Project Number: 1-14129.20

Mangawhai Water Reuse

HYDROGEOLOGICAL STUDY - HYDROLOGY

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 Introduction

WSP have been engaged by Kaipara District Council to investigate the feasibility of discharging excess treated wastewater from a nearby wastewater plant to the Mangawhai Golf Course and the surrounding bush. This area is approximately 45ha in total, which contains a shallow pan and three groundwater bores. To determine if this is appropriate, a high-level hydrology and soil analysis is required to assess the impacts of this proposed activity, particularly the risk of excess runoff of nutrients into the adjacent wetland.

This report details the hydrology analysis. The purpose of this piece of work is to determine how much water could be discharged to the area (i.e. 45ha) by assessing the current hydrology of the area in relation to the soil water holding capacity. As such, a key output of this report shows where on the proposed area excess water may be applied without likely causing excess runoff in the adjacent wetland.

2 Hydrometric data

Hydrometric data in the vicinity of Mangawhai is limited. There is a single rainfall site within Mangawhai; however, this rainfall record ended in 1990 after 73 of record. Therefore, a range of hydrometric data has been collected from around the region, which together provide a representation of the climate in Mangawhai.

Hydrometric data has been obtained from Northland Regional Council (NRC) or the National Climate Database (Cliflo). The climate sites used were chosen based on their proximity, and similarity in elevation and topography, to the Mangawhai Golf Course. The key parameters required for the assessment are rainfall and potential evapotranspiration, which are described in more detail in Table 2-1 and the data summarised in Table 2-2.

There are three rainfall sites in the area of the golf course; Mangawhai, Hakaru at Tara and Mangawhai Harbour at Tara (known as Hakaru at Tara Bore by NRC). Unfortunately, the Mangawhai rainfall site closed in 1990 making it unsuitable for analysis. To the west of the golf course are the two rainfall sites Hakaru at Tara and Mangawhai Harbour at Tara. The original rainfall site, Mangawhai Harbour at Tara, was replaced in 2013 with the Hakaru at Tara rainfall site, which is approximately 250m to the north east of the original site. Therefore, for the analysis, the two sites have been combined to create a single rainfall record, Mangawhai Harbour Combined. This provides sufficient length of record that will allow a more robust analysis of the rainfall. The suitability of this combined rainfall record is further discussed in Section 3.2.

Table 2-1: Summary of the hydrometric data used for the assessment of Mangawhai golf course.

Site	Recording Authority	Data Type	Start	End	Record Length	Number of gaps	% missing record
Hakaru at Tara*	NRC	Rainfall	1-Nov-2013	3-May-2021	8 years	0	0%
Leigh 2 EWS	NIWA	Rainfall	1-Jan-1967	3-May-2021	54 years	3	0.5%
		PET	2-Jan-1971	3-May-2021	50 years	15	4.5%
Mangawhai	NIWA	Rainfall	2-Jun-1917	1-Dec-1990	73 years	19	3%
Mangawhai Harbour at Tara*	NRC	Rainfall	12-Dec-1989	1-Nov-2013	23 years	3	0.6%

* Rainfall records combined to create Managawhai Harbour Combined rainfall dataset.

Table 2-2: Summary of the hydrometric data used for the detailed analysis of Mangawhai golf course.

Site Name	Data Type	Min	Max	Mean	Std Dev	L.Q.	Median	U.Q.
Leigh 2 EWS	PET	647	1228	1071	91	1034	1077	1116
Mangawhai	Rainfall	929	1753	1286	223	1114	1322	1449
Mangawhai Harbour Combined	Rainfall	1150	1851	1461	252	1206	1438	1658

A simple gap analysis was carried out on the available records (Table 2-1). This identified the number of gaps and their duration. Large gaps, or a large proportion of missing record, in the data may cause any rainfall analysis to be unrepresentative of the area, and not fit for use. In the absence of other data, it was assumed that those sites with missing data have no significant effect on the results of any analysis. It should be noted that no additional quality control has been undertaken on these data specific to this project. However, since the data are recorded from sites maintained to meet best practice, it is assumed accurate.

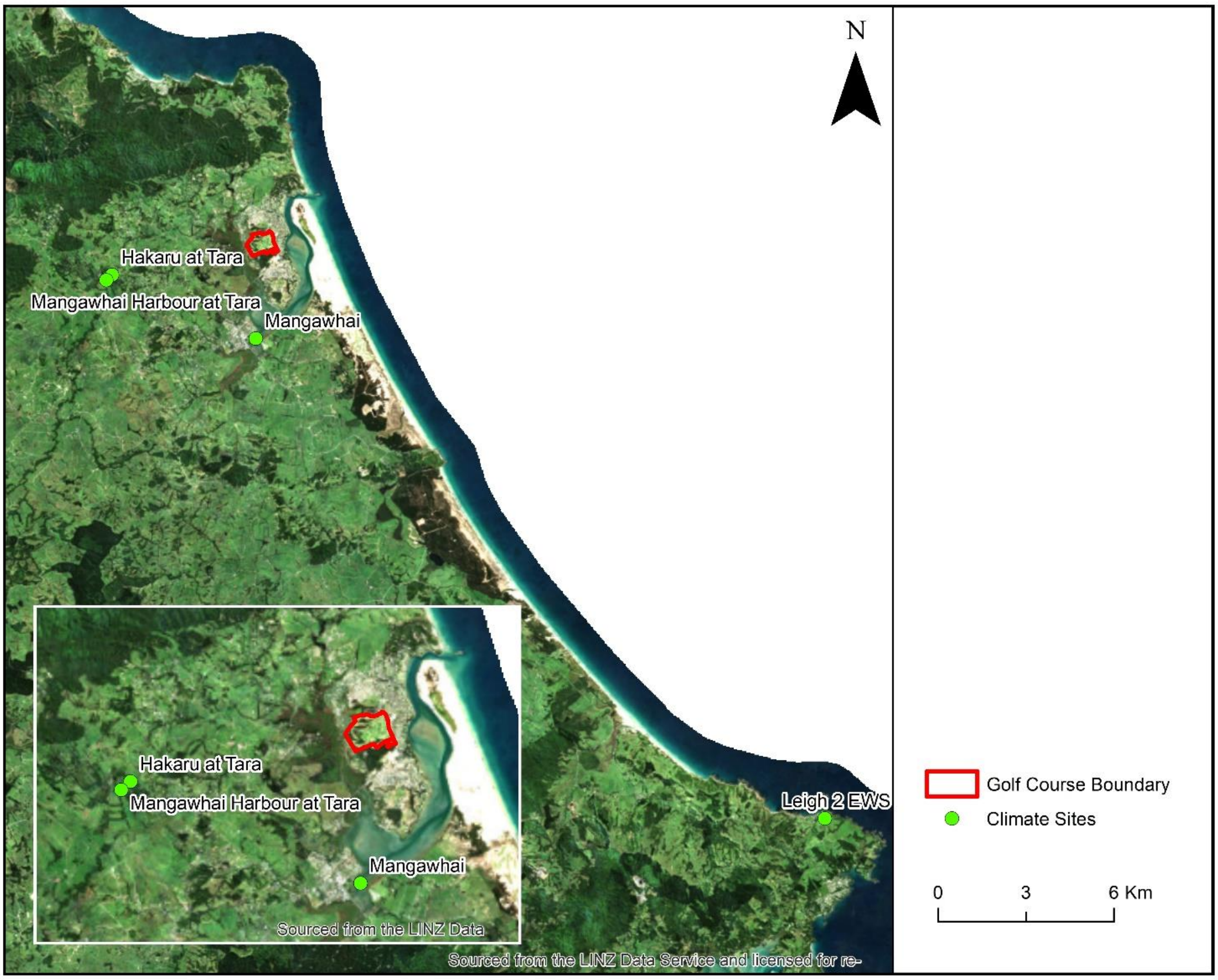


Figure 2-1: Locations of the climate sites used in hydrological analysis.

3 Climate

Mangawhai is located on the east coast of the Northland Region, south of Whangarei.

Northland is dominated by a mild, humid, and rather windy conditions due to its low elevation and proximity to the sea. The climate in Northland is particularly seasonal, with typically warm and humid summers and mild winters. This seasonality is controlled by the seasonal movement of high-pressure belts to the north of Aotearoa.

Wind direction, temperature and sunshine hours will not be discussed individually but will be briefly covered below.

The dominant wind direction in the region is from the southwest; particularly during winter and spring. During summer, the wind direction is proportionally split between southwest and easterly winds. Sea breezes are also common along the east coast in summer and autumn.

Northland has a particularly mild climate and experiences few extremes in temperature. In general, the region experiences roughly 2000 sunshine hours per annum.

3.1 Potential evapotranspiration

Potential evapotranspiration (PE) data is important for assessing irrigation application rates (i.e. potential rates of discharge for excess wastewater) as it describes the amount of evaporation that would occur from a surface if a sufficient water source were available. The higher the PE, the more water is lost through evapotranspiration and, therefore, could be applied to the land.

PE sites tend to be limited in distribution throughout Aotearoa; fortunately, PE has been shown to be relatively uniform across large areas. The closest PE site to the Mangawhai Golf Course, Leigh 2 EWS, is located approximately 27 km to the south east.

Leigh 2 EWS has an average daily PE of 5mm/day over summer; this drops to approximately 1.5mm/day during the winter months. PE can reach a maximum of 7.9mm/day (Figure 3-1).

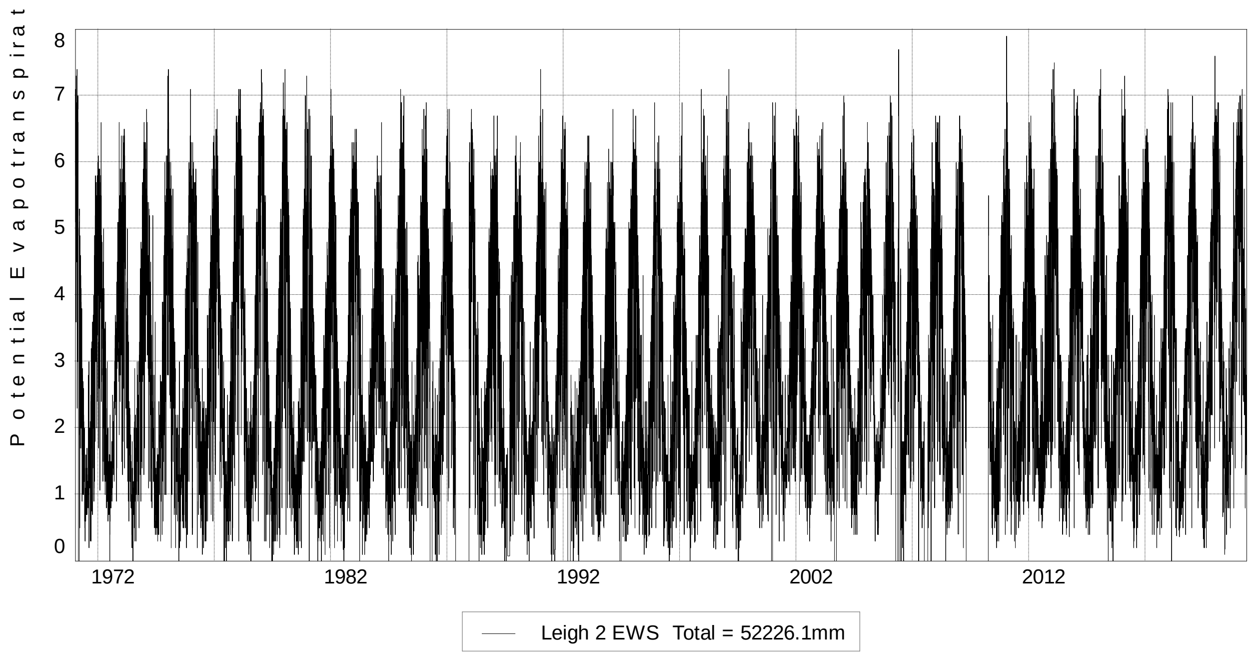


Figure 3-1: Daily potential evapotranspiration (mm) from the Leigh 2 EWS climate site (1971 – 2021).

3.2 Rainfall

Rainfall patterns in Northland can be particularly seasonal, with summer and autumn considered the drier months (Chappell, 2013). However, during summer and autumn, the region can experience high intensity rainfall periods associated with the passage of tropical or sub-tropical storms.

Summer cyclones also occur infrequently during La Niña weather phases occurring on average once every five years. These events produce very high rainfall of up to 100mm/hour and can cause widespread flooding, especially when they coincide with very high tides (Chappell, 2013). Additionally, isolated thunderstorm events can dump vast amounts of rain over very small areas causing extreme flash flooding (Chappell, 2013).

Due to the constantly changing rainfall patterns in the wider Northland Region it is important to accurately capture this variability at the local Mangawhai level. This will provide a more accurate understanding of the frequency and magnitude of storm and rainfall events, which in turn will influence the frequency of discharge to the golf course.

To assess the rainfall distribution across the catchment, and therefore the suitability of using the Mangawhai Harbour Combined climate site (Figure 3-2) for analysis, the Mean Annual Rainfall (MAR) has been used.

The MAR is interpolated using a thin-plate smoothing spline model based on latitude and longitude and the MAR recorded at gauges throughout New Zealand (Tait *et al.*, 2006). If the MAR is similar to the empirical data then it can be used to explain the spatial rainfall distribution across the area, as well as the suitability of using any nearby empirical data which is similar to the project site MAR.

The MAR around Northland demonstrates the rainfall gradient of higher rainfall in the mountainous regions north of Mangawhai, and lower rainfall at lower elevations (Figure 3-2).

A comparison of the empirical data at the specific rain gauges and the MAR rainfall estimate at the same location shows some variation (Table 3-1). The Mangawhai rain gauge shows relatively good agreement with the MAR; whereas the Mangawhai Harbour Combined rain gauge shows a moderate relationship, with a difference of 17% i.e. the empirical data is greater than the interpolated data.

The MAR at the golf course is 1181 mm, which is very similar to the MAR at the two rain gauges (i.e. Mangawhai and Mangawhai Harbour Combined) but is on average 16% less than the empirical rainfall recorded at these gauges. This suggests that the use of either of the rainfall records is likely to be appropriate for the project area in the absence of empirical data, as the difference is moderate.

In terms of the rainfall data to be used for further analysis, the Mangawhai record closed over 30 years ago and, as such, does not provide an accurate representation of the current weather patterns and recent storm events. Therefore, the Mangawhai Harbour Combined rainfall site is recommended to be used as in-situ rainfall data in the absence of measured data at the golf course.

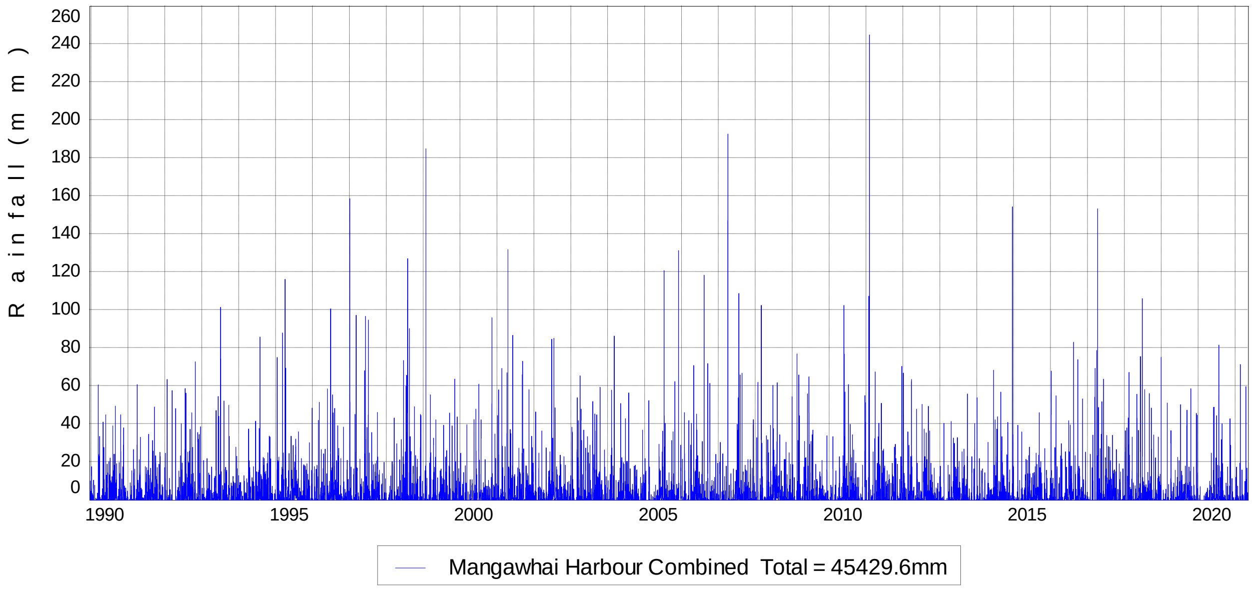


Figure 3-2: Mangawhai Harbour Combined daily rainfall record (1989 – 2021).

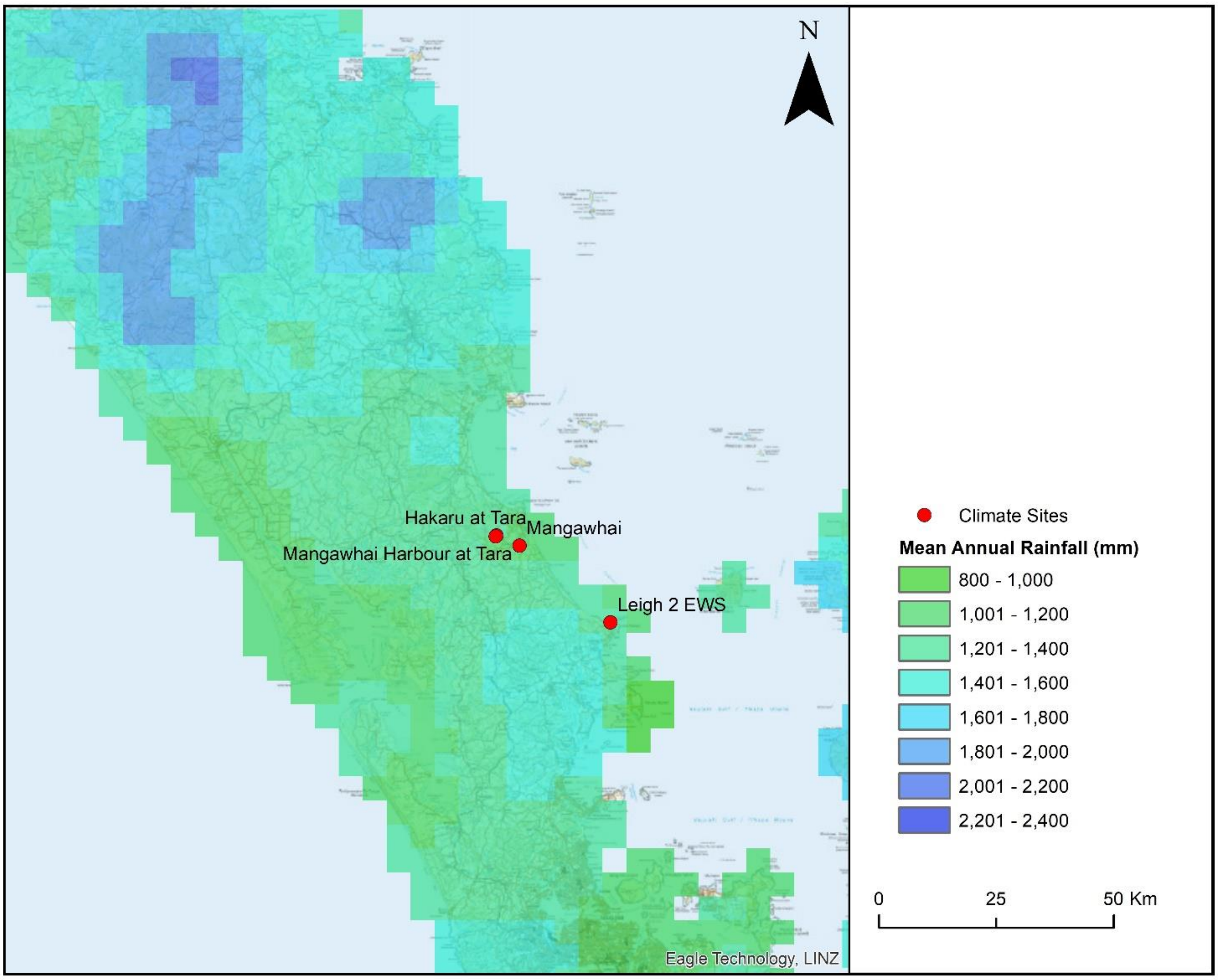


Figure 3-3: Mean annual rainfall (mm) of the wider project area.

Table 3-1: Comparison the MAR and annual average rainfall from the empirical rainfall records.

Site	Elevation (m)	MAR Rainfall (mm)	Empirical Rainfall (mm)	Difference (mm)	Difference (%)
Mangawhai at Tara Combined	104	1208	1461	253	17%
Mangawhai	4	1176	1286.44	110	9%
Mangawhai Golf Course	18	1181			

3.3 Surface water hydrology

There is a single unnamed stream which the wetland discharges to. Within this stream, the flow is likely to be highly dependent on the inflows and level of the wetland (Figure 3-4).

There are no empirical flow records available for the stream; therefore, the Mean Annual Low Flow (MALF), median, mean flow estimates and catchment areas have been derived from the NIWA River Maps site. The site provides a range of statistics for rivers and stream throughout NZ based on statistical models that relate observed patterns with landscape-scale patterns and then generate estimates for the entire New Zealand river network (Booker & Whitehead, 2017).

The Mean Annual Flood for the stream was derived from NIWA's New Zealand River Flood Statistics tool. This tool estimates flood statistics for ungauged streams and rivers based on a flood magnitude model which supersedes the McKerchar and Pearson's 1989 method for flood estimation. The new model utilises a dataset with twice as many sites, and three times the annual maxima. The accuracy of these theoretical estimates is unknown, but likely to be low where there are limited empirical data such as in the current situation. However, in the absence of measured flow they provide a general idea of the high flows in this stream.

It is important to remember that given the size and location of the stream, it is likely to be highly controlled by the wetland; any significant volume of water in this channel would likely be restricted to periods during, and immediately following, periods of intense or prolonged rainfall.

Table 3-2: Summary flow statistics (L/s) for the single unnamed channel derived from NZ River Maps and flood statistics tool (Booker & Whitehead, 2017).

Stream	NZ Segment	Catchment Area (Ha)	MALF (L/s)	Median Flow (L/s)	Mean Flow (L/s)	Mean Annual Flood (L/s)
1	1027575	0.6	1.9	6.4	16.8	520

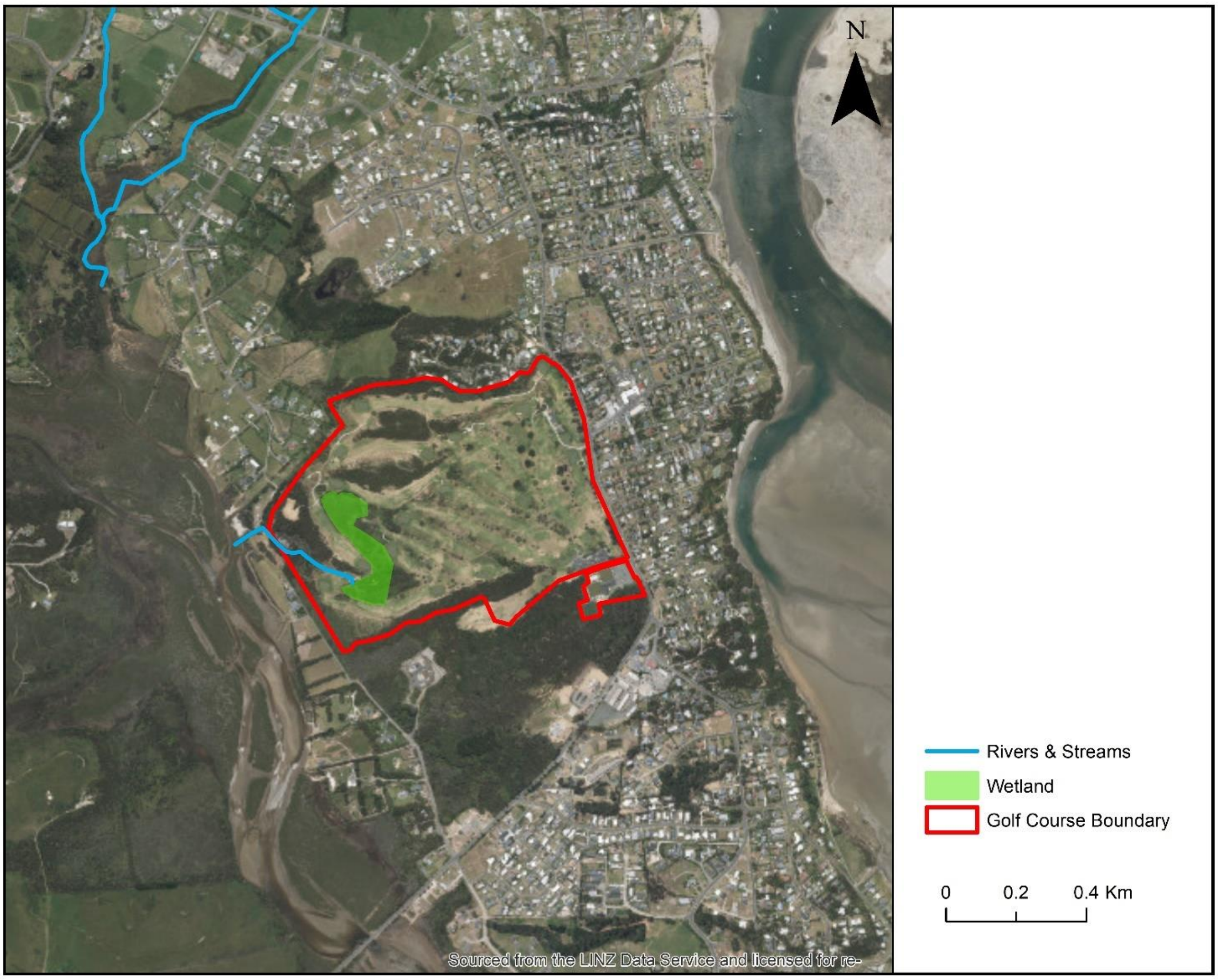


Figure 3-4: Location of the wetland and stream within the golf course.

4 Storm events

Understanding the frequency and magnitude of storm events in Northland will provide an indication of the appropriate time for irrigation of the golf course. Therefore, a high-level analysis of extreme events was carried out.

Extreme weather events are common in Northland due to its extensive coastline and exposure to intense weather systems. Gray (2003) identified the key rain bearing weather systems that bring rainfall to Northland, including;

- Ex-tropical cyclones,
- North Tasman lows – these lows develop over the warm waters off the coast of Queensland and bring persistent rain and strong winds, and
- Intense convection – these events are caused by unstable atmospheric conditions and bring flash flooding, lightening and hail.

The occurrence of these events is sporadic and their effect on localised areas depends on the direction the storm system is travelling. The orographic effect from the surrounding terrain will further influence the rainfall patterns on a local level.

Using the daily total rainfall, from the Mangawhai Harbour Combined rainfall site, the number of rain days and wet days in a month can be determined. Two thresholds were used to determine the mean and maximum number of days a month when rain occurred. The thresholds below are based on the analysis by Chappell (2013);

- 0.1 mm – rain days, and
- 1 mm – wet days.

The number of rain days varies from month to month but supports the notion that winter and spring are the wettest months. On average, the winter months of June, July, and August have a total of 58 rain days and 47 wet days, comparatively summer has a total of 30 rain days and 24 wet days.

Table 4-1: The mean and maximum number of days a month, over the whole record, when rainfall is ≥ 0.1mm or 1mm based on Mangawhai Harbour Combined record (1990 – 2021).

Threshold		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
0.1 mm	Mean	9	9	11	14	17	18	20	20	16	14	13	12	175
	Max	14	16	18	20	24	24	26	27	24	23	20	22	214
1 mm	Mean	7	7	9	11	14	15	16	16	14	11	10	9	139
	Max	13	14	15	18	22	21	23	24	20	17	17	16	161

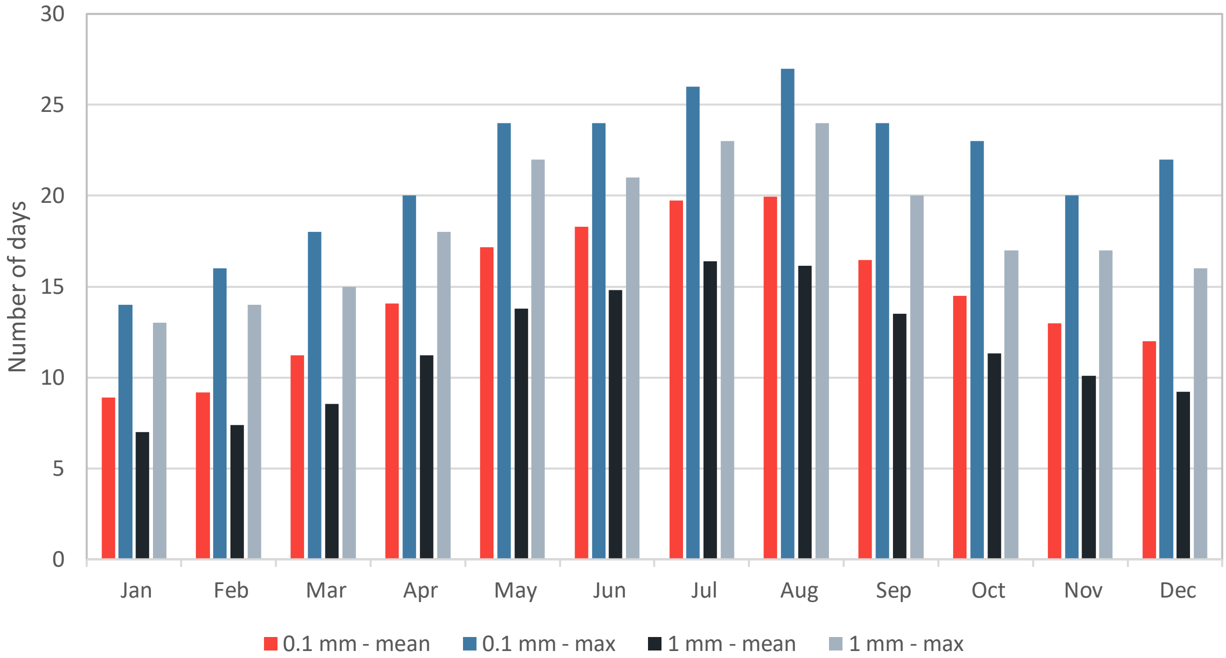
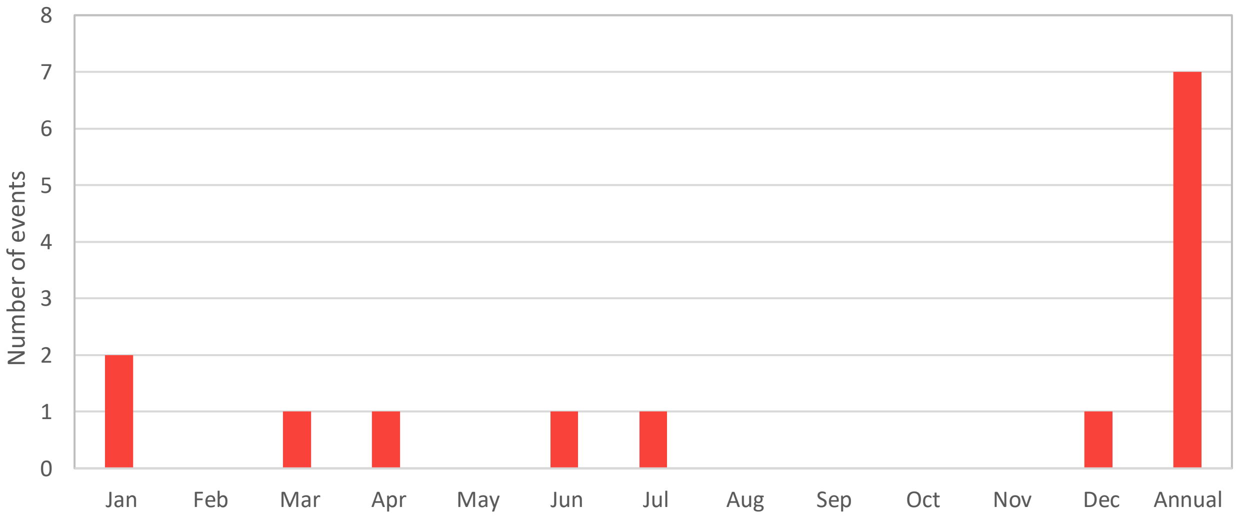


Figure 4-1: Visual representation of the mean and maximum number of days a month, over the whole record, when rainfall is ≥ 0.1mm or 1mm based on Mangawhai Harbour Combined record (1990 – 2021).

It is suggested that the ex-tropical cyclones occur, on average, once every 5 years, particularly during La Niña phases (NRC, 2011). Based on a return period (i.e. Average Recurrence Interval (ARI)) of 1-in-5-years, it was determined that a rainfall event with this ARI equated to a daily total of 150mm.



5 Water balance

A monthly soil moisture balance was used to estimate how much water could be applied to the golf course and potential timing of the discharge, seasonally. Water balances are useful in demonstrating periods when irrigation could be utilised as well as providing information on how much of a deficit of water could be filled by irrigation. This information is pertinent to reducing the risk of excess nutrient rich runoff contaminating the adjacent wetland.

Water enters the system as precipitation (P) and is lost through evapotranspiration and runoff. Potential evapotranspiration (PE) is the maximum amount of water lost to the system (assuming an unlimited supply) as a result of solar radiation, wind speed and vapour pressure deficit (McConchie, 2000). However, because of limitations to water availability, this maximum is often not achieved. Actual evapotranspiration (AE) is a function of both the PE and water availability, and therefore quantifies the actual amount of water lost to the system.

In the water balance, precipitation is initially used to meet the PE requirements. If precipitation or soil water content is sufficient, then AE will equal PE. Any excess water will recharge the soil water storage (ST), or when that reaches capacity, become a surplus (S) and run off. Water which is stored in the pores of the soil is released to the plants and atmosphere when water supply from precipitation is less than the PE. However, moisture within the soil may not be sufficient to fully meet PE. This results in a water deficit (D). Once the soil moisture is depleted irrigation demand will approximate the PE.

5.1 Available moisture

Data from the Mangawhai Harbour Combined long-term rainfall station, to the north west of the golf course, shows a seasonal pattern to the distribution of median monthly rainfall (Figure 5-1). Winter months receive ~50% more rainfall than the summer months. Average monthly rainfall during winter is approximately 154mm; while during summer it is approximately 71mm. There is considerable annual variation about the median. This variability can act as a major constraint on the volume of water that could be discharged to the golf course.

Since the total annual rainfall varies significantly over time, the median annual rainfall likely to be experienced in the current climate, across all years of data, was determined (Table 5-1).

While the above analysis provides an indication of rainfall variability, the use of total annual rainfall reduces the magnitude of any monthly extremes. Consequently, the analysis below will be conservative, i.e. potentially showing lower discharge potential than may be possible during extreme or prolonged dry periods.

Using the average proportion of the annual rainfall which falls in each month, it is possible to distribute the annual median rainfall across each month of the year (Figure 5-1 and Table 5-1). These values were subsequently used in the water balance model.

It has been assumed that PE is consistent across the wider study area. As such, the monthly PE data from the Leigh 2 EWS climate station was used to calculate the water balance for the golf club. As expected, there is a strong seasonal pattern to PE. During summer PE tends to be very high because of sunshine, energy, high temperatures and wind; while during winter PE is low. The monthly median values of PE were incorporated into the model (Table 5-1).

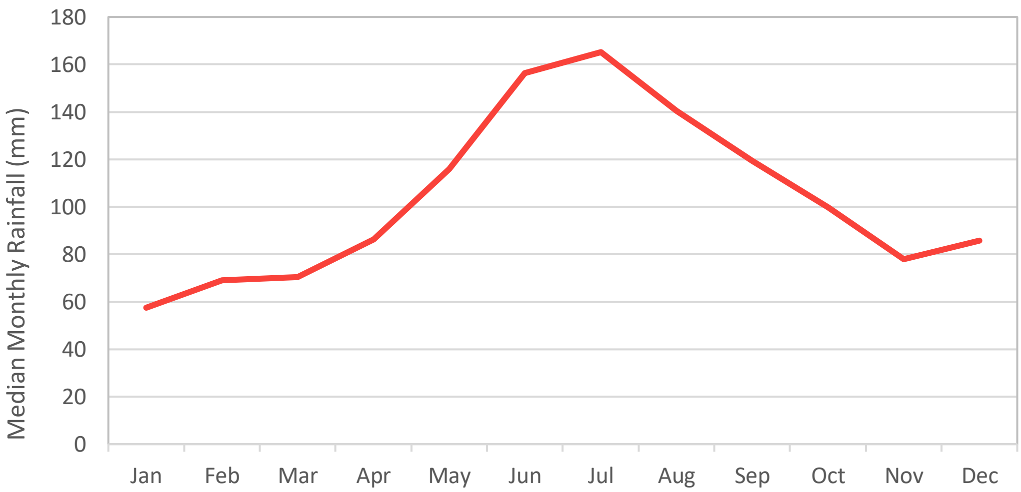


Figure 5-1: Median monthly rainfall at Mangawhai Harbour combined (mm).

Table 5-1: Median monthly rainfall (mm) at Mangawhai Harbour Combined, and median monthly evapotranspiration (mm) at Leigh 2 EWS.

Month	Median Monthly rainfall (mm)	Median monthly PET (mm)
Jan	57	150
Feb	69	125
Mar	70	109
Apr	86	73
May	116	49
Jun	156	35
Jul	165	39
Aug	140	52
Sep	119	72
Oct	100	101
Nov	78	123
Dec	86	146
Total	1243	1074

5.2 Soil moisture

The pores within a soil provide capacity to store moisture, and therefore act as a buffer against the natural inputs and losses of moisture, which would occur solely as a result of the climate.

The soil's Profile Readily Available Water content (PRAW), also known as Available Moisture Content (AMC), describes the water that can be readily absorbed by plant roots without resulting in water deficit stress. This is generally assumed to be the water content difference between field capacity and permanent wilting point. Field capacity describes the maximum amount of water a soil can hold against gravitational force. Wilting point is the moisture content below which plants can no longer extract water because of capillary tension. At this point plants will suffer extreme water stress and possibly die.

For a high-level desktop study such as this, the PRAW can be considered a conservative measure of the soil's water storage capacity. This is because the calculation of PRAW takes into account the soil depth, potential rooting depth, and soil moisture properties of the soil.

There is some variation in the soil water holding capacity across the golf course; therefore, the course was split into three 'zones' based on the dominant soil characteristics and infiltration results in the area. A PRAW value for each zone was then determined (Figure 5-2) and a water balance model was completed for each zone. The process used to differentiate the areas of the golf course is detailed in a separate soils report, *Mangawhai Water Reuse – Hydrogeological Study – Soils* (WSP, 2021).

The low PRAW soils have only a limited capacity to store moisture. This would increase the frequency of treated wastewater discharge (i.e. irrigation).

To provide a detailed 'water balance model' PRAW values of 46mm, 62mm, and 80mm were derived for use in the water balance.

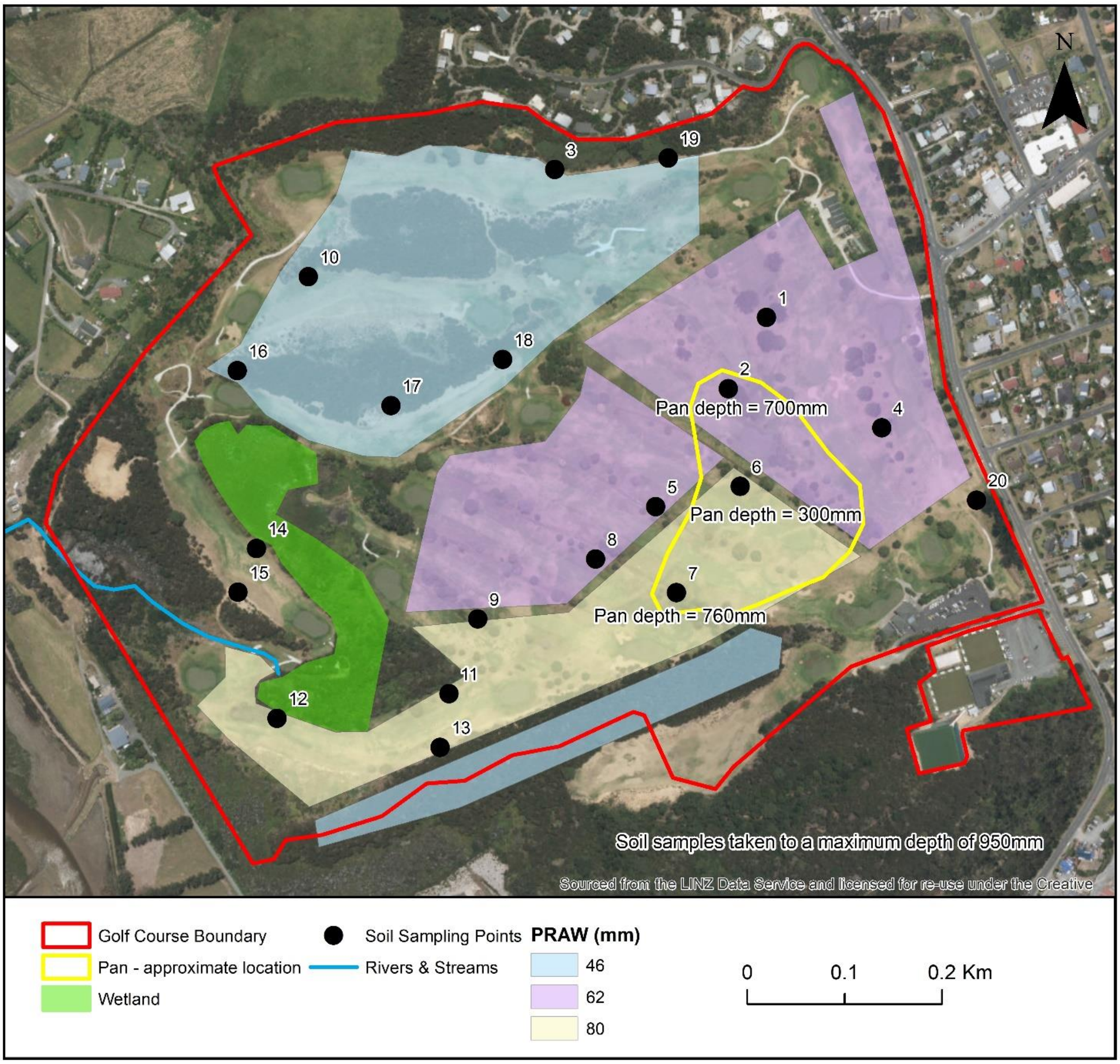


Figure 5-2: Zones of the golf course differentiated by water storage capacity based on soil characteristics.

5.3 Water balance

Three water balances' were calculated using the median modelled rainfall, the evapotranspiration data, and the three PRAW (Table 5-2 to Table 5-4 and Figure 5-3 to Figure 5-5).

Table 5-2: Water balance based on median rainfall (P) and evapotranspiration (PET) with 46mm of storage capacity.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
P	57	69	70	86	116	156	165	140	119	100	79	86	1243
PET	150	125	109	73	49	35	39	52	72	101	123	146	1074
P – PET	-93	-56	-39	13	67	121	126	88	47	-1	-44	-60	
ΔST	0	0	0	13	33	0	0	0	0	-1	-44	-1	
ST	0	0	0	13	46	46	46	46	46	45	1	0	
AE	57	69	70	73	49	35	39	52	72	101	123	87	
De	93	56	39	0	0	0	0	0	0	0	0	59	247
S	0	0	0	0	34	121	126	88	47	0	0	0	416

Table 5-3: Water balance based on median rainfall (P) and evapotranspiration (PET) with 62mm of storage capacity.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
P	57	69	70	86	116	156	165	140	119	100	79	86	1243
PET	150	125	109	73	49	35	39	52	72	101	123	146	1074
P – PET	-93	-56	-39	13	67	121	126	88	47	-1	-44	-60	
ΔST	0	0	0	13	49	0	0	0	0	-1	-44	-17	
ST	0	0	0	13	62	62	62	62	62	61	17	0	
AE	57	69	70	73	49	35	39	52	72	101	123	103	
De	93	56	39	0	0	0	0	0	0	0	0	43	231
S	0	0	0	0	18	121	126	88	47	0	0	0	400

Table 5-4: Water balance based on median rainfall (P) and evapotranspiration (PET) with 80mm of storage capacity.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
P	57	69	70	86	116	156	165	140	119	100	79	86	1243
PET	150	125	109	73	49	35	39	52	72	101	123	146	1074
P – PET	-93	-56	-39	13	67	121	126	88	47	-1	-44	-60	
ΔST	0	0	0	13	0	0	0	0	0	-1	-44	-35	
ST	0	0	0	13	80	80	80	80	80	79	35	0	
AE	57	69	70	73	49	35	39	52	72	101	123	121	
De	93	56	39	0	0	0	0	0	0	0	0	-25	213
S	0	0	0	0	0	0	126	88	47	0	0	0	261

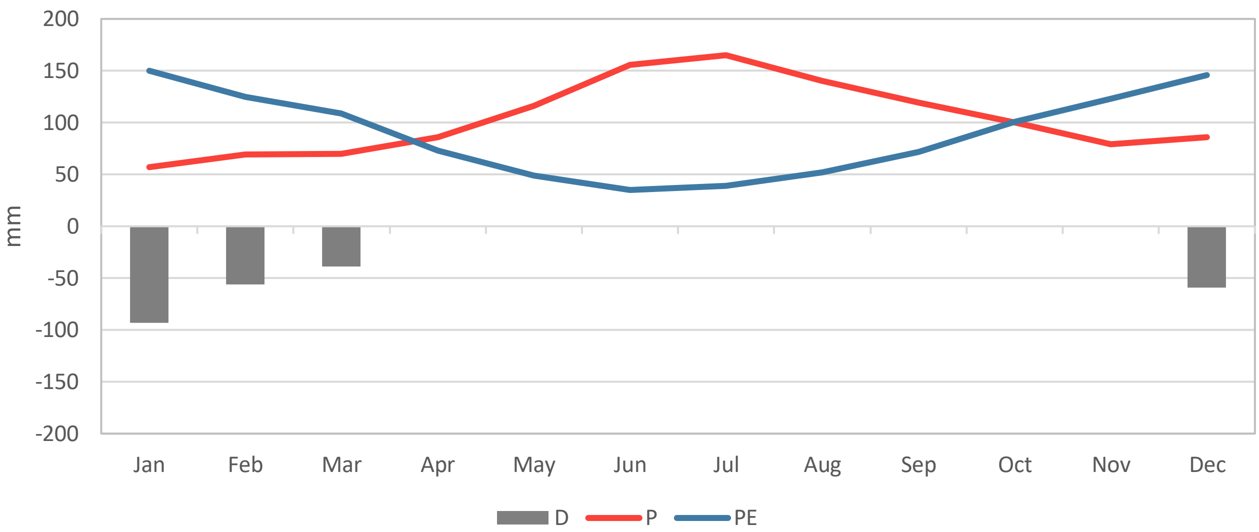


Figure 5-3: P, PE, and deficit curves for Mangawhai golf course with a soil storage capacity of 46mm during a median climate scenario.

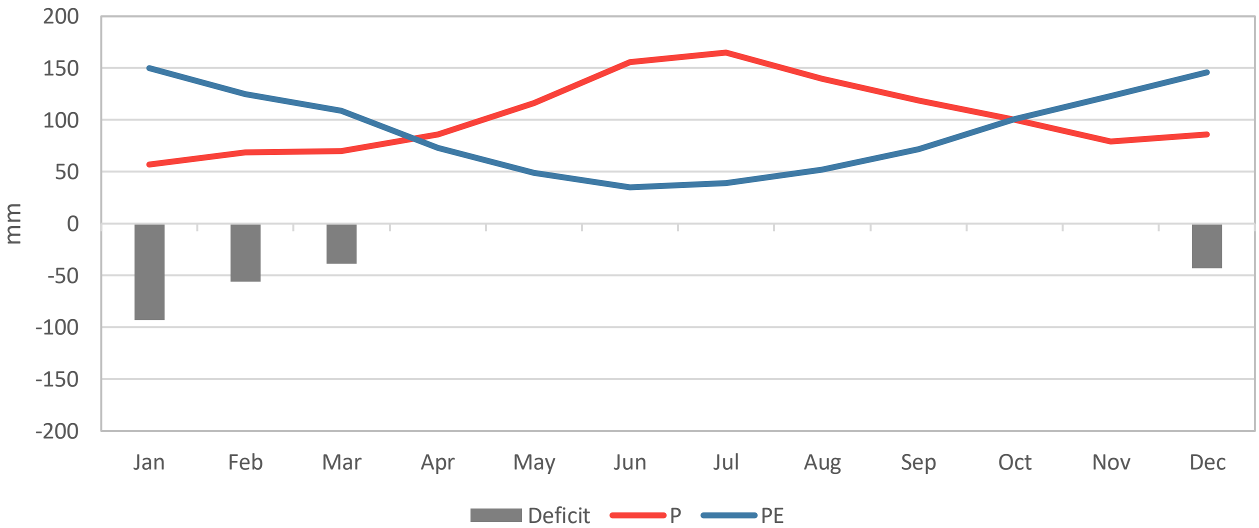


Figure 5-4: P, PE, and deficit curves for Mangawhai golf course with a soil storage capacity of 62mm during a median climate scenario.

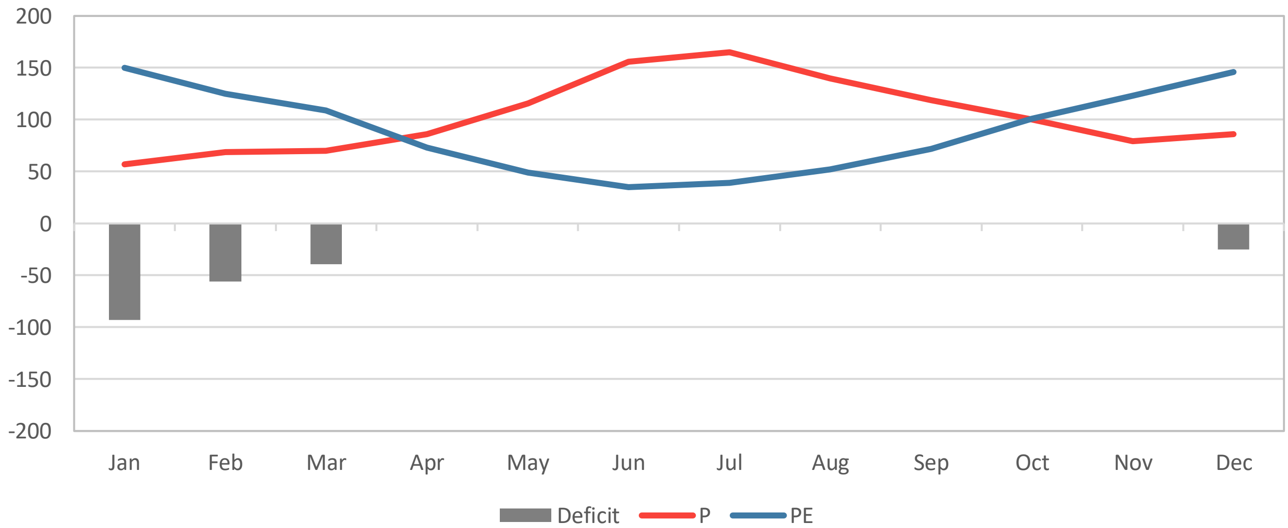


Figure 5-5: P, PE, and deficit curves for Mangawhai golf course with a soil storage capacity of 80mm during a median climate scenario.

The yearly moisture deficit for soil with a storage capacity of 42, 62, and 80mm would be 247, 231, and 213mm respectively (Table 5-2 and Figure 5-3). In the current climate, deficit irrigation of the golf course could start in December with relatively low applications of water, before ceasing in April.

It should be noted that monthly rainfall and PE can vary significantly from the median and consequently there may be considerable residual risk if this water balance is strictly applied. The water balance is based on monthly data and does not explicitly account the specific amount and timing of rainfall throughout the month. As such, it is possible that a large amount of rainfall could fall in one event. Much of this rainfall may run off. Consequently, the overall deficit may be larger than anticipated.

6 Irrigation potential

Based on the results of the water balance, the locations and maximum volume of treated wastewater that can be applied are shown in Figure 5-2 and Table 6-1. This suggests that the maximum volume of treated water, that could be applied across the total 45ha, is 111,150m^3. However, there may be considerable residual risk if this water balance is strictly applied, as well as, the inherent uncertainty in deriving irrigation rates and volumes, based solely on the rough catchment area of the different zones. Therefore, a conservative approach to development and construction of any irrigation system is recommended.

Table 6-1: The monthly and daily deficit, and monthly irrigation volume for individual zones and the total area of the golf course during potential irrigation months.

PRAW (mm)	Area (ha)	Daily Deficit (mm/day)				Monthly irrigation volume (m^3)				Total Volume (Dec – Mar; m^3)
		Dec	Jan	Feb	Mar	Dec	Jan	Feb	Mar	
46	12	2	3	2	1	6,986	11,011	6,630	4,618	29,244
62	12	1	3	2	1	5,267	11,390	6,859	4,777	28,292
80	6	1	3	2	1	1,597	5,940	3,577	2,491	13,605
46	45	2	3	2	1	26,550	41,850	25,200	17,550	111,150
62	45	1	3	2	1	19,350	41,850	25,200	17,550	103,950
80	45	1	3	2	1	11,250	41,850	25,200	17,550	95,850

* areas are approximate based on Figure 5-2, note values have been rounded to nearest whole number.

Although not detailed on any maps, a hard iron pan is known to be present across low lying areas of the golf course. The pan consists of chemically altered soils that form a relatively impermeable layer of soil at varying depths below the ground surface. Figure 5-2 shows an approximate location of the pan at varying depths from 800mm and shallower; however, its exact location and extent are unclear. In areas where the pan is present, the rate and/or volume of irrigation may be reduced due to its impermeable nature.

The combined soils, hydrology and irrigation analysis has confirmed that excess treated wastewater could be irrigated on the Mangawhai Golf Course and surrounding bush, in a way that the risk of runoff is limited; however, the success of this activity lies in how and when the irrigation system is operated. Ultimately, the decision to irrigate, given the above analysis, lies solely with the client based on their needs and desired outcomes.

6.1 Irrigation options

The purpose of this section is to articulate the implications of the water balance models on irrigation and the type of irrigation system that is suitable to apply treated wastewater to the golf course.

Before an irrigation design can be completed the size of the distribution area must be checked. It must be large enough to cope with the annual volume of treated wastewater such that soils never exceed field capacity. This is driven by the volume of treated effluent produced annually, the maximum volume of treated wastewater that can be applied and the size of disposal area.

Buffer storage will be required. This is because there are periods where treated effluent cannot be applied (winter months) due to soils being at or above field capacity.

It is assumed that the irrigation system is a deficit irrigation system. Therefore, the irrigation network will need to be able to be split into individually controlled zones that match the differences in soil types. Soils with higher water storage capacities tend to need irrigating less often but for greater volumes. Soils with lower water storage capacities need irrigating more often for smaller volumes. Each zone needs the ability to be turned on and off independently according to what the soil moisture of the soils are.

The most likely type of irrigation system will be a fixed sprinkler/ emitter system that will be unobtrusive as possible. Generally, for golf courses and sports fields this is achieved best with pop-up sprinkler systems or sub surface dripline.

7 Summary

A summary of the hydrology analysis is contained within the memo to which this report is attached. The two should be read in conjunction to ensure a comprehensive understanding of the uncertainties and limitations relating to this analysis.

8 References

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