed to the drainage system in Water Street would exacerbate existing issues and may involve costly reconstruction of multiple driveways along Cove Boulevard to provide a clear, unobstructed flow path. Formalising a drainage easement along the boundary of 10 Cove Boulevard is the action recommended at this site for managing flows that exceed the drainage system capacity.

4.3.3 Site 2b - Water Street

The recommended site actions for Site 2b are shown on Figure 4-4 and described in further detail below.

Residents have indicated that recent reshaping of table drains and driveway crossings within upper sections of Water Street (above Cove Boulevard) has been relatively successful at alleviating drainage issues for properties in this area. The main issues raised by the community are associated with the drainage system in the lower sections of the Water Street drainage system including an existing drainage pit and new rock-lined channel sections.

It is recommended that the existing drainage pit at the intersection of Water Street and Cove Boulevard be modified to ensure that the inlet opening does not exceed Council's standards. The size of the pit may need to be increased or a grate added to compensate for the loss of capacity associated with reducing the inlet height. Debris barriers should be considered adjacent to the pit to intercept large organic debris. It is recommended, in advance of construction pit modification works, that horizontal bars should be positioned across the inlet at an appropriate spacing to prevent children from being able to access the pit.

The lower section of the Water Street drainage system comprises three sections of rock-lined channel referred to below as the upper, middle and lower reaches.

The upper and middle reaches of the open channel are constructed at a slope exceeding 10%. Existing rock has been placed unevenly and directly over in situ soil (i.e. no liner). It is believed that these channel reaches are likely to be hard for Council to maintain due to weed invasion and the uneven rock surface. They are likely to erode due to the absence of a liner. The size of the rocks lining the channel is also variable. It is considered that the smaller rocks are incapable of withstanding the tractive stresses associated with higher velocity flows along this channel section. Loss of the smaller rocks this will create instability in the rock lining. It is expected, over time, this will result in the rock lining progressively collapsing into the bed of the channel and exposing the banks to erosion. The steep gradient of the channel and location within the public footway area also constitutes a safety risk to the community.

Replacement of the channel with a pipe is recommended as the preferred option for the upper and middle reaches of the channel. Reconstruction of the rock lining could also be undertaken

involving removal of the existing rock, reshaping of the channel, lining with an appropriate geofabric and placement of appropriately sized rock by an experienced contractor. The potential hazard of the reconstructed open channel to the community would also require consideration.

Survey data provided by Council indicates that the bed of the lower reach is between 0.5 and 1.4m AHD. The rock lining in this reach was constructed with a near vertical face. It appears that a combination of tidal flows and stormwater runoff has resulted in the rock becoming destabilised through erosion of the rock lining toe and high tractive stresses from flowing stormwater. It is recommended that the existing rock be removed and the rock lining reconstructed on a more stable slope with larger rocks and a suitable geotextile liner. The reconstruction should ensure that tidal flows are prevented from flowing behind the rock and eroding the soil behind the lining. Alternatively, replacement of the rock lined channel with a pipe could also be considered.

It is recommended that kerb and gutter be constructed along the lower section of Water Street and a small section of Cove Boulevard either side of Water Street to contain overland flows from Cove Boulevard and upper Water Street within the road reserve when the capacity of the existing minor drainage system is exceeded. This would reduce the volume of uncontrolled overland flow draining through properties located either side of Water Street.

Stormwater quality was a key community concern at this location, with sediment and organic debris observed to be regularly discharging into North Arm Cove. Whilst the upper section of Water Street has been sealed and the base of the newly formed table drains protected from erosion, an informal access track that forms the extension of Water Street between Eastslope Way and The Ridgeway is unsealed. This section of access road is likely to be contributing a significant load of sediment to the beach at the end of Water Street. It is recommended that Council consider closing and revegetating this access track to reduce erosion and prevent vehicular access. Low “whoa boys” (similar to speed humps refer Figure 4-1) should be provided to direct runoff into adjacent bush as sheet flow to filter the runoff and eliminate concentrated flow paths. Sealing the track is not recommended due to the associated increase in volume and velocity of runoff that would exacerbate drainage issues at the lower end of Water Street. Large boulders should also be placed across the track to prevent damage to the diversion bunds.

Inclusion of debris traps along Cove Boulevard is recommended to assist with trapping sediment and organic debris.

4.3.4 Site 2c - 49 Cove Boulevard

The recommended site actions for Site 2c are shown on Figure 4-4 and described in further detail below.

A number of residents have observed runoff flowing across the road near the existing road crest in front of 49 Cove Boulevard. Residents have indicated that this runoff continues to seep across the road for several days after conclusion of significant wet weather. The runoff then drains into properties on the low side of Cove Boulevard causing nuisance.

It appears that the construction of Cove Boulevard at this location is functioning similarly to a dam, restricting the flow of shallow groundwater in a direction towards North Arm Cove. Shallow ground water is potentially backing up behind the road pavement prior to resurfacing and flowing across the road. Saturation of road sub-base is also leading to accelerated pavement deterioration.

The recommended actions for this site are the formation of a concrete dish crossing on the high side from 43 to 47 Cove Boulevard to intercept low flows and direct this to the existing table drain located to the north. The dish crossing should be designed giving due consideration to vehicle access in order to avoid vehicles 'bottoming out'. Some vehicle crossings may need to be reconstructed to achieve this.

Property owners have indicated that continual seepage of runoff across the road for several days after a wet period is of most concern. It is recommended that a sub-soil drainage line be provided under the dish crossing and laid on top of the shallow bedrock. The sub-soil drain should be discharge to the existing table drain to the north.

Kerb and gutter should also be considered along the eastern side of the road between 54 and 36 Cove Boulevard to contain overland flow within the roadway and direct this to Water Street. Directing runoff away from these properties will increase flow to Water Street. It will be important that the drainage system in Water Street is upgraded to ensure that there are no additional impacts on properties in this area and that increased discharges at the end of Water Street do not increase erosion at the drainage outlet.

4.3.5 Site 3a – 70 Cove Boulevard

The existing drainage pit opposite 70 Cove Boulevard is the only drainage structure capturing surface runoff from a 4.4ha catchment (refer Figure 3-19). The existing inlet to the pit is deep (refer Figure 3-10), exceeds Council's standards and is considered particularly hazardous to the community. It is recommended that the existing drainage pit be modified to ensure that the inlet opening does not exceed Council's standards and is suitable for the particular location.

The size of the pit may need to be increased or a grate added to compensate for the loss of capacity associated with reducing the inlet height. In addition, the size may need to be increased to provide sufficient capacity for additional flows diverted from the adjacent catchment (refer Section 3.4.5). It is considered that in advance of construction works to modify the pit that horizontal bars should be positioned across the inlet at an appropriate spacing to prevent children from being able to access the pit.

Even with the current large opening, preliminary hydrologic calculations indicate that the drainage pit has insufficient capacity to capture surface runoff for the 10 year ARI event. This would result in overland flow across Cove Boulevard and through No. 70 during more regular events.

Preliminary analysis of the drainage line from Cove Boulevard through to the foreshore indicates that the existing drainage pit inlet capacity controls the quantity of water able to drain through this line. Survey data indicates that the pit discharges through a 900mm diameter concrete pipe that transitions to a 500mm diameter uPVC pipe at a pit located within No. 70. This arrangement suggests that large debris entering the pit at the upslope end of the drainage line can potentially block the line at the transition to the 500mm diameter pipe. Preventing large debris entering the system should be a high priority for this system and this would be achieved through modification of the inlet height. Debris barriers are recommended to be considered adjacent to the pit to also intercept large debris.

The recommended actions for this site include upgrading the existing stormwater pit to have an equivalent capacity as the 500mm diameter uPVC pipe downslope. It is recommended that a

formal drainage easement should also be negotiated with the property owner (if not currently in place).

It is considered that the catchment area draining to this pit should also be increased through diversion of runoff passing through 79 Cove Boulevard. This option is discussed further in Section 4.3.6.

4.3.6 Site 3b – 80-84 Cove Boulevard

Surface runoff from the upper, forested catchment follows a natural gully line through the vacant lot at 79 Cove Boulevard. The catchment (refer Figure 3-19) contributing to overland flow at this location is approximately 2.3ha and discharges into the Cove Boulevard road reserve near a crest.

There is currently no swale drain on the high side of Cove Boulevard to capture surface runoff. Surface runoff through 79 Cove Boulevard currently drains uncontrolled across Cove Boulevard into No's 80, 82 and 84 causing nuisance flooding for these property owners. A short section of swale is recommended to be constructed on the high side in front of 70 Cove Boulevard to initially direct runoff down the road and prevent overland flow spilling directly across the road crest at this location into 84 Cove Boulevard. Consideration was given to adjusting driveways further down the road on the high side to enable a swale drain to be formed. The extent of driveway adjustment that would be required is likely to be cost prohibitive.

The recommended solution for consideration is to provide kerb and gutter along the eastern side of Cove Boulevard to intercept and divert the overland flows to a new inlet pit at the front of 70 Cove Boulevard. The pit should be sized to ensure that there would be no impact on the 70 Cove Boulevard.

It is considered that the use of 79 Cove Boulevard for residential development will be restricted due to the presence of the natural overland flow path. It is recommended that Council consider negotiations with the current land owner to identify opportunities for purchase and/or negotiation on other Council owned land in North Arm Cove.

4.3.7 Site 3c – 102-110 Cove Boulevard

The main issues with this site are associated with stormwater runoff that naturally would have flowed through 104 Cove Boulevard being re-directed to a constructed drainage system that drains through 108 Cove Boulevard. A steep open channel adjacent to 108 Cove Boulevard is regarded as hazardous during major runoff events. A staged implementation plan is recommended for this site to reduce flows to the existing channel and improve drainage.

During small runoff events the stormwater system functions effectively. During higher runoff periods, stormwater flow is impeded by the driveway crossings and runoff spills across the road along a historical natural flow path through 104 Cove Boulevard. There is currently no drainage system aligned with the natural flow path to intercept runoff.

As a short term action, it is recommended that Council negotiate with the existing property owner of 104 Cove Boulevard to formalise a drainage easement to convey runoff that naturally would have drained through this property. This continues to occur when the constructed drainage system capacity is exceeded or the driveway crossings block flow. A drainage pit should be provided at the natural low point opposite 104 Cove Boulevard and a drainage pipe constructed to discharge

runoff into No. 104. Works should be completed within 104 Cove Boulevard to manage the discharges. Recommended actions include construction of a flow level spreader, flow bunds and vegetation stabilisation. Associated with this short term action, it is recommended that kerb and gutter be formed along the low side of the road in front of 110 Cove Boulevard to manage surface runoff diverted by the driveway crossing at 99 Cove Boulevard.

Debris barriers should be considered adjacent to the pit to intercept large organic debris. It is considered that in advance of construction works to modify the pit that horizontal bars should be positioned across the inlet at an appropriate spacing that would prevent a small child from entering the pit.

The recommended long term actions will require significant modifications to the existing drainage system at this site. Actions include disconnecting the existing drainage line discharging into the steep rock-lined channel adjacent to 108 Cove Boulevard. In addition, it is recommended that a new stormwater drainage line be constructed to a new pit opposite 104 Cove Boulevard. The driveway crossing at 99 Cove Boulevard should also be reconstructed to improve drainage to the pit across from 108 Cove Boulevard. Some additional excavation of a rock outcrop downslope of this driveway may also be necessary to improve drainage to the existing pit. The catchment draining to the channel adjacent to 108 Cove Boulevard will then be considerably reduced and it is recommended that this be reconstructed to create a shallow rock-lined swale.

Provision of a grassed pre-treatment swale/basin and biofiltration basin in 104 Cove Boulevard is recommended to manage stormwater quality from the upslope catchment prior to discharge into North Arm Cove. The lot is located in a natural overland flowpath for stormwater draining from the upslope catchment. Currently any development of this lot would be highly constrained by overland flow that discharges through the lot during significant storm events. Negotiation with the lot owner would be necessary to ensure that this option is feasible. Improvements to the management of overland flow through the lot would also form part of this option.

Preliminary MUSIC modelling has been completed for this catchment to size the pre-treatment swale/basin and biofiltration basin (refer Appendix B). The preliminary footprint of these measures is shown on Figure 4-6.

4.3.1 Site 4a – 33 The Esplanade

This site is located within an infilled natural overland flow path for runoff draining along the remaining ephemeral watercourse tributaries located upstream of the property. Preliminary estimated flooding extents for the 100 year ARI design event are shown on Figure 3-22. Overland flow events are likely to occur relatively frequently through this site in the current condition. We understand that the dwelling on this site was recently constructed and that there is currently no intention to modify the use of the land.

To alleviate the frequency of nuisance minor flooding at the property, a piped drainage system could be constructed through the property within a registered easement to manage runoff for flow up to an agreed standard with Council. It is suggested that a 2 year ARI design standard (minimum) that is equivalent to the typical bankfull flow for a watercourse may be an appropriate standard for this drainage line. A debris barrier would be required at the inlet located at the upstream side of the property. This would minimise the potential for property damage during most runoff events.

Construction of a minor piped drainage system will not prevent infrequent flooding from larger events that exceed the capacity of a constructed minor drainage system. These events will pose the greatest risk for damage to the property and more importantly to safety for residents of the property. The risk exposure is likely to increase if future upstream development proceeds, resulting in increased impervious areas and associated elevated flood volumes.

Council has also requested that an alternative option be considered to divert stormwater around the property by constructing a 100 year ARI capacity drainage channel in the adjacent lot. Negotiations with the adjacent lot owner would be required to confirm this option is feasible. If this option is feasible, consideration would be required of the residual flooding risk to 33 The Esplanade in the event that this channel was breached or became blocked and subsequently re-directed overland flows through the property.

It is recommended that a site-based flood risk management plan be developed for this property recognising both existing and future flooding potential. The extents of the overland flowpath through the property should be delineated and this flow path kept free of structures, fences and other infrastructure that could elevate or divert floodwaters and thus increase risks to the existing residents and adjacent properties. It is important that the current owners are educated on the existing risks to ensure that people in their care are kept safe and away from flood waters. Flooding of this property is likely to occur quite rapidly due to the steep, small size of the catchment and therefore time to prepare will be limited.

It will be important that flooding risks for this property are registered on a planning certificate for the property to ensure that future purchasers are made aware of the risk.

The concrete lined causeway located at the end of The Esplanade adjacent to the site should be sign posted to indicate that it functions as a floodway during large rainfall events. Community education should also be undertaken to raise awareness of this floodway and others that occur throughout North Arm Cove.

4.3.1 Site 4b – 51 The Esplanade

The main issue identified at this site is the presence of a natural overland flow path across the driveway access to this property which is regularly inaccessible following periods of heavy rainfall.

It is recommended that Council consider construction of a new multiple pipe culvert across The Esplanade. Existing survey data suggests that a multiple 375mm diameter pipe culvert potentially would be feasible. The culvert would capture runoff from the upstream catchment on the eastern side of the driveway and discharge this into the existing earth-lined swale on the southern side of The Esplanade. This new culvert should have sufficient capacity for the 5 year ARI flow. To ensure that access to downstream properties is not impacted by improving the efficiency of drainage in this area it is recommended that the pipe driveway crossings for downstream properties also be upgraded to at least a 5 year ARI standard.

To improve the function of the table drain on the northern side of the road it is recommended that the drain be re-graded to minimise the potential for water to pond. A crest should be formed midway along the table drain between the two culverts that convey runoff from the northern side of the road and discharge this into the swale on the southern side.

4.3.2 Site 5a – 91 Promontory Way

The main issue identified at this site is runoff regularly overflowing from the pits located on Promontory Way and flowing through properties. The existing drainage pit on the high side of the road opposite 91 Promontory Way is the only drainage structure capturing surface runoff from the upstream catchment (approximately 4.4 ha). The pit has an inlet height of 300mm, although the inlet height is not as large as some pits observed; it presents a safety hazard as children could climb into this pit.

Preliminary hydrological calculations have indicated that the drainage pit is undersized and has insufficient capacity to capture runoff for the 100 year ARI event. Assuming a 50% blockage the drainage pit does not have the capacity to even capture all surface runoff for the 5 year ARI event.

Preliminary analysis of the drainage line from Promontory Way through to the foreshore indicates that the existing drainage pit inlet capacity controls the quantity of water able to drain through this line. The size of the pit needs to be increased and a grate added to provide additional capacity.

The recommended actions for Site 5a include upgrading the main existing stormwater drainage pit to have an equivalent capacity as the 575mm pipe sloping down to the foreshore, between 91 and 93 Promontory Way. The second drainage pit and roadside kerb on the low side of Promontory Way should be updated to ensure the pit can capture majority of the flows from the road and kerb.

In the short term, it is recommended that Council negotiate with the existing property owner of 91 Promontory Way to construct an overland flow path/ swale through the property to allow excess surface runoff to be efficiently conveyed to the foreshore without constantly damaging the property driveway.

These site actions are shown on

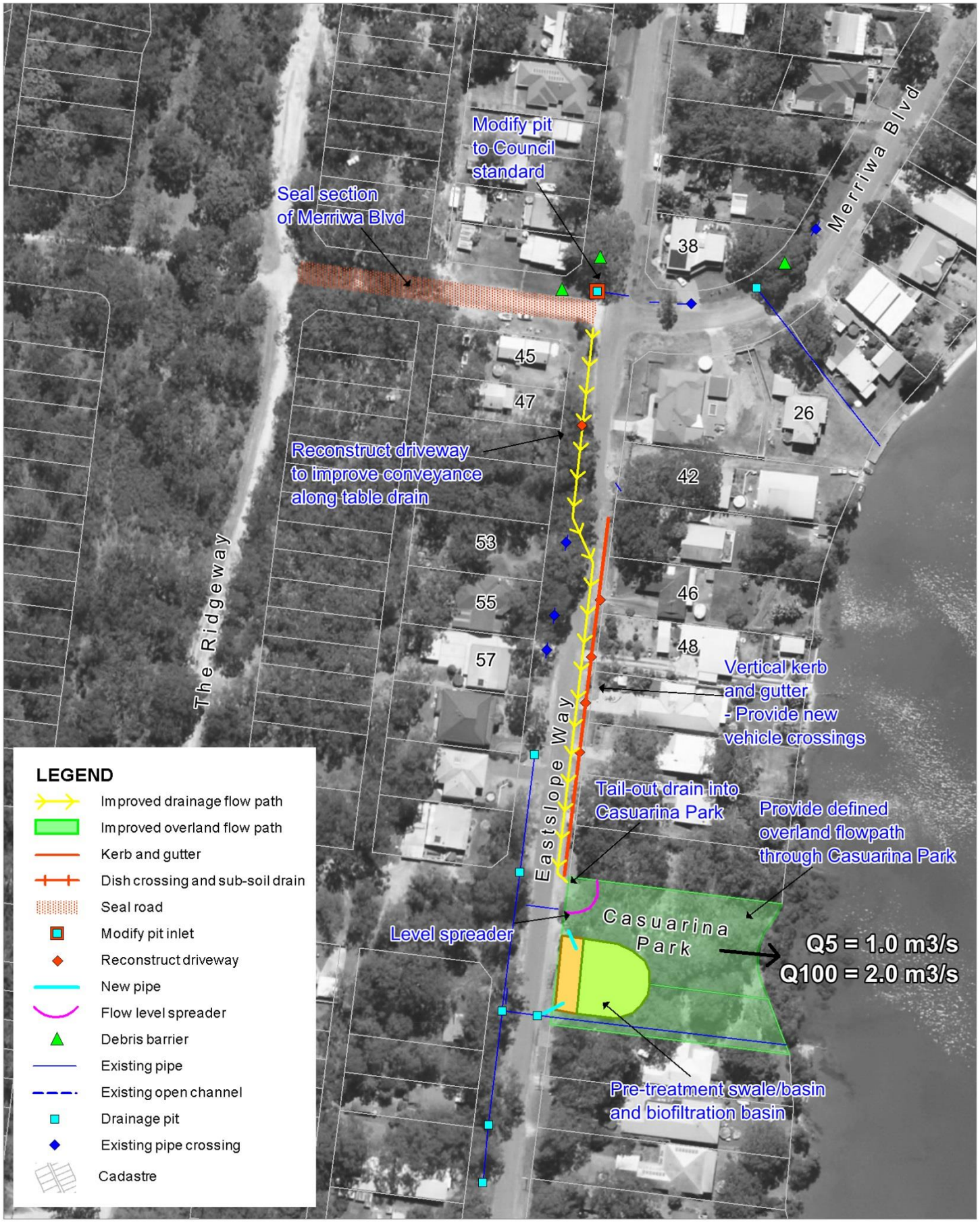
Figure 4-8. A short-medium term solution will be to provide/extend kerb and gutter all the way along the low side of Promontory Way to the Reserve access road. Additionally, filling and reshaping of the footpath and driveways should be undertaken to ensure a larger freeboard against overflows from the topside table drain in combination with increased waterway area (deepening) of the topside table drain.

4.3.3 Site 5b – 131 Promontory Way

The key issue at this site involves a drainage culvert conveying runoff directly onto a property. The culvert outside 131 Promontory Way diverts water under the road and discharges it onto the currently vacant lot. This issue needs to be resolved as the owners want to develop the lot. No existing drainage easement is believed to be held by Council to drain runoff through 131 Promontory Way.

As a short term action, it is recommended that Council negotiate with the existing property owner of 131 Promontory Way to formalise a drainage easement to convey runoff from the culvert that previously naturally drained through this property.

It is recommended that once an agreement on the drainage easement has been formalised that Council construct a new pit to take flows from the existing culvert and a new stormwater drainage line through 131 Promontory Way to divert flows through the drainage easement on the property to the foreshore. Road kerb and guttering should be modified to convey flows to the new pit and pipe.



Title:
Site 1 - Stormwater Management Concept

Figure: **4-3**

Rev: **B**

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Approx. Scale

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Title:
Sites 2a, 2b and 2c - Stormwater Management Concept

Figure: **4-4**

Rev: **B**

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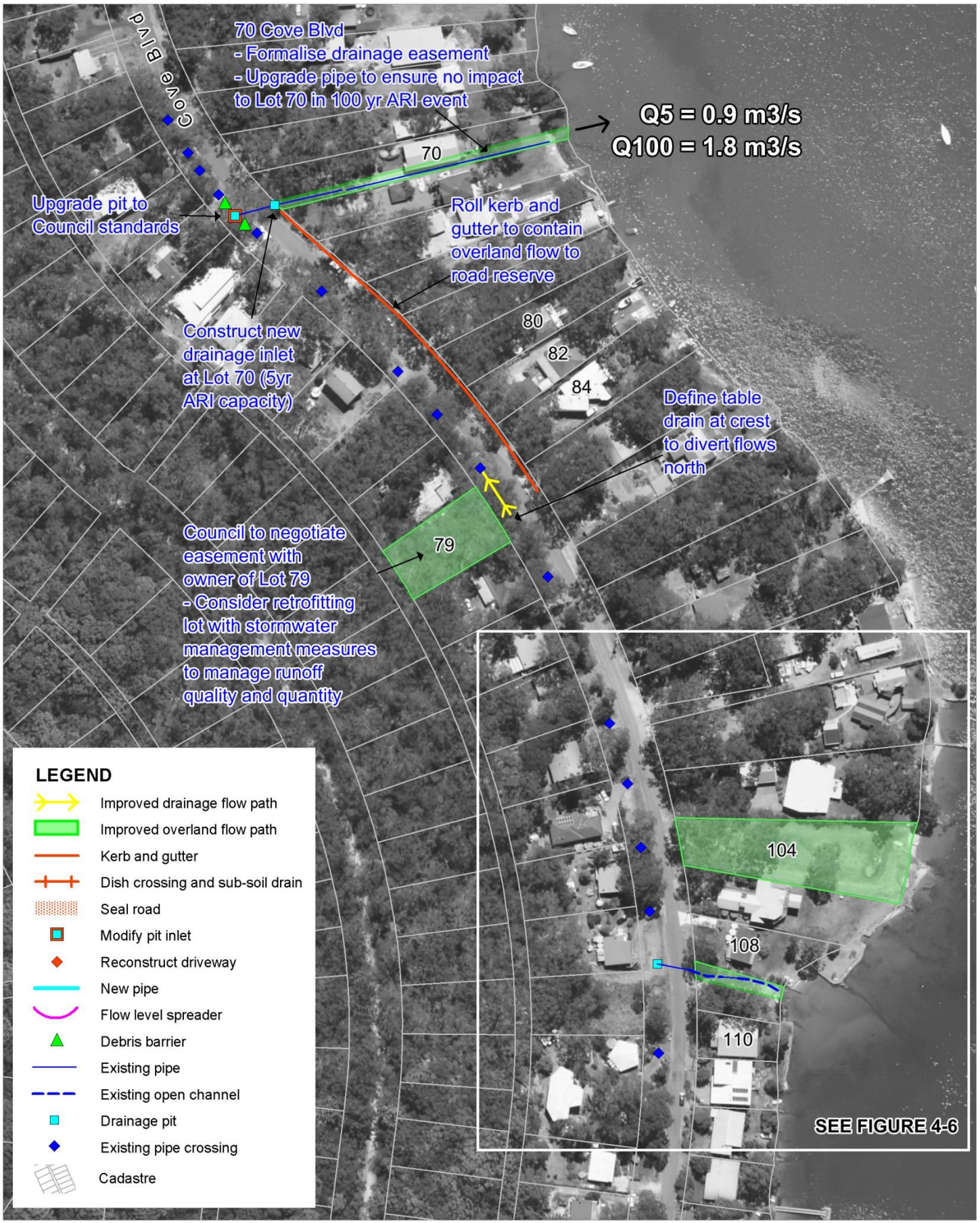

Title:
Sites 3a and 3b - Stormwater Management Concept

Figure: **4-5**

Rev: **B**

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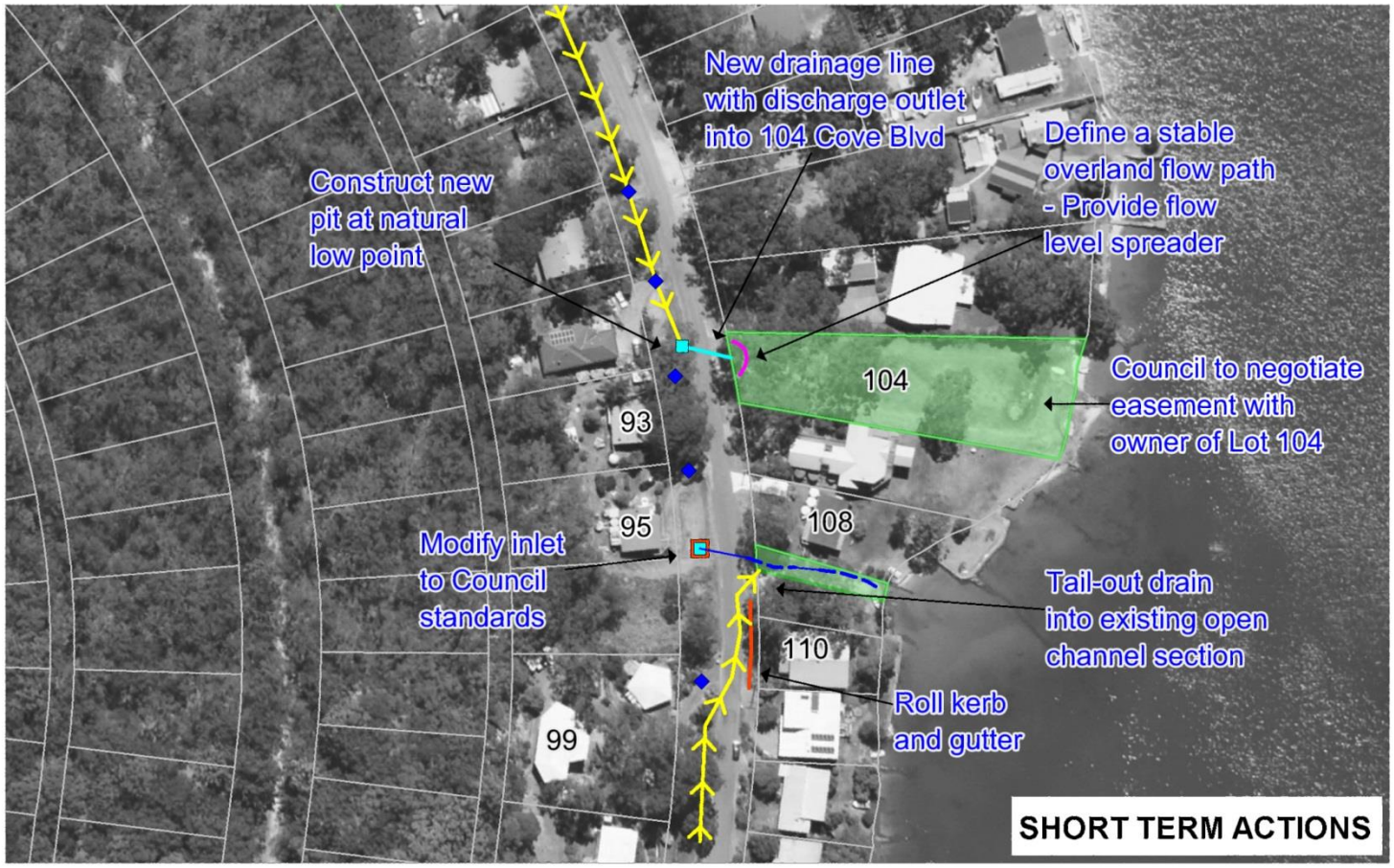

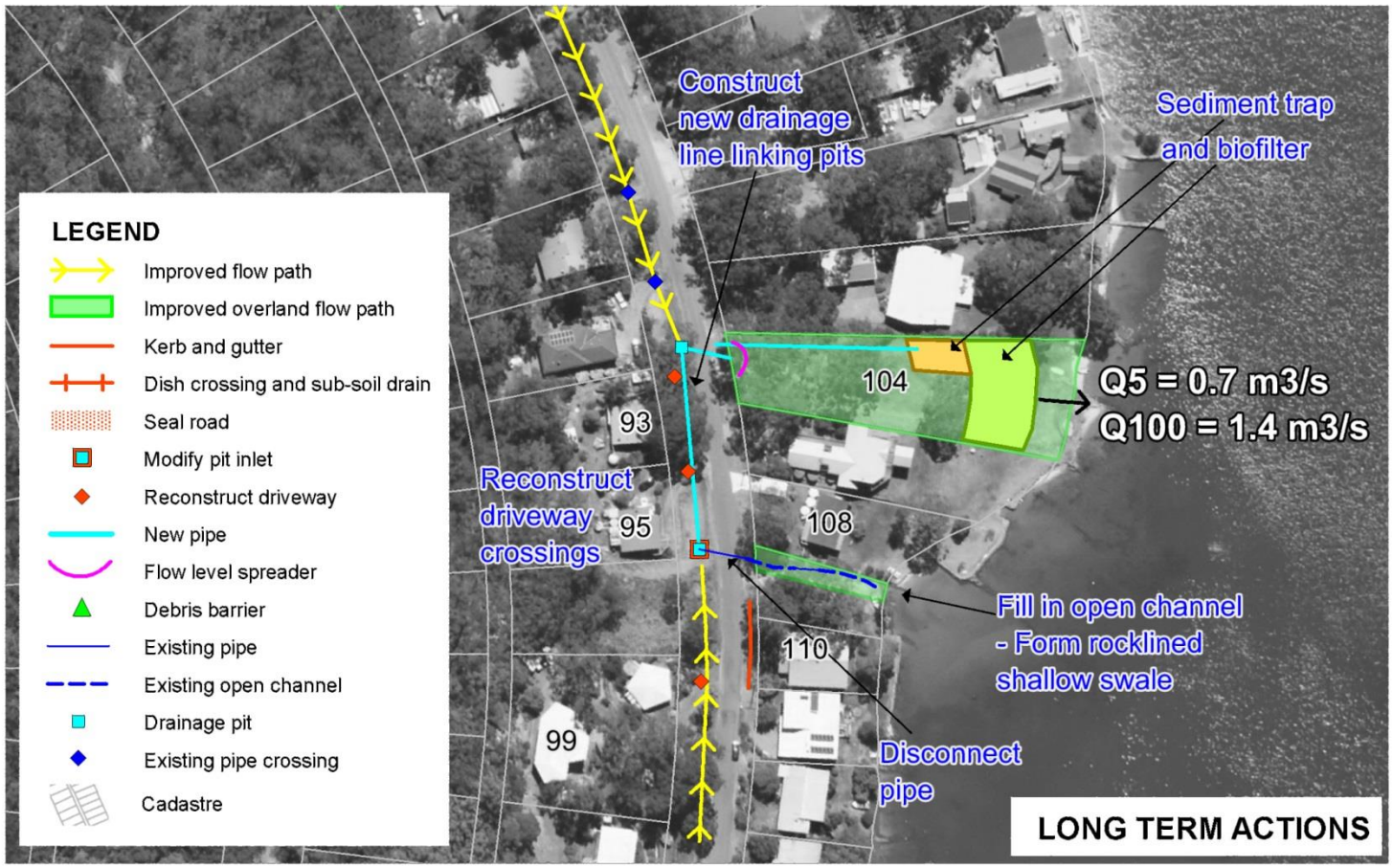

Title:
Site 3c - Stormwater Management Concept

Figure: **4-6**

Rev: **B**

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Approx. Scale

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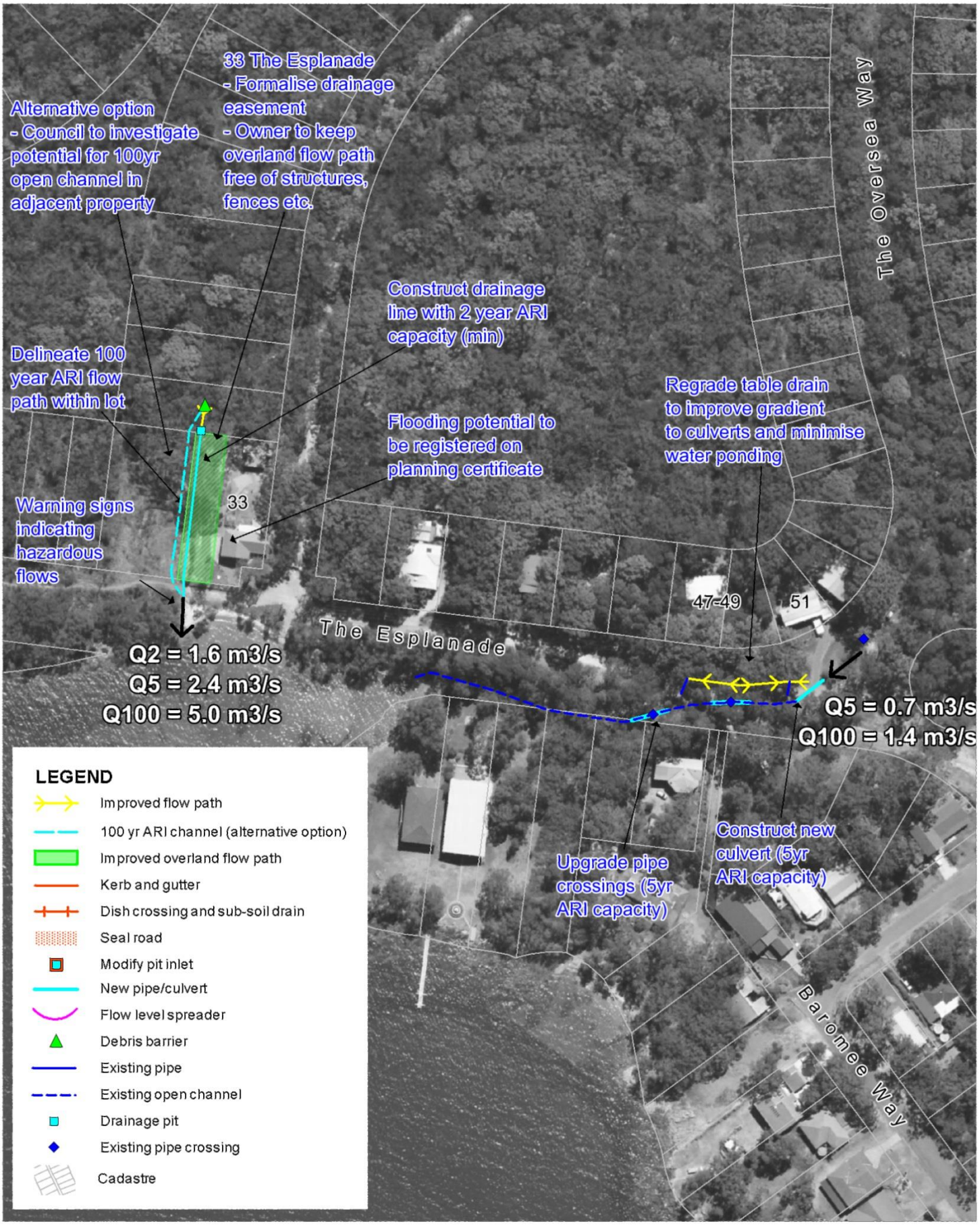

Title:
Sites 4a and 4b - Stormwater Management Concept

Figure: **4-7**

Rev: **B**

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Title:
Sites 5a and 5b - Stormwater Management Concept

Figure: **4-8**

Rev: **A**

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Approx. Scale

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5 Long Term Actions

5.1 Future Development Master Plan

The short term actions described in Section 4 focus on improving drainage, reducing frequent flooding and source management of runoff quality in the existing village. The long term actions outlined below include measures to be considered if any land were to be rezoned in North Arm Cove and additional low density residential development permitted.

There are a number of currently undeveloped small lots in North Arm Cove. Building dwellings on lots less than 40ha in most undeveloped lots in North Arm Cove (areas zoned RU2 Rural Landscape in the Draft Great Lakes Council LEP 2013) is currently prohibited. Prior to any further development occurring in the study area, it will be important that a master plan is prepared to completely revise the current road and lot layout in the undeveloped areas. In particular, this master plan would need to more appropriately respond to the terrain, and particularly the natural drainage corridors. Key elements of this master plan relevant to stormwater management are discussed in the following sections.

The long term actions also include measures to filter stormwater and improve runoff quality from existing developed areas following resolution of existing drainage issues.

5.2 Flooding and Drainage Master Plan

No rezoning or future development of the existing rural zoned lands to support further residential development should proceed until a drainage master plan is developed for the entire area. The Drainage Master Plan should confirm the floodways, overland flowpaths and riparian corridor widths within the study area. A lot and road layout should be developed that protects the watercourses and addresses other ecological and physical constraints of the study area.

BMT WBM has completed preliminary flooding investigations over the study area and preliminary mapping prepared showing indicative existing flooding extents for the 1% AEP design flood (refer Figure 3-22). The Master Plan should be prepared considering these preliminary flooding extents, whilst noting that further detailed investigations would be required prior to confirming potential development extents.

A number of lots in the undeveloped areas of North Arm Cove are currently impacted by overland flows during runoff events. Development within these lots will be considerably constrained, and may not be feasible in many circumstances. Existing lots located within major overland flow paths should be identified prior to progressing with any further development studies in North Arm Cove.

The Master Plan should identify opportunities to direct overland flows from future development away from existing development along unobstructed flow paths to the North Arm Cove estuary. Innovative planning of the road layout could also assist with reducing stormwater impacts on existing development by diverting stormwater from upslope areas to appropriate discharge locations. Master planning should identify existing lots within the undeveloped or developed areas that may need to be allocated as overland flowpaths or require easements to drain stormwater.

In situations where the Master Plan is unable to incorporate provisions to divert stormwater away from existing development and along an unobstructed flowpath to North Arm Cove, locations of

detention basins would need to be identified or development in some areas restricted to ensure that overland flooding issues in the existing North Arm Cove village are not increased.

It is recommended that ecological and water quality investigations also be completed to confirm the locations of watercourses within the study area and confirm appropriate riparian zones. These areas should be recognised as environmental assets to be protected. The locations of watercourses should be determined considering Council's policies and current guidelines published by the NSW Office of Water.

5.3 Stormwater Quality Master Plan

A Stormwater Quality Master Plan should be prepared as a component of the development Master plan. This Master Plan should be prepared in an integrated manner with the road and lot layout, as well as the Flooding and Drainage Master Plan. Confirmation of appropriate locations for particular stormwater quality management measures would require a revised road and lot layout to initially be developed.

The road layout will largely govern appropriate locations of stormwater quality management measures. A stormwater quality master plan relying on street scale measures will require roads to be aligned along the existing contours at longitudinal gradients less than 4% to ensure that vegetated systems would be effective. A stormwater quality master plan relying on lot scale measures could have roads on steeper gradients provided there is sufficient space available in the lots to site treatment measures. A stormwater quality master plan relying primarily on larger sub-catchment scale measures will require the identification of specific sites in lower areas of the development where measures can be sited.

The most appropriate solution to manage stormwater quality in any future development at North Arm Cove is likely to involve a mix of lot, street and sub-catchment scale measures. It is envisaged that Council will have an objective to minimise Council's maintenance requirements for these measures. Therefore, a stormwater quality management plan that relies on lot and sub-catchment scale treatment is likely to provide the optimum outcome and also a lower constraint to the development of a road layout.

The stormwater quality master plan should also consider management of runoff from the existing development in the North Arm Cove village. The short term actions in Section 4 include measures targeting an initial reduction in the loads of coarser pollutants including sediment, litter and organic debris. Following stabilisation of the catchment surfaces, education of residents to improve source management of water quality within lots, and improvements to the existing drainage system, it is recommended that stormwater quality measures targeting finer pollutants (e.g. suspended solids, nutrients, heavy metals) be retrofitted at appropriate central locations within the existing village as a component of the long term actions.

5.4 Developer Water Management Guidelines

Future development planning in North Arm Cove should consider appropriate, locally specific information on flooding, overland flow, drainage and runoff quality. It is therefore recommended that general water management guidelines be prepared for North Arm Cove that recognises local constraints and opportunities. It is envisaged that the guidelines would be prepared based on Council's current policies and similar guidelines to those for Wallis Lake. They should be tailored

to relevant local constraints and opportunities in North Arm Cove. It is recommended that the water management guidelines should include:

- Background information on the stormwater drainage issues experienced in the existing village and the causes.
- A description of the receiving environments and the key physical characteristics of North Arm Cove that influence the management of stormwater quality and quantity.
- Local objectives and targets that apply to managing stormwater quality and quantity specifically within North Arm Cove.
- Guidance on the alignment of new roads and lots to improve opportunities for better management of stormwater quality and quantity close to the source.
- Considerations for locating centralised stormwater management measures.
- A summary of stormwater quality and quantity measures that are considered to be most appropriate based on the physical, financial and environmental constraints specific to North Arm Cove.
- Management of water quality during construction and particularly in areas where dispersive soils are present.
- Cost-effectiveness and priority actions.

6 Stormwater Management Schedule

The recommended stormwater management actions for North Arm Cove are summarised in Table 6-1. The table outlines the actions discussed in Section 4 and Section 5 and provides preliminary estimates of the initial capital cost and annual operation/maintenance cost for the action when implemented.

Table 6-1 Stormwater Management Actions

Site ID	Action Description	Action objectives	Preliminary Cost Estimate		
			Capital	Annual	Priority
S1	Regrading and bitumen sealing of Merriwa Blvd	To reduce soil erosion along this steep section of road.	**$10-$20K**	**$0 - 2K**	
S1	Construction of table drain along Merriwa Blvd	To improve drainage of the road	**$2-$5K**	**$0 - 2K**	
S1	Reconstruct existing drainage pit at Merriwa Blvd / Eastslope Way intersection	To improve drainage inlet capacity, reduce hazard and increase drainage flows to the east along Merriwa Blvd	**$2-$5K**	**$0 - 2K**	
S1	Construct new debris barriers	To intercept large organic debris ahead of drainage inlet	**$2-$5K**	**$0 - 2K**	
S1	Reconstruct driveway at 47 Eastslope Way	To prevent overland flow crossing the road into 42 Eastslope Way and adjacent properties	**$2-$5K**	**$0**	
S1	Construct kerb and gutter along eastern side of Eastslope Way	To prevent overland flow crossing the road into properties between 44 Eastslope Way and Casuarina Park	**$5-$10K**	**$0**	
S1	Construct new vehicle crossings and partial driveways - 44 Eastslope Way to Casuarina Park	To provide access to properties where new kerb and gutter is proposed	**$5-$10K**	**$0**	
S1	Construct level spreader at drainage outlet into Casuarina Park	To generate sheet flow conditions through Casuarina Park to prevent scouring	**$10-$20K**	**$2-$5K**	

Stormwater Management Schedule

Site ID	Action Description	Action objectives	Preliminary Cost Estimate		
			Capital	Annual	Priority
S1	Construct pre-treatment swale/basin and biofiltration basin in Casuarina Park	To improve stormwater runoff quality prior to discharge into North Arm Cove	**$75-$125K**	**$5-$10K**	
S2a	Construct new drainage pit opposite 10 Cove Blvd	To capture runoff upslope of new driveway at 3 Cove Boulevard	**$2-$5K**	**$0 - 2K**	
S2a	Construct new drainage pipe between new drainage pit and 10 Cove Blvd	To direct runoff from new drainage pit to existing system	**$5-$10K**	**$0 - 2K**	
S2a	Formalise drainage easement through 10 Cove Blvd	To provide Council with a legal right to drain water through this property	**$2-$5K**	**$0**	
S2a	Reconstruct driveway for 10 Cove Blvd	To repair damage due to concentrated stormwater overflowing from Cove Blvd	**$5-$10K**	**$0**	
S2b	Reconstruct existing drainage pit at Water Street / Cove Blvd intersection	To reduce the hazard to the community associated with high ponding depth and large inlet	**$2-$5K**	**$0 - 2K**	
S2b	Construct new debris barriers	To intercept large organic debris ahead of drainage inlet	**$2-$5K**	**$0 - 2K**	
S2b	Remove rock lining in upper and middle channel reaches and lay new pipe	To reduce community hazard, reduce maintenance hazards and costs, reduce potential for bed and bank erosion	**$20-$35K**	**$0 - 2K**	
S2b	Remove and reconstruct rock lining in lower channel reach	To protect the bed and banks from erosion, prevent rock discharging onto the foreshore, avoid encroachment	**$10-$20K**	**$0 - 2K**	
S2b	Construct kerb and gutter, new vehicle crossings	To improve the management of overland flows along Water St and Cove Blvd to the lower channel reach	**$10-$20K**	**$0**	
S2b	Revegetation of existing informal track between Eastslope Way and The Ridgeway	To reduce erosion and sediment being conveyed down Water St to the foreshore and restrict vehicle access	**$10-$15K**	**$0**	

Site ID	Action Description	Action objectives	Preliminary Cost Estimate Capital	Annual	Priority
S2c	Construct sub-soil drainage system	To intercept seepage water prior to it backing up behind road pavement and overtopping the road	**$5-$10K**	**$0 - 2K**	
S2c	Construct concrete dish crossing	To intercept low flow runoff and direct it away from properties on the low side of Cove Blvd	**$2-$5K**	**$0**	
S2c	Re-construct driveway crossings	To ensure suitable access is retained to properties on the high side of Cove Blvd	**$2-$5K**	**$0**	
S2c	Construct new kerb and gutter between 36 and 54 Cove Blvd (east side) and adjust driveway accesses	To prevent runoff from high side of road draining into low side properties and maintain access to properties	**$20-$50K**	**$0**	
S3a	Reconstruct existing drainage pit opposite 70 Cove Blvd	To reduce the hazard to the community associated with high ponding depth and large inlet, improve hydraulics	**$2-$5K**	**$0 - 2K**	
S3a	Construct new debris barriers	To intercept large organic debris ahead of drainage inlet and reduce blocking potential of downstream pipe	**$2-$5K**	**$0 - 2K**	
S3a	Formalise drainage easement through 70 Cove Blvd	To provide Council with a legal right to drain water through this property	**$2-$5K**	**$0**	
S3b	Improve table drain on high side of road between 70 and 79 Cove Blvd, adjust driveways	To prevent overland flow through 79 Cove Blvd spilling into 80-84 Cove Blvd	**$10-$20K**	**$0 - 2K**	
S3b	79 Cove Blvd - negotiate with owner on easement	To restrict development in an existing lot that forms a key overland flowpath	**$2-$5K**	**$0**	
S3c	Formalise drainage easement through 104 Cove Blvd	To provide Council with a legal right to drain water through this property	**$2-$5K**	**$0**	
S3c	Construct new drainage pit at natural low point opposite 104 Cove Blvd	To capture runoff prior to uncontrolled spilling across Cove Blvd	**$2-$5K**	**$0 - 2K**	

Site ID	Action Description	Action objectives	Preliminary Cost Estimate		
			Capital	Annual	Priority
S3c	Construct new drainage line and culvert discharging into 104 Cove Blvd	To discharge runoff in a controlled manner into 104 Cove Blvd	**$5-$10K**	**$0 - 2K**	
S3c	Construct level spreader at drainage outlet into 104 Cove Blvd	To generate sheet flow conditions through 104 Cove Blvd to prevent scouring	**$10-$20K**	**$2-$5K**	
S3c	Construct kerb and gutter in front of 110 Cove Blvd	To direct overland flow crossing road away from existing property to drainage channel	**$2-$5K**	**$0**	
S3c	Construct new debris barriers	To intercept large organic debris ahead of drainage inlet	**$2-$5K**	**$0 - 2K**	
S3c	Disconnect existing pipe and modify existing rock lined channel at 108 Cove Blvd	Redundant pipe and channel following construction of new drainage line	**$5-$10K**	**$0 - 2K**	
S3c	Construct new pipe on high side of road from opposite 108 to 104 Cove Blvd	To divert runoff from discharging into existing steep rock lined channel, improve safety, reduce erosion	**$10-$20K**	**$0 - 2K**	
S3c	Reconstruct driveway crossing at 99 Cove Blvd	To prevent diversion of runoff across road into 108 Cove Blvd	**$2-$5K**	**$0**	
S3c	Construct pre-treatment swale/basin and biofiltration basin in 104 Cove Blvd (excludes cost of land purchase)	To improve stormwater runoff quality prior to discharge into North Arm Cove	**$75-$125K**	**$5-$10K**	
S4a	Construct new drainage pit at end of gully upslope of 33 The Esplanade	To capture frequent flows prior to overland flow through existing residential property	**$2-$5K**	**$0 - 2K**	
S4a	Construct new drainage line through 33 The Esplanade	To convey minor drainage flows below ground through the property	**$10-$20K**	**$0 - 2K**	
S4a	Construct new debris barrier	To intercept large organic debris ahead of drainage inlet	**$2-$5K**	**$0 - 2K**	

Site ID	Action Description	Action objectives	Preliminary Cost Estimate		
			Capital	Annual	Priority
S4a	Prepare flood management plan for 33 The Esplanade	To ensure property owners are aware of the flooding risks and have a plan to manage these risks	**$2-$5K**	**$0**	
S4a	Formalise drainage easement through 33 The Esplanade and delineate the easement	To ensure that property owners avoid erecting structures within the floodway	**$2-$5K**	**$0**	
S4a	Register the flood prone nature of the site on the properties planning certificate	To ensure that future owners are aware of the risk	**<$2K**	**$0**	
S4a	Erect floodway warning signs adjacent to the existing causeway	To warn road users of the risk during floods	**<$2K**	**$0**	
S4b	Construct new 5 year ARI culvert across The Esplanade near 51 The Esplanade	To improve access to 51 The Esplanade during wet weather, improve the durability of the driveway and reduce maintenance for the property owner	**$20-$50K**	**$0 – $2K**	
S4b	Regrade the existing table drain on north side of The Esplanade	To improve drainage and prevent ponding of water	**$2-$5K**	**$0 - $2K**	
S5a	Construct kerb and gutter in front of 91 Promontory Way and adjacent properties	To direct overland flow crossing road away from existing property and into stormwater drainage network	**$2-$5K**	**$0**	
S5a	Upgrade/modify drainage pits to increase capacity in line with receiving drainage line	To improve drainage and prevent water flowing overland down residential driveways and properties	**$2-$5K**	**$0 - $2K**	
S5a	Define overland flow path through 91 Promontory Way	To intercept overland flows and direct them through property to foreshore without scouring driveway	**<$2K**	**$0**	
S5b	Formalise drainage easement through 131 Promontory Way	To provide Council with a legal right to drain water through this property	**$2-$5K**	**$0**	
S5b	Construct new pit and drainage line through 131 Promontory Way	To capture and divert flows through property in underground drainage network	**$5-10K**	**$0 - $2K**	

Stormwater Management Schedule

Site ID	Action Description	Action objectives	Preliminary Cost Estimate		
			Capital	Annual	Priority
S5b	Construct kerb and gutter in front of 131 Promontory Way and adjacent properties	To direct overland flow crossing road away from existing property and into stormwater drainage network	**$2-$5K**	**$0**	
V1	Community liaison and education	To maintain the function of the stormwater management system in North Arm Cove		**$2-$5K**	
V2	Reduce erosion of unsealed roads	To improve runoff quality and improve trafficability of fire trails	**$10-$20K**	**$2-$5K**	
V3	Improved erosion and sediment control on constructions sites	To improve runoff quality		**$5-$10K**	
V4	Drainage pipe inspections	To identify existing damage or blockage of existing drainage lines	**$2-$5K**	**$0 - 2K**	
V5	Drainage pit inlet inspections	To identify unsafe or inefficient drainage inlets	**$2-$5K**	**$0 - 2K**	
V6	Improved maintenance of table drains	To reduce blockage of table drains and improve flows during storm events	**$5-$10K**	**$5-$10K**	
V7	Driveway crossing audit	To identify driveways that are currently significantly impeding flowpaths and redirecting surface water	**$2-$5K**	**$0 - 2K**	
V8	Update stormwater assets register	To ensure that Council has latest up-to-date information in their records to improve maintenance	**$5-$10K**	**$0 - 2K**	
LT1	Future Development Master Plan (stormwater elements only)	To ensure that any future development layout considered stormwater management system closely	**$10-$20K**	**$0**	
LT2	Flood and Drainage Master Plan	To ensure that any future development is planned with flooding and drainage as key considerations	**$10-$20K**	**$0**	

Site ID	Action Description	Action objectives	Preliminary Cost Estimate		
			Capital	Annual	Priority
LT3	Stormwater Quality Master Plan	To ensure that any future development is planned with stormwater quality as a key consideration	**$10-$20K**	**$0**	
LT4	Developer Water Management Guidelines	To ensure that locally specific guidance is available for future development planning	**$10-$20K**	**$0**	

7 Conclusion and Recommendations

A stormwater management plan for North Arm Cove that considers existing village and potential future development areas was prepared to identify management actions appropriate for mitigating current stormwater management issues and avoiding potential additional issues associated with further development. Based on issues identified by the community, several short term actions that focus on improving the management of stormwater quality and quantity in the existing village, and the planning of stormwater management systems as a component of any potential future development in the undeveloped lots were identified.

Key recommendations arising from this stormwater management strategy for the short term include:

- Construction of a pre-treatment swale/basin and biofiltration basin in Casuarina Park to improve stormwater runoff quality prior to discharge into North Arm Cove;
- Construction of a pre-treatment swale/basin and biofiltration basin in 104 Cove Blvd (excludes cost of land purchase) to improve stormwater runoff quality prior to discharge into North Arm Cove;
- Construction of a level spreader at drainage outlet into Casuarina Park to generate sheet flow conditions through Casuarina Park to prevent scouring;
- Regrading and bitumen sealing of Merriwa Blvd to reduce soil erosion along this steep section of road;
- Removal of rock lining in upper and middle channel reaches and lay new pipe to reduce community hazard, reduce maintenance hazards and costs, reduce potential for bed and bank erosion;
- Construction of a new 5 year ARI culvert across The Esplanade near 51 The Esplanade to improve access to 51 The Esplanade during wet weather, improve the durability of the driveway and reduce maintenance for the property owner; and
- Construction of new kerb and gutter between 36 and 54 Cove Blvd (east side) and adjust driveway accesses to prevent runoff from high side of road draining into low side properties and maintain access to properties.

Key recommendations to be considered by Council in the longer term include preparing:

- A Future Development Master Plan (stormwater elements only) to ensure that any future development layout considered stormwater management system closely;
- Flood and Drainage Master Plan to ensure that any future development is planned with flooding and drainage as key considerations;
- Stormwater Quality Master Plan to ensure that any future development is planned with stormwater quality as a key consideration; and
- Developer Water Management Guidelines to ensure that locally specific guidance is available for future development planning.

8 References

Murphy C.L. (1995). *Soil Landscapes of the Port Stephens 1:100,000 Sheet Report*, Department of Land and Water Conservation, Sydney.

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Appendix A Catchment Flood Modelling

A.1 Flood Hydrology

A.1.1 Overview

The hydrologic model simulates the rate at which rainfall runs off the catchment. The amount of rainfall runoff from the catchment is dependent on:

- catchment slope, area, vegetation and other characteristics;
- variations in the distribution, intensity and amount of rainfall; and
- antecedent conditions (dryness/wetness) of the catchment.

Flooding hydrology for the study area was evaluated applying two methods, a direct rainfall on grid approach (TUFLOW) and a hydrograph routing method (XP-RAFTS). Results of the two methods were compared at key locations within the study area to confirm that the methods were producing similar peak flows.

A.1.2 Direct Rainfall

The TUFLOW model was used to simulate catchment hydrology for the 1% AEP event. The direct rainfall approach was applied to simulate surface runoff and route this runoff along the overland flow paths and drainage gullies within the study area. The runoff routing and hydrological response of the catchment within the model is driven by the surface type and underlying topography.

Rainfall information is the primary input and driver of the hydrological model, which simulates the catchments response in generating surface run-off. Rainfall characteristics are described by:

- Rainfall depth – the depth of rainfall occurring across a catchment surface over a defined period (e.g. 270mm in 36hours or average intensity 7.5mm/hr); and
- Temporal pattern – describes the distribution of rainfall depth at a certain time interval over the duration of the rainfall event.

Both of these properties may vary spatially across the catchment.

For design events, rainfall depths are most commonly determined by the estimation of intensity-frequency-duration (IFD) design rainfall curves for the catchment. Standard procedures for derivation of these curves are defined in AR&R (2001). The rainfall intensities outlined in **Table A-1** were used to derive the direct rainfall inputs to the TUFLOW model.

The 2 hour storm was evaluated to be the critical duration for the catchment based on XP-RAFTS modelling (refer Section A.1.3). Therefore, 102.2mm (2 x 51.1mm) of rainfall was applied across the entire model grid covering the catchment draining through the study area over a 2 hour period. The rainfall was applied incrementally within the model according to the standard temporal patterns presented in AR&R (2001).

Table A-1 IFD Data for North Arm Cove (mm/hr)

Duration	ARI (years)						
	1	2	5	10	20	50	100
5 min	87.8	113	144	162	186	218	242
6 min	82.2	106	135	152	175	204	227
10 min	67.2	86.4	111	125	144	168	187
20 min	49.1	63.2	81.3	91.8	106	124	138
30 min	39.9	51.4	66.2	74.9	86.3	101	113
1 hr	26.9	34.8	45.0	51.0	58.9	69.3	77.2
2 hrs	17.5	22.6	29.5	33.5	38.8	45.8	**51.1**
3 hrs	13.4	17.4	22.8	26.0	30.1	35.6	39.9
6 hrs	8.50	11.1	14.6	16.7	19.5	23.1	25.9
12 hrs	5.45	7.10	9.43	10.8	12.6	15.0	16.9
24 hrs	3.56	4.64	6.15	7.05	8.24	9.80	11.0
48 hrs	2.31	3.00	3.95	4.52	5.27	6.25	7.01
72 hrs	1.73	2.25	2.96	3.38	3.93	4.66	5.22

The response of the catchment to the input rainfall data is dependent on the spatial distribution and hydrologic properties of the land use surface types. The properties assigned to each surface type (or material) within TUFLOW that influence the hydrologic response of the model are:

- Initial and continuing losses determine how much rainfall is lost to surface and soil storage etc. and therefore the effective rainfall contributing to surface runoff;
- Roughness parameters for sheet flow govern the speed with which the runoff will travel, influencing the hydrologic response of the model.

The material layers input to the model define these properties for each land use surface type within the catchment. Each material has an initial loss, continuing loss and roughness parameter assigned to it. Along with the model topography, it is these parameters which determine the runoff routing and hydrological response of the model.

Due to the nature of the direct rainfall approach, sheet flow is simulated across the entire catchment prior to the commencement of overland flow. Direct rainfall models can produce discharge hydrographs displaying a response that is more rapid than expected if sheet flow is allowed to behave as overland flow. A depth-varied Manning's 'n' can be incorporated into the model to accurately represent sheet flow behaviour at low depths across 'rough' surfaces such as forest floors. As a large portion of the study area is forested, it was necessary to include a depth-varying roughness value to appropriately simulate sheet flow.

Table A-2 Adopted Roughness Values and Rainfall Losses

Material	Roughness	IL	CL
Forest*	0.120	15.0	2.5
Roads	0.020	0.0	0.0
Unsealed tracks	0.035	5.0	0.0
Rural residential	0.050	15.0	2.5
Waterways	0.020	0.0	0.0

* The applied Manning's roughness was depth-varied, approaching 0.12 for depths of water representative of overland flow. For sheet flow (lower water depths), a higher roughness value was adopted.

A.1.3 Hydrograph Routing

XP-RAFTS flood routing software was also applied to generate outflow hydrographs for each sub-catchment using the IFD data presented in Table A-1. The XP-RAFTS results were compared with output from the TUFLOW direct rainfall model as a form of validation.

For XP-RAFTS modelling, each sub catchment was divided into impervious and pervious areas, based on percentage of residential development. Forested regions were assumed to be 100% pervious and were assigned a material roughness of 0.12. A material roughness value of 0.015 was adopted for impervious areas. An initial loss of 15mm and continuing loss of 2.5mm/hr were adopted for forested areas. Pervious areas were assumed to have 2mm initial loss only. Average vectored catchment slopes were determined from LiDAR data provided by Council.

Key locations used for validation of the TUFLOW direct rainfall method were the overland flow paths through 33 The Esplanade and 51 The Esplanade. At these locations, estimated 1% AEP peak flow rates from TUFLOW (direct rainfall approach) and XP-RAFTS (hydrograph routing) methods were similar and within 0.1m^3/s. Therefore, the TUFLOW modelled direct rainfall flows were adopted for evaluating the flood hydraulics.

A.2 Major Sub-catchment Hydraulics

A TUFLOW model was developed to simulate overland flooding and to identify major overland flow paths within the study area. A 2m digital elevation model (DEM) was derived from LiDAR data provided by Council and a model grid resolution of 5m was adopted. Direct rainfall was applied over the entire model extent, as detailed in Section A.1.2.

The adopted downstream boundary condition for the modelled simulations was a constant water level of 0.5m AHD, corresponding to an average water level for the Port Stephens estuary. The inland boundary condition was set as a constant water level of 0.5m AHD. This prevents stormwater from accumulating at the model boundary and allows for runoff from the study area to exit the model domain. As the inland model boundary is located a sufficient distance away from the study area, any influence of this boundary condition effectively "removing" water out of the model domain will not affect the results within the study area.

A.3 Minor Sub-catchment Hydraulics

The TUFLOW model provides representation of the major overland flow paths through the study area. This comprised two main sub-catchments located in the southern part of the study area. A number of other smaller sub-catchments drain along roads and through developed private properties in the study area. Drainage of these smaller sub-catchments is highly influenced by localised terrain changes and infrastructure that can significantly alter natural flow paths. The resolution of the TUFLOW model is typically not at a fine enough scale to simulate these distinct changes.

Therefore, discrete modelling of these small sub-catchments has been completed applying simplified modelling approaches. The smaller sub-catchments extents were confirmed by field survey in a number of cases, and the Probabilistic Rational Method was applied to estimate peak flow rates at key locations (typically road culverts and locations where overland flow cross existing roads).

The estimated flow rates were applied to estimate the hydraulic capacity of existing infrastructure, including pit and pipe drainage lines at key locations, and estimate overland flows exceeding the capacity of the below ground drainage systems.

The Probabilistic Rational Method modelling utilised the IFD data presented in **Table A-1** and estimates of flow travel time to the small catchment outlet (i.e. time of concentration). The time of concentration for each small sub-catchment was estimated considering various components of the flow travel time including:

- Sheet flow - from top of catchment to the point where runoff would concentrate against a fence or be intercepted by a minor channel or gully (estimated using Friend's equation);
- Concentrated overland flow - from the end of sheet flow to nearest kerb, channel or pipe inlet (estimated using average stream velocity values determined from catchment gradient); and
- Swale flow – flow along a roadside table drain until captured by an inlet (estimated using Manning's equation).

Figure 4-3 to Figure 4-7 provides estimated peak flows at key locations, as determined by the Probabilistic Rational Method.

Appendix B Catchment Runoff Quality Modelling

B.1 Overview

Stormwater quality for existing conditions and future development scenarios was assessed using the Model for Urban Stormwater Improvement Conceptualisation (MUSIC) software (Version 5.1) developed by eWater. The software has been specifically designed to allow for comparisons to be made between different stormwater management systems and thereby function as a decision support tool.

The MUSIC modelling focused on conceptual sizing of centralised stormwater quality management measures at key strategic locations within the existing village where it is considered that the potential for improving existing runoff quality is highest. Negotiations with existing private land owners would be required in some instances. Other locations align with current publicly owned land.

The MUSIC modelling process is detailed in the following sections.

B.2 Meteorological Template

The meteorological template includes the rainfall and areal potential evapotranspiration data. It forms the basis for the hydrologic calculations within MUSIC.

The nearest long-term Bureau of Meteorology (BoM) continuously recording rainfall station is located at Williamtown approximately 23km south of North Arm Cove. A long-term daily recording BoM rainfall station is also located at Nelson Bay approximately 12km to the east. Daily rainfall has been recorded by a resident in Tanilba Bay approximately 6km south-west of North Arm Cove since 2005 (http://www.tanilbabayweather.com/alan.html).

Comparison of the Williamtown and Nelson Bay rainfall data indicated a significant difference in mean annual rainfall. The average annual rainfall for Station 61078 Williamtown RAAF Base Station is 1121mm and for Station 61054 Nelson Bay (Nelson Head) is 1346mm. Based on this data, adoption of the Williamtown pluviograph data for modelling is likely to under estimate rainfall at North Arm Cove. Data were sourced from the Tanilba Bay weather station for the period 2005 to 2010 and compared with the BoM Williamtown and Nelson Bay rainfall stations for a similar period to assess which BoM site is likely to be most representative of rainfall at Tanilba Bay. Comparison of rainfall data over the 2005 to 2010 period (which is common to all stations) provided average annual rainfall totals of 1144mm, 1290mm and 1295mm for Williamtown, Nelson Bay and Tanilba Bay respectively. The monthly rainfall distribution for each of these sites was also evaluated, and these values are shown in Figure B-1.

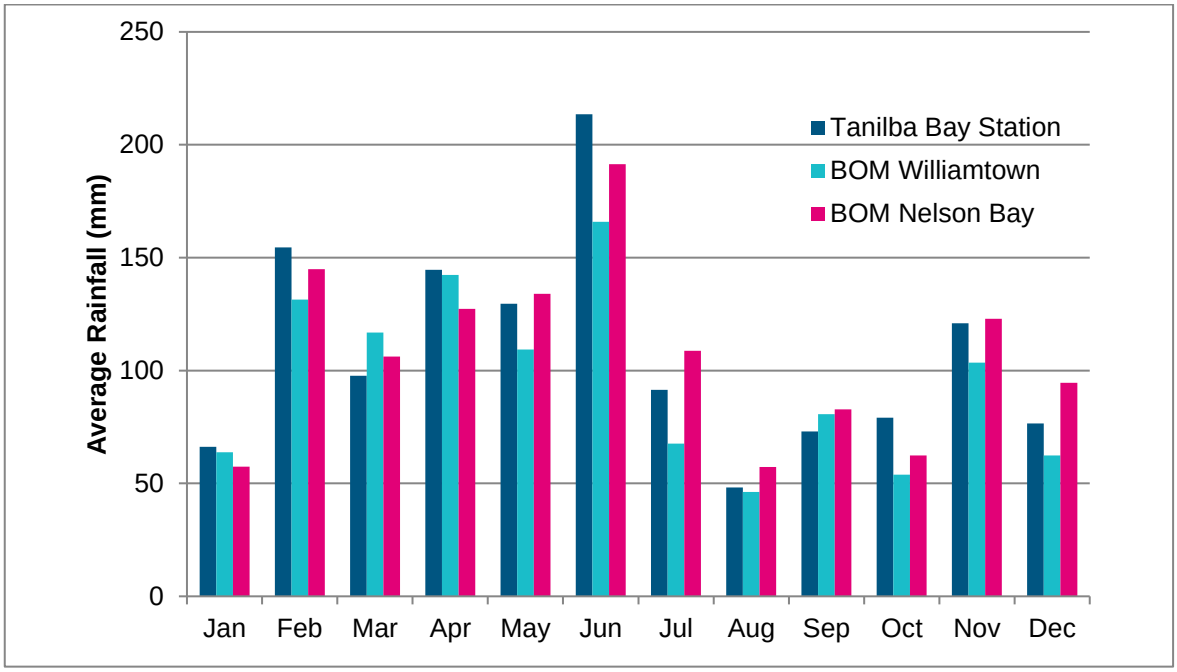

Figure B-1 Rainfall Data Comparison (2005 - 2010)

Consideration of the average annual rainfall totals and monthly rainfall distribution suggests that rainfall patterns at North Arm Cove/Tanilba Bay are closer to observations at Nelson Bay. MUSIC requires pluviograph data input which is only available for Williamtown. Williamtown pluviograph rainfall data were sourced and scaled to be more representative of long-term rainfall patterns at North Arm Cove.

Pluviograph rainfall data for 61078 Williamtown RAAF Base were sourced and reviewed for the 1953 to 2010 period to identify a continuous period of good quality data with an average annual rainfall similar to long term conditions. Review of the Williamtown rainfall data indicated that the 1996 to 2005 period was relatively free of data gaps and accumulated rainfall data. The mean annual rainfall for this period is 1105mm which is similar to the long-term mean annual rainfall of 1121mm at Williamtown (www.bom.gov.au/climate/averages/tables/cw_061078.shtml).

The Williamtown pluviograph data for the 1996 to 2005 period were extracted and scaled to reflect the typically wetter conditions at North Arm Cove. The data were scaled applying monthly scaling factors determined from comparison of monthly averages at Williamtown, Nelson Bay and Tanilba Bay.

Average monthly areal potential evapotranspiration (PET) rates adopted for the MUSIC modelling are summarised in **Table B-1**. These values were obtained from BOM gridded data. A 6-minute modelling time step was adopted for the MUSIC modelling.

Table B-1 Adopted Average Monthly Areal PET Rates

Month	Mean monthly areal PET (mm)
January	186
February	148
March	147
April	95
May	66
June	53
July	56
August	72
September	100
October	139
November	160
December	179

B.3 Rainfall-Runoff Parameters

Modelling of the rainfall-runoff process in MUSIC requires the definition of one impervious surface parameter and eight pervious surface parameters. The parameters can be estimated through a calibration and validation exercise for a particular catchment. The impervious surface parameter (rainfall threshold) was adopted considering industry accepted defaults. Preliminary modelling was undertaken to confirm appropriate pervious surface parameters based on the soil types and hydrological conditions typical of catchments similar to site.

The average annual rainfall fraction (ARF) was estimated for the proposed development by applying methods derived by Fletcher et al. (2005) for NSW catchments. The work by Fletcher et al. (2005) assists with estimating the surface runoff proportion for 100% pervious NSW catchments/sites based upon the local mean annual rainfall. It represents the proportion of rainfall that is typically converted to runoff for a particular catchment/site. Based on a mean annual rainfall (MAR) of 1340mm, it is estimated that the ARF would be approximately 33% for the site.

Runoff modelled within MUSIC includes surface runoff and base flow components. For this study, a base flow index (BFI) of 0.2 was adopted as being representative of the existing catchment conditions. This assumes that 80% of runoff observed in the watercourses is typically sourced from surface runoff, with the remaining 20% contributed by base flow during dry weather periods. The MUSIC hydrologic parameters estimated based on these assumptions are summarised in **Table B-2**.

Table B-2 Adopted MUSIC Rainfall-Runoff Parameters

Impervious Area Parameters	Value
Rainfall Threshold (mm)	1.0
Pervious Area Parameters	
Soil Storage Capacity (mm)	120
Initial Storage (% of capacity)	30
Field Capacity (mm)	85
Infiltration Capacity Coefficient – a	150
Infiltration Capacity Exponent - b	3.5
Groundwater Properties	
Initial Depth (mm)	10
Daily Recharge Rate (%)	25
Daily Baseflow Rate (%)	10
Daily Deep Seepage Rate (%)	0

B.4 Runoff Quality Parameters

The MUSIC input stormwater constituent concentrations were adopted from those recommended for NSW in Fletcher et al. (2005). Mean values for each parameter were calculated from the 'typical' values presented in Fletcher et al. (2005). The normalised values presented within that report were converted to logarithmic values for input into MUSIC. The existing default standard deviation values in MUSIC were adopted. This approach was consistent with that adopted for scenario modelling in Fletcher et al. (2005). The adopted log_{10} values are summarised in **Table B-3** and

Table B-4.

Table B-3 Storm flow concentrations for MUSIC modelling in NSW (log_{10})

	TSS		TP		TN	
	mean	std. dev	mean	std. dev	mean	std. dev
Residential	2.15	0.32	-0.60	0.25	0.30	0.19
Forest	1.60	0.20	-1.10	0.22	-0.05	0.24
Unsealed roads	3.00	0.32	-0.30	0.25	0.34	0.19

Table B-4 Base flow concentrations for MUSIC modelling in NSW (log_{10})

	TSS		TP		TN	
	mean	std. dev	mean	std. dev	mean	std. dev
Residential	1.20	0.17	-0.85	0.19	0.11	0.12
Forest	0.78	0.13	-1.52	0.13	-0.52	0.13
Unsealed roads	1.20	0.17	-0.85	0.19	0.11	0.12

B.4.1 Sub-catchments

Key inputs to MUSIC include the sub-catchment area and directly connected impervious area.

Sub-catchments were estimated for two centralised stormwater quality management measures. One is recommended for consideration in Casuarina Park and the other within land at 104 Cove Boulevard (subject to negotiation with the existing land owner). It is estimated that the Casuarina Park and 104 Cove Boulevard measures have similar sub-catchment areas of 6.41 ha and 6.43 ha respectively. The Casuarina Park sub-catchment comprises 40% residential land, 55% forested land and 5% unsealed roads. The 104 Cove Boulevard comprises 35% residential land, 60% forested land and 5% unsealed roads.

In addition to the total areas, MUSIC requires the input of an estimated directly connected impervious area which represents the area within a catchment that is linked through a continuous series of impervious surfaces to a receiving environment. It effectively represents the areas that will result in runoff being discharged to a particular location in all but the smallest of rainfall events.

The typical imperviousness of the residential areas was estimated by digitising the roof, driveway and paved areas within the lots. Based on the sampled area, it was estimated that the directly connected imperviousness of these areas was approximately 15% of the total residential area. It was also assumed that unsealed roads were 10% impervious to account for compaction of these surfaces that is likely to more regularly yield runoff than a pervious garden area.

Conservatively, it was assumed that rainwater tanks do not currently reduce the volume of roof runoff in the village areas. Conceptual design of the measures should incorporate consideration of roof water harvesting which is likely to marginally reduce the size of the modelled measures.

B.5 Stormwater Treatment Measures

It was assumed that a biofiltration basin (refer examples shown in Figure B-2) with a pre-treatment grassed swale/sediment basin would conceptually form the treatment series for the two modelled locations.

Figure B-2 Example Biofiltration Basins

Table B-5 Modelled Stormwater Treatment Measures

Parameter	Casuarina Park		104 Cove Boulevard	
	Pre-treatment swale/basin	Biofiltration Basin	Pre-treatment swale/basin	Biofiltration Basin
Extended detention surface area (m^2)	70	350	70	350
Extended detention depth (m)	0.6	0.60	0.6	0.60
Nominal detention time (min)	15	-	15	-
Planted biofilter area (m^2)	-	230	-	230
Filter depth	-	0.4m	-	0.4m
Total footprint (estimated) (m^2)	175	550	175	550

B.6 Results

The results of the MUSIC modelling for the stormwater treatment measure sizes summarised in **Table B-5** are shown in **Table B-6**. The modelling results indicate that the measures would achieve the adopted targets.

Table B-6 MUSIC model results

	Casuarina Park			104 Cove Boulevard		
Stormwater pollutant	Existing	Target[1]	Treated	Existing	Target[1]	Treated
TSS	4690	1400	1130	4450	1390	1110
TP	6.0	2.9	2.8	5.6	2.9	2.7
TN	47	32	31	44	31	30

1. Targeted load assumed that loads from forested areas remain unchanged. Loads from residential and unsealed road areas are to be reduced by 80%, 65% and 45% for TSS, TP and TN respectively.

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