ocdl
O'Callaghan Design Ltd
3 Lochiel Rd
Khandallah
Wellington, 6035
Phone: [redacted]
Email: [redacted]

PEKA PEKA FARM

HYDROLOGICAL REPORT

Prepared for

Waikanae North Developments Ltd

March 2026

Table of Contents

1 **INTRODUCTION** 1

2 **THE SITE** 1

3 **HYDROLOGY** 1

4 **GEOLOGY** 4

5 **HYDROGEOLOGY** 9

6 **WETLAND AREAS** 15

7 **PROPOSED DEVELOPMENT ON HYDROLOGICAL MATTERS** 16

8 **CONCEPTUAL MODEL** 24

9 **ASSESSMENT OF EFFECTS** 26

10 **SUMMARY/CONCLUSIONS** 33

11 **PROFESSIONAL EXPERTISE** 34

Figures

Figure 1 General Site 1

Figure 2 Ngarara Stream 1940 2

Figure 3 Photographs of On-site Culverts 2

Figure 4 Existing Flooding Extent in 1% AEP (with allowance for climate change) 3

Figure 5 Geomorphic Zoning Plan 4

Figure 6 Peat Presence 5

Figure 7 Groundwater Monitoring Results 7

Figure 8 Groundwater level contours overlaid on peat thickness 8

Figure 9 Cross section through development area 10

Figure 10 Profile through P013 – P07 10

Figure 11 1.2m dia. Culvert on Ngarara Stream 13

Figure 12 Ngarara Stream at the northeastern corner of the site 13

Figure 13 Flooding Extent in a 2-year Design Event 14

Figure 14 Wetland Areas 15

Figure 15 Hydrological Zones 17

Figure 16 Ngarara Stream Realignment 18

Figure 17 Typical Stream Channel Cross Section Downstream of Realigned Reach 18

Figure 18 Catchment Types 21

Figure 19 Lot-Level Stormwater Control Classification 21

Figure 20 Surface Water Catchments 22

Figure 21 Hydrological Zones 26

Figure 22 Peat Extent Adjacent to Wetland W11 30

Figure 23 Proposed Earthworks Adjacent to Wetland W11 30

Figure 24 Stormwater Treatment Basin Adjacent to wetland W11 31

Tables

Table 1 Low-lying Areas Characterisation 5

Table 2 Typical Groundwater Depths 7

Table 3 Groundwater levels relative to Ngarara Stream levels 12

Table 4 Wetland Hydrological Characteristics 16

Table 5 – Criteria For Mass Balance Assessment 28

Table 6 Mass Balance Assessment 29

1 INTRODUCTION

This report has been prepared for Waikanae North Developments Ltd (WNDL) in support of an application under the Fast-track Approvals Act 2024. This report sets out our assessment of hydrological issues relating to proposed residential development at 169-171 Peka Peka Road, Waikanae including how the proposal affects hydrology of the wetlands. The proposed development will involve bulk earthworks, alteration to drainage patterns, removal of peat and changes to surface water runoff patterns within the site. These works have a potential effect on the hydrologic systems within the site and potential effects on the hydrology related to existing and proposed wetlands within the site. The potential changes to these systems are described in this report to provide scale and context for the assessment of potential adverse effects associated with these changes. This report supports the application for approval via the Fast-track consenting process.

2 THE SITE

Peka Peka Farm is at 169 – 171 Peka Peka Road and has an area of approximately 139Ha. The site is shown in Figure 1 below:

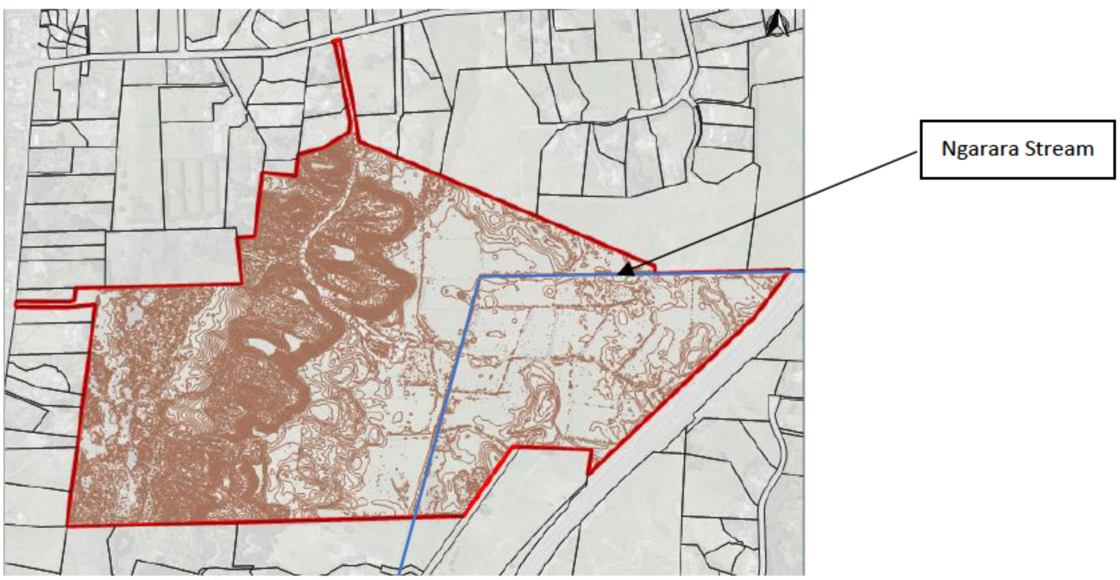

Figure 1 General Site

The site has been a working farm for several decades and the landform has been modified to some extent by farm tracks, the creation of farm drains and a large catchment drain, with associated culvert crossings on the farm. The notable elements in terms of the hydrology on the site include the presence of the Te Harakeke Swamp in the western side of the site, the low-lying areas within the eastern and southern zone of the site, which are at a level of approximately RL5.5 – 6.0m, several wetland areas, the Ngarara Stream which serves a large catchment area to the southeast and relatively small drains that have been constructed within the site over the decades of farming. The site is also in the flood plain of the Ngarara Stream and has floodwater inundation in modest to large rainfall events.

3 HYDROLOGY

The Ngarara Stream flows through the central/eastern portion of the site. As indicated by the Figure 1, the Ngarara Stream has been previously modified into a straight eastern section of stream approximately 850m long, entering the site from a culvert structure beneath the Kapiti Expressway. It then turns to the southwest and has a straight section approximately 750m long to the southern boundary of the site. The photograph from as early as 1940, shown in Figure 2 below, show the stream to be in this alignment. It can be reasonably expected that the modification to the natural alignment into this straightened alignment occurred many years before the 1940's.

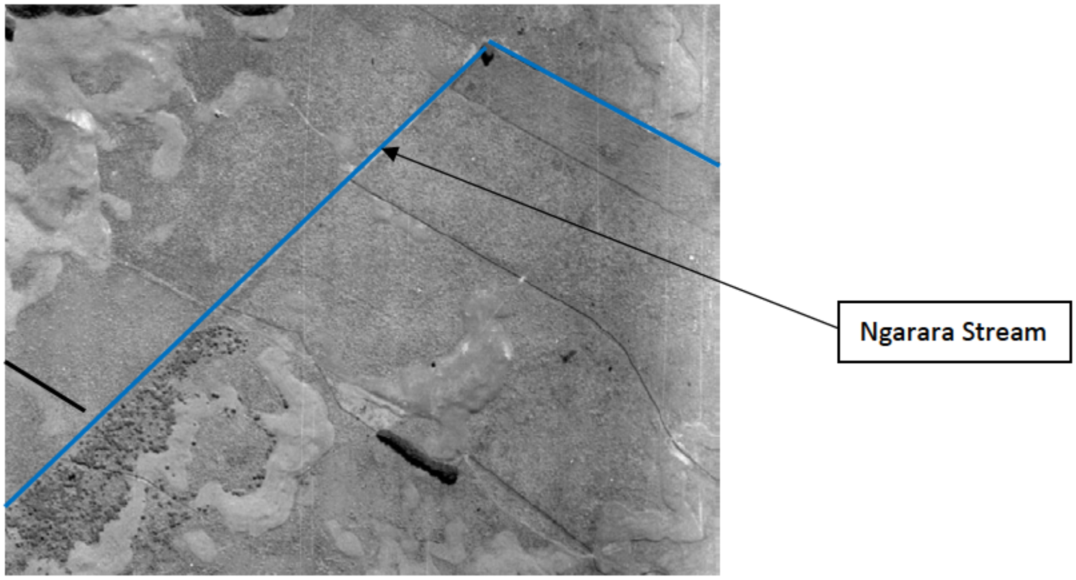

Figure 2 Ngarara Stream 1940

There are several culverts on Ngarara Stream within the site to provide farm access across the crossing points. An example of these are shown by the photographs in Figure 3.


Figure 3 Photographs of On-site Culverts

The land is very flat with a change of invert level of approximately 2m over a length of approximately 1,600m.

There are several constructed side drains connected to the Ngarara Stream within the site, and these have relatively short catchment lengths.

There are several wetland areas within the site, as described in the RMA Ecology Report. The RMA Ecology Report also describes some proposed new wetland areas that would be constructed as part of the development works. We refer the reader to that report for a description of these.

However, at a broad level, these can be categorized, for the purposes of this Report, as being the group of wetlands in the low-lying central/eastern portion of the site, the wetlands in the higher ground in the central area of the site and the Te Harakeke Swamp wetland in the western portion of the site. This differentiation is made in this report because the presence of drains, the Ngarara Stream and underlying peat soils and the frequent occurrence of surface water flooding has a notable impact on the hydrological systems associated with the low-lying wetlands in the central/eastern portion of the site. These elements are not applicable to the other two wetland portions of the site.

A notable factor influencing the hydrology of the low-lying central/eastern portion of the site is the frequency of flooding of this land when the Ngarara Stream overflows its banks. As indicated above, the site is very flat, the Ngarara Stream has been formed with a very limited cross sectional area and a depth of not much more than 2m. It therefore overflows in small to modest rainfall events. KCDC modelling of the existing surface in a 1% AEP event (including allowance for climate change) estimates the extent of surface water ponding on the site to be as shown in Figure 4.

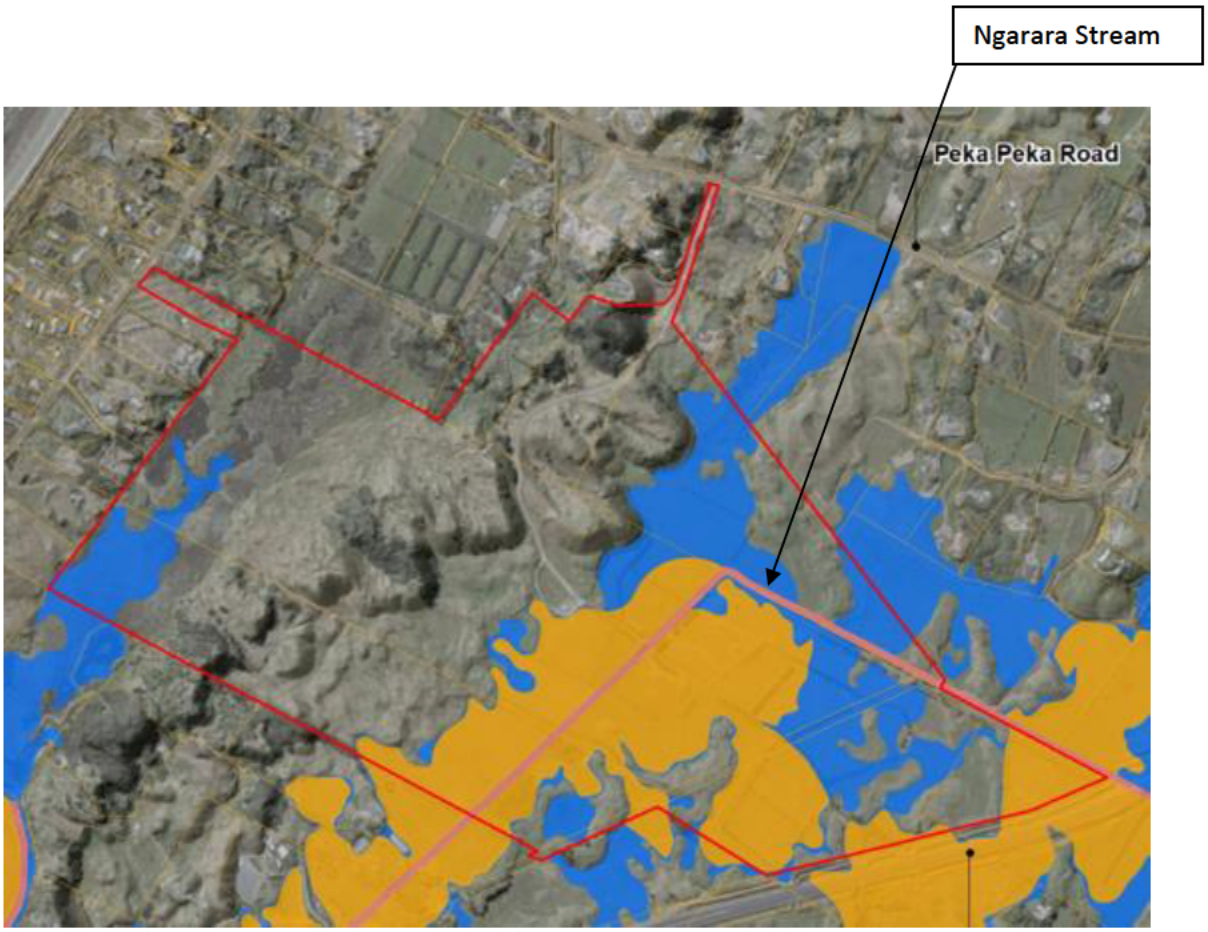

Figure 4 Existing Flooding Extent in 1% AEP (with allowance for climate change)

Essentially the entire low-lying area within the central/eastern portion of the site would be inundated in a 1% AEP event.

The velocities in the Ngarara Stream are approximately 0.5m/s in the 2-year and 10-year return period flood events.

4 GEOLOGY

A detailed geotechnical assessment of the site has been carried out, and the results of that assessment are described in the Geotechnical Assessment report prepared by CGW Consulting Engineers, dated 13 March 2026.

CGW have summarized the geology in the flowing terms:

> The site has been categorised into three geomorphic environments based on landform and subsurface conditions:
>
> - Low-lying areas: Located in the eastern and southern portions of the site, underlain by soft peat (up to 2.6 m thick), silty sand, and marine deposits. Groundwater is typically shallow (<1.5 m BGL).
> - Lower Dunes: Undulating terrain comprising loose to medium-dense sand, often moist, with no observed peat. Groundwater generally ranges from 1.1 to 3.7 m BGL.
> - Upper Dunes: Elevated dune ridgelines comprised of clean, well-drained sand that becomes dense below 1.5 m BGL with groundwater typically deeper than 3.0 m.

These three zones are shown in Figure 5.

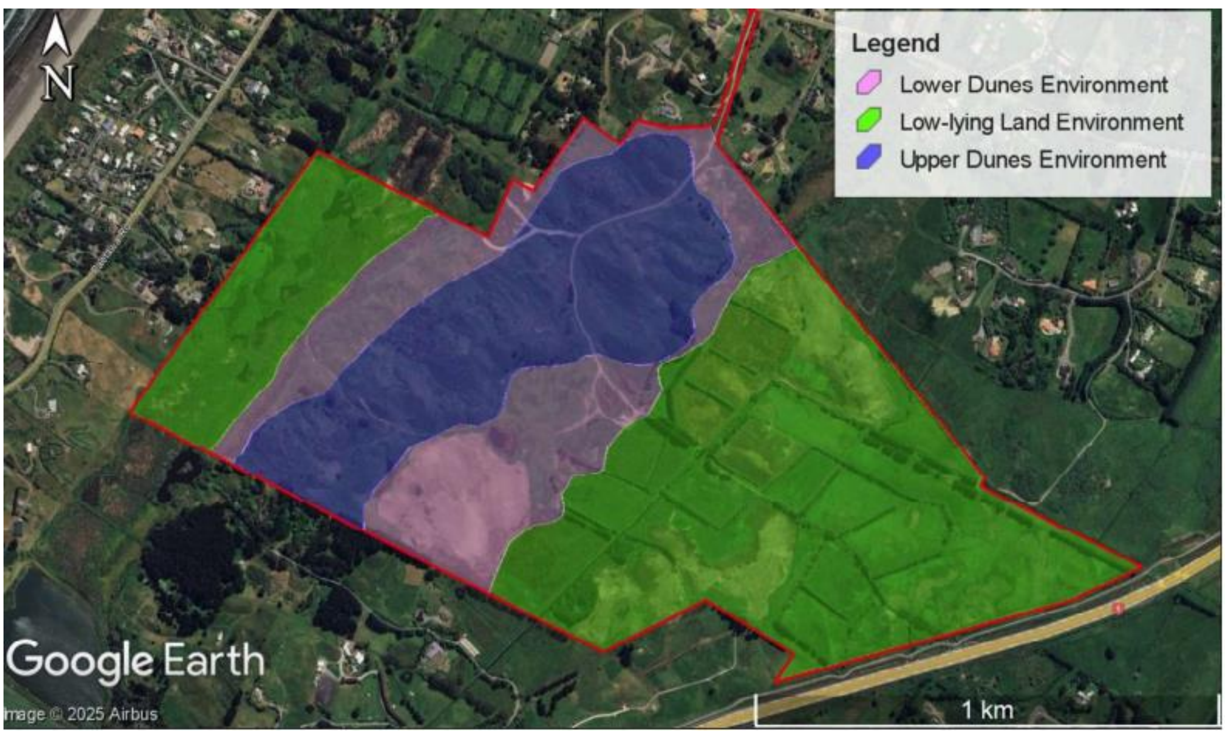

Figure 5 Geomorphic Zoning Plan

The pertinent aspects of the geology of the low lying portion of the central/eastern area of the site, relating to hydrogeology of the site are soil type, the presence of peat, soil permeability and groundwater behaviour. The geotechnical assessment concluded:

Low-lying areas

These areas are underlain by variable sequences of dune sand, swamp deposits (peat and organic silt), and deeper marine sands. Many CPTs show a loose surficial layer underlain by organic soils up to 2.5 m deep. However, the presence of peat is spatially variable — absent in some shallow ridges or historic shallow dunes.

Below the peat, loose to medium dense sands are commonly present, often interbedded with silts. In deeper CPTs, these sands extend beyond 10 m and are consistent with marine or estuarine origins.

They summarized these as shown in Table 1:

Table 3: Low-lying Areas			
Soil Type	**Depth to bottom of layer (m)**	**Typical Thickness (m)**	**Notes**
Silty SAND/ SAND (TOPSOIL)	Avg ~0.18	0.0 – 0.7	Moist, dark brown, rootlets common
Fine SAND[1] (DUNE DEPOSITS)	Avg ~0.40	0.2 – 0.6	Very Loose
Peat / Organic Silt (SWAMP DEPOSITS)	~0.2 – 3.5	Avg: ~1.21	Black to dark brown, fibrous, soft to firm
Fine to Medium SAND (MARINE SANDS)	>1.5 – >10	Variable	Grey, loose to medium dense

Notes:

- Note[1]: 6 of the hand augers encountered loose sand overlying the PEAT. In most cases the PEAT was lying directly under the topsoil.
- Peat zones underlie much of this area.
- Low bearing strength and high settlement potential.
- Nearby NZGD data indicates that gravel deposits may be encountered below 20 m bgl.

Table 1 Low-lying Areas Characterisation

The CGW Report states that significant peat deposits have been identified within the eastern and southern portions of the site, associated with low-lying wetland terrain and historic wetland features. The extent and thickness of the peat was based on over 65 hand auger investigations with additional input from previous investigations and regional geological mapping. Peat thickness varies from 0.2m – 2.6m, with an average thickness of 1.2m across the site where it is present. The report notes that not all low-lying areas contain peat. The variability of peat thickness is shown by Landlink drawing 2911-ALL-EW-202 and an insert of the drawing is shown in Figure 6.

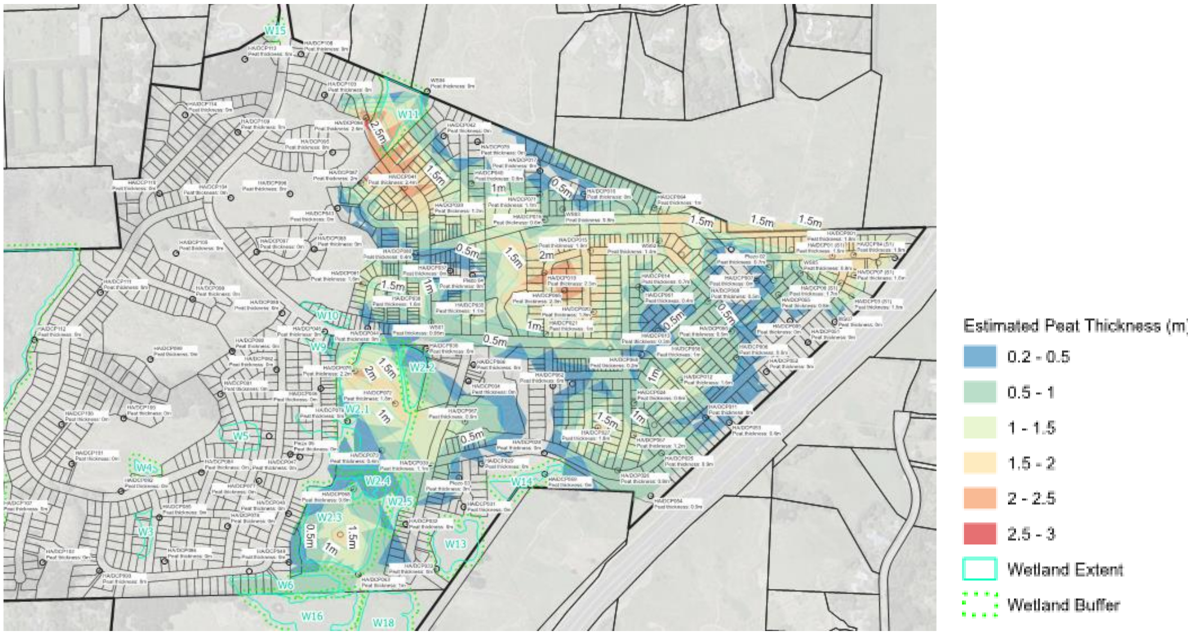

Figure 6 Peat Presence

Groundwater levels have been monitored in seventeen monitoring bores across the site for the period May 2025 – February 2026 and monitoring will continue. There is notable variation in the results from groundwater monitoring.

The location of the 17 monitoring bores is shown in Figure 7 below.

Figure 7 Groundwater Monitoring Piezometer Locations and inferred groundwater level contours

The CGW investigations found saturated conditions in peat-affected areas, the groundwater to be near the surface following rainfall and a persistent high groundwater table in the peat areas.

Results from monthly groundwater level monitoring across the site for the period May 2025 – February 2026 are shown in Table 2 below and all monitoring results are contained in Appendix 1. The minimum and maximum depth to the groundwater level at the monitoring wells is shown in Table 2. Table 2 shows that there is a general variation of 0.4 – 0.5m in the low-lying central area and the eastern portion of the site. Table 2 also shows quite shallow depths to groundwater for P05, P06, P07, P010 & P011. It should be noted that P06 & P07 are in areas that are to be raised for development and so these are outside proposed wetland areas. However, P05, P010 & P011 are areas that are not being raised and existing groundwater in these areas is relatively close to the surface.

Piezo ID	GL at Piezo	RL of GW		Depth to GW			Thickness of peat
		Max	Min	Max	Min	Aver. Depth	
01	6.95	6.41	5.46	1.49	0.54	0.94	0.7
02	6.72	5.17	4.71	2.01	1.55	1.76	0 – 0.5
03	6.35	5.41	4.97	1.38	0.94	1.12	0 – 0.5
04	9.01	4.53	4.40	4.61	4.48	4.55	0
05	5.13	4.76	4.30	0.83	0.37	0.52	0.5 – 1.0
06	5.96	5.53	5.30	0.66	0.43	0.55	0.5
07	6.81	6.76	6.24	0.57	0.05	0.29	0
08	6.03	5.49	5.03	1	0.54	0.76	0
09	6.88	5.31	4.84	2.04	1.57	1.79	0
010	5.06	4.86	4.53	0.53	0.2	0.36	2.0
011	5.04	4.69	4.34	0.7	0.35	0.48	1.0
012	10.87	not recorded, <RL6.3		not recorded, >4.6			0
013	5.50	5.02	4.70	2.76	0.48	0.64	1.5 - 2
014	6.90	4.30	3.85	1.08	2.6	2.76	0
015	3.85	2.82	2.73	2.31	1.03	1.08	0
016	5.10	2.90	2.60	2.88	2.2	2.31	0
017	6.38	3.65	3.18	3.2	2.73	2.88	0

Table 2 Typical Groundwater Depths

The monitoring consists of monthly readings with 9 – 10 readings for each piezometer, shown in Table 2 (in terms of 2016 vertical datum), has been used to develop a potentiometric surface map showing the shallow unconfined aquifer water table contours. The resulting estimated groundwater level contours are shown in Figure 7 by the blue lines.

The gradient of the surface of the groundwater level changes across the low-lying central and eastern portion of the site is not uniform. Investigation of this has confirmed a correlation between groundwater level profile and thickness of peat, as indicated by Figure 8 below.

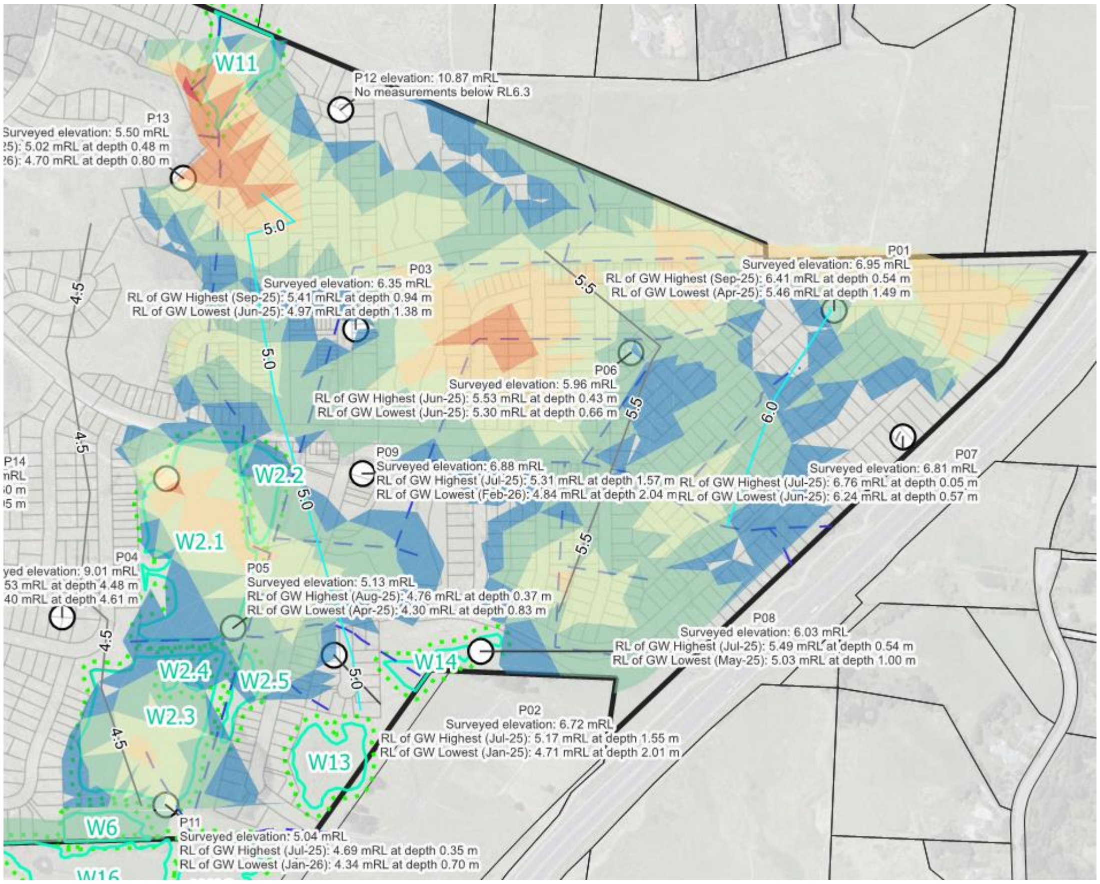

Figure 8 Groundwater level contours overlaid on peat thickness

Assessment of the groundwater contours indicates a steeper groundwater profile in the eastern area where the groundwater has a slope of approximately 0.33% between sites P01 & P06 and extending south to P08. The peat thickness assessment records peat through this zone is typically 0.5 -1m thick.

West of P06 there is a significant flatter gradient across the groundwater level contours (RL5.5 – RL5.0), to approximately 0.1% across to P03 and P09. This zone coincides with the area of peat thickness, which is recorded as being over 2m in this specific area (see Figure 8). It can therefore be concluded that the flow-path/gradient through the thicker peat is influenced by the thickness of the peat.

Figure 7 & 8 show the groundwater level contours changing to a grade of approximately 0.2% in the area between P09 and P010. This is also an area where peat thickness is typically close to 2m. The groundwater profile is also very flat between P05/P011 and P04. Peat is up to 1.5m thick through this zone and the ground surface is very flat.

Groundwater monitoring in the western part of the site, near the Te Harakeke Swamp wetland at P015 & P016 records average groundwater level at approximately RL2.8 along the western edge of the proposed main development. The groundwater at these monitoring sites is between 1 – 2.5m below ground level.

On-going monitoring of groundwater variability at the various monitoring wells will provide an increasing level of certainty about groundwater variability over the seasons. Monitoring data to date shows quite large increases of the groundwater levels between summer and winter, particularly in the central low-lying area of the site where it is proposed to enhance the area to create higher ecologically functioning wetlands The monitoring results are consistent with our on-site observations since 2021 and with the site owners observations, who have been involved with farm operations over recent years and who are familiar with general groundwater behaviour in the local region.

5 HYDROGEOLOGY

The geotechnical investigations, combined with the understanding of the Ngarara Stream flow patterns, and the associated side drains and the expected outcomes from the site wide stormwater collection and disposal strategy adopted for the development provide a basis for developing an appreciation for the potential changes in the hydrological elements triggered by the proposed development works.

The unconfined aquifer in this area, under-lying the sand deposits at a relatively shallow depth within the site, is expected to have low to moderate transmissivity values. GWRC estimate that the hydraulic conductivity of these soils is likely to be in the order of 2 – 5m/day (GWRC, 2014).

A detailed groundwater investigation for the Waikanae area was carried out by GWRC and is described in their report “Kapiti Coast groundwater investigation – Catchment hydrogeology and modelling report”, dated October 2014. Section 4.2 of that report discusses the upper water bearing zone (Holocene (Q1) sand and gravel deposit zone). The report states that these soils form an extensive unconfined aquifer system which is recharged by local rainfall as well as flow loss from the Waikanae River and the aquifer system is also hydraulically connected to numerous wetlands and streams on the coastal plains.

The report also found an almost instantaneous reaction in shallow groundwater immediately adjacent to the Waikanae River to changes in river stage with increasing lag and a decreased magnitude of response observed in bores further from the river. The report noted that groundwater levels respond rapidly to recharge following individual rainfall events.

Section 4.1 of the GW 2014 report describes the Waikanae zone Q1 alluvium sands being typically 15m thick in inland areas and up to 40m thick near the coast.

The groundwater monitoring at the development site confirms changes in groundwater depth of up to 0.5m over the monitoring period. This is consistent with wider observations in the sandy soils.

It is also observed that variations in the groundwater profile is influenced by peat thickness. This correlation indicates higher transmissivity through the thicker peat areas, relative to the thinner peat areas, resulting in a lower gradient of groundwater level contours. This difference in overall transmissivity is also influenced by the depth of underlying sand which is also part of the groundwater conveyance system. This change in gradient of the groundwater across the site is important in the consideration of how the groundwater profile might be affected in the areas where the peat is to be removed and replaced with compacted fill.

The groundwater gradient of 0.3% between sites P01 and P06 would indicate a hydraulic conductivity (K) rate of approximately 10^{-4} to 10^{-8} m/s. Conversely, a groundwater gradient of 0.1% between sites P03 and P09 would indicate a hydraulic conductivity (K) rate of approximately 10^{-3} to 10^{-4} m/s. However, as indicated above, the movement of groundwater through the underlying sand layer would be a large component of groundwater movement because it is likely to be 20 – 30m thick in the area of the site.

A typical profile through the development where there is a change in groundwater profile, variability of peat thickness and a zone where the peat is not going to be removed would be a section from P013 to P07, as shown on Figure 9 below:

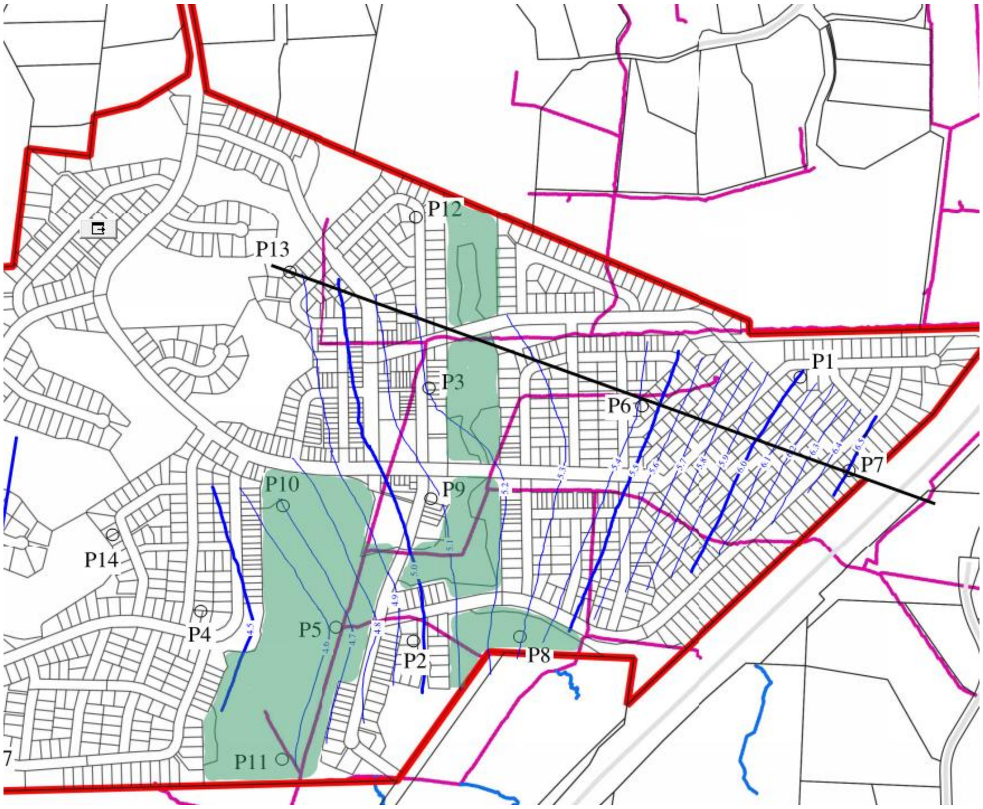

Figure 9 Cross section through development area

A profile along this section from P013 to P07, incorporating ground level, top and bottom of peat taken from numerous hand augers described in the CGW Geotechnical Report, recorded average groundwater levels taken from monitoring results is shown in Figure 10 below. The peat is shaded light brown, and the light green shaded area is a part of the site that will not have any peat removed as it is not going to have development on it. The changes in the gradient of the groundwater is clearly visible in Figure 10.

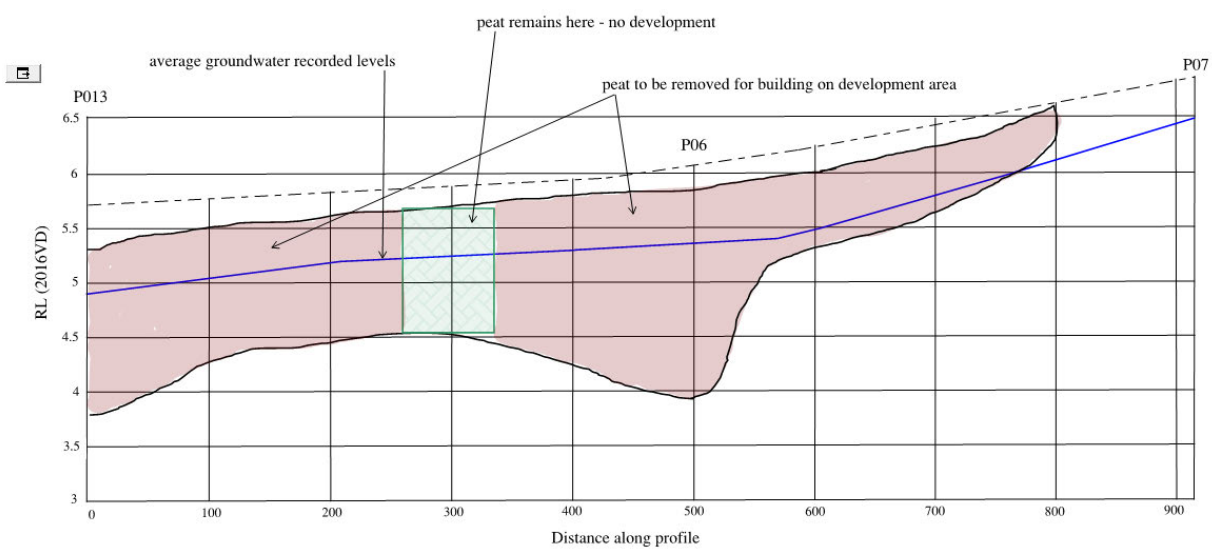

Figure 10 Profile through P013 – P07

The part of the site immediately to the left of the profile (beyond P-13) will not be disturbed as it is the base of a very large, steep sand dune that remains unaltered by the development. The section of the profile between 260m – 340m contains the section of the site that will not have peat removed (light green shaded zone).

The groundwater profile between 200m – 570m has a gradient of 0.05%. An assessment of the likely change in groundwater profile resulting from the removal of an average depth of peat of 1.7m over a 300m reach, assuming a $K = 5*10^{-5}$ m/s for peat, $K = 1*10^{-4}$ m/s for the underlying sand and $K=1*10^{-6}$ m/s for compacted sand replacing removed peat and a 20m depth of natural underlying sand revels the following:

Transmissivity $T_{peat} = 6.5*10^{-5} m^2/s$, $T_{sand} = 2*10^{-3} m^2/s$ and total natural $T = 2.065*10^{-3} m^2/s$. The peat contribution to this is approximately 3% of total transmissivity.

After peat removal, with a compacted sand/silt mix with $T = 1.3*10^{-6} m^2/s$, the total $T_{post\ peat\ removal} = 2.0013*10^{-3} m^2/s$. The change in groundwater gradient resulting from the peat removal over the 300m reach of the profile would be $T_{natural}/T_{post\ peat\ removal} = 2.065*10^{-3} / 2.0013*10^{-3} = 1.032$ i.e. the groundwater gradient increases by approximately 3.2%. This results in an increase of 5mm in groundwater level between *before* and *after* the peat removal exercise. This is a negligible change that would be difficult to record and is inconsequential when compared to the 500mm change occurring on an annual basis with seasonal variations.

The same assessment could be carried out for the reach 600m – 800m in the profile shown in Figure 10 but the change would be almost zero because there is very little peat removed from within the groundwater system in this cross section.

Consideration of another cross section profile from P04 – P07 would result in an even smaller change than that described above because there is no peat removal west of the 5.2m groundwater level contour and so even less length and depth of change is initiated.

We therefore conclude that removal of the peat and replacement with compacted sand & silt mix will not result in any measurable change in the rate of groundwater through the site. This is predominantly because the majority of groundwater movement occurs in the 20 - 30m deep layer of underlying sand, as discussed in GW's 2014 Kapiti Coast groundwater investigation report and the small change in transmissivity within the peat layer is not greatly influential in estimated post peat removal groundwater level over the length of peat removed, particularly when compared with seasonal changes in groundwater and near instantaneous changes resulting from heavy rainfall.

The groundwater is shallow in the areas where the peat has a thickness of at least 0.5m. This is indicated by the monitoring results shown in Table 2 for P05, P06, P010, P011 & P013 and is shown by Figure 10. However, it is also noted that the groundwater level was recorded to be very shallow at P07 (0.57 – 0.05) and relatively shallow at P08 (1.0 – 0.54) where peat is not present at these two monitoring sites. These two sites also show a groundwater rise of approximately 0.5m during the monitoring period . Similarly, a rise of 0.45m was recorded at P02 and there is very little peat at this location.

The low-lying central and eastern portion of the site is very large and very flat. There are no widely dispersed drainage systems across these areas. Rainfall onto these areas has a very low runoff coefficient, particularly due to the influence of the vegetation trapping most of the rainfall in localized tiny sub-catchments. This rainfall therefore soaks into the ground and part is absorbed by evapotranspiration to the vegetation. The GW 2014 report developed recharge model soil and runoff parameters (rainfall/PE zone 3 leads to recharge zone No's 8, 9,10 – (Table 16 in GW report) and with these inputs the GW model resulted in a value for mean annual recharge of approximately 300mm for the site (Figure 60 in GW 2014 report).

In addition, frequent shallow flooding over the low-lying area adds to the volume available to soak into the underlying soils. It is therefore concluded that the recorded increase in groundwater levels, over winter months, in the monitoring wells, within the site is highly influenced by the recharging from rainfall on the low-lying areas and surface flooding from the Ngarara Stream. The extensive peat layer absorbs this moisture (the CGW Geotechnical Report notes moisture content of 300 – 700% moisture (by weight) in the shallower peat) and creates an increase in the groundwater system after rainfall. This is consistent with the general findings on other sites in the area and with GWRC findings that groundwater level changes rapidly following rainfall and the available data indicates that shallow groundwater is hydraulically connected to the surface water streams (GWRC, 2014 & 2023).

An assessment of the minimum recorded groundwater levels within a zone of about 100m from the Ngarara Stream, compared against topographical survey levels of the stream water surface strongly indicates a direct interconnection of groundwater levels and stream levels during the summer months. This correlation is seen at groundwater monitoring sites P01, P05 & P011 The estimated average groundwater levels shown in Figure 7 also match the average Ngarara Stream levels. This is indicated by Table 3 below:

Location	GW level (Nov - Feb)	Stream water level recorded by survey
P01	6.07 – 6.13	Approx. 5.9
P05	4.54 – 4.59	Approx. 4.57
P011	4.34 – 4.54	4.51

Table 3 Groundwater levels relative to Ngarara Stream levels

The influence of the dry weather flow level in the Ngarara Stream on groundwater levels in the general vicinity of the Stream is important when assessing potential influences of the proposed development on the hydrological systems adjacent to the Ngarara Stream.

There is no reliable flow gauging records for the Ngarara Stream except for some data collected by GW and noted in Section 4.2.3 of their 2014 report. The report states that limited flow gauging on the Ngarara Stream indicate that the flow upstream of the Waimeha Stream confluence ranges from 30l/s to 400l/s. The report goes on to state that due to the ephemeral nature of the runoff to this stream (with significant contribution from urban stormwater), it is assumed that the lower figure represents the likely magnitude of baseflow discharge from shallow groundwater during summer conditions. We note that the development site is upstream of the majority of urban development and the flow rate of the Ngarara Stream, through the development site is therefore not greatly influenced by existing urban development.

Measurement of Ngarara Stream flow has not been attempted as part of preparation of the application for the Fast track planning approval, and nor is it considered necessary or reasonable to collect such data. The Ngarara Stream flow is relatively small, is highly influenced by soil and groundwater conditions, which are not going to change upstream of the site and the proposed works within the site are designed to provide improvement to the stream. However, flow conditions observed during the preparation of the application has included some survey work and site photographs. A site survey of an existing 1.2m culvert on the Ngarara Stream carried out in June 2024 included the photograph below, on which approximate dimensions have been added and this is shown in Figure 11 below:

Figure 11 1.2m dia. Culvert on Ngarara Stream

The dimensions shown on Figure 11 above indicate a flow depth of approximately 0.1 – 0.15m. The flow exiting the culvert is at critical flow conditions. A depth of flow of 0.1m in a 1.2m dia. culvert at critical flow conditions will have a flow rate of 36l/s. On this basis, it is reasonable to conclude that the Ngarara Stream has a flow rate of 30 – 50l/s at time of the survey (June 2024). This estimate of flow correlates with flow gauging carried out by GW as part of their 2014 report referred to above where they gauged flows of 30 – 400l/s, with the higher flows influenced by rainfall.

A further site photograph record of Ngarara Stream at the upstream section of the stream where it passes beneath the Expressway is shown in Figure 12 below:


Figure 12 Ngarara Stream at the northeastern corner of the site

Figure 12 shows that at the time of the photograph (June 2024) the flow in the stream was low as evidenced by no clear, distinguishable flow path through the streambed plant growth.

Thus, it is concluded that the scale and nature of the flow in Ngarara Stream is not significant in terms of overall hydrological issues within the site, when compared with the wider groundwater pattern in the central and eastern low-lying areas of the site.

It is likely that the relatively short term fluctuations in the stream water level during rainfall events are minor in scale compared to the magnitude of the volume of water collected on the surface and thus it is the volume and frequency of the surface water infiltration that is a much stronger influence on groundwater behaviour over the winter months, when rainfall is greater and more frequent.

To gain some judgement of water level changes in the Ngarara Stream for different flow conditions, the existing reach of the Ngarara Stream between points B to C, shown in Figure 16, has a gradient of approximately 1 in 2000. The stream cross section has a water surface width of approximately 2.6m at normal flows (30 – 50l/s.). At 50l/s the stream will have a depth of approximately 0.2m and a velocity of 0.1m/s. At 100l/s flow the depth will be 0.1m greater and the velocity will increase to 0.12m/s. At 200l/s flow the depth will be 0.4m. Thus, the changes in water depth for increasing flows in small rainfall events are in the 100 – 200mm range.

The shallow unconfined aquifer is recharged by direct infiltration of the rainfall and run-off from the Tararua Ranges and groundwater flows in a generally north-westerly direction towards the coast as shown in Figure 6.

An assessment of existing surface flooding and the expected floodwater behaviour on, and beyond, the site as a result of the proposed development has been assessed by Awa Consultants and is presented in their report Flood Hazard Assessment of Effects, dated March 2026. As part of their assessment, Awa modelled the estimated extent of existing surface water flooding in the 2030 and 2130 2-year events. They concluded flooding in this event would extend across much of the low-lying area, with depth ranging from 0.05 – 0.5m, as indicated by Figure 13 below.

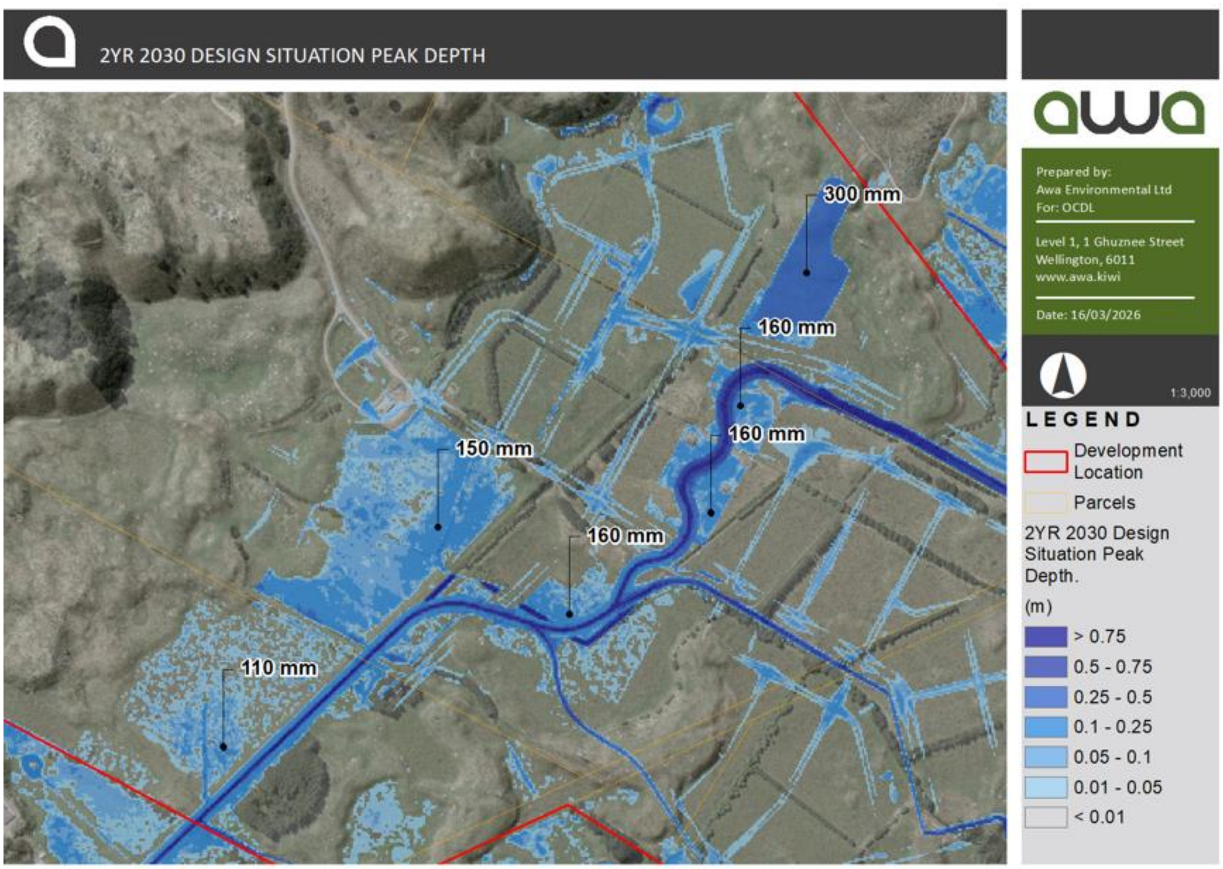

Figure 13 Flooding Extent in a 2-year Design Event

The existing flooding area in the 2030 2-year event, within the area containing wetlands W2.1, W2.2 & W2.3 has a total area of approximately 45,000m^2 with a weighted average depth of approximately 0.13m. This equates to a volume of almost 6,000m^3. The majority of this volume will soak into the underlying topsoil and peat soils and thus recharge the groundwater system in this zone. A similar scale of recharge occurs in the zone of the proposed Ngarara Stream re-alignment where existing average ponding of 0.1m occurs in the pre-developed 2030 2-year event. Some of the ponded water will drain back into Ngarara Stream and modelling has confirmed that it will take approximately 24 hours to drain a 2030 2-year event from the site and approximately 40 hours to drain a 10-year event. The 2130 2-year event is estimated to be similar to an existing (2030) 5-year event, and a 2130 10-year event is similar to an existing (2030) 25-year event.

The western side of the site, in the vicinity of the Te Harakeke Swamp, has a very different hydrogeology. The site within the development footprint does not contain peat (however peat has been observed within the wetland/swamp footprint), groundwater monitoring indicates the groundwater is typically at around RL2.7m – 2.9m as shown by Table 2 and the dune sands that form the main soil strata in this zone are free draining. There are no open water courses draining to the Te Harakeke Swamp from within the development site and little indication of surface water flow on the existing farm surface. The topsoil thickness in the western zone is also very thin in many areas and thus percolation of the majority of rainfall on this zone would soak into the well-draining soils below. The deep groundwater system in the part of the site, relative to ground level, also results in no groundwater fed watercourse on this part of the site.

6 WETLAND AREAS

As described in the Ecology Report prepared by RMA Ecology Ltd, the wetlands within the site include the Te Harakeke Swamp in the west, W3, W4 & W5 in the central southern portion of the site, W9 & 10 in the central portion of the site, W11 in the northern low-lying area and W2.1, W2.2, W2.3, W2.4, W6, W13, W14, W17, W16, W18 & W19 in the southern and eastern low-lying areas of the site. These are shown in Figure 14 below.

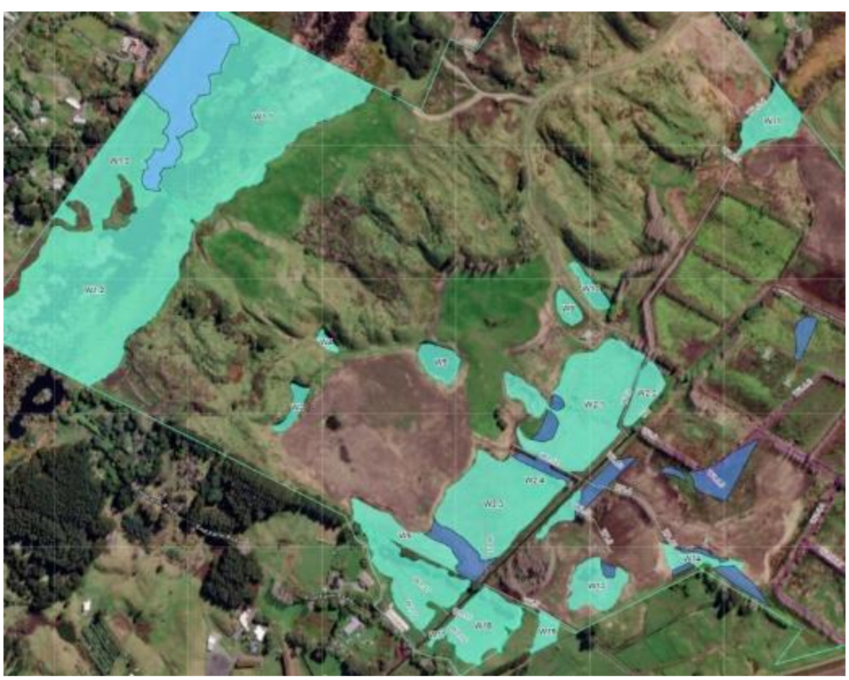

Figure 14 Wetland Areas

We note that W3, W5, W9 & W10 are proposed to be removed, and additional wetland areas will be formed, as described in the RMA Ecology Report.

The hydrology influencing these wetlands is described in Table 4 below.

Identifier	General ground level	water body present	Peat presence	Groundwater level (Figure 6 & monitoring results)	Water course source	Comment
W1.1	RL3.5 – 3.1	Yes	No	RL2.7 – 2.8	Yes, from the north, not associated with the development site	
W1.2	RL3.3 – 3.0	Yes	No	RL2.7 – 2.8	Yes, from the north, not associated with the development site	
W4	RL4.0	Yes		Untested – estimated RL3.5	No	Suspected perched water table.
W2.1, W2.2	RL5.1 – 5.0	No	Yes – Depth of 1 – 2m	RL5.1 – 4.5	Yes, small inflow from the north – may dry up in summer months. Ngarara Stream adjacent.	Small water course through the wetland. Runoff from the west.
W2.3, W2.4	RL5.2 – 5.0	No	Yes – Depth of 1 – 1.5m	RL4.8 – 4.3	Yes, small inflow from the north – may dry up in summer months. Ngarara Stream adjacent.	Runoff from the west.
W6	RL5.1 – 5.0	No	Yes – Depth of 0.5 – 1m	RL4.7 – 4.2	No	Runoff from the northwest.
W11	RL5.4 – 5.2	Yes	Yes – Depth of 1 – 2.5m	RL5.0 – 4.7	No	Drains to the north, very small overflow to the south.
W13	RL6.5	Yes	No	RL5.0 – 4.7	No	
W14	RL5.8 – 5.5	Yes	No	RL5.5 – 5.0	Yes, small flow from local water course.	
W16	RL4.9	Yes	Not tested	Approx. RL4.8 – 4.3	No	
W18	RL5.1 – 4.8	No	Not tested	Approx. RL4.8 – 4.3	No	

Table 4 Wetland Hydrological Characteristics

As discussed in Section 5, there is a strong correlation between the groundwater system, the presence of peat and the level of the Ngarara Stream and associated side drains.

7 PROPOSED DEVELOPMENT ON HYDROLOGICAL MATTERS

The proposed development can also be categorized into three distinct zones, with respect to hydrogeological conditions on the site:

- The western zone, containing the Te Harakeke Swamp and the western facing dune systems;
- The western side of the central zone is several metres above the low-lying central and eastern zone (i.e. existing natural level of RL 8 – RL15 and is unaffected by existing flooding); and
- The low-lying central and eastern zone that has to be raised above existing flooding where development is proposed. This area will also contain large areas of existing wetland and the re-aligned Ngarara Stream.

These are shown by Figure 15 below:

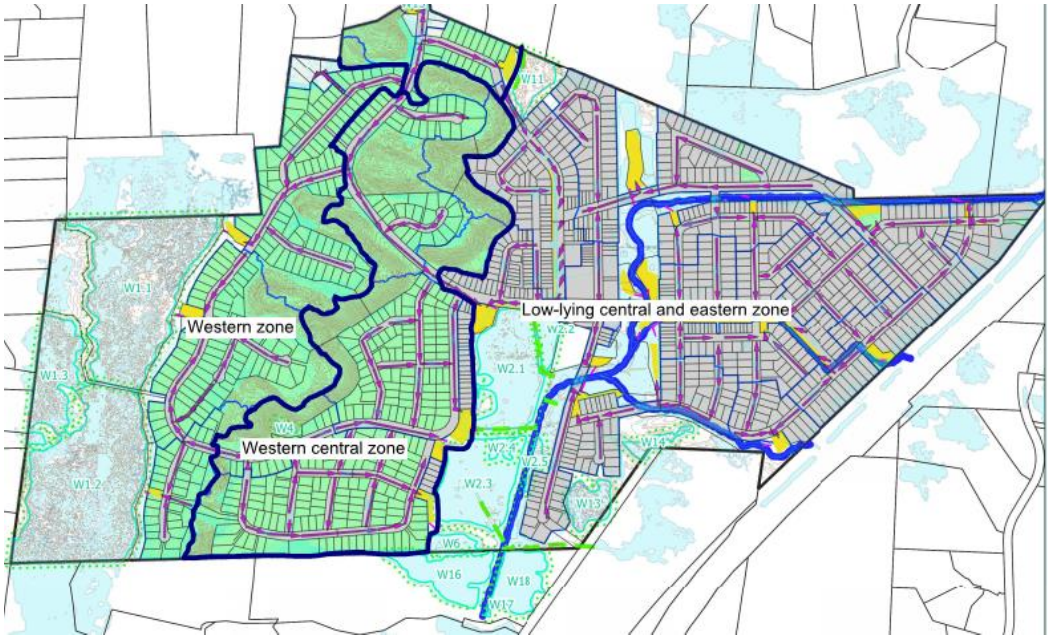

Figure 15 Hydrological Zones

Flood protection for the low-lying central and eastern zone of the site is a pivotal element of the development. As shown on page 3, this existing zone is flooded in only modest events and is predicted to flood over most of this zone in large events. Flood protection for the development proposal will be achieved by raising the land above the predicted future 100-year flood event and a detailed assessment of this is set out in the Flood Hazard Assessment of Effects Report prepared by Awa Consultants.

The flood mitigation solution incorporates a downstream flow control structure (dual culvert and weir structure) that will manage peak stormwater flows from the site in a manner that does not trigger an increase in peak flows beyond the site and achieves greater internal flood storage within the site in both volume and increased flood water level, to off-set the effects of displacement of existing flood water storage from the proposed bulk earthworks fill in parts of the existing flood storage area.

The operation of the downstream outlet control structure, in conjunction with the raised bed level of the reformed Ngarara Stream and some associated side drains will result in an increase in the water surface level of flood ponding within the site during rainfall events. However, the land will be raised above these increased levels where development is to occur, to achieve the required protection from flooding for the proposed new urban area.

Within the low-lying central and eastern zone, the area proposed for urban development will be earthworked to remove the existing peat, replace the removed peat with compacted soil and raise the development surface to the required level above estimated future flood levels. As described in the earthworks section of the Engineering & Infrastructure Report prepared by Landlink, it is estimated that approximately 475,000m^3 of peat will be removed from within the development footprint within the low-lying central and eastern portions of the site and replaced with compacted fill in order to create suitable building platforms for residential development. In addition, raising the land in the existing flood prone zone to ensure the development footprint is not at risk of flooding will require the placement of approximately 300,000m^3 of filling in this zone. We note that the excavation of the peat material within the development footprint will require excavation below the groundwater system and replacement with compacted fill material within the groundwater system.

As described in previous sections, the Ngarara Stream will be reformed and a section of it will be realigned in the central part of the site (reach C – D) and existing farm drains will be altered to fit with the proposed development pattern. An overview of the Stream location within the site is shown in Figure 16 below:

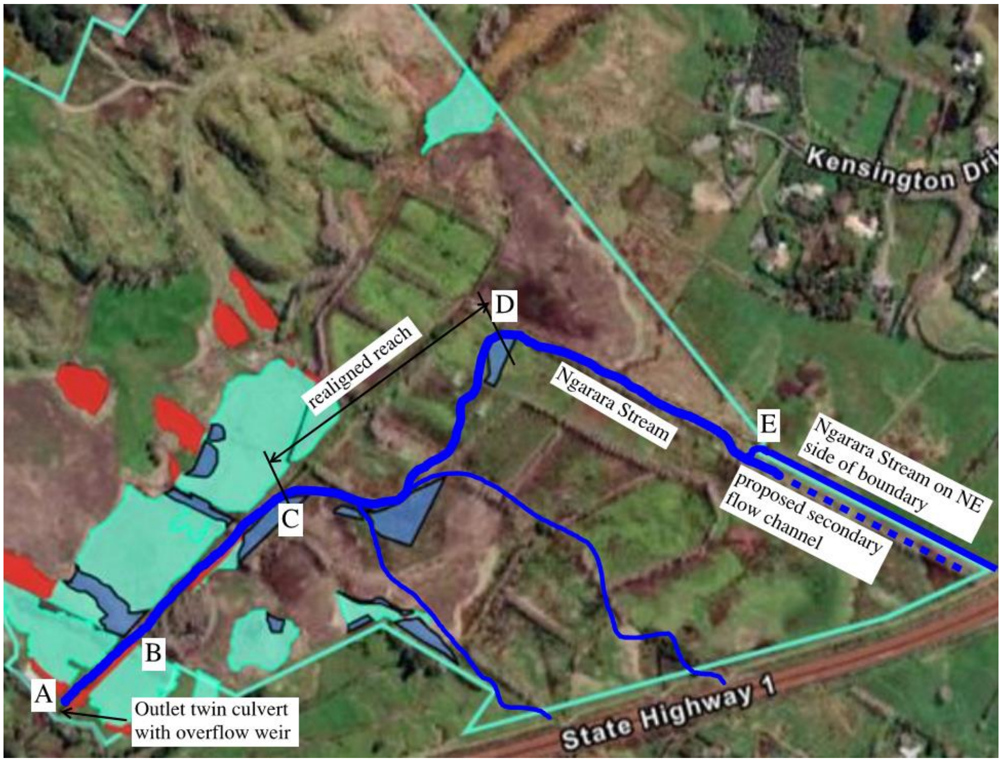

Figure 16 Ngarara Stream Realignment

The new Stream cross section has been designed to create the opportunity for habitat diversity, "side spill" flow in minor rainfall events and to achieve a more natural stream pattern. The typical cross section of the new stream is shown below:

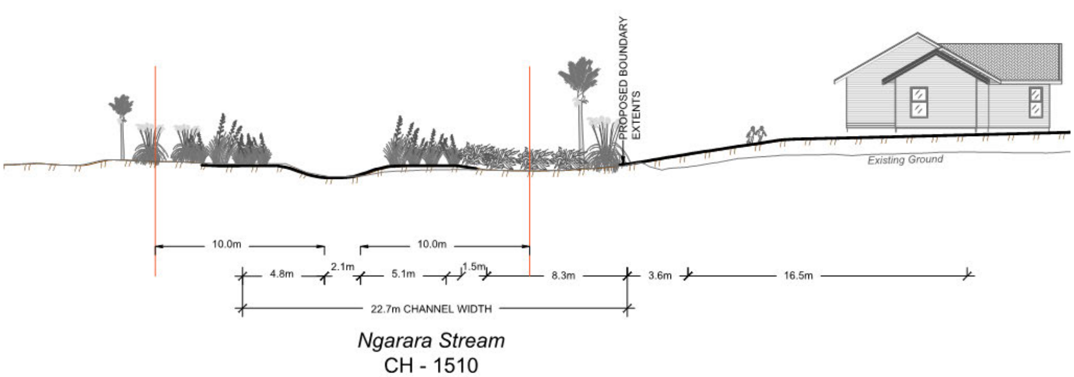

Figure 17 Typical Stream Channel Cross Section Downstream of Realigned Reach

The invert of the Ngarara Stream will also be higher than the existing invert. This is to increase the natural water levels through the wetland areas adjacent to the Ngarara Stream. The Stream invert level will be similar to existing invert levels at the top of the Stream where it enters the site (E). At the exit of the Stream where the twin culvert flow control structure will be (point A on Figure 16), the Stream invert will be RL4.40. This compares with an existing level of RL4.04 on the existing culvert immediately downstream of the outlet control structure.

At point B, at the southern boundary of the WNDL land, the new stream invert will be at RL4.47 compared to an existing invert level of RL3.73m, but we note the existing water surface at this point was RL4.51 at the time of survey. We therefore conclude there is a dip in the stream invert at this point because the invert of the existing Stream at point A is RL4.05, with a water surface of RL4.19 at time of survey. We anticipate a water depth of approximately 0.3m in the proposed new formed Stream at point B, which equates to RL4.8. Therefore, at point B we anticipate the normal dry weather water level will be approximately 0.3m higher than existing water level at this point.

At point C the proposed new Stream invert is RL4.62, which compares to an existing Stream invert at this point of RL4.22. The new stream will therefore be 0.4m higher at this point. The existing water depth in the Stream at this point was 0.35m at time of survey and we would expect a similar depth (0.3 – 0.35) in the new Stream channel.

Our assessment of the expected water depths at points B and C is not based on pure uninterrupted flow determined solely by hydraulics. Pure hydraulics would estimate lower water depths. However, as discussed in the Ecological Restoration Management Plan, the ecologist team are intending to include small, low level flow weirs, stumps, logs and other semi buried structures into the stream bed for habitat diversity. This will create a small increase in head loss where they are installed. The actual hydraulic grade is very flat (existing grade is approximately 0.05%) and stretches of stream that are not affected by these structures will have water depths of 0.1 – 0.15m, However, where it is desirable to have greater depths, such as at B & C above, instream structures will be used to create small pools and thus control the normal dry weather water surface where there are ecological advantages to do so.

At point D the proposed new Stream invert is RL4.87, which compares to an existing Stream invert at this point of approximately RL5.0. The new Stream will therefore be relatively similar in level to the existing Stream at this point.

The new Stream invert will have a generally consistent gradient from the top (point E) to the start of the diversion (point D) with a grade of 0.21% (1 in 480), which is generally consistent with the existing stream invert gradient.

Over the proposed realigned reach between point D and point C the gradient has been designed as 0.05% (1 in 2,000) to gain as much increase in stream water level at point C as is reasonably possible whilst retaining appropriate hydraulic flow. As described above, this achieves a rise in water level at point C of 0.4m. Even though this design invert gradient is minimal, some changes in velocity can be achieved by refining the invert, at detailed design, with some lengths of pools to gain some “run effect” on the remainder. The length of the diversion is approximately 500m with a change of grade over this length of 0.25m. If over the 500m length, 4 “pool” sections of approximately 50m long are formed (subject to confirmation from an ecological design perspective) and potentially 6 sections of approximately 30m long are formed at the design average 0.05% gradient, the remainder of the realigned portion could be formed at a grade of approximately 1 in 700, which is steeper than the average existing gradient between point D and point C. We envisage this refinement in invert levels, aimed at achieving habitat variability, to occur at the detailed design phase, with input from the ecologist so that a good balance between stream hydraulics and ecological enhancement can be achieved.

The design gradient of the proposed reconstructed Ngarara Stream from point C to point A is 0.05% to maximise an achievable increase in water surface level. We note that the existing water surface gradient from point C to point B is very flat with a change in water surface level of only 0.06m over a distance of approximately 370m. This equates to a water surface gradient of 1 in 6,166 (0.02%). Therefore, the new Stream section in this reach will improve velocity variability in this reach.

The objective of achieving a raised water surface level in Ngarara Stream is to maximise groundwater levels, and hence increase soil moisture adjacent to the Stream, along the corridor. This is in order to enhance adjacent wetland restoration, as described in the RMA Ecology Report.

There is a permanent flowing farm drain W1.2 which runs north of point C, between wetlands W2.1 & W2.2. The water level in this drain will also be raised above existing levels because of the backwater effect from the junction with Ngarara Stream at point C. It is also proposed to raise the water level in this drain further, with the use of low, weir type structures created with buried logs and rocks so that maximum soil moisture for the enhanced wetlands in this zone is achieved. This is discussed in the RMA Ecology Report.

The above detail on the proposed design invert and water surface levels of the reconstructed and realigned Ngarara Stream has a direct impact on the hydrogeology of the zone adjacent to the Stream. Wetlands 2.1, 2.2 and 2.3 are all influenced by the water surface level of the Ngarara Stream, as is the level of the groundwater system in this zone in periods excluding prolonged rainfall or large flood events. In addition, the increase in the design water surface level in drain W1.2 will also contribute to this change. The design objective is to maximise soil moisture within the wetlands. The proposed design levels of the reconstructed Ngarara Stream will increase groundwater levels in these wetland zones by 0.3 - 0.4m.

The design invert levels of the reconstructed Ngarara Stream place the new invert within the existing peat layer along the majority of the Stream length. This is shown on long section drawings 2911-E1-430 – 435. It is not proposed to excavate the remainder of the peat below the design invert as it is advantageous to retain peat material below the invert. However, in order to achieve improved bed substrate in the reconstructed stream, 0.15 – 0.2m of bed material below the design invert will be removed and replaced with an uncompacted graded river metal backfill material. The velocities in the reconstructed stream are generally less than 0.5m/s and the backfill material will have a grading of 50mm down to sand, but with a relatively low % of sand because sand will be mobilized without shielding from the larger pebble and gravel material.

As described in the previous section, the downstream outlet control structure will consist of a 2m wide twin * 0.8m high (flow depth but actual concrete base will be buried) box culvert with a 6m wide higher extreme event overflow weir. In most storm events the flow will be passed by the twin box culvert system. In extreme events the water will pond behind the culverts to a level above the top of the culverts and, if there is sufficient inflow, it will rise to the overflow weir level and discharge over that structure. The preliminary design for the development, and the associated Awa Flood modelling analysis has used a weir level of RL6.3 (VD2016). At the design 100-year event with allowance for climate change, it is estimated that $4m^3/s$ will pass through each of the twin culvert system and $1m^3/s$ will pass over the weir. The depth of flow over the weir in this event is estimated to be 0.2m. As discussed in previous sections, this structure, in conjunction with the new Stream cross-section, is designed to cause increased water over the wetland areas for ecological benefit and flood management.

The proposed works will also involve the enhancement of existing wetlands that are not affected by the development footprint and the creation of new wetland areas, as described in the Ecology Report prepared by RMA Ecology Ltd. The proposed ecological mitigation works includes the creation of hydrologically variable wetlands as described in the Ecology Report. This will, in some places require excavation of existing ground, in the area of these proposed new wetlands down to a similar level as adjacent wetlands and incorporating consideration of the groundwater level. As discussed in Section 4 above dealing with groundwater, existing groundwater varies approximately 0.5m between winter and summer. However, as also described in Section 4, the groundwater levels in the zone along Ngarara Stream are strongly influenced by the surface water level of the Stream. The proposed reconstruction of Ngarara Stream will result in a rise of approximately 0.3 - 0.4m in Stream water level and this will assist in maximizing soil moisture in the new wetlands. On-going monitoring of groundwater levels will improve judgement on the appropriate groundwater level to incorporate.

Stormwater runoff collected from the developed areas will be managed as described in the Stormwater Management Plan (SMP) prepared by Landlink Consultants. The stormwater management design is structured around a series of functional catchments, supported by lot-level controls, which together form the overall runoff management framework. These catchments are shown in Figure 18.

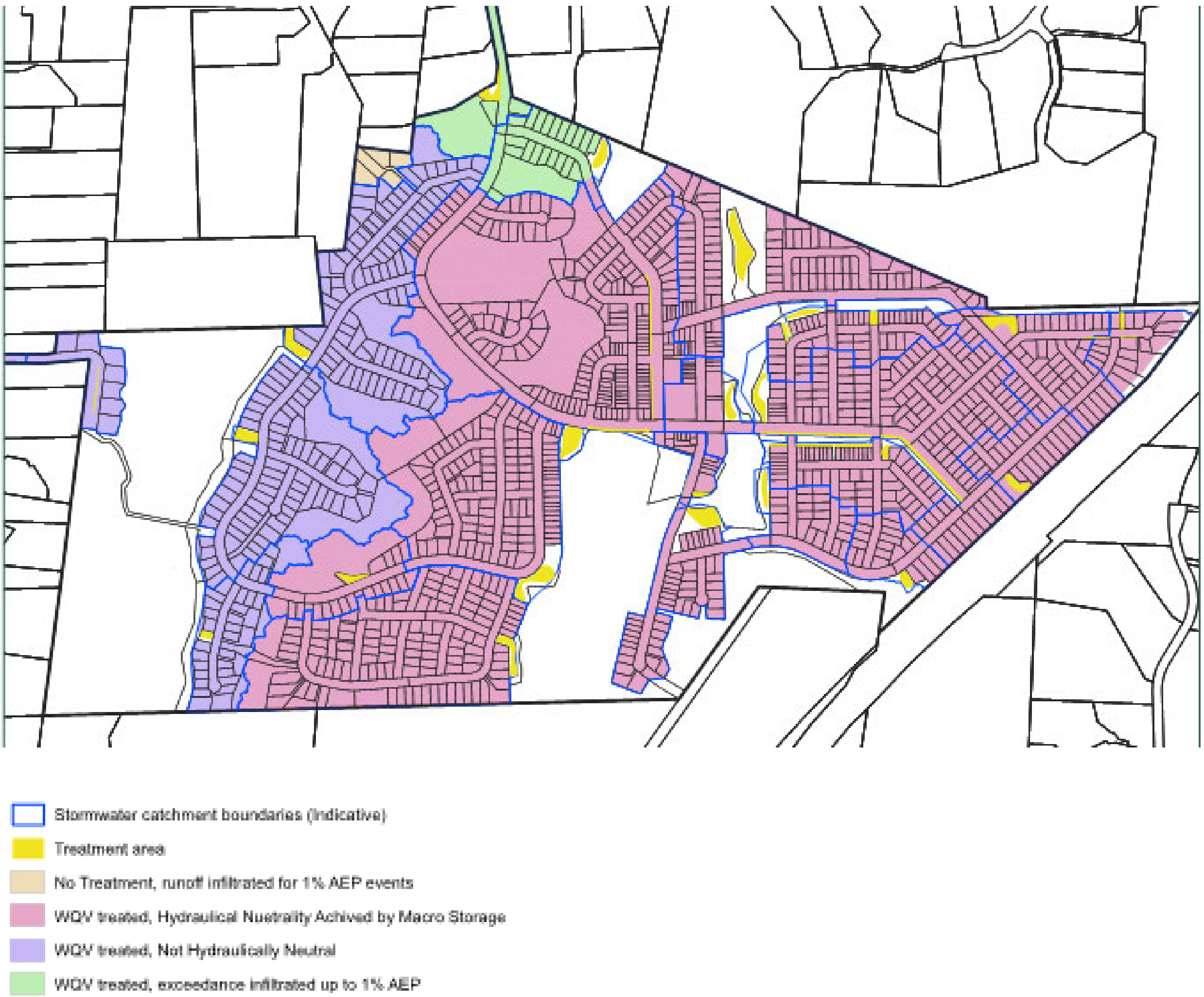

Figure 18 Catchment Types

The site is divided into a series of functional catchments reflecting the stormwater management strategy. Bioretention devices across the development are conceptually sized to treat approximately 27 mm of runoff, representing around one-third of the 50% AEP 24-hour design storm. Flows in excess of this treatment volume bypass the treatment media and are conveyed via defined overland and network flow paths to downstream wetland and storage systems, primarily during larger rainfall events. Increased flows to wetlands are intentional and support ecological function. The proposed stormwater management approach provides for diffuse, distributed recharge of treated flows across the low-lying areas of the site, particularly along wetland margins. This is consistent with the shallow groundwater recharge processes.

In addition to the catchment-based approach, lot-level stormwater discharge requirements are defined in the SMP and are applied across the site depending on location and available discharge pathways.

These are summarised as follows:

- Direct Discharge Lots: Runoff may discharge directly to the public stormwater network where downstream wetlands and treatment systems provide attenuation and treatment, achieving hydraulic neutrality at a catchment scale. No on-lot attenuation is required.
- Attenuated / Treated Discharge Lots: Runoff is required to be managed at the lot level to moderate peak flows and mimic greenfield conditions. This is typically achieved through detention tanks with restricted outlets or soakage systems.
- Ground Disposal Lots: Runoff is required to be discharged to ground at the lot level, generally where no secondary flow path or network connection is available. Systems are designed to accommodate runoff up to the 1% AEP event.

The spatial distribution of these lot-level stormwater control requirements is shown in Figure 19.

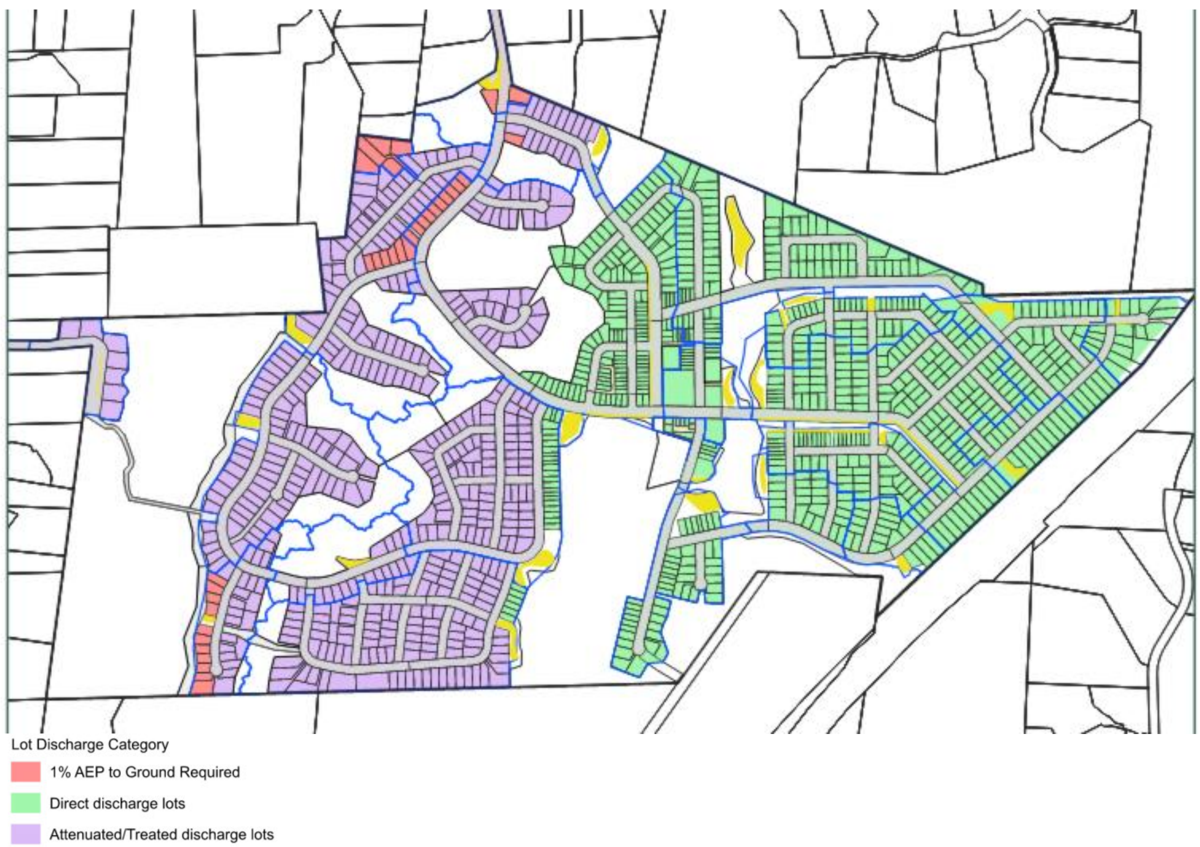

Figure 19 Lot-Level Stormwater Control Classification

<u>Eastern Catchments (Pink - Figure 18):</u>

Runoff is treated via bioretention devices and directed to wetlands and macro-storage areas within the central and eastern low-lying parts of the site, including via contour soakage drains that convey flow toward these receiving environments. Discharge is controlled via downstream structures to manage peak flows, achieving hydraulic neutrality at a catchment scale. Within these catchments, a significant proportion of lots operate as Direct Discharge Lots, reflecting the availability of downstream treatment and attenuation within the public stormwater system. In transitional and higher areas, Attenuated / Treated Discharge Lots are applied to moderate flows prior to discharge to the network.

Western Catchments (Purple – Figure 18):

Runoff is treated via bioretention devices and discharged to wetland systems without downstream flow control. These areas are not strictly hydraulically neutral and instead rely on wetland storage and attenuation within the receiving environment. At the device level, low flows are typically discharged to ground via soakage, with higher flows bypassing to surface conveyance systems, including contour drains that direct flow toward open space land upstream of Te Harakeke Swamp. Lots within these catchments are predominantly managed as Attenuated / Treated Discharge Lots, with on-lot controls used to mimic greenfield runoff conditions prior to discharge.

Local Infiltration Areas (Green – Figure 18):

Runoff is treated and managed via local infiltration systems, including soakage through bioretention devices and ground infiltration. Exceedance flows are contained within the site. These areas generally correspond to Ground Disposal Lots, where discharge to ground is required due to the absence of secondary flow paths or network connections.

Private Treatment Areas (Yellow – Figure 18):

Roof and lot-level runoff is managed through private systems, including soakage and rainwater tanks where applicable. These systems are not part of the public stormwater network but contribute to overall runoff management and reduction in downstream discharge volumes.

Stormwater management at the lot scale within the Kāpiti area commonly incorporates roof water re-use tanks for water demand reduction. These systems reduce potable water demand but are not relied upon as primary stormwater attenuation devices within the SMP framework.

Within the low-lying central and eastern portions of the site, ground conditions are influenced by raised finished levels associated with engineered fill and shallow groundwater. These conditions limit the suitability and effectiveness of soakage systems. As a result, roof runoff from lots in these areas is generally directed to re-use storage tanks only, with overflow discharged directly to the public stormwater network and associated treatment systems. This aligns with the Direct Discharge Lot approach adopted in these catchments.

In other parts of the development, where ground conditions are more suitable, lot-level controls such as soakage systems or detention tanks are implemented to attenuate runoff and mimic greenfield discharge characteristics prior to connection to the public stormwater network.

Runoff from lots and roads is conveyed via a combination of piped networks and surface systems, including swales and contour drains, to bioretention treatment devices and receiving wetland and storage areas, as described in the SMP. The proposed development alters existing surface flow patterns, and a revised sub-catchment layout has been developed to support the stormwater management design and sizing of infrastructure. The updated surface water flow pattern is shown in Figure 20.

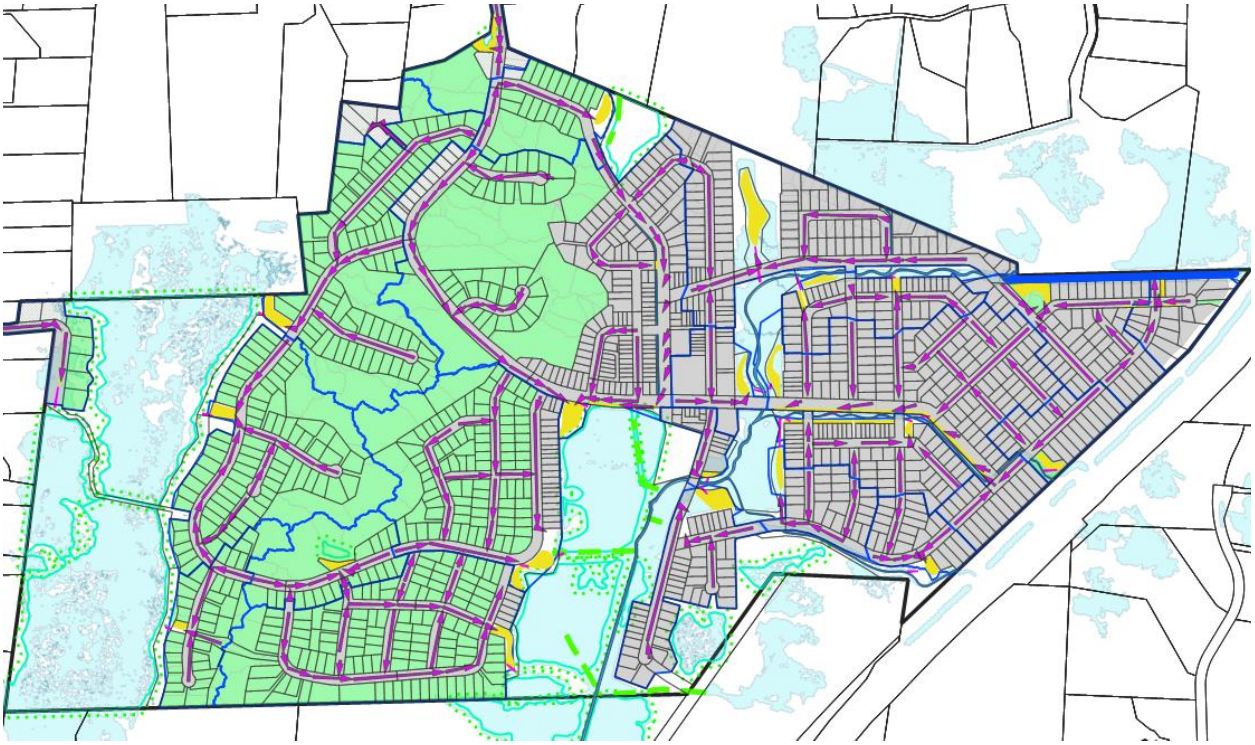

Figure 20 Surface Water Catchments

The modelling carried out for the stormwater assessment described in the SMP estimates a runoff of approximately 0.37 $m^3/s/ha$ for a 10% AEP event.

8 CONCEPTUAL MODEL

Based on the information outlined above, a basic conceptual model of the site hydrology has been developed and is summarized below. The site is very large, and this model assessment focuses on the large low-lying central/eastern catchment (Ngarara Stream) and the western catchment (Te Harakeke Swamp).

- The majority of the wetlands are located in the central/eastern low-lying area of the site;
- The majority of the existing wetlands in this zone will be enhanced by specific stormwater management solutions to enhance soil moisture opportunities;
- The proposed additional new wetlands to be created in the central/eastern low-lying zone will also have specific stormwater management solutions to enhance soil moisture opportunities;
- Existing peat soils within the undeveloped areas will not be disturbed, unless associated with wetland enhancement;
- Removal of peat beneath the development zone within the central/eastern low-lying portion of the site will reduce the existing groundwater storage volume. However, the groundwater is interconnected with the system in the $20m^+$ deep sands below and therefore any change will be temporary as the new compacted fill material will recharge quickly;
- As noted from groundwater monitoring in areas of minimal peat presence in the central/eastern low-lying area, the localized groundwater system is inter-related to the water level in Ngarara Stream. The increased water level in the Ngarara Stream after it is reconstructed will raise the localized groundwater level over a wide area when the groundwater system is below ground level;

- The creation of new wetland areas will involve the lowering of the existing surface to ensure the new wetland areas are similar to adjacent wetlands and within the underlying groundwater zone. These new lowered areas will provide additional water storage in times of rainfall;
- The proposed downstream outlet control structure will increase the occurrence of shallow flooding over the low-lying central/eastern zone to provide additional water for soil moisture retention within the wetland areas in events greater than the 50% AEP event;
- The proposed stormwater management elements includes stormwater attenuation, treatment attenuation, and diffuse disposal from the stormwater treatment basins. The low-lying central and eastern area will not include roof water runoff to soakage systems, and the runoff will be discharged to the bioretention basins. The bioretention basins are designed to deal with 1/3 of the runoff from a 50%AEP (will treat without by-pass for rainfall of up to approximately 27mm). The estimated runoff from a 1Ha area of developed surface, directed to a bioretention basin is 205m^3. The basin will contain 57 m^3 of this volume, with the remaining 148 m^3 discharged to ground via direct soakage beneath the basin and via an infiltration trench beneath the basin connected to a perforated discharge pipe conveying treated flows from the basin. The pipe and infiltration trench will generally follow the wetland margins, as indicated on Drawing SW480. The 57m^3 in the basin will also be discharged via soakage after the rainfall event and so this will also return to the groundwater system. The capacity of the bioretention devices are large compared to other developments and are capable of dealing with up to 27mm of rainfall without bypassing. This capacity enables a high proportion of flows from rainfall events to be managed by the device, with a high proportion of treated flow returned to the ground via soakage, as indicated in Table 5;
- The diffuse release of overflow from the bioretention basin will be achieved via a contour-aligned perforated discharge pipe connected to a perforated infiltration trench extending approximately 20 m along the wetland margin. This arrangement is intended to distribute flows across the low-lying vegetated wetland surface within the central and eastern zones, avoiding concentration into defined flow paths. This discharge flow will only be a portion of the inflow to the basins due to the larger portion discharged directly to subsurface soils via direct soakage from the base of the basin. This discharge flow from the basins on the western side of the central wetland zone will have to travel up to 170m to reach a Ngarara Stream, which is estimated to take over an hour due to the low velocity. This will provide sufficient time for much of the flow to soak into the surface soils;
- The by-pass drain arrangement at the bioretention systems will activate once the basin is full and this discharge (up to 411m^3/Ha in a 50% AEP) will also typically flow across a wide flat vegetated area before reaching a stream system. Thus, it is expected that bypass operation will be infrequent and a proportion of this flow will soak into the ground before reaching a water course;
- In rainfall events approaching the 50% AEP the Ngarara Stream will trigger mass ponding over the entire low-lying central and eastern area (undeveloped area) and thus this ponding will provide a source for recharging the groundwater system via soakage. Therefore, in this case there is not a significant loss of runoff that might otherwise “starve” the groundwater system post development;
- Rainfall absorbed into ground will also add to recharge of the groundwater system;
- These combined elements incorporated into the proposed works will improve opportunity for the groundwater system and surface drainage system to maintain soil moisture for wetland enhancement;
- In the western zone there is no peat within the development footprint, the soils are predominantly dune sand and stormwater runoff will be managed to deal with pretreatment prior to disposal to diffuse outlets that will drain overland to the Te Harakeke Swamp.

Stormwater neutrality is achieved in this zone with the combined use of on-lot detention/soak pits and bioretention devices for runoff from roads and remaining lot areas.

9 ASSESSMENT OF EFFECTS

Based on the conceptual understanding of the above matters, the key risks to the wetlands, associated with the proposed earthworks and alteration of existing runoff patterns are:

- Removal of the peat in the developed areas resulting in reduced water storage within the peat;
- Reduced infiltration to groundwater resulting from increased impervious surfaces/land-use, which could result in lower groundwater levels;
- Reduced local run-off into the low-lying wetland areas due to the construction of stormwater control infrastructure.

These risks are assessed below.

As discussed above, the proposal incorporates several elements to deal with these risks. A key element is potential changes to the groundwater system that could potentially create adverse effects for the wetlands in the low-lying central/eastern portion of the site. The assessment of groundwater changes is based on the following assumptions:

- an expected annual rainfall of 1350mm/yr (GWRC rainfall data from Waikanae Water Treatment Plant rainfall gauge) and associated values for existing evapotranspiration, soakage and runoff are set out in Table 5;
- performance criteria for roof water tanks, soak pits and bioretention devices are set out in Table 5. These have been assessed using the proposed volume, estimated distribution of rainfall, the estimated frequency of occurrence of rainfall bands and the nature of operation of the devices. The estimated proportion of flow discharged to these devices, on an annual basis, that can be handled and discharged to ground soakage systems is higher than some design criteria used for other sites. This is because the proposed devices are larger than some other sites (on a capacity per Ha catchment basis);
- The bioretention devices are estimated to be able to treat and discharge to ground soakage the majority of water discharged to them (on an annual volume basis) without the bypass operating except for rainfall events larger than 27mm of rainfall;
- Stormwater runoff from lots within the low-lying central and eastern catchments is generally directed to the public stormwater system (including swales, drains and bioretention systems), as these areas are formed by raised engineered fill overlying shallow groundwater, which limits the effectiveness and suitability of soakage systems. Roof runoff is typically routed via water re-use tanks for water demand reduction, with excess roof runoff discharged directly to the receiving stormwater network (swales, drains and bioretention systems). On-lot detention tanks will provide a source of water for toilet flushing and other re-use. This solution has been adopted in order to optimise discharge near the wetland areas;
- The communal bioretention devices are generally located on the perimeter of low-lying central and eastern zone and through the middle separated from the Ngarara Stream realigned section. Typical depths to groundwater are shown in Table 2 and these depths are from existing surface level. The developed surface is higher than existing ground levels and so the depth to groundwater at the basins will generally be greater than that shown in Table 2. As discussed in Section 8, discharge vis soakage from beneath the basin treatment zone (based on a soakage rate of 50mm/hr) will account for a high proportion of basin discharge. This will result in recharge of surface water runoff to the groundwater system and reduce direct loss to surface water systems.

- In the Central Western Zone and the Western Zone, lot controls include roof runoff directed to on-lot detention tanks (in addition to water reuse volumes) and/or soak pits. Roof runoff is therefore managed separately and does not discharge to the bioretention system. Bioretention devices within these catchments treat runoff from roads and remaining non-roof impervious areas. These devices are sized with sufficient capacity to retain and discharge a high proportion of inflows to ground via infiltration. Collectively, these measures are intended to achieve stormwater neutrality at a catchment scale, as summarised in Table 6;
- The downstream control system and reconstructed Ngarara Stream bed will raise the water level in the Ngarara Stream, and associate side drains by approximately 0.3 - 0.4m. These combined effects will trigger mass ponding on the flat low-lying wetland areas in rainfall events of 50% AEP and greater. This will increase the scale of surface ponding on the low-lying wetland areas from existing ponding and the frequency of this ponding. This will increase the frequency of groundwater recharge from surface ponding. It is expected that soakage into the underlying soils, will occur during periods of ponding over extensive areas, at the rate of 40mm/d over a 2-day period (some ponding will last longer than 2 days but there will be a decay in the soakage rate in a longer period). It is also expected that the raised stream channel and control system will increase the occurrence of mass ponding on the low-lying area by an average of 2 events per year over existing events. We consider this assumption is conservative, but a precautionary approach has been taken in the assessment.

A mass balance estimate of hydrological inputs for the three distinct areas of the site, and the results are set out in Table 5 and 6. The three zones are shown by Figure 21 below:

Figure 21 Hydrological Zones

The area labeled Western Side Central Zone drains to the bioretention basins on the eastern side of the zone. These basins are discharged to ground with overflow towards the low-lying wetland areas. There is no peat in the Western Side Central Zone, and the groundwater system is well below the surface in this zone. There is also only one small wetland (W4), which is considered to have a localised perched water table associated with it. The Western Zone drains towards Te Harakeke Swamp.

Mass Balance Assessment

Existing Situation - rural land use

Annual rainfall =	1,350	mm
Total volume per Ha	13,500	m3/yr

Existing hydrological distribution

Component	Depth (mm/yr)	% rainfall	annual volume/Ha (m3)
evapotranspiration	500	37%	5,000
Infiltration / groundwater recharge	700	52%	7,000
Surface runoff	150	11%	1,500
Total	1350	100%	13,500

Existing runoff depth = 135 mm/yr

Proposed Development on per Ha basis

Surface Type	**Area (m2)**	**%**	**runoff coeff.**	**annual runoff (m3)**
Roofs	2,990	30%	0.95	3,835
Driveways / paving	1,391	14%	0.90	1,690
Roads	1,619	16%	0.90	1,967
Landscaped pervious area, incl open space	4,000	40%	0.20	1,080
Total	**10,000**	**100%**		**8,572**

Post Development water balance (no mitigation)

Component	Area (m2)	rate (mm/yr)	Volume (m3)
Rainfall			13,500
Landscape area ATE	4,000	500	2,000
minor evaporation from hard surfaces	6,000	150	900
Total Evapotranspiration			2,900
Infiltration			2,028
Runoff			**8,572**

Runoff depth = 857 mm/yr

Post Development with mitigation (per Ha basis)

Effectiveness relative to rainfall

rainfall (mm)	0.1 - 5.0	>5	>20	>50	Total
Approx number of days per year rainfall occurring in Kapiti [1]	90	50	12	3	155
Approx. total rainfall distribution for Kapiti	180	600	360	210	1350

Proposed Mitigation Devices	Runoff Vol. (m3)					
max. possible volume per event from roof runoff/Ha (13 houses/ha @230m2)		6	34	85	199	
potential volume for roof water tank if all events captured		511	1704	1023	597	3835
Estimated effectiveness of rain tanks – peak flow reduced to small outlet flow which is captured by soakage in the system (where used) - 13/Ha @5m3		100%	60%	10%	0%	
Estimated volume/Ha for rainwater tanks (where used)	3,835	511	1023	102	0	1636
potential volume for soak pits if all events captured		511	1704	1023	597	3835
Effectiveness of soak pits (where used) - 13/Ha - E1 - 10 yr event		100%	100%	70%	30%	
Volume/Ha for soak pits where used (assuming no detention tank)	3,835	511	1704	716	179	3110
Effectiveness of bioretention devices if used where house roof area is on separate tank and/or soak pit		100%	100%	20%	10%	
Volume discharged to ground/Ha for bioretention devices, where used for roads (house roof areas excluded - have on-site devices) = 33% of 50%AEP	4,737	853	2842	341	99	4,136
Effectiveness of bio-retention devices if used where house roof area is included in discharge to bioretention device		100%	100%	20%	10%	
Volume discharged to ground/Ha for bioretention devices, where used for roads, roof and lot areas = 33% of 50%AEP - 205m3 capacity per event	8,572	1543	5143	617	180	7,483

Table 5 – Criteria For Mass Balance Assessment

1 Table 8 - Kapiti Airport, NIWA Climate & weather of Wellington, Chappell, 2nd Edition

Using the above design criteria, the mass balance assessment is set out in Table 6 below:

Mass Balance Assessment For Development Areas

Western Side of Central Area - Type 2 Catchment

Onsite soak pits & detention tanks for lots. Runoff from remaining lot area, roads etc to bioretention devices.

	undeveloped	developed	Comment
Development Areas (m2)	99,153	213,830	
%	32%	68%	
	pre-development	post development	
Total affected area (Ha)	21.4	21.4	
evapotranspiration (m3/yr)	106,915	62,011	
Infiltration / groundwater recharge	149,681	198,307	including discharges to ground from bioretention devices & soak pits
Surface runoff	32,075	28,353	unmitigated runoff less discharge to bioretention devices

Total	288,671	288,671	stormwater neutrality achieved
Low-lying central and eastern zone - Type 1 Catchment			
No onsite soak pits & detention tanks. Runoff from roof, lots and roads etc to bioretention devices.			
	undeveloped	developed	Comment
Development Areas (m2)	180,671	445,731	
%	29%	71%	
	pre-development	post development	
Total affected area (Ha)	44.6	44.6	
evapotranspiration (m3/yr)	222,866	129,262	
Infiltration / groundwater recharge	312,012	423,952	including discharges to ground from bioretention devices
Surface runoff	66,860	48,523	unmitigated runoff less discharge to bioretention devices
Total	601,737	601,737	stormwater neutrality achieved
Western Area - Type 2 Catchment			
Use of onsite soak pits & detention tanks. Runoff from remainder of lots and roads etc to bioretention devices.			
	undeveloped	developed	Comment
Development Areas (m2)	72,988	166,172	
%	31%	69%	
	pre-development	post development	
Total affected area (Ha)	16.6	16.6	
evapotranspiration (m3/yr)	83,086	48,190	
Infiltration / groundwater recharge	116,320	154,109	including discharges to ground from soak pits & bioretention devices
Surface runoff	24,926	22,034	unmitigated runoff less discharge to soak pits and bioretention devices
Total	224,332	224,332	stormwater neutrality achieved

Table 6 Mass Balance Assessment

Wetland W1.1 & W1.2

Wetland W1.1 & W1.2 form the Te Harakeke Swamp in the Western Zone. This zone has no peat within the development footprint, and the land is raised above Te Harakeke Swamp, with predominantly dune sandy soils. Stormwater runoff from roof areas within the developed area is discharged to either on-lot detention tanks or soak pits with the remainder of runoff discharged to bio-retention basins which discharge to ground via soakage. The overflow from the basins is to diffuse discharge systems. The by-pass at the basins discharge to surface flow, which is expected to flow overland to the Te Harakeke Swamp.

As shown in Table 6, there is not expected to be any notable change (slight reduction) in annual discharge to Te Harakeke Swamp, as stormwater neutrality is achieved.

It is therefore concluded that the effects of the changes in hydrology associated with this zone of the site, resulting from the proposed stormwater management associated with the development, will be minor.

Wetland W4

Wetland W4 is in the Western Side Central Zone. It is the only remaining wetland within this zone after development. This zone has no peat within the development footprint in the vicinity of W4, and the land is raised above the adjacent low-lying area to the east, with predominantly dune sandy soils. Groundwater monitoring bore P04 has not recorded the presence of groundwater in the general vicinity of W4. Stormwater runoff from the developed area within the zone is discharged to bio-retention basins on the eastern side of the zone. These are well separated from wetland W4 and as groundwater monitoring near W4 does not identify the presence of groundwater within a few metres below the surface, the discharge from the basins is not expected to influence the hydrological behaviour of W4.

There are no existing water courses or ephemeral systems draining to W4 of any note. We therefore conclude that W4 is influenced by a small localized perched water table, which is not expected to be disturbed or altered as part of the development works.

As shown in Table 6, the development proposal will not result in any reduction in hydrological supply to this zone because stormwater neutrality is achieved through a slight reduction in surface water flow and an increase in infiltration (after mitigation) for the post development scenario. The proposed design includes a small bio-retention device adjacent to W4, which serves a catchment of developed land-use of 1.3Ha. The discharge from the bio-retention basin will largely be to ground, via soakage and this will increase the hydrological supply to the localized perched groundwater system associated with W4.

We therefore conclude that there will be a small positive effect on hydrological conditions associated with W4.

Wetland W11

Wetland W11 (Peka Peka Road Swamp) is at the northwest corner of the Low-lying Central and Eastern Zone. There is peat present, up to 2.5m thick, adjacent to W11 as shown by Figure 22 below:

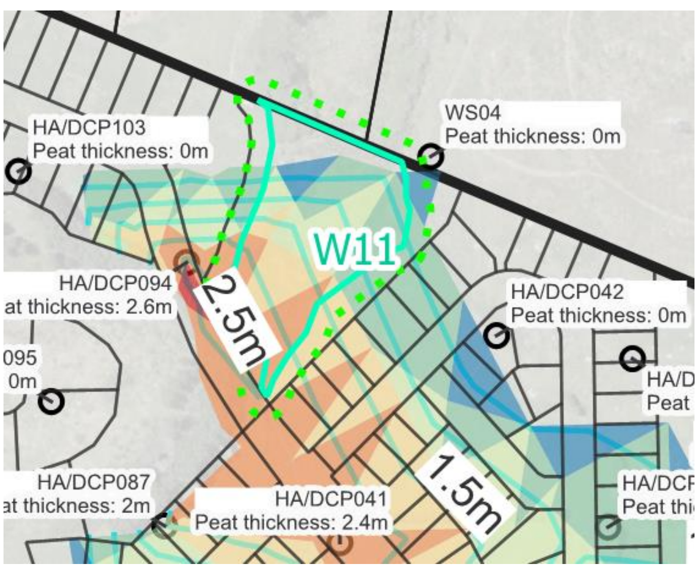

Figure 22 Peat Extent Adjacent to Wetland W11

The development footprint extends to the southern edge of W11 in the form of a road and proposed lots to the east. Proposed earthworks adjacent to W11 are shown by Figure 23 below:

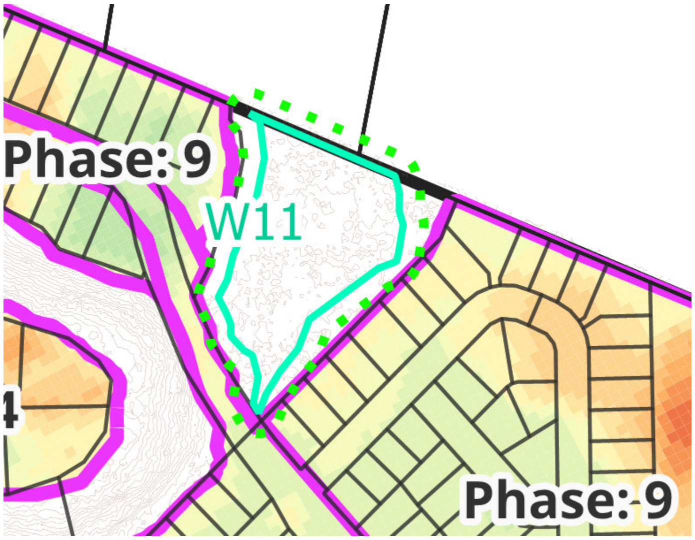

Figure 23 Proposed Earthworks Adjacent to Wetland W11

The light brown shading indicating earthworks adjacent to W11 represents earthworks cut of 0 – 1m in depth. These earthworks are greater than 10m from W11, except for the very southern corner where the road construction is within a 10m buffer. This encroachment is unavoidable due to the large hill face immediately opposite this point as excavation into the dune sand hill face is not feasible. Earthworks in the vicinity of W11 will involve removal of peat beneath the development footprint but will not involve disturbance of existing soils within a 10m buffer around W11, except for the corner road infringement.

As indicated by Table 4, there is no water course supplying W11 and W11 drains to the north with a small "overflow" discharge to the south, into the development area.

The mass balance assessment shown in Table 6 indicates hydraulic neutrality is achieved in this zone. At a more localized level, the supply of surface water and groundwater to W11 will be assisted by the proposed bio-retention basin immediately to the west of W11. This is shown by the yellow shaded area in Figure 24 below:

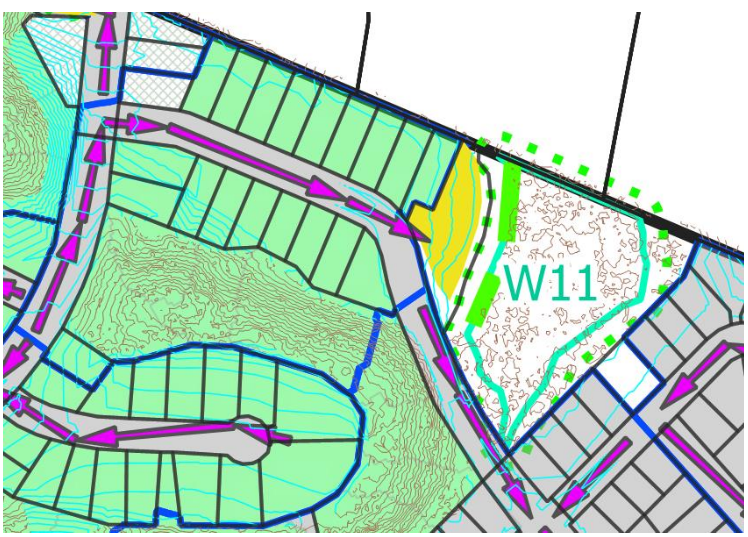

Figure 24 Stormwater Treatment Basin Adjacent to wetland W11

This bio-retention basin serves a catchment of developed land-use of 1.5Ha. The discharge from the bio-retention basin will largely be to ground, via soakage and this will increase the hydrological supply to the localized groundwater system associated with W11.

We therefore conclude that the proposed earthworks should not have an adverse effect on the behaviour of W11 because they are separated from W11 and that there is likely to be a small positive effect on hydrological conditions associated with W11 from the increase source to the groundwater system from the adjacent bio-retention basin.

Wetlands W2.1, W2.2, W2.3, W2.4, W6, W13, W14, W16, W17, W18 & W19

These wetlands are in the central, southern and eastern low-lying areas of the site. Most of these (excluding W13 & W14 and W16, 17 & 18 which are untested) are influenced by the presence of peat. These wetlands are influenced by the presence of near surface groundwater and the adjacent Ngarara Stream and/or its side drains.

The proposed earthworks associated with the development footprint will remove peat adjacent to these wetlands but not within a 10m buffer of them. Peat removed from within the development footprint will be replaced with compacted soils, consisting generally of sand and silt obtained from within the site. As discussed in Section 5, the removal of the peat is not expected to have appreciable effect on the groundwater level after replacement with compacted sand.

The sizing of the bioretention devices to achieve stormwater neutrality also provides an increase in hydrological supply to the groundwater system influencing these wetlands. This is shown by Table 6 where it is estimated that the discharge to infiltration and groundwater recharge will increase from the existing 312,000m^3/yr to 424,000m^3/yr in this area. This is by design because of the desire to increase soil moisture associated with these wetlands.

It is therefore concluded that the proposed earthworks, involving removal of peat within the development zone adjacent to these wetlands, should not have an adverse effect on the behaviour of these wetlands because the loss of groundwater storage within the removed peat will be replaced within a short period of time.

We conclude that the increased supply of groundwater to the low-lying wetlands, associated with the stormwater solution adopted and an expected increase in groundwater level in this immediate zone associated with raising the water level in the Ngarara Stream will have a positive effect on soil moisture associated with these wetlands.

The development proposal includes the creation of some additional mitigation wetlands within this zone. These will have the same hydrological conditions as the existing wetlands within this zone and hence are also expected to benefit from the proposed stormwater management associated with the development.

10 SUMMARY/CONCLUSIONS

A hydrological assessment of the potential effects of the proposed WNDL development on the wetlands associated with the development has been undertaken.

The key hydrological controls on wetland performance and associated soil moisture are expected to be groundwater level, the presence of peat, direct rainfall and management of surface water runoff from the developed areas.

A mass balance assessment of the development area has been carried out, which indicates that adverse effects on the groundwater system, resulting from the implementation of the development are expected to be minimal. The removal of the peat beneath the development area is not expected to result in any appreciable change in groundwater level.

The stormwater management solutions proposed for the development will achieve stormwater neutrality across the site, in both the low-lying central and eastern areas and in the western area that drains to the Te Harakeke Swamp.

The effects of the works on wetland soil moisture are expected to be positive in the low-lying central and eastern zone, due largely to the proposed stormwater management solutions adopted and the proposed improvements to the Ngarara Stream.

11 PROFESSIONAL EXPERTISE

This report has been prepared by Ray O'Callaghan, who is a Chartered Professional Engineer experienced in civil engineering and land development. Mr. O'Callaghan holds the qualifications and professional memberships of BE (Civil), Dip. Hydraulics (Delft) and is a Fellow of Engineering New Zealand.

Mr. O'Callaghan has extensive experience in both the design and construction management of large scale land development projects, earthworks and 3-waters infrastructure, particularly stormwater (and associated groundwater), and has provided expert evidence for numerous RMA processes and legal court proceedings involving these matters and is considered to be sufficiently qualified to undertake an assessment of this kind.

Although this document has not been written as a statement of expert evidence, I confirm that at all times I have complied with the Environment Court's Code of Conduct for Expert Witnesses contained in its Practice Note 2023 as well as the Engineering New Zealand Code of Ethics. No part of this report has been authored by an AI or other software.

I declare that in relation to my role in providing expert civil engineering and hydrology assessment and advice for this project I am not, to the best of my knowledge, subject to any real or perceived conflicts of interest.

APPENDIX 1 – Groundwater Monitoring Results

Piezo ID:	Piezo Installation Depth (m Below Ground Level):	LANDLINK SURVEY GROUND LEVEL AT PIEZO (2016nzvd)	Date (dd/mm/yyyy)	Time	Length of standpipe above ground level (m)	Groundwater level below top of standpipe (m)	Resultant groundwater level depth below ground level (m bgl)	LANDLINK CALCULATON Ground water level (NZVD 2016)	Weather Conditions	Notes: E.g., irrigation; broken piezo, missing cap, flooding nearby, ect.
P01	1.67	6.953	29/01/2025	1230	1.38	2.75	1.37	5.583	Sunny - Last Rainfall Not Recorded	n/a
P01	1.67	6.953	1/04/2025	Not Recorded	1.36	2.85	1.49	5.463	?	n/a
P01	1.67	6.953	3/06/2025	1525	1.45	2.51	1.06	5.893	8 mm rain. Dry for 4 days beforehand.	n/a
P01	1.67	6.953	11/06/2025	0946	1.35	2.27	0.92	6.033	currently raining	n/a
P01	1.67	6.953	19/06/2025	1155	1.3	2.23	0.93	6.023	currently raining	bailed
P01	1.67	6.953	9/07/2025	1020	1.42	2.05	0.63	6.323	Overcast Dry for 4 days beforehand	n/a
P01	1.67	6.953	8/08/2025	1300					currently raining 9.2mm. Last rain event 28/07-31/07 30.6mm	Snapped at base by cows
P01	1.67	6.953	10/09/2025	1450	0.7	1.24	0.54	6.413	Overcast/drizzle	Repaired pipe 100mm bgl
P01	1.67	6.953	6/10/2025	1305	0.7	1.48	0.78	6.173	No Rain for 2 days proir	
P01	1.67	6.953	6/11/2025	1220	0.7	1.58	0.88	6.073	Drizzle, dry for 4 days beforehand	
P01	1.67	6.953	10/12/2025	Not Recorded	NA	NA	NA			broken at base by cows
P01	1.67	6.953	14/01/2026	Not Recorded	NA	NA	NA			Unable to find
P01	1.67	6.953	18/02/2026	1600	0	0.84	0.84	6.113	Rained this morning. 21.2mm over last 7days	Replaced pipe 130mm bgl. Capped at GL
P02	2.01	6.72	29/01/2025	1245	1.38	3.39	2.01	4.71	Sunny - Last Rainfall Not Recorded	n/a
P02	2.01	6.72	1/04/2025	Not Recorded	1.38	3.38	2	4.72	?	
P02	2.01	6.72	3/06/2025	1611	1.4	3.23	1.83	4.89	8 mm rain. Dry for 4 days beforehand.	
P02	2.01	6.72	11/06/2025	1204	1.45	3.1	1.65	5.07	currently raining	n/a
P02	2.01	6.72	19/06/2025	1315	1.37	3.05	1.68	5.04	currently raining	n/a
P02	2.01	6.72	9/07/2025	1035	1.38	2.93	1.55	5.17	Overcast Dry for 4 days beforehand	n/a
P02	2.01	6.72	8/08/2025	1440	1.4	3.07	1.67	5.05	currently raining 9.2mm. Last rain event 28/07-31/07 30.6mm	Bailed
P02	2.01	6.72	10/09/2025	1530	1.37	3.04	1.67	5.05	Overcast/drizzle	
P02	2.01	6.72	6/10/2025	1400	1.36	DRY	DRY		No Rain for 2 days proir	
P02	2.01	6.72	6/11/2025	1310	1.4	DRY	DRY		Drizzle, dry for 4 days beforehand	cap on ground replaced.
P02	2.01	6.72	10/12/2025	1405	1.4	DRY	DRY			
P02	2.01	6.72	14/01/2026	1400	1.4	DRY	DRY			
P02	2.01	6.72	18/02/2026	1630	1.42	DRY @ 2.95	DRY		Rained this morning. 21.2mm over last 7days	
P03	1.49	6.353	29/01/2025	1315	1.48	2.95			Sunny - Last Rainfall Not Recorded	n/a
P03	1.49	6.353	1/04/2025	Not Recorded	1.47	DRY @ 1.49	DRY		?	
P03	1.49	6.353	3/06/2025	1633	1.46	2.84	1.38	4.973	8 mm rain. Dry for 4 days beforehand.	
P03	1.49	6.353	11/06/2025	1049	1.45	2.6	1.15	5.203	currently raining	n/a
P03	1.49	6.353	19/06/2025	1240	1.4	2.55	1.15	5.203	currently raining	n/a
P03	1.49	6.353	9/07/2025	1040	1.4	2.39	0.99	5.363	Overcast Dry for 4 days beforehand	n/a
P03	1.49	6.353	8/08/2025	1245	1.4	2.6	1.2	5.153	currently raining 9.2mm. Last rain event 28/07-31/07 30.6mm	Bailed

P03	1.49	6.353	10/09/2025	1235	1.44	2.38	0.94	5.413	Overcast/drizzle	
P03	1.49	6.353	6/10/2025	1245	1.44	2.5	1.06	5.293	No Rain for 2 days proir	
P03	1.49	6.353	6/11/2025	1200	1.42	Wet at BOH	W@BOH		Drizzle, dry for 4 days beforehand	
P03	1.49	6.353	10/12/2025	1200	1.44	Wet at BOH	W@BOH			
P03	1.49	6.353	14/01/2026	1124	1.41	DRY	DRY			missing cap
P03	1.49	6.353	18/02/2026	1610	1.48	DRY @ 2.52	DRY		Rained this morning. 21.2mm over last 7days	
P04	4.37	9.011	29/01/2025	1345	1.63	DRY @ 4.37	DRY		Sunny - Last Rainfall Not Recorded	n/a
P04	4.37	9.011	1/04/2025	Not Recorded	1.6	DRY @ 4.37	DRY			
P04	4.37	9.011	11/06/2025	1115	1.75	-	DRY		currently raining	Bent Piezo
P04	4.37	9.011	9/07/2025	1130	1.73	DRY @ 4.37	DRY		Overcast Dry for 4 days beforehand	Pipe slightly damaged and bent, pulled up slightly.
P04	4.37	9.011	8/08/2025	1530						Missing
P04	4.37	9.011	10/09/2025	Not Recorded	NA	NA	NA			Missing
P04	4.37	9.011	6/10/2025	Not Recorded	NA	NA	NA			Missing
P04	4.37	9.011	6/11/2025	Not Recorded	NA	NA	NA			Missing
P04	6	9.011	10/12/2025	1502	1.13	5.61	4.48	4.531		New Peizometer installed to 6.0 m bgl
P04	6	9.011	14/01/2026	1247	1.2	5.76	4.56	4.451		
P04	6	9.011	18/02/2026	1705	1.18	5.79	4.61	4.401	Rained this morning. 21.2mm over last 7days	
P05	3	5.132	29/01/2025	1430	0.2	0.92	0.72	4.412	Sunny - Last Rainfall Not Recorded	n/a
P05	3	5.132	1/04/2025	Not Recorded	0.26	1.09	0.83	4.302		
P05	3	5.132	11/06/2025	1123	0.25	0.7	0.45	4.682	currently raining	n/a
P05	3	5.132	9/07/2025	1110	0.2	0.6	0.4	4.732	Overcast Dry for 4 days beforehand	n/a
P05	3	5.132	8/08/2025	1500	0.23	0.6	0.37	4.762	currently raining 9.2mm. Last rain event 28/07-31/07 30.6mm	replaced cap. Bailed
P05	3	5.132	10/09/2025	1550	0.23	0.66	0.43	4.702	Overcast/drizzle	
P05	3	5.132	6/10/2025	1430	0.22	0.61	0.39	4.742	No Rain for 2 days proir	
P05	3	5.132	6/11/2025	Not Recorded	NA	NA	NA		Drizzle, dry for 4 days beforehand	Too many cows in paddock
P05	3	5.132	10/12/2025	Not Recorded	NA	NA	NA			Too many cows in paddock
P05	3	5.132	14/01/2026	1212	0.3	0.84	0.54	4.592		
P05	3	5.132	18/02/2026	1645	0.2	0.79	0.59	4.542	Rained this morning. 21.2mm over last 7days	
P06	1.5	5.96	8/05/2025	Not Recorded	0.65	1.85			Sunny - Last Rainfall 08/05/2025	Piezo Installation
P06	1.5	5.96	3/06/2025	1624	0.62	1.28	0.66	5.3	8 mm rain. Dry for 4 days beforehand.	
P06	1.5	5.96	11/06/2025	1022	0.65	1.08	0.43	5.53	currently raining	n/a
P06	1.5	5.96	19/06/2025	1230	0.64	1.16	0.52	5.44	currently raining	bailed
P06	1.5	5.96	9/07/2025	1024	0.63	1.1	0.47	5.49	Overcast Dry for 4 days beforehand	n/a
P06	1.5	5.96	8/08/2025	1410						Unable to access - too many cows
P06	1.5	5.96	10/09/2025	1510	NA	NA	NA		Overcast/drizzle	Broken pipe, can't find, suspect cows
P06	1.5	5.96	6/10/2025	1140	0.53	1.02	0.49	5.47	No Rain for 2 days proir	Repaired pipe 100mm bgl
P06	1.5	5.96	6/11/2025	1255	0.55	1.18	0.63	5.33	Drizzle, dry for 4 days beforehand	
P06	1.5	5.96	10/12/2025	Not Recorded	NA	NA	NA			Missing - broken by cows
P06	1.5	5.96	14/01/2026	1155	NA	NA	NA			Missing - shards evereywhere
P06	1.2	5.96	18/02/2026	1615	0	0.46	0.63	5.33	Rained this morning. 21.2mm over last 7days	Replaced piezo to 1.2m bgl

P07	1.5	6.813	8/05/2025	Not Recorded	0.65	1.65			Sunny - Last Rainfall 08/05/2025	Piezo Installation
P07	1.5	6.813	3/06/2025	1535	0.64	1.21	0.57	6.243	8 mm rain. Dry for 4 days beforehand.	N/A
P07	1.5	6.813	11/06/2025	0957	0.65	0.97	0.32	6.493	currently raining	n/a
P07	1.5	6.813	19/06/2025	12.05	0.64	0.88	0.24	6.573	currently raining	Bailed
P07	1.5	6.813	9/07/2025	1014	0.64	0.69	0.05	6.763	Overcast Dry for 4 days beforehand	n/a
P07	1.5	6.813	8/08/2025	1320	0.66	0.82	0.16	6.653	currently raining 9.2mm. Last rain event 28/07-31/07 30.6mm	Bailed
P07	1.5	6.813	10/09/2025	1350	0.66	0.79	0.13	6.683	Overcast/drizzle	
P07	1.5	6.813	6/10/2025	1300	0.66	0.92	0.26	6.553	No Rain for 2 days proir	
P07	1.5	6.813	6/11/2025	1210	0.65	1.03	0.38	6.433	Drizzle, dry for 4 days beforehand	
P07	1.5	6.813	10/12/2025	Not Recorded	NA	NA	NA			Broken at base by cows
P07	1.5	6.813	14/01/2026	1145	NA	NA	NA			Missing - Shards everywhere
P07	1.3	6.813	18/02/2026	1550	0	0.53	0.53	6.283	Rained this morning. 21.2mm over last 7days	Replaced piezo to 1.3m bgl
								0		
P08	1.55	6.033	8/05/2025	Not Recorded	0.65	1.65	1	5.033	Sunny - Last Rainfall 08/05/2025	Piezo Installation
P08	1.55	6.033	3/06/2025	1600	0.62	1.5	0.88	5.153	8 mm rain. Dry for 4 days beforehand.	N/A
P08	1.55	6.033	11/06/2025	1033	0.65	1.38	0.73	5.303	currently raining	n/a
P08	1.55	6.033	19/06/2025	1310	0.61	1.27	0.66	5.373	currently raining	n/a
P08	1.55	6.033	9/07/2025	1033	0.62	1.16	0.54	5.493	Overcast Dry for 4 days beforehand	n/a
P08	1.55	6.033	8/08/2025	1435	0.62	1.28	0.66	5.373	currently raining 9.2mm. Last rain event 28/07-31/07 30.6mm	Bailed
P08	1.55	6.033	10/09/2025	1520	0.62	1.2	0.58	5.453	Overcast/drizzle	
P08	1.55	6.033	6/10/2025	1350	0.62	1.3	0.68	5.353	No Rain for 2 days proir	
P08	1.55	6.033	6/11/2025	1300	0.64	1.4	0.76	5.273	Drizzle, dry for 4 days beforehand	cap on ground replaced
P08	1.55	6.033	10/12/2025	1400	0.65	1.52	0.87	5.163		
P08	1.55	6.033	14/01/2026	1405	0	0.97	0.97	5.063		Broken at base - GL
P08	1.55	6.033	18/02/2026	1620	1.42	2.26	0.84	5.193	Rained this morning. 21.2mm over last 7days	fixed standpipe
P09	2.5	6.883	8/05/2025	Not Recorded	0.45	2.65			Sunny - Last Rainfall 08/05/2025	Piezo Installation
P09	2.5	6.883	3/06/2025	1700	0.42	2.38	1.96	4.923	8 mm rain. Dry for 4 days beforehand.	N/A
P09	2.5	6.883	11/06/2025	1040	0.5	2.2	1.7	5.183	currently raining	n/a
P09	2.5	6.883	19/06/2025	1320	0.41	2.14	1.73	5.153	currently raining	n/a
P09	2.5	6.883	9/07/2025	1036	0.41	1.98	1.57	5.313	Overcast Dry for 4 days beforehand	n/a
P09	2.5	6.883	8/08/2025	1450	0.41	2.2	1.79	5.093	currently raining 9.2mm. Last rain event 28/07-31/07 30.6mm	Bailed
P09	2.5	6.883	10/09/2025	1540	0.44	2.08	1.64	5.243	Overcast/drizzle	
P09	2.5	6.883	6/10/2025	1415	0.44	2.2	1.76	5.123	No Rain for 2 days proir	
P09	2.5	6.883	6/11/2025	1340	0.43	2.36	1.93	4.953	Drizzle, dry for 4 days beforehand	hidden by grass
P09	2.5	6.883	10/12/2025	Not Recorded	NA	NA	NA			Broken at base by cows
P09	2.5	6.883	14/01/2026	1205	NA	NA	NA			missing
P09	2.5	6.883	18/02/2026	1640	0.6	2.64	2.04	4.843	Rained this morning. 21.2mm over last 7days	fixed standpipe
								0		
P10	2.5	5.059	8/05/2025	Not Recorded	0.5	2.7			Sunny - Last Rainfall 08/05/2025	Piezo Installation
P10	2.5	5.059	11/06/2025	1111	0.5	0.92	0.42	4.639	currently raining	m/a
P10	2.5	5.059	9/07/2025	1120	0.46	0.66	0.2	4.859	Overcast Dry for 4 days beforehand	n/a

P10	2.5	5.059	8/08/2025	1520	0.46	0.76	0.3	4.759	currently raining 9.2mm. Last rain event 28/07-31/07 30.6mm	Bailed
P10	2.5	5.059	10/09/2025	Not Recorded	0.44	0.67	0.23	4.829	Overcast/drizzle	
P10	2.5	5.059	6/10/2025	1155	0.41	0.72	0.31	4.749	No Rain for 2 days proir	surface water, boggy
P10	2.5	5.059	6/11/2025	1410	0.5	0.84	0.34	4.719		
P10	2.5	5.059	10/12/2025	1450	0.49	0.93	0.44	4.619		surrounding ground dryer
P10	2.5	5.059	14/01/2026	1243	0	0.53	0.53	4.529		broken at base - GL
P10	1.6	5.059	18/02/2026	1650	0	0.49	0.49	4.569	Rained this morning. 21.2mm over last 7days	Replaced piezo 1.6m bgl
P11	1.5	5.041	8/05/2025	Not Recorded	0.5	1.7			Sunny - Last Rainfall 08/05/2025	Piezo Installation
P11	1.5	5.041	11/06/2025	1134	0.55	0.93	0.38	4.661	currently raining	n/a
P11	1.5	5.041	9/07/2025	1140	0.51	0.86	0.35	4.691	Overcast Dry for 4 days beforehand	n/a
P11	1.5	5.041	8/08/2025	1544	0.52	0.9	0.38	4.661	currently raining 9.2mm. Last rain event 28/07-31/07 30.6mm	Bailed
P11	1.5	5.041	10/09/2025	Not Recorded	0.51	0.86	0.35	4.691	Overcast/drizzle	
P11	1.5	5.041	6/10/2025	1215	0.41	0.88	0.47	4.571	No Rain for 2 days proir	
P11	1.5	5.041	6/11/2025	1450	0.52	1.02	0.5	4.541	Drizzle, dry for 4 days beforehand	
P11	1.5	5.041	10/12/2025	1505	0.51	1.08	0.57	4.471		overgrown vegetation
P11	1.5	5.041	14/01/2026	1228	0.54	1.24	0.7	4.341		
P11	1.5	5.041	18/02/2026	1710	0.52	1.11	0.59	4.451	Rained this morning. 21.2mm over last 7days	
P12	4.6	10.867	9/05/2025	Not Recorded	0.65	DRY @ 4.6	DRY		Sunny - Last Rainfall 09/05/2025	Piezo Installation
P12	4.6	10.867	11/06/2025	1058	0.65	DRY @ 4.6	DRY		currently raining	n/a
P12	4.6	10.867	19/06/2025	1255	0.64	DRY @ 4.6	DRY		currently raining	n/a
P12	4.6	10.867	9/07/2025	1050	0.64	DRY @ 4.7	DRY		Overcast Dry for 4 days beforehand	n/a
P12	4.6	10.867	8/08/2025	1338	0	WET @ 4	WET @ BOH		currently raining 9.2mm. Last rain event 28/07-31/07 30.6mm	Snapped at ground level - tractor?
P12	4.6	10.867	10/09/2025	1310	0.64	0.407	ignore. Cgw data does not mak		Overcast/drizzle	Repaired pipe 100mm bgl
P12	4.6	10.867	6/10/2025	1315	0.64	WET @ 4	WET @ BOH		No Rain for 2 days proir	
P12	4.6	10.867	6/11/2025	1230	0.64	WET @ 4	WET @ BOH		Drizzle, dry for 4 days beforehand	
P12	4.6	10.867	10/12/2025	1325	0.64	Dry @ BOH	DRY			
P12	4.6	10.867	14/01/2026	1345	NA	NA	NA			missing, shards everywhere
P12	4.6	10.867	18/02/2026	1540	0.57	DRY @ 2.97	DRY		Rained this morning. 21.2mm over last 7days	broken Peizometer, depth indicates debris.-to be re
P13	2.55	5.502	9/05/2025	Not Recorded	0.45	2.35			Sunny - Last Rainfall 09/05/2025	Piezo Installation
P13	2.55	5.502	11/06/2025	1105	0.47	1.22	0.75	4.752	currently raining	n/a
P13	2.55	5.502	9/07/2025	1055	0.42	1	0.58	4.922	Overcast Dry for 4 days beforehand	n/a
P13	2.55	5.502	8/08/2025	1350	0.4	1	0.6	4.902	currently raining 9.2mm. Last rain event 28/07-31/07 30.6mm	Bailed. VERY wet paddock
P13	2.55	5.502	10/09/2025	1330	0.42	0.9	0.48	5.022	Overcast/drizzle	
P13	2.55	5.502	6/10/2025	1320	0.4	0.94	0.54	4.962	No Rain for 2 days proir	some surface water
P13	2.55	5.502	6/11/2025	1245	0.42	1.03	0.61	4.892	Drizzle, dry for 4 days beforehand	
P13	2.55	5.502	10/12/2025	1344	0.41	1.09	0.68	4.822		paddock is dry enough to drive on
P13	2.55	5.502	14/01/2026	13.44	0	0.8	0.8	4.702		Broken at ground level
P13	2.55	5.502	18/02/2026	1524	1.39	2.1	0.71	4.792	Rained this morning. 21.2mm over last 7days	fixed standpipe
P14	3.6	6.899	9/05/2025	Not Recorded	0.67	3.97			Sunny - Last Rainfall 09/05/2025	Piezo Installation

P14	3.6	6.899	11/06/2025	1221	0.65	3.7	3.05	3.849	currently raining	n/a
P14	3.6	6.899	9/07/2025	1230	0.7	3.52	2.82	4.079	Overcast Dry for 4 days beforehand	n/a
P14	3.6	6.899	8/08/2025	1550	0.68	3.3	2.62	4.279	currently raining 9.2mm. Last rain event 28/07-31/07 30.6mm	Replaced cap
P14	3.6	6.899	10/09/2025	1620	0.72	3.32	2.6	4.299	Overcast/drizzle	
P14	3.6	6.899	6/10/2025	1200	0.65	3.33	2.68	4.219	No Rain for 2 days proir	
P14	3.6	6.899	6/11/2025	1420	0.73	3.33	2.6	4.299	Drizzle, dry for 4 days beforehand	
P14	3.6	6.899	10/12/2025	1500	0.7	3.43	2.73	4.169		
P14	3.6	6.899	14/01/2026	1257	0.73	3.55	2.82	4.079		
P14	3.6	6.899	18/02/2026	1700	0.62	3.52	2.9	3.999	Rained this morning. 21.2mm over last 7days	fixed broken standpipe
P15	1.6	3.854	9/05/2025	Not Recorded	0.8	1.9	1.1	2.754	Raining During Installation	Piezo Installation
P15	1.6	3.854	11/06/2025	1239	0.65	1.75	1.1	2.754	currently raining	n/a
P15	1.6	3.854	9/07/2025	1210	0.62	1.72	1.1	2.754	Overcast Dry for 4 days beforehand	n/a
P15	1.6	3.854	8/08/2025	1608	0.63	2.86			currently raining 9.2mm. Last rain event 28/07-31/07 30.6mm	n/a
P15	1.6	3.854	10/09/2025	Not Recorded	0.64	1.67	1.03	2.824	Overcast/drizzle	
P15	1.6	3.854	6/10/2025	1210	0.61	1.67	1.06	2.794	No Rain for 2 days proir	
P15	1.6	3.854	6/11/2025	1510	0.64	1.69	1.05	2.804	Drizzle, dry for 4 days beforehand	
P15	1.6	3.854	10/12/2025	1517	0.65	1.72	1.07	2.784		
P15	1.6	3.854	14/01/2026	1327	0.68	1.8	1.12	2.734		
P15	1.6	3.854	18/02/2026	1725	0.66	1.73	1.07	2.784	Rained this morning. 21.2mm over last 7days	getting overgrown
P16	2.9	5.103	9/05/2025	Not Recorded	0.6	3.1	2.5	2.603	Raining During Installation	Piezo Installation
P16	2.9	5.103	11/06/2025	1247	0.6	3	2.4	2.703	currently raining	n/a
P16	2.9	5.103	9/07/2025	1206	0.62	2.86	2.24	2.863	Overcast Dry for 4 days beforehand	n/a
P16	2.9	5.103	8/08/2025	1612	0.63	2.86	2.23	2.873	currently raining 9.2mm. Last rain event 28/07-31/07 30.6mm	n/a
P16	2.9	5.103	10/09/2025	Not Recorded	0.63	2.83	2.2	2.903	Overcast/drizzle	
P16	2.9	5.103	6/10/2025	1520	0.63	2.84	2.21	2.893	No Rain for 2 days proir	
P16	2.9	5.103	6/11/2025	1520	0.62	2.88	2.26	2.843	Drizzle, dry for 4 days beforehand	
P16	2.9	5.103	10/12/2025	1520	0.62	2.95	2.33	2.773		overgrown
P16	2.9	5.103	14/01/2026	1333	NA	NA	NA			missing
P16	2.9	5.103	18/02/2026	1730	0.62	3	2.38	2.723	Rained this morning. 21.2mm over last 7days	Fixed broken standpipe
P17	3.9	6.378	21/05/2025	Not Recorded	0.5	4.1			Sunny - Last Rainfall 18/05/2025	Piezo Installation
P17	3.9	6.378	11/06/2025	1228	0.5	3.7	3.2	3.178	currently raining	n/a
P17	3.9	6.378	9/07/2025	1150	0.54	3.5	2.96	3.418	Overcast Dry for 4 days beforehand	n/a
P17	3.9	6.378	8/08/2025	1600	0.55	3.36	2.81	3.568	currently raining 9.2mm. Last rain event 28/07-31/07 30.6mm	n/a
P17	3.9	6.378	10/09/2025	1630	0.59	3.33	2.74	3.638	Overcast/drizzle	
P17	3.9	6.378	6/10/2025	1205	0.57	3.32	2.75	3.628	No Rain for 2 days proir	
P17	3.9	6.378	6/11/2025	1500	0.57	3.3	2.73	3.648	Drizzle, dry for 4 days beforehand	
P17	3.9	6.378	10/12/2025	1515	0.55	3.38	2.83	3.548		
P17	3.9	6.378	14/01/2026	1319	0.59	3.49	2.9	3.478		
P17	3.9	6.378	18/02/2026	1720	0.57	3.55	2.98	3.398	Rained this morning. 21.2mm over last 7days	area getting overgrown