Colac Otway Shire

Three Towns Stormwater Management Strategy

Concept Study

Final Report

October 2004

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Background

GHD was commissioned by the Colac Otway Shire (COS) to undertake a concept stormwater management study for the towns of Wye River, Separation Creek, and Kennett River (known as the 'Three Towns'), situated on the Great Ocean Road between Lorne and Apollo Bay. This concept study is the first stage of a more comprehensive stormwater management strategy for the three towns, with functional and detail design to be completed under future stages.

The existing system has largely developed in an *ad hoc* manner, with uncontrolled discharges between properties and the road drainage system. While a number of the newer subdivisions have kerb and channel drainage, particularly in Kennett River, most properties in the three towns have no access to a formal stormwater drainage system. In general, roof water is collected in rainwater tanks, with overflows directed into roadside table drains. Surface runoff from paved and pervious areas on private properties is largely uncontrolled, flowing down slope to adjacent properties and roads.

Two previous stormwater drainage designs have been proposed for the towns, the first by Garlic & Stewart in 1988 and the second by Fisher Stewart in 1997. The former recommended a reticulated system comprising separate low flow stormwater and sewerage, but was never adopted by Council. The latter design followed a standard urban drainage approach, consisting of pipes and pits.

Objectives

The broad objective of this strategy is to manage stormwater drainage in the three towns, recognising the constraints posed by the unique climatic, geological and environmental setting of the towns. The three towns are located in a landslide-prone, steep-terrain landscape, with high rainfall and high environmental values. While some standard urban drainage practices may be applicable to the three towns, the unique climatic, geological and environmental setting requires a substantially different approach to stormwater management. The key functions required of a stormwater drainage system for the three towns can be summarised as follows:

- Minimisation of stormwater runoff saturating soils on steep slopes;
- Control of nuisance flows that may damage property;
- Protection of public infrastructure assets, particularly roads;
- Separation of runoff and wastewater effluent; and
- Limit pollutants (sediment, nutrients and pathogens) entering receiving waters.

Source Control Recommendations

While stormwater drainage systems have traditionally been designed to dispose of stormwater as quickly as possible, the first and often least expensive approach to reducing drainage problems is to reduce or prevent stormwater runoff. To minimise and control stormwater at its source, it is recommended that the COS planning scheme be amended where necessary to ensure that site modifications such as property regrading, soil disturbance and vegetation removal are kept to a minimum, with drainage provided for all impervious surfaces on the property. It is also recommended that on-site stormwater detention systems be made mandatory for new developments.

Conveyance System Recommendations

While the emphasis of stormwater management in the three towns should be to minimise and control stormwater at its source, it is not feasible to contain all stormwater on-site. An off-site stormwater drainage system is required to control stormwater flows that exceed a property's on-site detention capacity and provide low-flow drainage disposal following storms. It is recommended that where conditions are suitable, the towns' existing pipe and pit systems be extended. Where properties have no access to a high flow piped drainage system, stormwater disposal should be to a roadside table drain (if available), or a low flow pipeline. Low flow pipelines should convey flows downslope to a stable discharge point such as a natural drainage line or vegetated area located on public land.

It is recommended that COS not proceed with implementation of the Fisher Stewart stormwater drainage design for Wye River, Separation Creek and Kennett River. The design is considered inappropriate for the study area on the basis of geotechnical risk, water quality risk, and cost.

Road Drainage Recommendations

In the three towns, inadequate road drainage has contributed to widespread damage of the road surface. It is recommended that where possible, poorly-draining unsealed roads in the three towns be re-graded with a crowned or cross-graded profile. Where roads shed drainage water onto a fill slope or private property, a berm should be provided on the outer edge of the road to contain runoff and direct it to the road drainage system. In some locations, table drains are absent or have inadequate capacity. It is recommended that table drains be provided along all roads without kerb and channel drainage. All driveway crossings should comprise a 300 mm diameter culvert, with a trash rack installed at the inlet.

Given the steep grade of the roads in the study area, cross drainage is in many cases inadequate, contributing to high flow velocities and scouring of the table drains. In addition to this, cross drainage is discharged onto fill slopes at a number of locations, often into private properties. It is recommended that additional cross drainage be provided where recommended spacings are exceeded. Due to the degree of development in the towns, there are in many cases no vegetated areas located adjacent to the road suitable for cross drainage discharge. In such cases, it is recommended that cross drainage discharge be directed down the slope to a stable discharge point via a slope drain. Where these drains pass through private property, drainage easements should be established along the pipe alignment.

Natural Drainage Line Recommendations

The design approach for stormwater management in the three towns will be to utilise natural drainage lines wherever possible. A system of gullies and streams through the study area provide suitable discharge points for most piped and open channel drainage. The design approach will aim to improve the connectivity of the existing drainage system, ensuring that table drains and pipelines are well connected to natural drainage lines. Given the importance of natural drainage lines to the functioning of the stormwater drainage system, it is recommended that no further development be allowed to occur over natural drainage lines in the three towns. A number of minor drainage lines in the study area are located on private property. It is recommended that drainage easements be established over all drainage lines located on private property which receive discharge from the drainage system.

Stormwater Disposal Recommendations

A number of table drains and pipes in the study area discharge directly to natural drainage lines, typically as concentrated, high-velocity flows. These concentrated discharges allow for no natural trapping of sediment and gross pollutants, and may directly contribute to erosion of gully beds and banks. It is recommended that where possible, sediment traps be provided at all drainage discharge points. To limit erosion to drainage lines and vegetated areas, all drainage discharge points and outfalls should be constructed to ensure dissipation of flow across a wide, well-vegetated area.

A number of stormwater drains in the three towns discharge directly to waterways or the foreshore. Where hydraulic constraints permit, it is recommended that these drainage outfalls be relocated upstream, above the level of receiving waters. At Kennett River, stormwater discharges from one of the catchments are passed through a constructed wetland before release into Kennett River. If capacity is available, it is recommended that additional drainage outfalls be routed through the wetland. This may require extension of the wetland or alternatively, construction of new wetlands.

Maintenance Recommendations

An important consideration in the design of any stormwater drainage system is the ongoing maintenance of new and existing infrastructure. The condition of many of the drainage assets in the three towns has deteriorated to a state where they are now inoperable or barely functional. In particular, many driveway culverts are partially or completely blocked, causing drainage water to flow over the road surface.

While COS has a responsibility to maintain roads and road drainage in the three towns, it is unrealistic to expect that the Shire can respond to and resource all maintenance needs in a timely manner. It is recommended that residents be encouraged to carry out low-level maintenance of drainage works located on or in the vicinity of their properties. Given that many of the towns' residents are not permanent, there will be times of the year when drainage maintenance demands cannot be met by the local community. To ensure an appropriate level of on-going drainage maintenance, it is recommended that a local resident be employed by COS to provide on-going monitoring and maintenance of the three towns stormwater drainage system.

While the increased participation of the local community in maintaining the drainage system will ensure increased reliability and sustainability, COS will retain the primary responsibility for maintenance. It is recommended that COS undertake a condition assessment of all roads and stormwater drainage assets in the three towns and establish a condition record on the Shire's GIS database. On the basis of this condition assessment, maintenance tasks should be prioritised and a maintenance program developed.

Implementation

While many of the concept drainage design recommendations can be implemented immediately, others will involve a gradual process of change, particularly where community education and cultural change are required.

Capital and maintenance works will generally be undertaken on a priority basis and as funds become available. While some maintenance works can be undertaken immediately, most capital works (such as the construction of new cross drains) will require functional and/or detailed design before they can be carried out. In most cases, functional and detailed design will require an accurate database of existing drainage assets. It is therefore recommended that COS update its GIS-based asset database for the three towns. While most of the drainage assets have been recorded on the database, many of the assets are unnamed and have no details recorded.

Because community education and cultural change are long term processes and fundamental to effective stormwater drainage management, it is suggested that education of the local community commence at the earliest possible opportunity.

1. Introduction

GHD was commissioned by the Colac Otway Shire (COS) to undertake a concept stormwater management study for the towns of Wye River, Separation Creek, and Kennett River (known as the 'Three Towns'), situated on the Great Ocean Road between Lorne and Apollo Bay. This concept study is the first stage of a more comprehensive stormwater management strategy for the three towns, with functional and detail design to be completed under future stages.

The stormwater management strategy was initiated by COS in response to the recommendations of the Coastal Community Revitalisation Project, undertaken by Council in 2003 (Dahlhaus *et al* 2003), and to facilitate implementation of the Colac Otway Stormwater Management Plan (KBR 2002).

The broad objective of the strategy is to manage stormwater drainage in the three towns, recognising the constraints posed by the unique climatic, geological and environmental setting of the towns. The three towns are located in a landslide-prone, steep-terrain landscape, with high rainfall and high environmental values. As such, the inappropriate application of urban drainage practices developed for flatter, more stable landscapes may in fact increase the risk of erosion, landslide and subsequent environmental degradation.

The objectives of this concept study were essentially twofold: to assess the adequacy of the existing stormwater drainage system in the three towns, including supporting Council policy, and to develop stormwater drainage options suitable for the landslide-prone, environmentally-sensitive setting. Specific tasks included:

- A review of stormwater drainage practices suitable for landslide-prone areas, and their potential application to the study area;
- An assessment of the adequacy of, and risks associated with the existing stormwater system, from a hydraulic, geotechnical (landslide) and environmental (particularly water quality) perspective;
- A review of relevant Council documents relating to stormwater management in the three towns, including the COS Stormwater Management Plan, COS Waste Water Strategy, and relevant COS Planning Scheme conditions; and
- The preparation of a concept stormwater drainage design for the three towns.

This report provides a summary of work undertaken for the concept study, and recommendations for stormwater drainage management in the three towns.

2. Previous Studies

The Three Towns Stormwater Management Strategy was initiated by Colac Otway Shire (COS) in response to the recommendations of the Coastal Community Revitalisation Project (CCRP), undertaken by Council in 2003 (Dahlhaus *et al* 2003). The principal focus of the CCRP was the collection of baseline environmental information for the townships of Wye River, Separation Creek and Kennett River. Included was a review of stormwater management and drainage, wastewater management, and landslide risk management in the three towns.

The CCRP included a comprehensive review of previous studies, and it is not intended to duplicate that effort here. Of particular relevance to stormwater management in the three towns however, are two previous engineering studies. The first was a preliminary investigation into potential sewerage and stormwater schemes for Wye River and Separation Creek (Garlick & Stewart 1988). The second was a study of drainage infrastructure in Wye River, Separation Creek and Kennett River (Fisher Stewart 1997) that comprised functional designs of stormwater drainage schemes for the three towns.

The Garlic & Stewart (1988) study identified the complete lack of a stormwater drainage system in either Wye River or Separation Creek, with stormwater flowing overland to natural drainage lines and watercourses. The study found that the lack of a stormwater drainage system, combined with discharge from septic systems, was contributing to permanent saturation of the soil. This in turn was presenting a public health hazard by increasing bacterial levels in the soil, and increasing the risk of landslide. The study considered three alternatives for minimising soil saturation:

- Separate reticulated stormwater and sewerage systems (standard);
- Combined effluent system (wastewater and stormwater); and
- Separate low flow stormwater and low flow septic tank effluent systems.

Of the three options, the first was rejected on the basis of cost and requirement for a reticulated water supply, while the second was rejected on the basis of health risk and the corrosive nature of sewage. The third option was assessed as offering the cheapest and most practical overall solution to stormwater and sewerage management in the towns.

Due to community opposition, the recommendations of the Garlick & Stewart (1988) study were never adopted by Council (Dahlhaus *et al* 2003).

The Fisher Stewart (1997) study comprised functional designs of stormwater drainage schemes for the three towns. The schemes followed a standard urban drainage approach, consisting of pipes and pits. Dahlhaus *et al* (2003) noted that the study did not consider the impacts of the proposed drainage scheme on the biophysical and environmental assets of the town, and recommended that this occur before implementation of the scheme.

3. Stormwater Drainage System Objectives

3.1 Introduction

Before developing a stormwater drainage system concept design for the three towns, it is imperative to ask the question: *'why have a stormwater drainage system?'*

In Australia, urban stormwater drainage systems have traditionally been designed to collect and convey stormwater to receiving waters, with minimal nuisance, danger or damage (IEAust 1998). The objective of urban stormwater drainage has been to dispose of stormwater as quickly as possible, through the construction of pits and drains, sealing and drainage of roads, filling of swamps, smoothing of surfaces, and lining and straightening of stream channels (Upper Parramatta River Catchment Trust 2004). Increasingly however, stormwater drainage systems are seen as an important component in the creation of sustainable urban environments. As such, stormwater systems are being designed to minimise stormwater pollution of receiving waters, and as a means of water conservation.

The fundamental guiding principles of stormwater drainage design, as outlined in Australian Rainfall and Runoff (IEAust 1998), provide a useful context for considering stormwater drainage in the three towns:

- Descriptions and analyses of stormwater drainage systems should be based on measured or observed real system behaviour;
- Drainage systems must be viewed in relation to the total urban system;
- Drainage systems should be designed and operated to maximise benefits to the community; and
- Designers should be influenced by professional considerations such as ethics, standardisation and innovation.

3.2 Three Towns Stormwater Drainage Functions

While some standard urban drainage practices may be applicable to the three towns, the unique climatic, geological and environmental setting of the towns requires a substantially different approach to stormwater management. The three towns are located in a landslide-prone, steep-terrain landscape, with high rainfall and high environmental values.

The key functions required of a stormwater drainage system for the three towns can be summarised as follows:

- Minimisation of stormwater runoff saturating soils on steep slopes;
- Control of nuisance flows that may damage property;
- Protection of public infrastructure assets, particularly roads;
- Separation of runoff and wastewater effluent; and
- Limit pollutants (sediment, nutrients and pathogens) entering receiving waters.

3.3 Minimisation of Stormwater Runoff Saturating Soils on Steep Slopes

The Otway Ranges rank among the most hazardous areas for landslides in Australia, with landslides having previously occurred in or near all three coastal towns (Dahlhaus 2003). The susceptibility to landslides is attributed to:

- High rainfall;
- Steep slopes;
- The unfavourable orientation of the strata;
- The inherently weak nature of the rock mass;
- Man-made alterations to slope morphology;
- Man-made alterations to slope hydrology and drainage;
- Loads induced on the slope by man-made structures;
- Occasional earthquake activity (seismicity); and
- Coastal erosion and valley erosion over geological time.

While landslides have been a feature of the study area for the past 5 000 years, development in the three towns has substantially increased the chance of landslides occurring. This has been a result of more weight being added to slopes, more intensive infiltration (septic tank effluent, gardens, roof and road runoff) and changes to slope morphology (Dahlhaus 2003).

Water is commonly the primary factor triggering landslides, often following intense rainfall. Landslides can be exacerbated by development, when soils on steep slopes become saturated by increased stormwater runoff. This may result from increased impervious areas, uncontrolled runoff, or drainage system failure. In the three towns, the lack of a well-maintained and planned drainage scheme has increased the probability of a landslide event resulting from heavy or prolonged rain events (Dahlhaus 2003).

As the saturation of slopes is the most common trigger for landslides, the management of stormwater drainage is an important strategy in landslide risk management (Dahlhaus 2003). Improving drainage is often the most cost-effective means of reducing the likelihood of landslides (Shipmen n.d.). Given this, the management and control of slope stability and erosion is regarded as the primary function of the proposed stormwater drainage system. This is in contrast to most stormwater drainage systems, which are designed to mitigate flooding and associated risks to lives and property.

3.4 Control of Nuisance Flows

While the steep topography of the three towns ensures that large-scale flooding is unlikely, some localised flooding may occur during periods of heavy rainfall. While some stormwater runoff is inevitable, nuisance flows may be exacerbated by alterations to slope morphology, hydrology and drainage. Such modifications include regrading of properties, alteration of drainage flow paths, removal of vegetation, disturbance or compaction of soils, ineffective drainage control, and pipes discharging onto slopes (Myers *et al* 1995). In the three towns, localised flooding may occur within a property as a result of runoff from an upstream property or road, or lack of adequate on-site drainage.

A key function of the stormwater drainage system will be to capture stormwater runoff that threatens property and convey the runoff to a stable discharge point.

3.5 Protection of Public Infrastructure Assets

As well as protecting private property in the three towns, the stormwater drainage system will be required to protect public infrastructure assets. The most important of these are the local roads that provide access to properties. The drainage of roads is critical for two reasons: to protect the road structure from damage, and to protect water quality. Other assets that require protection include privately constructed retaining walls, parking bays, embankments and fills located on the road reserve. While not strictly public assets, the ownership and therefore responsibility for these assets remains unclear.

While some of the roads in Wye River, Separation Creek and Kennett River are sealed and have kerb and channel drainage, a number of the steeper roads are unsealed. Poorly drained forest roads are prone to rutting where water ponds, while running water erodes the road surface (Storey *et al* 2003). Failure to remove runoff from the road system can cause erosion of the road surface, table drains, batters, and outlets (Cummings 1998). Effective drainage of these roads protects the road formation from damage, ensuring a more stable road surface. This in turn reduces maintenance and repair costs.

Poorly located, constructed or maintained forest roads are recognised as a major source of non-point source pollution, with roads over steep slopes, erodible soils or stream crossings having the greatest potential for degrading water quality (Holaday 1995). Inadequate or inappropriate drainage of unsealed roads results in the sedimentation of table drains, culverts and streams, leading to stream turbidity and damage to flora and fauna (Cummings 1998).

A key function of the stormwater drainage system will be to protect the towns' roads from water damage and prevent water quality degradation of receiving waters due to sediment loss from the roads. Provision of adequate road drainage will also reduce the risk of landslide. A number of studies have found that road drainage waters directed onto landslide prone locations, such as steep fill slopes, increases the risk of landslides (Oregon Department of Forestry 2003).

3.6 Separation of Runoff and Wastewater Effluent

Dahlhaus *et al* (2003) reported that surface water quality samples collected in the three towns exceeded the recommended upper nutrient limits set by the EPA's State Environment Protection Policies (SEPP) on nutrient objectives for waters in rivers and streams in the Otway region and the SEPP on marine and estuarine ecosystem protection for estuaries and inlets. Additional microbiological analysis completed as part of that study indicated that E.coli levels in Wye River were above the EPA limit for both sewage discharge requirements and recreational waters and seawaters.

Many of the water quality issues have been attributed to wastewater management practices in the three towns, which are unsewered. Concerns with public health risk and faulty septic systems prompted Council to prepare a Wastewater Management Strategy in 2001 (COS 2001). The Wastewater Management Strategy found that many of the wastewater disposal systems in the towns were defective and many were discharging treated effluent off-site, representing potential pollution problems should the systems fail (Dahlhaus *et al* 2003).

While many of the wastewater management issues have been addressed by the COS Wastewater Management Strategy and subsequent issues papers, the management of stormwater is an integral part of the solution. If it is not excluded from the wastewater disposal area, stormwater runoff has the potential to reduce the effectiveness of effluent disposal and may exacerbate any off-site pollution impacts should the wastewater disposal system fail. A key function of the stormwater drainage system will be to intercept and convey stormwater runoff away from wastewater disposal areas.

3.7 Limit pollutants entering receiving waters

The key functions described above deal with the collection and conveyance of stormwater runoff. An equally important consideration in the design of the stormwater system is the disposal of this runoff. A key function of the stormwater drainage system will be to limit the nutrient and sediment loads entering the riverine and marine waters of the towns.

The waterways in the study area of high environmental value, with condition ratings ranging from fair to excellent (Dahlhaus *et al* 2003). As described in the previous section, water quality in these waterways is potentially being impacted by stormwater and wastewater discharges from the three towns.

4. Conceptual Design Approach

4.1 Introduction

Based on the design objectives outlined in Section 3, a conceptual design approach has been developed for managing stormwater drainage in the three towns. In this report, the conceptual design approach has been divided into three main sections, each describing a major component of the stormwater drainage system:

- Stormwater collection (Section 4.2);
- Stormwater conveyance (Section 4.3); and
- Stormwater disposal (Section 0).

The overall drainage design concept is brought together in Section 4.6.

The conceptual design approach includes examples of drainage techniques that may be appropriate for application in the three towns, and examples of inappropriate practices. To assist with implementation of the conceptual design approach, recommendations are provided for each of the drainage system components. Recommendations are also summarised in Section 7.

Drainage management systems can be classified into two general types (Myers *et al* 1995):

- Drainage minimisation solutions; and
- Drainage control system solutions.

To provide the greatest benefit, a stormwater drainage system for the three towns will need to comprise techniques to both reduce or prevent stormwater runoff, and control flows that do occur. It is important to note that no single drainage practice or component can by itself address the broad range of stormwater drainage issues in the three towns.

4.1.1 Existing stormwater system

The existing stormwater drainage system in the three towns is assessed in detail in Section 5. While a number of the newer subdivisions have kerb and channel drainage, particularly in Kennett River, most properties in the three towns have no access to a formal stormwater drainage system. The system has largely developed in an *ad hoc* manner, with uncontrolled discharges between properties and the road drainage system.

In general, roof water is collected in rainwater tanks, with overflows directed into roadside table drains, usually via a PVC pipe. Surface runoff from paved and pervious areas on private properties is largely uncontrolled, flowing down slope to adjacent properties and roads.

The roadside table drains are mostly on the same grade as the roads, and discharge to natural drainage lines and gullies where they cross. In many cases, roadside table drains and cross drains discharge into private properties.

Some development has occurred across natural drainage lines, disrupting the connectivity of the drainage system and potentially reducing its capacity to convey stormwater flows.

4.1.2 Previous stormwater design proposals

As discussed in Section 2, two previous stormwater drainage designs have been proposed for the towns, the first by Garlic & Stewart (1988) and the second by Fisher Stewart (1997). The former assessed three alternative drainage arrangements and recommended a reticulated system comprising separate low flow stormwater and sewerage pipes as offering the cheapest and most practical overall solution to stormwater and sewerage management in the towns. Due to community opposition, the recommendations of the Garlick & Stewart (1988) study were never adopted by Council (Dahlhaus *et al* 2003).

The latter design followed a standard urban drainage approach, consisting of pipes and pits. The approach was criticised by Dahlhaus *et al* (2003), who noted that the study did not consider the impacts of the proposed drainage scheme on geological hazards (landslides), water quality, estuarine and coastal ecologies, and cultural and heritage assets. Dahlhaus *et al* (2003) recommended that this occur before implementation of the scheme, which as yet has not been presented to the community for endorsement.

4.2 Stormwater Collection

4.2.1 Introduction

While stormwater drainage systems have traditionally been designed to dispose of stormwater as quickly as possible, the first and often least expensive approach to reducing drainage problems is to reduce or prevent stormwater runoff (Myers *et al* 1995). Where development occurs on steep slopes, drainage problems tend to occur where rainfall collected from large impervious areas is discharged to adjacent pervious areas with insufficient capacity to dissipate the flow. This causes runoff to move across the site as uncontrolled surface flow, potentially leading to slope stability and erosion problems (Myers *et al* 1995).

The following practices deal with the minimisation and control of stormwater runoff for private properties in the three towns.

4.2.2 Site modification

The most simple approach to reducing stormwater runoff from private properties is to reduce the amount of impervious surfaces on each property (Myers *et al* 1995). This includes roof areas and paved surfaces. Drainage should be provided for all impervious surfaces in order to avoid uncontrolled surface flows to adjacent slopes.

If suitable areas are available on the property and slope stability won't be affected, the water collected from impervious surfaces should be reintroduced over a large pervious area (Myers *et al* 1995). Suitable areas would typically be stable, well vegetated, and undisturbed. For many properties in the three towns, the small allotment size and slope stability problems will mean that there are no suitable discharge areas to reintroduce collected stormwater.

The minimisation and control of stormwater runoff can also be achieved by limiting the degree of site modification on each property. To minimise slope stability problems for properties on steep slopes, the following modifications should be avoided (Myers *et al* 1995):

- Regrading of property;
- Construction of driveways which alter drainage flow paths;
- Disturbance or compaction of native soils;
- Removal of vegetation along a slope;
- Conversion of native vegetation into landscaped areas;
- Construction of unstable earth fills; and
- Installation of pipes discharging to a slope.

Recommendations relating to site modification are presented in Table 1.

Table 1 Site Modification Recommendations

A1	For new developments, amend the COS planning scheme where necessary to ensure that site modifications such as property regrading, soil disturbance and vegetation removal are kept to a minimum.
A2	Amend the COS planning scheme where necessary to ensure that drainage is provided for all impervious surfaces on the property, and directed to a suitable disposal point.
A3	For existing properties, encourage, through education and grants, the source control of stormwater runoff. This includes the removal of paved surfaces, the reinstatement of natural drainage paths, and revegetation with indigenous plants.

4.2.3 On-site stormwater detention

Urban development almost always results in a loss of natural flood storage. On-site stormwater detention systems address this problem directly by providing additional flood storage close to the location that rainfall occurs. The main objective of on-site stormwater detention is to prevent any increase in downstream peak flows from new developments by temporarily storing on-site the additional and quicker runoff generated (Upper Parramatta River Catchment Trust 2004).

Detention storages work by holding collected stormwater and releasing it at a controlled rate. Storages can be constructed as above-ground or below-ground tanks or as surface ponds (Myers *et al* 1995). A range of pre-fabricated polyethylene, steel, aluminium and concrete stormwater detention tanks are commercially available in Australia.

While surface storages are less expensive than storage tanks, they are generally less suited to the steeper topography of the three towns. It is possible that an inappropriately-located surface detention storage could exacerbate a slope stability problem, if water infiltrates into the slope. While their application will be limited in the three towns, any surface stormwater detention storages that are constructed should be lined to prevent soil infiltration.

A number of commercially-available underground stormwater detention tanks are designed to allow infiltration of detained stormwater into the surrounding soil through the walls of the tank or via an infiltration trench. Given the steep topography of the study area, these systems will generally not be suitable for application in the three towns. As with the surface detention storages, any increased infiltration into soils on steep slopes can reduce slope stability and increases the risk of landslide. Slopes greater than 10% are regarded as unsuitable for stormwater infiltration trenches (Lake Macquarie City Council 2002).

Because there is no reticulated water supply in Wye River, Separation Creek or Kennett River, all properties in the towns have rainwater tanks. These tanks already provide some stormwater detention capacity, and would be an element of any new stormwater detention systems for the properties. On-site stormwater detention systems for the three towns should typically comprise a rainwater tank to collect roof runoff, with overflows directed into additional above-ground rainwater tanks or below-ground stormwater detention tanks. Any overflows from the stormwater detention tanks should be discharged on-site over a large pervious area, where a suitable stable area is available, or discharged off-site to the stormwater drainage system. Stormwater collected in the stormwater detention tanks would be released at a controlled rate either on-site or to the off-site stormwater drainage system.

The following objectives should be met in the design of on-site stormwater detention systems for the three towns:

- No increase in downstream peak flows due to increased impervious area;
- All overflows from the stormwater detention system discharged to a suitable disposal point; and
- Site modifications to accommodate stormwater detention tanks kept to a minimum, particularly for below-ground tanks (refer Section 4.2.2).

Recommendations relating to on-site stormwater detention are presented in Table 2.

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Table 2 On-site Stormwater Detention Recommendations

B1	For new developments, amend the COS planning scheme to make on-site stormwater detention systems mandatory for all new developments. Detention systems should be designed to ensure no increase in downstream peak flow. (The current planning scheme conditions relating to stormwater detention systems, DRA005, DRA006 and DRA007 are discussed in 6.4).
B2	For existing properties, encourage, through education and grants, the installation or upgrading of on-site stormwater detention systems. Detention systems should be designed to ensure no increase in downstream peak flow.

4.3 Stormwater Conveyance

4.3.1 Introduction

While the emphasis of stormwater management in the three towns should be to minimise and control stormwater at its source, it is not feasible to contain all stormwater on-site. An off-site stormwater drainage system is required to control stormwater flows that exceed a property's on-site detention capacity and provide low-flow drainage disposal following storms.

As discussed in Section 4.1.1, most properties in the three towns have no access to a formal stormwater drainage system. While some of the newer subdivisions have piped stormwater drainage, stormwater runoff from most properties is discharged to roadside table drains.

Essentially, there are three options available for stormwater conveyance in the three towns:

- High flow piped drainage system;
- Low flow piped drainage system; and
- Surface (roadside) drainage system.

Due to the variable topography, slope stability, and landscape characteristics throughout the study area, it is likely that a combination of the options will be employed.

Whichever of the stormwater conveyance techniques are employed for a given area, the design approach will be to utilise natural drainage lines wherever possible. A system of gullies and streams through the study area provide suitable discharge points for most piped and open channel drainage. The design approach will be to improve the connectivity of the existing drainage system, ensuring that table drains and pipelines are well connected to natural drainage lines. Improving the connectivity of the drainage system will relieve demands on individual components of the system, thereby reducing the chance of failure.

4.3.2 High Flow Piped Drainage System

This is the standard urban stormwater drainage method employed in Australia, designed to convey stormwater from less frequent events without nuisance. In residential areas, piped drainage systems are typically designed with a design Annual Recurrence Interval (ARI) value of 2 to 5 years.

A functional design for such a system was prepared by Fisher Stewart for the three towns in 1997, based on a 10 year design ARI. The design followed a standard urban drainage approach, comprising a network of buried pipes and pits. The steep terrain of the study area meant that pipe sizes were generally kept to a minimum, and set in accordance with the Council's minimum pipe size guidelines (225 mm diameter for easements and 300 mm diameter for road reserves).

While the drainage system proposed by Fisher Stewart provides more-than-adequate hydraulic capacity for peak design flows up to 10 year ARI, Dahlhaus *et al* (2003) noted that the design failed to consider the proposed scheme's impacts on geological hazards and water quality in the study area. As discussed in Section 3.3, alterations to slope morphology, hydrology and drainage in the study area has significantly increased the chance of landslides. While a buried drainage system has obvious advantages, such a system may have the following impacts on slope stability:

- Deep pipe trenches will disturb soil, potentially contributing to slope stability problems;
- Pipe failure may pose a serious threat to slope stability by causing saturation of the slope; and
- If not constructed properly, backfilled trenches may convey flow preferentially, potentially contributing to slope saturation.

A high flow piped drainage system also has the potential to exacerbate downstream flooding and water quality problems in the three towns, as has occurred in many urban centres. Acceleration of stormwater flows through the drainage system may increase downstream flood levels and contribute to localised nuisance flooding should the system surcharge. Pollutant loads delivered to the towns' riverine and marine waters may also increase, with stormwater flows conveyed directly to receiving waters with little or no natural filtering. High flow velocities in the proposed system also have the potential to cause scouring at the drainage outfalls.

In some parts of the study area, construction of the proposed system would be difficult, due to steep topography, difficult access and shallow bedrock. A pipe and pit system would also require that all roads in the three towns be sealed, complete with kerb and channel.

Notwithstanding the problems associated with a high flow piped drainage system, such a system may be appropriate in some parts of the study area. A number of pipe and pit systems have been constructed in Kennett River, with a smaller number constructed in Wye River and Separation Creek. New systems may be appropriate where the following conditions are satisfied:

- Pipeline alignment is along stable slopes with limited landslide risk;

- Pipeline construction will not exacerbate downstream flooding;
- Pipeline will not increase pollutant loads to receiving waters; and
- Construction is practicable (site is accessible to heavy machinery, road can be sealed and kerb and channel constructed, excavation of trenches is feasible).

As a first priority, opportunities should be sought to extend the existing pipe and pit drainage systems.

Recommendations relating to high flow piped drainage are presented in Table 3.

Table 3 High Flow Piped Drainage System Recommendations

C1	Do not proceed with implementation of the Fisher Stewart stormwater drainage design for Wye River, Separation Creek and Kennett River. The design is considered inappropriate for the study area on the basis of geotechnical risk, water quality risk, and cost.
C2	Where conditions are suitable, extend the towns' existing pipe and pit systems. Pipelines should only be constructed on stable slopes with limited landslide risk, where pipeline construction does not exacerbate downstream flooding or increase pollutant loads to receiving waters.
C3	Establish drainage easements covering all COS high flow drainage pipelines located on private property.

4.3.3 Low Flow Piped Drainage System

As discussed in Section 2, Garlick and Stewart (1987) assessed three alternative drainage arrangements for the three towns and recommended a reticulated system comprising separate low flow stormwater and sewerage pipes as offering the cheapest and most practical overall solution to stormwater and sewerage management in the three towns.

The design intent of the small diameter PVC pipe system proposed by Garlick and Stewart was to pick up overflow from water tanks and groundwater drainage. Unlike traditional stormwater drainage systems, the low flow system would not have sufficient capacity for larger storm events, with runoff following surface drainage channels.

While the low flow stormwater system was recommended on the basis of cost, such a system would offer significant advantages in the context of this current study:

- Provides controlled disposal for on-site stormwater detention systems and interception drains;
- Use of small diameter PVC pipes minimises trenching depths, while pipes could also be run above ground;
- Lower flow rates would restrict the pollutant loads delivered to receiving waters; and
- For smaller events, separates the runoff collected on private property from the road drainage system.

Because the PVC pipe system is lightweight and flexible and does not require the construction of kerb and channel, all properties with no current access to a piped drainage system or suitable roadside table drain could be serviced relatively easily and inexpensively. On steep unstable slopes, where trenching may exacerbate slope stability problems, pipes could be run across the ground surface. Where pipes are laid on the ground surface, anchoring to the slope face is critical to ensure pipes do not move (Myers *et al* 1995).

Recommendations relating to low flow piped drainage are presented in Table 4.

Table 4 Low Flow Piped Drainage System Recommendations

D1	Where no access is available to a high flow piped drainage system or suitable roadside table drain, provide stormwater disposal via a low flow pipeline. Low flow pipelines should convey flows downslope to a stable discharge point such as a natural drainage line or vegetated area located on public land.
D2	Establish drainage easements covering all low flow drainage pipelines located on private property.

4.3.4 Surface (Road) Drainage System

Except for the areas served by a piped drainage system, stormwater drainage in the three towns is largely conveyed via a network of roadside table drains. These table drains are mostly on the same grade as the roads, and discharge to natural drainage lines and gullies where they cross. There are however a large number of low points and disconnected sections where water ponds, flows across the road surface and is discharged down the face of the slope. This lack of drainage connectivity contributes to:

- Less effective conveyance of storm flows;
- Road structural damage;
- Problems with fill slope erosion and stability; and
- Nuisance flows where drainage is obstructed.

The roadside table drains currently serve two important functions:

- Collection and conveyance of stormwater discharge from private properties; and
- Drainage of the road surface.

While the network of roadside table drains offers a cost-effective means of conveying stormwater runoff from private properties, it is important that the drainage system design ensures appropriate protection of the roads themselves. To provide this road drainage function, the following guidelines should be followed (NRE 1996):

- Roads should be cross-sloped or crowned with table drains provided to minimise the concentrations and velocity of runoff and ensure that water drains from the road surface;

- Spacing of cross drains and run-offs (spreader drains) should be spaced according to the road grade and the soil erosion hazard; and
- Discharges onto exposed erodible soils or over fill slopes must be avoided where possible.

Run-off from unsealed roads is a major contributor of sediment loads to waterways. To protect water quality, the following guidelines should be followed (NRE 1996):

- Drainage from roads must discharge onto undisturbed vegetation or energy dissipating structures; and
- Direct discharge into streams should be avoided, and silt traps should be provided where necessary.

In the three towns, inadequate road drainage has contributed to widespread damage of the road surface. Inadequate or inappropriate cross-sloping of roads causes ponding of water on the road surface, or runoff onto the fill slope.

It is recommended that where possible, poorly-draining unsealed roads in the three towns be re-graded with a crowned or cross-graded profile. On steeper slopes, roads should generally be inward-sloped, with runoff collected in a table drain. Where outward-sloped roads shed drainage water onto a fill slope, and it is not possible to re-grade the road, a berm should be provided on the outer edge of the road to contain runoff and direct it to the road drainage system.

In some locations, table drains are absent or have inadequate capacity. A particular problem area is at driveway crossings, where culverts are in many cases undersized, poorly maintained, or absent. Where the roadside table drains are blocked, drainage tends to pond or spread across the road surface, leading to scouring.

It is recommended that table drains be provided along all roads in the three towns without kerb and channel drainage. All driveway crossings should comprise a 300 mm diameter culvert, with a trash rack installed at the inlet. The sizing of the driveway crossings is consistent with Council guidelines for minimum pipe diameters, and is intended to prevent blockage of the culverts by silt and debris. Where the longitudinal grade is steep and there is potential for scouring of the drain bed, table drains should be protected using one of the following techniques:

- Rock beaching;
- Installation of a corrugated half pipe (polyethylene or steel); and
- Control structures (such as drop structures) to minimise flow velocities.

Many of the table drains in the study area are constructed in rock, and for these drains scouring is generally not a problem. However, as well as protecting the drain bed from scouring, the above methods control downstream velocities through energy dissipation. Sediment traps should be provided at the base of steep sections of table drain.

Given the steep grade of the roads in the study area, cross drainage is in many cases inadequate, contributing to high flow velocities and scouring of the table drains. In addition to this, cross drainage is discharged onto fill slopes at a number of locations, often into private properties.

It is recommended that additional cross drainage be provided where recommended spacings are exceeded. As an example, a cross drainage spacing of approximately 20 metres is recommended for a 10% slope on soils of high erosion potential (NRE 1996). Satisfying the recommended cross drainage spacings is difficult in the study area. Due to the degree of development in the towns, there are in many cases no vegetated areas located adjacent to the road suitable for cross drainage discharge. In such cases, it is recommended that cross drainage discharge be directed down the slope to a stable discharge point via a slope drain. Where these drains pass through private property, drainage easements should be established along the pipe alignment.

Recommendations relating to road drainage are presented in Table 5. A road drainage flow chart, outlining the process to be followed in providing appropriate road drainage for the three towns is provided in Appendix A.

Table 5 Road Drainage System Recommendations

E1	Where properties have access to suitable roadside table drains and no high flow piped drainage system is provided, dispose of stormwater overflows to a roadside table drain.
E2	Where unsealed roads are poorly drained, re-grade with a crowned or cross-graded profile. For steeper slopes or where properties are located below the road, re-grade with an inward cross-grade.
E3	Where outward-sloped roads shed drainage water onto fill slopes or properties below the road, and it is not possible to re-grade the road, provide a berm on the outer edge of the road to contain runoff and direct it to the road drainage system.
E4	Where the failure of roadside table drains poses a threat to properties located below the road, provide a berm on the outer edge of the road to contain overflows.
E5	Provide table drains for all roads in the study area without kerb and channel drainage.
E6	Where the longitudinal grade is steep and there is potential for scouring of the drain bed, table drains should be protected using rock beaching, corrugated half pipe, or control structures.
E7	Upgrade all driveway crossings in the study area to 300 mm diameter culverts with inlet trash racks. Initially, priority should be given to blocked or damaged structures and driveways with no cross drainage.
E8	Provide additional cross drains where recommended spacings are exceeded. Cross drainage should be discharged to natural drainage lines or stable vegetated areas located on public land, adjacent to the road. Where suitable discharge points are not available, discharge should be directed down the slope to a stable discharge point via a slope drain.
E9	Establish drainage easements covering all cross drain discharge pipelines located on private property.

4.4 Natural Drainage Lines

4.4.1 Introduction

As discussed above, the design approach for stormwater management in the three towns will be to utilise natural drainage lines wherever possible. A system of gullies and streams through the study area provide suitable discharge points for most piped and open channel drainage. The design approach will aim to improve the connectivity of the existing drainage system, ensuring that table drains and pipelines are well connected to natural drainage lines. Improved system connectivity will relieve hydraulic loadings on individual components of the drainage system, thereby reducing the chance of failure.

4.4.2 Obstructions to Drainage

Generally, natural drainage lines in the study area are well vegetated and unobstructed. At some locations however, houses have been built over drainage lines, particularly at the heads of gullies. Given the importance of natural drainage lines to the functioning of the stormwater drainage system, it is recommended that no further development be allowed to occur over natural drainage lines in the three towns. Where possible the effect of existing obstructions should be minimised.

A number of minor drainage lines in the study area are located on private property. Given that these drainage lines form part of the stormwater drainage system, it is recommended that drainage easements be established over all drainage lines located on private property which receive discharge from the drainage system.

Recommendations relating to natural drainage lines are presented in Table 6.

Table 6 Natural Drainage Line Recommendations

F1	Prevent further development over natural drainage lines in the study area, and where possible. Minimise the effect of existing obstructions.
F2	Establish drainage easements over all natural drainage lines located on private property which receive discharge from the stormwater drainage system.

4.5 Stormwater Disposal

4.5.1 Introduction

Development in the three towns has inevitable led to a deterioration in the water quality of waterways and marine waters in the study area. Dahlhaus *et al* (2003) reported that surface water quality samples collected in the three towns exceeded the recommended upper nutrient limits set by the EPA's State Environment Protection Policies (SEPP) on nutrient objectives for waters in rivers and streams in the Otway region and the SEPP on marine and estuarine ecosystem protection for estuaries and inlets. Conditions for the aquatic communities in the Wye and Kennett Rivers and Separation Creek are likely to be adversely affected by inflow from drainage lines feeding into the waterways (Dahlhaus *et al* 2003). These water quality problems are partly the result of wastewater management in the towns, however stormwater flows are likely to be delivering large sediment loads, nutrient loads and gross pollutants to the towns' receiving waters. While there is little data to determine the extent of influence of water quality impacts from the three towns, visible impacts include erosion of road embankments destabilising vegetation and causing sediment flow into drainage lines (Dahlhaus *et al* 2003).

Water quality impacts of the towns' stormwater drainage systems are illustrated in Figure 1, which shows a drainage outfall at Kennett River, with highly turbid stormwater being discharged into the relatively clear waters of Kennett River.

Figure 1 Turbid Stormwater Drainage Discharge at Kennett River

In addition to the wastewater management issues discussed previously, the degradation of water quality in the study area may be attributed to a number of factors:

- Inadequate erosion management on construction sites;
- Inadequate or inappropriate drainage of unsealed roads;
- Surface erosion resulting from uncontrolled runoff;
- Uncontrolled discharge at some drainage outfalls; and
- Inadequate treatment of stormwater throughout the drainage system.

Some of these factors are addressed in other sections of the report. The following sections relate to the control and treatment of stormwater at the point of disposal.

4.5.2 Disposal to Natural Drainage Lines

A number of table drains and pipes in the study area discharge directly to natural drainage lines, typically as concentrated, high-velocity flows. These concentrated discharges allow for no natural trapping of sediment and gross pollutants, and may directly contribute to erosion of gully beds and banks.

It is recommended that where possible, sediment traps be provided at all drainage discharge points. These will generally be shallow earthen depressions, as shown in Figure 2, designed to slow flow and promote sedimentation. For the high flow pipe systems, purpose-built structures may be required, comprising concrete pits or basins. Where discharge velocities are high, such as at culvert outlets, sediment traps should be combined with energy dissipation measures such as rock beaching.

To limit erosion to drainage lines and vegetated areas, it is recommended that all drainage discharge points and outfalls be constructed to ensure dissipation of flow across a wide, well-vegetated area. It is also recommended that where possible, all construction sites be stabilised following construction using indigenous species.

Recommendations relating to stormwater disposal to natural drainage lines are presented in

Table 7.

Figure 2 Table drain sediment trap (from Holaday 1995)

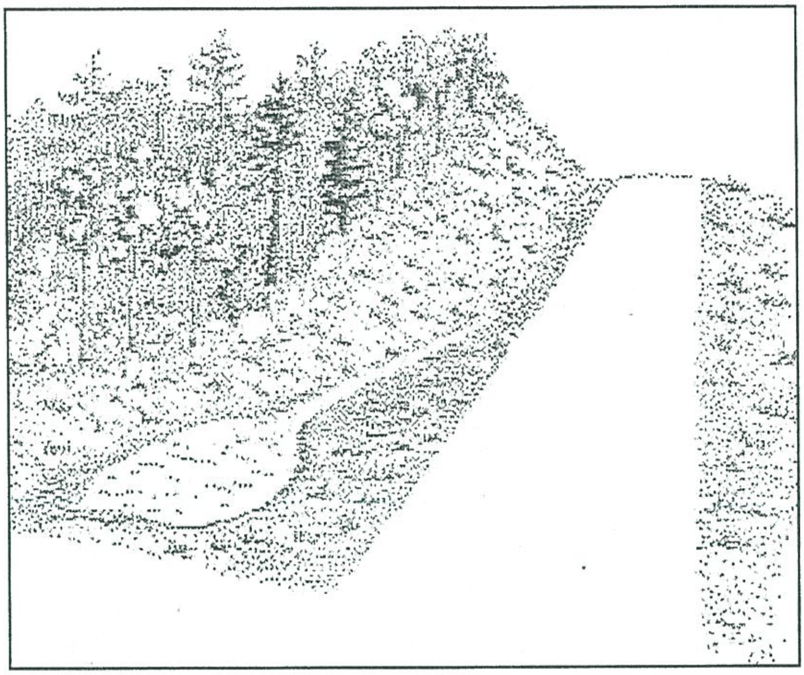

Table 7 Disposal to Natural Drainage Lines Recommendations

G1	Where possible, provide sediment traps at all points of disposal to natural drainage lines.
G2	Construct all drainage discharge points and outfalls to provide dissipation of flow across a wide, well-vegetated area. Where possible, stabilise all construction sites following construction using indigenous species.

4.5.3 Disposal to Waterways and Foreshore

A number of stormwater drains in the three towns discharge directly to waterways or the foreshore. As shown in Figure 1, the lack of buffering between the stormwater system and receiving waters can have a significant impact on water quality.

Where hydraulic constraints permit, it is recommended that these drainage outfalls be relocated upstream, above the level of receiving waters. Ideally, flow would outfall from pits set at natural surface, and be directed to receiving waters via grassed swales.

At Kennett River, stormwater discharges from one of the catchments are passed through a constructed wetland before release into Kennett River. A photo of the wetland is shown in Figure 3. If capacity is available, it is recommended that additional drainage outfalls be routed through the wetland. This may require extension of the wetland or alternatively, construction of new wetlands.

Figure 3 Constructed wetland at Kennett River

Recommendations relating to stormwater disposal to waterways and foreshore are presented in Table 8.

Table 8 Disposal to Waterways and Foreshore Recommendations

H1	Where hydraulic constraints permit, it is recommended that drainage outfalls discharging directly to waterways be relocated upstream and directed to receiving waters via grassed swales.
H2	If capacity is available, route additional drainage outfalls through the constructed wetland at Kennett River, and if necessary, extend the wetland. Where suitable areas are available, construct new wetlands to treat stormwater discharge.

4.6 Overall Drainage Arrangement

A stormwater drainage system for the three towns will comprise many of the drainage elements and techniques described in previous sections. As mentioned previously, no single drainage measure will provide the three towns with a stormwater drainage system that satisfies hydraulic, geotechnical and environmental objectives. The recommendations detailed in this section will need to be adopted in combination to ensure that the design objectives, described in Section 3, are satisfied. A concept drainage drawing, illustrating how the drainage techniques recommended in this section may be implemented, is provided in Appendix B.

The process to be followed in selecting an appropriate stormwater disposal system for properties in the three towns is provided as a flow chart in Appendix A.

4.7 Maintenance

An important consideration in the design of any stormwater drainage system is the ongoing maintenance of new and existing infrastructure. The condition of many of the drainage assets in the three towns has deteriorated to a state where they are now inoperable or barely functional. In particular, many driveway culverts are partially or completely blocked, causing drainage water to flow over the road surface.

While COS has a responsibility to maintain roads and road drainage in the three towns, it is unrealistic to expect that the Shire can respond to and resource all maintenance needs in a timely manner. As such, it is important that local residents be encouraged to carry out routine maintenance of drainage works located on and in the vicinity of their properties. This applies particularly to culverts, for which the most important maintenance is prompt removal from the inlet and outlet of any material that restricts water flow, such as woody debris, leaves, mud and gravel (Adams 1997).

Maintenance that could be carried out by local residents without the need for machinery includes:

- Removal of vegetation and other obstructions from culvert inlets and outlets;
- Removal of silt and gravel (by shovel) from culvert inlets and outlets; and
- Clearing of drainage outlets (where properties discharge to table drain).

It is recommended that residents be encouraged to carry out low-level maintenance of drainage works located on or in the vicinity of their properties. This would be best achieved through community education, highlighting the benefits of a shared approach to drainage asset maintenance.

Given that many of the towns' residents are not permanent, there will be times of the year when drainage maintenance demands cannot be met by the local community. To ensure an appropriate level of on-going drainage maintenance, it is recommended that a local resident be employed by COS to provide on-going monitoring and maintenance of the three towns stormwater drainage system. It is envisaged that the maintenance manager's role would involve monitoring of the stormwater drainage system, generally following storm events. The maintenance manager would support local residents in the clearing of driveway culverts and undertake low-level maintenance works on table drains and road culverts.

While the increased participation of the local community in maintaining the drainage system will ensure increased reliability and sustainability, COS will retain the primary responsibility for maintenance. It is recommended that COS undertake a condition assessment of all roads and stormwater drainage assets in the three towns and establish a condition record on the Shire's GIS database. On the basis of this condition assessment, maintenance tasks should be prioritised and a maintenance program developed. It is expected that the local maintenance manager (discussed previously) could provide COS with periodical assessments of assets requiring maintenance.

Drainage related maintenance responsibilities of COS include:

- Road grading;
- Clearing of table drains;
- Clearing of road culverts; and
- Cleaning of drainage pipes, pits and outfalls.

As part of the maintenance program development, it is recommended that COS reassess current maintenance scheduling in the three towns. Ideally, the schedule would comprise some level of routine drainage maintenance and some event-based maintenance.

It is worth noting that some clearing of table drains in the three towns by grading has actually resulted in increased erosion of the drain bed and subsequent blocking of downstream culverts. Where table drains are well graded and vegetated, the most appropriate form of maintenance may be to leave the table drain undisturbed. This also provides significant water quality benefits.

Recommendations relating to maintenance of the stormwater drainage system are presented in Table 9.

Table 9 Maintenance Recommendations

I1	Through education, encourage local residents to share responsibility for drainage system maintenance. This particularly applies to clearing of driveway culverts following storms.
I2	Employ a local resident to provide on-going monitoring and maintenance of the three towns stormwater drainage system.
I3	Undertake a condition assessment of all roads and stormwater drainage assets in the three towns and establish a condition record on the Shire's GIS database.
I4	Develop a COS maintenance program for drainage assets in the three towns, based on condition assessments and the relative importance of each asset to system function. Reassess current maintenance scheduling to provide routine and event-based drainage maintenance.
I5	Where table drains are well graded and vegetated, grading of the drain should not be carried out, except to remove isolated flow obstructions.

5. Assessment of Existing Stormwater System

The Three towns study area has been divided into the following five discrete areas for the purpose of describing the existing stormwater systems, assessment of their condition and connectivity, and identification of deficiencies and improvements.

- Wye River (South);
- Wye River (North);
- Separation Creek;
- Kennett River (North); and
- Kennett River (South).

Each of the above township areas consist of a network of natural drainage gullies connecting to the main waterways of Wye River, Separation Creek, Kennett River or direct to the coastal foreshore. The development of the towns has encroached on the natural drainage lines, with roads across gullies and in some cases properties located in gullies. The stormwater systems consist of predominately table drains along the roadside edge throughout the network of roads with some limited underground pipe drainage systems. There are approximately 80 individual discharge points to natural gullies, slope faces or direct entry to the creeks, throughout the study area. The connectivity of the table drains to the natural gullies and outlets, and provision of discharge flow paths to stable slopes are the key issues.

Field Appraisal of Existing Drainage Infrastructure

Detailed field inspections were undertaken of the existing stormwater systems. Colac Otway Shire provided GIS information of their drainage infrastructure for the three towns. This information provided a basis for understanding the layout of the existing systems, including the various discharge points. For each area an appraisal of each of the systems has been tabulated in Appendix D, with corresponding locality maps in Appendix C that essentially contain the system details as presented in the current GIS information. The main natural drainage lines and sub catchment ridgelines (based on contour information) have also been shown indicatively on the maps.

The areas have been divided into the main drainage catchments (for natural gullies), discharging to either the main streams or the coastal foreshore. Each drainage catchment consists of various local drainage systems (typically road table drains) discharging to individual discharge points into natural gullies or slope faces. Comment on each of these local systems and discharge points has been recorded, including key field observations and opportunities for improvement. The GIS label information for the drains, pits and culverts were used as the identifiers for each of the drainage systems. It is noted that the GIS is not complete and not all infrastructure that is shown has been labelled.

A brief description of the overall systems for each of the township areas and a summary of the key features and improvement opportunities is summarised below.

5.1 Wye River (South)

Wye River (south) is predominately on the east facing hill slope, with McCrae Road on a ridge on the west extent of the town, with natural drainage mostly towards the eastern foreshore. The majority of the township drainage is collected by table drains around the road circuit linking McCrae Rd, Slashers Rd and Morley Road, concentrating to the underground pipe system that commences at the Morley/McCrae Road intersection. There is a separate underground pipe system from Morley Road just upstream of the McCrae Road intersection.

The main issues associated with the existing systems include:

- Considerable lengths of table drains without relief points, compounded by the problem of undersized driveway culverts; (Morley Road);
- Gully erosion on steep sections of gravel road (Slashers Road, McCrae Road at lower end); and
- Flow unable to enter various existing cross culverts due to silting or blockage.

The key drainage improvement opportunities for Wye River (south) include upgrading of undersized driveway culverts, and reducing the load on the overall system by provision of cross culverts discharging to stable or protected slopes.

5.2 Wye River (North)

The Wye River (north) township area is spread across several natural drainage lines as described below:

- NG_A, NG_B - Small local gullies draining to Wye River floodplain at west extent of township area;
- NG_C - Natural gully (with significant u/s catchment) through township, discharging into lower end of Wye River;
- NG_D - Major Natural gully (with significant u/s catchment) through township with some allocated reserve, discharging into lower end of Wye River;
- NG_E, NG_F - Existing development has encroached into these less defined natural drainage lines discharging towards coastal foreshore area; and
- Various minor drainage lines on east side of town discharging towards coastal foreshore area.

The drainage systems typically consist of table drains associated with the road network carrying flow towards natural gullies. There is one discrete underground pipe system effectively separate from the other drainage systems.

The main issues associated with the existing systems include:

- Cross culvert discharge from table drains into private property, and inadequate definition and protection of discharge flow paths;
- Private property being developed across natural drainage lines, and absence of planning controls to manage this issue;

- Considerable lengths of table drains without relief points, compounded by the problem of undersized driveway culverts;
- Ineffective connectivity of table drains to natural gullies and discharge points due to silting and blockage of culverts; and
- Erosion along discharge flow paths towards vegetated slopes.

The key drainage improvement opportunities for Wye River (north) include the creation of drainage easements through existing private property for preferred flow paths associated with natural gullies, and provision of well vegetated, stable discharge flow paths (or slope drains). In some areas the number of discharge points could be consolidated towards the preferred flow paths (eg NG_E, NG_F), while in other areas there is opportunity to provide additional cross culvert relief point with more direct entry to natural gullies.

5.3 Separation Creek

The township of Separation Creek is located to the east of the stream of Separation Creek. The area consists of the following main drainage catchments:

- NG_W - Natural gully draining towards Separation Creek floodplain on west edge of township;
- $NG_{central}$ - Major natural gully through township discharging towards the coastal foreshore; and
- NG_{E1}, NG_{E2} - Small local gullies (not well defined) through eastern part of township discharging towards the coastal foreshore.

The drainage systems typically consist of table drains associated with the road network carrying flow towards natural gullies. There is an underground pipe system on the eastern side of the town, but it is uncertain how well connected this is to the surrounding table drains.

The main issues associated with the existing systems are similar (but less extensive) to the issues for Wye River, including:

- Cross culvert discharge from table drains into private property, and inadequate definition and protection of discharge flow paths (eg Mitchell); and
- Considerable lengths of table drains without cross culvert relief points (eg Harrington).

The key drainage improvement opportunity for Separation Creek consists of provision of cross culverts for more direct entry to the various natural gullies.

5.4 Kennett River (North)

The township area of Kennett River (North) is predominately on the east facing hill slope, with The Ridge (road) on the west extent of the area with natural drainage mostly towards the eastern foreshore. The area consists of the following main drainage catchments:

- NG_s - Natural gullies draining south towards Kennett River floodplain on west side of Ridge Road;
- $NG_{central}$ - Main natural gully through township discharging adjacent to Cassidy Road towards the coastal foreshore;
- NG_{SW} - Small local gully (not well defined) on south side of township discharging towards the coastal foreshore; and
- NG_{NW}, NG_N - Small local gullies (not well defined) on north side of township discharging towards another stream.

The drainage system consists of table drains associated with the road network carrying flow towards natural gullies and cross culvert discharge points.

The main issues associated with the existing system include:

- Low point in road where discharge relief is required;
- Considerable lengths of table drains without cross culvert relief points (eg Cassidy); and
- Cross culvert discharge from table drains into private property (eg Cara).

The key drainage improvement opportunity for Kennett River (North) consists of provision of cross culverts for more direct entry into the natural gullies and vegetated hill slopes.

5.5 Kennett River (South)

The township area of Kennett River (South) is situated on the south side of the Kennett River floodplain, rising up to the hill slopes further to the south. The stormwater drainage system is distinct form the other township areas in that underground pipe drainage infrastructure is located throughout the lower township areas.

All overland drainage including table drains and kerb and channel flow paths connect to the underground drainage infrastructure before discharging into Kennett River.

The main issues associated with the existing system include:

- Connectivity between table drains and underground systems (maintenance); and
- Water quality issues associated with direct connection of piped systems to Kennett River.

The drainage strategy for Kennett River (South) involves improving connectivity with the existing underground drainage system, and capitalising on water quality treatment opportunities by connecting additional discharge points to the existing wetland or other treatment zone prior to entry to Kennett River

6. Review of COS Stormwater Management Policy

6.1 Introduction

As part of this study, a review was undertaken of existing stormwater management policy in the Colac Otway Shire (COS). The review focussed on management strategies and planning scheme provisions relevant to stormwater management in the three towns. This review included the Colac Otway Stormwater Management Plan, COS Waste Water Strategy, and relevant COS Planning Scheme conditions.

The objective of the review was not to appraise the recommendations of the documents generally, but to identify potential issues regarding their application to the three towns.

6.2 Colac Otway Stormwater Management Plan (COSMP)

The Colac Otway Stormwater Management Plan (KBR 2002) is focussed primarily on stormwater quality objectives. The plan made a number of specific recommendations for the Coastal Settlements region, comprising Wye River, Kennett River, Separation Creek and Skenes Creek. These recommendations are generally consistent with the objectives outlined in this concept stormwater drainage design, with an emphasis on sediment/erosion control and improved wastewater management.

Recommendations that may conflict with the objectives of the stormwater drainage design are as follows:

- SE2 (education and awareness): encourage connection to sewer in line with the wastewater strategy; and
- SC1 (source control): advocate either extension of reticulated sewerage system to reach unserviced properties or provision of an alternative septic disposal technique.

First, it should be noted that the townships of Wye River, Separation Creek and Kennett River have no sewerage system to extend. If extension of a reticulated system were possible, the geotechnical risks would be similar to those described for a piped stormwater system. For many properties located on less-stable slopes, extension of a reticulated sewerage system will not be appropriate.

6.3 COS Waste Water Strategy

As part of the Colac Otway Waste Water Strategy, waste water issues papers were prepared for Kennett River and Wye River (COS 2002a & COS 2002b). The waste water options presented in these papers are generally consistent with the objectives outlined in this concept stormwater drainage design, and no potential issues regarding their application have been identified.

6.4 COS Planning Scheme

A number of conditions in the Colac Otway Planning Scheme are of relevance to stormwater management in the three towns. The following is a discussion of those conditions that may require amendment as a result of this study.

6.4.1 Drainage Conditions

- DRA004: All run off from stormwater, including overflow from water storage, must be taken to a legal point of discharge to the satisfaction of the responsible Authority.

The legal point of discharge for each property should be specified as either a high flow piped system, low flow discharge pipeline, or roadside table drain.

- DRA005: Prior to commencement of the development, a stormwater detention system designed by a qualified engineer must be lodged with the Responsible Authority verifying that post development stormwater discharge volume does not exceed pre-development stormwater discharge volume to the satisfaction of the Responsible Authority. Once approved such design must be endorsed and must form part of the permit issue.

The application of this condition should be mandatory. However, storing the increase in runoff volume due to development is in most cases unrealistic, and this should be changed to no increase in peak flow.

- DRA006: Stormwater discharge from the approved stormwater detention system must only be distributed across the property by sheet flow (i.e. along a contour) or to a legal point of discharge as approved by the Responsible Authority. No sheet flow discharge point may be permitted within five metres of the lowest boundaries and any discharge point must not be located so as to surcharge the septic effluent disposal system.

In general, discharge from the stormwater detention system will be to a legal point of discharge. Discharge as sheet flow is preferred, but should only be permitted on large well vegetated areas located on stable slopes with minimal landslide risk.

6.4.2 Carparking, Loading and Access Conditions

- ACC002: Vehicular crossing(s) must be constructed to the road to suit the proposed driveway(s) to the satisfaction of the Responsible Authority.

A culvert diameter of 300 mm is recommended, complete with inlet trash rack.

6.4.3 Landslip and Geotechnical Conditions

- GEO11: The proponent must supply a surface drainage plan showing stormwater falling onto or passing through the site will be directed away from the effluent disposal field, footings, retaining walls and other infrastructure. Drainage must be directed off site to a legal point of discharge and not in a manner that will cause erosion. The surface drainage plan requires approval by a Geotechnical Engineer.

The legal point of discharge for each property should be specified as either a high flow piped system, low flow discharge pipeline, or roadside table drain.

7. Recommendations

7.1 Concept Drainage Design

The following (Table 10) is a summary of recommendations for the concept drainage design. The recommendations are introduced in Section 4.

Table 10 Concept Design Recommendations

Site Modifications	
A1	For new developments, amend the COS planning scheme where necessary to ensure that site modifications such as property regrading, soil disturbance and vegetation removal are kept to a minimum.
A2	Amend the COS planning scheme where necessary to ensure that drainage is provided for all impervious surfaces on the property, and directed to a suitable disposal point.
A3	For existing properties, encourage, through education and grants, the source control of stormwater runoff. This includes the removal of paved surfaces, the reinstatement of natural drainage paths, and revegetation with indigenous plants.
On-site Stormwater Detention	
B1	For new developments, amend the COS planning scheme to make on-site stormwater detention systems mandatory for all new developments. Detention systems should be designed to ensure no increase in downstream peak flow. (The current planning scheme conditions relating to stormwater detention systems, DRA005, DRA006 and DRA007 are discussed in 6.4).
B2	For existing properties, encourage, through education and grants, the installation or upgrading of on-site stormwater detention systems. Detention systems should be designed to ensure no increase in downstream peak flow
High Flow Piped Drainage System	
C1	Do not proceed with implementation of the Fisher Stewart stormwater drainage design for Wye River, Separation Creek and Kennett River. The design is considered inappropriate for the study area on the basis of geotechnical risk, water quality risk, and cost.
C2	Where conditions are suitable, extend the towns' existing pipe and pit systems. Pipelines should only be constructed on stable slopes with limited landslide risk, where pipeline construction does not exacerbate downstream flooding or increase pollutant loads to receiving waters.
C3	Establish drainage easements covering all COS high flow drainage pipelines located on private property.

Low Flow Piped Drainage System	
D1	Where no access is available to a high flow piped drainage system or suitable roadside table drain, provide stormwater disposal via a low flow pipeline. Low flow pipelines should convey flows downslope to a stable discharge point such as a natural drainage line or vegetated area located on public land.
D2	Establish drainage easements covering all low flow drainage pipelines located on private property.

Road Drainage System	
E1	Where properties have access to suitable roadside table drains and no high flow piped drainage system is provided, dispose of stormwater overflows to a roadside table drain.
E2	Where unsealed roads are poorly drained, re-grade with a crowned or cross-graded profile. For steeper slopes or where properties are located below the road, re-grade with an inward cross-grade.
E3	Where outward-sloped roads shed drainage water onto fill slopes or properties below the road, and it is not possible to re-grade the road, provide a berm on the outer edge of the road to contain runoff and direct it to the road drainage system.
E4	Where the failure of roadside table drains poses a threat to properties located below the road, provide a berm on the outer edge of the road to contain overflows.
E5	Provide table drains for all roads in the study area without kerb and channel drainage.
E6	Where the longitudinal grade is steep and there is potential for scouring of the drain bed, table drains should be protected using rock beaching, corrugated half pipe, or control structures.
E7	Upgrade all driveway crossings in the study area to 300 mm diameter culverts with inlet trash racks. Initially, priority should be given to blocked or damaged structures and driveways with no cross drainage.
E8	Provide additional cross drains where recommended spacings are exceeded. Cross drainage should be discharged to natural drainage lines or stable vegetated areas located on public land, adjacent to the road. Where suitable discharge points are not available, discharge should be directed down the slope to a stable discharge point via a slope drain.
E9	Establish drainage easements covering all cross drain discharge pipelines located on private property.

Natural Drainage Lines	
F1	Prevent further development over natural drainage lines in the study area, and where possible. Minimise the effect of existing obstructions.
F2	Establish drainage easements over all natural drainage lines located on private property which receive discharge from the stormwater drainage system.

Disposal to Natural Drainage Lines	
G1	Where possible, provide sediment traps at all points of disposal to natural drainage lines.
G2	Construct all drainage discharge points and outfalls to provide dissipation of flow across a wide, well-vegetated area. Where possible, stabilise all construction sites following construction using indigenous species.

Disposal to Waterways and Foreshore	
H1	Where hydraulic constraints permit, it is recommended that drainage outfalls discharging directly to waterways be relocated upstream and directed to receiving waters via grassed swales.
H2	If capacity is available, route additional drainage outfalls through the constructed wetland at Kennett River, and if necessary, extend the wetland. Where suitable areas are available, construct new wetlands to treat stormwater discharge.

Maintenance Recommendations	
I1	Through education, encourage local residents to share responsibility for drainage system maintenance. This particularly applies to clearing of driveway culverts following storms.
I2	Employ a local resident to provide on-going monitoring and maintenance of the three towns stormwater drainage system.
I3	Undertake a condition assessment of all roads and stormwater drainage assets in the three towns and establish a condition record on the Shire's GIS database.
I4	Develop a COS maintenance program for drainage assets in the three towns, based on condition assessments and the relative importance of each asset to system function. Reassess current maintenance scheduling to provide routine and event-based drainage maintenance.
I5	Where table drains are well graded and vegetated, grading of the drain should not be carried out, except to remove isolated flow obstructions.

7.2 Implementation

While many of the concept drainage design recommendations can be implemented immediately, others will involve a gradual process of change, particularly where community education and cultural change are required.

It is recommended that where possible, COS implement immediately recommendations included in this report. Recommendations that could be implemented immediately include:

- Amendments to COS Planning Scheme (A1, A2, B1);
- Employment of local drainage maintenance manager (I2); and
- Abandonment of existing stormwater drainage design (C1).

Capital and maintenance works will generally be undertaken on a priority basis and as funds become available. The assessment of the existing stormwater system, detailed in Section 5, provides a basis for implementing many of the capital works and maintenance recommendations. It should be noted however that the assessment of the existing stormwater system was not exhaustive, and comprised only a qualitative evaluation of the system. While some maintenance works can be undertaken immediately, most capital works (such as the construction of new cross drains) will require functional and/or detailed design before they can be carried out.

In most cases, functional and detailed design will require an accurate database of existing drainage assets. It is therefore recommended that COS update its GIS-based asset database for the three towns. While most of the drainage assets have been recorded on the database, many of the assets are unnamed and have no details recorded. The asset database should include details of asset condition (refer I3).

Because community education and cultural change are long term processes and fundamental to effective stormwater drainage management, it is suggested that education of the local community commence at the earliest possible opportunity. An effective form of communication may include the development of stormwater management kits, containing practical information on stormwater management for local residents. Visual aids, such as the concept drawing provided in Appendix B, may increase community understanding of the stormwater system.

Recommendations relating to implementation of the concept drainage design are provided in Table 11.

Table 11 Implementation Recommendations

J1	Where possible, implement immediately recommendations included in this report (eg: A1, A2, B1, C1, I2).
J2	Update COS GIS-based asset database for the three towns.
J3	Develop to functional and detailed design stage the works recommendations presented in Section 5. These should be prioritised on the basis of asset condition and the relative importance of proposed works to system function.
J4	Commence community education on stormwater drainage management in the three towns by developing education kits.

8. Glossary

Berm: a low earthen wall, mound, or barrier.

Cross drains (roads): interception drains provided across the longitudinal direction of the road to remove any accumulated water (NRE 1996).

Cross-sloped (roads): the formation of a road surface to provide slope or camber so that water will drain from it (NRE 1996).

Crowned (roads): the formation of a road surface by a grader or dozer to a convex-shape from which water will freely drain (NRE 1996).

High-flow Piped Drainage System: in this study, a standard (below-ground) urban stormwater drainage system typically designed with an Annual Recurrence Interval value of 2 to 5 years (in Appendix B, shown as an extension of the existing pipe system).

Low-flow Piped Drainage System: in this study, a small diameter PVC pipe system (above or below-ground) providing controlled disposal for on-site stormwater detention systems and interception drains. The design capacity is likely to have an Average Recurrence Interval of less than 1 year (in Appendix B, shown as slope drains).

On-site Stormwater Detention: a system that collects and temporarily stores rain that falls on a site, releasing it slowly so that it doesn't worsen downstream flooding (Upper Parramatta River Catchment Trust 2004).

Run-off (Spreader Drain): a short graded channel angled away from road edges to divert road drainage water off the road into undisturbed vegetation (NRE 1996).

Slope Drain: A solid walled pipe which carries collected water down a steep slope gradient without exposing the slope face to soil saturation and channel erosion. Usually combined with an energy dissipating structure at the discharge point, the pipe may be buried or anchored to the ground surface (Myers *et al* 1995).

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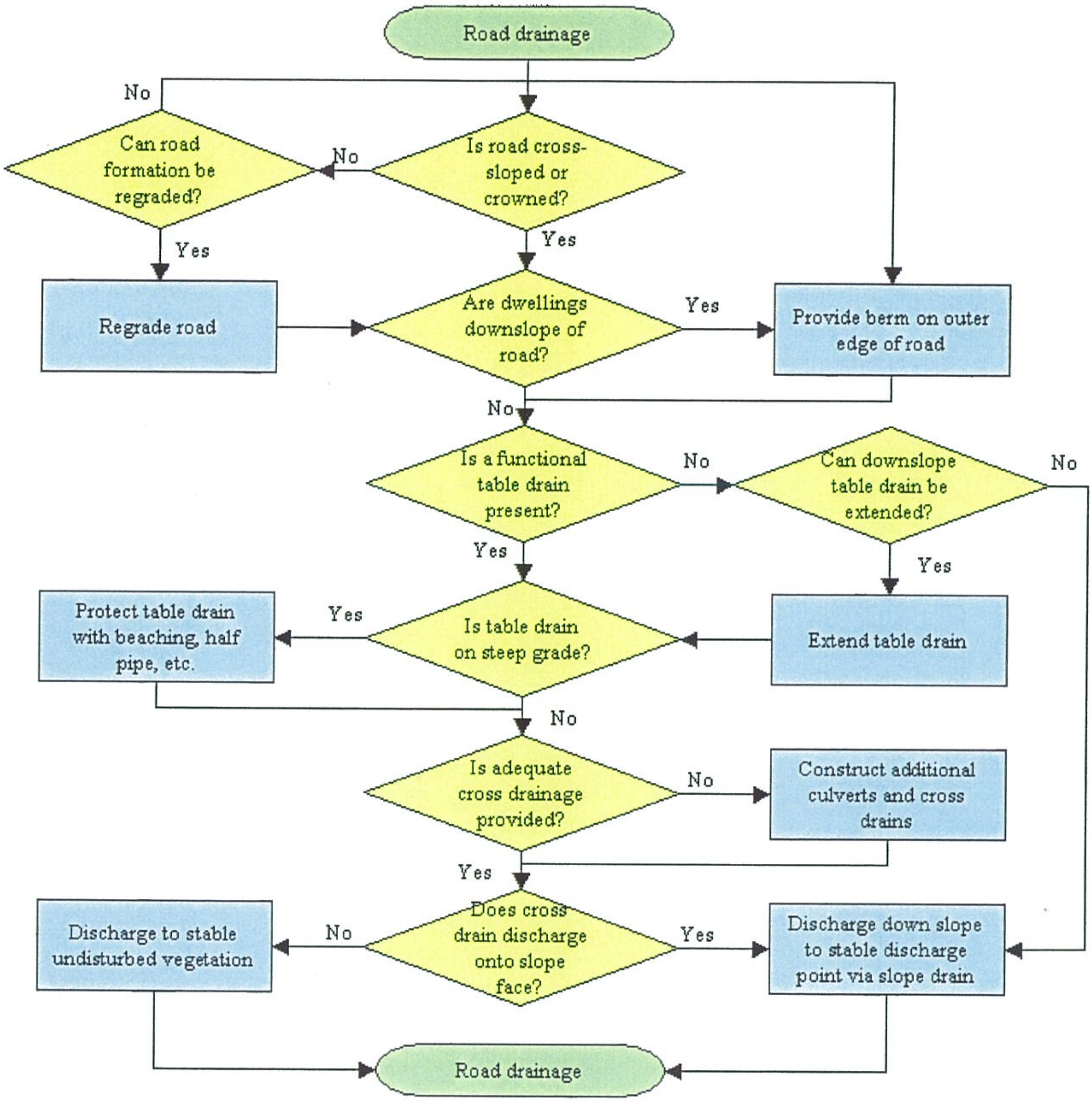
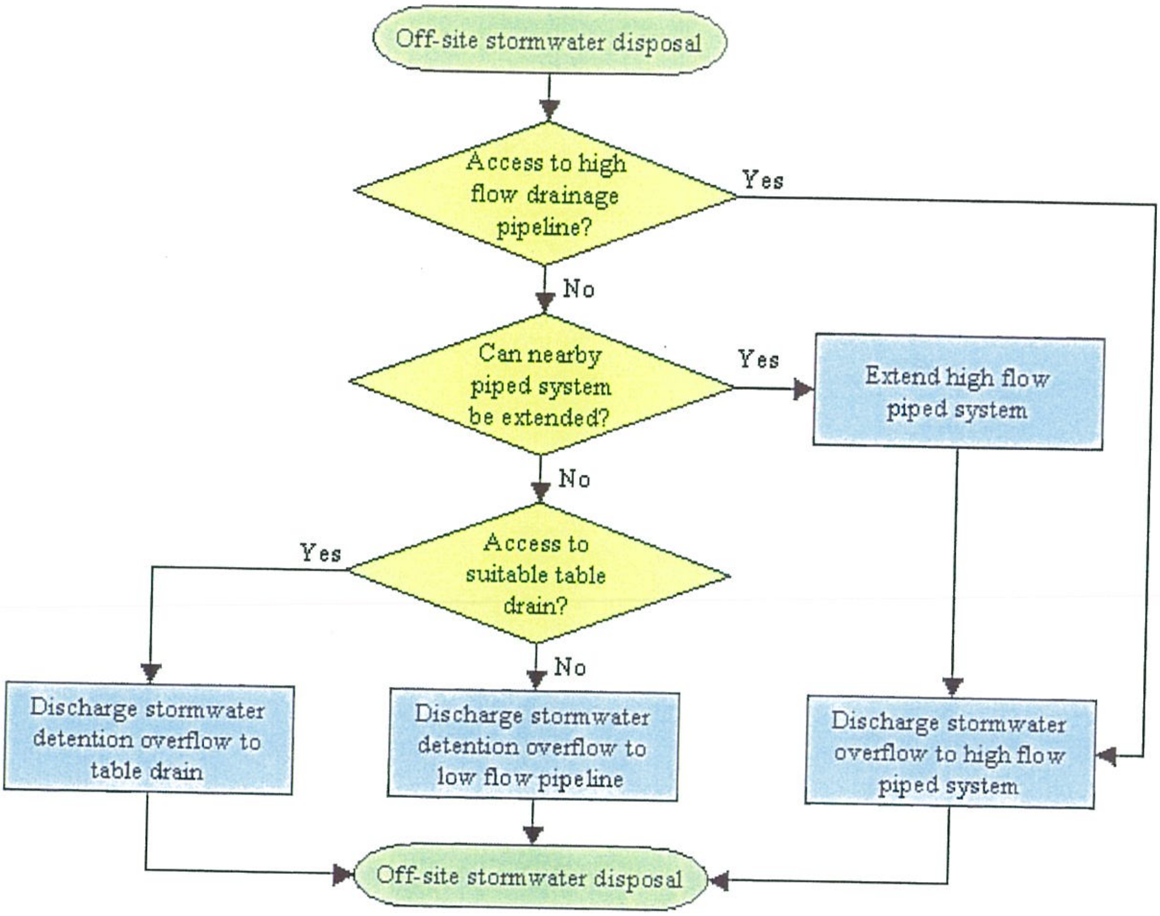
Appendix A

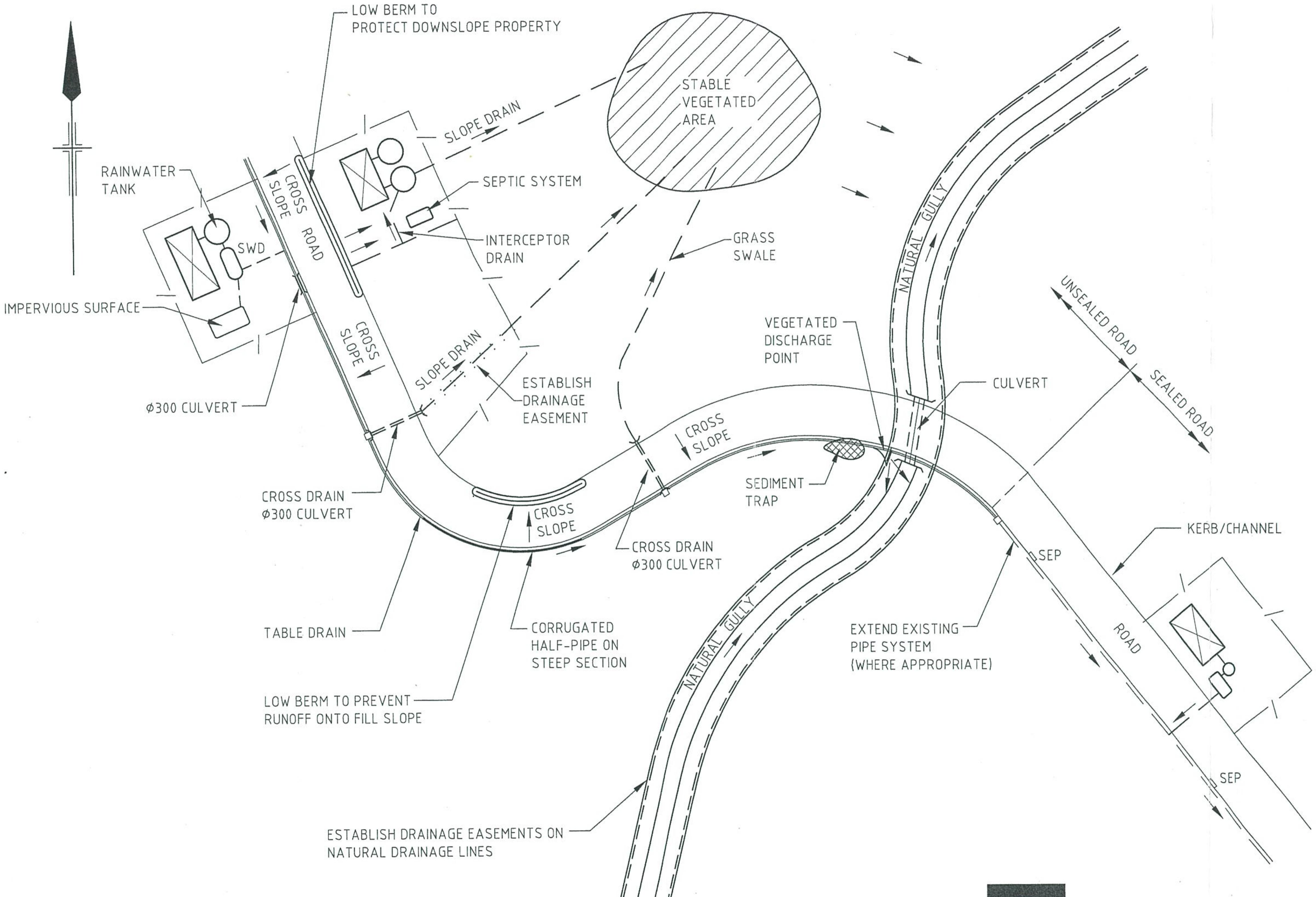
Concept Drainage Flow Charts


Road drainage
No
Can road formation be regraded?
No
Is road cross-sloped or crowned?
Yes
Yes
Regrade road
Are dwellings downslope of road?
Yes
Provide berm on outer edge of road
No
Is a functional table drain present?
No
Can downslope table drain be extended?
No
Yes
Yes
Protect table drain with beaching, half pipe, etc.
Yes
Is table drain on steep grade?
Extend table drain
No
Is adequate cross drainage provided?
No
Construct additional culverts and cross drains
Yes
Discharge to stable undisturbed vegetation
No
Does cross drain discharge onto slope face?
Yes
Discharge down slope to stable discharge point via slope drain
Road drainage


Off-site stormwater disposal
Access to high flow drainage pipeline?
Yes
No
Can nearby piped system be extended?
Yes
Extend high flow piped system
No
Access to suitable table drain?
Yes
No
Discharge stormwater detention overflow to table drain
Discharge stormwater detention overflow to low flow pipeline
Discharge stormwater overflow to high flow piped system
Off-site stormwater disposal

Appendix B

Concept Drainage Drawing



PLAN

SCALE N.T.S.

MANAGEMENT
ENGINEERING
ENVIRONMENT

THREE TOWNS STORMWATER MANAGEMENT STRATEGY CONCEPT DESIGN

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Plot Date: 23 August, 2004 - 9:40 AM

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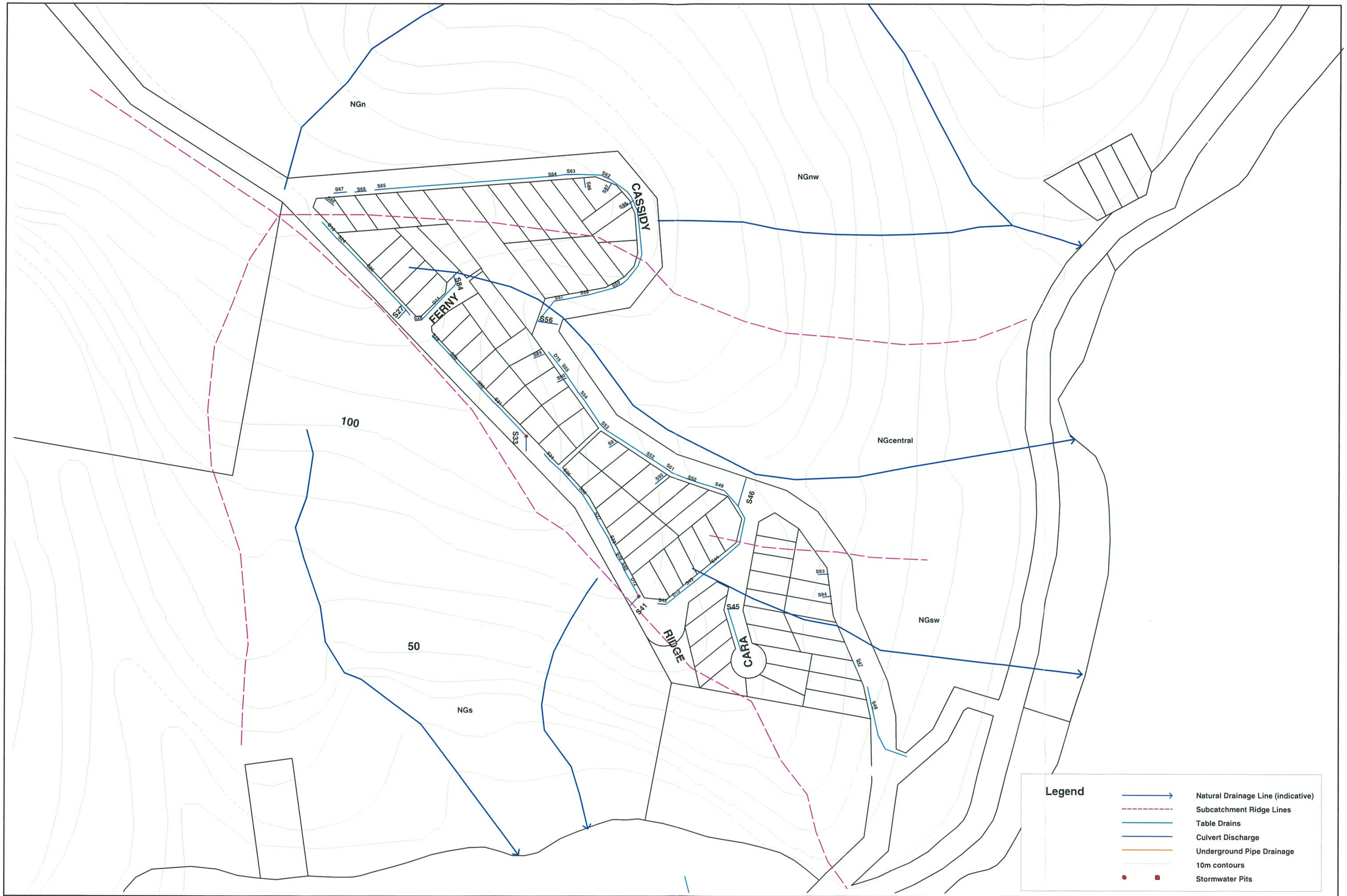
Appendix C

Existing Drainage Assessment - Maps



DATA SOURCE:
GIS information supplied by Colac Otway Shire

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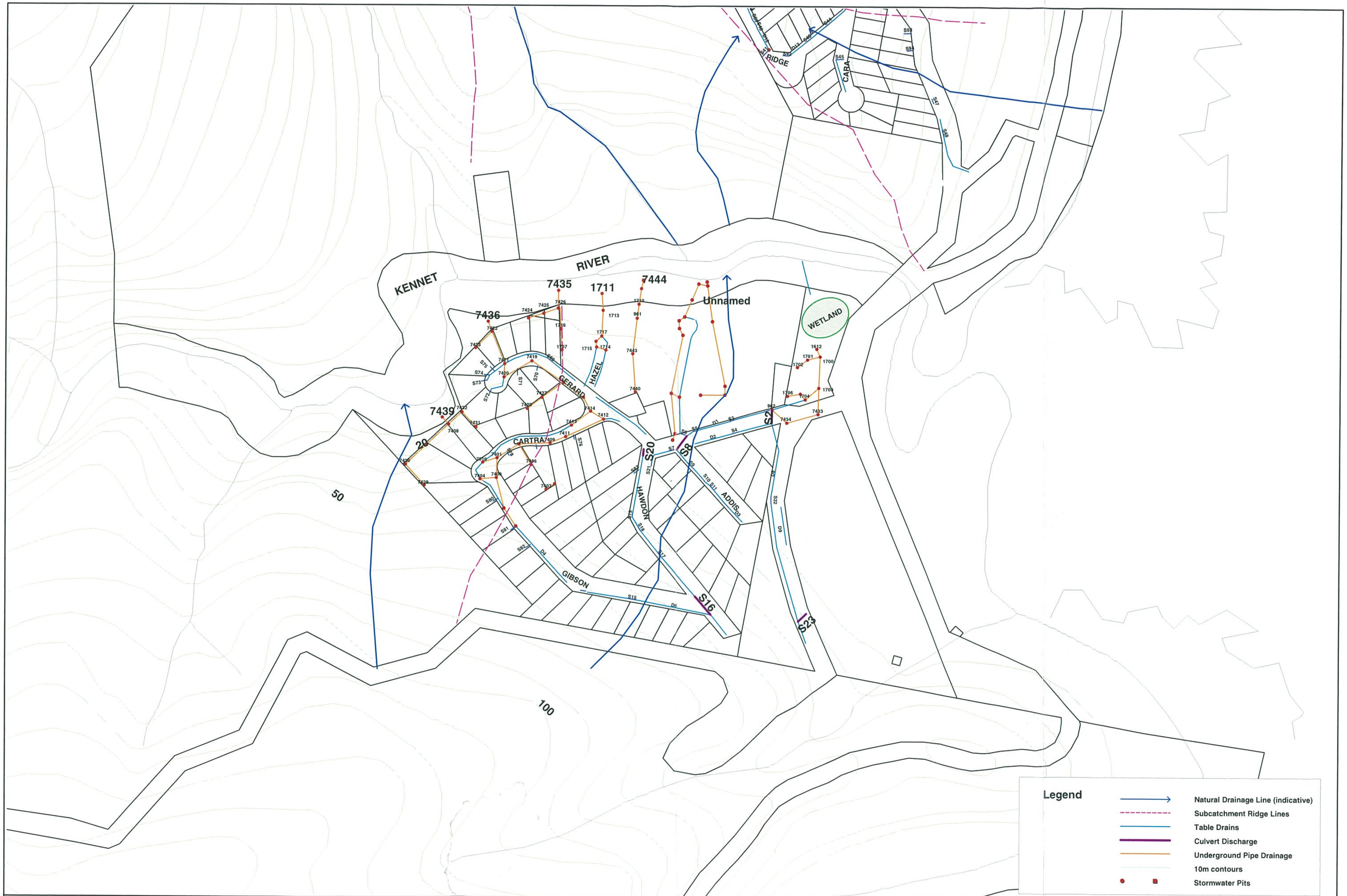
Approved.		Map Grid	AMG66 Zone54

North
SCALE 1 : 3000 at A3
METRES 15 0 15 30 45 60 75
LEVELS ARE TO AUSTRALIAN HEIGHT DATUM

GHD MANAGEMENT ENGINEERING ENVIRONMENT

Colac Otway Shire
Three Towns Stormwater Management Strategy
Figure C4 **Kennet River North - Drainage**

Project No. **3115441**	Date. **31/08/04**	Sheet 1 of 1	Rev. **C**



DATA SOURCE:

GIS information supplied by Colac Otway Shire

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Approved.		Map Grid	AMG66 Zone54

North

SCALE 1 : 4000 at A3

METRES 20 0 20 40 60 80 100

LEVELS ARE TO AUSTRALIAN HEIGHT DATUM

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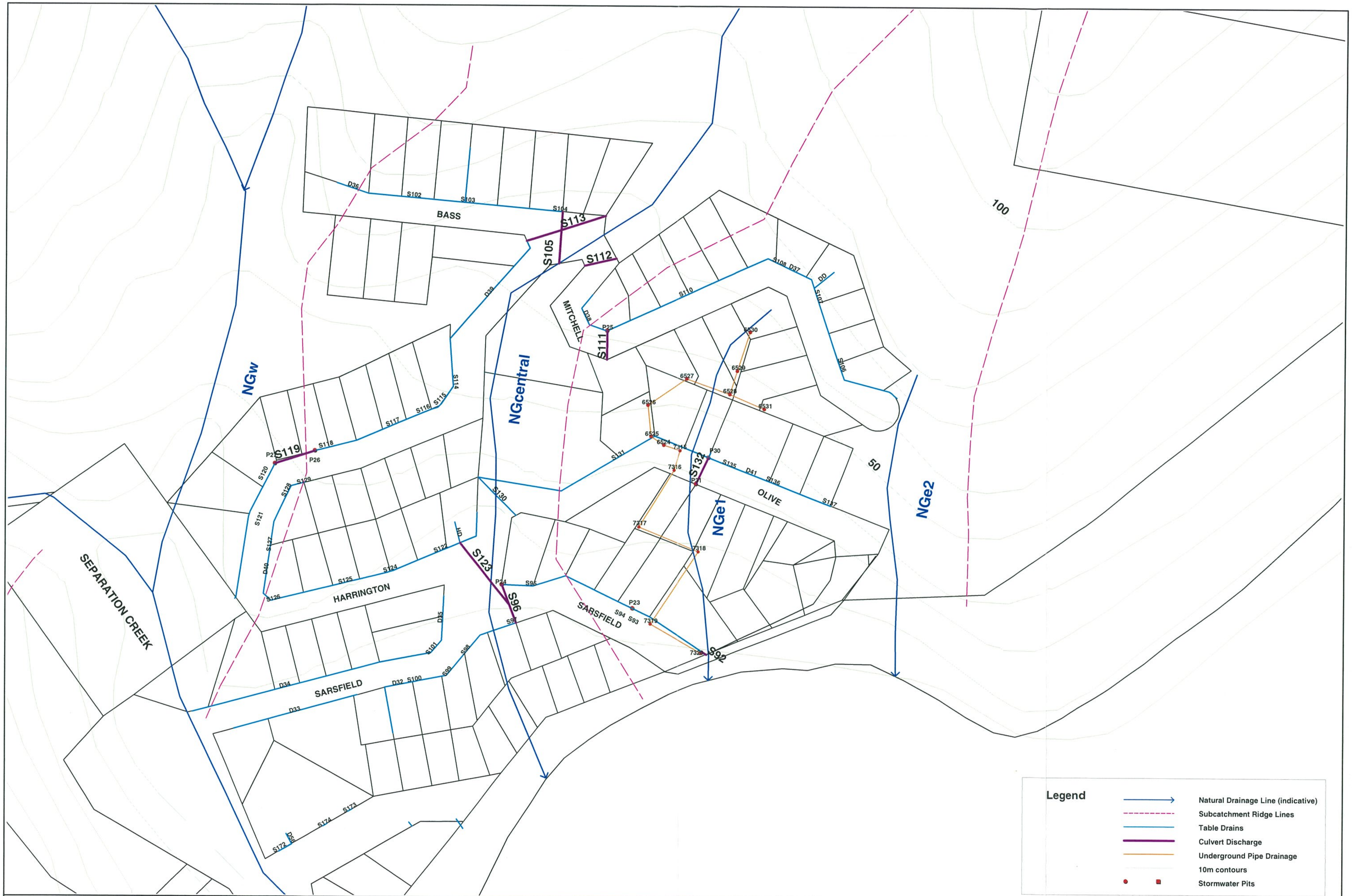
Three Towns Stormwater Management Strategy

Appendix C — Figure C5 — Kennet River South - Drainage Infrastructure

Project No. 3115441 — Date. 31/08/04 — Sheet 1 of 1 — Rev. C



DATA SOURCE:
GIS information supplied by Colac Otway Shire

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Approved.		Map Grid	AMG66 Zone54

North
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METRES 10 0 10 20 30 40 50
LEVELS ARE TO AUSTRALIAN HEIGHT DATUM

GHD MANAGEMENT ENGINEERING ENVIRONMENT

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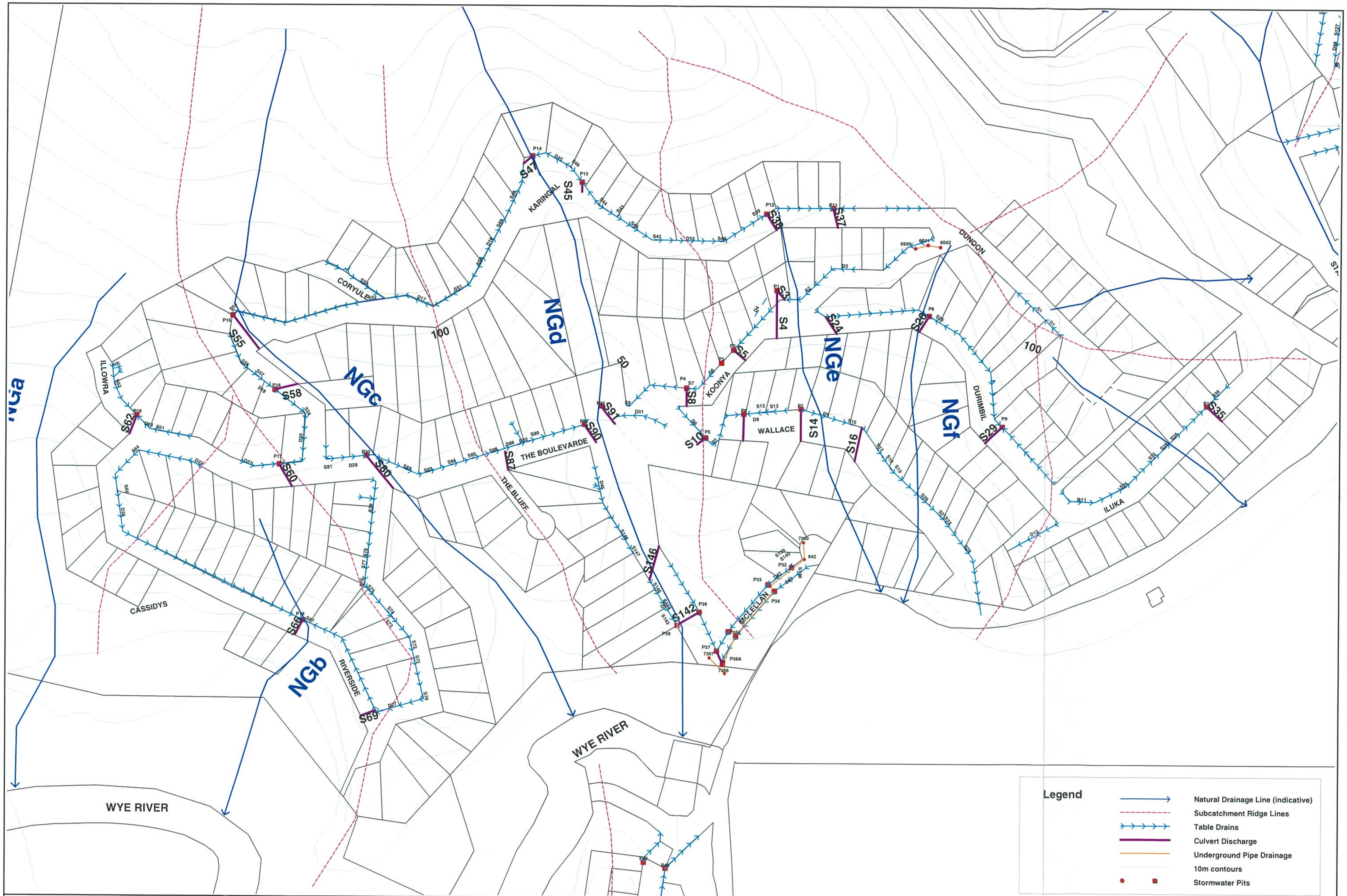
Three Towns Stormwater Management Strategy

Appendix C — Figure C3 — Separation Creek - Drainage Infrastructure

Project No. 3115441 — Date. 31/08/04 — Sheet 1 of 1 — Rev. C



DATA SOURCE:

GIS information supplied by Colac Otway Shire

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Approved.		Map Grid	AMG66 Zone54

North

SCALE 1 : 3000 at A3

METRES 15 0 15 30 45 60 75

LEVELS ARE TO AUSTRALIAN HEIGHT DATUM

GHD MANAGEMENT ENGINEERING ENVIRONMENT

Colac Otway Shire

Three Towns Stormwater Management Strategy

Appendix C Figure C2 Wye River North - Drainage Infrastructure

Project No. 3115441	Date. 31/08/04	Sheet 1 of 1	Rev. C

Appendix D

Existing Drainage Assessment - Tables

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COS - Three Towns Drainage Study
Drainage Infrastructure Appraisal

Wye River (north)

Drainage catchment (road system)	Local drainage system (inc. GIS references)				Description	Field Observations	Photo Ref.	Recommended Improvements	Priority High(H) Medium(M) Low(L)
	Location/Road	O/L Drain(s)	Pit/Inlet	Culvert outlets					
NG_A, NG_B					***Small local gullies draining to Wye River floodplain at west extent of township area***				
Ilowra	Ilowra Ave	D23	P18	S62	Table drain to culvert under road discharging to top of The Boulevarde	Cross drain at end of Illowra to table drain along Riverside before discharging via private property towards Nga	18	Vegetate preferential path on slope and create easement	M
Boulevard/Riverside	The Boulevard/Riverside Drive(north side)	D22, D25, D28	P19	S66	Table drain to culvert under road discharging via gully to Wye River floodplain (shown as private property)	Well formed drained with ideal discharge arrangement (i.e. into vegetated gully)	20, 23, 24	Relieve drain with additional cross drains to discharge points on vegetated slopes	M
	Riverside Drive (west side)	D27	-	Unnamed	Table drain to culvert (adjacent to S66) under road discharging via gully to Wye River floodplain (shown as private property)	Well formed drained with ideal discharge arrangement (i.e. into vegetated gully)	21, 22	Relieve drain with additional cross drains to discharge points through private property (Check S69)	L
NG_C					***Natural gully (with significant u/s catchment) through township, discharging into lower end of Wye River***				
Coryule/Karingal	Coryule Avenue	D18	-	S52 (Ø250)	Table drain connecting to Karingal Road Drain	Drain across Coryule Av is fully blocked	28	Reinstate culvert with inlet protection	M
	Karingal Drive (north side)	D17, D18	P15	S55 (Ø525)	Table drain into culvert under road discharging to NG_C	Table drain entry to headwall of road culvert for NGc	27	Reinforce at entry of table drain into headwall	M
Karingal/Boulevard	Karingal Drive (west side)	D18	P16	S58	Cross culvert discharging to NG_C	Culvert under road not observed		Confirm cross culvert operating effectively	L
	Karingal Drive / The Boulevard	D20, D21	P17	S60	Table drain into culvert under road discharging to private property	Cross culvert discharge flow path into private property (not found)	25, 26	Prove point of discharge then either create drainage easement along preferred alignment, and consider providing cross culvert across Karingal redirect drainage to system D28	H
	The Boulevard	D28 / unnamed	P20	S80 (Ø750)	Table drains from east and west into culvert under road, discharging to NG_C	Table drain connects to road culvert for NGd		Increase table drain capacity to accept additional flow from Karingal Rd (refer to above)	H
NG_D					***Major Natural gully (with significant u/s catchment) through township with some allocated reserve, discharging into lower end of Wye River***				
Karingal	Karingal Drive (north side)	D16, D15	P14	S47	Table drain from east and west into "culvert" under road discharging into NG_D	Silted culvert connection from table drain to road culvert for NGd	30, 31	Reinstate culvert with inlet protection; provision of road edge berm to protect properties below	L
	Karingal Drive	unnamed	P13	S45 (Ø300)	Table drain (short section) to culvert under road discharging to NG_D (?)	Cross culvert not observed		Confirm cross culvert (reinstate as required and supplement with additional cross culverts)	L
Boulevarde/Wallace/ Koonya	The Boulevard (north side)	unnamed	P21	S90 (Ø300)	Table drain to culvert under road, discharging to NG_D	Table drain connects to road culvert for NG_D	34	-	
	The Boulevard	unnamed	-	S87	Culvert under road, discharging to corner of The Bluff	Cross drain discharged into table drain on south side of road from The Bluff, with flow path via private property connects to drain for S147		Provide clear flow path through private property and create easement as required	M
	Wallace Street	NG_D	P22	S91 (Ø1050)	Road culvert for NG_D	Large diameter pipe in good condition	34	-	

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Wye River (north)

Drainage catchment (road system)	Local drainage system (inc. GIS references)				Description	Field Observations	Photo Ref.	Recommended Improvements	Priority High(H) Medium(M) Low(L)
	Location/Road	O/L Drain(s)	Pit/Inlet	Culvert outlets					
	Wallace Street	D31	-		Table drain towards d/s end of S91 outlet pipe	Short section of table drain discharging into NGd		-	
	Koonya Avenue	unnamed	-	S9 (Ø300)	Table drain (short section) discharge connection to NG_D (via steep drop)	Short section of table drain discharging into NGd		-	
Boulevarde(lower)	The Boulevard (west side)	D45	-	S147	Table drain connection to continuation of NGd from outlet of S146	Well maintained table drain with appropriate size driveway culverts		-	
	The Boulevard (crossing)	NG_D	-	S146	Road culvert crossing for NG_D	Large capacity pipe		-	
	The Boulevard (west side)	unnamed	P39, P38	S142	Table drain (west side below cross culvert headwall)	Discharge combines with NGd flow and from P39 continues along open drain before entering Wye River floodplain via vegetated gully	51	-	
McClellan/The Boulevarde	The Boulevard (east side)	unnamed	P37, P38A	unnamed	Table drain (short section) connects to d/s drainage infrastructure	Table drain from below P38 enters u/g drainage infrastructure	52	Maintain clear entry to pit	L
	McClellan (both sides)	unnamed, D43	P37, P38A	unnamed	Kerb and channel supplementing u/g drainage system (Ø300 mm pipe)	U/G drain discharges under road to foreshore	53, 54	-	
	McClellan (both sides)	U/G various	various	7306	U/G concrete pipe drains along road alignment, discharging under road towards foreshore	U/G drain discharges under road to foreshore		-	
NG_E, NG_F					***Existing development has encroached into natural drainage lines (less defined) discharging towards coastal foreshore area***				
Karingal	Karingal Drive (north side)	unnamed	P12	S38 (Ø525)	Table drain to culvert under road discharging via private property to NG_E	Discharge into vegetated slopes to flow path defined between existing dwellings	32	Form berm along outer edge of road; create easement through private property	H
	Karingal Drive (north side)	unnamed	P11	S37	Table drain from both directions (short sections) to culvert under road discharging to private property	Discharge into vegetated slopes to flow path defined between existing dwellings	42	Form berm along outer edge of road; create easement through private property	H
Koonya	Koonya Avenue	D3	P1	S3	Table drain, to pipe connection the culvert under road (S4)	Well maintained table drain with lip on outer edge of road	38	-	
	Koonya Avenue	-	-	S4 (Ø475)	Culvert under road - Discharges to NG_E in private property	Various u/g pits receiving from table drains and house connections- point of discharge of culvert in private property not found	36, 37	Prove point of discharge, provide protected flow path and create easement along preferred flow path; provide additonal edge berms for additional protection for lower properties	H
	Koonya Avenue (west side)	D3	P2	S5	Table drain to culvert under road discharging to private property	point of discharge of culvert in private property not found		Consolidate drainage via table drains to a preferred discharge flow path towards NGd	M
	Koonya Avenue	unnamed	P4	S8	Table drain to culvert under road (under discharge)	Cross culvert connection to Wallace St drain (D6)	35	Confirm connection to discharge flow path towards NGd	M

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Wye River (north)

Drainage catchment (road system)	Local drainage system (inc. GIS references)								
	Location/Road	O/L Drain(s)	Pit/Inlet	Culvert outlets	Description	Field Observations	Photo Ref.	Recommended Improvements	Priority High(H) Medium(M) Low(L)
	Wallace Street / Koonya Avenue	D6	P5	S10	Table drain to culvert discharging towards the NGd	Discharge to vegetated slope towards NGd		Provide or reinstate connections of above system to this point of discharge	M
Wallace	Wallace Street	D7, D8	P6	unnamed	Table drain (both directions), to culvert under Wallace Street discharging to private property	Discharge into vegetated slopes to defined flow path		Create easement for preferred drainage path; investigate opportunity to connect to u/g drainage at McClellan	M
	Wallace Street	-	P7	S14 (Ø675)	Culvert under road to private property	Discharge into vegetated slopes in private property	49	Create easement for preferred flow path	M
	Wallace Street	D9	-	S16	Table drain, towards culvert under road discharging to private property	Discharge into vegetated slopes in private property		Consolidate drainage to preferred path above or create additional easements	M
Wallace (lower)	Wallace St	unnamed	-	S23	Table drain to end of road and discharging via private property to NG	Well formed table drain discharging to vegetated slope towards foreshore		-	
Durimbil	Durimbil Avenue	unnamed	-	S24	Table drain (short section), culvert under road discharging to private property	Discharge to private property		Consolidate drainage to preferred path (towards NGe)	H
	Durimbil Avenue (north side)	-	-	S26	Table drain (both directions), to culvert under road discharging to private property	Dwelling constructed over drainage line - point of discharge from culvert not found	43, 44, 45	Prove point of discharge, provide protected flow path and create easement along preferred flow path	H
	Durimbil Avenue (east side)	unnamed	P9	S29	Table drain (both directions), to culvert under road discharging to private property	Discharge to vegetated slopes in private property towards NGf	46	Provide protected flow path and create easement along preferred flow path	H
Drainage to the East					***Various local catchments/minor drainage lines on east side of town discharging towards coastal foreshore area***				
Karingal	Karingal Avenue	unnamed	-	-	Table drain discharging towards Separation Creek	Discharge flow path to slope has formed eroded path to access track		Provide protected drainage flow path to stable vegetated area	L
Dunoon	Dunoon Road	unnamed	-	-	Table drain, unclear point of discharge	Poorly defined table drain along road	40, 41	Form table drain and discharge to preferred path of NGf, utilising existing easement	M
	Dunoon Road	not shown	-	-	series of 3 s/w pits at end of court	u/g system at end of court with unclear point of discharge		Confirm point of discharge and provide easement for flow path	M
Iluka	Iluka Avenue	D12	-	-	Table drain to end of street (cul-de-sac)	not observed		-	
	Iluka Avenue (north side)	unnamed	P10	S35	Table drain, to culvert under road discharging to foreshore via road reserve	Long length of table drain to cross culvert at low point	47, 48	Create easement for discharge flow path via private property, and consider relieving drain with additional cross drains (via additional easements)	M

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COS - Three Towns Drainage Study
Drainage Infrastructure Appraisal

Wye River (south)

Drainage catchment (road system)	Local drainage system (inc. GIS references) Location/Road	O/L Drain(s)	Pit/Inlet	Culvert	Description	Field Observations	Photo Ref.	Recommended Improvements	Priority High(H) Medium(M) Low(L)
Wye R valley (west)					***Small local gullys (not well defined) draining towards Wye River floodplain on west side of McRae Rd***				
					Currently no drainage infrastructure discharging flows to west side of ridge line				
Morley Drain (main drainage system)					***Overland drainage system on east side of ridge along main roads connecting to underground drainage infrastructure at lower end of system before discharging towards the Wye River foreshore connection***				
Restricted access road	Restricted access road	unnamed	-	S162	Table Drain along restricted access road near top of catchment - unclear point of discharge	not observed			
Slashers -McCrae	Slashers Road (to McCrae Rd)	not shown	-	-	Table Drains along local access road (not shown on GIS) to McCrae Rd	Steeply graded gravel road - significant rilling and erosion	14-17	Require cross drain culverts to inside bends; at "hairpin" bends in road facing towards Wye River valley, discharge via vegetated slope or slope drain	H
	McCrae Road (east side)	unnamed	P49	S152	Table Drain including several driveway crossovers flowing into u/g drainage infrastructure in Morley Avenue(lower).	Several driveway culverts blocked; Table drain not connected at d/s end	13	Slope drain or pipe drain to connect to Morley Rd u/g system	M
	McCrae Road (west side)	D51	P47	S150	Table Drain, to culvert under road	Assumed to connect to Morley Road u/g drain	12	-	
Morley	Morley Avenue (west side)	unnamed D47	-	S153	Table Drain commencing from Slashers Road continues along Morley Road to the lower end of town, connecting to underground pipes (assummed to connect to S152)	Many driveway culverts blocked; forcing overland flow across road to Private Property below road		Cross drain connections to vegetated slope or slope drain; upgrade driveway culverts including inlet protection; provsion of berm on edge of road	H
Morley(lower)	From Morley Av	U/G	various	7308	U/G pipe drain (300mm) through easement b/w properties to foreshore	Inlet pit blocked - flows will currently bypass	10-11	Clear inlet pit and reshape entrance	M
	Morley Avenue	D49	P41-P43	unnamed	Kerb and channel supplementing underground system	Discharges to foreshore near end of Wye River - no issues		-	
Drainage to the South					***Small local gullys (not well defined) discharging south towards the coastal foreshore***				
	Slashers Road (to Morley Road)	not shown		S159	Table Drains along west side of Slashers Road (not shown on GIS) discharging across Morley Road via culvert	Culvert across Morley Road fully silted; o/l flow path currently discharging to "reinforced" slope	2-5	Reinstate cross culvert with inlet protection and discharge to cement reinforced "slope drain" to fire access trail (suggest reconstruction of slope drain)	M
	Morley Av (south side)	D55	-	S161	E Drain (short length) - unclear point of discharge	Not found	6-9	Form table drain on south side of Morley Ave (coonect to S159 or creat additional discharge to vegetated slope(easement as required)	M
	Sturt Court	-	-	-	No drainage shown (falling towards coastal foreshore)	Although no formal drain is evident an overland path discharges at the end of the road to cleared slope	1	Form small table drain along Sturt Ave and discharge to vegetated slope or slope drain	M

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COS - Three Towns Drainage Study
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Separation Creek

Drainage catchment (draining to...)	Local drainage system (inc. GIS references) Location/Road	O/L Drain(s)	Pit/Inlet	Culvert	Description	Field Observations	Photo Ref.	Recommended Improvements	Priority High(H) Medium(M) Low(L)
NG_w					***To natural gully draining towards Separation Creek floodplain on west edge of township***				
Harrington	Harrington / (north side)	D39	P26	S119	Table Drain to culvert appears to continue to toward unnamed culvert	Culvert (S119) discharges via private property towards NGwest	67	Provide cross drain relief by discharging into $NG_{central}$	M
	Harrington / (north side)	unnamed		unnamed	Table Drain to unnamed culvert discharging to NG_{west}/Separation Ck	Culvert discharges to NGwest/Separation Ck	68	Maintain clear entry	M
$NG_{central}$					***Major natural gully through township discharging towards the coastal foreshore***				
Bass/Harrington	Bass Avenue (north)	D36	-	S105 (Ø225)	Table Drain to culvert under road, discharging to NGcentral	Cross culvert partially blocked		Reinstate and maintain clear entry to culvert	L
	Mitchell Av	NG central	-	S112	Road culvert for natural gully	Road culvert for NGcentral flow path		-	
	Harrington / Mitchell	-	-	S113	Pipe under road junction (?)	Culvert connection to road culvert		-	
Harrington/Olive	Harrington (west side)	D40	-	S123 (Ø375)	Table drain, to culvert under road at main road junction	Drainage from Harrington/Olive combine with and continue along Sarsfield table drain	66, 73	Maintain clear entry/exit to series of cross culverts	M
	Olive Street	unnamed	-	S130	Table drain along north side of road discharging to natural gully at amin road junction	Drainage from Harrington/Olive combine with and continue along Sarsfield table drain		Maintain clear entry/exit to series of cross culverts	M
Sarsfield (lower)	Sarsfield Street (north side-east flow)	unnamed	P24	S96	Table Drain, to culvert under road combining with u/s flows - connects to Drain d/s	Drainage from Sarsfield (S96) combines with Harrington/Olive and continues along Sarsfield table drain	71	Maintain clear entry/exit to series of cross culverts	M
	Sarsfield Street (north side)	D34, D35	-	-	Table drains to low point in road	Cross connection to D32 confirmed			
	Sarsfield Street (south side)	D33	-	-	Table drain towards D32	Drain connects to D32		Redirect some drainage to discharge directly to Separation Ck	L
	Sarsfield Street (south side)	D32	-	-	Table drain - carrying total catchment flows continues and appears to discharge towards foreshore via private property	Discharge to foreshore via cut drain through private property		Create easement for overland drainage path	M

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Separation Creek

Drainage catchment (draining to...)	Local drainage system (inc. GIS references)								
	Location/Road	O/L Drain(s)	Pit/Inlet	Culvert	Description	Field Observations	Photo Ref.	Recommended Improvements	Priority High(H) Medium(M) Low(L)
NG_{E1}					***Small local gully (not well defined) through eastern part of township discharging towards the coastal foreshore***				
Mitchell	Mitchell Grove (north side)	D37, D38	P25	S111	Table drain to culvert under road discharging to private property	Discharge to vegetated slope		Create easement for drainage path (confirm flow is towards $NG_{central}$)	**M**
Olive/Sarsfield St	Sarsfield Street (north side-west flow)	unnamed	-	S92	Table drain to end of road, discharging towards foreshore	Discharges under Great Ocean Road to foreshore			
	Olive/Sarsfield St	not shown		S92	Table drain along inside bend	Table drain connects to cross culvert S92 discharging to foreshore			
	Olive St -Sarsfield Street	U/G Drains	Various	7320	u/g pipe drains (300mm) for subdivison	Discharge to foreshore		Connection between table drains and u/g system to be investigated (to reduce load on NG_{east})	**M**
	Olive St	D41	P30	S132	Table drain along road to (likely) connection to u/g system	connection to u/g system not clear - drainage discharge to Ngeast		Connection between table drains and u/g system to be investigated (to reduce load on NGeast)	**M**
NG_{E2}					***Small local gully (not well defined) on east edge of township discharging towards the coastal foreshore***				
	Mitchell Grove	unnamed		unnamed	Table drain to end of street	Not well defined flow path to vegetated slope		Form discharge flow path to vegetated slope	**M**
	Olive St	unnamed	-	S137	Table drain to end of street	Discharging to vegetated slope		Connection between table drains and u/g system to be investigated (to reduce load on NGeast)	**M**

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COS - Three Towns Drainage Study
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Kennett River (North)

Drainage catchment (draining to...)	Local drainage system (inc. GIS references)				Description	Field Observations	Photo Ref.	Recommended Improvements	Priority High(H) Medium(M) Low(L)
	Location/Road	O/L Drain(s)	Pit/Inlet	Culvert					
NG_S					*Natural gullys draining towards Kennett River floodplain on west side of Ridge Road*				
Ridge	Ridge Rd	D10	-	S27	Table drain along top of catchment discharging towards Kennett R	Cross culvert discharging to vegetated slope		Maintain clear inlet to cross culverts, and supplement with additional culverts	L
	Ridge Rd	unnamed	P1	S33	Table drain along top of catchment discharging towards Kennett R	Cross culvert discharging to vegetated slope		Maintain clear inlet to cross culverts, and supplement with additional culverts	L
	Ridge Rd	D12	P2	S41	Table drain along top of catchment discharging towards Kennett R	Cross culvert discharging to vegetated slope	63	Maintain clear inlet to cross culverts, and supplement with additional culverts	L
$NG_{central}$					*Main natural gully through township discharging adjacent to Cassidy Road towards the coastal foreshore*				
Cassidy	Ferny Gr	D11	-	S84, S28	Table drain from The Ridge to end of Ferny Crt	Table drain below cross culvert (S27) to end of Ferny Crt discharging to NGcentral	62	Provide protected drainage path to $NG_{central}$ (create easement for $NG_{central}$	M
	Cassidy Dr	Unnamed	-	-	Table drain along top of catchment	Low point in Cassidy Road where ponding is expected		Provide cross drain discarge to vegetaed slope towards NG_N or creta drainage path and connect to $NG_{central}$	H
	Cassidy Dr	Unnamed	-	S56	Table drain along inner kerb of road to culvert under road discharging to $NG_{central}$	Table drain steepen around bend, signficant ersoion occuring		Relieve drain by providing cross drain discharging towards NG_{NW}	H
	Cassidy Dr	D15	-	S46	Table drain (south flowing) to culvert under road discharging to $NG_{central}$	No cross culverts evident across road to $NG_{central}$		Relieve drain with cross culverts directly dischraging to $NG_{central}$	M
	Cassidy Dr	D13	-	S46	Table drain (north flowing) to culvert under road discharging to $NG_{central}$	Well maintain drain connects to S46	64	-	
NG_{south}					*Small local gully(not well defined) on south side of township discharging towards the coastal foreshore*				
	Cara Crt	Unnamed	-	S45	Table drain from top of Court to low point in road	Discharge into private property		Create easement for dischrage flow path	M
	Cassidy Dr	Unnamed	-	-	Table drain to low point in road - unclear point of discharge	not obsevred			

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COS - Three Towns Drainage Study
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Kennett River (South)

Drainage catchment (road system)	Local drainage system (inc. GIS references)								
	Location/Road	O/L Drain(s)	Pit/Inlet	Culvert	Description	Field Observations	Photo Ref.	Recommended Improvements	Priority High(H) Medium(M) Low(L)
To Kennett River					*Overland drainage paths connect to underground drainage infrastructure before discharging to Kennett River floodplain*				
(behind) Cantara	Gerard Av/Cantara Cres (behind)			7439	U/G pipe drainage system behind properties discharging to Kennett R *(local catchment only)*	Discharge to Kennett R		discharge to buffer zone before entry to Kennett R	L
Gerard(south)/Cantara	Gibson Av	D4	various	various	Kerb & channel (concrete) drain to supplement to U/G system (7436)	kerb & channel to u/g system		-	
	Gerard Av	D4	various	various	Kerb & channel (concrete) drain to supplement to U/G system (7436) at lower end of system	kerb & channel to u/g system		-	
	Gerard Av/Cantara Cres			7436	U/G pipe drainage system along road discharging to Kennett R *(recieves flow from D4)*	Discharge to Kennett R		discharge to buffer zone before entry to Kennett R	H
Gerard(north)	Gerard Av		various	various	Kerb & channel (concrete) drain to supplement to U/G system (7436) at lower end of system	kerb & channel to u/g system		-	
	Gerard Av/Hazel crt (b/w)			7435	U/G pipe drainage system discharging to Kennett R *(local catchment only)*	Discharge to Kennett R		discharge to buffer zone before entry to Kennett R	M
Hazel	Hazel Crt	unnamed	various	various	Kerb & channel (concrete) drain to supplement to U/G system (1711)	kerb & channel to u/g system		-	
	Hazel crt			1711	U/G pipe drainage system discharging to Kennett R *(recieves flow from unnamed)*	Discharge to Kennett R		discharge to buffer zone before entry to Kennett R	M
local	Hazel crt/Joseph Crt (b/w)			7444	U/G pipe drainage system discharging to Kennett R *(local catchment only)*	Discharge to Kennett R		discharge to buffer zone before entry to Kennett R	L
Hawdon/Joseph	Gibson Av/Hawdon Av	D6, D5	-	S20	Table drain along roads to culvert discharging to U/G system	Cross culvert (s16) has silted up. System appear to connect to u/g system adajcent to Joseph Court	55, 57	Reinstate culvert and provide inlet protection	M
	Joseph Crt & Open Channel drain			unnamed	Parallel u/g pipe systems and open channel flow path in natural gully combine to discharge into Kennett R (local catchment only)	Connectivity between pipe systems and open channel not clear	56, 60, 61	Connect drainage from this system to wetland or discharge to buffer zone before entry to Kennett R	H
	Joseph crt	unnamed	various	unnamed	Kerb & channel drain for road connecting to U/G system (unnamed)	New drainage infrastructure currently being constructed as part of subdivision			
Hawdon(lower)	Addis Av	D3	various	S8	Table drain along road to culvert discharging under road to system D1	Cross culvert connection to table drain (D1)			
	Hawdon St	D1, D2	962	S1, S2	Table drain (D1) and concrete drain (D2) discharging into u/g drainage system (1612) that enters wetland	Table drain in lower area connects to u/g system via culvert			
	Grey R Rd	D8	962	S2	Table drain along road discharging into U/G drainage system (1612)	Table drain connects to u/g system via culvert		Relieve drain by providing cross culvert discharges downslope across road	L
	Hawdon Av			1612	U/G pipe drainage system discharging to Kennett R via wetland *(recieves flow from D1, D2, D3, D8)*	connectivity to wetland	58, 59		

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