Hedgehope Makarewa Catchment Group Project

Summary report of landscape data | Claymore Dairies

Executive Summary

Many farmers are actively seeking opportunities to reduce their environmental impact to meet their goals, regulations, consumer and community expectations.

Land and Water Science Ltd (LWS) have undertaken a new, high-resolution physiographic approach to mapping the inherent and varied susceptibility of the landscape to land use activities at property scales. Landscape variability has a significant role in governing the type and severity of water quality outcomes, even when land use is the same. Landscape variability also significantly affects soil greenhouse gas (GHG) production.

Linking the landscape susceptibility and farm system allows farmers to target mitigations and contaminant load reductions to reduce their environmental impact. This report summarises the datasets but does not deliver an integrated plan for mitigating environmental challenges. Instead, this data summary report seeks to *present* the key data and insights that can be used by the landowners and their farm systems specialists/advisors to apply mitigation opportunities to the identified areas.

Method

LWS, i. prepared the preliminary landscape data report which was supplied to the landowners of Claymore Dairies; ii. met with the landowners on farm; iii. walked the property; iv. sought the landowner's perspective on the environmental challenges they face, and; v. discussed their preferred pathway for mitigating environmental risk.

The Farm

The property is located at the end of Te Tipua Valley Road, Brydone, Southland. The farm is ~ 411 hectares in size, operates as a dairy farm, and has the Titipua Stream forming the eastern boundary of the property. The property is a mix of low relief and rolling country, with a mean slope of 6.9° and a range of 1 to 87° (reflecting steep sides of a drainage ditch), and lies between 50m and 115m Relative to Sea Level (RSL).

Environment Southland designates the property as occurring within the Makarewa Groundwater Management Zone.

The Catchment

Claymore Dairies is located within the Titipua sub-catchment and the eastern edge of the Hedgehop-Makarewa Catchment. The Hedgehope-Makarewa catchment is located within the greater Oreti catchment in Southland, New Zealand. It extends from the divide draining the southern side of the Hokonui Hills to the north of Invercargill. The total area of the catchment is approximately 111,940 hectares (ha).

The Titipua sub-catchment accounts for 14,512 hectares of land, or 13% of the wider catchment, and is drained by the Titipua Stream. This is fed by a diverse network of smaller streams (including College Stream), combining to run in a south-west direction through the sub-catchment. At the very bottom of the catchment the Titipua Stream converges with the Hedgehope Stream, which subsequently joins the Makarewa River towards the lower end of Hedgehope-Makarewa Catchment. The Makarewa River flows in a south-west direction before joining the Ōreti River and discharging to the sea via the New River Estuary at Invercargill.

Landscape Susceptibility

The landscape datasets generated for Claymore Dairies have been presented. The landscape package includes a farm-specific model of surface drainage, terrain ruggedness, and high-resolution (3 cm) drone captured photographic images. It is important to emphasise that the susceptibility models do not consider land use nor any existing management practices of physical mitigations (e.g., sediment traps, wetlands) already in place. As such, landscape susceptibility models only identify the inherent or natural susceptibility of the land, they do not indicate that the areas of elevated susceptibility are losing high rates of contaminants.

Within the context of the above paragraph, the main landscape susceptibilities associated with the property are thought to include:

i. Moderate NNN loss via the surface water or subsurface drainage network and yet low groundwater NNN susceptibility;

ii. Low mass wasting (slips, slumps, earthflows) and erosion (stream channel incision) susceptibility;

iii. Moderate PP, TKN, and microbial susceptibilities due to fine textured and poorly drained soils and areas of rugged terrain that favour runoff, and;

iv. A moderate soil-zone nitrous oxide susceptibility due to fine textured and poorly drained soils.

Of the above susceptibilities, PP, TKN, and a component of likely microbial losses could be reduced through managing runoff and direct discharge to the Titipua Stream. Nitrate-nitrite-nitrogen is best managed by reducing excess NNN in the soil before and during late autumn and early spring. With regards to soil nitrous oxide, several inhibitors are being trialled within the agricultural industry at present.

1. Objective

In the following landscape data report, existing soil and geological datasets and the physiographic classification provided by LandscapeDNA are used to provide a generalised overview of the farm setting before the presentation of a high-resolution and data-driven assessment of landscape susceptibility. Here the objective is to move beyond the low resolution of historic soil and geological maps towards property, paddock, and sub-paddock scale assessment of landscape susceptibility. The aim is to provide landscape knowledge capable of supporting a spatially targeted and highly efficient approach to mitigating soil GHG and water quality-related losses.

2. The Farm Landscape

2.1 Site description

The property is located at the end of Te Tipua Valley Road, Brydone, Southland. The farm is ~ 411 hectares in size, operates as a dairy farm, and has the Titipua Stream forming the eastern boundary of the property.

From the LandscapeDNA website (www.landscapeDNA.org), the property staddles two dominant physiographic environments. Along the eastern side of the property is the Reducing Soil Oxidising Aquifer family, and along the western side of the property is the Reducing Soil and Aquifer family; plus a small area of Strong Bedrock family in the south-west corner of the property (Fig. 1). The physiographic classes identify that any aquifers underlying the property are unlikely to be susceptible to nitrate leaching losses. Rather, the loss of nitrate via the drainage network, including via sub-surface artificial drainage, is more relevant for Claymore Dairies. The remainder of contaminants, as particulate phosphorus, organic and ammoniacal nitrogen, sediment, and microbes are more likely to be lost in response to surface runoff and via the subsurface artificial drainage network.

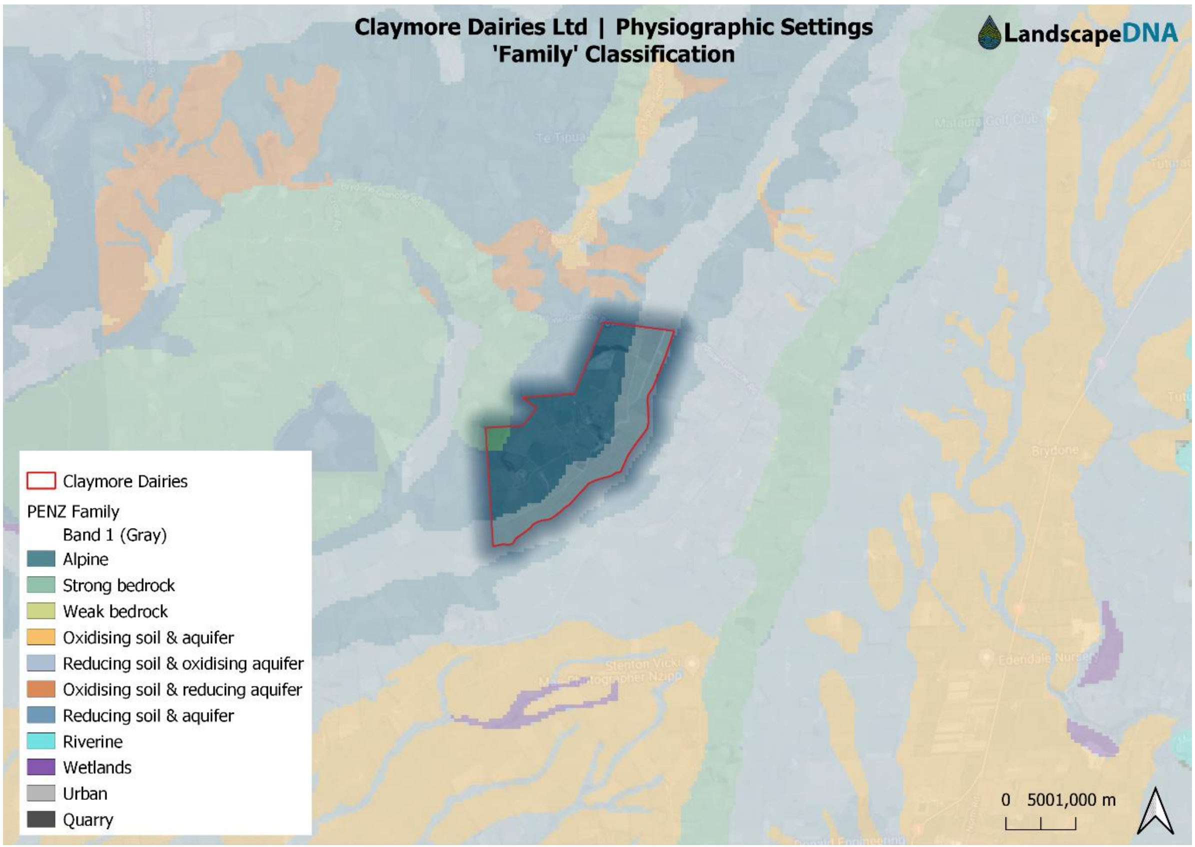

Figure 1. Case Study property – Claymore Dairies. Physiographic Families classification.

LandscapeDNA integrates geology, soil, and topographic variation to identify at a generalised broad level the susceptibility of the landscape to contaminant loss. The geological component identifies that the property resides within two geological units (blue lines in Fig. 2). The western part of the property is comprised of sandstone, with subordinate amounts of lignite, claystone and mudstone which is described as "sandstone with lignite and carbonaceous mudstone" by geological survey (Q-Map V3). The maximum age estimate of this landform is 27 million years old (Fig. 2). Across the eastern part of the property the main rock type is gravel, with subordinate amounts of sand, silt and peat that is described as "unconsolidated gravel; sand and peat in modern stream beds." The maximum age estimate of this landform is 14 thousand years old.

The soil component in LandscapeDNA is derived from S-Map. The S-Map (portal) identifies Woodlands and Makarewa soils as the two main soil types (Fig. 2); the Woodlands soil is described as deep, imperfectly drained, silt, and; the Makarewa soils is described as deep, poorly drained, clay. The S-Map portal specifies 'low' confidence in the accuracy of the soil mapping across the property. The high-resolution landscape susceptibility layers generated by Land & Water Science (LWS) have a resolution of 40 x 40 m (0.16 ha) and provide greater resolution over changes in soil properties than is currently provided by S-Map or LandscapeDNA.

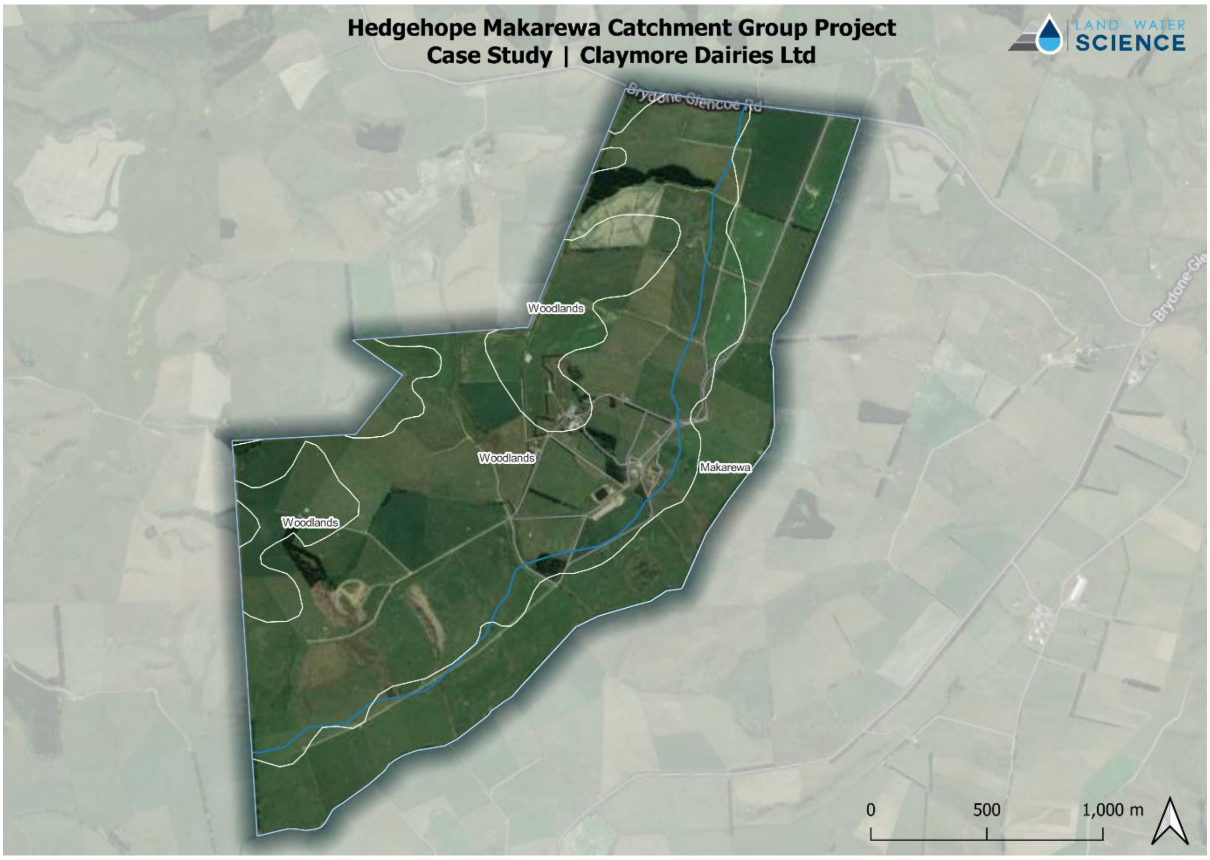

Figure 2. Case Study property – Claymore Dairies. The blue lines are from Q-Map denoting the geological units, the white lines and labels are from S-Map denoting the soil siblings. Please note that the soil polygons identified here are a general simplification of a more complex pattern which is subsequently described in the body of this report.

3. New soil map

Although not presented here, a new soil map was developed for the Hedgehope Makarewa Catchment Group as part of the Thriving Southland funded project. The map is available for viewing online in the catchment group's StoryMap application. The soil map was developed as a key step towards a more refined soil resource for the catchment.

4. Digital Terrain Model (DTM)

Claymore Dairies was surveyed with a drone to develop a high-resolution, Digital Terrain Model (DTM), with a horizontal resolution of 0.7m x 0. 7m and a vertical accuracy of 0.02cm. A DTM provides the basis for resolving in high-resolution the topographic variation across the property (Figs. 3 and 4). Topography is a dominant control over the movement of water across a property and as such the transport of contaminants from one area to another. The drone derived digital terrain model (DTM) of the property has a mean slope of 6.9° and a range of 1 to 87° (reflecting steep sides of a drainage ditch), and lies between 50m and 115m Relative to Sea Level (RSL) contour (Fig. 4). The mean slope of 6.9° is consistent with a mix of low relief and rolling country.

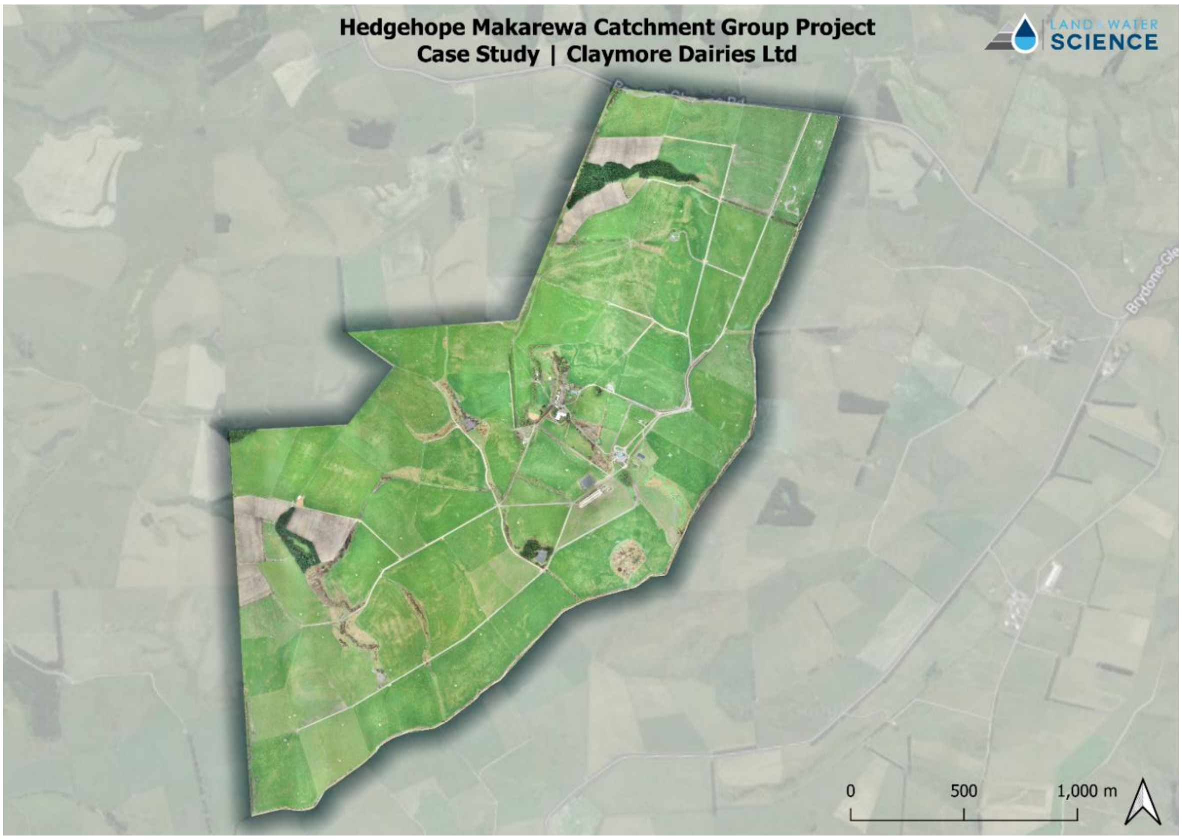

Figure 3. Claymore Dairies. The photogrammetry survey generates an orthomosaic output at 3cm resolution, producing a Digital Elevation Model of 12cm/pixel, with a vertical geolocation accuracy of 0.02cm. The high-resolution orthophotos are useful for identifying erosion-prone areas.

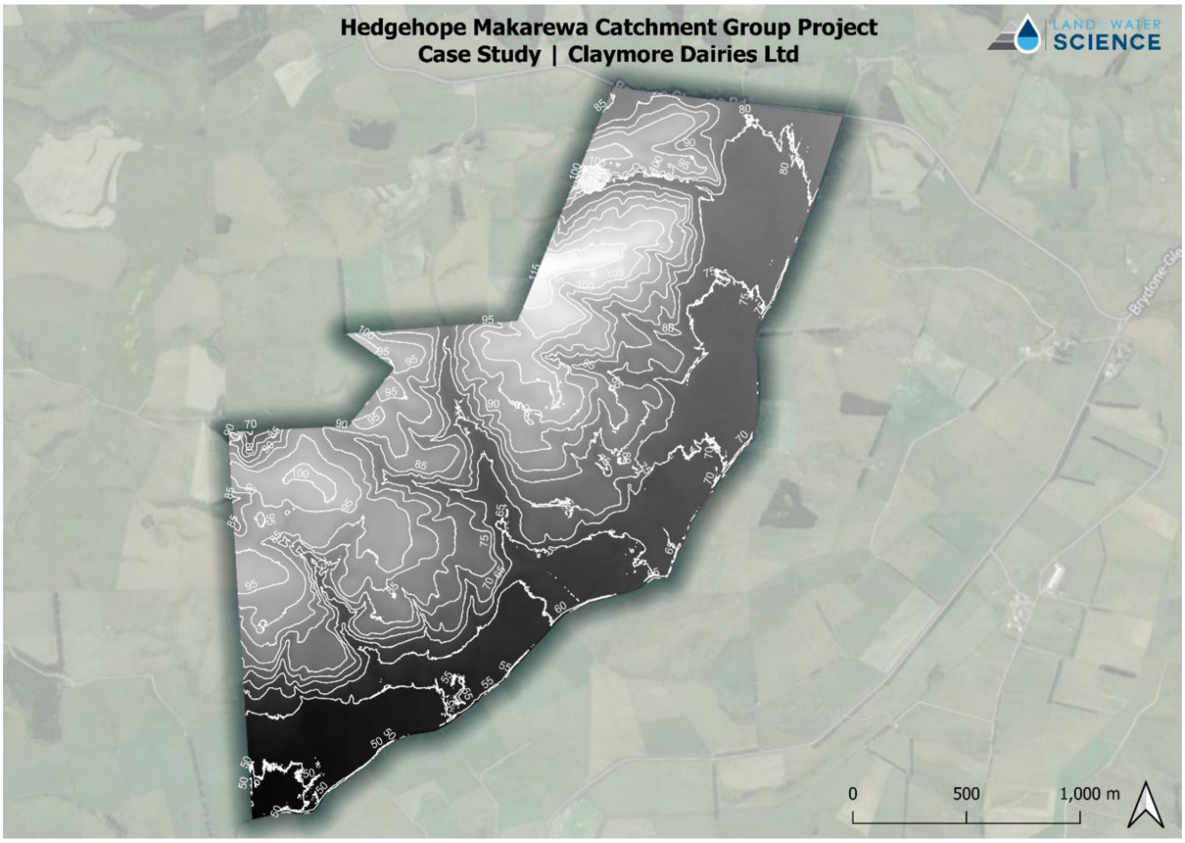

Figure 4. Shade model of elevation overlaid with elevation contours (5m) of property in meters relative to sea level. Note that the closer the spacing of contours, the steeper the land.

Following the survey, the DTM was utilised to build a digital model of the hydrology of the property, which includes the generation of watersheds, a digital drainage network, and nodes or junctions where drainage channels intersect or leave the property. The need to better define the hydrology of the property reflects the role of water in transporting contaminants from one area to another and at times, off-site.

Ultimately, water is the vehicle that transports contaminants from land to water. A better understanding of the area water collects from and drains to is a critical component of effective land management. Furthermore, soil moisture also tends to follow the drainage network, with higher soil moisture and greater incidences of saturation associated with low-lying areas that receive drainage from higher elevation parts of the property. The saturation of the soil with water also controls soil GHG generation (section 5.2).

4.1 Hydrological network for Claymore Dairies

Watersheds (Fig. 5), the drainage line and associated network (Fig. 6), discharge nodes (Fig. 7), and priority nodes (Fig. 8 & 9) were generated for the property. Watersheds encompass the area that collects and drains water to a node. Water drains towards a common collection point, following the lowest lying pathway to a drainage line. Hence the water that flows through a drainage channel during a runoff event is sourced from the entire area within the watershed. Discharge nodes identify the location at which water leaves the property and priority nodes identify where small drainage channels connect to and feed into larger drainage channels. Each drainage line or 'channel' is ranked (ordered) according to its level of branching. A low order drainage line e.g., order 1, defines the smallest drainage features, whereas a high order drainage network e.g., order 6, represents the largest drainage features, such as broad or incised swales, drainage ditches, and in some instances flowing stream channels. Typically, higher-order drainage lines are more likely to contain water for extended periods, whereas low order drainage lines may only channel water in response to wet conditions and associated surface runoff events.

Critically, the DTM does not detect nor consider any artificial drainage that has been undertaken. Where present, artificial drainage will significantly modify the hydrological properties and behaviour of water movement across or through the landscape. Accordingly, knowledge of artificial drainage is important given its role in water and contaminant export. Most typically, artificial drainage follows the topographic drainage, with many low-order drainage channels tiled or piped to expedite soil drainage and/or, in some settings, to prevent a shallow water table from rising and flooding the property. It will be helpful to discuss with the property owners the general extent and layout of any artificial drainage.

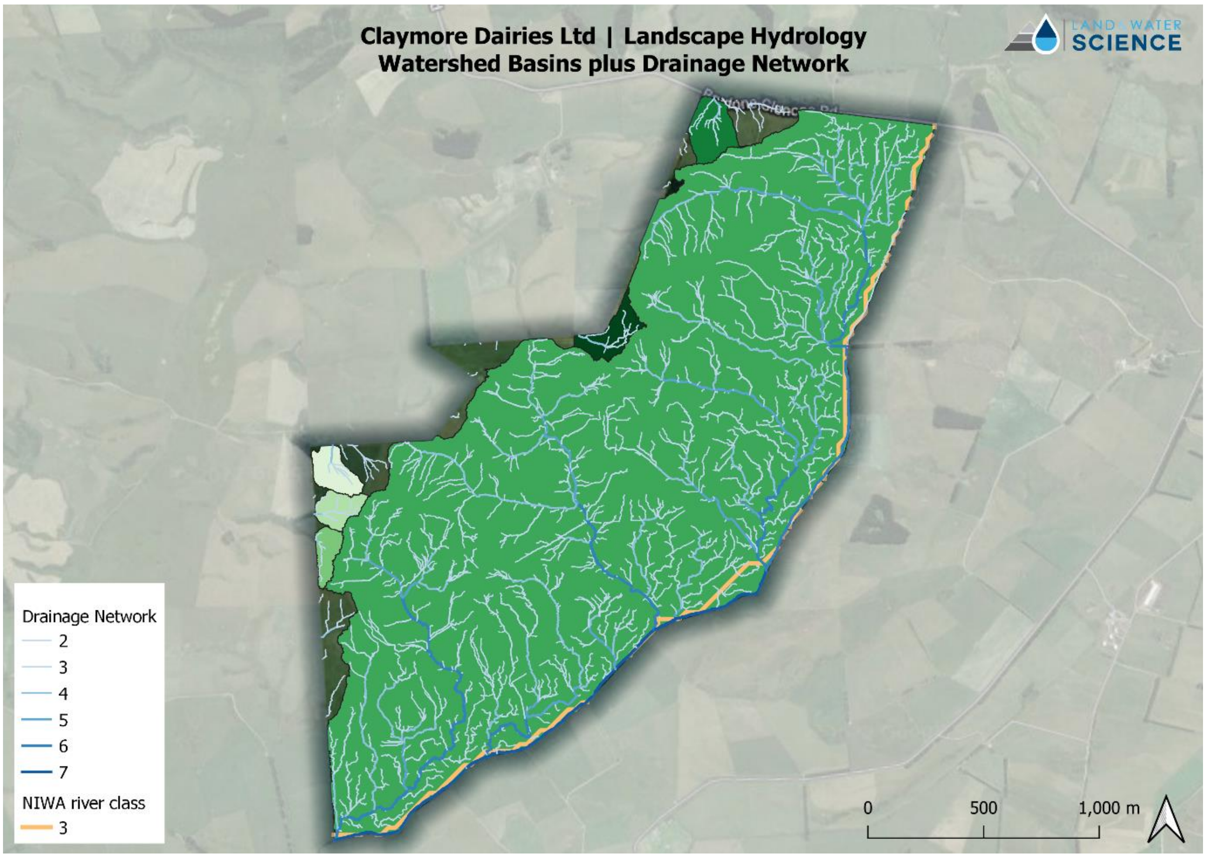

Figure 5. Claymore Dairies - landscape hydrology – watershed basins plus drainage order network. These watersheds can be further subdivided for each tributary. The majority of drainage from the property discharges directly into the Titipua Stream.

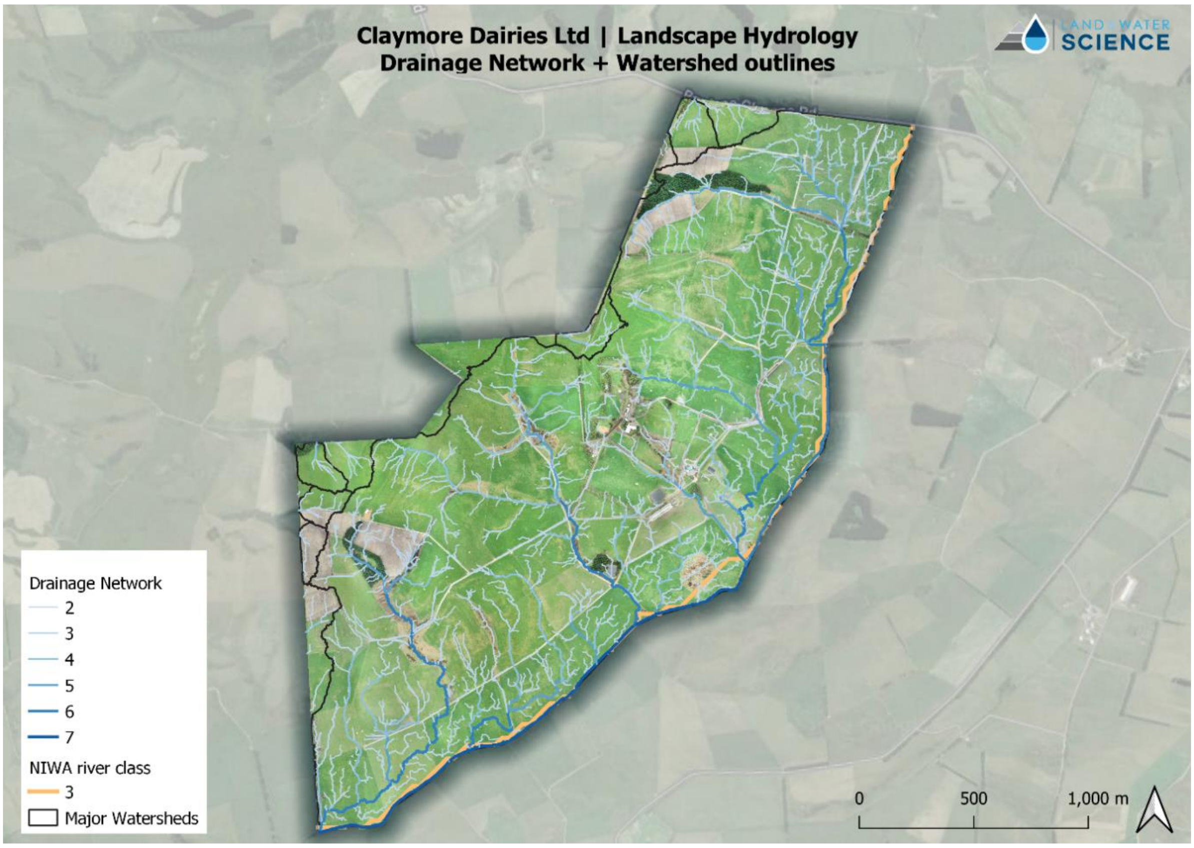

Figure 6. Claymore Dairies - landscape hydrology – drainage network. The legend denotes the 'order' of drainage lines, with low order drainage connecting to generate higher order drainage lines.

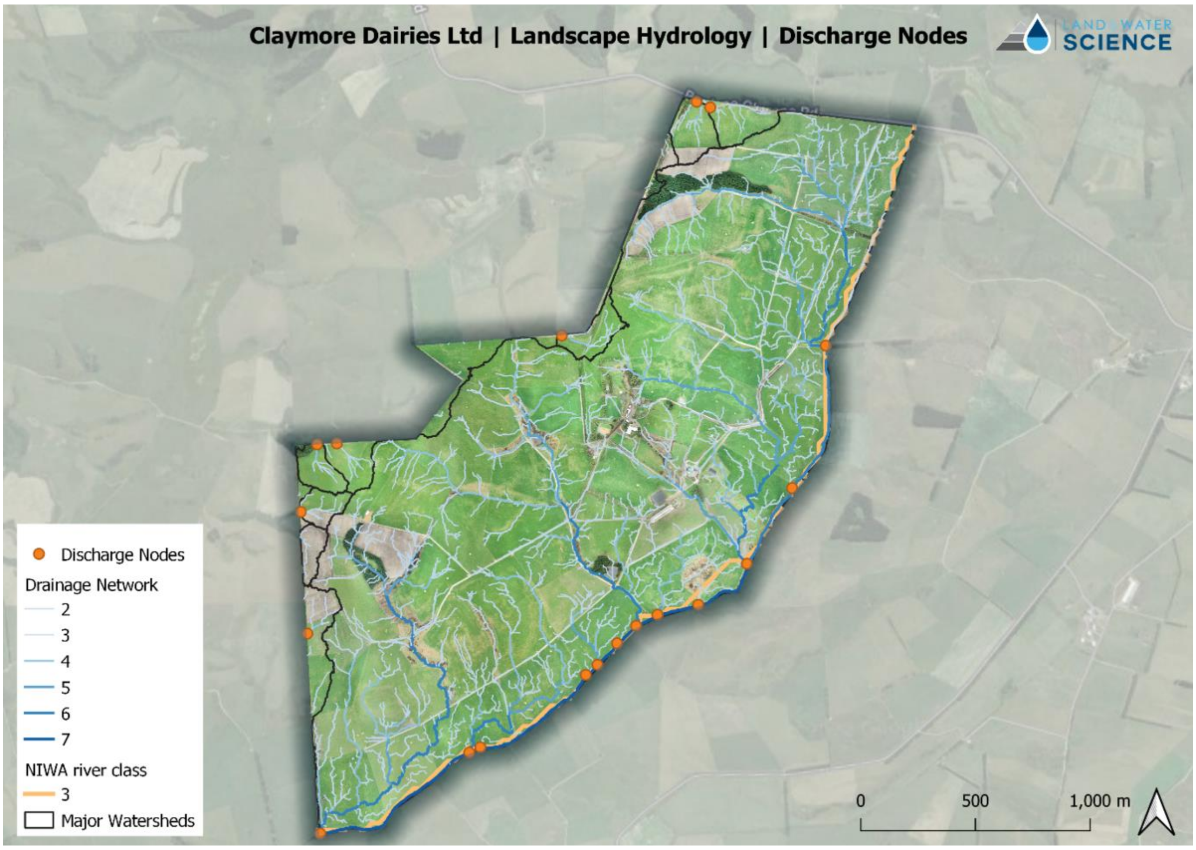

Figure 7. Claymore Dairies - landscape hydrology – 'discharge' nodes (orange circles) and drainage network. Discharge nodes are the points where the water leaves the property.

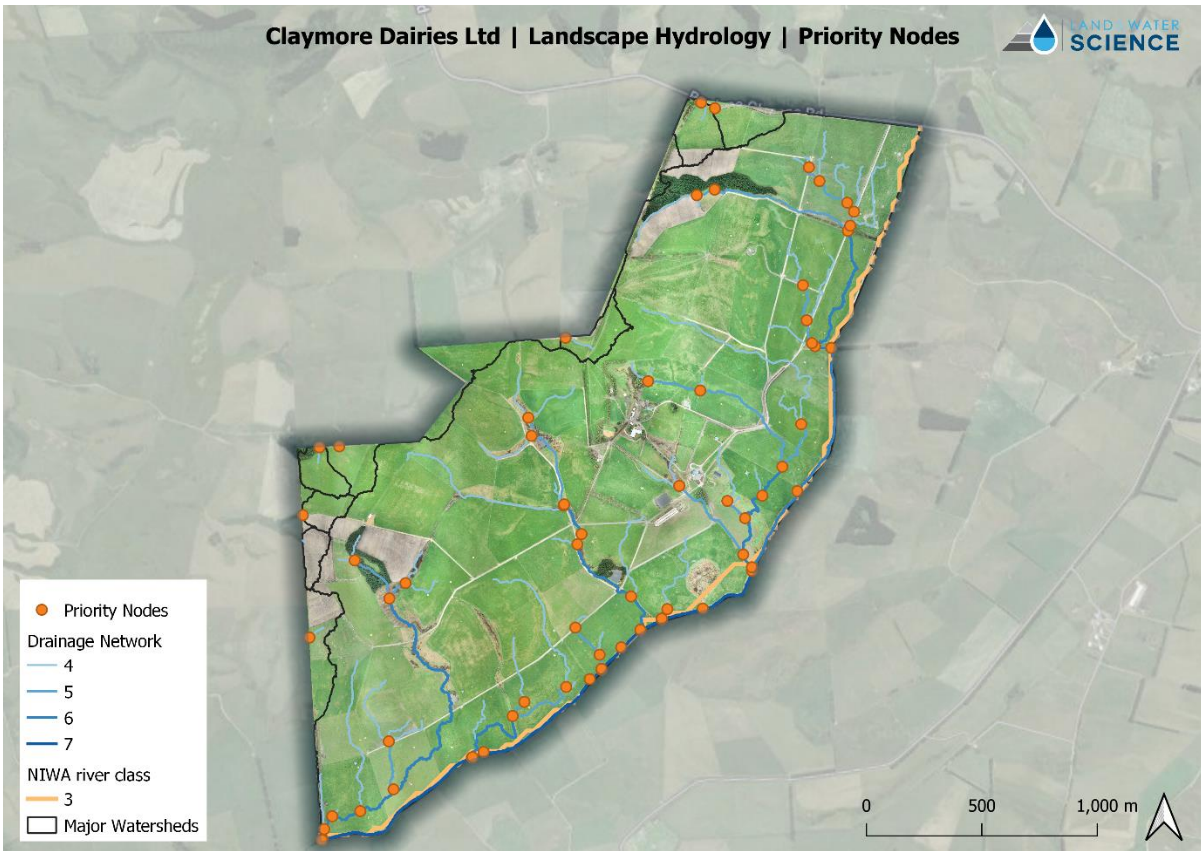

Figure 8. Claymore Dairies - landscape hydrology – drainage orders 4 - 7 only (i.e., the major drainage channels within the farm property), plus the related junctions and discharge nodes.

Figure 9. Claymore Dairies – zoomed in view of several priority nodes identified. Junction nodes (orange circles) identify where drainage channels converge or join.

The spatial context provided with the hydrological mapping creates insights as to the source and movement of water across the property. Again, water is the dominant control over contaminant loss. As such, the hydrological network generated here is seen as a critical starting point for understanding and prioritising possible mitigations to support a more resilient farm system, e.g., sediment traps ('Duck Ponds'), wetland areas etc. We recommend that the hydrological model of the property be used as a spatial framework through which the susceptibility of the farm landscape is viewed and ultimately managed.

5. Landscape Susceptibility for Claymore Dairies

The landscape is a significant driver of variability in the type and severity of water quality and soil GHG loss, even when land use is the same. Land & Water Science Ltd (LWS) have generated a new, high-resolution approach to mapping the inherent and varied susceptibility of the landscape to land use activities at property scales (Figs. 10 - 19).

The mapping provides integrated knowledge on the property-scale landscape factors that control water quality and soil nitrous oxide emissions across Southland. The maps of landscape susceptibility depict soil greenhouse gas (GHG) and water quality susceptibility as 'very low', 'low', 'medium', and 'high'. As with any model, ground truthing in partnership with rural communities is the best way to ensure that the outputs are relevant.

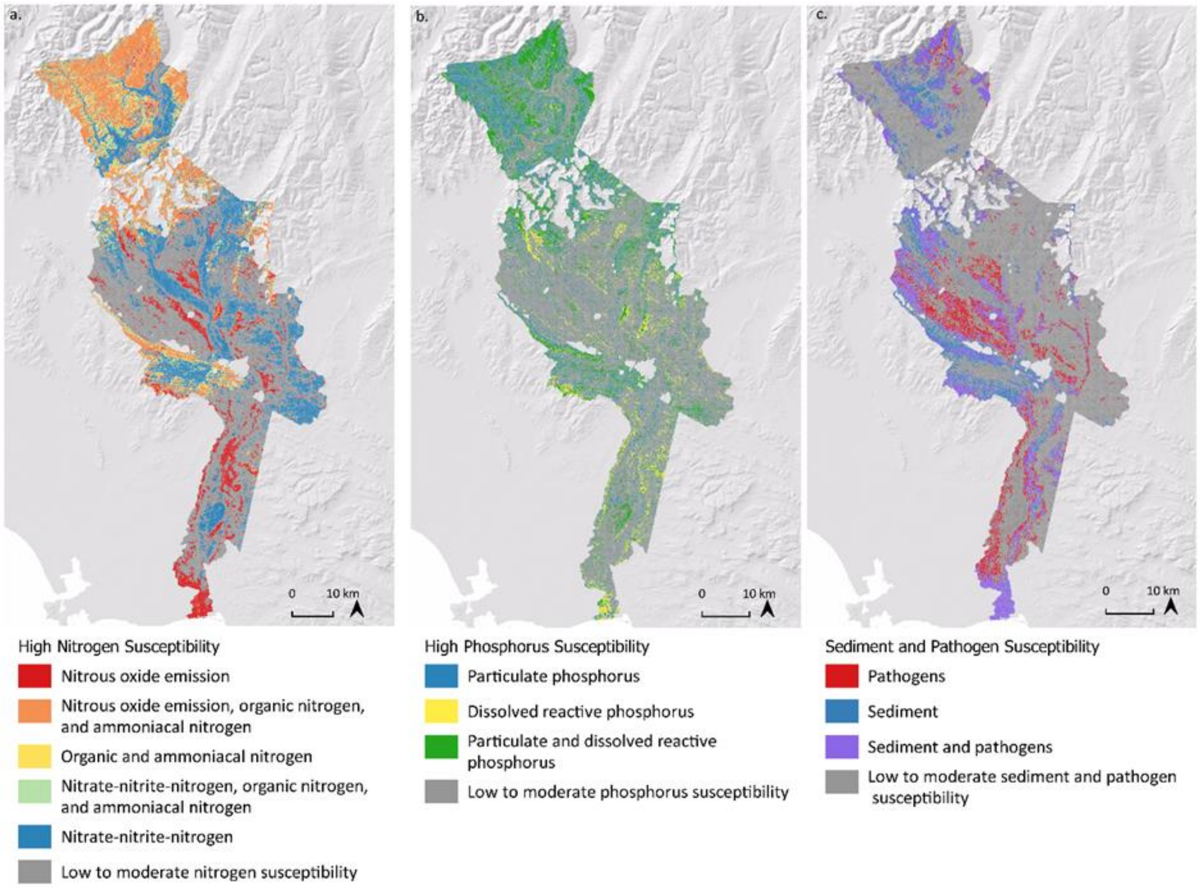

Figure 10. Example maps of landscape susceptibility (high) for the Mataura Catchment, Southland

Before reading any further, it is important to emphasise:

A. that the susceptibility models presented below do not take into account land use nor any existing management practices or physical mitigations (e.g., sediment traps, wetlands) that are already in place, and;

B. when reviewing the maps please note they are *not* identifying actual losses, rather they seek to identify the natural susceptibility of the landscape to inform land users of the risks and opportunities associated with their landscape.

5.1 Landscape Susceptibility to Erosion

To assess the susceptibility of the property to erosion, the drainage network derived from the drone survey was overlaid with an earlier classification of the susceptibility of the landscape to erosion and sediment loss (Fig. 11). The erosion susceptibility layer is based on the integration of several datasets, not limited to airborne radiometrics and a regional scale digital terrain model. Within the erosion susceptibility classification, hot to cool colours (red, orange to green and yellow) used to identify high to low susceptibility to mass wasting (slips, slumps, avalanche) and erosion (the incision of the land by running water). Claymore Dairies is associated with a low susceptibility to mass wasting and erosion, although there are a few small areas of moderate susceptibility.

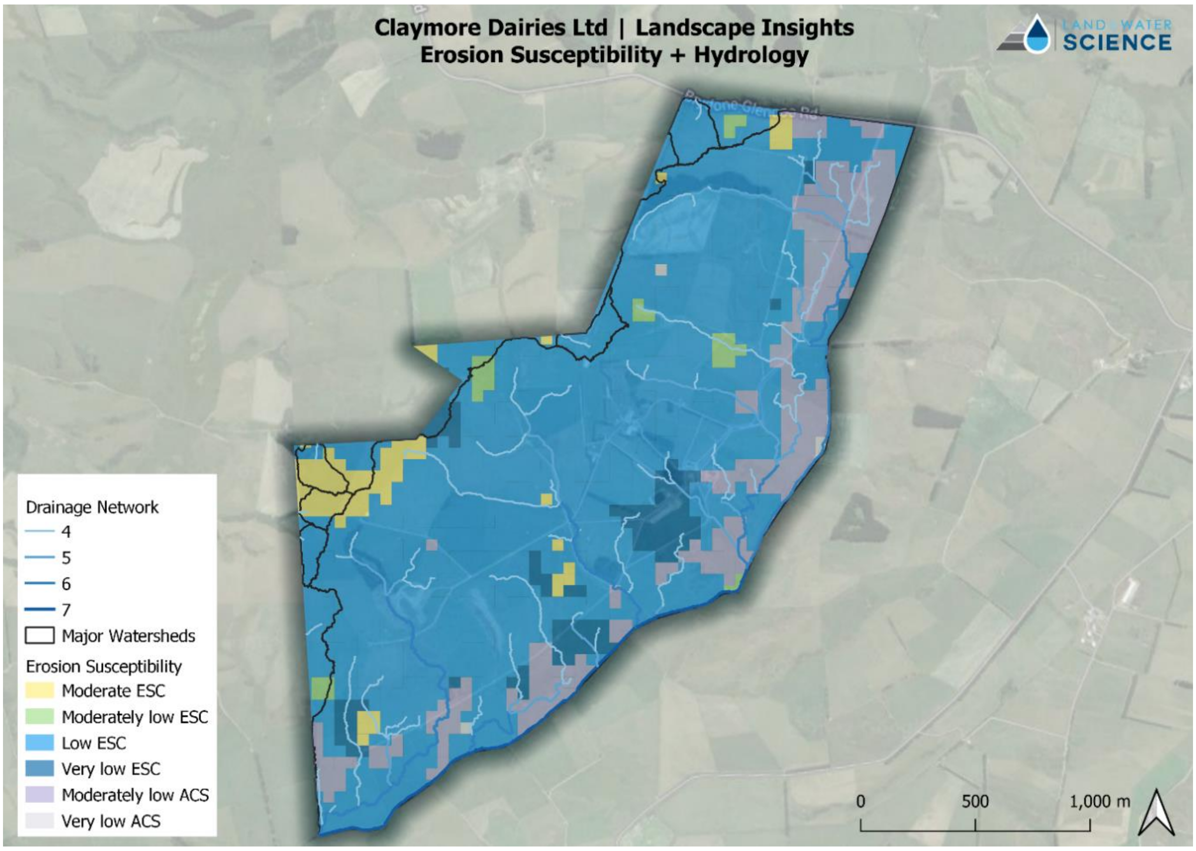

Figure 11. Claymore Dairies - landscape hydrology overlaid with Erosion Susceptibility (ESC), developed by Land and Water Science (2020).

Two different types of erosion susceptibility are identified. The lowest lying and flattest areas are associated with a mauve colour and a 'Moderate ACS' to 'Moderately low ACS.' Where ACS defines the 'activity status' of the low-lying area in terms of its susceptibility to sediment mobilisation in response to runoff.

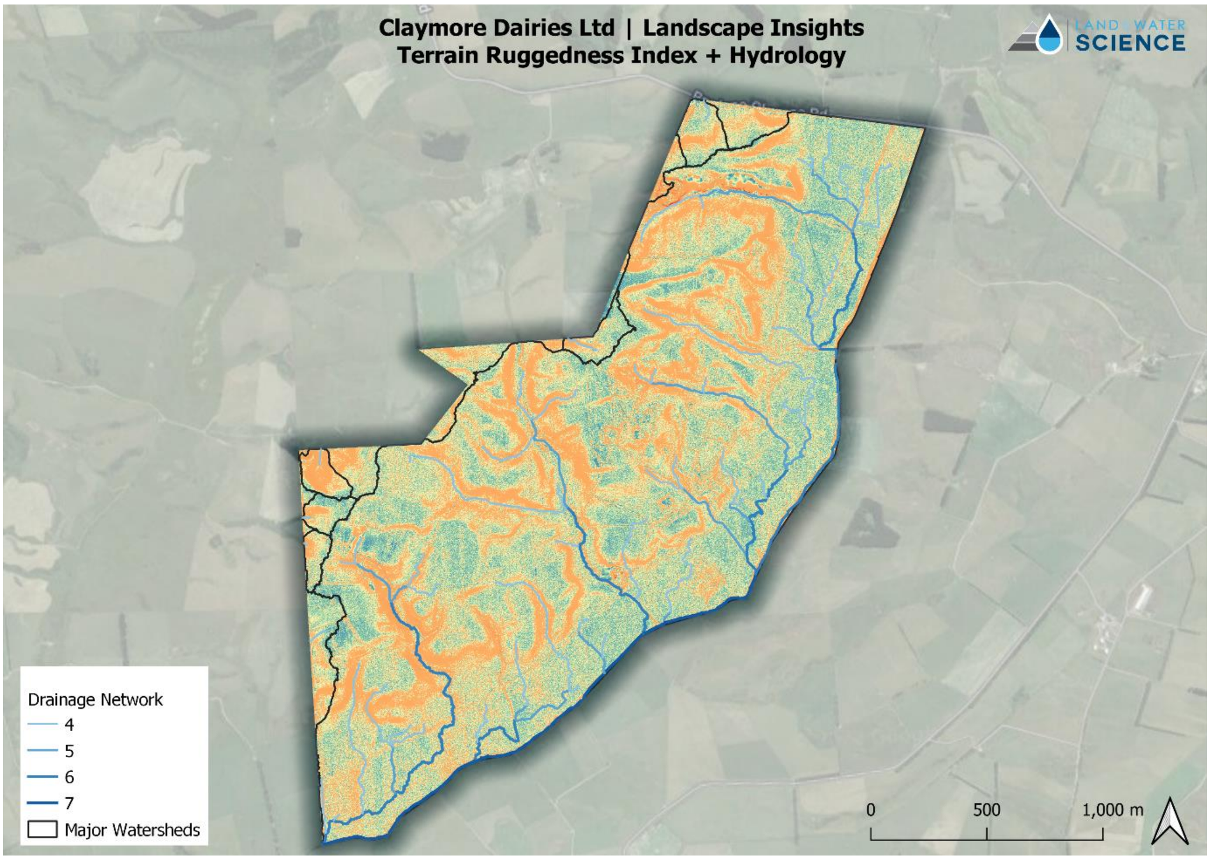

Figure 12. Terrain Ruggedness Index (TRI), orange colours are associated with the most rugged parts of the property.

The drone survey also enabled a new, higher resolution (0.7 x 0.7 m with a vertical resolution of 0.02 cm) model of terrain ruggedness to be defined for the property (Fig. 12). The Terrain Ruggedness Index (TRI) presented here is a new output that provides much finer scale resolution over the ruggedness of the landscape. The TRI has been widely used nationally and internationally to support identifying areas of active erosion. The new TRI layer can be utilised to identify sub-paddock scale erosional features such as slips, slumps, soil creep (terracettes), and erosional features that are generated in response to ephemeral runoff. The TRI map, when used in combination with the digital drainage network and landscape susceptibility models, could be used to narrow down ('hone in') the areas of highest susceptibility for mitigation. The utility of the TRI as a tool for sub-paddock scale identification of erosion will be provided as part of the farm visit.

The TRI output identifies the steeper slopes throughout the property as having the greatest susceptibility to erosion and sediment loss. Where high TRI coincides with poorly drained and slowly permeable soils, the risk of erosion and runoff is elevated. During a high-intensity rainfall event, e.g., a thunderstorm, runoff may result in these soils being incised, and the eroded soil carried to the drainage network. Included in the figure above is an overlay of the watersheds (black outlines) and drainage lines that receive and export sediment from the most rugged parts of the farm to lower-lying areas. This very high-resolution layer needs to be viewed at sub-paddock scales to extract the maximum value (i.e., Fig 13 & 14).

Figure 13. Claymore Dairies. High resolution zoomed in view from drone output looking at erosion susceptibility in the south-western area of the property. These drainage channels have been fenced off and there is evidence of naturalised vegetation.

Figure 14. Claymore Dairies. Corresponding location to Fig 13 above showing elevated TRI along the side slopes of incised channels.

Susceptibility to runoff and sediment loss is an important consideration for the property and is a natural phenomenon of contoured landscapes. However, land use does exacerbate the loss of sediment, with high-intensity land use on top of naturally susceptible areas associated with the highest rates of contaminant loss. Fortunately, through identifying the inherent susceptibility of the landscape to erosion, it is possible to design strategies to limit contaminant loss that are data-driven and targeted. In summary, inherently susceptible areas (highest TRI) are more likely to generate sediment and surface runoff when developed than less susceptible areas. Overall, the susceptibility of the property to mass wasting and erosion is considered low, but the potential for runoff is elevated. Managing runoff is an important approach to support the reduction of multiple different contaminants including sediment, phosphorus, nitrogen, and microbes to waterways.

5.2 Landscape susceptibility to soil zone nitrous oxide loss

When soil becomes saturated with water, even for a short period of time, it may generate nitrous oxide. Nitrous oxide is a potent soil GHG with a warming potential of c. 273 times that of carbon dioxide[1]. It is produced from soils that saturate easily, either due to a slowly permeable topsoil or imperfect to poor drainage. However, if the soil lacks nitrate then very little nitrous oxide will be produced. Urine patches, from livestock are a key source of urea that is rapidly converted to nitrate under the right conditions.

In brief, the volume of nitrous oxide produced is a factor of the surplus of nitrate in the soil, soil temperature, and the duration of saturation of the soil. Low volumes of nitrous oxide are generated when soil temperatures are low, soil nitrate concentrations are low, and the topsoil is not saturated. High volumes of nitrous oxide are generated when soil temperatures are elevated, soil nitrate concentrations high, and topsoil becomes saturated. The preliminary susceptibility map indicates that soil nitrous oxide is moderately important for Claymore Dairies. This is consistent with a significant area of imperfectly drained soils that, under specific conditions, can result in soil nitrous oxide generation. The new soil map (see section 4.0 above) for the catchment may help better support the identification of key management areas for soil nitrous oxide. Current research has identified an environmentally friendly product for reducing soil nitrous oxide emissions from agricultural soils. Work trialling this nitrous oxide inhibitor is ongoing, but should be available on the market within the next 24 months.

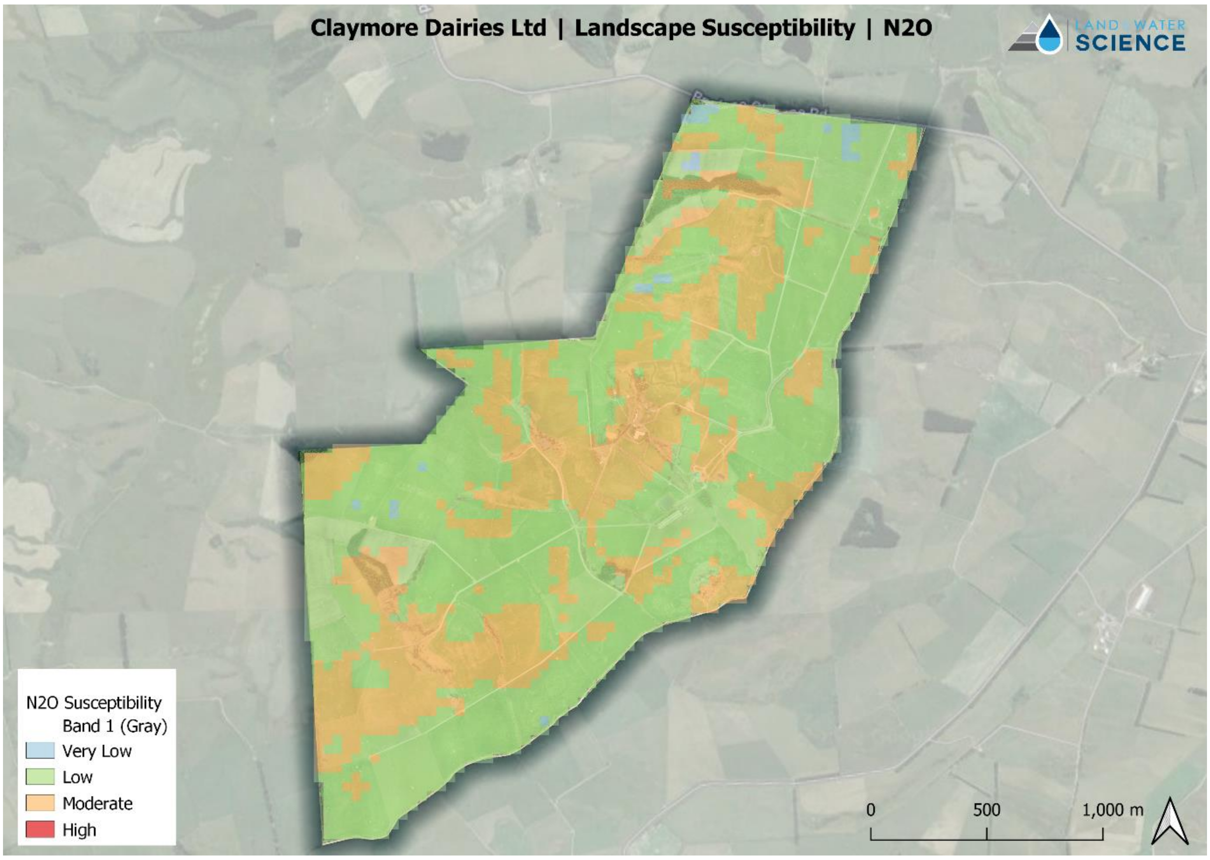

Figure 15. Claymore Dairies - landscape susceptibility to soil N_2O (Nitrous Oxide) emission.

5.3 Landscape susceptibility to nitrate-nitrite-nitrogen (NNN) loss

Nitrate and nitrite nitrogen (NNN) is highly soluble and is easily transported through the soil if not used by plants and microorganisms. NNN that moves below the root zone is at risk of being lost via lateral subsurface flow (including via mole-pipe drainage) and via vertical leaching to the underlying water table. Unlike organic or ammoniacal forms of nitrogen, NNN is not typically mobilised in surface runoff. Rather, it is 'rinsed' or leached from the soil and travels to the drainage network via subsurface flowpaths.

NNN leaching losses are often greatest where soils are permeable, well drained and deep. Typically, flatter land with well drained soils generate a greater proportion of NNN, which may be lost below the root zone during periods of soil water drainage - drainage usually occurs during the cooler months of the year. However, artificially drained soils and well drained hill country soils may also lose appreciable concentrations of NNN if intensively farmed.

The susceptibility of the subject property to NNN loss is moderate across the elevated parts of the property, where soils are naturally better drained, with some minor high susceptibility areas in the north, and adjacent to the Titipua Stream (Fig. 16). However, whether excess NNN loss occurs across the areas with high susceptibility will be strongly controlled by land use intensity. It is important to emphasise that the susceptibility models do not consider land use nor any existing management practices of physical mitigations (e.g., sediment traps, wetlands) already in place. As such, landscape susceptibility models only identify the inherent or natural susceptibility of the land, they do not indicate that the areas of elevated susceptibility are losing high rates of contaminants.

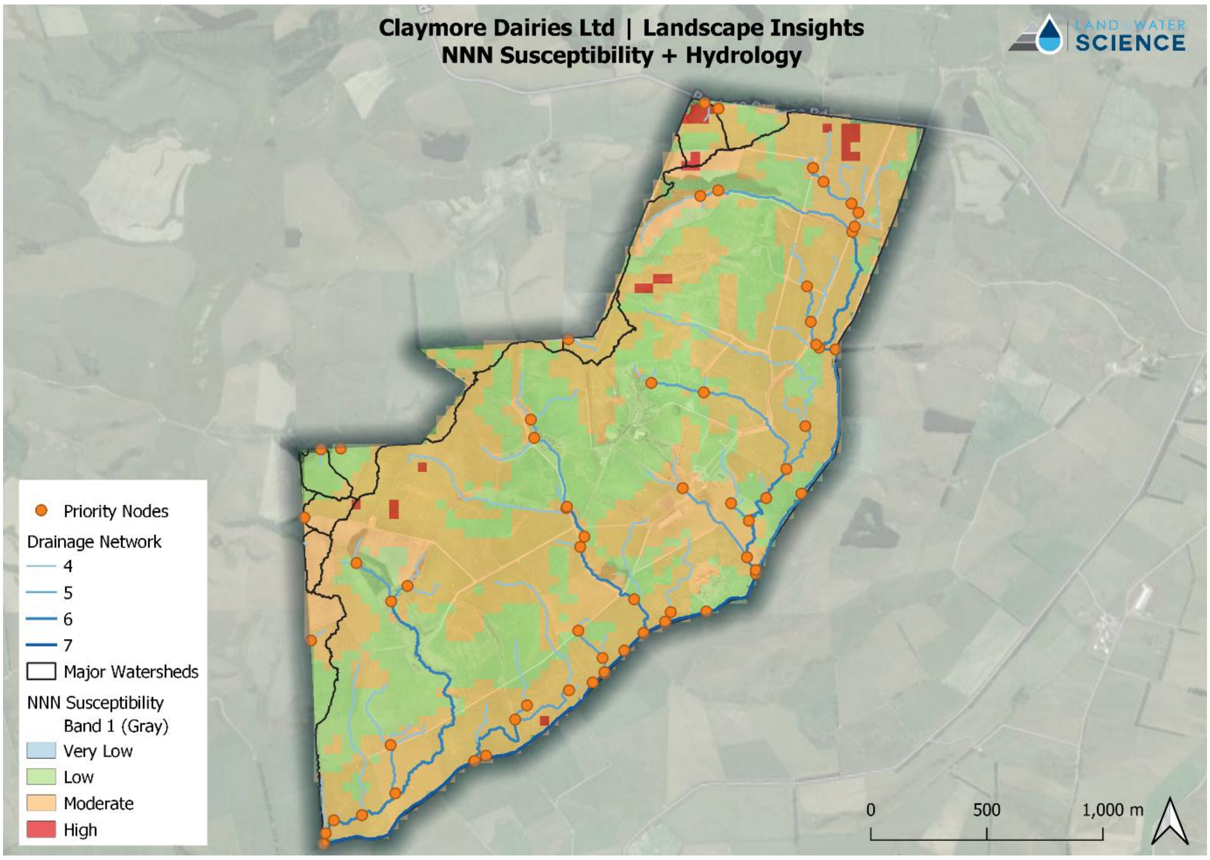

Figure 16. Claymore Dairies - landscape susceptibility to NNN (Nitrate-Nitrite Nitrogen) contaminants, overlaid with the hydrology.

An important factor when considering the landscape's susceptibility to contaminant loss is the presence or otherwise of artificial drainage. Drainage of formerly imperfectly to poorly drained soils (i.e., Makarewa soils) commonly favours NNN loss. In summary, the landscape settings suggest that NNN appears to be of moderate importance for Claymore Dairies.

5.4 Landscape susceptibility to Particulate Phosphorus (PP) loss

Particulate phosphorus (PP) refers to phosphorus that is attached to sediment that is mobilised in response to runoff. This includes organic and inorganic phosphorus from natural rock weathering, erosion of soil (stream or drainage channel erosion), animal manures, and fertiliser. Soils with high Olsen-P values can produce large quantities of PP if eroded. As with sediment, PP is transport by water across the land to the drainage network. As noted for NNN, it is important to emphasise that the susceptibility models do not consider land use or current environmental mitigations that are already in place. As such, they only highlight the inherent or natural susceptibility of the land.

Referring to the map image below, there are some elevated areas of PP susceptibility that tend to coincide with the steeper terrain (high TRI), as well as with the poorly drained Makarewa soils in the east, especially where the water table is elevated or where soils are prone to saturation. Given the majority of drainage discharges to the Titipua Stream, the potential for PP loss appears to be important for Claymore Dairies.

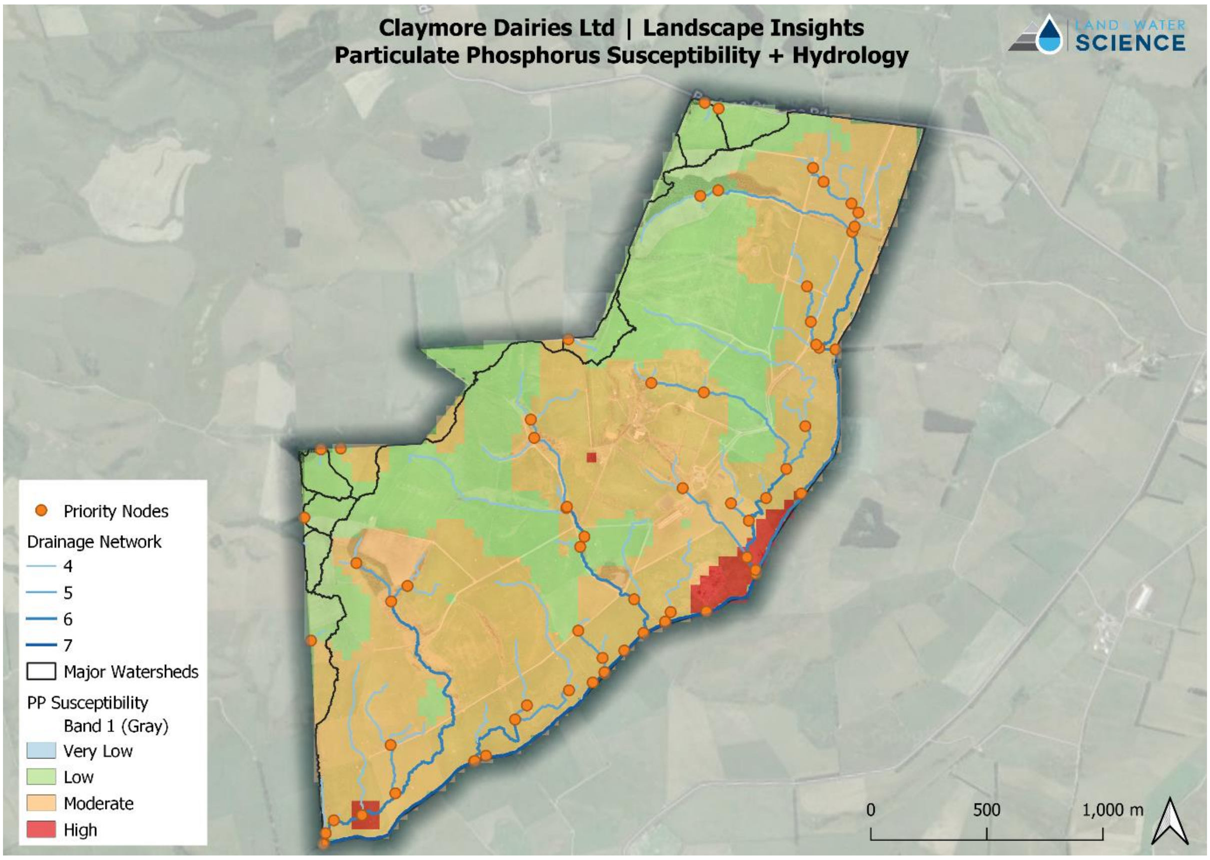

Figure 17. Claymore Dairies - landscape susceptibility to PP (Particulate Phosphorus) contaminants, overlaid with farm hydrology.

5.5 Landscape susceptibility to Dissolved Reactive Phosphorus (DRP) loss

Excess P, both as DRP and PP, is a key nutrient for plants and algae, with high concentrations leading to weed growth and algae blooms in waterways. Dissolved reactive phosphorus (DRP) refers to the phosphorus compounds that are dissolved in water as opposed to those that are attached to sediment i.e., PP. Typically, DRP is characterised by very small molecules that are strongly held by most soil and geological materials. As DRP binds strongly to soil and geological materials it will become PP if the soil is eroded or fine sediment is lost via the subsurface artificial drainage network.

The DRP susceptibility map for Claymore Dairies indicates low landscape susceptibility (Fig. 18). The landscape settings suggest that DRP susceptibility is unlikely to be important for this property. However, areas of artificial drainage may act as a conduit for subsurface DRP loss.

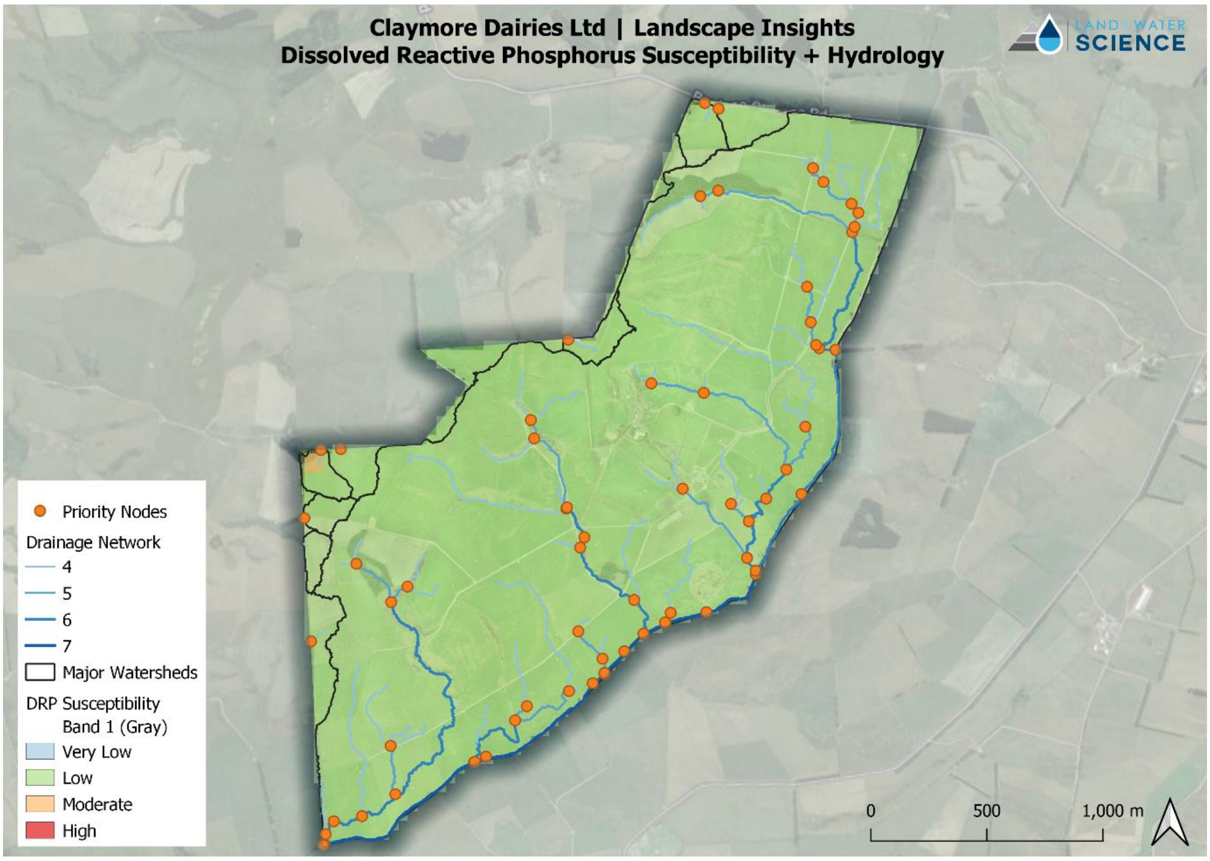

Figure 18. Claymore Dairies - landscape susceptibility to DRP (Dissolved reactive phosphorus) contaminants, overlaid with the hydrology content.

5.6 Landscape Organic and Ammoniacal Nitrogen (TKN) Susceptibility

Total Kjeldahl Nitrogen (TKN) is a measure of organic and ammoniacal N. Organic and ammoniacal nitrogen are derived from the breakdown of organic matter, soil organic matter, manure, and animal urine. Organic nitrogen is mineralised to ammoniacal N, ammoniacal N is oxidised to nitrite, and ultimately nitrate. The loss of excessive TKN from land e.g., from a recently cultivated paddock, is therefore an important factor controlling stream health. However, it is important to note that all natural systems generate TKN, with TKN loss occurring from natural state landscapes and farmed land. The main difference between natural state and any developed landscapes are the magnitude of losses.

Commonly, natural TKN losses are elevated for soils that are imperfectly to poorly drained or prone to saturation for extended periods of the year. The TKN susceptibility map for Claymore Dairies indicates moderate susceptibility to TKN loss with a spatial relationship between steeper areas with elevated runoff risk (high TRI) and low lying areas where soils are poorly drained. Given the majority of drainage discharges to the Titipua Stream, managing runoff to reduce TKN loss appears to be important for Claymore Dairies.

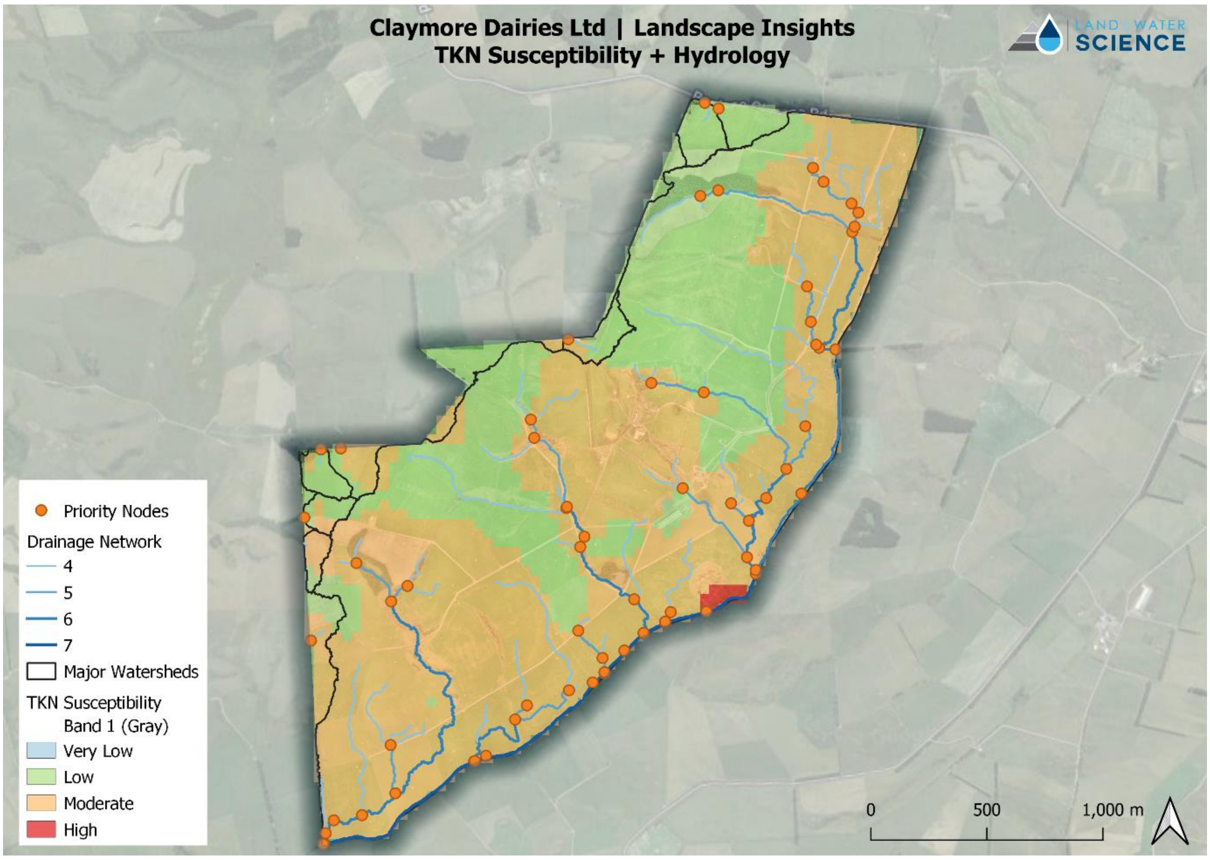

Figure 19. Claymore Dairies - landscape susceptibility to TKN (total Kjeldahl nitrogen – being organic and ammoniacal nitrogen) contaminants, overlaid with the hydrology content.

6. Next steps

This report introduces the landscape datasets and insights available for Claymore Dairies and provides an assessment of the susceptibility of the farm's landscape. We hope that the datasets presented here provide some helpful insights that can be used to support aligning the farm system with the landscape variability through input from specialist farm systems experts, and feedback from other farmers during the planned field day.