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Port Stephens Council On-site Sewage Management Technical Manual – Revision

Final Report

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Port Stephens Council
On-site Sewage Management Technical Manual – Revision

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Synopsis :	This document presents a technical justification for the revision of Council policy relating to the planning and approval of on-site sewage management systems in the Port Stephens Local Government Area (LGA). This includes the unsewered development of land through rezoning and subdivision. Spatial analysis, hazard mapping and catchment water quality modelling have been used to a) classify unsewered land according to the minimum level of technical investigation required for the approval of a development; b) nominate a minimum lot size based on analysis of local development characteristics; and c) nominate maximum on-site system densities for different areas within the LGA based on the maintenance of water quality. This Technical Manual also contains guiding information and useful resources for fulfilling the obligations of the Development Assessment Framework.

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Addenda

Section	Document Element	Changes	Page
5	On-site Sewage Management Hazard Mapping	Adoption of revised LCA risk matrix and hazard class logic, and mapping updated.	6-8, 15-20
5.1.2	Soil Moisture Hazard Mapping	Revised soil moisture hazard mapping procedure.	12-13
8	Developing Acceptable Solution Tables	Updated to be consistent with *ASNZS1547:2012* and hydraulic sizing procedure discussed in Section 9.2	58-62
9.2	Hydraulic Design of Land Application Areas	Adoption of sizing procedure consistent with other councils rather than monthly water balance.	67-69
10	Cumulative Impact Assessment Procedure	Standard and Detailed CIA procedure revised to be consistent with other councils.	77-87

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1 INTRODUCTION

BMT WBM has recently completed a project entitled *Sustainable Development of On-site Sewage Management Systems in Port Stephens* on behalf of Port Stephens Council (Council). The project involved a revised, broad scale land capability assessment of the Port Stephens Local Government Area (LGA) to establish local benchmarks for safe, effective on-site sewage management incorporating issues such as maximum lot density and minimum lot size. This technical basis for sustainable on-site sewage management was then used in the formation of a Development Assessment Framework (DAF) for the assessment and approval of on-site sewage management systems and unsewered developments generally. The DAF streamlines the approval process for on-site systems located in lower risk areas. It also provides clear guidance on the supporting information and Minimum Standards required for higher risk locations.

1.1 Aims and Objectives

This *On-site Sewage Management Technical Manual* (the Technical Manual) has been prepared to;

- document the broad scale land capability assessment process as a technical basis for on-site sewage management policy development; and
- provide guidance on scientific and engineering principles and techniques that can be used to demonstrate compliance with the DAF (particularly with regard to High and Very High Hazard allotments).

The main objectives of the Technical Manual are as follows.

- Provide a transparent technical rationale for the On-site Sewage Management Hazard Map, minimum allotment size and maximum allotment density determinations.
- Describe and demonstrate the use of specific methods / tools in the assessment of on-site sewage management system applications.
- Describe and demonstrate the use of specific methods / tools to undertake cumulative impact assessments for unsewered developments involving an increase in building entitlements and non-domestic systems.

1.2 Use of the Technical Manual

This Technical Manual is designed primarily for use by environmental / engineering consultants completing wastewater management investigations on behalf of applicants for installation of individual on-site systems and unsewered development applications involving an increase in building entitlements. Specifically it may be used to;

- confirm or assess the basis for On-site Sewage Management Hazard Class for a particular lot;
- confirm or assess the basis for minimum allotment sizes / maximum densities included in the DAF;
- undertake more complex assessment and design procedures required for High and Very High Hazard lots; and
- undertake a site specific cumulative impact assessment to determine maximum lot density / minimum lot size.

2 BACKGROUND

The diversity of bio-physical conditions observed across Port Stephens (and many other LGA's) limits the opportunities for a 'one size fits all' approach to on-site sewage management. Diversity is increased once consideration is given to the variation in the nature and extent of unsewered development. Council have previously investigated ways to standardise approval and regulatory processes for on-site systems in the face of this variation. In 1999 Council engaged Martens and Associates to prepare a *Broad Scale Study of On-site Effluent Disposal Suitability in the Port Stephens Council LGA, New South Wales* (the Broad Scale Study). This study was completed in the early phases of Council's on-site sewage management program at a time when information and guidance relating to systems in Port Stephens and generally, was limited. It provided a summary of;

- the regulatory framework pertaining to on-site sewage management;
- a review of relevant environmental factors influencing design and performance;
- land capability mapping to classify land in terms of on-site sewage management hazard;
- broad scale water balance and calculation of wet weather storage requirements;
- the outcomes of an audit of 100 on-site systems; and
- recommendations to Council on the management of existing and new on-site systems.

Since that time, Council have adopted and implemented their *On-site Sewage Management Strategy* in addition to a number of other programs and projects targeted at improving Council's understanding and management of on-site sewage management risks. As a result, information relating to the nature and performance of existing systems has improved greatly, as have design procedures and available technology options. Spatial data available for land capability assessment using Geographic Information Systems (GIS) has also increased dramatically in conjunction with the capabilities of GIS software to manipulate this data.

Issues have also arisen relating to suitable minimum lot sizes to allow for sustainable long-term management of effluent and maximum lot densities to ensure the cumulative impacts of systems are adequately managed. Limited guidance was provided in Martens and Associates (1999) on these matters. Advancements in modelling tools, available data and understanding of system performance provide an opportunity to develop a robust framework for sustainable unsewered development in Port Stephens. The need for this framework has recently been made clearer following detection of human virus organisms in oysters sourced from Tilligerry Creek (July 2005). On-site systems are highly likely to be the source of this contamination.

In commissioning this project, Council identified the need for an assessment framework for on-site systems that balances adaptability to the diverse range of circumstances faced by system owners with the provision of a clear set of requirements for the approval of new and upgraded on-site systems and unsewered development. BMT WBM has utilised a range of best practice tools and information relating to on-site sewage management to complete a revised broad scale land capability assessment and make determinations on sustainable lot sizes and densities for unsewered development. The outcomes of this work were then used to establish a Development Assessment Framework for on-site sewage management that is integrated with Council policies and plans.

3 STRUCTURE OF THE DEVELOPMENT ASSESSMENT FRAMEWORK

The Development Assessment Framework (DAF) has been developed to better integrate the design, approval and construction of On-site Sewage Management Systems (OSMS) into broader development planning requirements and provide a standardised and clear process for applicants, designers and installers. The OSMS DAF incorporates Minimum Standards and Acceptable Solutions for each of the four On-site Sewage Management Hazard Classes. It covers applications to install or alter individual on-site systems (domestic and non-domestic) and Development Applications (DA) that increase building entitlements on unsewered allotments. It is designed as a ready reference for system installers and environmental consultants who design on-site systems. This DAF also refers to other council policy and guideline documents in addition to external technical publications that will assist in meeting Councils Minimum Standards and Acceptable Solutions.

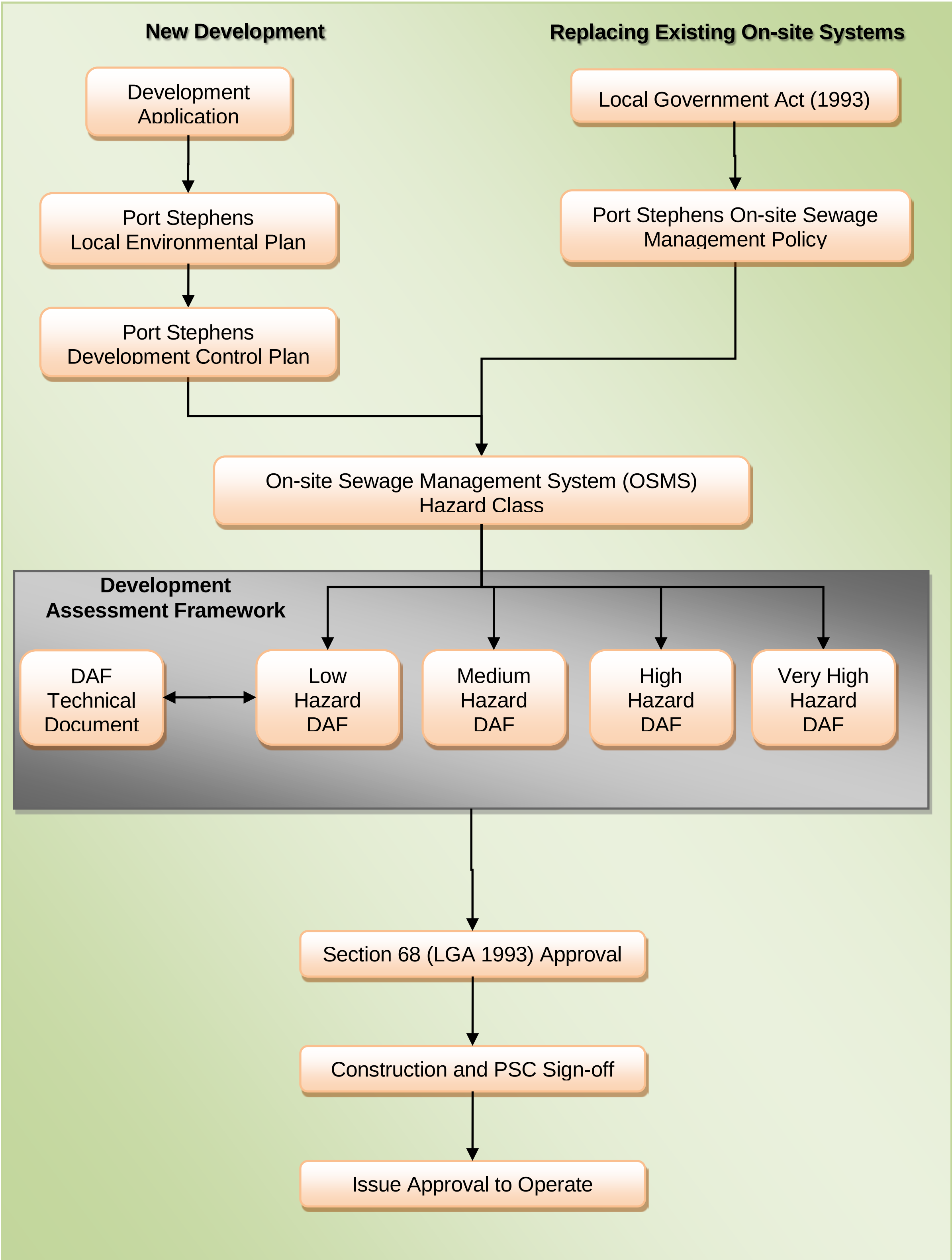
A checklist is provided for each Hazard class that can be used to confirm if the proposed on-site sewage management system or unsewered subdivision meets Councils Minimum Standards and Acceptable Solutions standards. **Where an application meets these standards, approval will be granted promptly. If not, further information will be requested by Council to allow approval.**

Minimum Standards apply to all aspects of the assessment, design and approval process and are divided into the following components.

- Site and Soil Assessment:
- System Selection and Sizing:
- Constructability:
- Increasing Building Entitlements.

The DAF document sets out how applications to install on-site sewage management systems and development applications that increase existing building entitlements can meet Minimum Standards and Acceptable Solutions and recommends resources, tools, standards and guidelines to be used in demonstrating compliance. **An application to install an individual on-site system or unsewered subdivision is unlikely to be approved where an applicant fails to use the recommended resources, tools, standards and guidelines to demonstrate compliance.** Notwithstanding, the DAF does provide flexibility for individual applicants to develop innovative or site specific on-site system designs by allowing for a performance based approach where clear justification is provided and a specific level of assessment and design is undertaken.

In the majority of cases, Councils DAF will reduce the uncertainty associated with how much information is required for approval and streamline / expedite the approval process. However, where specific applications are clearly in contrast to Councils objectives for sustainable and cost appropriate on-site sewage management, the DAF will also make it clear what additional information is required for Council to approve the system / development.


New Development
Replacing Existing On-site Systems
Development Application
Local Government Act (1993)
Port Stephens Local Environmental Plan
Port Stephens On-site Sewage Management Policy
Port Stephens Development Control Plan
On-site Sewage Management System (OSMS) Hazard Class
Development Assessment Framework
DAF Technical Document
Low Hazard DAF
Medium Hazard DAF
High Hazard DAF
Very High Hazard DAF
Section 68 (LGA 1993) Approval
Construction and PSC Sign-off
Issue Approval to Operate

4 TECHNICAL BASIS FOR THE FRAMEWORK

The technical basis for the DAF is founded in the following key components.

- Assignment of an On-site Sewage Management Hazard Class to unsewered lots in the LGA based on a range of bio-physical and built characteristics. A separate hazard class was assigned for individual on-site sewage management and increases in building entitlements on unsewered lots. These hazard classifications provide a general guide to the potential for hazards to impair the performance of on-site systems.
- Identification of sustainable minimum allotment size(s) that ensure sustainable, safe and efficient sewage management can take place for the life of a development.
- Determination of maximum sustainable on-site system densities for new unsewered developments designed to provide a high level of protection from cumulative impacts on ecosystems and human health.
- A set of Acceptable Solutions for on-site sewage management on Low and Medium Hazard allotments that allow Council to promptly approve systems/developments with confidence that they will deliver long-term sustainability.

Chapters 5 to 8 of this Technical Manual document the rationale, methodology and outcomes of these four elements of the DAF.

5 ON-SITE SEWAGE MANAGEMENT HAZARD MAPPING

The use of Geographical Information System (GIS) analysis has enabled Council to undertake a revised broad scale land capability assessment of all unsewered lots in the LGA. The process is similar to the site and soil assessment process typically undertaken for single lots and unsewered subdivisions as guided by DLG (1998) and *ASNZS1547:2012*. The availability of a wider range of data sets which, in some cases are of greater accuracy has allowed the GIS analysis and mapping process to be vastly improved on the previous attempt (Martens, 1999). Revised mapping has incorporated a wide range of built and natural features of the LGA into assignment of On-site Sewage Management Hazard Classes for all allotments.

Derivation of the final On-site Sewage Management Hazard Class involved comprehensive analysis of the range of individual parameters that typically influence the sustainability of on-site systems. This analysis required a range of hazard classes (e.g. low, medium and high) to be assigned to each parameter based on the degree to which general conditions observed on a site influence the design, construction and operation of systems. Hazard class represents a relative assessment of the likelihood and consequence associated with a particular condition. A simple example is provided by slope. Sites with slopes less than 10% typically do not restrict options for the design, construction and operation of on-site systems and as a result a Hazard Class of 1 (Low) is assigned. Sites with slopes greater than 20% severely restrict options for sustainable on-site sewage management and as such a Hazard Class of 3 (High) is applied.

The method for assessing land capability was undertaken in two stages. Initially, a base hazard level was derived using soil, slope and climate inputs. This process has been limited to consideration of these three fundamental parameters for the following reasons:

- Insufficient data was available for the Study Area to enable more detailed parameters to be evaluated:
- Soil (particularly depth to rock or groundwater), slope and climate constraints are the dominant factors influencing land capability for on-site wastewater management in Post Stephens (and most locations):
- BMT WBM has previously developed a robust, groundtruthed risk assessment matrix using these parameters that has been thoroughly tested in adjacent LGAs.

This base hazard (Stage One) class represents the constraints to design, construction and operation of an effluent land application area (i.e. hazards that influence the relative risk of failure). Stage Two then involved adjustment of this base hazard level based on the proximity to and sensitivity of receiving environments (i.e. the likely consequence of any failure).

Stage one of the process utilised three spatial data layers:

- Soil Landscape Hazard – derived from existing soil landscape mapping and associated soil characteristics. The logic for assignment of soil hazard class is documented in Section 5.1.1;
- Climate Hazard – derived from the soil parameters and monthly rainfall data. The logic for assignment of climate hazard class is documented in Section 5.1.2; and

- Slope Hazard – derived from the Digital Elevation Model. Areas where slopes are <10% were assigned a low hazard level, 10-15% as a medium hazard, 15-30% as a high hazard and >30% as a very high hazard.

These three layers were combined to assign an initial land capability hazard level using the matrix presented in Table 5-1.

Table 5-1 Stage One Land Capability Assessment Matrix

Soil Hazard	Climate Hazard	Slope Hazard: Low (<10%)	Slope Hazard: Medium (10-15%)	Slope Hazard: High (15-30%)	Slope Hazard: Very High (>30%)
Low	Low	Low	Low	High	Very High
Low	Medium	Low	Medium	High	Very High
Low	High	Medium	Medium	High	Very High
Medium	Low	Low	Medium	High	Very High
Medium	Medium	Medium	Medium	High	Very High
Medium	High	Medium	High	Very High	Very High
High	Low	Medium	High	Very High	Very High
High	Medium	Medium	High	Very High	Very High
High	High	High	High	Very High	Very High

The initial hazard levels from the matrix were then adjusted where an area was within a specified proximity to sensitive receptors. A proximity hazards layer (Stage Two) was derived from the data sources listed in Table 5-2.

Table 5-2 Stage Two Hazard Class Logic

Proximity Hazards	Proximity	Hazard Application
Minor Watercourse / Open Stormwater Drain	40m	Raise hazard class by 1 for each proximity hazard present. Total hazard capped at 4.
Major Watercourse / Waterbody	100m	
Floodprone Land	Within	
Hunter Water Special Areas – Aquifers	Within	
Receiving Environments		
SEPP14 Wetlands	100m	Raise hazard class by 2 for each proximity hazard present. Total hazard capped at 4.
SEPP62 Aquaculture Zones	500m	

For areas in proximity to the intermittent watercourses, permanent waterbodies and flood prone land, the initial land capability hazard was increased by one level. For areas in proximity to SEPP14 Wetlands and SEPP62 Aquaculture Zones, the initial land capability hazard was increased by two levels. Examples of the mapping methodology are presented in Figure 5-2 and Figure 5-3.

The final land capability map provided a hazard level ranging from low to very high for all locations in the Study Area. The land capability map for the Study Area is presented in Figure 5-4. The land capability map (in addition to being a useful output in itself) has been used in the evaluation of available area for effluent management in addition to on-site system performance modelling. The following flow chart summarises the On-site Sewage Hazard Map development process as detailed in the following sections.

Groundwater aquifers within the Hunter Water Corporation service area were included as a proximity hazard (hazard increase by 1) to capture the potential contamination risk of drinking water sourced from these aquifers.

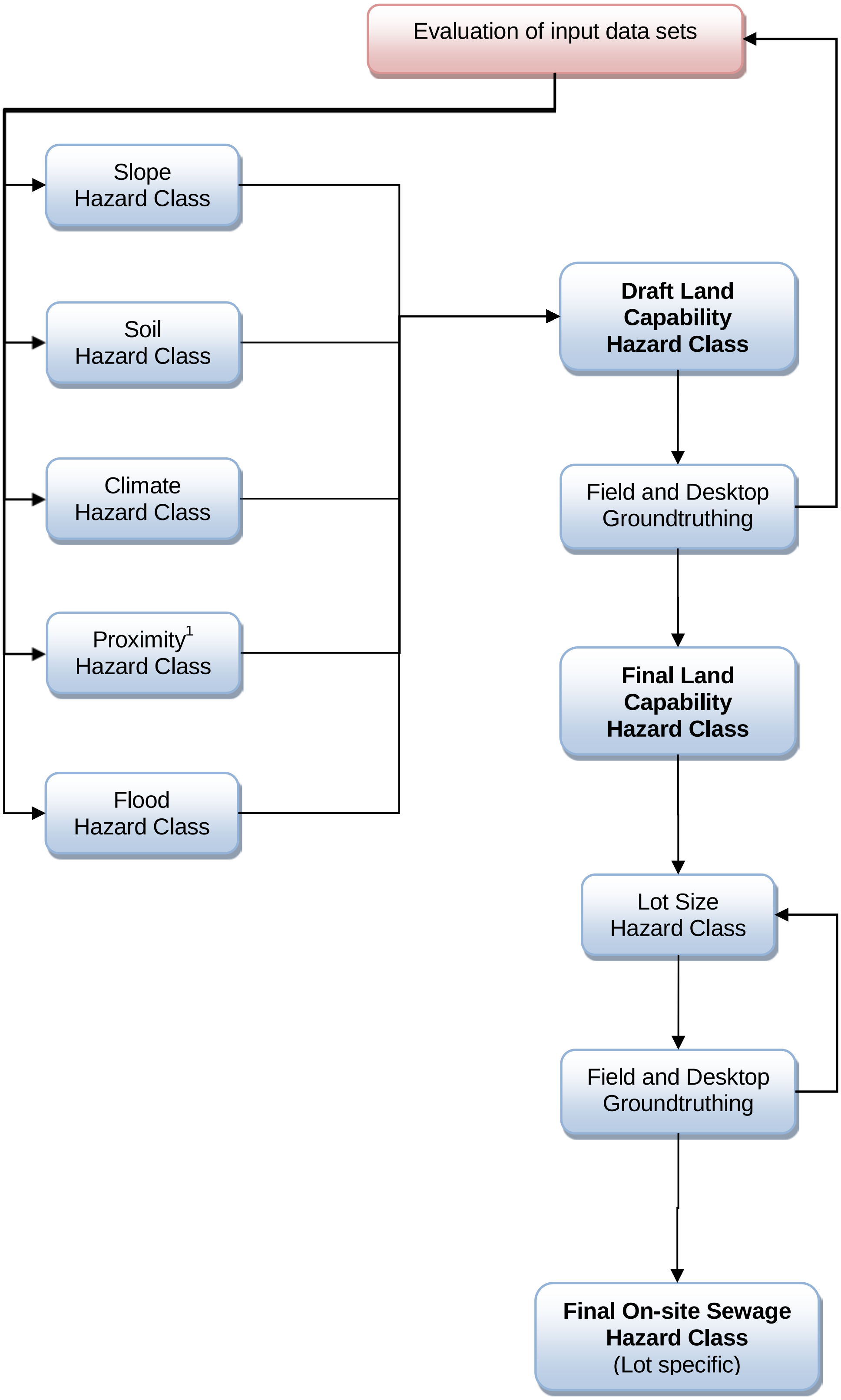
5.1 Input Data for Land Capability Mapping

Eight data sets were used in the creation of the land capability hazard map.

- Digital Elevation Model (DEM) created from LiDAR data (where available) and 10 metre topographical contours (NSW LPMA).
- Soil hazard map created through desktop and ground-truthing of NSW Government and the Department of Conservation and Land Management (DCLM) soil landscape mapping.
- Climate hazard map created through calculation of gridded monthly water balance for the entire Post Stephens LGA (refer to Section.
- The following data layers were supplied by Port Stephens Council (or available from state government websites) for use as proximity hazards.
  - Major Waterways.
  - SEPP14 Wetlands.
  - Whole LGA Drainage.
  - Flood Planning Levels.
  - SEPP62 Priority Aquaculture Zones.
  - Hunter Water Special Areas – Groundwater.

The land capability map was then finalized through the merging of adjacent polygon fragments which shared the same composite hazard class, to create larger continuous polygons of similar hazard class. The final Land Capability Hazard Map is shown in Figure 5-4.

More detailed descriptions of the key input data sets are provided in the following subsections.



Note 1: Includes proximity to watercourses, wetlands, Hunter Water groundwater protected areas, aquaculture and drains.

5.1.1 Soil Hazard Map

Derivation of a single Hazard Class that encapsulates the range of soil characteristics relevant to on-site sewage management requires experienced judgement based on sound soil science principles. A good understanding of soil landscapes and their mapping is also important to ensure the Hazard Class acknowledges the uncertainty associated with broad scale soil landscape mapping. Polygon data sets for both the *Soil Landscapes of the Newcastle 1:100,000 Sheet* (Matthei, 1995) and *Soil Landscapes of the Port Stephens 1:100,000 Sheet* (Murphy, 1995) were obtained from DECCW for use in land capability mapping. Both layers were combined and trimmed to cover the entire LGA.

The published descriptions contained in the soil landscape reports include a wide range of physical and chemical characteristics. Eight parameters were selected for derivation of the soil hazard class and can be grouped into three broad categories. Soil hazard parameters are summarised in the following table.

Table 5-3 Parameters Adopted for Derivation of Soil Hazard Class

<table>
<tr><th>Hazard Type</th><th>Parameter</th><th>Hazard Class</th><th colspan="2">Description</th></tr>
<tr><td rowspan="3">Depth Hazard</td><td rowspan="3">Profile Depth</td><td>Low</td><td>Greater than 2 metres profile depth</td><td rowspan="3">Greater depths of unsaturated soil provide increased treatment of effluent and reduced potential for lateral water movement.</td></tr>
<tr><td>Medium</td><td>1 – 2 metres profile depth</td></tr>
<tr><td>High</td><td>Less than 1 metre profile depth</td></tr>
<tr><td rowspan="4">Hydraulic Hazard</td><td>Texture</td><td>Low</td><td colspan="2">Pedal loam to clay loam soils with mid-range permeability and moderate to free drainage.</td></tr>
<tr><td>Structure</td><td rowspan="2">Medium</td><td colspan="2" rowspan="2">Generally imperfectly drained, weakly structured clay loams and light clays or deep, rapidly drained sands (e.g. sand hills).</td></tr>
<tr><td>Indicative Permeability</td></tr>
<tr><td>Drainage</td><td>High</td><td colspan="2">Generally, shallow, structureless clays and sands in either very rapidly or very poorly drained landscapes.</td></tr>
<tr><td rowspan="3">Pollution Hazard</td><td>Nutrient Retention</td><td>Low</td><td colspan="2">Generally soils with high cation exchange (CEC) and / or phosphorus sorption capacity, no sodicity potential and good organic content in topsoil.</td></tr>
<tr><td>Sodicity</td><td>Medium</td><td colspan="2">Generally soils with moderate CEC, phosphorus sorption capacity, minor sodicity potential and moderate organic content in topsoil.</td></tr>
<tr><td>Organic Content</td><td>High</td><td colspan="2">Generally soils with low CEC, phosphorus sorption capacity, sodicity potential and/or limited organic content.</td></tr>
</table>

A final soil hazard class was then derived using a weighted average score as summarised in the following table. Weightings were based on the relative influence the various parameters have on the design, construction and operation of on-site systems.

Table 5-4 Weighted Average Logic for Soil Hazard Class

<table>
<tr><th>Hazard Type</th><th>Hazard Scores (HS)</th><th>Weighting (w)</th><th>Calculation</th></tr>
<tr><td>Profile Depth</td><td rowspan="3">Low Hazard = 1
Medium Hazard = 2
High Hazard = 3</td><td>1.5</td><td rowspan="3">Final Hazard Class
= [(Depth HS x w) + (Hydraulic HS x w) + (Pollution HS x w)] / 3
Weighted average hazard classes
1 – 1.5 = Low Soil Hazard
1.5 – 2.5 = Medium Soil Hazard
2.5 – 3 = High Soil Hazard</td></tr>
<tr><td>Hydraulic</td><td>1</td></tr>
<tr><td>Pollution</td><td>0.5</td></tr>
</table>

Final soil hazard classes for all mapped soil landscapes in the Port Stephens LGA are summarised in Table 5-5.

Table 5-5 Results of the Soil Hazard Class Development

Soil Landscape	Code	Profile depth	Depth Hazard	Texture	Structure	Indicative ksat	Drainage	Hydraulic Hazard	Nutrient retention	Sodicity	Organic	Pollution Hazard	FINAL SOIL HAZARD
Boyces Track	AEbt	>3m	**Low**	Sand	Massive	>3m/day	Very Rapid	**Medium**	Poor	No	Poor	**High**	**Medium**
Hawks Nest	AEhn	>3m	**Low**	Sand	Massive	>3m/day	Very Rapid	**Medium**	Poor	No	Poor	**Medium**	**Low**
Lower Pindimar	SWlp	<0.7m	**High**	Sand	Massive	>3m/day	Poor	**High**	Poor	No	Medium	**High**	**High**
Erunderee Swamp	SWes	<0.5m	**High**	Peat	Massive		Inundated	**High**				**High**	**High**
Bobs Farm	Esbf	<0.6m	**High**	OL/HC	WS/MS	<0.06m/day	Very poor	**High**	Medium	No	High	**Medium**	**High**
Shoal Bay	AEsb	>3m	**Low**	Sand	Massive	>3m/day	Very rapid	**Medium**	Poor	No	Poor	**Medium**	**Low**
Shoal Bay a	AEsba	>3m	**Low**	Sand	Massive	>3m/day	Very rapid	**Medium**	Poor	No	Poor	**High**	**Medium**
Shoal Bay c	AEsbc	<0.7m	**High**	Sand	Massive	>3m/day	Poor	**High**	Poor	No	Medium	**High**	**High**
Soal Bay Swamp	SWss	<0.5m	**High**	Peat	Massive		Inundated	**High**				**High**	**High**
Gan Gan	COgg	<0.8m	**High**	SL/SCL	WK/MS	0.12m/day	Imperfect	**High**	Poor	Yes	Medium	**High**	**High**
Gan Gan a	COgga	<2m	**Medium**	SL/SCL	WK/MS	0.12m/day	Poor	**High**	Poor	Yes	Medium	**High**	**High**
Fingal Head	AEfh	>3m	**Low**	Sand	Massive	>3m/day	Well	**Medium**	Poor	No	Poor	**High**	**Medium**
Fullerton Cove	ESfc	<0.5m	**High**	Peat	Massive		Inundated	**High**				**High**	**High**
Tea Gardens	AEtn	1m	**Medium**	Sand	Massive	>3m/day	Variable	**Medium**	Poor	No	Poor	**High**	**Medium**
Tea Gardens a	AEtna	<1m	**High**	Sand	Massive	Variable	Variable	**Medium**	Poor	No	Poor	**High**	**High**
Tea Gardens b	AEtnb	<1m	**High**	S/SCL	Massive	0.12m/day	Variable	**High**	Poor	No	Medium	**High**	**High**
Mallabula Point	ERmp	<1m	**High**	SL/SCL/C	WS	0.12m/day	Imperfect	**High**	Medium	Yes	Medium	**High**	**High**
Stockton Beach	BEsk	>3m	**Low**	Sand	Massive	>3m/day	Very Rapid	**Medium**	Poor	No	Poor	**Medium**	**Medium**
North Arm Cove	REnc	1-2m	**Medium**	SCL/MC	WS/SS	0.06m/day	Poor	**High**	Poor	Yes	Medium	**High**	**High**
Hexham Swamp	SWhs	<0.5m	**High**		Massive		Inundated	**High**				**High**	**High**
Hungry Hill	COhh	1m	**Medium**	SCL/MC	Weak	0.06m/day	Imperfect	**Medium**	Medium	No	Medium	**Medium**	**Medium**
Gilmore Hill	COgi	<1m	**High**	SCL	WS/MS	0.12m/day	Imperfect	**High**	Poor	No	Poor	**High**	**High**
Glen William	ERgw	1-2m	**Medium**	SL/SCL/MC	WS	0.12m/day	Imperfect	**Medium**	Medium	Yes	Medium	**Medium**	**Medium**
Glen William a	TRgwa	1-2m	**Medium**	SL/SCL/MC	WS/MS	0.12m/day	Imperfect	**Medium**	Low	Yes	Medium	**Medium**	**Medium**
Williams River	ALwr	2-3m	**Low**	SCL	WS	0.5m/day	Moderate	**Medium**	Medium	No	Medium	**Medium**	**Low**
Hunter	ALhu	2m+	**Low**	CL/MC	SS	0.12m/day	Moderate	**Medium**	High	No	High	**Low**	**Low**
Hunter variant a	SWhua	1-2m	**Medium**	MC	SS	0.06m/day	Imperfect	**Medium**	High	No	High	**Low**	**Medium**
Hunter variant b	ALhub	2m+	**Low**	SCL	WS	0.12m/day	Imperfect	**Medium**	High	No	High	**Low**	**Medium**
Rivermead	REri	2m+	**Low**	SCL/MC	MS/SS	0.06m/day	Moderate	**Medium**	Medium	Yes	High	**Medium**	**Medium**
Bolwarra Heights	ERbh	1-2m	**Medium**	L/LC	WS/MS	0.12-1.5m/day	Imperfect	**Medium**	Poor	~	Medium	**Medium**	**Medium**
Bolwarra Heights a	ERbha	0.5m	**High**	SCL	WS	1.5m/day	Moderate	**Medium**	Poor	No	Medium	**High**	**High**
Wallalong	REwg	1-2m	**Medium**	SCL/HC	WS/SS	0.06-0.12m/day	Imperfect	**High**	Poor	Yes	Poor	**High**	**High**
Wallalong a	TRwga	2m+	**Low**	SCL/HC	WS/SS	0.06-0.12m/day	Poor	**High**	Poor	Yes	Medium	**High**	**Medium**
Seaham	ERse	1m	**High**	SCL/MC	WS/SS	0.06-0.12m/day	Moderate	**Medium**	Poor	Yes	Medium	**High**	**High**
Seaham a	COsea	<1m	**High**	SCL	WS	0.12m/day	Well	**Medium**	Poor	No	Poor	**High**	**High**
Seaham b	TRseb	<0.5m	**High**	SCL/HC	WS	0.06m/day	Imperfect	**High**	Poor	Yes	Medium	**High**	**High**
Vacy	TRva	1-2m	**Medium**	SCL/MC	WS/MS	0.06-0.12m/day	Imperfect	**High**	Medium	Yes	Medium	**Medium**	**Medium**
Mount Johnstone	COmj	1m	**High**	SL/LC	WS/MS	0.12-1.5m/day	Well	**Medium**	Poor	Yes	Poor	**High**	**High**
Black Camp Creek	STbc	1-2m	**Medium**	CL/LC	WS/SS	0.12m/day	Imperfect	**Medium**	Medium	Yes	Medium	**Medium**	**Medium**
Millers Forest	ESmf	1-2m	**Medium**	SCL/MC	SS	0.12m/day	Poor	**Medium**	High	Yes	High	**Low**	**Medium**
Glenurie Hill	ERgl	0.5-1m	**High**	SL/SCL/MC	WS/MS	0.12m/day	Moderate	**Medium**	Poor	Yes	Medium	**High**	**High**
Brecon	REbr	<1m	**High**	SL/SCL/MC	WS/MS/SS	0.12m/day	Imperfect	**Medium**	Poor	Yes	Medium	**High**	**High**
Brecon a	ERbra	>2m	**Low**	SL/MC	WS/SS	0.12m/day	Well	**Medium**	Poor	Yes	Medium	**High**	**Medium**
Ten Mile Road	ERtm	1-2m	**Medium**	SL/MC	MS/MS	0.06-0.5m/day	Moderate	**Medium**	Poor	Yes	Medium	**Medium**	**Medium**
Ten Mile Road a	ERtma	1-2m	**Medium**	SL/MC	MS/MS	0.06-0.5m/day	Moderate	**Medium**	Poor	Yes	Medium	**Medium**	**Medium**
George Trig	VEgt	<1m	**High**	OL/SL	WS/MS	0.5-1m/day	Moderate	**High**	Poor	No	High	**High**	**High**
Beresfield	REbe	2m+	**Low**	SL/SCL/MC	WS/MS/WS	0.06m/day	Imperfect	**Medium**	Medium	Yes	High	**High**	**Medium**
Clarencetown	ERcl	<1m	**High**	SL/SCL/MC	MS/MS	0.06m/day	Poor	**High**	Poor	Yes	Poor	**High**	**High**
Sandy Creek	ALsc	1-2m	**Medium**	SL/SCL	WS	0.5m/day	Moderate	**Low**	Medium	No	Medium	**Medium**	**Medium**
Birdsview a	ERbia	<1m	**High**	SL/SCL/MC	WS/MS/MS	0.12m/day	Well	**Medium**	Medium	No	Poor	**Medium**	**Medium**
Mount Douglas	REmd	1-2m	**Medium**	CL/MC	SS	0.12-1.5m/day	Well	**Low**	High	No	High	**Low**	**Low**
The Branch	REtb	2m+	**Low**	StL/StCL/MC	WS/M/MS	0.06-1m/day	Poor	**High**	Poor	Yes	Medium	**Medium**	**Medium**
The Branch b	EStbb	<1m	**High**	OL/MC	M	<0.06m/day	Very poor	**High**	Poor	No	High	**High**	**High**
Nungra	TRng	2m+	**Low**	SL/SCL/MC	WS/M	0.06m/day	Poor	**High**	Poor	Yes	High	**High**	**Medium**
Tacoma Swamp	SWts	<0.5m	**High**		Massive		Inundated	**High**				**High**	**High**
Medowie	REme	1-2m	**Medium**	SCL/HC/GCL	WS/SS/MS	0.06-0.5m/day	Moderate	**Medium**	Medium	No	Medium	**Medium**	**Medium**
Blind Harrys Swamp	SWba	<0.5m	**High**		Massive		Inundated	**High**				**High**	**High**
Bobs Farm a	BEbfa	2m+	**Low**	Sand	Massive	>3m/day	Very Rapid	**Medium**	Poor	No	Poor	**High**	**Medium**
Nerong Waterholes	LAnw	1-2m	**Medium**	LS/MC	WS/MS	0.06-1.5m/day	Poor	**High**	Poor	Yes	Medium	**High**	**High**

5.1.2 Soil Moisture Hazard Map (Climate)

The Soil Moisture Hazard Map (SMHM) was developed to provide a more meaningful assessment of the degree to which climate limits or enhances opportunities for the land application of effluent. It was adopted in preference to an assessment of rainfall and evapo-transpiration alone based on the significant variation in soil hydraulic properties observed across the LGA and the importance of soil water storage capacity and moisture content in effluent management.

The SMHM classifies the Port Stephens LGA based on the number of average climate months where soil moisture is above field capacity. This represents periods where significant deep drainage or surface surcharging of effluent is more likely to occur because evapo-transpiration is providing limited or no assistance in assimilating wastewater. Grid cells with limited or no average months with soil moisture above field capacity represent sites with good evapo-transpiration capacity available for effluent assimilation.

There are two stages in the development of the SMHM. Creation of mean monthly soil moisture grids followed by application of a hazard class to each grid cell based on the number of average months where soil moisture is above field capacity.

5.1.2.1 Creation of Mean Monthly Soil Moisture Grids

Mean soil moisture grids represent a continuous 1 year soil water balance

Baseline data layers include;

- 2.5 km^2 grid of mean monthly rainfall (BOM Climate Atlas); www.bom.gov.au/climate/averages/climatology/gridded-data-info/metadata/md_ave_rain_1961-90.shtml
- 10 km^2 grid of mean monthly areal Potential Evapo-transpiration grid (BOM Climate Atlas); and http://www.bom.gov.au/climate/averages/climatology/gridded-data-info/metadata/md_ave_et_1961-90.shtml
- Soil landscape polygon data file (MapInfo table).

The soil data required pre-processing in the form of insertion of the following data as four separate columns against each soil facet.

- Initial soil moisture (ISM) in mm;
- Field capacity (FC) in mm;
- Permanent wilting point (PWP) in mm; and
- Daily recharge rate (DR) as a decimal.

These data were obtained from laboratory testing undertaken as part of soil landscape mapping (Matthei, 1995 and Murphy, 1995). The daily recharge rate was adopted based on MacLeod (2008) based on indicative hydraulic conductivity and drainage characteristics and represents the proportion of soil water above field capacity that drains following rainfall. The soil landscape vector dataset was converted to a raster format with a cell size of 40m, in order to retain a reasonable level of detail. The rainfall and evapotranspiration data for each month were converted from lat/long co-ordinates to an MGA projection and then interpolated on to the same 40m grid alignment as the soil landscape raster. The soil moisture calculations detailed below were undertaken using these 40m grid inputs.

Firstly, the following calculations were undertaken to produce the mean monthly soil moisture balance (mm).

January Calculation

$SM_{jan} = ISM + Rf_{jan}(1 - [C_v \times 0.8])$

Remaining Months

$SM_{feb.....} = SM_{jan} + Rf_{feb}(1 - [C_v \times 0.8])$ etc...

Where;

SM = Soil moisture for the month (mm);

ISM = Initial Soil Moisture (mm);

Rf = Rainfall (mm/month);

C_v = Runoff Coefficient (obtained from gridded BOM data); and

0.8 = adjustment for baseflow (rainfall that becomes streamflow via subsurface flow).

There are two other conditions / calculations to make depending on the answer to equations 1 and 2.

If SM < PWP then SM = PWP should be applied to each monthly calculation.

If SM > FC then final soil moisture = the greater of (SM x [1-DR]) or FC.

Where;

PWP = Permanent Wilting Point;

FC = Field Capacity; and

DR = Drainage Rate (from MacLeod, 2008).

The final output of this grid analysis was a single soil moisture value (mm) for each month of an average statistical year. The results of these soil moisture calculations were then used to determine an appropriate soil climate hazard level for each soil type.

5.1.2.2 Creation of Final Soil Moisture Hazard Map

The final SMHM (or climate hazard map) was created through classification of grid cells in accordance with the following logic.

Low hazard = 0 months with soil moisture ≥ field capacity.

Medium hazard = 1-3 months with soil moisture ≥ field capacity.

High hazard = 4 or more months with soil moisture ≥ field capacity.

Figure 5-1 to Figure 5-6 show the final climate hazard map and how it integrates with other hazards.

5.2 Derivation of Lot-Based Land Capability

Following the development of the land capability map, it was necessary to determine suitable land capability hazard classes for each lot within the LGA. This was undertaken through the intersection of the land capability map with the Council cadastral boundaries. Average land capability hazard class numbers were then calculated for each lot using an aerial weighted combination of the hazards from the land capability map. Average hazard class numbers were rounded to the nearest integer.

The final mapping output required two hazard maps to be produced – one for a single lot unsewered development and another for unsewered subdivision or rezoning.

5.2.1.1 Single Lot

The following logic was applied to cadastral data to produce the single lot hazard class.

Lots >= 4000 m^2 = Average land capability hazard class number (for each lot).

Lots 2000 – 4000 m^2 = Greater of 3 (high hazard) and the average land capability hazard class.

Lots <2000 m^2 = Very high (4) hazard (regardless of land capability).

5.2.1.2 Multiple Lot

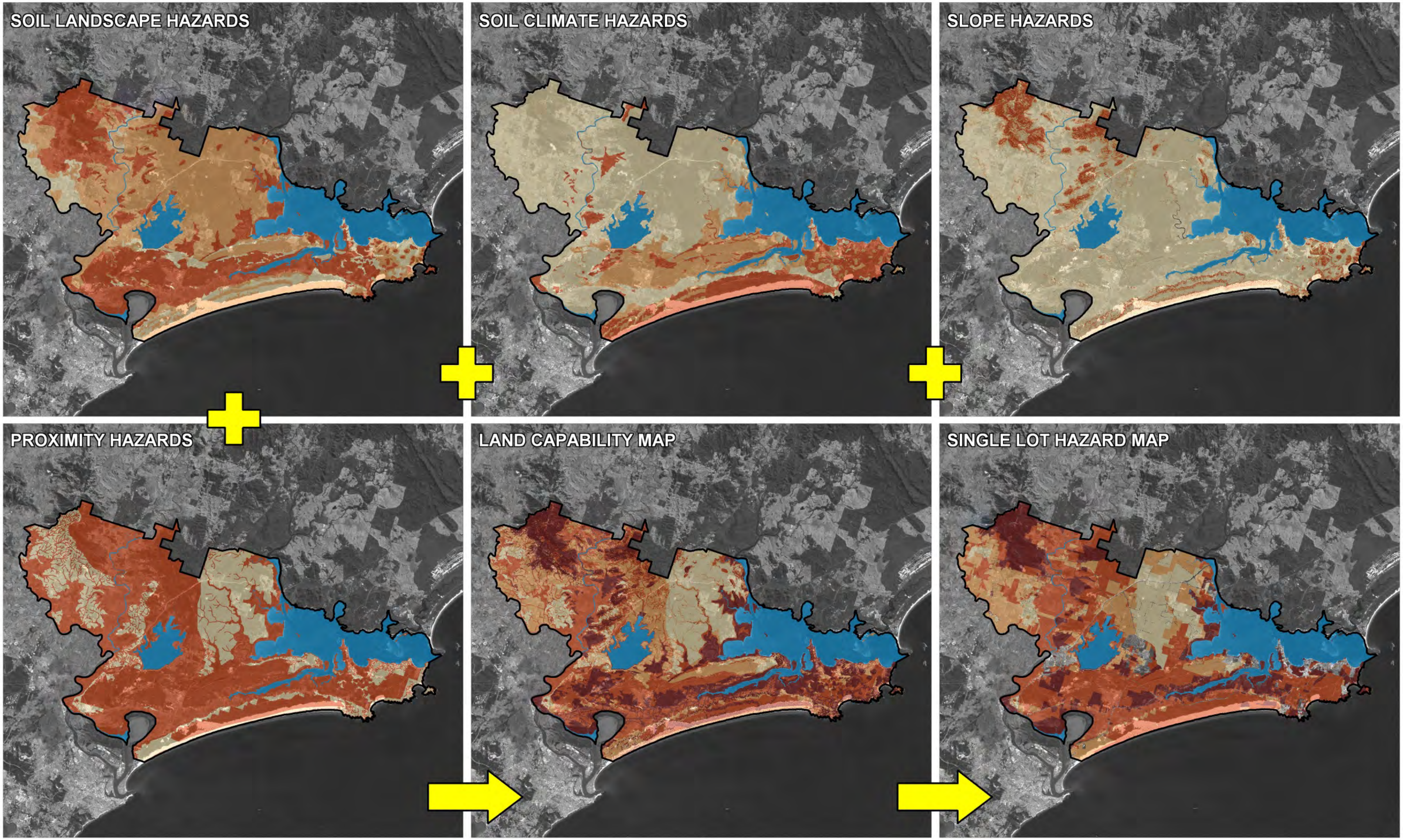
The following logic was applied to cadastral data to produce the multiple lot hazard class.

Lots >= 8000 m^2 = Average land capability hazard class number (for each lot).

Lots 4000 – 8000 m^2 = Greater of 3 (high hazard) and the average land capability hazard class.

Lots <4000 m^2 = Very high (4) hazard (regardless of land capability).

The following figures present the final Land Capability Hazard Map, Final On-site Sewage Management Hazard Maps and two example close ups illustrations of how the individual elements were combined to create the final maps.



LEGEND

Hazard Class

- Low Hazard
- Medium Hazard
- High Hazard
- Very High Hazard
- Water Bodies

Title:

Port Stephens On-site Sewage Managment
Hazard Map Methodology

Figure: 5-1

Rev: A

N

0 10 20km

Approx. Scale

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www.wbmpl.com.au

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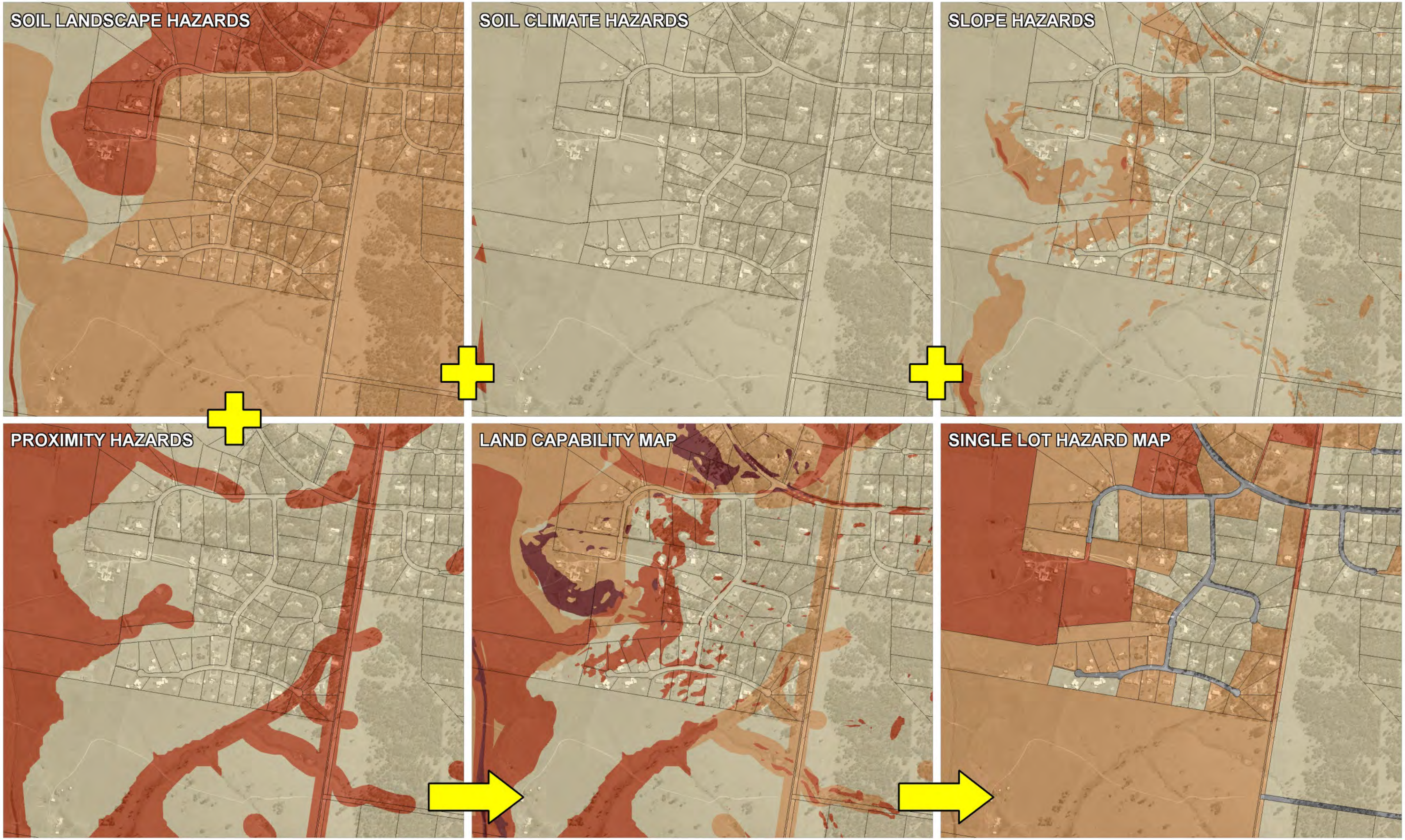


LEGEND

Hazard Class

- Low Hazard
- Medium Hazard
- High Hazard
- Very High Hazard
- Water Bodies

Title:

Port Stephens On-site Sewage Managment
Hazard Map Methodology at Brandy Hill

Figure: **5-2**

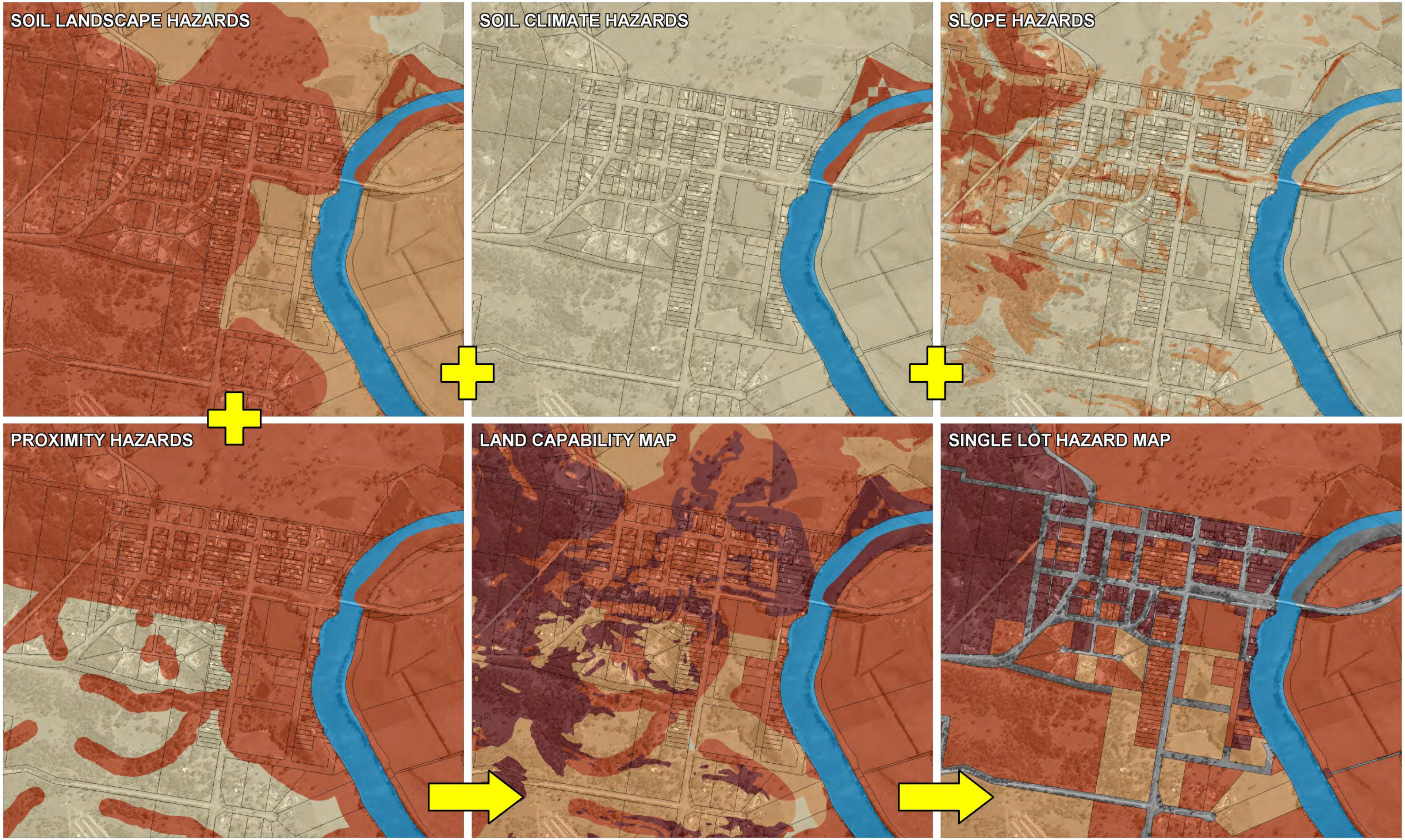
Rev: **A**

N

0 375 750m
Approx. Scale

BMT WBM
www.wbmpl.com.au

Filepath : K:\N1650_Port Stephens_On-site_Sewage_Mgt_Study\Data\MI\Workspaces\DRG_006_100810_Methodology_Brandy_Hill.wor



LEGEND

Hazard Class

- Low Hazard
- Medium Hazard
- High Hazard
- Very High Hazard
- Water Bodies

Title:

Port Stephens On-site Sewage Managment
Hazard Map Methodology at Seaham

Figure: **5-3**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

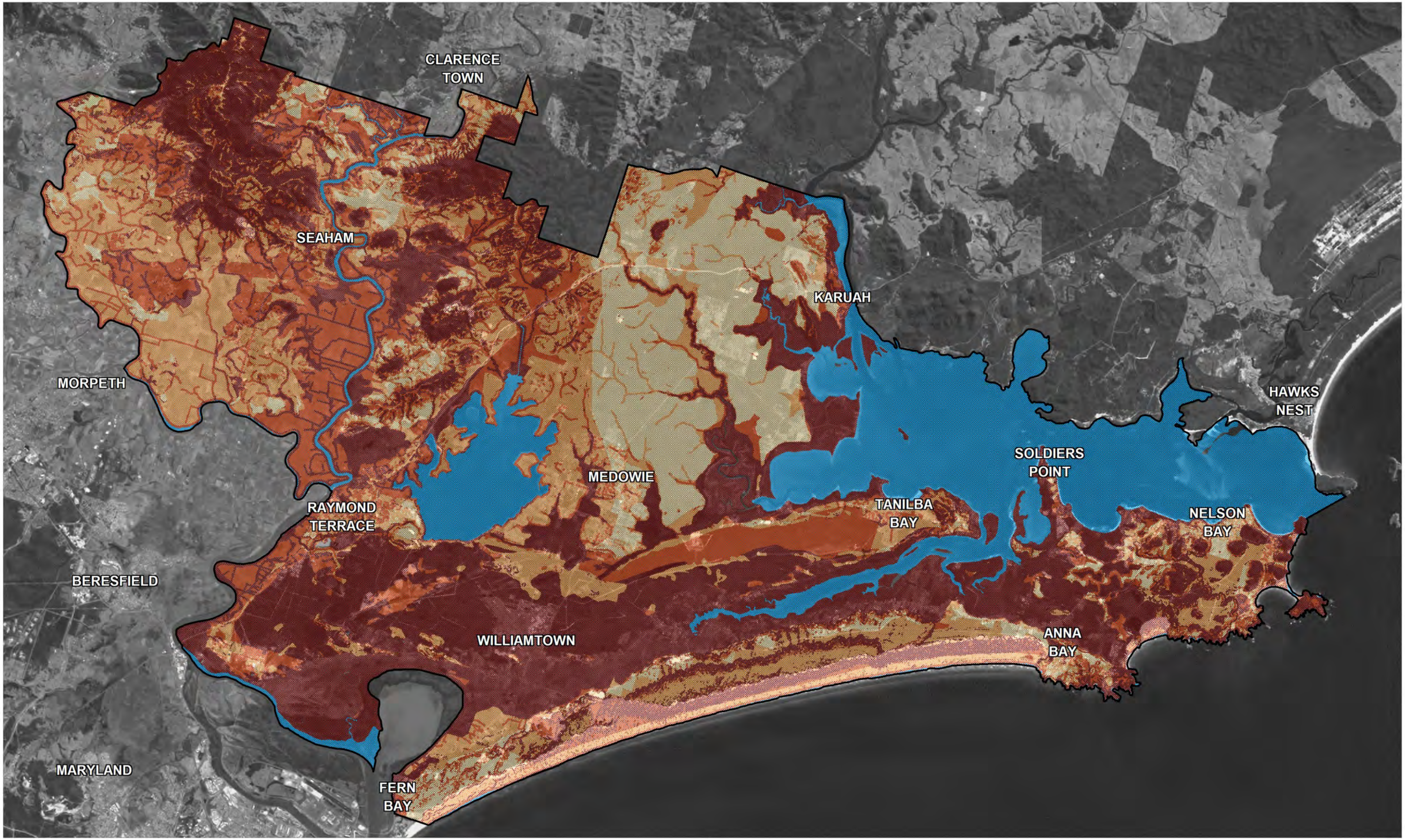
0 375 750m

Approx. Scale

BMT WBM

www.wbmpl.com.au

Filepath : K:\N1650_Port Stephens_On-site_Sewage_Mgt_Study\Data\MI\Workspaces\DRG_005_100810_Methodology_Seaham.wor



LEGEND

Land Capability Hazard Class

- Low Hazard
- Medium Hazard
- High Hazard
- Very High Hazard
- Water Bodies

Title:

Port Stephens On-site Sewage Managment
Final Land Capability Hazard Map

Figure: **5-4**

Rev: **A**

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N 0 3.75 7.5km
Approx. Scale

BMT WBM
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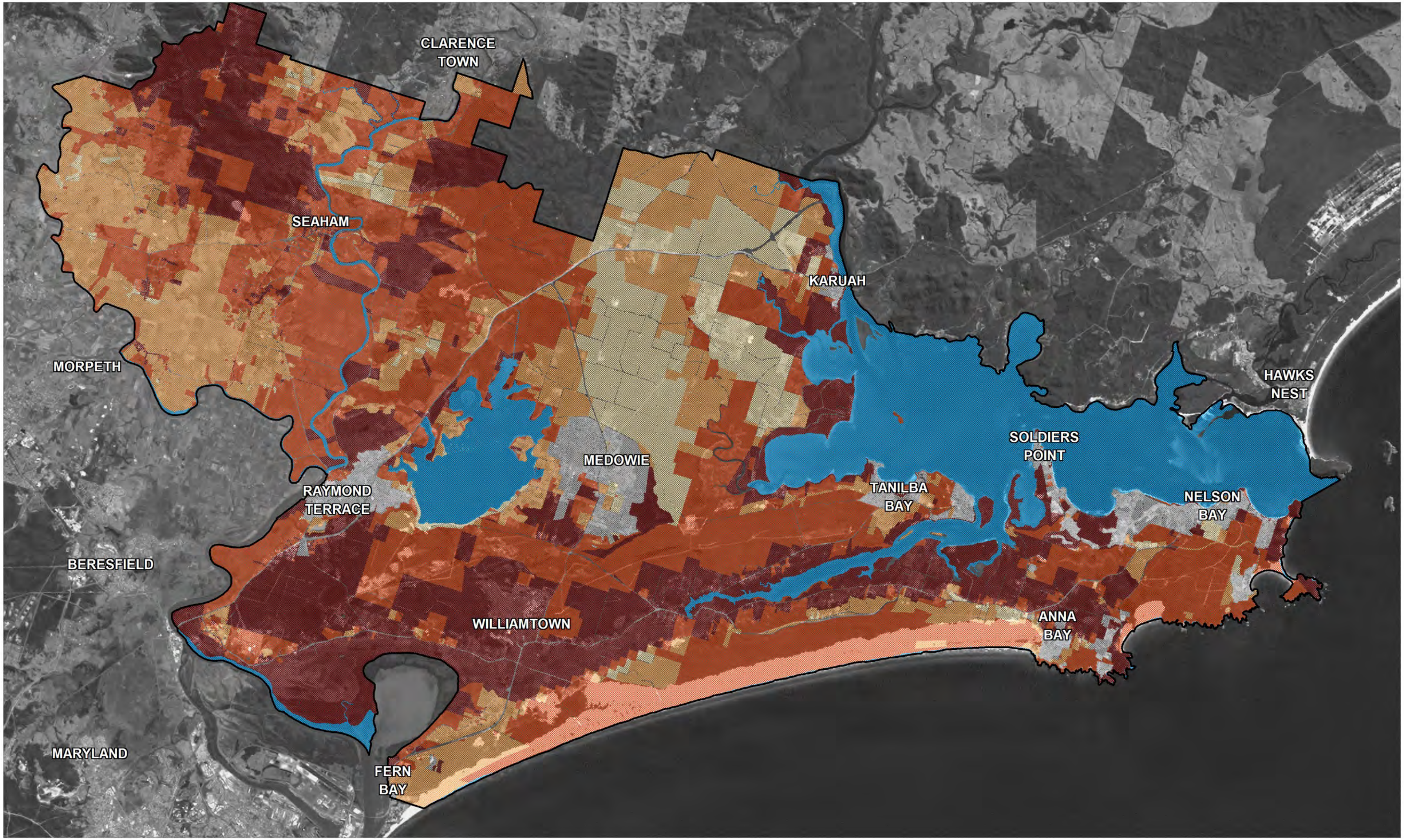
Filepath : K:\N20301_PSC_DAFUpdate\MI\Workspaces\DRG_001_100809_Land_Capability.wor



LEGEND

Single Lot On-site Sewage Hazard Class

- Low Hazard
- Medium Hazard
- High Hazard
- Very High Hazard
- Water Bodies

Title:

Port Stephens On-site Sewage Managment
Final On-site Sewage Hazard Map (Single Lots)

Figure: **5-5**

Rev: **A**

N

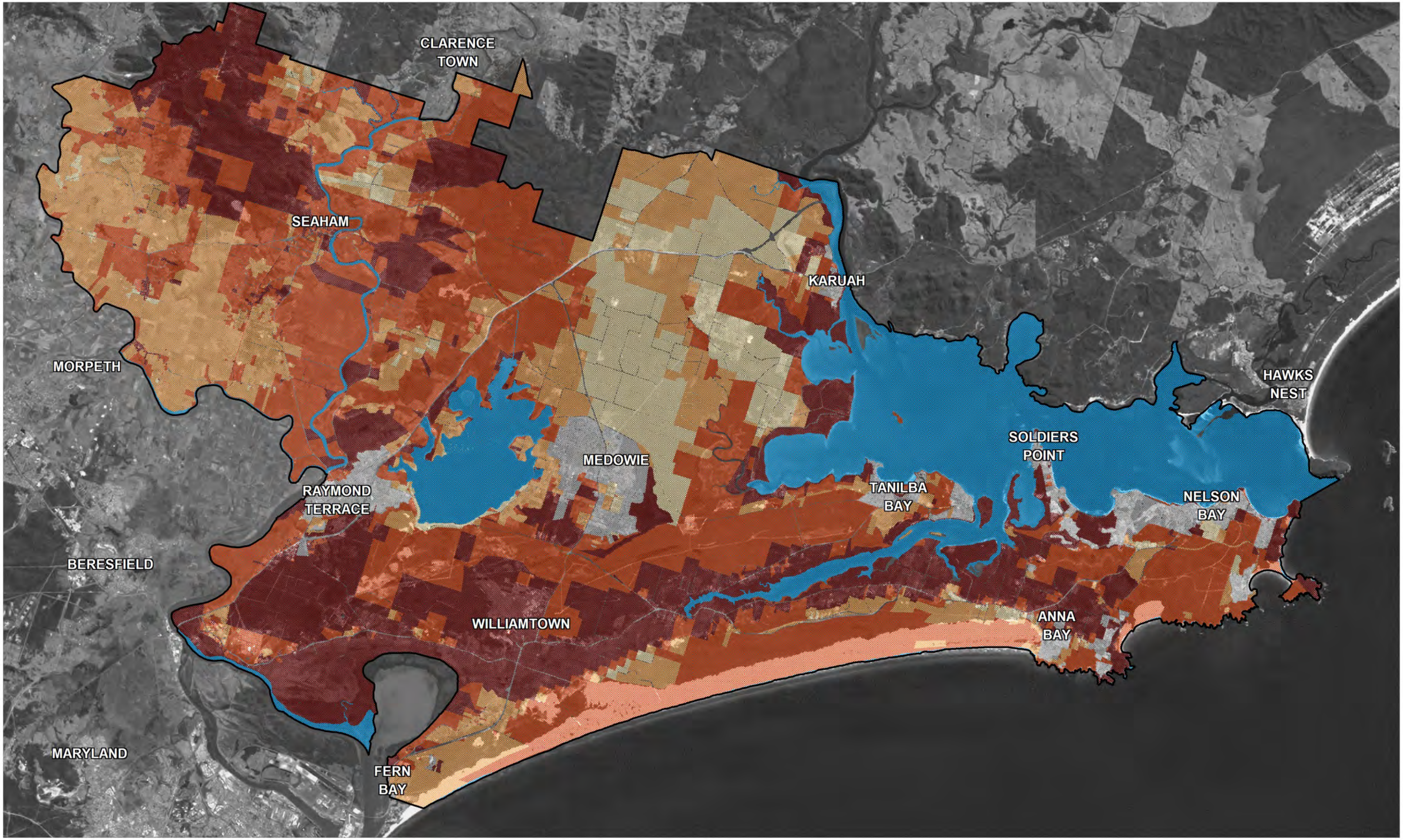
0 3.75 7.5km

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : K:\N1650_Port Stephens_On-site_Sewage_Mgt_Study\Data\MI\Workspaces\DRG_002_100809_Hazard_Class_Single.wor



LEGEND

Single Lot On-site Sewage Hazard Class

- Low Hazard
- Medium Hazard
- High Hazard
- Very High Hazard
- Water Bodies

Title:

Port Stephens On-site Sewage Managment
Final On-site Sewage Hazard Map (Multiple Lots)

Figure: 5-6

Rev: A

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N

0 3.75 7.5km

Approx. Scale

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Filepath : K:\N20301_PSC_DAFUpdate\MI\Workspaces\DRG_003_100809_Hazard_Class_Multiple.wor

5.3 Limitations of Hazard Mapping

The final On-site Sewage Management Maps assign a Hazard Class to individual unsewered allotments in the Port Stephens LGA. It is important to recognise that this site specific Hazard Class was derived using a range of data collected at a range of scales. LiDAR data sourced for creation of slope grids provides a very high level of detail while soil landscape data was mapped at 1:100,000 scale and digitised. Essentially, the Hazard Class assigned to each lot should still be considered a broad scale on-site sewage management hazard. However, this does not preclude the Hazard Maps from being used to at the individual lot scale as long as consideration is given to limitations and uncertainty associated with scale and data source.

The DAF primarily uses the Hazard maps to guide the level of detail required in supporting information for applications to install on-site systems or unsewered development. They have not been used to prescribe site specific conditions of approval relating to system selection, design and construction. They simply establish a Minimum Standard of supporting information to ensure Council can be satisfied that a proposed unsewered development is sustainable. In fact, where broad scale hazard mapping has identified a higher risk, Council will require site specific investigations to be undertaken to confirm conditions. There will be a minority of occasions where these field investigations will identify lots where data scale and accuracy may have resulted in an inaccurate hazard classification.

A number of elements of the hazard mapping were undertaken to minimise the potential for data scale and accuracy to reduce the benefit of the On-site Sewage Hazard Maps.

- Extensive desktop and field based groundtruthing of the Land Capability and Final On-site Sewage Hazard maps throughout the LGA to confirm that land and allotments have been appropriately classified.
- Iterative testing and refinement of the hazard map development protocol based on the outcomes of groundtruthing.
- Adoption of a set of logic statements to create the final maps rather than a deterministic mathematical scoring, weighting and ranking algorithm. This allowed superior consideration to be given to the cumulative impact of multiple hazards on unsewered development in addition to allowance for data scale and accuracy issues.

5.4 Outcomes

As a result of this study, all known unsewered lots in the Port Stephens LGA have been assigned an On-site Sewage Management Hazard Class. This Hazard Class provides a technically justifiable basis for setting requirements for supporting information to be submitted with applications for on-site systems and unsewered development.

6 MINIMUM ALLOTMENT SIZE

A review was undertaken of sustainable *minimum* allotment sizes for on-site sewage management within the Port Stephens LGA. Sustainable minimum lot size was considered to allow for typical levels of site development (based on applicable land use zoning) in addition to a conservatively sized land application system (likely to be the 90^{th}% LAA) and provision of adequate separation distances from sensitive receptors.

Sustainable lot size was then compared with current minimum lot sizes specified in the Port Stephens LEP (2013) and Draft DCP (2014) to determine the most appropriate way to integrate land use planning and wastewater management considerations.

6.1 Methodology

A conservative land area requirement for sustainable on-site sewage management was calculated by the following procedure.

1. A design occupancy of 6 persons for a 4 bedroom house (using reticulated water) was adopted to represent the typical design residential development scenario.

2. A typical system configuration of secondary treatment and subsurface irrigation was assumed. This scenario also allowed for primary dosed trenches and beds (discussed further below).

3. A mean monthly water and annual nutrient balance was undertaken based on the above occupancy and the most limiting combination of climate and soil Design Loading Rate (DLR) data within the LGA. The resulting LAA size was $670m^2$. It is considered that the vast majority of proposed on-site systems within the LGA would require $670m^2$ of area or less.

Primary dosed trenches and beds (which are not always suitable for observed site and soil conditions) occupy approximately half the land area of a secondary dosed irrigation system. However, allowance for a reserve area must be made for primary dosed subsurface systems which results in a comparable land area requirement to that of a secondary dosed irrigation system.

An assessment was then undertaken of a sample of allotments within unsewered zones of the LGA. Forty allotments were assessed to determine the capacity to provide $670m^2$ of area for sewage management in addition to area occupied by development and separation distances (taken from Council's DAF from objects such as;

- building structures;
- driveways and paths;
- swimming pools and other dedicated recreational areas (e.g. tennis courts);
- land occupied by livestock or horses;
- property boundaries; and
- dams, intermittent and permanent watercourses.

The assessment was undertaken through orthophoto investigations and GIS creation of buffers around the abovementioned objects. Statistics on the area of land and proportion of total lot area occupied by each component (inclusive of buffers) were recorded for analysis. The 40 lots assessed were selected to provide a representative sample of typical development in unsewered areas including Wallalong, Brandy, Hill, Hinton and Medowie.

Statistics obtained from this assessment were analysed to identify any patterns or relationships between lot size, land use zones and area available for effluent LAA's. A scatter plot of lot size and the proportion of the lot unavailable for effluent management were created and the relationship used to test possible minimum lot sizes.

6.2 Results

Results of mean monthly water and annual nutrient balance calculations for the most limiting combinations of soil and climate characteristics are presented in Table 6-1. A conservative land application area of 670m^2 was adopted as a result of this assessment. The larger footprint is considered appropriate for planning purposes and allows for situations where issues such as irregular shaped areas and slope limit the proportion of available land that can actually be occupied by a land application system. It is important to note that the outcomes of this minimum allotment size assessment have not been used in a prescriptive or deterministic fashion. Individual applicants are able to undertake additional site specific investigations to confirm the appropriateness of Council's general minimum lot size for their site.

Table 6-1 Summary of Most Limiting Land Application Area Calculations

	Western LGA	Medowie	Taylor's Beach
Water Balance	670 m^2	620 m^2	480 m^2
Nitrogen Balance	380 m^2	380 m^2	380 m^2
Phosphorus Balance	440 m^2	490 m^2	670 m^2

A moderate relationship between lot size and land area unavailable for effluent management was observed in the sample data (R^2 = ~0.6). The less than optimal correlation can largely be attributed to the 20-30% of lots (regardless of lot size) observed to be severely constricted by the presence of one or more of the following.

- A dam or intermittent watercourse.
- Open stormwater drains or pits.
- Permanent watercourses.

This 20-30% component of sampled lots appeared (through further orthophoto investigation and groundtruthing) to be typical of Rural and Rural Small Holdings zones throughout the LGA (refer to Figure 6-2 for examples). Testing of a number of minimum lot sizes ranging from 3,000 – 20,000m^2 found that examples of lots with insufficient area available for effluent management were observed until a minimum lot size of 18,000 m^2 was tested. Given that far too many lots less than 1.8 ha in area are easily capable of sustainable on-site sewage management it is not considered appropriate to adopt a 'most limiting' approach to establishment of minimum lot size.

An optimal balance was achieved through use of the observed relationship between lot size and area unavailable for effluent management to establish a *minimum Useable Area* criterion. Essentially, area occupied by watercourses, dams and stormwater drains and pits (and associated buffer distances) needs to be considered over and above typical lot size. Statistical analysis of sampled lot data indicates that minimum developable area for sustainable on-site sewage management is 3,750 m^2. This figure is sufficiently close to 4,000 m^2 (the existing minimum lot size specified in Council policy and planning instruments) that variation from 4,000 m^2 is not warranted. Figure 6-1 contains the results of this analysis (sample size = 40).

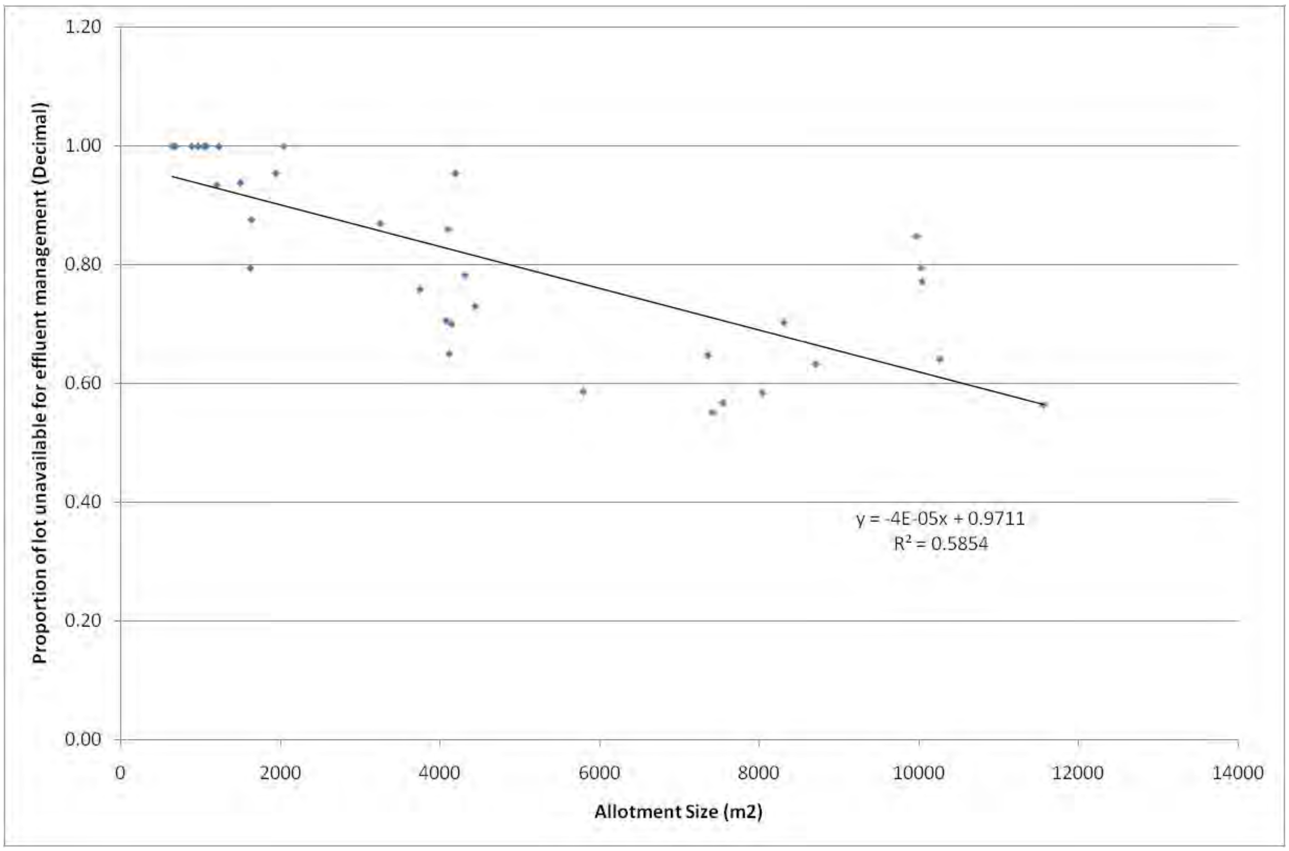

Figure 6-1 Result of Minimum Lot Size Evaluation for Port Stephens LGA

6.3 Outcomes

For the purpose of development planning, a minimum lot size of 4,000 m^2 should be considered the default value for the subdivision of unsewered land. Applicants should be required to demonstrate that each proposed allotment contains 4,000 m^2 of *useable land*. Useable land (for the purpose of on-site sewage management) can be considered to be;

Total allotment area excluding dams, intermittent and permanent watercourses and open stormwater drains and pits in addition to the relevant buffer distances prescribed in the Port Stephens Council Development Assessment Framework for those objects.

Where this cannot be demonstrated, more detailed, site specific investigations may be necessary to justify that an individual proposal is sustainable. Refer to the Development Assessment Framework for more details.

Title:

Example of Minimum Allotment Size Assessment Procedure

Figure: 6-2

Rev: A

N

0 50 100m

Approx. Scale

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7 MAXIMUM LOT DENSITY

The previous chapter summarised the process followed to establish a *minimum allotment size* based on ensuring lots have sufficient usable land to contain a sustainable on-site sewage management service. In addition, consideration must also be given to maximum lot (and subsequently, on-site system) density. The range of natural and built environments throughout the LGA display different capacities to receive and safely assimilate effluent loads from on-site systems. A major element of this study involved the development of a methodology for assessing cumulative impacts from on-site systems that strikes a balance between useability, technical rigour and the ability to account for critical factors influencing the impact of multiple systems on a receiving environment.

Local Councils are faced with a great deal of uncertainty when assessing and predicting the long-term performance of existing and proposed decentralised (on-site and cluster) wastewater management systems. Financial resources are rarely available for collection of sufficient field data to isolate and quantify the magnitude and frequency of impacts from existing systems with adequate certainty. In the case of *proposed* decentralised systems, there is no field data to collect. These limitations have led to the development of a range of water cycle modelling tools to assist in decision making by shedding some light on areas of uncertainty. When used in conjunction with realistic amounts of field data, modelling tools can greatly assist in reducing or defining uncertainty in a working environment consistently and indefinitely constrained by available financial resources.

Affordable modelling tools that can practically be applied to on-site and cluster wastewater management system assessment are available that can be drawn from fields such as hydrology, catchment modelling, groundwater assessment and water sensitive urban design in addition to wastewater management. This chapter presents two case studies illustrating how these tools can assist in the assessment of long-term ecosystem and human health impacts and decision making. The case studies have been used to guide policy development regarding maximum lot density.

7.1 Rationale

In developing a procedure for Cumulative Impact Assessment (CIA) from on-site systems the following principles were applied.

- The CIA procedure(s) should utilise models and tools that are economically and practically viable for use in assessing typical unsewered development applications.
- CIA procedure(s) should be adaptable to varying levels of risk.
- Performance targets for CIA's need to be meaningfully measurable and proportionate to targets for non-wastewater pollution sources (e.g. urban stormwater).
- CIA procedure(s) should not be expected to be deterministic tools but rather indicative tools to provide guidance on the potential risk of impacts (i.e. likelihood, consequence and uncertainty).

The maximum lot density assessment aimed to estimate the relative impact of properly designed, constructed and maintained on-site systems on long-term nutrient and pathogen loads to receiving environments. In completing this assessment, the following assumptions were made.

- Each lot was capable of being serviced by an on-site system designed, sized, constructed and operated in accordance with Councils Development Assessment Framework. This includes land application areas sized to prevent hydraulic surcharging in an average climate year.
- As a result, local impacts arising from poorly performing on-site systems were assumed to be within acceptable levels (e.g. surface hydraulic surcharging and the associated health risks).
- All land application areas comply with relevant separation distances from constructed and natural water bodies and drainage lines.

7.2 Methodology

Available desktop data was used to build a spatial model to simulate hydrology, catchment pollutant export, on-site system operation, groundwater recharge / pollutant discharge and nutrient / pathogen attenuation in groundwater flow for two sites. The models operate on a daily timestep (with the exception of groundwater pollutant attenuation) and have been parameterised using site specific data to provide the best representation of actual conditions in light of limited/no data for calibration.

The models have been used to estimate the long-term hydraulic, nutrient and pathogen loads exported from the study area under existing conditions and the indicative long-term average concentrations of site runoff and groundwater discharge. They have then been used to simulate unsewered subdivision of the sites at a range of lot densities for quantitative comparison to the existing situation. Models also provide an estimate of the frequency, magnitude and distribution of the surface failure of OSWMS to assist in estimating local risks to human health and community amenity impacts.

The development of the models involved the integration of three modelling tools as shown in Figure 7-1. In principle, the model shown below is a daily mass balance model that simulates the water / pollutant balance process for the study area for the purpose of estimating long-term hydraulic, nutrient and pathogen loads discharging to receiving surface and groundwater.

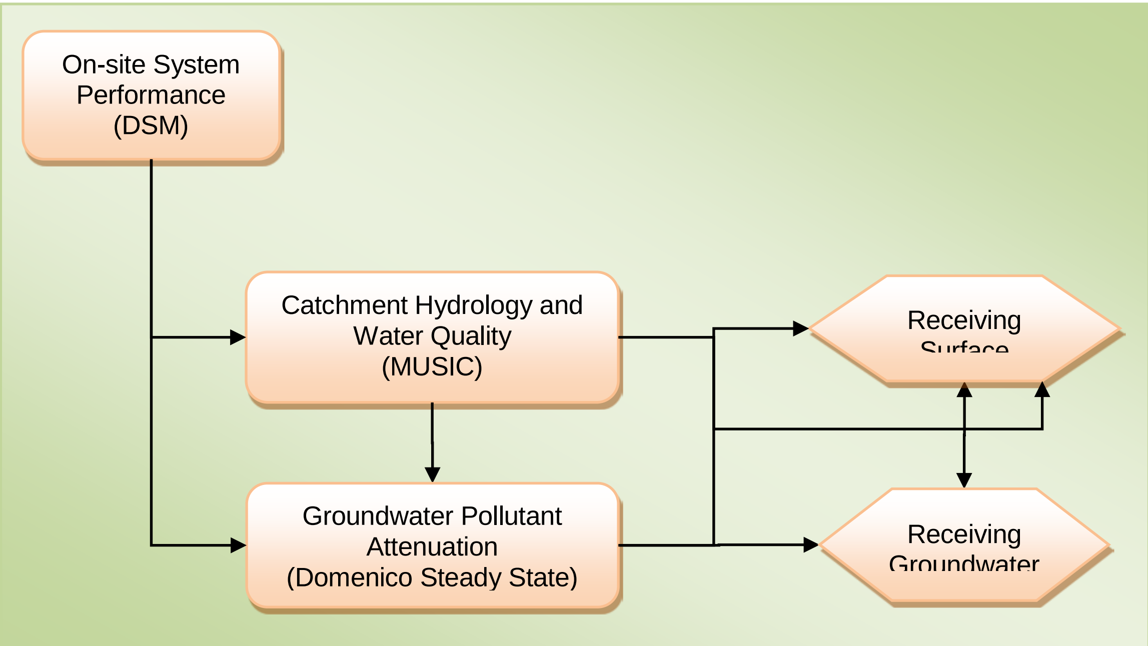


Figure 7-1 Structure of the Lot Density Assessment Models

7.2.1 On-site System Performance: DSM

The Decentralised Sewage Model (DSM) is a GIS based decision support tool designed to assess and compare a range of wastewater servicing options from on-site sewage management to conventional gravity sewerage with central treatment and reuse/disposal. The DSM was developed jointly by BMT WBM and Whitehead & Associates Environmental Consultants. It has the capacity to rapidly assess the long-term environmental/human health performance of wastewater systems in addition to assisting in the concept design and costing of various servicing options. The DSM is comprised of five modules as described in Figure 7-2. Each module of the DSM is able to be used in isolation or collectively depending on the needs of the project.

On-lot Performance Model (OLPM); simulates the performance of individual wastewater discharges to land application systems at a daily timestep. Hydraulic, nutrient and pathogen dynamics within the land application system are modelled with daily surplus loads surcharging to the ground surface and discharging below the rootzone recorded as model outputs.

Particle Tracking Model (PTM); tracks the flow path from individual wastewater systems to receiving waters of surplus surface (and shallow subsurface) hydraulic, nutrient and pathogen loads calculated using the OLPM. A user defined pollutant decay rate can be applied to the PTM where suitable data are available. The PTM assists in identifying likely hotspots for sewage pollution and assessing the feasibility of gravity reticulation for community wastewater management.

Node-Link Model (NLM); allows the OLPM outputs for individual wastewater systems to be grouped into Management Units (MU). MU's may be based on physical subcatchments (e.g. for the purpose of input of data into a catchment model) or user defined groups (e.g. for the purpose of scenario testing or concept design of community wastewater systems). Grouped OLPM outputs are linked to a downstream model component such as a pump station, central treatment system, reuse/disposal facility or discharge to a receiving water. The NLM also allows treated effluent from central management components to be linked back to MU's for reuse (e.g. to simulate dual reticulation).

Central Management Components (CMC); simulate the operation of pump stations or central treatment, disposal and/or reuse systems. The CMC uses similar algorithms to the OLPM to simulate hydraulic, nutrient and pathogen processes.

Costing Model (CM); estimates the capital and operating costs of the modelled wastewater servicing scenarios from on-lot to central components. The CM utilises inputs from the NLM to define unit costs for elements of the CMC.

Figure 7-2 Summary of the Structure of the DSM

For this project, data outputs from the OLPM and NLM models were used as inputs into a catchment hydrology and stormwater quality model to assess the contribution of on-site systems to surface water contamination. Additionally, outputs were used in the development of analytical, steady state groundwater models for assessment of groundwater contamination.

The DSM was selected on the basis that it is the most comprehensive tool available for simulating the long-term operation of multiple on-site systems. A summary of the algorithms used in the DSM can be provided as a separate document for interested parties.

7.2.2 Catchment Hydrology and Water Quality: MUSIC

Model for Urban Stormwater Improvement Conceptualisation (MUSIC) is an Australian tool developed by the Cooperative Research Centre for Catchment Hydrology (now eWater) as part of their catchment modelling toolkit (see www.toolkit.net.au for more information including a comprehensive user manual). MUSIC is designed to simulate urban and rural residential stormwater systems operating at a range of temporal and spatial scales; catchments from 0.01 km^2 to 100km^2 and modelling time steps ranging from 6 minutes to 24 hours to match the catchment scale.

While primarily an urban stormwater quality modelling tool, users with a sound knowledge of rainfall-runoff processes, soil hydrology and pollutant generation and transport processes can readily adapt MUSIC for use in rural residential applications. BMT WBM has been directly involved in the development of MUSIC and its use in a wide variety of environments including those similar to the two study sites. Importantly, MUSIC is relatively simple to use, allowing models to be developed for small study areas in a relatively short amount of time.

MUSIC was used to simulate rainfall-runoff processes and the ‘background’ nutrient and pathogen loads associated with sources other than wastewater. It also provided an estimate of groundwater recharge and associated nutrient concentrations.

7.2.3 Steady State Analytical Groundwater Modelling

Groundwater impacts associated with on-site systems can vary significantly depending on a number of bio-physical and landscape characteristics. The two sites chosen for lot density assessment allow testing of cumulative impacts in the two dominant groundwater environments found in Port Stephens.

- Rolling hills of residual, colluvial and erosional soils in the western portion of the LGA with bedrock creating relatively shallow episodic perched water tables that discharge to local ephemeral drainage lines and creeks.
- Low lying sandy environments underlain by a shallow unconfined aquifer that is directly connected to the Port Stephens estuary (e.g. Tilligerry Creek catchment).

The focus of the groundwater modelling was to estimate the long-term attenuation of nutrients and pathogens in effluent that has leached into episodic perched water tables or the shallow unconfined aquifer prior to discharge to drains, streams or estuaries. Simplistic two dimensional (2D) groundwater modelling was undertaken to estimate the potential transport and fate of nitrogen, phosphorus and pathogens discharging below the root zone as deep drainage. Modelling was undertaken for a selection of representative on-site systems and an assumed point of discharge to a drain or stream. Sensitivity testing of groundwater modelling was completed to provide an indication of the level of accuracy of results.

A 2D steady state analytical approach using the Domenico Equation was adopted for the following reasons.

- There is consistently a lack of available data to construct and calibrate a numerical groundwater model for most unsewered development proposals under 100 lots.
- Modelling of average annual pollutant loads in deep drainage indicates that the risk of export through groundwater flow and discharge to drains or a stream is very low in most scenarios.
- Steady state analytical modelling has been undertaken adopting very conservative input parameters and assumes an almost unrealistic worst case scenario for upper bound estimates.

The Domenico equation calculates pollutant concentration at a given point from a finite, planar, continuous source of pollutant under steady state (i.e. equilibrium) conditions. A full description of the equation is provided in Alvarez and Illman (2006). Analytical modelling was applied to average annual leaching concentrations from on-site systems to give an order of magnitude assessment of pollutant loads and risks to use of shallow groundwater. Modelling of unsaturated groundwater flow (i.e. lateral flow along limiting layers) was not specifically undertaken. Instead, attenuation rates obtained for saturated flow were assumed under all flow conditions. This is conservative as unsaturated flow typically results in greater attenuation of pollutants.

The outcome of groundwater modelling was a set of steady state (average annual) pollutant attenuation factors for the two representative environments. These attenuation factors were then applied to average annual on-site system loads estimated from the DSM modelling. A range of potential scenarios were tested to derive a suitably realistic but conservative attenuation rate that could be applied broadly to comparable environments. The limitations of this approach are recognised by the authors however it represents a method that is consistent with other groundwater management fields where risks to groundwater are low (UK Environmental Agency, 2006). It is also important to recognise the limited benefit in adopting more complex methods of estimating subsurface pollutant attenuation for on-site sewage management system assessment. The data required to undertake site specific monitoring programs or build transient numerical groundwater models will almost never be cost effectively collected for developments of this nature.

7.3 Study Sites

Following the outcomes of the on-site sewage hazard mapping and minimum lot size assessment it was determined that two representative environments needed to be used to investigate maximum lot densities in Port Stephens.

- Rolling hills of residual, colluvial and erosional soils in the western portion of the LGA with bedrock creating relatively shallow episodic perched water tables that discharge to local ephemeral drainage lines and creeks.
- Low lying sandy environments underlain by shallow unconfined aquifers directly connected to the Port Stephens estuary (e.g. Tilligerry Creek catchment).

These two environments provide a good representation of the cross section of critical environments where the cumulative impacts of on-site systems can be of concern. The assessment of both sites was completely hypothetical. Neither site is currently subject to any actual development application for an unsewered subdivision.

7.3.1 Site 1: Butterwick

A site in the western section of the LGA was selected from the Butterwick area and it is shown in Figure 7-3. The site is located on residual and erosional mid-slopes dissected by three natural ephemeral drainage lines that discharge to a floodplain wetland that drains to the Paterson River at Woodville via a network of constructed channels. The site is currently cleared of native vegetation and used for grazing. The site lies adjacent to an existing rural residential subdivision that is unsewered.

The site contains soils of the residual Wallalong landscape and erosional Seaham landscape (Matthei, 1995). The Wallalong soils on the subject site generally consist of moderately deep brown and yellow podzolic soils or sodosols / chromosols according to the Australian Soil Classification (Isbell, 2008). Soils feature a bleached A_2 horizon, sodic clay subsoil with typical depths between 1-2 metres. The Seaham soil landscape consists of comparable soils to the Wallalong landscape on mid-slopes and also features brown / yellow podzolic soils with sodic sub-soils. The main differentiation between the two soil landscapes found on the study site is in soil depth with Seaham soils typically featuring depths less than one metre, terminating on weathered sandstone. Given the influence soil depth can have on on-site system performance, the model was constructed to include both landscapes.

Subsurface hydrology is likely to be dominated by interflow via episodic perched water tables that would form along limiting horizons (namely the boundary between the A_2 and B_1 horizons and at weathered sandstone). This would be the dominant transport pathway for effluent discharging from on-site systems within the Butterwick study site. Figure 7-3 shows the location of the two surface and subsurface discharge points off-site. A brief review of hydrogeology for the area confirmed that connectivity with permanent groundwater would be unlikely within the study site. Subsurface flows would most likely discharge onto the floodplain and recharge alluvial aquifers or enter surface drains.

7.3.2 Site 2: Salt Ash

A second site for completion of maximum lot density modelling was nominated in Salt Ash and is shown in Figure 7-4. Whilst this study site consists of an existing rural residential development, it has been treated as a Greenfield site for the purpose of this assessment. It was chosen based on its combination of representative site conditions and proximity to interconnected drains and Tilligerry Creek. The site is located on the lower section of the Aeolian Tomago Sandbeds immediately adjacent to the Holocene depression that forms Tilligerry Creek and links to Fullerton Cove. The site is flat (slopes less than 0.5%), low lying and soils are predominantly sands to sandy loams with some indurated lenses (coffee rock) throughout. Groundwater is typically one metre from the ground surface.

Very little surface runoff occurs from the site and hydrology is dominated by rapid recharge of the unconfined alluvial aquifer that underlies the site. This aquifer is connected to Tilligerry Creek however, groundwater discharge to the estuary as aquifer flow would be limited by the very low hydraulic gradients. The primary hydraulic output is likely to be groundwater discharge via the complex, interconnected surface drains constructed throughout and surrounding the site. The primary study site discharge points are shown in Figure 7-4.

The Salt Ash study site represents a highly sensitive and constrained environment in terms of on-site sewage management. Council have previously implemented a number of strategies to address on-site system impacts within the Tilligerry Creek catchment including standard designs for on-site systems to ensure risks to human health and ecosystems are adequately managed. This lot density assessment also allowed further testing of the effectiveness of these standard designs.

7.4 On-site System and Lot Density Scenarios

It was determined that a wide range of lot density scenarios would be assessed (between 1,000 m^2 / 0.1 ha and 2 ha). In the case of lots less than 4,000 m^2, for the purpose of this exercise it was assumed that an on-site system sized to a mean monthly water balance was able to be constructed and operated in a sustainable fashion. As detailed in Section 6, it is unlikely that lots less than 4,000 m^2 will be capable of containing a sustainable system. However, this theoretical assumption allowed testing of the minimum lot size assessment outcomes in conjunction with lot density. As shown in Figure 7-3 and Figure 7-4, useable or developable land was determined by establishing exclusions zones based on separation distances (as listed in the DAF). A further 10% reduction was made in useable land to account for road reserves and other public or utility land within a typical rural residential development. It is important to note that in some cases useable land may only constitute part of each allotment (e.g. a subdivision that contains floodprone land).

Each lot was assumed to contain a four bedroom house with a reticulated (or unconstrained) water supply. A mean monthly water balance was then conducted to size a generic land application system based on local site and soil characteristics and climate data. In the case of the Butterwick site, lot density modelling was conducted for two on-site system types.

- Secondary treatment system to subsurface irrigation.
- Primary treatment system to trenches or beds.

It is acknowledged that the subject site is unlikely to be suitable for primary dosed trenches and beds. These systems were modelled purely to provide a theoretical comparison of cumulative impacts. On-site system options for the Salt Ash study site were derived based on Council's *Standard Designs for On-site Sewage Management in Tilligerry Creek* (2005). A combination (50/50%) of Wisconsin Mounds dosed with primary effluent and secondary treatment systems dosing raised subsurface irrigation beds was adopted. System sizes were obtained from the above document.

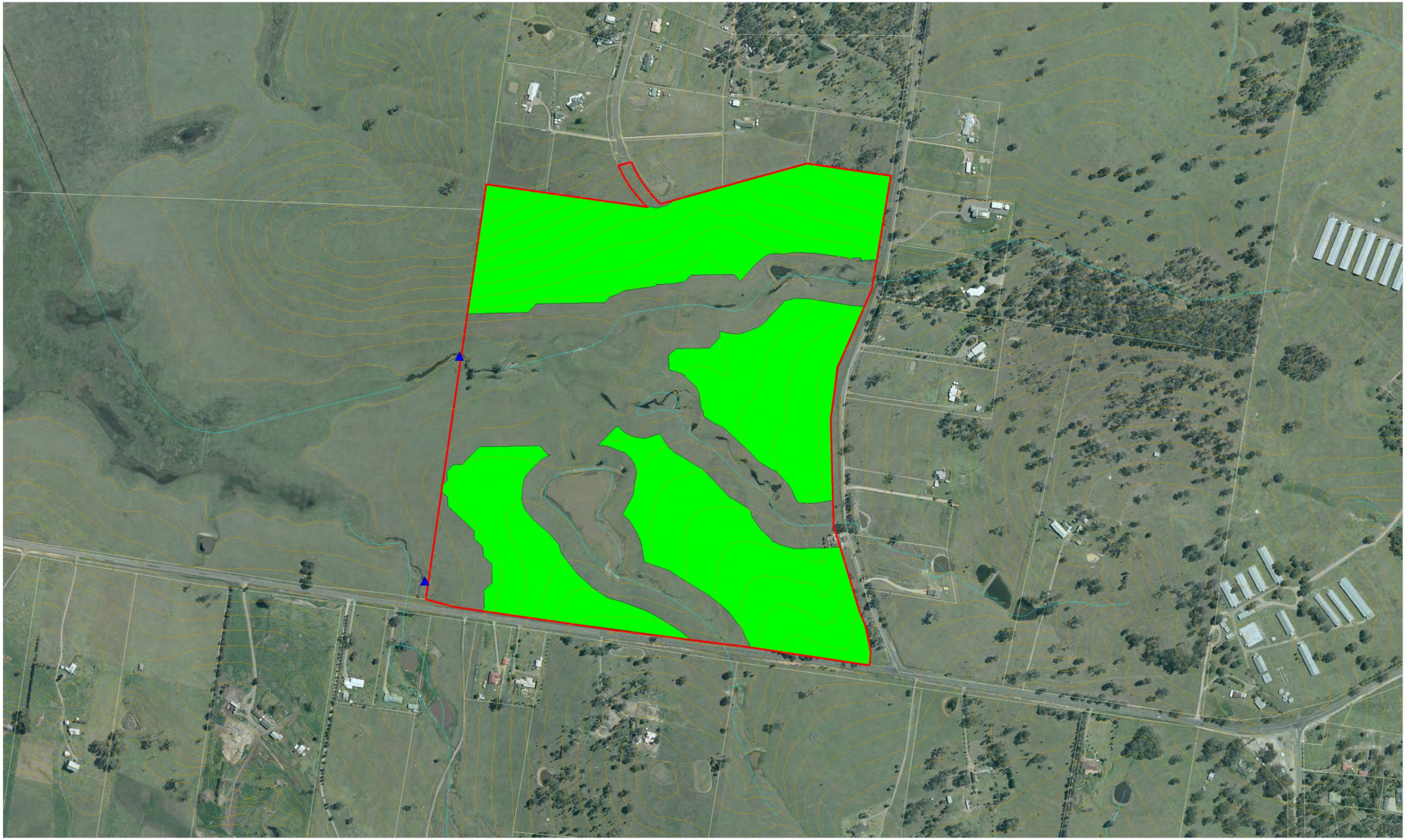
In modelling each study site, consideration was given to including existing on-site systems and general pollutant loads in the assessment. This was not considered appropriate for a number of reasons. Namely;

- there are a number of legal issues surrounding the inclusion of impacts from existing developments previously approved by Council that should be dealt with externally to modelling;
- inclusion of pollutant contributions from external sources significantly increases the size and complexity of the model;
- completion of a site specific mass balance is consistent with stormwater pollutant load assessments for general residential development (e.g. MUSIC modelling); and
- inclusion of external pollutant sources in mass balance models will only improve accuracy or reduce uncertainty where sufficient data is available to do so in a robust manner.

The modelling conducted for this lot density assessment and carried through to the DAF for Cumulative Impact Assessment (CIA) purposes is designed for use as a decision making tool but will not necessarily produce results that accurately reflect measured pollutant loads to receiving waters. Instead it aims to conduct a site mass balance to allow users and decision makers to assess predicted increases in pollutant loads against existing conditions or alternative development concepts.

Table 7-1 Summary of Development Configurations for Lot Density Assessment

	0.1 ha	0.2 ha	0.4 ha	0.6 ha	0.8 ha	1 ha	1.2 ha	1.4 ha	1.6 ha	1.8 ha	2 ha
Butterwick											
Total Land	54 ha										
Useable Land	29 ha										
Total Systems	290	145	73	48	36	29	24	21	18	16	15
Configuration	Two scenarios: Secondary Treatment Systems (STS) to Pressure Compensating Subsurface Irrigation Primary Treatment Systems (PTS) to absorption trenches or Evapo-transpiration (ETA) beds										
Salt Ash											
Total Land	49 ha										
Useable Land	24 ha										
Total Systems	240	120	60	40	30	24	20	17	15	13	12
Configuration	50% of systems: PTS dosing Wisconsin Mounds 50% of systems: STS dosing raised pressure compensating subsurface irrigation beds										



LEGEND

- Useable Land
- Watercourse
- 10m Contours
- Site Boundary
- Study Area Discharge Points
- Cadastre

Title:
Port Stephens On-site Sewage Management
Butterwick Study Area for Maximum Lot Density Assessment

Figure: 7-3

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

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Approx. Scale

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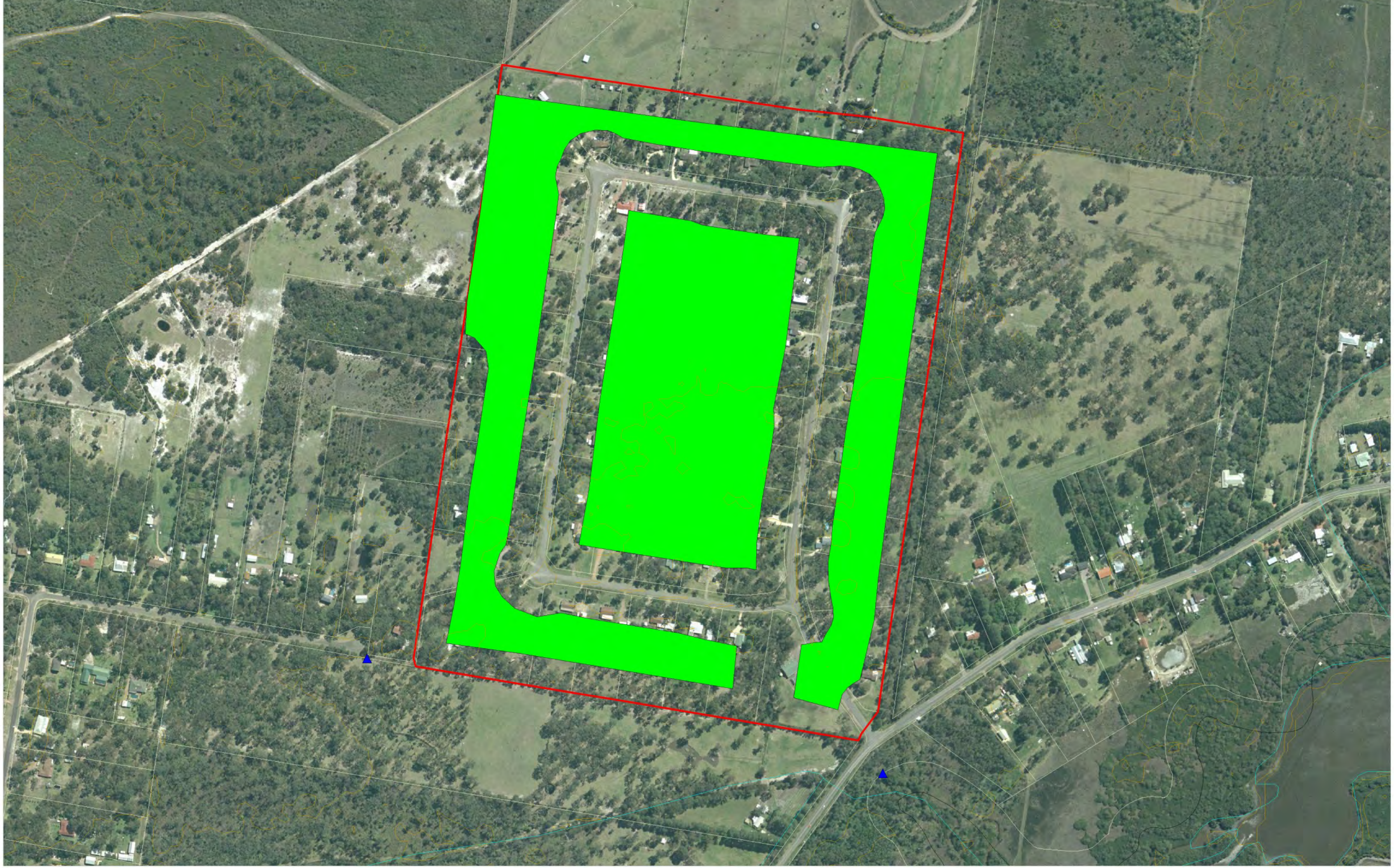

LEGEND

Useable Land	Site Boundary
Watercourse	Study Area Discharge Points
10m Contours	Cadastre

Title:

Port Stephens On-site Sewage Management
Salt Ash Study Area for Maximum Lot Density Assessment

Figure: **7-4**

Rev: **A**

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Approx. Scale

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7.5 Data Inputs

As is often the case, there is limited data available to construct a fully parameterised, calibrated and validated risk assessment model for the purpose of a maximum lot density assessment. However, sufficient data and information has been made available through limited field investigations and PSC data to ensure a useful decision support tool for wastewater servicing can be established. If considered beneficial, opportunities to collect water quality, quantity and on-site system data can be used to refine accuracy of the modelling.

7.5.1 General Data Inputs

A range of general data were used in development of all components of the lot density models. These datasets were primarily used to construct a spatial model of key bio-physical features of the study area. They are summarised in Table 7-2.

Table 7-2 General Data Used to Construct Spatial Model of Study Sites

Parameter	Source	Purpose
Climate (daily) Rainfall Potential Evapo-transpiration Average Air Temperature	SILO Data Drill Interpolated Data Butterwick: Lat: -32.65, Long: 151.65 1984 – 2003 (20 years) Salt Ash: Lat: -32.8, Long: 151.9 1982 – 2001 (20 years)	Used in water balance calculations for the DSM (on-site systems) and MUSIC (rainfall-runoff model). Air temperature used for DSM pathogen model in lieu of ground temperature.
Digital Elevation Model (DEM) Created in ArcGIS™ through triangulation adopting a 2m grid.	Light Detection and Ranging (LiDAR) data supplied by PSC.	Surface model of the study area used to determine; Hydrologic pathways Groundwater elevation DSM slope interrogation
Soil Landscape Information	Previous local field investigation data. Soil landscape mapping (Matthei, 1995)	Development of soil profiles and input parameters for DSM on-lot performance model MUSIC rainfall-runoff model
Groundwater / Aquifer Data Butterwick: Episodic perched water table Salt Ash: Unconfined shallow aquifer connected to Tilligerry Creek	NSW DECCW Groundwater Bore Logs Previous local field investigation data.	Recharge properties for MUSIC rainfall-runoff model DSM soil and system properties Hydraulic aquifer properties and dimensions for modelling
Landuse / Cadastre and **Aerial Photography**	Port Stephens Council	Assessment of current and potential future development configuration in study area. Available area for land application systems (DSM) Effective Impervious Area (EIA) assessment for MUSIC. Drainage configuration.
Hydrology Hydrologic configuration Subcatchment boundaries	PSC GIS data Previous local field investigation data.	Hydrologic and pollutant pathways Upstream contributions Groundwater discharge points

7.5.2 DSM Inputs

There are three data sets required to run the DSM a shown in Figure 7-5.

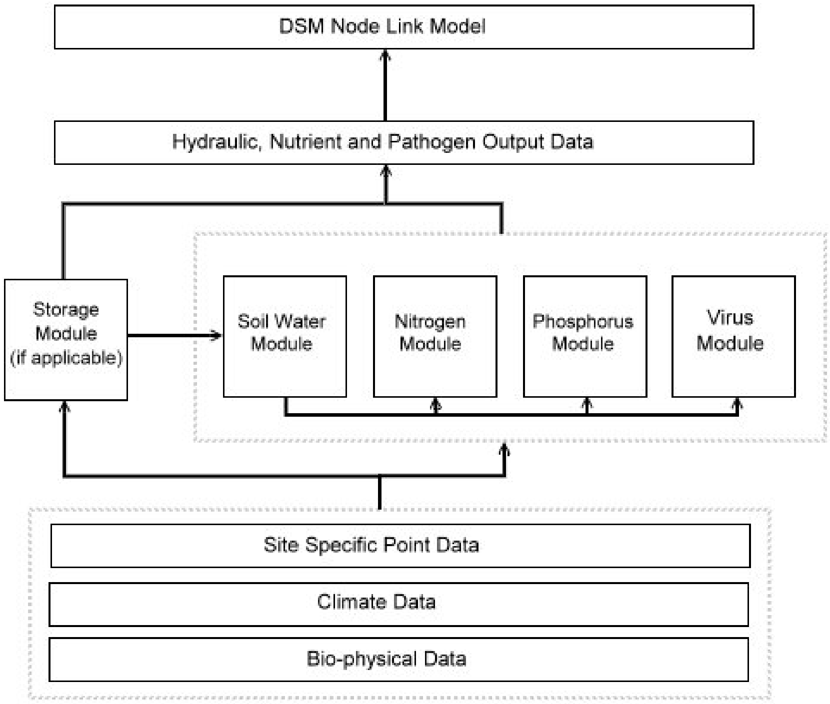

Figure 7-5 Overall Structure of the On-lot Performance Model

7.5.2.1 Site Specific Point Data

A point data file (e.g. MapInfo) was created for the study areas that identified individual on-site systems for each lot density scenario. This data file contained fixed (i.e. non-temporally varying) information specific to each system (e.g. type and size of system, effluent quality). This file was populated through data collected during desktop investigations. A summary of the key on-site system data used in the DSM is provided in Table 7-3 and Table 7-4. Each system within each lot density scenario was attributed the same configuration.

7.5.2.2 Climate Data

A separate data input file was also created containing climate data in a daily timestep as specified in Table 7-2. The modelling period of 20 years was adopted based on availability of data and the need to ensure phosphorus sorption processes reach equilibrium.

Table 7-3 On-site System Input Data for the Butterwick DSM

Data Input	System Type		Unit	Source
Scenario	STS/SSI	PTS/AT/ETA		
Land Application Area	707 (Wallalong Soil) 482 (Seaham Soil)	385 (Wallalong Soil) 190 (Seaham Soil)	m^2	Sized using a Mean Monthly Water Balance in accordance with Council's DAF. Paterson Climate Data adopted. Design Loading Rates (DLRs) taken from *ASNZS1547:2012.*
Effluent TN concentration	30	60	g/m^3	Assumed based on effluent produced by typical systems. Virus numbers for effluent from Asano *et al* (2007).
Effluent TP concentration	12	15		
Effluent virus concentration	5	1000	MPN/100ml	
Wastewater flow	1.08		m^3/day	Based on a 4 bedroom house occupied by 6 persons at 180 L/person/day for all properties in the study area.

Table 7-4 On-site System Input Data for the Salt Ash DSM

Data Input	System Type		Unit	Source
Scenario	STS/SSI	PTS/Mound		
Land Application Area	380	194	m^2	Sized using the PSC *Standard On-site Wastewater Management System Designs for Tilligerry Creek* (2005)
Effluent TN concentration	30	60	g/m^3	Assumed based on effluent produced by typical systems. Virus numbers for effluent from Asano *et al* (2007).
Effluent TP concentration	12	15		
Effluent virus concentration	5	1000	MPN/100ml	
Wastewater flow	1.08		m^3/day	Based on a 4 bedroom house occupied by 6 persons at 180 L/person/day for all properties in the study area.

7.5.2.3 Bio-physical Data

Necessary bio-physical data was obtained through analysis of the data and information supplied to BMT WBM by PSC as detailed in Table 7-2. Two different soil landform elements were present within the Butterwick study area with the primary difference between elements being depth to limiting layer and the associated limitations to drainage and phosphorus sorption. Bio-physical input parameters adopted for the two model scenarios are presented in Table 7-5 and Table 7-6. Input parameters were developed to cover both soil elements and the range of land application system types adopted.

Screenshots of example DSM models are shown in Figure 7-6 and Figure 7-7 for the 4000 m^2 scenario.

Table 7-5 Bio-physical Input Data for the Butterwick DSM

Data Input	Wallalong Soil		Seaham Soil			Source
	STS/SSI	PTS/ATS/ETA	STS/SSI	PTS/ATS/ETA	Unit	
Soil water at effective saturation	248	214	222	192	mm	Based on texture, structure and drainage characteristics of typical observed soil profile from Matthei (1995). Hydraulic properties assigned based on Hazelton and Murphy (2007). On-site system properties also adjusted to reflect the assumed configuration of different LAAs.
Field capacity	207	98	190	90		
Permanent Wilting Point	136	34	97	24		
Saturated hydraulic conductivity	24				mm/day	
Soil depth for phosphorus sorption	1.6	1.2	1.0	0.4	m	Based on typical observed soil profile and configuration of the land application system.
Bulk density	1400				kg/m^3	Based on observed texture and structure with reference to Hazelton and Murphy (2007).
Dry soil infiltration rate	150				mm/day	Based on texture, structure and drainage characteristics of typical observed soil profile and McLeod (2008).
Infiltration exponent	2.5				dimensionless	
Freundlich adsorption coefficient	200		173		g/L	Obtained though comparison of p-sorption lab results from Matthei (1995) with similar 5-point sorption tests from BMT WBM library.
Freundlich adsorption exponent	0.2		0.21		dimensionless	
Freundlich desorption exponent	0.1		0.1			Assumed to be half of the adsorption rate in the absence of specific data.
Crop factors	1					Assumed equal to ET_o.
Crop nitrogen uptake	125				kg/ha/year	A slightly lower uptake was assumed for the on-site scenario due to reduced vegetation harvesting and maintenance.
Crop phosphorus uptake	15					
Slope	Site specific				%	Slope calculated using the DEM and average slope for each polygon of available area calculated.

Table 7-6 Bio-physical Input Data for the Salt Ash DSM

Data Input	System Type			Source
	STS/SSI	PTS/Mound	Unit	
Soil water at effective saturation	266	303	mm	Based on texture, structure and drainage characteristics of typical observed soil profile from Matthei (1995). Hydraulic properties assigned based on Hazelton and Murphy (2007). On-site system properties also adjusted to reflect the assumed configuration of different LAAs.
Field capacity	160	191		
Permanent Wilting Point	32	42		
Saturated hydraulic conductivity	3000		mm/day	
Soil depth for phosphorus sorption	0.8	1.2	m	Based on typical observed soil profile and configuration of the land application system.
Bulk density	1200		kg/m^3	Based on observed texture and structure with reference to Hazelton and Murphy (2007).
Dry soil infiltration rate	350	200	mm/day	Based on texture, structure and drainage characteristics of typical observed soil profile and McLeod (2008).
Infiltration exponent	0.5	2	dimensionless	
Freundlich adsorption coefficient	173		g/L	Obtained though comparison of p-sorption lab results from Matthei (1995) with similar 5-point sorption tests from BMT WBM library.
Freundlich adsorption exponent	0.1		dimensionless	
Freundlich desorption exponent	0.05			Assumed to be half of the adsorption rate in the absence of specific data.
Crop factors	1			Assumed equal to ET_o.
Crop nitrogen uptake	200		kg/ha/year	A slightly lower uptake was assumed for the on-site scenario due to reduced vegetation harvesting and maintenance.
Crop phosphorus uptake	25			
Slope	Site specific		%	Slope calculated using the DEM and average slope for each polygon of available area calculated.

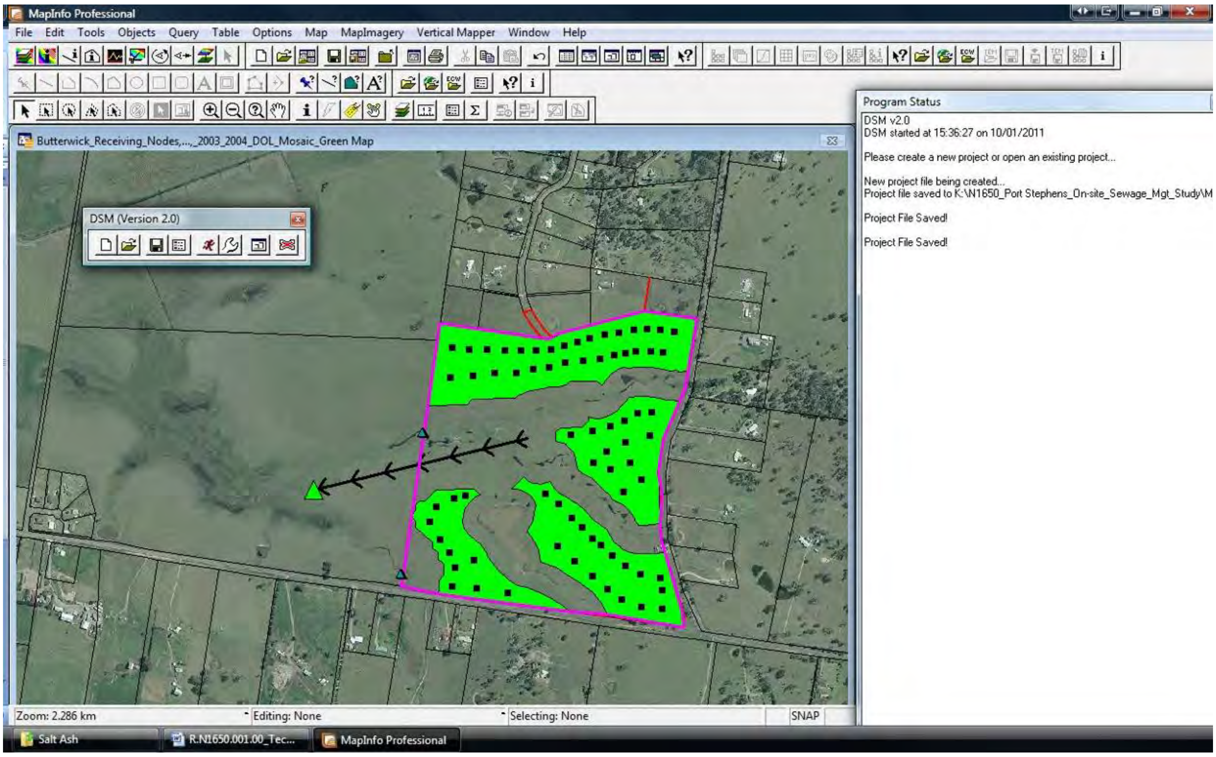

Figure 7-6 DSM Screenshot for Butterwick 0.4 ha Scenario

Black Points = Hypothetical On-site Systems Green Triangle = Receiving Node.
Pink Polygon = Management Unit

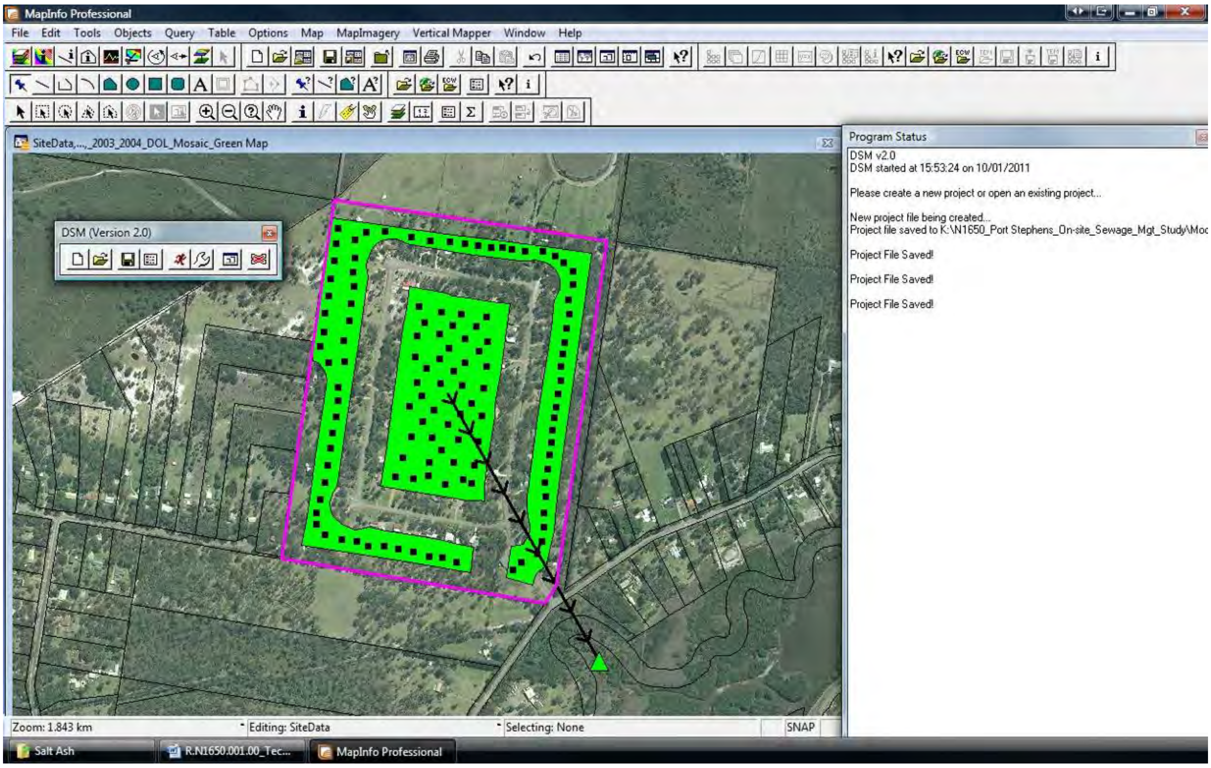

Figure 7-7 DSM Screenshot for Upgraded On-site Scenario

Black points = Hypothetical On-site System. Green Triangle = Receiving Node Pink Polygon = Management Unit

7.5.3 MUSIC Inputs

MUSIC requires the input of climate data, soil hydrologic, landuse and pollutant generation characteristics in order to derive runoff volumes, baseflow to groundwater and nutrient and pathogen loads at each study site. Given that MUSIC is a process based mass balance model, adaptation to a rural residential setting is not problematic. A summary of inputs is provided below.

Stormwater quality was modelled with the MUSIC software considering water quality constituents including TN, TP, and faecal coliform (using TSS as a surrogate parameter). Both sites were modelled in their existing undeveloped condition. At present Council does not specifically require modelling of long-term stormwater pollutant loads as part of rural residential development assessment processes. To retain simplicity, on-site system impacts have been assessed against ***existing undeveloped loads***. This is considered conservative and will allow Council to approve unsewered subdivisions on Low and Medium Hazard lots with confidence that cumulative impacts will be adequately managed. There may be scope in the future to complete modelling of this nature in conjunction with stormwater quality and quantity modelling using MUSIC or similar software.

The MUSIC models for each site are shown in Figure 7-8 and Figure 7-9.

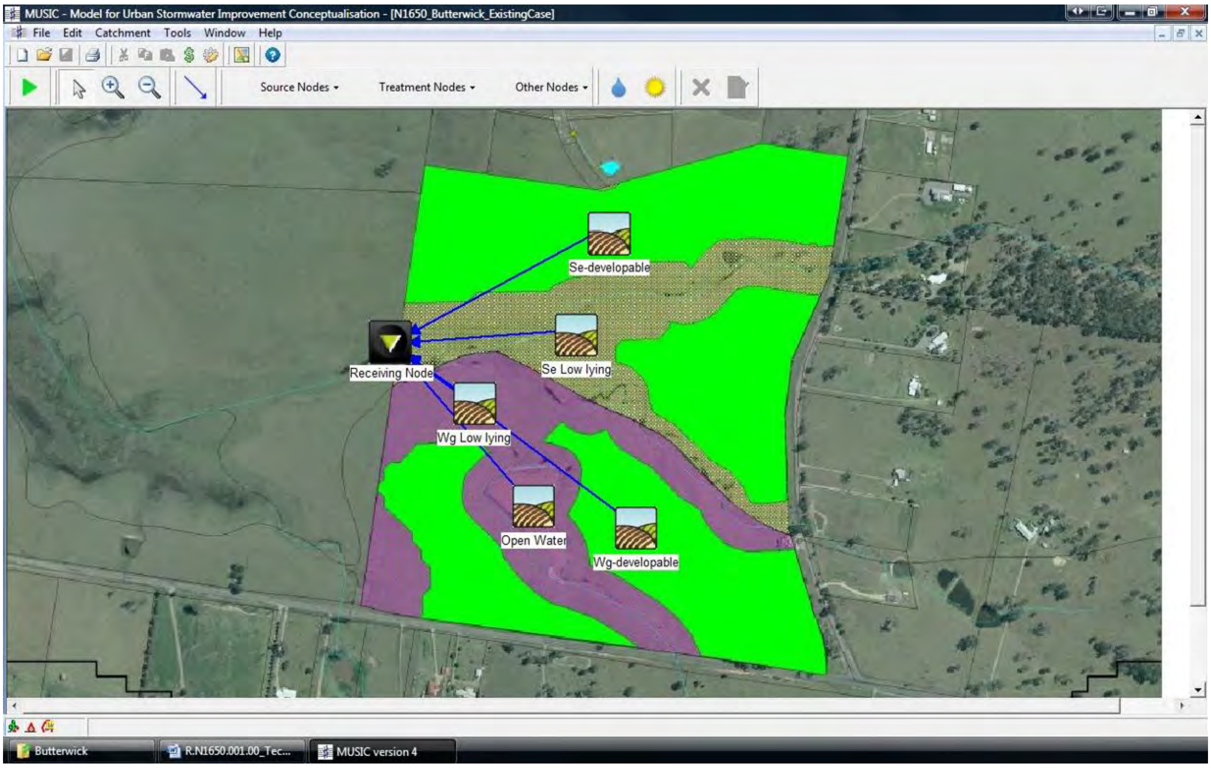

Figure 7-8 Butterwick MUSIC Model

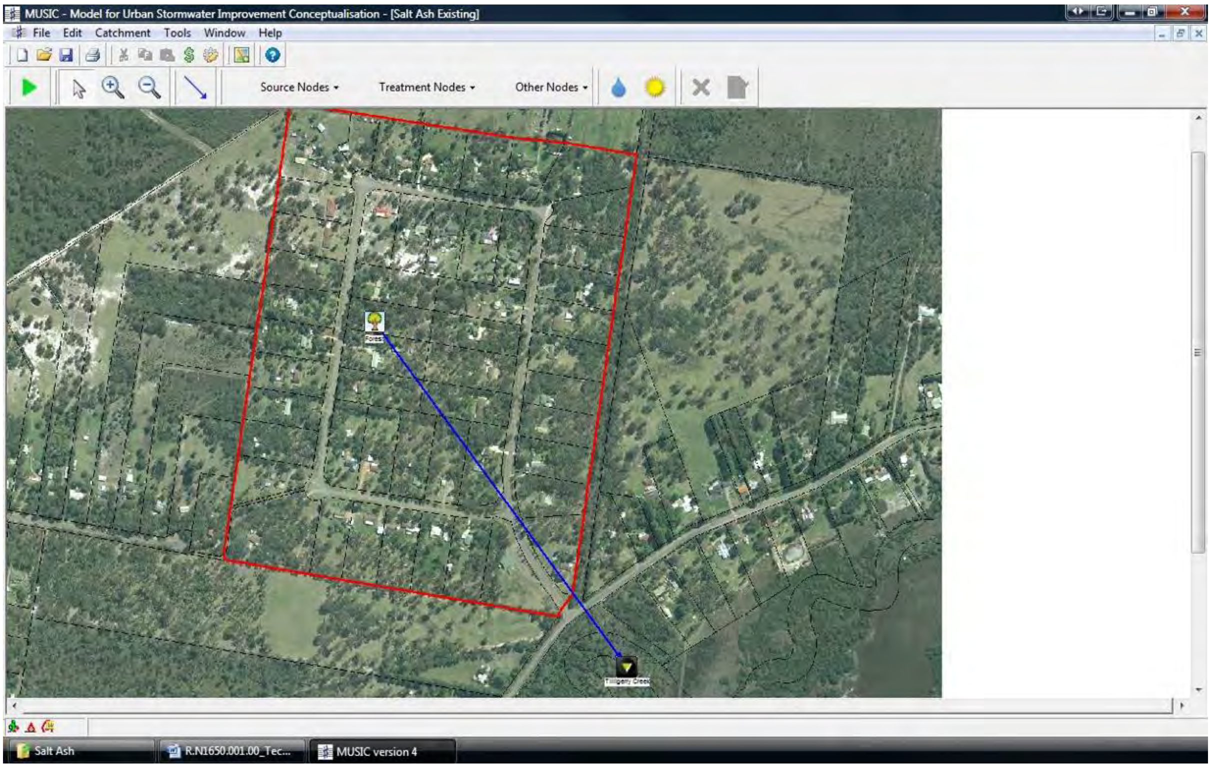

Figure 7-9 Salt Ash MUSIC Model

7.5.3.1 Meteorological Template

The climate data listed in Table 7-2 was used as the template for the MUSIC model. A daily timestep was adopted which is considered appropriate for a long-term volume based rainfall-runoff model with no routing through stormwater measures.

7.5.3.2 Source Nodes

Within MUSIC the user is required to specify source nodes. The source nodes represent the pollutant generating characteristics of particular land uses/surfaces within the site. MUSIC has three source nodes to represent urban, forest and agricultural land-uses. The source nodes have default parameters for soil properties and storm and base flow pollutant concentrations which represent the different land uses. The option exists within MUSIC for the user to alter the default parameters as required to best represent a specific land use or surface type being modelled, particularly when the land use or surface type does not correspond with the urban, forest or agricultural defaults supplied in MUSIC. MUSIC also requires the user to enter the Effective Impervious Area (EIA) for each source node.

7.5.3.2.1 Soil Hydrologic Parameters

Default rainfall-runoff parameters within MUSIC are not appropriate for use at these sites. Careful rainfall-runoff parameterisation is crucial to accurate modelling of the existing hydrologic regime. Site specific rainfall-runoff parameters have been developed for each source node based on MacLeod (2008) and using the understanding of soil / groundwater characteristics available within the project team following field and desktop investigations. Reference was made to Fletcher *et al* (2004) and

Australian Runoff Quality (2005) in finalising parameters to ensure site water balance, runoff coefficient and base flow index were reflective of similar sites.

Parameters for the Existing Butterwick MUSIC model are presented below. Five different source nodes were developed to represent the varying soil facets and landscape characteristics (low hills and footslopes) observed in addition to the open water of the large dam in the south of the site.

Table 7-7 Rainfall-Runoff Parameters for Butterwick

<table>
<tr><th>Parameter</th><th>Seaham Useable</th><th>Seaham Low-lying</th><th>Wallalong Useable</th><th>Wallalong Low-lying</th><th>Open Water</th></tr>
<tr><td colspan="6">Impervious Area Parameters</td></tr>
<tr><td>Rainfall threshold (mm/day)</td><td colspan="5">1</td></tr>
<tr><td colspan="6">Pervious Area Parameters</td></tr>
<tr><td>Soil Storage capacity (mm)</td><td>119</td><td>59</td><td>129</td><td>149</td><td rowspan="5">None</td></tr>
<tr><td>Initial Storage (% of capacity)</td><td colspan="4">30</td></tr>
<tr><td>Field Capacity (mm)</td><td>96</td><td>50</td><td>114</td><td>131</td></tr>
<tr><td>Infiltration Capacity Coefficient – a</td><td>100</td><td>120</td><td>120</td><td>110</td></tr>
<tr><td>Infiltration Capacity Exponent - b</td><td>2</td><td>2.5</td><td>2.5</td><td>2.2</td></tr>
<tr><td colspan="6">Groundwater Properties</td></tr>
<tr><td>Initial depth (mm)</td><td colspan="4">10</td><td rowspan="4">None</td></tr>
<tr><td>Daily Recharge Rate (%)</td><td>50</td><td>10</td><td>40</td><td>10</td></tr>
<tr><td>Daily Baseflow Rate (%)</td><td>17</td><td>6</td><td>11</td><td>4</td></tr>
<tr><td>Daily Deep Seepage Rate (%)</td><td>1</td><td>5</td><td>1</td><td>2</td></tr>
</table>

A key consideration for flat, low lying sites such as Salt Ash is the need to account for depression storage and post-event infiltration of stormwater into groundwater and the lag time between groundwater recharge and discharge to downstream receiving waters. Soil parameters have been adjusted to ensure the MUSIC model produces a volumetric coefficient of runoff (C_v) comparable to similar sites. Soil parameters are provided in Table 7-8. Testing of model sensitivity indicated a single set of soil parameters for all source nodes was acceptable.

Table 7-8 Rainfall-Runoff Parameters for Salt Ash

Parameter	Source Nodes
Impervious Area Parameters	
Rainfall threshold (mm/day)	1
Pervious Area Parameters	
Soil Storage capacity (mm)	158
Initial Storage (% of capacity)	30
Field Capacity (mm)	68
Infiltration Capacity Coefficient – a	350
Infiltration Capacity Exponent - b	0.5
Groundwater Properties	
Initial depth (mm)	10
Daily Recharge Rate (%)	90
Daily Baseflow Rate (%)	20
Daily Deep Seepage Rate (%)	0

7.5.3.2.2 Effective Impervious Area and Landuse

EIA and landuse have been estimated through GIS analysis of aerial photography and field investigations. This included confirmation of directly connected impervious areas compared to areas discharging to the ground surface. For the purpose of this exercise, both sites were assumed to have 100% pervious area. The Butterwick site was classified as a rural land use with pollutant generation rates based on general rural / grazing land from Fletcher *et al* (2004). The Salt Ash site was classified as a “Forested” site for the purposes of selecting pollutant generation rates.

7.5.3.2.3 Pollutant Generation Rates

Fletcher *et al* (2004) provides a comprehensive set of values obtained from a wide range of catchment studies from Australia and overseas and provides values recommended by NSW DECC for site/catchment modelling within NSW. These concentrations are summarised in Table 7-9 and Table 7-10. It is acknowledged that local data on non-wastewater pollutant loads would be preferable to this approach.

Table 7-9 Base Flow Concentration Parameters (Fletcher et al, 2004)

Concentration (mg/L)						
	Faecal Coliform (cfu/L)		TP		TN	
	mean	std. dev	mean	std. dev	Mean	std. dev
Land use/zoning						
Rural	1000	15	0.06	1.55	0.9	1.32
Forest	100	9.7	0.03	1.35	0.3	1.35

Table 7-10 Storm Flow Concentration Parameters (Fletcher et al, 2004)

Concentration (mg/L)						
	Faecal Coliform (cfu/L)		TP		TN	
	mean	std. dev	mean	std. dev	Mean	std. dev
Land use/zoning						
Rural	6000	16.6	0.22	1.8	2.0	1.5
Forest	600	32.4	0.08	1.66	0.9	1.74

7.5.3.2.4 Receiving Node

One node is used to represent the discharge point for each study area which is shown in Figure 7-8 and Figure 7-9. Given the absence of available data from adjacent up and downstream areas, the models have been established as mass balance tools for the study area only. As a result, MUSIC outputs for the assigned receiving node are not a simulation of actual conditions at that point.

7.5.4 Groundwater Modelling Inputs

Simplistic two dimensional (2D) groundwater modelling has been undertaken to estimate the potential transport and fate of nitrogen, phosphorus and pathogens discharging to groundwater as baseflow.

This is considered important as the DSM does not model attenuation of flows and loads from on-site wastewater management systems prior to discharge off-site. A 2D steady state analytical approach using the Domenico Equation was adopted as previously discussed.

The Domenico Equation calculates pollutant concentration at a given point from a finite, planar, continuous source of pollutant under steady state (i.e. equilibrium) conditions. A full description of the equation is provided in Alvarez and Illman (2006). It has been used to estimate the likely long-term average pollutant concentrations at the study area boundaries / discharge points and subsequent nitrogen, phosphorus and virus attenuation rates across the study area.

Sensitivity testing of pollutant concentration at the source, porosity, hydraulic gradient and hydraulic conductivity indicates that the uncertainty associated with estimating long-term average values for these parameters is highly unlikely to influence the outcomes of the lot density assessment.

Modelling has been undertaken for a series of hypothetical on-site systems that best represent the variation in groundwater discharge of sewage and proximity to the study area discharge point. For the purpose of catchment modelling, the average, minimum and maximum annual discharge concentration for all on-site systems was used and the 'plume' assumed to cover the entire study area (i.e. we modelled on-site groundwater discharge as a large uniform plume). Sample system plumes helped to confirm the validity of this approach.

Following a review of the above modelling results, suitable study area wide attenuation rates were selected that are considered conservative (toward the upper bound result of sensitivity testing) given the lack of site specific aquifer stratigraphy and groundwater level dynamic information available. The rate for virus attenuation was converted to a bacterial value by adopting a virus:faecal coliform ratio derived in Surbeck *et al* (2006). A summary of groundwater modelling inputs for the two sites are provided in Table 7-11 and Table 7-12. Resulting attenuation rates for catchment modelling are discussed in 7.5.5.

The Butterwick study site is unlikely to be directly connected to permanent aquifers as previously described in Section 7.3.1. Conservative modelling of episodic perched water tables was undertaken assuming saturated flow conditions using the Domenico Equation. This is likely to underestimate attenuation to some degree given unsaturated conditions will exist for much of the time however this has been accounted for in development of the final catchment wide attenuation logic (Section 7.5.5). It is also considered appropriate given the uncertainty associated with catchment attenuation processes.

Groundwater models for the Salt Ash site, while still simplistic are based on both site specific and locally applicable data from very similar environments. Attenuation rates derived through groundwater modelling for Salt Ash are considered to be more representative of catchment processes than the Butterwick outputs. Notwithstanding, there is still uncertainty associated with the results.

Table 7-11 Analytical Groundwater Modelling Data Input: Butterwick

Data Input	Value		Unit	Source
	STS/SSI	**PTS/AT/ETA**		
Initial TN, TP and virus concentration at plume source. (Lower – Mid – Upper)	TN: 0.5 – 1.1 – 4.8 TP: 0.08 – 0.13 – 0.34 Virus: 5 – 35 - 1700	TN: 1.2 – 2.1 – 8.6 TP: 0.25 – 0.38 – 1.1 Virus: 17 – 90 – 1800	mg/L or MPN/L	Average long-term concentrations from the daily subsurface outputs from the DSM. Sensitivity testing undertaken using the minimum and maximum concentrations.
Plume geometry	**Individual On-site Plumes:** **Study Area Plume:**	Width – 20 Thickness – 1 Width – 750	m	Based on typical configuration of land application systems and study area width.
Aquifer thickness	1		m	Based on average soil depth below land application areas. Based on peak episodic perched water table conditions.
Bulk density of aquifer material	1.4		kg/m^3	Assumed based on Hazelton & Murphy (2007) densities for different geological materials.
Effective porosity of aquifer material	0.2		fraction	Published value ranges for clay subsoil materials from Alvarez and Illman (2006).
Hydraulic conductivity of aquifer	0.5		m/day	
Hydraulic gradient	3		%	Based on observed DEM interrogation and estimation of likely perched water table depths during wet weather.
Distance to compliance point	Individual On-site Plumes: 40 – 300 Study Area Plume: 80		m	Measured in GIS for a range of individual systems in addition to study area.
Biodegradation / decay rate half life.	TN – 0.000016 TP – 0.000002 Virus – 0.14		days^{-1}	Calculated using Buscheck and Alcantar (1995) as described in Alvarez and Illman (2006) using Tuncurry STP groundwater monitoring data. This involved the use of over 10 years of groundwater elevation and quality data for 7 bores within a shallow coastal unconfined aquifer. Values would be conservative for this site. No local data available.
Retardation factor (Partition coefficient)	TN – 33 TP – 900 Virus – 3		L/kg or L/MPN	Nutrient factors calculated based on reported phosphorus sorption capacity of the in-situ soils, typical published values for ammonia-N and the R factor for viruses was obtained directly from Powelson and Gerba (1994).
Longitudinal Dispersivity	2.59		m	Calculated using method developed by Xu and Eckstein (1995).

Table 7-12 Analytical Groundwater Modelling Data Input: Salt Ash

Data Input	Value		Unit	Source
	STS/SSI	PTS/Mound		
Initial TN, TP and virus concentration at plume source. (Lower – Mid – Upper)	TN: 0.6 – 2.1 – 6.8 TP: 0.17 – 1.2 – 5.3 Virus: 10 – 200 - 2000	TN: 1.7 – 2.5 – 7.7 TP: 0.38 – 12 – 38 Virus: 17 – 90 – 1800	mg/L or MPN/L	Average long-term concentrations from the daily subsurface outputs from the DSM. Sensitivity testing undertaken using the minimum and maximum concentrations.
Plume geometry	**Individual On-site Plumes:** **Study Area Plume:**	Width – 20 Thickness – 1 Width – 750	m	Based on typical configuration of land application systems and study area width.
Aquifer thickness	13		m	Based on limited bore data sourced from www.waterinfo.nsw.gov.au.
Bulk density of aquifer material	1.6		kg/m^3	Assumed based on Hazelton & Murphy (2007) densities for different geological materials.
Effective porosity of aquifer material	0.2		fraction	Published value ranges for clay subsoil materials from Alvarez and Illman (2006).
Hydraulic conductivity of aquifer	10		m/day	
Hydraulic gradient	0.5-1		%	Based on observed DEM interrogation and data collected as part of the study published by Lucas *et al*, 2007).
Distance to compliance point	Individual On-site Plumes: 40 – 600 Study Area Plume: 40 – 600		m	Measured in GIS for a range of individual systems in addition to study area.
Biodegradation / decay rate half life.	TN – 0.000016 TP – 0.000002 Virus – 0.14		$days^{-1}$	Calculated using Buscheck and Alcantar (1995) as described in Alvarez and Illman (2006) using Tuncurry STP groundwater monitoring data. This involved the use of over 10 years of groundwater elevation and quality data for 7 bores within a shallow coastal unconfined aquifer. Values would be conservative for this site. No local data available.
Retardation factor (Partition coefficient)	TN – 33 TP – 25 Virus – 3		L/kg or L/MPN	Nutrient factors calculated based on reported phosphorus sorption capacity of the in-situ soils, typical published values for ammonia-N and the R factor for viruses was obtained directly from Powelson and Gerba (1994).
Longitudinal Dispersivity	2.59		m	Calculated using method developed by Xu and Eckstein (1995).

A range of on-site system plume scenarios were modelled to gauge the variation in subsurface attenuation likely within each study site. Attenuation rates varied between 85 – 99.8% for all three pollutants across a range of hydraulic and pollutant concentration scenarios. It was observed that for the Butterwick site, increases and decreases in soil water content had a significant influence on attenuation rates. For the Salt Ash site, outcomes of the study completed by Lucas *et al* (2007) and the local experience of BMT WBM have previously identified connectivity of groundwater with constructed drains to be a critical determining factor in the transport of pollutants to receiving waters. Groundwater modelling confirmed that attenuation of nutrients and pathogens in groundwater is almost 100% when the water table is not connected to surface drains. However, attenuation rates dropped noticeably once groundwater was able to discharge into these drainage networks and travel by surface flow to the estuary.

7.5.5 Catchment Attenuation Logic

Daily time series from the DSM and MUSIC models were inserted into a comprehensive mass balance spreadsheet for application of attenuation in surface and groundwater flow. This then allowed calculation of total hydraulic and pollutant loads for the study area. The procedure for determining indicative groundwater attenuation rates is described in the previous section. It is not appropriate to assume full wastewater loads discharged to the ground surface are conveyed to surface drains and into stormwater runoff. During dryer weather (when soil is not saturated) the capacity for re-infiltration of this water and entrained pollutants will be substantial. In order to address this issue the following logic was developed to apply approximate surface flow attenuation factors from Jelliffe (2000) which in turn were obtained through field investigations for a doctoral thesis undertaken in Sydney by Martens (1996).

Following the outcomes of DSM, MUSIC and groundwater modelling, a logic for the attenuation of pollutants was developed. This logic was developed using the following procedure.

- Soil water content from the MUSIC model results were used to classify individual days in the 20 year modelling period based on potential for pollutant attenuation / transport.
- In the case of Salt Ash, rainfall, groundwater level and drain depth data collected by Lucas *et al* (2007) were used to develop rules for connectivity of drains to groundwater based on rainfall depths.
- Attenuation rates derived through groundwater modelling were used to assign attenuation rates (and subsequent proportions of pollutant loads reaching receiving nodes) to subsurface outputs from DSM results. Rates varied based on soil water content for that day and in the case of Salt Ash, as groundwater connectivity with surface drains occurred.
- Surface attenuation rates from Jelliffe (2000) were adapted to both sites based on soil water content and groundwater/drain connectivity and applied to surface outputs from the DSM.
- Daily DSM outputs were multiplied by decay rates or inverse values of attenuation rates (i.e. as % of pollutant load discharging to receiving nodes) for the 0.4 ha lot density scenario.
- Average annual attenuation rates for total loads (surface and subsurface loads combined) were then calculated based on the daily attenuation logic and applied to all lot density scenarios.

Final pollutant attenuation rates are summarised in the following table.

Table 7-13 Adopted Attenuation Rates for Catchment Modelling

Hydrologic Element	Hydraulic	Nitrogen	Phosphorus	Pathogen
Butterwick				
Hydrologic Scenario: Soil moisture less than field capacity.				
Deep drainage	100%			
Interflow/Surface Surcharge				
Hydrologic Scenario: Soil moisture halfway between field capacity and saturation.				
Deep drainage	0%	95%	95%	100%
Interflow/Surface Surcharge	80%	90%		95%
Hydrologic Scenario: Soil moisture greater than halfway between field capacity and saturation.				
Deep drainage	0%	90%	90%	95%
Interflow/Surface Surcharge	60%	80%		90%
Hydrologic Scenario: Soil moisture at saturation.				
Deep drainage	0%	80%	85%	90%
Interflow/Surface Surcharge	40%	70%	70%	70%
Salt Ash				
Hydrologic Scenario: Groundwater below elevation of drain invert.				
Deep drainage	50%	100%		
Interflow/Surface Surcharge	70%			
Hydrologic Scenario: Groundwater at/above elevation of drain invert and soil moisture below field capacity.				
Deep drainage	10%	98%	95%	100%
Interflow/Surface Surcharge	40%			
Hydrologic Scenario: Groundwater at/above elevation of drain invert and soil moisture above field capacity.				
Deep drainage	0%	98%	95%	100%
Interflow/Surface Surcharge	20%			
Hydrologic Scenario: Groundwater at/above elevation of drain invert and soil moisture at saturation.				
Deep drainage	0%	96%	90%	100%
Interflow/Surface Surcharge		78%	75%	80%

7.5.6 Final Outputs

Attenuated average annual sewage flows from the DSM were then combined with average annual MUSIC outputs in a mass balance to provide a representation of relative impacts associated with on-site systems. Results have been assessed against baseline existing case MUSIC outputs across the range of lot density scenarios described in Table 7-1.

7.6 Results

Results of lot density modelling are summarised in the following figures. Critical lot density was identified as the point where combined on-site system and undeveloped background pollutant loads meet or fall below undeveloped background loads alone. That is, a neutral or beneficial effect (NORBE) is theoretically achieved. This performance objective is not meant to provide a realistic representation of actual pollutant loads discharging at a specific point in time. The results do however provide a realistic estimate of pollutant loads exported from the study site in isolation (i.e. excluding upstream inputs from other existing properties). This target is conservative and provides a high level of assurance that well operated systems meeting the target are not going to create cumulative impacts. It also avoids the need to assess existing catchment pollutant loads when assessing a single development proposal.

7.6.1 Butterwick

Lot density modelling for the Butterwick study site indicates that adoption of secondary treatment with subsurface irrigation results in **4,000 m^2 of Useable Land** per allotment achieving NORBE with respect to cumulative impacts. This equates to 2.5 systems per hectare of Useable Land. In the case of a primary treatment system scenario, approximately 1-1.2 hectares of Useable Land per allotment was required to achieve NORBE on undeveloped existing loads. It should be noted that this scenario was completed to provide a relative comparison to servicing by secondary treatment system. Absorption trenches and evapo-transpiration beds would not be suitable for construction on the Butterwick study site.

The faecal coliform target was set as a concentration (30 cfu/100ml) given the limited usefulness of loads as a measure of health protection. The value matches primary contact recreation water quality objectives and exceeds targets for protection of aquaculture. This target was not exceeded for any lot density scenario further supporting current understanding of on-site system performance that identifies prevention of hydraulic failure of land application systems as the most important mechanism for health protection.

7.6.2 Salt Ash

Lot density modelling results for Salt Ash displayed more variability than the Butterwick results. Nitrogen outputs indicated that 4,000 m^2 of Useable Land (2.5 system per hectare of Useable Land) is required to achieve NORBE on existing undeveloped loads whilst phosphorus outputs indicated 1.1 hectares of Useable Land is required (0.91 systems per hectare of Useable Land). Faecal coliform modelling suggests theoretically, allotments with 1,500 m^2 of Useable Land would achieve cumulative impact targets although this result should be not be seen as justification of adoption of this as policy. This lot density modelling assumes that each lot is capable of containing a typical level of rural residential development in addition to an on-site system sized in accordance with the DAF and located to meet setback distances to relevant items. The outcomes of the Minimum Allotment Size assessment (Section 6) showed that 1,500 m^2 was consistently insufficient to achieve this.

While results for phosphorus suggest less than one system per hectare is required to strictly achieve NORBE on existing undeveloped loads, it is recommended that **4,000 m^2 of Useable Land** (2.5 systems per hectare of Useable Land) be adopted for low lying coastal environments. The following justification is provided.

- On-site system loads for the 4,000 m^2 scenario are only 10% higher than existing undeveloped loads which is still a high level of protection.
- Average annual *concentrations* for the 4,000 m^2 scenario are equivalent to the NORBE target (0.03 mg/L).
- Port Stephens (primarily Tilligerry) estuary are not currently sensitive to such small increases in phosphorus loads.

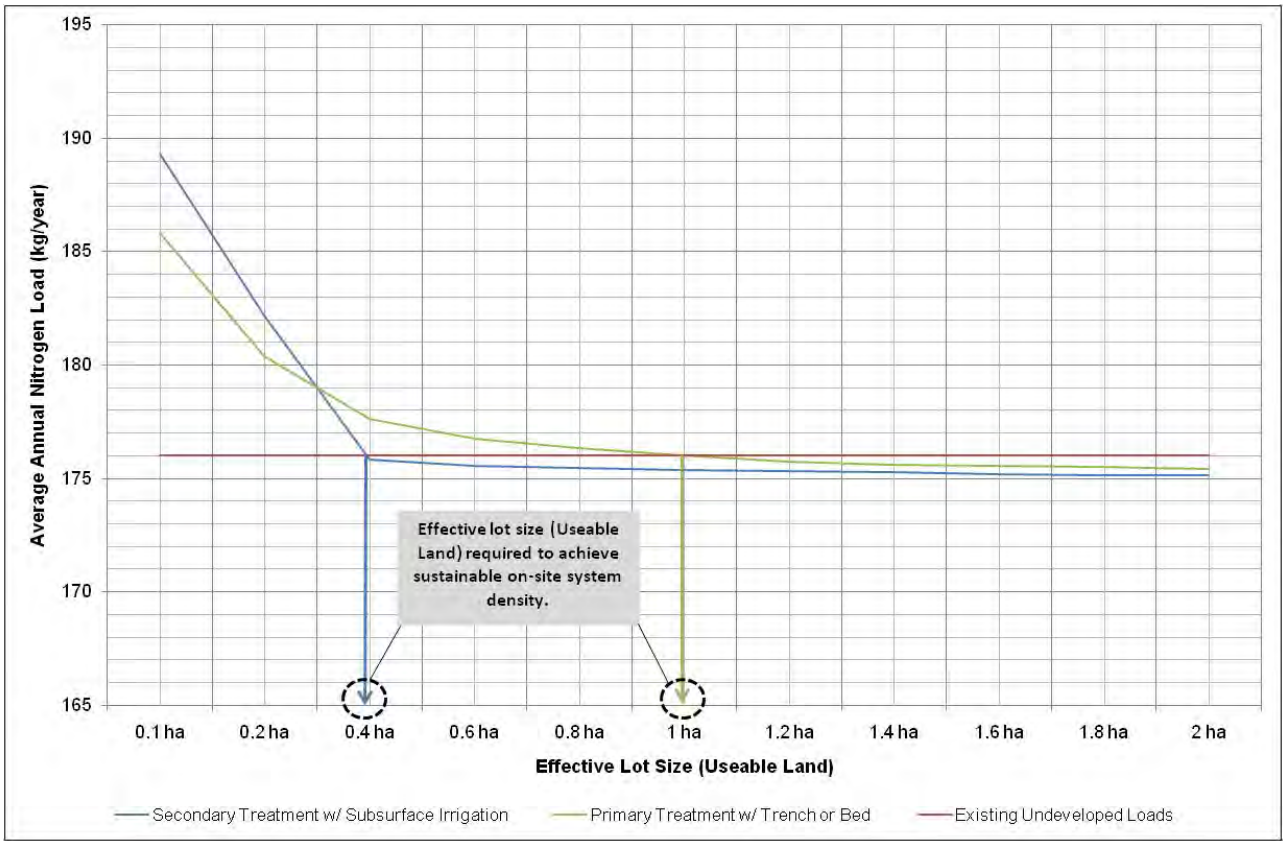

Figure 7-10 Lot Density Modelling Results for Butterwick: Nitrogen Loads

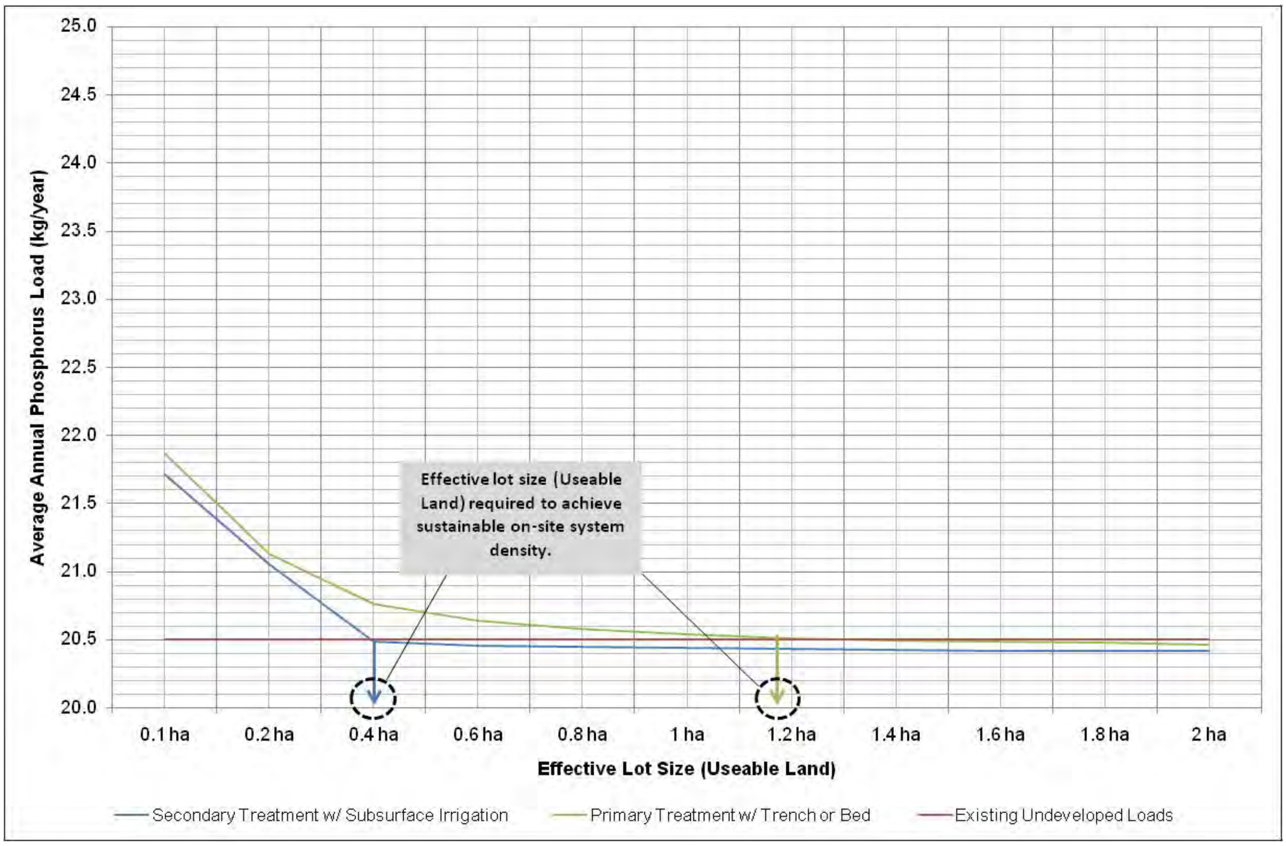

Figure 7-11Lot Density Modelling Results for Butterwick: Phosphorus Loads

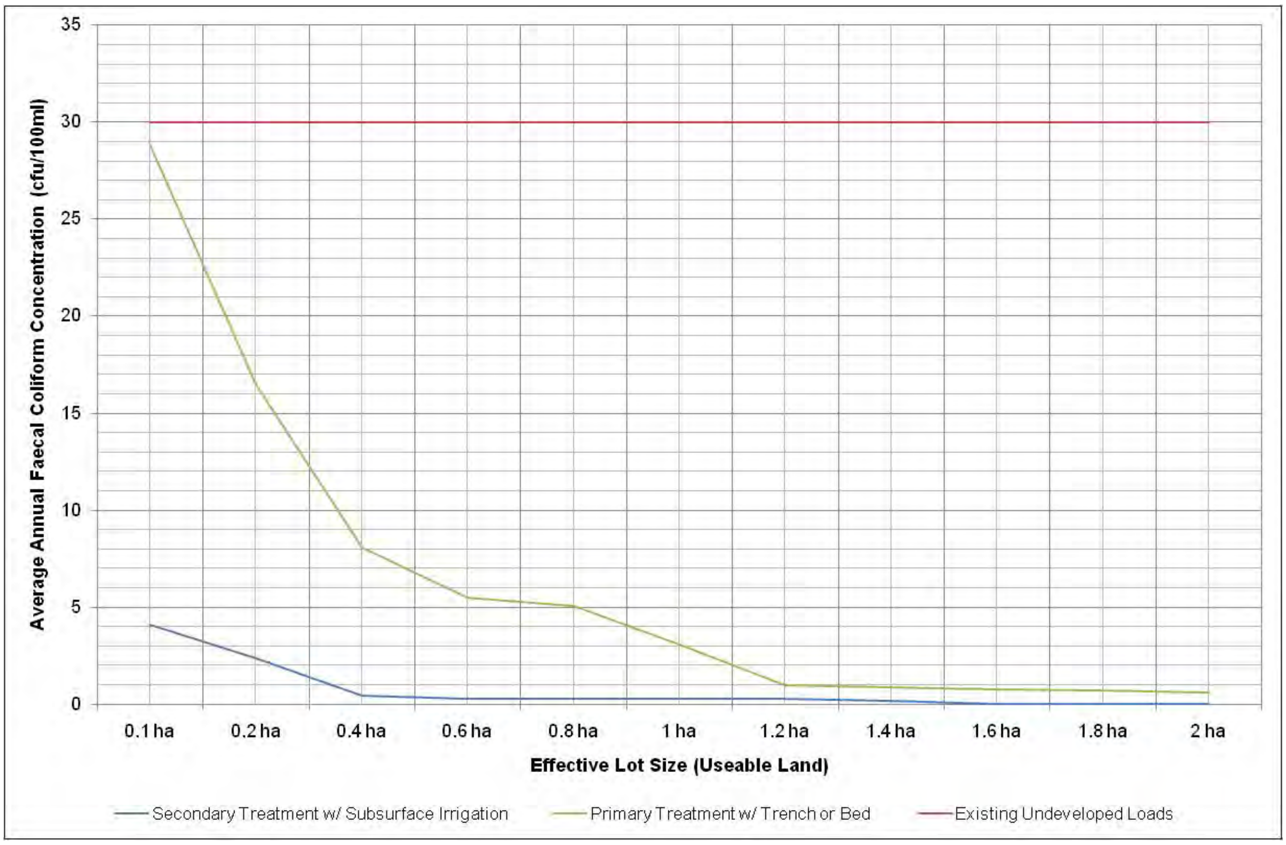

Figure 7-12 Lot Density Modelling Results for Butterwick: Faecal Coliform Concentrations

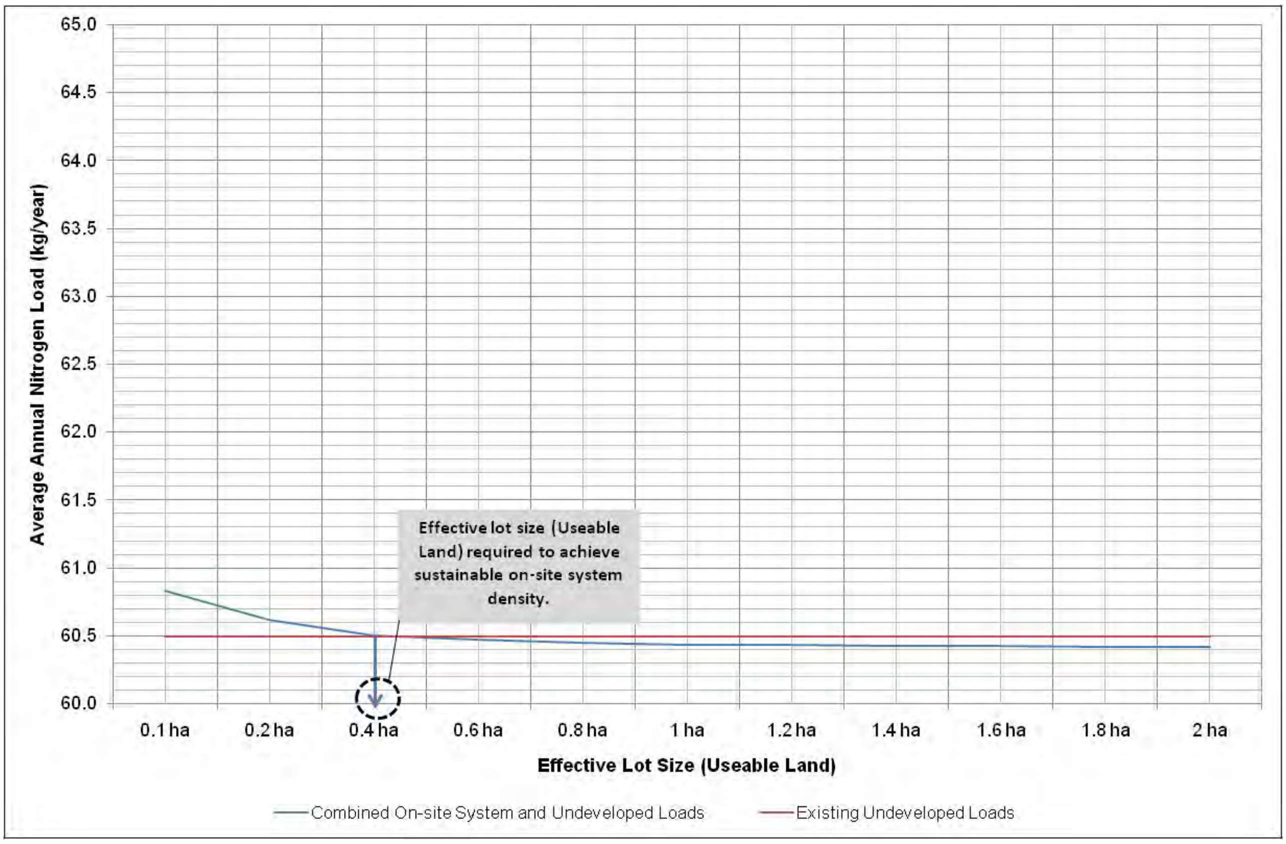

Figure 7-13 Lot Density Modelling Results for Salt Ash: Nitrogen Loads

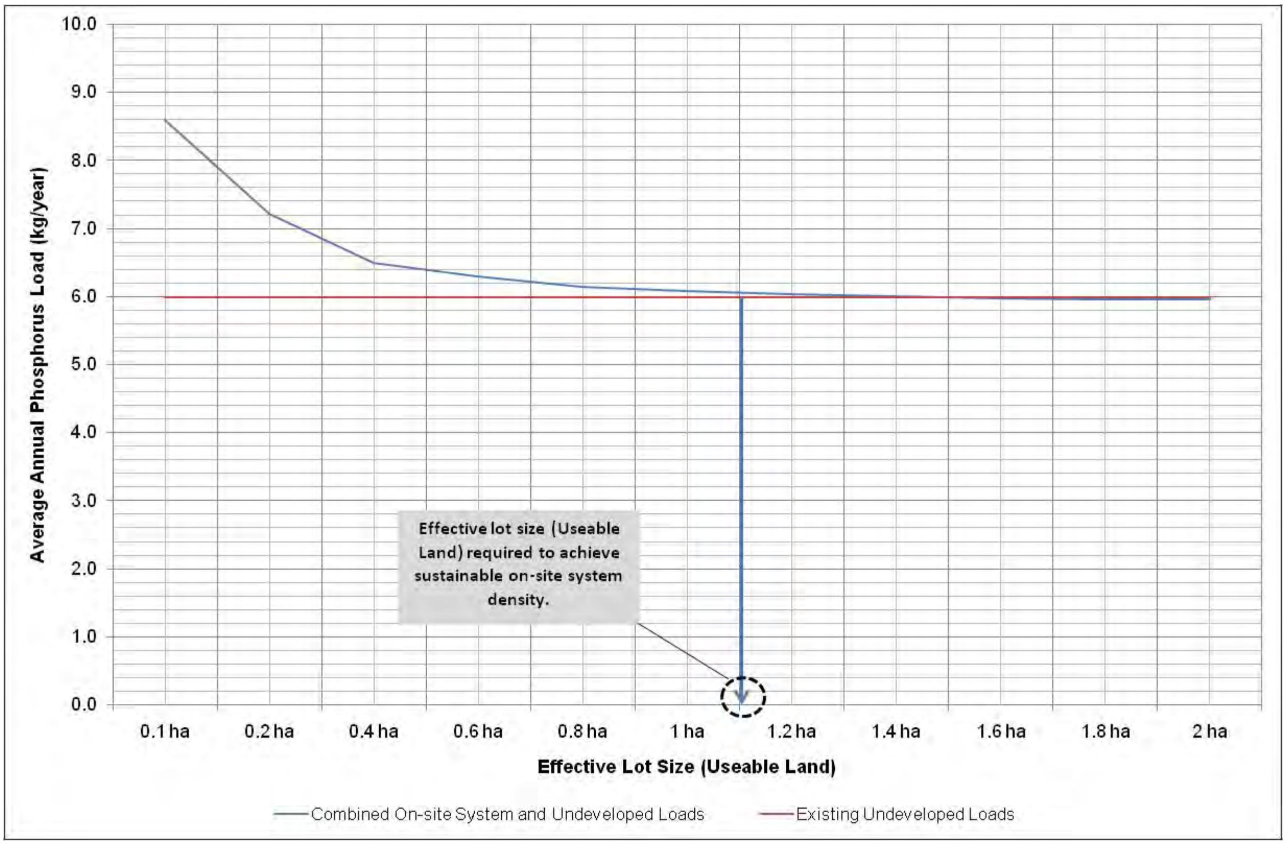

Figure 7-14 Lot Density Modelling Results for Salt Ash: Phosphorus Loads

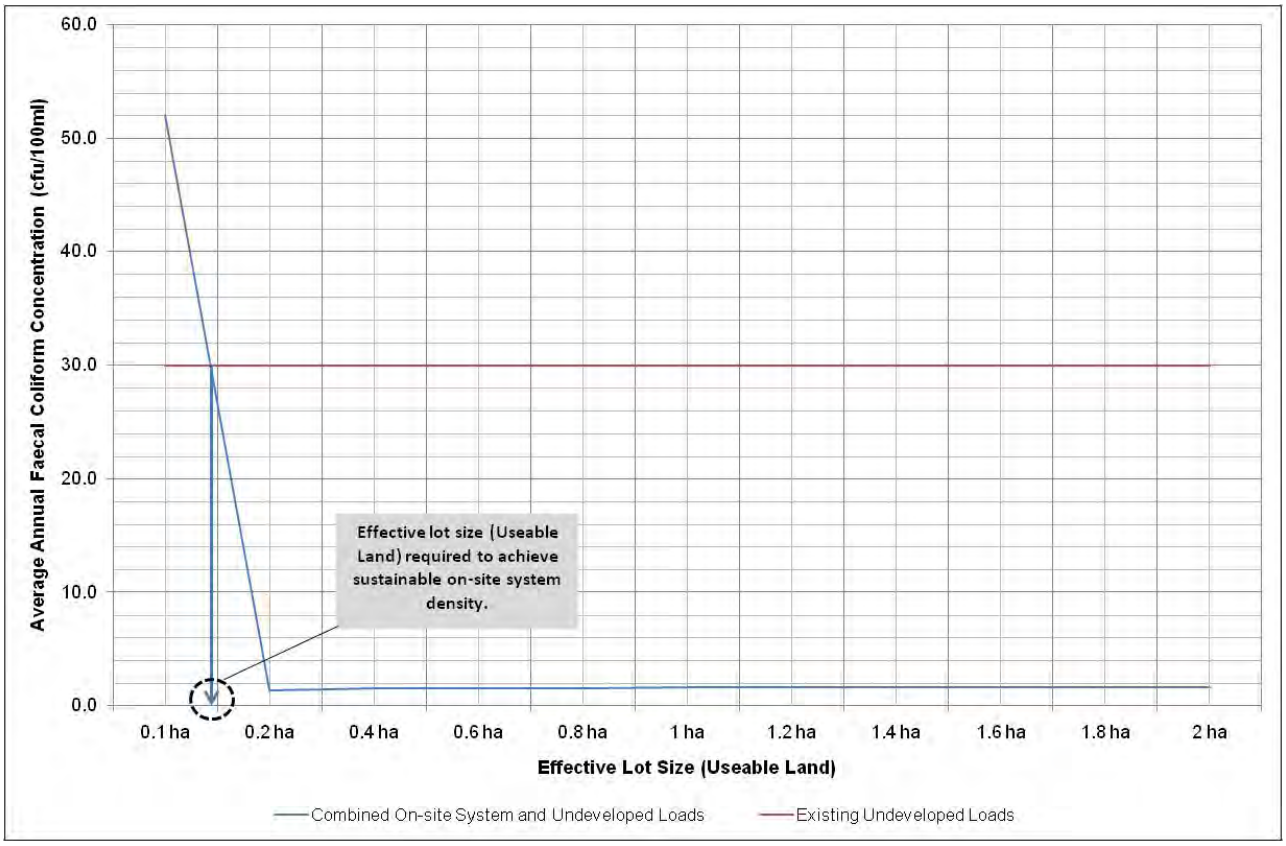

Figure 7-15 Lot Density Modelling Results for Salt Ash: Faecal Coliform Concentrations

7.7 Outcomes

The results of lot density modelling were analysed in conjunction with outcomes of the Minimum Lot Size assessment (Section 6) in order to make a final 'most limiting' determination on lot size for unsewered development.

It was concluded that the provision of a minimum of 4,000 m^2 of Useable Land (as defined in the DAF) is an appropriate minimum allotment size to enable construction and design of a robust on-site sewage management system and provide a high level of protection with respect to cumulative impacts on heath and ecosystems.

This equates to 2.5 on-site systems per hectare of Useable Land. The Useable Land concept was found to be critical to effective on-site sewage management as the shape of allotments and/or presence of intermittent / permanent water bodies or floodprone land had the ability to prevent construction of a sustainable system on lots up to 2 hectares. Identification of Useable Land has been incorporated into DAF procedures for all unsewered developments proposing to increase accessible building entitlements.

This minimum lot size is consistent with current Council policy (and previous research into cumulative impacts from on-site systems) and typical rural residential development in the LGA. The outcomes of this project do not justify altering the value but do introduce the Useable Land concept.

The water quality target of NORBE on existing undeveloped pollutant loads is considered conservative and provides a high level of confidence to Council where development is approved and carried out in accordance with the DAF. It must be acknowledged that this target is more stringent than current objectives for other pollutant sources. However it is the simplest and most achievable target to use without conducting a Cumulative Impact Assessment (CIA) for an entire sub-catchment. The target ensures any proposed unsewered development is self-sustaining with effective management of sewage risk within the site.

It should also be noted that this NORBE target has only been assigned to Acceptable Solution development under the DAF. In other words, developments that meet Acceptable Solution criteria of;

- **4,000 m^2 of Useable Land per lot;**
- **achievement of setback distances to sensitive receptors;**
- **classified by Council as Low or Medium On-site Sewage Management Hazard; and/or**
- **being residential development;**

will be considered to adequately manage cumulative impacts without the need for site specific assessment or modelling. Individual applicants are able to complete their own site specific CIA using the procedures summarised in Section 10 based on locally applicable targets (see Section 10.1.2 and Table 10-8**).**

8 RATIONALE FOR ACCEPTABLE SOLUTION TABLES

As part of the Development Assessment Framework (DAF), a series of Acceptable Solution tables were developed comprising minimum sustainable land application areas (LAA) required for five common on-site system types. These Acceptable Solution tables have been provided in Appendix A of the DAF as a system selection and design option for Low and Medium Hazard allotments. The tables present minimum land application area sizes (in m^2 basal area) for a wide range of common residential development scenarios possible throughout the LGA. A total of 900 possible combinations were modelled using the water balance methodology discussed in Section 9.2 and an annual nutrient balance varying the following broad characteristics:

- Three climate zones;
- Six soil types;
- Two water supply system types;
- Number of bedrooms (1-5);
- Five wastewater system types.

Figure 8-2 illustrates the range of on-site system configurations considered in the Acceptable Solution tables.

8.1 Inputs for Minimum Land Application Areas

The Port Stephens LGA was broken down into three climate zones (western, central and eastern) as shown in Figure 8-1. The division between climate zones were assigned using gridded average annual rainfall data from the BOM Climate Atlas by identifying the spatial mid-point in average rainfall between stations. Each climate zone was assigned monthly values for rainfall, evaporation and crop factor based on climate data from three BoM stations, with the western climate zone adopting climate data from the Paterson gauge, the central climate zone adopting data from the Williamtown RAAF gauge and the eastern zone adopting climate data from the Nelson Bay gauge. The monthly values for the three BoM gauges are shown in Table 8-1 - Table 8-3.

Table 8-1 Paterson (TOCAL AWS) Climate Data

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
Rainfall	103	122	116	80	73	77	41	37	49	66	87	78	**929**
Evaporation	192	148	130	96	74	63	74	105	132	161	174	208	**1,570**
Crop Factor	0.70	0.70	0.70	0.60	0.50	0.45	0.40	0.45	0.55	0.65	0.70	0.70	**0.59**

Table 8-2 Williamtown RAAF Climate Data

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
Rainfall	98.6	123.2	120.6	104.3	113.7	121.4	71.9	77.4	61.3	74.5	81	80.2	**1,125.9**
Evaporation	213.9	173.6	151.9	114	83.7	75	80.6	108.5	138	173.6	189	226.3	**1,715.5**
Crop Factor	0.70	0.70	0.70	0.60	0.50	0.45	0.40	0.45	0.55	0.65	0.70	0.70	**0.59**

Table 8-3 Nelson Bay (Nelson Heads) Climate Data

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
Rainfall	100	113.3	118.4	126.7	151	154.7	140.9	105.1	90.2	78.5	79	95.4	**1,351.2**
Evaporation	186.0	151.0	129.1	96.9	71.2	52.5	56.4	76.0	110.4	138.9	151.2	196.9	**1,406.7**
Crop Factor	0.70	0.70	0.70	0.60	0.50	0.45	0.40	0.45	0.55	0.65	0.70	0.70	**0.59**

Six general soil types were considered ranging from sand to medium/heavy clays. Each soil type was assigned a value for phosphorous sorption (mg/kg) and DLR (mm/day) as shown in Table 8-4. These soils were considered as 'design' soils (i.e. the most limiting soil horizon used to design an on-site system land application area). DLRs were adapted from *ASNZS1547:2012* and phosphorus sorption values were adopted based on local experience conducting site and soil assessments.

Table 8-4 Soil Types and Adopted Parameter Values

Soil Type	Soil P-Sorption (mg/kg)	DLR (mm/day)		
		Primary Trenches/Beds	Secondary Trenches/Beds	Irrigation
Sand	100	20	50	5
Sandy loams	150	15	30	5
Loams	200	10	30	4
Clay loams	300	7	20	3.5
Light clays	350	5	8	3
Medium / heavy clays	400	5	5	2

The daily design wastewater flow was estimated based upon the number of bedrooms per dwelling (1-5) and type of water supply (reticulated or tank). The design wastewater flow values are shown in Table 8-5. It can be seen that occupancy and per capita wastewater generation were based on *ASNZS1547:2012*.

LEGEND

Western Rainfall Zone (adopts Paterson (TOCAL AWS) rainfall data)
Central Rainfall Zone (adopts Williamtown RAAF rainfall data)
Eastern Rainfall Zone (adopts Nelson Bay (Nelson Head) rainfall data)
Rainfall Gauge Locations

Title:
Adopted Climate Zones

Figure: 8-1

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0 3.75 7.5km

Approx. Scale

BMT WBM

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Filepath : K:\N1650_Port Stephens_On-site_Sewage_Mgt_Study\Data\MI\Workspaces\DRG_007_Rainfall_Zones.wor

Table 8-5 Design Wastewater Flow

Number of Bedrooms	Number of Occupants	Design Wastewater Flow (L/d)	
		Reticulated Supply	Tank Supply
1	2	300	240
2	4	600	480
3	5	750	600
4	6	900	720
5	7	1,050	840

Five wastewater system types were considered including primary and secondary trench systems; primary and secondary Evapo-transpiration / Absorption (ETA) bed systems; and (subsurface) irrigation systems. Given that the Acceptable Solution tables will only be used for proposed systems on Low and Medium Hazard lots, more traditional primary dosed trenches and beds have been included. However, it is acknowledged that opportunities for adoption of primary dosed trenches and beds are limited and in some cases, may not be as cost effective as secondary treatment and subsurface irrigation. A value for void space ratio, Total Nitrogen (TN) and Total Phosphorous (TP) effluent concentrations, maximum depth of storage in trenches/beds, and percentage of nitrogen lost to soil processes were assigned for each system type as shown in Table 8-6.

Table 8-6 Wastewater System Types

System Type	Void Space	Max. Depth (mm)	Effluent TN (mg/L)	Effluent TP (mg/L)	%N Soil
Primary Trench	0.3	450	60	18	0.4
Secondary Trench	0.3	450	30	12	0.2
Primary ET Bed	0.3	300	60	18	0.4
Secondary ET Bed	0.3	300	30	12	0.2
Irrigation	1	0	30	12	0.2

8.2 Assignment of Minimum Land Application Areas

The input parameters summarised above were compiled into a macro enabled water and nutrient balance spreadsheet. The macro enabled a mean monthly water balance and annual nutrient balance to be completed for each of the 900 possible combinations of on-site system scenario and the 2700 results output into a table. Results were then assessed and reduced through consideration of a number of practical and design limitations associated with the various land application system types. Values were also rounded up to the nearest practical value (i.e. an installer is unlikely to vary sizes by small increments). This is considered acceptable given the relative accuracy of design procedures. Further justification for not using a monthly water balance is provided in Section 9.

It is important to recognise that the Acceptable Solutions have been offered as a conservative standard design option for applicants on Low and Medium Hazard lots who wish to fast track their approval whilst providing Council with confidence that their proposal is sustainable. They will not be permitted for adoption on High and Very High Hazard lots, commercial / industrial development or any lot with constraints not identified through the hazard mapping process.

The following points summarise how raw outputs from modelling were reduced and simplified. Further details can be found in the DAF.

- Limitations were placed on maximum allowable slope for trenches and beds to be considered an Acceptable Solution.
- Limitations were placed on allowance of gravity dosing of trenches and beds where even distribution of effluent could prove difficult.
- A minimum of 600mm of soil must be present between the base of any land application system and any limiting layer or water table.
- Limitations were placed on the maximum basal area allowable for trenches and beds considered an Acceptable Solution based on construction challenges associated with achieving level bases across large areas.

8.3 Outcomes

A set of Acceptable Solution tables have been included in the DAF for use as a 'deemed to comply' option for system selection and design on Low and Medium Hazard lots. The minimum land application system sizes are considered conservative for a range of possible development scenarios. Applicants are however free to complete site specific design calculations to derive their own sizing.

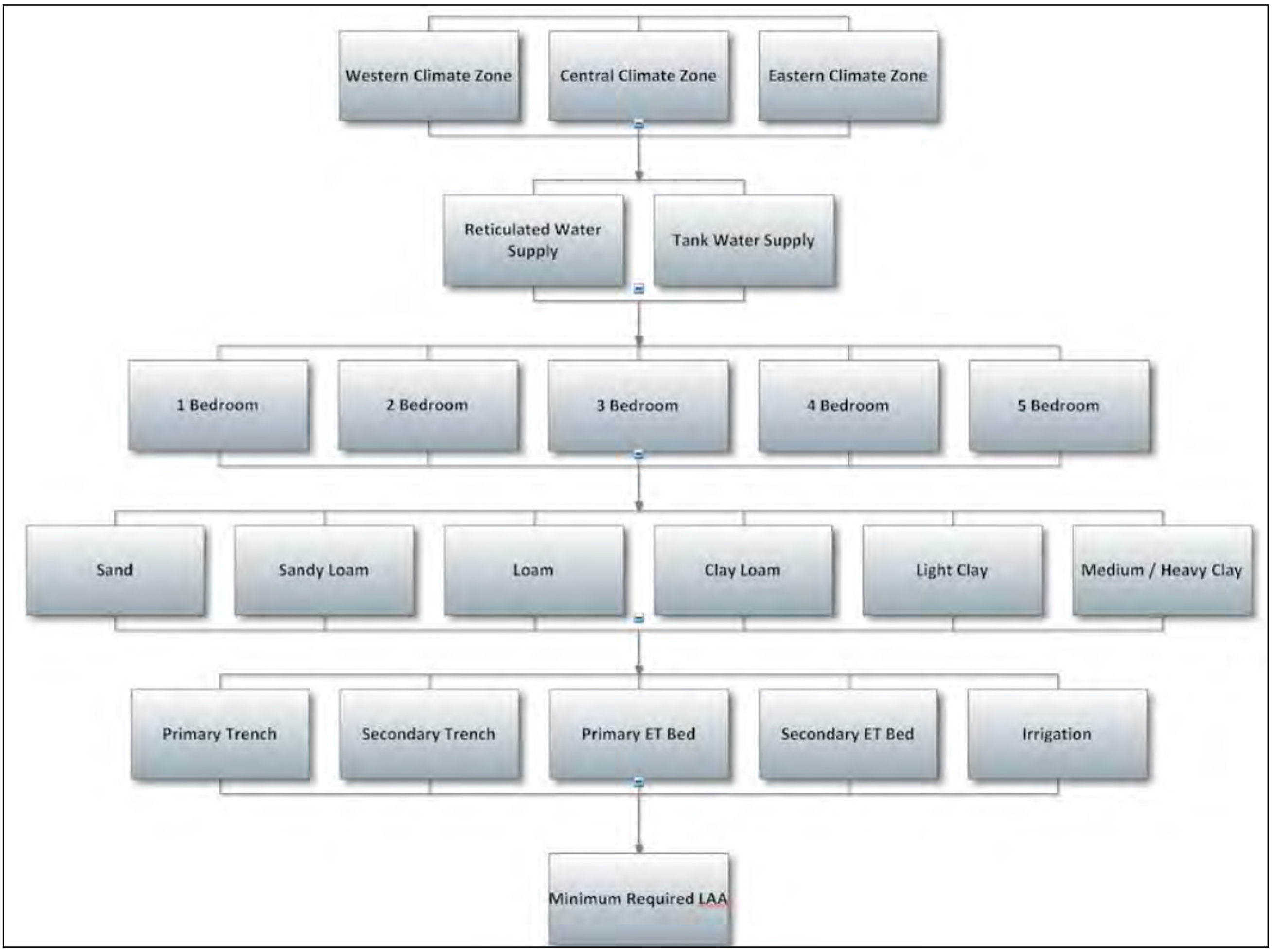

Figure 8-2 Decision Tree for Selection of Acceptable Solutions

9 DAF DESIGN PROCEDURES

The Development Assessment Framework (DAF) sets out a number of design procedures that vary in complexity and information requirements depending on relative risk. Some procedures are already a requirement of on-site sewage management system design. Others are more advanced procedures often limited in use to larger, non-domestic wastewater management systems. Since the implementation of Councils On-site Sewage Management Strategy in 1999, it has become apparent that traditional assessment and design procedures associated with domestic on-site systems are not always capable of a) ensuring a system will be capable of managing design loads or b) demonstrating a proposed system will not pose an unacceptable risk to ecosystems and human health. Particular issues have arisen on small allotments that feature one or a number of bio-physical constraints to sustainable on-site sewage management. Larger non-residential on-site systems can also require more comprehensive design and assessment procedures.

This leaves Council in a position where they must either request additional information from an applicant or make a determination on an application without confidence. This chapter summarises general guideline information for undertaking key on-site system design procedures required under the DAF. It is not however a design manual and consultants are still expected to use the recommended resources provided below to develop their own procedures and tools to meet Councils Minimum Standards.

9.1 Wastewater Characterisation

When designing domestic on-site sewage management systems, use of standard published guideline values (e.g. *ASNZS1547:2012*) for wastewater flow and constituent loads is normally adequate. However, this is not always the case on highly constrained sites or for non-domestic systems. In some cases the sensitivity of the receiving environment may make the inevitable inaccuracies of typical published values critical to performance. Alternatively, the unique site activities associated with non-domestic facilities may limit the suitability of typical published values. **Guiding information** and recommended data sources are provided in the following chapter. There are two occasions within the DAF where wastewater flow and constituent load generation rates beyond *ASNZS1547:2012, AS1546:2008* and NSW Health (2001 and 2005) are required.

9.1.1 Very High Hazard Domestic On-site Systems

The presence of significant constraints to sustainable on-site sewage management on Very High Hazard lots increases the level of detail and accuracy needed during design procedures to ensure a robust system is installed that is capable of managing these constraints. In the case of new developments, existing water consumption or wastewater generation data are not typically available. In these cases it is important to adopt conservative design wastewater generation rates. Notwithstanding, care should also be taken to not be over conservative resulting in oversizing of treatment and/or land application systems to the point where they do not receive sufficient loads to enable adequate biological activity.

In the case of applications to upgrade or replace an on-site system servicing an existing facility, design wastewater flows and loads should be validated or derived from actual site data wherever possible. The following table provides a summary of guiding information on calculation of design wastewater flows and loads for Very High Hazard domestic on-site systems.

Table 9-1 Calculation of Design Wastewater Flows and Loads: Very High Hazard Domestic

Scenario	Calculation Process	Resources
New Dwelling	**Wastewater Flow** Occupancy calculated at minimum 1.6 persons per bedroom. No allowance for water reduction fixtures/facilities. Seasonal variation to be considered for intermittently occupied / holiday homes (design for peak daily/weekly occupancy). **Constituent Loads** Published domestic loads (e.g. g/day) with conservative allowance made for any non-domestic activities (e.g. hairdressing, cheesemaking).	(Appendix H Table H1of *AS1547*). *AS1646*, NSW Health (2001, 2005).
Existing Dwelling	**Wastewater Flow** Analyse existing water consumption data (or wastewater flow data) and use to validate adopted design flow profile. Consideration should be given to seasonal / monthly variation shown in data. **Constituent Loads** Published domestic loads (e.g. g/day) will normally be sufficient. Existing wastewater quality sampling may be warranted where specific non-domestic activities (e.g. hairdressing, cheesemaking) are occurring.	As above. Consideration should be given to permanently or temporarily installing a Smart Meter to collect detailed water use data where significant variation is likely. As above.

9.1.2 Non-domestic On-site Systems

Non-domestic facilities commonly produce wastewater that varies in quantity and quality over time. They can involve mixed use facilities where domestic wastewater is generated in combination with commercial, industrial or agricultural wastewater. Adoption of domestic wastewater generation rates and constituent loads (e.g. from *AS1547, AS1546*, NSW Health guidelines) should not be undertaken without confirmation that they are applicable to the specific site. As a minimum, typical published wastewater flow and load generation rates should be sourced from industry recognised, applicable sources. It must be recognised however that even these values are generalised average values obtained from sites with a wide range of activities and unique characteristics. Wherever possible, site specific data should be collected for all non-domestic systems and larger flow domestic systems (>10 kL/day).

There is no NSW guideline document available that relates specifically to non-domestic / package wastewater treatment system applications. There are however a small number of nationally and internationally recognised texts and guidelines that should be used for any non-domestic wastewater management system design process. **Applications for non-domestic on-site systems that propose to "scale up" an off the shelf domestic wastewater treatment plant without supporting justification (process design) will not typically be accepted.** The following technical and guidelines documents are recommended for guidance in the design of non-domestic on-site wastewater management systems.

- Crites and Tchobanoglous (1998) *Small and Decentralised Wastewater Management Systems*. McGraw-Hill.
- Asano *et al* (2007) *Water Reuse: Issues, Technologies and Applications*. Metcalf and Eddy.

- Tchobanoglous *et al* (2003) *Wastewater Engineering: Treatment and Reuse*. 4th Edition. Metcalf and Eddy.

Locally, selected components of the following document may be useful.

- EPA Victoria (1997) *Code of Practice for Small Wastewater Treatment Plants*. EPA Victoria Publication 500.

In particular, Crites and Tchobanoglous (1998) and Asano *et al* (2007) are internationally recognised, comprehensively peer reviewed design manuals and planning guidelines that cover a substantial amount of the necessary processes encountered within the Port Stephens LGA. Chapter 4 of Crites and Tchobanoglous (1998) and Chapter 13-3 of Asano *et al* (2007) emphasise the need for a wastewater characterisation process for larger systems rather than simply an adoption of standard values.

Table 9-2 Calculation of Design Wastewater Flows and Loads: High/Very High Non-domestic

Scenario	Calculation Process	Resources
New Facility	**Wastewater Flow**[1] Development of a seasonal/monthly/daily time series (time step applicable to nature of temporal variation) of design wastewater flow. This flow profile should be developed using site specific occupancy / process information e.g. • Anticipated seasonal variation in occupation in a tourist facility. • Anticipated seasonal / monthly / daily variation in production in an industrial facility. • Predicted customer numbers / turnover for a proposed commercial facility. Where site specific information is not available, data should be sourced from similar facilities, preferably local ones. **Constituent Loads**[1] At least the average, minimum and maximum concentrations should be obtained and used to calculate design loads. Local data from similar facilities should be sourced where possible. Published constituent loads (e.g. g/day) may be acceptable where data not available.	**Non-domestic** Section 4: Crites and Tchobanoglous (1998) Section 13-3: Asano *et al* (2007) Lesikar *et al* (2006) EPA Victoria (1997) **Domestic (>10kL/day)** Appendix H of *AS1547* *AS1646*, NSW Health (2001, 2005).
Existing Facility	**Wastewater Flow**[1] Development of a seasonal/monthly/daily time series (time step applicable to nature of temporal variation) of design wastewater flow. This flow profile should be developed using site specific monitoring data from the existing facility. Analyse existing water consumption data (or wastewater flow data) and use to validate adopted design flow profile. **Constituent Loads**[1] At least the average, minimum and maximum concentrations should be obtained through monitoring of existing facility operation and used to calculate design loads. Local data from similar facilities should be sourced where significant deviation from existing conditions expected.	As above. Consideration should be given to permanently or temporarily installing a Smart Meter to collect detailed water use data where significant variation is likely. Composite or grab sampling of raw wastewater is strongly recommended to assist in wastewater characterisation.

Note 1: In the case of Low/Medium Hazard Non-domestic systems (and domestic systems 2-10 kL/day), a single, conservative design value for wastewater flows and constituent loads may be acceptable if it can be demonstrated that there is <10% variation in that parameter over 12 months or sufficient flow equalisation is provided to attenuate peaks.

9.2 Hydraulic Design of Land Application Areas

NSW on-site sewage management guidelines (DLG, 1998) currently recommend the use of monthly water balance (in conjunction with annual nutrient balances) to size land application areas (LAA)). Historically, ASNZS1547:1994 also included a recommended procedure for completion of monthly water balance calculations. However, ASNZS1547:2000 and recently ASNZS1547:2012 do not specify the use of a monthly water balance and rather make more general informative statements. In essence, ASNZS1547:2012 adopts a risk based approach, recommending consideration of water balance where it is possible that climate may play an important role in performance.

The DAF specifies the use of a steady state (essentially annual) water balance calculation for Low, Medium and High Hazard residential system designs. It was concluded that a simplified hydraulic sizing approach would be adopted for on-site systems on Low, Medium and High Hazard allotments. This relates to limitations on the useability and applicability of monthly water balance calculations in moderate to high rainfall areas. It also relates to the limited purpose of monthly water balance calculations for design sizing of subsurface irrigation systems or mounds (the two dominant modern land application options).

Monthly water balance calculations for ***irrigation*** land application areas should not include any cumulative storage allowance in the soil. Daily continuous modelling is required to do this with any accuracy. The DLG (1998) method commonly adopted in NSW only uses the “wettest” month of the year (the month with the smallest difference between retained rainfall and crop evapo-transpiration) to size a Land Application Area (LAA). Monthly water balance calculations do allow an estimate of any wet weather storage tanks proposed. However, these are not advocated for residential systems within the DSC DAF or amongst other NSW Councils.

It is acknowledged that monthly water balance calculations do enable consideration of storage capacity within a primary dosed trench or bed (i.e. where effluent is draining from a saturated body of gravel controlled by a biomat). However the use of a Climate Adjustment Factor (CAF) as presented below achieves the equivalent outcome through a simpler method of calculation with reduced potential for error or manipulation. Reference should be made to Asquith *et al* (2012) for more justification on this approach.

Hydraulic sizing of land application areas shall be undertaken using Equation 1 below.

$$LAA = \frac{Q}{(DLR - CAF)} \qquad \text{Equation 1}$$

Where;

LAA = Land Application Area (basal area in m^2)

Q = Design Wastewater Generation Rate (L/day)

DLR = Design Loading Rate (mm/day)

CAF = Climate Adjustment Factor (mm/day)

Detailed land application system modelling was used to support design experience in the sizing of land applications within the LGA. The Climate Adjustment Factor (CAF) enables design loading rates to be adjusted to reflect the degree to which climate influences hydraulic performance. They have been determined based on analysis of the frequency and magnitude of hydraulic failure for a range of on-site system types in different climate regions (consistent with the climate zones adopted for the Acceptable Solutions).

In very wet climates the CAF reduces the daily DLR to reflect the limitation placed of hydraulic capacity by consistently high soil moisture. In dry climates the CAF may increase the DLR based on a higher evapo-transpiration output of applied effluent. The result is comparable to a monthly water balance with respect to rigour of design (resulting LAAs are typically <10% larger or smaller). However, it is a simpler approach that requires limited time to calculate. As previously mentioned it also removes significant potential for unnecessary error or artificial manipulation of results.

Climate adjustment factors can be found in Table 9-3 below for trenches/beds or irrigation LAAs in two broad climate zones. The climate zones applicable to these CAFs are presented in Figure 8-1. These CAF values have been tested and are suitable for the variation in site specific climate observed within each of these zones. Design loading rates should be obtained from *ASNZS1547:2012*.

Table 9-3 Climate Adjustment Factors for Hydraulic Design Equation 1

Climate Zones	Climate Adjustment Factor (CAF)
Paterson (West) / Williamtown (Central)	0
Nelson Bay (East)	0.5

These CAFs were calculated based on an average annual water balance utilising the inputs summarised in Table 9-4.

Table 9-4 Summary of Input Data for CAF Calculations

Parameter	West	Central	East
Average Annual Rainfall	929 mm	1,126 mm	1,351 mm
Volumetric Runoff Coefficient	0.83	0.79	0.74
Pan Evaporation	1,570 mm	1,716 mm	1,407 mm
Average Crop Factor	0.59		

In the case of trenches and beds, allowance should ***not*** be made for sidewalls in addition to basal area where Design Loading Rates (DLRs) from *ASNZS1547:2012* are adopted. DLRs are purely a best estimate of the long-term hydraulic capacity of land application systems. It is not a physically measurable parameter like Long Term Acceptance Rate (LTAR) as measured by Laak (1973 and 1986). Work undertaken by Tyler and Converse (1994), Beal *et al* (2006) and others has shown that hydraulic pathways from trenches and beds typically oscillate between equilibrium of sidewall and basal area discharge. The dominant flow path at any point in time depends on a number of factors including biomat thickness, effluent quality, hydraulic head and soil hydraulic conductivity. DLR is not a physical measurement of these processes but a general long-term estimate of ***total*** hydraulic output from a LAA (whether sidewall or basal area discharge).

Given the relative accuracy of any hydraulic design equations, rounding of minimum LAA sizes is acceptable to the nearest $10m^2$.

9.3 Annual Nutrient Balance

DLG (1998) also advocate the use of annual nutrient balance calculations in sizing LAAs for domestic on-site systems. The PSC DAF requires annual nutrient balance calculations to be completed in some circumstances, depending on relative risk. Outcomes of lot density modelling (Section 7) supported the assumption that nutrients will be adequately assimilated where the following conditions are achieved.

- LAAs are sized using a monthly water balance.
- LAAs are located in accordance with PSC buffer distances.
- LAAs are contained within an allotment containing 4,000 m^2 of Useable Land.

As such site specific nutrient balance calculations are not required on Low, Medium and *some* High Hazard allotments that meet the above conditions.

Council recognise the conservatism associated with some elements of the DLG (1998) nutrient balance process and advocate use of a slightly modified method as described and demonstrated in the Municipal Association of Victoria's *Model Land Capability Assessment Report – February 2006* (MAV 2006). The reader is directed to nutrient balance elements contained on pages 18-19, 25 and 35-37 of that document. MAV (2006) can be downloaded from http://www.mav.asn.au/policy-services/environment/water/domestic-wastewater/Pages/default.aspx. DLG (1998) also provides ***nominal*** plant nutrient uptake rates purely to demonstrate use of the nutrient balance procedure. These nominal values are very conservative and underestimate the level of plant uptake occurring in most cases. Council strongly recommend consultants seek more appropriate nutrient uptake values from Table 4.2 of DECCW (2004) *Use of Effluent by Irrigation*. In order to allow for the reduced efficiency in crop production (grass growth) associated with a typical domestic lawn, Council recommend adoption of 50% of published nutrient uptake rates in DECCW (2004). In most cases, use of data for kikuyu will be appropriate and example calculations of nutrient uptake rate are provided below.

Kikuyu Nutrient Uptake

Average dry matter yield (t/ha/year) = 20 TN = 2.6% TP=0.3% (From Table 4.2 of DECCW 2004)

TN = 0.026 x 20,000 = 520 kg/ha/year x 0.5 (conservative allowance for domestic lawn harvesting)

TN = ***260*** *kg/ha/year = 71 mg/m^2/day.*

TP = 0.003 x 20,000 = 60 kg/ha/year x 0.5

TP = ***30*** *kg/ha/year = 16 mg/m^2/day.*

Where a vegetation cover that is clearly different to kikuyu is being adopted, site specific nutrient uptake rates should be calculated following the above procedure. Where harvesting and removal of vegetation is not going to occur, limited nutrient uptake can be assumed.

9.4 Continuous Daily On-site System Modelling

The DAF requires a higher level of on-site system water, nutrient and pathogen modelling in circumstances where risks to ecosystem and human health are elevated. Lots with a Very High On-site Sewage Hazard Class warrant this more comprehensive analysis for two key reasons.

- Availability of suitable land for siting of an effluent land application area is often highly limited. Continuous daily on-site system modelling maximises potential to achieve a sustainable design.
- Continuous daily on-site system modelling provides a higher level of accuracy when assessing potential impacts on what are typically sensitive receiving environments.

Continuous daily soil water, nutrient modelling has been included as an assessment tool to simulate performance of land application systems on Very High Hazard lots and for larger non-domestic systems. One dimensional viral dieoff modelling (Cromer *et* al, 2001) is also required as a method for estimating pathogen export potential. This approach is widely considered current best practice in land application system design, particularly effluent irrigation design. There are two commercially available tools that can be used to complete this modelling or alternatively, consultants may construct their own in spreadsheet form (subject to review and endorsement by Council).

9.4.1 Rationale

Continuous daily on-site system modelling does require more data and a higher level of understanding of soil water, nutrient and pathogen dynamics. As such, it cannot be justified in the context of lower hazard on-site systems. However, on severely constrained sites and in the case of non-domestic facilities, monthly water balance spreadsheets such as that advocated in DLG (1998) are not capable of answering key questions about a systems performance. Prior to the availability of computers with sufficient processing capacity to undertake long-term daily modelling, the monthly spreadsheet approach was an acceptable, practical (albeit conservative) method that allowed climatic influences on crop growth to be incorporated into design. However, daily continuous soil water modelling has been a recognised standard for at least the last 10 years. Some of the limitations of a monthly lumped approach are as follows.

Monthly water balances calculate soil water balance for each month in isolation. While cumulative storage is calculated for the gravel void space in trenches or a wet weather storage tank, this is limited to a twelve month period and the assumption is made that the storage volume returns to zero prior to the next winter. This means the method cannot account for antecedent soil moisture or rainfall conditions over the design life of a system. This occurs on an intra-annual basis and between years. Continuous daily modelling simulates soil/plant water dynamics over decades on a daily basis. This ensures both inter-annual and intra-annual variation in a wide range of conditions (beyond rainfall and cumulative storage volume) is accounted for in the design. Essentially, it simulates wet and dry periods in climate history.

The Monthly method assumes infinite soil water storage with no sound method to quantify water lost to deep drainage prior to evapo-transpiration. As a result, it is assumed that all excess water drains at the end of each month and is not carried over (particularly during winter). Continuous daily models dynamically calculate infiltration, soil water storage, plant uptake, deep drainage and runoff for multiple soil horizons on a daily basis. They then carry water in soil storage over to the next day, month and year to ensure antecedent conditions are accounted for.

As previously stated, the most obvious advantage of a daily model is its ability to identify and quantify dry periods within what may be a 'wet' month. Continuous daily modelling enables opportunities for irrigation within wetter months to be identified and taken where appropriate.

At the time of original publication of DLG (1998), lumped monthly water balances did represent best practice for the time and computing power readily available to stakeholders. However, environmental modelling has progressed dramatically in the proceeding 12 year period. Selected models utilise scientifically validated algorithms that have been extensively tested and peer reviewed. Reference should be made to Gardner and Davis (1998) and Martens (1999b) for further description and justification of continuous daily modelling approach for higher risk sites.

9.4.2 Available Modelling Tools

Two commercially available modelling packages are summarised below that can be used to complete continuous daily modelling in accordance with the DAF.

- Model for Effluent Disposal by Land Irrigation (MEDLI).
- Land Application Mass Balance (LAM).

MEDLI is a proprietary software package that needs to be purchased from the Queensland Department of Environment and Resource Management (DERM). LAM is a freely available program under subscription arrangement or as an enhanced version for purchase from BMT WBM. A brief summary of each model is provided below with further detail available from the individual software supplier.

Pathogen (vial die-off) modelling can be completed using a spreadsheet application of the method advocated by Cromer *et al*, (2001).

9.4.2.1 MEDLI

MEDLI is a water and nutrient mass balance model developed by the Queensland Department of Natural Resources and Mines (now DERM) and the CRC for Waste Management and Pollution Control (Gardner and Davis, 1998). It is capable of simulating storage pond dynamics, irrigation scheduling, plant growth, transpiration and nutrient uptake, soil water and nutrient dynamics and salinity on a daily time step over long periods (up to 100 years). The structure of MEDLI is shown in Figure 9-1.

MEDLI currently represents the most sophisticated and technically robust modelling tool for designing effluent irrigation schemes available in Australia and has been in the public domain for over ten years. However, it is less suited to on-site sewage management system modelling as a result of its strong reuse / agronomic focus. The MEDLI Technical Manual (Gardner and Davis, 1998) provides a comprehensive description of the algorithms and modules which have been extensively peer reviewed and validated. Importantly, MEDLI is a process based mass balance model that includes dynamic, daily calculation of infiltration (rainfall and effluent), plant growth, transpiration, deep drainage, runoff and soil profile water. There is limited benefit in repeating small elements of the comprehensive Technical Manual (Gardner and Davis, 1998) here. Readers can obtain a copy of the software (or possibly at least the Technical Manual) from the Queensland Department of Environment and Resource Management (http://www2.dpi.qld.gov.au/environment/5721.html).

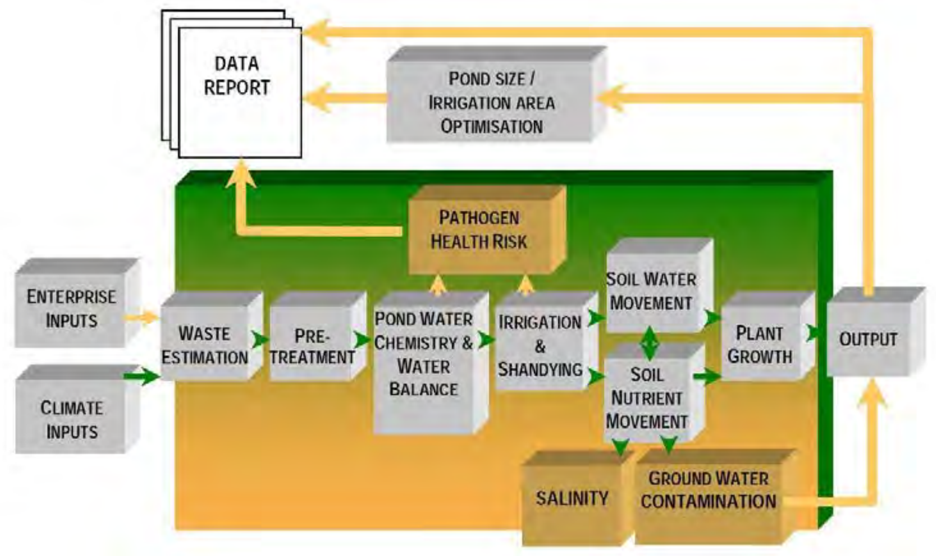

Figure 9-1Structure of MEDLI (Source: MEDLI Technical Description, Queensland DNR)

9.4.2.2 LAM

LAM is a daily soil water, nutrient and pathogen mass balance model developed by BMT WBM specifically for the design and assessment of domestic and non-domestic on-site wastewater land application systems. Algorithms from the Decentralised Sewage Model (See Section 10.3) have been tailored to suit a single site application. In contrast to other tools, LAM focuses on common approaches to effluent land application at domestic and medium scale non-domestic settings such as subsurface irrigation, raised (mound) systems, trenches and beds. A description of LAM is available from BMT WBM (newcastle@bmtwbm.com.au). The structure of the model is depicted in the following figure.

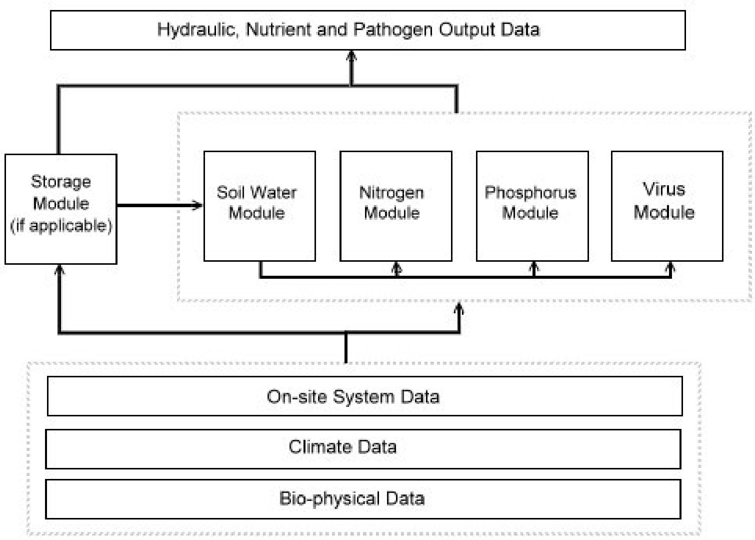

Figure 9-2 Structure of the LAM Model

9.4.2.3 Spreadsheet Based Models

It is possible to construct continuous daily on-site system models in standard spreadsheet software such as MS Excel™. However, both authors and users require significant expertise and experience in soil water, nutrient and pathogen dynamics. Approval from Council will be required should individual consultants wish to build and use their own daily soil water, nutrient and pathogen models. Approval will typically involve some level of peer review of algorithms and testing of the model.

9.4.3 Data Inputs and Outputs

Data requirements and professional resources required for building and running of continuous daily soil water, nutrient and pathogen mass balance models are inevitably greater than current typical practice. However, the experience of many Councils and practitioners supports an increased level of scrutiny in the design and assessment of systems in highly constrained environments. Similarly, poor operational performance can be reduced through the application of a daily modelling approach for non-domestic systems. All of the example modelling tools described in Section 9.4.2 can be operated using readily obtainable field and desktop data whilst producing a meaningful result.

The lot density modelling process undertaken as part of this project (see Section 7) included continuous daily soil water, nutrient and pathogen modelling using the Decentralised Sewage Model (DSM) – the parent modelling engine of LAM. The tables contained in Section 7.5.1 and 7.5.2 of this Technical Manual provide an example of the range of parameters and data required to populate these models. These tables include reference to data sources used for this study to provide an indication of where and how information can be obtained.

Continuous daily modelling enables a more comprehensive design and assessment process for on-site systems and provides Council with a higher level of assurance that a system is sustainable. The following list is a guide to how daily modelling can be used under the DAF for Very High Hazard and non-domestic systems.

- A more accurate calculation of minimum land application area size that ensures the occurrence of hydraulic failure (surface surcharge) is restricted to extreme climate events. This increased accuracy can sometimes allow smaller land application area sizes in comparison to monthly calculations.
- Realistic sizing of any wet weather storage facilities for non-domestic systems. Monthly calculations should never be used to size wet weather storage facilities. Council do not advocate wet weather storage for domestic systems.
- More realistic estimate of hydraulic, nutrient and pathogen loads leaching into subsurface environments as deep drainage to enable a more detailed assessment of potential impacts.
- Derivation of long-term hydraulic, nutrient and pathogen loads leaching via deep drainage and discharging to the ground surface for input into Cumulative Impact Assessment modelling.

9.5 Hydraulic and Process Design

The DAF recognises that there are a number of circumstances in on-site sewage management where “off the shelf” design and technology options cannot provide a sustainable solution. Furthermore, there are circumstances where a more rigorous engineering and design process should be undertaken and provided to Council to enable a decision. Historically, there has been limited input to NSW on-site sewage management guidelines and legislation from hydraulic and process engineering disciplines. This is not the case in other jurisdictions and countries where designs for on-site systems are expected to follow engineering principles of design including the preparation of specifications and design drawings.

In creating the DAF, Council acknowledge that there is limited need for higher level engineering input to proposals for domestic on-site systems on Low and Medium Hazard lots. However, as the nature and extent of constraints increase, so does the need for a sound, engineered system capable of being taken from concept to reality. There have been occurrences of on-site system designs being submitted to Council that "on paper" are capable of meeting performance objectives. However, the ability to convert a conceptual sketch to a final constructed system is either limited or cost prohibitive. This can be prevented through the submission of engineering calculations, specifications and drawings that demonstrate that a system is feasible.

The technical resources listed in Table 9-6 are a sample of key information and guidance available to allow engineering design of on-site systems. "Black Box" technologies put forward without supporting process design information and performance data for non-domestic systems will not be accepted. The references provide a plethora of design procedures, data and guidance to enable sound designs to be developed.

Table 9-5 Different Stages of the Engineering Process

Engineering Stage	Description	DAF Requirement
Feasibility Study	High level identification of potential options. "Rule of thumb" design calculations based on limited, predominantly desktop data. Multi criteria analysis of shortlisted options.	Increase in building entitlements on Low / Medium Hazard lots. First phase of a project involving a non-domestic system >10 kL/day.
Concept Design	Limited field data collected to enable development of conceptual layout (footprint of each major component) and key sizing calculations for critical system elements such as land application / effluent management systems. Typically used to define site performance targets, undertake an initial environmental assessment and prepare a high level cost estimate (e.g. +/-20%). Will usually be sufficient for domestic systems on Low/Medium Hazard lots.	Domestic systems on Low / Medium Hazard lots. Increase in building entitlements on High/Very High Hazard lots.
Preliminary Design	Design stage bridging the gap between concept and detail. Commonly completed to develop specifications for Design and Construct (D&C) contracts intended for technology providers with in-house detailed design capabilities. Preliminary designs contain sufficient detail to prepare a performance specification and confirm that the conceptual design can be taken through to construction with confidence. Usually involve preliminary site surveys, detailed site and soil assessment and hydraulic / process design. Enables cost estimate (+/-15%)	Domestic systems on High / Very High Hazard lots. Non-domestic systems on Low / Medium Hazard lots (<10 kL/day).
Detailed Design	Comprehensive investigation, survey and design calculations/modelling to produce CAD design drawings and specifications sufficient to enable construction. Hydraulic, treatment process, structural/civil engineering design of all components. Enables preparation of a schedule of quantities.	Non-domestic systems on High / Very High Hazard lots or >10 kL/day.

Table 9-6 Recommended Resources for Hydraulic/Process Engineering of On-site Systems

Resource	Drainage / Collection	Pre-treatment / Flow Balancing	Treatment	Disinfection and Storage	Land Application	Water Reuse
Crites and Tchobanoglous (1998) *Small and Decentralised Wastewater Management Systems*. McGraw-Hill	✓	✓	✓	✓	✓	
Tchobanoglous and Burton (2003) *Wastewater Engineering: Treatment and Reuse*. Metcalf and Eddy.		✓	✓	✓		
Asano *et al* (2007) *Water Reuse: Issues, Technologies and A pplications*. Metcalf and Eddy.			✓	✓	✓	✓
Crites *et al* (2006) *Natural Wastewater Treatment Systems*. Taylor and Francis.			✓	✓	✓	
Water Environment Federation (2008) *Alternative Sewer Systems: Manual of Practice FD-12*. 2nd Edition. McGraw-Hill.	✓	✓				
USEPA (1991) *Alternative Collection Systems Design Manual*.	✓	✓				
Consortium of Institutes for Decentralized Wastewater Treatment *University and Practitioners Curricula*. www.onsiteconsortium.org	✓	✓	✓	✓	✓	
Converse and Tyler (2000) *Wisconsin Mound Soil Absorption System: Siting, Design and Construction Manual*. http://www.soils.wisc.edu/sswmp/online_publications.htm provides a range of other useful publications.					✓	
DECCW (2004) *Environmental Guidelines: Use of Effluent by Irrigation*.					✓	✓
USEPA (2006) *Process Design Manual: Land T reatment of Municipal Wastewater Effluent*.					✓	
The Water Environment Research Federation provide a range of information. http://www.decentralizedwater.org/	✓	✓	✓	✓	✓	✓
Netafim provide a design manual, hydraulic design software, standard drawings and checklists to assist in design of drip irrigation systems. http://www.netafim.com.au/index.php?sectionid=165					✓	✓
Geoflow provide a range of material (including a hydraulic design spreadsheet) to assist in design of drip irrigation systems http://www.geoflow.com/design_w.html					✓	✓
Orenco Systems Incorporated have a comprehensive engineering library applicable to a range of systems. http://www.orenco.com/corporate/technical_resources/	✓	✓	✓	✓	✓	✓

10 CUMULATIVE IMPACT ASSESSMENT PROCEDURES

There is no ‘one size fits all, black box’ tool for undertaking this type of assessment. However, effective use of available models and tools is possible through establishment of a Minimum Standard for assessment of risks associated with proposed increases in unsewered building entitlements. The level of detail and complexity can be varied to reflect the potential risk (a function of the likelihood and/or consequence of failure) a specific proposal poses to human and ecosystem health. The DAF has used the outcomes of hazard mapping, minimum lot size and maximum lot density assessments to develop an adaptable Cumulative Impact Assessment (CIA) procedure. Reference should be made to the DAF for guidance on the circumstances in which CIA is required.

In order to maintain simplicity in CIA procedures, the following indicative performance objective has been adopted.

No more than 10% increase in average annual nitrogen and phosphorus loads (kg/year) from existing undeveloped loads

Average virus concentrations in effluent (following attenuation) of <1 MPN/100ml.

All land application areas sized to ensure hydraulic failure (surcharging) accounts for only 5% of total wastewater generated (i.e. 95% containment via evapo-transpiration and deep drainage).

It is readily acknowledged that these targets are arbitrary values. It has been adopted after careful consideration of a range of alternatives. Other more conventional targets immediately require significantly more detailed investigations to be undertaken that were disproportionate to potential risk. They also require holistic, integrated assessment of pollutant loads from a development (e.g. stormwater pollutants) which is currently not required for most developments in Post Stephens. Based on the outcomes of lot density modelling (Section 7), the adopted target will strike an effective balance between protection of ecosystems and human health and the need to undertake detailed technical investigations.

Health impacts will be considered to be adequately managed where all land application areas are sized in accordance with Section 9.2 ***and*** the daily water balance modelling indicates no change in surcharge frequency on existing conditions. This assumption is appropriate for environments where subsurface pollutant export is minimal. In other circumstances, the Detailed CIA will be completed which models pathogen export explicitly.

10.1 Standard Cumulative Impact Assessment Procedure

The Standard CIA procedure involves daily water and nutrient balance modelling of the proposed range of on-site systems in addition to use of standard background pollutant loads and pollutant attenuation rates to evaluate the potential for the increase in on-site systems to significantly alter nutrient loads or pathogen export risks within a subcatchment. It draws on standard data for NSW (background loads) and locally applicable parameters derived as part of the *Sustainable On-site Sewage Management* Study (attenuation rates). An example methodology and case study demonstrating how a Standard CIA should be undertaken is provided below. Alternative methodologies will be considered but must meet or exceed the Minimum Standards listed below in order to be approved by Council.

Table 10-1 Minimum Standard for Standard Cumulative Impact Assessments

Risk Assessment Component	Minimum Standard
On-lot Land Application Area (LAA) Assessment	• Daily water and nutrient mass balance modelling for each general on-site system LAA type within the subject site used to derive average annual hydraulic and pollutant loads to surface and subsurface export routes. Also used to estimate frequency of hydraulic failure (surcharge).
Rainfall-Runoff	• Average annual estimate of runoff volume using a volumetric coefficient of rainfall. Recommend use of Figure 2.3 (and subsequent equations) from Fletcher *et al* (2004).[1] See web link below.
Surface and Subsurface Pollutant Export	• Application of catchment attenuation factor (provided in Table 10-7 of the Technical Manual) to combined surface and subsurface on-site loads based on broad characteristics of the receiving environment.[2] • Mass balance combining attenuated on-site system flows and loads with catchment inputs.
Background Pollutant Loads / Concentrations	• Sourced from Tables 2.44 - 2.45 or Figures 2.15 – 2.23 of Fletcher *et al* (2004).[1] • Acceptable export rates / concentrations sourced from published local studies.
Environment and Health Protection Targets[3]	• No more than 10% increase in average annual nitrogen and phosphorus loads (kg/year) based on existing undeveloped background loads. • Average virus concentrations <1 MPN/100ml after application of attenuation rates. • All land application areas sized to ensure hydraulic failure (surcharging) accounts for only 5% of total wastewater generated (i.e. 95% containment via evapo-transpiration and deep drainage).

Note 1: Fletcher et al (2004) available from http://www.catchment.crc.org.au/pdfs/technical200408.pdf.
Note 2: Refer to Section 10.1.2 for explanation of attenuation factor derivation.
Note 3: Site specific targets can be developed and justified on a case by case basis. Outcomes must meet or exceed those achieved by the above targets.

In the case of Standard CIA procedure it is sufficient to complete daily modelling of the anticipated range of general system types, wastewater generation rates (e.g. maximum) and soil characteristics. Results can then be extrapolated based on an assumed breakdown of system types and dwelling sizes / design flows. Development of a site specific daily water, nutrient and pathogen model for every proposed allotment is not necessary.

The Standard CIA is intended to be able to be completed relatively quickly (0.5 to 2 days following field work) for a typical residential subdivision or commercial development. Necessary information for completion is largely provided in this Technical Manual or Fletcher *et al* (2004) with the exception of the daily water, nutrient and pathogen modelling. Refer to Section 9.4 for guidance on daily modelling.

10.1.1 Example Standard CIA Procedure

An example Standard CIA is provided below for the following hypothetical unsewered subdivision.

- An existing 5 ha site is proposed to be subdivided into 10 rural living or rural residential lots.
- The hazard class is Medium due to moderate soil constraints and the presence of an intermittent watercourse through the site.
- The proposed subdivision plan indicates a number of the lots would contain between 2,000 – 4,000 m^2 of Useable Land.
- The developer wishes to locate two proposed Effluent Management Areas (EMAs) 30 metres from the intermittent watercourse (i.e. 50-100% achievement of PSC setback distances in Table 6-8 of the DAF.

- The developer wishes to retain the option to install absorption / evapo-transpiration beds on the higher lots where deeper, structured soils were observed during site and soil investigations.

Reference to Table 2-13 in the PSC DAF confirms that the proposed subdivision requires a Standard CIA to be completed.

10.1.1.1 On-lot Land Application Area (LAA) Assessment

Daily LAA water, nutrient and pathogen modelling was undertaken using LAM for two broad system types.

- Four bedroom house (reticulated water supply), secondary treatment system to subsurface irrigation.
- Four bedroom house (reticulated water supply), primary treatment to evapo-transpiration / absorption beds.

One soil type was identified during field investigations and site and soil assessment which was a residual mid-slope profile generally consisting of;

- moderately structured loam topsoil overlying;
- moderately structured clay loam B_1 horizon overlying;
- strongly structured light clay.

Total soil depth of 1.2 metres and a typical root depth of 600mm. Phosphorus sorption was moderate to high. The site is on a mid to lower slope.

Key input parameters are summarised in the following table.

Table 10-2 Summary of Daily LAA Modelling Inputs

Parameter	Unit	System 1	System 2
System Characteristics			
LAA Type		**Conventional Trenches / Beds**	**Sub-surface Irrigation**
Effluent Volume per Working Day	m3	0.9	0.9
Total Phosphorous	mg/L	15	12
Total Nitrogen	mg/L	60	35
Virus	MPN/L	1000	100
Crop Characteristics			
Crop P Uptake	kg/ha/yr	20	20
Crop N Uptake	kg/ha/yr	200	200
Crop Factor		Grass	Grass
Parameter	**Unit**	**Trench / Bed**	**AWTS**
		Light Clay	**Light Clay**
LAA Type		Conventional Trenches / Beds	Sub-surface Irrigation
DLR (from ASNZS1547:2012)	mm/d	8	3.5
LAA	m2	115	260
System Type		**Sub-surface Irrigation**	**Conventional Trenches / Beds**
Soil Type		**Light Clay**	**Light Clay**
Parameter	**Unit**		
Effective Saturation	mm	390	170
Permanent Wilting Point	mm	160	30
Field Capacity	mm	300	65
Saturated Hydraulic Conductivity	mm/day	100	40
Bulk Density	kg/m3	1400	1400
Soil Depth for P Sorption	m	1.25	1.25
INF	mm/day	225	225
Exp 1	-	1.5	1.5
A1	-	240	240
B1	-	0.20	0.20
B2	-	0.10	0.10

LAM produced the following average annual outputs for surface and subsurface hydraulic, nutrient and pathogen (virus) loads.

Table 10-3 Average Annual Loads from On-site System Types

Average Annual Output (per system)	Secondary Treatment Subsurface Irrigation	Primary Treatment ETA Bed
Mean Annual Overflow (m3) =	0	0
Mean Annual Overflow N (kg) =	0	0
Mean Annual Overflow P (kg) =	0	0
Mean Annual Overflow V (MPN) =	0	0
Mean Annual Surface Runoff (m3) =	0	16
Mean Annual Surface N (kg) =	0	0.05
Mean Annual Surface P (kg) =	0	0.66
Mean Annual Surface V (MPN) =	0	455525
Mean Annual Deep Drainage (m3) =	252	287
Mean Annual Deep Drainage N (kg) =	0.17	1.39
Mean Annual Deep Drainage P (kg) =	2.21	3.24
Mean Annual Deep Drainage V (MPN) =	512975	410518

The proposed 260 m^2 irrigation LAA resulted in 100% containment of average annual wastewater generated by the household as deep drainage / evapo-transpiration (i.e. 0% hydraulic surcharging), and as such met the DAF criteria for health protection. The proposed 115 m^2 ETA bed resulted in 95% containment of average annual wastewater generated (i.e. 5% hydraulic surcharging), and thus also met the DAF Minimum Standard.

10.1.1.2 Surface and Subsurface Pollutant Export

Reference was then made to Table 10-7 to select the appropriate catchment attenuation rate for the proposed development. This attenuation rate represents the loss and assimilation of *wastewater* loads (discharging as deep drainage or surface surcharge) as it moves from the land application areas to receiving environments. The attenuation rates were then applied to the average annual wastewater system loads for the proposed development as decay factors. Three primary dosed ETA bed systems were assumed with the remaining seven being secondary dosed subsurface irrigation systems.

Table 10-4 Summary of Final On-site System Loads at Receiving Water

Parameter	Attenuation	Average Loads	Average Concentration
Hydraulic	40%	1.6 ML/year	
Total Nitrogen	90%	0.6 kg/year	0.38 mg/L
Total Phosphorus	98%	0.5 kg/year	0.3 mg/L
Virus	99%	61,000 MPN/year	<1 MPN/100ml

10.1.1.3 Rainfall-Runoff

The equation from Fletcher *et al* (page 8) was used to estimate the annual volume of runoff from the proposed development for the existing case. An Effective Impervious Area (EIA) of zero was adopted making the equation;

$C = 0.0013R^{0.8} – 0.095.$

Average annual rainfall for the site was 1247 mm which equates to a volumetric runoff coefficient (C_v) of 0.29.

Average annual runoff therefore equals 362 mm which equates to 18 ML/year.

10.1.1.4 Background Pollutant Loads / Concentrations

Tables 2.4.4 and 2.4.5 in Fletcher *et al* (2004) were then used in conjunction with runoff volume to estimate background pollutant concentrations and loads. A land use of rural was adopted for the semi-cleared, unimproved pasture site. It is reasonable to apply dry weather concentrations for 20% of the runoff volume and wet weather concentrations to the remaining 80%.

Table 10-5 Summary of Background Pollutant Loads / Concentrations

Parameter	Average Loads	Average Concentrations
Total Nitrogen (TN)	32 kg/year	1.8 mg/L
Total Phosphorus (TP)	3.2 kg/year	0.18 mg/L

10.1.1.5 Environment and Health Protection Targets

Average annual on-site system and background flows and loads were combined in a mass balance to provide an estimate of long-term catchment loads from the proposed on-site systems.

Table 10-6 Results of Site Mass Balance for Cumulative Impact Assessment

Parameter	Average Loads	Percent Increase	Average Concentrations
Flow	20 ML	9%	
Total Nitrogen (TN)	32.6 kg/year	2%	1.63 mg/L
Total Phosphorus (TP)	3.7 kg/year	16%	0.19 mg/L
Virus	N/A		<1 MPN/100ml

The results indicate greater than 10% increase in Total Phosphorus loads as a result of the proposed mix of on-site sewage management system. All other targets were met. Options to bring TP loads down to compliance include;

- eliminating the option for primary effluent dosed trenches and beds (this alone doesn't meet the target);
- improving effluent quality at the treatment system;
- increasing the LAA size to reduce the nutrient loading rate;
- reducing the number of lots to nine; or
- undertaking a Detailed CIA including site specific calculation of attenuation rates which may demonstrate compliance.

In this case, the proponent chose to eliminate the option of primary dosed beds and proposed to increase the minimum subsurface irrigation area to 300 m^2 which enabled the development to meet the DAF Minimum Standards.

10.1.2 Minimum Outputs for Standard CIA's

As advised in the relevant Minimum Standards tables in the DAF, it is envisaged that Standard Cumulative Impact Assessments (CIA) will typically be contained in 5-10 pages within the Wastewater Management Report. The following elements should be provided to enable Council to assess the CIA.

- Summary of approach taken and confirmation of compliance with the Minimum Standards documented in Table 10-1.
- Methodology documenting the basis and source of input data including reference to site specific data, published information or the *Technical Manual* to justify use.
- Results of monthly water balance and annual nutrient balances to demonstrate minimum land application system sizing.
- Results demonstrating compliance with local water quality objectives and adequate management of health risk as defined and demonstrated in Section 10.1.1.
- Brief discussion of long-term risks to health and environment and recommended management measures to address impacts.

10.2 Catchment Pollutant Attenuation

10.2.1 Standard CIA

In the case of Standard CIAs reference can be made to the following table to select and apply catchment attenuation rates. These rates should be applied to the wastewater flows and loads only (i.e. not the background loads) prior to calculating the site mass balance. They have been derived through a series of modelling processes (using the Domenico steady state equation) and on the back of previous experience. They correlate reasonably well with previous studies. However it should be noted that they are generalised estimates only. More accurate determination requires comprehensive site monitoring and modelling processes that will only be justified for proposed systems in highly sensitive environments where risks are high.

Table 10-7 Catchment Pollutant Attenuation Rates for Standard CIA

<table>
<tr><th></th><th>Hydraulic</th><th>Nitrogen</th><th>Phosphorus</th><th>Pathogen</th></tr>
<tr><td colspan="5">West
Rolling hills of residual, colluvial and erosional soils in the western portion of the LGA with bedrock creating relatively shallow episodic perched water tables that discharge to local ephemeral drainage lines and creeks.</td></tr>
<tr><td>PSC Setbacks[1] Achieved</td><td>60%</td><td>95%</td><td rowspan="3">98%</td><td rowspan="3">99%</td></tr>
<tr><td>50% PSC Setbacks</td><td>40%</td><td>90%</td></tr>
<tr><td><50% PSC Setbacks[2]</td><td>20%</td><td>80%</td></tr>
<tr><td colspan="5">East
Low lying sandy environments underlain by shallow unconfined aquifers directly connected to the Port Stephens estuary (e.g. Tilligerry Creek catchment).</td></tr>
<tr><td>PSC Setbacks[1] Achieved</td><td>40%</td><td colspan="2">90%</td><td rowspan="3">99%</td></tr>
<tr><td>50% PSC Setbacks</td><td>30%</td><td colspan="2">80%</td></tr>
<tr><td><50% PSC Setbacks[2]</td><td>20%</td><td colspan="2">60%</td></tr>
<tr><td colspan="5">Attenuation factors should be applied to combined surface/subsurface average annual on-site system loads (kg/year) as an inverse (decay) decimal (i.e. 1-AF)</td></tr>
</table>

Note 1: PSC Setbacks as follows – open drainage, intermittent and permanent watercourses, groundwater bores and farm dams.

Note 2: Sites where any land application system is proposed within 20 metres of a natural or artificial watercourse will require site specific determination of pollutant attenuation.

10.2.2 Detailed CIA

Site specific modelling using the Domenico steady state approach must be undertaken for Detailed CIAs. This approach involves spreadsheet application of the above equations using parameters readily obtained of inferred to a sufficient level of accuracy through site and soil and desktop evaluations. A freely available spreadsheet model that includes this equation can be obtained from the United Kingdom EPA (http://www.environment-agency.gov.uk/research/planning/40373.aspx).

10.3 Detailed Cumulative Impact Assessment Procedure

The Detailed CIA procedure set out below and in the DAF is based on the approach adopted for the Maximum Lot Density Assessment documented in Section 7. It involves daily simulation of individual on-site systems using mass balance calculations for water, nutrients and (in specific circumstances) pathogens. Wastewater discharge into surface and groundwater is then input into a continuous catchment water quality and runoff model to simulate surface runoff and groundwater recharge. The attenuation of pollutants derived from on-site systems as they move down the catchment is also incorporated based on the outcomes of lot density modelling. The modelling is designed to simulate long-term average conditions but incorporates dynamic conditions on a daily time step to improve accuracy. It also allows assessment of intra-annual variation in results where conditions vary (e.g. areas with holiday homes or highly variably climate).

The models utilised in the Detailed CIA (DSM and MUSIC) do represent current best practice tools for water quantity and quality modelling. However, alternative models do exist and will be considered by Council subject to an initial peer review. As an example, modelling of long-term catchment water quantity and quality can be completed using a number of proprietary models including MUSIC and MIKE NAM. There are no known proprietary models for the simulation of multiple on-site systems on a daily time step other than the DSM. However, it can be done using excel spreadsheet models where the user has expertise in on-site system bio-physical processes and mass balance modelling. It can also be completed using single site models such as MEDLI and LAM (see Section 9.4.2). The development of a 'Minimum Standard' specification for risk assessment modelling will provide control over the quality of any non-proprietary modelling tools.

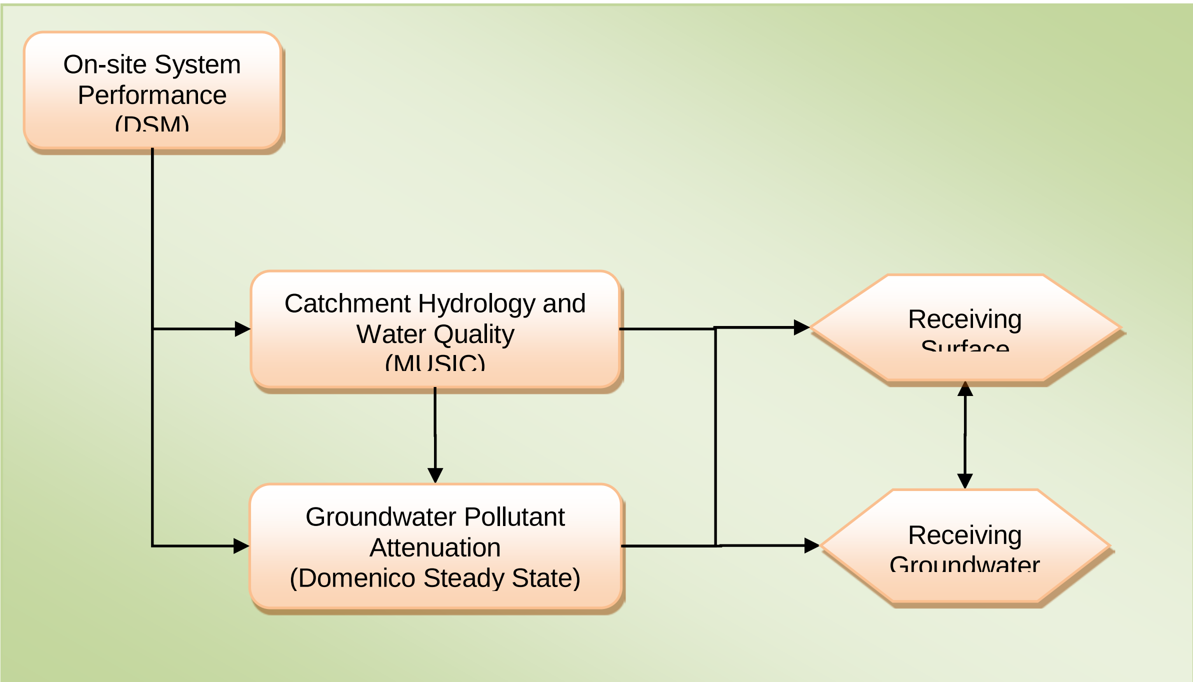

Figure 10-1 Structure of the Detailed CIA Modelling Procedure

The DAF requires a Detailed CIA to be completed in the following circumstances.

- Unsewered increases in building entitlements with any lot containing <2000m^2 Useable Land.
- Unsewered increases in building entitlements on Very High Hazard lots.
- Unsewered increases in building entitlements on High Hazard lots where buffer distances for open drainage, intermittent and permanent watercourses, groundwater bores and farm dams are less than 50% of those documented in the DAF.
- Non-domestic systems that do not meet buffer distances.
- Non-domestic systems on High and Very High Hazard lots where sufficient Useable Land for the proposed system cannot be demonstrated.

Provided in this section are a set of Minimum Standards for completion of a Detailed CIA and catchment attenuation factors derived through the lot density assessment process. It is acknowledged that the Detailed Risk Assessment Procedure adopted for the lot density assessment represents only one methodology for undertaking this type of work. Alternative methodologies put forward by consultants / developers should meet or exceed these Minimum Standards.

Table 10-8 Minimum Standards for Detailed Cumulative Impact Assessment Procedure

Risk Assessment Component	Minimum Standard
On-lot Land Application Area (LAA) Assessment	• Daily water and nutrient mass balance modelling on a site specific basis used to derive average annual hydraulic and pollutant loads to surface and subsurface export routes. Viral die-off modelling.
Rainfall-Runoff and Groundwater Recharge	• Continuous daily rainfall-runoff, nutrient and pathogen mass balance modelling using MUSIC (or equivalent) used to derive average annual values.
Background Pollutant Loads / Concentrations	• Sourced from Chapter 2 of Fletcher *et al* (2004). • Acceptable export rates / concentrations sourced from published local studies. • Site specific data where available or necessary.
Surface and Subsurface Pollutant Export	• Site specific calculation of catchment attenuation factors for both surface and subsurface on-site loads based on data obtained through desktop and field site and soil investigations and representative of the characteristics of the receiving environment.[2] • Mass balance combining attenuated on-site system flows and loads with catchment inputs.
Environment and Health Protection Targets[3]	• No more than 10% increase in average annual nitrogen and phosphorus loads (kg/year) based on existing undeveloped background loads. • Average virus concentrations <1 MPN/100ml after application of attenuation rates. • All land application areas sized to ensure hydraulic failure (surcharging) accounts for only 5% of total wastewater generated (i.e. 95% containment via evapo-transpiration and deep drainage).

Note 1: Fletcher et al (2004) available from http://www.catchment.crc.org.au/pdfs/technical200408.pdf.
Note 2: Refer to Section 10.2.1 for explanation of attenuation factor derivation.
Note 3: Site specific targets can be developed and justified on a case by case basis. Outcomes must meet or exceed those achieved by the above targets.

A comprehensive case study for the application of the Detailed CIA is provided in Section 7 as part of the maximum lot density assessment. This assessment will require more comprehensive skills and experience in catchment modelling and the modelling of on-site system performance. As such it is only required for very high risk proposals. Nonetheless it is consistent with assessment and modelling approaches for stormwater impact assessment and other potentially polluting activities.

10.3.1 Minimum CIA Outputs to be Provided

As advised in the relevant Minimum Standards tables in the DAF, it is envisaged that Detailed Cumulative Impact Assessments (CIA) will typically be contained in 10-20 pages within the Wastewater Management Report. The following elements should be provided to enable Council to assess the CIA.

- Summary of approach taken and confirmation of compliance with the Minimum Standards documented in Table 10-8.
- Methodology documenting the basis and source of input data including reference to site specific data, published information or the *Technical Manual* to justify use.
- Summary of results of daily modelling for adopted on-site system types including (as a minimum):
  - Average annual nutrient loads and concentrations:
  - Average annual surface surcharge and deep drainage volumes:
  - Average annual pathogen concentration in deep drainage (where applicable): and
  - Average annual frequency of surface failure (surcharge) of land application systems.
- Summary results of viral dieoff modelling or any other groundwater modelling undertaken.
- Mean annual outputs from the MUSIC (or similar) model.
- Results demonstrating compliance with local water quality objectives and adequate management of health risk as defined and demonstrated in Section 10.1.1.5.
- Brief discussion of long-term risks to health and environment and recommended management measures to address impacts.

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