Report to Tabitha Manderson, WSP, on soil drainage at the proposed Ratana effluent disposal site.

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Introduction

I have examined the landscape and soils of the proposed discharge of Ratana wastewater to land at the end of Whangaehu Beach Road. I spent half a day there on reconnaissance, followed by a full day walking the block, digging soil profiles and observing water-tables and above ground ponding. Twenty seven soil profile pits were dug, described and the water-table measured as control points.

The entire block consists of young sand dunes, sand flats and incipient peat bogs. There are three areas of rugged duneland in the vicinity of the block, one just outside the proposed disposal area to the northeast, one in the southwest, and another, also outside the proposed disposal area in the northwest. These three blocks have all had mature trees harvested in the last 4-5 years (a Google Earth image in 2020 shows the trees had been harvested by then) and new trees planted which are now 3-5m tall. There is very little topsoil, if any, on most of these dunes and it is likely that the trees were planted to stabilize shifting sands. There is a dominant WNW-ESE lineation to the dunes indicating the prevailing wind direction. Outside of the forestry blocks, any dunes, particularly along the eastern boundary, are lower, more rounded, generally have a topsoil cover, and are less aligned to the wind.

The overall fall of the land-surface on the block is from NE to SW and this is reflected in the groundwater table and extant surface water at the time of sampling.

Fig 1. View south from near entrance to the block (17/2/2023). The water-table was also above the ground surface in several of the areas of pasture. Small differences in elevation dictate the drainage status of the soil.

Soils

The entire block is covered by black sand belonging to the Waitarere phase of sand accumulation. Sands of this age are thought to have been mobilized by the effects of cattle being moved along the coast to newly cleared pastures. Accidental or purposeful fires helped to clear the original shrubby vegetation and native grasses about 150 years ago. Attempts to pastorally farm the coastal dunes resulted in dunes continuing to be active right up until the time they were forested under Pinus radiata, a process that began in the 1950s.

The young age of all the soils on the block mean that pedogenic soil features are not well expressed. Topsoils, where present are no more than 8-10cm thick, except in a few permanently waterlogged areas which have developed peaty sandy loam up to 15cm thick. This is a further indication of an age of about 150yrs for the soils assuming a peat accumulation rate of 1mm/yr.

Cowie et al (1967) recognized two soil series on the Waitarere phase sand country; Waitarere soils on the dunes and Hokio soils on the sand flats between. The ultimate source of the sand is the beach, a few hundred metres to the southwest. As the sand is blown inland, accumulating as dunes, the sand flats between become further sources of sand. Wind erosion can scour down to the capillary fringe, approximately 20-30cm above the summer water-table. Wet sand will not be moved by the wind. The positioning of the dunes then affects the water table between them, so that when the sand is stabilized by vegetation, there is left a pattern of high sand flats with free to somewhat excessive drainage; low sand flats with imperfect drainage and swampy areas with poor drainage. The swampy areas with peaty topsoils are permanently wet, but the low and high sand flats have fluctuating water-tables between summer and winter. These water-tables in these areas are also expected to be very responsive to periods of high rainfall at any time of the year, increased evapotranspiration through forestry, irrigation and external influences such as irrigation, recontouring and forestry.

Cowie (1967) mapped Hokio weakly mottled sand on higher parts of the sand flats, Hokio strongly mottled sand where the water-table fluctuates markedly between seasons, Hokio sand on the lower sand flats and Hokio peaty loam on the poorly drained permanently wet areas. Cowie was mapping in Manawatu, where the sand has a higher quantity of quartz and feldspar. In other words the volcanic content of the sand has been diluted by sedimentary input from the Turakina and Rangitikei River. The sand at the mouth of Whangaehu River is far richer in volcanic derived minerals and more diluted in quartz and feldspar from sedimentary materials. This may explain why mottling is only faint or not present at all in the Hokio soils on the disposal block. This makes delineating different drainage classes in the sand very difficult. Rather than mottling, seasonally high water-tables are seen in a change of colour in the sand to a deeper black, rather than a brownish or olive tinge to the black sand in well drained areas. In poorly drained areas with or without a peaty topsoil, there are commonly reddish brown coatings

When examined, water-tables on the disposal block were unusually high for a summer inspection. There was surface water lying where it would not normally be in summer.

Evidence for this is areas of kikuyu-clover pasture that were inundated. These species would not tolerate prolonged inundation for more than a week or two. Areas that are more often saturated had a high proportion of Yorkshire-fog, bent-grass and rushes. It is not clear whether the inundation witnessed was entirely due to the preceding rainfall, or seepage from the pivot irrigator on higher ground to the east. Harvest of the forestry blocks (2019?) is also likely to have raised water-tables long term because of the sudden decrease in evapotranspiration under the new sparse weedy and grassy vegetation compared to the pine trees.

Mapping of the area in February 2023 (Fig 2) followed a prolonged wet winter and abnormally wet summer and thus water-tables on the block were higher than normal.It appears that the water-table across the block was lower when the most recent Google Earth image was taken in 2020, and in previous Google Earth images and also historical air photos. Because of the sandy nature of the soil, the water-table was observed to closely follow the overall slope on the landscape towards the south-west. On the sand-flats between the dunes, small differences in elevation, caused by either excavation of sand during dune construction, or deposition of wind blown sand, led to soil drainage differences over short distances (Fig 2). Caveats to the long-term veracity of the map are the impact of a drier season or year (lowering water-tables), growth of the pine trees planted in 2019 or 2020 (lowering watertables), the centre-pivot irrigation to the east (raising water-tables) and the harvesting of pine trees to the south-east (raising water-tables).

Soil Physical properties

The National Soils Database, administered by Landcare Research has several records of Waitarere sand profiles taken from different parts of the coastal sand country of the Manawatu-Whanganui and Horowhenua regions. There are no analyses from close to the proposed disposal site to my knowledge. Waitarere and Hokio soils that have been subject to prolonged agricultural development have quite different properties to those under natural vegetation or exotic forestry. In particular, soils that have been irrigated for dairy have deeper and more organic matter rich topsoils, and lower pH throughout the profile.

Waitarere soils have loamy sand topsoils from a few cm to 10cm thick over pure medium sand. Dry bulk densities are generally in the range 0.7-1.1 Mg/m3 in the topsoil and 1.2-1.6 in the subsoil. Generally darker sands with more heavy minerals of volcanic source have higher particle and bulk densities.

The Waitarere and Hokio soils have very limited moisture storage capacity. The bulk of the profiles are pure sand with Total Available Water holding capacity (TAWC) of less than 5%. In other words if we take a grass root zone of 50cm, only 25mm of moisture is able to be stored. Some records on the NSD show even less TAWC, as little as 25mm for an entire metre depth.

The NSD does not contain actual measurements of hydraulic conductivity nor infiltration rate, but modelled assessments are available on soil fact sheets associated with S-Map from Landcare Research. Both infiltration rate and hydraulic conductivity of Waitarere and nonpeaty Hokio soils is likely to be rapid (> 72mm/hr). As the peat content increases in topsoils of the Hokio soils, hydraulic conductivity will slow to moderate levels (20-72 mm/hr).

Soil Chemical properties

Topsoils of Waitarere soils usually contain 0 (bare sand) to 5% organic carbon with negligible amounts below. Poorly drained Hokio soils may contain 5-10% organic carbon and up to 20% for peaty phases, but negligible amounts below. Where there has been long established pasture on Waitarere and Hokio soils, pH in the topsoil may be 6 or below, but in the subsoil pH is commonly 7 or above, especially where broken shell material is still present, as is the case at the disposal site. Base saturation may be lower, around 50% in topsoils but rapidly climbs to 100% in the subsoil where the exchange complex is flooded with calcium from the shell material. The organic matter in the topsoil contributes to a medium cation exchange capacity, but in the subsoil there is little clay or organic matter to provide sites for negative charge. The sand is essentially unweathered and even in well drained sites for the Waitarere soils, there are essentially no iron coatings on the sand particles and very little clay or short range order material capable of adsorbing anions. As a consequence phosphate retention is very low (10-20% in topsoils and 5% or less in subsoils). Hokio soils that are permanently wet will have had any potential incipient iron coatings stripped by reduction, further reducing the likelihood of any anion storage.

Notes on wastewater application

Because of the nature of the wind-blown sand (medium to coarse sand with very little silt or clay), the water-table on the disposal block is likely to be highly labile, responding quickly to cumulative rainfall. Applied water that escapes the root zone on the irrigated block to the east is also likely to have an impact almost immediately on the disposal block. The only way to follow this accurately is via a series of monitored piezometers.

If the soil is already moist from rainfall, wastewater application would need to be very low and slow if the water was to be held within the root zone to be used for grass growth. In this method we are using the soil as a sponge. The alternative is to use the soil as a filter and apply higher rates, and to allow wastewater not taken up by plants to enter the groundwater. The ability of the soil profile to treat the wastewater must then be considered. This soil chemistry indicates that there is limited opportunity for uptake of phosphate from wastewater, once it is below the root zone. However, there may be better treatment and denitrification of nitrate once it has travelled through the oxidised sands on the dunes and high sand flats, and makes its way to the poorly drained areas. This raises the possibility of enhancing the poorly drained areas as denitrification wetlands.