Brisbane Water Estuary Management Study

MUSIC Catchment Modelling

FINAL

LJ2717/R2596V3

Prepared for Gosford City Council*

October 2010

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Report No:_____

Document Control

Version	Status	Date	Author		Reviewer	
1	Draft	26 October 2009	Sarah Fitzsimons	SKF	Louise Collier	LCC
2	Revised Draft	12 November 2009	Sarah Fitzsimons	SKF	Louise Collier	LCC
3	Final	October 2010	Sarah Fitzsimons	SKF	Louise Collier	LCC

* Gosford City Council has prepared this document with financial assistance from the NSW Government through the Department of Environment, Climate Change and Water (DECCW). This document does not necessarily represent the opinions of the NSW Government or DECCW.

Cover Photo: Koolewong Foreshore Reserve, Brisbane Water Drive. Photo taken during site inspections in June 2009.

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Glossary and Abbreviations

BASIX	Building Sustainability Index
BoM	Bureau of Meteorology
CDS	Continuous Deflective Separation
CRC	Cooperative Research Centre
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DECC	Former NSW Department of Environment and Climate Change
DECCW	NSW Department of Environment, Climate Change and Water
EMS	Estuary Management Study
GCC	Gosford City Council
GPT	Goss Pollutant Trap
LGA	Local Government Area
MHL	Manly Hydraulics Laboratory
PET	Potential Evapotranspiration
SMCMA	Sydney Metropolitan Catchment Management Authority
TN	Total Nitrogen
TP	Total Phosphorous
TSS	Total Suspended Solids
WAE	Work-as-Executed
WSUD	Water Sensitive Urban Design

1 Introduction

A MUSIC water quality model was established for Brisbane Water as part of the *Brisbane Water Estuary Processes Study* (Cardno, 2008). This MUSIC model formed the basis for subsequent modelling of five Scenarios, as described below, conducted as part of the Brisbane Water Estuary Management Study (EMS).

This report follows the following structure:

Section 2 gives an overview of the establishment of the MUSIC water quality model for the *Brisbane Water Estuary Processes Study* (Cardno, 2008).

Sections 3 to **7** detail MUSIC model Scenarios 1 to 5 respectively, which were developed to support the options assessment process within the Brisbane Water EMS. The five scenarios are as follows:

- *Scenario 1* incorporates Gross Pollutant Traps (GPTs) into the existing MUSIC model to simulate present day catchment conditions, with existing treatment devices;
- *Scenario 2* models predicted 2030 catchment conditions based on the assumption of a 25% intensification by area of residential zones within the Woy Woy and Gosford areas. Scenario 2 also incorporates one known 'greenfield' development area, which is the proposed industrial development at Somersby. All new development would involve rainwater tanks and generic treatment devices to meet Council's stormwater treatment requirements contained in the *Water Cycle Management Guidelines* (GCC, 2007);
- *Scenario 3* updates the generic treatment devices performance incorporated in Scenario 2 with DECCW's proposed stormwater treatment targets in *Managing Urban Stormwater: Environmental Targets* (DECC and SMCMA, 2007); load reductions of TSS, TP and TN by 85%, 65% and 45% respectively;
- *Scenario 4* incorporates regional treatment devices into the Scenario 3 model, representing an 'ultimate development scenario' in 2030. Treatment devices considered include GPTs, Bioretention Systems and Rainwater Tanks for reuse, which are all Water Sensitive Urban Design (WSUD) features aimed at reducing pollutant loads in the stormwater. These regional treatment devices have been cross-referenced based on those management options relating to water and sediment quality, presented in the Brisbane Water EMS; and
- *Scenario 5* incorporates the top five most effective regional treatment devices, selected from the full suite of devices modelled in Scenario 4. Council could realistically implement these top five devices in the next five to ten years, with beneficial impacts on the overall water quality of Brisbane Water and its associated major tributaries.

Section 8 presents the results of all five Scenarios.

Section 9 discusses and concludes the outcomes of all five Scenarios and relates the implications of these results to the DELFT3D modelling undertaken for the *Brisbane Water Estuary Processes Study* (Cardno, 2008).

2 MUSIC Water Quality Model

A MUSIC model for Brisbane Water was developed and verified as part of the *Brisbane Water Estuary Processes Study* (Cardno, 2008), to model pollutant loads in the stormwater for the Brisbane Water catchment. The following three pollutants, considered key stressors for aquatic habitats, were modelled:

- Total suspended solids (TSS);
- Total phosphorous (TP); and
- Total nitrogen (TN).

For full details of the MUSIC model refer to Appendix B of the *Brisbane Water Estuary Processes Study* (Cardno, 2008), which contains the catchment modelling report *Brisbane Water Estuary Processes Study, Catchment Modelling – MUSIC, Appendix B* (Cardno, 2007).

2.1 Model Development

Climate data sources included rainfall data sourced from Manly Hydraulics Laboratory (MHL) and rainfall and monthly potential evapotranspiration (PET) data sourced from the Bureau of Meteorology (BoM). This data was analysed to determine the average (50 percentile), dry (lower 10 percentile) and wet (upper 10 percentile) rainfall conditions. Three conditions were modelled for the Estuary Processes Study to establish loads under current conditions (a baseline); the representative average, wet and dry rainfall years. Only the representative average rainfall year (1995) has been considered for further modelling undertaken as part of this report.

The Brisbane Water catchment was broken up into 233 sub-catchments based on hydrological and land use considerations (**Figure 1**). The area in hectares and impervious percentage was defined for each sub-catchment, as provided in Cardno (2007).

There are a number of tributaries that enter Brisbane Water, with the six major tributaries being Narara, Erina, Kincumber, Woy Woy, Coorumbine and Ettalong Creeks (**Figure 1**).

2.2 Results and Outcomes

Results obtained from the baseline MUSIC model are shown in **Table 2.1**.

Table 2.1: Baseline Conditions – Annual Loads for Representative Average Year (1995)

Location	Area (ha)	Annual Flow (ML/yr)	Runoff Coefficient	Annual Loads (kg/yr)		
				TSS	TP	TN
Upper Narara	2811	8920	0.26	831000	1810	15000
Lower Narara	4565	16800	0.30	1680000	3820	30600
Upper Erina	1926	4370	0.18	246000	541	5420
Lower Erina	3252	9310	0.23	774000	1860	15500
Kincumber Creek	484	2050	0.34	238000	604	4540
Woy Woy Creek	588	1760	0.24	167000	260	2470
Ettalong Creek	780	3350	0.35	348000	981	7080
Coorumbine Creek	361	1450	0.33	160000	329	2710
Direct to Brisbane Water*	1699	10490	0.50	1216000	3795	25680
Total Catchment	**16466**	**58500**	**0.29**	**5660000**	**14000**	**109000**

* The pollutant loads and flow delivered directly to Brisbane Water have been back-calculated as the difference between 'Total Catchment' pollutant loads in Brisbane Water and the sum of pollutant loads from the major tributaries as listed in **Table 2.1**and reported in Cardno (2008). MUSIC reports all outputs rounded to three significant figures; hence it should be noted that this back-calculation method may incur slight errors due to rounding.

Key outcomes of the comprehensive catchment modelling were:

- Narara Creek was shown to deliver a large proportion of the pollutant load entering the Brisbane Water Estuary; approximately 42% (averaged over TSS, TP and TN loads). This is a function of the larger size of its catchment and also the development within its catchment.
- By comparison, Erina Creek is well developed in the lower reaches of the catchment, while the upper catchment is largely rural and forested. As a result, Erina Creek produces less than half the pollutant loads of Narara Creek; approximately 18%.
- The smaller major tributaries including Kincumber, Woy Woy, Ettalong and Coorumbine Creeks contribute a much smaller proportion of the pollutant load entering the Brisbane Water, totalling approximately 16%.
- The sub-catchments that drain directly to the Brisbane Water Estuary represent approximately 24% of the total pollutant load that enters the Estuary, which is quite a substantial proportion. A number of these sub-catchments comprise highly developed, water-front land. This situation results in a higher proportion of impervious area, and hence greater runoff and associated pollutant loads.
- In terms of pollutant load intensity, Kincumber Creek produces a greater pollutant load per hectare than the other major tributaries of Brisbane Water. Kincumber Creek has a mixture of industrial and residential areas, all of which have high proportions of impervious area. Similarly, Ettalong Creek, with runoff sourced from some of the highly developed Woy Woy area, has high pollutant load intensity. The sub-catchments that drain directly to Brisbane Water, however, have the highest pollutant load intensities.
- The pollutant load intensities from Woy Woy Creek and Upper Erina Creek are low when compared with the rest of the sub-catchments. Both of these catchments have a low proportion of impervious areas, and as a result, a reduction in runoff. Furthermore, Woy Woy Creek has a high proportion of forested area, which naturally has lower stormwater pollutant concentrations.

3 Scenario 1 - Gross Pollutant Traps

3.1 Data Sources

Gross Pollutant Trap (GPT) data and GIS layers were provided by Gosford City Council to assist with schematising the Scenario in the model. A list of 103 existing GPTs in the LGA area was provided by Council.

This list was refined by excluding GPTs not within the bounds of the Brisbane Water Catchment (i.e. the study area defined in **Figure 1**), and excluding those GPTs which only capture gross pollutants and do not generally achieve any reduction in TSS, TN or TP loads, including:

- Ecosol Pit Baskets;
- Steel Pratten Traps;
- Nettechs;
- Floating Booms; and
- Tidal Gates.

3.1.1 GPT Type and Location

After refinement, as discussed above, 11 GPTs were incorporated into the MUSIC model. These included the following types of proprietary GPT devices:

- Humeceptors;
- Humegards;
- CDS Units;
- Rocla Unit (assumed to be a CleansAll); and
- Ecosol Solid Pollutant Filter RSF 4000.

Other treatment systems, such as wetlands, sediment basins, bioswales etc are not listed in Council's records of treatment devices and therefore only GPTs (as provided by Council) have been included in the Scenario 1 model.

Relevant details regarding location and type of GPT, as provided by Gosford City Council, are given in **Table 3.1**.

Table 3.1: GPT Type and Location

Council Asset Number	Device Type	Number of Units	Catchment	Suburb	Street	Locality Description	Outlet Type	Outlet Size (mm)
GPT 9	Humeceptor	1	Narara Creek	West Gosford	Manns Rd near Yandina Rd	Grass in front of Isuzu Trucks near Yandina Rd	*	*
GPT 10	Humeceptor	1	Cockle Broadwater	Kincumber	Opp No.1 Kerta Rd cnr Hawke St	On the road	*	*
GPT 11	Humegard	1	Cockle Broadwater	Kincumber	Cnr Kerta Rd & Empire Bay Dr	On grass area above the shops	*	*
GPT 13	CDS	1	Woy Woy Peninsula	Blackwall	Lalina Ave	Off the road, southern end of Council's pathway	*	*
GPT 15	Rocla Unit	1	Woy Woy Peninsula	Ettalong Beach	Schnapper Rd	Near toilet block	*	*
GPT 18	Ecosol Solid Pollutant Filter RSF 4000	1	Woy Woy Peninsula	Umina Beach	Melbourne Ave	Carpark near tennis club	Pipe	900
GPT 20	CDS	1	Erina Creek	Erina Heights	Carlton Rd	Carlton Rd footpath near The Entrance Rd roundabout	*	*
GPT 21	Humeceptor	1	Erina Creek	Erina Heights	The Entrance Rd	Off Serpentine Rd	*	*
GPT 22	CDS	1	Erina Creek	Erina Heights	The Entrance Rd	472 The Entrance Rd	*	*
GPT 23	Humegard	2	Narara Creek	Wyoming	Pacific Hwy	In the vicinity of the culvert bridge near Willows Motor Inn	*	*
GPT 24	Humegard	1	Erina Creek	Springfield	Cobbedah Dr	Corner Noorumba Rd beyond wet detention basin	*	*

* Not specified in Council records.

3.2 GPT Catchment Areas

The locations of the 11 GPTs within their respective MUSIC sub-catchments were assessed in relation to the sub-catchment pipe drainage, distance to the overall sub-catchment outlet location and direction of surface flow. Based on this assessment, and in the absence of design data and work-as-executed (WAE) drawings for the GPTs, individual GPT catchment areas where defined. These catchment or treatment areas are shown in **Figure 2**. The sizes of the GPT catchment areas, as shown in **Figure 2**, are given in **Table 3.2**.

Table 3.2: GPT Catchment Areas and MUSIC Source Nodes

Council Asset Number	Sub-Catchment Treated	GPT Catchment Areas (ha)*
GPT 9	W_Gosford6(b)	12
GPT 10	Kincumber4(b)	7
GPT 11	Kincumber5(b)	9
GPT 13	Woy_P8(b)	111
GPT 15	Woy_P10(b)	19
GPT 18	Umina1(b)	3
GPT 20	Erina_Ck1(b)	24
GPT 21	Erina_Ck3(b)	2
GPT 22	Chetwynd1(b)	2
GPT 23 (2 Units)	Wingello1(b)	4
GPT 24	Chertsey5(b)	11

* Assumptions were made regarding the treatment catchment size due to the absence of WAE drawings.

3.3 GPT Treatment Efficiency Details

The performance data and pollutant treatment efficiencies of each GPT device type as input into MUSIC, derived from technical manuals for the products or otherwise assumed as indicated, are given below in **Table 3.3**.

Table 3.3: MUSIC Input Parameters for GPT Treatment Efficiencies

Parameter	GPT Device Type				
	Humeceptor	Humegard	CDS Unit	Rocla CleansAll Unit	Ecosol Solid Pollutant Filter RSF 4000
Low Flow By-pass (m^3/s)	0*	0*	0*	0*	0
High Flow By-pass (m^3/s)	0.2*	0.4*	0.4*	0.48†	0.485^
TSS Reduction	80%	85%	70% (between 75 and 700mg/L)	70%	91%
TP Reduction	30%	0%	30% (between 0.5 and 4.5mg/L)	0%*	30%
TN Reduction	30%	0%	0%	0%*	13%
Performance Data Source(s)	Humes, 2007	Humes, 2008	Rocla and CRC for Catchment Hydrology, 2005	Rocla, 2002 and University of South Australia, 1998	Ecosol and Ecosol, 2006

* These values have been assumed.

† Based on a weir height of 0.3m (University of South Australia, 1998).

^ Based on the treatable flow rate of the Ecosol RSF 4750 Unit, which is within the Ecosol RSF 4000 product range (Ecosol).

Routing

When determining routing of drainage links it was assumed that all the GPTs were located at the outlets of the sub-catchments. Therefore, no routing was used for the drainage link from the GPT device to its outlet node in MUSIC.

Routing for the drainage link from the GPT source node (as listed in **Table 3.2**) to the GPT remained as for the baseline MUSIC model (i.e. either Muskingum-Cunge routing or no routing).

4 Scenario 2 – 2030 Intensification and Development

4.1 Data Sources

Information regarding Gosford City Council's planned 2030 land use changes and projected growth was obtained from the *Central Coast Regional Strategy* (DoP, 2008) and from consultation with Gosford City Council's Landuse Planning Adviser (Michael Bowman, pers. comm.).

Brownfields Development

Projected land use changes and development within the Brisbane Water Catchment by 2030 will encompass primarily brownfields development, in the form of intensification of residential areas, with little greenfields development. In 2030, no new areas will be rezoned as residential zones, but rather all additional new dwellings will be located within existing residential zones, as part of the process of urban renewal.

The breakdown of additional new residential dwellings, based on information from Council, is as follows:

- Gosford (Regional City) 6,000 additional new dwellings; and
- Woy Woy (Town) 2,200 additional new dwellings.

Approximately 20% intensification by area of residential zones within the Gosford LGA was indicated by Council. To simplify the modelling process it was determined that only intensification of residential zones within the Gosford and Woy Woy areas would be undertaken in the MUSIC model. This is reasonable as the majority of new residential dwellings by 2030 are focused within these areas.

To account for intensifying residential zones in only the Gosford and Woy Woy areas in the MUSIC model, 25% intensification was modelled.

Greenfields Development

The only greenfields development indicated by Council for inclusion in the 2030 Scenario is the proposed industrial development at Somersby, indicated in **Figure 3**. Of Precincts 1 to 5 of the industrial area only part of Precinct 5 (20 ha in area) is included within the MUSIC model catchment boundary.

To represent the rezoning and development of this area (within the MUSIC model catchment boundary), three sub-catchments were resized or rezoned to represent the land use changes, as indicated in **Table 4.1**. The new Somersby1 sub-catchment (formerly Fagan6) represents the proposed industrial development and the resized Fagans3 and Fagans4 sub-catchments are indicated on **Figure 4**.

Table 4.1: 2030 Greenfields Development for Scenario 2

2009				2030 (Scenario 2)			
Sub-Catchment	Area (ha)	Zoning	Impervious Area (%)	Sub-Catchment	Area (ha)	Zoning	Impervious Area (%)
Fagans3	200	Forest	5	Fagans3	197	Forest	5
Fagans4	44	Rural	5	Fagans4	35	Rural	5
Fagans6	9	Quarry	70	Somersby1	20	Industrial	80
TOTAL	**253**				**252**		

4.2 Stormwater Treatment Requirements

Rainwater Tanks

To comply with the BASIX water target requirements for the Gosford LGA (40% reduction in potable water supply compared to a similar dwelling), all 2030 additional new dwellings have been assumed to have a rainwater tank on site. This will facilitate the sustainable reuse of rainwater on site to meet the potable water demand reduction.

According to Sydney Water (2007), a rainwater tank size of 2,000L for each dwelling, assuming an average of three people per household, is sufficient for using rainwater for some household uses such as toilet flushing and watering a small garden area.

An estimated weekly rainwater requirement for an average three person household was calculated according to the information reported in Sydney Water (2007) (**Table 4.2**).

Table 4.2: Estimated* Weekly Rainwater Requirement (After: Sydney Water, 2007)

Activity	Water	Frequency	=
Toilet flush (4-star rated dual flush)	12 litres per person a day	No. of people = **3** x 12 litres x 7 days	**252L**
Garden watering	1,000 litres an hour	No. of hours per week = **0.5** x 1,000 litres	**500L**
Estimated weekly rainwater requirement		TOTAL	**752L**
Estimated daily rainwater requirement		TOTAL	**107L**

* Bold text indicates inputs and calculations made.

The projected numbers of additional dwellings for Gosford and Woy Woy for 2030 are 6,000 and 2,200, respectively, as discussed earlier. The numbers of dwellings for Gosford and Woy Woy were divided up between the sub-catchments based on proportion area in hectares. This method assumes a constant density of additional dwellings in 2030 in the Gosford and Woy Woy sub-catchments marked for 2030 intensification, respectively.

Generic Stormwater Treatment Devices

To comply with Gosford City Council's stormwater treatment requirements for urban development's contained in the *Water Cycle Management Guidelines* (GCC, 2007) all intensified residential areas, and the Somersby industrial area, will be treated by stormwater treatment devices in order to reduce pollutant loads in stormwater from these developments. Council's stormwater treatment requirements for developments, as a percentage retention of the annual average load of stormwater discharge from the developed conditions, are given in **Table 4.3**.

Table 4.3: Gosford City Council Stormwater Treatment Requirements (After: GCC, 2007)

Pollutant	Stormwater Treatment Requirements
Total Suspended Solids (TSS)	80% (Narara Creek Catchment) 70% (Brisbane Water Catchment)
Total Phosphorus (TP)	45% (Narara Creek Catchment) 30% (Brisbane Water Catchment)
Total Nitrogen (TN)	45% (Narara Creek Catchment) 30% (Brisbane Water Catchment)

All intensified residential zones within the Woy Woy area are located within the Brisbane Water Catchment; hence require TSS, TP and TN reduction by 70%, 30% and 30% respectively (**Table 4.3**). All intensified residential zones within the Gosford area, except sub-catchment Gosford3 in the Brisbane Water Catchment, are located within the Narara Creek Catchment; hence require TSS, TP and TN reduction by 80%, 45% and 45% respectively (**Table 4.3**).

A portion of the proposed industrial development at Somersby (sub-catchment Somersby1) is located within the Narara Creek Catchment; hence require the Narara Creek Catchment stormwater treatment requirements as per **Table 4.3**.

4.3 Intensified Residential Zones

To incorporate the 2030 intensified conditions into MUSIC 16 residential sub-catchments were nominated. These 16 sub-catchments, eight in each of the Gosford and Woy Woy areas as shown in **Figure 4,** are listed in **Table 4.4**. **Table 4.4** also indicates the 2009 and subsequent sub-catchment areas as input into MUSIC. The original residential area (indicated with A), is 75% of the 2009 area and the intensified residential area (indicated with B and BT; discussed further in subsequent discussions), is 25% of the 2009 area i.e. 25% intensification by area.

The percentage of impervious area for the original (A) residential areas was not changed in the MUSIC model. Gosford City Council's *Water Cycle Management Guidelines* (2007) indicate that higher density residential development requires a minimum pervious area of 10% of the site. Therefore, the percentage of impervious area for the intensified (B and BT) residential areas was set to 90% in the MUSIC model, as indicated in **Table 4.4**.

Figure 4 also indicates which major tributaries each of the 2030 modified areas drain to. Two of the intensified residential zones in Gosford drain to the Upper Narara Creek tributary, five drain to the Lower Narara Creek tributary and one drains directly to Brisbane Water. One of the intensified residential zones in Woy Woy drains to Ettalong Creek and seven drain directly to Brisbane Water. The proposed industrial development at Somersby drains to Coorumbine Creek.

Table 4.4: MUSIC Residential Sub-catchments Modified for 2030 Intensification

2009 Sub-Catchment	2009 Sub-Catchment Area (ha)	2030 Sub-Catchment	2030 Sub-Catchment Area (ha)	2030 Impervious Area (%)
GOSFORD AREA				
Brady2	116	Brady2A	87	40
		Brady2B	16	90
		Brady2BT	13	90
Fountain1	83	Fountain1A	62	30
		Fountain1B	11	90
		Fountain1BT	9	90
Fountain2	31	Fountain2A	23	30
		Fountain2B	4	90
		Fountain2BT	3	90
Gosford3	46	Gosford3A	34	40
		Gosford3B	6	90
		Gosford3BT	5	90
W_Gosford10	31	W_Gosford10A	23	40
		W_Gosford10B	4	90
		W_Gosford10BT	3	90
W_Gosford9	26	W_Gosford9A	20	40
		W_Gosford9B	4	90
		W_Gosford9BT	3	90
Wingello1	165	Wingello1A	124	40
		Wingello1B	23	90
		Wingello1BT	18	90
Wyoming1	173	Wyoming1A	130	40
		Wyoming1B	24	90
		Wyoming1BT	19	90
WOY WOY AREA				
Woy_P1	257	Woy_P1A	193	40
		Woy_P1B	36	90
		Woy_P1BT	29	90
Woy_P10	104	Woy_P10A	78	50
		Woy_P10B	14	90
		Woy_P10BT	12	90
Woy_P11	180	Woy_P11A	135	50
		Woy_P11B	25	90
		Woy_P11BT	20	90
Woy_P12	180	Woy_P12A	135	50
		Woy_P12B	25	90
		Woy_P12BT	20	90
Woy_P6	66	Woy_P6A	50	50
		Woy_P6B	9	90
		Woy_P6BT	7	90
Woy_P7	94	Woy_P7A	71	50
		Woy_P7B	13	90
		Woy_P7BT	10	90
Woy_P8	116	Woy_P8A	87	50
		Woy_P8B	16	90
		Woy_P8BT	13	90
Woy_P4	88	Woy_P4A	66	50
		Woy_P4B	12	90
		Woy_P4BT	10	90

Roof Area Determination

The intensified residential area was divided into two components (B and BT; where T stands for Tank, in **Table 4.4**), to determine the proportion of the intensified catchment that drains to a rainwater tank (i.e. roof areas only).

An analysis was carried out using recent aerial photography and cadastral data on a sample section of the existing residential zone in sub-catchment Gosford3, to determine the existing roof area percentage and total impervious percentage of the sample section. A roof area of 35% and a total impervious area of 70% were determined for the existing residential density. The percentage impervious of new residential dwellings for 2030 has been assumed to be 90%; hence the sample section results were scaled accordingly to determine the percentage of roof area for the intensified development condition in 2030. This calculation assumes the sample section analysed in sub-catchment Gosford3 is representative of the Gosford and Woy Woy areas. The scaled results indicate a proportion of roof area of 45%.

Therefore the sub-catchment areas in **Table 4.4** suffixed by BT, indicating the roof area draining to rainwater tanks, were calculated as 45% of the total intensified residential area. The areas suffixed by B were therefore assigned to be 55% of the total intensified residential area.

4.4 MUSIC Inputs

In the MUSIC model 45% of each intensified residential area (the roof area) was treated by a rainwater tank, followed by a generic treatment device, forming a treatment train. The remaining 55% of each intensified residential area was only treated by the generic treatment device.

The treatment efficiencies of the generic treatment devices were set to match Council's stormwater treatment requirements (**Table 4.3**), as opposed to matching performance criteria of existing stormwater treatment devices.

A schematic of the MUSIC model setup, for a sample intensified residential area, is shown in **Figure 5**.

Rainwater Tanks

All rainwater tanks for all intensified sub-catchments in the MUSIC model had the following common properties:

- Low flow by-pass (m^3/s) 0
- High flow by-pass (m^3/s) 100
- Depth above overflow (m) 0.2
- Overflow pipe diameter (mm) 90

Rainwater tank design properties, including the overflow pipe diameter (90mm) and the tank surface area (1.4m^2), were sourced from a typical product that might be used (i.e. the Nylex *Rainwater Tanks* (2008) brochure) for a 2kL tank.

Table 4.5 details the MUSIC inputs for rainwater tanks, specific to each intensified residential sub-catchment.

Table 4.5: MUSIC Inputs for Scenario 2 Rainwater Tanks

2030 Sub-Catchment	Number of 2kL Rain Tanks (i.e. Assumed Number of Dwellings)*	Storage Properties		Re-Use Properties
		Total Volume Below Overflow Pipe (kL)	Total Surface Area (m^2)	Total Daily Demand (kL/day)
GOSFORD AREA				
Brady2(B + BT)	1042	2084	1459	112
Fountain1(B + BT)	743	1485	1040	79
Fountain2(B + BT)	273	547	383	29
Gosford3(B + BT)	408	816	571	44
W_Gosford10(B + BT)	275	550	385	29
W_Gosford9(B + BT)	233	467	327	25
Wingello1(B + BT)	1479	2958	2071	158
Wyoming1(B + BT)	1547	3093	2165	165
Total	**6000**	**12000**	**8400**	**642**
WOY WOY AREA				
Woy_P1(B + BT)	521	1042	730	56
Woy_P10(B + BT)	211	421	295	23
Woy_P11(B + BT)	365	730	511	39
Woy_P12(B + BT)	365	730	511	39
Woy_P6(B + BT)	134	269	188	14
Woy_P7(B + BT)	191	381	267	20
Woy_P8(B + BT)	236	471	330	25
Woy_P4(B + BT)	178	355	249	19
Total	**2200**	**4400**	**3080**	**235**

* This approach conservatively assumes that one dwelling consists of only one house in the intensification Scenario i.e. no multi-storey units or duplex style dwellings have been incorporated, which would increase daily demand levels.

Generic Stormwater Treatment Devices

All generic stormwater treatment devices for intensified sub-catchments in the Narara Creek catchment had the following common aggregated input properties in the MUSIC model, in accordance with Council's requirements (**Table 4.3**):

- Low flow by-pass (m^3/s) 0
- High flow by-pass (m^3/s) 100
- Transfer functions
  - TSS 80% reduction
  - TP 45% reduction
  - TN 45% reduction

Similarly, all generic stormwater treatment devices for intensified sub-catchments in the Brisbane Water catchment had the following common aggregated input properties in the MUSIC model, (**Table 4.3**):

- Low flow by-pass (m^3/s) 0
- High flow by-pass (m^3/s) 100

- Transfer functions
  - TSS 70% reduction
  - TP 30% reduction
  - TN 30% reduction

Only a generic treatment device (as opposed to the inclusion of a rainwater tank), with MUSIC inputs based on the Narara Creek Catchment requirements (**Table 4.3**), was used to treat stormwater discharge from the proposed greenfields industrial development at Somersby1.

5 Scenario 3 – 2030 Development with DECCW Targets

5.1 Data Sources

Scenario 3 updated the Scenario 2 MUSIC model by replacing Council's stormwater treatment requirements, for the generic stormwater treatment devices, with the proposed DECCW stormwater targets.

The proposed DECCW stormwater targets were obtained from *Managing Urban Stormwater: Environmental Targets* (DECC and SMCMA, 2007).

DECCW Stormwater Targets

The DECCW stormwater targets, as a percentage reduction in the average annual loads, are given in **Table 5.1**.

Table 5.1: DECCW Stormwater Targets (After: DECC and SMCMA, 2007)

Pollutant	Stormwater Treatment Requirements
TSS	85%
TP	65%
TN	45%

5.2 MUSIC Inputs

Updated Generic Stormwater Treatment Devices

All generic stormwater treatment devices for the 16 intensified residential sub-catchments (**Table 4.4**) and the greenfields Somersby industrial development, incorporated in Scenario 2, were updated to the following common aggregated input properties in the Scenario 3 MUSIC model, in accordance with DECCW's requirements (**Table 5.1**):

- Low flow by-pass (m^3/s) 0
- High flow by-pass (m^3/s) 100
- Transfer functions
  - o TSS 85% reduction
  - o TP 65% reduction
  - o TN 45% reduction

6 Scenario 4 – Regional Treatment Devices

6.1 Data Sources

Scenario 4 modelled the full suite of management options for the Estuary suggested by Council or the community, where applicable, which addressed the management goal of Water and Sediment Quality. Eight management options, as listed in **Table 6.1**, were assessed for incorporation into the MUSIC model. Scenario 4 updated the Scenario 3 MUSIC model, assuming that Council adopts the DECCW stormwater targets (DECC and SMCMA, 2007) for future developments described in Scenario 3 by 2030.

Table 6.1: Management Options (Addressing Water and Sediment Quality Management Goals) Modelled in MUSIC for Scenario 4

EMS Option ID	Strategy Outline	Location
P05	Investigate the need for sediment traps and other stormwater management measures to control any erosion and sedimentation from sloping lands draining to the stormwater outlet opposite Byalla Lane.	Saratoga
W10	Remediate (or pipe) open drains and install sediment traps for those drains running from Wilkie King Ave and Mundoora Ave, Yattalunga.	Yattalunga
W04	Provide additional sediment traps for locations draining to Correa Bay. Sediment traps should target catchment inflows from the Bulls Hill Quarry and Garbage tip.	Correa Bay
W13	Develop and implement measures to address stormwater quality issues associated with runoff from fire trails on Blackwall Mountain.	Blackwall
W06	Install and maintain as required sediment traps targeting stormwater flows draining from the escarpment at Hardy's Bay.	Hardy's Bay
W17	Implement a program of maintenance to address the accumulation of litter in the open drain near Beach Street. Long term management of this issue should also be considered, for example, public education and/or the implementation of additional gross pollutant traps.	Ettalong
W14*	Develop and implement measures to address stormwater quality issues associated with runoff from the access road and fire trails near Fisherman's Parade.	Daley's Point
W01	Investigate options for implementing catchment-based WSUD features in the catchment in order to manage stormwater quality and quantity, with a priority focus on the Narara and Erina Creek catchments, followed by Kincumber Creek catchment.	Catchment-wide

* This option was not modelled in MUSIC.

Only one management option from **Table 6.1** was not modelled in MUSIC; W14. Based on the assessment of pits, pipes and topographic data this option was determined as not feasible as there is a lack of pits/pipes infrastructure in this area to incorporate an end of pipe GPT device and the area is too steep to facilitate WSUD features such as bioretention systems (which are generally most effective on flatter slopes). Further investigations are required at this site to identify suitable treatment options.

6.2 Regional Treatment Devices

The full suite of regional treatment devices, as indicated in **Table 6.2**, was incorporated into the MUSIC model for Scenario 4. Each 'Treatment Train' in **Table 6.2** involves the following devices in series: GPT (assumed to be a CDS Unit), Bioretention System and Rainwater Tank for irrigation purposes.

Table 6.2: Regional Treatment Devices Incorporated into Scenario 4

EMS Option ID	Adjusted MUSIC Sub-Catchment (i.e. Drains These Catchments)	WSUD Feature(s) Incorporated	Device Name in MUSIC	Major Tributary (i.e. Drains to These Tributaries)
P05	Saratoga1	GPT (CDS Unit)	Byalla Ln CDS	Direct to Brisbane Water
W10(1)	Saratoga1, Saratoga2	GPT (CDS Unit)	Wilkie King Ave CDS	Direct to Brisbane Water
W10(2)	Egan3	GPT (CDS Unit)	Mundoora Ave CDS	Direct to Brisbane Water
W04	W_Inlet9	Bioretention System	Bulls Hill Quarry Bioretention	Woy Woy Creek
W13	Woy_P9	GPT (CDS Unit)	Blackwall Mountain CDS	Direct to Brisbane Water
W06	Hardy4	GPT (CDS Unit)	Hardy's Bay CDS	Direct to Brisbane Water
W17	Woy_P11A	GPT (CDS Unit)	Ettalong Beach/Beach St CDS	Direct to Brisbane Water
W01	W_Gosford1	Treatment Train (1)*	Treatment Train 1	Direct to Brisbane Water
	Kincumber3, Kincumber25	Treatment Train (2)*	Treatment Train 2	Kincumber Creek
	Nunn2, Nunn3	Treatment Train (3)*	Treatment Train 3	Lower Erina Creek
	Hylton_Pk1, Hylton_Pk2, Hylton_Pk3	Treatment Train (4)*	Treatment Train 4	Lower Erina Creek
	W_Gosford3, W_Gosford4, W_Gosford5	Treatment Train (5)*	Treatment Train 5	Lower Narara Creek
	Wyoming1A	Treatment Train (6)*	Treatment Train 6	Lower Narara Creek
	Narara1, W_Gosford10A	Treatment Train (7)*	Treatment Train 7	Lower Narara Creek
	Fountain1A, Fountain3	Treatment Train (8)*	Treatment Train 8	Upper Narara Creek
	Caroline1, Caroline2, Caroline3	Treatment Train (9)*	Treatment Train 9	Direct to Brisbane Water

* Each Treatment Train involves the following devices in series: GPT (assumed to be a CDS Unit), Bioretention System and Rainwater Tank for irrigation purposes. Details and sizes of the features are described in the following sections.

The general locations of each of these regional treatment devices and the treatment trains within the Brisbane Water Catchment are indicated on **Figure 6**.

Table 6.2 also indicates which major tributaries each of these regional treatment devices drain to. Eight devices drain directly to Brisbane Water, while four drain to Narara Creek and two drain to Erina Creek. One device (W04) drains to Woy Woy Creek, which feeds into Correa Bay, and one Treatment Train drains to Kincumber Creek.

The locations of each of these regional treatment devices were determined based on desktop assessments, using GIS layers of pits, pipes, 2m contours, waterways (such as creeks and major tributaries) and recent aerial photography. It should be noted that these locations are approximate and no site-specific assessments have been undertaken to evaluate the engineering feasibility or practical implications of these devices in these areas i.e. available space for a CDS unit of a specific size. The treatment devices assessed in this scenario cannot be directly implemented to improve sediment and water quality in the catchment without further assessment. Prior to implementation of any of the devices incorporated in this scenario, a detailed social, environmental and economic assessment on a localised scale would need to be undertaken and site-specific practicalities such as site access to the devices for maintenance would need to be considered.

Gross Pollutant Traps

CDS Units were selected to treat the management options which identified sedimentation issues. Each of the CDS Units incorporated into Scenario 4 had the same treatment capacities as the CDS Units incorporated into Scenario 2 and provided in **Table 6.3**. CDS Units are generally more effective in retaining suspended solids and particulate matter than treating TP and TN, as indicated in **Table 6.3**.

Table 6.3: MUSIC Input Parameters for CDS Unit Treatment Efficiencies for Scenario 4

Parameter	CDS Unit
Low Flow By-pass (m^3/s)	0*
High Flow By-pass (m^3/s)	0.4*
TSS Reduction	70% (between 75 and 700mg/L)
TP Reduction	30% (between 0.5 and 4.5mg/L)
TN Reduction	0%
Performance Data Source(s)	Rocla and CRC for Catchment Hydrology, 2005

* These values have been assumed.

The catchment areas draining to the CDS Units identified in **Table 6.2** are contained in **Table 6.4**. The source nodes in MUSIC were adjusted as necessary to represent these treated catchment areas, which are also indicated on **Figure 7**.

Table 6.4: CDS Unit and Bioretention System Treatment Areas for Scenario 4

EMS Option ID	Treatment Device	Device Treatment Area (ha)	MUSIC Sub-Catchments Drained	Device Treatment Area From Each Sub-Catchment (ha)
P05	CDS Unit	8	Saratoga1(2)	8
W10(1)	CDS Unit	24	Saratoga1(3)	10
	CDS Unit		Saratoga2	14
W10(2)	CDS Unit	2	Egan3(2)	2
W04	Bioretention System	37	W_Inlet9	37
W13	CDS Unit	5	Woy_P9(2)	5
W06	CDS Unit	5	Hardy4(2)	5
W17	CDS Unit	61	Woy_P11A(2)	61

Bioretention Systems

A Bioretention System was selected to treat the stormwater from the Bulls Hill Quarry, to also target TP and TN as well as reduce the sediment pollutant loads from the site. The treatment area for the Bioretention System is indicated in **Table 6.4** and **Figure 7**, and encompasses the entire Bulls Hill Quarry site. No suitable location for a similar Bioretention System could be found for the Garbage tip site based on the information available (as noted in **Table 6.1**; also referred to as the Woy Woy Waste Disposal Depot), hence this aspect of Management Option W04 was not modelled.

Treatment Trains

To address the catchment-wide Management Option W01, the following approach was used:

- Recent aerial photography was inspected to locate playing fields and reserves within the study area where irrigation is likely required, and then these areas were mapped as 'Tank Irrigation Areas';
- Available GIS layers were inspected to roughly determine suitable locations for Bioretention Systems, proximal to these areas requiring irrigation; and
- The priority focus for these treatment trains was in the Narara and Erina Creek catchments, followed by the Kincumber Creek catchment, to reduce pollutant loading within these Creeks.

Each Treatment Train incorporates a GPT (CDS Unit) for initial treatment, followed by a Bioretention System for further, extended treatment of pollutants, followed by a rainwater tank to collect stormwater for irrigation of the indicated playing fields and reserves (**Figure 7**). The general setup of this Treatment Train in MUSIC can be seen in **Figure 8**.

The catchment areas draining to the 'Treatment Trains' identified in **Table 6.2** are contained in **Table 6.5**. The source nodes in MUSIC were adjusted as necessary to represent these catchment areas, which are also indicated on **Figure 7**.

Table 6.5: Treatment Train Catchment Areas for Scenario 4

EMS Option ID	Treatment Device	Nominated Playing Field / Reserve for Rainwater Tank Irrigation	Device Catchment Area (ha)	MUSIC Sub-Catchments Drained*	Device Catchment Area From Each Sub-Catchment (ha)
W01	Treatment Train 1	Garnet Adcock Memorial Park	26	W_Gosford1	26
	Treatment Train 2	Frost Reserve	28	Kincumber3(2)	4
				Kincumber25(2)	24
	Treatment Train 3	Erina Oval	32	Nunn2(2)	4
				Nunn3(2)	28
	Treatment Train 4	Hylton Moore Park	161	Hylton_Pk1(2)	20
				Hylton_Pk2	106
				Hylton_Pk3	35
	Treatment Train 5	Victoria Park (Gosford Golf Course)	82	W_Gosford3(2)	26
				W_Gosford4	17
				W_Gosford5(2)	39
	Treatment Train 6	Alan Davidson Park	8	Wyoming1A(2)	8
	Treatment Train 7	Gavenlock Oval	10	Narara1(2)	3
				W_Gosford10A(2)	7
	Treatment Train 8	Narara Valley High School Playing Fields	46	Fountain1A(2)	39
				Fountain3(2)	7
	Treatment Train 9	St Edwards Christian Brothers School Playing Fields	58	Caroline1(2)	5
				Caroline2(2)	35
				Caroline3(2)	18

* If the MUSIC Sub-Catchment name is suffixed by (2), this indicates that the original MUSIC node was split, as indicated in **Figure 8**, so that part of the catchment flow could be routed through the relevant treatment device.

The GPT (CDS Unit) component of each Treatment Train was set to the same treatment efficiencies as per **Table 6.3**. Specific inputs into MUSIC are detailed in **Section 6.3**.

The Bioretention System component followed the GPT in each Treatment Train. These treatment devices were approximately sized based on available space through inspection of recent aerial photography. Specific inputs into MUSIC are detailed in **Section 6.3**.

Lastly, the Rainwater Tank component followed the Bioretention System in each Treatment Train. These rainwater tanks were all set to a standard large size of 350kL, as these was considered to be the largest tank size feasible at the majority of the sizes. The purpose of these tanks is to collect stormwater, via the pits and pipe system, from the entire treatment area, for irrigation use on the nominated playing fields and reserves (listed in **Table 6.5**). In order to calculate the daily demand irrigation requirements for each playing field/reserve, the areal potential evapotranspiration data input into the MUSIC model was used to determine how demand might vary monthly over the course of an average rainfall year. The evapotranspiration data (mm) was also used to determine how much moisture would be lost from the area of each playing field/reserve (m^2), and hence what volume of water (m^3) would be required to replace this, assuming no rainfall occurs.

The monthly areal potential evapotranspiration data used, taken from the *Climate Atlas of Australia* (BoM, 2003) and results of this analysis are contained in **Table 6.6**.

Table 6.6: Monthly Areal Potential Evapotranspiration

Month	Monthly Areal Potential Evapotranspiration (mm)	Percentage of Annual (%)
January	179	14
February	142	11
March	139	11
April	91	7
May	57	4
June	44	3
July	47	4
August	62	5
September	89	7
October	130	10
November	153	12
December	164	13
Annual	**1297**	**100**

Specific inputs into MUSIC for each Rainwater Tank are detailed in **Section 6.3**.

6.3 MUSIC Inputs

Gross Pollutant Traps

All GPTs (CDS Units) incorporated in Scenario 4 had the following common aggregated input properties in the MUSIC model, based on product information (Rocla) and the MUSIC Manual (CRC for Catchment Hydrology, 2005):

- Low flow by-pass (m^3/s) 0
- High flow by-pass (m^3/s) 0.4
- Transfer functions
  - TSS 70% reduction (between 75 and 700mg/L)
  - TP 30% reduction (between 0.5 and 4.5mg/L)
  - TN 0% reduction

Bioretention Systems

All Bioretention Systems incorporated in Scenario 4 had the following common aggregated input properties in the MUSIC model. These properties were assumed based on standard practice.

- Low flow by-pass (m^3/s) 0
- High flow by-pass (m^3/s) 100
- Extended detention depth (m) 0.15
- Seepage loss (mm/hr) 0
- Filter depth (m) 0.6
- Filter median particle diameter (mm) 5
- Saturated hydraulic conductivity (mm/hr) 100
- Depth below underdrain pipe (% of Filter depth) 17
- Overflow weir width (m) 5

It was assumed that the Bioretention Systems would be lined to prevent infiltration to groundwater; hence seepage loss was assumed to be 0mm/hr.

Table 6.7 provides the specific Bioretention System input properties that were calculated for each Bioretention System for the MUSIC model.

Table 6.7: Bioretention System Inputs into MUSIC

Device Name	Approximate Surface Area (m^2)	Approximate Filter Area (m^2)*
Bulls Hill Quarry Bioretention	12,120	12,120
BioR1 (of WSUD Treatment Train 1)	2,200	2,200
BioR2 (of WSUD Treatment Train 2)	2,820	2,820
BioR3 (of WSUD Treatment Train 3)	1,900	1,900
BioR4 (of WSUD Treatment Train 4)	8,850	8,850
BioR5 (of WSUD Treatment Train 5)	7,100	7,100
BioR6 (of WSUD Treatment Train 6)	4,450	4,450
BioR7 (of WSUD Treatment Train 7)	1,100	1,100
BioR8 (of WSUD Treatment Train 8)	12,080	12,080
BioR9 (of WSUD Treatment Train 9)	5,000	5,000

* The filter area was set equal to the surface area. In doing this, it is being assumed that the Bioretention System is a box shape, with vertical side slopes, as opposed to a trapezoidal shape with sloping sides. This is reasonable for the purposes of this assessment.

Rainwater Tanks

All Rainwater Tanks incorporated in Scenario 4 had the following common aggregated input properties in the MUSIC model. These properties were assumed based on standard practice.

- Low flow by-pass (m^3/s) 0
- High flow by-pass (m^3/s) 100
- Volume below overflow pipe (kL) 350
- Depth above overflow (m) 0.2
- Surface area (m^2) 120
- Overflow pipe diameter (mm) 225

It was assumed, for practical reasons, that no tanks greater than 350kL would be installed. Assuming a height of approximately 3m for these tanks, a surface area of approximately 120m^2 was assumed. Elements of the concept design of these tanks (i.e. whether they would be located above or below ground) have not been considered in this assessment and would need to be investigated further on a site-specific and localised scale.

Table 6.8 provides the specific Rainwater Tank input properties that were calculated for each Rainwater Tank for the MUSIC model, based on irrigation requirements, as explained in **Section 6.2**.

Table 6.8: Rainwater Tank Inputs into MUSIC

Device Name	Approximate Annual Demand (kL/year)*
Tank1 (of WSUD Treatment Train 1)	140,600
Tank2 (of WSUD Treatment Train 2)	55,100
Tank3 (of WSUD Treatment Train 3)	27,000
Tank4 (of WSUD Treatment Train 4)	11,500
Tank5 (of WSUD Treatment Train 5)	539,000
Tank6 (of WSUD Treatment Train 6)	46,100
Tank7 (of WSUD Treatment Train 7)	22,600
Tank8 (of WSUD Treatment Train 8)	85,700
Tank9 (of WSUD Treatment Train 9)	50,500

* The total kL per year reported here, as Annual Demand, is distributed according to the distribution given in **Table 6.6**.

7 Scenario 5 – Selected Regional Treatment Devices

7.1 Data Sources

Scenario 5 updated the Scenario 4 MUSIC model and provides Council with the top five most effective regional treatment devices, based on the management options presented in the Brisbane Water EMS. It is considered that these five most effective regional treatment devices various target 'hotspot' areas and major tributaries within the Brisbane Water catchment and can feasibly be implemented by Council in the next five to ten years.

7.2 Selected Regional Treatment Devices

A comparison was made between the 16 modelled regional treatment devices from Scenario 4, assessing how effective each device was in removing pollutant loads from Brisbane Water. The 16 devices were ranked to determine the top five, according to which captured and removed the most pollutants from the system. Only the key pollutants TSS, TP and TN (key aquatic ecosystem stressors) were considered. The results of the ranking are shown in **Table 7.1**.

Table 7.1: Ranking of Scenario 4 Regional Treatment Devices by Effectiveness

EMS Option ID	Annual Load Removed by Device (kg/yr)			Sum of Load Removed (kg/yr)	Ranking^
	TSS	TP	TN		
P05	1,862	0	0	1,862	-
W10(1)	1,757	0	0	1,757	-
W10(2)	470	0	0	470	-
W04	69,647	39	246	69,932	1
W13	0	0	0	0	-
W06	814	0	0	814	-
W17	10,486	0	0	10,486	-
W01(TT1)	3,853	7	59	3,920	-
W01(TT2)	15,367	34	184	15,585*	5*
W01(TT3)	16,212	33	169	16,414	-
W01(TT4)	62,250	125	599	62,975	2
W01(TT5)	1,062	9	102	1,173	-
W01(TT6)	5,510	13	81	5,605	-
W01(TT7)	4,907	11	60	4,977	-
W01(TT8)	20,787	45	237	21,068	4
W01(TT9)	22,468	47	249	22,763	3

^ The ranking is colour coded as follows: Yellow = 1st, Purple = 2nd, Pink = 3rd, Green = 4th and Blue = 5th.

* Treatment Train 2 (TT2) was selected over Treatment Train 3 (TT3), even though TT3 had the higher Total Load Captured, because a greater weighting was given to TP and TN here, over TSS. The modelling indicates that TT2 captures and retains both TP and TN more effectively than TT3.

Table 7.2 is the list of the top five selected regional treatment devices, which were incorporated into the Scenario 5 MUSIC model. All device details were as given in Scenario 4 (**Section 4**).

Table 7.2: Selected Regional Treatment Devices Incorporated into Scenario 5

EMS Option ID	WSUD Feature	Major Tributary (i.e. Drains to These Tributaries)
W04	Bulls Hill Quarry Bioretention System	Woy Woy Creek
W01 (TT2)	Treatment Train 2*	Kincumber Creek
W01 (TT4)	Treatment Train 4*	Lower Erina Creek
W01 (TT8)	Treatment Train 8*	Upper Narara Creek
W01 (TT9)	Treatment Train 9*	Direct to Brisbane Water

* Each Treatment Train involves the following devices in series: GPT (assumed to be a CDS Unit), Bioretention System and Rainwater Tank for irrigation purposes.

8 Results

8.1 Scenario 1

The results from Scenario 1, incorporating GPTs into the Brisbane Water MUSIC model, are given in **Table 8.1**.

Table 8.1: Scenario 1 Annual Loads for Representative Average Year (1995) with GPTs

Location	Area (ha)	Annual Flow (ML/yr)	Runoff Coefficient	Annual Loads (kg/yr)			Percentage Change from Baseline Model (%)		
				TSS	TP	TN	TSS	TP	TN
Upper Narara	2,811	8,920	0.26	831,000	1,810	15,000	0.0	0.0	0.0
Lower Narara	4,565	16,800	0.30	1,670,000	3,810	30,500	-0.6	-0.3	-0.3
Upper Erina	1,926	4,380	0.18	245,000	541	5,420	-0.4	0.0	0.0
Lower Erina	3,252	9,310	0.23	771,000	1,860	15,500	-0.4	0.0	0.0
Kincumber Creek	484	2,050	0.34	225,000	599	4,500	-5.5	-0.8	-0.9
Woy Woy Creek	588	1,760	0.24	167,000	260	2,470	0.0	0.0	0.0
Ettalong Creek	780	3,350	0.35	346,000	979	7,080	-0.6	-0.2	0.0
Coorumbine Creek	361	1,450	0.33	160,000	329	2,710	0.0	0.0	0.0
Direct to Brisbane Water	1,699	10,480	0.50	1,185,000	3,812*	25,820*	-2.5	0.4*	0.5*
Total Catchment	**16,466**	**58,500**	**0.29**	**5,600,000**	**14,000**	**109,000**	**-1.1**	**0.0**	**0.0**

* The calculated increase in TP and TN; 0.4% and 0.5% respectively, is likely erroneous due to the rounding of MUSIC outputs from the baseline model (see **Table 2.1** for discussion) and can reasonably be assumed to be 0% and 0% respectively i.e. no change in the loads of TP and TN for Scenario 1.

8.2 Scenario 2

The results from Scenario 2, with 25% intensification of Gosford and Woy Woy residential areas (brownfields development) and the proposed Somersby industrial development (greenfields development) in the 2030 Brisbane Water MUSIC model are given in **Table 8.2**. These, and subsequent results, have been compared with the Scenario 1 results, as Scenario 1 represents a less conservative and more realistic assessment of pollutant loads than the baseline condition.

Table 8.2: Scenario 2 Annual Loads for Representative Average Year (1995) with 25% Intensification and Greenfields Development for 2030

Location	Area (ha)	Annual Flow (ML/yr)	Runoff Coefficient	Annual Loads (kg/yr)			Percentage Change from Scenario 1 (%)		
				TSS	TP	TN	TSS	TP	TN
Upper Narara	2,811	9,020	0.26	820,000	1,810	15,000	-1.3	0.0	0.0
Lower Narara	4,565	17,300	0.31	1,590,000	3,780	30,400	-4.8	-0.8	-0.3
Upper Erina	1,926	4,380	0.18	245,000	541	5,420	0.0	0.0	0.0
Lower Erina	3,252	9,310	0.23	771,000	1,860	15,500	0.0	0.0	0.0
Kincumber Creek	484	2,050	0.34	225,000	599	4,500	0.0	0.0	0.0
Woy Woy Creek	588	1,760	0.24	167,000	260	2,470	0.0	0.0	0.0
Ettalong Creek	780	3,500	0.36	326,000	988	7,170	-5.8	0.9	1.3
Coorumbine Creek	361	1,530	0.34	145,000	339	2,760	-9.4	3.0	1.8
Direct to Brisbane Water	1,699	11,250	0.54	1,101,000	3,923	26,780	-9.5	3.4	4.3
Total Catchment	**16,466**	**60,100**	**0.30**	**5,390,000**	**14,100**	**110,000**	**-3.8**	**0.7**	**0.9**

8.3 Scenario 3

The results from Scenario 3, which updated the Scenario 2 MUSIC model to incorporate the DECCW stormwater targets (DECC and SMCMA, 2007) in place of Council's current stormwater treatment requirements (GCC, 2007) for the generic stormwater treatment devices, are given in **Table 8.3**.

Table 8.3: Scenario 3 Annual Loads for Representative Average Year (1995), Updating Scenario 2 with DECCW Stormwater Targets for Generic Stormwater Treatment Devices

Location	Area (ha)	Annual Flow (ML/yr)	Runoff Coefficient	Annual Loads (kg/yr)			Percentage Change from Scenario 1 (%)		
				TSS	TP	TN	TSS	TP	TN
Upper Narara	2,811	9,020	0.26	819,000	1,790	15,000	-1.4	-1.1	0.0
Lower Narara	4,565	17,300	0.31	1,580,000	3,680	30,400	-5.4	-3.4	-0.3
Upper Erina	1,926	4,380	0.18	245,000	541	5,420	0.0	0.0	0.0
Lower Erina	3,252	9,310	0.23	771,000	1,860	15,500	0.0	0.0	0.0
Kincumber Creek	484	2,050	0.34	225,000	599	4,500	0.0	0.0	0.0
Woy Woy Creek	588	1,760	0.24	167,000	260	2,470	0.0	0.0	0.0
Ettalong Creek	780	3,500	0.36	317,000	929	6,980	-8.4	-5.1	-1.4
Coorumbine Creek	361	1,530	0.34	143,000	328	2,760	-10.6	-0.3	1.8
Direct to Brisbane Water	1,699	11,250	0.54	1,063,000	3,613	24,970	-12.6	-4.8	-2.8
Total Catchment	**16,466**	**60,100**	**0.30**	**5,330,000**	**13,600**	**108,000**	**-4.8**	**-2.9**	**-0.9**

8.4 Scenario 4

The results from Scenario 4, which updated the Scenario 3 MUSIC model to incorporate a suite of regional treatment devices that correlated with management options assessed in the Brisbane Water EMS, are given in **Table 8.4**.

It should be noted that the percentage change from previous results has been calculated in comparison to Scenario 3 results, rather than Scenario 1 results. This provides a better indication of pollutant load reductions achieved by the regional treatment devices.

Table 8.4: Scenario 4 Annual Loads for Representative Average Year (1995), Incorporating a Suite of Regional Treatment Devices

Location	Area (ha)	Annual Flow (ML/yr)	Runoff Coefficient	Annual Loads (kg/yr)			Percentage Change from Scenario 3 (%)		
				TSS	TP	TN	TSS	TP	TN
Upper Narara	2,811	8,990	0.26	798,000	1,750	14,800	-2.6	-2.2	-1.3
Lower Narara	4,565	17,100	0.30	1,520,000	3,550	29,700	-3.8	-3.5	-2.3
Upper Erina	1,926	4,380	0.18	245,000	541	5,420	0.0	0.0	0.0
Lower Erina	3,252	9,280	0.23	693,000	1,700	14,700	-10.1	-8.6	-5.2
Kincumber Creek	484	2,020	0.34	209,000	565	4,310	-7.1	-5.7	-4.2
Woy Woy Creek	588	1,760	0.24	97,300	220	2,230	-41.7	-15.4	-9.7
Ettalong Creek	780	3,500	0.36	317,000	929	6,980	0.0	0.0	0.0
Coorumbine Creek	361	1,530	0.34	143,000	328	2,760	0.0	0.0	0.0
Direct to Brisbane Water	1,699	11240	0.54	1,037,700	3,617	25,100	-2.4	0.1*	0.5*
Total Catchment	**16,466**	**59,800**	**0.29**	**5,060,000**	**13,200**	**106,000**	**-5.1**	**-2.9**	**-1.9**

* The calculated increase in TP and TN by 0.1% and 0.5% respectively from Scenario 3 results is likely erroneous due to the rounding of MUSIC outputs from the baseline model and can reasonably be assumed to be 0% and 0% respectively i.e. no change in the loads of TP and TN from Scenario 3.

8.5 Scenario 5

The results from Scenario 5, which refined the Scenario 4 MUSIC model by selecting only the top five most effective regional treatment devices, are given in **Table 8.5**.

It should be noted that the percentage change from previous results has been calculated in comparison to Scenario 3 results, rather than Scenario 1 results. This provides a better indication of pollutant load reductions achieved by the regional treatment devices.

Table 8.5: Scenario 5 Annual Loads for Representative Average Year (1995), Incorporating the Selected Regional Treatment Devices

Location	Area (ha)	Annual Flow (ML/yr)	Runoff Coefficient	Annual Loads (kg/yr)			Percentage Change from Scenario 3 (%)		
				TSS	TP	TN	TSS	TP	TN
Upper Narara	2,811	8,990	0.26	798,000	1,750	14,800	-2.6	-2.2	-1.3
Lower Narara	4,565	17,300	0.31	1,560,000	3,630	30,200	-1.3	-1.4	-0.7
Upper Erina	1,926	4,380	0.18	245,000	541	5,420	0.0	0.0	0.0
Lower Erina	3,252	9,300	0.23	709,000	1,740	14,900	-8.0	-6.5	-3.9
Kincumber Creek	484	2,020	0.34	209,000	565	4,310	-7.1	-5.7	-4.2
Woy Woy Creek	588	1,760	0.24	97,300	220	2,230	-41.7	-15.4	-9.7
Ettalong Creek	780	3,500	0.36	317,000	929	6,980	0.0	0.0	0.0
Coorumbine Creek	361	1,530	0.34	143,000	328	2,760	0.0	0.0	0.0
Direct to Brisbane Water	1,699	11220	0.54	1,051,700	3,597	25,400	-1.1	-0.4	1.7*
Total Catchment	**16,466**	**60,000**	**0.30**	**5,130,000**	**13,300**	**107,000**	**-3.8**	**-2.2**	**-0.9**

* The calculated increase in TN by 1.7% from Scenario 3 results is likely erroneous due to the rounding of MUSIC outputs from the baseline model and can reasonably be assumed to be 0% i.e. no change in the loads of TN from Scenario 3.

9 Discussion and Outcomes

The annual loads presented in **Section 8** indicate pollutant loads from the main tributaries within the model and the smaller sub-catchments which drain directly to Brisbane Water.

9.1 Scenario 1

Scenario 1 indicated no substantial changes to pollutant loads from the baseline conditions due to the 11 modelled GPTs. An overall reduction in TSS delivered to Brisbane Water by 1.1% was noted, with no overall change to the loads of TP and TN delivered.

Scenario 1 showed that the Narara Creek catchment still represents the largest contributor of pollutant loads to Brisbane Water with existing GPTs; being approximately 42% of the total load. The Erina Creek catchment still produces approximately 18% of the pollutant load, while the smaller major tributaries still contribute a total of approximately 16%.

The sub-catchments that drain directly to the Brisbane Water Estuary, such as highly developed foreshore catchments, still represent approximately 24% of the total pollutant load that enters Brisbane Water.

The Kincumber Creek and Ettalong Creek catchments and the sub-catchments that drain directly to Brisbane Water still produce the greatest pollutant loads per hectare, compared to the other major tributaries of Brisbane Water.

9.2 Scenario 2

Scenario 2 indicated that intensified residential development by 2030 will not have a substantial impact on the overall pollutant loads delivered to Brisbane Water from the catchment if stormwater treatment devices, including rainwater tanks, are implemented in accordance with Gosford City Council's Stormwater Guidelines (2007). An overall reduction in TSS and minor overall increases (less than 1%) of TP and TN delivered to Brisbane Water is noted due to new development with associated treatment (**Table 8.2**).

Changes to pollutant loads from Coorumbine Creek for Scenario 2 are solely due to the land use change for the proposed portion of the Somersby industrial development. There was an increase in loads of TP and TN (3% and 1.8%, respectively) from this major tributary (**Table 8.2**). This can in part be explained by the absence of the use of rainwater tank treatment within the treatment train at this site (the demand is potentially low but dependent on the type of industry that could be expected), but is also due to the high impervious areas and pollutant loads associated with industrial sites. These results indicate that, even with the application of Council's current stormwater targets for the Narara Creek Catchment, a slight overall increase in TP and TN pollutant loads from this tributary will be delivered to Brisbane Water.

An increase in loads of TP and TN (3.4% and 4.3%, respectively) was also noted for sub-catchments that drain directly to Brisbane Water (**Table 8.2**). There are two factors driving this increase. Firstly, the increase in impervious areas (to 90%) for these intensified catchments will lead to increased runoff and hence increased pollutant loads. Secondly, all intensified sub-catchments that drain directly to Brisbane Water are located within the

Brisbane Water Catchment and therefore Council's less stringent stormwater requirements (see **Table 4.3**) were applied to generic treatment devices for these areas. These results indicate that, even with the application of Council's current stormwater targets for the Brisbane Water Catchment, a slight overall increase in TP and TN pollutants loads from these direct sub-catchments will be delivered to Brisbane Water.

9.3 Scenario 3

If Council were to adopt DECCW's targets for stormwater treatment requirements for future developments, Scenario 3 indicates that an overall and more substantial reduction in pollutants in Brisbane Water would be achieved compared with Scenario 2 (**Table 8.2**).

Notably Scenario 3 results in a decrease in TSS and TP pollutants loads delivered from Coorumbine Creek due to part of the proposed Somersby industrial development, but not a decrease in TN. This indicates that DECCW's targets are effective in reducing pollutant loads for TP from the proposed Somersby industrial site (**Table 8.3**), where Council's current targets were less so. However, more stringent targets for the site are required to reduce TN loads in Coorumbine Creek to maintain the loads at existing levels (i.e. no change).

Scenario 3 also results in a decrease in all pollutants delivered from sub-catchments draining directly to Brisbane Water. This indicates that DECCW's targets are relatively effective in reducing pollutant loads for TP and TN from intensified residential areas such that the current loads are not exceeded.

9.4 Scenario 4

Scenario 4 incorporated 16 regional treatment devices into the Scenario 3 MUSIC Model, including GPTs (assumed to be CDS Units), Bioretention Systems, Rainwater Tanks and Treatment Trains combining all three device types. The 16 regional treatment devices directly relate to the relevant Management Options presented in the Brisbane Water EMS.

Scenario 4 indicates that the implementation of these regional treatment devices throughout the Brisbane Water catchment would reduce TSS, TP and TN annual pollutant loads to Brisbane Water Estuary by 5.1%, 2.9% and 1.9% respectively (**Table 8.4**), compared with Scenario 3 results.

All of the standalone GPT devices modelled drain directly to Brisbane Water. **Table 8.4** indicates that generally these GPT devices, when used alone, are not effective in reducing TP and TN loadings and only reduce TSS loadings by a minimal amount. The most substantial reduction in pollutant loads is evident in Woy Woy Creek, which drains to Correa Bay. These results are due solely to Management Option W04, which incorporated a standalone Bioretention System to treat stormwater from the Bulls Hill Quarry site.

9.5 Scenario 5

The top five most effective regional treatment devices from Scenario 4 were selected for incorporation into the Scenario 5 MUSIC Model. An analysis of the treatment efficiencies of the devices and the incoming pollutant loads being treated was undertaken (**Table 7.1**) and indicated that the Bulls Hill Quarry Bioretention System (Management Option W04) was the most effective treatment device of those evaluated, followed by the multi-device Treatment Trains 2, 4 8 and 9 (Management Option W01). These types of WSUD features are able to treat nutrients (TP and TN), as well as suspended solids (TSS).

Scenario 5 indicates that the implementation of these top five most effective regional treatment devices throughout the Brisbane Water catchment would reduce TSS, TP and TN annual pollutant loads to Brisbane Water Estuary by 3.8%, 2.2% and 0.9% respectively (**Table 8.5**), compared with Scenario 3 results.

When analysed on an overall basis this change may not appear significant, but when the results are considered on a more localised level, focusing on pollutant loads to the major tributaries of Brisbane Water, much more substantial reductions are tangible. For example results for the Bulls Hill Quarry Bioretention System indicate a reduction in TSS, TP and TN loads by 41.7%, 15.4% and 9.7%, respectively for that catchment (**Table 8.5**), which is a significant local reduction in pollutant loading.

9.6 Relationship Between Catchment Loads and Estuary Responses

The relationship between catchment loads and estuary response, in terms of estuarine hydraulic processes, morphology and siltation, and water quality processes, was considered explicitly using DELFT3D modelling for the *Brisbane Water Estuary Processes Study* (Cardno, 2008). Whilst MUSIC modelling was undertaken to evaluate catchment loads, no further DELFT3D modelling was undertaken for this report to explicitly consider estuarine responses. Instead, these responses have been inferred from the previous DELFT3D modelling.

The results of the DELFT3D modelling are presented in full in the Estuary Processes Study (Cardno, 2008). The relevant key findings of this DELFT3D modelling and any impacts/changes to this modelling as a result of the MUSIC modelling undertaken in this report are discussed below.

Flushing Times and Water Quality: Flushing of the Brisbane Water Estuary is generally complex, being of relatively short duration at locations strongly influenced by tides (such as The Rip and Ettalong), and longer in areas further upstream and in embayments. Flushing is the primary control on water quality through the dispersion and dilution of pollutants and promotion of mixing (Cardno, 2008). For example, DELFT3D modelling determined that the Gosford Broadwater has a flushing time of up to 30 days. Narara Creek, which flows to the Gosford Broadwater, is a major source of nutrients and suspended solids (**Section 8**). Therefore, water quality in the Gosford Broadwater may be compromised in this location due to the coincidence of elevated catchment loads and relatively long flushing times. Nonetheless, water quality data analysis in the Estuary Processes Study (Cardno, 2008) indicated a general trend towards water quality improvement in more recent years, although whether this is due to catchment based controls or changing rainfall patterns (i.e. drought) is unclear.

Sediments and Sedimentation: Estuarine geomorphology is a result of interactions between catchment inputs and coastal/estuarine processes. Bed sediments may be sourced from catchment inflows (fluvial) or marine inputs. The present rate (with existing

GPTs) at which sediments are delivered to the Estuary was determined in Scenario 1 to be approximately 5.6 million kg/year (**Table 8.1**). Where land use changes occur in the catchment, such as the proposed Somersby industrial development, the annual load of sediment inputs from the catchment may be affected. Industrial sites generally have high impervious areas and hence larger runoff. However, if stormwater treatment devices are used effectively, increased sediment loads can be mitigated. Scenario 3 indicates that, with DECCW stormwater targets in place and new developments and residential intensification by 2030, this sediment delivery rate could by reduced to approximately 5.3 million kg/year (**Table 8.3**), if effective stormwater treatment devices are incorporated. The proportional contributions of the major tributaries and sub-catchments that drain directly to Brisbane Water are indicated in **Section 8**.

Heavy Metal Contamination: Human activities can impact on the quality of sediments via the introduction of a range of pollutants, including heavy metals. The Estuary Processes Study (Cardno, 2008) identified that lead, copper and zinc were present in the highest concentrations. These metals are associated with roads and some industrial activities. The most significant source of heavy metal contaminants appeared to be Narara Creek, followed by Erina Creek (Cardno, 2008). These results concur with the MUSIC catchment modelling results for TSS, as indicated in **Section 8**. The results are consistent with land use, high runoff volumes, high concentrations of contaminants and larger sizes of the respective sub-catchments. Heavy metal contamination is most pronounced in the northern reaches of the Brisbane Water Estuary (Cardno, 2008). The implications of heavy metal contamination for the scenarios considered are further discussed under Ecological and Recreational Impacts.

Transient Conditions and Wet Weather: DELFT3D modelling (Cardno, 2008) showed that TP and TN introduced to the Estuary by freshwater inflows were generally found to exhibit similar characteristics, with a noticeable stratification effect in nutrient concentrations related to freshwater flows overlying saline flows. Tidal flows are one of the primary factors governing mixing and flushing in estuarine environments. DELFT3D modelling (Cardno, 2008) showed that in the lower reaches of the Estuary (Paddy’s Channel, Lintern Channel, St Hubert’s Island, The Rip, Entrance Channel and Pretty Beach) nutrient concentrations fluctuated with the tides and waters appeared well mixed with little difference between surface and bed waters. These results concurred with the findings relating to flushing times of the different parts of the Estuary; flushing times for locations south of The Rip were of the order of 2 to 3 days (Cardno, 2008).

Analysis of water quality data in the Estuary Processes Study found that in 2001 and 2002, the highest nutrient concentrations were observed at Narara, Erina and Kincumber Creeks, which is consistent with MUSIC catchment modelling for all Scenarios. Narara and Erina Creek also recorded higher average nutrient concentrations in 2006 and 2007 (Cardno, 2008). However, Woy Woy and Cockle Creeks also appear to be important sources of TN and TP. In general, Booker Bay has lower average nutrient concentrations, likely due to higher rates of flushing at this location by marine water (Cardno, 2008). The implications of elevated nutrient concentrations for the scenarios considered are further discussed under Ecological and Recreational Impacts.

Ecological and Recreational Impacts: Based on the water quality data used to assess ambient water quality in the Estuary Processes Study (Cardno, 2008), as well as modelling of transient conditions, it is apparent that water quality is an issue for the Brisbane Water Estuary, particularly with respect to nutrient and sediment inputs and heavy metals. MUSIC modelling undertaken for this report indicated no significant changes to TSS, TP and TN inputs into Brisbane Water by 2030 (Scenario 3), indicating approximately a 5%, 3% and 1% decrease for TSS, TP and TN loads delivered to Brisbane Water respectively (**Table 8.3**). As heavy metals are generally associated with finer particles, they are likely to enter the Brisbane Water Estuary attached to fine suspended solids (TSS). Hence, under Scenario 3, an associated minor decrease in heavy metal loads may be inferred from a minor overall decrease in delivered TSS loads.

Climate Change Scenarios: A comparison between wet and dry years in the Estuary Processes Study (Cardno, 2008) suggests that predicted changes in rainfall patterns may lead to a decline in water quality (e.g. wetter periods are likely to result in higher loads of pollutants delivered to the Estuary, while dryer periods will result in lower loads of pollutants delivered to the Estuary). Overall, the future rainfall predictions vary for climate change, but CSIRO and BoM (2007) indicates an average annual reduction in rainfall.

10 References

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Figures

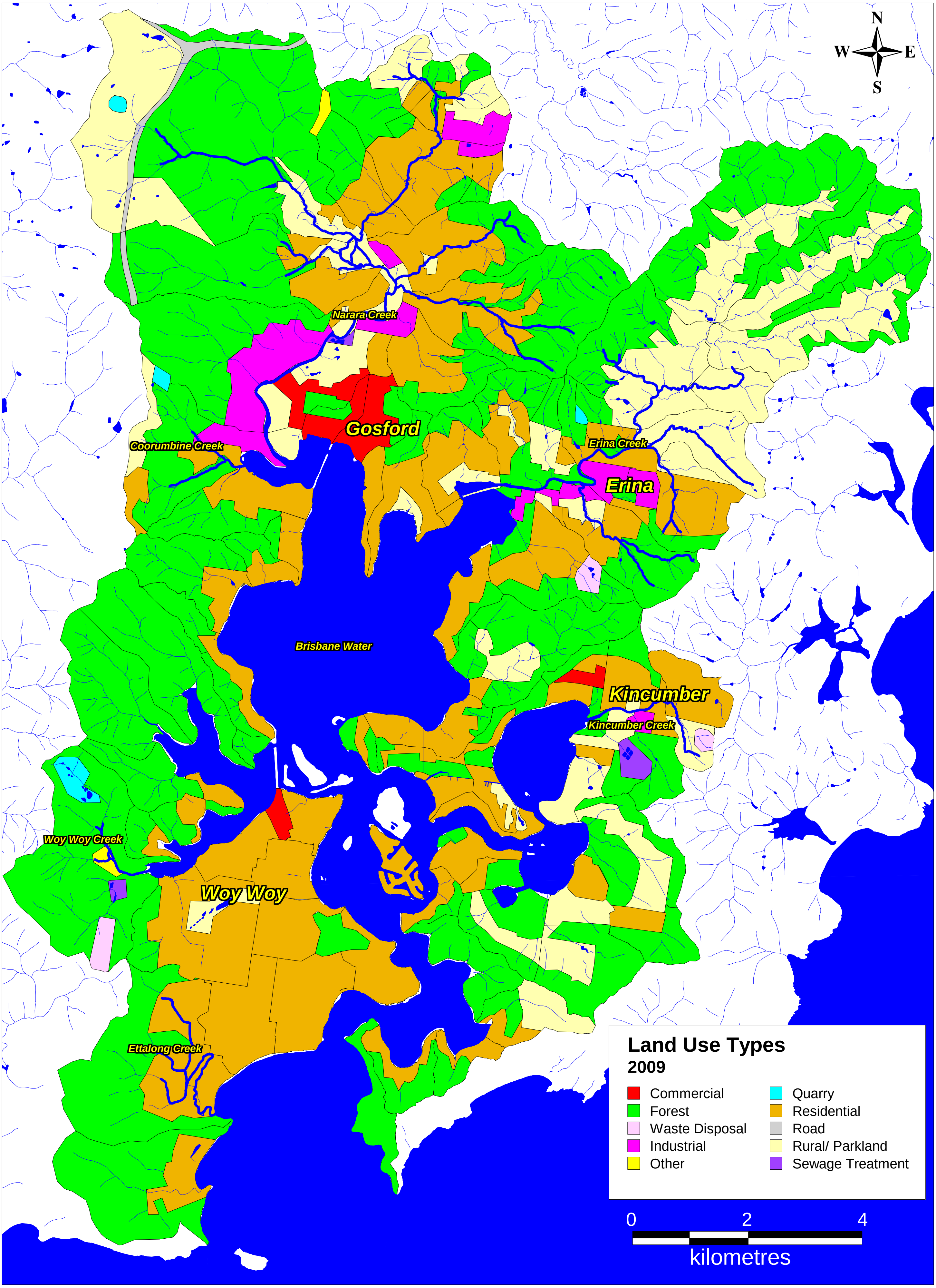

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FIGURE 1
Estuary Processes Study MUSIC Model
Layout and Sub-Catchments

LJ2717 - Brisbane Water EMS&P\Figures\MUSIC Report\Figure 1

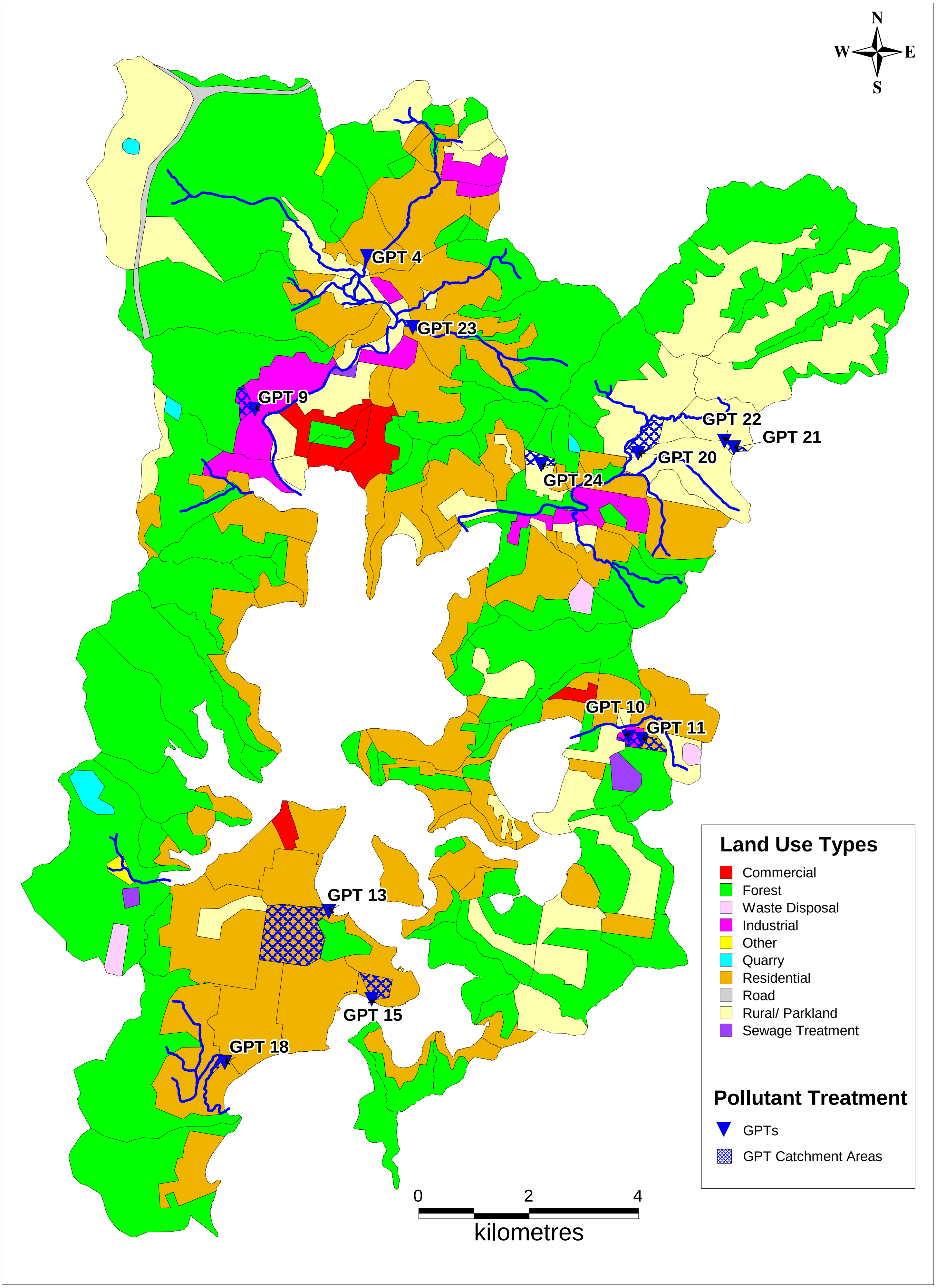

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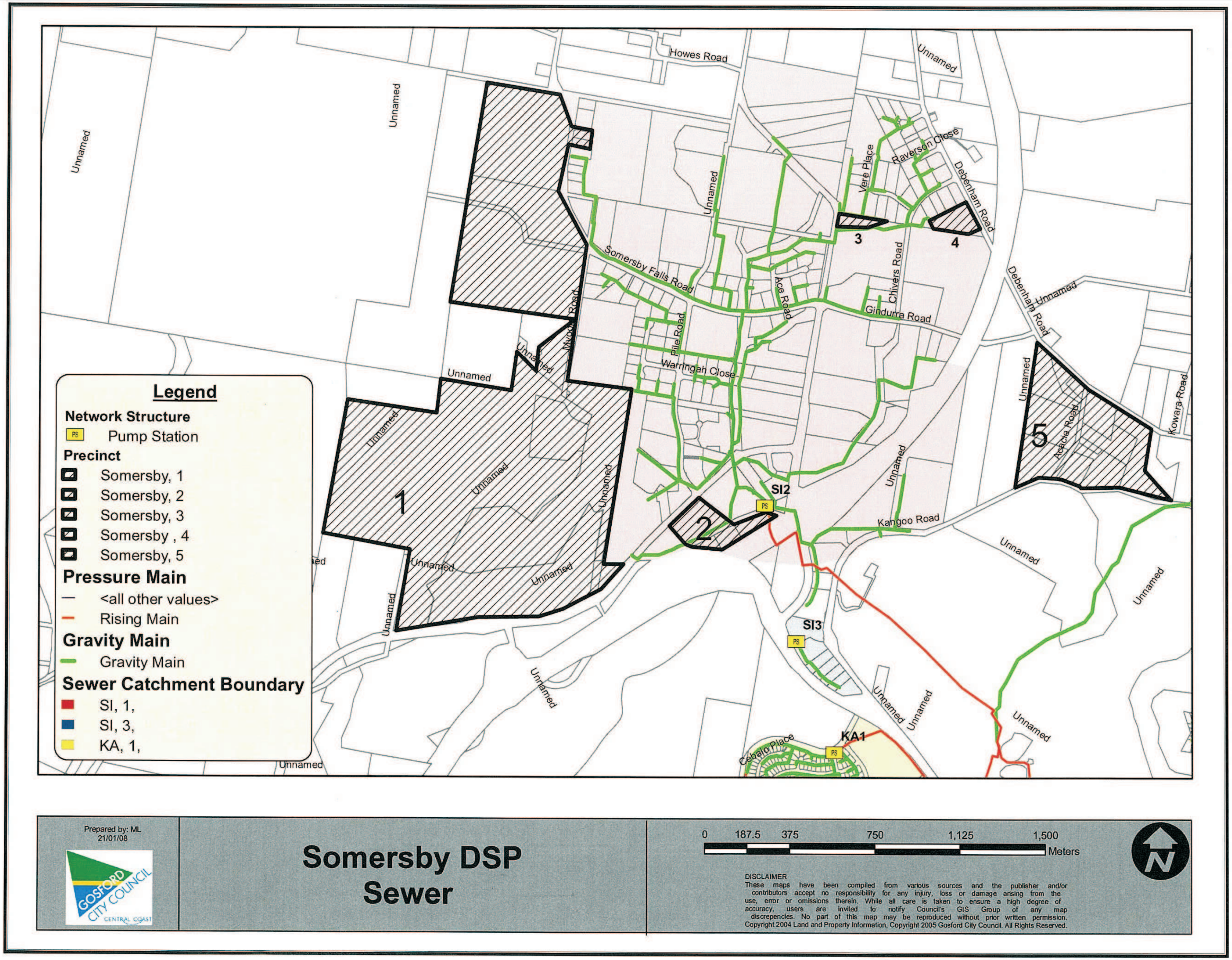
FIGURE 2
Scenario 1 - GPTs and
GPT Treatment Areas



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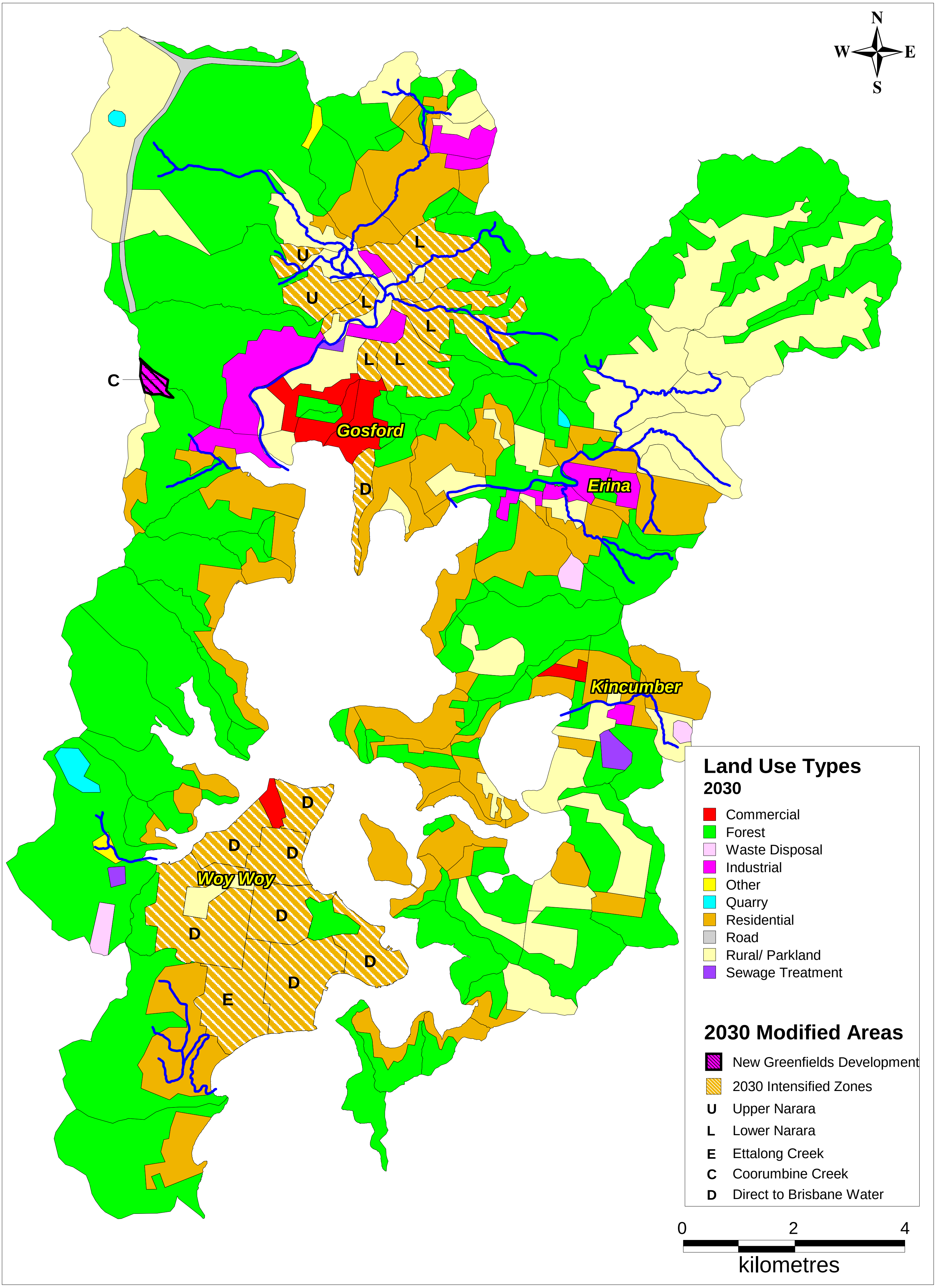

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FIGURE 4
Scenario 2 - Intensified Residential
Sub-Catchments and New Development by 2030

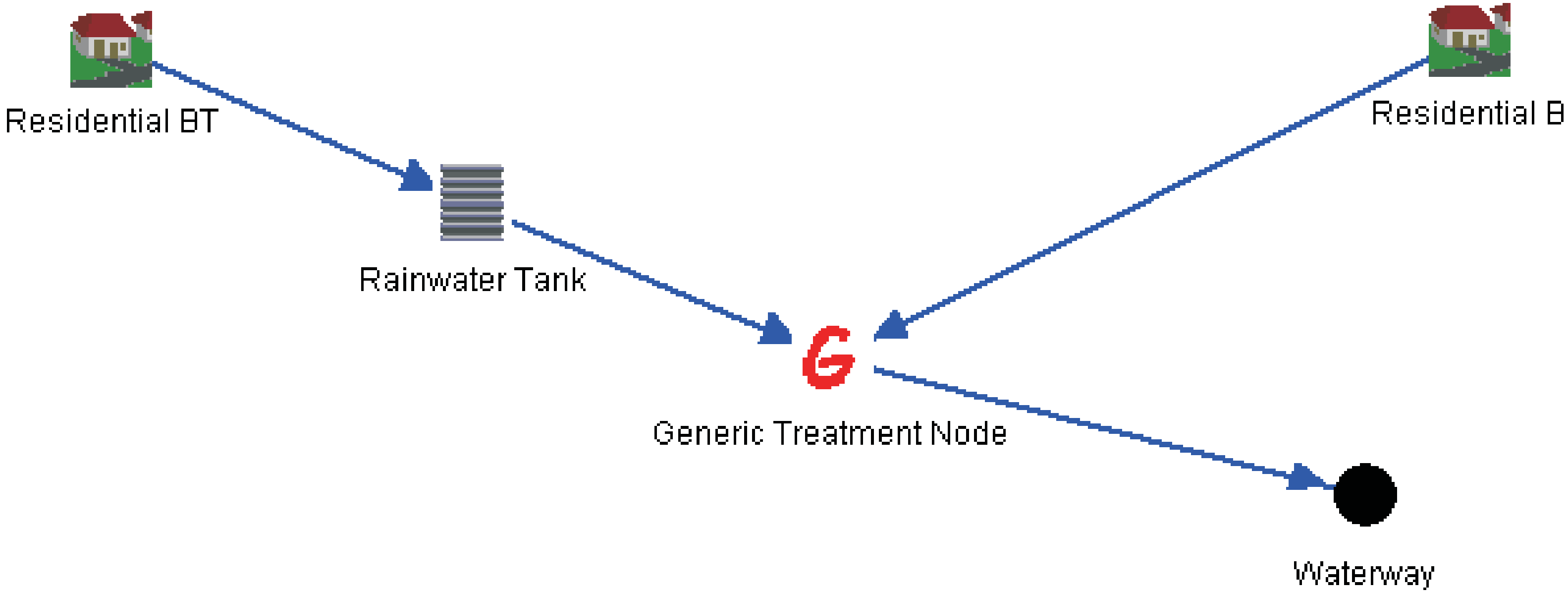

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FIGURE 5
Scenario 2 - Sample MUSIC Model Configuration

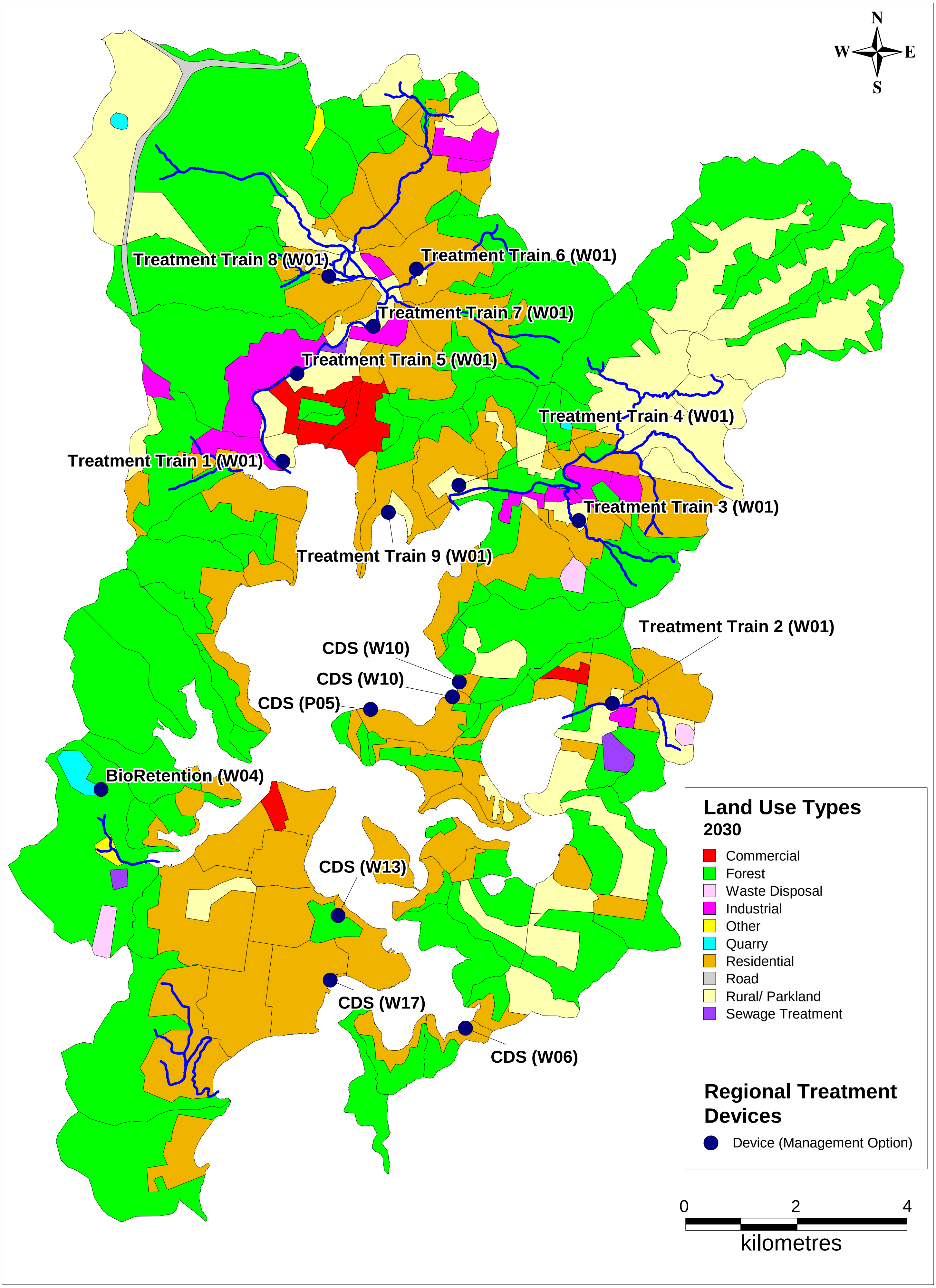

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FIGURE 6
Scenario 4 - Regional Treatment Devices
Full Suite Relating to Management Options

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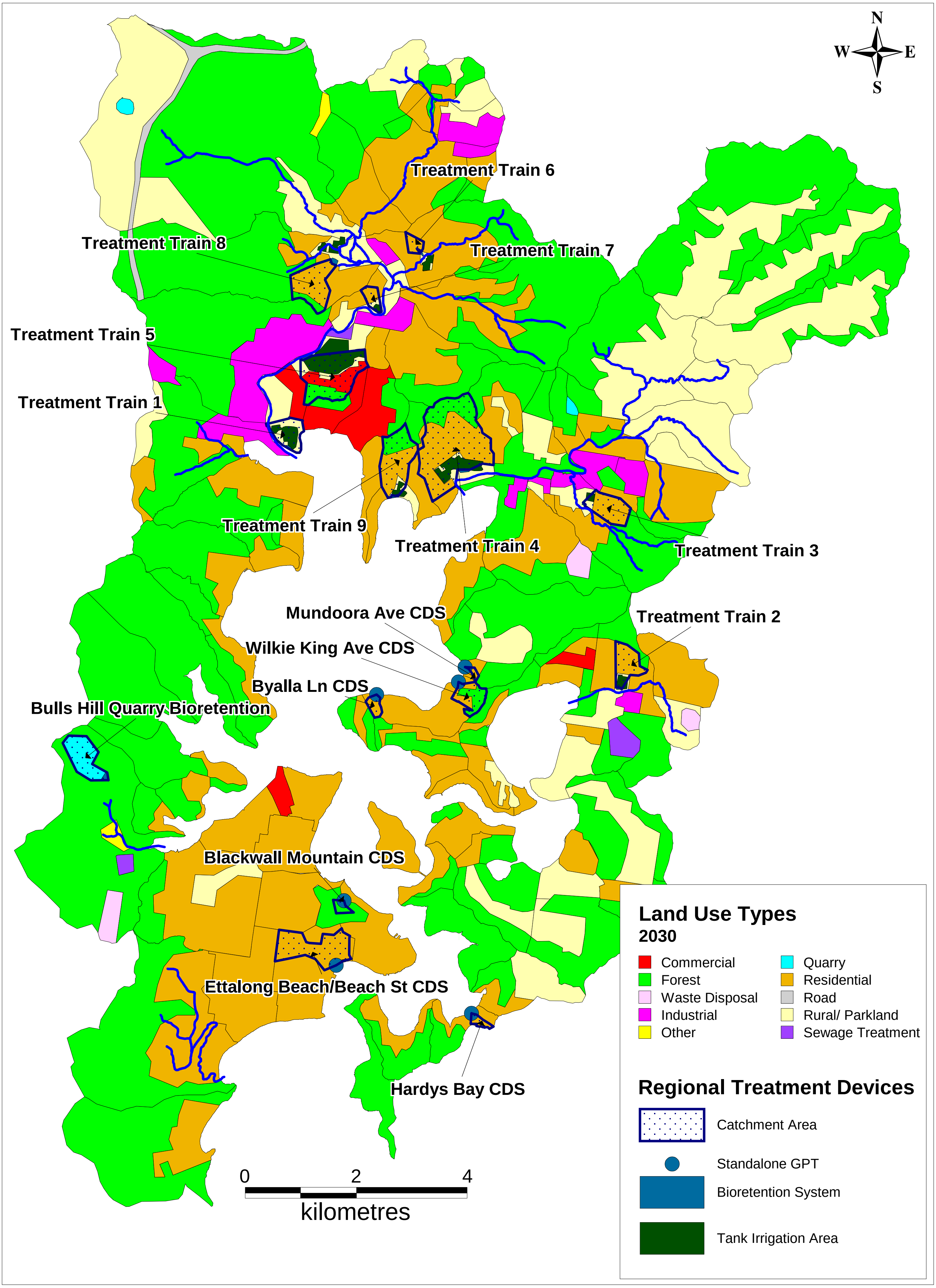

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FIGURE 7
Scenario 4 - Treatment Areas and Irrigation Areas for Regional Treatment Devices

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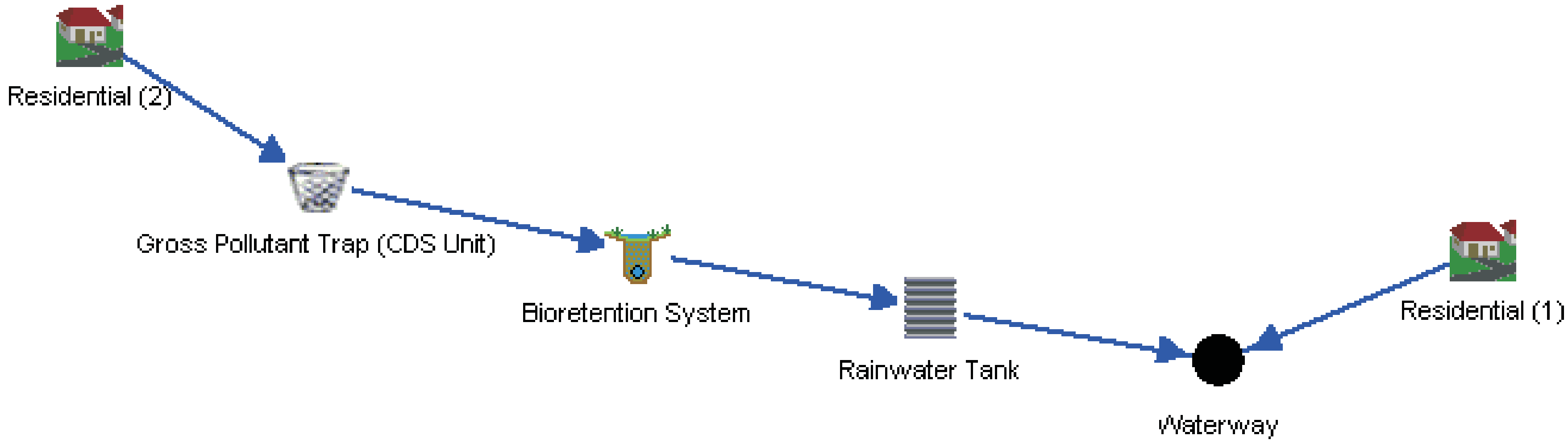

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FIGURE 8
Scenario 4 - Sample Treatment Train Configuration in MUSIC