Project Number: 1-14129.20

Mangawhai Water Reuse

HYDROGEOLOGICAL STUDY - SOILS

20 May 2021

CONFIDENTIAL

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Contents

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This report ('Report') has been prepared by WSP exclusively for [Kaipara District Council] ('Client') in relation to the proposed discharge of excess treated wastewater to the Mangawhai Golf Course and the surrounding bush ('Purpose') and in accordance with the Short form Agreement with the Client dated 28/4/2021]. The findings in this Report are based on and are subject to the assumptions specified in the Report and Offer of Services dated 11-May-2021. WSP accepts no liability whatsoever for any reliance on or use of this Report, in whole or in part, for any use or purpose other than the Purpose or any use or reliance on the Report by any third party.

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1 Project background

1.1 Mangawhai Golf Course

Kaipara District Council is proposing to discharge excess treated water from a nearby wastewater plant to the Mangawhai Golf Course and surrounding bush. This area is approximately 45ha in total. To determine if this is appropriate, a high-level hydrology and soil analysis is required to assess how much water can be discharged to this area.

1.1.1 Soil assessment

The soil analysis of this hydrogeological study was carried out in three phases

1 Desktop analysis of existing data;

2 Field work to collect infiltration rates and analyse the soil profiles; and

3 Analysis and interpretation of the data.

The soil features which impact an irrigation system design are the soil texture and water holding capacity

The relative proportions of sand, silt and clay give the soil its texture. Soil texture is an important characteristic because it gives an indication of water storage, drainage and nutrient supply. A fine textured soil has a greater ability to hold water in its many small (micro) pores, making it less available for plant uptake. These soils generally are poorly drained and have low infiltrations rates. This is turn influences application rates.

A course textured soil in comparison holds less water due to large (macro) soil pores; the water is lost easier from the soil profile through drainage because of the high infiltration rates.

The water holding capacity of the soil can be expressed in several ways, to determine the soil water balance the amount of water which a soil can store for plant growth is used. This is called Profile Readily Available Water Content (PRAW) also known as Available Water Capacity (AWC). This is the amount of water stored at Field Capacity (FC) - amount of water left in micropores after rapid drainage has occurred and soil water content has become stable minus the amount of water held at Permanent Wilting Point (PWP)- moisture content below which plants can no longer extract water because of capillary tension.

PRAW = FC – PWP

Lower PRAW numbers are expected in courser free draining soils (sandy) with large macropores and less micropores compared to finer textured soils (clay) with many micropores.

Soil infiltration rates are taken to assess the rate at which water can be applied to the soil without saturating it. This is important once the amount of irrigation that can be applied is calculated then infiltrations rates are used to work out at which rate this water can be applied to the soil without effecting the soil structure and have detrimental environmental impacts

2 Assessing soil suitability for irrigation

2.1 Methodology

Step 1

A complete desktop analysis of existing data was carried out. Soil surveys of the area and typical soil descriptions were reviewed. The resource used was the New Zealand Fundamental Soil Layer (FSL) created by Landcare Research NZ. This layer brings together a wide range of physical resource themes (e.g. land use capabilities, lithology, soil etc.) to create a single comprehensive spatial archive of New Zealand's physical resource information (Newsome et al., 2008). Also, the Northland Regional Councils Soil layer was reviewed and the accompanying soil description (Northland Regional Council 2021).

Step 2

Field work was undertaken on May 4th and 5th 2021.

Soil profiles were exposed from holes dug by spade and auguring at 20 locations across the course; observations occurred at track cuttings and other places where the soil could easily be exposed. Representative profiles were described in general accordance with Milne et al 1995 and photographed. Figure 2-1 highlights where each soil hole was located. Of the 20 holes, 13 were infiltration tested to provide infiltration rates to help assess the application rates of irrigation onto the soil.

General observations and findings were recorded through discussions with Golf Club employees and players as well as observations made across the two days.

Detailed methodology and results of the infiltration testing are included in Appendix A.

Step 3

Analysis and interpretation of the desktop and field data was carried out to assess soil suitability for irrigation. A combination of data available, the soil samples exposed and infiltrated tested and observations made during the field work resulted in a conclusion on the suitability of the soil types for irrigation.

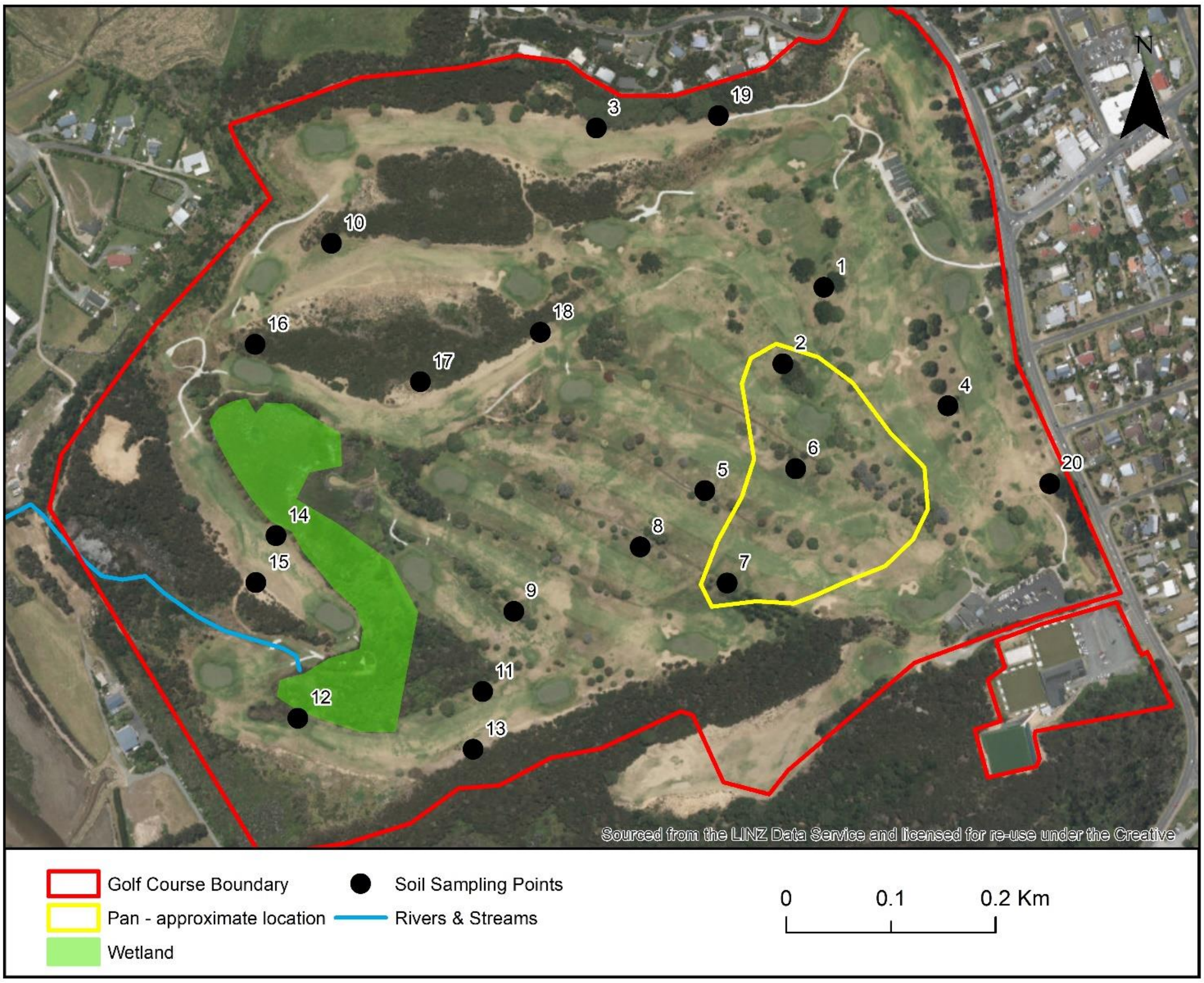

Figure 2-1: Soil sampling and infiltration sites.

2.1.1 Site description and observations

The Mangawhai Golf Course features two terraces. The lower terrace is in the middle of the course and covers about 70% of the area. This lower terrace is surrounded by an upper terrace on all sides, except the eastern boundary. The topography on the lower terrace is predominantly flat with the upper terrace being rolling topography with some areas steep and others just rolling (Figure 2-2).

Observations made during the two days of field work were:

- The topography of the golf course appears suitable for an irrigation system. However, there are steeper sections in the bush areas that might not be able to be irrigated easily.
- The upper northern terrace is the driest.
- There are several compacted areas across the course.
- Where grass cover is well maintained the soil retains moisture and has higher infiltration rates.
- Areas with little grass cover and thin topsoil show signs of soil hydrophobicity.
- Pan found at varying depths on the lower terrace.
- Infiltration rates varied across the golf course.

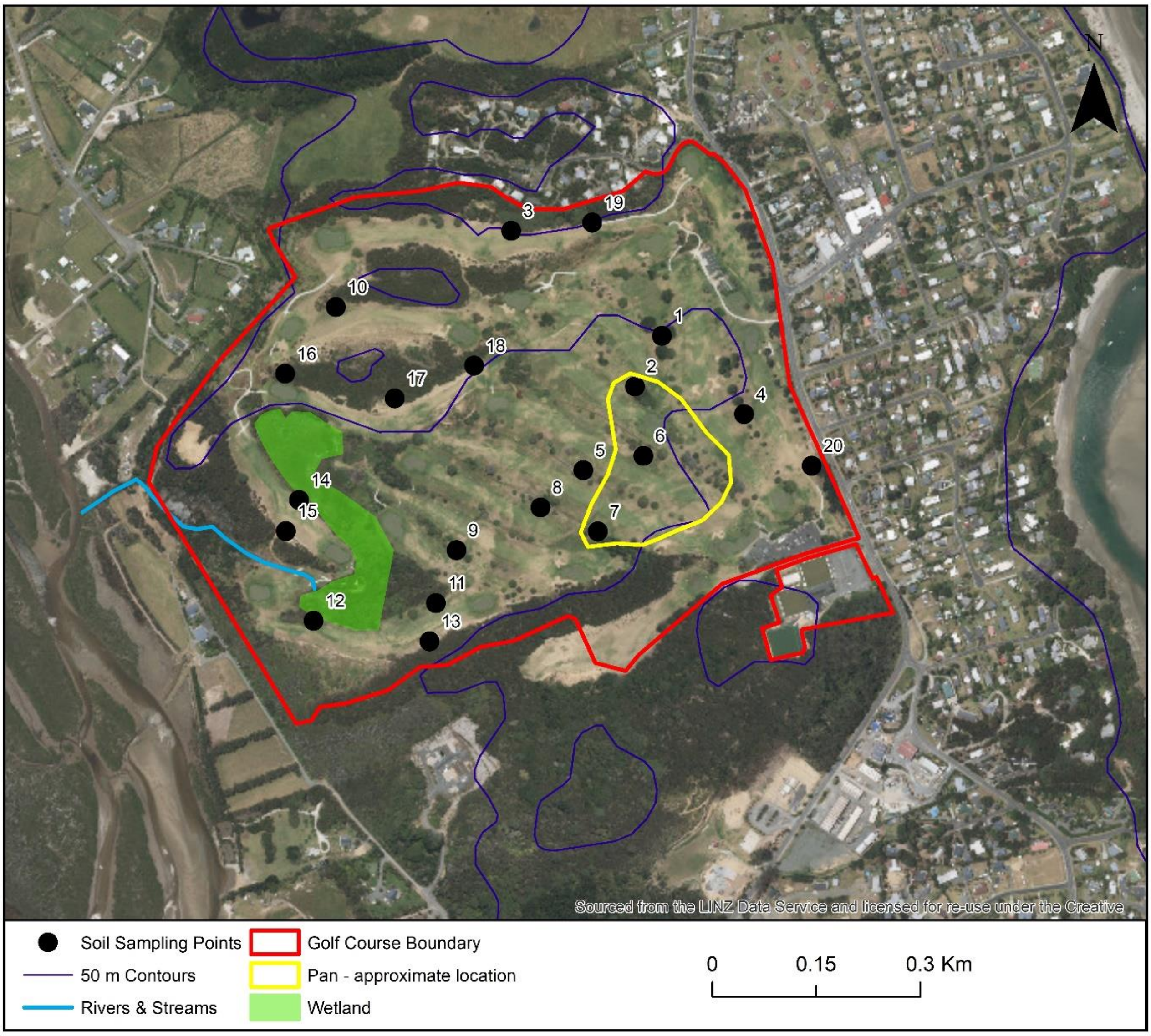

Figure 2-2: Map showing contours and approximate location of iron pan.

2.1.2 Factors in soil formation

Table 2-1 highlights key parameters that have influenced the soil formation on the Mangawhai Golf Course. These soils formed on consolidated sand dunes. Alluvium washed from upstream has been deposited from flooding events, then worked through the soil horizons and formed the soils we see today. The upper terraces of the course are mostly sandy soils. The lower terrace is sandy loam with variation in sand, silt and clay ratios resulting in different physical and chemical properties.

Table 2-1: Key factors that influence soil formation for Mangawhai Golf Course

Site Elevation	10m -38m
Annual Rainfall	1181mm
Parent Material	Sedimentary rock and alluvium

2.2 Results

2.2.1 Soil observations

Red hill sand and sandy loam found on the golf course are of the orthic brown soil type. This soil type has a brown or yellow brown subsoil below the topsoil. This brown colour is caused by thin coatings of iron oxide weathered from the parent material (Landcare Research, 2020). These soils formed on the iron rich sands and as a result there is subsoil impeding drainage due to the presence of an iron pan (Wright & Lyons, 2019).

Field work discovered the depths of sands and varying textures in the soil types across the golf course. The alluvium parent material has deposited varying amounts of silt and clay amongst the sand. The red hill sand is found on the higher terraces of the golf course. The lower terrace is sandy loam with different ratios of silt and clay. The soils can be split into five groups, which are described below.

A map summarising the groupings of soils are displayed in Figure 2-3.

Soil description	Photo
Sandy loam A 0 - 15cm Top soil Very friable Fine textured No mottling or gleying B 15cm – 80cm Yellow brown sandy loam Very friable No signs of iron oxides Courser texture No mottling or gleying C 80cm – 95cm Brown sandy loam Fine textured No mottling or gleying Site 1,2,4	

Sand A 0-10cm Top Soil Very friable No mottling or gleying B 10- 50cm Red yellow sand Vary friable No mottling or gleying B2 50cm-95cm Consolidated sands More compact Signs of sandstone Note: Distinction between horizons difficult to see. Site 3, 13, 15, 16, 17, 18, 19, 20	
Sandy loam A 0 -15cm Top Soil Very friable No mottling or gleying B 15 – 80cm High silt content Brown loam Course textured No mottling or gleying Friable C 80 – 95cm Large silt aggregates No mottling or gleying Courses textured Site 5,8	

Sandy loam A 0 – 15cm Top soil Friable Fine textured No mottling or gleying B 15cm to 50cm Friable No mottling or gleying Clay, Silt and Sand B^2 50cm to 95cm Large clay aggregates Less friable No mottling or gleying Site 7, 9, 11, 12, 14	
Sandy loam A 0 – 20cm Top soil Friable Fine textured No mottling or gleying B 15cm to 30cm Friable No mottling or gleying Fine textured Pan found at 300mm Site 6	

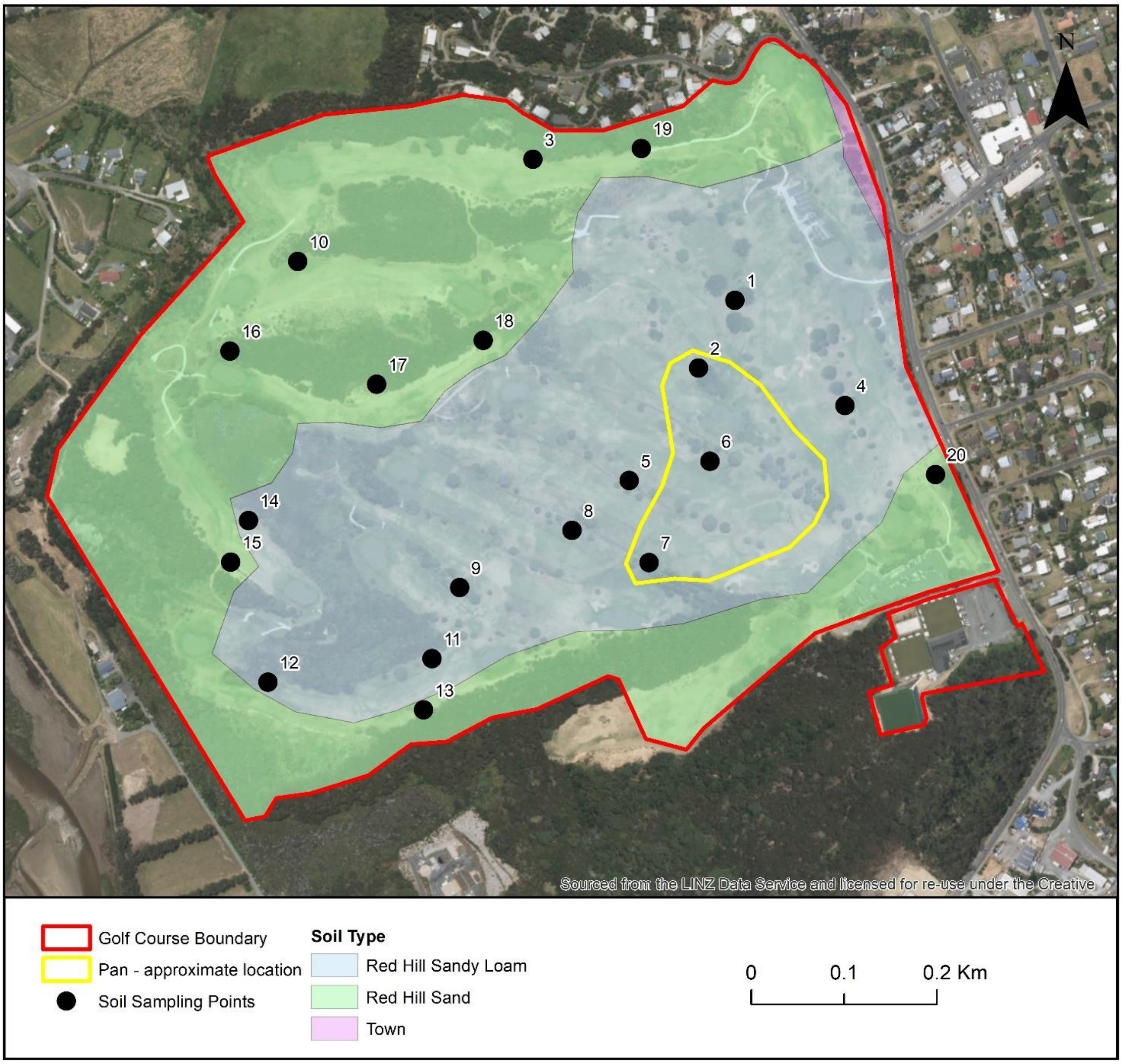

Figure 2-3: Location of soils on the course

2.2.2 Soil Moisture Content

Figure 2-4 below shows PRAW values vary across the course based on the soil texture and depth. The light blue area with the lowest PRAW (46mm) value is the course textured sandy soils which are very free draining.

The purple central area with a PRAW value of 62mm is the sandy loam soil. This soil has more silt content then the sandy soil and a very small amount of clay. This would allow the soil to hold onto moisture for longer as it has a number of micropores.

The yellow area on the southern section of the course is also sandy loam however has a higher ratio of clay content in the soil. This clay content increases the ratio of micropores in the soil allowing more water to be stored in the soil aggregates. This results in a greater profile readily available water content, of 80mm.

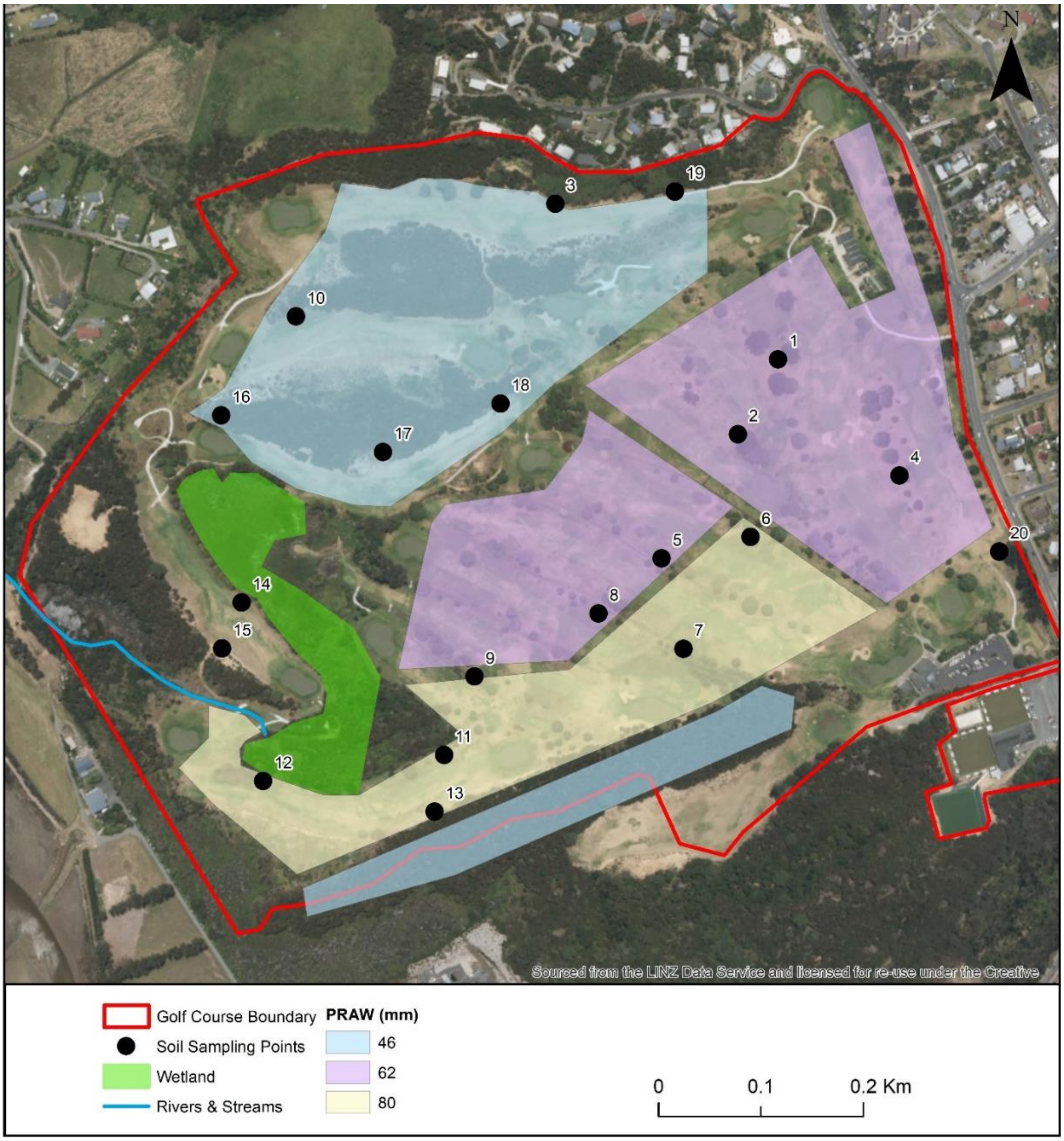

Figure 2-4: Soil Profile readily Available Water Content

2.2.3 Other observations

Soil depths

During field work, it was noted that in the centre of the course the soil depths varied. A pan is present in areas due to the high iron concentration of the soil weathered from parent materials. This pan is almost impermeable, effecting drainage of the soil and the suitability for irrigation. Of the 20 sites sampled, three showed signs of a pan within 950mm. The pan is at varying depths from 300mm to 800mm. However, this was only discovered in the low-lying centre of the course (sites 2, 6, and 7). However, it is possible it is more widespread at depths below a metre. It can be mitigated accordingly through the management of the irrigation system to minimises soil saturation and surface runoff.

Highly Modified Environment

Significant earthwork has been carried out to establish the golf course. This has modified the natural landscape as soil has been carved out and built up in different areas. As a result, soil types may have been different prior to this earthwork. Also, with several small drains established in the centre of the course, soil has been dug out and potentially dropped next to the drain, again having an influence on the soils surrounding the drains.

Machinery driven across the course is concentrated in areas which contributes to soil compaction. Compaction effects the ability for water to infiltrate the soil and alters soil porosity. These factors have increased the variance in soil textures, depths and compaction across the course.

Infiltration Rates

Where grass cover has been maintained and moisture retained in the soils, infiltration rates were higher compared with areas of little to no grass cover. These areas with little grass and thin topsoil resulted in exposed sands. Exposed sands showed signs of hydrophobicity. Hydrophobicity is where the sand particles repel water due to non-polar waxy compounds coating the sand particles (Deurer M., Muller K 2010). Infiltration took longer to begin in these areas and may result in surface runoff when irrigated. The infiltration rates can be viewed in the Appendices of this report.

Wetland

There is a large wetland in the western section of the course which most of the course catchment drains into. Irrigation would increase the nutrient and sediment load of this wetland and nutrient modelling will need to be done to assess the current load compared with potential irrigated load.

3 Conclusions

Concluding the soils assessment, the Mangawhai Golf Course can be irrigated for several reasons, based on the topography, soil texture and soil depth analysis. Specifically, the topography of the golf course is flat to rolling, the soil texture is either sand or sandy loam which is free draining, and generally the soils are deep.

However, there are areas of the golf course that need to be managed carefully to minimise saturation and surface runoff. Compacted areas as a result of the day to day activities occurring on a golf course need to be identified. The pan in the centre of the course needs to be considered when managing the irrigation. Exposed areas of sand with little grass cover will need to be monitored to ensure hydrophobicity isn't occurring causing pooling and runoff. Steeper sections in the bush areas might not be able to be irrigated easily.

4 References

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5 Appendix A – Infiltration Methodology and Results

5.1 Infiltration methodology

13 measurements were taken to calculate the infiltration rate across the Mangawhai Golf Course

Double ring infiltration was the methodology chosen to measure infiltration. The larger ring had a depth of 10 cm with a 20 cm diameter while the smaller ring also had a depth of 10 cm with a 10 cm diameter.

On selecting a site for the infiltration rings, flat ground with no tree roots was chosen. Before inserting rings into the ground, the grass was trimmed as short as possible. At each sampling site, as many infiltration tests were undertaken in the time allowed.

Each small ring was inserted into the ground to a depth of 5 cm, followed by the larger ring being inserted into the ground around the smaller ring to a depth of 5 cm.

The outside ring (large one) was filled with water until the 9.5 cm height mark, followed by the inner ring also being filled to the 9.5 cm mark. Once the inner ring was filled with water to the 9.5 cm mark a stopwatch was started.

Time reads were taken every 0.5 cm drop in liquid level – reading from the measurement markers inside each of the small rings. Once the water level was 0.5 cm above ground level both the inner ring and outer ring were refilled with water until the 9.5 cm height. The rings were not allowed to dry out.

Measurements were stopped once the time interval between each 0.5 cm drop were as close as possible.

5.2 Infiltration testing results

Site 1	Time	Raw time (min)	Raw time (seconds)	time (mins)	split (mins)	mm/min	mm/hr	rolling avg (mm/hr)	
0	0								
0.5	1.33	1	33	1.55	1.55	3.23	193.5484		
1	4.08	4	8	4.13	2.58	1.94	116.129		
1.5	9.39	9	39	9.65	5.52	0.91	54.38066		
2	16.59	16	59	16.98	7.33	0.68	40.90909	101.24	
2.5	25.38	25	38	25.63	8.65	0.58	34.68208	61.53	
3	34.17	34	17	34.28	8.65	0.58	34.68208	41.16	
3.5	43.07	43	7	43.12	8.83	0.57	33.96226	36.06	
4	52.2	52	20	52.33	9.22	0.54	32.54973	33.97	
4.5	1.00.44	60	44	60.73	8.40	0.60	35.71429	34.23	
5	1.09.18	69	18	69.30	8.57	0.58	35.01946	34.31	
5.5	1.18.00	78	0	78.00	8.70	0.57	34.48276	34.44	47.12

Site 1.5	Time	Raw time (min)	Raw time (seconds)	time (mins)	split (mins)	mm/min	mm/hr	rolling avg (mm/hr)
0	0							

0.5	36		36	0.6	0.60	8.33	500		
1	1.47	1	47	1.78	1.18	4.23	253.5211		
1.5	3.29	3	29	3.48	1.70	2.94	176.4706		
2	7.1	7	10	7.17	3.68	1.36	81.44796	252.86	
2.5	9.43	9	43	9.72	2.55	1.96	117.6471	157.27	
3	14.13	14	13	14.22	4.50	1.11	66.66667	110.56	
3.5	18.34	18	34	18.57	4.35	1.15	68.96552	83.68	
4	23.19	23	19	23.32	4.75	1.05	63.15789	79.11	
4.5	28.22	28	22	28.37	5.05	0.99	59.40594	64.55	124.7
5									
5.5									
6									

Site 2	Time	Raw time (min)	Raw time (seconds)	time (mins)	split (mins)	mm/min	mm/hr	rolling avg (mm/hr)	
0	0								
0.5	40		40	0.67	0.67	7.50	450.0		
1	2.03	2	3	2.05	1.38	3.61	216.9		
1.5	3.56	3	56	3.93	1.88	2.65	159.3		
2	7.11	7	11	7.18	3.25	1.54	92.3	229.6	
2.5	9.38	9	38	9.63	2.45	2.04	122.4	147.7	
3	13.27	13	27	13.45	3.82	1.31	78.6	113.2	
3.5	16.11	16	11	16.18	2.73	1.83	109.8	100.8	
4	19.31	19	31	19.52	3.33	1.50	90.0	100.2	
4.5	22.27	22	27	22.45	2.93	1.70	102.3	95.2	
5	25.32	25	32	25.53	3.08	1.62	97.3	99.8	126.6

Site 4	Time	Raw time (min)	Raw time (seconds)	time (mins)	split (mins)	mm/min	mm/hr	rolling avg (mm/hr)	
0	0								
0.5	44		44	0.73	0.73	6.82	409.09		
1	1.57	1	57	1.95	1.22	4.11	246.58		
1.5	3.18	3	18	3.30	1.35	3.70	222.22		
2	4.53	4	53	4.88	1.58	3.16	189.47	266.84	
2.5	6.35	6	35	6.58	1.70	2.94	176.47	208.69	
3	8.2	8	20	8.33	1.75	2.86	171.43	189.90	
3.5	10.18	10	18	10.30	1.97	2.54	152.54	172.48	
4	12.05	12	5	12.08	1.78	2.80	168.22	167.17	
4.5	14.17	14	17	14.28	2.20	2.27	136.36	157.14	
5	16.43	16	43	16.72	2.43	2.05	123.29	145.10	
5.5	19.14	19	14	19.23	2.52	1.99	119.21	136.77	
6	21.16	21	16	21.27	2.03	2.46	147.54	131.60	175.08

Site 5	Time	Raw time (min)	Raw time (seconds)	time (mins)	split (mins)	mm/min	mm/hr	rolling avg (mm/hr)	
0	0								
0.5	1.11	1	11	1.18	1.18	4.23	253.52		
1	3.1	3	10	3.17	1.98	2.52	151.26		
1.5	6.26	6	26	6.43	3.27	1.53	91.84		
2	10.35	10	35	10.58	4.15	1.20	72.29	142.23	
2.5	14.41	14	41	14.68	4.10	1.22	73.17	97.14	
3	18.25	18	25	18.42	3.73	1.34	80.36	79.41	
3.5	22.03	22	3	22.05	3.63	1.38	82.57	77.10	
4	25.56	25	56	25.93	3.88	1.29	77.25	78.34	
4.5	30.11	30	11	30.18	4.25	1.18	70.59	77.69	91.98

Site 8	Time	Raw time (min)	Raw time (seconds)	time (mins)	split (mins)	mm/min	mm/hr	rolling avg (mm/hr)	
0	0								
0.5	1.01	1	1	1.02	1.02	4.918033	295.08		
1	3.12	3	12	3.20	2.18	2.290076	137.40		
1.5	6.2	6	20	6.33	3.13	1.595745	95.74		
2	10.31	10	31	10.52	4.18	1.195219	71.71	149.99	
2.5	16.55	16	55	16.92	6.40	0.78125	46.88	87.93	
3	23.3	23	30	23.50	6.58	0.759494	45.57	64.98	
3.5	30.39	30	39	30.65	7.15	0.699301	41.96	51.53	
4	38.03	38	3	38.05	7.40	0.675676	40.54	43.74	79.63

Site 9	Time	Raw time (min)	Raw time (seconds)	time (mins)	split (mins)	mm/min	mm/hr	rolling avg (mm/hr)	
0	0								
0.5	16.11	16	11	16.18	16.18	0.31	18.53759		
1	23.44	23	44	23.73	7.55	0.66	39.7351		
1.5	31	31		31.00	7.27	0.69	41.2844		33.2
2									

Site 10	Time	Raw time (min)	Raw time (seconds)	time (mins)	split (mins)	mm/min	mm/hr	rolling avg (mm/hr)
0	0							
0.5	57		57	0.95	0.95	5.26	315.79	
1	1.58	1	58	1.97	1.02	4.92	295.08	
1.5	3	3	0	3.00	1.03	4.84	290.32	
2	3.57	3	57	3.95	0.95	5.26	315.79	304.25
2.5	4.5	4	50	4.83	0.88	5.66	339.62	310.20
3	6.05	6	5	6.08	1.25	4.00	240.00	296.43
3.5	7.47	7	47	7.78	1.70	2.94	176.47	267.97
4	9.52	9	52	9.87	2.08	2.40	144.00	225.02
4.5	11.48	11	48	11.80	1.93	2.59	155.17	178.91

5	13.25	13	25	13.42	1.62	3.09	185.57	165.30	
5.5	15.52	15	52	15.87	2.45	2.04	122.45	151.80	
6	17.33	17	33	17.55	1.68	2.97	178.22	160.35	
6.5	19.06	19	6	19.10	1.55	3.23	193.55	169.95	223.02

Site 11	Time	Raw time (min)	Raw time (seconds)	time (mins)	split (mins)	mm/min	mm/hr	rolling avg (mm/hr)	
0	0								
0.5	12.53	12	53	12.88	12.88	0.39	23.29		
1	30.1	30	10	30.17	17.28	0.29	17.36		20.32
1.5									
2									

Site 12	Time	Raw time (min)	Raw time (seconds)	time (mins)	split (mins)	mm/min	mm/hr	rolling avg (mm/hr)	
0	0								
0.5	1.08	1	8	1.13	1.13	4.411765	264.71		
1	4.47	4	47	4.78	3.65	1.369863	82.19		
1.5	8.2	8	20	8.33	3.55	1.408451	84.51		
2	13.07	13	7	13.12	4.78	1.045296	62.72	123.53	
2.5	17.58	17	58	17.97	4.85	1.030928	61.86	72.82	
3	22.08	22	8	22.13	4.17	1.2	72.00	70.27	
3.5	26.22	26	22	26.37	4.23	1.181102	70.87	66.86	
4	30.13	30	13	30.22	3.85	1.298701	77.92	70.66	
4.5	34.18	34	18	34.30	4.08	1.22449	73.47	73.56	79.62
5									

Site 14	Time	Raw time (min)	Raw time (seconds)	time (mins)	split (mins)	mm/min	mm/hr	rolling avg (mm/hr)	
0	0								
0.5	7.46	7	46	7.77	7.77	0.64	38.62661		
1	17.57	17	57	17.95	10.18	0.49	29.4599		
1.5	25	25		25.00	7.05	0.71	42.55319		
2	32.3	32	30	32.50	7.50	0.67	40		37.66
2.5									

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