Water Cycle Management Study

for proposed 7-lot subdivision of Portion 14, Parish of Narrabarba and Lot B DP 33573, Wonboyn Lake

Prepared by:

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Document Certification

This report has been developed based on agreed requirements as understood by SEEC Morse McVey at the time of investigation. It applies only to a specific task on the nominated lands. Other interpretations should not be made, including changes in scale or application to other projects.

Any recommendations contained in this report are based on an honest appraisal of the opportunities and constraints that existed at the site at the time of investigation, subject to the limited scope and resources available. Within the confines of the above statements and to the best of my knowledge, this report does not contain any incomplete or misleading information.

Mark Passfield
Director
SEEC Morse McVey

22 February 2008

Summary

The following report is a Water Cycle Management Study, designed to comply with the requirements of various consent authorities that require that new developments demonstrate a level of environmental responsibility by maintaining or improving water quality.

This report contains:

(i) a detailed site description (Section 3),

(ii) a description of the proposed development (Section 2),

(iii) an investigation into how the proposed development will affect the site (Section 4),

(iv) a series of measures to offset the potential impacts and fix any major existing issues (Section 5),

(v) modelling to justify the proposed measures contained in Section 5 (Section 6).

The most important component of this report for the developer is Section 5.

Section 5 contains a series of measures to be implemented as part of the development that will offset any potential problems that might be caused by the development and address any major existing issues. This is referred to as a *Water Cycle Management Plan*. It takes into account the existing conditions (Section 3) and the likely impacts of the development (Section 4).

In most cases, the planned measures in Section 5 of this report will become "conditions of consent" if the development application (DA) is approved. They *must* be implemented as part of the development. In many cases, the consent authority will request a refundable bond from the developer to ensure that these works are undertaken as directed in Section 5 of this report.

In developing the Plan in Section 5 of this report, we have been mindful of the cost/benefit of each of the recommended measures, with the ultimate goal being to achieve measurable environmental benefits at a reasonable cost. In doing so, development can occur in a manner that is sustainable, with long-term benefits for all catchment users.

Contents

1 Introduction

SEEC Morse McVey have been commissioned by Mr Doug Hemmingway of Picnic Point P/L to provide this *Water Cycle Management Study* (WCMS). It is required to accompany an application to subdivide Portion 14, Narrabarba ("the site" Figure 1) into seven new rural lots as shown on the layout plan in Figure 2, prepared by RW Surveying (reference 0833 B Rev. 7). It includes:

(i) an investigation into the existing water cycle;

(ii) an assessment of how the proposed development will affect the management of the water cycle;

(iii) a plan for managing the water cycle to achieve a neutral or beneficial effect on the quality of water leaving the site.

The site is in the Wonboyn Lake Catchment. Bega Valley Shire's DCP 36 (which applies to nearby lands that drain to the lake) requires that any new development demonstrates a neutral or beneficial effect (NorBE) on receiving waters. Because the proposed development also drains to the Lake we have aimed to show that NorBE will be met here too.

SEEC Morse McVey staff inspected the site on 19th October 2007. At that time the weather was cool and dry.

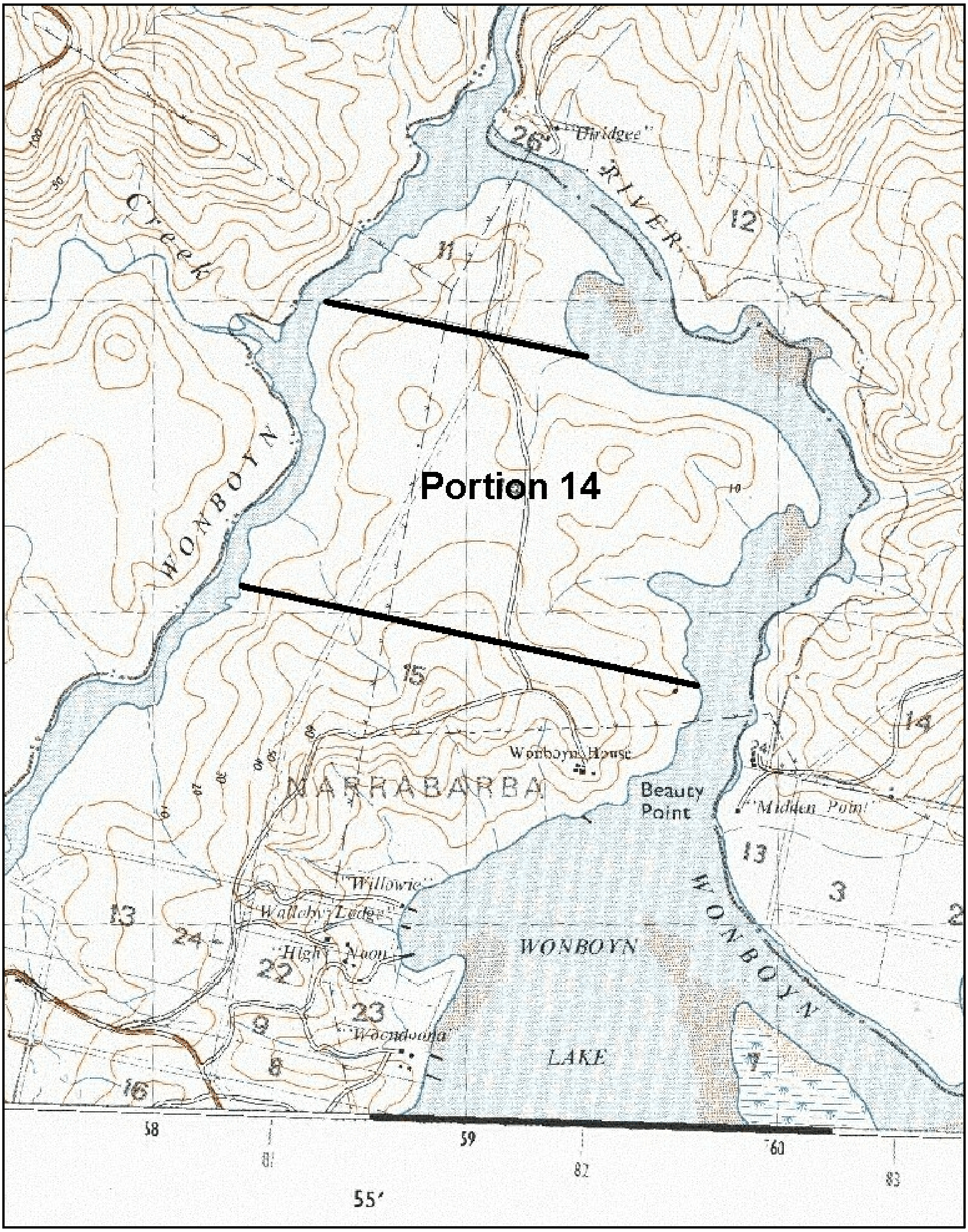

Figure 1 - The site, topographic map © Dept Lands

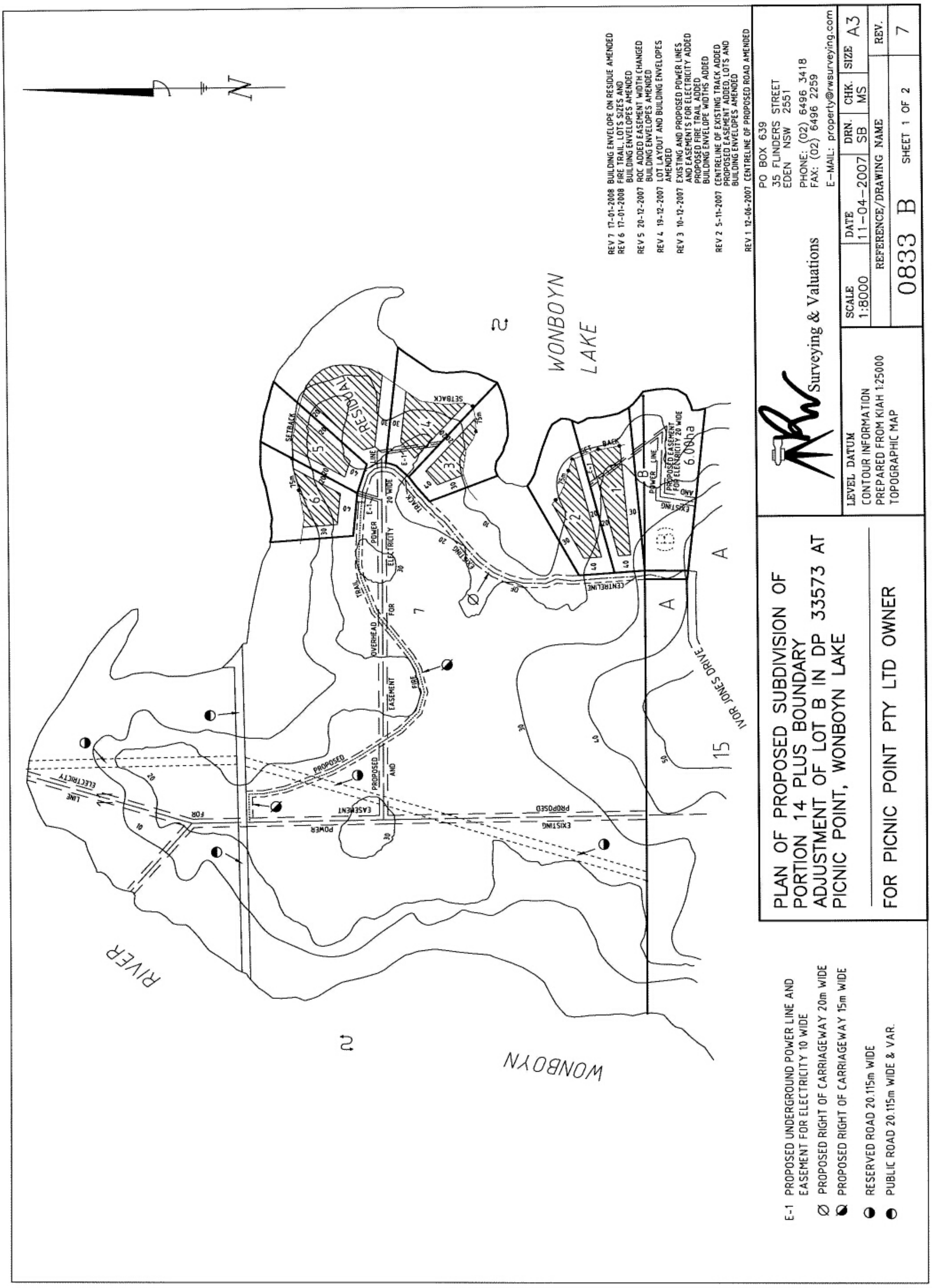

Figure 2 – The Proposed Subdivision

2 The Proposed Development

The proposed development involves (Figure 2):

(i) subdividing the site into seven new rural lots as follows:

- Lot 1 at 3.91 ha
- Lot 2 at 3.95 ha
- Lot 3 at 3.22 ha
- Lot 4 at 4.07 ha
- Lot 5 at 2.83 ha
- Lot 6 at 3.54 ha; and
- Lot 7 = residual

(ii) building a new right of carriageway (ROW) to access each new lot (see SEEC Morse McVey drawing number 07000168-01);

(iii) building seven new driveways from the ROW to access each home site; and

(iv) building a new fire trail from the end of the ROW to Portion 11 (Picnic Point) (Figure 2).

Although we expect a house will be constructed on all new lots these are not included as part of this DA. However, to demonstrate the feasibility for onsite disposal of effluent on each lot, a dwelling envelope was identified on each and the site and soil conditions tested to ensure conformity with Australian Standards plus Council requirements (Appendix 1).

Note that due to bushfire issues the initial lot layout was altered slightly after our site visit and some of the selected dwelling envelopes have moved slightly. This applies to Lots 1, 2 and 3 only. As the topography in this area is quite consistent, this has not posed a problem for this report (Appendix 1).

For the purpose of design it is assumed that a five bedroom home will be built on each lot and that each home will be supplied with tank water.

3 The Site

3.1 General Topographic Conditions

Portion 14 occupies part of a peninsula of land located on the western shore of Wonboyn Lake (Figure 1). It is bound in the east and west by Wonboyn River. Most of the proposed development will be on the east of the peninsular but the fire trail will be built in the central north of the site (Figure 2).

Much of Portion 14 occupies a broad plateau with slope gradients less than 10 percent. Most of the proposed ROW and the fire trail will be in this area. The proposed dwelling envelopes will be located on the east-facing side slope of Wonboyn Lake. Here the slope varies from 6-7 percent on Lots 1 to 4 to 20 percent on Lots 5 to 7. Figures 3 and 4 show the typical conditions in the proposed development areas.

Figure 3 – Typical Conditions around proposed home sites on Lots 1 and 2

3.2 Soils and Geology

3.2.1 Mapping

Soil Landscape mapping for this area was conducted by M. Tulau (2005), Department of Natural Resources (DNR, now part of the Department of Environment and Climate Change, DECC). It shows that Portion 14 lies on four soil landscapes (Figure 5). Site and soil investigations by SEEC Morse McVey staff was limited to the areas proposed for development, i.e. the ROW and the dwelling envelopes. Here we confirmed the mapping to be mostly accurate.

Figure 4 – Proposed dwelling envelope, Lot 7

The four soil landscapes mapped on the development site are:

(i) The Bournda SL in the west

(ii) The Timbillica SL in the centre and centre-east;

(iii) The Merrica SL in the east; and

(iv) The Wonboyn Lake SL in a small area in the far east of Lot 7.

All of the identified dwelling envelopes plus most of the proposed ROW are on the Merrica Soil Landscape, facet "mec". This is a colluvial soil landscape derived on the Merimbula Group sandstones and siltstones. The soil landscape descriptions note "mec" facet as very rocky on steep slopes but that is not the case here – none of the lands inspected had rock outcrop (except on the shore) and the soils had a low to moderate percentage of coarse fragments. Therefore, I believe the soil facets present here are:

(i) me2 (a brown sandy loam); and

(ii) me3 (a dull yellowish sandy clay.

Subsoils on the Merrica SL can vary within short distances and can be dispersive. M. Tulau (2005) recommends that these soils be site-specific tested before earthworks, and that has been undertaken here (Section 3.2.3). The soils are noted as having a moderate susceptibility to erosion by concentrated flow but a low susceptibility to erosion by wind or sheet flow. However, the erosion hazard is high in urban development.

A small part of the ROW, and most of the fire trail, will be on the Timbillica Soil Landscape. It consists of coarse grained sandy topsoils and sandy clay subsoils derived on Tertiary fluvial sediments. Generally, this soil landscape is very similar to the Merrica SL although where it was sampled (on the proposed road alignment, near to Lot 2) the clay subsoil was absent (replaced with a clayey sand).

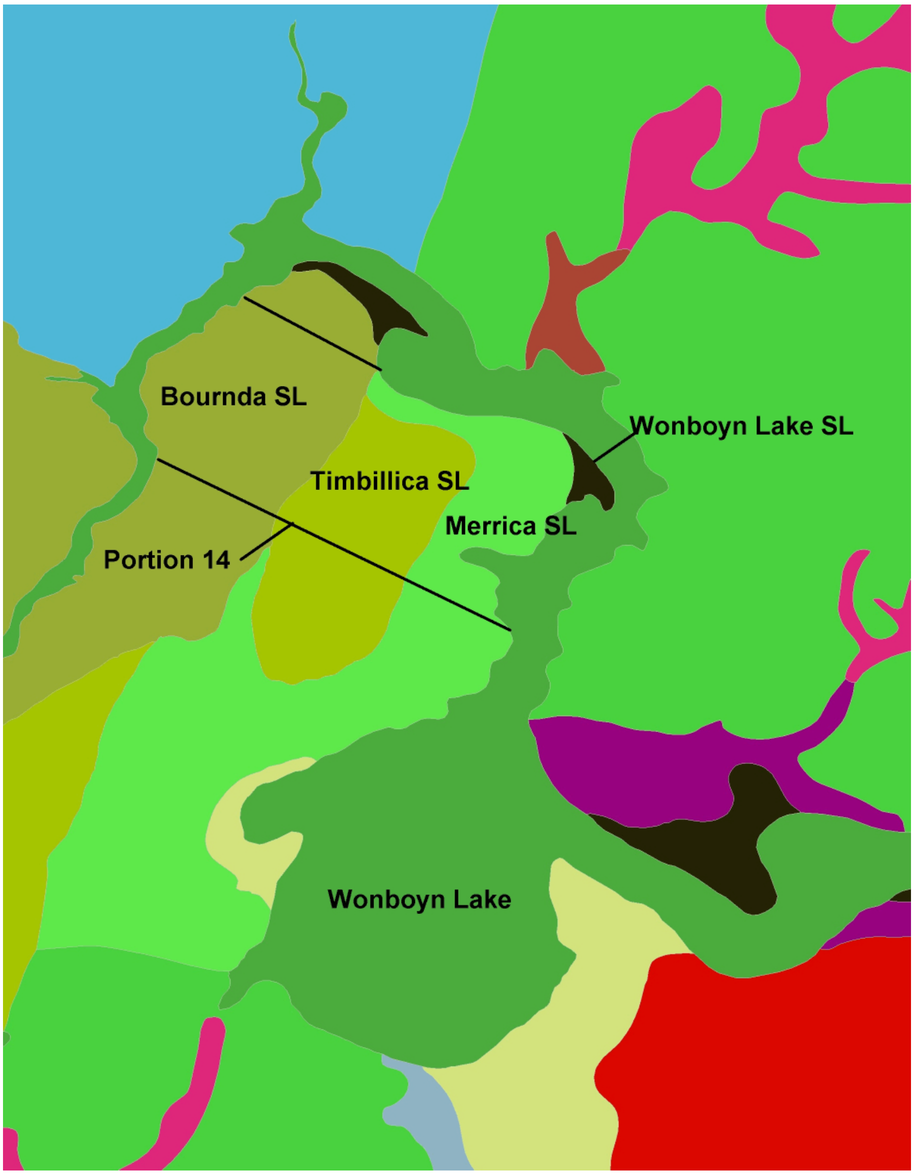

Figure 5 – Soil mapping of Portion 14

3.2.2 *Site Specific*

Test pits were dug by hand and supplemented by Dynamic Cone Penetrometer (DCP) tests to prove depth to bedrock. The individual soil description are given in Appendix 1. All test pits except TP1 showed a consistent soil profile of:

0 - (200-300) mm	Grey sandy loam, massive
(200-300) - (800-900) mm	Yellow brown sandy clay loam to light clay, moderately pedal.

Bedrock was normally encountered within 1,000 mm although one DCP test (near Lots 5 and 6) proved a soil depth of 1,200 mm.

TP1 represents the Timbillica Soil Landscape. It showed gritty and sandier soils than elsewhere. As these soils would be less erodible than the Merrica SL, they were not sent for testing (i.e we have assumed the worst case).

3.2.3 Laboratory Testing

Soil samples representing the Merrica Soil Landscape we sent to Scone Research Laboratories for testing. Two suites of tests were undertaken:

(i) An "erosion and sediment control" suite of tests to:

- determine the erodibility (K-Factor); and
- determine the dispersion percentage

(ii) An "effluent management" suite of tests to determine the suitability of the soils for onsite effluent disposal.

The results of these tests are given below in Table 1.

Table 1 - Soil Testing Results (Dept. Lands)

Lab No	Method	C1A/4	C2A/3	C5A/3 CEC & exchangeable cations (me/100g)						C8B/1		C6A/2	P9B/2
	Sample Id	EC (dS/m)	pH	CEC	Na	K	Ca	Mg	Al	P sorp (mg/kg)	P sorp index	OC (%)	EAT
1	07000168 Layer 1	0.01	5.1	6.6	0.4	0.2	0.9	1.0	<0.1	152	1.5	1.38	2(1)
2	07000168 Layer2	0.01	5.6	9.1	0.5	0.2	0.4	1.6	1.5	401	3.0	0.44	2(1)

Lab No	Method	P7B/1 Particle Size Analysis (%)						P8A/2	P7C/1 Particle Size Analysis – mechanical dispersion (%)					
	Sample Id	clay	silt	vf sand	cf sand	c sand	gravel	D%	clay	silt	vf sand	cf sand	c sand	gravel
1	07000168 Layer 1	7	12	32	13	32	4	54	4	13	31	13	35	4
2	07000168 Layer2	26	15	21	9	26	3	82	23	18	19	9	28	3

END OF TEST REPORT

They show the soils:

- are silty sand (topsoil) or silty clayey sand (subsoil)
- are strongly acidic
- are marginally sodic;

- are significantly dispersive (dispersion percentage of fines = 82%, dispersion percentage of whole soil = 26 percent); and
- have a low K-Factor (erodibility) of 0.025
- have low CEC (low ability to entrain nutrients or pollutants)
- have a moderate ability to sorb phosphorous (calculated at 4,700 kg/ha, assuming 900 mm depth)
- have low organic matter (coupled with their fine sandy loam texture this means they can be hard-setting)
- have low potassium

3.3 Surface and Subsurface Hydrology

Most of the proposed development is on the east-facing side slope of Lake Wonboyn, with the ROW and the fire trail proposed on the plateau. Stormwater is shed from the plateau east and west towards the lake. On the eastern side it concentrates in three depressions (Figure 2) but there are no watercourses with defined bed or banks. The ROW crosses the upper reaches of these depressions. Up-slope catchments vary from 4 ha to 15 ha. Nevertheless, where the ROW intercepts these depressions it is considered connected to receiving waters (Section 4.3). The proposed fire trail alignment has been adopted so that it does not intercept any depressions or watercourses.

The soils are classified as hydrologic Class C - even though rainfall is expected to infiltrate the permeable near-surface soils. This is because they are shallow in nature and clayey at depth. Soils of this classification shed rainfall under moderate to high rainfall events.

We have not specifically investigated groundwater at this site and there are no registered bores on it from which to draw information. Infiltrated water would be expected to move along the bedrock surface, approximately parallel to the ground surface. The bedrock is a mix of permeable sandstone and less permeable siltstone, perched watertables could occur at depth, especially on the plateaux areas.

3.4 Climate and Erosion Potential

Wonboyn has a temperate coastal climate, with warm summers and temperatures below 15°C in winter. Mean annual rainfall at nearby Eden or Green Cape is about 750 mm (Australian Bureau of Meteorology). Rainfall is fairly consistent throughout the year. The estimated rainfall erosivity for Wonboyn is 2,500, which is moderate. The site has a generally low erosion risk (Figure 4.6, Landcom, 2004) but this increases to high (just) where the slope is greater than 10 percent (e.g. at the dwelling envelopes on Lots 5 and 6 and for part of the ROW where it is near a depression).

A Preliminary Erosion and Sediment Control Plan has been prepared for the site by SEEC Morse McVey, our reference (07000168-SWMP-01). In brief it shows that sediment basins are not required because of the low soil loss classes and a general suite of best management practices are sufficient. Nevertheless, it will be critical to ensure ground cover is very quickly reinstated to prevent the potentially dispersible soils being eroded.

3.5 Vegetation and Biodiversity

Vegetation and bushfire issues are addressed by others but suffice it say here that the site is heavily timbered with native vegetation and native biodiversity ranges from reasonable to excellent. Areas under native woodland are in very good condition.

3.6 Salinity

Observations by SEEC Morse McVey staff did not identify any surface indications of salinity at this site. M. Tulau (2005) does not suggest that the local soils are prone to salinity.

3.7 Acid Sulfate Soils

Acid sulfate soil risk mapping by the Department of Land and Water Conservation (DLWC, now part of DECC) identifies several small patches of coastal land at this site that have a high risk of being acid sulphate soils. The main patch is in the small bay between Lots 2 and 3 (Figure 2). Although we did not specifically investigate this area for acid sulphate soils, we would concur that there is a high risk they could occur here. However, none of the proposed development is here, or in any other land that might have a similar risk. All development is on relatively elevated lands where acid sulphate soils will not occur.

3.8 Current Land Use

At the time of inspection, the majority of the site was unused and left under native timber. There is a wide electricity easement in the west of the site (Figure 6) and this has been used by other people to gain access to Picnic Point, which is off-site. The track along this easement is now closed. There is also an existing dirt track in the south east of the site that joins the electricity easement, although it is rarely used.

3.9 Existing Issues

At the time of inspection the site was in very good condition. There were no key issues to water quality, although there is some existing erosion along the electricity easement (Figure 6). However, as most of the easement is disconnected from receiving waters and on a gentle slope, eroded soils are not entering receiving waters and are being re-deposited on adjoining well vegetated lands.

Figure 6 View north along existing transmission line. Notice sandy soils that are eroding but receiving waters are distant.

3.10 Pre Development Sediment and Pollutant Loads

Section 6 of this report includes modelling to compare the pre and post development sediment and pollutant loads from the parts of this site that will be altered and are also part of the connected stormwater system. The pre development model takes into account the site conditions detailed above.

4 Identifying Future Water Quality Issues

4.1 Production, Management and Disposal of Wastes

4.1.1 Domestic Waste

We anticipate that new residences will have access to Council's waste transfer stations (as part of annual rates). As such, we expect that no domestic waste will be deposited onsite.

4.1.2 Effluent Disposal

The site is not serviced by reticulated sewer, so new houses will require onsite treatment and disposal systems for domestic effluent. A potential effluent management area has been identified on each new lot and these are discussed in Section 5.5.

4.1.3 Other Pollutants

It is unlikely that the proposed development will generate significant quantities of other pollutants that might become entrained in stormwater runoff.

4.2 Land Surface Changes

Land surface changes include (refer to plan in Figure 2):

(i) a new sealed ROW. This will:

- be approximately 1,000 m long;
- will be built in a 20 m road corridor;
- have a 4 m wide sealed pavement with passing bays (total assumed 30 percent actual impervious);
- be crowned to drain to table drains on both sides wherever possible (Section 5.2)

(ii) although not technically part of this DA, it is assumed there will be seven new houses built on the site. Each will be contained in an inner asset protection zone of approximate dimensions 7,000 m^2 (40 m on three sides, 20 m on the lake side plus 20 m x 10 m house). Each is assumed to have a roof area of 300 m^2 and other impervious areas of 400 m^2);

(iii) although technically not part of this DA, each house will require an access. Where possible at least part of each access will be shared, to reduce the need for clearing. In total it is estimated that there will be about 700 m of access at 4 m wide and contained in a 16 m wide easement (25 percent actual impervious);

(iv) the unused earth track in the south east of the property will be allowed to regenerate (mulch it first). However, none of this track is considered connected to receiving waters as it mostly follows a ridge;

(v) a new 1 km long fire trail will be built from the end of the new ROW west to the boundary with Portion 11. None of this fire trail is considered directly connected to receiving waters, as it mostly follows a ridge and its alignment has been chosen specifically to avoid areas of concentrated flow (Figure 2). It is assumed to be 4 m wide in a 16 m easement i.e. 25 percent actual impervious.

4.3 Connectivity to Receiving Waters.

Only where pavements cross drainage depressions are they likely to lead to significantly higher flows in water courses. In these locations, pavement drainage cannot be sheeted onto adjacent land before reaching them. The proposed ROW crosses three drainage depressions. Assuming a spacing between mitre drains of 50 m, by our estimation there is approximately 300 m of pavement that is directly "connected" to receiving waters. None of the driveways or the fire trail cross a watercourse.

Dwelling envelopes are situated at least 40 m from depressions and 75 m from Wonboyn Lake. However, their proximity to Wonboyn Lake, and the fact that some are on moderately steep slopes, means we have assumed they are connected to receiving waters (the lake). Therefore, runoff from the "urbanised" areas (i.e the inner protection zone) must be infiltrated into the surrounding soils (Section 5.3), embracing the inherent treatment offered by the permeable soils at this site.

4.4 Pre vs Post Assessment

There is a potential that the proposed future land use at this site will lead to an increase in stormwater discharge and pollutant production. Section 5 of this report contains a Water Cycle Management Plan that shows how a neutral or beneficial effect on water quality can be achieved given the assumptions in Section 4. Section 6 contains modelling using a computer tool known as MUSIC to justify the effectiveness of that plan.

5 Water Cycle Management Plan

5.1 Construction Phase Erosion and Sediment Control

Council's DCP requires a Soil and Water Management Plan (SWMP) to be provided for proposals such as these. Volume 2 of the Blue Book (in draft) applies to linear structures such as roads and it requires a Preliminary Erosion and Sediment Control Plan to be prepared (rather than a SWMP). This has been done by SEEC Morse McVey in an accompanying report referenced 07000168-SWMP-01.

5.2 Pavement Design

5.2.1 Generic Design

(i) Wherever possible (and this is the case for most of the road) table drains will be built on both sides and the pavement cambered to drain to them, refer to SEEC Morse McVey Drawing number 07000168-08). Tail-out drains will be provided at about 50 m intervals to regularly sheet water from the table drains onto well vegetated land. Tail-outs are to be at-grade and will have a sill at their end to encourage minor ponding of water (and subsequently to promote infiltration).

(ii) Cut and fill batters will not exceed 1(V):2.5(H). Any steeper makes vegetation establishment difficult in this climate.

(iii) Cut and fill batters will be stabilised immediately following construction and compaction using hydroseed or hydromulch spraying (or equivalent) to lower C-factors [1] and aid the establishment of grasses.

(iv) Table drains will be stabilised immediately following construction using bitumen-sprayed jute matting (or equivalent).

(v) Sediment fencing will be erected 1 m from the toe of any fill batters until vegetation establishment has stabilised them sufficiently.

(vi) The ROW will be sealed for its entire length.

(vii) The driveways will also be sealed.

5.2.2 Watercourse Crossings

(i) The ROW crossings will use shallow causeways, sized according to the expected flow in the 100-year storm event. Trickle flow will be taken by concrete pipes under the causeway. Rip-Rap with geotextile underlay will be placed downslope of the causeways (SD 5-8) to dissipate flow.

(ii) Any fill batters within 50 m of the watercourses will be stabilised immediately following construction with coconut fibre or heavy-duty jute

1 C-Factor is a measure of ground cover. It varies from 1.0 for bare soil to 0.05 for well vegetated land

fibre blankets. Grass seed will be sown onto or under (depending on manufacturer's recommendations) the blankets.

(iii) Table drains are to discharge into regular mitre drains and immediately up and/or downslope of the edge of fill batters. Discharge points are to be stabilised with an appropriately sized energy dissipater (SD 5-8), made from riprap (i.e. locally-sourced rock).

(iv) Any runoff from the pavement is not to be dropped into a watercourse from the pavement height. It is to discharge onto a stable energy dissipater.

(v) The ROW is to be provided with table drains on either side. If their gradient is more than 5 percent, rock check dams (SD 5-4) will be installed to reduce it. This encourages infiltration.

(vi) The ROW table drains are to have the following characteristics and conceptual dimensions:

- a trapezoidal channel as follows:

  – base width: 0.5 m
  – top width: 2.3 m
  – depth: 0.3 m
  – side batters: 1(V):3(H).

(vii) Driveways will also be provided with table drains on either side (if slope permits. Driveway table drains will have the same conceptual dimensions as above.

(viii) All table drains will:

- be lined with topsoil (pH adjusted) to promote grass growth;
- be lined with bitumen-sprayed jute matting *immediately* following construction, with grass seed sown under or onto the matting (depending on manufacturer's instructions); and
- discharge water onto an energy dissipater (SD 5-8) (if discharging into a watercourse) or tail-out structures at 50 m spacings.

5.3 Individual Houses

Any new houses should include:

(i) A rainwater tank (or series of tanks) to capture roof runoff. These tanks:

- are to be sized according to roof area and expected demand. A five-bedroom home normally necessitates at least 40 to 60,000 L of water tanks for 90% supply confidence in this area;
- are to be plumbed to provide all internal and external water;

- are to be plumbed to capture as much of the roof runoff as is feasibly possible. This is normally easily achieved through the use of charged pipelines;
- are to have their overflow directed to the infiltration contour bank described below;
- are to have a first-flush device;
- are to be screened and sealed to prevent the entry of leaves, twigs and mosquitos;
- are to be installed and maintained according to the manufacturer's instructions.

(ii) Water saving fixtures for any fittings. Toilets are to have AAA-rated (minimum), dual flush cisterns.

(iii) An infiltration contour bank [2] (Figure 7) to trap and percolate runoff water into the soil. This contour bank will:

- be located downslope of each house, at the extremity of the inner protection zone;
- be long enough (about 100 m) to capture runoff from the entire urbanised area (inner protection zone);
- have a 1 m wide base that will be scarified and have gypsum incorporated into it to improve percolation rate and control potential dispersiveness;
- be well vegetated with local native grasses.

(iv) A stabilised up-slope diversion bank to deflect run-on away from the "urbanised" area. The up-slope diversion drain must not drain to the contour bank (to prevent the infiltration contour bank being over-loaded).

2 The use of measures that encourage infiltration of rainwater into soils is appropriate at this site, in keeping with the ideals of Water Sensitive Urban Design (WSUD)

Figure 7 - Infiltration trench/garden. Diagrammatic only.

5.4 Vegetation Management

(i) Wherever possible, existing areas of trees are to be maintained, as per the current NSW vegetation management regulations. Only those areas of native vegetation that require clearing for access or for the inner asset protection zone will be cleared.

(ii) The outer asset protection zone will remain under native vegetation, although it will be thinned to the requirements of the bushfire management plan. Although it will be thinned, the ground cover will not be removed and so the change in vegetative cover will not be enough to affect water quality. Therefore, these areas are considered unchanged in the MUSIC model.

5.5 Onsite Wastewater Management

The site is not on reticulated sewer and so each lot must sustainably manage treated wastewater on site. There are a number of constraints to onsite wastewater management, particularly regarding the soils:

- soils are shallow;
- the clay fraction of the subsoils is dispersive;
- soils are infertile;
- soils have a low CEC;
- soils have a moderate to low phosphorous sorption; and
- soils are strongly acidic.

In addition:

- for Lots 5 and 6, the dwelling envelopes are on moderately steep land (15 percent);
- the houses might not be occupied all the time (intermittent use);
- land available for effluent management is currently under native vegetation; and
- Wonboyn Lake requires a buffer from effluent management areas (EMAs) of at least 100 m and the dwelling envelopes are in closer proximity than that (75 m).

These constraints mean:

- The shallow, potentially dispersive, and clay rich subsoils preclude the use of a traditional septic tank to absorption trenches system;
- The proximity of Wonboyn Lake precludes the disposal of primary treated effluent and at least secondary treatment is recommended;
- The likely intermittent use at most sites precludes the use of aerated wastewater treatment systems (AWTS), as they require a regular, steady inflow of wastewater to perform optimally;
- Irrigation is not preferred because hydraulic and nutrient modelling requires a large EMA to be provided. This has two negative implications:
  - more clearing is required; and
  - it will be difficult to re-establish suitable vegetation in those areas because of the low soil fertility.

After considering these constraints we propose that each new lot is serviced by an Ecomax® system (ecomax.com.au). This system provides primary effluent treatment in a standard septic tank followed by secondary treatment by filtration and microbial activity in the core of an amended-soil mound. This is similar to a standard "Wisconsin" type sand mound but the amended soil also provides additional phosphorous removal by encouraging phosphorous adsorption to the amended soil particles.

The high reduction in the levels of nutrients and pathogens provided by Ecomax® makes it far less likely for the treated wastewater to pollute any receiving waters. In addition, by selecting a raised mound system, not only can the absorption potential of the soil be utilised (around the perimeter of the amended soil cores) but also evapotranspiration can be improved over the whole mound (due to improved air circulation, and better vegetative growth). Moisture that is not evapotranspired is absorbed into the soils beneath, or around the perimeter of, the amended soil cores. This means it is very unlikely for effluent to be at the surface, where it could otherwise become entrained in stormwater runoff.

The required footprint of the Ecomax® mounds is small (about 150 m^2, Appendix 3) and so the requirement for clearing will be negligible. Ecomax® is also ideally suited to intermittent and shock loads.

In all lots it is proposed that the Ecomax® mounds be placed up slope of the dwelling envelopes. This is to ensure maximum buffer to Wonboyn Lake and to ensure the mounds are not built on land steeper than about 6 percent (as their bases are cut into the natural soils).

The Ecomax® mounds need some minor maintenance (Section 5.6.3) and so they should be located where they are easily accessible and within regular sight of the new owners. We suggest that they are placed next to the driveways where they first enter each lot.

5.6 Monitoring and Maintenance

An ongoing regime for maintenance of the various water quality control measures will be required to ensure their continued performance and stability. Monitoring and maintenance will need to consider the following:

5.6.1 Pavements and Watercourse Crossings

(i) These need to be checked regularly, paying particular attention to:

- table drains, to ensure they are stable and well armoured against erosion;
- pavement surfaces, to ensure they are not subject to deterioration;
- pipe outlets, to ensure they are free from blockages and are appropriately armoured against erosion;
- batters, to ensure they are well vegetated and do not show signs of sheet or rill erosion;
- tail-out drains, to ensure:
  - they are not filled with sediment;
  - they are stable; and
  - they remain connected to the main table drains
- causeways, to ensure they are free from blockages and are providing suitable passage for water;
- drainage systems, to ensure they are operating as intended and are not causing erosion issues elsewhere.

5.6.2 Diversion Drains and Infiltration Contour Banks

(i) These need to be checked regularly, paying particular attention to:

- the bases - to ensure they are well vegetated and stable under flow
- the level-spreader outlets (SD 5-8) to ensure flow is dissapated.

5.6.3 Onsite Wastewater Management Systems

It is proposed to use Ecomax® wastewater management systems (Section 5.5). These systems use a septic tank near the house, and a set of two treatment cells some distance away from the house. The systems do not require regular maintenance by the supplier but there are some maintenance requirements by the householders. These are:

(i) switch the active cells every six months (the suppliers send out a reminder to do this);

(ii) ensure the pumps are working properly (pumps are necessary as the cells will be located up-slope of the septic tanks);

(iii) ensure the high-water alarm on the pump-wells are working properly and, if they are activated, respond to them immediately;

(iv) ensure the treatment cells are well vegetated at all times and maintain this vegetation as necessary (mow or trim it); and

(v) ensure the distribution pipes remain buried and are not damaged.

6 Water Quality Modelling

6.1 MUSIC Modelling - Inputs

6.1.1 Modelling Introduction

MUSIC contains algorithms based on the known performance characteristics of common stormwater quality improvement structures used in Australia. These data are derived from research undertaken by the CRC and others. The models are appropriately calibrated and all amendments to MUSIC defaults are noted in Appendix 2. The modelling quantifies:

(i) the levels of the principal pollutants before and after the development; and
(ii) changes in export levels because the development is there.

Statistics are produced in MUSIC for the following parameters:

(i) Flow (ML/yr)
(ii) TSS - Total Suspended Solids (kg/yr)
(iii) TP - Total Phosphorus (kg/yr)
(iv) TN - Total Nitrogen (kg/yr)
(v) Gross Pollutants (kg/yr).

Statistics can also be exported detailing pollutant concentrations in stormwater.

6.1.2 Climate Data

Creation of a MUSIC catchment file requires an associated meteorological data file. The data used here is that for Green Cape 1974 to 1975 (inclusive) in 6 minute time steps. Data for this period were chosen because:

- Combined they have a an average close to the long term average (779 mm compared to 750 mm); and
- 1974 was a wet year.

Potential evapotranspiration (PET) data are derived from BOM monthly data for Genoa, Victoria, which is close by. Basic rainfall and PET statistics are in Table 4 and the time-series graph is in Figure 8.

Table 2 Rainfall and PET statistics for Green Cape, 1974 to 1975

Measure	Statistics						
	mean	median	maximum	minimum	10%ile	90%ile	mean annual (mm)
Rainfall (mm/6 minute steps)	0.009	0	4.9	0	0	0	779
Potential ET (mm/day)	3.061	2.67	5	1.29	1.33	4.68	1117

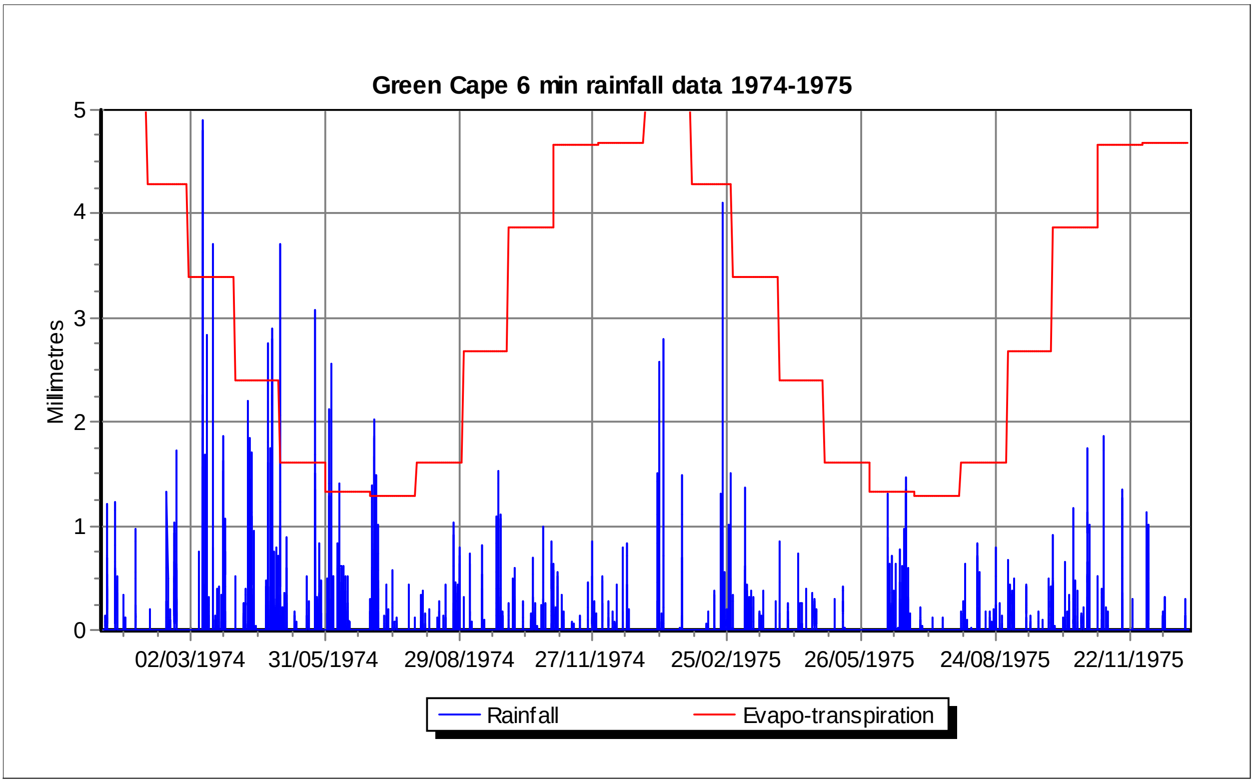

Figure 8 – Green Cape 6 min rainfall data 1974 - 1975

6.1.3 Modelling Assumptions

MUSIC is primarily designed for urbanised catchments but it can be adapted for use with rural developments such as here. Source nodes are set up in the model to represent different land uses. Each of these nodes is given a percentage of imperviousness, to represent paved surfaces/roofs etc. It is important to know that the nominated percentage of imperviousness is not simply the *actual* area of impervious surfaces but is an estimation of *effective* imperviousness. For instance, if stormwater from a road pavement, or a paved surface around a house, flows onto a broad area of low gradient, well-vegetated, land it is not directly connected to receiving waters.

Brisbane City Council, 2003 gives reduction factors to be applied to the *actual* areas of impervious surfaces for different land uses. They recommend that for rural residential land use the *effective* impervious area be taken as 55 percent of the actual impervious areas. We have adopted this recommendation here.

The MUSIC modelling is based on the following calculations and assumptions:

(i) Only areas being altered are considered in the modelling and, for each of those, an estimation of the degree of *effective* imperviousness is made. 9.96 ha of land will be changed and in summary:

- The ROW will be 1,000 m long, 4 m wide in a 20 m easement and with passing bays. Actual impervious area = 30 percent, effective impervious area = 16 percent.

- The driveways will be 4 m wide in a 16 m easement. There will be about 700 m of them. Actual impervious area = 25 percent, effective impervious area = 14 percent
- The Proposed Fire Trail is about 1,000 m long, 4 m wide in a 16 m easement. Actual impervious area = 25 percent, effective impervious area = 14 percent
- All pavements are modelled using an urban node, calibrated for either a sealed surface (ROW, driveways) or an unsealed surface (fire trail). Calibration details are in Appendix 2.
- All pavements will be crowned where possible and will drain to well formed, vegetated, table drains as described in Section 5.2. These are assumed to have an infiltration rate of 10 mm per day (clayey sand subsoil).
- The houses will maintain appropriate buffers to watercourses and/or to Lake Wonboyn. However, infiltration contour banks are proposed to trap runoff from the 'urbanised' area. Each house site is modelled as follows:
  - a 300 m^2 roof modelled with a non-default "Roof" source node, calibrated as in Appendix 2 and draining to a 50,000 L rainwater tank that drains to the infiltration contour bank;
  - reuse from that tank is assumed to be 800 L/day;
  - 6,700 m^2 of other "urbanised" areas (equivalent to the inner protection zone). Assumed other impervious areas of 400 m^2. Actual impervious area = 6 percent, effective impervious area = 3 percent. Modelled with a MUSIC default "Urban" source node and draining to the infiltration contour bank;
  - the infiltration contour bank is modelled with a swale node, 100 m long, gradient of 3 percent and with a percolation rate of 10 mm/hour (clayey sand subsoil).

(ii) Pre-development, all the lands that will change (9.96 ha) are modelled with single MUSIC default Forest source node.

(iii) Section 5 of this report includes an extensive set of recommendations for good road and lot-access design to minimise the risk of stormwater pollution entering watercourses. These measures are designed to disconnect runoff from the roads from the concentrated flow stream and are therefore integral to the assumptions made in this modelling.

(iv) The pervious area infiltration, storage and runoff characteristics for all source nodes are calibrated according to the properties of the Merrica Soil

Landscape (Appendix 2). They reflect their permeable (especially near-surface) nature of the soil and their moderate to shallow depth.

6.2 Results of Modelling

6.2.1 Mean Annual Loads

Two scenarios were modelled:

(i) Pre development (i.e. existing) conditions; and

(ii) Post development (i.e. proposed) conditions including the water quality management measures from Section 5.

Table 3 contains the results of the modelling. The modelling suggests a very clear benefit to water quality if the proposed measures are adopted. However, these results need qualification.

The measures proposed are (mostly) infiltration techniques (table drains, infiltration banks and even roof water that eventually is returned to base flow via the Ecomaxs). MUSIC removes any infiltrated water from the model, hence the high reduction in mean annual flow shown in Table 3. However, in reality, infiltrated water will either become base flow, will be lost to groundwater or will be evapotranspired by the forest.

Looking at the results simplistically 2.9 ML per year of water that would have runoff the site is now is infiltrated into the soils. If a (extremely) conservative assumption is made that it all becomes base flow (i.e. none drains to groundwater or is used by evapotranspiration) then this base flow will ultimately enter Wonboyn Lake from woodland areas and will have a quality represented by the base flow parameters given in a MUSIC default Forest source node, i.e:

- Suspended Solids at 8 mg/L
- Phosphorous at 0.0316 mg/L; and
- Nitrogen at 0.724 mg/L.

These concentrations may be added back into the model (after multiplying by 2.9 ML) to give the adjusted mean annual loads given in Table 3.

Even after doing this (and, remember, this has conservatively ignored percolation to groundwater or loss to evapotranspiration) a neutral or beneficial effect (NorBE) is still achieved

Table 3 Results of MUSIC modelling during average rainfall years

	Flow (ML/yr)	TSS (kg/yr)	TP (kg/yr)	TN (kg/yr)
Pre Development (A)	3.23	77.5	0.14	2.61
Post Development - with treatment measures (B)	0.33	4.67	0.04	0.49
Post Development including treatment measures, base flow added back in (C)	-	46.3	0.14	0.69
Change Pre to Post Development (A vs C) %	**-**	**-67**	**0**	**-74**

6.2.2 *Water Quality Targets - Pollution Concentrations*

DCP 36 (which applies to nearby lands draining to Wonbeyan Lake) gives initial targets for pollutant concentrations as follows:

- TP: 0.3 mg/L (50th percentile); and
- TN: 1.0 mg/L (50th percentile)

MUSIC produces data for pollutant concentrations as cumulative frequency graphs. The results from MUSIC are shown in Figures 8 and 9. They show that pollutant concentrations will be lower than these targets.

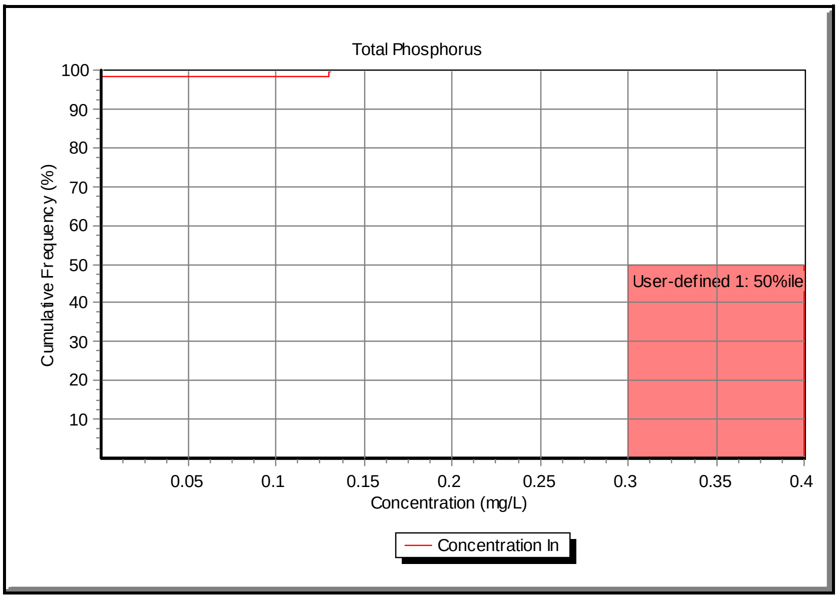

Figure 9 – Cumulative frequency graph for phosphorous (surface water)

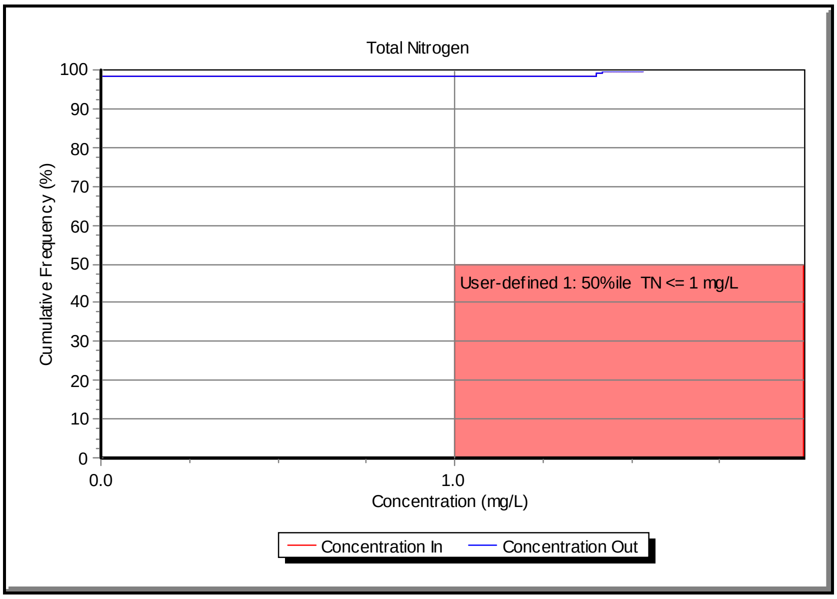

Figure 10 – Cumulative frequency graph for nitrogen (surface water)

6.3 Conclusions

The results of the MUSIC modelling demonstrate that a beneficial effect can be achieved, providing that the proposed Water Cycle Management Plan (Section 5) is implemented.

Without these specific measures, the development could potentially have a negative impact on water quality in the local watercourses. This Plan includes a set of long-term maintenance strategies to ensure that the effectiveness of the proposed measures provides ongoing benefits for water quality.

Section 5 of this report details the measures required to achieve a neutral or beneficial effect. We recommend that this plan be implemented in full, as it provides an integrated management strategy for water quality control.

7 References

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DECC (2007). *Managing Urban Stormwater: Soils and Construction. Volume 2d - Main Road Construction* (Draft).

Fletcher, T., Duncan, H., Poelsma, P., Lloyd, S. (2004). *Stormwater Flow and Quality, and the Effectiveness of Non-Proprietary Stormwater Treatment Measures - A Review and Gap Analysis*. Technical Report 04/8 Monash University and the Cooperative Research Centre for Catchment Hydrology.

Landcom (2004). *Managing Urban Stormwater: Soils and Construction.* 4th Edition. NSW Government.

Tulau, M.J. (2005). *Soil landscapes of the Eden-Green cape 1:100 000 Sheet* DLWC

Wong, T.H.F. (Ed.) (2005). *Australian Runoff Quality.* Sydney, Australia: Institute of Engineers, Australia.

8 Appendices

8.1 Specific Site Descriptions [3]

Lot number represented:	Lot 1	**GPS reference:**	0759610	5874920
Slope position:	Gentle side slope		**Slope:**	**8 %**
Run-on, flooding:	low, none			
Exposure/aspect:	Moderate, east			
Erosion:	none			
Ground cover:	native bush			
Proximity to watercourses etc:	Wonboyn Lake approx 75 m to east			
Rock outcrop:	none			

Soil profile:	**Depth**	**Colour, texture, pedality, mottles, fragments**
Layer 1	0 - 250	Grey sandy loam to clay loam, massive
Layer 2	250 - 800	Orange brown sandy light clay, strongly pedal

Photo, comments

3 Note that these specific site locations represented the originally proposed house sites. Bush fire issues have since changed the lot layout and so, in the case of Lots 1,2 and 3 these sites are not now the actual sites. However, the landscape is consistent enough for these descriptions to be representative.

Lot number represented:	Lots 1 and 2	**GPS reference:**	0759611	5874973
Slope position:	mid slope		**Slope:**	**8 %**
Run-on/ flooding:	low/none			
Exposure/aspect:	Moderate, east			
Erosion:	none			
Ground cover:	native vegetation			
Proximity to watercourses etc:	Wonboyn Lake about 75 - 100 m east			
Rock outcrop:	none			

Soil profile:	**Depth**	**Colour, texture, pedality, mottles, fragments**
Layer 1	0 - 250	Grey sandy loam to clay loam, massive
Layer 2	250 - 800	Orange brown sandy light clay, strongly pedal
Layer 3		

Photo, comments

Lot number represented:	Lot 2	**GPS reference:**	0759558	5875009
Slope position:	Gentle side slope		**Slope:**	**7 %**
Run-on, flooding:	low, none			
Exposure/aspect:	Moderate, east			
Erosion:	none			
Ground cover:	native bush			
Proximity to watercourses etc:	Wonboyn Lake approx 75 -100 m to east			
Rock outcrop:	none			

Soil profile:	**Depth**	**Colour, texture, pedality, mottles, fragments**
Layer 1	0 - 400	Grey sandy loam to clay loam, massive
Layer 2	400 - 800	Orange brown sandy light clay, moderately pedal
Layer 3		

Photo, comments

Lot number represented:	Lots 3 and 4	**GPS reference:**	0759746	5875235
Slope position:	Gentle side slope		**Slope:**	**5-6 %**
Run-on, flooding:	low, none			
Exposure/aspect:	Moderate to poor (dense vegetation), south			
Erosion:	none			
Ground cover:	native bush			
Proximity to watercourses etc:	Wonboyn Lake >100 m to south east			
Rock outcrop:	none			
Soil profile:	**Depth**	**Colour, texture, pedality, mottles, fragments**		
Layer 1	0 - 250	Grey sandy loam to clay loam, massive		
Layer 2	250 - 400	Yellow sandy loam, massive		
Layer 3	400 - 600+	Yellow sandy clay loam, moderately pedal		

Photo, comments

Lot number:	Lot 5	**GPS reference:**	0759803	5875623
Slope position:	Mid to lower side slope		**Slope:**	**20 %**
Run-on, flooding:	moderate to high, none			
Exposure/aspect:	Moderate to poor, east			
Erosion:	none			
Ground cover:	native bush			
Proximity to watercourses etc:	Wonboyn Lake approx 75 m to east. Propose that EMA be on higher lands near to entrance.			
Rock outcrop:	none			

Soil profile:	**Depth**	**Colour, texture, pedality, mottles, fragments**
Layer 1	0 - 250	Grey sandy loam to clay loam, massive
Layer 2	250 - 800	Orange brown sandy light clay, strongly pedal
Layer 3		

Photo, comments

EMA will be on higher lands where less steep.

<table>
<tr><td>Lot number:</td><td>Lot 6</td><td>GPS reference:</td><td>0759760</td><td>5875683</td></tr>
<tr><td>Slope position:</td><td colspan="2">Mid to lower side slope</td><td>Slope:</td><td>15 %</td></tr>
<tr><td>Run-on, flooding:</td><td colspan="4">high, none</td></tr>
<tr><td>Exposure/aspect:</td><td colspan="4">poor, east</td></tr>
<tr><td>Erosion:</td><td colspan="4">none</td></tr>
<tr><td>Ground cover:</td><td colspan="4">native bush</td></tr>
<tr><td>Proximity to watercourses etc:</td><td colspan="4">Wonboyn Lake approx 75 m to east. Propose that EMA be on higher lands, near to entrance.</td></tr>
<tr><td>Rock outcrop:</td><td colspan="4">none</td></tr>
<tr><td>Soil profile:</td><td>Depth</td><td colspan="3">Colour, texture, pedality, mottles, fragments</td></tr>
<tr><td>Layer 1</td><td></td><td colspan="3"></td></tr>
<tr><td>Layer 2</td><td></td><td colspan="3"></td></tr>
<tr><td>Layer 3</td><td></td><td colspan="3"></td></tr>
<tr><td colspan="5">Photo, comments
EMA will be on higher lands where less steep.</td></tr>
</table>

Lot number:	Lot 7	**GPS reference:**	0759875	5875495
Slope position:	Gentle upper side slope		**Slope:**	**8 %**
Run-on, flooding:	low, none			
Exposure/aspect:	Moderate to poor, east			
Erosion:	none			
Ground cover:	native bush			
Proximity to watercourses etc:	Wonboyn Lake approx 100 m to east			
Rock outcrop:	none			
Soil profile:	**Depth**	**Colour, texture, pedality, mottles, fragments**		
Layer 1	0 - 300	Grey sandy loam, massive		
Layer 2	300 - 700	yellow brown sandy clay loam, moderately pedal		
Layer 3	700 -800+	yellow brown sandy light clay		

Photo, comments

8.2 Appendix 2: Universal MUSIC Calibration

Table 4 presents the universal calibrations used for calibrating the event mean concentrations (EMCs) of various surfaces and land uses. These are derived from Wong (2005) and Fletcher *et al.* (2004).

Table 4 Stormflow concentration calibrations used in MUSIC at this site

	TSS mean (log mean)	TSS std dev (log std dev)	TP mean (log mean)	TP std dev (log std dev)	TN mean (log mean)	TN std dev (log std dev)
Rural road (sealed)	69 (1.893)	1.935 (0.660)	0.23 (-0.638)	1.185 (0.170)	2.1 (0.322)	1.972 (0.295)
Rural road (unsealed)	800 (2.9)	1.935 (0.660)	0.23 (-0.638)	1.185 (0.170)	2.1 (0.322)	1.972 (0.295)
Roof	36 (1.556)	2.4 (0.380)	0.13 (-0.886)	1.941 (0.288)	2.0 (0.301)	1.778 (0.250)

The pervious area characteristics for each node are calibrated based on soil, infiltration and groundwater conditions for the Merrica Soil Landscape with data derived from Charman and Murphy (2000). Calibration for each is as shown in Table 5.

Table 5 Pervious area calibrations used in MUSIC

Soil storage capacity	250 mm
Initial storage	30%
Field capacity	200 mm
Infiltration capacity coefficient	225 mm/hr
Infiltration capacity exponent	1
Groundwater initial depth	30 mm
Daily recharge rate	50%
Daily baseflow rate	5%
Daily deep seepage rate	10%

Note that all treatment nodes use default MUSIC parameters, as changing these criteria is not recommended in the absence of alternative measurements. Assumptions used in the modelling are in Section 6 of this report.

8.3 Appendix 3 - Ecomax sizing

Ecomax Water Balance Calculation

Parameters: Green Cape 70th percentile rainfall and Genow Evaporation

Household Data:

Number of Persons	7	[6 for standard house, otherwise justify value]
Daily Flow per Person (L)	115	[From AS/NZS1547:2000 Appendix 4.2D]
Average Daily Flow	805	[Number of Persons x Daily Flow per Person]

Planting and Soil Data:

Planting Selection:	Grass	[As selected by Client/Designer]
Surface Runoff Coefficient[ROC]	0.3	[Variable and Site dependent on locality, suggest 0.2[conservatively] to 0.4]
DLR - Soakage [mm/day]	10	[Determined by SSE/permeability testing and AS/NZS1547:2000 Appendix 4.2A]

Ecomax Unit data [single cell only]

Evapotranspiration Area

Perimeter Evapotranspiration Area - Single Cell [m^2]	46.4	[Area to perim. subsurface soakage sand,from Ecomax Unit selection]
Internal Evapotranspiration Area - Single Cell [m^2]	32.3	[Amended Soil Area - Single Cell only]
Total Evapotranspiration Area - Single Cell [m^2]	78.7	[Perimeter Evapotranspiration Area + Internal Evapotranspiration Area

Soakage Area and Storage Volume:

Total Sandbase Soakage Area [m^2]:	111	[Total subsurface sand area available for soakage]
Sandbase Depth [m]:	0.25	[From Ecomax unit selection]
Void Ratio:	0.3	[From Ecomax]
Void Storage Volume [L]:	8325	[Volume available for storage = Sand base area x Depth x Void Ratio]

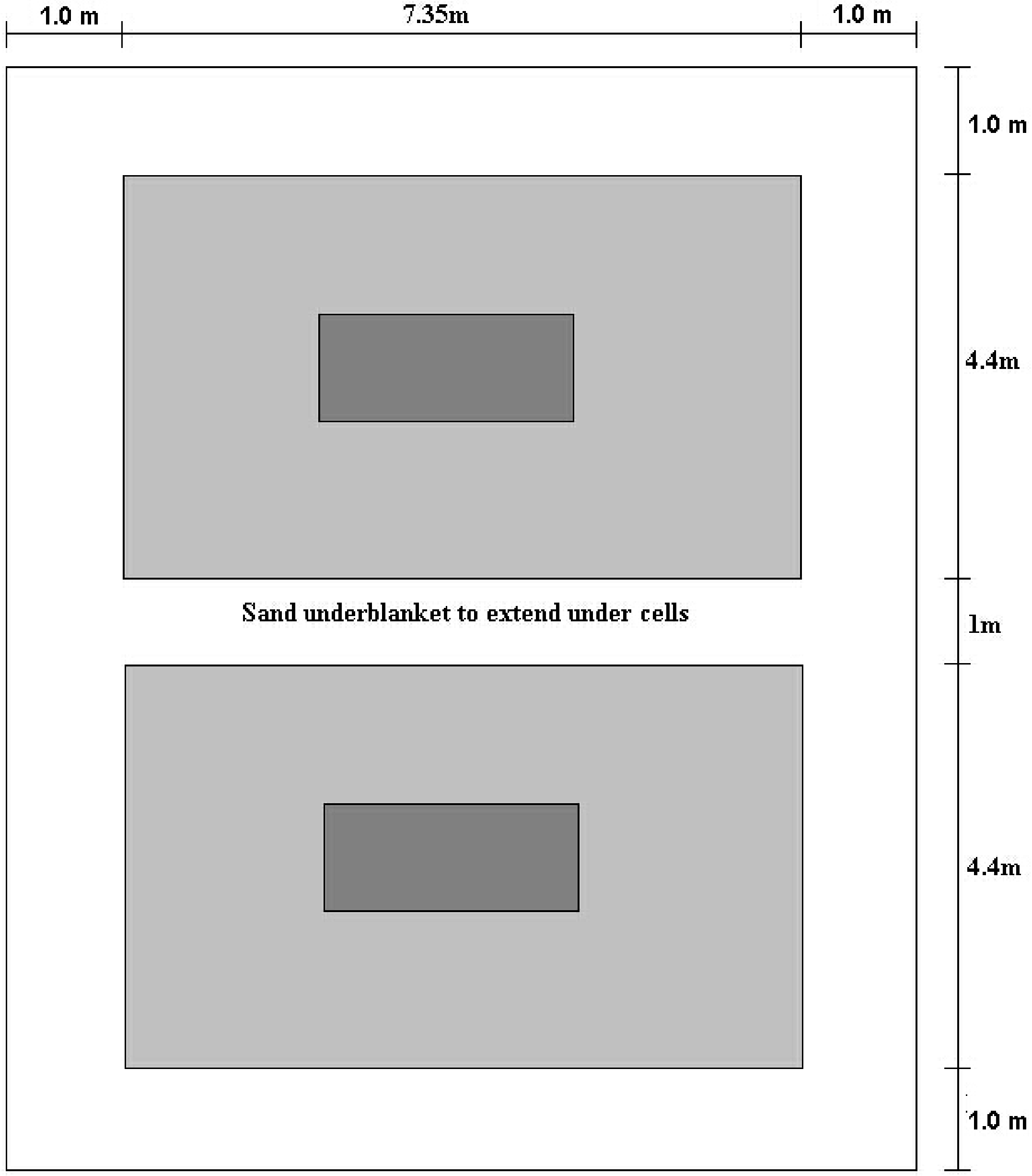
Climatic and Planting Data:

			Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
70th %ile Monthly Rainfall:	[mm]	[From Bureau of Meteorology]	71.2	76.5	74.6	81	68.9	87.1	77	78	69.7	75.7	57.1	69.7	
Average Monthly Evaporation:	[mm]	[From Bureau of Meteorology]	120	140	145	155	120	105	72	50	40	40	50	80	
Planting Selection Crop Factor:		[From Irrigation data Sheets of Dept of primary Industries]	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.7	0.6	0.6	0.6	0.7	

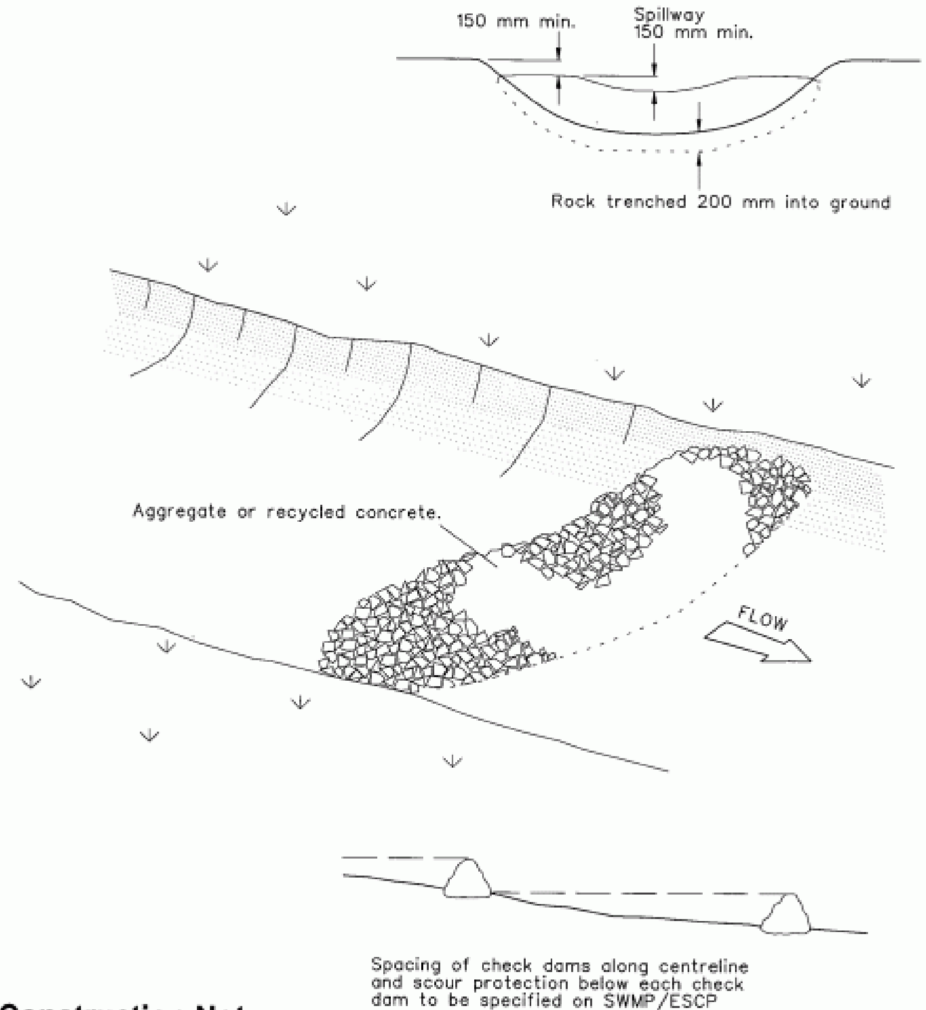
Water Balance:

			Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
System Inflow:															
Household Inflow:	[L]	ADF x days	24955	24150	24955	24955	23345	24955	24150	24955	24150	24955	24955	24150	294630
70th %ile Monthly Rainfall:	[mm]		71	77	75	81	69	87	77	78	70	76	57	70	887
Retained rainfall:	[mm]	rainfall x [1-ROC]	50	54	52	57	48	61	54	55	49	53	40	49	621
Retained Rainfall:	[L]	Retained rainfall [mm] x Total Evapotranspiration Area	3922	4214	4110	4462	3796	4798	4242	4297	3840	4170	3146	3840	48837
Total Inflow:	[L]	Household Inflow + Retained Rainfall	28877	28364	29065	29417	27141	29753	28392	29252	27990	29125	28101	27990	343467
Perimeter Surface Evapotranspiration Loss of Rainfall and Effluent:															
Crop Take-up:	[mm]	Evaporation x Crop factor - Retained rainfall [>O]	46	58	64	67	48	23	4	0	0	0	0	7	317
Perimeter Surface Evapotranspiration Loss of Rainfall and Effluent:	[L]	Crop Take-up[mm] x Perimeter Evapotranspiration Area	2142	2712	2959	3123	2217	1069	172	0	0	0	0	335	14727
Internal Surface Evapotranspiration Loss of Rainfall only:															
Maximum Monthly Crop Take-up:	[mm]	Evaporation x Crop Factor - Retained rainfall [>O]	46	58	64	67	48	23	4	0	0	0	0	7	317
Retained Monthly rainfall:	[mm]	Average rainfall x [1 - ROC]	50	54	52	57	48	61	54	55	49	53	40	49	621
Actual Monthly Crop Take-up:	[mm]	Minimum of Maximum Crop Take-up and Retained Rainfall	46	54	52	57	48	23	4	0	0	0	0	7	290
Internal Surface Evapotranspiration Loss of Rainfall only:	[L]	Actual Crop Take-up x Internal Area	1491	1730	1687	1831	1543	744	120	0	0	0	0	233	9378
Total Subsurface Sand Area Seepage Loss:															
Total Subsurface Sand Seepage Loss:	[L]	DLR[mm/day] x Total Subsurface Sand Area [m^2] x days	34410	33300	34410	34410	32190	34410	33300	34410	33300	34410	34410	33300	406260
Monthly Gain or Loss:															
Stored Volume in Void Area of Sand Base at Start of Month:	[L]	Equal to Stored Volume at end of Previous Month	0	0	0	0	0	0	0	0	0	0	0	0	
Nett Gain[+] or Loss[-]:	[L]	Total Inflow - Perim E/T Loss - Internal E/T Loss-Soakage	-9165	-9377	-9991	-9947	-8809	-6469	-5199	-5158	-5310	-5285	-6309	-5878	-86898
Void Storage Volume at End of Month:[≥ O, ≤ Max. Void Storage]	[L]	Stored Volume at Start of Month ± Nett Gain or Loss	0	0	0	0	0	0	0	0	0	0	0	0	
Overflow from System:[≥O]	[L]	Start Void Storage Volume ± Nett Gain or Loss - Max.Void Vol	0	0	0	0	0	0	0	0	0	0	0	0	0
Required Sizing for Overflow System:	[L]	Maximum Monthly Overflow from System													0

Proposed Layout of Ecomax



8.4 Appendix 4 Standard Drawings



Construction Notes

1. Check dams can be built with various materials, including rocks, logs, sandbags and straw bales. The maintenance program should ensure their integrity is retained, especially where constructed with straw bales. In the case of bales, this might require their replacement each two to four months.

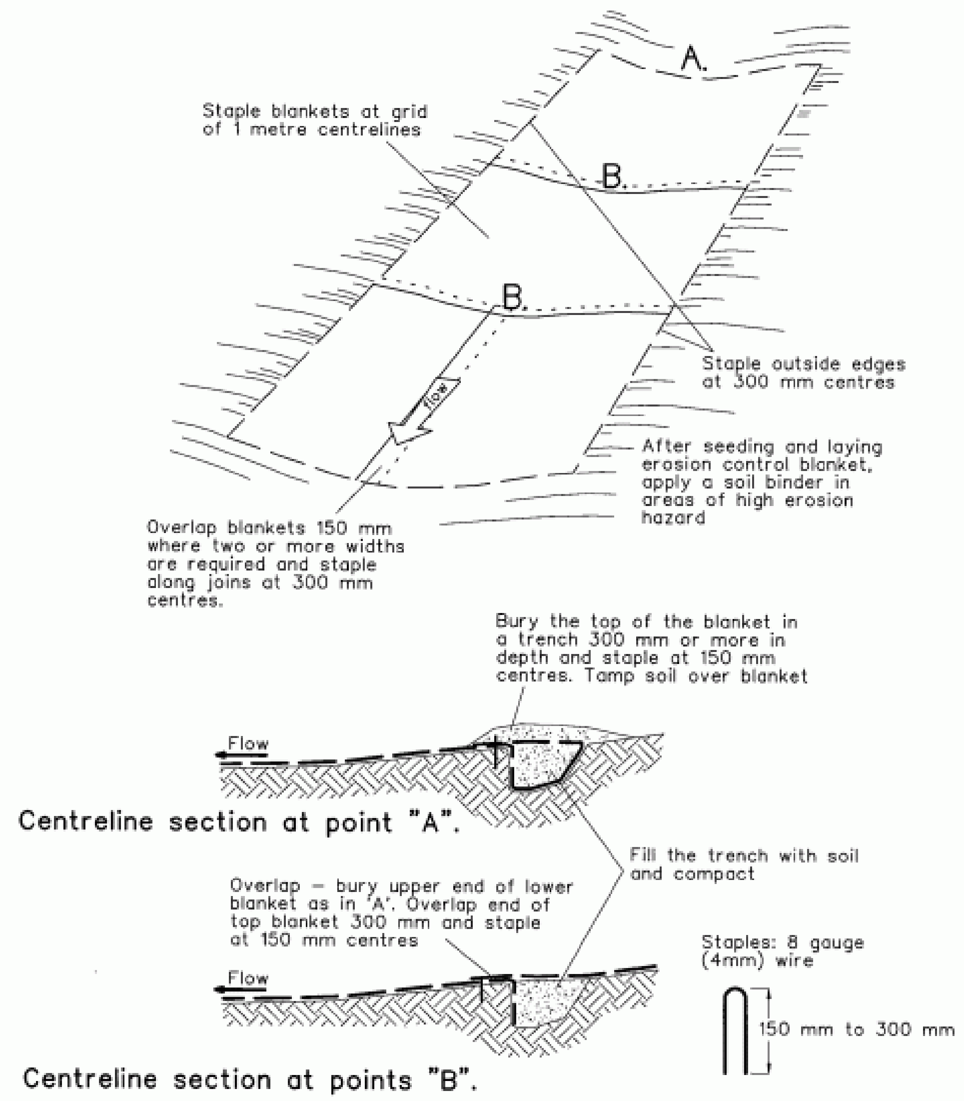
2. Trench the check dam 200 mm into the ground across its whole width. Where rock is used, fill the trenches to at least 100 mm above the ground surface to reduce the risk of undercutting.

3. Normally, their maximum height should not exceed 600 mm above the gully floor. The centre should act as a spillway, being at least 150 mm lower than the outer edges.

4. Space the dams so the toe of the upstream dam is level with the spillway of the next downstream dam.

ROCK CHECK DAM

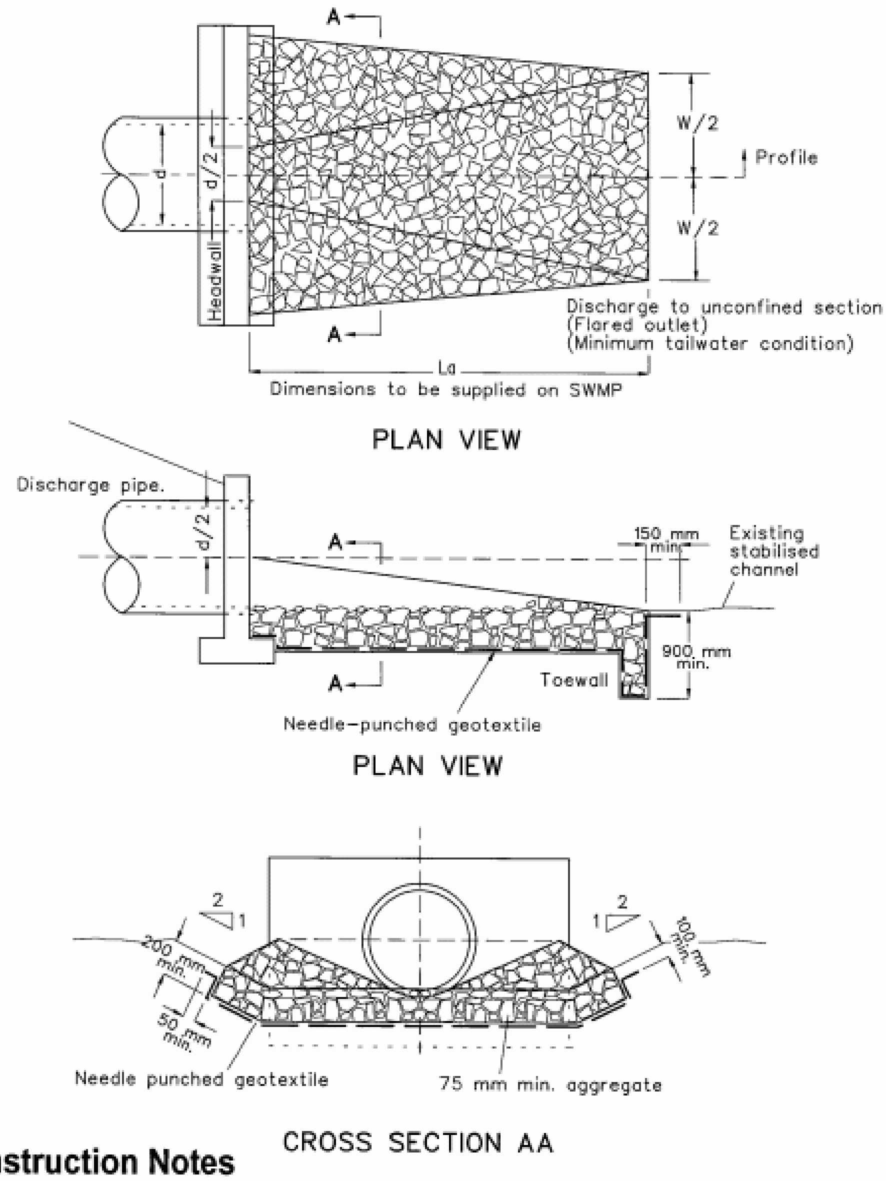
SD 5-4



Construction Notes

1. Remove any rocks, clods, sticks or grass from the surface before laying matting
2. Ensure that topsoil is at least 75 mm deep.
3. Complete fertilising and seeding before laying the matting.
4. Ensure fabric will be continuously in contact with the soil by grading the surface carefully first.
5. Lay the fabric in "shingle-fashion", with the end of each upstream roll overlapping those downstream. Ensure each roll is anchored properly at its upslope end (Standard Drawing 5-7b).
6. Ensure that the full width of flow in the channel is covered by the matting up to the design storm event, usually in the 10-year ARI time of concentration storm event.
7. Divert water from the structure until vegetation is stabilised properly.

RECP : CONCENTRATED FLOW **SD 5-7**



Construction Notes

1. Compact the subgrade fill to the density of the surrounding undisturbed material.
2. Prepare a smooth, even foundation for the structure that will ensure that the needle-punched geotextile does not sustain serious damage when covered with rock.
3. Should any minor damage to the geotextile occur, repair it before spreading any aggregate. For repairs, patch one piece of fabric over the damage, making sure that all joints and patches overlap more than 300 mm.
4. Lay rock following the drawing, according to Table 5.2 of Landcom (2004) and with a minimum diameter of 75 mm.
5. Ensure that any concrete or riprap used for the energy dissipater or the outlet protection conforms to the grading limits specified on the SWMP.

ENERGY DISSIPATER **SD 5-8**