Evaluation of Soils to Receive Porangahau and Te Paerahi's Wastewater

(LEI, 2020:P:B.15)

Prepared for

Central Hawke's Bay District Council

Prepared by

Lowe Environmental Impact

December 2020

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1 EXECUTIVE SUMMARY

Central Hawke's Bay District Council (CHBDC) are currently investigating options for the upgrade and discharge regime of wastewater for the communities of Porangahau and Te Paerahi. One of these alternative discharging options is the incorporation of a combined land treatment system for part or all of the wastewater discharge from the Porangahau and Te Paerahi Wastewater Treatment Plants (WWTPs).

A neighbouring property between the two WWTPs has been evaluated for its suitability to receive wastewater with site investigations taking place on the 23rd, 24th and 25th of November 2020 by Lowe Environmental Impact (LEI) staff. This property contains two property parcels and will collectively be referred to as the Stoddart Farm, comprising 114 ha. This report outlines, presents the results and discusses the key findings following these investigations.

Investigations included:

- A site survey (both site walkover and drone flyover);
- Soil descriptions (1 m soil test pits);
- Hydraulic conductivity measurements;
- Groundwater standpipe installation; and
- Soil chemistry measurements.

The Stoddart Farm is located on both the alluvial plain of the Porangahau River, as well as a series of coastal sand dunes with the property evenly distributed across each of these. Two main soil types identified on-site are:

- Kairaki Sandy Loam (60 ha); and
- Kaiapo Silt Loam (47 ha)

A soil map showing the location of these is given in Appendix A. The Kaiapo Silt Loam contains an underlying clay subsoil as is referred to as being a 'clay soil.'

Soil hydraulic conductivity is a measure of the rate water can enter and move through soil. Measured soil saturated hydraulic conductivity (K_{sat}) reflected the soil types identified and ranged between 37 mm/h on clay soils and 106 mm/h on sandy soils. Measured unsaturated hydraulic conductivity ($K_{-40\ mm}$) also reflected soil conditions with rates in the order of 11 mm/h on clay soils and 14 mm/h on sandy soils.

For long term discharge of low strength wastewater, such as treated municipal wastewater, a rate of up to 79 mm/d for clay soils and 101 mm/d for sandy soils is considered sustainable for soil health. It should be noted however, that the actual application depth on any day will be influenced by plant demand, the depth to groundwater and sensitivity of groundwater; as well as management practices and may be less than these design irrigation rates for the respective soil types.

Due to the varying landform types and proximity to waterways, depth to groundwater, varies across the Site. Standpipes show groundwater to be in the order of <1.5 m in the south-eastern extent of the property, with this increasing in depth in proximity to the Porangahau River (~2-2.5 m) and underlying the higher elevated sand dunes (>3 m). Groundwater is estimated to be at a relatively equal elevation across the site with a slight dip towards the river, with variation in recorded water levels likely to be due to variation in standpipe elevations. Seasonal groundwater fluctuations are expected to be significant within the underlying clay layer due to its low permeability characteristics.

Soil testing indicates that the Stoddart farm has good fertility, likely due to the property's management history. The capacity to retain phosphorus is low which may have implications for the amount of phosphorus that can be applied to the site, avoiding losses from the soil profile. This may result in a lower application depth than can be supported by the soil hydraulic conductivity.

The total irrigable area of the site is considered to be approximately 91 ha following the inclusion of buffers, however it is likely that the actual area irrigated will be less than this following land owner aspirations, irrigation design, accessibility and areas available per paddock. From this 91 ha of available land, 37 ha is clay soil (Kaiapo Silt Loam), and 53 ha is sandy soil (Kairaki Sandy Loam).

2 INTRODUCTION

2.1 Background

Central Hawke's Bay District Council (CHBDC) are currently investigating options for the upgrade and discharge regime of wastewater for the communities of Porangahau and Te Paerahi. One of these alternative discharging options is the incorporation of a combined land treatment system for part or all of the wastewater discharge from the Porangahau and Te Paerahi Wastewater Treatment Plants (WWTPs).

For Porangahau, CHBDC hold resource consent (DP030233W) allowing the discharge of Porangahau's wastewater from the WWTP to the adjacent Porangahau River.

For Te Paerahi, CHBDC hold resource consent (DP030234La) allowing the discharge of Te Paerahi's wastewater from the WWTP to adjacent sand dunes via soakage. Both of these consents are scheduled to expire on the 31st of May 2021.

A neighbouring property between the two WWTPs has been evaluated for its suitability to receiving wastewater with site investigations taking place on the 23rd, 24th and 25th of November 2020 by Lowe Environmental Impact (LEI) staff. This property contains two property parcels and will collectively be referred to as the Stoddart Farm, comprising 114 ha. This report outlines, presents the results and discusses the key findings following these investigations.

2.2 Scope

This report gives the results of these site investigations for the property. Information provided includes:

- A site description and location information;
- Details of the soil investigation methodology and results of these soil investigations;
- Soil hydraulic parameters measured for the site;
- Standpipe installation methodology and groundwater findings; and
- Soil chemistry parameters measured for the site.

3 SITE DETAILS AND LOCATION

3.1 Site Description

The Porangahau and Te Paerahi townships are located within the south-eastern extent of the Central Hawke's region, both situated adjacent to the Porangahau River, approximately 45 km south of Waipukurau. These townships are six kilometres apart from one another, with Te Paerahi situated directly at the coast. The Porangahau WWTP is located one kilometre east of the Porangahau township, at the end of Jones Street, with the Te Paerahi WWTP located one kilometre north of Te Paerahi within nearby sand dunes.

The property under investigation here and identified to potentially receive Porangahau and Te Paerahi's wastewater, has been selected primarily due to its proximity to the two communities and likely suitable land use and soil conditions to assimilate applied wastewater. This farm is used for drystock farming and the growing of fodder crops such as chicory and oats.

Details of the property are provided within Table 3.1. Figure 3.1 represents the location of the property operated by the Stoddart's. The property is located directly between the two townships with Porangahau being to the west and Te Paerahi to the east. Distances recorded from the respective plants to the site are via roading networks.

Table 3.1: Stoddart Farm Site Details

	Southern Parcel	Northern Parcel
Legal Description	LOT 2 DP 3877	LOT 3 DP 2741
Property Address	474 Beach Road, Porangahau	474 Beach Road, Porangahau
Map ref, centre of parcel (NZTM)	1910345 E, 5533282 N	1910729 E, 5533831 N
Area (ha)	81.2	33.1
Distance to Porangahau WWTP (km)	3.3	4.1
Distance to Te Paerahi WWTP (km)	2.4	3.8

Figure 3.1: Stoddart Farm Site

The site contains a total of 20 paddocks, each with their own names as provided by the land owner. Figure 1, Appendix A represents the location and names of these paddocks referred to throughout this report.

3.2 Waterways and Topography

The site is located adjacent to the Porangahau River running along the property's eastern extent, with the river mouth approximately 4 km to the north. The elevation difference between the property boundary and the river is in the order of 3 m in the south and 2 m in the north during higher tides. The Porangahau River water level at the site appears to fluctuate between 1-2 m between high and low tides. The overall elevation across the site varies between 1-8 m.a.s.l.

Throughout the property's extent are a series of small streams and drains conveying water from the hills in the west to the Porangahau River in the east. There are two main flowing streams running in a west to south-east direction through the property's southern extent. Both streams enter the property from the west and flow in an east to south-east direction before converging and flowing to the Porangahau River. The southern stream has been realigned, with both streams irregularly lined with willow trees. At the time of investigations, the northern stream and downstream of where these converge, had been excavated to remove the accumulation of sediment and weed. It should be noted that both of these two main streams originate in the hills to the west of the property and are therefore influenced by farming practices and climatic conditions to the west of the Stoddart Farm.

In addition to these streams, there are a series of small drains running throughout the property, however at the time of investigations, none of these drains contained water.

Furthermore, a small pond containing water of 0.2 ha is located within the northern extent of the property in the Dam paddock. This pond appeared shallow at no more than 0.5 m deep.

The site contains a series of wind blown dune ridges running through the northern extent of the property. These ridges reside on the heavy clay, alluvial plain of the Porangahau River and run in a north-south direction between the Dump and Cattle Yards paddocks and represent the highest points across the property. These ridges are approximately 2-3 m higher than the surrounding lower lying alluvial floodplain.

The site contains a series of sudden depressions within the land surface, characteristic of former dune blowouts. These blowouts vary in size but are approximately 2-3 m depth. The largest of these blowouts is located predominantly within the Rough paddock and is likely to be the location of a proposed storage pond for wastewater irrigation. Smaller dune blowouts are located within Dump and Cattle Yards paddocks.

A site map containing these key features of the property including all streams, drains, ponds and dune blowouts is provided within Figure 2, Appendix A.

3.3 Infrastructure in Locality

There is minimal infrastructure outside of fences, gateways, and small stream culverts and crossings across the property. Within the southern parcel, approximately 200 m from Beach Rd within the Hay Barn paddock is a barn surrounded by a series of larger trees.

3.4 Archaeological Features

The Porangahau coastline between Porangahau in the south to Blackhead Point in the north contains a strong cultural and spiritual connection to local Māori iwi and because of this, there are numerous sites of significance along the coastline.

The Stoddart farm contains a series of historic pits, presumably dug by Māori, which are now represented as depressions within the landscape. Up to six large and numerous small pits are present within the northern extent of the Aerodrome, Pump and Hay Barn paddocks. The location of these pits are shown within Figure 2, Appendix A.

3.5 District Plan

The Site is located within the Rural Zone under the Central Hawke's Bay District Plan maps (Map 19).

3.6 Flooding Risk

According to HBRC (2020), in terms of flooding from the Porangahau River and streams, the entire property extent is at risk of flooding to varying degrees. Areas classified as being flood risk areas are confined to the southern extent of the parcel, as well as to the land within close proximity to the two flowing streams. Land to the north, residing on the sand dunes and higher elevated regions are classified as being low risk areas to flooding.

In terms of coastal inundation from a tsunami type event, HBRC represents modelled inundation extents for two scenarios; a near source and distant source inundation event. These scenarios are both for a worst case scenario, being up to a 2,500 year return period. Based on these modelled inundation extents, for a near source tsunami event, the entire property is classified as being at risk. For a distant source tsunami, at risk regions are confined to the north-eastern corner, adjacent to the Porangahau River.

4 SITE INSPECTION AND DESCRIPTION

4.1 General

An initial desktop assessment of land surrounding the Porangahau and Te Paerahi WWTPs was undertaken which identified the suitability of the proposed property (474 Beach Road) to receive Porangahau and Te Paerahi's wastewater (Lowe Environmental Impact, 2020). Field investigations were undertaken where the property of interest was examined through:

- A site survey (both site walkover and drone flyover);
- Soil descriptions (on-site 1 m deep soil pits);
- Hydraulic conductivity measurements (saturated and unsaturated conditions);
- Groundwater standpipe installation; and
- Soil chemistry measurements.

Soil descriptions, hydraulic conductivity and chemical analysis results, as well as installed standpipe groundwater observations and findings are presented within the following sections.

4.2 Site Survey

4.2.1 Purpose

On site ground/aerial surveys are designed to give a better understanding of the designated application site prior to further work taking place. These investigations allow comparisons to be made between what has been identified through desktop site analysis and what is present in reality. This is vital as it essentially enables aspects that may be missed or not made aware of during a simple desktop analysis to be identified and examined. Furthermore, on site investigations enable parameters such as soil boundaries and conditions or elevations to be measured with higher accuracy than what may have been simply modelled through a desktop study.

Information gathered during the survey included:

- Current land uses;
- Identification of landforms within the investigation area;
- Land condition;
- Location and type of erosion/deposition features; and
- Assessment of similarities and disparities between testing sites.

4.2.2 Site Observations

Specific site and soil observations were undertaken at five sites across the property. Here soil hydraulic conductivity was measured, alongside soil descriptions to 1 m depth. Soil samples were also collected. The five site locations are shown in Figure 3, Appendix A. Sites 1-3 were all located on lower elevated clay soils within the southern extent of the property. Site 4 was located on the higher elevated central sand dunes, overseeing the southern portion of the property. Site 5 was located to the north-east on the alluvial flats, adjacent to the river. The following sub-sections describe key site characteristics:

Current Land Uses:

The current site land use is described as a low intensity sheep and beef finishing block. During investigations there were a mixture of predominantly cattle (steers) and sheep, with chickens, boar and a horse also present. All cattle appeared to be of similar age (<2 years), with these spilt into 3-4 herds in respective paddocks. Approximately 60 cattle were present on site, with herds located in Aerodrome, Cattle Yards, Oats and Hay Barn paddocks on both soil types. Sheep were also split to respective flocks within particular paddocks. In total approximately 200-250 sheep were located across the site, split into four mobs, located within Rams, Killer, Cattle Yards and Crossing paddocks.

Throughout the majority of the property, ryegrass was the dominant form of vegetation cover. Both an oats and chicory crop had been recently planted within Dam and Triangle paddocks respectively. Dump, Rough and Cattle Yards paddocks were grown in a mixture of cocksfoot, marram grass and ryegrass, with Humps, Lane and Oats paddocks grown in cocksfoot grass.

The Plantation paddock to the north was previously a pine forest plantation with this harvested in 2016. Since then, this block has been replanted in pine with trees being <2 years old at no more than 1 m in height.

Identification of Landforms within the Investigation Area

The Site resides on the combination of the alluvial floodplain of the Porangahau River, as well as a series of wind blown sand dunes from the coast.

Paddocks including and south of Pump, Aerodrome and Hay Barn, as well as Far River, Dam and Triangle to the north-east, all reside on the alluvial floodplain of the Porangahau River. These paddocks are all lower lying in comparison to those through the property's northern and central extent. The northern extent of Pump, Aerodrome and Hay Barn, as well as the western extent of the Dam and Triangle paddocks, all contain gentle slopes to the higher elevated sand dune paddocks. Figure 4.1 below represents the variation in elevation across the property with values shown in metres above sea level.

All remaining paddocks (Cattle Yards, Plantation, Pigs, Rough, Oats, Humps, Lane and Dump) all reside on sand dunes and are therefore vary topographically with regards to slope and elevation.

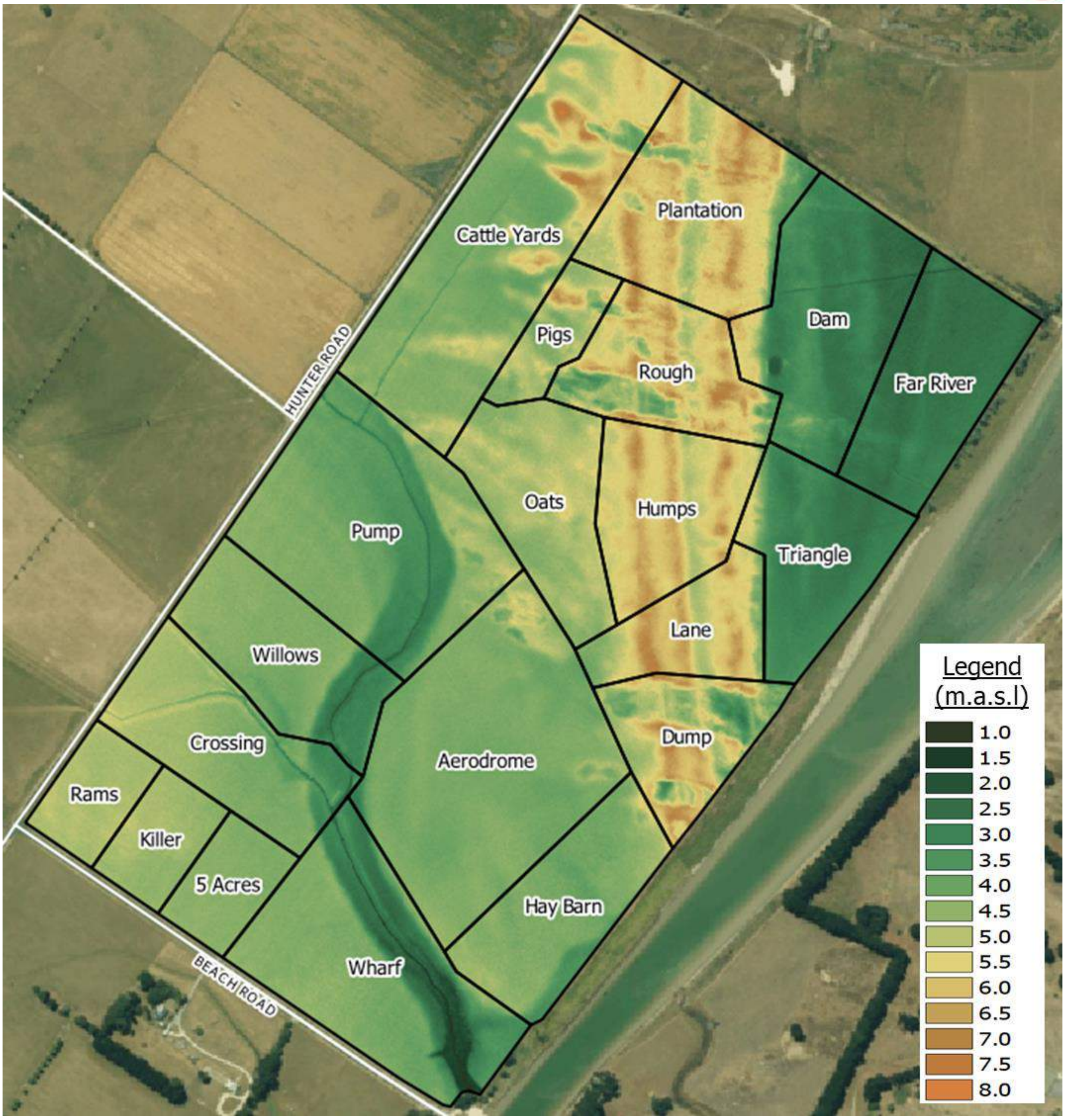

Figure 4.1: Elevation Map of the Stoddart Farm

*Lidar imagery provided by HBRC contained a z value of +10 m which has been accounted for within elevation imagery and numbers supplied within this report.

Land Condition

Following site investigations, there did not appear to be any significant limitations of the site to receiving wastewater. All paddocks outside of those on the central sand dunes (to the south and north-east) appeared to contain adequate pasture growth for a property within close proximity to the coast and a clay subsoil.

The landowner noted the ability to establish pasture growth on paddocks residing on the sand dunes to be difficult, primarily due to minimal to no soil structure below the shallow topsoil layer. Removal of this topsoil promotes the mobilisation of underlying sand particles through wind erosion at a greater rate than what new grass can establish. The landowner noted the previous implementation of direct seed drilling, however this also had its difficulties with pasture establishment. Success in achieving pasture cover for Dump, Lane and Humps paddocks was through cocksfoot pasture species over ryegrass, which appeared to have better success at establishment with the mobile subsoil. Emphasis was placed on the careful management practices required to manage stocking numbers and type, grazing periods and cultivation to ensure that the topsoil layer remains intact, preventing wind erosion from mobilising the underlying sand.

Furthermore, regarding the cropping blocks, the landowner noted the presence of slugs to be having a major impact on crop establishment. This is an ongoing issue, with no clear solution seeming to have a significant impact. Although both cropping blocks appeared to have reduced growth rates and degrees of patchiness, the Triangle block appeared to be greatest affected with patches of this block being resown multiple times to attempt at establishing the chicory block currently present.

Location and type of Erosion/Depositional Features

Across the site, the most significant erosional/depositional feature is wind erosion. Although wind does have the ability to be a source of deposition when there is an intact topsoil layer, supplying sand particles to the soil surface, the greatest risk to the site comes from its erosional capabilities. As mentioned, there is minimal topsoil protecting the underlying subsoil in the sandy dune areas, meaning should the topsoil layer be removed, establishing pasture cover to prevent this wind erosion can be very difficult. Loss of soil with minimal structure through wind erosion can be catastrophic through loss of nutrients, loss of soil particles and a dramatic reduction to farm productivity. Site investigations and discussions with the landowner confirmed the risk of wind erosion through both past farm experiences and the presence of former dune blowouts across the site.

Furthermore, the Porangahau River can also be a source of erosional/depositional processes. Although the river does have the ability to erode, within this case, it is considered to be a source of deposition. With the southern and north-eastern extents of the property located on the alluvial plain of the Porangahau River, these regions are likely to receive alluvial material (sands and silts) during significant flooding events.

4.2.3 Drone Flyover

As part of field investigations, aerial imagery for the entire property was captured using a drone. Captured imagery included photos, videos and a whole site flyover. Photos and videos were taken across the site, providing a better perspective of the site to what can be experienced on the ground. Photos of the Site are shown within Figure 4.2 through Figure 4.6. The red line represents the property boundary for the Site.

Figure 4.2: SW looking E

Figure 4.3: W looking E

Figure 4.4: W looking NE

Figure 4.5: NW looking SE

Figure 4.6: NE looking W

A site flyover was undertaken using a drone to capture updated aerial imagery of higher quality and greater accuracy than what was previously available for the Site. The drone was flown at a height of 60 m from the starting takeoff elevation. The drone was pre-programmed to fly the Site, taking vertical images that were later stitched together creating an updated imagery layer for the Site.

4.3 Soil Description

On site 1 m test pits were hand dug at each of the five testing locations to describe soil conditions of the topsoil and underlying subsoil. This enables similarities and differences between sites to be understood and analysed in greater depth than what would be possible through desktop analysis. It also enables unusual features or layers that would not be represented through desktop analysis such as pans, buried topsoil or vegetation, peat or charcoal from fires to be identified.

Estimated soil boundaries produced through a combination of desktop investigations as well as on site observations are provided in Figure 4, Appendix A.

4.3.1 Purpose

The purpose of soil profile description is to obtain information to assess the lateral continuity of subsurface features and identify any horizons which may impede the passage of water within the soil. Changes in soil morphology due to variations in the landform and land use across the site can be used to identify areas of preference for applying wastewater.

4.3.2 Descriptions

Individual soil descriptions for each of the five sites are provided within Appendix B. To undertake soil field investigations, initial desktop evaluations to understand the property need to occur with these provided below. A summary of the classified soil types from Smap for the Stoddart Farm are as follows:

The Stoddart Farm can be divided into two main soil types; clay soils and sandy soils. For the clay soil as shown in Figure 4, Appendix A, there appears to be two similar but contrasting soil types described by Smap; the Kaiapo Silt Loam and the Hastings Silt Loam. Smap notes the presence of both of these soils, however there is reduced confidence in terms of the boundaries for these two soils. Following historic landscaping of the property and influencing of the groundwater level through draining, neither of these soils completely match what was observed on site but rather represent a combination of these two soil types. A summary of these soils from Smap are as follows:

> Kaiapo Silt Loam (Flaxton_69a.1): This gley soil is classified as being a deep, silt over clay textured, poorly draining soil with a 37-54 cm rooting depth and a rooting barrier being anoxic conditions. This soil is stoneless, with a 25-35% topsoil clay range and a medium topsoil P retention with a moderate over slow permeability status.
>
> Hastings Silt Loam (Hast_29a.1): This gley soil is classified as being a deep, loam over sand textured, poorly draining soil with unlimited rooting depth and no barrier for roots. This soil is also stoneless with a 19-21% topsoil clay range and a medium topsoil P retention with a moderate over rapid permeability status.

The clay soil on site contained a 30 cm deep, silty loam topsoil with a nutty/crumb structure, overlying a heavy clay. Rooting depth was to ~40 cm with the barrier limiting rooting depth being the clay layer. There were no signs of anoxic conditions, other than mottling within the clay layer, indicating a varying water table. The topsoil contained minimal clay content, which is likely to have had a low P retention and a poorly drained permeability status.

The other soil occupying the northern sand dunes of the site is as follows:

> Kairaki Sandy Loam (Kyra_15a.2): This soil is classified as being a raw soil with a sand texture with no barrier to rooting depth. This soil is deep and well drained with a rapid permeability profile. Due to this rapid permeability profile from being a sand dune essentially and very low profile available water, the potential rooting depth for the soil is only 5-10 cm. This soil extends throughout much of the north and central extent of the property, occupying the steeper slopes typical of sand dunes.

A variation of the Kairaki Sandy Loam occupies the alluvial plain adjacent to the Porangahau River to the north-east which differs to the Kairaki Sandy Loam overlying the dunes. Topsoil depth, structure, colour, and texture are similar between these soils, however greater pasture production is noticed on the lower elevated land to the north-east compared to the dunes. This is likely due to greater profile available water and/or lower permeability status of these lower lying soils compared to those on the dunes. At 65 cm depth, this soil contains the same heavy clay noticed in the southern extent of the property and therefore represents a combination of the Kairaki Sandy Loam (topsoil) and the Kaiapo Silt Loam (>65 cm).

It is likely that its position on the landscape influences this soil to the north-east. Due to being positioned at a lower elevation, it is influenced by the deposition of the Porangahau River depositing the lower lying clay layer, which has subsequently received wind blown sandy material supplying the dunes.

Factsheets for each of the soils listed are available at Smap (2020) by entering the bracketed name above into the 'soil name' category.

Assessment of Similarities/Disparities between Testing Sites

Three of the testing sites were located on the clay soils where between these sites there was minimal variation within the soil profile, with essentially each of these being on the same soil type. Between each of these three sites, topsoil and subsoil depth, colour, texture and structure were relatively similar with the only minor difference being ~20% mottles noticed in the subsoil at Site 5 with ~10% noticed for Sites 1 and 2.

Site 3 topsoil was relatively similar to lower elevated sites in terms of depth, colour and structure with the main variation coming within the sandy subsoil. Here the subsoil was comprised of a structureless brownish-gold sand, typical of a sand dune, with no presence of the clay layer up to a metre depth.

Located on the alluvial floodplain to the north-east, Site 4 contained the same clay layer as noticed for Sites 1, 2 and 5, however this was at greater depth. As with all other sites, the topsoil appeared to be relatively similar, with this closely reflecting that of Site 3. Variation for this location to other sites was the presence of a thin black layer between the topsoil and clay subsoil, representative of either a charcoal layer from a historic forest burn, or a former back dune peat swamp.

4.3.3 Clay/Sand Soil Boundary

Investigations were undertaken to understand the soil boundary between the Kaiapo Silt Loam and Kairaki Sandy Loam. This soil boundary runs across the property along the northern extent of the Pump, Aerodrome and Hay Barn paddocks. Soil auger holes along the sand side of this boundary indicated that sand appears to override the clay with clay being reached at approximately 20 cm below the surface. It is estimated that south of this boundary, minimal sand is present within the Kaiapo Silt Loam. Northwards of this boundary, it is estimated that the clay remains at an equivalent elevation noticed in the southern and north-eastern extents of the property, and the Kairaki Sandy Loam simply overrides this clay to varying depths, changing the topography of the land.

A series of scarps were observed on the steeper bank of the Porangahau River between the water edge and the Stoddart fenceline. These scarps were viewed to assess whether there was any variation in the soil profile at the edge of the property to what was assessed for each testing site. Scarps were also to assess how groundwater flows through the Site and meets with the Porangahau River. From these scarps, the soil profile appeared to be similar to what was noted at the testing sites in that clay was noticed nearer the land surface in the south and north, with this not being visible through the central reaches of the property where there was a sand overlay. In addition to this, there was no sign of groundwater seepage through the clay layer at the scarp face, implying that groundwater percolates to such depth before it moves laterally to meet with the Porangahau River prior to reaching the edge of the Stoddart property.

4.4 Soil Descriptions: Summary and Implications for Land Treatment

Both structureless sand and heavy clay at various sites may cause potential limitations for wastewater irrigation and will need to be managed accordingly. Sand can be great for irrigation as soil permeability and porosity tends to be much greater meaning more wastewater can be applied to the land. However, this increase in permeability can reduce the period at which wastewater containing nutrients will be able to interact with and be taken up by plants, potentially increasing leaching risks.

In contrast, clay tends to have limited permeability and porosity, meaning irrigation rates will need to be reduced, in order to reduce the risk of surface ponding. Despite each of these factors to be aware of, neither of these are expected to prevent wastewater irrigation to the site.

5 SOIL HYDRAULIC CONDUCTIVITY

5.1 General

Soil hydraulic conductivity (K) is a measure of the rate at which water is able to enter soil and move through the profile. K is dependent on multiple soil properties including, particle size, mineralogy, degree of packing, permeability, porosity, and pressure head. Direct measurements of soil hydraulic conductivity can be undertaken either within the field itself or through laboratory testing methods.

5.2 Purpose

Locations for site soil hydraulic measurements were selected to give a representative picture of various soil types and landforms spanning the site. By undertaking hydraulic measurements on varying soil types and landforms, areas of a property that may be limited to receiving wastewater can be identified and an appropriate designated application rate can be calculated. The measurement of K was undertaken to allow an assessment of the ability of the site to receive wastewater under varied application regimes. The location where measurements were undertaken are provided within Figure 3, Appendix A.

5.3 Testing Methodology

Two testing methodologies for soil hydraulic conductivities were used as follows:

5.3.1 Soil Saturated Hydraulic Conductivity by Double Ring Infiltrometer

For determination of the soils ability to receive wastewater to the soil surface at a high rate, K_{sat} was measured using a double ring infiltrometer, a preferred method for establishing K_{sat} near the soil surface. The double ring method measures vertical flow only, eliminating possible overestimation of infiltration due to lateral flow of water within the soil.

The rings are seated level in the soil, to a depth of several centimetres, then filled with water; the outside ring first, then the internal ring. Timed recording then measures the rate of water level fall in the inner ring over time to determine K_{sat}. A total of 4 replicates where undertaken for each site.

5.3.2 Soil Unsaturated Hydraulic Conductivity by Plate Permeameter

For determination of the soils ability to receive wastewater to the soil surface at a low rate, soil unsaturated hydraulic conductivity ($K_{-40\ mm}$) was measured using a CSIRO plate permeameter apparatus (Perroux and White, 1988). The permeameter method enables measurement of soil near-saturated hydraulic conductivity. Near-saturated soil conditions are favoured over saturated soil conditions in consideration of low rate application sites because:

- Near-saturated conditions more closely reflect typical soil conditions; and
- Saturated hydraulic conductivity may cause overestimation of infiltration due to the initiation of bypass flow under saturated conditions.

The goal of near-saturated hydraulic conductivity tests for wastewater irrigation is to determine the rate at which the soil has the capacity to draw water into the soil matrix whereby the potential for ponding, runoff, excessive wetness and preferential flow (excessive flow through the macro-pores) is reduced. Typically, it is desired in a land application system to avoid flow through the larger macro pores. Preferential flow is an issue as it reduces the time in which soil has to interact with applied wastewater, thus reducing the volume of applied nutrients within wastewater that can be adsorbed to soil surfaces or taken up by plants. The rate at which water can flow (be absorbed) into the soil avoiding macropores is often defined as the flow rate when the matrix potential is less than -40 mm (i.e. $K_{-40\ mm}$) (Sparling et al, 2004).

The plate permeameter comprises a porous plate covered with a membrane. The plate is placed on a levelled soil surface which may have a thin layer of sand added to ensure good contact between the plate and soil is achieved. Water is held under suction in water towers above the plate. A known suction is applied to the water. The ability of the soil to draw water from the plate reflects the rate at which the soil's matrix potential can effectively and sustainably accept the applied water. The soil hydraulic conductivity is determined by a relationship between a measured drop in the water level in the water tower relative to the diameter of the plate.

Measurements of the drop in water level were taken at regular intervals and continued until the drop in water level reached a steady state for at least 3 readings. Three replicate tests were performed for each site.

The plate permeameter apparatus results in three dimensional flow of water under the plate (i.e. vertical and horizontal flow is measured). In order to avoid overestimation of soil hydraulic conductivity, the measured flow is converted to one dimensional flow (i.e. vertical flow only) using the Woodings (1968) equation. Data obtained from three levels of varying matrix potential (-100, -40 and -20 mm) are used to determine to $K_{-40\ mm}$ for vertical flow.

5.4 Results

A summary of the hydraulic conductivity results is provided below. The test locations are shown in Figure 3, Appendix A.

5.4.1 Double Ring Infiltrometer Results

The K_{sat} at the surface of each of the Sites was measured in quadruplicate. The average results for each of the sites are represented within Table 5.1 below.

Table 5.1: Soil Saturated (K_{sat}) Results

Testing Location	Soil Saturated Hydraulic Conductivity K_{sat} (mm/h)	Smap Drainage Class
Site 1	42 ± 25	Poorly drained
Site 2	25 ± 31	Poorly drained
Site 3	124 ± 17	Well drained
Site 4	88 ± 22	Well drained
Site 5	44 ± 29	Poorly drained
Clay Sites (Sites 1, 2 & 5)	**37 ± 28**	**Poorly drained**
Sandy Sites (Sites 3 & 4)	**106 ± 20**	**Well drained**

Infiltrometer results appear to represent good correlation with currently identified soil drainage statuses retrieved through Smap descriptions. Sites on well drained soils, appear to have greater hydraulic conductivities than those on poorly draining soils which is to be expected. This therefore means that application rates will need to vary depending on the underlying soil type. The reasoning for high standard deviation values, particularly for the clay sites, is due to the slow permeability status of the soil.

5.4.2 Plate Permeameter Results

The plate permeameter tests were conducted in triplicate. Plots of the $K_{-40\ mm}$ results for each of the five locations on the Stoddart Farm Site are given in Appendix C. These plot shows the soil hydraulic conductivity at the three matrix potentials as mentioned in Section 5.3.2 above. Table 5.2 represents a summary of the $K_{-40\ mm}$ results for each of the locations.

Table 5.2: Soil Unsaturated ($K_{-40\ mm}$) Results

	Soil Unsaturated Hydraulic Conductivity $K_{-40\ mm}$ (mm/h)
Site 1	15.50 ± 3.95
Site 2	7.37 ± 4.46
Site 3	18.36 ± 1.8
Site 4	9.1 ± 4.23
Site 5	9.0 ± 4.1
Clay Sites (Sites 1, 2 & 5)	**10.63 ± 4.17**
Sandy Sites (Site 3 & 4)	**13.73 ± 3.02**

Based on both on-site, alongside desktop observations, it is considered that the $K_{-40\ mm}$ value that should be adopted for clay regions of the site to be 10.63 (11) mm, and for sandy regions to be 13.73 (14) mm. Any irrigation applied to the site should be at a rate that does not exceed these respective volumes.

5.5 Determination of Sustainable Hydraulic Loading Rate

In addition to allowing for the ability of water to enter the soil, consideration should be given to the effect of wastewater constituents, as opposed to clean water effects which are typically observed during field measurements. Organic material, solids and nutrients in the wastewater can allow the development of microbial growth commonly referred to as biofilm, which in turn can result in a 'clogging' effect of the soil pores, particularly near the soil surface. This in turn reduces the soil's infiltration capacity. In addition, the salt concentration will influence the soil wetting by altering the water tension.

There are limited empirical methods for developing an 'enriched' water rate from 'clean' water observations. This is because the rate is variable depending on the type of wastewater, nutrient and organic content, soil type, application method and application regime. A range in the order of 4 to 10 % is often used for 'clean' water to wastewater conversion (USEPA, 2006). The conversion rate implied in AS/NZS 1547:2000 ranges from 0.17 to 5 %. Both references mentioned above refer to a conversion between saturated hydraulic conductivity (not unsaturated conductivity) and wastewater application rates.

The need for 'clean' water to wastewater conversion is noted by Crites and Tchobanoglous (1998) who report an empirical method to determine a wastewater rate from a clean water measurement. The measured instantaneous rates can be translated into a daily hydraulic design irrigation rate using the following equation, which is modified from Crites and Tchobanoglous (1998):

$$P\ (\text{daily}) = K_{-40\ mm}\ (0.1\text{-}0.3)\ (24\ \text{h/d})$$

Where:
P = the design irrigation rate
Is a function of 10-30% of the $K_{-40\ mm}$
Over 24 hours in the day.

The use of this equation and a conservative 30% function of the unsaturated (not saturated) infiltration rate at $K_{-40\ mm}$ provide a maximum hydraulic design irrigation rate of 79 mm/d (for clay soils) and 101 mm/d (for sandy soils). At this rate, the site is likely to be able to accept water without the generation of adverse effects on the immediate receiving environment and the soils itself. This is considered the maximum rate that can be accepted by the site however, consideration needs to be given to the resulting nutrient loading, land management practices and the site's attenuation ability, which may result in a reduction of the actual rate.

5.6 Soil Hydraulic Properties: Implications for Land Treatment

The soil saturated hydraulic conductivity (K_{sat}) is 37 ± 28 mm/hr for clay sites and 106 ± 20 mm/hr for sandy sites. The unsaturated hydraulic conductivity ($K_{-40\ mm}$) is 11 mm/hr for clay sites and 14 mm/hr for sandy sites. In order to avoid excessive loss of water, nutrients and other contaminants to adjacent surface water a rate more closely related to the $K_{-40\ mm}$ is recommended. For long term discharge with a short irrigation return time a rate of up to 79 mm/d (for clay sites) and 101 mm/d (for sandy sites) is recommended for the Stoddart Farm Site.

6 SHALLOW GROUNDWATER OBSERVATIONS

6.1 General

Drainage from wastewater land treatment systems can impact groundwater. Ideally nutrients are stripped within the soil matrix, however, drainage volumes influence groundwater levels which then in turn influence groundwater flow direction. Depending on groundwater (and soil) conditions, water movement can be limited and drainage may see water level rising towards the surface.

6.2 Purpose

Groundwater depth will likely vary across a Site, reflecting variations in topography, drainage and seasonal changes during wetter or drier periods. Standpipes provide an opportunity to gather basic groundwater level information and can be used to determine groundwater contours and flow directions. Installation of standpipes in a grid like fashion can allow cross sections to be produced, representing groundwater variations in relation to the land surface.

6.3 Installation Methodology

A standpipe system sees a thin slotted hollow metal pipe driven vertically into the ground to a desired depth, with slots along the pipe allowing for groundwater infiltration providing a simple measure of groundwater depth.

A standpipe is made from three components, a drive cone, an end pipe, and an extension pipe. As the name suggests, the drive cone is pointed and fixed to the end pipe and acts as a means of reducing resistance as the pipe is driven into the ground. The end pipe is attached to the drive cone and contains a series of vertical slits enabling water to infiltrate into and out of the pipe. The drive cone is designed to be wider than the end pipe, enabling the vertical slits to not become blocked as the pipe moves vertically into the ground. Once the top of end pipe is near the soil surface an extension pipe can be placed on top and driven in further, increasing the total depth of the standpipe. The end pipe length is 1.75 m with each of the extension pipes being 1.25 m.

Standpipes were installed using a hydraulic ram of a soil coring trailer. Standpipes were installed along fencelines at low elevations. Installing pipes at lower elevations, increases the likelihood of reaching groundwater. Installing standpipes along fencelines allows standpipes to be out of the way of general farming practices such as cultivation, as well as reduces the risk of damage from stock.

6.4 Standpipe Locations

A total of 11 standpipes were installed throughout the property, providing a good distribution to measure depths and the establishment of a hydraulic gradient. Where possible, standpipes were installed in locations where cross sections can be produced. Figure 5, Appendix A represents the distribution of standpipes throughout the Stoddart Farm.

6.5 Results

Table 6.1 represents standpipe characteristics for the Stoddart Farm. Standpipes were installed over the first two days of site investigations and water levels were recorded on the morning of the third. This was to allow sufficient time for water to percolate through the soil and into the pipe, which for certain soil types, particularly clay, can be slow.

Table 6.1: Installed Standpipe Characteristics

	Total Depth (TOC) (m)[1]	Total Depth (GL) (m)	Casing Height (m)	Water Level (GL) (m) (25/11)	Water Level (GL) (m) (21/12)[3]	Location
SP1	2.80	2.50	0.297	None	1.37	-40.295781°S, 176.645230°E
SP2	2.81	2.44	0.370	0.46	0.59	-40.294210°S, 176.648673°E
SP3	2.85	2.57	0.281	2.28	2.30	-40.29602°S, 176.65199°E
SP4	2.80	2.49	0.312	None	None	-40.28875°S, 176.65201°E
SP5	2.53	2.22	0.313	2.03	2.01	-40.29256°S, 176.65123°E
SP6	2.79	2.49	0.304	0.26	0.78	-40.29092°S, 176.64769°E
SP7	2.85	3.08	-0.230[2]	None	None	-40.29150°S, 176.65576°E
SP8	2.82	2.55	0.273	None	None	-40.29007°S, 176.65500°E
SP9	2.92	2.61	0.313	2.05	1.01	-40.28874°S, 176.65202°E
SP10	2.49	2.19	0.304	1.40	1.58	-40.28972°S, 176.65756°E
SP11	2.62	2.24	0.382	2.23	None	-40.28539°S, 176.65382°E

[1] TOC – Top of casing. When a standpipe is installed, a section remains above the land surface (casing). When a probe is sent down the pipe, depths are recorded against the top of the casing. This casing height must be removed from the recorded water level to give the actual water level relative to ground level. Both ground level columns have had this casing height removed.
[2] The top of this standpipe has been installed at 23 cm below the land surface. This was due to issues with the coring trailer where there is typically a maximum depth that the trailer has the ability of drilling to. This maximum depth was suddenly reached at 3.08 m. Due to this standpipe top being below the land surface, the surrounding land was partially levelled, and the standpipe casing head increased, allowing accessibility.
[3] Groundwater levels from the standpipes were recorded at two different dates, one being on the final day of fieldwork and the other being a month later to allow for sufficient time for groundwater to enter the standpipes. Groundwater levels from the latter date (21/12) will be used for standpipe cross sections below.

6.5.1 Cross Sections

A cross section depicts a 2D representation of groundwater depth relative to the land surface. Groundwater depths can be estimated using standpipe recordings.

A total of four cross sections have been produced for the Stoddart Farm. The location of these are represented within Figure 6, Appendix A. Measured water levels used within the below cross section diagrams are from the sampling run done on the 21st of December, allowing sufficient time following standpipe installation for groundwater levels to stabilise.

Transect A to A' (SP6 to SP4)

This cross section encompasses three standpipes (SP6, SP5, and SP4) extending in a west to east direction. These standpipes were positioned enabling groundwater levels to be assessed running across the width of the property rather than the length.

Figure 6.1 represents the groundwater cross section across these standpipes, with levels recorded in two of these. Groundwater at SP6 (Hunter Road) was recorded at 0.78 m below ground level, increasing in depth to 2.01 m at SP5. SP5 and SP6 are relatively similar in elevation with the only difference being the stream flowing between these. From SP6, groundwater is likely to slowly drop to be at the surface at the stream. Eastwards of the stream, the land appears to increase at a greater rate than the rise of groundwater. This is expected and explains the groundwater depth increase at SP5 compared to SP6.

SP4 is at a similar elevation to SP5 and SP6, however no groundwater has been recorded at this location. This can be explained through the r drop in groundwater depth relative to the land surface within proximity of the adjacent Porangahau River. As noted for the stream between SP6 and SP5, groundwater drops/dips to be level with the invert/flowing water body. At SP4, it would be expected that groundwater would be reached within an extra metre or so depth of drilling, as it flows eastwards to the river.

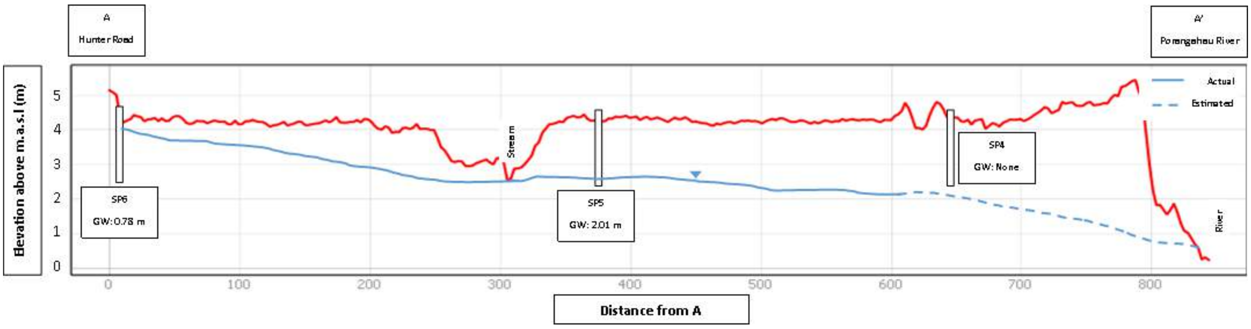

Figure 6.1: Transect A Cross Section

Transect B to B' (SP1 to SP11)

Transect B encompasses five standpipes (SP1, SP2, SP6, SP9 and SP11) extending south to north along the property, adjacent to Hunter Road.

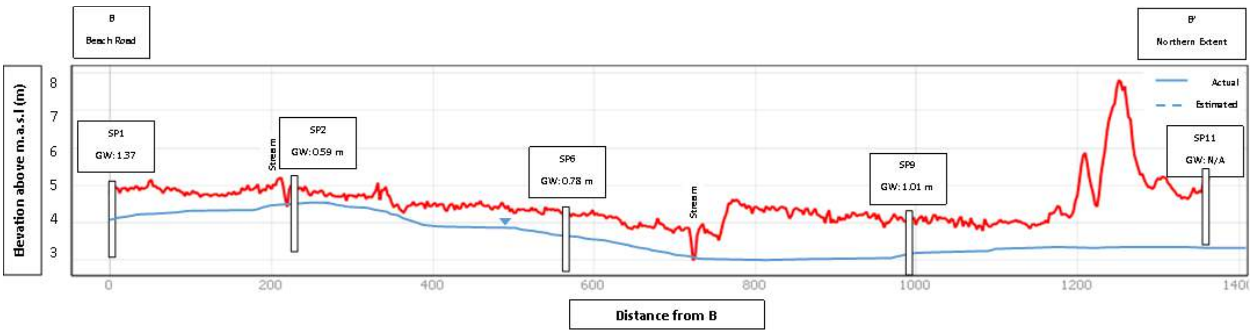

Figure 6.2: Transect B Cross Section

Figure 6.2 represents the cross section across five standpipes with levels recorded in four. Groundwater was recorded to be 1.37 m below the land surface at SP1 with this rising to be 0.59 m below ground level at SP2 and then dropping to be 0.78 m at SP6. Groundwater depth across these three standpipes are estimated to be relatively even with changes in ground level relative to groundwater to be the reason for varying depths here. Northwards of SP6, ground level remains relatively flat at SP9 at a depth of 1.01 m. Ground level rises to SP11 with no groundwater being reached for the latest sampling run. It is estimated that groundwater is likely within half a metre or so from the bottom of the standpipe with groundwater being measured at the base within the initial sampling run which has now dropped below this following no significant rainfall recently.

As with Transect A, groundwater appears to not align with the land surface as to be expected, but rather conforms to low gradient fluctuations to align with waterways and topographical lows across the transect.

Transect C to C' (SP3 to SP10)

Transect C encompasses four standpipes (SP3, SP4, SP7 and SP10) extending south to north, parallel to Transect B, although adjacent to the Porangahau River (Figure 6.3). This cross section is important as typically groundwater is known to drop suddenly towards a flowing surface water body, irrespective of the land surface. Understanding this sudden drop can be important to assess how the eastern extent of the property may be used for irrigation.

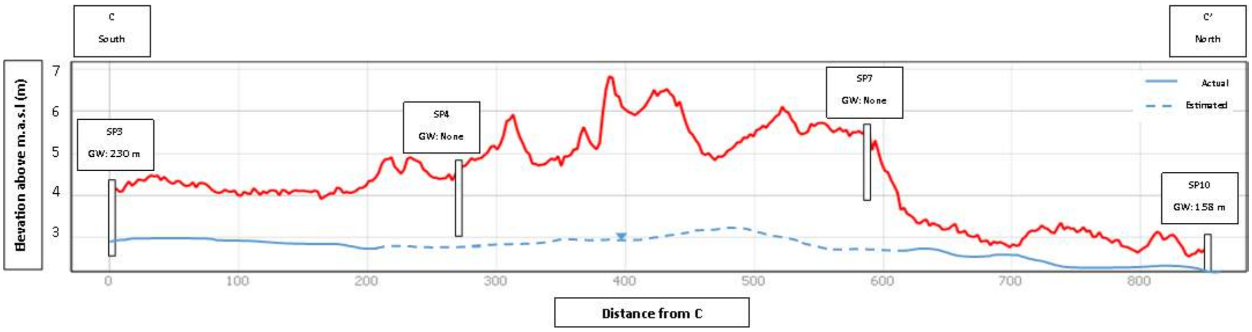

Figure 6.3: Transect C Cross Section

This cross section encompasses the higher elevated sand dunes in which SP7 is located on, as well as the alluvial plain to the north and south of the property. Groundwater depths were recorded for both SP3 and SP10 in the northern and southern extent, however, were not reached at SP4 and SP7 through the central sand dunes. Groundwater was recorded at SP3 to be 2.30 m below ground level. As mentioned, no groundwater was recorded for either SP4 or SP7, however it was reached for SP10 with this being 1.58 m from the land surface.

This indicates that, as with other transects, there is likely to be minimal variation in groundwater depth between what has been recorded on the alluvial plain to the north and south.

Transect D to D' (SP1 to SP10)

Transect D encompasses five standpipes (SP1, SP2, SP5, SP8 and SP10) extending in a southwest to northeast direction, running diagonally throughout the property. This cross section essentially encompasses standpipes running throughout the property and alongside Transects A, B and C, gives a complete overview of groundwater fluctuations across the Site using all standpipes (Figure 6.4).

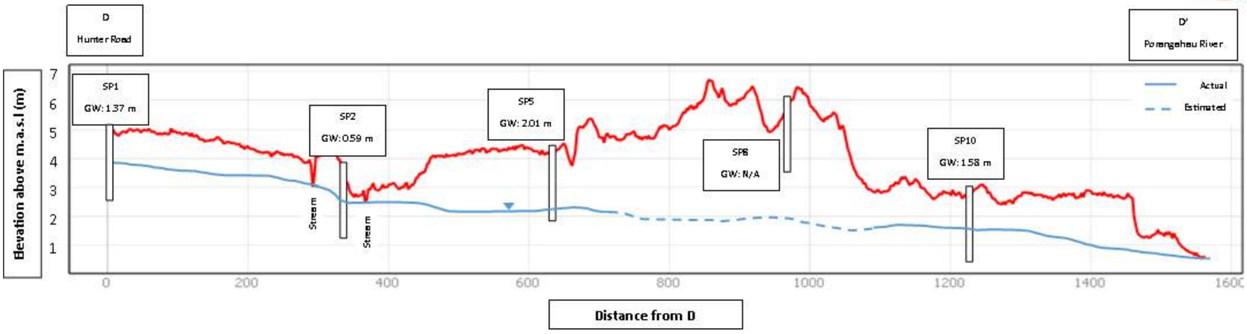

Figure 6.4: Transect D Cross Section

Groundwater was measured within four of the five standpipes with the only standpipe not reaching groundwater being SP8, located on the higher elevated sand dune. SP1 recorded groundwater at a depth of 1.37 m with this being recorded at 0.59 m from the land surface at SP2. The land surface drops towards SP2, with SP2 located within a low point between the two streams, implying that groundwater is likely to be at a relatively uniform level between these two standpipes, and the difference in groundwater depth being due to topographical variation. Land elevation rises to SP5 located on the alluvial plain of the river with groundwater here measured to be 2.01 m below the land surface. No groundwater was recorded within SP8 due to this being located on the higher elevated sand dunes. Located on the low lying north-eastern alluvial plain, groundwater was recorded to be 1.58 m below the land surface here.

Groundwater flows along Transect D appear to conform to observations noticed for Transect C in that there appears to be reduced fluctuation in groundwater height between the lower lying clay sites and the higher elevated sandy sites. The reduction in the depth to groundwater for SP10 relative to SP5 can be explained through the variation in elevation between the two sites, with groundwater likely being at very similar depth between these but appear different due to topographical variation. This essentially means that if SP8 was deeper into the ground so that the bottom of the standpipe was at the equivalent depth of where groundwater was reached between SP5 and SP10, then it would be expected for groundwater to be reached here also.

6.6 Summary

Groundwater recordings from the 11 standpipes provide good overview for how shallow groundwater flows and varies across the Site. Over the two sampling runs, groundwater through the lower lying clay sites varies between 0.78 m below ground level at SP6 to 2.30 m at SP3. All standpipes on the clay soil returned groundwater between these levels, with no significant variation in ground level between these indicating, minimal fluctuation of groundwater throughout this southern and north-eastern extent of the property.

Standpipes on higher elevated dunes didn't contain groundwater, despite being driven to 2.5-3 m, indicating groundwater doesn't significantly rise from lower elevation as observed in clay soils. Groundwater absence here indicates that applied water will soak in and rapidly drain to groundwater that is likely at equivalent elevation to that measured for clay soil sites. Groundwater was measured for lower lying sandy sites (SP9/SP11) although at depth, further supporting the idea of groundwater remaining within the underlying clay layer at depth and showing minimal evidence of rising into the overlying sand layer.

Across the Site, it appears groundwater doesn't substantially reflect topography changes, but rather appears to be at a particular elevation, with very minor fluctuations in response to changes in topography. It is expected however that seasonal groundwater fluctuation will be significant within the underlying clay layer due to its low permeability characteristics.

7 SOIL CHEMISTRY

7.1 Soil Chemistry Sampling

Soil samples were retrieved for soil chemistry analysis within the proximity of each of the five locations where soil conductivity testing occurred. Samples were retrieved using a foot corer to a depth of 75 mm. Approximately 20 samples were retrieved for each testing location. Foot corer samples aim to give a representative overview of soil conditions. Collected samples per location were from the same landform type, away from influencing features such as gateways, fencelines, troughs, vehicle tracks etc. These samples were sent to Hills Laboratories with the following parameters analysed:

7.2 Soil pH

All sites contained slightly acidic topsoils ranging in pH between 5.9 to 6.7 pH units (Figure 7.1). Site 2 contained the most acidic topsoil (5.9), with Site 5 being the least acidic (6.7). The ideal pH range for sedimentary soil is between 5.8 and 6.2 pH units. Sites 1 and 2 are within this range, however Sites 3, 4 and 5 are not and all contain less acidic (more neutral/basic) topsoil pH statuses.

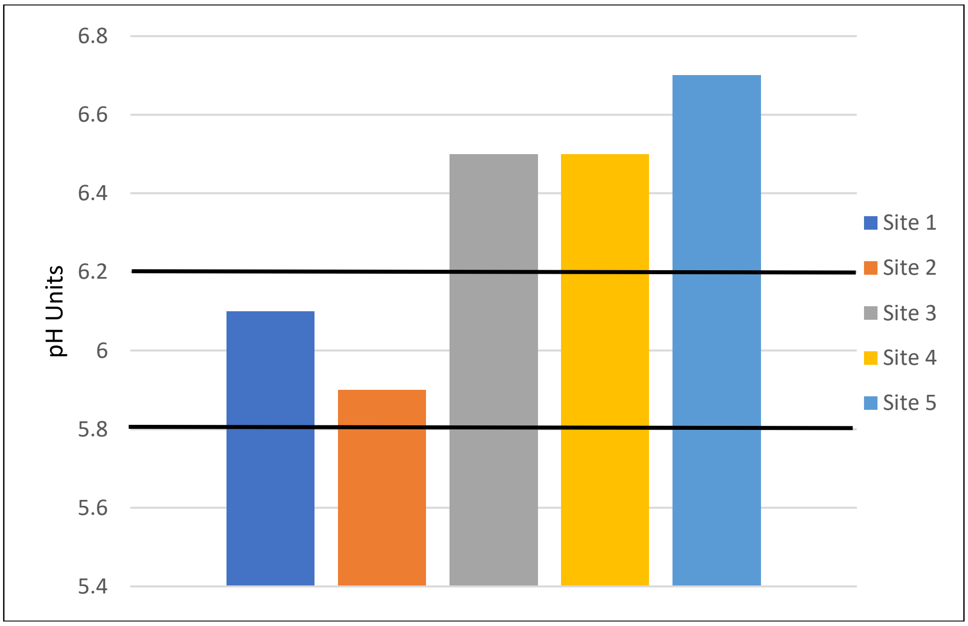

Figure 7.1: Soil pH Results

7.3 Soil Phosphorus and Anion Storage Capacity

Olsen P and Anion Storage Capacity (ASC) results are represented within Figure 7.2 and Figure 7.3 respectively. For sedimentary soil, the ideal range for Olsen P is between 20-30 mg/L, with only Site 1 (29 mg/L) being within this range. Site 2 (18 mg/L) showed a lower than optimal Olsen P value, with Sites 3, 4 and 5 all containing elevated Olsen P between 46-49 mg/L.

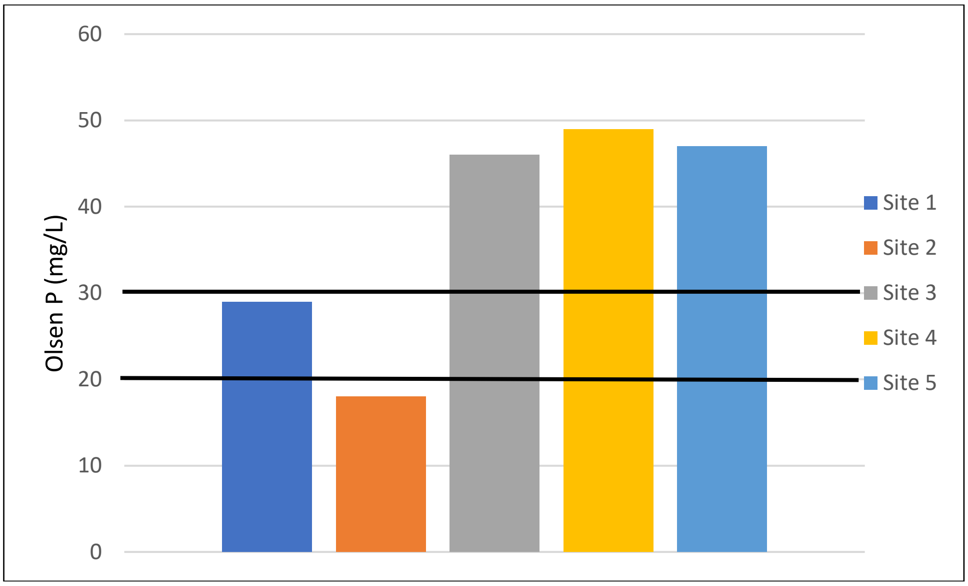

Figure 7.2: Soil Olsen P Results

As expected, all sites contain low ASC values with this greatest for Site 1 (26%) and lowest for Site 3 (14%) (Figure 7.3) (Hills Laboratories, n.d.). ASC values are greater for sites on clay to the south, with these lower on sandy sites. Between these figures, there is not a clear relationship between Olsen P and ASC, with this represented through Site 3 for example where the site has an elevated Olsen P, but a low anion storage capacity (14%).

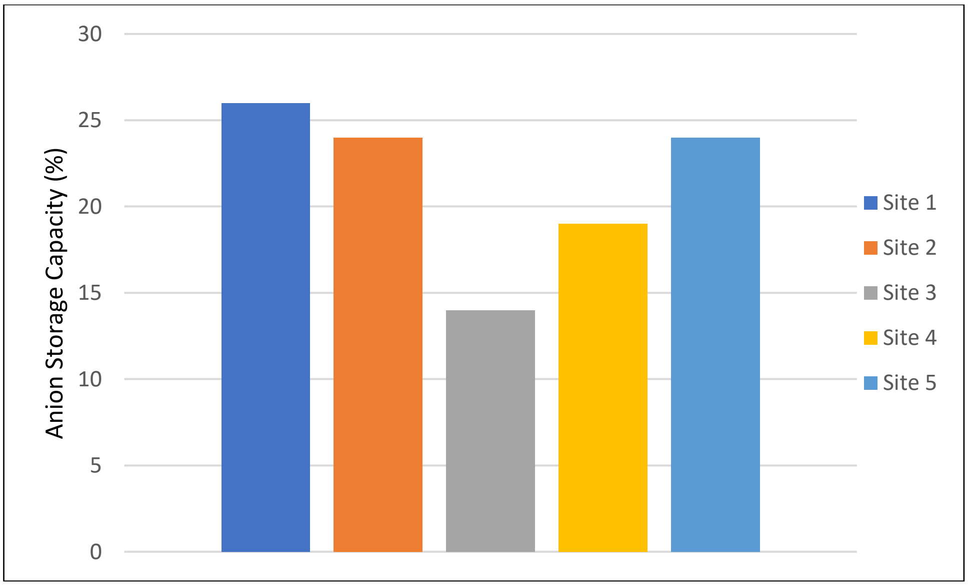

Figure 7.3: Anion Storage Capacity Results

7.4 Soil Sulphate

Sulphate-S is represented within Figure 7.4, with Sites 2 and 5 containing greater but adequate sulphate-S concentrations. The optimal range for sulphate-S for sedimentary soil is 10-12 mg/kg. From this, Sites 2 and 5 are at the lower end of this range with Sites 1, 3 and 4 all being below this with Site 3 containing the lowest sulphate-S concentrations.

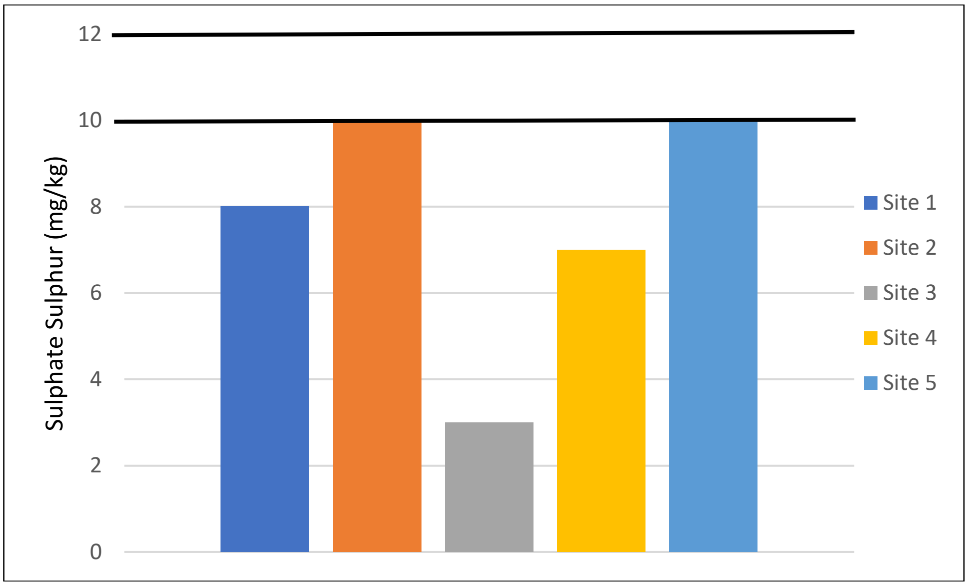

Figure 7.4: Sulphate Sulphur Results

7.5 Carbon and Nitrogen Dynamics

Results relating to carbon and nitrogen concentrations and relationships between them are shown in Figure 7.5 through Figure 7.8. Figure 7.5 shows soil carbon concentrations varying between 2.6% and 6.8%, with these greatest for Sites 1 and 2 (6.7% and 6.8% respectively), and lowest for Site 3 (2.6%). As with ASC and sulphate-S concentrations, this demonstrates the variability between sandy and clay soils in terms of nutrient status.

Figure 7.6 and Figure 7.7 show total N and potentially available N concentrations, respectively. Total N quantifies the percentage of soil N in all nitrogen forms (organic or inorganic), whereas potentially available N is a measure of the volume (kg/ha) of soil N considered plant available. Between graphs, the relationship of total nitrogen and potentially available nitrogen between sites is very similar. Sites 1 and 5 contain the highest total and potentially available nitrogen concentrations, with Site 3 containing the least, again representing the variation between sandy and clay sites.

From Figure 7.6, total N varies between 0.24% (Site 3) and 0.65% (Site 5). Hills Laboratories (n.d.) identifies total N values between 0.2-0.5% to be of a medium status with values between 0.5-1.0% characteristic of a high total N content. Sites 2, 3 and 4 are all classified has having medium total N contents, with Sites 1 and 5 being high.

For potentially available N, the optimal range is between 150-250 kg/ha. From this, it is apparent that only Sites 3 and 4 are within this range with all sites on clay, being substantially greater (>300-350 kg/ha). These particularly high available nitrogen concentrations on clay sites may be due to recent fertiliser applications, resulting in increased plant available N within the topsoil.

Figure 7.8 represents C:N ratios for each of the sites with these varying between 10.4 and 11. When comparing these values with those identified by Hill Laboratories, these are all classed as medium (10-15).

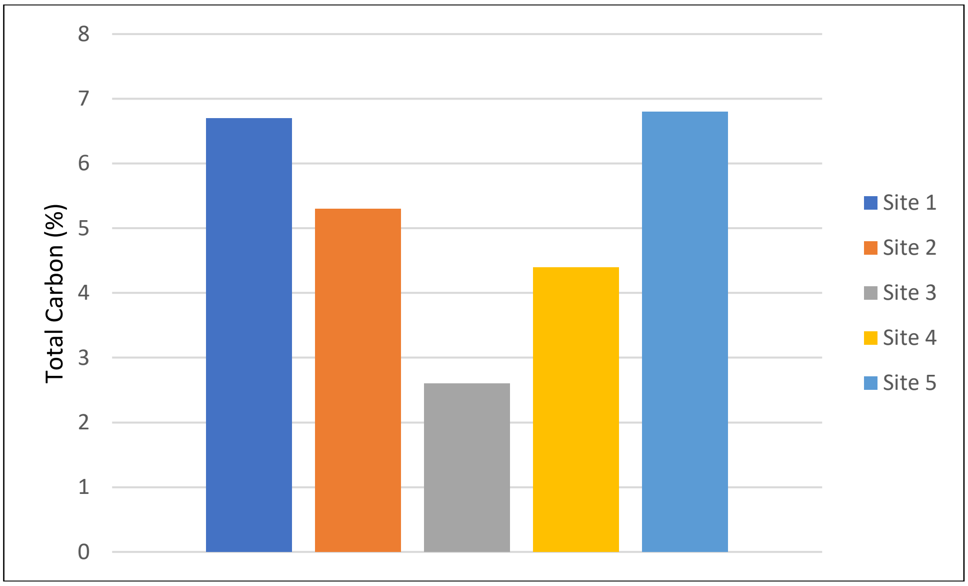

Figure 7.5: Total Carbon Results

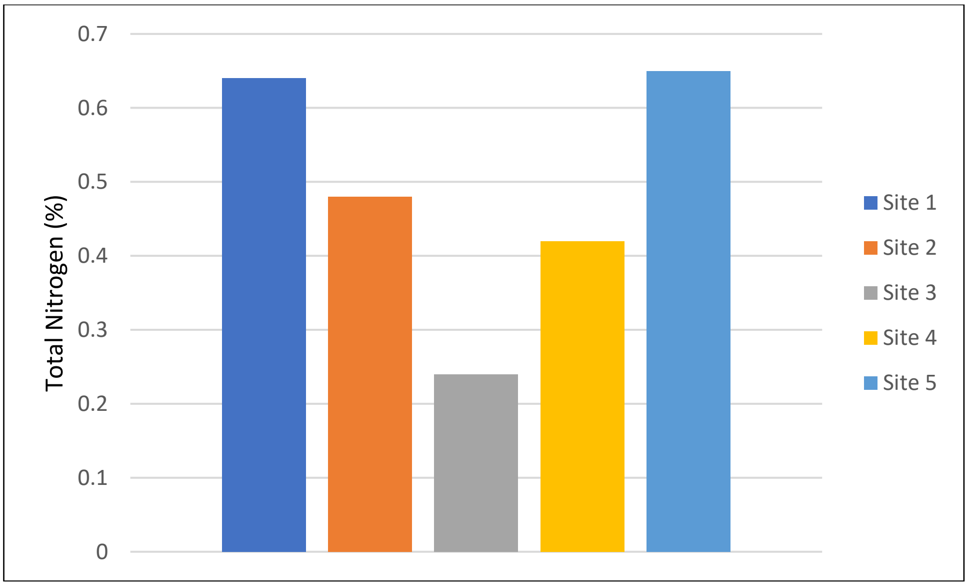

Figure 7.6: Total Nitrogen Results

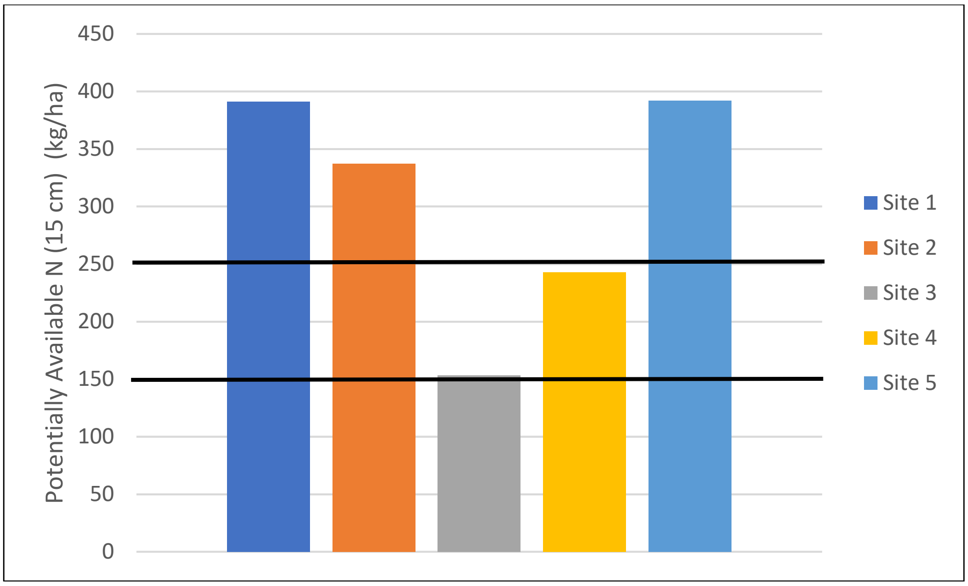

Figure 7.7: Potentially Available N Results

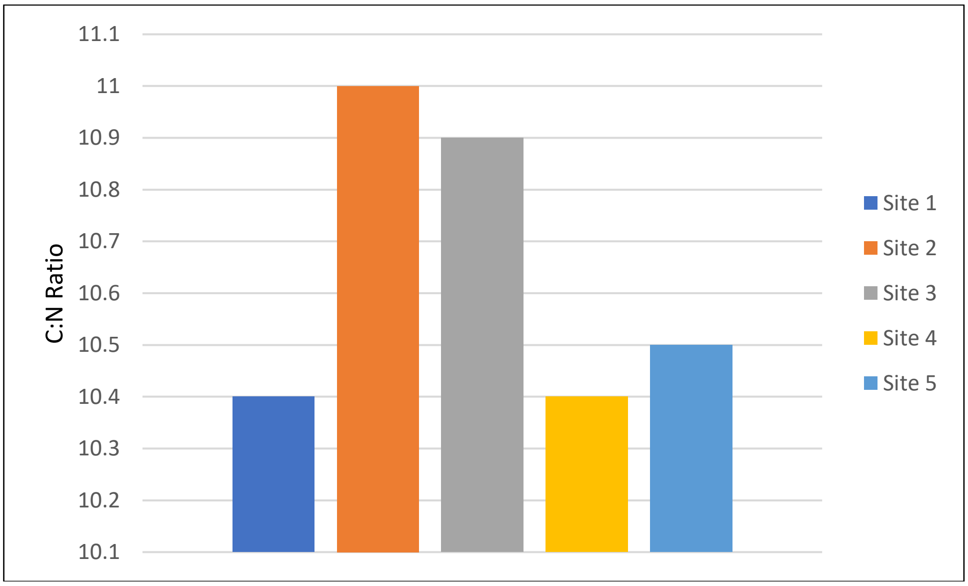

Figure 7.8: C:N Ratio Results

7.6 Cation Status and Cation Exchange Capacity

Figure 7.9 represents the variation in four key cations across the site; Potassium (K), Calcium (Ca), Magnesium (Mg) and Sodium (Na). Each of the five sites are represented moving from left to right (Site 1 = left, Site 5 = right).

For Potassium, exchangeable K is lowest at Site 3 (0.43 me/100g), increasing to 1.35 me/100g at Site 4. The optimal range for exchangeable K for pasture is between 0.3-0.4 me/100g, implying that, all five sites currently contain elevated potassium concentrations.

Calcium concentrations range between 7.3 me/100g (Site 3) and 39 me/100g (Site 5). In terms of optimal ranges, for pasture, this is between 4.0-10.0, and between 5.0-12.0 for cropping blocks. From this, only Site 3 is within this optimal range with all other sites containing elevated concentrations, with Site 5 containing substantially high calcium concentrations.

Magnesium concentrations range between 0.55 me/100g (Site 3) and 3.63 me/100g (Site 5). For optimal ranges, these are between 0.4-0.6 me/100g for pasture and between 0.6-1.2 me/100g for cropping blocks. From this, as with calcium concentrations, only Site 3 is within the optimal range with all other sites containing elevated magnesium concentrations.

Sodium concentrations range between 0.09 me/100g (Site 3) and 0.43 me/100g (Site 5). There are no designated optimal ranges for exchangeable sodium by Hill Laboratories.

In terms of cation exchange capacity (CEC), this is greatest for Site 5 (46 me/100g) and lowest for Site 3 (11 me/100g). As expected, these CEC values closely reflect the overall exchangeable cation concentration results in that the higher the CEC, the greater the concentration of exchangeable cations.

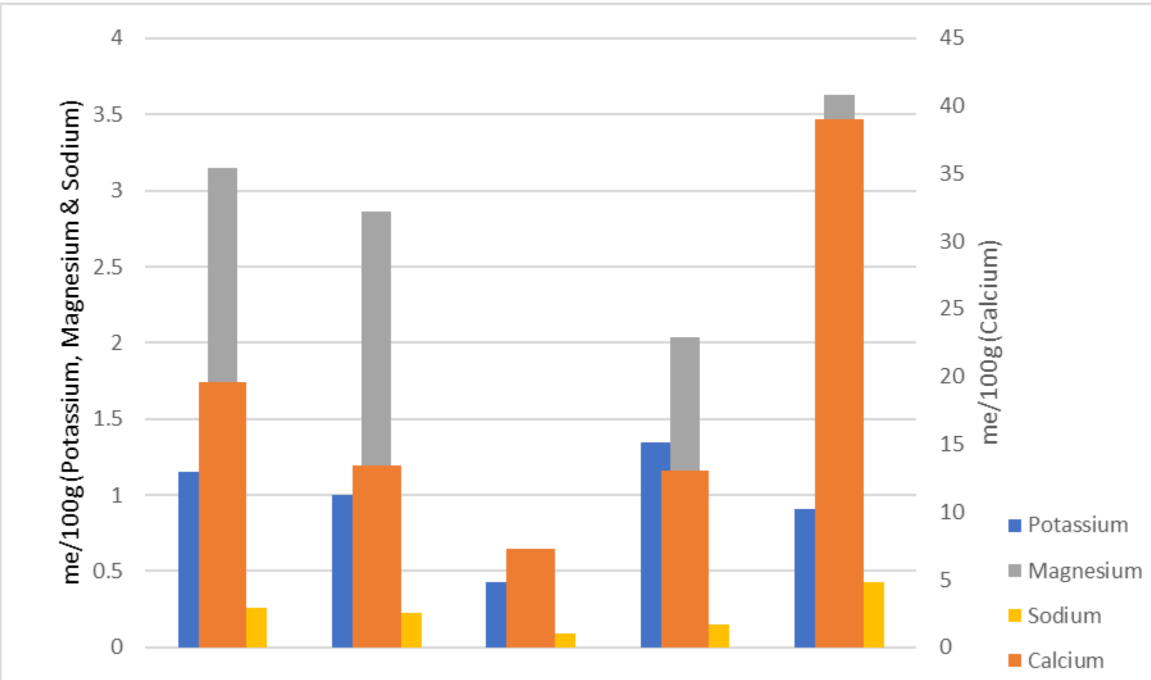

Figure 7.9: Exchangeable Cation Results

7.7 Summary of Soil Chemistry

The key implications of the soil chemical analysis results are:

- Sites 1 and 2 contain pH values within ideal ranges (6.1 and 5.9 respectively), however Sites 3, 4 and 5 all contain less acidic (more neutral/basic) pH values.
- Site 1 contains a suitable Olsen P value (29 mg/L) with Site 2 (18 mg/L) being lower than optimal. Sites 3, 4 and 5 contain elevated Olsen P values (46-49 mg/L). Furthermore, ASC is typically low across the Site with no clear relationship between Olsen P and ASC values for each location.
- Sites 2 and 5 contain sulphate-S concentrations within the lower end of the ideal range (10 mg/kg), with Sites 1, 3 and 4 all containing sulphate-S concentrations lower than this optimal range.
- Total C and total N concentrations appear to resemble one another in that sites overlying clay in the south, appear to contain greater total C and N concentrations than those on sandy sites. For total N, sites vary between 0.24% and 0.65%. Sites 2, 3 and 4 are all classed as having medium total N concentrations, with Sites 1 and 5 being high.
- Sites 3 and 4 contain adequate potentially available N between the range of 150-250 kg/ha, however Sites 1, 2 and 5 are all substantially higher than this (>300-350 kg/ha). This very high available nitrogen may be due to recent fertiliser applications to clay soils.
- Cation concentrations across the property are all particularly high with Site 3 being within the optimal range for potassium, calcium and magnesium, however outside of this, all sites contain high cation levels, some exceptionally high. Site 5 in particular contains particularly high calcium and magnesium concentrations.
- Cation exchange capacity is greatest for Site 5 (46 me/100g) and lowest for Site 3 (11 me/100g) and closely resembles exchangeable cation concentrations in that the greater the CEC, the greater the concentration of exchangeable cations.
- Overall, there appears to be significant variation between clay and sandy sites. Similarities are evident between Sites 1, 2 and 5 (clay) and Sites 3 and 4 (sandy), but variation between these groups in terms of sulphate-S, total C, total N, potentially available N and all cation concentrations.

Soil chemistry results are represented within Table 7.1.

Table 7.1: Soil Chemistry Results

	Units	Testing Locations				
		Site 1	Site 2	Site 3	Site 4	Site 5
Soil Sample Depth	mm	75 mm	75 mm	75 mm	75 mm	75 mm
pH	pH Units	6.1	5.9	6.5	6.5	6.7
Olsen P	mg/L	29	18	46	49	47
Anion Storage Capacity	%	26	24	14	19	24
Sulphate Sulphur	mg/kg	8	10	3	7	10
Potassium	me/100g	1.15	1	0.43	1.35	0.91
Calcium	me/100g	19.6	13.4	7.3	13.1	39
Magnesium	me/100g	3.15	2.86	0.55	2.04	3.63
Sodium	me/100g	0.26	0.23	0.09	0.15	0.43
Total Carbon	%	6.7	5.3	2.6	4.4	6.8
Total Nitrogen	%	0.64	0.48	0.24	0.42	0.65
C:N Ratio	-	10.4	11	10.9	10.4	10.5
Cation Exchange Capacity	me/100g	30	25	11	20	46
Total Base Saturation	%	80	71	75	82	95
Volume Weight	g/mL	0.7	0.66	1.01	0.84	0.73

8 SITE ASSIMLATIVE CAPACTIY AND CONCLUSIONS

Site investigations have indicated that in general, the Stoddart Farm soils are suitable for the application of wastewater under appropriate management practices. The site is capable of assimilating up to 79 mm/d of Porangahau's wastewater per application event for land on clay soils and up to 101 mm/d for land on sandy soils. At this rate of application, the applied water, nutrients and contaminants could be expected to be assimilated by the soil under a regime avoiding the soils field capacity being exceeded.

The total irrigable area of the site is considered to be approximately 91 ha following the inclusion of buffers, however it is likely that the nominated irrigated area will be less than this following land owner preferences, irrigation design and layout, accessibility and total area available per paddock. From this 91 ha of available land, 37 ha is clay soil and 53 ha is sandy soil. It should be noted however, that the actual area on any day will be influenced by soils moisture (which could be impacted by shallow groundwater levels) and may be less than the design irrigation rate for clay or sandy soils.

Due to the varying landform types and proximity to waterways, depth to groundwater, varies across the Site. Standpipes show groundwater to be in the order of <1.5 m in the south-eastern extent of the property, with this increasing in depth in proximity to the Porangahau River (~2-2.5 m) and underlying the higher elevated sand dunes (>3 m). Groundwater is estimated to be at a relatively equal elevation across the site with a slight dip towards the river, with variation in recorded water levels likely to be due to variation in standpipe elevations. Seasonal groundwater fluctuations are expected to be significant within the underlying clay layer due to its low permeability characteristics.

9 REFERENCES

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10APPENDICES

Appendix A	Figures
Appendix B	Soil Descriptions
Appendix C	Unsaturated ($K_{-40\ mm}$) Hydraulic Conductivity Plots

APPENDIX A

Figures

LEGEND

Paddock Boundaries

CLIENT

CENTRAL HAWKE'S BAY DISTRICT COUNCIL

TITLE

Figure 1 - Stoddart Farm Paddocks

LOWE Environmental Impact

STATUS

SCALE
NOT TO SCALE

DATE/TIME
2020-12-16 16:11

JOB NUMBER
10684

LEGEND

- Paddock Boundaries
- Drain
- Stream
- Natural Pond
- Proposed WW Pond (Dune Blowout)
- Dune Blowout
- Kumara Pit

CLIENT

CENTRAL HAWKE'S BAY DISTRICT COUNCIL

TITLE

Figure 2 - Stoddart Farm Key Site Features

LOWE Environmental Impact

STATUS

SCALE	**DATE/TIME**
NOT TO SCALE	2020-12-22 14:41

JOB NUMBER
10684

LEGEND

Paddock Boundaries

Testing Locations

CLIENT

CENTRAL HAWKE'S BAY DISTRICT COUNCIL

TITLE

Figure 3 - Stoddart Farm Testing Locations

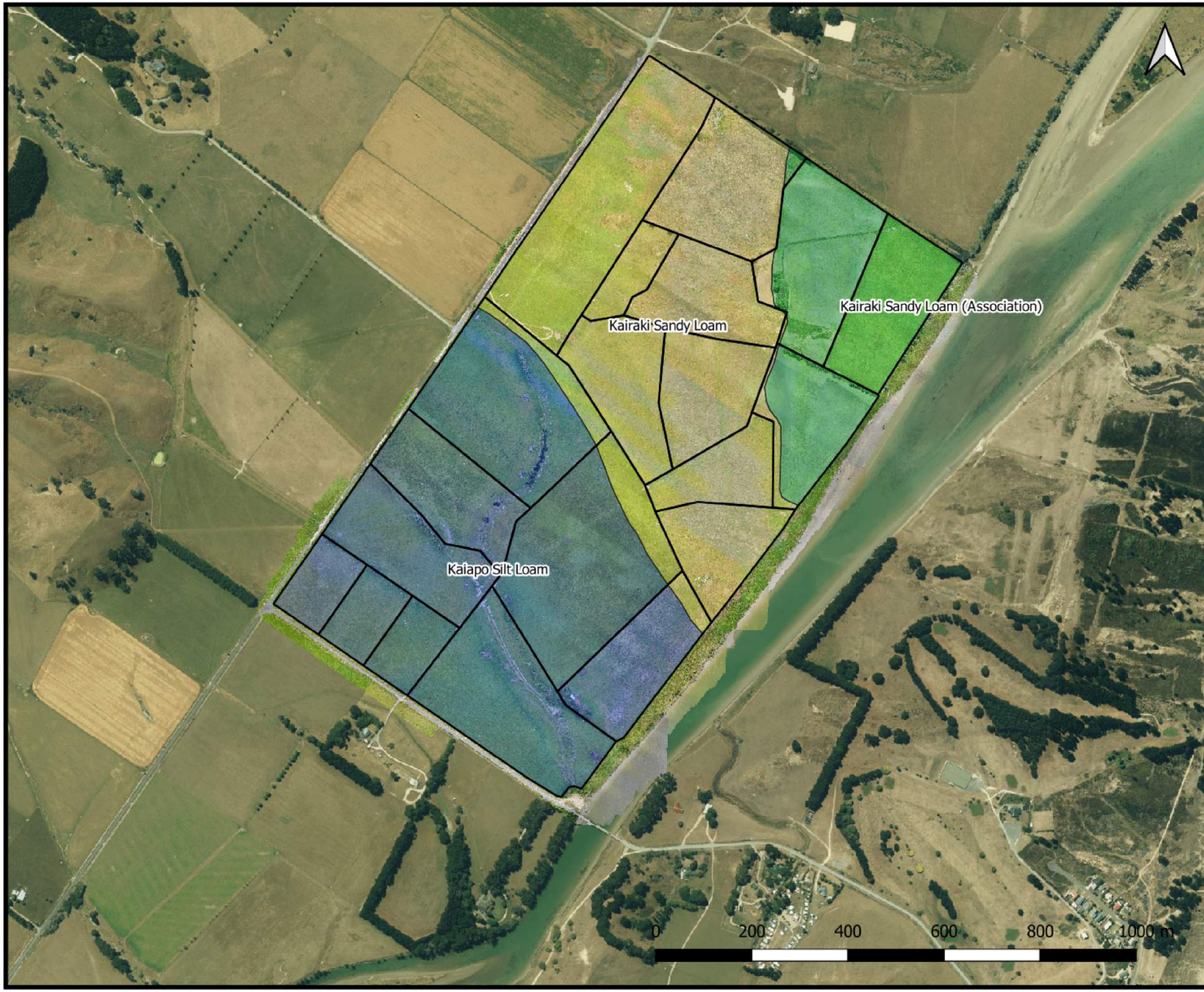
LOWE Environmental Impact

STATUS

SCALE
NOT TO SCALE

DATE/TIME
2020-12-16 16:39

JOB NUMBER
10684



LEGEND

Paddock Boundaries

Soil Types

Kaiapo Silt Loam

Kairaki Sandy Loam

Kairaki Sandy Loam (Association)

CLIENT

CENTRAL HAWKE'S BAY DISTRICT COUNCIL

TITLE

Figure 4 - Stoddart Farm Soil Map

LOWE Environmental Impact

STATUS

SCALE NOT TO SCALE

DATE/TIME 2020-12-17 08:55

JOB NUMBER 10684

LEGEND

Paddock Boundaries

Standpipes

CLIENT

CENTRAL HAWKE'S BAY DISTRICT COUNCIL

TITLE

Figure 5 - Stoddart Farm Standpipe Locations

LOWE Environmental Impact

STATUS

SCALE
NOT TO SCALE

DATE/TIME
2020-12-17 08:59

JOB NUMBER
10684

LEGEND

- Transect A
- Transect B
- Transect C
- Transect D
- Standpipes

CLIENT

CENTRAL HAWKE'S BAY
DISTRICT COUNCIL

TITLE

Figure 6 - Stoddart Farm Cross Section Transects

LOWE Environmental Impact

STATUS

SCALE
NOT TO SCALE

DATE/TIME
2020-12-17 09:35

JOB NUMBER
10684

APPENDIX B

Soil Descriptions

Soil	Kaiapo Silt Loam
Location	Site 1 - (5 Acres)
Drainage	Poorly drained (Smap, Landcare)
Topsoil depth (cm)	30 cm
Limiting horizon	None
Landform	Alluvial floodplain of the Porangahau River
Comments	Clay content appears to increase with depth within the subsoil layer.

<table>
<tr><th>Horizon</th><th>Depth (cm)</th><th>Description</th><th>Image</th></tr>
<tr><td>Topsoil</td><td>0-30</td><td>Brown (10YR 4/3) silty loam; no gravels; non sticky; slightly plastic; nut and crumb structure; fine roots to 40 cm; wavy, indistinct boundary (30-40 cm); cool; no mottles present</td><td rowspan="2"></td></tr>
<tr><td>Subsoil</td><td>40-100</td><td>Strong brown (7.5 YR 5/6) & light gray (5YR 7/1) clay loam; no gravels; sticky; plastic; blocky structure; damp & cold; 20-30% mottles present (5YR 5/8)</td></tr>
</table>

Soil	Kaiapo Silt Loam
Location	Site 2 – (Aerodrome)
Drainage	Poorly drained (Smap, Landcare)
Topsoil depth (cm)	20 cm
Limiting horizon	None
Landform	Alluvial floodplain of the Porangahau River
Comments	Clay content appears to increase with depth within the subsoil layer.

Horizon	Depth (cm)	Description	Image
Topsoil	0-20	Brown (10YR 4/3) silty loam; no gravels; non sticky; slightly plastic; nut and crumb structure; fine roots to 40 cm; wavy, indistinct boundary (20-35 cm); cool; no mottles present	
Subsoil	35-100	Strong brown (7.5 YR 5/6) & light gray (5YR 7/1) clay loam; no gravels; sticky; plastic; blocky structure; damp & cold; 15% mottles present (5YR 5/8)	

Soil	Kairaki Sandy Loam
Location	Site 3 – (Humps)
Drainage	Well drained (Smap, Landcare)
Topsoil depth (cm)	20 cm
Limiting horizon	None
Landform	Coastal sand dune overlying alluvial floodplain
Comments	No clay content noticed within upper 1 m of soil. Clay layer of the alluvial floodplain believed to be at equal elevation underlying this dune to Sites 1 & 2.

Horizon	Depth (cm)	Description	Image
Topsoil	0-20	Brown (7.5YR 4/2) sandy loam; no gravels; non sticky; non plastic; minimal structure, minor nut/crumb; fine roots to 45 cm; wavy, indistinct boundary (20-35 cm); cool; no mottles present	
Subsoil	35-100	Brownish yellow (10YR 6/8) sand; no gravels; non sticky; non plastic; no structure; cool; no mottles present;	

Soil	Kairaki Sandy Loam over clay
Location	Site 4 – (Far River)
Drainage	Well drained (Smap, Landcare)
Topsoil depth (cm)	35 cm
Limiting horizon	None
Landform	Alluvial floodplain of the Porangahau River containing wind blown sand.

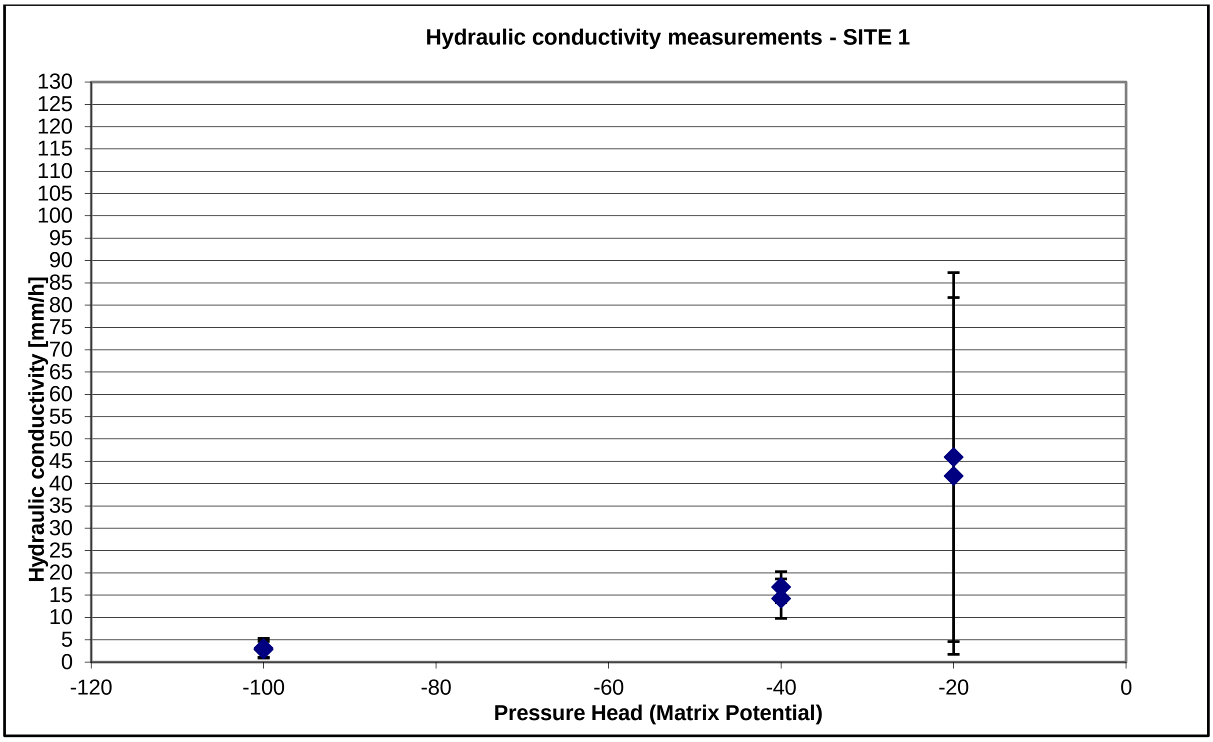
Horizon	Depth (cm)	Description	Image
Topsoil	0-35	Dark brown (7.5YR 3/2) sandy loam; no gravels; non sticky; non plastic; minimal structure, minor nut/crumb; fine roots to 50 cm; wavy indistinct boundary (35-45 cm); cool; no mottles present	
Subsoil	45-55	Black (10YR 2/1) silty loam; no gravels; non sticky; non plastic; nut/crumb structure; wavy distinct boundary (55-65 cm); cool; no mottles present	
Subsoil	65-100	Strong brown (7.5 YR 5/6) & light gray (5YR 7/1) clay loam; no gravels; sticky; plastic; blocky structure; damp & cold; 20-25% mottles present (5YR 5/8)	

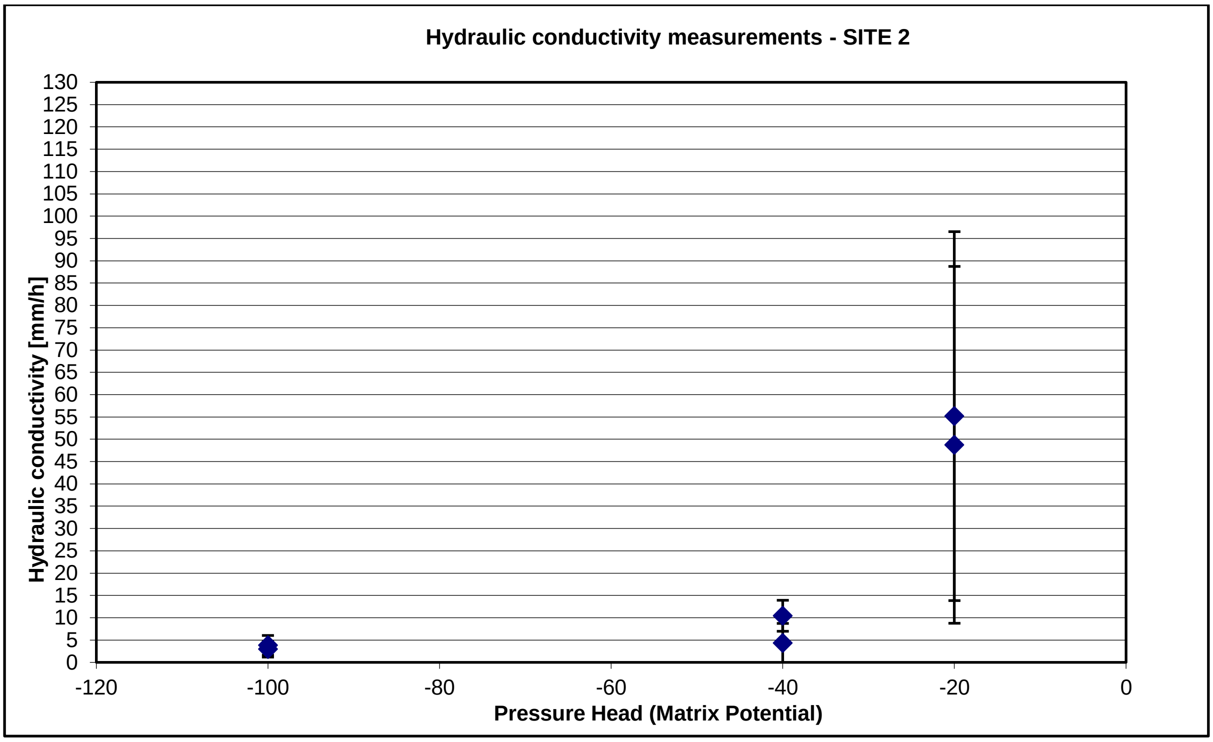
Soil	Kaiapo Silt Loam
Location	Site 5 – (Pump)
Drainage	Poorly Drained (Smap, Landcare)
Topsoil depth (cm)	30 cm
Limiting horizon	None
Landform	Alluvial floodplain of the Porangahau River
Comments	Clay content appears to increase with depth within the subsoil.

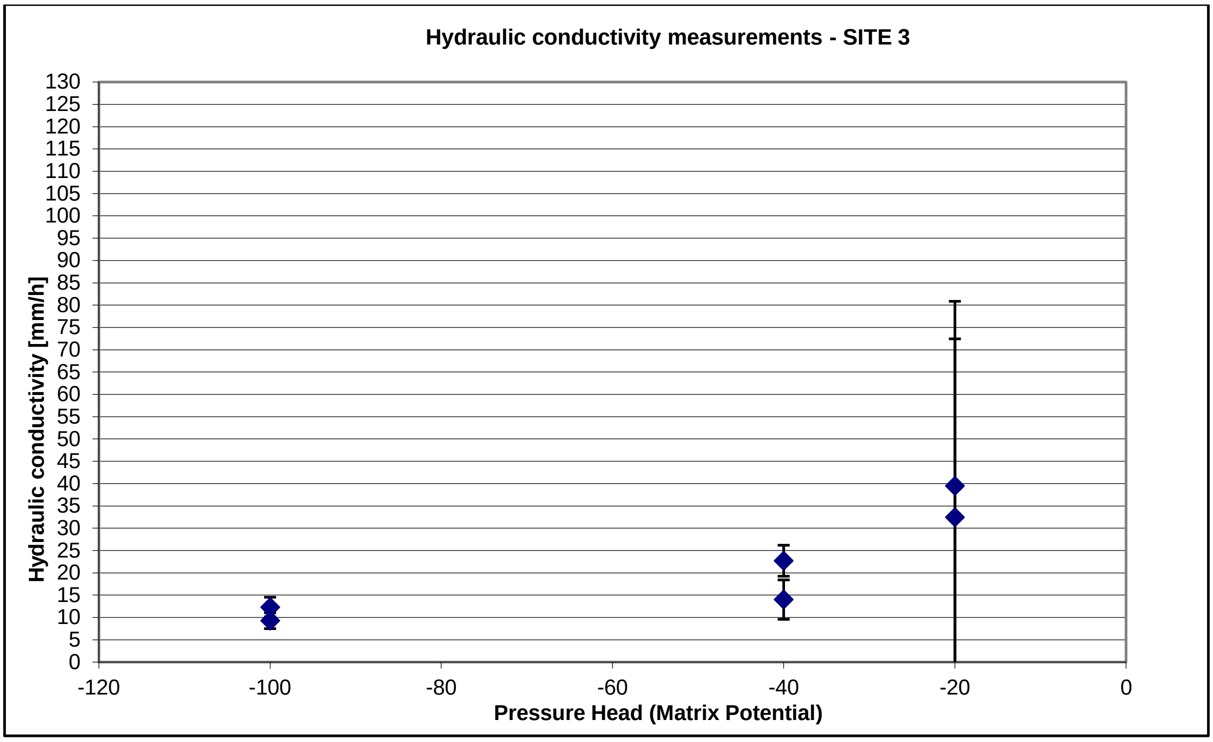
Horizon	Depth (cm)	Description	Image
Topsoil	0-30	Brown (10YR 4/3) silty loam; no gravels; non sticky; slightly plastic; nut and crumb structure; fine roots to 40 cm; wavy, indistinct boundary (30-40 cm); cool; no mottles present	
Subsoil	40-100	Strong brown (7.5 YR 5/6) & light gray (5YR 7/1) clay loam; no gravels; sticky; plastic; blocky structure; damp & cold; 20% mottles present (5YR 5/8)	

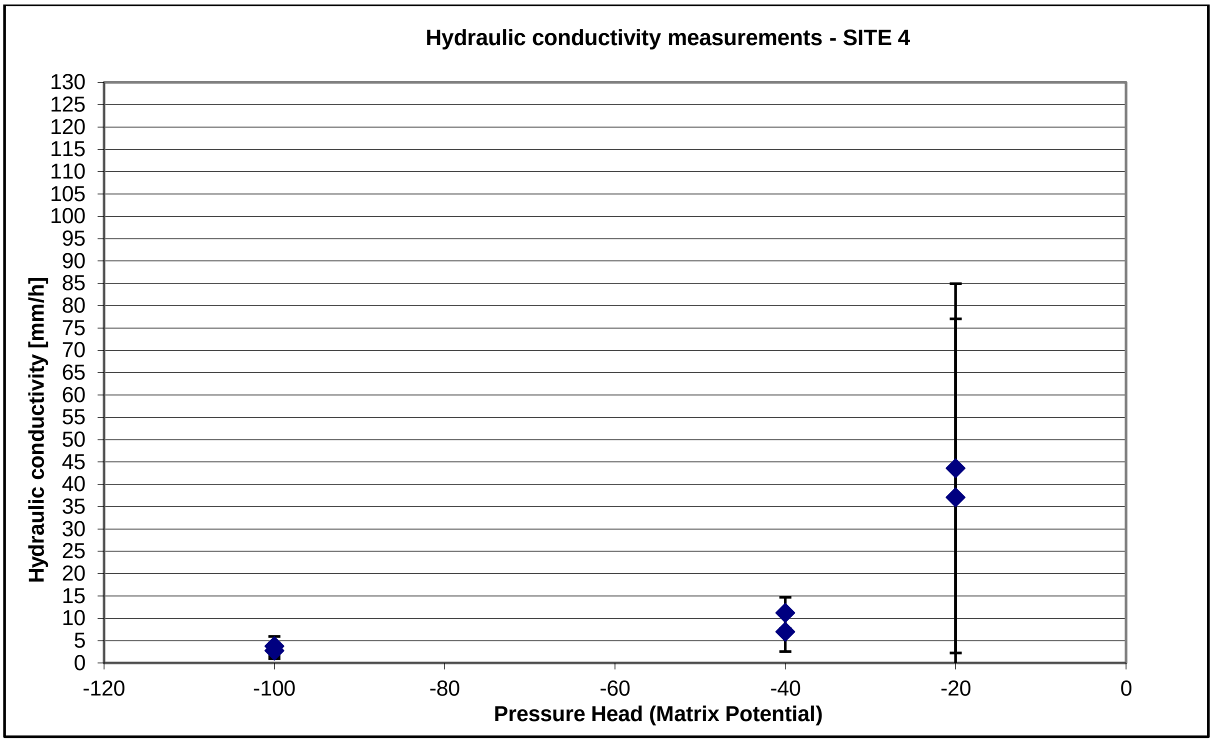
APPENDIX C

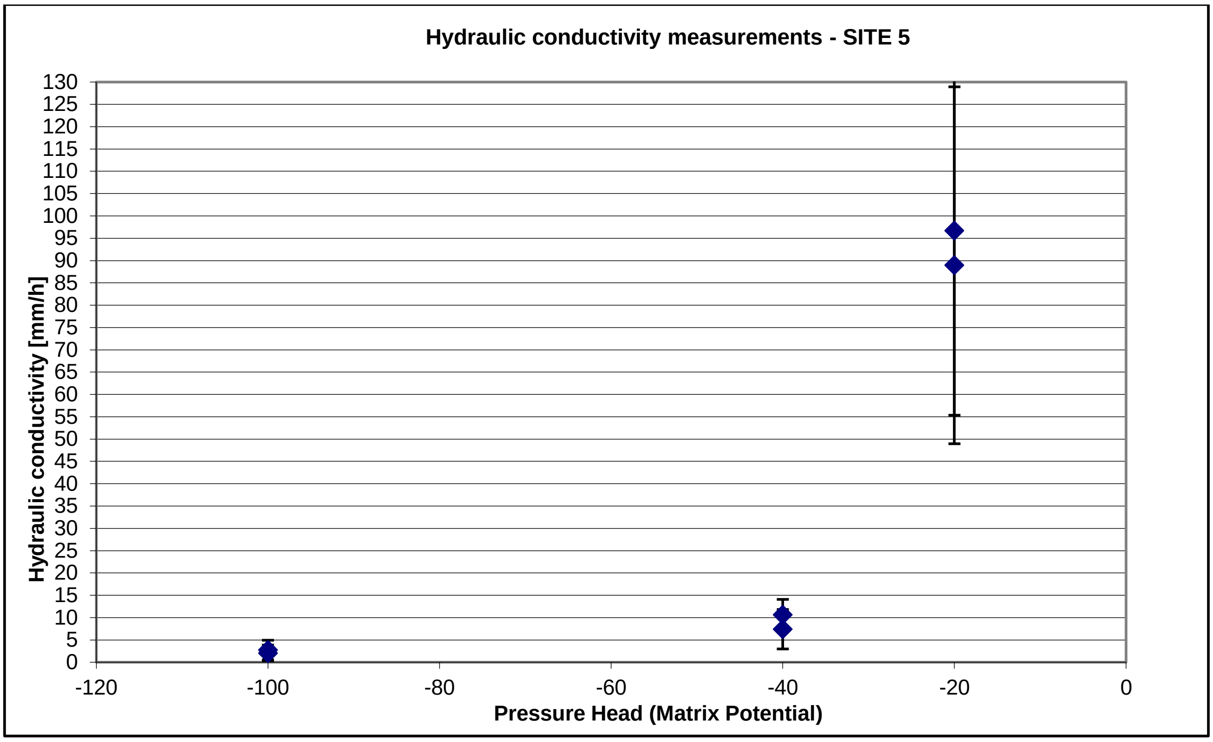
Unsaturated ($K_{-40\ mm}$) Hydraulic Conductivity Plots


Hydraulic conductivity measurements - SITE 1
Hydraulic conductivity [mm/h]
130
125
120
115
110
105
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-120
-100
-80
-60
-40
-20
0
Pressure Head (Matrix Potential)


Hydraulic conductivity measurements - SITE 2
Hydraulic conductivity [mm/h]
130
125
120
115
110
105
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-120
-100
-80
-60
-40
-20
0
Pressure Head (Matrix Potential)


Hydraulic conductivity measurements - SITE 3
Hydraulic conductivity [mm/h]
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
105
110
115
120
125
130
-120
-100
-80
-60
-40
-20
0
Pressure Head (Matrix Potential)


Hydraulic conductivity measurements - SITE 4
Hydraulic conductivity [mm/h]
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
105
110
115
120
125
130
-120
-100
-80
-60
-40
-20
0
Pressure Head (Matrix Potential)



Hydraulic conductivity measurements - SITE 5
Hydraulic conductivity [mm/h]
130
125
120
115
110
105
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-120
-100
-80
-60
-40
-20
0
Pressure Head (Matrix Potential)