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**Attention: Nathanael Savage**

Dear Nathanael

**Rotokauri North ICMP: Desktop Review of Hydrogeological Conditions Influencing Stormwater Design**



# 1 Introduction

Hamilton City Council (HCC) proposes to develop the Rotokauri North Development Area (RNDA) in accordance with the Rotokauri Structure Plan. Beca has been engaged by HCC to undertake a desk top review of the current state of knowledge of the hydrogeological conditions at RNDA.

A key outcome of this review is an initial assessment of potential implications for stormwater design to inform the Rotokauri North Integrated Catchment Management Plan (herein referred to as the Rotokauri ICMP). The conceptual stormwater design options are set out in the report "Stormwater Catchment Management Plan" (prepared by CKL, herein referred to as CKL (2017)).

This letter report presents the findings of the desktop assessment and identifies what additional investigation or analysis would be needed to confirm option viability or provide a higher level of certainty to support design.

# 2 Stormwater Design Options

A conveyance system is required to take runoff within the Rotokauri North catchment to the Waipa Stream, with smaller out flows towards SH 39 to the North, Te Kowhai Rd drain outlet to the North East, and Rotokauri South outlet to the South East. Various options for conveyance and attenuation of stormwater have been considered with the objective of maximizing discharge to the downstream catchment, whilst providing sufficient upstream attenuation and storage for a 100 year ARI. Options that preserve and promote ecological and landscape character are preferred.

The preferred concept option has been identified as a central drain / green corridor (Figure 1). The typical depth of the channel is intended to be 2 m. It is proposed in the center of the corridor, a relatively small main channel (26-30 m wide) will support permanent base-flows in a run-riffle-pool type arrangement, with the wider corridor (53-76 m wide) profiled to accommodate larger events, similar to that outlined for the overarching Rotokauri ICMP.

Where storage basins are required they are likely to be largely accommodated within the corridor footprint; however, offline storage in adjacent reserves could still be required.

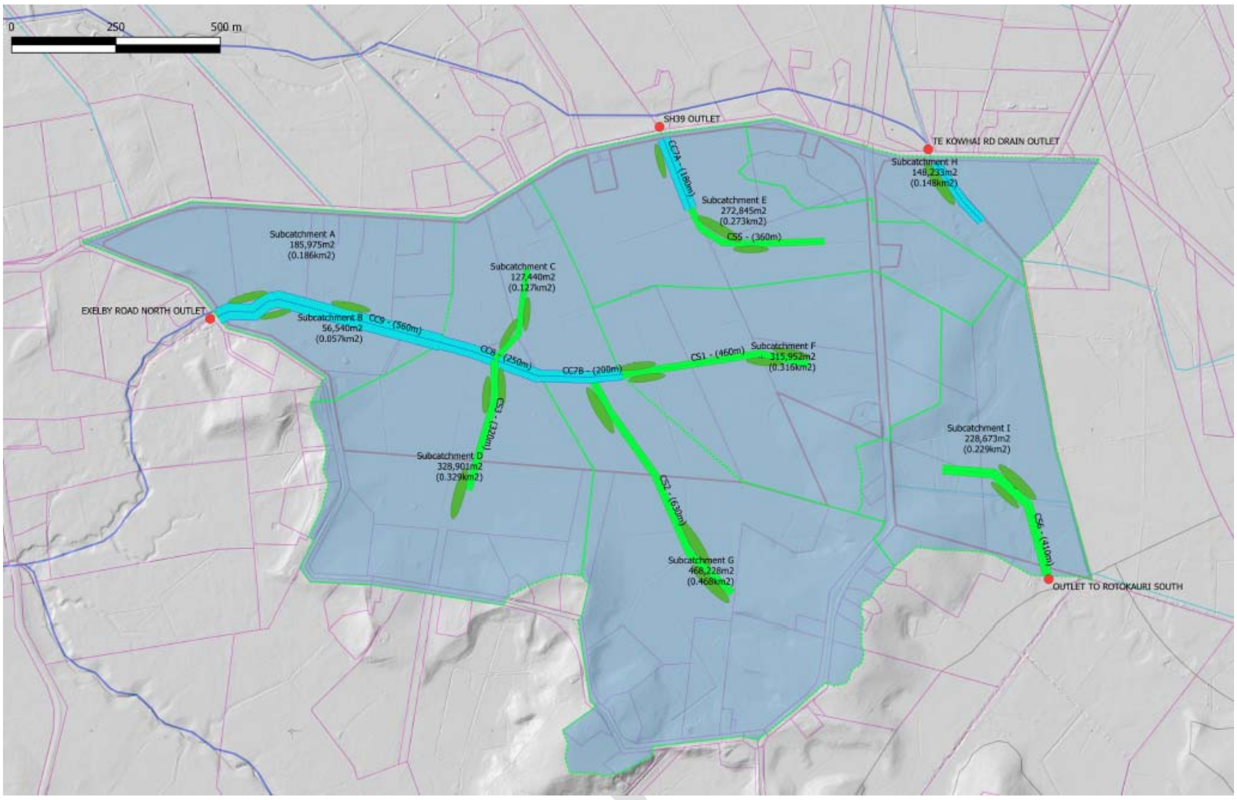


**Figure 1: Rotokauri north development area concept stormwater layout (CKL, 2017)**

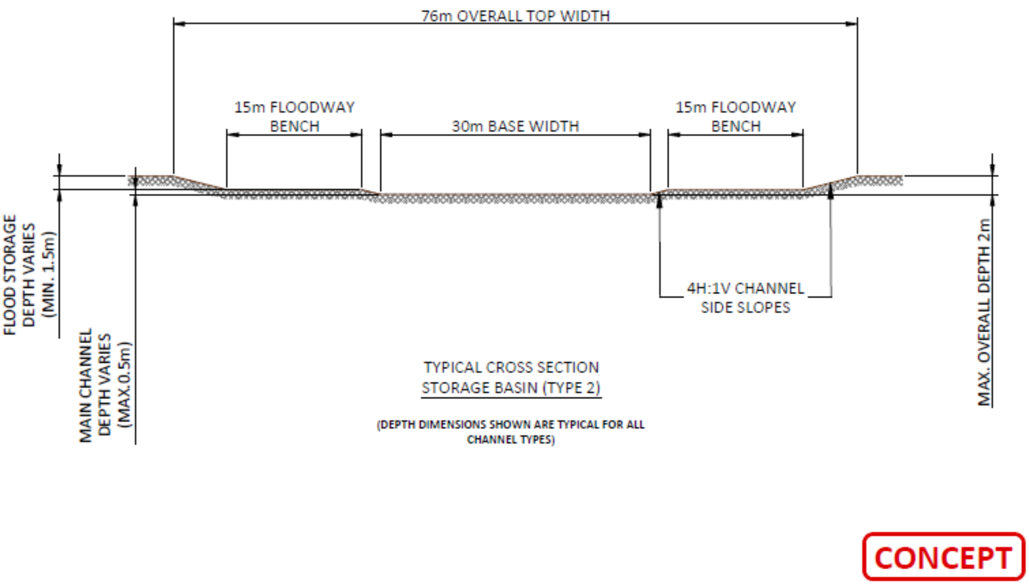


**Figure 2: Typical details of Storage channels (CKL, 2017). The center of the corridor, a relatively small main channel will support permanent base-flows in a run-riffle-pool type arrangement, with the wider corridor profiled to accommodate larger events**

# 3 Hydrogeological Setting

## 3.1 Geology

The published geological map identifies that the site is liekly to be underlain by Hinuera Formation (Figure 3, which in turn is underlain by Walton Subgroup.

The Hinuera Formation soils were deposited in a fluvial environment and so it is expected that individual layers will vary in thickness and extent.

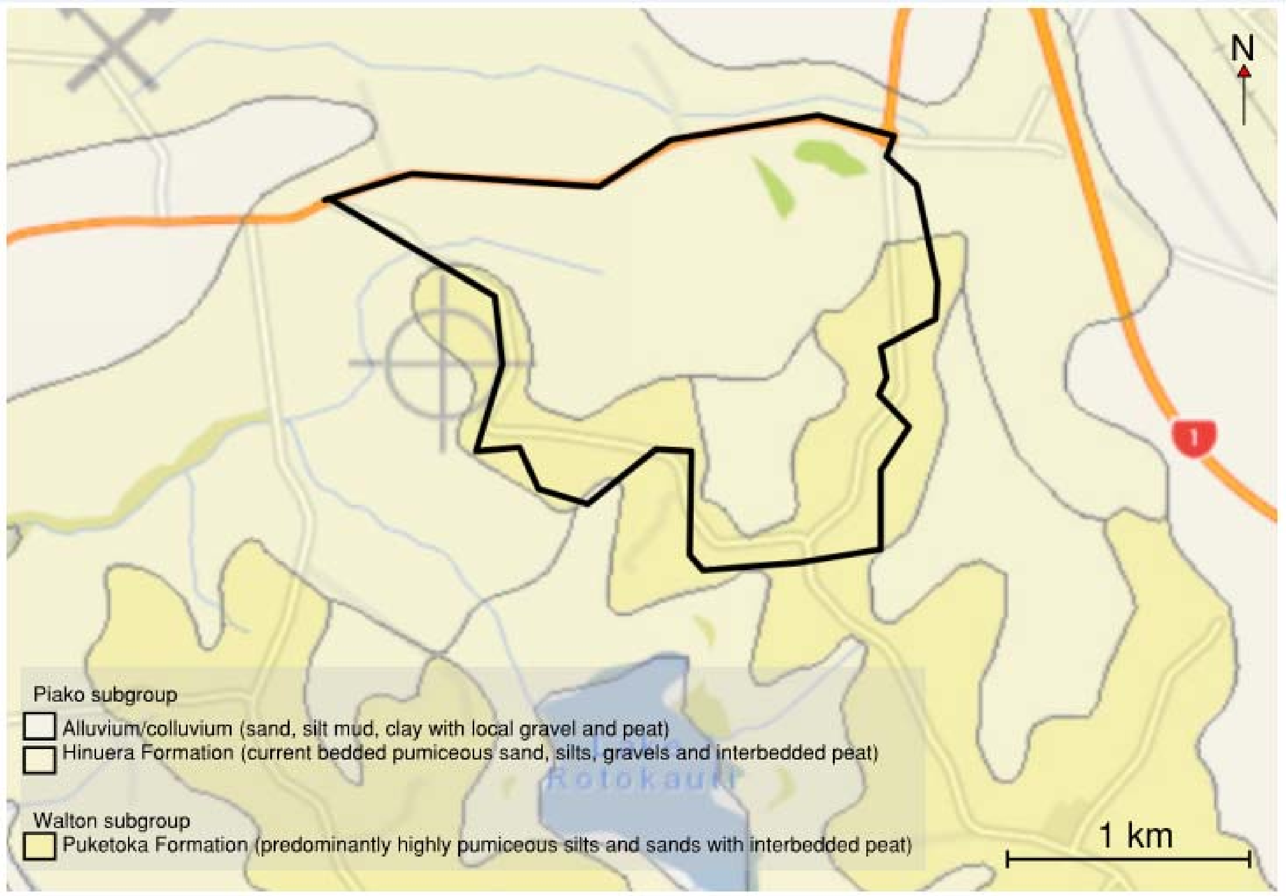


**Figure 3: Geological map indicating the site is underlain by Hinuera Formation overlaying Walton Subgroup.**

Review of limited, available site investigation data confirms that the profile across the site is comprised of soils (sands, silts and gravels) of the Piako Sub-group (Hinuera Formation). Feasibility level investigations undertaken by HD Geotechnical have been shallow (< 2.4 m depth); however, the upper part of the soil profile is consistent with that identified in the wider Rotokauri Structure Plan area (Table 1). On this basis the near surface Piako Subgroup soils are liekly to range from 0.5 m to 3 m thickness across the RNDA.

The underlying Walton Sub-group outcrops, through the Piako formation forming the low lying hills along the southern boundary of the RNDA.

No peat has been identified in prior investigations at the site, however it was identified (be it inconsistent, both spatially and in thickness) during investigations for the Rotokauri ICMP; therefore, there is some possibility of peat being encountered within the RNDA.

## 3.2 Hydrogeological Properties of Soils

High level hydrogeological properties of the soils have been determined from initial ground investigations at site, publically available borehole investigation data, relevant Environment Waikato bore data, and experience for similar projects in the area, notably investigations from the neighbouring Rotokauri ICMP (that included long term groundwater level monitoring, in-situ permeability testing and grain size analyses).

Layer descriptions (and their corresponding expected hydrogeological properties) are presented in Table 1 below. The depth and soil properties are largely based on deep investigation drilling undertaken in Rotokauri, however, initial site investigation data from RNDA ( HD Geotechnical, 2018) indicates hydraulic conductivities that are likely in the range of $1x10^{-6}$ to $4x10^{-7}$ and hence are broadly consistent.

Layer 1 is likely to have an overall low hydraulic conductivity, controlled by the fines component of the soils and are likely to be strongly anisotropic (that is, the layering in the alluvial soils means that flow occurs more rapidly in a horizontal direction than in a vertical direction, albeit slowly in both cases).

Site specific investigations for Rotokauri indicated that it was possible to further distinguish a coarser, more permeable unit with depth (layer 2). Investigations undertaken for the RNDA to date are not of sufficient depth to confirm if such a layer is present across the site. If present, layer 2 is likely to have a coarser grain size and will likely be more permeable.

**Table 1: High-level assessment of liekly hydrogeological properties of the RNDA**

| Unit | Layer | Description | Depth to top of layer (m bgl) | Thickness (m) | Hydraulic Conductivity (m/s) | $K_v/K_h$ ratio |
|---|---|---|---|---|---|---|
| Piako Subgroup | 1 | Sandy silty CLAY/sandy SILT | 0 | 0.1 – 10 (typical=1.5) | $10^{-6}$ to $10^{-8}$ (Low) | 0.1 |
| | 2 | Fine to coarse SAND/ silty fine SAND/ gravelly SAND/SILT | 1 – 10 | 0.5 - 21.5+ (typical=8.7) | $1 \times 10^{-5}$ (mod-high) | 1 |

## 3.3 Groundwater Levels

The RNDA consists of three sub-catchments which are understood to drain to three separate outlet locations (CKL, 2017). The surface water catchments are constrained by ridgelines formed from low lying Walton Subgroup hills that are located along the southern boundary (coincident with Exelby Road) and running north-south (along Burbush Road). The majority of surface water runoff occurs within these two ridgelines and is expected to drain west towards the Exelby Road North culvert which is at an elevation of ~29 m.

A broadly similar pattern is expected in the groundwater though there is limited site specific investigation to confirm.

Te Rapa bypass investigation (Te Rapa bypass, 2005) undertaken within the RNDA compiled mostly of hand auger data indicted groundwater levels were 1-1.5 meters below ground level (m bgl). The measurements were taken in July 2005, immediately after drilling.

An initial site investigation (for high level assessment of geotechnical feasibility) was recently undertaken by HD Geotechnical. As part of this investigation shallow, temporary piezometers were installed to depths of 0.6 m to 1.3 m bgl and data loggers were deployed for one week to record the short term groundwater response to rainfall.

These piezometers indicate that groundwater levels ranged from 0.1 m bgl (i.e. near ground surface level) and 1.1 m bgl. Groundwater levels (in individual piezometers) varied by typically 0.3 m but up to 0.5 m over the period of monitoring in response to rainfall. Using the water table method (where recharge can be assumed based on specific yield and the observed change in groundwater level) the rainfall recharge over this limited period is estimated to be close to 100 % indicating a very direct connection to rainfall.

# 4 Key Hydrogeological and Geotechnical Constraints for Stormwater Design

## 4.1 Stormwater Options

A central drain / green corridor has been identified as the preferred option. The corridor is nominally 50 m to 70 m wide with a maximum depth of 2 m. Where storage basins are required they are likely to be largely accommodated within the corridor footprint (to the scale shown in Figure 1).

A preferred option has been identified; however we understand some further design development is likely hence the following sub-sections have considered catchment-wide constraints.

With the preferred stormwater conveyance channel option in mind, and the existing publically available data it is possible to draw some high-level assessment of potential constraints and opportunities relating to stormwater management. A typical cross section summarising this information is seen in figure 4.

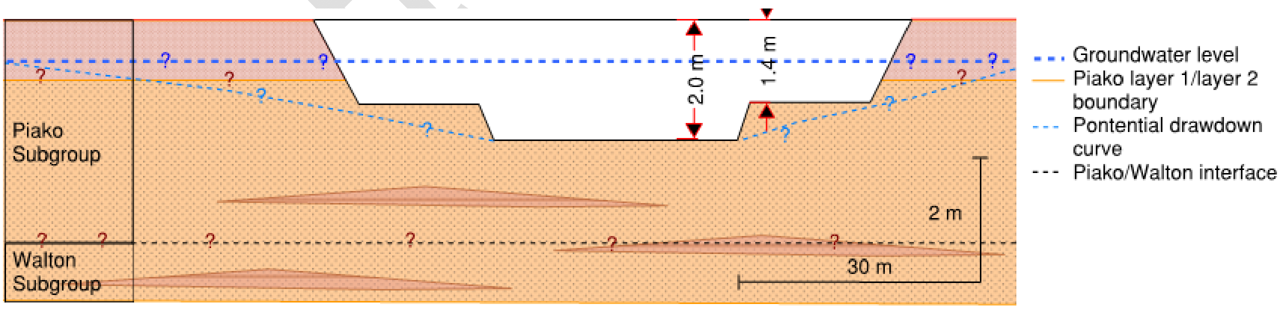


**Figure 4: Simplified sketch (not to scale) indicating a typical Conveyance Channel, geological profile, groundwater level and potential drawdown.**

## 4.2 Hydrogeological Constraints

### 4.2.1 Depth to groundwater

Initial (short duration) results from the high level feasibility investigations indicate a winter groundwater level that is a maximum of 1.1 m bgl, but in locations as high as 0.1 m bgl with a direct response to rainfall. Levels could be higher after large rain events such that the water table is likely to be encountered at or close to ground surface in some locations. This may locally constrain the maximum achievable unlined channel (or basin) depth. If an unlined basin or channel extends below the groundwater table in places, part of the storage will be taken up by groundwater which may drain from a wider area up-gradient.

Where excavations are in soil of low permeability, excavations are unlikely to encounter significant inflows. However should more permeable layers be encountered, groundwater inflows, in addition to being a construction nuisance, could reduce the storage capacity of the channel / basin.

Conversely, should the summer groundwater levels drop below the base of the channels it could be difficult to maintain a wetted base.

Uncertainties:

- What are the current groundwater levels at the specific location of the proposed channels?
- Are the shallowest groundwater levels (indicated by the 2018 investigations) perched (i.e. would they discharge on excavation through them)?
- What is the seasonal variation of groundwater levels across the site?

### 4.2.2 Drawdown of the groundwater table

Where excavations are required below the groundwater table, drawdown (as shown on Figure 3) could occur with the potential for:

- Groundwater drawdown induced consolidation settlement. This is a risk in areas where excavation of the waterway will encounter sandy materials that are located below the ground water level. In this situation the channel could drain groundwater from further away causing settlement of the overlying compressible soils. The risk of settlement to neighbouring structures requires further consideration as the need to limit drawdown may be a constraint on the maximum depth of cut.
- Loss of channel or storage basin capacity. If the channel is unlined, some of the volume would be taken up by groundwater; if it is lined then upward groundwater pressures would need to be considered in design.
- Groundwater drawdown could affect surface water bodies, however, our desktop study has not identified any significant natural surface waterbodies.

In general, a shallow drain could be expected to have less groundwater impact in terms of drawdown (as well as lesser geotechnical issues) however initial indications are that the excavations will be below the groundwater level. Key to understanding the potential risk of consolidation will be understanding the summer low groundwater levels.

Where the excavation is fully within silty soils, the extent of drawdown and associated effects are likely to be more localised, however drawdown in the more permeable sand layers may extend somewhat further.

Uncertainties:

- How far is any drawdown likely to extend from the basins/ channel in the long term?

### 4.2.3 Infiltration Rates

Generally within the Hamilton area, soakage (with storage) is expected to be utilised for on-site management of stormwater where soils are indicated to be of high permeability.

There is limited hydraulic conductivity or infiltration data available for the site (in terms of either existing rainfall recharge at the surface or site specific testing of vertical infiltration rates) however given the shallow depth to groundwater, relatively low permeability and strong rainfall response indicated by short term testing and expected low overall vertical permeability of the upper soils, there is likely to be limited potential for larger scale infiltration of stormwater.

Even where more permeable layers are present at the surface they may be underlain by lower permeability layers which will constrain the rate of any larger scale vertical infiltration. However, where these layers are encountered in basin or channel excavations above the groundwater table some losses of stormwater to the ground through the base and sides, are likely to occur. Whilst this could be of some benefit for stormwater management it could also result in groundwater mounding and associated effects discussed in later sections.

Uncertainties:

- Could water conveyed or stored in channels and basins infiltrate the ground?
- How consistent is the soil profile across the site?

### 4.2.4 Other design considerations

a. Lining of Channels and Basins

As noted above some gains to or losses from the channels could occur. Based on limited monitoring to date the water table is expected to be above the base of the channels/ basins, hence water is expected to discharge from the ground into the waterway(s). It may be necessary to line sections of channels / basins where groundwater infiltration is sufficiently high that it reduces storage capacity or impacts on channel or basin slope stability.

b. Groundwater seepage/infiltration leading to mounding

There is a risk that where stormwater is able to infiltrate through the base or sides of a channel or basin, it could lead to elevated groundwater levels (localised mounding) that reach or exceed the ground surface and result in surface flooding. This would be particularly significant for newly developed low-lying land or overland flow paths. It may be necessary to restrict groundwater infiltration in areas with shallow depths to water and limited freeboard.

## 4.3 Geotechnical Constraints

### 4.3.1 Stability of cuts

A shallow depth to groundwater (and the potential for seepage to reduce the stability of batter slopes) may require lower slope angles which would increase the area of the channel or basin. This is likely to be most significant where deep excavations are planned that are located below the groundwater level and in the more permeable layers.

In these areas there may be constraints on cut slope angle, and/ or maximum depth of excavation.

#### 4.3.2 Lateral Spreading

Lateral spreading occurs when earthquake shaking induces soil to lose cohesion and move, resulting in the soil mass acting like a fluid. Three key elements are all required for liquefaction, and thus lateral spreading, to occur:

1. Loose non-plastic soil (typically sands and silts)
2. Saturated soil
3. Sufficient ground shaking

While a geotechnical evaluation is required to understand the liquefaction potential of the site (and this not within the scope of our work) the soil types that are present at the site are considered potentially susceptible to liquefaction (MBIE, 2017) e.g. quaternary aged soils that are below the groundwater table or are saturated.

Where a wetted base occurs in a swale or basin (either due to ponded or stored water in the base, or, due to being excavated close to or below the groundwater level) the side slopes may be susceptible to lateral spreading, as the underlying material will be saturated and likely to liquefy during an earthquake. This will require specific consideration during further design phases.

## 5 Recommendations

### 5.1 Additional Site Investigation

The existing publically available data, and high level site investigations undertaken by HD Geotechnical, provide a high-level overview of the ground and groundwater conditions at the site and the uncertainties/ issues that might need to be addressed. It highlights some unknowns that are likely to influence the selection and design of the preferred stormwater option.

Preliminary site specific investigations are now required, with the intention to get a better representation of the geological conditions, groundwater levels and permeabilities at the site. This will allow for a higher level of certainty in this assessment.

We suggest that additional investigations be staged, with an initial first group of investigations aimed at confirming ground and groundwater conditions to support option selection. Should further design development than alter the locations of specific features, further site specific investigations may be required as part of design optimisation.

Indicative timings and a rough order of costs for the initial confirmatory investigations are provided for programme / budgeting purposes.

This first group of investigations is aimed at answering the following questions:

- What are the current groundwater levels at the site, and what are the seasonal ranges in water level.
- Are the shallow groundwater levels recorded locally perched? If so, does it matter if they are drained or should / could these areas be avoided?
- What are the permeabilities of the soils

Indicative locations for the confirmatory site investigations are shown below (Figure 5).

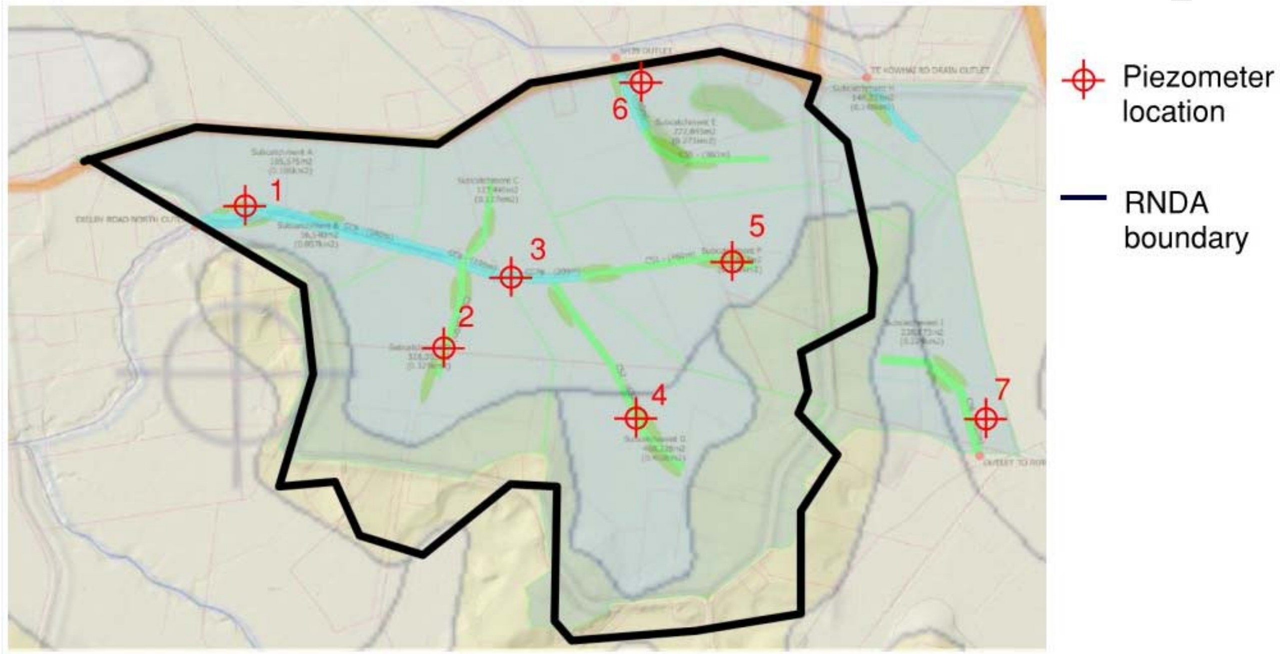


**Figure 5: Indicative (approximate) locations showing ideal piezometer locations relative to the concept catchment plan. Note: the locations shown have not taken into account any real-world / logistical restrictions that maybe encountered on site.**

a. Investigation drilling and installation of piezometers

Boreholes should be completed as piezometers screened at or just below proposed excavation depth and would comprise a minimum of 1 piezometer at each of the locations shown above in order to assess local variability (particularly where the wetland / basin areas are large). It would also be prudent at a selection of locations to install a deeper piezometer immediately adjacent to confirm if the shallow water table identified in the recent investigations is perched. Each site is likely to take 1 – 2 days to drill and complete at an estimated contractor cost of $2,500 per day (not including any geological logging).

Piezometers installed at these locations would ideally be monitored for one year. This will give confidence in the annual groundwater variation and better constrain groundwater levels.

It is recommended that data loggers be installed to record the more detailed variations in groundwater level that will allow better correlation with changes in environmental conditions.

Data loggers could take up to 3 weeks to be shipped (depending on local availability) and we suggest disbursements of $11,000 ex GST for their purchase (assumes 10 No. data loggers) and around $2,500 for installation. This cost allows for all shallow piezometers and two deeper piezometers across the catchment to be monitored continuously with manual monitoring in the remaining deep piezometer.

Once installed the data loggers could be downloaded every 1 to 3 months (at a rough cost of $2,100 per download). Groundwater level data will be available after the first download, with a good feel for winter groundwater levels available by mid to late September 2018. We suggest a first download 2 weeks after installation to check all loggers are operating correctly.

b. In-situ permeability testing in piezometers

Permeability testing will be important to inform the need for lining, and for calculation of inflows and the extent of drawdown or mounding during construction and in the long term. In-situ permeability testing will provide an indication of the horizontal permeability at the site.

We suggest allowance for say 3 days of field work to undertake tests in new piezometers ($4,200). It is likely that such work could be undertaken at the same time as investigations in 5.1.1a (above) to limit cost duplication.

c. Vertical infiltration testing

Should the developer wish to progress with soakage, site specific infiltration testing will be required to confirm the likely capacity of the site. Noting the findings above (that soakage may not be practical) we have not proposed any testing at this time.

d. Grain size distribution analysis

To support the permeability analysis, it is recommended that grain size distribution analysis be completed at key locations to assist in refining the permeability of the soils at the site.

We suggest 12 samples (allowance for 1 to 2 per piezometer site) at a cost of ~$10,000+ GST.

e. Factual reporting of the above

Indicative costs for coordinating the investigation, geological logging and factual reporting are likely to be of the order of $30,000.

## 5.2 Numerical analysis

Previous assessments at Rotokauri have included 2D and 3D groundwater modelling in order to better understand the potential magnitude and extent of groundwater effects. It is recommended that the existing 3D groundwater model for the Rotokauri area be updated to consider RNDA, including results of additional investigations and the effects of the selected stormwater option.

The model can be used to:

- Better understand the overall groundwater catchment
- Assess the magnitude and extent of any drawdown resulting from excavation (for use in consolidation settlement calculations)
- Assess the magnitude of groundwater inflows during construction and in the long term

- Assess the potential for losses through the base and sides of unlined channels / basins and the extent of groundwater mounding.

The model can be developed without the final design solution in mind, and hence could be used to test the effects of different options such that it can also contribute to optioneering and design optimisation.

The existing Rotokauri groundwater model can be updated to include the Rotokauri North Development Area. Depending on the site specific investigations, the model may require re-calibrating. In this case we suggest allowance of $40,000 (for the analysis and reporting) and a period of six weeks to complete. However, it is possible the model will be suffice as is, in which case time and effort could be reduced.

Whilst the model can be developed without the final concept in mind, model construction will be most efficient if undertaken once the bulk of any new site investigations have been completed (in order to avoid rework). We therefore recommend that this work be commenced once the confirmatory investigations have been completed.

## 6 Summary and Conclusion

We understand an optimised Stormwater catchment solution is likely to comprise a central channel associated with a green corridor some 30 m to 70 m wide and up to 2 m deep. Short term groundwater monitoring indicate levels across the site varies between near ground level to some 1.1 m bgl, and so it is anticipated that there will be excavation below the groundwater table in some areas.

Where there are sensitive surface features or settlement sensitive structures, there may be constraints on the depth and extent of excavations in order to reduce the potential for adverse effects. In other areas while there may not be environmental constraints, design or construction issues could include the management of construction inflows (for constructability and slope stability considerations), the need for lining etc. These constraints are consistent with observations and recommendations for Rotokauri.

Additional site investigations are recommended at the specific locations of large or deep excavations to better inform design. Such work should include the updating of the existing Rotokauri 3D groundwater model which can be used for both environmental assessment and design optimisation.

Indicative costs and timeframes have been provided for the additional investigations however we would be pleased to provide a more detailed scope and fee and cost estimate for the suggested additional work as the programme proceeds, and look forward to the opportunity to discuss this with you and the wider team in more detail so that key elements can be prioritised.

Yours sincerely

**Roy Nutsford**
Hydrogeologist

on behalf of

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