Puerua-Waitepeka Catchment Group

Advice on Designing a Water Quality Monitoring Programme

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Review and Recommendation of Sampling Methodologies for the Shallow Water Table and tidally influenced portions of the Puerua-Waitepeka Catchment and the broader Lower Clutha Delta area.

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Review and Recommendation of Sampling Methodologies for the Shallow Water Table and tidally influenced portions of the Puerua-Waitepeka Catchment and the broader Lower Clutha Delta area.

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1.1. Objective

This collaborative project between A2E, LWS, and members of the Puerua-Waitepeka Catchment Group aims to provide effective options for monitoring the quality of freshwater across the low-relief areas of the Lower Clutha Delta area. Due to the area's low elevation and proximity to the coast, tidal saltwater incursions present significant challenges.

This report evaluates the best methodologies for catchment group members to sample freshwaters within their farm boundaries, providing a comprehensive understanding of water quality as it leaves farms and enters the Puerua Stream, Koau, and Matau branches of the Clutha River.

1.2. Deliverables

This report concludes the successful completion of several key project deliverables:

- Site Visit and Stakeholder Meetings: Conducted a site visit to the Glenomaru Catchment and held meetings with catchment group leaders and farmers to discuss findings and recommendations.
- GIS Project Development: Creation of a GIS project for the Glenomaru and wider Lower Clutha Delta areas, which hosts all data used for water quality assessment and supports the evaluation of sampling technologies.
- Data Assessment and Video Summary: Production of a farmer-friendly video summary of water quality data collected from two long-term monitoring sites within the Glenomaru Catchment.
- Field Day Demonstration: Delivered a field day to demonstrate the utility of different monitoring technologies, supporting the accurate sampling of 'freshwater' for local water quality representation.

1.3. Main Findings and Recommendations

The primary finding of this report is the feasibility of sampling freshwater quality across the Lower Clutha Delta area with minimal barriers.

Key recommendations include:

1. Focus on Farm-Originating Waters: Emphasise sampling waters originating within farm boundaries, such as springs, seeps, open drains, small tributaries, and shallow groundwater, to generate an accurate and locally specific picture of water quality.

2. Avoid Large River Systems: Sampling larger streams, particularly the Koau and Matau branches of the Clutha River, is unlikely to provide relevant information about the quality of freshwater leaving local farms across the Lower Clutha Delta area.

3. Develop a Farm-Scale Monitoring Network: Establish a farm-scale network of monitoring sites across the Lower Clutha Delta area to support catchment group members in understanding local water quality.

4. Utilise Recommended Technologies: Implement low-cost electrical conductivity meters (EC Pens) to identify sources of freshwater discharge at farm scale, differentiate between

fresh and salt-affected tidal streams, and use direct-push groundwater sampling technologies to isolate shallow groundwaters for analysis.
5. Adhere to National Protocols: Employ national sampling protocols and use IANZ-accredited laboratories for the analysis of collected samples to ensure high-quality data.

By following these recommendations, farmers of the Puerua-Waitepeka Catchment Group and the wider Lower Clutha Delta area can effectively monitor and manage water quality, informing their investment in good management and mitigation actions.

2. Site Visit and Exploration of Lower Clutha Delta Area

2.1. Site Visit

During our initial site visit to the Lower Clutha Delta area, we conducted an extensive tour of the Landsdown Pamu Dairy Farm, excavated a soil pit adjacent to the Puerua River to assess the character of the soil and the depth of the water table (c. 1 m below ground level), and were provided with a tour of the Puerua River and its lock systems. This visit aimed to familiarise us with the landscape and unique challenges posed by the local environment.

2.2. Landsdown Pamu Dairy Farm Tour

Farm manager Matthew Hamilton, along with catchment coordinators Rebecca Begg and Craig Simpson of Otago South River Care, guided us through key areas of the farm. We were shown the V-drains, which are prominent features in the Lower Clutha Delta area. Discussions centred around the tidal range, the nature of the V-drains, and the challenges associated with sampling water from these drains, particularly concerning the potential presence of saltwater.

2.3. Preliminary Assessment and Observations

One of the critical issues raised by Otago South River Care members was the uncertainty about whether the V-drains, groundwaters, or streams contained saltwater. On the field day, V-drain waters, and shallow groundwaters were accessed via driven piezometers, these were installed on the day. Measures of electrical conductivity of the Puerua River all indicated freshwater source (EC <300 uS/cm).

These field day results suggest that saltwater influence might be more acute for farms immediately adjacent to the coast, where drainage systems (including V-drains) are directly connected to the ocean. However, current knowledge of the importance of saltwater influence across the Lower Clutha Delta area is limited by a lack of measurement.

2.4. Exploration of the Puerua River and Lock Systems

Our exploration of the Puerua River and its lock systems provided additional context for understanding the water flow and potential saltwater intrusion in the region. The tidal influence and its impact on the freshwater systems were discussed in detail. It became evident that a thorough and systematic approach is required to monitor and manage the water quality effectively.

2.5. Drive of the Lower Clutha Delta area

The Land and Water Science team drove around the Lower Clutha Delta area, including the coastal area and the low hills surrounding the floodplain. Stops were made at various locations to observe the landscape settings.

3. GIS Resources and Environmental Settings

3.1. Development of a GIS Resource

A GIS project of relevant datasets was compiled for the Puerua-Waitepeka Catchment group of the Glenomaru and wider Lower Clutha Delta area. The data layers included:

i.	Glenomaru Water Quality Data and Analysis
ii.	LiDAR and MERIT Digital Elevation Models
iii.	Raster models of Slope and Elevation
iv.	NIWA's digital stream network (River Environment Classification v 2.5; 2024)
v.	The National Equilibrium Water Table layer (GNS Science; Westerhoff et al., 2019)
vi.	Geological Survey (Q-Map v3 GNS Science; GNS Science. (May 2024.).
vii.	Soil Survey (FSL; Manaaki Whenua, May 2024)
viii.	The Land Resource Inventory (LRI) of New Zealand (Manaaki Whenua; Lynn, 1985)
ix.	Topo50 maps and aerial imagery. Retrieved August 9, 2024, from Toitū Te Whenua Land Information New Zealand (LINZ), (May 2024).
x.	Physiographic Environments of New Zealand (PENZ)

All layers were produced, centralised on the Lower Clutha Delta area which also includes the Glenomaru Catchment. The GIS project was then packaged and sent to Rebecca Begg and Craig Simpson of Otago South River Care.

3.2. Glenomaru Catchment

The 4,818 ha Glenomaru Catchment is located within southeastern Otago, inland of Kaka Point. The catchment ranges between 1.0 to 537.2 metres relative to sea level (m RSL), with a median elevation of 157 m RSL. Slope ranges between 0 and 44.5° with a median of 10.8°. Exotic pastures with significant areas of native bush and minor exotic tree plantations dominate the land cover. The Glenomaru Stream, a small 3rd order stream, drains the valley and joins the larger Puerua River northeast of the Owaka Highway (Figure 1).

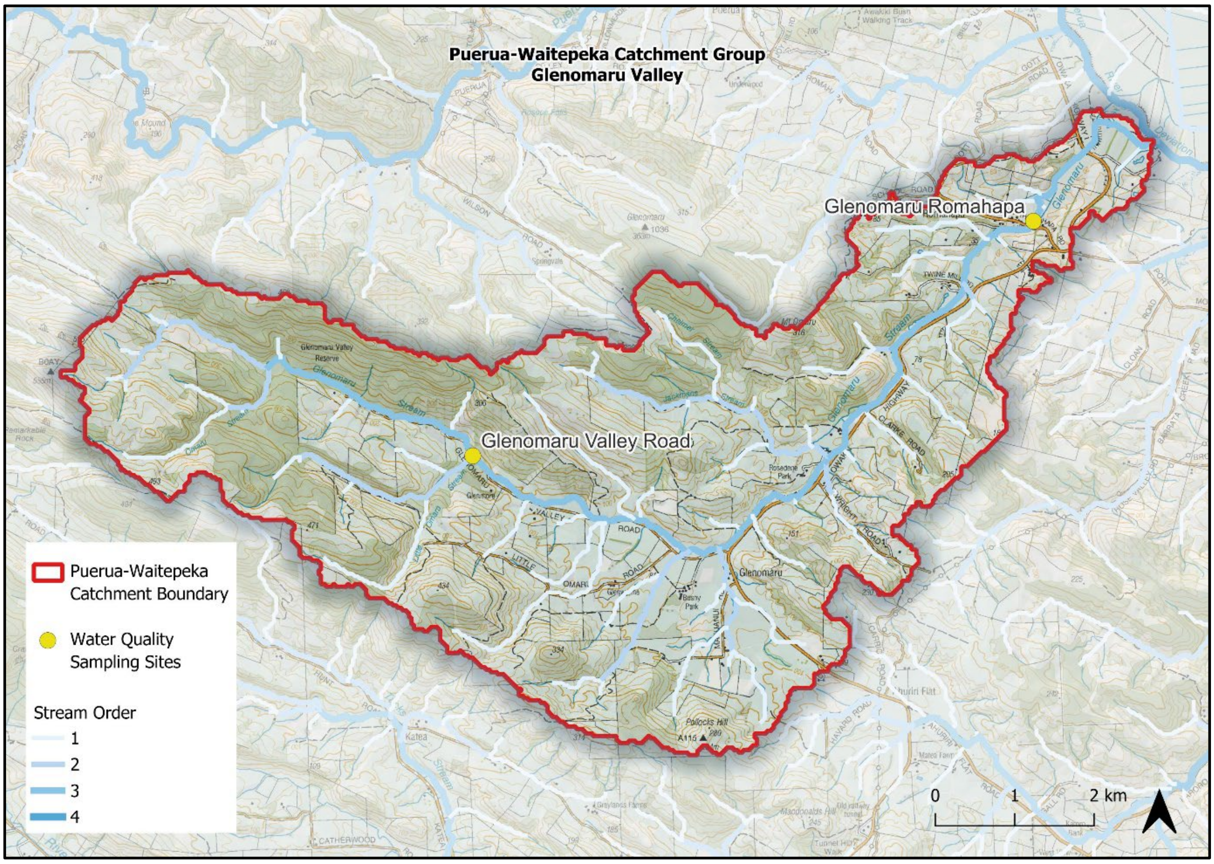

Figure 1 The Glenomaru Catchment (red outline) and surrounds. The New Zealand Topo50 map[1] is draped over a Digital Elevation Model, with the National Institute of Water and Atmosphere digital river network[2] displayed in blue.

The Glenomaru Catchment is comprised mainly of Eastern Province sedimentary basement rocks, with the Diamond Peak Group (fine sandstone and siltstone with rare conglomerate tuff and grit beds), Taringatura Group (sandstone with minor tuff; mudstone; tuff; shell beds and granitic conglomerate), North Range Group (well-bedded siltstone; sandstone; tuff; shell beds and conglomerate), and Willsher Group (folded sandstone with subordinate mudstone and minor tuff and conglomerate) rocks the main component (Heron, 2020).

The soils of the Puerua-Waitepeka Catchment display a continuum from well-drained steep land hill soils (i.e., Kaihiku (Argillic Orthic Melanic) and Waimahaka (Acidic Firm Brown)), through to moderately well-drained Owaka (Typic Firm Brown) and Chasland (Mottled Firm Brown) soils where the terrain is more gently sloping. Hinahina (Typic Orthic Podzol) soils are poorly drained and occupy steep south-facing slopes. With decreasing elevation and slope, soils transition to imperfectly drained Warepa (Mottled Fragic Pallic), with poorly drained Taieri (Typic Orthic Gley) and Puerua (Peaty Orthic Gley) soils occupying the valley floor. At the mouth of the Puerua-Waitepeka valley, the Waitepeka (Acidic Mesic Organic) soil series is associated with recent swamp deposits.

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[1] Land Information New

[2] Whitehead, A.L., Booker, D.J. (2020). *NZ River Maps: An interactive online tool for mapping predicted freshwater variables across New Zealand*. NIWA, Christchurch. https://shiny.niwa.co.nz/nzrivermaps/

3.3. Lower Clutha Delta Area

The Glenomaru Catchment occurs within the broader Balclutha/Lower Clutha Delta area. Immediately south of Balclutha, the Clutha River divides into the Koau and Matau branches. These two branches of the Clutha have moved between the low hills that constrain the Lower Clutha Delta area over the last 14,000 years. The floodplain is comprised of unconsolidated river gravels, sand, minor silt, and clays, with inclusions of peat associated with modern stream beds and over bank deposits. Closer to the hills there are significant peat swamps (e.g., along the Owaka Highway, north of Lake Tuakitoto).

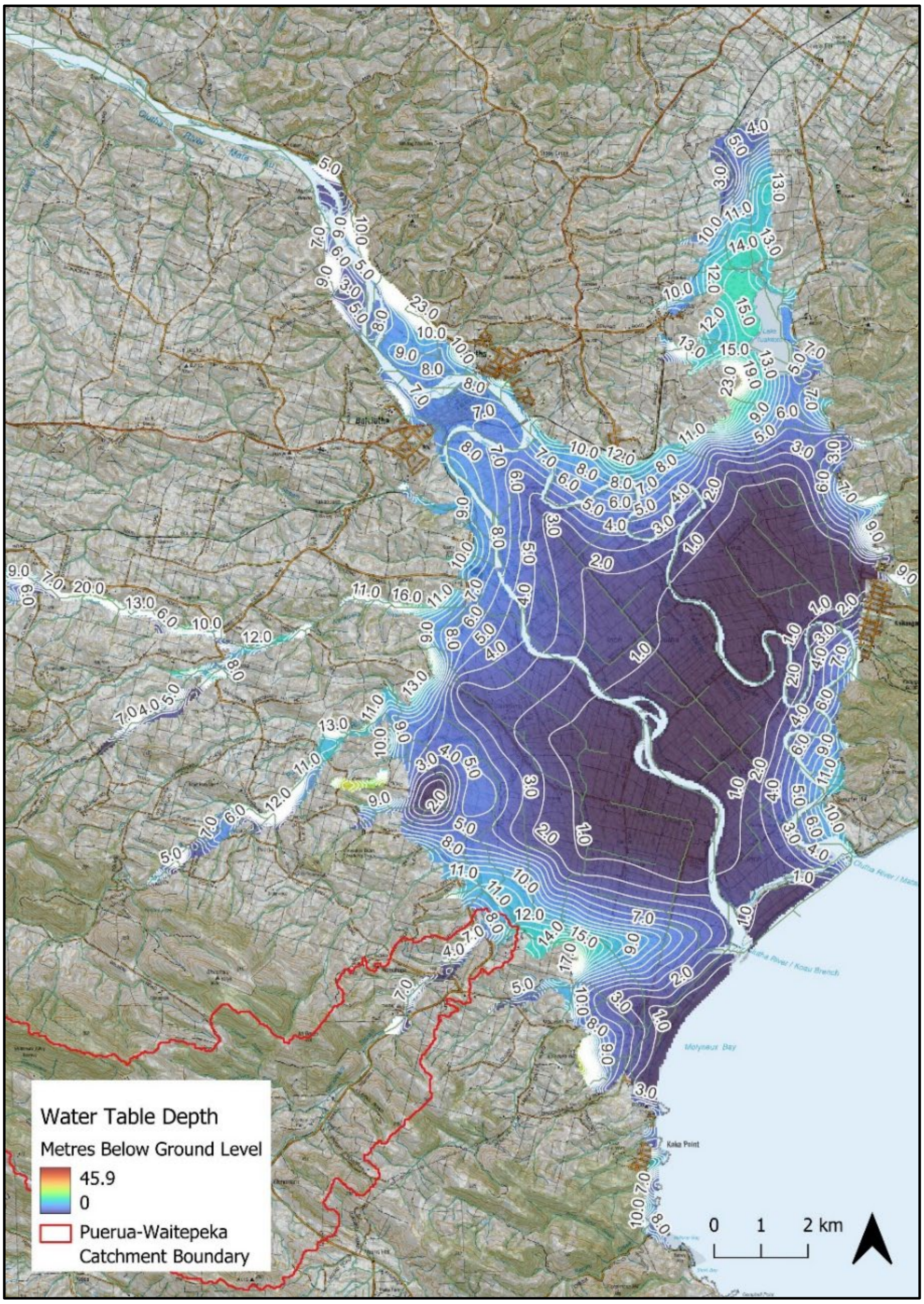

Figure 2. *Lower Clutha Delta area and the Equilibrium Water Table layer of Westerhoff et al. (2019) and 1 m contours of groundwater level identify large areas of the Lower Clutha Delta region have a shallow water table.*

The shallow water table at the mouth of the Glenomaru catchment is evident in the large area of water table impacted soils i.e., Taieri, Puerua, Waitepeka soil series, and the abundance of Holocene swamp deposits. Across the broader area of the Lower Clutha Delta floodplain, the water table progressively shallows towards the coast and with proximity to the Koau and Matau branches of the Clutha River (Figure 2). The Equilibrium Water Table (EWT) layer of Westerhoff et al. (2019), reveals that a large area of the floodplain has a water table that is <1 m below ground level (bgl). Due to its coastal aspect and low relief the many drainages, both natural and artificial, are known to be tidally influenced. Unfortunately, there is scant knowledge of the distance inland that saltwater extends during high tides.

3.4. General Water Quality Setting

The Lower Clutha Delta area is characterised by a wide range of water quality settings as defined by the Physiographic Environments of New Zealand (PENZ; Rissmann et al., 2018; 2019; 2024). The PENZ subdivides the landscape into classes that behave similarly to a broadly equivalent land use intensity. The PENZ classes represent the combination of the natural landscape features and alterations (artificial drains etc) that control spatial variation in the type and severity of water quality contaminant losses.

A recent assessment of the PENZ classification against New Zealand’s national river network identified that spatial variation in the land beneath our feet accounted for more than 2x the spatial variability in water quality than land use did (Rissmann et al. 2024). This means that although land use is the dominant source of poor water quality, the landscape itself strongly influences the type, e.g., leaching of nitrate to a shallow aquifer or erosion of sediment from a hillside, and the severity of the issue encountered. In other words, Mother Nature/Papatūānuku has a large say in the kind of water quality challenges across a property or catchment.

According to the PENZ classification, 78% of the Lower Clutha Delta area in Figure 2 is classified as belonging to the Bedrock Hill family, within which there are 6 different classes (*Table 2*). The remaining 22% belongs to the Lowland family, within which there are 11 different classes, all of which have distinct susceptibilities to contaminant loss. The dominant pathways through which contaminants are lost e.g., overland flow (runoff) or leaching to an aquifer are identified for each PENZ class (3). The overall susceptibility of a PENZ class to different water quality contaminants is provided in Table 3. By identifying the dominant pathway and contaminant susceptibility it is possible to target mitigations that are appropriate and effective. The PENZ classification also enables a user to understand the processes that control the different pathways and susceptibilities to contaminant loss.

The main pathways of contaminant loss are shown in Table 2 below.

Table 1 Main pathways of contaminant loss in Puerua-Waitepeka Catchment

1. **Overland Flow and Storm Flow:** Water flows just below the surface (stormflow) or over the land (overland flow). Rapidly flowing water easily picks up nutrients, and entrains or detaches sediments, and organic contaminants. This pathway is common in areas with limited infiltration capacity, steep slopes, and/or shallow water tables.
2. **Lateral Drainage along the Contact with Bedrock:** Water flows along the boundary between soil and bedrock, which can lead to the movement of contaminants like nitrate and dissolved phosphorus. Lateral drainage of water is most common where soil overlies poorly permeable bedrock in hill country areas. Water accumulates and moves slowly downhill at contact with the bedrock, discharging as seeps or springs.
3. **Deep Drainage through the Soil Profile:** Water infiltrates deeply into the soil, reducing surface runoff but potentially leaching nitrate to the underlying aquifer or a

bedrock layer. Deep drainage may occur anywhere there are well-drained soils. However, it is most prevalent where the land is flat, soils are coarse textured and well drained (e.g., gravel soils), and the water table is at least several metres below ground level. Deep drainage may also occur through organic soils, especially where the organic material is hydraulically conductive.
4. **Artificial Drainage:** imperfectly to poorly drained soils or soils impacted by shallow water tables are often artificially drained. Artificial drains rapidly discharge runoff from the land directly to connected waterways.

It is important to note that the ‘susceptibilities’ assigned to the landscape are independent of land use, do not represent actual losses, and do not account for existing good management, or mitigation actions. They are purely, an assessment of the landscape susceptibility, with no consideration given to land use type.

Some parts of the landscape may be dominated by a single pathway (e.g., Deep drainage often dominates across flat low-lying areas of well-drained and highly permeable gravel soils), whereas others may have multiple pathways (e.g., fine-textured and well-drained hill soils for which episodic runoff). For landforms with more than one pathway, as to which pathway dominates at any one time is a function of climate both seasonal and event (thunderstorms etc).

*Table 2 Physiographic Class and Dominant Contaminant Loss Pathway and Landscape Susceptibilities (*Bedrock (Hill Country) Family, shown in grey.)*

PENZ Class	Area (ha)	Elevation (m RSL)	Slope	Percentage by Area	Dominant Pathway	Dominant Susceptibilities
Oxidising soil & aquifer - High deep drainage	494	6.3	2.2	0.8	Deep drainage is dominant where and when the water table > 2 m bgl, otherwise may exhibit episodic overland flow and storm flow	High susceptibility to nitrate leaching to groundwater. Particulate contaminant susceptibility is elevated where and when the water table is close to the surface.
Oxidising soil & aquifer - Increased lateral & overland flow	1364	6.1	2.2	2.1	Deep drainage is dominant where and when the water table >2m bgl; episodic overland flow and storm flow where and when the water table is close to the surface, or soils are slowly permeable	If the water table is >2m bgl for most of the year, then nitrate leaching is the dominant susceptibility. Otherwise, susceptibility to particulate contaminants is low. If the water table is close to the surface, then susceptibility to episodic runoff increases and particulate contaminant loss increases.
Oxidising soil & aquifer - Strong bedrock*	5352	130.2	8.8	8.1	Deep drainage depending on the depth of soil profile and its permeability, lateral subsurface drainage, with episodic overland flow, and storm flow	In this PENZ class susceptibility to nitrate leaching from the topsoil to the shallow aquifer system is elevated. Depending on soil permeability (infiltration rate) and slope this setting can also generate particulate contaminants during episodic storm events.
Oxidising soil reducing aquifer - Moderate aquifer reduction	164	50.8	11.1	0.2	Deep drainage is dominant where and when the water table > 2 m bgl, otherwise may exhibit episodic overland flow and storm flow	Although this PENZ class has a heightened susceptibility to soil zone nitrate leaching, the underlying aquifer naturally removes any leached nitrate. If these soils pond or the water table gets close to the surface, susceptibility to episodic runoff and particulate contaminant loss is elevated.
Oxidising soil-reducing	1183	96.1	10.4	1.8	Deep drainage depending on the depth of soil profile, lateral	In this PENZ class susceptibility to nitrate leaching from the topsoil to the shallow aquifer system is elevated. Depending on soil permeability (infiltration rate) and slope this setting

PENZ Class	Area (ha)	Elevation (m RSL)	Slope	Percentage by Area	Dominant Pathway	Dominant Susceptibilities
aquifer - Strong bedrock*					subsurface drainage, with episodic overland flow/storm flow	can also generate particulate contaminants during episodic storm events.
Reducing soil & aquifer - High soil reduction	612	5.8	4.2	0.9	Episodic overland flow, storm flow, lateral subsurface drainage, artificial drainage, and deep drainage if organic soils are permeable	High susceptibility to episodic particulate contaminant loss. Low susceptibility to nitrate leaching to groundwater.
Reducing soil & aquifer - Moderate soil reduction	243	9.6	5.0	0.4	Episodic overland flow, storm flow, lateral subsurface drainage, artificial drainage	Moderate-high susceptibility to episodic particulate contaminant loss. Moderate-low susceptibility to nitrate leaching to groundwater.
Reducing soil & aquifer - Strong bedrock*	1352	27.0	6.5	2.1	Episodic overland flow, storm flow, and lateral subsurface drainage	As above description, despite the lower overall slope the presence of imperfectly to poorly drained soils increase runoff risk and particulate susceptibility, minor lateral subsurface losses of dissolved phosphorus and ammoniacal nitrogen.
Reducing soil oxidising aquifer - High soil reduction	4633	5.1	2.6	7.0	Episodic overland flow, storm flow, lateral subsurface drainage, artificial drainage, and deep drainage if organic soils are permeable	High susceptibility to episodic particulate contaminant loss. Low susceptibility to nitrate leaching to groundwater.
Reducing soil oxidising aquifer - Moderate	2424	12.6	4.2	3.7	Episodic overland flow, storm flow, lateral subsurface drainage, artificial drainage, minor deep drainage	Moderate susceptibility to episodic particulate contaminant loss. Moderate-low susceptibility to nitrate leaching to groundwater.

PENZ Class	Area (ha)	Elevation (m RSL)	Slope	Percentage by Area	Dominant Pathway	Dominant Susceptibilities
soil reduction						
Reducing soil oxidising aquifer - Strong bedrock*	19925	25.0	7.4	30.3	Episodic overland flow, storm flow, and lateral subsurface drainage	As above description, despite the lower overall slope the presence of imperfectly to poorly drained soils increase runoff risk and particulate susceptibility.
Riverine - High deep drainage	259	5.8	2.1	0.4	Deep drainage is dominant where and when the water table > 2 m bgl, otherwise may exhibit episodic overland flow and storm flow	High susceptibility to nitrate leaching and soluble contaminants where gravels are coarse textured. Particulate contaminant susceptibility where and when the water table is close to the surface.
Riverine - Increased overland flow	2283	7.6	2.1	3.5	Deep drainage is dominant, with episodic overland flow and storm flow where and when the water table is close to the surface	High susceptibility to nitrate leaching and soluble contaminants where gravels are coarse textured. Particulate contaminant susceptibility where and when the water table is close to the surface.
Strong Bedrock – Hill*	23259	109.1	12.2	35.3	Episodic overland flow, storm flow, and lateral subsurface drainage	Particulate materials including surface and shallow subsurface debris i.e., animal manure, organic matter, loose or bare topsoil, dissolved nitrogen and phosphorus in topsoil. Note these materials contain abundant pathogens, nitrogen, phosphorus, and pathogens, mainly as organic and particle reactive (attached to silt, clay, organic matter) contaminants. Organic matter, especially from improved pasture contains abundant N and P and contributes to in-stream eutrophication. Dissolved phosphorus, ammoniacal nitrogen, and in places small amounts of nitrate may be lost via lateral subsurface drainage.

PENZ Class	Area (ha)	Elevation (m RSL)	Slope	Percentage by Area	Dominant Pathway	Dominant Susceptibilities
Strong Bedrock - Low relief*	499	24.9	7.0	0.8	Deep drainage depending on the depth of soil profile and its permeability; lateral subsurface drainage, with episodic overland flow/storm flow	Depending on soil permeability, drainage class, and depth, deep drainage, and lateral subsurface drainage conduct nitrate to valley floors, especially during the winter months. Deeper lateral subsurface flow conducts dissolved ammoniacal nitrogen and phosphorus to the valley floor during the summer and autumn months. Will generate episodic runoff in response to storm events but the frequency is likely lower than in steeper hill country classes.
Wetlands - Hill and Alpine*	88	33.7	7.9	0.1	Episodic overland flow, storm flow, and lateral subsurface drainage where sloping	Particulate materials including surface and shallow subsurface debris i.e., enriched organic matter, ammoniacal nitrogen, organic nitrogen, and organic + particle reactive phosphorus.
Wetlands - Lowland	1103	3.0	1.8	1.7	Episodic overland flow, storm flow, lateral subsurface drainage, artificial drainage, and deep drainage if organic soils are permeable	Particulate materials including surface and shallow subsurface debris i.e., enriched organic matter, ammoniacal nitrogen, organic nitrogen, and organic + particle reactive phosphorus. If organic soils are permeable then the risk of leaching of soluble organic and inorganic P, soluble organic N and ammoniacal N is high.
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*Bedrock (Hill Country) Family, shown in grey.

3.5. Pathways and Contaminant Types across the Lower Clutha Delta area

The main pathways of contaminant loss within the Lower Clutha Delta area include overland flow and storm flow, lateral drainage along the contact with the bedrock, deep drainage through the soil profile, and artificial drainage.

Overland flow and storm flow refer to the movement of water just below the surface (stormflow) or over the land (overland flow). This rapidly flowing water easily picks up nutrients and entrains or detaches sediments, pathogens, and organic contaminants. These pathways are common in areas with limited infiltration capacity (slowly permeable topsoils), imperfectly to poorly drained soils, steep slopes, or shallow water tables. The types of contaminants transported by overland flow and storm flow include clay, silt, organic matter, animal wastes (manure), pathogens (e.g., *E.coli*), dissolved and particulate phosphorus, and dissolved and particulate nitrogen. During heavy storms, overland flow becomes a critical pathway as it can transport large amounts of particulate contaminants. A few significant runoff events a year may export the majority of annual losses from a farm to waterways.

Lateral drainage along the contact with bedrock occurs when water infiltrates through the soil and pools at the contact with poorly permeable bedrock. This pathway is most common where soil overlies slowly permeable bedrock in hill country areas. The primary contaminants associated with this pathway are dissolved phosphorus, ammoniacal nitrogen, and potentially nitrate.

Deep drainage through the soil profile involves water infiltrating deeply into the soil, which reduces surface runoff but enhances the susceptibility of the landscape to nitrate leaching into the subsurface. This pathway dominates in lowland areas which are flat and associated with well-drained, coarse-textured soils (e.g., gravel soils). Where the soils are well drained and comprised of gravels, sand, silt or clay, susceptibility to nitrate leaching to an underlying aquifer is elevated. However, these soils are naturally highly effective at removing organic matter, phosphorus, and pathogens. However, if the soils are organic and relatively permeable (hydraulically conductive), these soils are known to have a naturally elevated susceptibility to the leaching of organic and inorganic phosphorus and organic and inorganic (ammoniacal) nitrogen (see section 2.9).

Artificial drainage is common in imperfectly to poorly drained soils or soils impacted by shallow water tables, where artificial drains (V-drains) are used to rapidly discharge runoff or groundwater from the land directly to connected waterways. Surface runoff can carry both particulate and dissolved nutrients, including plant debris, manure and animal urine, along with pathogens, ammoniacal nitrogen and dissolved phosphorus, directly to drains and then directly to streams. Shallow groundwater discharge may conduct elevated concentrations of organic and inorganic P, organic N and ammoniacal-N directly to V-drains.

In summary, each pathway has distinct characteristics that influence the types and amounts of contaminants transported.

- Overland flow and storm flow are particularly significant during episodic events (storms), transporting large loads of particulate and dissolved nutrients, sediments, and organic contaminants.
- Lateral drainage along bedrock often shows strong seasonality in contaminant loss, with nitrate dominating during the wetter and cooler months of the year and dissolved phosphorus and ammoniacal nitrogen during the summer and autumn (as per Glenomaru Catchment water quality assessment).
- Artificial drainage rapidly transports a wide range of contaminants, including ammoniacal nitrogen, dissolved phosphorus, sediments, and pathogens.

Understanding these pathways and their associated contaminants is crucial for managing water quality and contaminant transport in the Lower Clutha Delta area.

3.6. Interpretation of dominant contaminant susceptibility for the coastal floodplain of the Lower Clutha Delta area to inform the selection of sampling methods and technologies

Across the floodplain of the Lower Clutha Delta area, overland flow, artificial drainage, and deep profile drains are the dominant pathways via which water and contaminants leave the landscape.

A dominance of organic and poorly drained soils in conjunction with shallow water tables highlights the susceptibility of this landscape to pathogen, phosphorus, ammoniacal, and organic nitrogen losses in response to runoff. Episodic runoff of water to V-drains may only occur a handful of times per year but is likely a critical pathway of loss from farm to surface waterways. Susceptibility to contaminant loss associated with episodic runoff can be mitigated through good management practices (strategic grazing and buffer zones) and edge-of-field mitigation options such as wetlands, detention bunds, and duck ponds.

Across those low-lying areas characterised by organic soils, shallow water tables, and high densities of V-drains the landscape is naturally susceptible to leaching and loss of both organic and inorganic P, ammoniacal N and organic-N from farm. The V-drains receive groundwater discharge, and the outflows are conducted to connected waterways.

It is important to note that organic soils with low anion storage capacity (low ability to hold on to positively charged ions) are characterised by an elevated susceptibility to leaching of soluble phosphorus and ammoniacal nitrogen (Phillips, 2001; Sapek, 2008). These susceptibilities are exacerbated by waterlogging and seasonal groundwater table fluctuations.

The same organic soils have a natural affinity for nitrogen and are typically characterised by high levels of ammonium associated with the breakdown of peat. The high levels of ammonium increase the solubility of phosphate, contributing to high concentrations of both nutrients in groundwater during periods of low water tables (Sapek, 2008).

An elevated susceptibility to the leaching of phosphorus, ammoniacal, and organic nitrogen to shallow groundwater tables is likely a natural feature of the large areas of the coastal floodplain of the Lower Clutha Delta area. This reflects the very low bulk density of the organic soils and their elevated permeability (hydraulic conductivity) as was observed during the excavation of soil pits and the installation of direct push piezometers.

Practical farm mitigations to reduce ammoniacal nitrogen and organic-N leaching include recognising that organic soils have a natural abundance of ammoniacal and organic nitrogen. This approach takes advantage of the existing nitrogen in the soil, ensuring that additional fertilisers do not exacerbate leaching losses (Vogeler et al., 2015; Jiang et al., 2020). Applying fertilisers in smaller, more frequent doses and synchronising them with crop uptake can help ensure that plants absorb the nutrients more efficiently, reducing the risk of leaching. This is particularly effective in temperate climates where precipitation patterns can influence leaching (Cameron et al., 2013). The use of standoff pads, wintering sheds, or other during periods of water logging can be used to reduce nutrient leaching during the cooler and wetter times of the year.

Planting diverse pastures, including mixtures of ryegrass, herbs, and legumes, can lower nitrogen excretion by dairy cows and reduce nitrogen leaching. Diverse pastures have been shown to produce similar dry matter yields with lower nitrogen content compared to standard ryegrass-clover pastures (Beukes et al., 2014).

Feeding low-protein supplements, such as maize or whole-crop wheat silage, to dairy cows can reduce urinary nitrogen excretion and lower nitrogen leaching. This strategy helps balance the nitrogen content in the diet, leading to more efficient nitrogen use (Wilkinson & Waldron, 2017).

Applying lime to acidic peat soils can help reduce ammoniacal nitrogen leaching by increasing soil pH and enhancing nitrogen retention. This practice can decrease nitrogen volatilisation and improve overall nitrogen use efficiency. Assuming, appropriate pH management, the implementation of cover crops and appropriate crop rotations can help absorb excess nitrogen, reducing the risk of leaching. Cover crops like Trifolium subterranean (subterranean clover) can enhance soil nitrogen retention and reduce weed pressure, contributing to a more sustainable nitrogen cycle (Scavo et al., 2020).

Based on the inherent susceptibilities of the landscape of the Lower Clutha Delta area, the following assessment identifies the most effective sampling technologies and methods for farmers to sample local water quality associated with runoff and soil zone leaching to shallow groundwater.

4. Evaluating Sampling Technologies and Sampling Guidance

To support farmers in understanding the quality of freshwater leaving their properties, particularly in wetland environments with tidal influences, shallow water tables, and organic soils, the following text draws on existing literature and expert knowledge to recommend technologies and methods for sampling freshwater in tidal wetland environments.

4.1. Sampling Technologies and Methods

4.1.1. Electrical Conductivity (EC) Pens

Technical Details

EC pens are handheld devices that measure the electrical conductivity (EC) of water, correlating with its salt content. The measurement of EC for differentiating between freshwater and saline or brackish water is especially useful for identifying freshwater sources on farms and for validating when to sample from a tidal tributary or river.

*Figure 3. Example of a waterproof electrical conductivity tester (Hanna Instruments, July 2024). *Make sure you select an EC pen that has a wide measurement range.*

Advantages

- Low cost, with most sensors ranging between $150 to $500.
- Rapid measurement response, near instantaneous.

Disadvantages

- Limited to guiding sampling times and locations; does not provide direct information about biological or chemical contaminants.
- Requires regular calibration.

Operational Protocols

- Measure conductivity at multiple points along V-drains and streams.
- Conduct sampling during outgoing tides or low tide periods to minimise saline water influence.

Local Application

In the Lower Clutha Delta region, EC pens are invaluable for identifying sites of freshwater discharge across farm (e.g., springs, seeps, open drains), along with validating the suitability of waters for sampling in tidally influenced tributaries, drains, and streams.

For example, measuring conductivity in V-drains and streams helps to identify when freshwater is flowing and when it is influenced by tidal saline water. This ensures that the collected samples are representative of the true freshwater conditions.

4.1.2. Suction Cup Lysimeters

Technical Details

Suction cup lysimeters collect soil pore water without significantly altering the water composition. They are particularly useful in environments where soil conditions do not suit more invasive methods. Ceramic and Teflon are common materials for the cups.

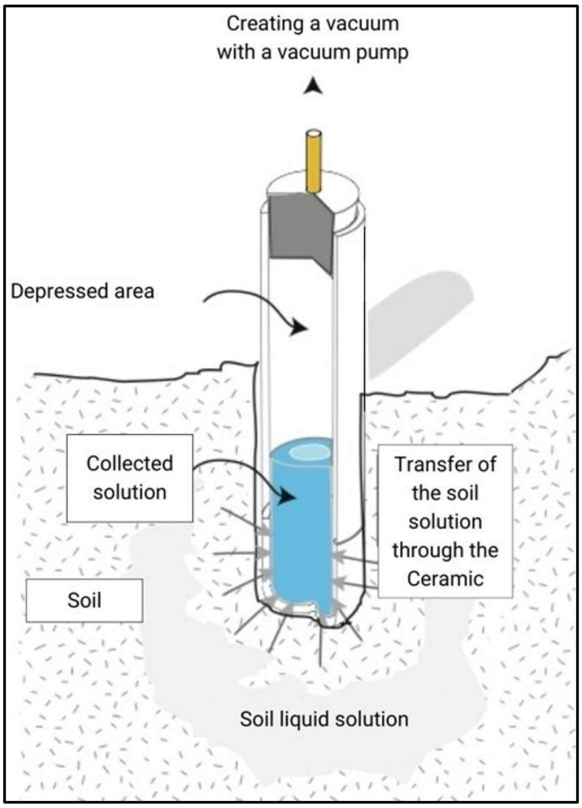

Figure 4 Soil solution suction cup lysimeter example (Ecotech, 2024).

Figure 5 Ceramic suction cup (left), and Teflon suction cup (right) lysimeters for soil water extraction (Ecotech, 2024).

Advantages

- Provide detailed information on soil water content and solute concentrations.
- Less invasive compared to other sampling techniques.
- Useful for informing soil nutrient management, minimising excess nutrient application and loss.

Disadvantages

- Ceramic lysimeters can clog in fine or organic-rich soils and may adsorb solutes.
- Teflon lysimeters have small chambers limiting sample volume and are delicate.
- Only dissolved contaminants are sampled.
- Do not provide information on surface-deposited particulate concentrations or groundwater.

Operational Protocols

- Install the lysimeter at the desired depth.
- Apply a vacuum to draw water into the chamber.
- Retrieve the sample after a certain period, depending on soil moisture and type.

Local Application

In the Lower Clutha Delta area, Teflon lysimeters are more appropriate due to their chemical inertness. However, their fragility and small sample volume may limit their utility in robust environmental monitoring.

These lysimeters can be particularly useful for sampling soil water in organic-rich environments typical of the region, providing data on nutrient leaching and contamination levels. Lysimeters do not provide information on particulates or runoff-derived contaminants.

4.1.3. Passive Diffusion Samplers

Technical Details

Passive diffusion sampler bags (PDBs) work on the principle of diffusion, where contaminants in spring, stream, or groundwater diffuse across a semi-permeable membrane into the sampler bag, which is filled with deionised water. Over time, an equilibrium is established between the concentration of contaminants in the groundwater and the concentration in the deionised water inside the bag. Importantly, the concentration of dissolved water quality contaminants in the PDB provides a picture of the average concentration of contaminants over the deployment period, not a cumulative total.

Figure 6 Example of passive diffusion samplers (CLU-IN, 2024; Solinst, 2024).

PDBs are typically made from a medical-grade, low-density polyethene membrane. This material is selectively permeable, allowing dissolved contaminants to diffuse into the bag while excluding particulates and other larger molecules. The absorbing medium inside PDBs is deionised water, into which contaminants diffuse.

A: Diffusion Bag with Polyethylene Mesh
B: Diffusion Bag Without Mesh
C: Diffusion Bag and Mesh Attached to Bailer Bottom

Passive diffusion bags come ready for deployment from a supplier. The PDB is carefully submerged in a freshwater source (e.g., springs, saturated soils, streams, or groundwater). The local freshwater and the deionised water in the bag are separated by the semi-permeable membrane of the PDB. The semi-permeable membrane allows water molecules and dissolved substances (like nitrate, and dissolved forms of phosphorus) to pass through and mix with the deionised water inside the bag. This process is called diffusion. Diffusion continues until the concentration of dissolved substances inside the bag matches the concentration outside in the environment. This point is called equilibrium. A deployment period of 14 days is recommended to ensure equilibration between the environment and the PDB is reached.

After the deployment period, the PDBs are carefully retrieved. The water inside the PDBs is transferred to appropriate sampling bottles for couriering and analysis by a certified laboratory. This process is typically done by the person who retrieves the bags from the sites. The laboratory that receives the PDB waters analyses them as per any ordinary water sample.

Advantages

- Low-cost.
- Set and forget deployment.
- Low-tech way of understanding average water quality.

Disadvantages

- Limited to dissolved substances; cannot measure particulate-bound pollutants or biological components like *E.coli*, which are likely to be important in the Lower Clutha Delta area.
- Unsuited to areas of saltwater incursion.
- Are fragile and require careful handling and deployment.
- Still need to pay for analysis of the sample.

Operational Protocols

- Install the sampler within the soil, V-drain, stream, or groundwater well.
- Allow sufficient time, c. 14-days, for equilibration with the surrounding water.
- Retrieve and store sampled water in suitable sample bottles for transport to the lab.

Local Application

The dynamic nature of the water table and tidal influences in the Lower Clutha Delta area may limit passive diffusion samplers, which require more immediate and responsive sampling methods.

However, they can be effective for long-term monitoring of specific water quality contaminants in areas that do not experience saltwater incursion (see 2.4.1).

Availability in New Zealand – where to source equipment.

ALS Global provide passive diffusion samplers in New Zealand. Their PDBs are made from high-quality medical-grade, low-density polyethylene and come pre-filled with laboratory-grade, analyte-free, deionised water. ALS offers a variety of PDB options, including standard sizes and custom lengths, designed to withstand harsh field conditions with features such as heat-sealed seams and protective mesh covers.

EON Products also provides a range of passive water samplers, including the Equilibrator™ and HydraSleeve™, which are suitable for various water quality monitoring needs. These samplers are designed for ease of use and cost-effectiveness, making them a viable option for environmental sampling in New Zealand. Note these although these companies focus on the use of PDB for groundwater, PDB have a long history of use for evaluating the average concentration of water quality contaminants in springs, seeps, saturated soils (wetlands), and river systems.

Cost of PDB – does not include laboratory fees for analysis

Small Diameter PDBs (ex GST):

0.75 cm x 45 cm (80 ml capacity):	$34.40
1.3 cm x 45 cm (150 ml capacity, with mesh protection):	$36.20
1.3 cm x 60 cm (250 ml capacity, with mesh protection):	$41.80
1.3 cm x 90 cm (375 ml capacity, with mesh protection):	$46.50

4.45 cm x 45 cm (350 ml capacity):	$42.60
4.45 cm x 60 cm (500 ml capacity):	$48.60
4.45 cm x 90 cm (750 ml capacity):	$83.60

It is possible to purchase your semi-permeable bags and lab-certified deionised water separately. This way you can fill a bag and deploy as and when you need.

4.1.4. Narrow Guage, Direct-Push Piezometers for Targeted Groundwater Sampling

The direct push piezometer method is an effective technique for precision sampling of shallow groundwater. This method is particularly useful in areas where traditional drilling methods face challenges, such as collapsing sediments or difficult ground conditions. What follows is an explanation of the principle, process, and considerations for using narrow gauge, direct push piezometers, supplemented with information from relevant technical documents.

Figure 7 Example of a lost cone and steel casing used for direct push piezometer installation.

Principle

The lost cone method involves driving a steel casing into the ground using a drive cone and pneumatic hammer. The casing is left in place while the HDPE tubing (or stainless, or Teflon) is installed inside it. The HDPE tube includes one or more screens and slotted sections of the tubing that allow groundwater ingress. The screened component of the piezometer tubing is normally fitted with a nylon sock or fine stainless-steel mesh to further exclude sand and silt and limit the clogging of slots. Once the piezometer is in place, the casing is removed, leaving the piezometer in the borehole. The borehole is then backfilled and sealed to prevent contamination and ensure accurate measurements.

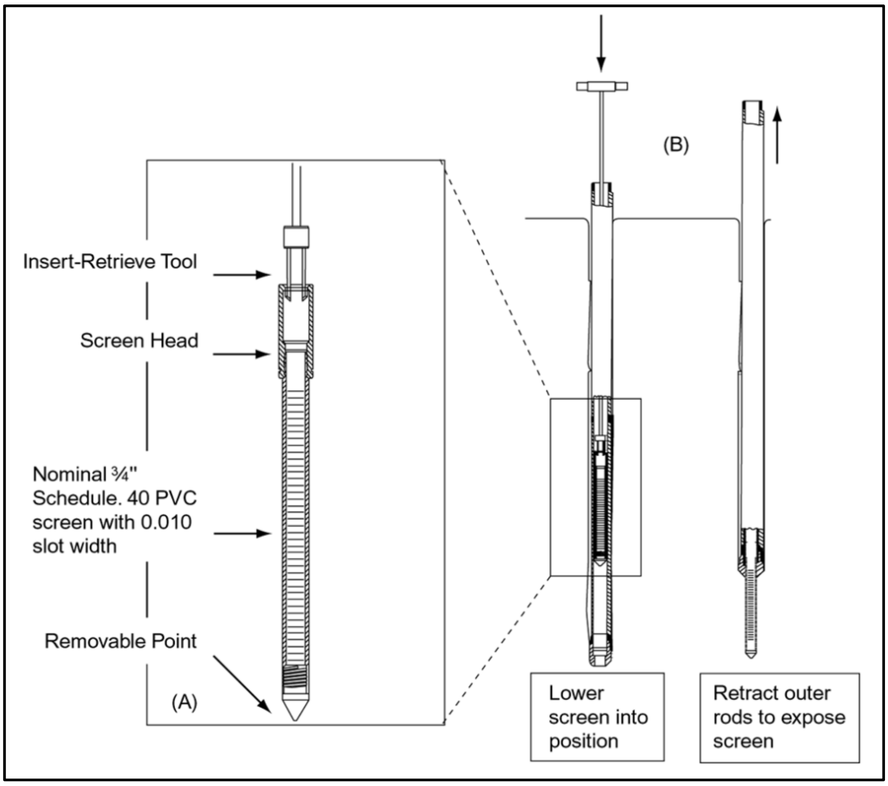

Figure 8, (A). Internal tubing (HDPE piezometer tube, screened tubing, and nylon filter sock) for insertion into the driven steel casing system. (B). The internal tubing is lowered through the steel casing. Once the internal tubing (screen) is at the base of the outer casing. The casing is retracted as the screen is held in position for accurate placement (U.S. Environmental Protection Agency, 2005).

Installation Process

Refer to Figures 7 and 8.

1. **Driving the Casing**: A drive cone is used to punch a steel casing (typically 40mm x 50mm diameter) into the ground. The casings are one metre long and are screwed together to reach the required depth, which can be up to 10 metres depending on ground conditions.

2. **Installing the Piezometer:** A high-density polyethene (HDPE) piezometer pipe (25mm x 32mm) is installed inside the steel casing. The piezometer includes screened pipe sections (with 0.3mm slots) in the saturated zone and blind pipe sections toward ground level. A nylon or fine stainless-steel mesh sock is inserted over the slotted screen and secured in place.

3. **Extracting the Casing:** The steel casing is carefully extracted, leaving the piezometer in place within the borehole.

4. **Backfilling and Sealing:** The borehole is backfilled with washed sand (normally quartz), and the upper section is sealed with bentonite (a swelling clay) clay to prevent surface water from infiltrating and moving down along the annulus of the piezometer to the groundwater table. A concrete monument for ‘well-head’ is installed around the piezometer tube, often with a steel pipe off-cut cemented in placed within which the protruding piezometer head is secured. A cap is often added to the steel wellhead tube.

Figure 9 Extraction of steel casing (left), and piezometers installed at various depths on the Pamu Landsdown farm during the field day.

Landsdown Piezometers at the Field Day

Piezometers were installed at various depths at the Landsdown property during the field day. The Landsdown team have installed an electric fence about the piezometers and a concrete monument is to be poured to protect the wellheads shown in Figure 9. The piezometer tubes will be trimmed to within 300 mm of the wellhead and a steel off-cut metal pipe, ~50 mm in diameter and 400 mm long, inserted into the cement to protect the completed piezometer tubes. The piezometer can then be capped with a steel lid that can be screwed into the steel pipe.

Key Piezometer Considerations

- **Ground Conditions:** large boulders, shallow bedrock, or other obstacles can cause refusal, slowing down the process. In such cases, alternative methods like window sampling gouges may be required for the first meter (as demonstrated on the field day).

- **Site Logistics:** Factors such as travel between locations, health and safety inductions, and service clearances onsite can impact the efficiency and cost of the installation process.

- **Protectio**n: It is essential to protect the installed piezometers. Electric fences or monuments over the piezometers can help prevent damage.

Cost Estimate

Given the relatively easy ground conditions of the Lower Clutha Delta area, it is estimated that between six to eight driven piezometers can be installed per day for $3,500/day. There is an additional fee of $35 per meter for installation materials and approximately $200/wellhead monument.

Under ideal conditions, the cost per piezometer ranges between $780 - $950.

Advantages

- Provides precise, depth-specific sampling.
- Robust and secure.
- Cost-effective, once installed they provide a secure sampling location that is likely to last for decades.
- Relevant to one of the main pathways of contaminant loss across the Lower Clutha Delta area.

Disadvantages

- Installation requires mechanical equipment and skilled operation.
- Less effective in areas with large boulders or shallow bedrock.

Local Application

Given the low-lying nature of the catchment, relatively soft sediments, and proximity to tidal influences, direct-push technology is ideal for accessing and monitoring groundwater quality reflecting the drainage of soil waters to the uppermost part of the shallow aquifer system. Shallow groundwaters, those immediately beneath a farm that is used exclusively for monitoring, are more likely to reflect local contributions from land use than deeper wells and pumped wells, which may draw water from many kilometres away. The advantage of this approach is the ability to test the salinity of the groundwater (see 2.4.1) as the piezometer is being driven. The latter is ideal for isolating freshwater.

Important to Note

Importantly, any direct push piezometer should be constructed according to the current standard for drilling and construction of groundwater bores in New Zealand as per NZS 4411:2001 -Environmental Standard for Drilling of Soil and Rock if it is to be considered fit for sampling. Failure to follow the standard increases the risk of localised contamination by animal wastes, thereby generating an unrealistically poor picture of local groundwater quality. In addition to infilling and sealing, we strongly recommend that any driven bores be in elevated areas, relative to the surrounds, as ponded water in the vicinity of a bore, even one constructed to National Standards, increases the risk of localised contamination. Standard NZS 4411:2001 includes requirements for bore casing, sealing, and backflow prevention mechanisms to ensure groundwater protection (Standards New Zealand, 2003).

Table 3 Tabular Summary of Sampling Technologies and Methodologies for Lower Clutha Delta

Device	Technical Details	Advantages	Disadvantages	Operational Protocols	Local Application
Electrical Conductivity (EC) Pens	EC pens are handheld devices that measure the electrical conductivity of water, which correlates closely with its salt content. Measurement of EC easily differentiates between freshwater and saline or brackish water, especially in tidal areas.	Excellent tool for identifying freshwater discharges on farms or assessing tidal influence. Simple but effective tool for identifying optimal locations to sample on the farm.	Does not provide direct information on biological or chemical contaminants, only indicates where to sample.	Measure the conductivity of waters discharging via springs, seeps, open drains, farm tributaries, and shallow aquifers; For large, tidally influenced rivers or streams, sampling should ideally be conducted during outgoing tides or low tide periods to minimise the influence of saline water.	Given the potential for saltwater influence, EC pens are invaluable for identifying the locations of freshwater discharges on farms and for the timing of sampling, ensuring collected samples represent only freshwater.
Suction Cup Lysimeters	Suction cup lysimeters employ a porous material or membrane for collecting soil pore water without significantly altering the water composition. Common materials include ceramic and Teflon, with ceramic suited for nitrate sampling and Teflon for a wider range of contaminants.	Provide detailed information on soil water content and solute concentrations; Less invasive; Direct measure of soil water contaminants	Ceramic lysimeters can clog easily in fine or organic-rich soils and may adsorb solutes; Teflon lysimeters have small sample volumes and are delicate; Limited to dissolved substances and easily damaged by livestock, cultivation, or farm machinery. Very technical processes that require specialist training and expertise.	Install the suction cup at the desired depth; Apply a vacuum to draw water into a chamber; Retrieve the sample after a period, depending on soil moisture and type; Careful handling and precise vacuum control are necessary.	High organic content and fine sediments in Lower Clutha Delta may cause clogging and sample contamination, especially with ceramic lysimeters; Teflon lysimeters are more appropriate due to chemical inertness but their fragility and small sample volume may limit their usefulness.

Device	Technical Details	Advantages	Disadvantages	Operational Protocols	Local Application
Passive Diffusion Bag (PDB)	Passive diffusion samplers use a semi-permeable membrane to allow contaminants to diffuse into the sampler, filled with deionised water, providing long-term monitoring of groundwater pollutants.	Low-cost and Low-tech; Require minimal maintenance; Useful for understanding average water quality in almost any setting e.g., spring, seep, V-drain, shallow aquifer.	Limited to dissolved substances; May be fragile, so careful handling is required. Somewhat unknown or not typically used in NZ although widely applied in US and Europe.	Place the PDB within the soil, V-drain, or stream; Allow sufficient time (approx. 14 days) for equilibration; Retrieve and store sampled water in suitable bottles for transport to the lab	Dynamic water table and tidal influences may limit effectiveness; Suitable for long-term monitoring of specific water quality contaminants in non-saline areas only; Availability from ALS Global and EON Products in New Zealand, with options for self-filling.
Direct-Push Groundwater Piezometer	These samplers involve mechanically hammering a steel casing and inserting a sampling tube to extract groundwater samples from specific depths, especially suited to areas with shallow water tables and relatively soft (unconsolidated) sediments.	Precise, depth-specific sampling; low cost-to-value ratio; Represents local conditions; Robust and enduring solution.	Requires mechanical equipment and skilled operation; Must be installed to NZ Standards if to be a valid source of data; Not suitable for areas with shallow bedrock or large boulders.	Target the shallowest part of the aquifer system (uppermost); Follow NZS 4411:2001 standards for bore construction and sealing to prevent contamination; Sample waters using NZ Groundwater sampling protocol.	Ideal for accessing and monitoring groundwater most likely to represent farm-derived inputs; Enables testing salinity during installation to isolate freshwater; Must be installed to NZ standards to avoid localised contamination from surface water or animal waste.

4.2. Recommended Tidal Wetland Water Quality Sampling Equipment and Strategy

Given the significance of runoff (overland flow) and the prevalence of particulate matter (silt, clay, organic matter, pathogens, etc.) across the Lower Clutha Delta area, coupled with the technical challenges associated with suction cup lysimeters and Passive Diffusion Bags (PDB), the recommended strategy employs both EC pens and direct-push piezometer technology for a comprehensive approach to water quality monitoring**.**

This integrated approach allows for adaptive management strategies that respond to water table fluctuations, water logging, runoff events, and tidal changes, which can be used to generate robust data for farmers across the Lower Clutha Delta area.

4.3. Guide to Using an EC Pen for Discriminating Freshwater from Brackish or Salt-Affected Waters

An Electrical Conductivity (EC) pen is a simple, cost-effective tool used to measure the electrical conductivity of water, which correlates closely with its salt content. This tool is particularly useful for identifying freshwater sources on farms, such as springs, seeps, open drains (V-drains), small tributaries, and shallow groundwater. Additionally, EC pens can help distinguish the salt content of tidal streams, providing valuable information for water quality monitoring.

4.4. Electrical Conductivity Ranges

When identifying source water utilising an EC pen, typical results would be interpreted as:

- Freshwater (Coastal Surface Waters): 100 to 300 micro siemens per centimetre (μS/cm)
- Freshwater (Groundwaters): 100 to 400-600 μS/cm
- Brackish Water: Above 750 μS/cm
- Seawater: Above 30,000 μS/cm

Note that EC conductivity may vary between locations due to the different environmental conditions e.g., different rock types or soils. Groundwaters typically have higher EC values than surface waters; spring waters (groundwater-derived) should have EC values more typical of groundwater.

4.3.2 Using the EC Pen

Preparation

- Ensure the EC pen is calibrated according to the manufacturer’s instructions. Calibration should be done using standard solutions of known conductivity.

Field Sampling

- Identify Possible Sampling Locations: Identify potential freshwater sources such as springs, seeps, open drains, or small tributaries on farm.

- Tidal Streams: For tidal streams, sample during different tidal stages (low tide and high tide) to understand the variation in salt content. Use tide tables to inform when to sample.

Measurement Procedure

- Immerse the Probe: Submerge the probe of the EC pen into the water sample – a food-grade plastic jug is often recommended; ensure you rinse the jug 3x with the sample water before testing to minimise contamination from other sites. Ensure the probe is fully immersed and free of air bubbles.
- Stabilisation: Wait for the reading to stabilise. This usually takes a few seconds.
- Record the Reading: Note the EC value displayed on the pen.

Interpreting Results

- Compare the recorded EC values with the standard ranges:
  - 100 to 300 µS/cm is considered the most typical of coastal freshwaters (surface waters).
  - 100 to 400-500 µS/cm for spring or groundwaters.
  - Above 700 µS/cm indicates brackish water, suggesting the mixing of fresh with salt water.
  - Above 30,000 µS/cm indicates seawater or high salt content.

Identify Freshwater Sources

Use the EC pen readings to locate and map freshwater sources on the farm. Springs, seeps, and open drains with EC readings within the freshwater range are likely good sources of freshwater.

Monitor Tidal Influence

For tidal streams, take multiple readings at different tidal stages. Record EC value, tide status, time of day and date. Note the variations in EC values to distinguish between freshwater influx and tidal saltwater.

Practical Tips

- **Sampling Times:** Conduct sampling during low tide to minimise the influence of saline water.
- **Multiple Measurements:** Take several measurements at different points along V-drains and streams to identify freshwater influx points accurately.
- **Regular Calibration:** Regularly calibrate the EC pen to ensure accuracy, especially before extensive fieldwork.
- **Environmental Factors:** Be aware of environmental factors such as recent rainfall, which can dilute salt concentrations and affect readings.

Using an EC pen is an effective and straightforward method for farmers and catchment group members to discriminate between fresh, brackish, and salt-affected waters. This tool aids in accurately identifying and mapping freshwater sources on farms, contributing to better water quality monitoring and management practices.

4.5. Surface Water Sampling Protocols

Surface water quality sampling in New Zealand involves a systematic approach to ensure accurate, consistent, and legally defensible data collection. Once suitable freshwater sampling sites have been identified sampling can commence. Following established protocols helps to maintain high standards and supports environmental monitoring and management.

Minimum Regime

We recommend sampling freshwater springs, V-drains and small farm tributaries under a variety of flow and climatic conditions. The frequency of sampling is up to the community, but a minimum of 7 to 8 samples yearly is recommended:

- 1x sample at low flow, peak summer or peak dry weather conditions;
- 2x sample of a winter runoff (overland flow) event and if relevant;
- 1 x sample of a summer runoff event, and;
- 1x sample for each season.

<u>Never put yourself at risk sampling surface water</u>.

If possible, the use of a field sensor capable of measuring Temperature, EC, DO (Dissolved Oxygen), and ORP (Oxygen Reduction Potential) is advised, although not essential. If only an EC pen is used, record the type of event being sampled, water temperature and EC of the sample.

Materials and Equipment

- Use clean, non-reactive materials such as glass or high-density polyethene (HDPE) for sampling containers.
- Ensure all equipment, including containers, is pre-cleaned and stored properly to avoid contamination.
- Use manual grab samplers, e.g., a bottle on a grab pole, for direct collection of water samples.
- Never put yourself at risk of slipping or falling into a waterway.

Sampling Procedure

- **Sampling Point Selection:** Using knowledge of your farm and the EC pen choose locations that represent the likely quality of water leaving your property.
- **Frequency** (see above): Depends on the catchment group's objectives; routine monitoring might require monthly or quarterly samples, while event-based sampling focuses on specific incidents like rainfalls or spills.
- **Timing:** Consistency is important. If possible collect samples at the same time of day to account for diurnal variations.

Sampling Methods

- **Physical-Chemical Sampling:** Collect water samples for analysis of parameters such as pH, temperature, dissolved oxygen (DO), electrical conductivity (EC), and nutrients.
- **Pathogen Sampling:** Use sterile techniques to collect samples for microbial analysis, ensuring no contamination. *E.coli* samples must be with the lab within 24 hours.

Sample Handling and Preservation

- **Transport:** Immediately place samples in coolers with ice or refrigeration packs to maintain a temperature of 4°C during transport to the laboratory.
- **Stabilisation and Storage:** Some samples may require chemical preservatives to stabilize specific analytes. Follow guidelines for preservatives and storage duration to prevent degradation.

What should be analysed by the laboratory?

We recommend that surface water samples be analysed for Total Nitrogen, Total Phosphorus, Dissolved Reactive Phosphorus, Total Kjeldahl Nitrogen, Ammoniacal Nitrogen, Nitrate and Nitrite Nitrogen, Turbidity, and *E.coli*.

This suite of measures will provide insight into the type and abundance of the different contaminant forms in local surface waters before reaching the Koau and Matau branches of the Clutha River and to a lesser extent the Puerua Stream.

Training and Expertise

While anyone can be trained in surface water sampling, it is a specialised area. Many qualified professionals are available to undertake sampling, ensuring it is done correctly and efficiently. Many farmer-led catchment groups across New Zealand have implemented their water quality monitoring programme. The best (most rigorous) of these programmes have utilised expert technicians for sampling of surface and groundwaters.

4.6. Guide for using and sampling from direct drive groundwater wells for targeted sampling of shallow groundwater

Direct push piezometers are considered a valuable access point for evaluating shallow groundwater across the Lower Clutha Delta area. They provide a precise and cost-effective method for sampling shallow groundwater, particularly in regions with challenging ground conditions. Here is a simplified overview of the typical groundwater sampling protocol using direct push piezometers.

Once a piezometer has been installed and developed, regular sampling includes:

- **Dipping the Well:** Before sampling, the water level in the piezometer is measured using a water level meter to ensure accurate readings. Groundwater quality commonly fluctuates with water level.

- **Well Purging:** The well-being purged by a small, peristaltic pump is recommended, to remove stagnant water, ensuring the sample represents the actual groundwater. Using a flow cell to monitor temperature, electrical conductivity (EC), and dissolved oxygen (DO) helps determine when the piezometer has been purged. It is critical not to over-pump the well when seeking to sample water, low-flow sampling techniques are recommended.

- **Sample Collection:** Once the well is purged (e.g., DO, EC, and Temp have stabilised), samples are collected directly from the piezometer. It is essential to follow proper sampling techniques to avoid contamination and ensure the samples are of high quality.

    - A field sensor capable of measuring Temperature, EC, DO, and ORP is recommended.

    - The groundwater samples should be analysed for Total Nitrogen, Total Phosphorus, Total Kjeldahl Nitrogen, Ammoniacal Nitrogen, Nitrate and Nitrite Nitrogen, and Dissolved Reactive Phosphorus. This suite of measures will provide insight into the type and abundance of the different contaminant forms in local groundwaters.

Training and Expertise

While anyone can be trained in ground water sampling, it is a specialised area. Many qualified professionals are available to undertake sampling, ensuring it is done correctly and efficiently. Many farmer-led catchment groups across New Zealand have implemented their water quality monitoring programmes. The best (most rigorous) of these programmes have utilised expert technicians for sampling of surface and groundwaters.

4.7. Considerations for Farm and Catchment-Wide Water Quality Monitoring

It is important to emphasise that any data collected by a catchment group is their property. It is for the catchment group to decide whether this data is to be shared with anyone. Water quality data collected at farm and small catchment scales is a powerful asset for most rural communities.

Where rural communities or individual farmers have initiated local water quality monitoring, it has been used to monitor progress towards improved water quality outcomes, support funding applications, prioritise areas for investment in mitigations, and support consenting and compliance-related activities. Ultimately, a robust local scale monitoring network can be used to inform both day-to-day and longer-term farm and catchment management. For example, identifying areas that channel runoff and high contaminant loads during a storm event can be used to inform mitigation activities.

Some catchment groups have also used their water quality monitoring data to better inform their understanding of how the landscape controls different water quality outcomes. For example, one catchment used detailed groundwater sampling to identify the main area of nitrate leaching into an aquifer. Having located the area, they studied the soils and aquifer system and used this knowledge to avoid wintering and cultivation in these areas, shifting wintering to less leaky soils and employing direct drilling methods to minimise mineralisation and nitrate production.

Consequently, catchment groups, individual farm business, irrigation companies, and other rural enterprises have implemented their water quality sampling programmes to better inform their understanding of local water quality, given that regional scale monitoring networks administered by regional councils are not designed to provide farm scale or even small catchment scale information on water quality. Regional council monitoring networks are valuable for assessing broad patterns and are often focused on larger streams and deeper parts of regional aquifer systems. Whilst incredibly valuable for regional reporting of state and trend they are seldom sufficiently resolved to provide relevant information to local farming communities seeking to better understand the quality of waters leaving farms.

5. Conclusion

With some simple tools, there appears to be little barrier to locally targeted water quality monitoring across the Lower Clutha Delta area (Puerua-Waitepeka Catchment Group).

By utilising EC pens and direct push piezometers, farmers can easily identify local freshwater sources originating on farms and monitor the quality of local waters that end up in the Puerua Stream, Koau and Matau branches of the Clutha River, and ultimately the ocean. Low-cost EC pens are particularly suited for identifying freshwater discharges on farms and distinguishing between freshwater and saltwater, which is crucial given the area's proximity to tidal influences.

Rural communities monitoring their local water quality is a growing trend in New Zealand. Many catchment group members, individual farmers, and larger agricultural business entities note that high-quality data empowers them to manage their land more effectively, ensuring sustainable agricultural practices and minimising environmental impacts. The insights gained from regular monitoring can guide investments in good management and mitigation actions, such as improving drainage systems, optimising fertiliser use, and implementing buffer zones to reduce runoff.

Moreover, the data collected from these monitoring efforts is proprietary to the farmers and the catchment group, ensuring that they retain control over how the information is used. This autonomy encourages community involvement and fosters a sense of ownership and responsibility towards local water resources. The data also supports consenting and regulatory compliance through the provision of locally specific data. The latter is critical given most regional monitoring networks are not designed to provide farm or small catchment scale water quality detail.

By establishing a robust and localised water quality monitoring network, the Puerua-Waitepeka Catchment Group can make informed decisions that benefit both agricultural productivity and environmental stewardship. This proactive approach not only safeguards the health of local waterways but also enhances the long-term sustainability of farming practices in the Lower Clutha Delta area.

For further information on the natural susceptibility of your landscape please explore www.landscapeDNA.org.

If you have any questions about any of the information or recommendations contained within this report, please do not hesitate to contact us.

Kind regards,

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6. Appendix A Records of Field Day 15th May 2024

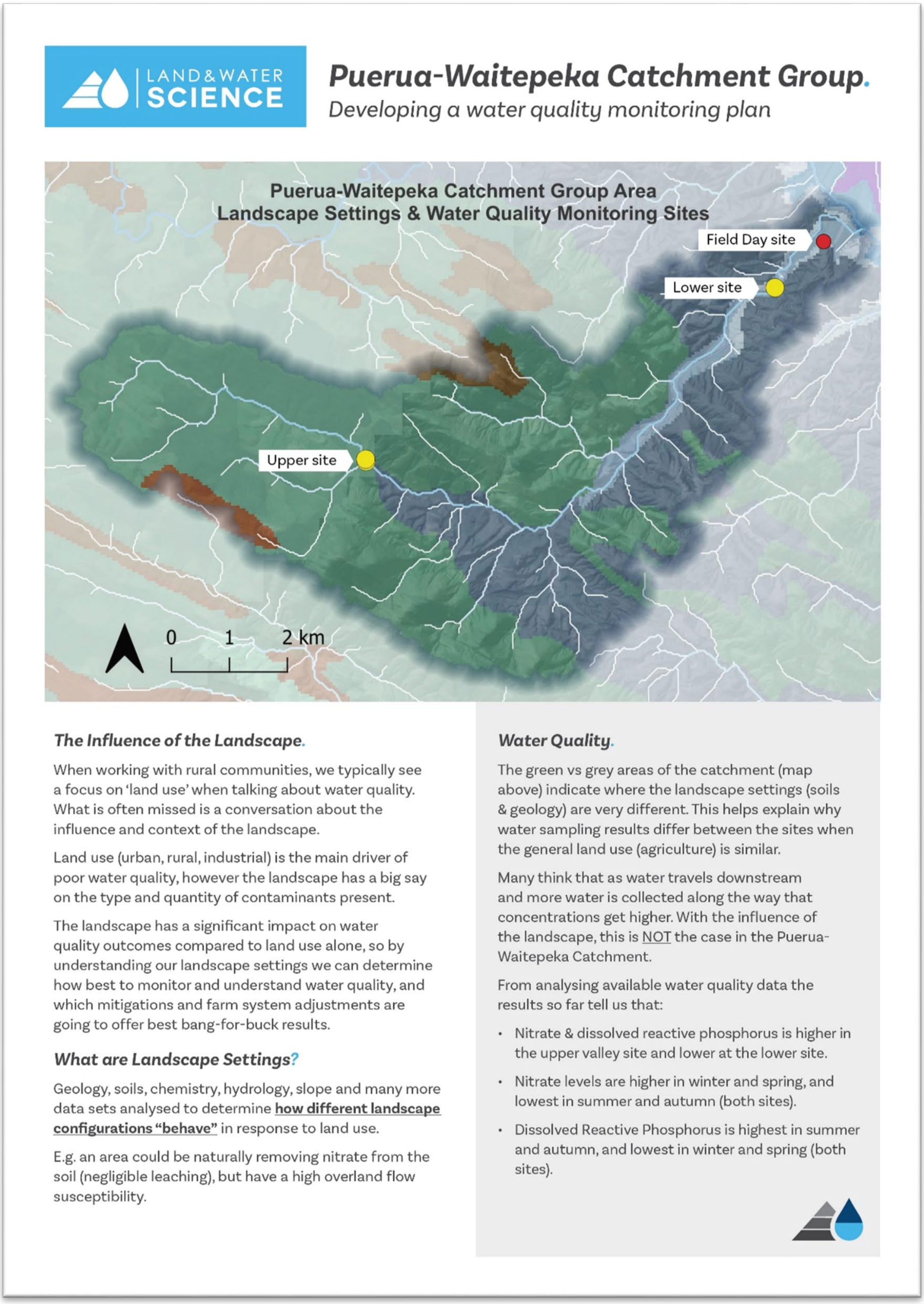
Driven piezometers were installed in a “nested” formation at 3 different depths by Dirk Van Walt of Van Walt Ltd.

Nested direct push piezometers were installed during the field day.

Dr. Clint Rissmann (Land and Water Science) discusses water sampling methodologies and instrumentation that are applicable and relevant for this catchment at the field day.

Dirk Van Walt (Van Walt NZ), installing a direct push piezometer at Landsdown during the field day

7. Appendix B Field day Handout



Puerua-Waitepeka Catchment Group.

Developing a water quality monitoring plan

The Influence of the Landscape.

When working with rural communities, we typically see a focus on 'land use' when talking about water quality. What is often missed is a conversation about the influence and context of the landscape.

Land use (urban, rural, industrial) is the main driver of poor water quality, however the landscape has a big say on the type and quantity of contaminants present.

The landscape has a significant impact on water quality outcomes compared to land use alone, so by understanding our landscape settings we can determine how best to monitor and understand water quality, and which mitigations and farm system adjustments are going to offer best bang-for-buck results.

What are Landscape Settings?

Geology, soils, chemistry, hydrology, slope and many more data sets analysed to determine **how different landscape configurations "behave"** in response to land use.

E.g. an area could be naturally removing nitrate from the soil (negligible leaching), but have a high overland flow susceptibility.

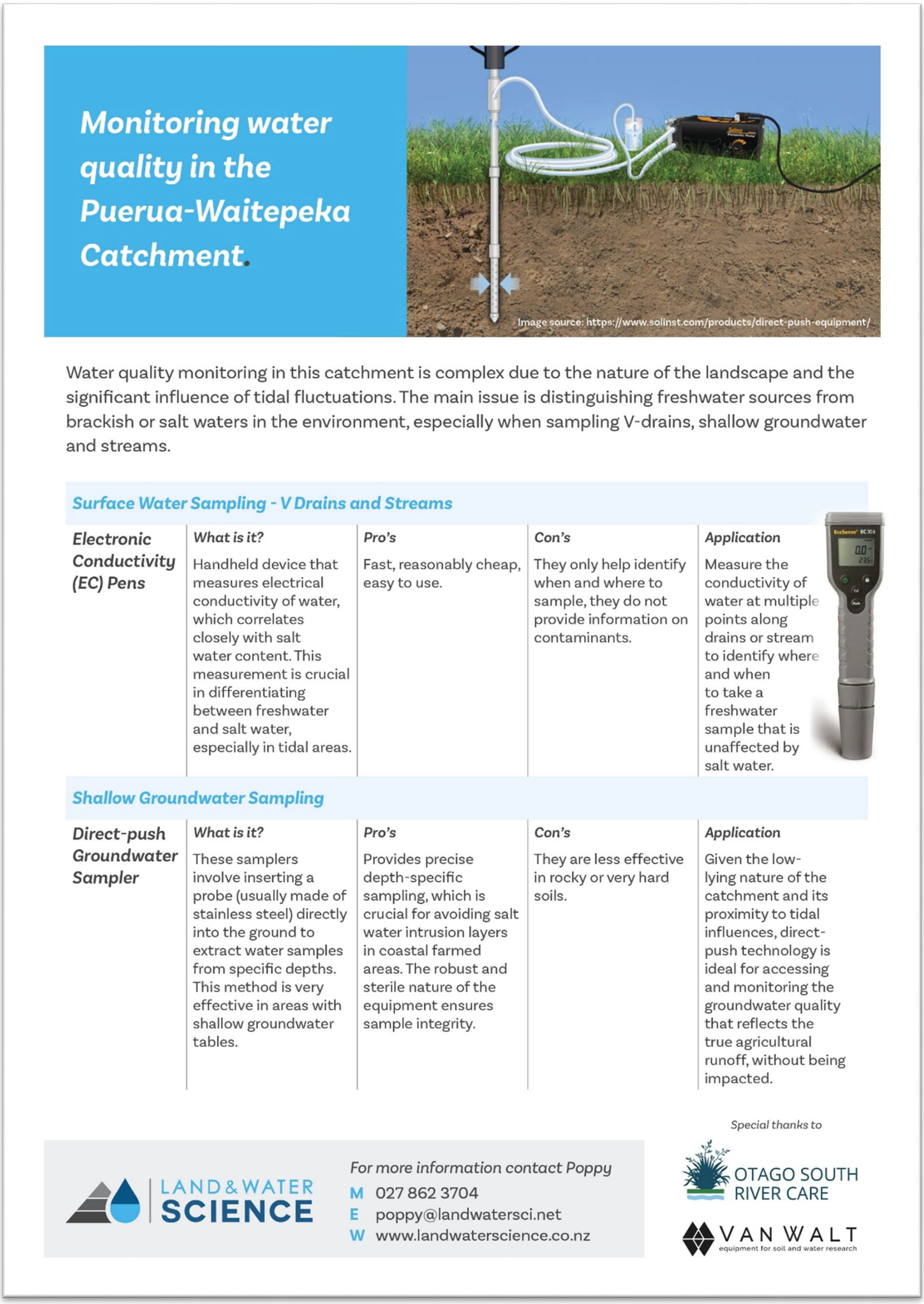
Water Quality.

The green vs grey areas of the catchment (map above) indicate where the landscape settings (soils & geology) are very different. This helps explain why water sampling results differ between the sites when the general land use (agriculture) is similar.

Many think that as water travels downstream and more water is collected along the way that concentrations get higher. With the influence of the landscape, this is NOT the case in the Puerua-Waitepeka Catchment.

From analysing available water quality data the results so far tell us that:

- Nitrate & dissolved reactive phosphorus is higher in the upper valley site and lower at the lower site.
- Nitrate levels are higher in winter and spring, and lowest in summer and autumn (both sites).
- Dissolved Reactive Phosphorus is highest in summer and autumn, and lowest in winter and spring (both sites).



Monitoring water quality in the Puerua-Waitepeka Catchment.

Image source: https://www.solinst.com/products/direct-push-equipment/

Water quality monitoring in this catchment is complex due to the nature of the landscape and the significant influence of tidal fluctuations. The main issue is distinguishing freshwater sources from brackish or salt waters in the environment, especially when sampling V-drains, shallow groundwater and streams.

Surface Water Sampling - V Drains and Streams

	What is it?	Pro's	Con's	Application
Electronic Conductivity (EC) Pens	Handheld device that measures electrical conductivity of water, which correlates closely with salt water content. This measurement is crucial in differentiating between freshwater and salt water, especially in tidal areas.	Fast, reasonably cheap, easy to use.	They only help identify when and where to sample, they do not provide information on contaminants.	Measure the conductivity of water at multiple points along drains or stream to identify where and when to take a freshwater sample that is unaffected by salt water.

Shallow Groundwater Sampling

	What is it?	Pro's	Con's	Application
Direct-push Groundwater Sampler	These samplers involve inserting a probe (usually made of stainless steel) directly into the ground to extract water samples from specific depths. This method is very effective in areas with shallow groundwater tables.	Provides precise depth-specific sampling, which is crucial for avoiding salt water intrusion layers in coastal farmed areas. The robust and sterile nature of the equipment ensures sample integrity.	They are less effective in rocky or very hard soils.	Given the low-lying nature of the catchment and its proximity to tidal influences, direct-push technology is ideal for accessing and monitoring the groundwater quality that reflects the true agricultural runoff, without being impacted.

LAND & WATER SCIENCE

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Special thanks to

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VAN WALT
equipment for soil and water research

8. Appendix C Glenomaru Valley, Water Quality Analysis Summary Video

The link below takes the reader to a summary video discussing our findings on what is happening in the Puerua-Waitepeka Catchment in terms of landscape influence and water quality outcomes.

https://youtu.be/BWyX6sKrTk4