SOUTHLAND
PHYSIOGRAPHIC ZONES

WATER AND LAND 2020 & BEYOND

LIGNITE/MARINE TERRACES
Technical information

Physiographic zones are part of the *Water and Land 2020 & Beyond* project that aims to maintain and improve water quality in the Southland region, and to help us as a community achieve our goals for water.

Understanding our water

The Physiographics of Southland project was developed to better understand the evolution of water across Southland. By understanding where water comes from and the processes it undergoes as it moves through drainage networks, we can better understand the reasons for different water quality outcomes across the region.

The findings of the Physiographics of Southland project have been published in two reports, which identify the key drivers of hydrochemistry and water quality variability in Southland (Rissmann *et al*., 2016), and describe a classification system for managing land use effects on water quality (Hughes *et al*., 2016).

Physiographic zones and water quality

Physiographic zones represent areas of the landscape that have a common influence over water quality. The proposed Southland Water and Land Plan identifies nine physiographic zones in Southland that can be used to manage land use effects on water quality.

Physiographic zone technical information

The purpose of this booklet is to describe generalised water quality risks associated with individual physiographic zones. A companion booklet titled *Guide for using the Southland physiographic zones technical information* explains the terms and source data used in this booklet.

What's inside

environment SOUTHLAND REGIONAL COUNCIL
Te Taiao Tonga

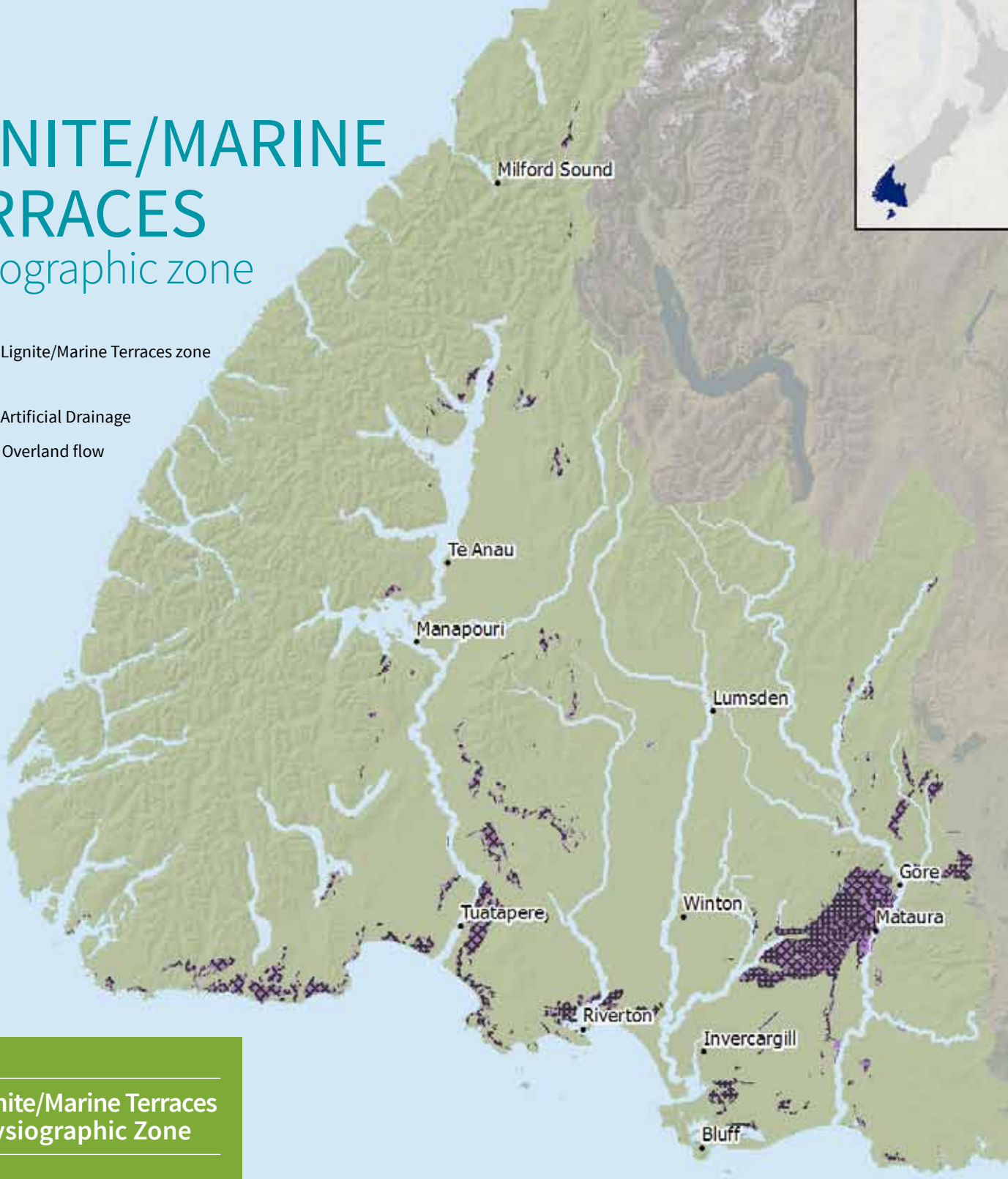
LIGNITE/MARINE TERRACES
physiographic zone

Lignite/Marine Terraces zone

VARIANTS

Artificial Drainage

Overland flow



Lignite/Marine Terraces Physiographic Zone

APPROXIMATE AREA

100,710 hectares

GEOGRAPHIC DISTRIBUTION

Along the south coast between Bluecliffs and Awarau Bay, Fortrose and the Haldane Estuary. Inland areas of Eastern Southland where lignite measure sediments occur near the land surface.

MAIN SURFACE WATERWAYS

Te Tipua Stream, Hedgehope Stream

Go to our online BEACON mapping service to view the physiographic zones of Southland in more detail.

Overview

The Lignite/Marine Terraces physiographic zone occurs along the south coast and in areas of eastern and western Southland where organic-rich sediments occur at or near the land surface.

Key features

- Located where the underlying geology is highly to moderately reducing.
- Mostly flat to gently undulating terrain.
- Soils are fine-textured with slow subsoil permeability.
- The redox state of groundwater varies according to the thickness of alluvium overlying organic-rich sediments.
- Surface water quality is influenced by groundwater quality (baseflow), overland flow and artificial drainage.

Water quality implications

- When soils are wet, episodic contaminant loss occurs via overland flow or artificial drainage in response to precipitation.
- The potential for elevated nitrate concentrations in groundwater can be limited by high denitrification potential.

WATER QUALITY RISK	LIGNITE/MARINE TERRACES	LIGNITE/MARINE TERRACES(a)	LIGNITE/MARINE TERRACES(o)
Contaminant pathways	Deep drainage	Artificial drainage	Overland flow
Dilution and attenuation processes	Reducing aquifers	Reducing aquifers	Reducing aquifers
Primary receiving environments	Aquifers	Surface waterways	Surface waterways
Water quality risk	Low	Nitrogen, phosphorus, sediment, microbes	Nitrogen, phosphorus, sediment, microbes

Variants and associations

Variants

Variants identify areas within physiographic zones where there is increased water quality risk when soils are wet. Contaminant losses from variants occur along alternate drainage pathways that have lower attenuation potential.

The Lignite/Marine Terraces physiographic zone has two identified variants.

Lignite/Marine Terraces(a) – Artificial Drainage variant

Areas of undulating land that have slow subsoil permeability and may be seasonally wet. This results in an increased potential for artificial drainage to maintain agricultural production.

Approximate area: 37,000 ha

Lignite/Marine Terraces(o) – Overland Flow variant

Areas of gently undulating to rolling land that have elevated potential for overland flow, due to a combination of steeper slopes and/or less well drained soils.

Approximate area: 58,730 ha

Associations

The Lignite/Marine Terraces physiographic zone is commonly associated with three physiographic zones in Southland (Figure 1).

Bedrock/Hill Country

Streams originating from the Bedrock/Hill Country zone provide headwater discharge to surface waterways draining the Lignite/Marine Terraces zone along the south coast, east of Riverton.

Peat Wetlands

Along the south coast, east of Invercargill, the Lignite/Marine Terraces zone occurs on near-surface lignite measure sediments adjacent to the Peat Wetlands zone. Discharge from the Lignite/Marine Terraces zone provides flow to wetland areas.

Gleyed

The Lignite/Marine Terraces zone occurs adjacent to the Gleyed zone in the Hedgehope and Waimumu areas where Quaternary alluvium thins and lignite sediments occur at or near the land surface.

In the lower Aparima catchment, the Lignite/Marine Terraces zone occurs on remnant marine terraces, which are located within the more extensive alluvial deposits of the Gleyed zone.

Drainage from the Lignite/Marine Terraces zone contributes to baseflow of small streams that also drain the Gleyed zone.

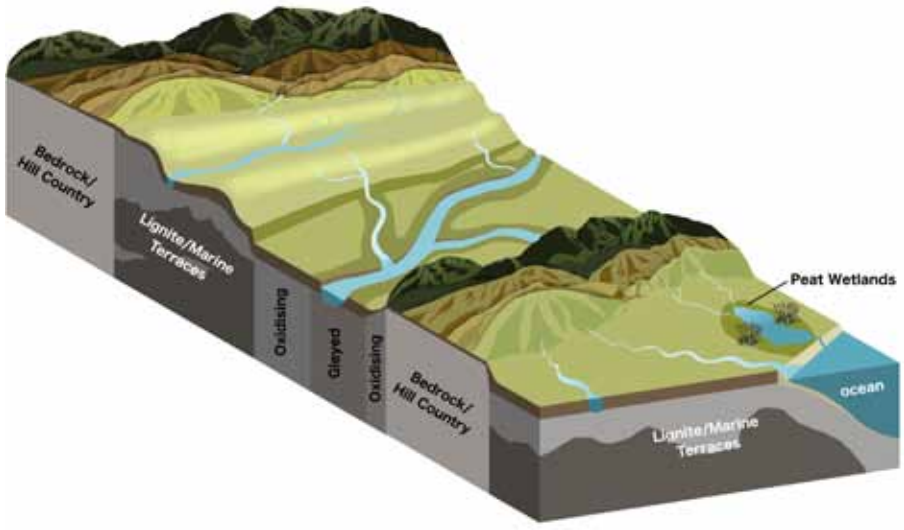
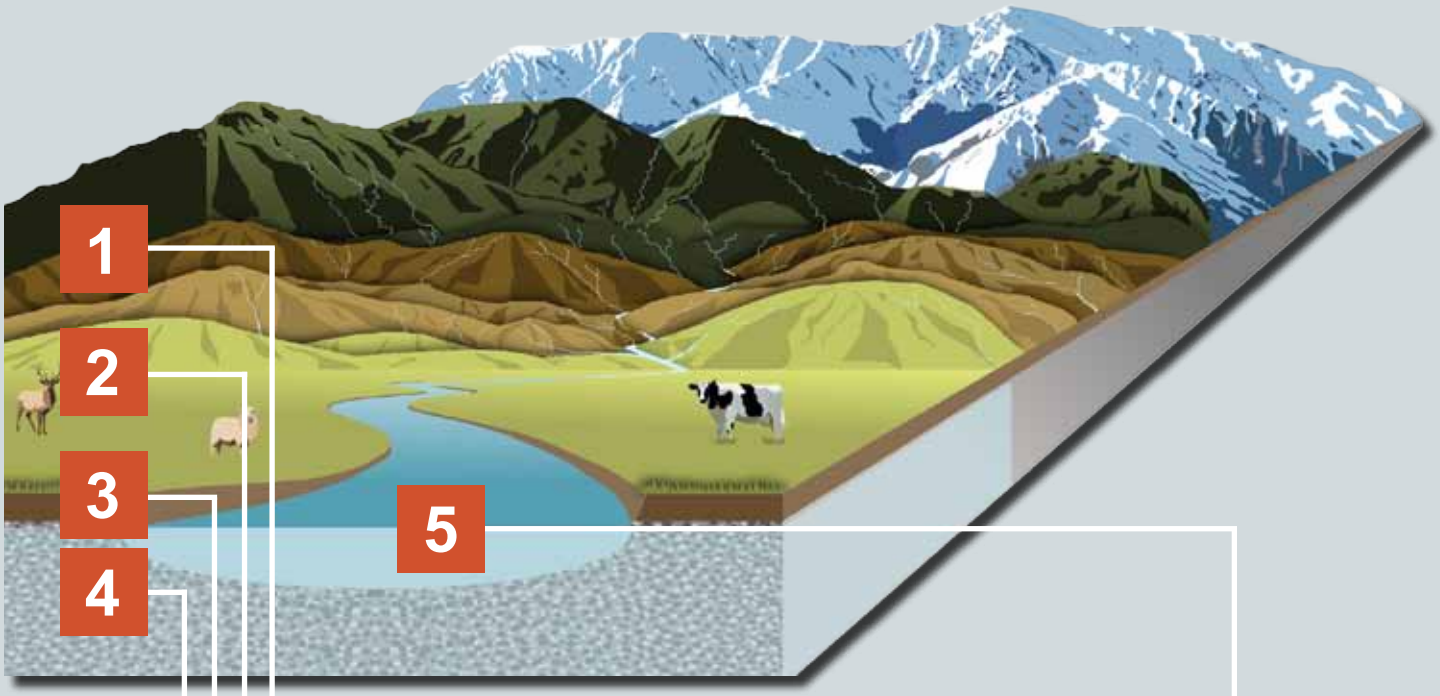


Figure 1: Landscape context image illustrating the relationship between the Lignite/Marine Terraces zone and neighbouring physiographic zones. The Lignite/Marine Terraces zone occurs in two physical settings: elevated terraces on the Southland Plains which are underlain at shallow depths by Tertiary (lignite measure) sediments and low-lying marine terraces along the south coast, which are often associated with the Peat Wetlands zone. The Lignite/Marine Terraces zone receives recharge from rainfall and often discharges to streams draining the Gleyed zone inland of the coastal margin, or to the coast.

Dominant characteristics that affect water quality



Landscape characteristics

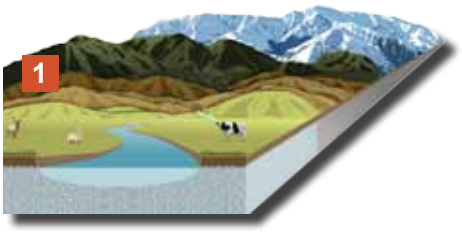
Surface zone characteristics

Soil zone characteristics

Saturated zone characteristics

Water quality implications

1 Landscape characteristics



The Lignite/Marine Terraces physiographic zone occupies marine terraces along the south coast between Bluecliffs and Awarua Bay, and between Fortrose and the Haldane Estuary. It also extends across a large area between Grove Bush and Upper Charlton where Gore Lignite Measure sediments occur near the land surface. In the Ohai area, this zone occurs where Beaumont Coal Measure sediments are similarly exposed.

Topography

Elevation

Most of this zone occurs at elevations less than 220 metres relative to sea level (m RSL). This reflects the spatial distribution of this zone across downlands in the lower Mataura catchment and alluvial terraces around the coastal margin.

Slope

Most of this zone occurs on flat to undulating land (≤7° slope).

Steeper areas generally occur in the Overland Flow variant, which occupies predominately flat to rolling land (≤15° slope).

Flatter areas with less well drained soils typically occur in the Artificial Drainage variant (≤3° slope).

Geology

This zone is associated with two distinct geological environments:

Marine terraces of late Quaternary age (Q5 to Q7)

- Located along the south coast
- Comprised of a mix of reworked alluvium and variable amounts of fine-grained sediment and organic materials

Organic-rich Tertiary sediments of the East Southland Group, with surface or near surface exposure (<15 m below ground level)

- Located across a broad area extending along the southern margin of the Hokonui Hills (from Grove Bush to Upper Charlton) and in the vicinity of Ohai
- The main sub-rock types are lignite and coal

Climate

Average annual rainfall in this zone varies spatially between 773 and 6,553 mm, with higher rainfall occurring on isolated marine terraces along the Fiordland coast.

Lignite/Marine Terraces LANDSCAPE zone characteristics

ELEVATION
0 – 220 m RSL

SLOPE
Flat to undulating

GEOLOGY
Hard rock and Quaternary sediments

LANDFORM AGE
Pre-Quaternary

AVERAGE ANNUAL RAINFALL
1,346 mm per year

Lignite/Marine Terraces(a) LANDSCAPE zone characteristics

ELEVATION
0 – 140 m RSL

SLOPE
Flat to gently undulating

GEOLOGY
Quaternary sediments

LANDFORM AGE
Q2-Q4 and Pre-Quaternary

AVERAGE ANNUAL RAINFALL
1,102 mm per year

Lignite/Marine Terraces(o) LANDSCAPE zone characteristics

ELEVATION
0 – 320 m RSL

SLOPE
Flat to rolling

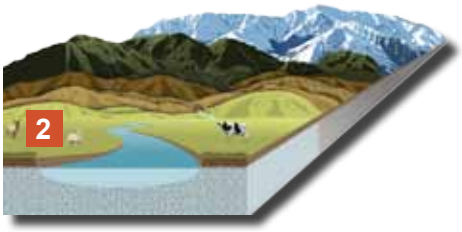
GEOLOGY
Hard rock

LANDFORM AGE
Pre-Quaternary

AVERAGE ANNUAL RAINFALL
1,506 mm per year

2 Surface zone characteristics

Recharge to the Lignite/Marine Terraces zone predominantly occurs from local precipitation infiltrating through the soil matrix. Runoff from adjacent higher elevation land provides minor recharge in some areas.



Dilution

This zone is predominately recharged via land surface recharge (matrix flow). There is less potential for dilution of contaminant concentrations with this recharge mechanism.

Surface waterways

This zone is predominately drained by a network of lower order streams. In flatter areas that are prone to seasonal waterlogging, streams are augmented by artificial drainage.

This network of lower order streams and artificial drainage discharges to short, higher order streams (3rd order and above). These drain either to the coast or to adjacent physiographic zones.

Temporal discharge is characterised by frequent high flow events following precipitation, particularly when soils are wet.

As soils dry, the water holding capacity and permeability of the soils mean increasingly large precipitation events are required to initiate quickflow. This results in extended periods of stable baseflow when soil moisture is seasonally low.

Overland flow

In steeper areas, or on rolling topography where subsoil permeability is low, overland flow can be generated during sustained wet periods.

Soils in this zone have a high water holding capacity. Therefore, soil moisture may be maintained at or around field capacity for extended periods, particularly in coastal areas with regular precipitation. This increases the potential for saturation excess overland flow.

Lignite/Marine Terraces SURFACE zone characteristics

DILUTION POTENTIAL
Low recharge flux

DRAINAGE DENSITY
Moderate

STREAM ORDER
Mixed

OVERLAND FLOW POTENTIAL
Moderate to very low

Lignite/Marine Terraces(a) SURFACE zone characteristics

DILUTION POTENTIAL
Low recharge flux

DRAINAGE DENSITY
High

STREAM ORDER
Mixed

OVERLAND FLOW POTENTIAL
Low to very low

Lignite/Marine Terraces(o) SURFACE zone characteristics

DILUTION POTENTIAL
High to low recharge flux

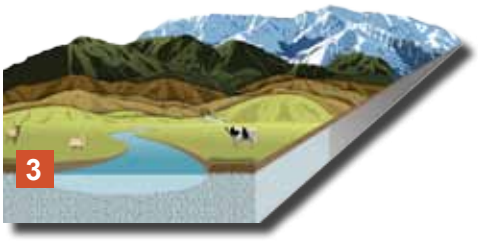
DRAINAGE DENSITY
Low

STREAM ORDER
Predominately small

OVERLAND FLOW POTENTIAL
Moderate to moderately high

3 Soil zone characteristics

Soils in this physiographic zone are typically deep and fine-grained. These soils are generally formed in windblown loess on older alluvial terrace surfaces and comprise moderately permeable topsoil overlying a compact, moderate to slowly permeable subsoil.



Soils

Brown soils occur extensively across near surface exposures of Gore Lignite Measure sediments in eastern Southland, with Gley soils more commonly associated with marine terraces along the south coast.

Soils in this zone typically have very low to moderate base saturation and moderate to high soil anion storage capacity.

Reduction potential

Soils in this zone have moderate reduction potential due to their moderate to poor internal drainage and slightly elevated organic carbon content. This means some denitrification may occur within the soil profile, reducing nitrate losses from the land surface to underlying aquifers.

Artificial drainage

During sustained wet periods, areas with compact, slowly permeable subsoils are prone to waterlogging. Where this land is developed, these soils often have artificial drainage to maintain agricultural productivity. Such areas are included in the Artificial Drainage variant.

Lateral drainage

In soil types that have restricted drainage, lateral flow may occur along slowly permeable layers within the soil profile.

Lignite/Marine Terraces SOIL zone characteristics

SOIL ORDER
Brown

PROFILE DRAINAGE
Poorly to moderately well drained

PERMEABILITY
Moderate over slow and moderate, slow

ANION STORAGE CAPACITY
Moderate

REDUCTION POTENTIAL
Moderate

ARTIFICIAL DRAINAGE DENSITY
Low to moderate

LATERAL DRAINAGE POTENTIAL
Localised

Lignite/Marine Terraces(a) SOIL zone characteristics

SOIL ORDER
Brown

PROFILE DRAINAGE
Poorly to imperectly drained

PERMEABILITY
No data**

ANION STORAGE CAPACITY
No data**

REDUCTION POTENTIAL
Moderate

ARTIFICIAL DRAINAGE DENSITY
Moderate to high

LATERAL DRAINAGE POTENTIAL
Localised

Lignite/Marine Terraces(o) SOIL zone characteristics

SOIL ORDER
Brown

PROFILE DRAINAGE
Moderately well to poorly drained

PERMEABILITY
No data**

ANION STORAGE CAPACITY
No data**

REDUCTION POTENTIAL
High to moderate

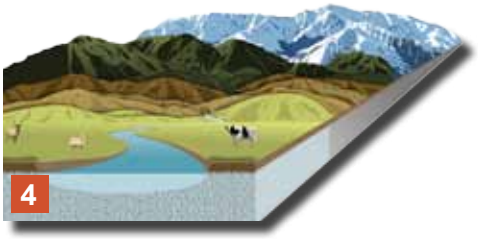
ARTIFICIAL DRAINAGE DENSITY
Low to none

LATERAL DRAINAGE POTENTIAL
Localised

**A majority (>90%) of the zone does not have available data

4 Saturated zone characteristics

Groundwater in the Lignite/Marine Terraces physiographic zone varies according to the underlying geology.



Groundwater

Alluvial aquifers

Due to their origin and age (typically Q5 and older), the surficial alluvium generally is comprised of quartz-rich gravels in a highly weathered silty clay matrix. As a consequence, aquifers hosted in such sediments exhibit low to very low permeability.

The extent of the groundwater resource varies according the thickness of alluvial deposits overlying lignite and coal measure sediments.

Groundwater from these aquifers is primarily discharged as baseflow to surface waterways.

Tertiary aquifers

Tertiary sediments underlying inland areas of this zone host extensive aquifers. These are located in coarser-grained sand and gravel zones, which are interspersed between low permeability mudstone and lignite sediments.

These aquifers form part of a regional-scale flow system which is slowly permeable and ultimately discharges at or near the coast.

Recharge to these deeper confined aquifers is likely to form a minor component of the overall water balance in this zone.

Groundwater levels

Groundwater levels are generally close to the land surface (<2 metres) in lower lying areas adjacent to rivers and streams.

However, levels may be up to 15 metres below ground under elevated marine terraces along the south coast.

Reduction potential

Alluvial aquifers

Alluvial aquifers tend to exhibit a vertical redox gradient where alluvium sediments are thick. Groundwater is oxidised (oxic) when shallow, but becomes increasingly reduced with depth (due to increasing residence time and disconnect from oxygen source).

Tertiary aquifers

Tertiary aquifers groundwater hosted in Tertiary lignite measure sediments is generally anoxic.

Deep drainage

Deep drainage to groundwater occurs at a slow rate through poorly to imperfectly drained soils and comprises a significant component of the water balance in this zone.

However, deep drainage is not a major contaminant pathway due to filtration and sorption in the soil profile and denitrification associated with strongly reducing conditions in the underlying geology.

Lignite/Marine Terraces SATURATED zone characteristics

WATER TABLE DEPTH
Moderate to shallow

AQUIFER PERMEABILITY
Low

ACTIVE GROUNDWATER STORAGE
Moderate

REDUCTION POTENTIAL
Low to high

DEEP DRAINAGE POTENTIAL
Moderate

Lignite/Marine Terraces(a) SATURATED zone characteristics

WATER TABLE DEPTH
Moderate to shallow

AQUIFER PERMEABILITY
Low

ACTIVE GROUNDWATER STORAGE
Moderate

REDUCTION POTENTIAL
Low to high

DEEP DRAINAGE POTENTIAL
Moderate

Lignite/Marine Terraces(o) SATURATED zone characteristics

WATER TABLE DEPTH
Moderate*

AQUIFER PERMEABILITY
Low

ACTIVE GROUNDWATER STORAGE
Minor

REDUCTION POTENTIAL
Low to high

DEEP DRAINAGE POTENTIAL
Moderate

* A significant proportion (>50%) of the zone does not have available data

5 Water quality implications

The main water quality issues for this physiographic zone are nitrogen, phosphorus, sediment and microbial contaminant losses via artificial drainage and overland flow to surface waterways.

Influencing factors

Factors that influence water quality in the Lignite/Marine Terraces zone include:

- the presence of near-surface carbon-rich (reducing) sediments which have high reduction potential
- variable reduction potential in soils with moderate to poor drainage
- elevated potential for artificial drainage in flat-lying developed areas with poorly drained soils
- elevated potential for overland flow on sloping land with poorly drained soils

Water quality issues

Nitrogen losses from this zone are moderated by soil and aquifer denitrification (Figure 3).

However, the actual extent of denitrification depends on nutrient load and residence time of water within the soil zone.

In overland flow (Figure 4) and artificial drainage (Figure 5), large amounts of nitrogen can be mobilised during heavy precipitation events due to the limited time available for denitrification to occur.

Groundwater

Denitrification within aquifers containing elevated organic carbon moderates nitrate concentrations in this zone.

Surface waters

Nitrogen concentrations are typically low in surface waters, particularly during baseflow. This reflects the influence of reducing groundwater to baseflow. Phosphorus concentrations are also generally low due to retention of P in the soil zone.

Contaminant losses can become significantly elevated during high flow events that occur in response to heavy or sustained precipitation events. This reflects the rapid transport of water to streams via overland flow and artificial drainage.

Key HYDROCHEMICAL features

- Water types are predominantly Na-Cl in coastal areas (reflecting marine aerosol deposition) and Ca-HCO_3 in inland areas (reflecting elevated alkalinity associated with soil zone processes)
- Where waters are reducing, dissolved iron (Fe^{2+}), manganese (Mn^{2+}) and ammoniacal nitrogen can be elevated while nitrate (NO_3) is low

What affects water quality in the Lignite/Marine Terraces zone?

WHERE	KEY CHARACTERISTICS	CONTAMINANT PATHWAYS	ATTENUATION PROCESSES	WATER QUALITY RISK
All areas	Land surface recharge Moderately well to well drained soils	Lateral drainage through the soil zone	Attenuation of particulate and microbial contaminants by filtration and adsorption. Variable denitrification potential in the soil zone	Low water quality risk
		Deep drainage to groundwater when soils are wet	Attenuation of particulate and microbial contaminants by filtration and adsorption. Variable denitrification potential in the soil zone and elevated denitrification potential in the saturated zone	Low water quality risk
Artificial drainage variant	Low subsoil permeability Flat topography	Artificial drainage in response to sustained or heavy precipitation events	Some filtration, adsorption may occur in water moving through the soil matrix. Limited denitrification may also occur in water moving slowly through soils with an elevated reduction potential	Nitrogen Phosphorus Microbes Sediment Contaminants discharged rapidly to surface water
Overland flow variant	Sloping topography Low subsoil permeability	Overland flow in response to sustained or heavy precipitation events	Limited attenuation of contaminants	Nitrogen Phosphorus Microbes Sediment Contaminants discharged rapidly to surface water

CONTAMINANT PATHWAY	MITIGATION OBJECTIVES
Overland flow	Protect soil structure, particularly in gullies and near stream areas Manage critical source areas Reduce phosphorus use or loss
Artificial drainage	Protect soil structure, particularly in gullies and near stream areas Reduce phosphorus use or loss Reduce the accumulation of surplus nitrogen in the soil, particularly over autumn and winter Avoid preferential flow of effluent through drains Capture contaminants at drainage outflows

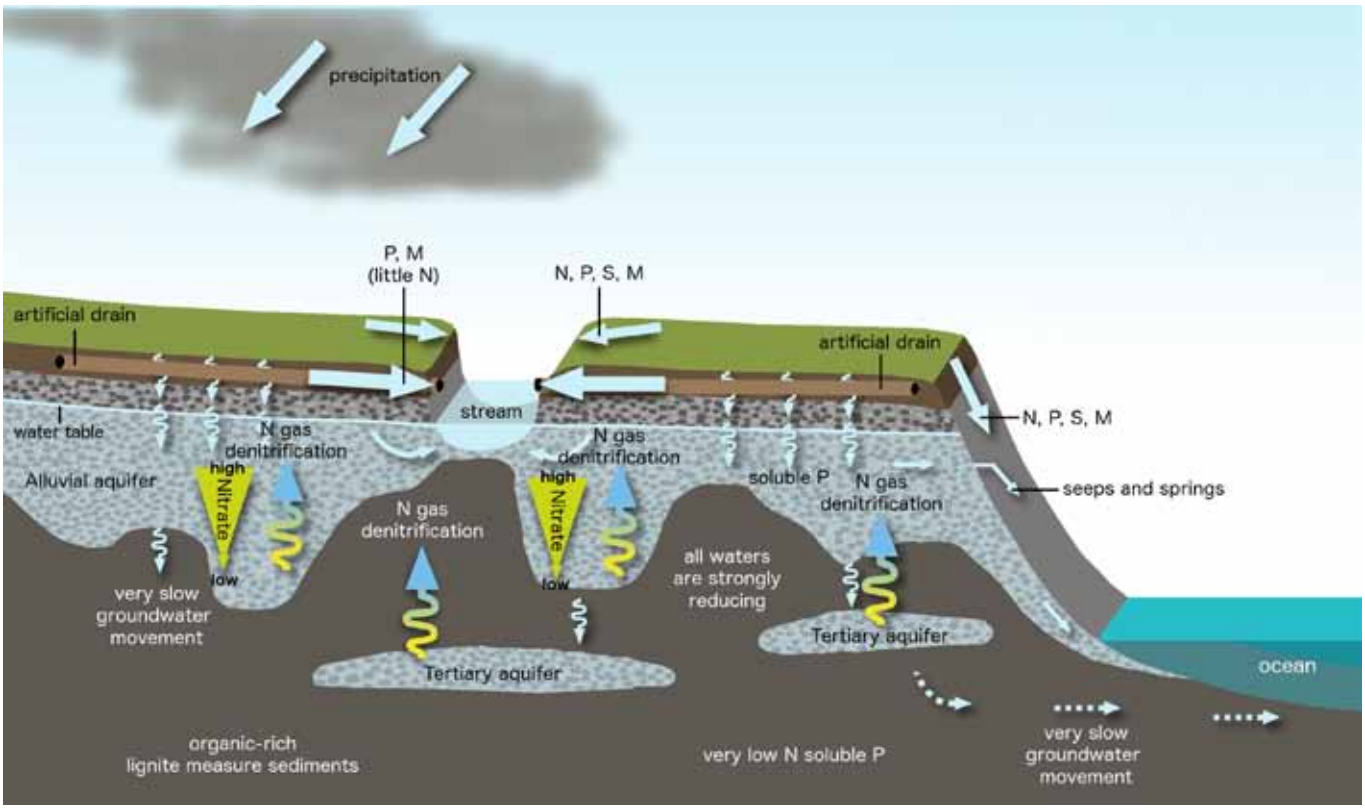


Figure 2: **Main zone** – Groundwater nitrate concentrations are strongly influenced by distribution of organic-rich lignite and marine sediments. Generally, aquifer denitrification potential aggrades from low to high within alluvial aquifers and is high throughout Tertiary aquifers. Phosphorus may be mobilised in reduced groundwater.

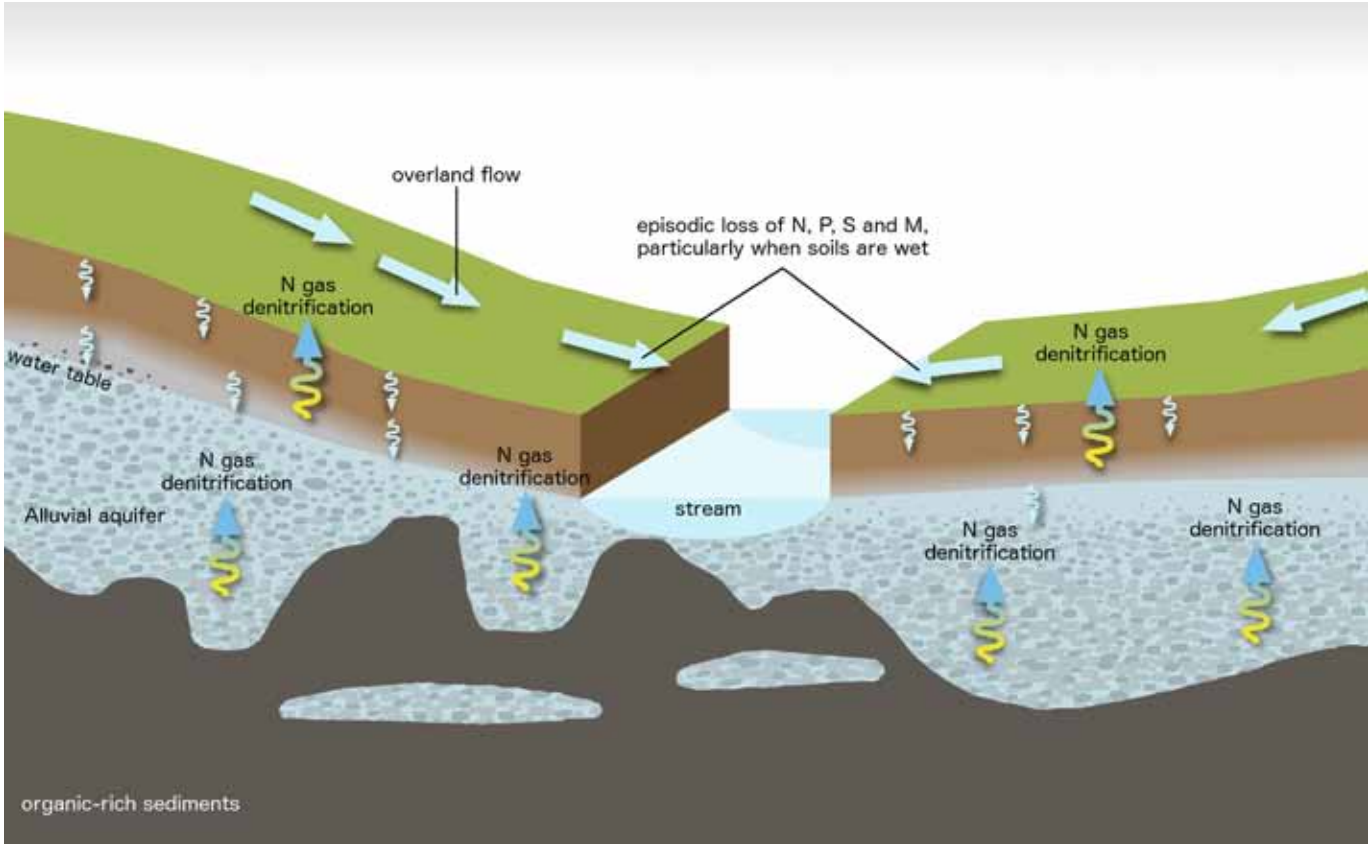


Figure 3: **Overland flow variant** – Overland flow provides a pathway for episodic losses of nitrogen (N), phosphorus (P), sediment (S) and microbes (M). Overland flow occurs because of seasonal water excess in moderately to slowly permeable soils.

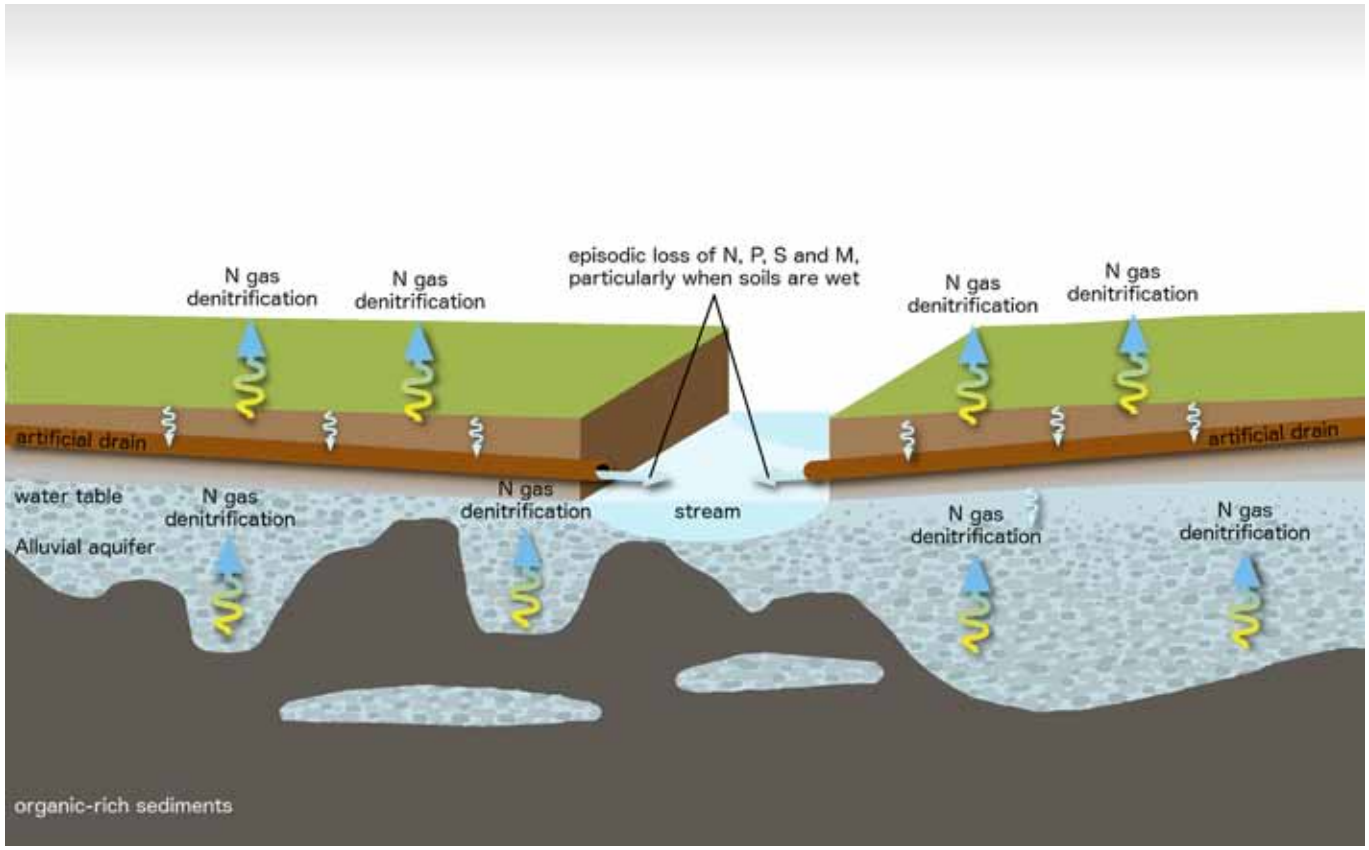


Figure 4: **Artificial drainage** – Mole-pipe drainage provides a pathway for episodic losses of nitrogen (N), phosphorus (P),sediment (S) and microbial (M) contaminants to surface waters.