environment SOUTHLAND

Te Taiao Tonga

Contribution of On-site Wastewater Disposal to Cumulative Nutrient Loadings in the Southland Region

Technical Report

July 2014

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Consultant for Environment Southland

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Community Summary

The effects of wastewater from un-sewered areas in rural Southland

On-site wastewater disposal, such as that from septic tanks, is the main way of disposing of domestic wastewater in rural parts of Southland that don't have access to sewers. Instead of being treated by a wastewater treatment plant, domestic wastewater is discharged to a disposal field on a property, carrying with it potential contaminants.

Wastewater from septic tanks contains high levels of nutrients, microbial contaminants and viruses. These have the potential to contaminate soil, groundwater or nearby streams and rivers.

Scientists at Environment Southland have estimated the contribution wastewater makes to the total nitrogen and phosphorus load for the Mataura River, Oreti River, Aparima River and Waiau River catchments. They compared levels of potential contamination from wastewater with other sources of contamination, such as agricultural runoff. They also looked at the risk of contamination from wastewater reaching groundwater across the region.

How does on-site wastewater disposal work?

Septic tanks are the most common form of on-site wastewater treatment in rural Southland. The main role of a septic tank is to separate out solid from liquid waste. Domestic wastewater forms three main layers within the tank. A scum layer forms at the top, containing waste such as greases and oils. Heavy solids settle to the bottom of the tank forming a sludge layer. A middle layer of wastewater can then be piped to a 'disposal field', which is made up of a series of trenches lined with gravel or coarse sand (see Figure 1).

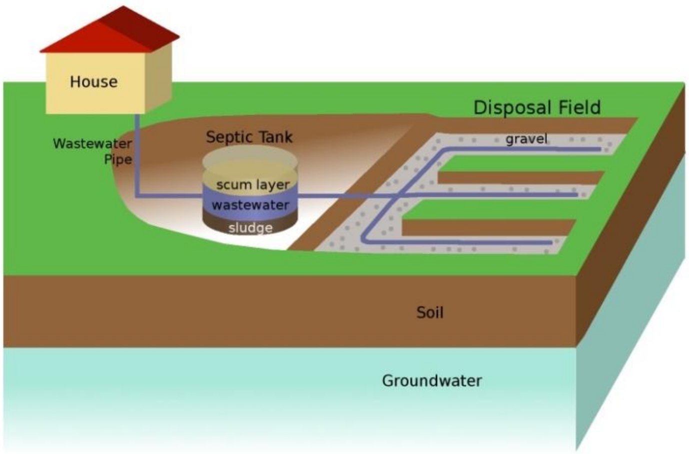


Figure 1

On-site wastewater disposal and potential contamination

When wastewater is piped to a disposal field it carries with it a range of potential contaminants. Of particular concern are:

- **microbial contaminants**, such as bacteria and viruses that can make people and livestock sick;
- **chemicals** that have come from household waste, for example from pharmaceuticals or household cleaners;
- **excess nutrients**, such as nitrogen and phosphorus.

Did you know…

On average a single person generates about 180 litres of wastewater per day.

(A family of four could generate about 720 litres of wastewater each day!)

Nitrogen in the form of nitrate can accumulate in groundwater to a level that is toxic to people and livestock, making it unsafe for drinking. Excess nitrogen and phosphorus can also promote excess plant growth in waterways.

How much contamination reaches groundwater or streams and rivers depends largely on soil type and drainage. Contamination from wastewater can reach groundwater more easily when soils drain freely and when groundwater is shallow. Where soils are poorly drained, wastewater can ‘pool’ on the surface or seep sideways through the soil system to waterways.

Figure 2 shows potential movement of wastewater from a disposal field. Some water will be lost vertically up through the system via the roots of plants growing above, or via evapotranspiration (drying up). Wastewater can also percolate down through the soil, potentially reaching groundwater or seeping horizontally and entering waterways via runoff.

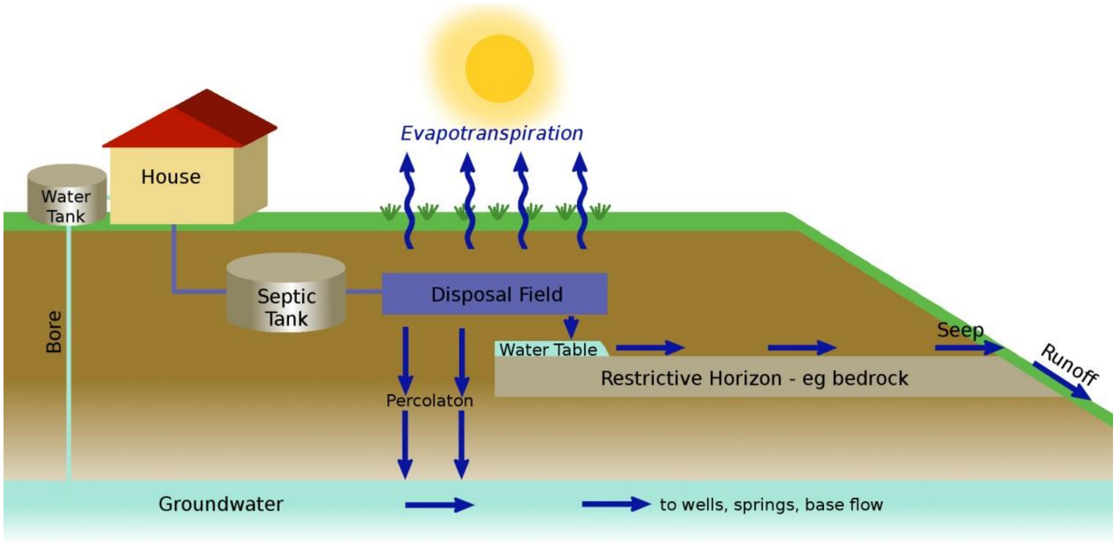


Figure 2

Nutrient loading from wastewater – is it a problem?

Scientists estimated the amount of nitrogen and phosphorus that may be entering waterways from on-site wastewater disposal. They estimated that on-site wastewater disposal contributes between 0.8% and 2.2% (129 and 366 tonnes) of total nitrogen (TN) and between 0.4% and 0.85% (2.7 and 5.4 tonnes) of total phosphorus (TP) load, across the region per year.

Nitrogen

Nitrogen in the form of nitrate is water soluble, which means it can easily contaminate ground and surface water. The following table shows how much total nitrogen (TN) is entering the Oreti, Mataura, Waiau and Aparima catchments from wastewater.

The table below shows the number of occupied dwellings in each catchment that are likely to have on-site wastewater disposal, and associated estimates for total nitrogen (TN). The highlighted column shows the likely contribution wastewater makes to the amount of nitrogen that enters a catchment.

Catchment	Occupied Dwellings	Annual TN loads from wastewater (tonnes per year)	Contribution of wastewater nitrogen to cumulative catchment load (%)
Oreti	5,367	55-156	0.5-1.4
Mataura	1,410	32-90	1.0-2.8
Waiau	834	10-27	0.5-1.3
Aparima	825	11-31	0.2-0.6

Results indicate that on-site wastewater disposal is a minor contributor to the total nutrient load across most of Southland.

Phosphorus

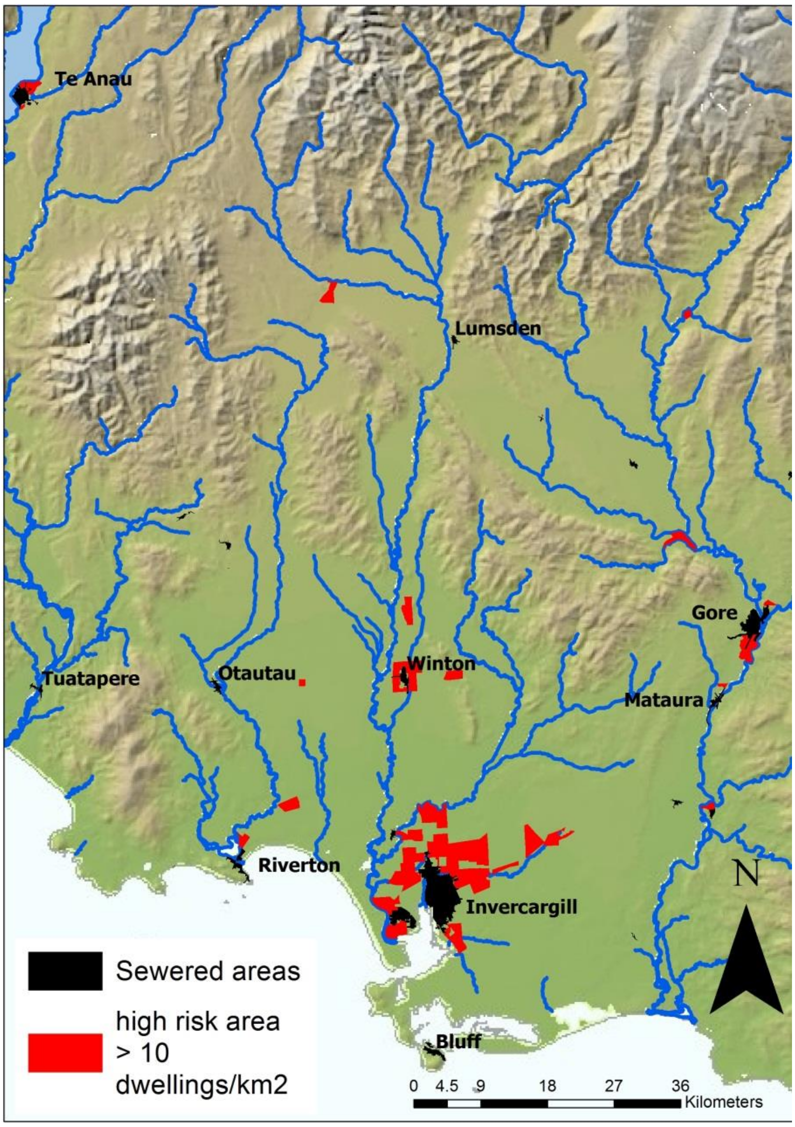
In a properly functioning disposal field, the majority of phosphorus will be absorbed by the soil with minimal amounts leaving the system. However, if a disposal field is not functioning, effluent may run over the land into a nearby stream or river, carrying with it excess phosphorus.

Risk to groundwater

The areas with the highest nutrient loadings occur in rural residential areas located around the edges of major population centres (e.g. Invercargill and Winton) or in small unsewered townships (e.g. Waikaia). However, even in these areas estimated nutrient loadings are considerably lower than those typically associated with intensive agriculture.

Overall, results showed that the potential risk of groundwater contamination from on-site wastewater disposal varies across Southland. Areas with the highest risk tend to have higher population densities, permeable soils and a shallow water table.

Map showing areas at high risk of groundwater contamination from on-site wastewater disposal



Protecting our water – what you can do

Minimise the risk of contamination from your on-site wastewater disposal by making sure your system is well maintained. As a general rule, your septic tank should be inspected once a year and pumped out every 3-5 years (or more often if necessary), by a certified contractor.

Localised contamination of groundwater through poor well-head protection is a major cause of groundwater quality problems in Southland. Taking a few minutes to check the condition of your bore may help prevent you or your family getting sick, and will help protect the quality of our groundwater resource.

Bores and wells utilised for domestic supply should be tested to ensure they are free from contamination. Having the microbial (bacterial) quality of your water supply tested is particularly important as many waterborne illnesses can be transmitted via contaminated water supplies.

Download the pamphlet "***How well is your well: A guide to protecting the quality and reliability of your groundwater supply***" for more information about looking after your groundwater supply (www.es.govt.nz).

Full report of Liquid Earth Limited follows

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July 2014

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Executive Summary

On-site wastewater treatment is utilised as the primary method of disposal of domestic wastewater across semi-rural and rural areas of Southland. This report utilised Census 2013 population data to estimate cumulative nutrient loadings associated with on-site wastewater disposal at a sub-catchment scale across the Southland Region assuming a nominal level of effluent treatment and attenuation.

Results of the assessment indicate that on-site wastewater disposal is likely to make a minor contribution (<1.5 %) to cumulative nutrient loadings across a majority of the region except in the Oreti catchment where, due to the higher population density, it may contribute up to 2.8% of cumulative nitrogen loads at the bottom of the catchment (New River Estuary).

The assessment also indicates the highest risks to groundwater quality associated with on-site wastewater disposal are likely to occur in semi-rural areas around the larger population centres (Invercargill and Winton) where a relatively high density dwellings serviced by on-site wastewater disposal systems overlie areas assessed by Olgilvie *et al* (2013) as having a high risk to groundwater quality.

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1. Introduction

On-site treatment is utilised as the primary means of domestic wastewater disposal in unsewered areas of Southland. Effluent from on-site wastewater treatment systems contains elevated levels of nutrients, microbial contaminants and viruses which have the potential to affect water quality in receiving waters. While effects associated with point source discharges such as individual on-site wastewater treatment systems tend to be localised, such discharges also contribute to cumulative loadings of nutrients and microbial contaminants at a regional scale.

1.1. Previous Work

Olgilvie *et. al.* (2013) developed a relatively simple assessment of potential risks to groundwater quality in Southland associated with on-site wastewater disposal based on a combination of soil physical characteristics and depth to groundwater. The investigation also utilised address point data held by Environment Southland to highlight areas of highest risk based on the overall density of on-site wastewater systems. Overall, the assessment showed potential risks to groundwater quality associated with on-site wastewater disposal vary with geographic location across Southland. Areas with the highest groundwater quality risk tend to be those with permeable soils overlying a shallow water table while areas with lower permeability soils or deeper water tables were classifies as having a lower risk.

Aqualinc (2014a) developed a regional scale water quality classification for Southland based on assessment of existing water quality data and modelling cumulative nutrient loadings resulting from agricultural land use and consented wastewater discharges. The assessment identified diffuse sources from agricultural land as the most significant contribution to nutrient contamination at a regional scale. While point source discharges (industrial and municipal wastewater discharges) were identified as contributing <10% of estimated total nitrogen (TN) loads and between <5% to <25% of estimated total phosphorus (TP) loads, the contribution of small-scale consented discharges to land from non-agricultural sources to cumulative nutrient loadings was not specifically included in the analysis due to their assumed minor contribution.

1.2. Report Objective

The original objective of this report was to provide an estimate of the potential contribution of discharges associated with on-site wastewater disposal and consented discharges to land to cumulative catchment scale-nutrient loadings in the Southland Region.

However, due to the lack of readily available data to enable calculation of loadings associated with consented discharges to land, the scope of the report was ultimately restricted to on-site wastewater disposal.

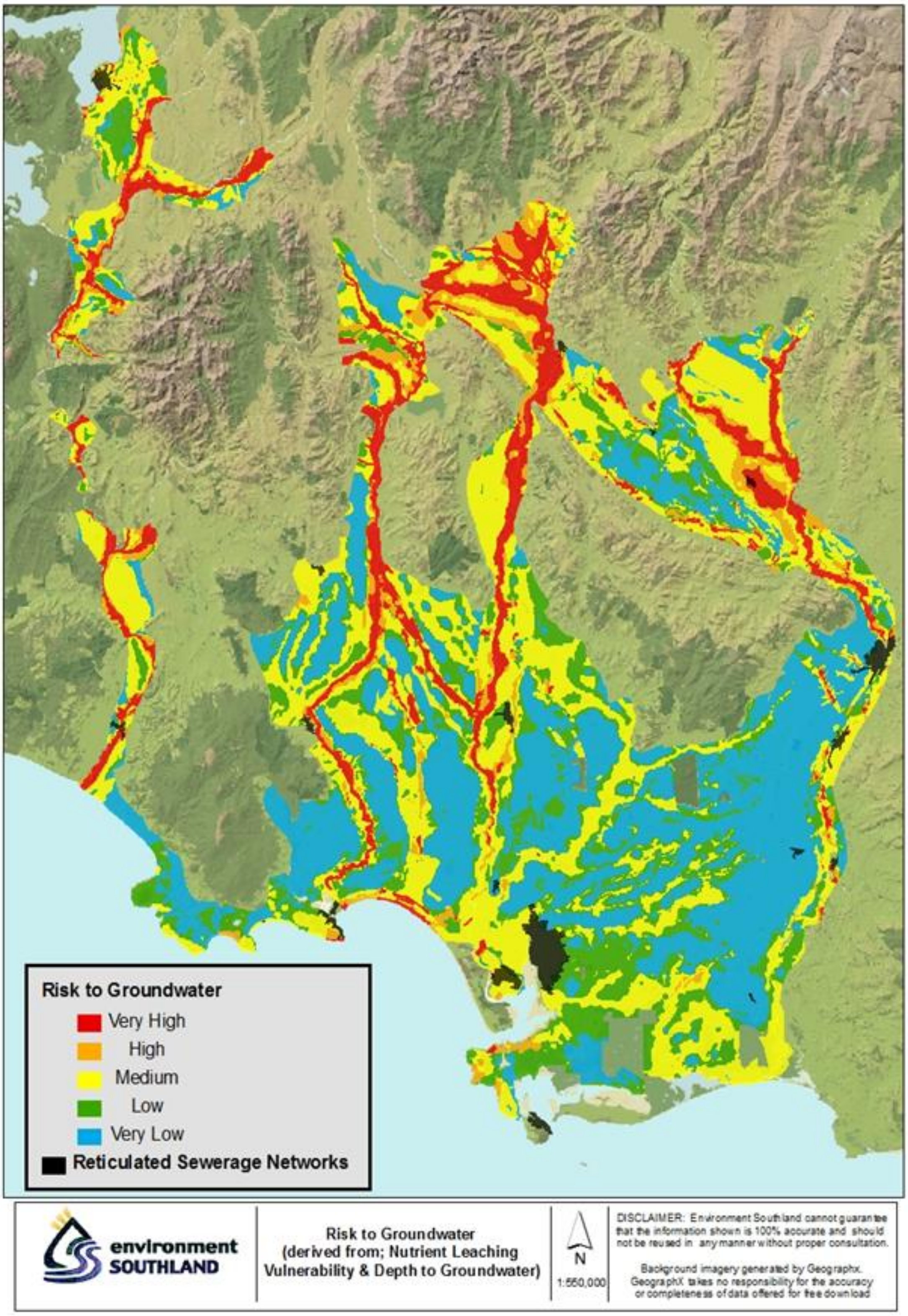

Figure 1. Relative risk to groundwater quality associated with on-site wastewater disposal in the Southland Region (from Olgilvie *et al,* 2013)

2. On-site Wastewater Disposal

2.1. Septic Systems

On-site wastewater disposal systems provide treatment of domestic wastewater via discharge to ground within the property of origin. A range of on-site systems are available, designed to treat wastewater to varying degrees before final discharge to the environment.

Septic tanks are the most common form of on-site wastewater treatment utilised in Southland. These systems have two primary components, a solids settling tank (i.e. the septic tank) and a disposal field typically comprising soakage trenches or driplines as illustrated in **Figure 2** below.

The septic tank is a watertight box (usually concrete or fibreglass) with an inlet and outlet pipe. The septic tank provides primary treatment of the effluent by retaining wastewater for a sufficient period to allow for solids and liquids to separate. The wastewater forms three layers inside the tank. Solids lighter than water (such as greases and oils) float to the top forming a scum layer. Solids heavier than water settle to the bottom of the tank forming a layer of sludge. A middle layer of partially clarified wastewater forms between these layers. The layers of sludge and scum remain in the septic tank, where bacteria occurring naturally in the wastewater work to break down the solids. The sludge and scum that cannot be broken down are retained in the tank, while the clarified wastewater is discharged to the drainage field.

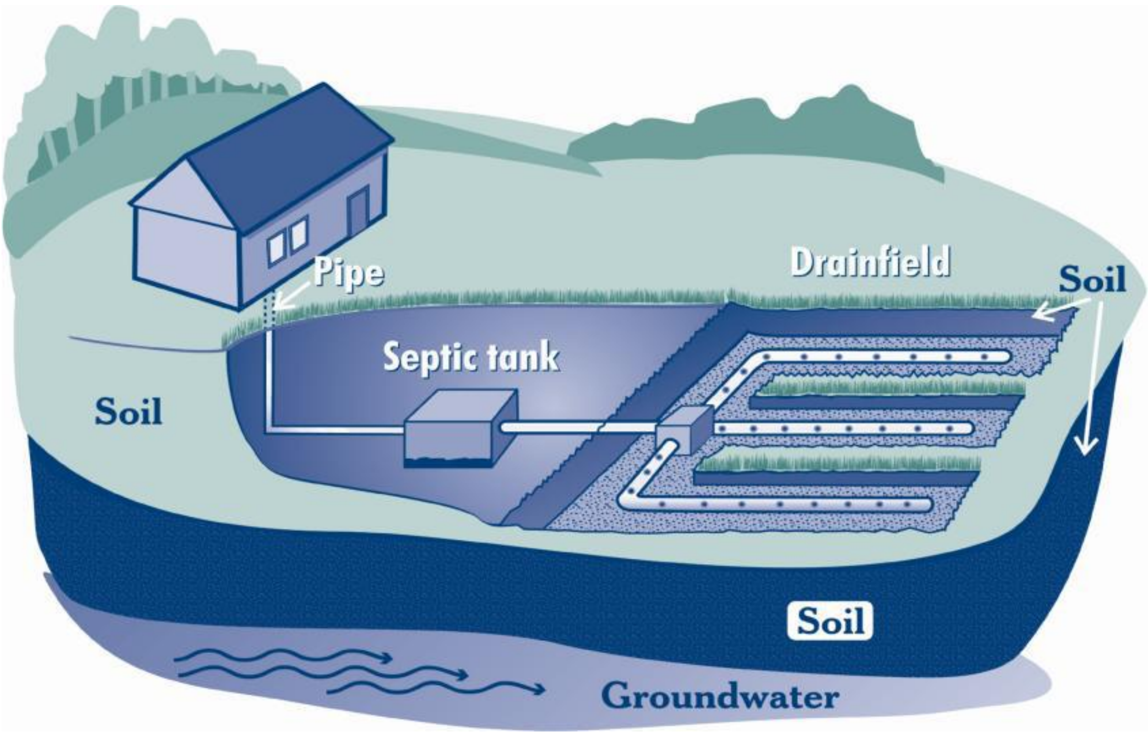

Figure 2. Schematic illustration of a typical on-site wastewater treatment system[1]

[1] From www.waternz.org.nz

A standard drainfield consists of a series of trenches lined with gravel or coarse sand buried at a shallow depth beneath the land surface. Clarified wastewater is distributed to the drainfield by a pump (or gravity in older systems) and infiltrates into the underlying ground via perforated pipes. The sand and soil media surrounding the drain act as a biological filter which provides a degree of secondary treatment for the effluent.

The majority of effluent treatment occurs within the soil underlying the disposal area with the primary function of the septic tank being the removal of solids that may otherwise reduce drainage within the disposal field. Therefore, the physical characteristics of the soil into which effluent is discharged has a significant influence on overall treatment effectiveness. If soils are highly permeable, the groundwater table high or subsurface drainage structures provide connectivity, effluent can rapidly infiltrate to underlying groundwater. Conversely, if soils are poorly drained and hydraulic loadings too high, effluent may pond on the land surface creating a health hazard or move laterally through the soil and discharge directly into surface water.

2.2. Characteristics of Septic Tank Effluent

The physical, chemical and microbial characteristics of septic tank effluent can vary significantly between individual installations reflecting a range of factors including:

- Temporal patterns in wastewater generation and the total volume of wastewater produced;
- The sources of wastewater within the household (i.e. the relative contribution of 'grey water' and 'black water' to cumulative effluent volumes);
- The use of various appliances (e.g. dishwashers, washing machines and waste disposal);
- The household water supply utilised (e.g. reticulated supply, bore or roof water); and
- The condition and maintenance history of the septic tank.

Estimates of the volume of wastewater generated in a 'typical' septic tank system vary widely. Typically, a volume of 180 L/person/day is assumed (ARC Technical Publication No.58) which reduces to around 140 L/person/day for houses utilising roof water supplies (Wheeler *et al*, 2012).

In terms of effluent quality, USEPA (2002) is a widely cited reference which provides a range of values for mass loadings and concentrations in typical residential wastewater outlined in **Table 1**.

Table 1. Constituent mass loadings and concentrations in typical residential wastewater (USEPA, 2002)

Constituent	Mass Loading (grams/person/day)	Concentration (mg/L)
Total Solids (TS)	115 - 200	500 - 880
Total Suspended Solids (TSS)	30 - 75	155 - 330
5-day biochemical oxygen demand (BOD_5)	35 - 65	155 - 286
Chemical oxygen demand (COD)	115 - 150	500 - 660
Total nitrogen (TN)	6 - 17	26 - 75
Ammonia (NH_4)	1 - 3	4 - 13
Nitrates and nitrites (NO_2-N, NO_3-N)	<1	<1
Total Phosphorus (TP)	1 - 2	6 - 12
Fats, oils and grease	12 - 18	70 - 105
Volatile organic compounds (VOC)	0.02 - 0.07	0.1 - 0.3
Surfactants	2 - 4	9 - 18
Total Coliforms (TC)		10^8 - 10^{10}
Faecal Coliforms (FC)		10^6 - 10^8

A majority of New Zealand studies adopt wastewater loadings and/or concentrations consistent with the figures outlined by USEPA (2002). For example, Potts and Elwood (2000) note the typical nutrient concentration in septic tank effluent is around 10 gram of Total Nitrogen (TN) per person per day and 3 grams of total phosphorus (TP) per day, with average concentrations of 60 g/m^3 TN and 15 g/m^3 TP respectively. Bay of Plenty Regional Council (BOPRC, 2013) apply a typical Nitrogen concentration of 40 g/m^3 in septic tank effluent, equivalent to a mass loading of ~8 g/person/day[2] or 2.9 kg/person/year. Horizons Regional Council (2007) report typical TN concentrations of 40 to 100 g/m^3 and TP concentrations of 7 to 20 g/m^3 in typical single chamber septic tank effluent. Wheeler *et al*, 2010 adopted TN concentrations of 125.4 g/m^3 and TP concentrations of 17.1 g/m^3 in typical rural septic tank effluent equating to annual loadings of 6.4 kg TN/person/year and 0.87 kg TP/person/year.

For the purposes of this report the wastewater concentrations reported by USEPA (2002) are assumed to be broadly representative of 'typical' concentrations likely to be found in septic tank effluent in the Southland Region.

2.3. Potential fate and transport of contaminants

On-site wastewater disposal has the potential to adversely impact on water quality in the receiving environment. Primary contaminants of concern include nutrients (nitrogen and phosphorus), microbial

[2] Equivalent to a mass loading of ~8 g/person/day assuming typical wastewater flows of 180 L/person/day and 2.6 persons/household

contaminants (bacteria and viruses) and various organic and inorganic chemicals (ranging from pharmaceuticals to organic compounds contained in household cleaners and other domestic products).

A majority of nitrogen in domestic effluent occurs in the form of organic nitrogen or ammonia. Within a septic tank concentrations of organic nitrogen are reduced by the removal of solids but anoxic conditions mean little nitrification occurs to convert ammonia to nitrate. Once discharged to the soil treatment system, ammonia is typically converted relatively rapidly to nitrate which is highly soluble in water and is readily transported through the soil zone into underlying groundwater. However, nitrate concentrations in wastewater discharged from the disposal field may be significantly reduced due to a combination of volatilization and denitrification and in some cases uptake by overlying vegetation (where the discharge is shallow and/or vegetation sufficiently deep rooted).

Phosphorus is typically strongly adsorbed to soil surrounding the disposal field until the sorption capacity of the soil is reached (highly dependent on soil type and associated anion storage capacity which may be influenced by changes in redox conditions in the soil zone).

Concentrations of microbial contaminants also reduce significantly in the soil zone underlying the disposal field due to a combination of filtration, adsorption and natural die-off

USEPA (2002) report typical reductions of 10 to 40 percent in TN concentrations during soil infiltration, with 85 to 95 percent reduction in TP concentrations and 99 to 99.99 percent removal of Coliform bacteria. Wheeler *et al* (2010) adopted a figure of 30 percent removal to account for reductions in nitrogen concentrations during soil infiltration. For this report, the mid-point of 20 percent Nitrogen removal and 90 percent Phosphorus removal from the USEPA (2002) figures were adopted as representative of typical on-site wastewater treatment system performance in the Southland Region.

Figure 3 provides a schematic illustration of the transport and fate of contaminants discharged to an on-site wastewater treatment system. The figure shows that in the absence of low permeability horizons in the soil or sub soil, wastewater will infiltrate vertically until it reaches the water table where it mixes with native groundwater. This mixing results in dilution and dispersion of the applied nutrient load, typically forming a narrow elongate plume containing slightly elevated nitrate concentrations (concentrations of TP are dependent of soil type and redox conditions). Such discharges will contribute to cumulative groundwater nutrient loadings resulting from surrounding land use and ultimately to the total baseflow nutrient load to surface waters.

Where low permeability horizons are present in the subsoil, infiltrating wastewater can move laterally increasing the potential for discharge into artificial drainage (e.g. moles, tiles) or directly to surface waterways. In such situations on-site wastewater disposal has the potential to result in direct nutrient inputs to surface water.

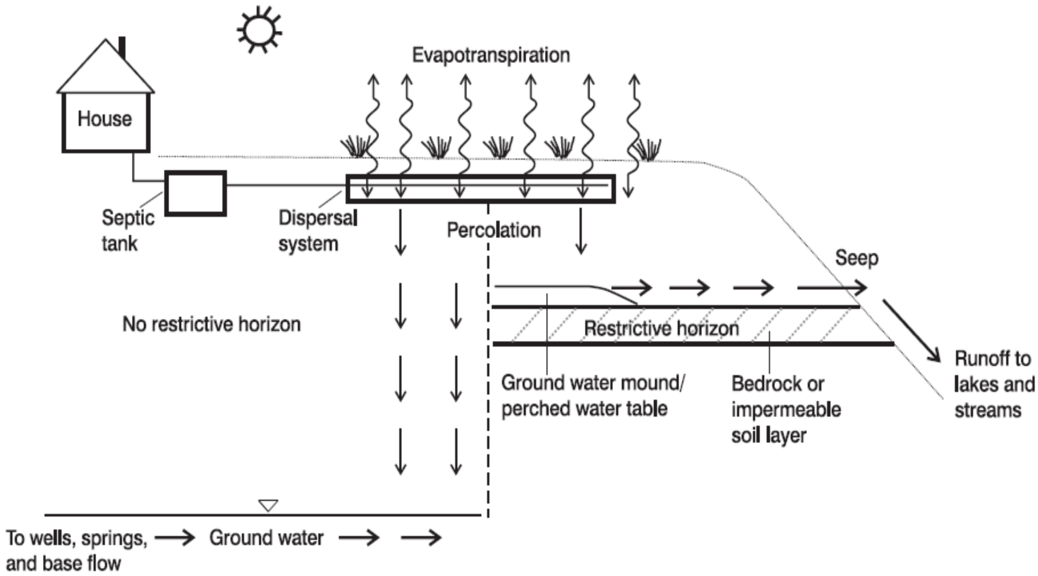

Figure 3. Transport and fate of contaminants from on-site wastewater disposal (USEPA, 2002)

3. Results

3.1. Derivation of population and dwelling data

Initial development of the assessment followed the methodology utilised by Ogilvie *et al.* (2013) to estimate the number of on-site wastewater systems in the Southland Region using a simple modification of the address points layer held by Environment Southland. This GIS coverage contains an entry for each registered dwelling based on records compiled by Land Information New Zealand (LINZ) with each address point located outside the identified boundaries of existing reticulated sewage schemes assumed to represent the location of an on-site wastewater treatment system in the vicinity of the primary dwelling.

However, comparison with records of usually resident population and occupied dwellings recorded in the 2013 census[3] indicated that use of the address points layer was likely to result in a significant over-estimate of dwellings and/or resident population due to the assignment of address points (i.e. owner details) for individual land parcels based on ownership rather than residency. For example, **Figure 4** shows the location of address points assigned to a rural area in the Waituna Lagoon catchment overlain on a 2012 aerial photograph[4]. The figure clearly shows a number of address points assigned to land parcels which do not contain an occupied dwelling.

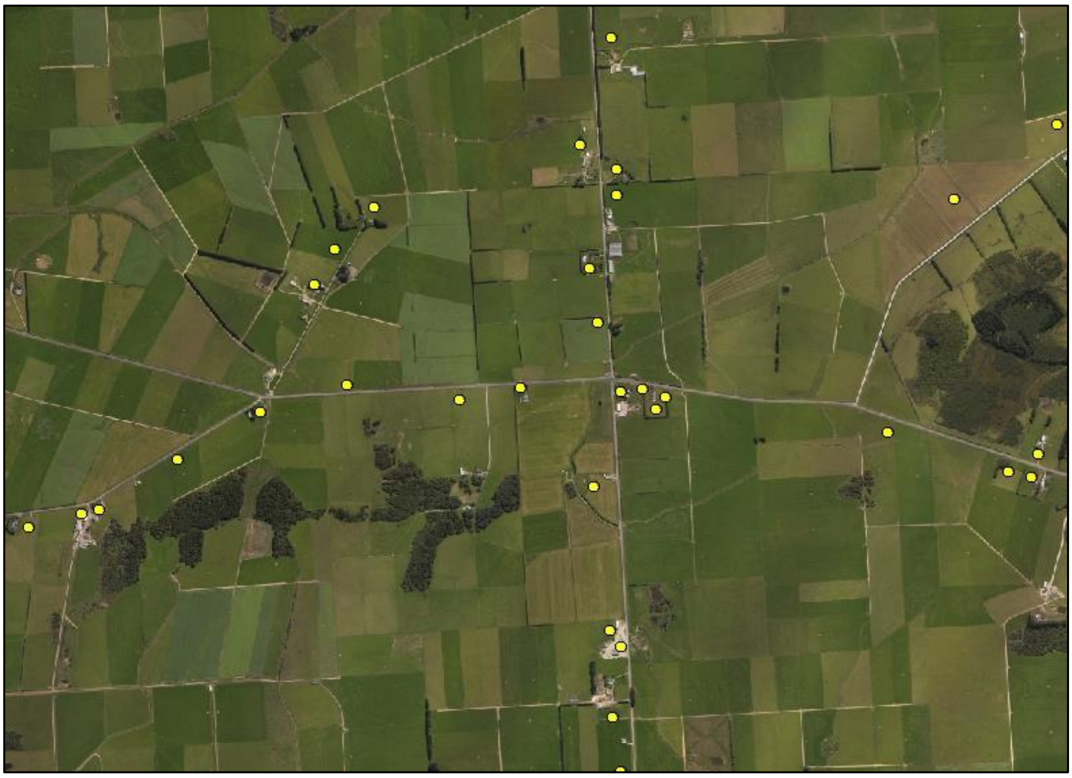

Figure 4. Overlay of address points layer on a 2012 aerial photograph of the Waituna catchment

[3] http://www.stats.govt.nz/Census/2013-census.aspx?gclid=CI_BrrXemL8CFZclvQodxTsACQ

[4] The most recent aerial photo library held by Environment Southland

Table 2 compares the number of address points recorded in the five major catchments with the usually resident population recorded for the equivalent area in the 2013 census. Again this clearly indicates use of the address points layer is likely to result in significant over-estimation of the number of on-site wastewater systems using the previous assumption that each address point corresponds to an occupied dwelling.

Table 2. Comparison of the address points and occupied dwellings recorded in the 2013 census for the five major catchments

Catchment	Address points	Occupied Dwellings
Aparima	1,730	825
Mataura	2,577	1,410
Oreti	9,861	5,367
Waiau	1,622	834
Waimatuku	648	333

As an alternative, the 2013 census data was used to provide an improved catchment-scale estimate of estimate of the resident population and likely number of on-site wastewater systems. However, it is acknowledged that this approach also has limitations including:

- Resident population and occupied dwelling data is recorded on the basis of cumulative totals per mesh block rather than as individual data points (i.e. dwellings) ;
- Individual mesh blocks do not necessarily match hydrological boundaries; and
- The census dwelling data does not include records of locations not permanently occupied (e.g. schools, business premises, halls etc) which may have on-site wastewater systems.

3.2. Assessment methodology

Resident population and occupied dwelling data from the 2013 Census meshblock data set for Southland[5] were combined with geographic coverages[6] to form a ArcGIS shapefile containing the relevant population and dwelling data at the meshblock scale. Meshblocks overlapping with the existing coverage of existing reticulated sewage schemes were removed and each remaining meshblock assigned to one of the sub-catchments shown in **Figure 5** below. The extent of individual sub-catchments (derived from the standard Environment Southland hydrological coverage[7]) were modified to provide a convenient scale for assessing cumulative nutrient loadings (e.g. upper/mid/lower Mataura catchment) and, as far as practicable, provide a reasonable match between mesh blocks and hydrological boundaries.

[5] http://www.stats.govt.nz/Census/2013-census/data-tables/meshblock-dataset.aspx#excelfiles

[6] http://www.stats.govt.nz/browse_for_stats/people_and_communities/Geographic-areas/digital-boundary-files.aspx

[7] M:\GIS\Data\hydrology\minor catchments.shp

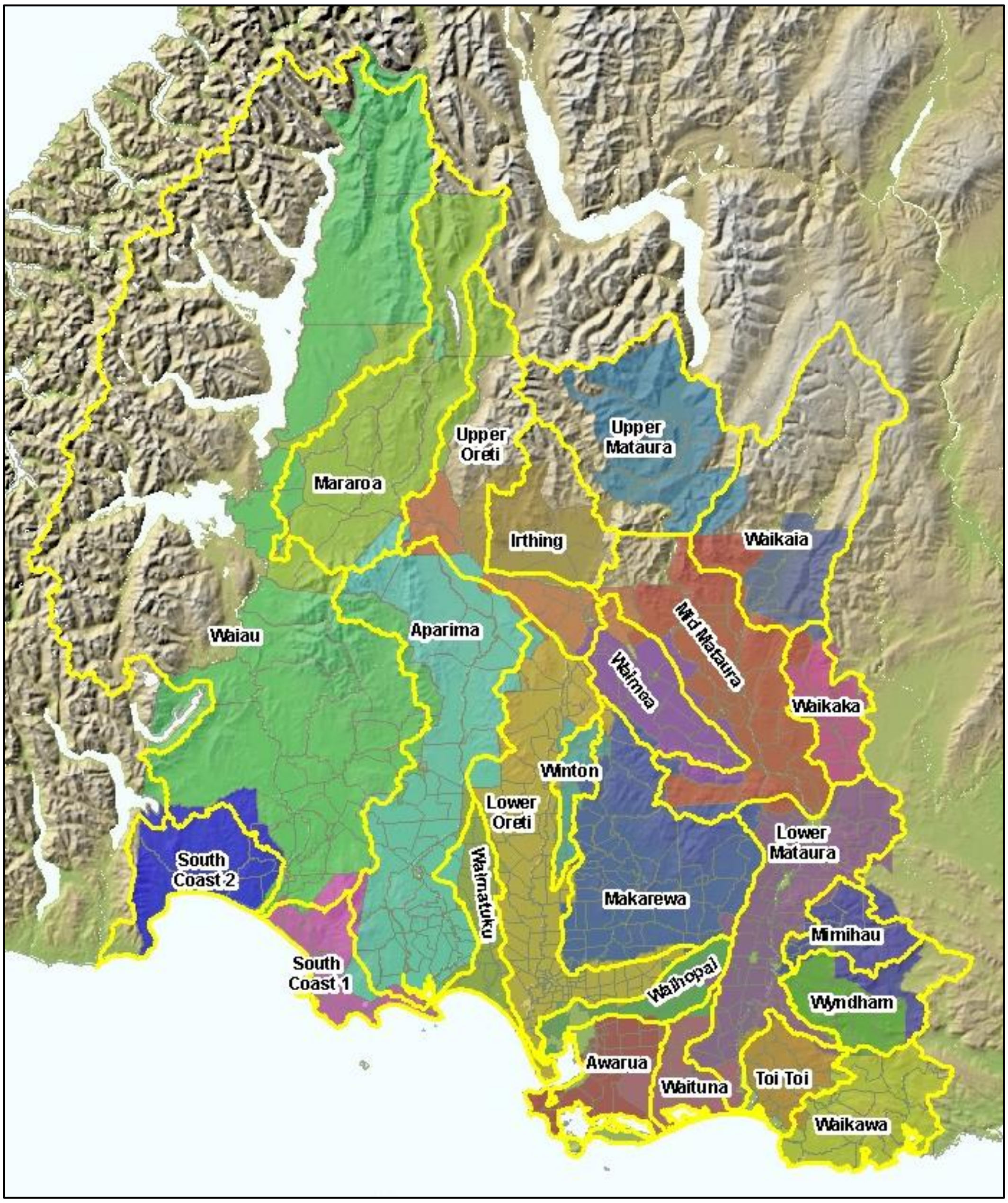

Figure 5. Assignment of individual mesh blocks to sub-catchment areas

Annual nutrient loadings from on-site wastewater disposal for each meshblock were then calculated using the usually resident population figures multiplied by the minimum, average and maximum TN and TP loadings in septic tank effluent outlined in **Section 2.2** (including an allowance for the anticipated reductions in nutrient loadings associated with soil treatment identified in **Section 2.3** to better reflect actual loadings reaching the receiving environment). The estimated nutrient loading to groundwater/surface water resulting from on-site wastewater disposal is therefore equivalent to:

- 1.8 to 5.0 kg TN/person/year

- 0.04 to 0.07 kg TP/person/year

These loadings were multiplied by the 2013 census population in each sub-catchment/catchment to provide an estimate of cumulative nutrient loadings from on-site wastewater disposal. Although the assessment by Olgilvie *et al* (2013) indicated variable risks to groundwater quality associated with on-site wastewater disposal across the Southland Region, the assessment did not provide any quantitative assessment of the likely impact of such variations on the attenuation of contaminant loadings. As a consequence, the standard attenuation factors for TN and TP derived from USEPA (2002)[8] were applied across the entire region.

3.3. Results

Table 3 and **Table 4** provide a summary of estimated nutrient loadings associated with on-site wastewater disposal calculated at a sub-catchment and catchment scale. At a regional scale, results indicate on-site wastewater disposal contributes between 129 and 366 tonnes of TN and between 2.7 and 5.4 tonnes of TP to water per year.

Annual TN loads in the major catchments range between 55 to 156 tonnes in the Oreti catchment, 32 to 90 tonnes in the Mataura catchment, 10 and 27 tonnes in the Waiau catchment and 11 to 31 tonnes in the Aparima catchment. For TP, the results indicate a cumulative annual loading of between 1.1 and 2.3 tonnes in the Oreti catchment, 0.6 to 1.3 tonnes in the Mataura catchment, 0.2 to 0.4 tonnes in the Waiau catchment and 0.2 to 0.5 tonnes in the Aparima catchment.

On a sub-catchment basis, calculated annual maximum nutrient loadings range from 0.0004 kg N/ha and 0.00001 kg P/ha in South Coast 2 catchments to 0.015 kg N/ha and 0.00022 kg P/ha in the Waihopai catchment. Unsurprisingly, at a sub-catchment scale, the most significant loadings occur in lower catchment areas on the Southland Plains with the highest population density (e.g. Waihopai River, Awarua Plains and Waimatuku Stream).

Figure 6 shows the spatial distribution of the calculated maximum TN loadings (i.e. resident population x nominal loading/person) for each meshblock. The figure shows spatially aggregated annual TN loadings are less than 1 kg N/ha across a majority of the region except for restricted areas around the periphery of major population centres where loadings may approach 10 kg N/ha. Total phosphorus loadings show a similar pattern but with somewhat lower loadings averaging 0.1 kg P/ha over a majority of the region increasing to a maximum of approximately 1.0 kg P/Ha in areas with extensive rural residential development (e.g. Invercargill and Winton peri-urban areas) or small unsewered townships (e.g. Waikaia). This analysis does however highlight the significant increase in spatially averaged nutrient loadings in areas with a high density of on-site wastewater disposal systems.

[8] Discussed in Section 2.3

Table 3. Calculated sub-catchment and cumulative total nitrogen (TN) loads resulting from on-site wastewater disposal in Southland

						Low	Average	High		
Sub Catchment	Population	Dwellings	Area (km^2)	Population Density (persons / household)	System Density (dwellings / km^2)	Load (kg)	Load (kg)	Load (kg)	Average aerial Load (kg/ha)	Maximum aerial Load (kg/ha)
Mataura Catchment										
Upper Mataura River	231	102	698	2.26	0.33	1,109	1,848	3,142	0.0003	0.000
Mid Mataura River	1,191	453	863	2.63	1.38	5,717	9,528	16,198	0.0011	0.002
Waimea Stream	690	243	440	2.84	1.57	3,312	5,520	9,384	0.0013	0.002
Waikaia River	234	111	273	2.11	0.86	1,123	1,872	3,182	0.0007	0.001
Sub total (Gore)	*2,346*	*909*	*2,273*			*11,261*	*18,768*	*31,906*	*0.0008*	*0.001*
Waikaka Stream	516	183	236	2.82	2.19	2,477	4,128	7,018	0.0018	0.003
Mimihau Stream	243	81	361	3.00	0.67	1,166	1,944	3,305	0.0005	0.001
Wyndham Stream	270	96	256	2.81	1.06	1,296	2,160	3,672	0.0008	0.001
Toi Toi Stream	354	141	226	2.51	1.57	1,699	2,832	4,814	0.0013	0.002
Lower Mataura River	2,907	1176	1168	2.47	2.49	13,954	23,256	39,535	0.0020	0.003
Total (Fortrose)	*6,636*	*2,586*	*4,520*			*31,853*	*53,088*	*90,250*	*0.0012*	*0.002*
Oreti Catchment										
Irthing Stream	246	99	444	2.48	0.55	1,181	1,968	3,346	0.0004	0.001
Upper Oreti River	519	204	341	2.54	1.52	2,491	4,152	7,058	0.0012	0.002
Sub total (Ram Hill)	*765*	*303*	*785*			*3,672*	*6,120*	*10,404*	*0.0008*	*0.001*
Winton Stream	453	165	135	2.75	3.37	2,174	3,624	6,161	0.0027	0.005
Makarewa River	2,229	795	1,099	2.80	2.03	10,699	17,832	30,314	0.0016	0.003
Waihopai River	2,130	744	196	2.86	10.85	10,224	17,040	28,968	0.0087	0.015
Lower Oreti River	5,895	2,154	1,043	2.74	5.65	28,296	47,160	80,172	0.0045	0.008
Total (New River)	*11,472*	*4,161*	*3,257*			*55,066*	*91,776*	*156,019*	*0.0028*	*0.005*

Waiau Catchment										
Mararoa River	561	231	1416	2.43	0.40	2,693	4,488	7,630	0.0003	0.001
Waiau River	1,434	603	3,174	2.38	0.45	6,883	11,472	19,502	0.0004	0.001
Total (Te Wae Wae)	*1,995*	*834*	*4,591*			*9,576*	*15,960*	*27,132*	*0.0003*	*0.001*
Aparima River	2,247	825	1,532	2.72	1.47	10,786	17,976	30,559	0.0012	0.002
Waimatuku Stream	882	333	242	2.65	3.64	4,234	7,056	11,995	0.0029	0.005
South Coast 1	486	201	314	2.42	1.55	2,333	3,888	6,610	0.0012	0.002
South Coast 2	129	54	483	2.39	0.27	619	1,032	1,754	0.0002	0.000
Awarua Plains	2,025	744	233	2.72	8.70	9,720	16,200	27,540	0.0070	0.012
Waituna Lagoon	444	150	270	2.96	1.65	2,131	3,552	6,038	0.0013	0.002
Waikawa River	567	213	461	2.66	1.23	2,722	4,536	7,711	0.0010	0.002
Cumulative Total	**26,883**	**10,101**	**15,902**			**129,038**	**215,064**	365,609	0.0014	0.002

Table 4. Calculated sub-catchment and cumulative total phosphorus (TP) loadings resulting from on-site wastewater disposal in Southland

						Low	Average	High		
Sub Catchment	**Population**	**Dwellings**	**Area (km^2)**	**Population Density (persons / household)**	**System Density (dwellings / km^2)**	**Load (kg)**	**Load (kg)**	**Load (kg)**	**Average aerial load (kg/ha)**	**Maximum aerial load (kg/ha)**
Mataura Catchment										
Upper Mataura River	231	102	698	2.26	0.33	23	35	46	0.00000	0.00001
Mid Mataura River	1191	453	863	2.63	1.38	119	179	238	0.00002	0.00003
Waimea Stream	690	243	440	2.84	1.57	69	104	138	0.00002	0.00003
Waikaia River	234	111	273	2.11	0.86	23	35	47	0.00001	0.00002
Sub total (Gore)	*2,346*	*909*	*2,273*			235	352	469	*0.00002*	*0.00002*
Waikaka Stream	516	183	236	2.82	2.19	52	77	103	0.00003	0.00004
Mimihau Stream	243	81	361	3.00	0.67	24	36	49	0.00001	0.00001
Wyndham Stream	270	96	256	2.81	1.06	27	41	54	0.00002	0.00002
Toi Toi Stream	354	141	226	2.51	1.57	35	53	71	0.00002	0.00003
Lower Mataura River	2,907	1,176	1,168	2.47	2.49	291	436	581	0.00004	0.00005
Total (Fortrose)	*6,636*	*2,586*	*4,520*			664	995	1,327	*0.00002*	*0.00003*
Oreti Catchment										
Irthing Stream	246	99	444	2.48	0.55	25	37	49	0.00001	0.00001
Upper Oreti River	519	204	341	2.54	1.52	52	78	104	0.00002	0.00003
Sub total (Ram Hill)	*765*	*303*	*785*	*2.52*	*0.97*	77	115	153	*0.00001*	0.00002
Winton Stream	453	165	135	2.75	3.37	45	68	91	0.00005	0.00007
Makarewa River	2,229	795	1,099	2.80	2.03	223	334	446	0.00003	0.00004
Waihopai River	2,130	744	196	2.86	10.85	213	320	426	0.00016	0.00022
Lower Oreti River	5,895	2,154	1,043	2.74	5.65	590	884	1179	0.00008	0.00011

Total (New River)	*11,472*	*4,161*	*3,257*	*2.76*	*3.52*	1,147	1,721	2,294	*0.00005*	*0.00007*
Waiau Catchment										
Mararoa River	561	231	1,416	2.43	0.40	56	84	112	0.00001	0.00001
Waiau River	1,434	603	3,174	2.38	0.45	143	215	287	0.00001	0.00001
Total (Te Wae Wae)	*1,995*	*834*	*4,591*			200	299	399	*0.00001*	*0.00001*
Aparima River	2,247	825	1,532	2.72	1.47	225	337	449	0.00002	0.00003
Waimatuku Stream	882	333	242	2.65	3.64	88	132	176	0.00005	0.00007
South Coast 1	486	201	314	2.42	1.55	49	73	97	0.00002	0.00003
South Coast 2	129	54	483	2.39	0.27	13	19	26	0.000004	0.00001
Awarua Plains	2,025	744	233	2.72	8.70	203	304	405	0.00013	0.00017
Waituna Lagoon	444	150	270	2.96	1.65	44	67	89	0.00002	0.00003
Waikawa River	567	213	461	2.66	1.23	57	85	113	0.00002	0.00002
Cumulative Total	**26,883**	**10,101**	**15,902**			**2,688**	**4,032**	**5,377**	**0.00003**	**0.00003**

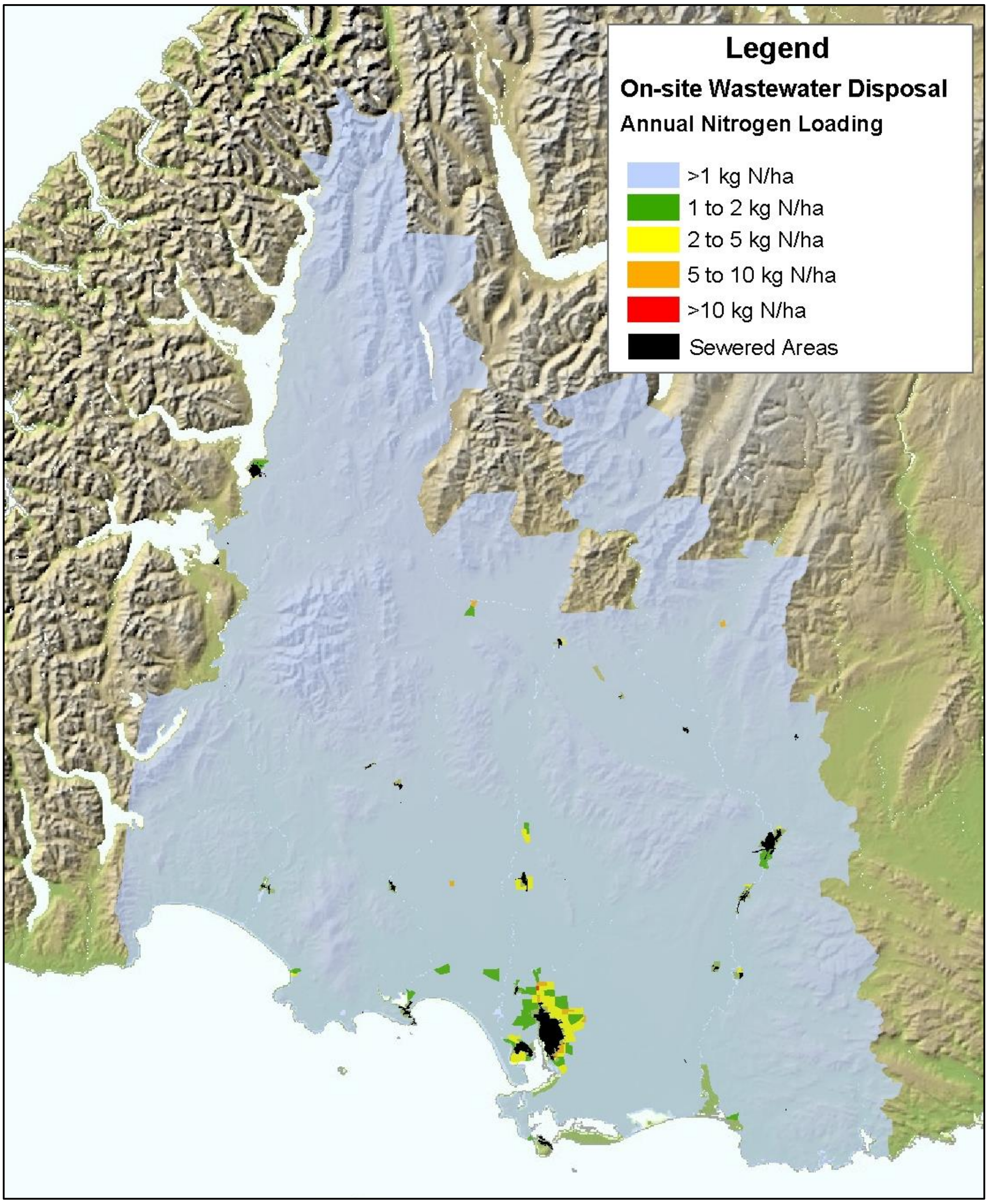

Figure 6. Spatial distribution of calculated maximum annual TN loadings from on-site wastewater discharge

3.4. Nutrient loadings from on-site wastewater disposal in a regional context

Nitrate leaching rates from agricultural land use range from <5 kg N/ha/year and <0.2 kg P/ha/year for forestry to between 40 to 50 kg N/ha/year and 1.0 to 1.5 kg P/ha/year for intensive dairying (Aqualinc, 2014a). In comparison, as outlined in the previous section, potential aerial loadings of Nitrogen and

Phosphorus associated with on-site wastewater disposal average are less than 10 kg N/ha/year and 1 kg P/ha/year in the most highly populated unsewered areas.

Table 5 provides a comparison of calculated TN loads from on-site wastewater discharge against total catchment source catchment loads estimated by Aqualinc (2014b). The data indicate on-site wastewater discharge makes a relatively small contribution to cumulative regional nitrogen loads (<1.5 %) except in the Oreti catchment where, due to a higher population density, it may contribute up to 2.8% of cumulative nitrogen loads at the bottom of the catchment (New River Estuary).

Table 5. Contribution of calculated Total Nitrogen loads from on-site wastewater disposal to cumulative catchment loadings

Catchment	**Total catchment source nitrogen load (t/year)**[1]	**Estimated on-site wastewater nitrogen load (t/year)**	**Wastewater contribution to cumulative catchment load (%)**
Mataura River (Toetoes Harbour)	6,617	31.8 - 90.3	0.5 - 1.4
Oreti River (New River Estuary)	5,513	55.1 - 156.0	1.0 - 2.8
Aparima River (Jacobs)	2,133	10.8 - 27.1	0.5 - 1.3
Waiau River (Te Wae Wae)	4,970	9.6 - 27.1	0.2 - 0.6

[1] Data from Aqualinc (2014b)

3.5. Groundwater quality risk associated with on-site wastewater disposal

Figure 7 shows a map of areas where 2013 census meshblocks with a nominal on-site wastewater disposal system density greater than 10/km^2 overlie areas classified by Ogilvie *et al* (2013) as having a high risk[9] to groundwater quality. This analysis again suggests rural residential areas around the larger population centres are likely to have the greatest potential for on-site wastewater discharge to adversely affect the quality of the underlying groundwater resource. Due to the overall assimilative capacity of the groundwater resource it is inferred that the potential for adverse groundwater quality effects in such areas is likely to be relatively localised.

Across the remainder of the Region, it is inferred that on-site wastewater disposal is likely to make a relatively small contribution to overall contaminant loadings to the groundwater system.

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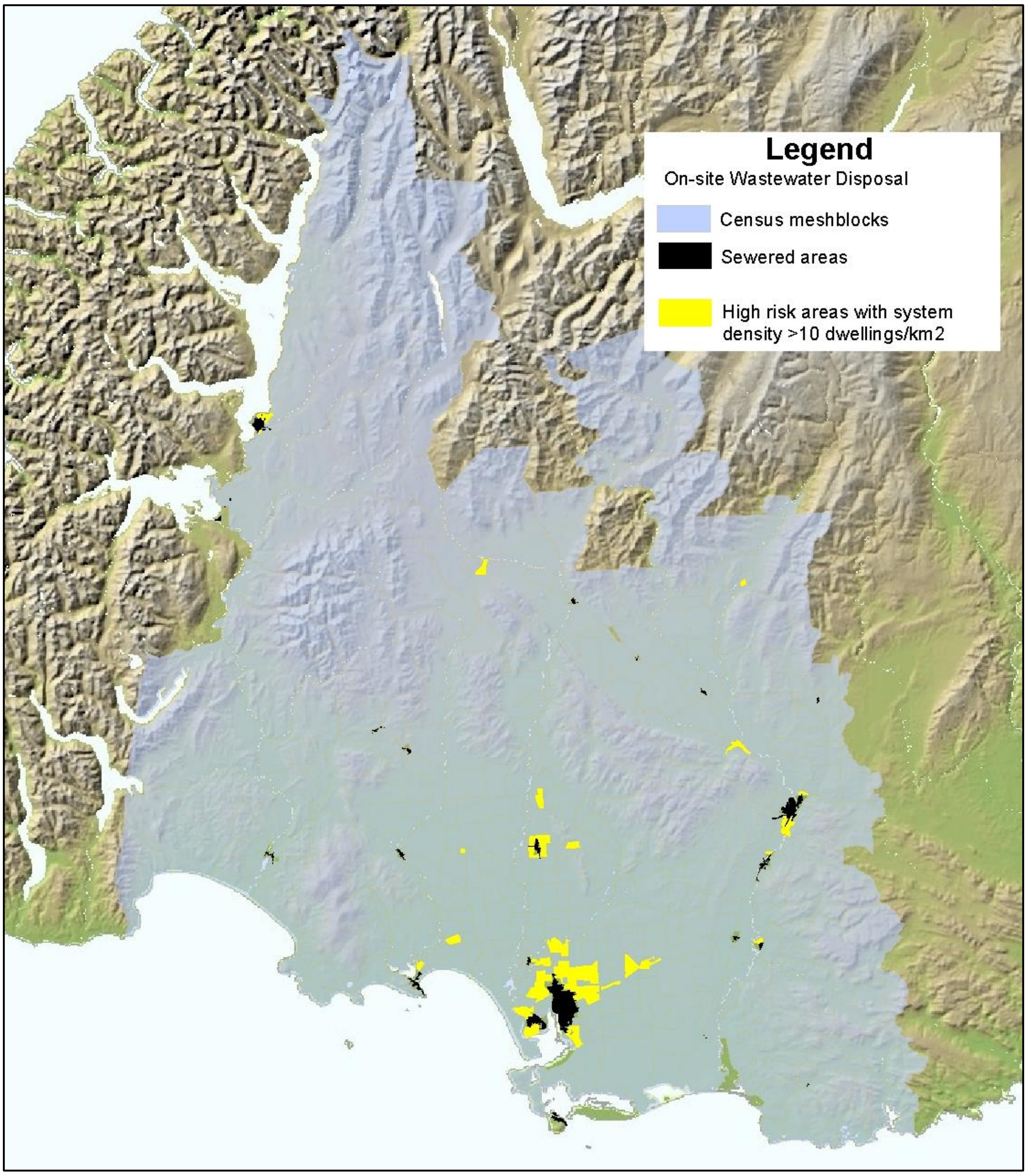

Figure 7. Map highlighting 2013 Census meshblocks with a on-site wastewater system density >10/km^2 which overlie areas classified as having a high groundwater quality risk associated with on-site wastewater disposal

4. Discussion

On-site wastewater disposal is the primary means of domestic wastewater treatment utilised across rural areas of the Southland Region. Performance of these systems is likely to vary significantly between individual installations reflecting the characteristics of wastewater generation, the age, design and maintenance history of the system as well as the physical and hydraulic characteristics of the receiving environment.

Previous estimates of the density of on-site wastewater disposal systems in Southland (e.g. Olgilvie *et al*, 2013) are likely to have over-estimated the number of on-site wastewater systems and associated contaminant loadings. For this study 2013 meshblock data was used to estimate nutrient loadings based on resident population and a range of typical nutrient loadings in septic tank effluent (including an allowance for nutrient removal within the land disposal system).

Results indicate nutrient loading from on-site wastewater disposal systems is likely to make a relatively minor contribution to cumulative nutrient loadings across the Southland Region. Calculated nutrient loadings indicate a contribution of up to 55 to 156 tonnes of TN and 1.1 and 2.3 tonnes of TP in the Oreti catchment equivalent to less than 2.5 percent of the total nutrient loading across the catchment. Nutrient loadings from on-site wastewater disposal in other catchments are proportionally lower reflecting the lower overall population density in these areas.

The areas with the highest spatially averaged nutrient loadings occur in rural residential areas around the periphery of major population centres (e.g. Invercargill and Winton) or in small unsewered townships (e.g. Waikaia). However, it is noted that even in these areas estimated nutrient loadings are significantly lower than those typically associated with intensive agriculture.

It is noted that the original intention of this report was to document cumulative nutrient loadings associated with both on-site wastewater discharges and consented discharges to land to capture discharges not specifically included in recent regional-scale assessments (e.g. Aqualinc 2014a, Aqualinc 2014b). However, while it was possible to estimate nutrient loadings associated with on-site wastewater discharges based on nominal population and wastewater quality estimates, insufficient data was available (within the scope of this project) to document potential loadings associated with consented discharges to land to an adequate level. It is noted that this in part reflects the limited data available for individual consents to quantify representative wastewater volumes, concentrations overall loadings associated with individual discharges. It is suggested that Environment Southland consider placing standard conditions on discharges to land which specify nominal aerial loadings and require compliance monitoring to ensure appropriate data is collected to enable nutrient accounting for all discharges.

5. References

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