



# Artificial subsurface drainage in Southland

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## Technical Report

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# 1. Executive Summary

Artificial subsurface drainage, along with overland flow and deep drainage are the three main pathways for the transport of contaminants from land to water. Artificial subsurface drainage in Southland is typically a mole-pipe network, also known as tile drainage. Mole-pipe drains usually comprise of an extensive fissure network that drains into mole channels, which are linked to a connector pipe or tile to remove the water. Most connector pipes in Southland are installed in contour patterns following the natural depressions of the landscape. Where artificial subsurface drainage exists there is potential for contaminants to bypass the soil matrix allowing less time for absorption and retention of contaminants in the soil, especially nitrogen and phosphorus, sediment and faecal organisms.

A framework was developed for estimating where artificial subsurface drainage systems are likely to be present in Southland. Soil permeability and drainage class attributes provided an indication of the density of drainage required to make land suitable for agriculture. Artificial subsurface density classes ranged from none to very high and included categories for non-agricultural areas and the influence of slope on drainage type. This assessment of artificial subsurface drainage is to be used with the Physiographic Units to allow for the identification of variants within a defined unit, where artificial subsurface drainage may be a dominant contaminant pathway for the unit. The aim is to improve on the knowledge of flow pathways across Southland to provide targeted mitigation approaches for contaminant loss.

This approach suggests that artificial subsurface drainage systems cover approximately three quarters of agricultural land in Southland. Areas of high density to very high density artificial drainage systems are predominantly on the Central Southland Plains and around the Awarua-Waituna wetland complex, where wetlands have been converted to pasture for agricultural use. Areas where none to low subsurface drains are present are located on well drained gravely soils close to the main-stem rivers.

Published research has shown contaminants transported from agricultural systems increase when mole-pipe drains are active, most significantly over the wetter months of autumn, winter and early spring. Artificial drainage bypasses other soil pathways decreasing the retention time for nutrient attenuation in the soil from weeks/years to the order of minutes to hours. This framework will help inform assessments of contaminant losses from Southland's varied landscapes.

## 2. Introduction

Artificial subsurface drainage, along with overland flow (surface runoff) and deep drainage (leaching) are the three main pathways for the transport of contaminants from land to water. The quantity, duration and intensity of excess water falling on soil along with soil infiltration rate and the drainage coefficient of any artificial drainage system affects how water is transported from the system. Subsurface drainage in Southland is typically a mole-pipe network, also known as tile drainage. Mole-pipe drainage networks are used in fine textured soils, where natural drainage is slow, or where a temporary perched water table exists in winter (Monaghan, 2014).

Mole-pipe drains usually comprise of an extensive fissure network (created by dragging a mole plough through the soil) that drains into mole channels, which are linked to a connector pipe or tile to remove the water (Figure 1). This type of drainage is widespread in Southland's Fragric Pallic soils, like Pukemutu and Waikoikoi silt loams, which contain impermeable or slowly-permeable subsoil layers (Crops for Southland, 2002a and b). Mole-pipe drains benefit the soil as topsoil strength returns sooner after heavy rain, creating more safe grazing days and the topsoil is returned to an aerobic state faster, which improves plant growth and soil health (Monaghan, 2004). In areas where there is insufficient slope to install mole-pipe drainage, soak holes are sometimes used to prevent surface ponding. Typically a soak hole is dug to a depth past the impeding horizon and filled with a gravel substrate to allow for the rapid transport of water away from the soil surface. This type of drainage system is used in Southland on flat land, where soils are well drained but slowly permeable (e.g. Edendale). Artificial subsurface drainage systems are also used to drain seeps and springs as well as ephemeral or first order streams on agricultural land. Where these artificial subsurface drainage systems exist, there is potential for contaminants to bypass the soil matrix allowing less time for absorption and retention of contaminants in the soil, especially nitrogen and phosphorus, sediment and faecal organisms (Houlbrooke and Monaghan, 2009).

Mole-pipe drains are typically installed in one of two arrangements in Southland: conventional and contour patterns (Figure 2). Conventional drainage is used in conjunction with open ditches when the land surface is a constant slope (no undulations) to lower the water table to a uniform depth. Contour drainage is used most on undulating or sloping land, or where wetter areas of a paddock are present and drain into an open waterway (or ditch). The tiles/pipes are laid in hollows or swales and follow the natural contour of the landscape. The depth that the tiles are

installed varies depending on the depth of the water table and the amount of fall necessary to drain the area. Tiles are typically found at 60-80 cm depth, between 20 – 100 m apart and mole drains are typically ploughed at 45 cm depth and can be as close as 2 m apart (Houlbrooke and Monaghan, 2009).

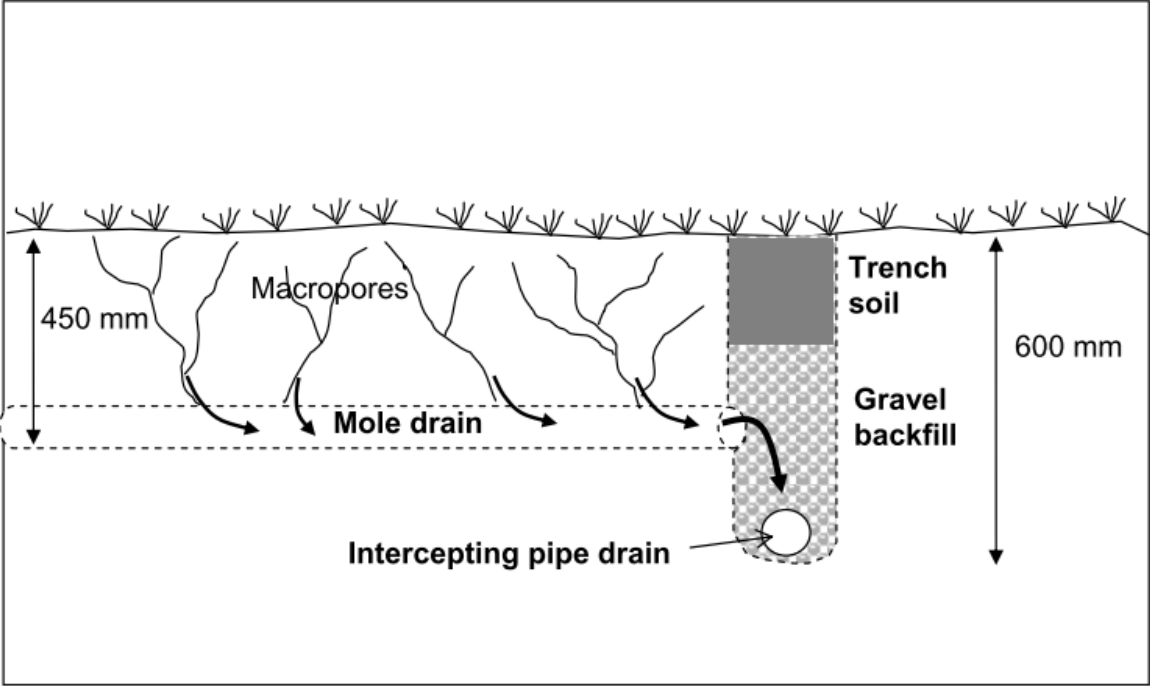


Figure 1: Diagrammatic representation of a mole-pipe drained soil (Houlbrooke and Monaghan, 2009)

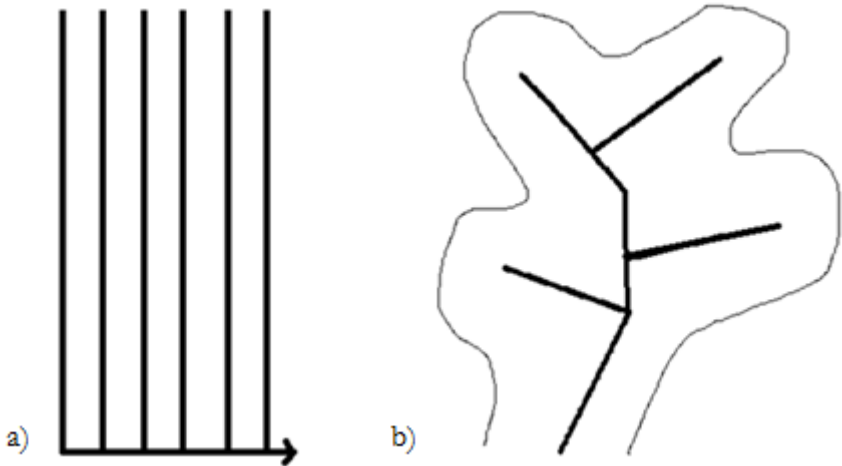
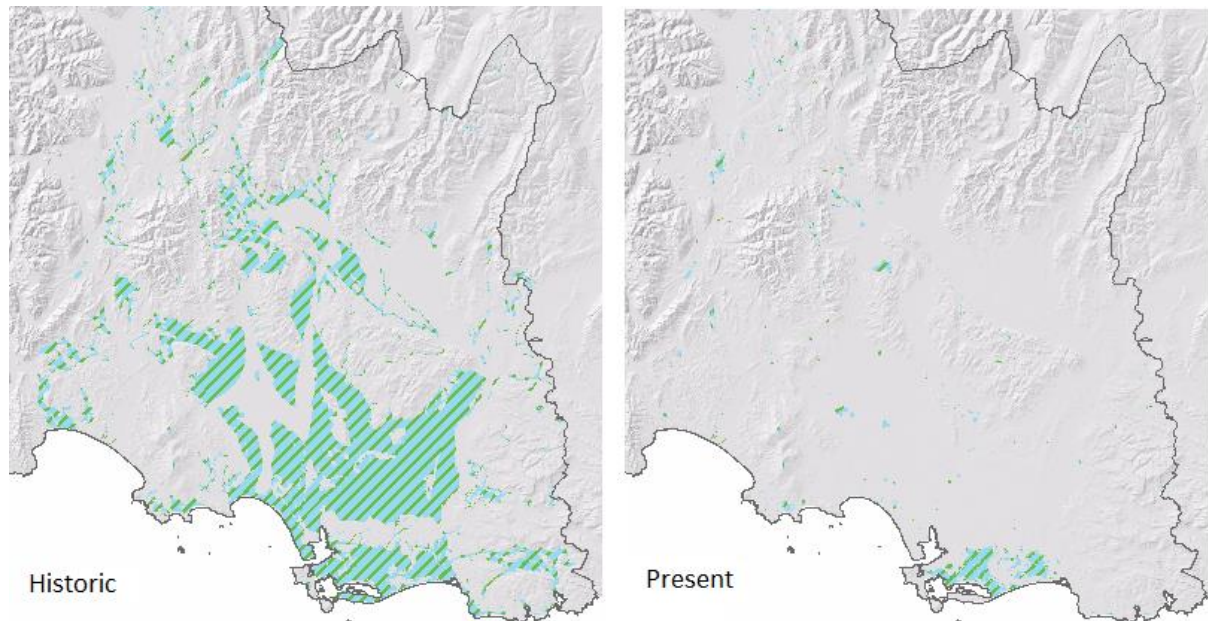


Figure 2: Tile/pipe drainage showing a) conventional (grid) and b) contour drainage (random) patterns (Trafford and Trafford, 2011)

The extent of artificial drainage in Southland is evident when viewing the extent of historic (c. 1840) to present wetlands (c. 2011) (Clarkson et al., 2011). There has been a reduction of 90 % of wetlands in Southland over this time and highlights areas where significant drainage modifications had to be undertaken to make the land suitable for agriculture (Figure 3, Clarkson et al., 2011).



**Figure 3: Historic (c. 1840) and present (c. 2011) extent of Southland wetlands (Clarkson, 2011)**

The objective of this investigation is to determine the extent of artificial subsurface drainage systems across Southland. This assessment of subsurface drainage is to be used with the Physiographic Units to allow for the identification of variants within a defined unit, where subsurface drainage may be a dominant or an insignificant contaminant pathway. The aim is to improve on our knowledge of flow pathways across Southland to provide targeted mitigation approaches for managing contaminant losses.



## **3. Method**

### **3.1 Soil GIS maps**

Soil GIS maps were obtained from three sources and combined to create one GIS Soil layer for Southland. Topoclimate South (2001) mapped soil types in Southland and extensively described the soil properties for each. The mapping was undertaken at a 1:50,000 scale and covered approximately 825,000 hectares of intensively farmed land. To extend coverage of Southland soils beyond the extent of Topoclimate South, soil information from Wallace County (O’Byrne, 1986) and Land Resource Inventory (LRI) (DSIR, 1968) soil maps was used. See Appendix 1 for a map of NZSC Soil Orders in Southland.

The output of this study is a GIS Subsurface drainage layer which is located on Environment Southland’s server as follows: <M:\GIS\Projects\ArcMap\Environmental Info\Tile Drain Sampling\Lisa files for TileDrains>.

### **3.2 Subsurface Drainage**

Areas where artificial drainage is likely to be present were determined using the Land Cover Database, version 4.1 (LCDB4.1) and selecting areas where land cover was classified as ‘high producing exotic grassland’, ‘low producing grassland’ or ‘short-rotation cropland’ to identify the area of Southland in agricultural production. Areas not in agricultural production are either in a natural state or under other land uses and were deemed unlikely to have subsurface drainage.

Artificial drainage maps were sourced from within Environment Southland’s records (resource consent applications, ES lease land, research projects (i.e. Living streams and field studies) to determine the density of drainage across Southland. The maps included open ditch drains as well as the location of tiles (pipes); however the latter had poor coverage in many areas. Mole-pipe drains are found near receiving open ditch drains or open waterways and the density of open waterways can be used to determine the likelihood of subsurface drains present in an area.

A classification for determining approximate drainage densities was determined using soil drainage class and permeability. The ratings for these soil properties were determined by Topoclimate South for each soil and are the sum of the ratings for each horizon, limited to 90 cm depth, for which data is available for the soil type.

Soil drainage classes are assessed using criteria of soil depth and water table inferred from soil colours and mottles. Drainage classes used here are the same as those used in the NZ Soil Classification (Hewitt, 1993) and outlined by Milne et al. (1995) in Appendix 2.

- **Well drained** – These soils have adequate aeration year round.
- **Moderately well drained** – These soils have adequate aeration all year except winter at depths usually below 0.45 m and generally below 0.9 m.
- **Imperfectly drained** – These soils have aeration limitations in the upper 0.45 m for <6 months during winter, part of spring and part of autumn.
- **Poorly drained** – These soils are potentially anaerobic for 6 – 10 months in most of the upper 0.45 m layer, and commonly all year below 0.45 m.
- **Very poorly drained** - These soils are anaerobic for most of the year.

Soil drainage class was assessed as part of the Topoclimate South soil mapping project and reported for each soil type in the respective Technical Information sheet (Crops for Southland, 2002b). This information was digitised by creating a new field in the existing Topoclimate South shapefile. Where no Topoclimate South Technical Report existed for the soil type, S-map Online factsheets were used to obtain the drainage class for the soil ([www.smap.landcareresearch.co.nz](http://www.smap.landcareresearch.co.nz)). Soil drainage class was amended if variants, as identified by Topoclimate South, were found for a soil polygon. Variants are described where there is a difference in a single soil property that is insufficient to justify separation into a new soil, but where all other soil properties remain the same as the 'parent' soil (Crops for Southland, 2003).

Permeability was also assessed during the Topoclimate South Soils project and provides the soil's overall permeability based on the horizon with the slowest permeability class and the depth at which this layer occurs. The permeability classes are based on those used in the NZ Soil Classification (Hewitt, 1993) and outlined below:

- **Slow** - less than 4 mm/hr
- **Moderate** – between 4 – 72 mm/hr
- **Rapid** – greater than 72 mm/hr

By intersecting these two attributes, thirteen categories were identified as not all combinations of drainage class and permeability occur. These categories were then further refined to 5 classes based on the area of each category and the likely intensity of artificial drainage in the areas. These were classified as very low to none, low, moderate, high and very high sub surface drainage density.

Topoclimate South soil polygons which contained multiple soils were assessed using a weighted average of the percentage of soil type within a polygon and assessed for permeability and drainage class. The overall rating given to the soil was determined by the limiting soil properties. This level of precision was not possible with Wallace County or LRI soil polygons.

Soils with a slope greater than 8 degrees (rolling) were given a separate classification of low drainage density due to slope (Low (slope)) regardless of permeability and drainage class of the soil. Slope was determined by Topoclimate South (Crops for Southland, 2002).

The Land Cover Database (LCDB, version 4) surveyed in 2012, was used to assess whether land was used for agricultural production. By selecting for the following attributes, high producing exotic grassland and short rotation cropland the extent of likely artificial subsurface drainage systems were determined.

## **4. Results and Discussion**

Subsurface drainage maps, identified from Environment Southland's records, showed a vast network of mole-pipe drainage across areas of Southland. The layout of drainage systems were typically conventional patterns in very poorly and poorly drained soils and contour patterns in imperfectly drained to well drained areas (Table 1). In Southland, approximately 120 m of tiles per hectare are required in mole-tile systems to achieve adequate drainage (John Scandrett, Drainage Engineer, pers com). Drainage layout is also dependent on the density of open ditch drains to tiles. For example, the lower Mataura has a very high density of tiles discharging to open ditches, while the lower Oreti has a dense network of open ditches and fewer tiles connecting to them (Figure 4). This is likely to be a result of the slope of the land, with the lower Oreti very flat and unable to achieve the fall needed for the tiles.

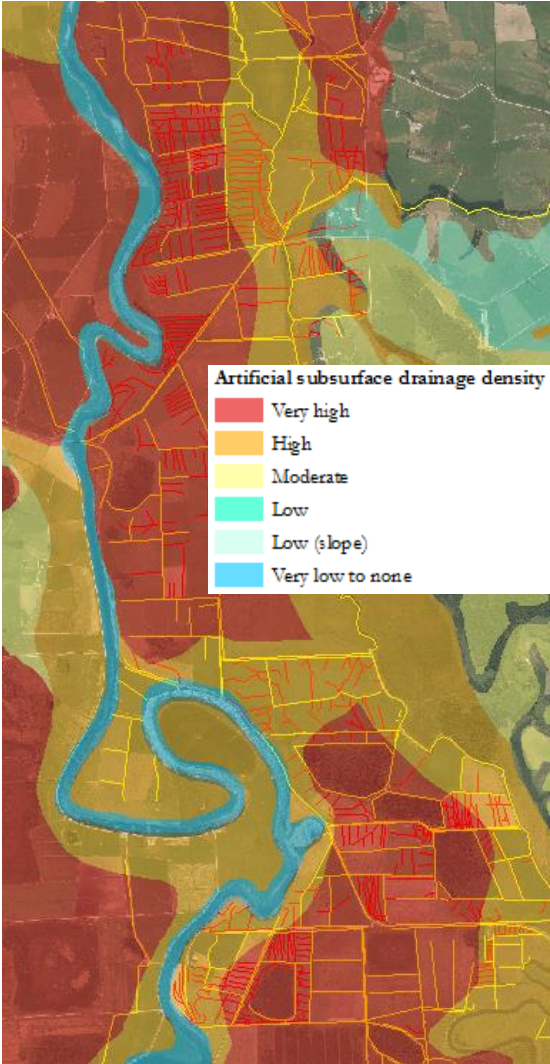
**Table 1: Approximate artificial drainage density as determined using soil permeability and drainage class attributes**

<b>Drainage density</b>	<b>Drainage Pattern</b>	<b>Permeability</b>	<b>Drainage class</b>
Very high	Conventional	Slow	Very poor
High	Mix of conventional and contour (slope dependant)	Slow	Poor
		Moderate	Poor
		Rapid	Poor
Moderate	Mix of conventional and contour (slope dependant)	Slow	Imperfect
		Moderate	Imperfect
		Rapid	Imperfect
		Slow	Moderately well
Low	Contour and soak hole (flat only)	Moderate	Moderately well
		Slow	Well
Very low to none	Typically feeder drains from other areas	Rapid	Well
		Moderate	Well

Overall, the coverage of known tile locations for Southland was poor and subsurface drainage densities were extrapolated based on attributes for soil permeability and drainage class of the mapped areas (Table 1). Density classes ranged from none to very high and included categories for non-agricultural areas and the influence of slope on drainage type (Figure 5). There is approximately 18,240 km<sup>2</sup> of agricultural land in Southland, of which 13,870 km<sup>2</sup> (76 %) is likely to have some form of artificial drainage. High density to very high density areas of artificial subsurface drainage systems are predominantly located on the Central Southland Plains and around the Awarua-Waituna wetland complex (Figure 5).

Soils grouped in the very high category are slowly permeable and very poorly drained. This group consists of Organic soils and are likely to represent areas where high density drainage is used to make former wetland areas suitable for agriculture. Due to the scale of the mapping (1: 50 000), small wetland areas (< 5 ha) may be included in this category, and drainage densities will be misrepresented as they are presently wetland areas. However, there is likely to be significant drainage around the remaining wetland to maintain the land outside the wetland for agriculture. The areas determined by Clarkson et al. (2011) as the extent of historic wetlands align well with areas of moderate to very high density subsurface drainage, which would be consistent with what is required to convert and maintain a wetland area for agriculture. Present wetland areas, as mapped by Clarkson et al. (2011) are used to show wetland extent in Figure 5.

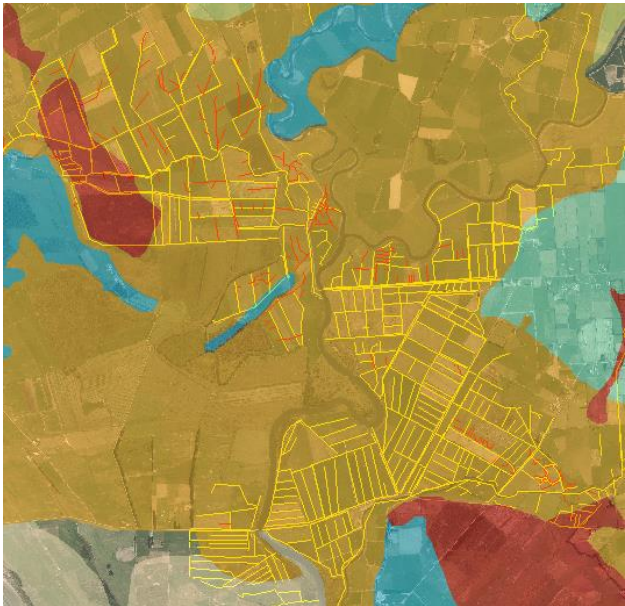
Areas that are identified as having very low to no subsurface drainage are those where stony soils and gravel are present close to the main stem river systems or where river channels existed in the past in northern Southland. Although these soils are well drained, it is possible to find artificial subsurface drainage through these areas often as connecting drains from less well drained areas.



Lower Matura – open ditch with very high to high density tiles.



East Invercargill (Otepunu Ave) – high to moderate density tiles feeding to an open ditch.



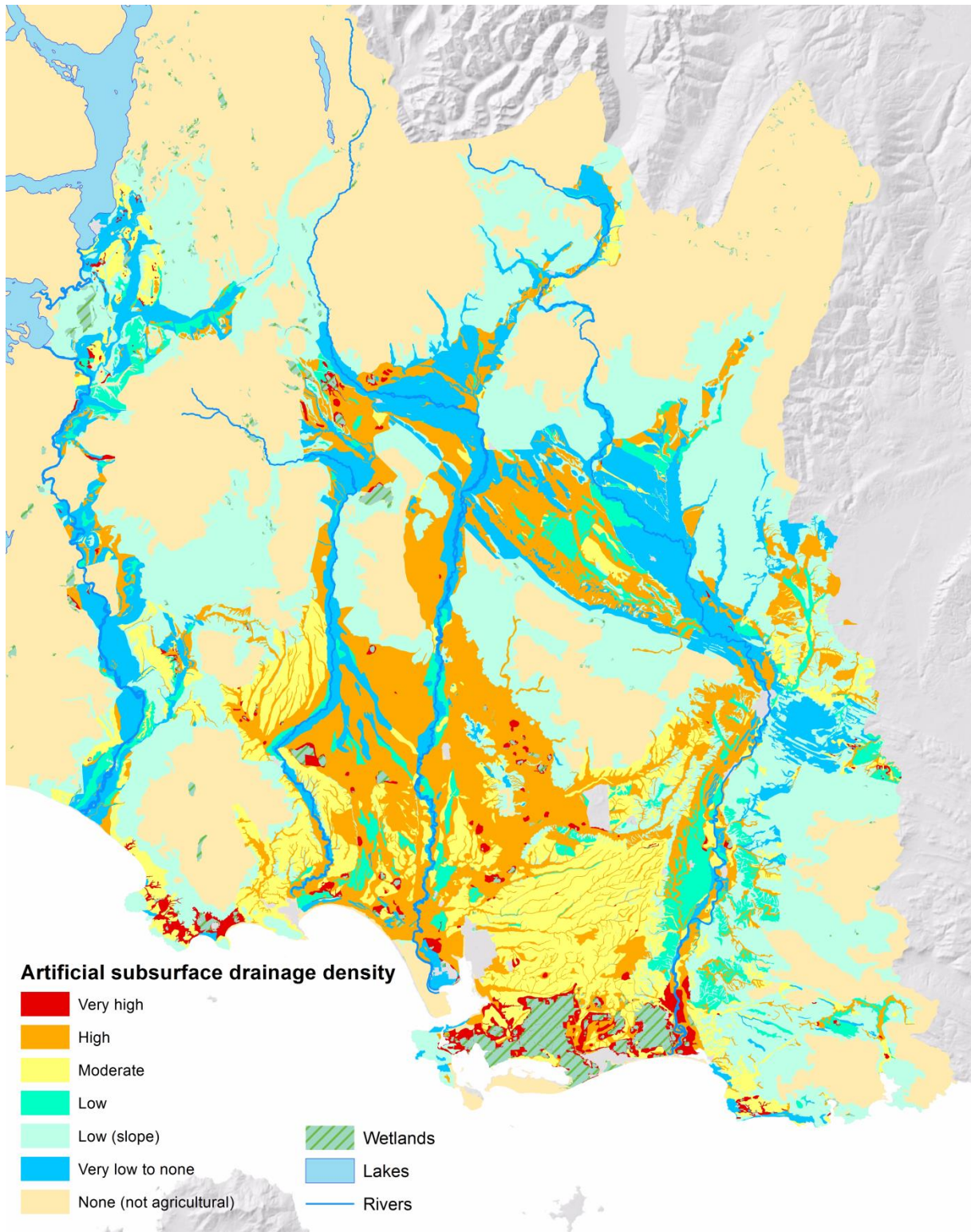
Lower Oreti – high density open ditch with tiles.

**Figure 4: Open ditch drainage network (yellow lines) with known tile (pipe) locations (red lines). Assigned artificial subsurface drainage density classes are overlain**  
*Note: Tile locations are incomplete and densities have been approximated from well mapped areas. Open ditch drains mapped are those maintained by Environment Southland only, private drains not included.*

There are a number of locations around Southland where the presence of secondary soils has increased the likely density of subsurface drainage. An example of this is the lowland Southland Plains, which comprises predominantly well drained Brown soils (Waikiwi), but have been classified as 'moderate' due to associated soils (Mokotua, Woodlands) with imperfect drainage within the mapped polygons and the slow rate permeability of the soils. These areas also drain into swales where poorly drained Gley soils (Dacre, Titipua) with slow permeability are found. Tiles discharging into these areas often extend over multiple property boundaries.

The seasonality of when subsurface drains are active has significant implications for contaminant loss from agricultural land (Monaghan, 2014). Artificial drainage bypasses other soil pathways decreasing the retention time for nutrient attenuation in the soil from weeks/years to the order of minutes to hours (McKergow et al., 2007). Cameron et al. (2014) reported that the majority of nitrogen leaching from a dairy demonstration farm in Southland occurred during spasmodic events when the farm drains were running between May and the end of July. Measured mole-pipe drainage from three study sites in Southland and Otago captured between 55 and 95 % of surplus rainfall as mole-pipe drainage and identified the drainage system as a significant pathway for contaminant loss (Monaghan et al., in prep.; Monaghan et al., 2005; Monaghan and Smith, 2004; Smith and Monaghan, 2003).

A category to separate drainage density based on slope was used for rolling hill country (slopes < 8 degrees) to identify areas where installation patterns and densities may differ to that used on flat and undulating land surfaces. Artificial subsurface drainage may also be installed to drain seeps and springs from these hill country areas and is unable to be assessed using this method.



**Figure 5: Approximate subsurface drainage densities across the Southland region**

## 5. Conclusion

A framework was developed for estimating where artificial subsurface drainage systems are likely to be present in Southland. Densities have been mapped by proximal assumptions from limited drainage maps and may not be representative of actual drainage within an area. Soil permeability and drainage class attributes provide an indication of the density of drainage required to make land suitable for agriculture. Due to the scale that soil mapping was undertaken (1:50,000), consideration of limiting soil properties within mixed soil polygons was made.

This approach suggests that artificial subsurface drainage systems cover approximately three quarters of agricultural land in Southland. This overlaps reasonably well with historical mapping of wetland areas in Southland.

Published research has shown contaminants transported from agricultural systems increase when mole-pipe drains are active, most significantly over the wetter months of autumn, winter and early spring. This framework will help inform assessments of contaminant losses from Southland's varied landscapes.



## 6. References

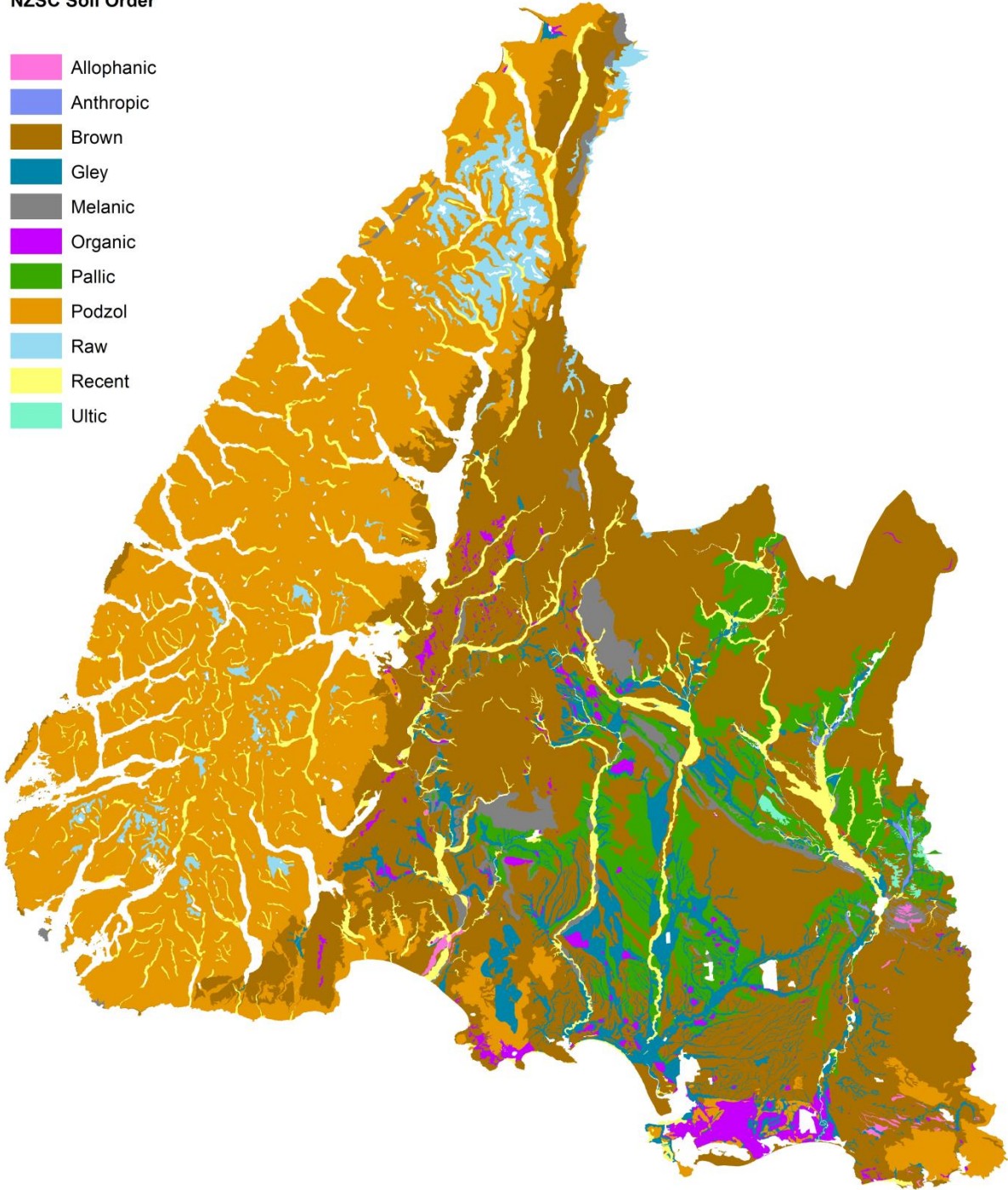
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# Appendix 1: Map of NZSC Soil Orders

**NZSC Soil Order**

- Allophanic
- Anthropoc
- Brown
- Gley
- Melanic
- Organic
- Pallic
- Podzol
- Raw
- Recent
- Ultic



## Appendix 2: Classification of Drainage Class

From Milne et al. (1995)

- **Well drained** – Soils that have no horizon within 90 cm of the mineral soil surface with 2 % or more redox segregations.
- **Moderately well drained** – Soils that have a horizon between 60 and 90 cm of the mineral soil surface with 50 % or more low-chroma mottles on cut faces or ped faces **or** have a horizon between 30 and 90 cm of the mineral soil surface with 2 % or more redox segregations.
- **Imperfectly drained** – Soils that have 50 % or more low-chroma mottles on cut ped faces between 30 and 60 cm of the soil surface, but not within 15 cm of the base of the A horizon, **or** soils that have either a) within 15 cm of the base of the A horizon **or** b) within 30 cm of the mineral soil surface 1) 2 % or more redox segregations **or** 2) 50 % or less low-chroma colours on cut faces or ped faces.
- **Poorly drained** – Soils that have a distinct topsoil and that a) within 15 cm of the base of the A horizon, **or** b) within 30 cm of the mineral soil surface, have either 50 % or more low-chroma colours on cut faces or dominant on ped faces.
- **Very poorly drained** - Soils that have an O horizon (but no F or H horizon) with an Er, Br or Cr horizon immediately below **or** lack a distinct topsoil and have 50 % or more low-chroma colours on cut faces at less than 10 cm from the mineral soil surface.