Strategic Water Cycle Assessment: Falls Creek - Woollamia Deferred Areas Planning Proposal (Rezoning) - Proposed Rural Residential Subdivision

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Document Certification

This report has been developed based on agreed requirements as understood by SEEC 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.

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Document Table

Issue Number	By	Reviewed by	Date
15000126-WCMS-0A DRAFT	MP	NL	26th August 2015
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1 INTRODUCTION AND SCOPE OF WORK

SEEC have been commissioned by Shoalhaven City Council under Council reference 38279E (D15/166545) to prepare this Strategic Water Cycle Assessment to inform and assist preparation of a Planning Proposal (rezoning) for the Falls Creek/Woollamia Deferred Areas investigation area ("the subject land"). The Planning Proposal (PP) seeks to fulfil the requirements specified in the Jervis Bay Settlement Strategy 2003 (JBSS) for the Falls Creek/Woollamia Deferred Areas, specifically to determine if additional subdivision can be accommodated where appropriate.

The JBSS states that an absolute minimum lot size of 1 ha can be considered, subject to detailed investigation of a number of issues including cumulative impacts on water quality and hydrology, and onsite effluent management.

It should be noted that the Falls Creek/Woollamia Deferred areas identified in the JBSS comprised 353 lots but, as a result of constraints analysis and landowner consultation undertaken by Council, the area now under consideration is limited to 15 lots.

The Scope of Work is defined in the terms of engagement referenced 88279E (D15/166545):

(i) A before and after assessment of the cumulative changes to water quality and hydrology within the catchment.
(ii) Recommendations on whether the proposed subdivisions would achieve a neutral or beneficial effect on the water quality of Currambene Creek downstream of the investigation areas.
(iii) Soil sampling and mapping to assist any future onsite effluent disposal calculations.
(iv) Recommendations of suitable methods of treatment and management of household effluent.
(v) Identify what, if any, limitations should be placed on the developments to protect water quality for Jervis Bay receiving waters.
(vi) Recommendations of realistic measures regarding future resident/landowner responsibilities e.g. landscape area measures for future development controls.

2 SITE DESCRIPTIONS

2.1 Subject land and Investigation Areas

The Falls Creek-Woollamia Deferred Areas Planning Proposal (PP) **subject land** comprises 15 individual lots on Woollamia Road and Seasongood Road. All the lots are within Deposited Plan Number 15266. Within the subject land, potential subdivision would be limited to the **investigation area** identified through strategic environmental and land capability assessments undertaken thus far. The subject land and investigation areas are listed in **Table 1** and shown in **Figure 1** and **Figure 2** for Woollamia Road and Seasongood Road respectively.

Table 1 – List of Lots

Property Address	Lot Details	Total lot area (Subject land) (ha)	Investigation Area (ha)
111 Woollamia Rd	Lot 159A DP 15266	6.53	4.47
59 Woollamia Rd	Lot 157 DP 15266	6.19	2.10
53 Woollamia Rd	Lot 155A DP 15266	6.9	2.11
49 Woollamia Rd	Lot 155 DP 15266	7.18	1.83
	Sub Total 1	**26.8**	**10.51**
7 Seasongood Rd	Lot 118A DP 15266	3.95	3.69
5 Seasongood Rd	Lot 118 DP 15266	4.03	3.81
3 Seasongood Rd	Lot 119A DP 15266	4.09	3.51
1 Seasongood Rd	Lot 119 DP 15266	4.18	3.44
20 Seasongood Rd	Lot 123 DP 15266	3.29	2.79
18 Seasongood Rd	Lot 122A DP 15266	3.84	3.20
13 Seasongood Rd	Lot 115 DP 15266	4.61	1.49
23 Seasongood Rd	Lot 113A DP 15266	6.51	4.59
21 Seasongood Rd	Lot 113 DP 15266	6.35	4.29
11 Seasongood Rd	Lot 116A DP 15266	4.88	2.29
9 Seasongood Rd	Lot 116 DP 15266	5.29	2.78
	Sub Total 2	**51.02**	**35.88**
	Total area	**77.82**	**46.39**

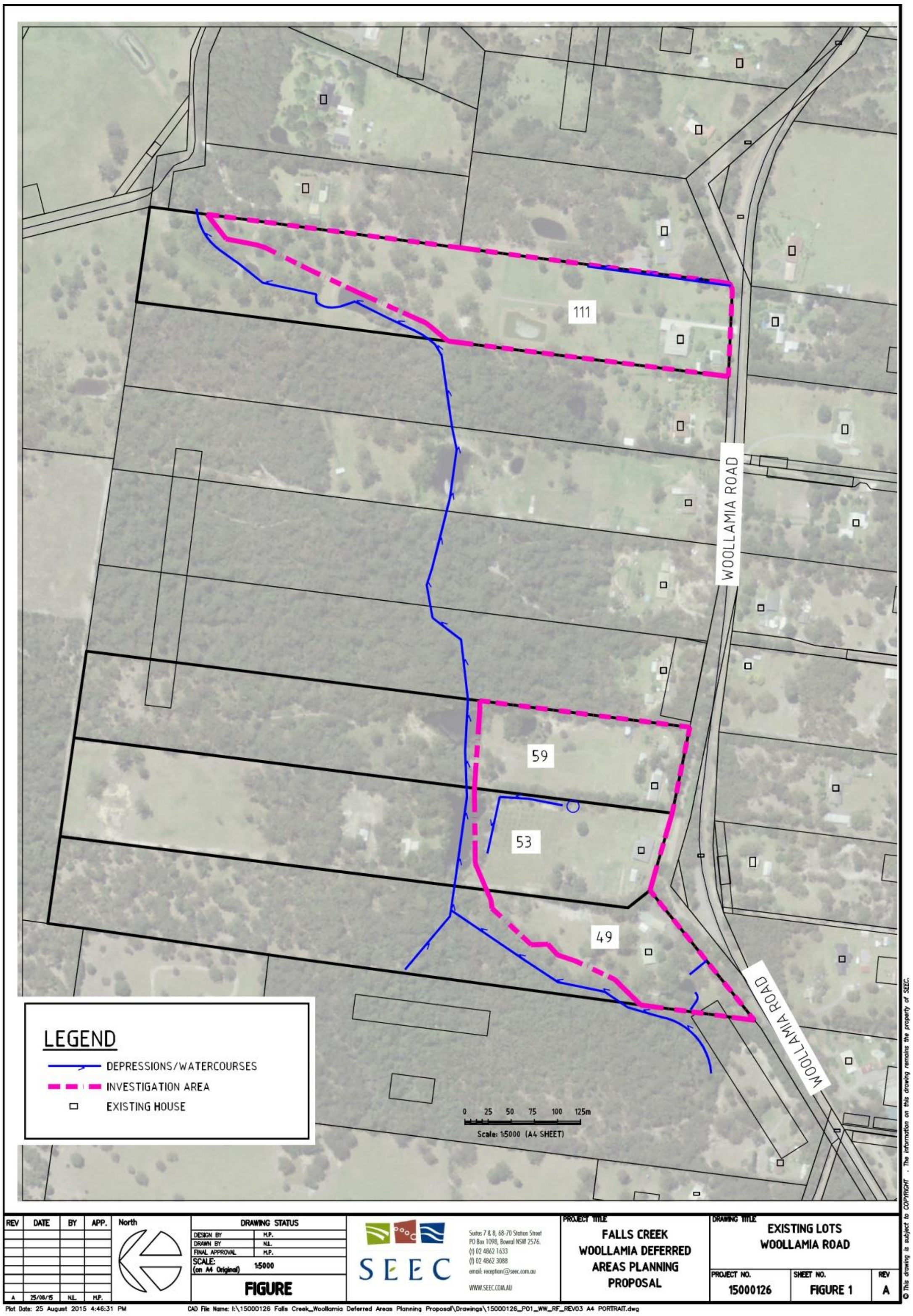


Figure 1 – Existing Lots, Woollamia Road

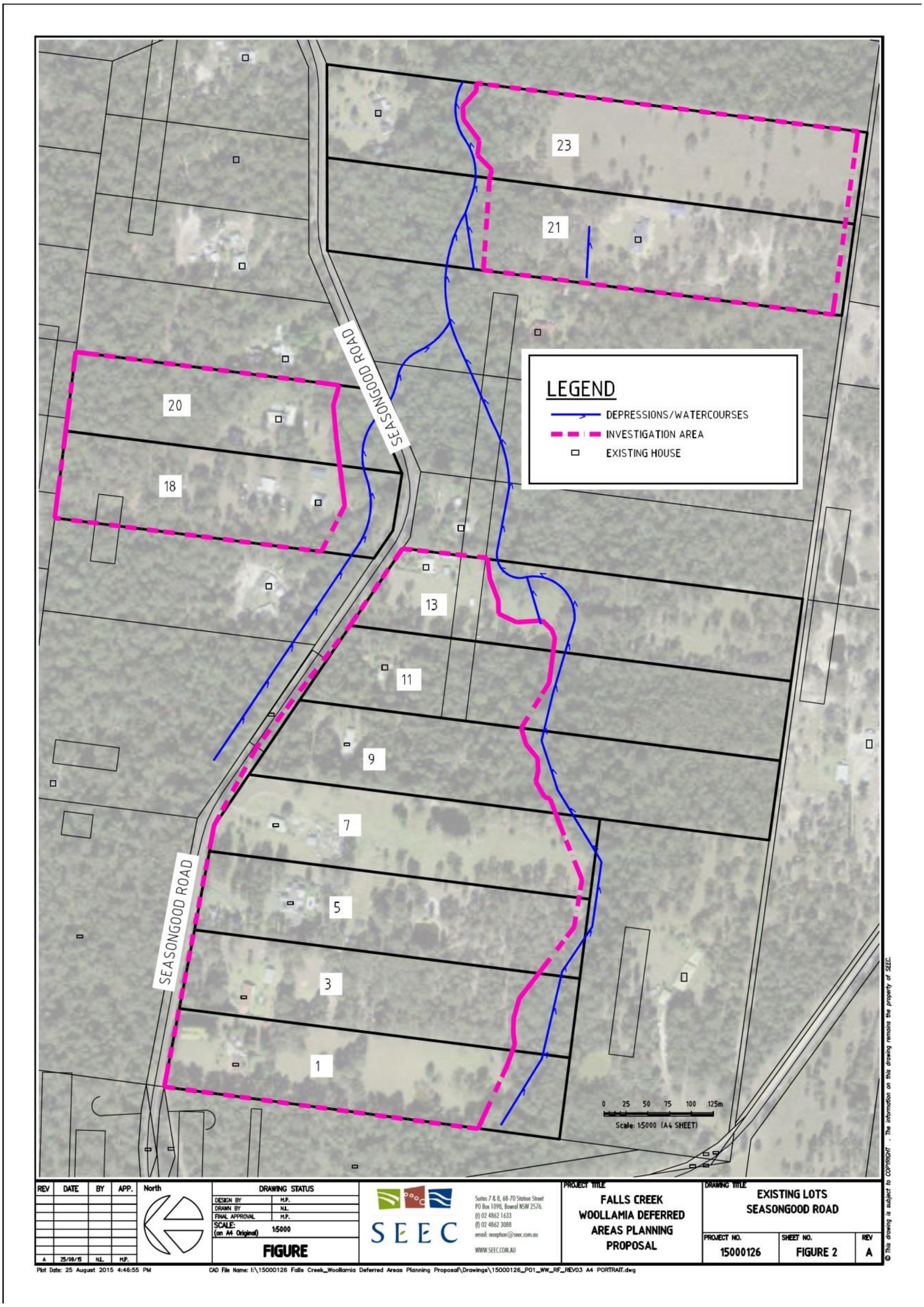


Figure 2 – Existing Lots, Seasongood Road

2.2 Catchment Description

2.2.1 Introduction

The subject land lies within two sub-catchments of Currambene Creek, which flows into Jervis Bay at Huskisson. The Currambene Creek catchment has a total area of 15,859 ha (158.59 km^2). The subject land totals 78 ha and so represents 0.49% of the total catchment.

Currambene Creek has a variable catchment comprising a mixture of forest, agricultural lands and rural residential lands. Agricultural lands west of the Princes Highway represent a significant portion of the catchment (about 16%). Currambene Creek drains to Jervis Bay Marine Park and a number of SEPP 14 wetlands are located along it downstream from the subject land. **Figure 3** shows the context of the Subject land.

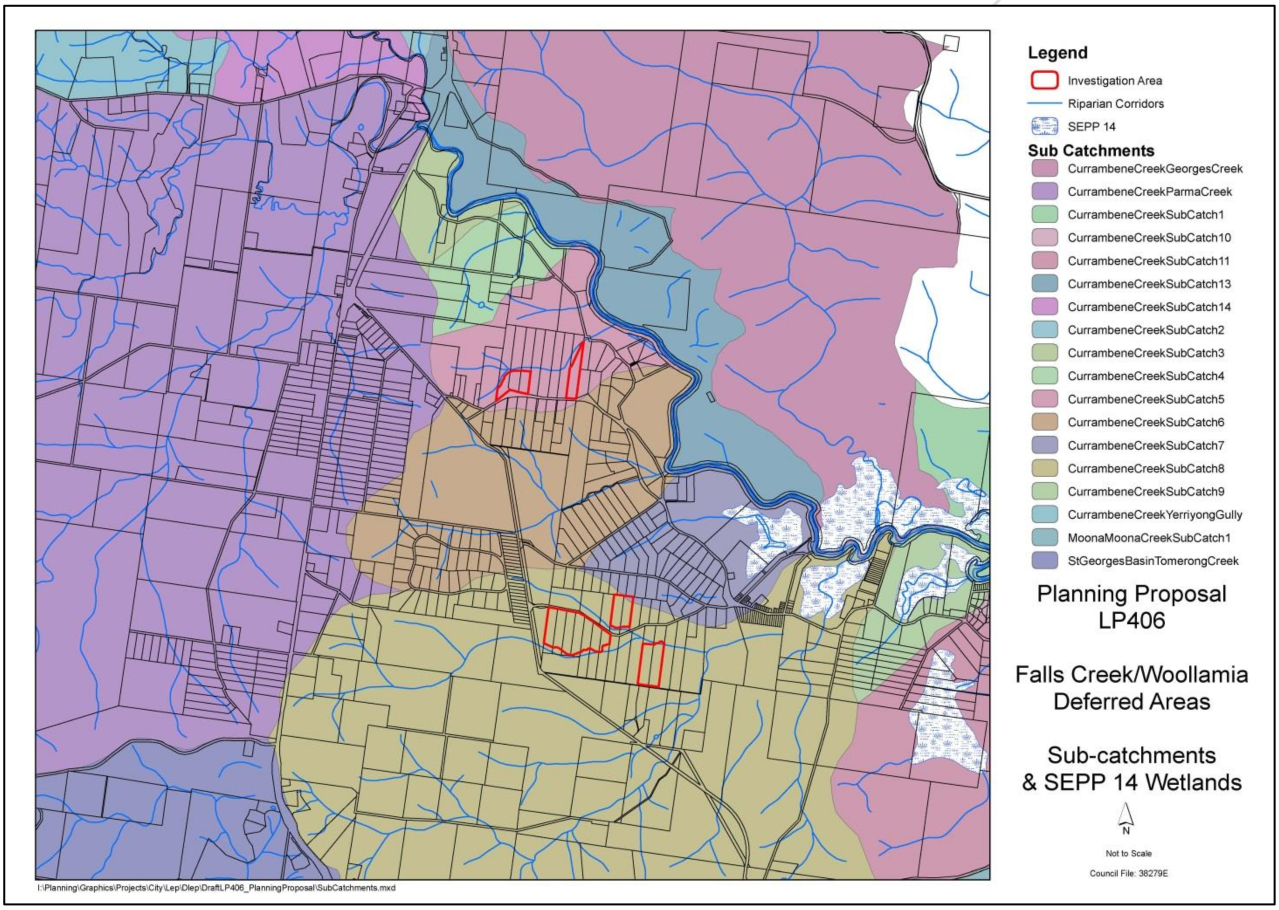


Figure 3 - The Context of the Subject land

2.2.2 Sub-catchment 1 - Woollamia Road

Four existing lots north of Woollamia Road (**Figure 1 and Figure 3**) are located within a sub-catchment of 210 ha. The total investigation area within this sub-catchment is 10.5 ha, 5% of the sub-catchment area identified in **Figure 3**. All four lots drain north towards an un-named second order[1] watercourse which drains east to SEPP 14 Wetland No. 331 and thence Currambene Creek. A first order watercourse also flows through the western part of number 49. The watercourses were inspected during the site investigation and the second order watercourse was flowing at that time. There are a number of farm dams located on the second order watercourse.

The investigation areas are mainly cleared lands and with and existing dwelling on each of the lots. All lots currently have a typical rural residential land use. Number 111 is used as a stud for small ponies and so has a slightly more "agricultural" land use. Slope gradients on these properties are typically 5 to 10% and total relief is typically less than 10 m.

2.2.3 Sub-catchment 2 - Seasongood Road

Eleven existing lots on Seasongood Road are within a sub-catchment of 2007 ha (**Figure 2** and **Figure 3**). The total investigation area within this sub-catchment is 35.9 ha, 2% of the sub-catchment area identified in **Figure 3**. Nine of the lots lie to the south of Seasongood Road, two lie to the north. At the time of investigation all the lots had a typical rural residential land use and some had a few sheep on them. These areas are cleared or partly-cleared lands and each lot has an existing dwelling.

The two lots north of Seasongood Road (numbers 18 and 20) drain south towards a first order watercourse which flows east approximately parallel to the road. The northern parts of numbers 1, 3, 5, 7, 9, 11 and 13 drain north towards the same watercourse, although it is on the other side of Seasongood Road. The central and southern parts of these lots drain south towards an un-named third order watercourse. The same watercourse flows east through the northern parts of numbers 21 and 23 (**Figure 2**). Small farm dams are located on numbers 1, 5, 7 and 23, although they are not online to the watercourse. Minimal impervious surfaces such as roofs, roads, paving are directly connected to receiving waters. Slope gradients on these properties are typically 5 to 10% and total relief is typically less than 10 m.

2.3 Climate

The area has a warm temperate climate with variable rainfall distribution that is generally summer-dominated. The closet Bureau of Meteorology (BOM) weather station is Station 68072, Nowra RAN Air Station; it is about 10 km to the northwest. Since the station opened in 2000 mean annual rainfall has been 904.9 mm and median annual rainfall has been 890 mm. Pan evaporation is relatively high, approximately 1,671 mm/year. Prior data from Station 68076, also at Nowra RAN Air Station (1945–2000), gives mean and median annual rainfall of 1,112 mm and 1,135 mm respectively.

[1] On the Strahler Classification System

2.4 Soils

2.4.1 Mapping

The Woollamia Road properties are contained on Hazelton P.A (1992) which is the Kiama 1:100,000 soil landscape map produced by the Soil Conservation Service of NSW. They are shown to lie on the Nowra Soil Landscape which is a depositional soil landscape derived on the Nowra Sandstone.

The soil landscape mapping does not extend to the Seasongood Road properties but the 1:500,000 Geology Map shows they lie on the same geology i.e. the Nowra Sandstone and so are likely to have the same soil landscape. The 1:500,000 geology map also shows areas of Quaternary Sediments along the main watercourses.

The Nowra Soil Landscape typical comprises of a duplex soil horizon with sandy topsoil overlying weakly structured sandy light to medium clay subsoil. It is a consistent soil landscape having little variation over large areas.

2.4.2 Fieldwork

SEEC staff inspected the sites on 30th June 2015. Weather on that day was cool and dry but followed recent rainfall (**Figure 4**).

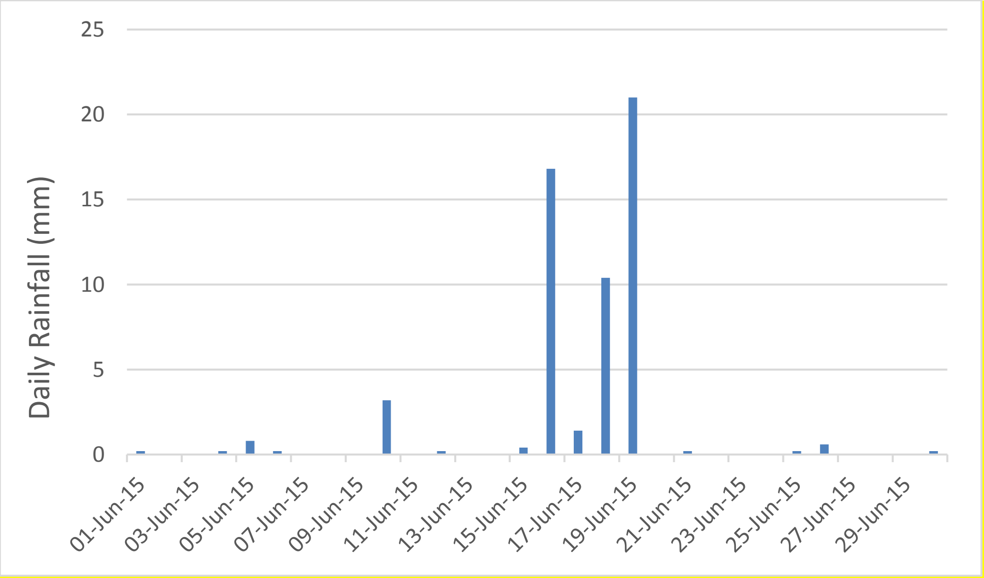


Figure 4 - Daily rainfall totals for June 2015 at Nowra (Station 69072)

A site specific soil investigation was undertaken by SEEC using a petrol-driven corer which is able to sample soils to about 1,200 mm. A series of ten soil bores were taken where shown in **Figures 5 and 6.**

The individual logs are given in **Appendix 1** and the following typical soil profile is indicative of all locations except 13 Seasongood Road (BH7) which had a profile of alluvial clayey sand.

Table 2 – Typical Soil Profile at all locations except 13 Seasongood Road

Soil Layer Depth (mm)	Description
0 - 300	Dark brown weakly pedal sandy loam to sandy clay loam, bleached at base
300 - 1,000+	Variously coloured (brown, orange, red), massive, light to medium clay. Grey mottling common from 600-900 mm.

3 STRATEGIC ONSITE WASTEWATER ASSESSMENT

3.1 Introduction

Existing and future properties would not be connected to sewer and so wastewater generated in each home must be managed on each lot. Each subdivision application would need to be supported by a site-specific onsite effluent management assessment prepared in accordance with Chapter G8 (Onsite Sewage Management) in Shoalhaven Development Control Plan 2014. However, for the purpose of this report, a preliminary investigation of the Subject lands' capability for onsite effluent management has been done.

3.2 Site and Soil Analysis

3.2.1 Soils

Samples of topsoil and subsoil were sent to NSW Department of Lands' Scone Research Laboratory and tested for a suite of effluent-disposal related tests. Six tests were done in all; three on composited samples of topsoil and three on composited samples of subsoil. The samples tested, and the results are given in **Table 3**.

Table 3 - Soil Laboratory Test Results

Lab No	Method	C1A/5	C2A/4	C2B/4	C5A/4 CEC & exchangeable cations (cmol (+)/kg)					C8B/1	P9B/2	
	Sample Id	EC (dS/m)	pH	pH ($CaCl_2$)	CEC	Na	K	Ca	Mg	P sorp (mg/kg)	EAT	Texture
1	15000126 Core1 5cm & 15000126 Core4 5cm	0.04	5.8	4.8	6.8	0.3	0.3	3.2	2.0	280	8	Sandy loam
2	15000126 Core1 35-50cm & 15000126 Core4 35-50cm	0.04	5.3	4.3	13.8	0.4	0.3	1.0	4.4	890	6	Silty clay
3	15000126 Core5 5cm & 15000126 Core6 5cm	0.01	5.4	4.2	6.5	0.3	0.3	2.1	2.0	370	8	Sandy clay loam
4	15000126 Core5 45-60cm & 15000126 Core6 45-60cm	0.02	5.6	4.2	12.4	0.6	0.3	0.5	4.9	760	5	Light clay
5	15000126 Core9 5cm & 15000126 Core10 5cm	0.01	6.1	4.7	8.4	0.4	0.7	3.5	3.1	310	8	Clay loam sandy
6	15000126 Core9 40-50cm & 15000126 Core10 40-50cm	0.05	5.2	4.0	14.6	0.7	0.4	0.3	4.1	720	3(1)	Medium clay

In summary, the boreholes and soil testing showed the soils within the investigation area:

- Are consistently more than 1,000 mm deep (*Minor Limitation*) [2];
- Are duplex soils with sandy loam overlying light to medium clay;
- Are strongly to moderately acidic (*Moderate Limitation*);
- Are not saline (*Minor Limitation*);
- Are non-sodic (*Minor Limitation*);

[2] Limitations are those described in DLG (1998)

- Are not significantly dispersive *(Minor Limitation);*
- Have moderate potential (topsoil) and a high potential (subsoil) to sorb phosphorous *(Moderate to Minor Limitation);*
- Have a low Cation Exchange Capacity (topsoil) to moderate Cation Exchange Capacity (subsoil) *(Moderate Limitation)*.
- Are moderately drained on crests and higher side slopes but less well drained on lower slopes where grey mottling occurs in the clay subsoil (*Minor to Moderate Limitation*);
- Are not suited to disposal of primary treated effluent in an absorption system because of their low permeability.

3.2.2 Physical Site Constraints

Buffers

All lots within the subject land are affected by watercourses and some are affected by the presence of farm dams. All watercourses are intermittent in nature (identified on the appropriate 1:25,000 topographic map and by anecdotal evidence) and so would require a 40 m overland-flow buffer from any effluent management area. The same buffer applies to depressions and farm dams. However, a discussion with some of the owners suggests dams might be drained and filled with locally-derived soil if necessary to gain the maximum lot yield.

The following on-lot setbacks apply to onsite effluent land application (Chapter G8 of Shoalhaven DCP, 2014).

All land application systems

- 100 metres to permanent surface waters (e.g. river, streams, lakes, etc.)
- 100 metres to domestic ground water bores
- 40 metres to other waters (e.g. farm dams, intermittent waterways and drainage channels, etc.)

Surface spray irrigation (tertiary treated effluent) (Irrigation systems to conform to AS 1547)

- 6 metres if area up-gradient and 3 metres if area down-gradient of driveways and property boundaries.
- 15 metres to dwellings
- 3 metres to paths and walkways
- 6 metres to swimming pools and buildings

Surface drip and trickle irrigation (tertiary treated effluent with disinfection or higher)

6 metres if area up-gradient and 3 metres if area down-gradient of swimming pools, property boundaries, driveways and buildings, including dwellings.

Sub-surface irrigation (secondary treated effluent or higher)

6 metres if area up-gradient and 3 metres if area down-gradient of swimming pools, property boundaries, driveways and buildings, including dwellings.

Absorption system (primary treated effluent or higher)

- 12 metres if area up-gradient and 6 metres if area down-gradient of property boundary
- 6 metres if area up-gradient and 3 metres if area down-gradient of swimming pools, driveways and buildings, including dwellings.

Drainage and Flooding

Lands that are poorly drained or which receive run-on e.g. from road pavements should be avoided for land application or should be remediated. An example of that is found on 111 Woollamia Road (**Figure 5**).

All wastewater treatment systems and application areas must be located above the 1 in 20 year flood level. Treatment systems with electrical components must be located above the 1 in 100 year flood level; however, only a very small part of the investigation area is below the 1 in 100 year flood level based on recent mapping provided by Council (**Figures 5 and 6**).

3.3 Recommended Treatment and Land Application Methods

3.3.1 Overview

At a minimum secondary treatment should be adopted. The use of surface spray-irrigation is not preferred due to the risk of runoff in wet weather, particularly on slopes greater than 6%. However, provided household wastewater is treated to a secondary standard, and it is applied to correctly designed and maintained subsoil irrigation systems or evapotranspiration/ absorption beds, the risk of pollution runoff is considered low. These disposal systems do not require separate wet-weather management and so are much easier to manage. Based on economics, subsurface irrigation is the most likely disposal system that would be adopted on new lots.

3.3.2 *Existing Systems*

Many of the existing onsite effluent management systems comprise a septic tank and absorption trench(es), which is not ideal given the soil characteristics. If it is determined during a subdivision application that an existing system is failing (i.e. effluent is coming to the surface) it should be upgraded according to the recommendations in this report.

3.3.3 *Irrigation Area Sizing*

Nutrient Balance

Effluent contains nutrients in the form of nitrogen (N) and phosphorous (P). These nutrients are used by the vegetation in the effluent management area and, in the case of phosphorous, also adsorbed by the soil. **Section 2.4.2** details the typical soil profile found across most investigation areas and **Section 3.2.1** gives the soils' chemical properties. Assuming a five-bedroom home was built on each lot and it produced 1,050 L/day of wastewater, and assuming effluent was disposed in an area consisting of poorly managed[3] lawns, to balance the input and uptake of nutrients an effluent management area of 970 m^2 based on the N balance, would be required (**Table 4**).

Hydraulic Balance

Chapter G8 (Onsite Sewage Management) in Shoalhaven DCP 2014 requires a monthly water balance to be done to reduce the risk of runoff/system failure. The hydraulic inputs are:

- Retained median rainfall (i.e. median rainfall less an allowance for run-off) and
- The applied effluent load (assumed at 1,050 L/d).

Hydraulic outputs are:

- Evapotranspiration (taken as pan evaporation multiplied by a crop factor which varies through the year) and
- Percolation into the soil.

Median rainfall and pan evaporation values are taken from Nowra RAN Air Station as presented in Chapter G8 and crop factors vary from 0.8 in summer to 0.6 in winter. The percolation rate is assumed to be the same as the hydraulic design loading rate (DIR) for a light clay (10 mm/d) (AS/NZS1547:2012). The hydraulic balance is given in **Table 5** and shows, only 105 m^2 of area is required, although council require an equally-sized reserve area so the total would be 310 m^2. However, this is less than that required for nutrient assimilation and so 970 m^2 would be adopted.

[3] i.e. slashed lawns with clippings remaining

Table 4- Nutrient Balances

Nutrient Balances

Wastewater Volume 1050 (L/day)

NOTE: The area required to uptake nutrients varies on what vegetation is adopted in the EMA.

Vegetation in EMA **Lawn - Unmanaged**

Nitrogen Balances
A = (C x Q) / Lx
Where:
A = Land Area (m2)

C = Concentration of Nutrient =	30	mg/L
Q = Wastewater Flow =	1050	L/day
Lx = Critical Loading Rate =	32.5	(mg/m^2/day)

A = 969 m^2 of subsurface irrigation under Lawn - Unmanaged

Phosphorus Balances
Step 1: P Sorption Calculation

Psorb (topsoil)	clay loam	320	mg/kg	
Psorb (subsoil)	clay	790	mg/kg	
Bulk Density (topsoil)	clay loam	1500	kg/m3	from SCA (2012)
Thickness (topsoil)		200	mm	
Coarse Frags (topsoil)		5	%	
Bulk Density (subsoil)	clay	1300	kg/m3	from SCA (2012)
Thickness (subsoil)		800	mm	
Coarse Frags (subsoil)		5	%	
Calculated Psorb (topsoil)		912	kg/ha	
Calculated Psorb (subsoil)		7805	kg/ha	
Assumed P-sorb		3051	kg/ha	(insitu P-sorb is 35% calculated P-sorb)

Step 2: Determine the required area to sorb phorphorus (50 year design life) :

P absorbed	=	8717	x 0.35
	=	3051	kg/ha
	=	0.31	kg/m2
P uptake	=	3.25	mg/m2/day

Determine the amount of phosphorus generated over that time:

Concentration of phosphorus =		12	mg/L
Phosphorus generated =	Concentration x volume of wastewater =	229.95	kg

Area Required:
P generated / (P sorbed + P uptake) = 631 m^2 of Lawn - Unmanaged

Reference: SCA (2012) Designing and Installing Onsite Wastewater Systems

Table 5 – Hydraulic Balance

Hydraulic Balance (DCP Chapter G8)

Rainfall Station	Nowra	
Evaporation Zone	Nowra	
Wastewater Load	1050	**L/day**
Percolation Rate	10	**mm/day**
Land Area	105	**m^2**
Storage Required	0	**m^3**

Month	Days in month	Median Precipitation (mm)	Evaporation (mm)	Crop Factor
Jan	31	72.9	194.4	0.8
Feb	28	70.9	161.1	0.8
Mar	31	76.6	144.6	0.8
Apr	30	51.6	118.7	0.7
May	31	72.2	95	0.7
Jun	30	62	85.8	0.6
Jul	31	40.4	94.7	0.6
Aug	31	36.4	127.6	0.7
Sep	30	47.7	148.1	0.7
Oct	31	68.8	194.4	0.8
Nov	30	64.4	161.1	0.8
Dec	31	69.8	144.6	0.8

INPUTS

	Retained Rainfall (mm)	Effluent Irrigation (mm)	Total Inputs (mm)
Jan	58.32	310.00	368.32
Feb	56.72	280.00	336.72
Mar	61.28	310.00	371.28
Apr	41.28	300.00	341.28
May	57.76	310.00	367.76
Jun	49.6	300.00	349.60
Jul	32.32	310.00	342.32
Aug	29.12	310.00	339.12
Sep	38.16	300.00	338.16
Oct	55.04	310.00	365.04
Nov	51.52	300.00	351.52
Dec	55.84	310.00	365.84

OUTPUTS

	Evapotranspiration (mm)	Percolation (mm)	Outputs (mm)	Storage (mm)
Jan	155.52	310.00	465.52	-97.20
Feb	128.88	280.00	408.88	-72.16
Mar	115.68	310.00	425.68	-54.40
Apr	83.09	300.00	383.09	-41.81
May	66.5	310.00	376.50	-8.74
Jun	51.48	300.00	351.48	-1.88
Jul	56.82	310.00	366.82	-24.50
Aug	89.32	310.00	399.32	-60.20
Sep	103.67	300.00	403.67	-65.51
Oct	155.52	310.00	465.52	-100.48
Nov	128.88	300.00	428.88	-77.36
Dec	115.68	310.00	425.68	-59.84

3.3.4 Evapotranspiration/Absorption Beds

If the slope gradient was less than 10%, and assuming favourable soil conditions, an alternative to irrigation method might be the use of evapotranspiration/absorption beds. The required area might be as low as 105 m^2 but a 970 m^2 disposal area should still be set aside for nutrient assimilation.

3.4 Pollutant Transport Potential

3.4.1 Nutrients

The nutrient balances are done to ensure that nutrients in treated wastewater are assimilated in each effluent management area (EMA). Therefore, provided each land application system is correctly sized, designed, installed and maintained, nutrients should not be exported into the downstream environment.

The soils and vegetation on each lot are shown to be sufficient to assimilate nutrients within the designated EMAs for a period of at least 50 years, which is the generally adopted design life for onsite wastewater management systems (DLG 1998). Only the top 1 m of soil profile is assumed in the calculations and so the nutrient balances ensure there will be minimal risk of groundwater contamination.

3.4.2 Pathogens

Because of the highly sensitive nature of the receiving waters it is critical that pathogens do not reach them. Once in the soil pathogens and viruses will be outside of their preferred environment and they will progressively die over a period of time. The potential distance travelled during that time is dependent on the quality of the effluent, the temperature in the ground, the soil's permeability and the hydraulic gradient.

Cromer *et al* (2001) describes a method of calculating the time and distance that pathogens and viruses can be expected to travel in soils.

Subsurface application of secondary treated effluent with disinfection would result in a faecal coliform count of no more than 10^2 cfu/100 ml. Therefore, to reach *no* residual coliforms an additional two log cycle reductions are required before the treated water reaches receiving waters. Therefore, in this case the calculation inputs are:

- Required additional log cycle reduction = 2 log cycles.
- Permeability (worst case) is 3 m/day [1].

1This represents a high value expected of sandy loam topsoil (AS/NZS1547:2012)

- Soil thicknesses = 0.3 m.
- Porosity of the soil is 25 percent (0.25).
- Hydraulic gradient is taken as the slope gradient (worst case = 10%).
- Ground temperature is taken as the mean annual temperature (17°C).

At a temperature of 17°C, the estimated time to achieve a two-log cycle reduction is 11 days. Over that time, the calculated sub-surface travel distance is 13 m which is less than the adopted 40 m.

3.5 Wastewater Conclusion

The risk of nutrients and pathogens in treated wastewater being exported from the subject land can be managed by:

- Ensuring household wastewater is treated to a secondary standard (with disinfection) or better;
- Applying the treated effluent to an appropriately designed, constructed and managed subsurface irrigation system;
- Managing surface stormwater so it does not flow into a disposal area;
- Ensuring the disposal areas are kept well vegetated.

If a failure occurred and effluent was released at the surface the adopted buffers from water features are designed to reduce the connectivity to receiving waters, allowing time for re-infiltration into the soils.

4 STRATEGIC STORMWATER ASSESSMENT

4.1 Introduction

The hydrology of land alters with changes in land surfaces; e.g. if forested land is cleared for residential purposes or if pervious land is sealed with road pavements, roofs, paving etc. However, the construction of an impervious surface does not necessarily mean an increase in surface runoff under all rainfall events.

If an impervious surface drains directly to a concentrated flow (e.g. to stormwater drain or a watercourse) the runoff from the impervious surface is unlikely to enter the soil profile and the surface is considered to be *effectively impervious*. However, if an impervious surface sheds water onto surrounding pervious land most runoff would still enter the soil profile and the surface would not be considered *effectively impervious.*

The *effective impervious area* (EIA) is an important parameter in stormwater modelling. To estimate potential change to the EIA, it is first necessary to estimate the potential lot yields in each investigation area.

4.2 Estimation of Potential Lot Yield

A range of factors limit the subdivision potential of individual lots including, but not limited to, the following:

- Planning for bushfire protection requirements, particularly in relation to provision of road and property access and bushfire Asset Protection Zones (APZs).
- Council setback requirements: front setbacks to buildings would generally be 30m, side setbacks would be 10m and rear setbacks would be 7.5m.
- Each lot must have safe access to the local roads. At this stage, no assessment has been made of the adequacy of sight distances along Woollamia or Seasongood Roads.
- Provision of appropriate riparian buffers along watercourses.
- Flood planning requirements in relation to buildings, access and effluent management areas.
- The location of existing buildings, driveways and farm dams.
- Existing lot configuration and owners' preferences.

This section provides a subdivision layout for the purpose of this report only, it is not intended to replace the need for site-specific investigations. Planning constraints such as

Planning for Bushfire Protection, traffic considerations, building setback requirements have not been assessed and the land's subdivision potential may be less than indicated below. Assuming each property is subdivided separately (i.e. not pooled and re-subdivided) the subdivision layout assumed for the purpose of this assessment is shown in **Figures 5 and 6.**

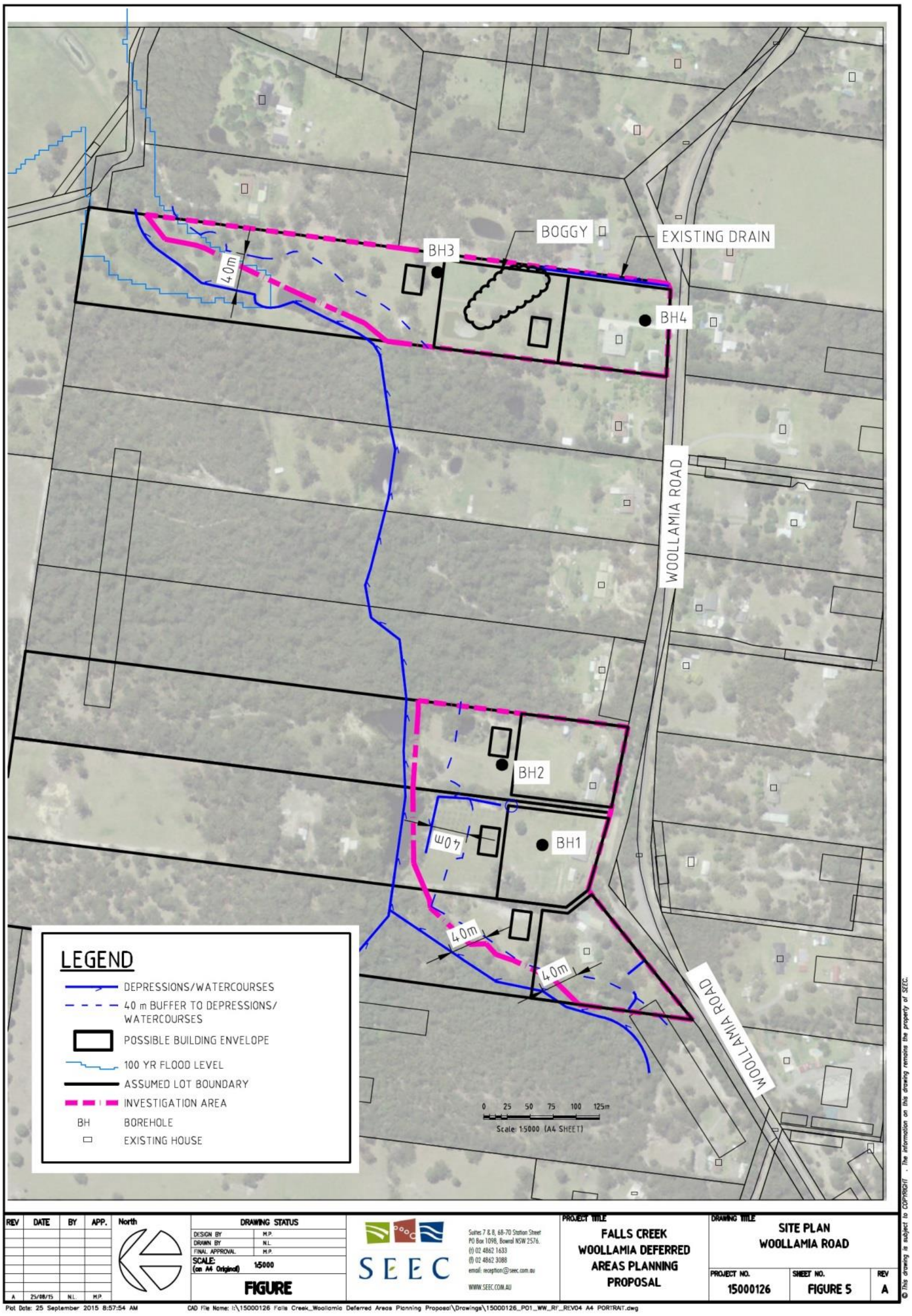


Figure 5 – Assumed subdivision layout, Woollamia Road

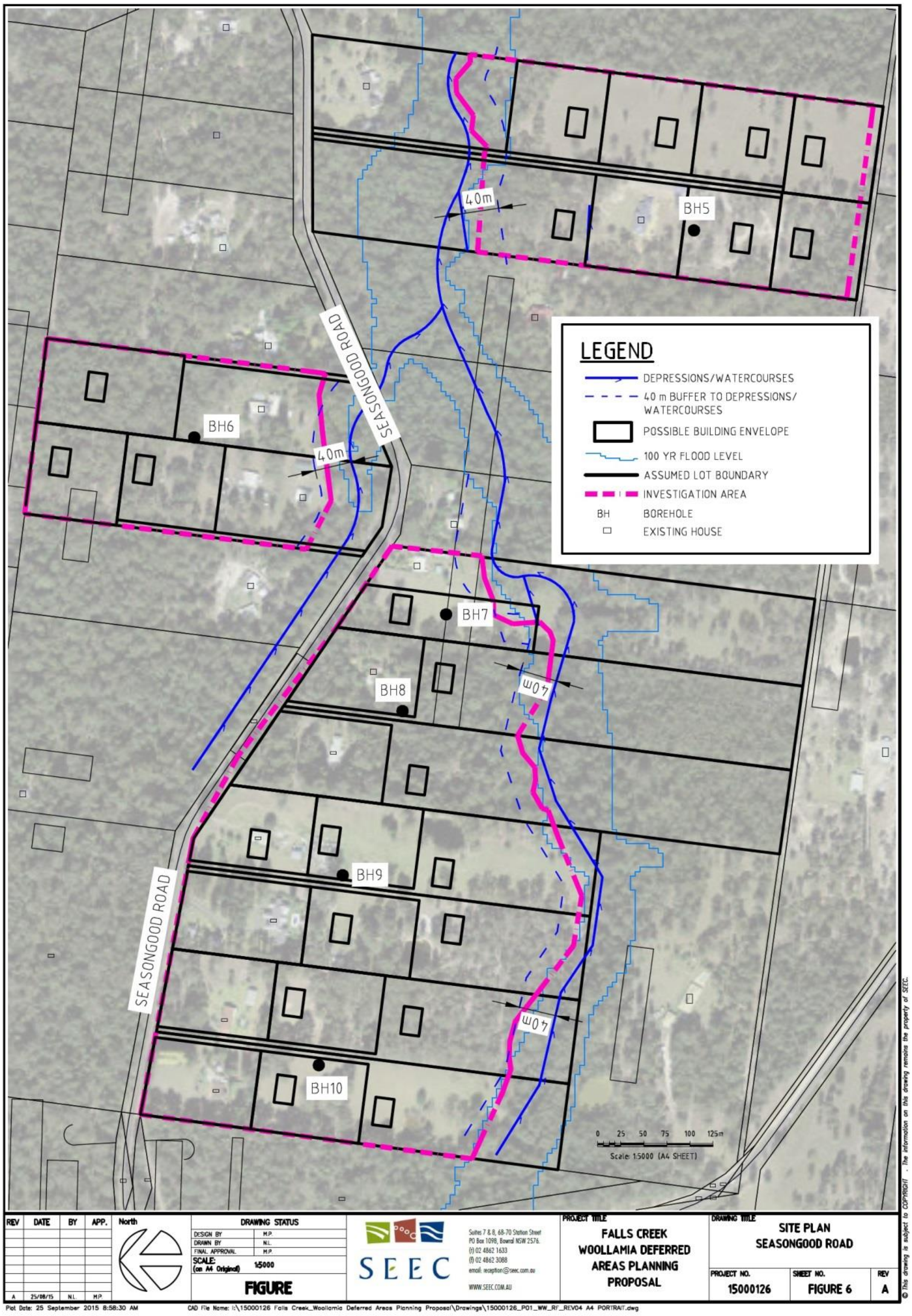


Figure 6 – Assumed Subdivision Layout Seasongood Road

4.3 Stormwater Modelling

4.3.1 Introduction

The estimated pre and post development sediment and pollutant loads were modelled using MUSIC (Model for Urban Stormwater Improvement Conceptualisation) Version 6, developed by eWater. MUSIC was developed primarily for the purpose of preparing conceptual stormwater management systems in an urban context. MUSIC is also the accepted model for undertaking Neutral or Beneficial Effect (NorBE) assessments for development within Sydney's drinking water catchments, including for the assessment of residential and rural-residential subdivisions.

MUSIC is used to quantify:

- Stormwater flow and volume before and after development;
- Concentration of principal pollutants in stormwater before and after development; and
- Total annual export of principal pollutants before and after development.

Statistics are produced in MUSIC for the following parameters:

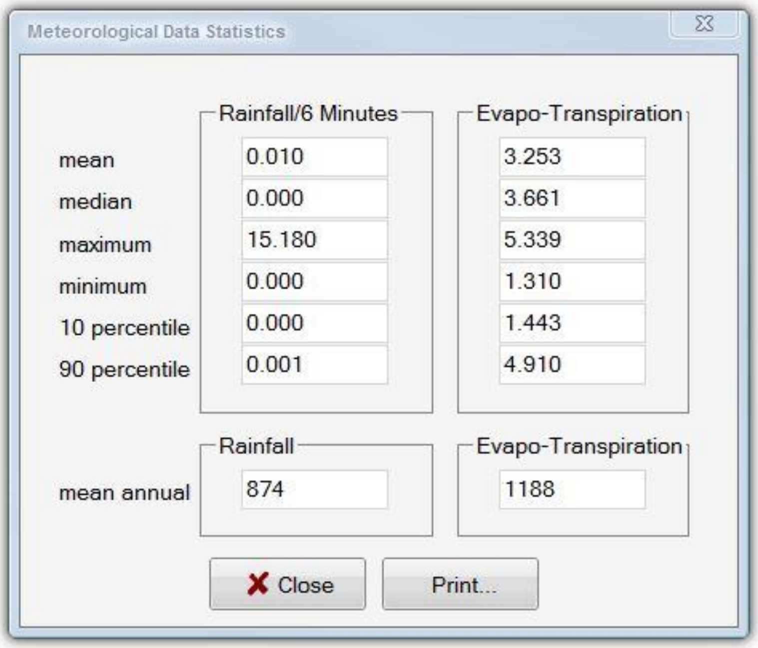
- Flow (ML/yr)
- Peak flow (m^3/s)
- TSS - Total Suspended Solids (kg/yr)
- TP - Total Phosphorus (kg/yr)
- TN - Total Nitrogen (kg/yr)
- Gross Pollutants (kg/yr)

The results provided in this section enable a broad comparison to be made of potential changes to the subject lands' stormwater quality and hydrology resulting from a change from essentially 'low density' rural-residential land use to a slightly higher density rural-residential land use. A simplified catchment setup has been used that treats the subject land as a single discrete catchment, rather than separately modelling each sub-catchment. This approach provides an estimation of the overall changes that might affect the larger catchment downstream. Model setup is described in the following sections and the input values are provided in **Table 7** and **Table 8**.

4.3.2 Climate Data

Creation of a MUSIC catchment file requires an associated meteorological data file. SMCMA (2010) recommends using data obtained from the Bureau of Meteorology's pluviograph rainfall station at Nowra for the period 1964 to 1970. That data has a mean annual rainfall value of 874 mm (**Table 6**) which is close to the subject sites'.

Table 6 - Rainfall and PET statistics


Meteorological Data Statistics

	Rainfall/6 Minutes	Evapo-Transpiration
mean	0.010	3.253
median	0.000	3.661
maximum	15.180	5.339
minimum	0.000	1.310
10 percentile	0.000	1.443
90 percentile	0.001	4.910

	Rainfall	Evapo-Transpiration
mean annual	874	1188

4.3.3 Node Properties

Table 8 presents the stormwater pollutant concentration properties used for the MUSIC model. They are derived from SMCMA (2010).

Table 7 - Stormwater pollutant concentration properties used in MUSIC

	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 residential (cleared) land	89 (1.95)	2.1 (0.32)	0.22 (-0.66)	1.8 (0.25)	2 (0.3)	1.55 (0.19)
Forest	39.8 (1.6)	1.58 (0.2)	0.08 (-1.1)	1.66 (0.22)	0.89 (-.05)	1.74 (0.24)

The pervious area properties for both pre and post development modelling are as in **Table 8.**

Table 8 - Pervious area properties used in MUSIC

Parameter	Value
Soil storage capacity	140
Initial storage	30
Field capacity	90
Infiltration capacity coefficient	180
Infiltration capacity exponent	3
Groundwater initial depth	30
Daily recharge rate	35
Daily base flow rate	25
Daily deep seepage rate	0

4.3.4 Catchment Hydrology Check

To check the model's hydrological calibration, the outflow from a 1 ha, 5% impervious node was checked against the Annual Runoff Fraction (**Figure 7**). The subject site's mean annual rainfall is 868 mm so the annual runoff fraction for 5% impervious should be about 0.23 which equals about 2 ML/ha/yr. The soil storage capacity and the soil field capacity were adjusted until this fraction was reached (+/- 10%); the model's value was 2.1 ML/ha/yr, which is acceptable.

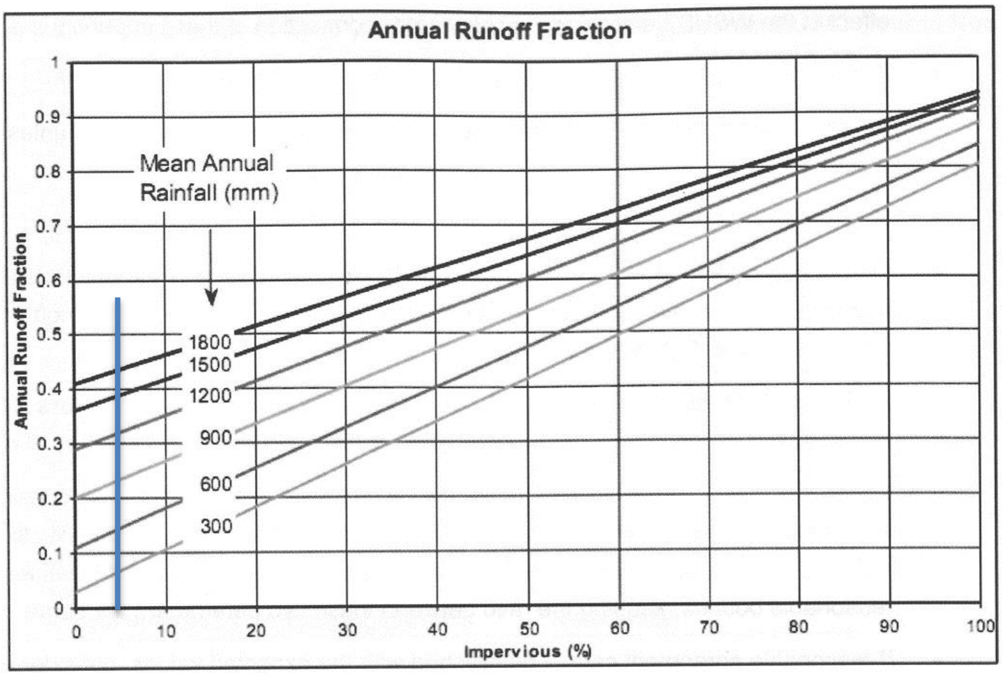


Figure 7 - Annual Runoff Fraction

4.3.5 Existing (pre-development) Land Uses

Using satellite imagery and the results of the site inspection an estimation of the different types of land uses and the effective impervious surfaces on each existing lot can be made. There are two primary land uses identified:

- Predominantly cleared land (rural residential); and
- Land still predominantly vegetated with native trees (forest)

The estimated areas of each are in **Table 9**, along with the estimated percentage of effectively impervious surfaces contained on the rural residential lands.

Table 9 - Existing (pre-development) Land Uses for the Subject land (approx. ha)

Property	Rural residential	Forested	Total	% Effective Imperviousness[4]
1 Seasongood Road	3.6	0.6	4.2	2
3 Seasongood Road	2.5	1.6	4.1	2
5 Seasongood Road	2.4	1.6	4	5
7 Seasongood Road	4	0	4	1
9 Seasongood Road	1	4.3	5.3	1
11 Seasongood Road	1.3	3.6	4.9	1
13 Seasongood Road	4.2	0.4	4.6	2
18 Seasongood Road	2.9	1	3.9	3
20 Seasongood Road	1.7	1.6	3.3	3
21 Seasongood Road	3.8	2.6	6.4	2
23 Seasongood Road	6	0.5	6.5	2
49 Woollamia Road	2.4	4.8	7.2	3
53 Woollamia Road	5.9	1	6.9	3
59 Woollamia Road	4.2	2	6.2	1
111 Woollamia Road	6.5	0	6.5	1
Totals	**52.4**	**25.6**	**78**	**Mean 2.13**

4.3.6 Post Development Land Uses

For the purpose of this assessment, it is assumed the investigation areas would be subdivided into lots of 1 ha or greater. In terms of changes to land use, some existing forested areas in the investigation areas would become rural residential. The land use outside of the investigation areas would remain unchanged. The overall land use composition for the subject land post-development is shown in **Table 10** together with an estimate of the new percentage of effective imperviousness.

[4] percentage of the rural residential component

Table 10 – Post-Development Land Uses for the Subject land (approx. ha)

Property	Rural residential	Forested	Total	% Effective Imperviousness
1 Seasongood Road	3.6	0.6	4.2	5
3 Seasongood Road	3.5	0.6	4.1	5
5 Seasongood Road	3.4	0.6	4	5
7 Seasongood Road	4	0	4	5
9 Seasongood Road	2	3.3	5.3	3
11 Seasongood Road	2.3	2.6	4.9	3
13 Seasongood Road	4.2	0.4	4.6	3
18 Seasongood Road	3.9	0	3.9	5
20 Seasongood Road	3.3	0	3.3	5
21 Seasongood Road	4.4	2	6.4	7
23 Seasongood Road	6	0.5	6.5	7
49 Woollamia Road	2.8	4.4	7.2	5
53 Woollamia Road	5.9	1	6.9	3
59 Woollamia Road	4.2	2	6.2	3
111 Woollamia Road	6.5	0	6.5	4
Totals	**59.23**	**18.05**	**78**	**Mean 4.53**

4.3.7 Model Set-Up

For the purpose of this assessment the subject land was grouped together and modelled with two source nodes:

- A forest node for lands that will remain significantly vegetated; and
- A rural residential node for lands that will become residential. Based on **Tables 9 and 10** this node is set to 2% and 5% effective impervious for pre and post development respectively.

The properties of each node are given in **Table 7** and the MUSIC model is shown diagrammatically in **Figure 8**. The model consists of two parts:

- The subject land pre subdivision; and
- The subject land post the assumed subdivision but with no water quality measures.

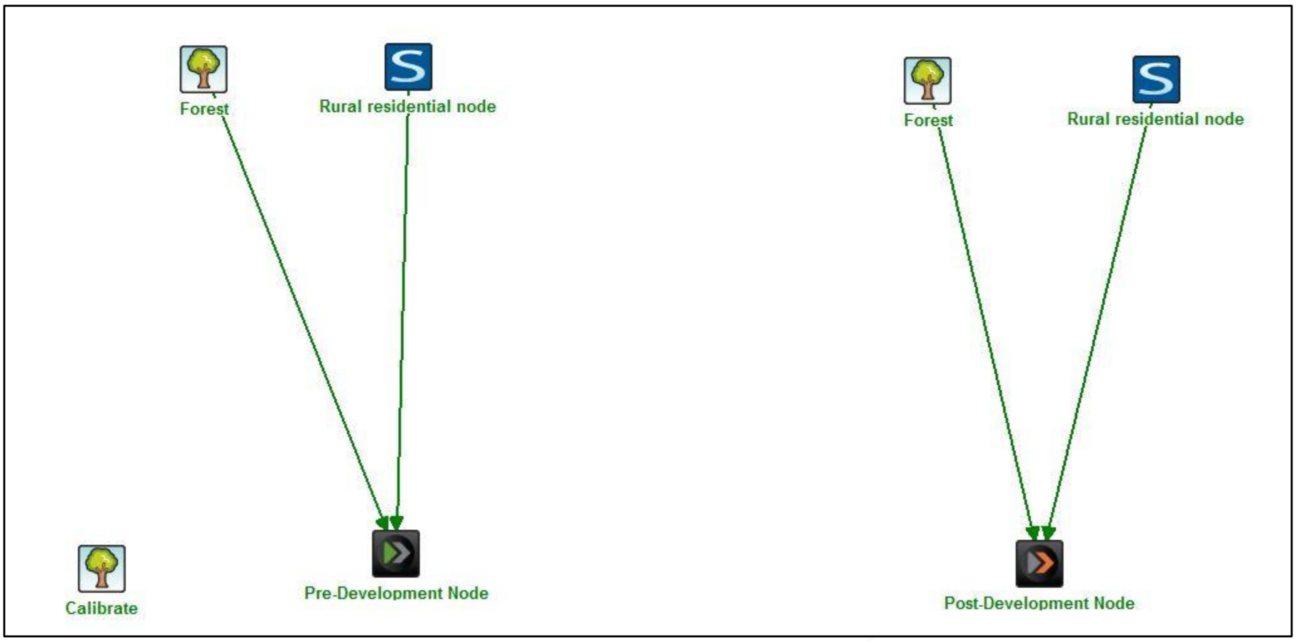


Figure 8 - MUSIC Model Schematic

4.3.8 Modelling Results

Total and Peak Flow and Mean Annual Loads Without Stormwater Treatment

Table 11 shows the pre and post development results for the modelled catchments. The results show that, without any water quality measures, the development of the subject land could increase total runoff by about 7% and that might have a corresponding increase of about 15-20% in export of sediment and nutrients. MUSIC predicts there would be almost no effect on peak flows; possibly because these are related to storm events (i.e. short high intensity rainfall events) rather than "rainfall" events (which are slower less intense rainfall events and which make up the majority of total rainfall volume).

Table 11 - MUSIC Results in Mean Annual Loads[5]

	Pre	Post (no measures)	Change %	Change (units)
Flow (ML/yr)	148	158	7	10
Peak Flow (m^3/s)	17.8	17.8	0	0
Total Suspended Solids (kg/yr)	9,000	10,800	19	1,800
Total Phosphorus (kg/yr)	21.2	25.4	20	4.2
Total Nitrogen (kg/yr)	207	238	15	31

[5] SEEC internal reference = 12000126 Run 1

Pollutant Concentrations

Figures 9 to 11 show the concentration graphs for suspended solids, total phosphorous and total nitrogen respectively. They show that, without any water quality measures, there should be effectively no change to concentrations of sediment but a very slight increase in the concentrations of phosphorous and nitrogen.

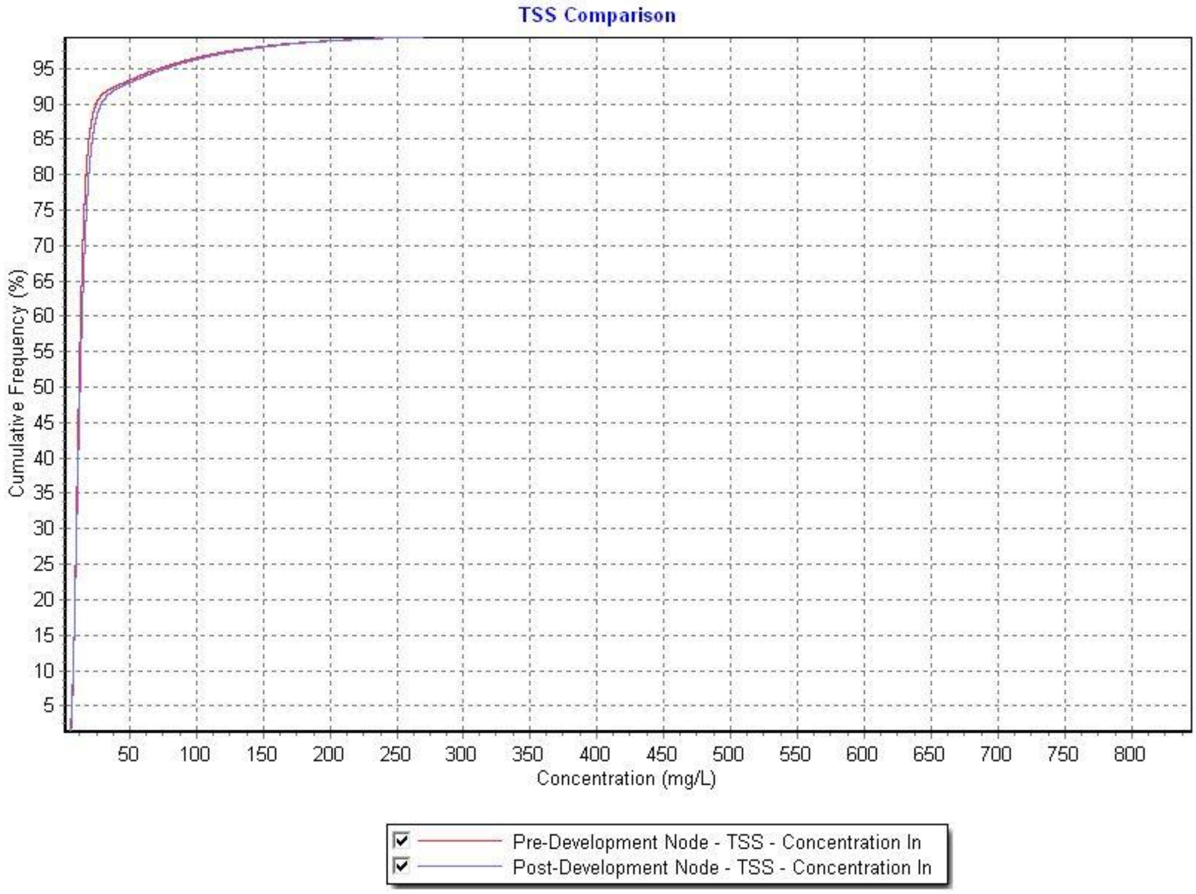


Figure 9 – Pre versus post for total suspended solids

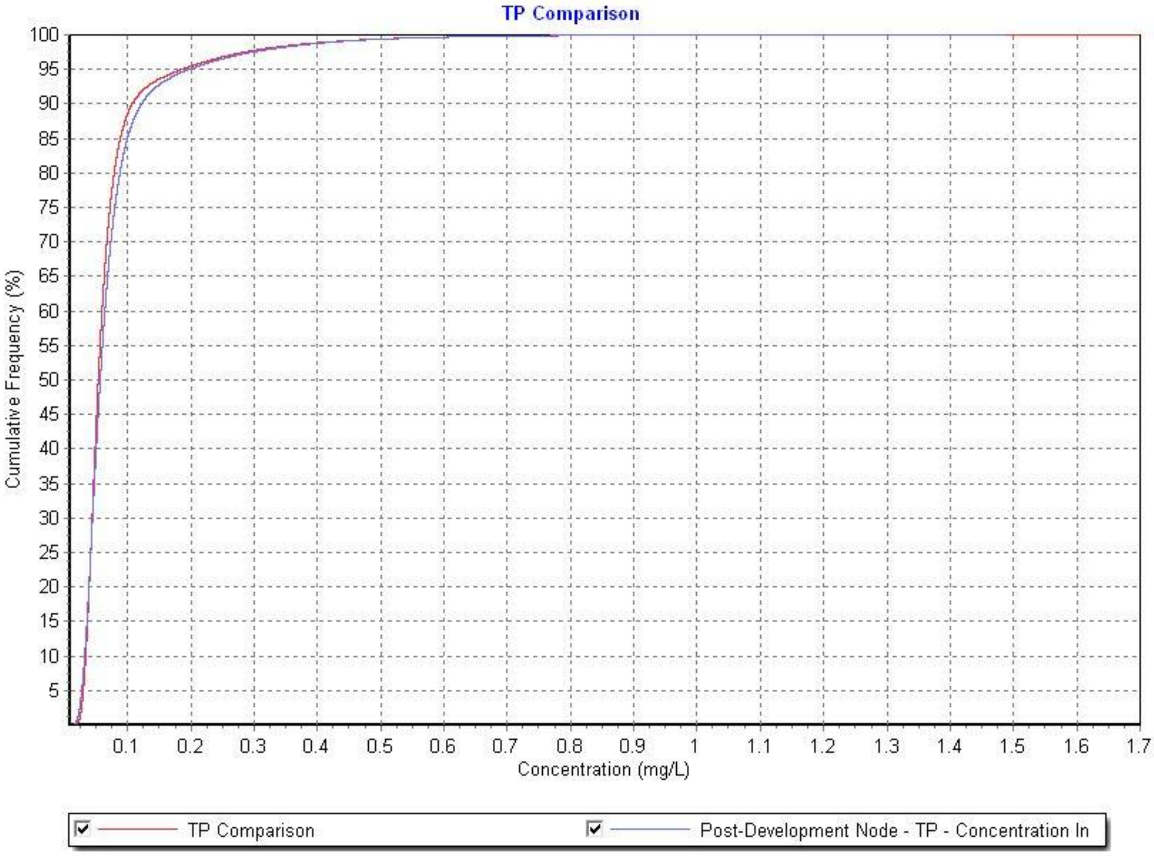


Figure 10 – Pre versus post for total phosphorous

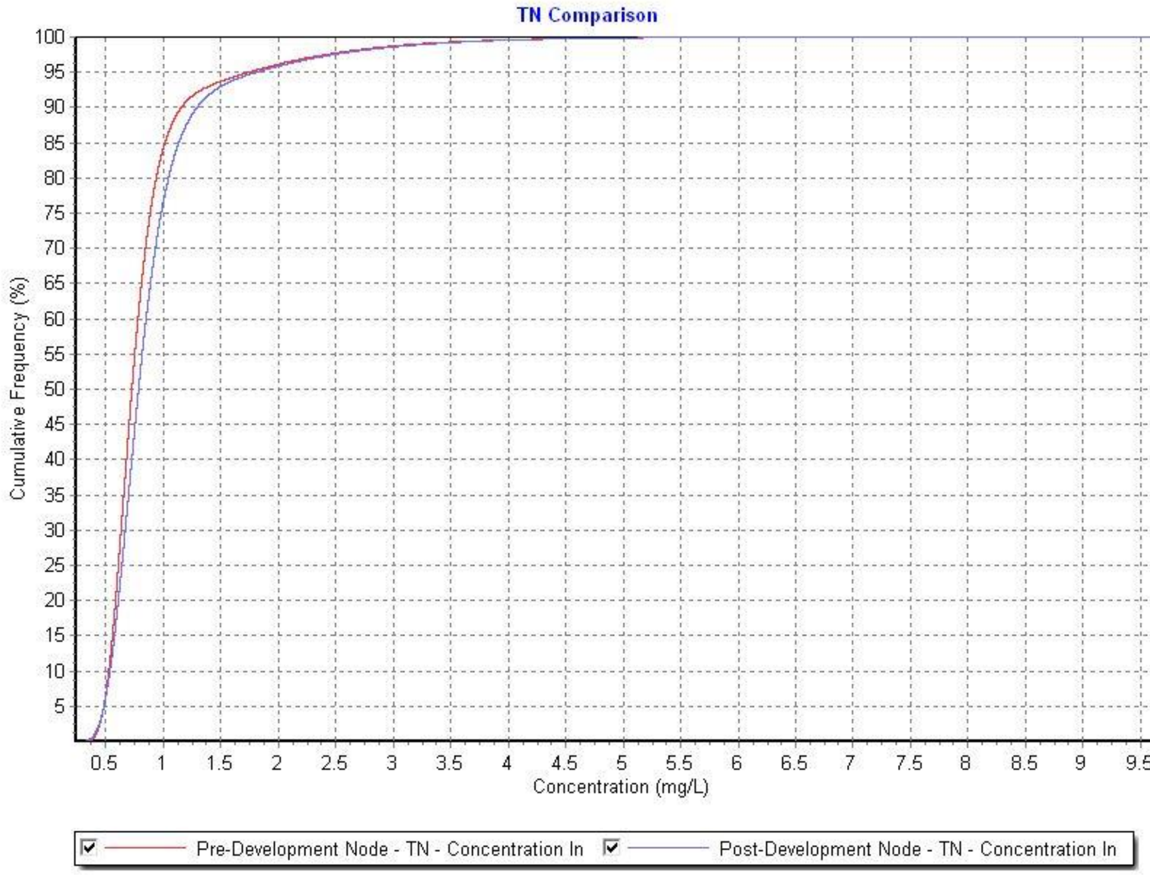


Figure 11 - Pre versus post for total nitrogen

4.4 Stormwater Management

4.4.1 Introduction

The South Coast Regional Strategy (2007) essentially requires rural residential subdivision in the catchments of SEPP 14 wetlands to achieve a neutral or beneficial effect on water quality (NorBE). The modelling presented in Section 4.3 suggest that appropriate site-specific stormwater management measures would need to be incorporated into each subdivision to ensure that the downstream environment is protected.

4.4.2 Recommended Assessment at Subdivision Stage

Any new subdivision application on each subject lot should address the issue of water quality and provide sufficient detail to show how NorBE would be met, as is required in the drinking water catchments managed by Water NSW.

Each subdivision application should each be accompanied by a site-specific Water Cycle Management Study (WCMS) which takes into account not only the proposed civil works to permit subdivision (i.e. land clearing, proposed roads or ROWs) as well as a detailed MUSIC assessment of increase in effective imperviousness from dwellings and associated structures on the lot.

The WCMS would describe the site's hydraulic conditions before and after development and what measures would be installed by the developer and/or future home owners to treat stormwater runoff. Given the large lot sizes, and the sloped topography, it should be a reasonably simple exercise to achieve NorBE.

The following sections suggest water quality measures that could be installed at the initial subdivision stage and/or at the subsequent building stage to help achieve a NorBE outcome.

4.4.3 Managing Stormwater at Subdivision Stage

Construction of new public roads, driveway access within access handles/Rights of Way (ROW) and perimeter fire trails would be required at Subdivision Stage. Where a public road or ROW is constructed, drainage must be provided in accordance with Chapter G11 (Subdivision of Land) in Shoalhaven DCP 2014 and Council's Engineering Design Specifications. Where a ROW or road provides access to two or more lots it would most likely be built at subdivision stage. Where applicable (and possible), drainage must be discharged into any existing drainage system.

With good design and construction it would be possible to ensure new pavements are disconnected from the natural drainage system as much as possible e.g. by the use of vegetated table drains, shedding water onto adjacent pervious surfaces and/or treating concentrated flow in raingardens before it is released. Fire trails, for example, could have a firm base but have a veneer of grass over the surface. Stormwater management should consider and utilise the natural hydrological and ecological processes of the surrounding environment, e.g. use existing dams for onsite detention/re-use, vegetated buffers, grassed swales etc.

4.4.4 Managing Stormwater at Dwelling Stage

There are some simple designs that any new home owner could incorporate into their Development Application to ensure impervious surfaces are disconnected from receiving waters as much as possible:

- Roof water should be collected in a large rainwater tank(s) for use in and around the new homes.
- Rainwater tank overflow should be directed into a stormwater absorption trench/raingarden.
- Driveways should adopt the same measures as for roads and ROWs i.e. they should drain to vegetated swales/table drains which could terminate in small raingardens for final treatment before release. Pavement drainage should be shed onto pervious lands where possible.
- Runoff from the urbanised portion of the site (house and surrounds) could be collected in a vegetated swale and delivered to a raingarden for treatment before release.
- Alternatively, runoff could be collected in a small dam sized to meet the property’s harvestable right (0.115ML/ha) and used for garden irrigation.

4.4.5 Hypothetical Example of Neutral or Beneficial Effect (NorBE)

To show that a neutral or beneficial effect could be met by future home owners a hypothetical MUSIC model has been done for one of the likely subdivisions in which 6.4 ha of land comprising 3.8 ha of rural residential land and 2.6 ha of forest is subdivided into four lots resulting in 4.4 ha of rural residential land and 2 ha of forest.

Each roof would drain to a (min) 20kL rainwater tank for use indoors and outdoors. It is assumed 80% of the new rural residential lands would drain to a raingarden on each new lot by means of a surface drain (a swale). Each raingarden is 60 m^2 in area with 40 m^2 of filter bed. The depth of ponding is 300 mm. The schematic of the model and the results are in given in Appendix 2 and they show NorBE can be met by adopting readily available water quality measures.

5 CONCLUSIONS AND RECOMMENDATIONS

The Falls Creek-Woollamia Deferred Areas Planning Proposal seeks to potentially allow rural residential subdivision of 15 existing lots to yield lot sizes of no less than 1 ha. The subject land consists of two areas on Woollamia Road and Seasongood Road. Both areas lie on the Nowra Soil Landscape and soil conditions across them are reasonably uniform. The areas are both within the catchment of Currambene Creek which drains to Jervis Bay Marine Park. A number of SEPP 14 wetlands are located in the Currambene Creek floodplain, including SEPP 14 Wetland No. 331 which is located downstream from the Seasongood Road investigation area.

This strategic water cycle assessment includes an onsite wastewater assessment and a stormwater assessment. The stormwater assessment examines the likely changes to hydrology and water quality resulting from rural residential subdivision and the associated development and changes to land use.

5.1 Onsite Wastewater Management

Nutrient balance calculations show a typical five-bedroom home on town water could typically be serviced by an Aerated Wastewater Treatment system (AWTS) with disposal of secondary-treated effluent by 970 m^2 of subsurface irrigation. Effluent Management Areas (EMA) should be located at least 40 m (when measured in the direction of flow) from local watercourses, dams (if they remain) and drainage depressions.

If new wastewater systems are designed, installed, managed and maintained appropriately there should be little impact of wastewater on the receiving waters; nutrients and pathogens should be assimilated by the soils and/or used by the vegetation. If existing wastewater systems were found to be failing they should be upgraded as part of the subdivision process.

5.2 Stormwater Management

Subdivision and development of the subject land would slightly increase the percentage of effectively impervious surfaces, particularly where new public roads or rights of way are required. While much of the investigation area has been cleared in conjunction with existing rural residential development, some bushland would be cleared to enable rural residential development.

Stormwater quality modelling of a hypothetical catchment comprising just the subject land shows that the export of sediment and nutrients would potentially increase by 15% to 20% if no stormwater management measures are used. Peak flows would remain essentially unchanged.

However, a range of stormwater management measures can be incorporated into subdivision and dwelling application stages to mitigate the potential changes to water quality and ensure that sensitive downstream environments are protected. Examples of simple measures that could be adopted are given in this report.

To ensure this will be achieved, future subdivision applications should be assessed using the Neutral or Beneficial Effect (NorBE) assessment methodology. Each subdivision application should be accompanied by a site-specific Water Cycle Management Study (WCMS) that takes into account not only the proposed civil works to permit subdivision (i.e. land clearing, proposed roads or ROWs) but also a realistic assessment of changes to imperviousness as a result of dwellings and associated structures, driveways, paving etc. on each lot. The WCMS would describe the site's hydraulic conditions before and after development and what measures would be installed by the developer and/or future home owners to treat stormwater runoff so that NorBE is met. Note that the NorBE test is only applied to sediment, phosphorous and nitrogen loads and concentrations. It is accepted that overall flows will increase with an increase in effective imperviousness.

To demonstrate that NorBE can be achieved, a conceptual stormwater treatment train was designed and modelled for a hypothetical subdivision. The results, which are provided in Appendix 2, show that NorBE could be met with readily-adopted water quality measures.

If future subdivisions are designed and built to ensure a NorBE is met, it can be assumed there would be minimal risk of a negative impact to the local catchments.

6 REFERENCES

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7 APPENDICES

7.1 Appendix 1 – Soil profiles

(overpage)

SEEC

ENGINEERING LOG - EXCAVATIONS

		Project Number:	15000126
Client	Shoalhaven Council	Date excavated	30/06/2015
Project	Falls Creek/Woollamia Deferred Areas Planning Proposal	Logged By	NL
Location		Slope %	

Excavation Dimensions — Core No. 1

Method	Sampling	Depth (m)	Layer Change	Description	Moisture	Consistency /Strength	Remarks
C	CS			Dark brown, weakly pedal, sandy loam			
				Grey, massive, sand			
				Brown, massive, Light to Medium clay			
	CS						
				Red & grey mottled, massive, Light to Medium clay			
		1.0 m					
				Layer continues			
		2.0 m					

Excavation Dimensions — Core No. 2

Method	Sampling	Depth (m)	Layer Change	Description	Moisture	Consistency /Strength	Remarks
C				Dark brown, weakly pedal, sandy loam			
				Grey, massive, sand			
				Brown, massive, Light to Medium clay			
				Grey & orange mottled, massive, Light to Medium clay			
		1.0 m					
				Layer continues			
		2.0 m					

Key

Method		Sampling / Testing			Consistency / Strength			
N	natural exposure	HP	hand penetrometer	The classification symbols and soil descriptions are based on the Unified Soil Classification System (Corps of Engineers, 1953) and AS 1726:1993, Geotechnical Site Investigations	VS	very soft	Fb	friable
A	hand auger	DCP	dynamic cone penetrometer		S	soft	VL	very loose
ES	shovel	O	other		F	firm	L	loose
EB	backhoe	CS	composited sample		St	stiff	MD	med. dense
ED	bulldozer	**Moisture Condition**			VSt	very stiff	D	dense
EG	grader	D	dry		H	hard	VD	very dense
G	gully	MM	moderately moist		**Comments**			
C	core sample	M	moist					
O	other	W	wet					

This log must be read with the accompanying report by SEEC — Rev 1, 09/12

SEEC

ENGINEERING LOG - EXCAVATIONS

		Project Number:	15000126
Client	Shoalhaven Council	Date excavated	30/06/2015
Project	Falls Creek/Woollamia Deferred Areas Planning Proposal	Logged By	NL
Location		Slope %	

Excavation Dimensions — Core No. 3

Method	Sampling	Depth (m)	Layer Change	Description	Moisture	Consistency /Strength	Remarks
C				Dark brown, mod. pedal, sandy clay loam			
				Orange, massive, Light to Medium clay			
				Grey & red mottled, massive, Light to Medium clay			
		1.0 m					
				Layer continues			
		2.0 m					

Excavation Dimensions — Core No. 4

Method	Sampling	Depth (m)	Layer Change	Description	Moisture	Consistency /Strength	Remarks
C	CS			Dark brown, mod. pedal, sandy clay loam			
				Brown, massive, sand			
	CS			Brown, massive, Light to Medium clay			
		1.0 m					
				Layer continues			
		2.0 m					

Key

Method		Sampling / Testing			Consistency / Strength			
N	natural exposure	HP	hand penetrometer	The classification symbols and soil descriptions are based on the Unified Soil Classification System (Corps of Engineers, 1953) and AS 1726:1993, Geotechnical Site Investigations	VS	very soft	Fb	friable
A	hand auger	DCP	dynamic cone penetrometer		S	soft	VL	very loose
ES	shovel	O	other		F	firm	L	loose
EB	backhoe	CS	composited sample		St	stiff	MD	med. dense
ED	bulldozer	**Moisture Condition**			VSt	very stiff	D	dense
EG	grader	D	dry		H	hard	VD	very dense
G	gully	MM	moderately moist		**Comments**			
C	core sample	M	moist					
O	other	W	wet					

This log must be read with the accompanying report by SEEC

Rev 1, 09/12

SEEC

ENGINEERING LOG - EXCAVATIONS

		Project Number:	15000126
Client	Shoalhaven Council	Date excavated	30/06/2015
Project	Falls Creek/Woollamia Deferred Areas Planning Proposal	Logged By	NL
Location		Slope %	

Excavation Dimensions — Core No. 5

Method	Sampling	Depth (m)	Layer Change	Description	Moisture	Consistency /Strength	Remarks
C	CS			Dark grey, weakly pedal, sandy clay loam			
				Yellow brown, weakly pedal, sandy clay loam			
	CS			Red mottled yellow brown, massive, Light to Medium			
		1.0 m		Grey & red mottled yellow brown, massive, light to medium clay			
				Layer continues			
		2.0 m					

Excavation Dimensions — Core No. 6

Method	Sampling	Depth (m)	Layer Change	Description	Moisture	Consistency /Strength	Remarks
C	CS			Dark grey, weakly pedal, sandy clay loam			
				Orange, massive, Light to Medium clay			
	CS						
		1.0 m		Grey mottled orange, massive, Light to Medium clay			
				Layer continues			
		2.0 m					

Key

Method		Sampling / Testing			Consistency / Strength			
N	natural exposure	HP	hand penetrometer	The classification symbols and soil descriptions are based on the Unified Soil Classification System (Corps of Engineers, 1953) and AS 1726:1993, Geotechnical Site Investigations	VS	very soft	Fb	friable
A	hand auger	DCP	dynamic cone penetrometer		S	soft	VL	very loose
ES	shovel	O	other		F	firm	L	loose
EB	backhoe	CS	composited sample		St	stiff	MD	med. dense
ED	bulldozer	**Moisture Condition**			VSt	very stiff	D	dense
EG	grader	D	dry		H	hard	VD	very dense
G	gully	MM	moderately moist		**Comments**			
C	core sample	M	moist					
O	other	W	wet					

This log must be read with the accompanying report by SEEC — Rev 1, 09/12

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ENGINEERING LOG - EXCAVATIONS

		Project Number:	15000126
Client	Shoalhaven Council	Date excavated	30/06/2015
Project	Falls Creek/Woollamia Deferred Areas Planning Proposal	Logged By	NL
Location		Slope %	

Excavation Dimensions — Core No. 7

Method	Sampling	Depth (m)	Layer Change	Description	Moisture	Consistency /Strength	Remarks
C				Dark brown, weakly pedal, sandy loam			
				Grey, massive, sand			
				Light to Medium brown, massive, loamy sand			
				Orange brown, weakly pedal, loamy sand/ clayey sand			
		1.0 m					
				Layer continues			
		2.0 m					

Excavation Dimensions — Core No. 8

Method	Sampling	Depth (m)	Layer Change	Description	Moisture	Consistency /Strength	Remarks
C				Dark brown, mod. pedal, sandy clay loam			
				Grey, weakly pedal, sandy loam			
				Red mottled yellow brown, massive, Light to Medium clay			
				Red mottled grey, mottled, Light to Medium cl			
		1.0 m					
				Layer continues			
		2.0 m					

Key

Method		Sampling / Testing			Consistency / Strength			
N	natural exposure	HP	hand penetrometer	The classification symbols and soil descriptions are based on the Unified Soil Classification System (Corps of Engineers, 1953) and AS 1726:1993, Geotechnical Site Investigations	VS	very soft	Fb	friable
A	hand auger	DCP	dynamic cone penetrometer		S	soft	VL	very loose
ES	shovel	O	other		F	firm	L	loose
EB	backhoe	CS	composited sample		St	stiff	MD	med. dense
ED	bulldozer	**Moisture Condition**			VSt	very stiff	D	dense
EG	grader	D	dry		H	hard	VD	very dense
G	gully	MM	moderately moist		**Comments**			
C	core sample	M	moist					
O	other	W	wet					

This log must be read with the accompanying report by SEEC — Rev 1, 09/12

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ENGINEERING LOG - EXCAVATIONS

		Project Number:	15000126
Client	Shoalhaven Council	Date excavated	30/06/2015
Project	Falls Creek/Woollamia Deferred Areas Planning Proposal	Logged By	NL
Location		Slope %	

Excavation Dimensions — Core No. 9

Method	Sampling	Depth (m)	Layer Change	Description	Moisture	Consistency /Strength	Remarks
C	CS			Dark brown, mod. Pedal, sandy clay loam			
				Grey, weakly pedal, sandy loam			
				Red grading to orange, massive, Medium clay			
	CS						
				Grey mottled orange, massive, Medium clay			
		1.0 m					
		2.0 m					

Excavation Dimensions — Core No. 10

Method	Sampling	Depth (m)	Layer Change	Description	Moisture	Consistency /Strength	Remarks
C	CS			Dark brown/grey, mod. pedal, sandy clay loam			
				Red, massive, Medium clay			
	CS						
				Red mottled grey, massive, Medium clay			
		1.0 m					
		2.0 m					

Key

Method		Sampling / Testing			Consistency / Strength			
N	natural exposure	HP	hand penetrometer	The classification symbols and soil descriptions are based on the Unified Soil Classification System (Corps of Engineers, 1953) and AS 1726:1993, Geotechnical Site Investigations	VS	very soft	Fb	friable
A	hand auger	DCP	dynamic cone penetrometer		S	soft	VL	very loose
ES	shovel	O	other		F	firm	L	loose
EB	backhoe	CS	composited sample		St	stiff	MD	med. dense
ED	bulldozer	**Moisture Condition**			VSt	very stiff	D	dense
EG	grader	D	dry		H	hard	VD	very dense
G	gully	MM	moderately moist		**Comments**			
C	core sample	M	moist					
O	other	W	wet					

This log must be read with the accompanying report by SEEC

Rev 1, 09/12

7.2 Appendix 2 – A Hypothetical subdivision with stormwater treatment: MUSIC Model

To show that a neutral or beneficial effect could be met by future home owners, a hypothetical MUSIC model has been done for one of the likely subdivisions in which 6.4ha of land currently comprising 3.8 ha of rural residential land and 2.6 ha of forest is subdivided into four lots resulting in 4.4 ha of rural residential land and 2 ha of forest.

Conceptual Stormwater Treatment Train:

Each roof would drain to a (min) 20kL rainwater tank for use indoors and outdoors. It is assumed 80% of the new rural residential lands would drain to a raingarden on each new lot by means of a surface drain (a swale). Each raingarden is 60 m^2 in total area with 40 m^2 of filter bed. The depth of ponding above the filter is 300 mm.

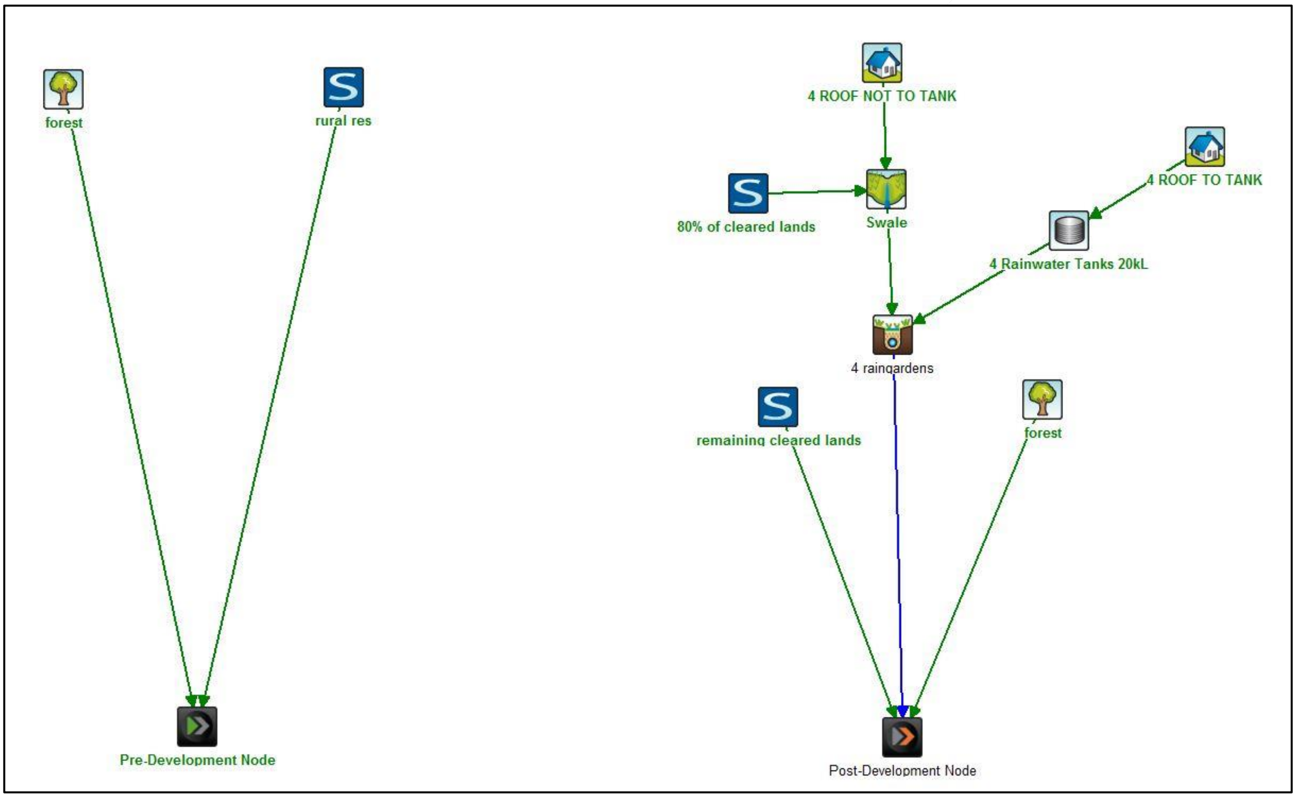

Figure 12 – Hypothetical MUSIC Schematic

Results:

Table 12 - Hypothetical subdivision MUSIC Results[6]

	Pre	Post	Change %
Total Suspended Solids (kg/yr)	623	353	-43
Total Phosphorus (kg/yr)	1.49	1.41	-5
Total Nitrogen (kg/yr)	14.7	14.7	0

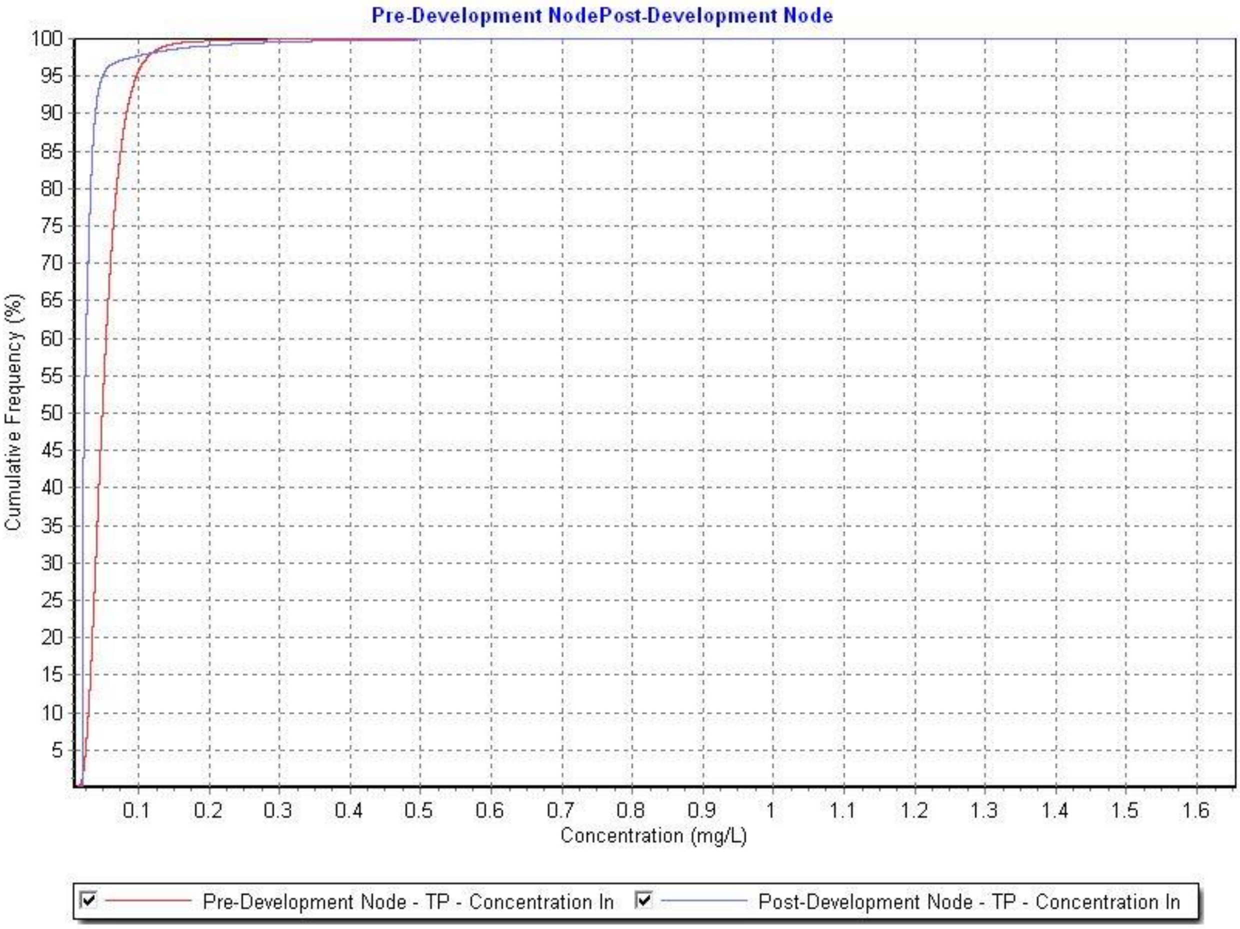

Figure 13 - Hypothetical Total Suspended Solids

[6] SEEC internal reference = 15000216 Run 4

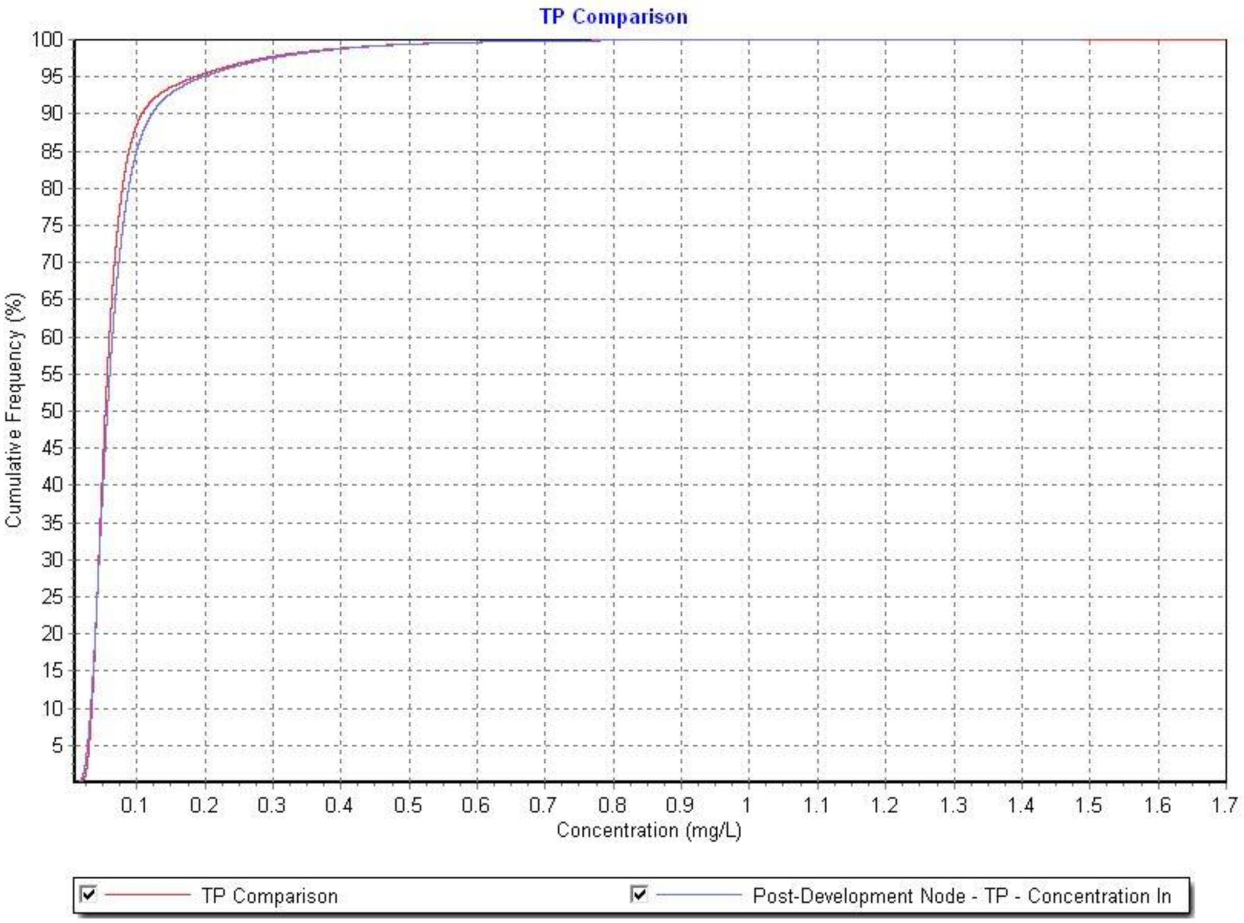

Figure 14 - Hypothetical Total Phosphorous

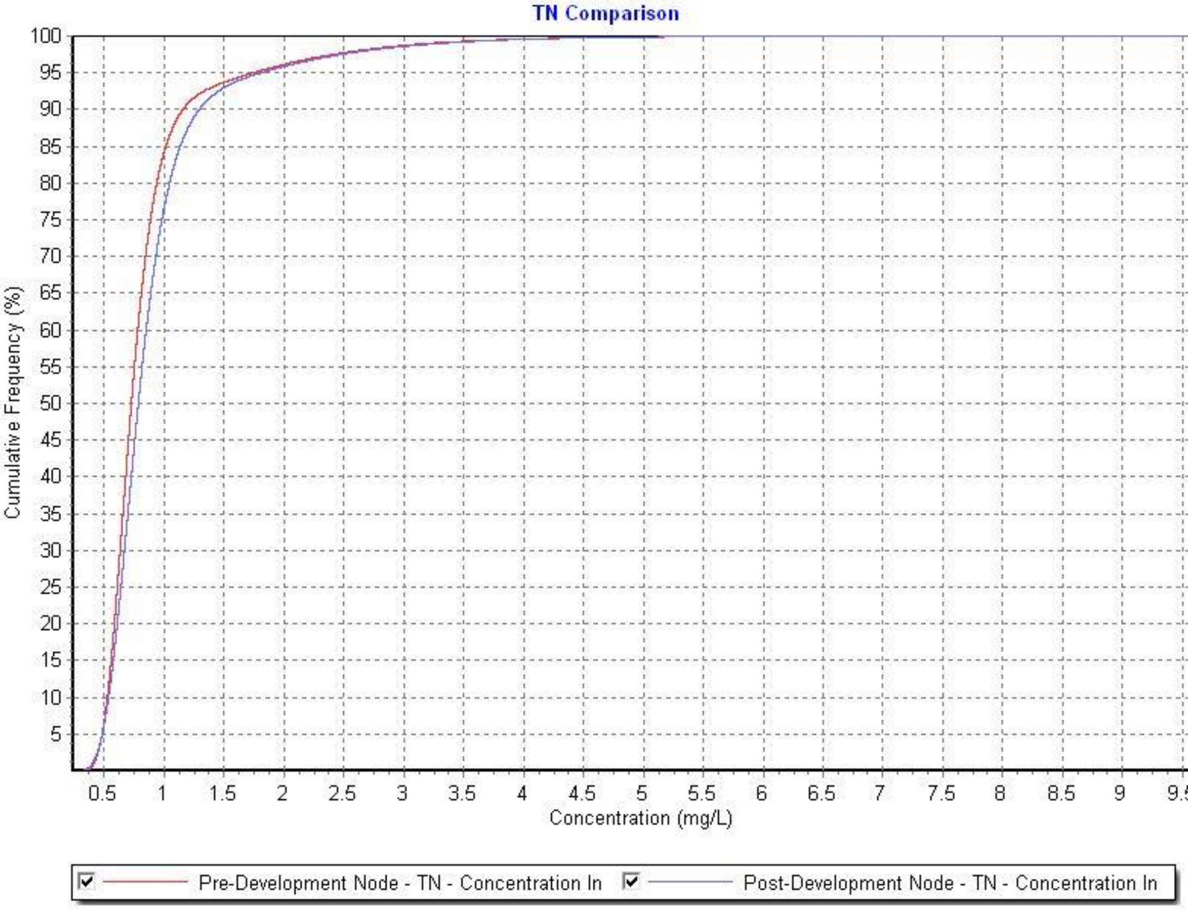

Figure 15 - Hypothetical Total Nitrogen