RiverLink

Notices of Requirement for Designations and Applications for Resource Consent

Volume Four: Supporting Technical Reports

Technical Report #4

Hydrogeology

IN THE MATTER OF	The Resource Management Act 1991
AND	
IN THE MATTER OF	Resource consent applications under section 88, and Notices of Requirement under section 168, of the Act in relation to the RiverLink project
BY	**Waka Kotahi NZ Transport Agency** Requiring Authority **Greater Wellington Regional Council** Requiring Authority **Hutt City Council** Requiring Authority

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RIVERLINK
TECHNICAL ASSESSMENT # 4
Groundwater

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1. INTRODUCTION

1. My full name is Dr Theodora Avanidou, and I am a Technical Director in GHD's Environmental Group based in Christchurch.

1.1 Qualifications and experience

2. I have the following qualifications and experience relevant to the evidence I shall give:

   i. I hold a Bachelor of Science and Master of Science in Civil and Environmental Engineering (1997) from the Aristotle University of Thessaloniki, Greece and a Master of Science (2000) and Doctor of Philosophy in Groundwater hydrology (2003) from the University of South Carolina USA;

   ii. I have 23 years of experience in civil engineering projects in New Zealand, in Greece, and in the United States of America. Over the last 16 years I have been involved in the design of major highway projects for the Greek Ministry for the Environment, Physical Planning and Public Works and the Waka Kotahi NZ Transport Agency, and

   iii. Of particular relevance to the Riverlink project are the following:

      (a) I have been leading the Mackays to Peka Peka (M2PP) groundwater and settlement monitoring programme during and post construction;

      (b) I have prepared the assessment of effects for a confidential development in Auckland and prepared the monitoring and contingency plan to meet the resource consent conditions;

      (c) I have been assisting Auckland Council to peer review AEEs and supporting technical documents in order to understand effects (drawdown, mechanical and consolidation settlement) on third parties; and

      (d) I have also assessed the potential settlement effects from the construction and operation of the proposed East West Link (EWL) expressway project in Auckland.

1.2 Code of Conduct

3. I confirm that I have read the Code of Conduct for expert witnesses contained in the Environment Court Practice Note 2014. This assessment has been prepared in compliance with that Code, as if it were evidence being given in Environment Court proceedings. In particular, unless I state otherwise, this assessment is within my area of expertise, and I have not omitted to consider material facts known to me that might alter or detract from the opinions I express.

1.3 Purpose and scope of assessment

4. My assessment:

   i. Describes the existing regional and local geological and hydrogeological conditions;

   ii. Describes the proposed construction works that have the potential to affect groundwater environs;

   iii. Describes the methodology for assessing the effects of construction and operation of new infrastructure on groundwater environs, with a particular focus on the Waiwhetu aquifer;

iv. Identifies proposed management and mitigation plans to be implemented during construction works, and

v. Identifies proposed monitoring procedures and locations, if required, during construction phase of the Project.

5. During this assessment I have conferred with the following technical experts for the Project: Andrew Whaley – Construction lead, Geoff Farquhar – Geotechnical lead, Andrew McMenamin Structures lead, and Christian Vossart – Noise and Vibration lead.

2. EXECUTIVE SUMMARY

2.1 Existing Environment

6. This brief presents the results of my groundwater assessment of the potential effects due to construction and operation of the proposed Riverlink Project.

7. Preliminary site ground investigations which are summarised in the Geotechnical Interpretive Report (GIR) (attached as Appendix C to the Natural Hazards and Geotechnical Technical Assessment #15) and a review of published work (Begg and Mazengarb, 1996; Begg and Johnson, 2000; Begg, 2020) were undertaken to define the underlying geology and hydrogeology within the Project Area.

8. The Lower Hutt valley is a wedge-shaped, fault-bound, sediment-filled basin adjacent to Wellington Harbour. Gravel-rich layers in a thick sequence of alluvial and glacial outwash sediments host a significant groundwater resource. Stevens (1956) subdivided the Hutt Formation into six geological units: Taita Alluvium, Melling Peat, Petone Marine Beds, Waiwhetu Artesian Gravels, Wilford Shell Bed and Moera Basal Gravel.

9. The Hutt River plays a significant role in the hydrogeology of the Lower Hutt groundwater basin, as it is the main recharge source to the underlying aquifer system. The Taita Alluvium and the Waiwhetu and Moera aquifers are recharged by losses from the Hutt River in the upper catchment where the aquifer is unconfined (upstream of Boulcott) (EIM, 2014).

10. The Waiwhetu aquifer is considered to be a sensitive aquifer as it is utilised for potable water supply. Within the general Project area the Waiwhetu aquifer is considered to be confined, which means that it has a natural level of protection from activities at the land surface due to the low permeability soil layer (aquiclude) that overlies the aquifer unit. There is limited geological data to confirm the extend and thickness of the aquiclude near the Kennedy Good Bridge area. Pumping from the Waiwhetu aquifer at the nearby Waterloo well field by Wellington Water Ltd (WWL) can generate downward vertical hydraulic gradients between the water table in Taita aquifer and the Waiwhetu aquifer. This inversion of the vertical hydraulic gradients can increase the vulnerability of the Waiwhetu aquifer to surface-derived contamination. However, it is noted that the short-term temporal changes in vertical hydraulic gradient pose a lessor risk to aquifer contamination when compared to the numerous private wells that are installed in the general vicinity of the works and the Waterloo bore field radius of influence (particularly during a flood event or intense rainfall events). For these reasons, it is important that the Waiwhetu aquifer is recognised as a sensitive aquifer and as such appropriate steps are taken in the Project planning, construction and operation phases to mitigate the potential for contamination that could be created by the Project activities.

2.2 Proposed works

11. The Project is to construct, operate and maintain Riverlink. Proposed works that will intercept groundwater include:

    i. Earthworks for a revised river channel and stopbank design to accommodate a greater flood flow;

    ii. Earthworks and ground improvement for the construction of an interchange on SH2 at Melling and new local road connections and layouts;

    iii. Earthworks and ground improvement for the construction of the new Melling bridge and pedestrian bridge over Te Awa Kairangi with piles that penetrate the Waiwhetu aquifer; and

    iv. Relocation of network utilities, upgrades of culvert outlets and stormwater pump stations.

2.3 Potential Effects from Proposed Works and Mitigations

12. Gravel extraction from the channel and excavation and fill in the upper and lower berms are to occur between Kennedy Good and Ewen Bridges (riverbed reprofiling). The gravel extraction works are a combination of lowering the riverbed and widening the channel with protected banks, using either riprap or planting for berm protection.

13. During and immediately following the proposed riverbed reprofiling (gravel extraction), ongoing seepage of shallow groundwater from the Taita aquifer to the river within the Project area is expected to occur when the river stage is lower than the groundwater levels in the Taita Alluvium (i.e. during low flow in the river). Steady state two-dimensional groundwater modelling has been undertaken to quantify the increase in discharge rate and the groundwater drawdown extent during low flows from the deepened riverbed. The assumptions, data used, and detailed modelling results are presented in **Appendix B.**

14. The results of the modelling (presented in **Appendix B**) indicate the rate of seepage to the river may increase between 0.1 and 0.4 m^3/day per metre of river length when compared to current discharge rates which reflect the present riverbed elevation and average groundwater levels as monitored in the project's piezometers (September 2020-April 2021). The modelling results also indicate that the proposed lowering of the riverbed will not result in reduced yield in the Waiwhetu aquifer. The model results indicate that the groundwater exchange between the Waiwhetu to Taita aquifers, and then to the river, under very conservative assumptions is calculated to increase by approximately 71 m^3/day to 210 m^3/day across the full length of the proposal, which includes the potential recharge losses from Taita Alluvium. This represents a very small percentage of the total aquifer volume and pumped daily rates from Waterloo wellfield. These small additional "groundwater losses" from the shallow Taita alluvium to the river are likely to be reduced with time' as fines and gravels will be re-deposited.

15. Furthermore, modelling results indicate a small drawdown of the groundwater level in the order of 0.25 m within 75 m is from the excavation is estimated. This change is within the seasonal range of groundwater levels (1-2 m in the shallow Taita Alluvium) and no adverse effects are expected on groundwater levels and groundwater flow direction from the proposed works. For a 300 m river section, shallow drawdowns can be larger and up to 0.50 m at some 100 m from the riverbed reducing to 0.25 m approximately 200 m from the excavation. In all cases considered the effects on the Waiwhetu aquifer water levels are very small (less than 1 cm).

16. The groundwater – river interaction is complex and the Taita aquifer within the Project area may be recharged by the Hutt River during high river water levels (e.g. flood events). Therefore, management of the river water quality during construction is expected to minimise any potential to affect the groundwater quality in the shallow aquifer. However, it is important to recognise that flood events which already occur in the river naturally will recharge the shallow aquifer with water which has increased turbidity associated with the flood event. Details on suspended sediment concentration for different flow events are discussed in technical report #3. Furthermore, Technical report #3, includes a draft overarching Erosion and Sediment Control Plan (ESCP) to articulate the strategy to avoid, remedy or mitigate the potential effects of erosion and sediment discharges to the receiving environment. The ESCP will be updated, and a Site-Specific Erosion and Sediment Control Plan (SSESCP) will be prepared for particular construction activities to ensure measures are tailored to the location, unique constraints and different teams of people involved. In addition, a Chemical Management Plan (CMP) has been prepared and is appended to Technical Report #3 to set out the procedures and practise for use of chemical flocculant at structural treatment devices.

17. Modelling results (presented in **Appendix B**) indicate that under river "flood" conditions with simultaneous high pumping at the Waterloo well field, "river losses" to groundwater are expected to increase by up to 0.4 m^3/day per linear m when compared to the existing state. Most of the "river losses" are expected to be to the Taita Alluvium, with only 61 m^3/day and up to 85 m^3/day additional flow expected to reach Waiwhetu (i.e. ~1 L/s). The additional inflow rate is considered to be negligible and immeasurable when compared to the Waiwhetu aquifer volumes of water and the broader recharge to the aquifer system from the river upstream of the site (which is in the order of 60,000 m^3/day to 100,000 m^3/day). Therefore, I do not anticipate any measurable change to the Waiwhetu water quality properties (turbidity, pH, DO, hardness) at the Waterloo bore field that could be attributed to the proposed works.

18. To provide a level of comfort to the relevant stakeholders regarding the effects on water quality and quantity from the proposed works, it is recommended that monitoring of the shallow and deep groundwater levels and groundwater quality (including turbidity, pH, Dissolved Oxygen (DO), hardness, Ecoli) in the vicinity of the Project be undertaken pre-construction, during and post-construction through the existing and proposed additional telemetered piezometers and in accordance with the attached in **Appendix D** draft Groundwater Management Plan (GMP) to confirm the assessed envelope of effects.

19. I understand that Wellington Water Limited (WWL) is in the process of commissioning a regional 3-dimensional groundwater model, to update the previous regional model (referred to as the HAM3 model). I also understand that the objective of this modelling exercise is to provide a more updated understanding of the Waiwhetu aquifer dynamics to improve management of the resource. I consider that there may be some merit to interrogate the new model, once calibrated and verified, to overlay the proposed changes in river morphology to confirm implications of the works on the regional water balance. However, in my experience, there is a high likelihood that the structure and scale of the regional groundwater model may not be suitable to provide the resolution required to further refine my conservative assessment. That said, I note that the regional model will have a better chance of being useful for this project if some additional monitoring wells are installed adjacent to the works area. These additional monitoring wells have been discussed with WWL, and I understand that WWL will consider this detail in the construction of the regional model. If pre-construction monitoring results or additional site investigations and/or additional modelling undertaken by Wellington Water Limited (WWL) indicate different site conditions than those assumed here which are likely to result in an

increase in effects to the groundwater system, then this assessment should be updated to confirm the assessed envelope of effects.

20. Once the river channel is widened no additional effects on groundwater are anticipated during the operation of the Project. The construction of the stopbanks and berms are not expected to affect the current groundwater flow direction or significantly alter the river/groundwater interaction.

21. The proposed construction methodology for the piles that will penetrate the confining layer and into the Waiwhetu aquifer, and specifically the use of double casing methodology and sealing (grouting) around the casing of the aquiclude, is considered a robust and proven construction methodology to address the potential quality and quantity risks to groundwater. A similar methodology was successfully applied in the past (1995) during the construction of the Ewen Bridge piles in the same river (Graham Ramsay, 1995; Ramsay and Marshall, 1995). Therefore, I expect that the proposed methodology will be suitable to manage the risks of leaching and or leaking water from and to the Waiwhetu aquifer.

22. However, I consider that the pile construction methodology should be reviewed once geology is confirmed (following drilling) at the locations of the piles and updated if required. The localised geology could influence the construction method, such as the extent and depth of aquitard and/or Waiwhetu gravels. I would expect that any updates on the methodology and technical justification should be submitted to GWRC (in its consent authority capacity) for certification before commencement of pile construction. This approach is considered to be best practice in terms of ensuring that the proposed construction methodology is aligned to the in-situ ground conditions.

23. Monitoring is proposed to record groundwater levels and monitor groundwater quality (including turbidity, pH, Dissolved Oxygen (DO), hardness, Ecoli) prior to, during, and following construction of the piles. This will allow actual changes to groundwater to be checked against those estimated, and appropriate responses to be implemented, if needed.

24. No adverse effects from the bridge piles are anticipated during the operation of the Project. The piles are of limited extent spatially, and hence groundwater flow will re-establish around them, and they will not impede the groundwater flow. Modelling results (presented in **Appendix B**) indicate that the placement of piles creates a very small mounding effect (<0.01 m) within each of the piles. The introduction of the piles causes groundwater to flow around each pile before resuming flow in the normal flow direction. No additional long-term effects on groundwater are anticipated from the bridge piles.

25. The existing Melling bridge will be deconstructed (removed) to the riverbed level. Existing bridge piles will be cut to riverbed level. This will minimise/eliminate disturbance of the underlying aquifers. Therefore, I consider there are no effects on groundwater quality or quantity expected.

26. I expect that during detailed design when the location and excavation depths for network utilities, culvert outlets, and stormwater pump stations are confirmed, additional hydrogeological investigations will be undertaken near the proposed excavations to define any dewatering requirements. A dewatering assessment and an assessment of potential settlement effects should be undertaken prior to construction to update and finalise the Construction Environmental Management Plan (CEMP).

27. Any dewatering activities are expected to be managed with standard construction practices to minimise the potential of adverse effects on groundwater and adjacent structures. The attached draft GMP should be updated to include additional groundwater and settlement monitoring if required. Any short-term dewatering for the Project will not affect the long term overall shallow groundwater flow direction.

28. Given the small scale, magnitude and extent of changes identified I consider the potential adverse effects of the Project on groundwater overall to be minor. Any potential effects can be appropriately addressed through the standard-practice management measures (including the draft GMP) I have recommended to be finalised and included as part of the overall Project CEMP.

3. PROJECT DESCRIPTION

3.1 Introduction

29. A detailed Project description is available in the Assessment of Environmental Effects Report ("**AEE**"). The following section relies on excerpts of the AEE relevant to the assessment of potential effects on the groundwater system.

30. RiverLink's three separate but interdependent projects include:

    i. Flood Protection (GWRC) - widening Te Awa Kairangi/Hutt River channel and berms and raising the height of the stopbanks

    ii. Urban regeneration (HCC) - urban renewal and regeneration through improved access from the CBD to and alongside the river through the creation of a promenade, a new pedestrian bridge, a riverside park and enabling attractive supporting development, and

    iii. Melling Intersection Improvements (Waka Kotahi) - a new grade separated interchange and river bridge at Melling, new intersections with local roads, enhanced pedestrian and cycle routes and better public transport integration at a new Melling Railway Station (to replace the existing Melling Station).

31. The Project area is shown in my Figure 1 below.

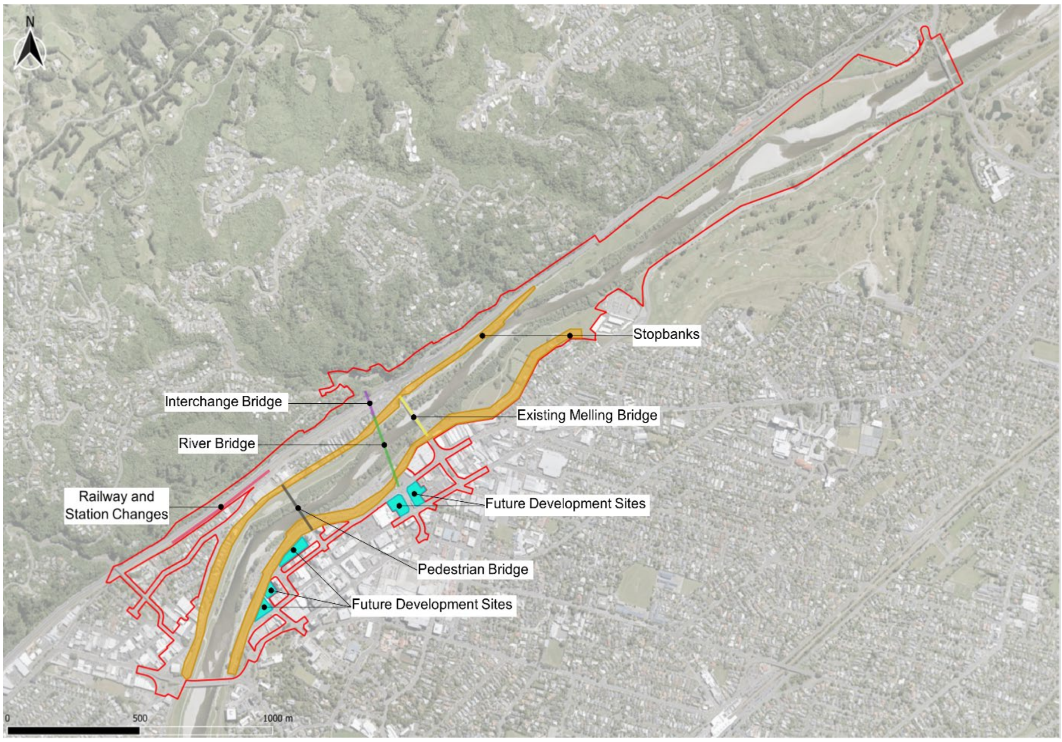

Figure 1 Project area plan

32. The key components of the Project are as follows:

i. Upgrade and raising of the existing stopbanks and construction of new stopbanks on both sides of Te Awa Kairangi/Hutt River, between Ewen Bridge and Mills Street.

ii. Instream works between the Kennedy Good and Ewen Bridges to realign and widen the active river channel.

iii. The replacement of the two signalised at-grade intersections of SH2/Harbour View Road/Melling Link and SH2/Tirohanga Road with a new grade separated interchange.

iv. Construction of an approximately 215 m long and up to 7-span road bridge with a direct connection across the River from the new interchange to Queens Drive.

v. Removal of the existing Melling Bridge.

vi. Changes to local roads.

vii. Changes to the Melling Line rail network and supporting infrastructure.

viii. Construction of an approximately 177 m long and 4-span pedestrian/cycle bridge over the river.

ix. Construction of a promenade located along the stopbank connecting with future development, running between Margaret Street and High Street. This includes new steps and ramps to facilitate access between the city centre and the promenade.

x. Integration of infrastructure works with existing or future mixed-use development.

xi. Associated works including construction and installation of culverts, stormwater management systems (treatment wetlands), signage, lighting, landscaping, landscape and street furniture, pedestrian/cycle connections within the Project area, and maintenance facilities.

3.2 Other matters

33. My opinions, conclusions and any recommendations are based on information set out in section 4, which describes my understanding of the regional and local geology and hydrogeology of the project area. In particular, as is standard practice at this stage of a project, information has to be extrapolated from specific sample points. I have applied my expert assessment when undertaking such extrapolations but more detailed investigations during detailed design, and actual construction, will be required to better define site conditions and confirm the envelope of effects as currently assessed across the Project area. Site specific investigations undertaken in respect of this report are constrained by the particular site conditions, such as the location of buildings, services and vegetation. As a result, not all relevant site features and conditions may have been identified in this report.

34. Any numbers, area or dimensions outlined in this report are approximate and may change because of detailed design. The final design of the project (including the design and location of components such as stormwater pump stations or treatment devices) will be refined and confirmed at detailed design stage.

35. Effects on river water quality from the construction and operation of the Project are dealt with separately by Mr Ed Breese (Technical Assessment Report #3).

36. My assessment is also based on information for the Hutt River catchment detailed by Mr Gary Williams (Technical Assessment Report #5), information contained in the Design Philosophy Statement, the Preliminary Site Investigations report discussed by Mrs Sarah Schiess (Technical Assessment Report # 13) and the Construction Water Quality and Erosion Sediment Control (Technical Assessment Report #3).

37. The following supporting information is attached to this report:

    i. Appendix A – Groundwater level monitoring data

    ii. Appendix B - Groundwater Users

    iii. Appendix C – Groundwater Modelling Assumptions and Results,

    iv. Appendix D – Draft Groundwater Management Plan

    v. Appendix E – Turbidity Data – Waterloo Wellfield and

    vi. Appendix F – References.

4. EXISTING ENVIRONMENT

4.1 Planning and policy context

38. The following national statutory and non-statutory documents apply to this Project:

    i. Resource Management Act 1991 (“RMA”), and

    ii. Proposed National Environmental Standard for Sources of Human Drinking Water.

39. The following regional and district level statutory and non-statutory documents apply to this Project:

    i. Proposed Natural Resources Plan (pNRP)

    ii. Regional Freshwater Plan, and

iii. Hutt River Flood Management Plan.

4.2 Hutt River

40. Te Awa Kairangi/Hutt River is a steep alluvial river that starts in the Southern Tararua Range, flows through the Hutt Valley and discharges to the Petone foreshore on Wellington Harbour. The Hutt River has a total length of 54 km and a catchment area of approximately 655 km^2. From the headwaters to the Kaitoke floodplain the river flows primarily over bedrock. As the grade reduces through the Upper Hutt floodplain the river transitions into a braided form with a gravel bed overlaying bedrock.

41. The river has been managed and modified in its lower reaches within the Hutt Valley for over 100 years. Today, the river undergoes a series of twist and turns as it emerges from the foothills of the Kaitoke floodplains, before running in parallel with Wellington Fault and discharging into Wellington Harbour.

42. A 25-year flood event in the Hutt River on 6 January 2005 resulted in higher than anticipated flood levels in the Hathaway Avenue area. It was believed that the increased flooding was partly due to the increased riverbed levels in the reach between Melling and Kennedy Good Bridges (GWRC, 2009). The GWRC (2009) report stated that the gravel balance between Ewen Bridge and Kennedy Good Bridge indicated an annual gravel supply rate of 39,861 m^3/year.

43. The Hutt River plays a significant role in the hydrogeology of the Lower Hutt groundwater basin as it is the main recharge source to the underlying aquifer system. The Taita Alluvium and the Waiwhetu and Moera aquifers are recharged through Hutt River in the upper catchment where the aquifer is unconfined (upstream of Boulcott) (EIM, 2014).

44. The river - groundwater interaction within the shallow Taita Alluvium aquifer is complex, but generally the Hutt River loses water (recharges) to the underlined aquifers in the area between Taita Gorge and Boulcott/Kennedy Good Bridge (EIM, 2014).

45. Between Boulcott and the coastline the Waiwhetu aquifer is likely semiconfined /confined and the groundwater within the Taita alluvium discharges to the river. Furthermore, the river is tidal up to Ewen Bridge (EIM, 2014).

46. An interpreted extent of the onshore unconfined -semiconfined -confined Waiwhetu aquifer is presented in Figure 2 (WWL, 2020).

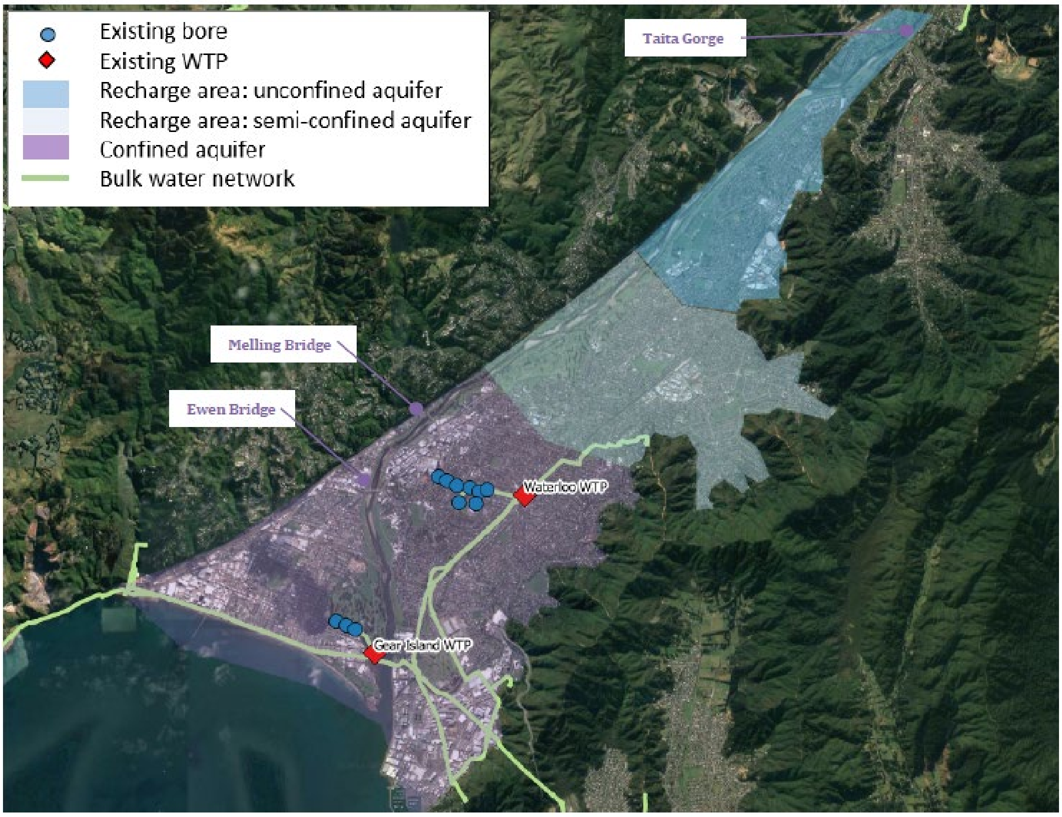

Figure 2 Plan view of the interpreted extent of the onshore unconfined/ confined Waiwhetu aquifer (excerpt from WWL, 2020 report)

47. The river flood capacity is actively managed by GWRC through gravel extraction at specific locations and in accordance with the current consent conditions and the Hutt River Floodplain Management Plan (HRFMP). The objective of the current gravel extraction consent WGN130264 (River management activities for flood protection, erosion control and public amenity purposes) is to maintain the river channel within its design channel alignment as defined in the HRFMP (1998 design levels) and the mean bed levels (MBLs) to a design profile that maintains a balance between flood capacity, channel asymmetry and erosion potential.

48. Specifically, resource consent WGN130264 (expires 27 May 2055), permits the following river management activities in the bed and on the banks, berms and stopbanks of Te Awa Kairangi/Hutt River: for flood protection, erosion control and public amenity purposes:

i. Temporary or permanent diversion of River flows as a result of river management for flood protection

ii. Extraction of gravel from the riverbed using wet and dry methodologies, and

iii. Discharge of sediment-laden stormwater resulting from the above river management activities.

49. River cross section surveys are conducted about every five years to monitor gravel mobility and river flood capacity.

4.3 Regional Geology and Hydrogeology

50. In order to understand the groundwater systems, an understanding of the regional and local geology of the Project area is needed.

51. The geology of the Hutt Valley has been investigated previously, and a summary is included in the 1:50,000 geological map (Begg and Mazengarb, 1996) in the 1:250,000 scale “Qmap” (Begg and Johnson, 2000) and in Begg, 2020. Figure 3 below presents the geological map of the Project area, after Begg and Mazengarb, 1996. The geology is also discussed within the Geotechnical Interpretive Report (GIR) of the Project (attached as Appendix C to the Natural Hazards and Geotechnical Technical Assessment #15). A general description of the geology based on these references, is summarised below (paragraphs 57 - 64).

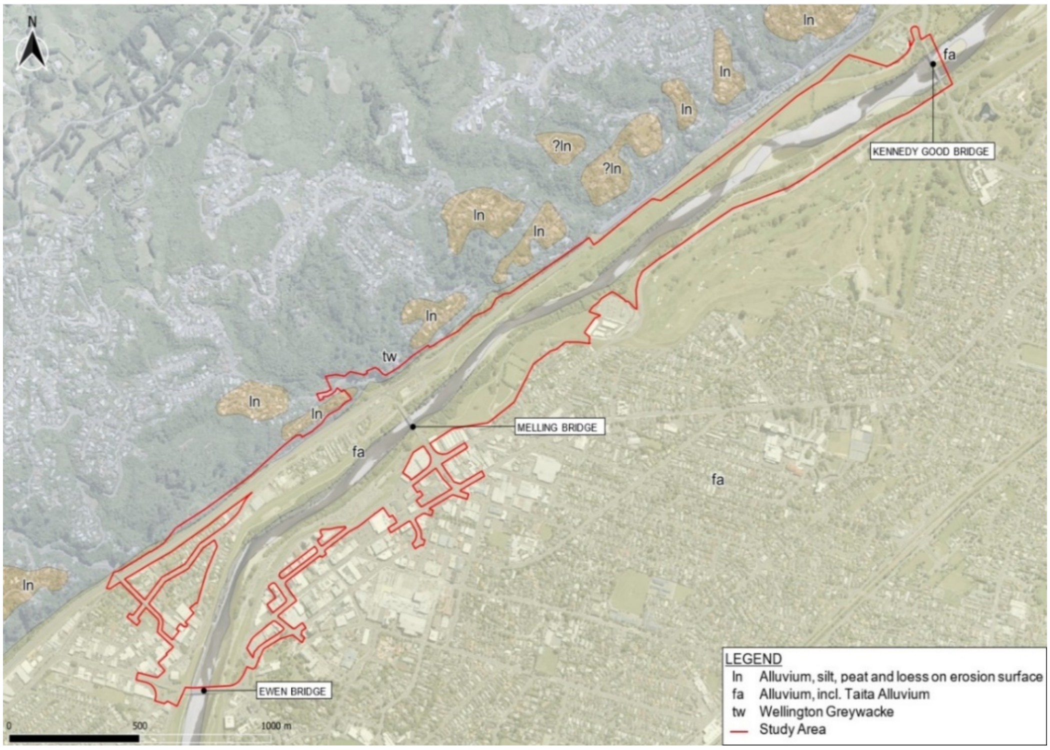

Figure 3 Geological map of the Project area

52. The Hutt Valley – Wellington Harbour alluvial basin is the southernmost and largest of a series of basins that have developed along the south-eastern side of the active Wellington Fault.

53. The Lower Hutt valley is a wedge-shaped, fault-bound, sediment-filled basin adjacent to Wellington Harbour. Sediment fill thickness is ~ 350 m near the Petone foreshore where the basin is 5 km wide and shallows to ~0 m at Taita Gorge, 12 km to the northeast where the basin is less than 1 km wide.

54. Gravel-rich layers in a thick sequence of alluvial and glacial outwash sediments host a significant groundwater resource. Stevens (1956) subdivided the Hutt Formation into six geological units: Taita Alluvium, Melling Peat, Petone Marine Beds, Waiwhetu Artesian Gravels, Wilford Shell Bed and Moera Basal Gravel.

55. A conceptual model of the Lower Hutt hydrogeology is shown in Figure 4. The Taita Alluvium is not labelled, but it comprises the uppermost light blue layer that overlies the orange shaded Petone Marine Beds.

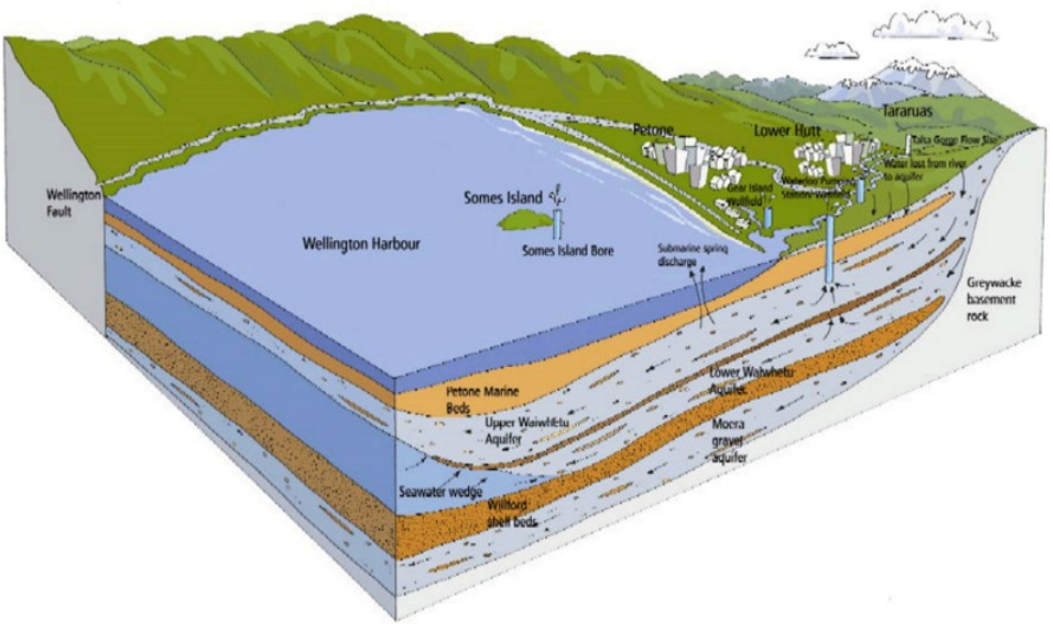

Figure 4 Conceptual 3D model of the Lower Hutt Groundwater zone

(http://www.gw.govt.nz/assets/Our-Environment/Water-Supply/PDFs/Hutt-groundwater-diagram.jpg)

56. The Waiwhetu Aquifer is an extensive alluvial gravel layer that provides a significant proportion (40% -70%) of the annual municipal water demand for the Wellington Region (WWL, 2017).

57. The Taita Alluvium is more laterally extensive across the Hutt Valley. It comprises coarse fluvial deposits with moderate to high permeability and forms an unconfined aquifer above the Waiwhetu aquifer.

58. The Melling Peat and the Petone Marine deposits also extend across the width of the Hutt Valley but pinch out up-valley near the Kennedy Good Bridge where the Taita Alluvium overlies the Waiwhetu Aquifer directly (Figure 3).

59. A 3-dimensional geological model that can be used to take off long-sections and cross-sections for both geotechnical and groundwater analysis has been developed by Greater Wellington Regional Council (GWRC), (Begg, 2020). Access to the online model was provided to the Project team by GWRC and the model was used to interrogate geologic and hydrogeologic conditions within the project area.

4.4 Local Geology and Hydrogeology

60. The Project area is located within Lower Hutt City, along the lower reaches of the Hutt River between the Kennedy-Good Bridge and the Ewen Bridge (Figure 1).

61. The geology of the Project area is described and discussed in Section 2 of the Geotechnical Interpretive Report for the Project (Tonkin & Taylor (T&T), 2020). The GIR also includes details of historical and recent site investigations and testing undertaken to characterise the local geological and hydrogeological conditions.

62. I have summarised the key information contained in the GIR, which I rely on in forming my opinion on the potential nature and scale of adverse effects, in the following paragraphs. The GIR report and drawings are attached as Appendix C to the Natural Hazards and Geotechnical Technical Assessment #15.

63. Geological formations relevant to the Project area include Taita Alluvium overlying Petone Marine Beds and Melling Peat. Underneath is the Waiwhetu Artesian Gravels (Aquifer). Figure 5 presents the conceptual model of the stratigraphy of the Lower Hutt Valley as presented in Begg and Morgenstern (2017) and Begg (2020) illustrating the sequence of the geological layers expected in the Project area.

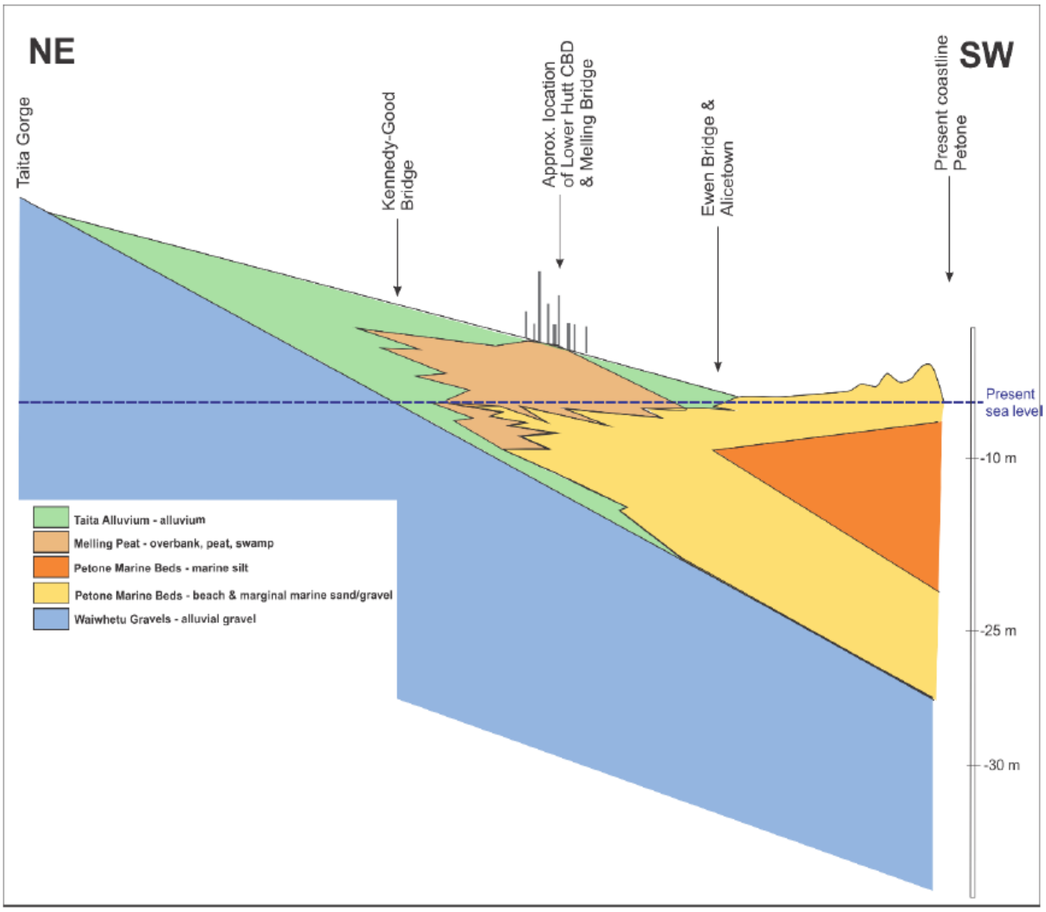

Figure 5 Conceptual model of stratigraphy of the Lower Hutt valley (extract from Begg, 2020)

64. As noted above, below the Waiwhetu Aquifer there are older sedimentary deposits such as the Moera gravels (shown in Figure 4). However, I consider that these deposits are unlikely to be relevant to the Project and my assessment of potential effects on the groundwater system due to their depth.

65. Project specific subsurface investigations, local *in-situ* testing and laboratory testing, and groundwater level monitoring have been carried out over a period of two years. Project investigations included:

i. 7 Machine drilled boreholes

ii. 29 Cone Penetration Tests

iii. 3 standpipe piezometer installations

iv. 5 Vibrating wire piezometer installations, and

v. 1 Permeability (Falling head) Test (BH18-15 screened in the Taita Alluvium).

66. During the site-specific investigations (Stantec, 2019 and 2020; T&T, 2020) shallow groundwater was encountered between 0.7 m bgl (BH18-15) to 3.5 m bgl (BH19-2) on the left side of the river and 1.2 m bgl (BH18-1) to 2.5 m bgl (BH18-16) on the right bank of the river at the Project area.

67. GWRC maintain a groundwater level and water quality monitoring network for the Lower Hutt Groundwater zone (Figure 6). Near the Project area, the GWRC monitoring wells are monitoring water levels in the Waiwhetu and the deeper Moera gravels. The data from this monitoring network and data from the Project investigations were reviewed to gain an understanding of the groundwater and surface water systems within the proposed area of works.

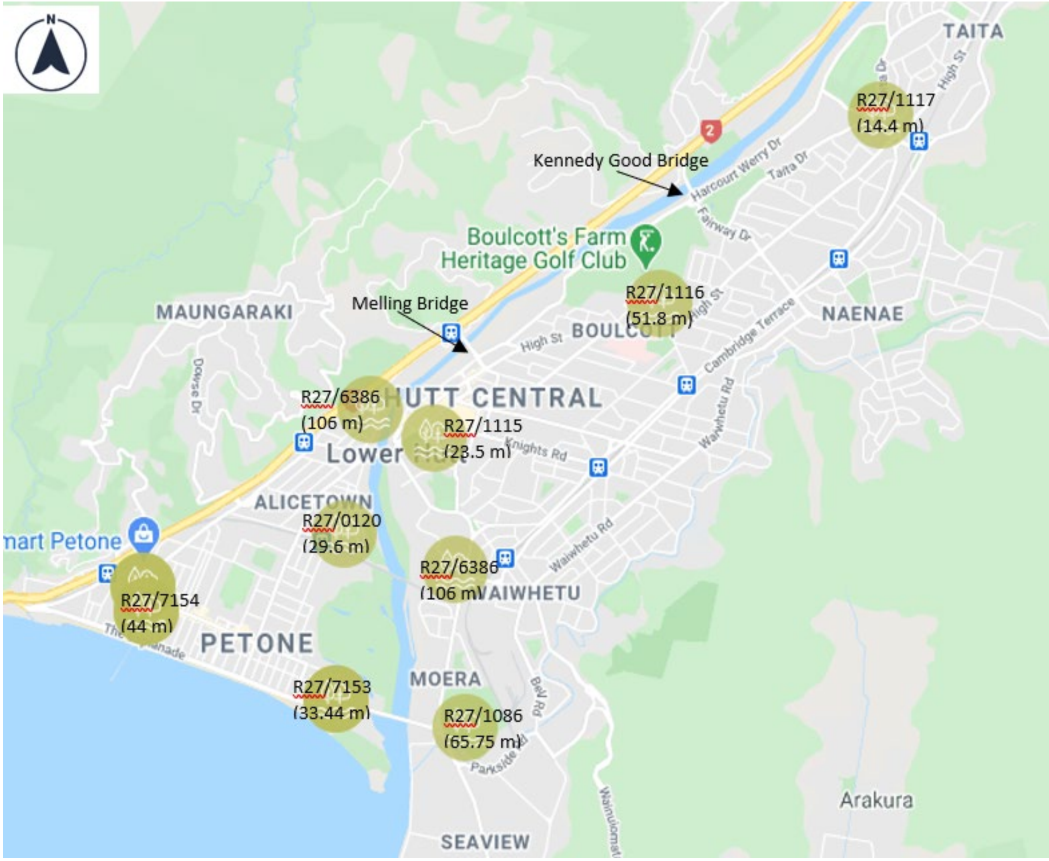

Figure 6 Location of GWRC groundwater level monitoring points (well ID and well depth shown in the parenthesis)
(not in scale from http://graphs.gw.govt.nz/)

68. At the Project area continuous telemetered groundwater level monitoring has been undertaken since September 2020 in five locations as shown in Figure 7. Table 1 summarises the current (April 2021) instrumentation and groundwater monitoring at the Project area.

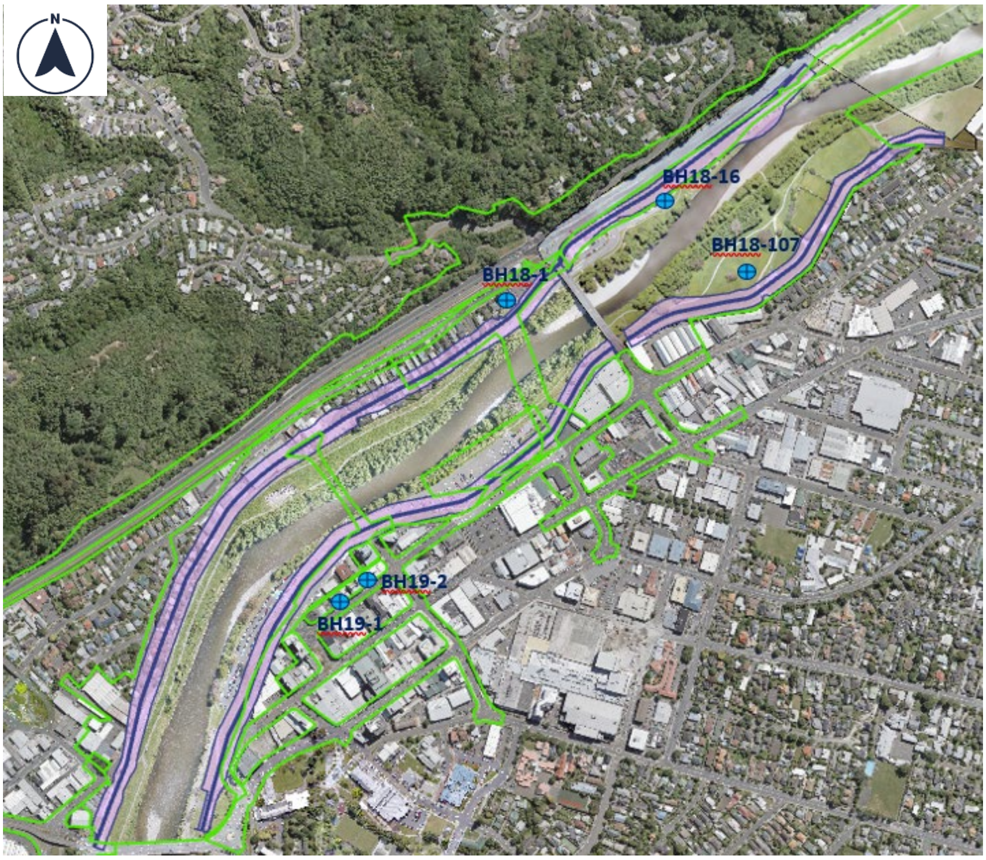

Figure 7 Project's Telemetered Piezometers Location Plan (not in scale)

Table 1 Summary of current (April 2021) instrumentation and groundwater monitoring at the Project area

ID	Type	Ground surface elevation[1] RL (m)	Screen / vibrating wire installation depth (m bgl)	Geological unit
BH18-1	Vibrating Wire Piezometer	7.89	17	Taita Alluvium
BH18-107	Standpipe Piezometer	6.5	3.0 – 4.0	Taita Alluvium
BH18 -16	Standpipe Piezometer	6.5	4.5 – 7.5	Taita Alluvium
BH19-1	Vibrating Wire Piezometer	5.0	11, 15 and 24	Taita Alluvium, and Waiwhetu Aquifer
BH19-2	Standpipe Piezometer	4.5	7.5 – 11.5	Taita Alluvium

[1] Elevation based on Hutt City LiDAR 2016 in terms of Wellington 1953 vertical datum

69. The local groundwater levels within the shallow aquifer (Taita Alluvium) and the underlying Waiwhetu Gravels were reviewed to determine the potential hydraulic interaction between the river and the groundwater system. This included an assessment of the potential vertical movement of water between the shallow unconfined system and the confined Waiwhetu Gravel aquifer.

70. Groundwater level monitoring data collected from the Project's piezometers (standpipes and vibrating wire piezometers) are presented in **Appendix A**.

71. The long term and short-term monitoring records indicate that groundwater levels in the Taita Alluvium are influenced by rainfall and by the water level of the Hutt River (as shown in Figure 8).

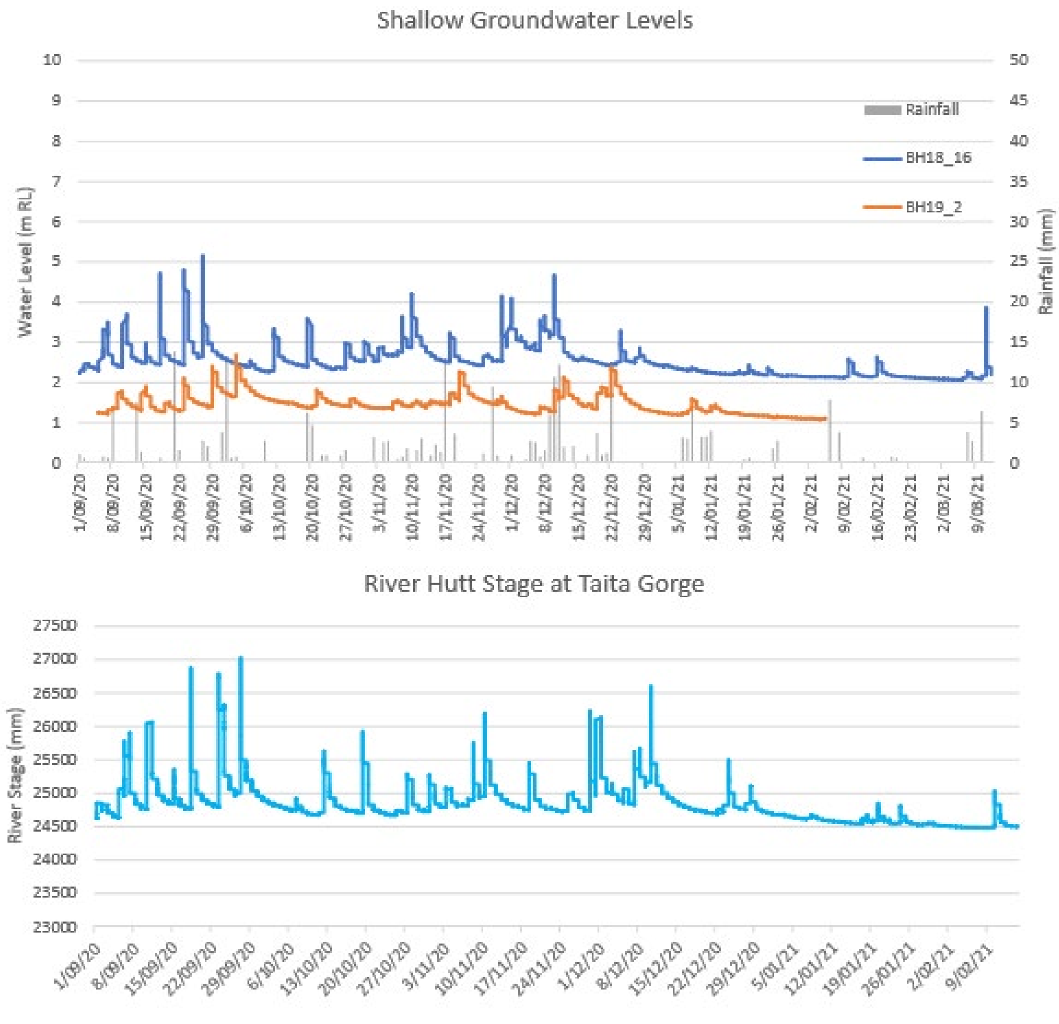

Figure 8 Shallow groundwater levels plotted with rainfall (recorded in central Hutt city) and Hutt River water level recorded at Taita Gorge (upgradient of the Project site)

72. The long-term historical groundwater level variation between summer low elevations and winter high elevations in Taita Alluvium is approximately 1 – 2 m (based on data from GWRC's monitoring well R27/1117[1] monitored between 1969-2021).

[1] http://graphs.gw.govt.nz/?siteName=R27/1117&dataSource=Stage .

73. Groundwater in the Taita Alluvium close to the Project area ranges between 0.7 m bgl (BH18-15) to 2.7 m bgl (BH19-2) on the left side of the river and 1.2 m bgl (BH18-1) to 2.5 m bgl (BH18-16) on the right bank of the river.

74. Based on groundwater level monitoring in project's piezometers, our conceptual geological and groundwater model, the regional geological model, the numerical groundwater model results (EIM, 2014) and historical concurrent flow gauging (EIM, 2014) in the river within the Project area (Kennedy Good Bridge to Ewen Bridge), the shallow groundwater within the Taita Alluvium near the project area is expected to mainly flow towards the Hutt River (Figure 9).

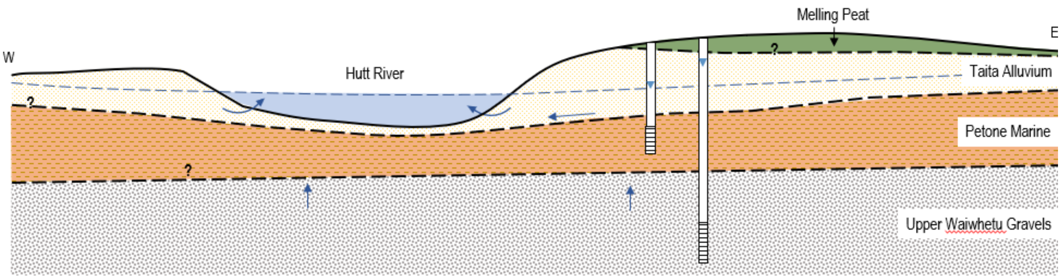

Figure 9 Conceptual groundwater model

75. Previous groundwater modelling and long-term groundwater level monitoring undertaken by GWRC indicate that groundwater levels in the Upper Waiwhetu Aquifer are influenced by river recharge and groundwater abstraction, as well as by tidal pressure effects. For that reason, the system is complex, and it is difficult to assess the natural groundwater level variability of the Waiwhetu Aquifer (EIM, 2014).

4.5 Groundwater users

76. The GWRC open database[2] for wells and bores within 2 km of the project area and associated water use resource consent was accessed March 2020 and cross checked. The search did not identify any water use consent associated with wells screened in the Taita Alluvium. Well details and existing water use consents are summarised in Tables C1 and C2 and their location is shown in Figure C1 presented in **Appendix C**.

77. Eight municipal water supply wells located along the "Knights Road spine" (known as Waterloo wellfield) are approximately 520 m – 1250 m south / south-east of the Project site. The water is treated and used for supply to Hutt City and Wellington. The well locations (Waterloo bore field) are shown in Figure 10. The wells are all approximately 40 m deep and screened in the Waiwhetu aquifer (WWL, 2017).

[2] https://data-gwrc.opendata.arcgis.com/datasets/wells-and-bores and

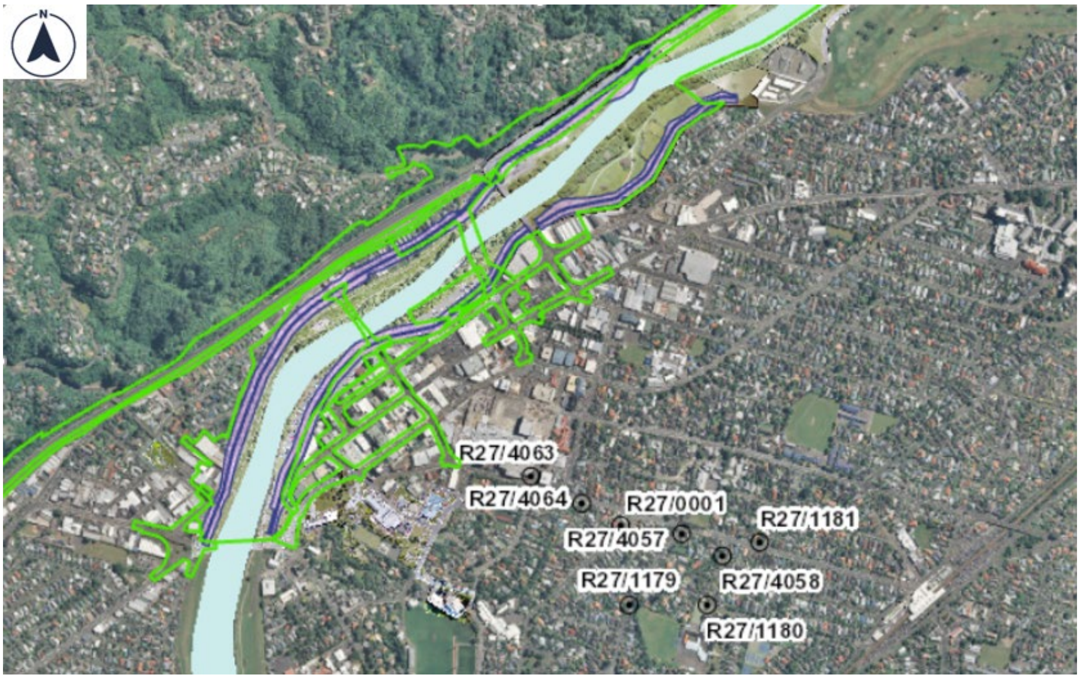

Figure 10 Location plan showing the Waterloo bore field

(https://maps.huttcity.govt.nz/portal/apps/webappviewer/index.html?id=c59391794322466388820d2a5b0ae183)

78. Within the bore field and for a big proportion of the Project area (approximately from Melling Bridge to Ewen Bridge) the Waiwhetu aquifer is expected to be confined and the aquifer water has an upward hydraulic gradient (when not pumped). This is supported by artesian pressures measured in project's piezometers BH18-1 and BH19-1 (location is shown in Figure 7).

79. If a bore is screened in a confined aquifer, the water level that will be established in the bore is above the upper surface of the aquifer. This condition is known as artesian, and it usually means that the aquifer water is inherently protected from any surface derived contamination because the gradient opposes any leaching downward into the aquifer water. Pumping from an artesian aquifer can change the natural vertical hydraulic-gradient and create a downward flow gradient (i.e. a negative vertical gradient; the gradient value will be negative since groundwater flows from high head to low head). If this occurs, the Waiwhetu aquifer would be more susceptible to contamination.

80. Modelling of pumping scenarios has been undertaken recently by EIM (2020) using the Hutt Aquifer Model (HAM3) groundwater model to analyse the negative vertical (downward) flow gradients in the Waiwhetu aquifer for the definition of delineation areas and setback zones that may impact groundwater quality in the Waiwhetu aquifer (T&T, 2020).

81. The modelled vertical groundwater head differences around the Waterloo Wellfield during pumping since 2002 are illustrated in Figure 11 below. The authors of the figure note that that negative vertical gradients were not encountered often when pumping at historic rates and were attributed to a combination of rainfall/river recharge and elevated groundwater levels in the Taita Alluvium (EIM, 2020). However, a negative hydraulic gradient is expected when the wellfield is pumping at a constant rate of 100,000 m^3/day and its extent is shown in Figure 12.

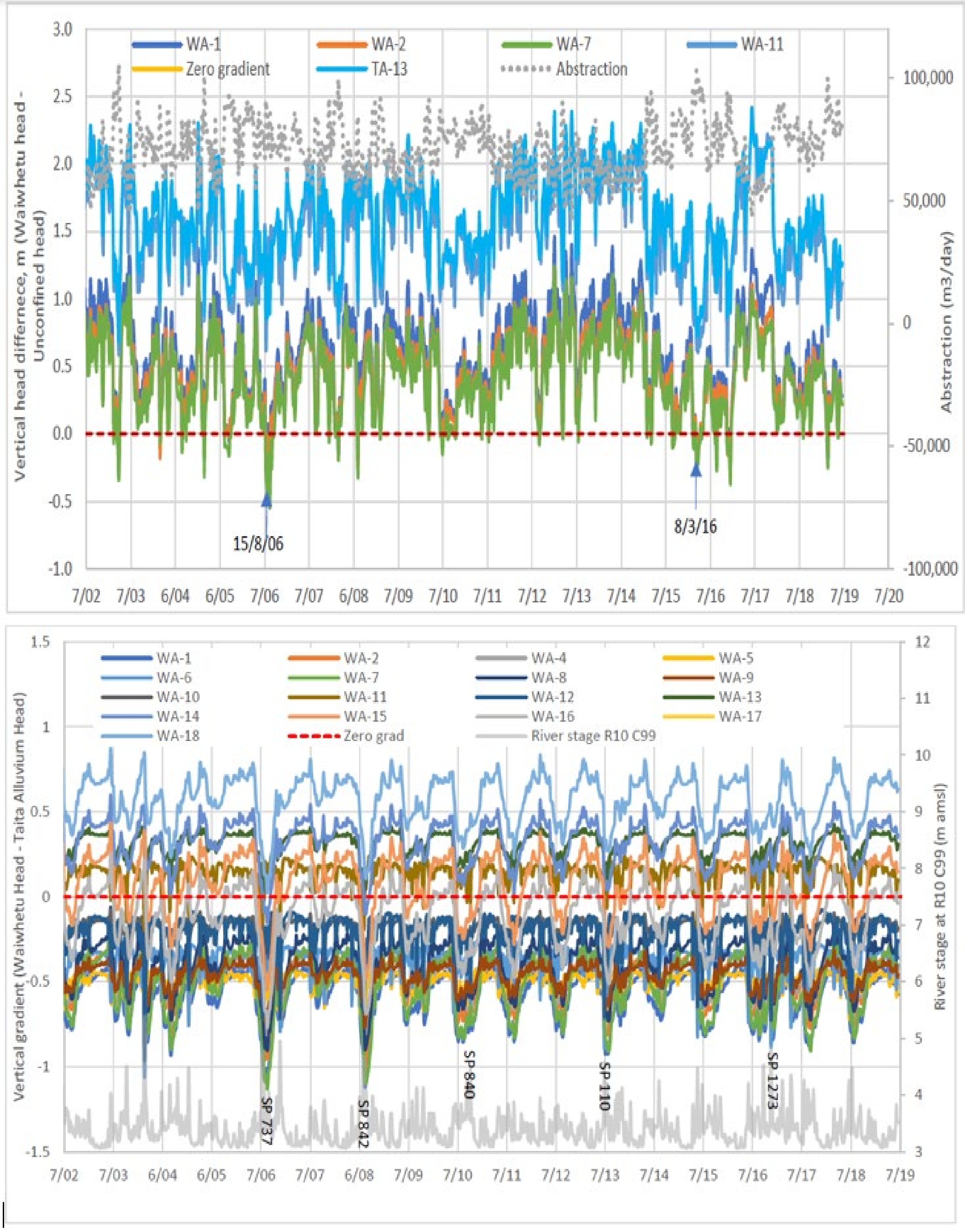

Figure 11 Modelled vertical groundwater head differences around the Waterloo Wellfield during pumping at historical rates and when the wellfield is pumping at a constant rate of 100,000 m^3/day (extract from EIM, 2020)

82. The estimated area where negative vertical hydraulic gradients may be generated between the Waiwhetu Aquifer and the Taita Alluvium by Waterloo Wellfield pumping is shown in Figure 12 (T&T, 2020). On this basis, T&T proposed an immediate source protection zone (SPZ1) of 30 m to 170 m from the water supply wells (as shown in Figure 12 below).

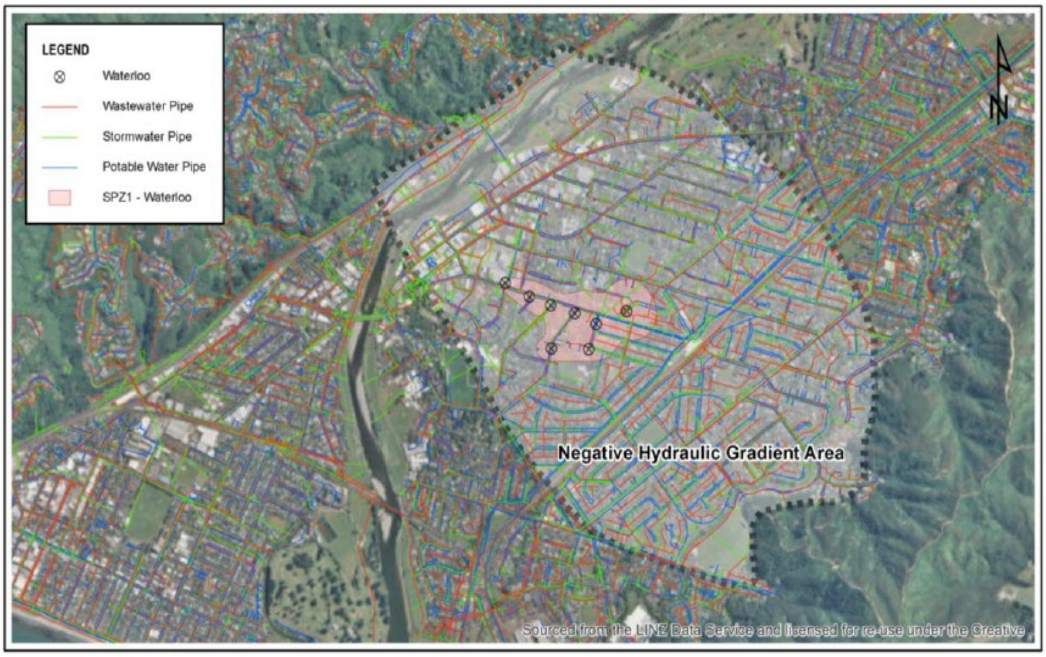

Figure 12 Plan showing the proposed SPZ1 for Waterloo bore field and the estimated area of potential negative hydraulic gradient (extract from T&T, 2020)

5. ASSESSMENT METHODOLOGY

83. The following assessment methodology has been used to assess the potential groundwater effects from the construction and operation of the Project:

i. Review of available geological and hydrogeological data in the Project area to understand existing groundwater levels, current groundwater use and groundwater/surface water interactions;

ii. Review of relevant reports that include assessments on the Waiwhetu aquifer (listed in the references section);

iii. Review of the consent drawings (included in Volume 5 of the AEE) and indicative construction methodology included in Chapter 5 of the AEE, to identify features that may affect groundwater during construction and operation of the Project Review of the proposed construction methodology for the installation of piles for the construction of the bridges that penetrate Waiwhetu aquifer;

iv. Investigation of the potential to affect yield or quality of water at existing abstraction bores by altering groundwater flow patterns;

v. Prepare four two-dimensional groundwater models (two cross sectional and one plan view models) to assess effects of construction excavations and piling on the Waiwhetu aquifer;

vi. Identify opportunities to mitigate potential environmental effects through design and construction sequencing. This also includes consideration of monitoring and reporting mechanisms to confirm the management and mitigation of potential adverse effects.

vii. Recommend appropriate consent conditions.

6. ASSESSMENT OF EFFECTS ON GROUNDWATER DURING CONSTRUCTION

84. Indicative construction programme, sequence, and construction methodology, for Riverlink are detailed in the AEE report. The main construction activities for the Project are listed below.

    i. River channel works
    ii. Access to specific sites (culverting and access bridges)
    iii. Ground improvements
    iv. Earthworks
    v. Structures
    vi. Pavements and surfacing, and
    vii. Completion works (traffic services, landscaping).

85. Construction activities that have the potential to affect groundwater during construction are assessed in detail below.

6.1 Assessment of potential effects on groundwater during construction of river channel works

6.1.1 River works

86. The Project requires reshaping of the riverbed (width and depth) to establish a new natural meander pattern suitable for a widened channel. The re-shaping requires the removal of gravel and vegetation across the full extent of the river channel (between the two existing stopbanks) between Kennedy Good and Ewen Bridges. The objectives of the River works are presented in the AEE. The river works are described in more detail in the Alternatives Assessment in Appendix E of the AEE in Volume 2 of the Application.

87. As described in more detail in the Technical Assessment No.5 Geomorphology Report, the overall purpose of the river works is to:

    i. Increase the standard of flood protection along the Project length between Kennedy-Good and Ewen Bridges; and
    ii. Achieve a better balance between the natural behaviour of the river and the measures used to manage the river which will reduce the degree of maintenance interventions required to maintain the River. In particular, the Project aims to contain the amount of sediment deposition (which requires regular maintenance and removal) to the upper reach of the Project and minimise the sediment maintenance requirements in the lower reach. The reach locations are shown below in Figure 13.

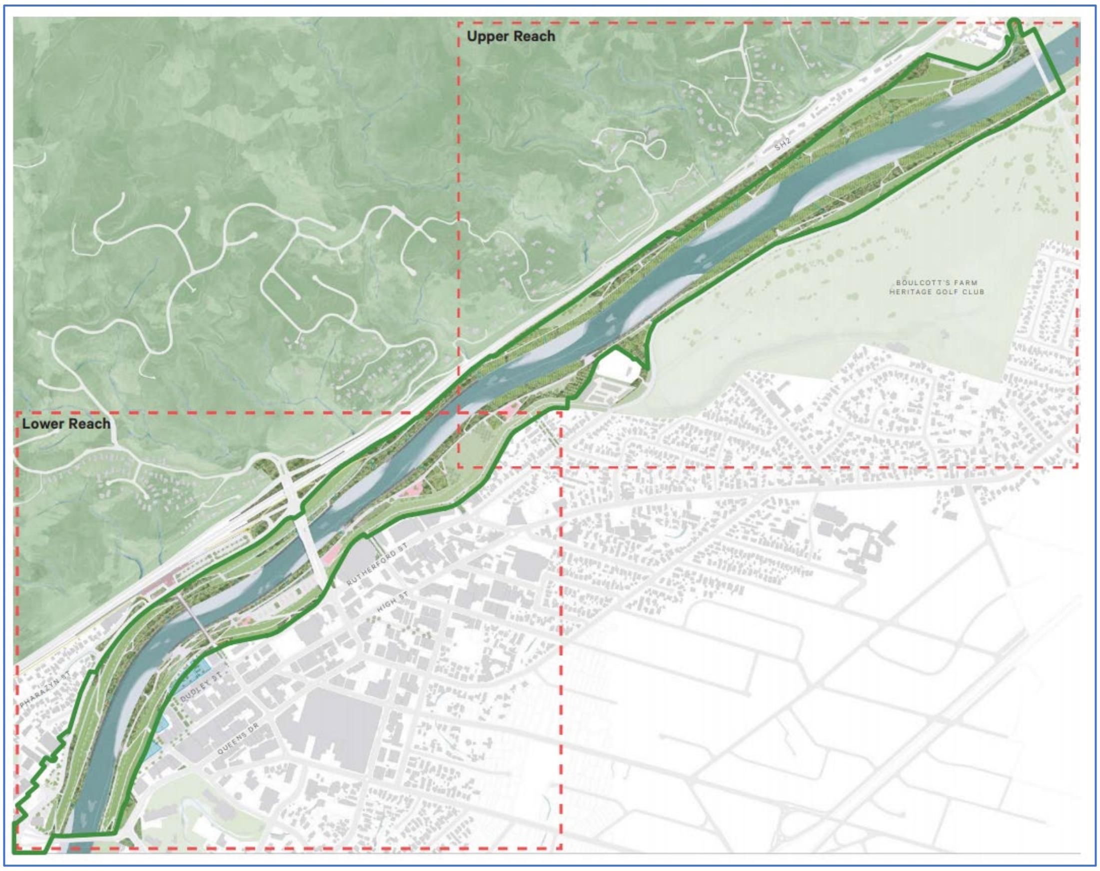

Figure 13 Upper and lower reaches of the Project

88. The extent (length and depth) of the proposed river works is presented in the layout plans and river cross sections drawings (A16-4381-SB140 and A16-4381-SB141, A16-4381-SB400– A16-4381-SB433 included in Volume 5 of the AEE).

89. The widening of the channel, being the construction of the berms and widened channel, will be completed as dry works to just above river level, with excavated material being either cut to fill, cut to waste (unsuitable material), or cut to stockpile for processing to be used in the overall Project works.

90. In the lower reach (Figure 13), the new river corridor between the stopbanks will consist of a 70 m wide active channel with a 10 m wide lower bench on each side, giving a channel width of 90 m, plus an upper berm of at least 25 m on each side. The total minimum width of the river corridor will be approximately 140 m. Rock linings will be placed along the outer (deep pool) side of the bends of the meandering active channel, from below bed levels to the level of the lower bench. These will alternate with vegetated lower berms consistently throughout the lower reach to deliver increased flood protection.

91. In the upper reach, the active channel will widen from 70 to 100 m in width, with a 30 m berm width provided on each side of the river. The lower berm will be lowered, widened, and planted with a combination of willows and native plants to act as a buffer to river currents.

92. Gravel extraction from the channel and excavation and fill in the upper and lower berms are to occur for the full extent of the proposed river works. The gravel extraction works are a combination of lowering the riverbed and widening the channel with protected banks, either riprap or planting.

93. Groundwater in the Taita alluvium close to the Project area ranges between 0.7 m bgl (BH18-15) to 2.7 m bgl (BH19-2) on the left side of the river and 1.2 m bgl (BH18-1) to 2.5 m bgl (BH18-16) on the right bank of the river (Figure 2 and **Appendix A**).

94. Groundwater will most likely be encountered near the riverbed at approximately river water elevations, but the river works (gravel excavation and construction of riprap and berms) are not expected to require groundwater pumping for dewatering. The Project construction methodology currently does not envisage dewatering to manage river or groundwater inflows for the river works component of the Project.

95. Details on the earthworks (cuts & fills) for the riverbed widening are presented in the AEE report and river cross sections drawings (A16-4381-SB400 – A16-4381-SB433 dated 09/04/2021 in Volume 5 of the Application).

96. The proposed lowering of the riverbed for the Project along the lower reach is to encourage bed material deposition in the upper reach, where it can be more easily removed, and maintain a throughput sediment transport zone along the lower reach. Details are provided in the River Channel Design Report (G & E Williams Consultants and Christensen Consulting Ltd, 2021) provided in Volume 4 of the AEE. An example of the proposed channel reprofiling is shown in Figure 14 below. This figure shows the new riverbed profile (represented by the red line). This shows the lowering of the riverbed and widening of the channel, as well as the creation of berms above each riverbank before returning to existing ground levels prior to the stop banks.

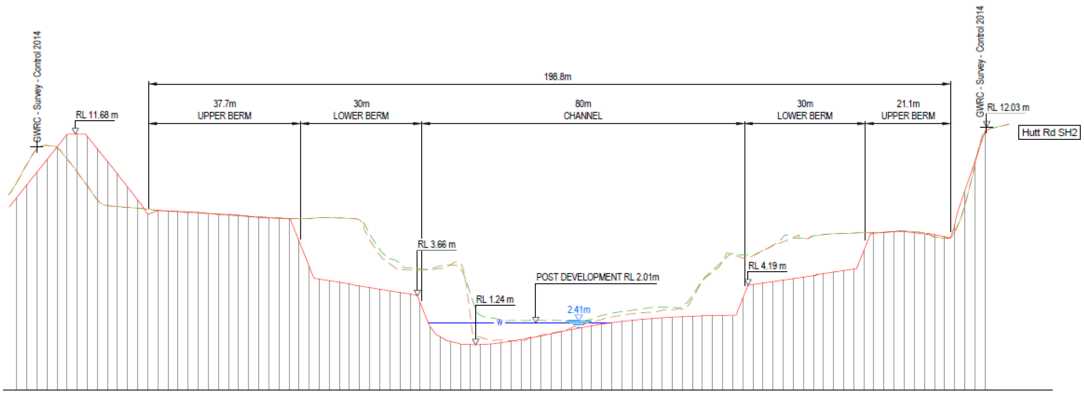

Figure 14 River Section 500 - extract from drawing A16-4381-SB418

97. Figure 15 shows the most recent riverbed survey (2019) at that location (cross section 500) that overlays the 1987, 1993, 1998, 2004, 2009 and 2014 riverbed surveys.

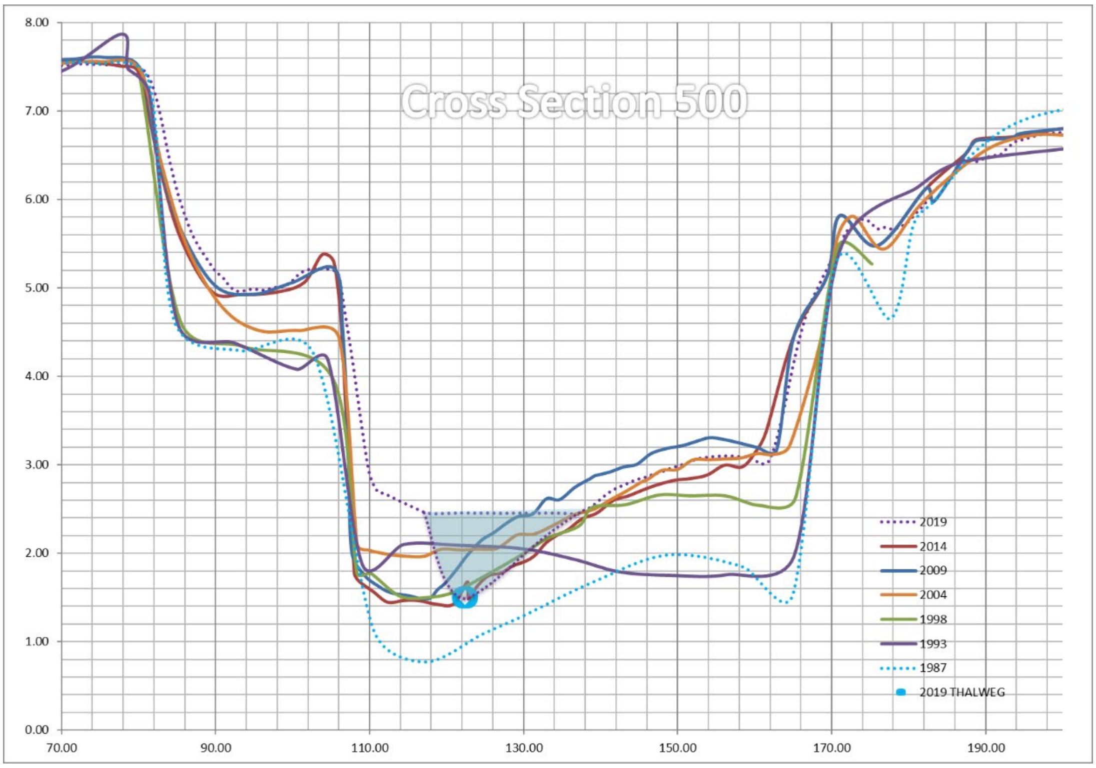

Figure 15 River cross section 500 from Hutt River Cross section 2019 survey (data from GWRC)

98. The proposed lower riverbed excavation level is at R.L.-2.18 m as shown in River Cross Section-360 (Drawing No A16-4381-SB404in Volume 5 of the AEE). Historical survey results at that location show that the proposed lower riverbed elevation is similar to the 1998 riverbed level (Figure 16).

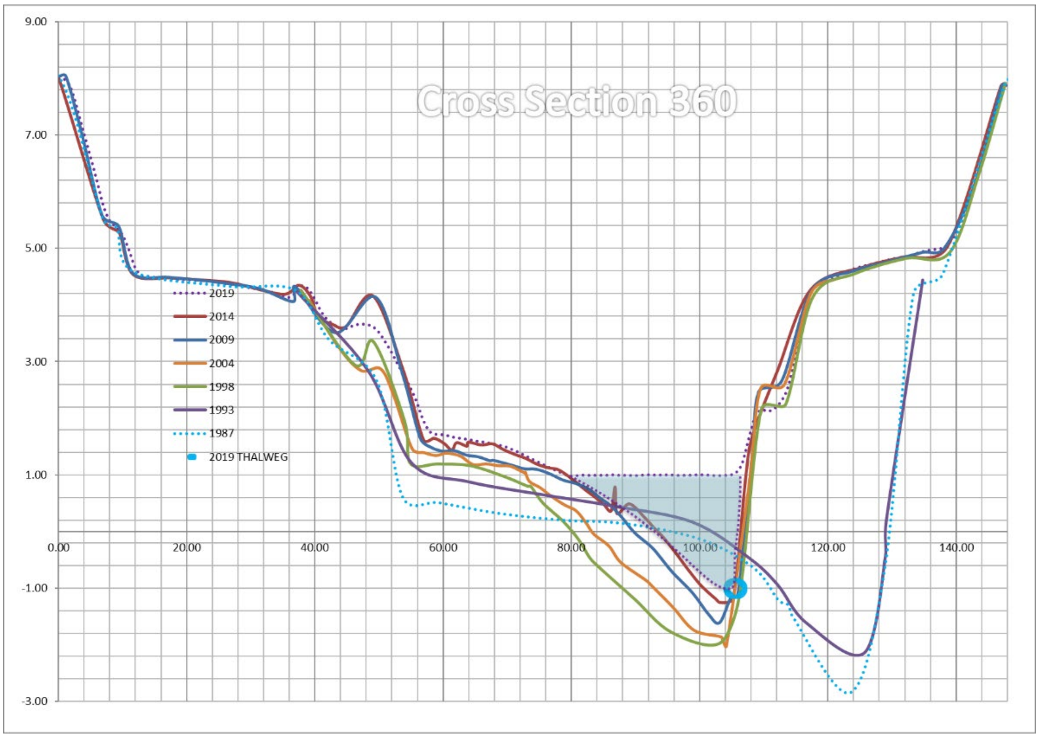

Figure 16 River cross section 360 from Hutt River Cross section 2019 survey (data from GWRC)

6.1.2 Groundwater / river water interaction and Groundwater Levels

99. As noted above, the river has a complex recharge - discharge relationship with the shallow unconfined Taita aquifer. Quantification of river losses and gains to groundwater has been undertaken through a limited number of concurrent river flow gaugings (1993 – 2013) under low flow conditions (EIM, 2014).

100. The EIM data shows that upstream of the Project, between the Taita Gorge and the Kennedy Good Bridge, the river loses water to the aquifer. Historic consecutive gauging under low flow conditions showed that the river in this section loses from 800 L/s to about 1,500 L/s (approximately 69,000 m^3/day to 130,000 m^3/day), and these losses recharge the underlying aquifers (EIM, 2014).

101. Downstream of Kennedy Good Bridge, including the Project area, the river flows start to increase, indicating that the shallow (Taita aquifer) groundwater is discharging to the river.

102. A number of factors affect the river losses/gains in addition to the river flow rates. The main factors that influence the river/groundwater flow exchange are the groundwater level in the unconfined Taita aquifer and groundwater abstraction in the confined Waiwhetu Aquifer. The most influential abstraction from the Waiwhetu aquifer is from the Waterloo Wellfield, which is regulated to avoid saline intrusion to the Waiwhetu aquifer. There are also other industrial and commercial abstractions from the Waiwhetu aquifer across the Hutt Valley.

103. Modelling results (EIM, 2014) using the 1998 riverbed elevation levels (which are similar to the proposed levels), show that between Taita Gorge and Kennedy Good Bridge the river losses to the aquifer due to pumping (induced recharge) from 25,000 m^3/day to 40,000 m^3/day that equates 45% of the total measured river losses (60,000 m^3/day – 100,000 m^3/day). Furthermore, results indicated that induced recharge constitutes about 40% and 60% of the Waterloo Wellfield pumping rates.

104. Downstream of Kennedy Good Bridge, the EIM (2014) modelling results estimate that the river gains approximately 20,000 m^3/day in the summer and about 40,000 m^3/day during winter.

105. Modelling was undertaken under my guidance and the assumptions and detailed modelling results are presented in **Appendix B**. The goal of the modelling was to understand the difference in river inflows or groundwater flow patterns after construction (excavating and lowering the riverbed). Therefore, it is considered appropriate (and conservative) to simulate steady state conditions (i.e. one river level or constant head condition) as it is the flow difference at one particular time which is of interest. Modelling results and current monitoring data indicate seepage of shallow groundwater to the river near the project area (from Melling Bridge to Ewen Bridge). The difference in groundwater inflows to the river from existing to post-development state range from 0.1 to 0.4 m^3/day per metre river length. Current discharge rates reflect the present riverbed elevation and average groundwater levels as monitored in the project's piezometers (September 2020-April 2021). Even when conservative assumptions are applied i.e. negative hydraulic gradient caused by pumping the Waterloo wellfield and removal of the confining layer (aquitard) the increase of inflows in to the river is small ranging from 0.8 to 1.2 m^3/day per metre river length. Modelling results indicate that the proposed lowering of the riverbed will not result in reduced yield in the Waiwhetu aquifer due to groundwater losses from Waiwhetu to the river. Under very conservative assumptions (detailed in Appendix B) the additional Waiwhetu losses under 7-Day Mean Annual Low Flow (MALF) are in the order

of 71 m^3/day to 210 m^3/day across the full length of the proposal which includes the potential recharge losses from Taita. This represents a very small percentage of the total aquifer volume and pumped daily rates from Waterloo wellfield.

106. As noted above the lowering of the bed level will be approximately at the 1998 bed levels (i.e. within the historical range of bed levels and design levels of the HRFMP). Previous modelling analysis (EIM, 2014) indicates that the confined Waiwhetu aquifer is relatively insensitive to small bed level variations that naturally occur. This is in agreement with modelling undertaken (Appendix B) where an increase of (**Appendix B**) where an increase of 71 m^3/day (and up to 210 m^3/day) in river flows is contributed from the Waiwhetu aquifer. This is very small compared to the volumes of water within the Waiwhetu aquifer. As a result, I do not expect any significant changes to the confined aquifer groundwater levels. from the proposed works

107. Furthermore, modelling results indicate a small drawdown of the groundwater level in the order of 0.25 m within 75 m from the riverbed excavation. This change is within the seasonal range of groundwater levels (measured 1-2 m in the shallow Taita Alluvium) and no adverse effects are expected on groundwater levels and groundwater flow direction from the proposed works. For a 300 m river section, shallow drawdowns can be larger and up to 0.50 m at some 100 m from the riverbed reducing to 0.25 m approximately 200 m from the excavation. In all cases considered the effects from the proposed river works on the Waiwhetu aquifer water levels are very small (less than 1 cm).

108. The lowering of the bed level will be approximately at the 1998 bed levels (i.e. within the historical range of bed levels and design levels of the HRFMP). Previous modelling analysis (EIM, 2014) indicated that the confined Waiwhetu aquifer is relatively insensitive to small bed level variations that naturally occur. Modelling results and my assessment is in agreement with that conclusion. As a result, I do not expect any significant changes to the confined aquifer groundwater levels from the proposed works.

6.1.3 Groundwater quality

109. As discussed above, the groundwater – river interaction is complex and the Taita aquifer within the Project area may be recharged by the Hutt River during high river water levels.

110. Water quality in the Hutt River that is affected by the works (i.e. increased turbidity) may result in an increase in turbidity in the shallow groundwater of the Taita aquifer. However, it is important to recognise that flood events which already occur in the river naturally will recharge the shallow aquifer with water which has increased turbidity associated with the flood event. Details on suspended sediment concentration for different flow events and are discussed in technical report #3. Furthermore, Technical Assessment Report #3, includes a draft overarching Erosion and Sediment Control Plan (ESCP) to articulate the strategy to avoid, remedy or mitigate the potential effects of erosion and sediment discharges to the receiving environment. The ESCP will be updated, and a Site-Specific Erosion and Sediment Control Plan (SSESCP) will be prepared for particular construction activities to ensure measures are tailored to the location, unique constraints and different teams of people involved. In addition, a Chemical Management Plan (ChMP) has been prepared and is appended to Technical Assessment Report #3 to set out the procedures and practise for use of chemical flocculant at structural treatment devices.

111. The extent of potentially contaminated land (location and level of risk of contaminated land runoff to the surrounding environment) is discussed in the Technical Assessment # 13 – Contaminated Land. Further detail regarding the extent and type of contaminated land will be identified as part of the Detailed Site Investigations (DSI). The potential of effects on environmental receptors from contaminated land runoff ranges from minor to

high as described in Technical Assessment No. 13 (Contaminated Land). The magnitude of the effect and type of remedial works depend on the extent, type of contaminant, and toxicity to receptors. The extent of contaminated land will be documented in the DSI and remedial works in the Contaminated Land Site Management Plan. While potential effects of contaminated land runoff on environmental receptors range, the completion of the DSI and implementation of measures in both the ESCP and Contaminated Land Site Management Plan (CLSMP) reduce any potential effects to river water quality and groundwater to low.

112. Due the nature of the Taita aquifer (i.e. sand and silt) the suspended sediments are expected to be filtered by aquifer material within a short distance from the river as it occurs naturally during high river flows. WWL has also noted that they have not recorded, through their monitoring of their supply wells, turbidity spikes associated with increased river stage in the Hutt River. No adverse effects are expected of increased turbidity in the shallow aquifer from the proposed works. However, I recommend that some management measures are adopted to manage the residual risk (albeit small), by monitoring and mitigating turbidity issues that may arise. As noted above management of the river water quality during construction will be detailed in the ESCP, in the SSESCP and in CMP, included as drafts in the Construction Water Quality Assessment (Technical Report #3). In my opinion this will further minimise any low potential to affect the groundwater quality in the shallow aquifer.

113. Modelling results (presented in Appendix B) indicate that under river “flood” conditions with simultaneous high pumping at the Waterloo well field, “river losses” to groundwater are expected to increase by up to 0.4 m^3/day per linear m when compared to the existing state (i.e. less than 0.01 l/s per linear m). Most of the river losses are expected to be to the Taita Alluvium with only 61 m^3/day and up to 85 m^3/day additional flow expected additional flow expected to reach Waiwhetu. The additional inflow rate is considered to be negligible and immeasurable when compared to the Waiwhetu aquifer volumes of water. Therefore, I do not anticipate any measurable change to the Waiwhetu water quality properties (turbidity, pH, DO, hardness) at the Waterloo bore field that could be attributed to the proposed works.

114. Flow paths and aquifer groundwater velocities are not expected to change because of the proposed river works. Travel times and natural attenuation reduction is likely, from the proposed riverbed excavation and the removal of the silty layer. I consider that quantifying this change with reasonable confidence is extremely difficult, given the lack of tracer studies in the Waiwhetu aquifer and particularly in the vicinity of the Hutt River. Additional inflows to the aquifer from the proposed excavations in the riverbed, are estimated to be very small and the increase in risk is considered small. This risk is expected to decrease with time, as fine material is redeposited in the riverbed. Water quality monitoring as detailed in the draft-GMP (Appendix D) should be undertaken to manage any contamination risk in case of a flood event.

115. If pre-construction monitoring results or additional hydrogeological site investigations and/or additional modelling undertaken by WWL indicate different site conditions than those assumed here which are likely to result in an increase in effects to the groundwater system, then this assessment should be updated to confirm the assessed envelope of effects.

6.2 Assessment of effects on groundwater during construction of Melling Interchange, Melling River bridge and pedestrian bridge

116. The Melling interchange and bridge works are shown in the General layout plans C201-211 and the bridge plans and drawings S101, S102, S201 and S202 (included in Volume 5 of the AEE).

117. The Project includes:

    i. Ground improvements (concrete driven piles) to a depth of 10 m (-1 m RL) at the base of the southbound interchange with SH2 and where the bridge lands on the true left bank (Rutherford Street);

    ii. Construction of a new Melling River bridge including pile construction in the river channel, including penetration into the upper Waiwhetu Aquifer;

    iii. Removal of the existing Melling River bridge;

    iv. Construction of a new link road connecting Tirohanga Road to Harbour View Road adjacent to the new northbound on-ramp;

    v. Construction of a new approximately 31 m long by 8 m high single span bridge over SH2; and

    vi. Construction of a pedestrian bridge over the river including construction of piles in the river channel including penetration into the upper Waiwhetu Aquifer.

118. The construction of the piles that will penetrate the upper Waiwhetu aquifer have the potential to affect the quality of groundwater (contamination risk) and quantity through leakage of the water from the artesian aquifer.

6.2.1 Construction of piles into the artesian Waiwhetu Aquifer – Melling Bridge

119. Six 2.7 m diameter reinforced concrete bored piles in full length permanent steel casings are proposed in the design drawing A16-4381-S201 (Volume 5 of the AEE). Additionally, ten reinforced concrete bored piles (of smaller diameter) in full length permanent steel casings are proposed for the construction of the Melling Bridge abutments (five in each abutment). The piles for the proposed Melling Bridge are expected to intercept the upper Waiwhetu Aquifer.

120. The following construction methodology is proposed for the construction of the piles into the Waiwhetu aquifer as detailed in the construction methodology in Chapter 5 of the AEE:

    i. Prior to the commencement of works on site, further geotechnical investigations will be completed. These will provide further details on the level of the aquifer and aquiclude, along with other ground conditions impacting the final design at each pile location);

    ii. Install the nominal 4 m diameter temporary steel casing into the aquiclude. The intent of this is to provide a confined working environment for the subsequent piling works. In the event of a leak around the pile, the quantity of leakage can be contained and remediated without significant volumes of water escaping or entering the aquifer. This temporary casing will be grouted between the outside of the casing and the surrounding ground at the aquiclude level. The top of casing is to extend above the static water level in upper Waiwhetu gravels;

iii. Excavate material from inside casing down to a level that maintains a seal at the base of the excavation.

iv. The temporary casing will then be tested to ensure that it holds water.

v. Drill and drive the 2.7 m structural pile casing to founding depth of pile in upper Waiwhetu gravels. This will likely be driven using a pile hammer until refusal, likely to the top of the Waiwhetu gravel layer, where it may require drilling or coring to achieve the required depth. The casing will likely require a piling shoe with some slight overcut to overcome ground friction to be able to achieve the required pile depth which includes some additional depth for the concrete plug to be cast at the base. While this pile is driven, the water level inside the temporary works can be balanced with the aquifer pressure, to minimise any potential leakage.

vi. Excavate material from inside the casing down to founding depth (allowing water to fill the casing and the caisson to the static water level in the aquifer).

vii. Concrete a plug into the bottom of the pile casing. Weld the caisson to the casing and add kentledge to balance the anticipated uplift pressure on the casing. At the completion of the grouting, the seal can be tested by raising or lowering the water in the temporary casing.

viii. Place mass non-structural concrete underwater in the annulus between the 4 m caisson and the 2.7 m pile casing.

ix. Dewater the pile, place reinforcement and concrete up in the dry.

x. Cut off the caisson at an agreed level and leave the buried portion of caisson in the ground.

xi. Construct the 2.7 m diameter pier on top of the pile.

121. A sketch illustrating the proposed piling construction methodology is presented in Figure 17.

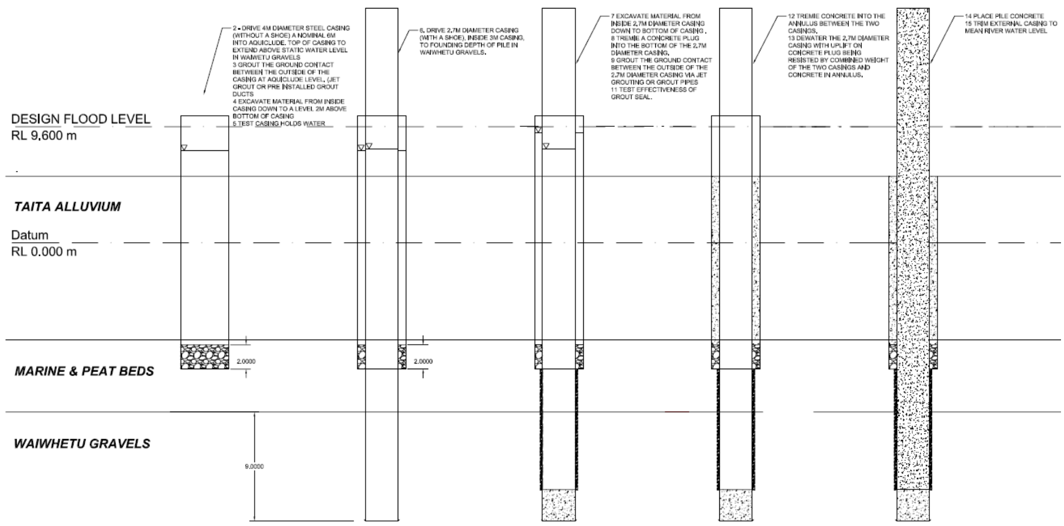

Figure 17 Piling method (extract from construction methodology Chapter 5 - AEE)

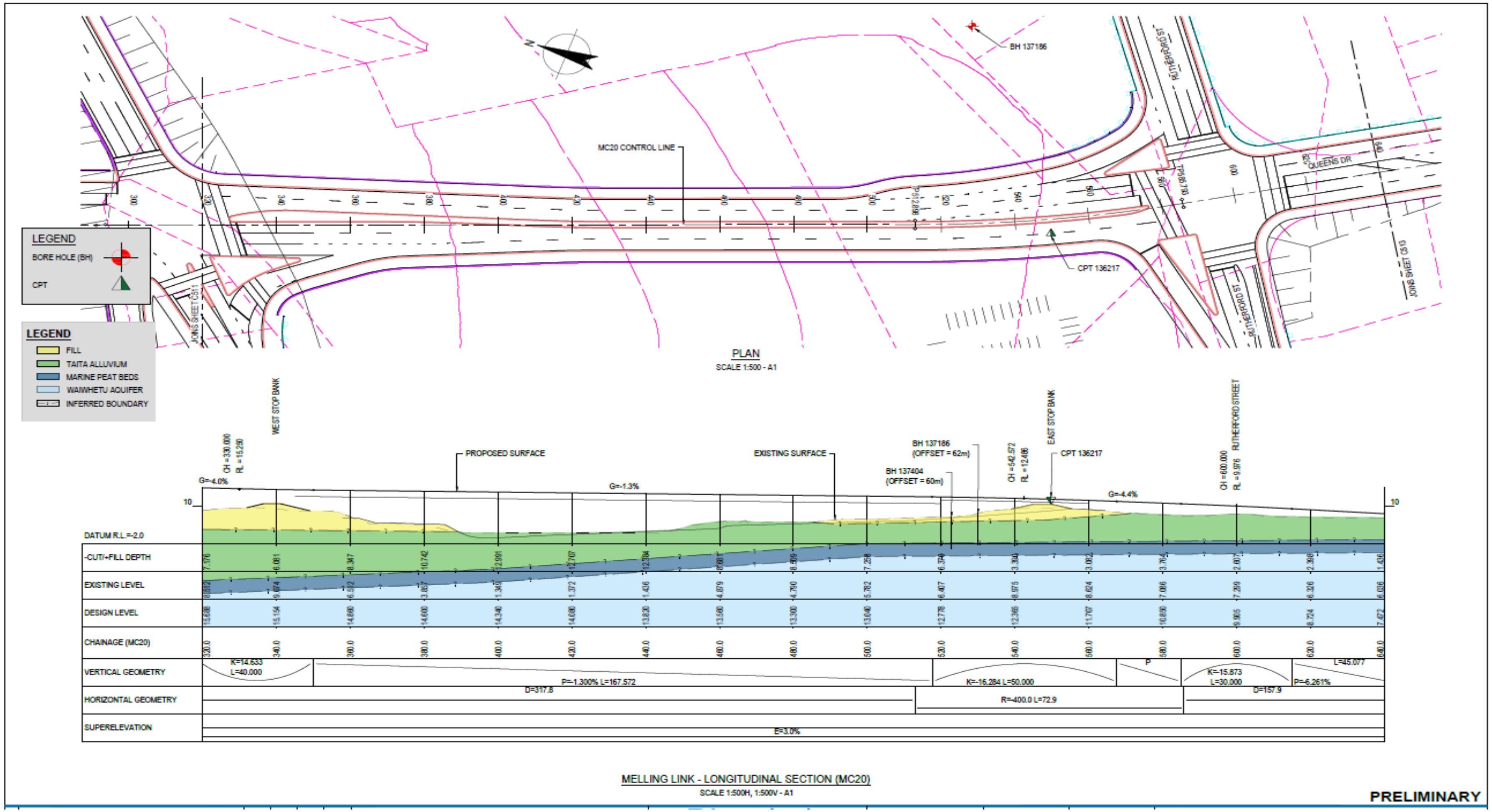

Figure 18 Geological profile at the approximate location of the proposed Melling Bridge

122. The expected geology of the Project's area described and discussed in Section 2 of the Geotechnical Interpretive Report for the Project (Appendix C of Technical Assessment #15). It is also presented in Figure 19 below. The cross section has been created using the GWRC Hutt Valley 3D Geological model. The Petone Marine aquiclude may be of limited thickness between the Taita alluvium aquifer and the Upper Waiwhetu aquifer at the location of the bridge piles. The project's vibrating wire piezometers (BH18-1 and BH-19) installed in the Upper Waiwhetu Gravels are recording artesian pressures that implies the presence of a confining layer.

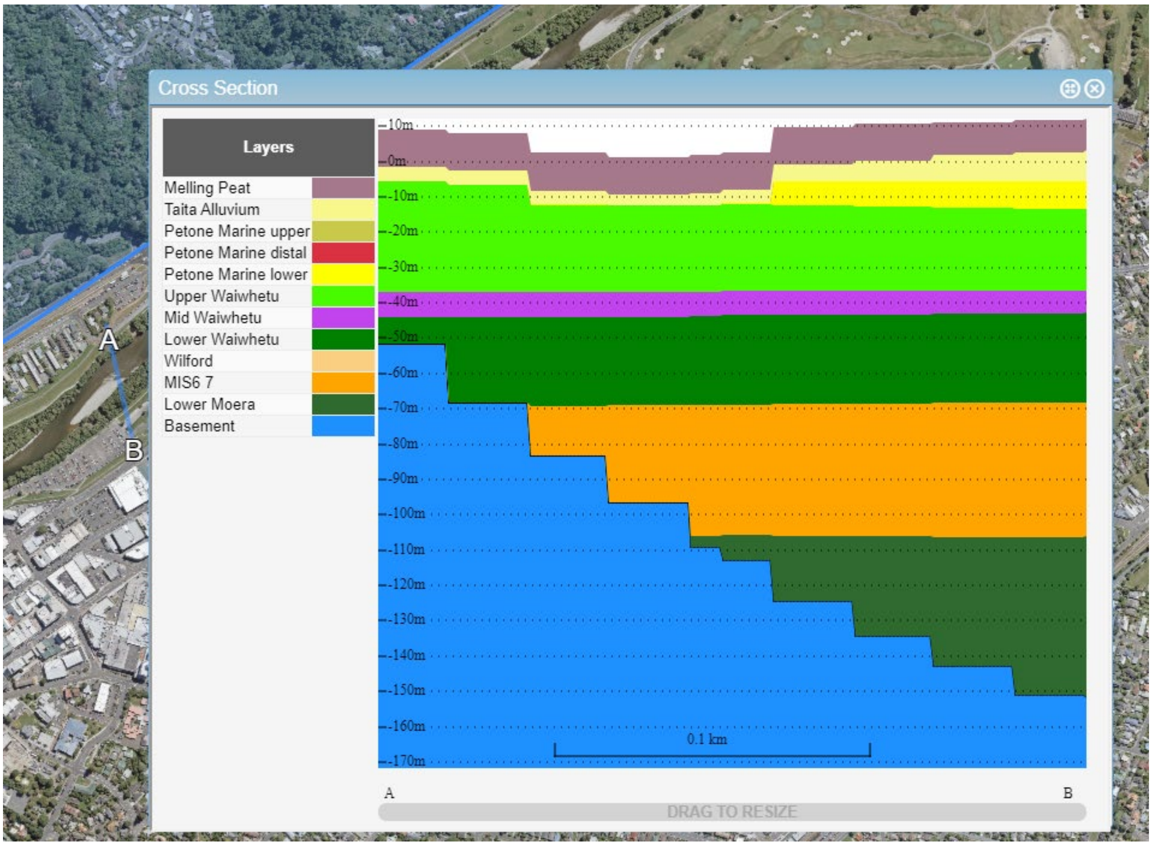

Figure 19 Geological profile at the approximate location of the proposed Melling Bridge (GWRC Hutt Valley 3D Geological model)

123. The main potential adverse effects from the construction of the piles are:

i. If incorrectly constructed, the piling could result in a breach in the aquitard above Waiwhetu Gravels, resulting in localised aquifer depressurisation and provide a potential pathway for an increased exchange of flow of groundwater into and from the artesian aquifer, and

ii. If incorrectly constructed the piles may create a pathway for contaminants to enter the confined artesian aquifer in circumstances of a negative hydraulic gradient or contaminants that are denser than water (e.g. chlorinated solvents).

124. In addition, discussions with Wellington Water (WWL) have highlighted a potential concern associated with turbidity spikes within some of their Waterloo wells following earthquake events. WWL raised a concern that the act of piling may result in disturbance of sediment in the Waiwhetu aquifer, which may be transported to their supply wells and affect the turbidity at the well source. WWL provided recent turbidity data recorded in the eight Waterloo wells (data from 01/04/2020 – 27/04/2021).

125. The proposed construction methodology for the piles that will penetrate the Waiwhetu aquifer and specifically the use of double casing methodology and sealing (grouting) around the casing of the aquiclude is a robust, commonly used and proven construction methodology to address the potential quality and quantity risks to groundwater. Furthermore, the construction methodology provides guidance on testing the sealing (grouting) and minimises the risks of de-pressurising the aquifer. A similar methodology was successfully applied in the past (1995) during the construction of the Ewen bridge piles in the same river. Therefore, I expect that the proposed methodology is suitable to manage the risks of leaching and or leaking water from and to the Waiwhetu aquifer.

126. Driving the casing of the piles that will penetrate the upper Waiwhetu aquifer, will temporarily disturb the soils immediately around the casing. If the hydraulic conditions are as per modelling scenarios summarised above (section 4.5) and described in detail in EIM (2020), and a negative vertical hydraulic gradient develops in the area around the piles, then fines may mobilise downward with groundwater flow. However, I consider that this risk is very low and only likely to be associated with the area immediately adjacent to the piles.

127. I also note that a literature search of scientific journals did not reveal any studies that have estimated the spatial extent of soil disturbance that may create turbidity spikes in nearby groundwater wells during pile construction.

128. It is not unexpected to record increased turbidity during an earthquake event, as the whole aquifer is vibrating and may mobilise fine particles in the pore space of the aquifer or fines accumulated in the sump of the wells. WWL monitors water quality data for the Waterloo wellfield (sensor recording turbidity every 5 minutes). The turbidity spikes measured in the majority of Waterloo wells (for the period 01/04/2020 – 27/04/2021) were found to dissipate after 5 minutes (Figures E1 -E11 in **Appendix E**). Turbidity data were compared against earthquake events reported in the Geonet database for the same period of time in the area (https://www.geonet.org.nz/data/types/eq_catalogue). No obvious connection or clear pattern has been identified. There were some dates where earthquake events (magnitude M1.6 to M4.3) and turbidity spikes in some wells coincided, but the turbidity spikes were recorded before the earthquake event and not after (see Figures E13 –E18 in **Appendix E**).

129. The vibration that will occur from driving the casing of a pile will be an event of much smaller magnitude and extent when compared to an earthquake event. Vibration effects from piling are discussed in detailed in Mr Christian Vossart's report (Technical assessment Report #10). Therefore, I consider that the risk of increased turbidity in response to piling for the Project is very low and only likely to be associated with the area immediately adjacent to the piles. Management measures need to be adopted to manage the risk (albeit small), by monitoring of groundwater quality (including turbidity) in the upper Waiwhetu Gravel aquifer and mitigating turbidity issues that may arise. This is detailed in the draft GMP attached as Appendix D.

130. I consider that the pile construction methodology should be reviewed following detailed design and once geology is confirmed at the locations of the piles and updated if required. Any updates on the methodology and technical justification should be submitted to GWRC for certification before commencement of piles' construction.

6.2.2 Assessment of effects from removal of existing Melling Bridge

131. The existing Melling Bridge will be deconstructed (removed) to the riverbed level. Existing bridge piles will be cut to riverbed level. This will minimise/eliminate disturbance of the underlying aquifers. Therefore, I consider that there are no effects on groundwater quality or quantity expected.

6.2.3 Assessment of effects from ground improvements for the SH2 bridge abutments

132. Ground improvements (driven concrete piles) will extend to -1 m RL and will be founded in the Taita Alluvium. The geological cross section through the proposed interchange bridge based on site specific data is shown in Figure 9 of Technical Assessment #15. These piles will not breach the aquiclude.

133. The ground improvement piles are of small diameter and length and will not impede shallow groundwater flow.

134. The proposed driven concrete piles are not expected to be drilled through contaminated soil as reported in the Contaminated Land Assessment (Technical Assessment #13).

135. No adverse effects on groundwater quality or quantity are expected from this activity.

6.2.4 Assessment of effects on groundwater during construction of Earthworks

136. Earthworks including excavation and filling, reuse of onsite material, removal of waste material and importing material are proposed across the Project. Earthworks are associated with removing the existing stopbanks, widening of the river corridor, establishment of berms and stopbanks, raising the land on the western side of the river to achieve design levels for the new interchange and supporting infrastructure, and construction of the new railway station and the realigned rail line, and for ground improvement works across the Project.

137. Details on both cut and fill (for the new interchange and supporting infrastructure and the realigned rail line, and for ground improvement works across the Project) are still to be confirmed in detailed design, but the maximum cut depth will be 5 m and the maximum height of fill will be 5.5 m.

138. Fills and cuts for the State Highway 2 Melling Interchange are shown in drawings A16-4381-C501 to A16-4381-C591 (Volume 5 of the AEE). Maximum cut proposed is approximately 2.75 m bgl (excavation of existing surface 23.9 m RL to 22.8 m RL) for the construction of the Tirohanga Rd. Groundwater level monitoring in that area (as recorded in telemetered piezometer BH18-16) indicates that groundwater level ranges from 3.5 to 4.5 m RL. Therefore, excavations are expected to be above the level of the shallow groundwater table, meaning that dewatering is unlikely to be required during earthworks construction. As a result, there are no effects on groundwater from the construction or operation of the State Highway 2 Melling Interchange.

6.2.5 Assessment of effects on groundwater from dewatering during construction (relocation of existing services, construction of culverts etc)

139. I note that groundwater drawdown in itself is not an adverse effect, but potential effects may arise as a result of the drawdown. These effects include pore pressure reduction that might result in ground settlement, or changes to groundwater flow and direction that might affect surface water or movement of contaminants.

140. Additional hydrogeological investigations and a quantitative dewatering assessment on groundwater should be undertaken during detailed design or possibly earlier for tendering purposes, when exact locations and dimensions of excavations that may require dewatering (utilities replacement, construction of culverts, pump stations etc) will be known.

141. I recommend that the Construction Environmental Management Plan (CEMP) should include a requirement for a dewatering assessment for all works within the groundwater community drinking water supply zoned (as defined in the PNRP) that may encounter groundwater, to identify appropriate measures to undertake during excavations.

142. The dewatering assessment should include the following as a minimum:

   i. Depth at which the aquitard is expected to be encountered within the area of proposed excavation;

   ii. Duration, location, volume and rate of dewatering required;

   iii. Quality of water to be discharged;

   iv. Effects of land subsidence;

   v. Effects on surface water bodies and interference effects on lawfully existing water takes; and

   vi. Measures to avoid and/or mitigate any potential adverse effects from dewatering activities and appropriate discharge of pumped water.

7. ASSESSMENT OF EFFECTS ON GROUNDWATER DURING OPERATION

7.1 River works

143. The long-term operational effects from the widened and deepened riverbed are going to be similar to those anticipated during construction.

144. Initially, shallow groundwater discharges to the river within the Project area are expected to increase slightly when compared to current discharge rates, in response to a steeper hydraulic gradient to the river.

145. The initial increases in shallow groundwater flow to the river will result in a slight (~0.25 m within 75m of the riverbed excavation) decrease in water level in the shallow aquifer. This change is well within the seasonal variation ranges of groundwater levels previously observed in the Project area.

146. Once the river channel is widened no additional effects on groundwater are anticipated during the operation of the Project.

147. The construction of the stopbanks and berms are not expected to affect the current groundwater flow direction. Any potential effects on groundwater are most likely to occur during construction.

7.2 Bridge piles

148. No adverse effects are anticipated during the operation of the Project from the bridge piles. The piles are of limited extent spatially and hence groundwater flow will re-establish around them, and they will not impede the groundwater flow. Modelling results indicate a very slight (<0.01 m) deviation from existing state groundwater levels after the addition of low-permeability piles (Figure B5 in Appendix B). This <0.01 m mounding effect is considered negligible compared to overall pressures within the artesian aquifer. The groundwater flow vectors (Figure B6 and B7 in Appendix B) also showed a deviation in typical groundwater flow patterns (downgradient) with groundwater flow veering around each pile which is to be expected. While this may increase the flow between the piles, this is not considered to cause a significant effect to overall groundwater flow within the Waiwhetu aquifer. No additional long-term effects on groundwater are anticipated from the bridge piles.

8. CONSULTATION WITH WELLINGTON WATER LIMITED (WWL)

149. Seven meetings have been undertaken with WWL's representatives from (15/12/2020 to 05/07/2021) to discuss the progress of the design and proposed works for the RiverLink project.

150. Four specific queries /concerns were raised by WWL in respect to the proposed riverbed works:

i) ***Reduced yield to the Waterloo wellfield due to loss of water from the Waiwhetu aquifer to the river.***

Steady state two-dimensional groundwater modelling has been undertaken to quantify the increase in discharge rate from groundwater to the river during low flows from the deepened riverbed and lower river stage. The modelling results indicate that the proposed river works will not result in reduced groundwater yield from the Waiwhetu aquifer. Details are presented in the attached **Appendix B** and in section 6.1 of this report.

ii) ***Change in physical water quality properties impacting treatment processes (e.g. elevated turbidity).***

Due the nature of the Taita aquifer (i.e. sand and silt) the suspended sediments are expected to be filtered by aquifer material within a short distance from the river as it naturally occurs during high river flows. No adverse effects are expected of increased turbidity in the shallow aquifer from the proposed works. In addition to the management of the river water quality discussed in the Construction Water Quality Assessment (Technical Report #3) I recommend that some management measures are adopted (**Appendix D**) to manage the residual risk (albeit small), by monitoring groundwater quality near the project works and mitigating turbidity issues that may arise. This point is discussed further in section 6.1 of this report.

iii) Change in chemical water quality properties impacting treatment processes (e.g. pH, DO, hardness, etc due to bore field production containing an altered proportion of younger river water)?

Modelling results (details presented in **Appendix B** and section 6 of this report) indicate that only 61 m^3/day and up to 85 m^3/day additional flow is expected to reach Waiwhetu during flood events. The estimated additional inflow rate is considered to be negligible and immeasurable when compared to the Waiwhetu aquifer volumes of water and the broader recharge to the aquifer system from the river upstream of the site (which is in the order of 60,000 m^3/day to 100,000 m^3/day). Therefore, I do not anticipate any measurable change to the Waiwhetu water quality properties (turbidity, pH, DO, hardness) at the Waterloo bore field that could be attributed to the proposed works.

iv) ***Greater potential for chemical or microbiological contaminants in the river to reach the bore field through reduced travel time and natural attenuation (i.e. the impact of project activities on contamination sources, pathways and receptors):***

Flow paths and aquifer groundwater velocities are not expected to change because of the proposed river works. Travel times and natural attenuation reduction is likely, from the proposed riverbed excavation and the removal of the silty layer. I consider that quantifying this change with reasonable confidence is extremely difficult, given the lack of tracer studies in the Waiwhetu aquifer and particularly in the vicinity of the Hutt River. Additional inflows to the aquifer from the proposed excavations in the riverbed, are estimated to be very small and the additional risk is considered small. This risk is expected to decrease with time, as fine material is redeposited in the riverbed. The extent of potentially contaminated land (location and level of risk of contaminated land runoff to the surrounding environment) is discussed in Technical Assessment # 13 – Contaminated Land. Further detail regarding the extent and type of contaminated land will be identified as part of the Detailed Site Investigations (DSI). The extent of contaminated land will be documented in the DSI and remedial works in the Contaminated Land Site Management Plan. While potential effects of contaminated land runoff on environmental receptors range, the completion of the DSI and implementation of measures in both the ESCP and Contaminated Land Site Management Plan (CLSMP) reduce any potential effects to river water quality and groundwater to low. Groundwater quality monitoring as detailed in the draft-GMP (Appendix D) should be undertaken to manage any contamination risk in case of a flood event.

151. I understand that WWL is in the process of commissioning a regional 3-dimensional groundwater model, to update the previous regional model (referred to as the HAM3 model). I also understand that the objective of this modelling exercise is to provide a more updated understanding of the Waiwhetu aquifer dynamics to improve management of the resource. I consider that there may be some merit to interrogate the new model, once calibrated and verified, to overlay the proposed changes in river morphology to confirm implications of the works on the regional water balance.

152. However, in my experience, there is a high likelihood that the structure and scale of the regional groundwater model may not be suitable to provide the resolution required to further refine my conservative assessment. That said, I note that the regional model will have a better chance of being useful for this project if some additional monitoring wells are installed adjacent to the works area. These additional monitoring wells have been discussed with WWL, and I understand that WWL will consider this detail in the construction of the regional model. If pre-construction monitoring results or additional site investigations and/or additional modelling undertaken by Wellington Water Limited (WWL) indicate different site conditions than those assumed here this assessment should be updated to confirm the assessed envelope of effects.

9. MEASURES TO AVOID, REMEDY OR MITIGATE ACTUAL OR POTENTIAL ADVERSE EFFECTS ON GROUNDWATER

9.1 Proposed mitigation measures

9.1.1 Construction

153. I understand that once the construction contract(s) for the Project have been awarded and a contractor (or contractors) are in place, the construction methodology will be further refined and developed. This refinement will be undertaken in compliance with conditions of the designation and resource consents which will be in place to manage the effects of the construction activities. To ensure that this refinement works efficiently I recommend that a Groundwater Management Plan (a draft template is presented in **Appendix D**) be implemented and form part of the CEMP.

154. The purpose of the GMP is to manage potential adverse effects on groundwater during construction of the project.

155. The GMP shall as a minimum include:

  i. Location of further investigations and frequency of Groundwater level and quality monitoring sites
  ii. Baseline monitoring data taken in advance of works
  iii. Trigger levels
  iv. Review and reporting requirements
  v. Roles and responsibilities
  vi. Contingency measures to be implemented if Alert or Alarm levels are exceeded including a response plan.

156. I consider that two piezometers should be installed close to the Project area (50 m to 100 m from the riverside) at the location of the bridge and be screened in the upper Waiwhetu gravels. Both piezometers will monitor groundwater turbidity/conductivity, temperature, pressure (head), using sensors to provide high temporal resolution data. The monitoring must commence at least one month before any drilling activity is to take place in the Waiwhetu aquifer, including pile driving. I consider that the monitoring can cease seven days after such activities have been completed. These monitoring wells can be used as early warning systems for triggering the implementation of mitigation measures identified in the GMP.

157. All tools must be cleaned and disinfected with appropriate solvent (e.g. DECON 90) including the steel casings that will be utilised for the construction and encasement of the bridge piles. Tools must be cleaned and disinfected in between each pile.

158. Once the contractor has been engaged, I recommend that an Artesian Aquifer Interception Management Plan, which will include a Grouting Management Plan for the construction of the bridge piles, be developed and submitted to the consenting authority for certification before construction starts, as part of the overall Construction Environmental Management Plan (CEMP) for the Project.

159. I consider that the additional boreholes as proposed in the construction methodology should be drilled at the exact location of the piles to confirm geology.

160. The pile construction methodology may be updated if needed once geology is confirmed at the exact locations of the piles and a contractor has been engaged. I recommend that any updates on the piling construction methodology, as well as technical justification and management of potential risks to the aquifer for the proposed changes, should be submitted to GWRC for certification before construction of the piles.

161. I also recommend that groundwater level and quality monitoring of the shallow groundwater in the vicinity of the river works should be undertaken through the existing telemetered piezometers and as proposed in the GMP.

162. At Detailed Design stage and prior to construction a final GMP (part of the CEMP) should be submitted to GWRC for certification. The updated management plan should include requirements for managing excavations that may encounter groundwater in the groundwater community drinking water supply zone (as defined in pNRP) and submitted to the consenting authority for approval when exact locations and dimensions of excavations that may require dewatering (utilities replacement, construction of culverts, pump stations etc) are known and before construction starts.

163. The CEMP should include a dewatering assessment for the works that may encounter groundwater and the following as a minimum:

i. Depth at which the aquitard is expected to be encountered within the area of proposed excavation

ii. Duration, location, volume and rate of dewatering required

iii. Quality of water to be discharged

iv. Effects of land subsidence

v. Effects on surface water bodies and interference effects on lawfully existing water takes

vi. Measures to avoid and/or mitigate any potential adverse effects from dewatering activities and appropriate discharge of pumped water

vii. Groundwater level monitoring requirements and trigger levels required during dewatering.

10. Conclusions

164. Long term and short-term monitoring groundwater level records indicate that groundwater levels in the Taita Alluvium are influenced by rainfall and by the water level of the Hutt River.

165. Gravel extraction from the channel and excavation and fill in the upper and lower river berms will occur (between the two existing stopbanks) between Kennedy Good and Ewen Bridges. The gravel extraction works are a combination of lowering the riverbed and

widening the channel with protected banks, either riprap or planting. The proposed riverbed levels for construction are consistent with historical (1998) levels (RHFMP) and as such fall within the natural range that has been measured in this area.

166. A number of factors affect the river losses/gains in addition to the river flow rates. The main factors that influence the river/groundwater flow exchange are the groundwater level in the unconfined Taita aquifer and the groundwater abstraction in the confined Waiwhetu Aquifer. During the proposed riverbed reprofiling, shallow groundwater discharges to the river within the Project area are expected to result in groundwater exchange from Waiwhetu to the Taita in the order of 71 m^3/day to 210 m^3/day across the full length of the proposal, which includes the potential recharge losses from Taita. This represents a very small percentage of the total aquifer volume and pumped daily rates from Waterloo wellfield.

167. The groundwater – river interaction is complex and the Taita aquifer within the Project area may be recharged by the Hutt River during high river water levels (e.g. flood events). Therefore, management of the river water quality during construction is expected to minimise any potential to affect the groundwater quality in the shallow aquifer.

168. Modelling results (presented in **Appendix B**) indicate that under river "flood" conditions with simultaneous high pumping at the Waterloo well field, "river losses" to groundwater are expected to increase by up to 0.4 m^3/day per linear m when compared to the existing state. Most of the "river losses" are expected to be to the Taita Alluvium, with only with only 61 m^3/day and up to 85 m^3/day additional flow expected to reach Waiwhetu (i.e. ~1 L/s). The additional inflow rate is considered to be negligible and immeasurable when compared to the Waiwhetu aquifer volumes of water and the broader recharge to the aquifer system from the river upstream of the site (which is in the order of 60,000 m^3/day to 100,000 m^3/day).

169. To provide a level of comfort to the relevant stakeholders regarding the effects on water quality and quantity from the proposed works, it is recommended that monitoring of the shallow and deep groundwater levels and groundwater quality (including turbidity, pH, Dissolved Oxygen (DO), hardness, Ecoli) in the vicinity of the Project be undertaken pre-construction, during and post-construction through the existing and proposed additional telemetered piezometers and in accordance with the attached in **Appendix D** draft Groundwater Management Plan (GMP) to confirm the assessed envelope of effects.

170. The proposed construction methodology for the piles that will penetrate the confining layer and into the Waiwhetu aquifer, and specifically the use of double casing methodology and sealing (grouting) around the casing of the aquiclude, is considered a robust and proven construction methodology to address the potential quality and quantity risks to groundwater. I consider that the pile construction methodology should be reviewed once geology is confirmed (following drilling) at the locations of the piles and updated if required. The localised geology could influence the construction method, such as the extent and depth of aquitard and/or Waiwhetu gravels. I would expect that any updates on the methodology and technical justification should be submitted to GWRC (in its consent authority capacity) for certification before commencement of pile construction. This approach is considered to be best practice in terms of ensuring that the proposed construction methodology is aligned to the in-situ ground conditions.

171. Any dewatering activities are expected to be managed with standard construction practices to minimise the potential of adverse effects on groundwater and adjacent structures. Additional hydrogeological investigations should be undertaken near any proposed excavations that may be required for relocation of utilities, culvert outlets and stormwater pump stations.to define any dewatering requirements. A dewatering

assessment and an assessment of potential settlement effects should be undertaken prior to construction to update and finalise the Construction Environmental Management Plan (CEMP). The attached draft GMP should be updated to include additional groundwater and settlement monitoring if required. Any short-term dewatering for the Project will not affect the long term overall shallow groundwater flow direction.

172. Given the small scale, magnitude and extent of changes identified I consider the potential adverse effects of the Project on groundwater overall to be minor. Any potential effects can be appropriately addressed through the standard-practice management measures (including the GMP) I have recommended to be included as part of the overall Project CEMP.

23 July 2021

Dr Theodora Avanidou

Appendix A – Groundwater level monitoring data

Groundwater Monitoring

At the Project area continuous telemetered groundwater level monitoring has been undertaken since September 2020 in five locations as shown in Figure C1. Table C1 summarises the current (April 2021) instrumentation and groundwater monitoring at the Project area

Figure A1 Location Plan of Project's Piezometers

Table A1 Summary of current (April 2021) instrumentation and groundwater monitoring at the Project area

ID	Type	Ground surface elevation[1] RL (m)	Screen / vibrating wire installation depth (m bgl)	Geological unit
BH18-1	Vibrating Wire Piezometer	7.89	17	Taita Alluvium
BH18-107	Standpipe Piezometer	6.5	3.0 – 4.0	Taita Alluvium

BH18 -16	Standpipe Piezometer	6.5	4.5 – 7.5	Taita Alluvium
BH19-1	Vibrating Wire Piezometer	5.0	11, 15 and 24	Taita Alluvium, and Waiwhetu Aquifer
BH19-2	Standpipe Piezometer	4.5	7.5 – 11.5	Taita Alluvium

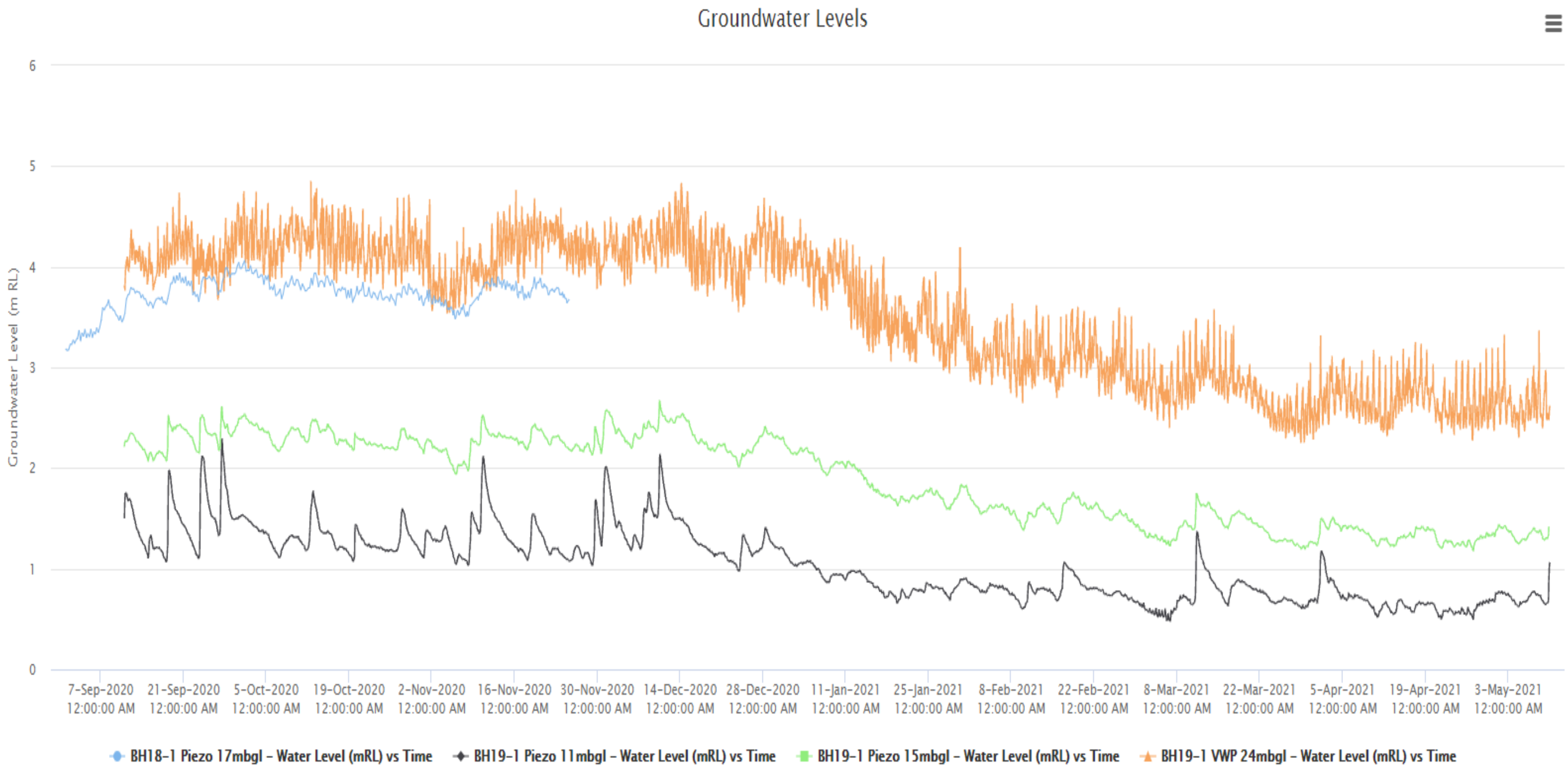

Figure A2 Groundwater level monitoring in Vibrating Wire Piezometers (graph extracted from GWRC site set up by Geotechnics for Riverlink Project https://www.geotechnicssolutions.com/#/private/reports/containerxyreport)

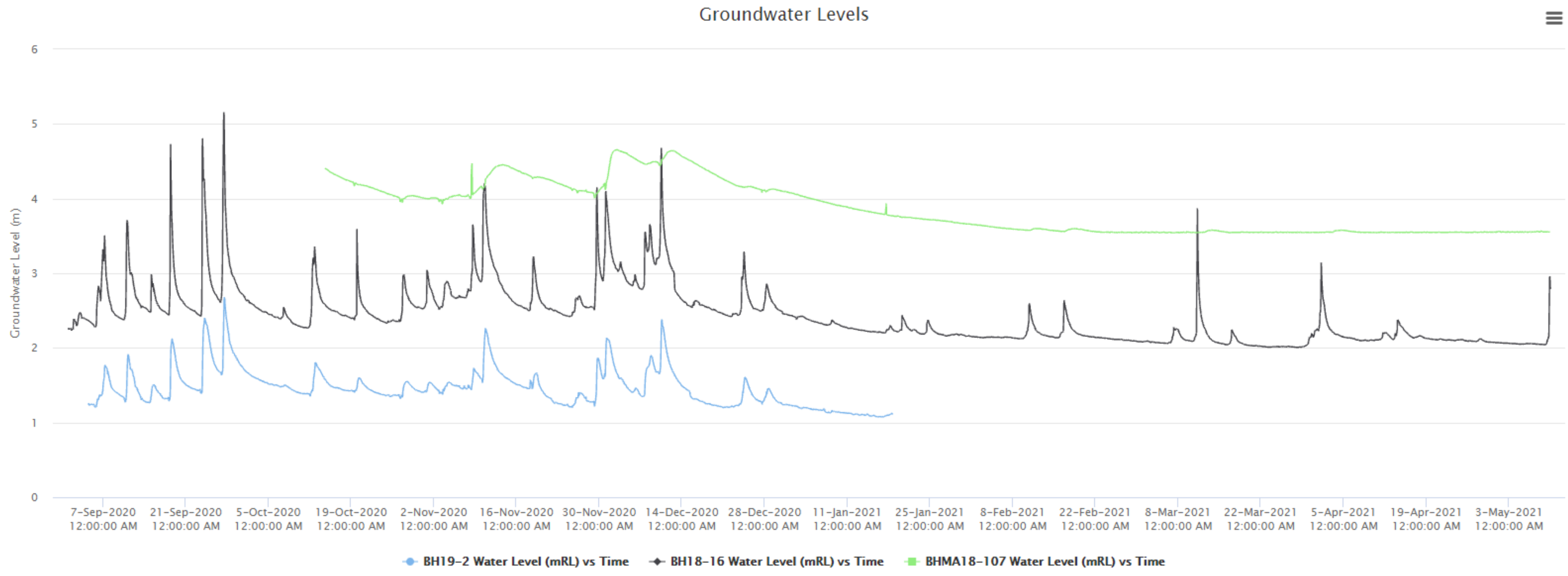

Figure A3 Groundwater level monitoring in Standpipe Piezometers graph extracted from GWRC site set up by Geotechnics for Riverlink Project https://www.geotechnicssolutions.com/#/private/reports/containerxyreport)

Appendix B – Groundwater Modelling Assumptions and Results

Groundwater Modelling Technical Appendix

1.1 Introduction

Two-dimensional modelling was undertaken using Geostudio 2019 SEEP/W finite element numerical modelling software. Two different types of modelling were undertaken: 1) three cross sections were created to estimate the potential changes in the groundwater – surface water interaction due to newly excavated river profiles and 2) plan view modelling to identify if any significant changes could be expected in the artesian aquifer groundwater flow dynamics due to the introduction of the proposed bridge piles. This technical appendix details the models' set up, modelling limitations and assumptions, sensitivity analyses, and the results.

The decision to use 2D modelling, over 3D was based on the following:

- 2D numerical assessments are inherently more conservative. Stresses are simulated as uniformly extending in the third dimension, increasing the simulated magnitude of potential effects. Often, 3D modelling is considered when the 2D simulation results are deemed overly conservative.
- Potential effects on the underlying Waiwhetu aquifer are expected to be mainly due to very localised effects, such as discontinuities in confinement near the project works. These effects can be better represented (albeit greatly exaggerated) in a 2D model, with more localised detail, much finer discretisation, and very targeted stresses.

1.2 Model Set Up

Four groundwater flow models were created to represent existing and proposed conditions at four sites within the Riverlink project area. Details about each model are summarised in Table B1 including the references to information used to create each section.

One model was created in plan view to simulate the overall horizontal flows within the Waiwhetu aquifer.

Three cross sectional models were created perpendicular to the Hutt River (upgradient and downgradient of Melling bridge) at river cross sections 360, 500, and 600. The sections were chosen as representative of the deepest proposed gravel excavation within the existing riverbed as well as the proposed widening of the riverbed. Two of the cross sections (360 and 500) were also close to the telemetered piezometers. This was deemed important as the models were calibrated to measured groundwater levels in both the Taita Alluvium and upper Waiwhetu Gravels. Furthermore, sections 500 and 600 are more likely to represent the semiconfined / unconfined upper Waiwhetu Gravels as site specific data and the 3D geological model show a thin layer of confining material. Section 600 is located close to the Kennedy Good Bridge and was modelled such as to assess the effects of a "losing" section of the Hutt River during low flow conditions (although there is no groundwater level monitoring in that area to conceptualise the river groundwater interaction near the Kennedy Good Bridge). Furthermore, there is modelled an approximately 1.3 m river water stage drop under low flow conditions (7-Day Mean Annual Low Flow) due to the proposed river works.

The river cross section locations are shown on the Stopbank Overall Layout Plans, Drawings No A16-4381-SB140 & SB141 (Volume 5 of AEE). Existing and future river profiles (Figure B1 – Figure B3) were extracted from Melling Update river cross section drawings (A16-4381-SB400 –

A16-4381-SB433) in Volume 5 of AEE. Extended section topography was adapted from Greater Wellington Regional Council (GWRC) publicly available ground surface contours.

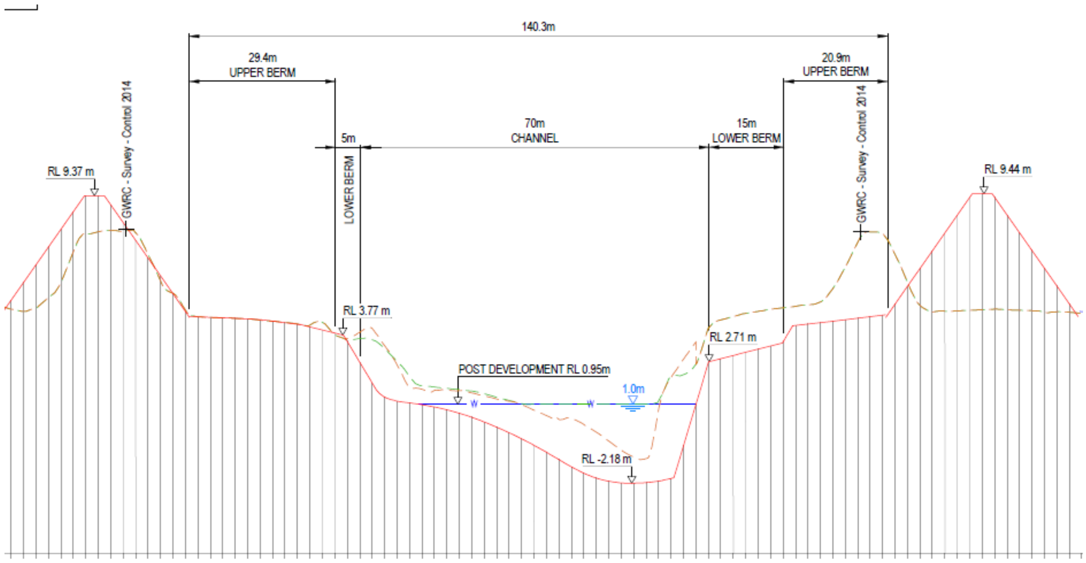

Figure B1 River Section 360 - extract from drawing A16-4381-SB418

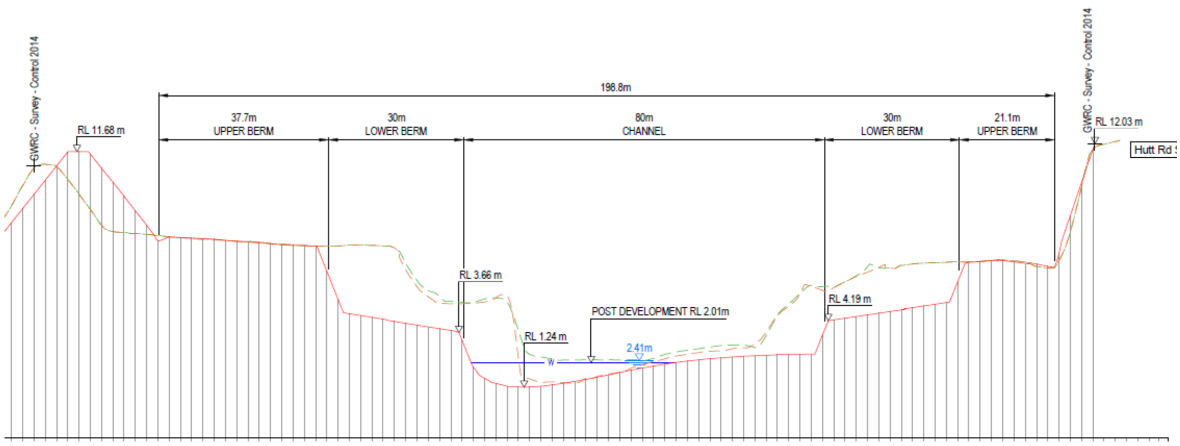

Figure B2 River Section 500 - extract from drawing A16-4381-SB404

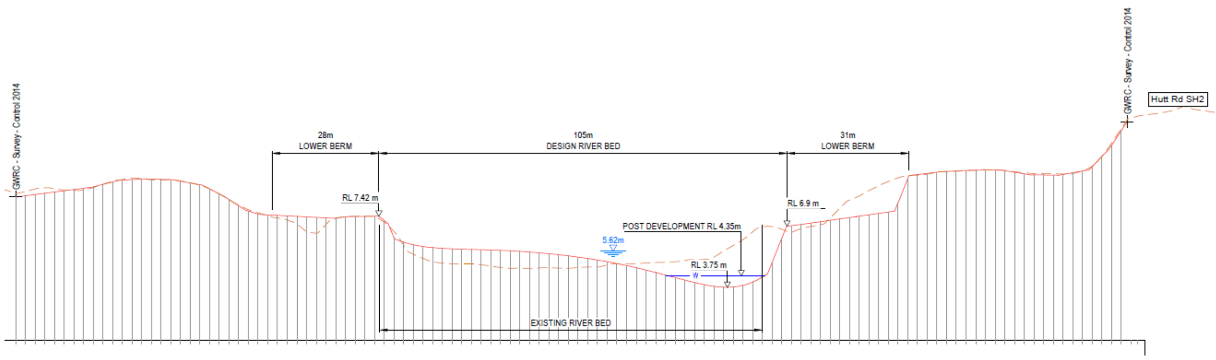

Figure B3 River Section 600 - extract from drawing A16-4381-SB428

Stratigraphy was created based on geological interpretation from publicly available bore logs from the New Zealand Geotechnical Database (NZGD), recently drilled boreholes (Stantec

2019, & 2020 and T&T, 2020) as part of initial phases of this project, as well as the GWRC's regional 3D-geological model.

Table B1 SEEP/W Section Details

Section	Type	Length (m)	Nearest bores (NZGD or Riverlink or GWRC)	Volume 5 of AEE drawings reference
XS360	Cross section	800	BH_114791 BH_19-2	A16-4381-SB404
XS500	Cross section	500	BH_144891 BH_114699	A16-4381-SB418
XS600	Cross section	700	NZGD 83875 NZGD 83876 NZGD 83855	A16-4381-SB428
Waiwhetu plan view	Plan view	1,500 x 2,000	R27/1116, R27/1115	A16-4381-S202

- Each model was run under steady state conditions. This assumption is considered conservative as it assumes long term high stresses within the Hutt River and underlying aquifers, while aquifer dynamic responses are expected to mitigate the simulated effects.
- The existing state models were calibrated to groundwater levels observed in proximal piezometers within the project area located close to the modelled cross sections. In the absence of groundwater level data information for section 600 water levels were simulated to reflect the reported conceptual understanding of the groundwater system near upgradient of Kennedy Good Bridge (i.e. river level is modelled 0.5 m above far field groundwater levels). A head difference of 0.5 m between the river level and shallow piezometers close to the river was recoded in historic shallow piezometers located ~1.3 Km upgradient of Kennedy Good Bridge (EIM, 2014) where the aquifer is unconfined.
- Post calibration, the model geometry was modified to simulate the proposed works (proposed riverbed levels and modelled river stage changes).
- Sensitivity analysis was undertaken to determine if the modelled outputs are particularly sensitive to the main model assumptions (soil parameters, extend of confining layer above the Waiwhetu gravels, negative hydraulic gradient in Waiwhetu Gravels due to Waterloo wellfield pumping).

The models' set up (base case) are shown in Figures B4 to B7.

Color	Name	Model	Vol. WC. Function	K-Function	Ky'/Kx' Ratio
	Basement - Greywacke	Saturated / Unsaturated	Silt	Basement rock, Ksat = 3.0e-08 m/s	1
	Clay / silt - confining layer	Saturated / Unsaturated	Clay/Silt	Clay/Silt, Ksat = 1e-07 m/s	0.1
	Gravel /sand and silt riverbed	Saturated / Unsaturated	Silty Sand	Silty Sand, Ksat = 2.0e-6 m/s	0.1
	Sandy gravel, some silt	Saturated / Unsaturated	Fine sand	Sand and Gravel some silt, Ksat=3.5e-04m/s	0.5
	Sandy Silt / Silty Sand	Saturated / Unsaturated	Sandy Silt	Sandy Silt, Ksat = 2e-05 m/s	0.3
	Stopbank / Fill material	Saturated / Unsaturated	Silt	Sandy Silty Clay. Ksat = 3e-07 m/s	0.1
	Upper Waiwhetu Gravels	Saturated / Unsaturated	Sand	Uniform sand, Ksat=1.6e-02m/s	1

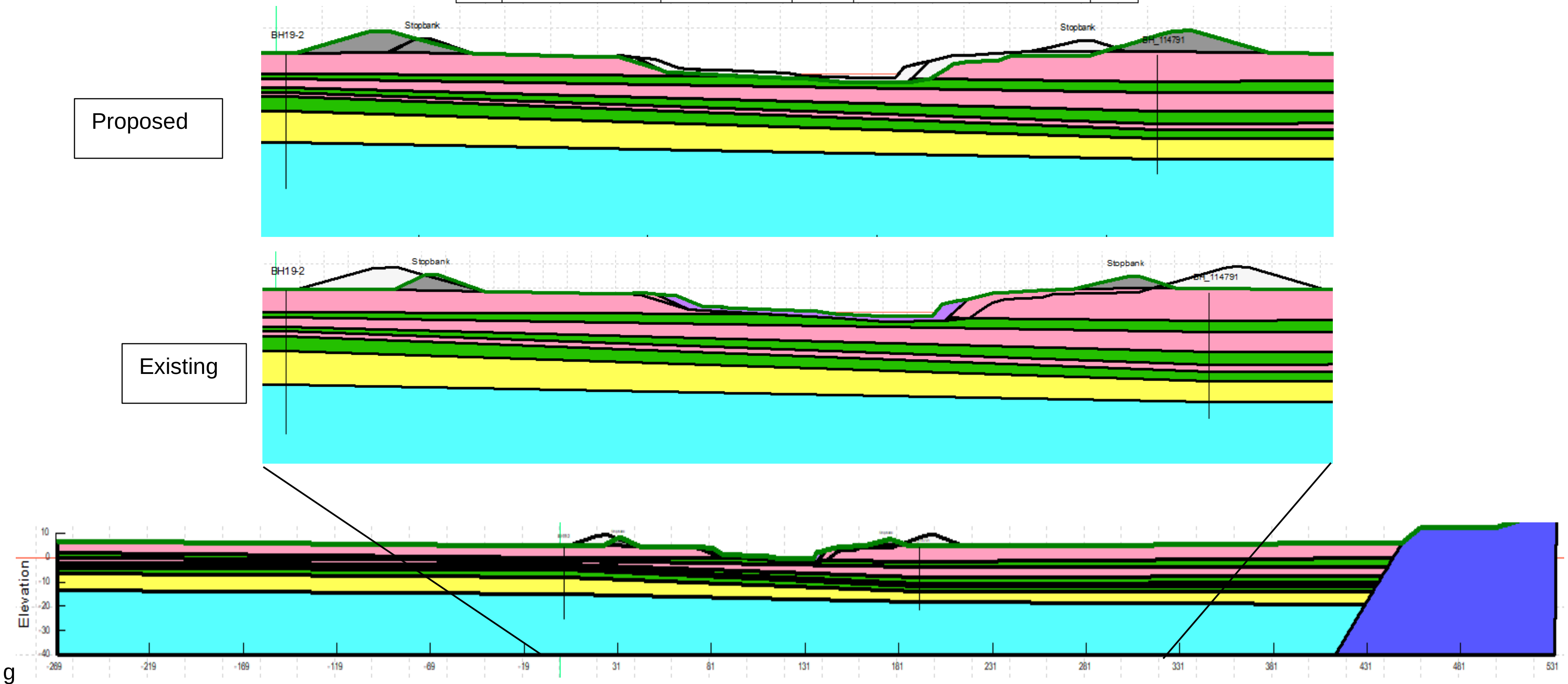

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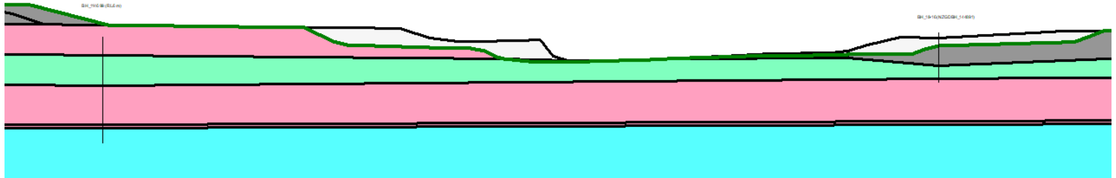
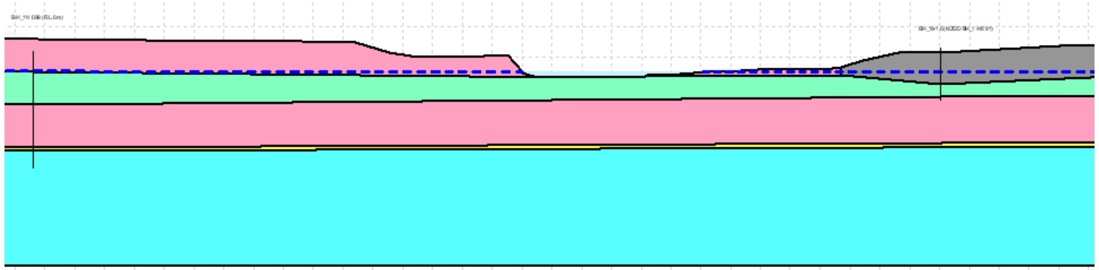
Figure B4- SEEP/W Cross Section 360 – Base case Set Up (existing & proposed excavation)

Color	Name	Model	Vol. WC. Function	K-Function	Ky'/Kx' Ratio
	Basement - Greywacke	Saturated / Unsaturated	Silt	Silty Clay Ksat = 3.0e-08 m/s	1
	Sand, silt, and some gravel	Saturated / Unsaturated	Sandy Silt	Silty Sand, Ksat= 9.0e-5 m/s	0.1
	Sandy Silt/Silty Sand	Saturated / Unsaturated	Sandy Silt	Sandy Silt, Ksat= 2e-05 m/s	0.1
	Silt with minor Sand / Fill	Saturated / Unsaturated	Silt	Sandy Silty Clay. Ksat = 3e-07 m/s	0.1
	Silt/Clay - Confining Layer	Saturated / Unsaturated	Clay/Silt	Clay/Silt, Ksat = 1e-07 m/s	0.1
	Upper Waiwhetu Gravels	Saturated / Unsaturated	Sand	Uniform sand, Ksat= 1.7e-02m/s	1

Proposed



Existing



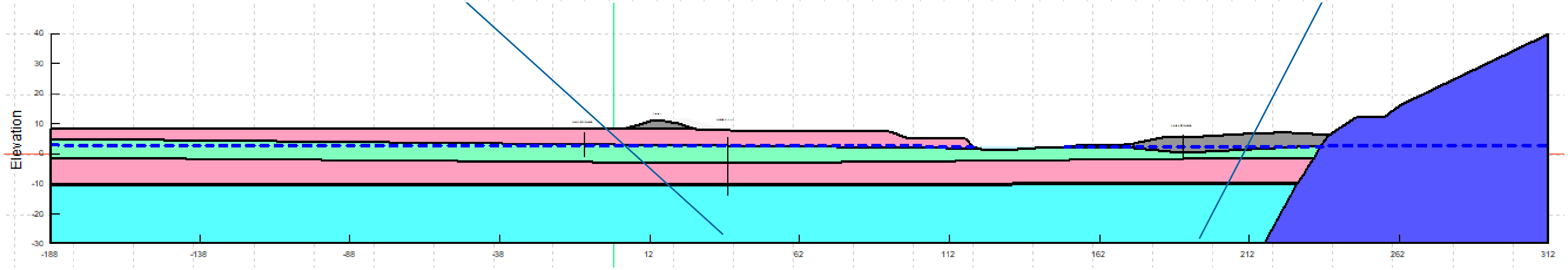


Figure B5 SEEP/W Cross Section 500 – Base Case Set Up

Color	Name	Model	Vol. WC. Function	K-Function	Ky'/Kx' Ratio
	Basement - Greywacke	Saturated / Unsaturated	Silt	Silty Clay, Ksat = 3.0e-08 m/s	1
	Gravel	Saturated / Unsaturated	Sandy Silt	Gravel, Ksat = 5e-05 m/s	0.1
	Gravel /sand and silt riverbed	Saturated / Unsaturated	Silty Sand	Silty Sand, Ksat = 2.0e-6 m/s	0.1
	Sandy Silt/Silty Sand	Saturated / Unsaturated	Sandy Silt	Sandy Silt, Ksat = 2e-05 m/s	0.1
	Silt/Clay - Confining Layer	Saturated / Unsaturated	Clay/Silt	Clay/Silt, Ksat = 1e-07 m/s	0.1
	Upper Waiwhetu Gravels	Saturated / Unsaturated	Sand	Uniform sand, Ksat=1.7e-02m/s	1

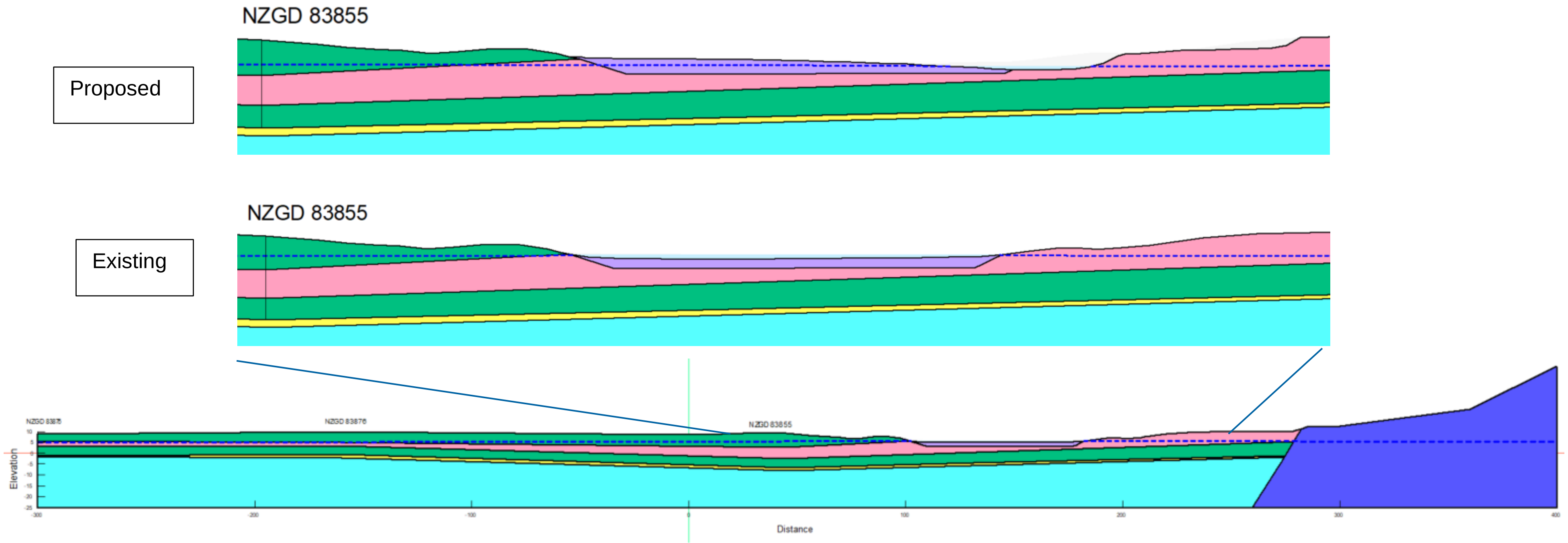


Figure B6 SEEP/W Cross Section 600 – Base Case Set Up

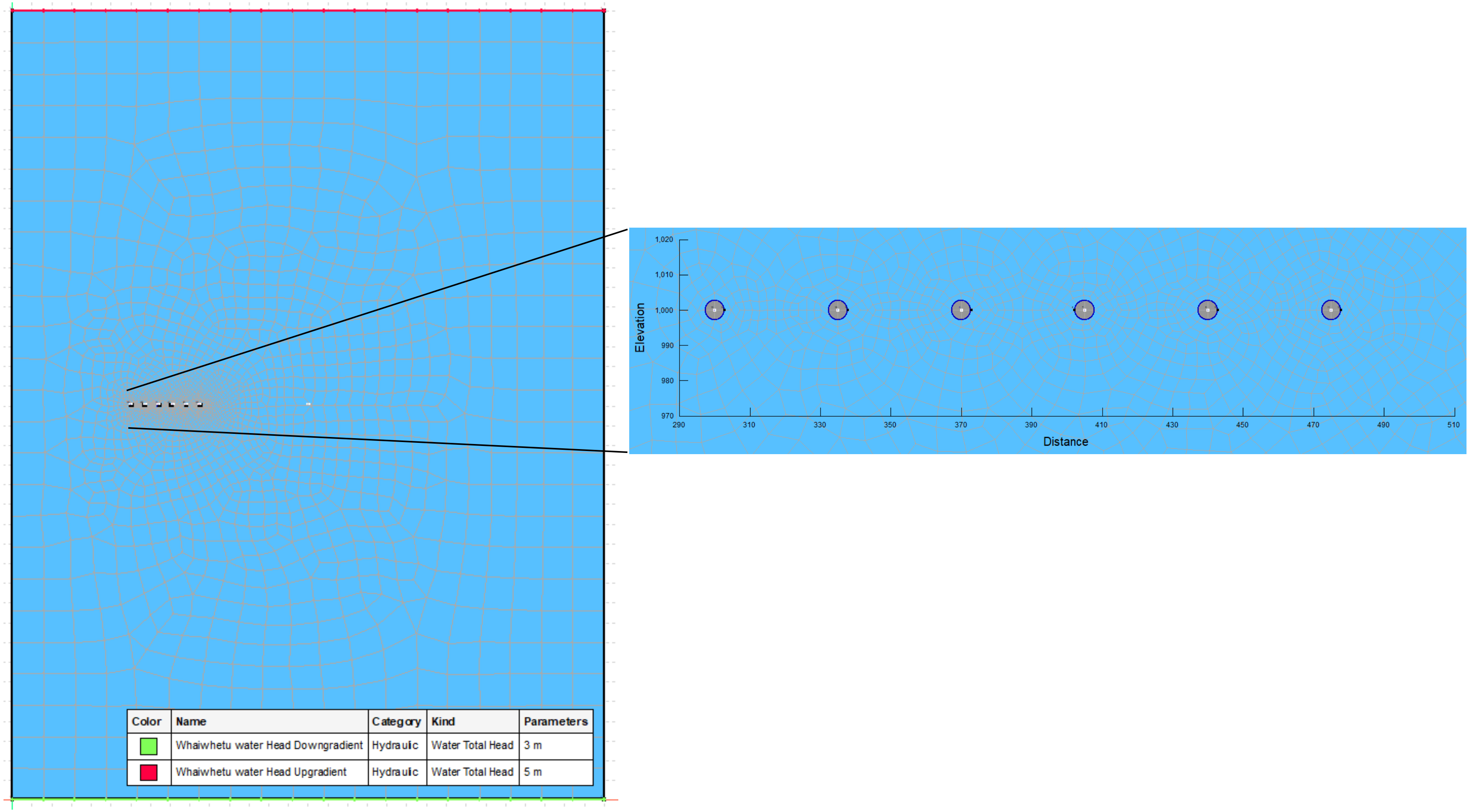


Figure B7 SEEP/W Plan View (Waiwhetu) Set Up (with piles)

Modelling of pumping scenarios has been undertaken recently by EIM (2020) using the Hutt Aquifer Model (HAM3) to analyse the negative vertical (downward) flow gradients in the Waiwhetu aquifer for the delineation of areas and setback zones that may impact groundwater quality in the Waiwhetu aquifer (T&T, 2020). The modelled vertical groundwater head differences around the Waterloo Wellfield during pumping since 2002 are illustrated in Figure B8 below. As the authors (EIM, 2020) note this figure indicates that negative vertical gradients were not encountered often during pumping at historical rates and when they did, they were attributed to a combination of rainfall/river recharge and elevated groundwater levels in the Taita Alluvium.

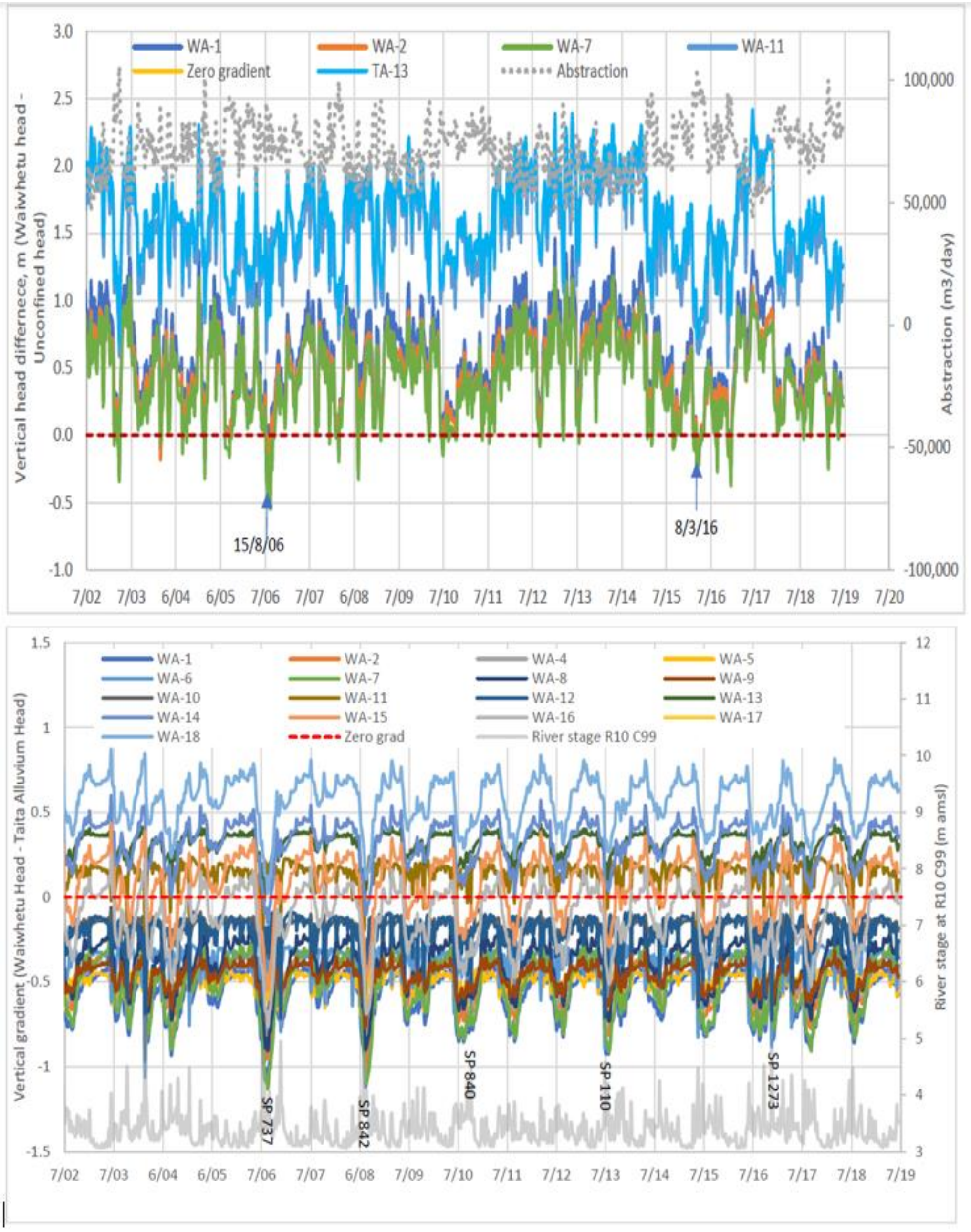


Figure B8 Modelled vertical groundwater head differences around the Waterloo Wellfield during pumping at historical rates and when the wellfield is pumping at a constant rate of 100,000 m3/day (extract from EIM, 2020)

To simulate the potential of a negative hydraulic gradient in the upper Waiwhetu Gravels near the project area, an additional scenario has been simulated. This scenario assumes a lower head (Waiwhetu head – Taita Alluvium head = - 0.5 m) in the Waiwhetu Gravels.

1.3 Modelling Assumptions and Limitations

- A constant head boundary was set on the east/southeast edges of cross section models XS360, XS500 and XS600. No flow boundary conditions were assumed on the western edges set beyond the Wellington Fault. This is considered reasonable as the fault likely acts as a no-flow barrier and basement rock beyond the fault is understood to have low permeability. Therefore, the groundwater flow introduced from the west is not considered to be significant.

- Ground conditions and water levels have been modelled and calibrated based on our conceptual understanding of the site, built on previous investigations and recent available information (site specific investigations and 3-D geological model). Water levels and geological conditions further away from the alignment may vary from what was modelled. Sensitivity analyses have been run to account for the natural heterogeneity in ground conditions.

- The goal of the modelling was to understand the difference in river inflows or groundwater flow patterns after construction (excavating and lowering the riverbed). Therefore, it is considered appropriate (and conservative) to simulate steady state conditions (i.e. one river level or constant head condition) as it is the flow difference at one particular time which is of interest.

1.4 Material Properties

Figure B9 (a-d) shows the material properties adopted for each of the base case models. The hydraulic conductivity (K) and water content functions of the materials are based either on the range of limited regional specific data (EIM, 2014) or in the case of non-existing site-specific measurements or estimates reported values from the literature were used.

In general, for natural soils and sedimentary materials, the vertical hydraulic conductivity is lower than the horizontal conductivity. Therefore, some Ky/Kx anisotropy was assigned to some stratigraphic units. Boundary conditions applied to each model are detailed in Table D2.

a) River cross section 360

Color	Name	Model	Vol. WC. Function	K-Function	Ky'/Kx' Ratio
	Basement - Greywacke	Saturated / Unsaturated	Silt	Basement rock, Ksat = 3.0e-08 m/s	1
	Clay / silt - confining layer	Saturated / Unsaturated	Clay/Silt	Clay/Silt, Ksat = 1e-07 m/s	0.1
	Gravel /sand and silt riverbed	Saturated / Unsaturated	Silty Sand	Silty Sand, Ksat = 2.0e-6 m/s	0.1
	Sandy gravel, some silt	Saturated / Unsaturated	Fine sand	Sand and Gravel some silt, Ksat=3.5e-04m/s	0.1
	Sandy Silt / Silty Sand	Saturated / Unsaturated	Sandy Silt	Sandy Silt, Ksat = 2e-05 m/s	0.1
	Stopbank / Fill material	Saturated / Unsaturated	Silt	Sandy Silty Clay. Ksat = 3e-07 m/s	0.1
	Upper Waiwhetu Gravels	Saturated / Unsaturated	Sand	Uniform sand, Ksat=1.6e-02m/s	1

b) River cross section 500

Color	Name	Model	Vol. WC. Function	K-Function	Ky'/Kx' Ratio
	Basement - Greywacke	Saturated/ Unsaturated	Silt	Silty Clay Ksat = 3.0e-08 m/s	1
	Sand, silt, and some gravel	Saturated/ Unsaturated	Sandy Silt	Silty Sand, Ksat= 9.0e-5 m/s	0.1
	Sandy Silt/Silty Sand	Saturated/ Unsaturated	Sandy Silt	Sandy Silt, Ksat= 2e-05 m/s	0.1
	Silt with minor Sand / Fill	Saturated/ Unsaturated	Silt	Sandy Silty Clay. Ksat = 3e-07 m/s	0.1
	Silt/Clay - Confining Layer	Saturated/ Unsaturated	Clay/Silt	Clay/Silt, Ksat = 1e-07 m/s	0.1
	Upper Waiwhetu Gravels	Saturated/ Unsaturated	Sand	Uniform sand, Ksat= 1.7e-02m/s	1

C) River cross section 600

Color	Name	Model	Vol. WC. Function	K-Function	Ky'/Kx' Ratio
	Basement - Greywacke	Saturated / Unsaturated	Silt	Silty Clay, Ksat = 3.0e-08 m/s	1
	Gravel	Saturated / Unsaturated	Sandy Silt	Gravel, Ksat = 5e-05 m/s	0.1
	Gravel /sand and silt riverbed	Saturated / Unsaturated	Silty Sand	Silty Sand, Ksat = 2.0e-6 m/s	0.1
	Sandy Silt/Silty Sand	Saturated / Unsaturated	Sandy Silt	Sandy Silt, Ksat = 2e-05 m/s	0.1
	Silt/Clay - Confining Layer	Saturated / Unsaturated	Clay/Silt	Clay/Silt, Ksat = 1e-07 m/s	0.1
	Upper Waiwhetu Gravels	Saturated / Unsaturated	Sand	Uniform sand, Ksat=1.7e-02m/s	1

C) Plan view Waiwhetu

Color	Name	Model	Sat Kx (m/sec)	Ky'/Kx' Ratio	Volumetric Water Content	Compressibility (/kPa)
	Concrete	Saturated Only	1e-10	1	0.1	0
	Waiwhetu Gravel	Saturated Only	0.017	1	0.2	0

Figure B9 a-d Model material properties

Table B2 Model boundary conditions

Model	Parameter	Adopted Value	Reference
XS360 XS500 XS600	Far field constant head boundary	Section-360: 1.5 m RL in Taita Alluvium (representing the head measured in BH19-2) and 3.5 m RL in Upper Waiwhetu Gravels (representing the artesian pressure head measured in BH19-1)	The far field constant head boundaries were set by calibrating the models to generally match the observed water levels in bores (Table D1) Groundwater Levels measured are presented in

Model	Parameter	Adopted Value	Reference
		Section 500: 3 m RL in both Taita Alluvium and Waiwhetu Gravels Section 600: 5 m RL in both Taita Alluvium and Waiwhetu Gravels	Appendix A of Technical Assessment #5. Approximate head level simulated in HAM3 model (EIM, 2014)
XS360 XS500 XS600 Simulation of negative hydraulic gradient	Far field constant head boundary	Section-360: 2 m RL in Taita Alluvium and 1.5 m RL in upper Waiwhetu Gravels to simulate a negative hydraulic gradient Section 500: 3 m RL in Taita Alluvium and 2.5 m RL in upper Waiwhetu Gravels to simulate a negative hydraulic gradient Section 600: 5 m RL in Taita Alluvium and 4.8 m RL in upper Waiwhetu Gravels to simulate a negative hydraulic gradient	The modelled negative hydraulic gradient understood to be present in the Taita & Waiwhetu aquifers under constant pumping conditions of 100,000 m^3/day from Waterloo Wellfield (conservatively assumed that the negative hydraulic gradient is permanent)
Plan view	Upgradient and Downgradient far field constant head boundary	Waiwhetu plan view Upgradient: 5 m RL Waiwhetu plan view Downgradient: 3 m RL	Constant Head Boundaries have been set based on values from long-term continuous monitoring undertaken in GWRC monitoring bores (R27/1116 and R27/1117) screened in upper Waiwhetu Gravels
XS360 XS500 XS600	Constant river head boundary (current)	XS360: 1.0 m RL XS500: 2.41 m RL XS600: 5.62 m RL	7 Day Mean Annual Low Flow (MALF) From consent drawings modelled river water levels
XS360 XS500 XS600	Constant river head boundary (post-development)	XS360: 0.95 m RL XS500: 2.01 m RL XS600: 4.35 m RL	Based on consent drawings modelled river water levels for the proposed riverbed dimensions
XS360 XS500 XS600	Constant river head boundary	XS360: 3 m RL XS500: 3.5 m RL XS600: 7.62 m RL	To simulate flood conditions / a higher river stage than groundwater levels measured in Taita Alluvium

1.5 Sensitivity Analyses

As all materials have not undergone site-specific testing, there is likely to be localised variation in hydraulic conductivity from what was adopted in the base case. Therefore, sensitivity analyses are undertaken to estimate the variability in groundwater inflows due to natural variation in ground conditions and what effect it has on the magnitude of these inflows from existing to future state conditions. Sensitivity analysis was also used to conservatively stress-test the model outcomes, in terms of flow and hydrogeological conditions, which may be locally different than those simulated in the base cases. The sensitivity analyses modelled for each section are described in Table B3 but generally incorporated increasing and decreasing the material hydraulic conductivity values surrounding the riverbed by half order of magnitude. Additional scenarios modelled are: the assumption of a negative hydraulic gradient (EIM, 2020) between the Taita Alluvium and Upper Waiwhetu gravels from the Waterloo wellfield pumping, the removal of the confining layer to account for the uncertainty around the extent and thickness of the aquitard as well as a scenario where there is no aquitard and a negative hydraulic gradient is still applied in the model sections. Some of these scenarios are not supported by the available field data but are considered here as "worst case" scenarios given the importance of the Waiwhetu aquifer as a critical source of drinking water for the Wellington metropolitan area. We also note that in the majority of the modelled scenarios there is the conservative assumption that the material excavated and removed from the existing riverbed have a low permeability (more than one order of magnitude lower than the silty sand and gravelly sand layers of Taita Alluvium. This is considered conservative as the proposed excavations (~1998 surveyed bed levels) are above the historical surveyed low riverbed levels and a lower permeability layer is expected to extend at lower elevations from historical deposits.

Table B3 Sensitivity analysis scenarios

Sensitivity Scenario	Description
XS360	
S1	Increase hydraulic conductivity of silty sand material by a half order of magnitude
S2	Increase hydraulic conductivity of sandy gravel material by a half order of magnitude
S3	Decrease hydraulic conductivity of silty sand material by a half order of magnitude
S4	Decrease hydraulic conductivity of sandy gravel material by a half order of magnitude
Negative Hydraulic Gradient	Waiwhetu Gravels Head – Taita Alluvium Head = -0.5 m
Removal of confining layer	Replacement of the confining layer (silty/clay layer) with a more permeable silty sand material (increase of two orders of magnitude of hydraulic conductivity)
Removal of confining layer and negative hydraulic gradient	Replacement of the confining layer (silty/clay layer) with a more permeable silty sand material (increase of two orders of magnitude of hydraulic conductivity)

	Waiwhetu Gravels Head – Taita Alluvium Head = -0.5 m
Increase of River Stage and negative hydraulic gradient	Increase of the river stage by 2 m from the base case scenario (7-Day Mean Annual Low Flow) Waiwhetu Gravels Head – Taita Alluvium Head = -0.5 m
XS500	
S1	Increase hydraulic conductivity of “silt with some sand /fill” material by a half order of magnitude
S2	Increase hydraulic conductivity of sand material by a half an order of magnitude
S3	Increase hydraulic conductivity of silty sand material by a half order of magnitude
S4	Decrease hydraulic conductivity of fill material by a half order of magnitude
S5	Decrease hydraulic conductivity of sand material by a half order of magnitude
S6	Decrease hydraulic conductivity of silty sand material by a half order of magnitude
Negative Hydraulic Gradient	Waiwhetu Gravels Head – Taita Alluvium Head = -0.5 m
Removal of confining layer	Replacement of the confining layer (silty/clay layer) with a more permeable silty sand material (increase of two orders of magnitude of hydraulic conductivity)
Removal of confining layer and negative hydraulic gradient	Replacement of the confining layer (silty/clay layer) with a more permeable silty sand material (increase of two orders of magnitude of hydraulic conductivity) Waiwhetu Gravels Head – Taita Alluvium Head = -0.5 m
Increase of River Stage and negative hydraulic gradient	Increase of the river stage by 2 m than the base case scenario (7-Day Mean Annual Low Flow) Waiwhetu Gravels Head – Taita Alluvium Head = -0.5 m
XS600	
S1	Increase hydraulic conductivity of silty sand material by a half order of magnitude
S2	Increase hydraulic conductivity of gravel material by a half an order of magnitude
S3	Decrease hydraulic conductivity of silty sand material by a half order of magnitude
S4	Decrease hydraulic conductivity of gravel material by a half order of magnitude

S5	Decrease far field constant head boundary by 0.5 m to simulate steeper gradient between river level and groundwater levels
Negative Hydraulic Gradient	Waiwhetu Gravels Head – Taita Alluvium Head = -0.2 m
Removal of confining layer	Replacement of the confining layer (silty/clay layer) with a more permeable silty sand material (increase of two orders of magnitude of hydraulic conductivity)
Removal of confining layer and negative hydraulic gradient	Replacement of the confining layer (silty/clay layer) with a more permeable silty sand material (increase of two orders of magnitude of hydraulic conductivity) Waiwhetu Gravels Head – Taita Alluvium Head = -0.5 m
Increase of River Stage	Increase of the river stage by 2 m than the base case scenario (7-Day Mean Annual Low Flow)

1.6 Modelling Results

1.6.1 Hutt River Inflow Rates Pre and Post Development

Results of the seepage modelling (including sensitivity analysis) scenarios for XS360, XS500, and XS600 are presented in Table D4. The 2-D modelling results represent the sum of inflows into a 1 m section of riverbed in m^3/day. To estimate the total groundwater seepage flow for each excavation, the modelled seepage would need to be multiplied by the relevant river length, however, groundwater flow dynamics may shift along the river (i.e. losing versus gaining) and this may not be always appropriate.

Section 360

The base case scenario for section 360 represents areas where the Waiwhetu aquifer is confined, and artesian pressures are measured in the site's piezometers (i.e. BH19-1 and BH18-1). As noted earlier for the modelled scenarios there is the conservative assumption that the material excavated and removed from the riverbed have a low hydraulic conductivity value (more than one order of magnitude lower than the silty sand and gravelly sand layers of Taita Alluvium. Section 600 is considered to be representative of ~ 1400 m river section (from XS300 – to XS460). This section represents the

Modelling results indicate that the difference in inflow rates (river gains from groundwater) from the existing state to post-development state for the base case and four of the nine sensitivity scenarios are estimated to be approximately 0.2 m^3/day per linear m (Table B4). This small increase on inflow rate into the river is from the Taita Alluvium as expected from the proposed river stage lowering and the removal of silty material from the riverbed. Only a very small portion of this rate is contributed from the Waiwhetu aquifer (approx. ~0.02 m^3/day per linear m).

Some of the sensitivity analysis results suggest that river inflows can increase up to 1.2 m^3/day per linear m (Table B4) if there is no confining layer (replaced with a "silty sand" material in the simulations) and there exists a negative hydraulic gradient. Similarly, to above this river inflow rate increase is expected to be mainly from the Taita Alluvium, with only a very small portion (~0.12 m^3/day per linear m) contributed from the Waiwhetu aquifer.

These modelling results indicate that the proposed lowering of the riverbed will not result in reduced yield in the Waiwhetu aquifer due to water losses from the Waiwhetu to the river.

When river flood conditions are simulated (river stage is modelled at 3 m RL i.e. 2 m higher than the 7-Day MALF) in combination with pumping (simulated as the maximum historic simulated negative hydraulic gradient at the project area) “river losses” to groundwater are estimated to increase approximately 0.25 m^3/day per linear m. Under these conditions, Waiwhetu recharge from the river is expected to increase by a very small rate (~0.02 m^3/day per linear m). This inflow rate is negligible when compared to the Waiwhetu aquifer water takes and therefore is not expected to change the Waiwhetu water quality properties (Temperature, pH, conductivity, Dissolved Oxygen, hardness) at the bore field.

These small “groundwater losses” from the shallow Taita Alluvium to the river are likely to be reduced with time as fines and gravels will be deposited.

Section 500

The base case scenario for section 500 represents areas where the Waiwhetu aquifer is semi-confined / unconfined (with no artesian pressures) as only a thin layer of confining material was encountered in the limited deep investigations that extended in the Waiwhetu Gravels. Another difference to the conditions expected in section 360, is that the Waiwhetu Gravels are encountered at higher elevation and therefore closer to the existing riverbed. Section 500 is considered representative of ~ 1400 m river section (from XS460 – to XS600).

Modelling results indicate that the proposed riverbed works will result in small river inflow increases, when compared to the existing state. Most of the inflow increases are from the shallow Taita Alluvium due to the proposed lower riverbed and stage. For the base case and five of the nine sensitivity scenarios are estimated to be less than 0.2 m^3/day per linear m (Table B4). This river inflow increase is mainly from the Taita Alluvium and only a small portion is contributed from the Waiwhetu aquifer (~0.02 m^3/day per linear m).

The river inflows from shallow groundwater are expected to increase by up to 0.8 m^3/day per linear m (Table B4) if the confining layer is absent (replaced with a “silty sand” material in the simulation) and a negative hydraulic gradient is present. Similarly, to above, this additional river inflow is expected to be from the Taita Alluvium, with only ~0.1 m^3/day per linear m contributed from the Waiwhetu aquifer.

Similar to above, modelling results indicate that the proposed lowering of the riverbed will not result in reduced yield in the Waiwhetu aquifer due to losses from the Waiwhetu aquifer to the river.

When river flood conditions are simulated (river stage is modelled at 4.5 m RL -2 m higher than the 7-Day MALF) in combination with pumping (simulated as negative hydraulic gradient), river losses to groundwater are estimated to increase from the existing case by approximately 0.4 m^3/day per linear m (Table B4). A small portion of these losses (~0.03 m^3/day per linear m) is expected to reach Waiwhetu. This inflow rate is negligible when compared to the Waiwhetu aquifer volumes of water and therefore is not expected to change the Waiwhetu water quality properties (Temperature, pH, conductivity, Dissolved Oxygen, hardness).

As noted above these small “groundwater losses and gains” from the shallow Taita Alluvium to the river are likely to be reduced with time as fines and gravels will be deposited.

Section 600

Similarly, to section 500, the base case scenario for section 600 represents areas where the Waiwhetu aquifer is semi-confined / unconfined (with no artesian pressures) as only a thin layer of confining material was encountered in the limited deep investigations that extended in the Waiwhetu Gravels. Another difference to the conditions expected in sections 500 and 360, is that section 600 represents a losing section of the river. Section 600 is considered to be representative of ~ 500 m river section (from XS600 – to XS650).

Modelling results indicate that the proposed riverbed works will result in small river inflow increases mainly from the shallow Taita Alluvium due to the proposed lower riverbed and stage. For the base case and five of the nine sensitivity scenarios groundwater flows to the river are estimated to increase be less than 0.4 m^3/day per linear m (Table B4). Only a small portion of these inflows is contributed from the Waiwhetu aquifer (0.02 m^3/day per linear m).

The river inflows from shallow groundwater are expected to increase by up to 0.9 m^3/day per linear m (Table B4) if the confining layer is absent (replaced with a “silty sand” material in the simulation) and a negative hydraulic gradient is present. This additional river inflow is expected to be from the Taita Alluvium, with ~0.1 m^3/day per linear m contributed from the Waiwhetu aquifer.

Similar to above, the modelling results for section 600 also indicate that the proposed lowering of the riverbed will not result in reduced yield in the Waiwhetu aquifer due to losses from the Waiwhetu aquifer to the river.

When river flood conditions are simulated (river stage is modelled at 7.62 m RL -2 m higher than the 7-Day MALF) in combination with pumping (simulated as negative hydraulic gradient), river losses to groundwater are estimated to increase from the existing case by approximately 0.2 m^3/day per linear m (Table B4). A small portion of these losses (0.03 m^3/day per linear m) is expected to reach Waiwhetu. This inflow rate is negligible when compared to the Waiwhetu aquifer volumes of water and therefore is not expected to change the Waiwhetu water quality properties (Temperature, pH, conductivity, Dissolved Oxygen, hardness).

As noted above these additional small “groundwater losses and gains” from the shallow Taita Alluvium to the river are likely to be reduced with time as fines and gravels will be redeposited.

Previous modelling (HAM3) suggests that downstream of Kennedy Good Bridge long term river gains from the Taita Alluvium are estimated to be of the order of 3.3 m^3/day per linear m. This estimate includes approximately 3 km of predominantly gaining river section downgradient from the Riverlink project proposed works. Our modelling results suggest that immediately downgradient of the transition zone (where the river changes from losing to gaining) current gains are of the order of 0.3 m^3/day/linear m, increasing to up to 1.5 m^3/day/linear m post development. Considering that:

1. we simulate only permanent low flow and low recharge conditions;
2. the purpose of our model was not to simulate the flow exchange between the river and the alluvium, but the changes that the proposed development will cause to this exchange;
3. the previous modelling assumes riverbed elevations more in line with our proposed post development levels;
4. we conservatively (for the purposes of our assessment) assume that both the river bottom and the riverbanks are currently silted, limiting river gains from the alluvium,

we consider that our river gain estimates are in reasonable agreement with these earlier modelling results.

Table B4 Summary of river / groundwater flow exchange rates

Scenario	Groundwater inflow rate per metre river length (m^3/day /m)			
XS360	**Existing**	**Post - development**	**Difference**	**Post-development notes**
Base case	0.270	0.428	0.159	Increased flow into river from Taita Alluvium
S1	0.293	0.505	0.212	Increased flow into river from Taita Alluvium
S2	0.387	1.224	0.838	Increased flow into river from Taita Alluvium
S3	0.244	0.375	0.131	Increased flow into river from Taita Alluvium
S4	0.201	0.246	0.045	Increased flow into river from Taita Alluvium
Negative Hydraulic Gradient	0.280	0.445	0.165	Increased flow into river from Taita Alluvium
Removal of confining layer (no aquitard)	0.311	1.468	1.157	Increased flow into river from Taita Alluvium
Removal of confining layer and negative hydraulic gradient	0.318	1.496	1.177	Increased flow into river from Taita Alluvium
Increase of River Stage and negative hydraulic gradient	-0.381	-0.603	-0.223	Increased losses from river to groundwater
XS500	**Existing**	**Post-development**	**Difference**	**Post-development notes**
Base case	0.09	0.245	0.156	Increased flow into river from Taita Alluvium
S1	0.224	0.389	0.165	Increased flow into river from Taita Alluvium
S2	0.550	0.969	0.419	Increased flow into river from Taita Alluvium
S3	0.344	0.565	0.221	Increased flow into river from Taita Alluvium

S4	0.224	0.389	0.165	Increased flow into river from Taita Alluvium
S5	0.145	0.241	0.096	Increased flow into river from Taita Alluvium
S6	0.186	0.330	0.144	Increased flow into river from Taita Alluvium
Negative Hydraulic Gradient	0.095	0.256	0.161	Increased flow into river from Taita Alluvium
Removal of confining layer and negative hydraulic gradient	0.150	0.869	0.719	Increased flow into river from Taita Alluvium
Increase of River Stage and negative hydraulic gradient	-1.976	-2.371	-0.395	Increased losses from river to groundwater
XS600	**Existing**	**Post-development**	**Difference**	**Post-development notes**
Base case	-0.154	0.148	0.30	River changes from losing to gaining
S1	-0.184	0.196	0.38	River changes from losing to gaining
S2	-0.241	0.260	0.50	River changes from losing to gaining
S3	-0.128	0.108	0.24	River changes from losing to gaining
S4	-0.120	0.104	0.22	River changes from losing to gaining
Lowering the shallow groundwater level	-0.277	0.034	0.31	River changes from losing to gaining
Negative Hydraulic Gradient	-0.192	0.037	0.23	River changes from losing to gaining
Removal of confining layer and negative	-0.696	0.190	0.89	River changes from losing to gaining

hydraulic gradient				
Increase of River Stage	-0.291	-0.077	0.21	Increased losses from river to groundwater
(-) Negative value indicates river flow to groundwater (losing river) (+) Positive value indicates river flow to groundwater (gaining river)				

Table B5 summarises the estimated additional outflows from Waiwhetu aquifer under base case assumption and "worst case" scenario that assumes complete lack of confining material across the cross section and along the relevant river section. Modelling results indicate that the proposed lowering of the riverbed will not result in reduced yield in the Waiwhetu aquifer due to groundwater losses from Waiwhetu to the river. Under very conservative assumptions the proposed works are expected to result in groundwater exchange from Waiwhetu to the Taita in the order of 71 m^3/day and up to 210 m^3/day across the full length of the proposal, which includes the potential recharge losses from Taita. Under river flood conditions the additional recharge to Waiwhetu from the river is very small (61 m^3/d and up to 85 m^3/d) when compared to the Waiwhetu aquifer volumes of water and therefore no significant change in the Waiwhetu water quality properties (turbidity, pH, DO, hardness) is expected at the Waterloo bore field.

Table B5 Summary of Waiwhetu Aquifer flow exchange rates range

Cross Section	Representative Length of the River	Change in Losses from Waiwhetu (m^3/d/m)	Additional Losses from Waiwhetu (m^3/d)	Change in Inflows to Waiwhetu (m^3/d/m)	Additional Inflows to Waiwhetu (m^3/d)
XS360	1400 m (XS320 -XS460)	0.01 (up to 0.014)	14 (up to 20)	0.016 (up to 0.02	23 (up to 28)
XS500	1400 m (XS460 – XS600)	0.03 (up to 0.1)	42 (up to 140)	0.02 (up to 0.03)	28 (up to 42)
XS600	500 m (XS600 - XS650)	0.03 (up to 0.1)	15 (up to 50)	0.02 (up to 0.03)	10 (up to 15)
➢ Values in parenthesis correspond to max estimates from sensitivity analysis and scenario testing					
		Total	71 m^3/d (up to 210 m^3/d)		61 m^3/d (up to 85 m^3/d)

1.6.2 Groundwater Flow after Piling

Six 2.7 m diameter reinforced concrete bored piles in full length permanent steel casings are proposed in the design drawing A16-4381-S201 (Volume 5 of the AEE). The proposed construction methodology for the construction of the piles into the Waiwhetu aquifer is detailed in the construction methodology in Chapter 5 of the AEE:

The Waiwhetu plan section model showed a very slight (<0.01 m) deviation from existing state groundwater levels after the addition of low-permeability piles (Figure B10). This <0.01 m mounding effect is considered negligible compared to overall pressures within the artesian aquifer. The groundwater flow vectors (Figure B11 and B12) also showed a deviation in typical groundwater flow patterns (downgradient) with groundwater flow veering around each pile which is to be expected. While this may increase the flow between the piles, this is not considered to cause a significant effect to overall groundwater flow within the Waiwhetu aquifer.

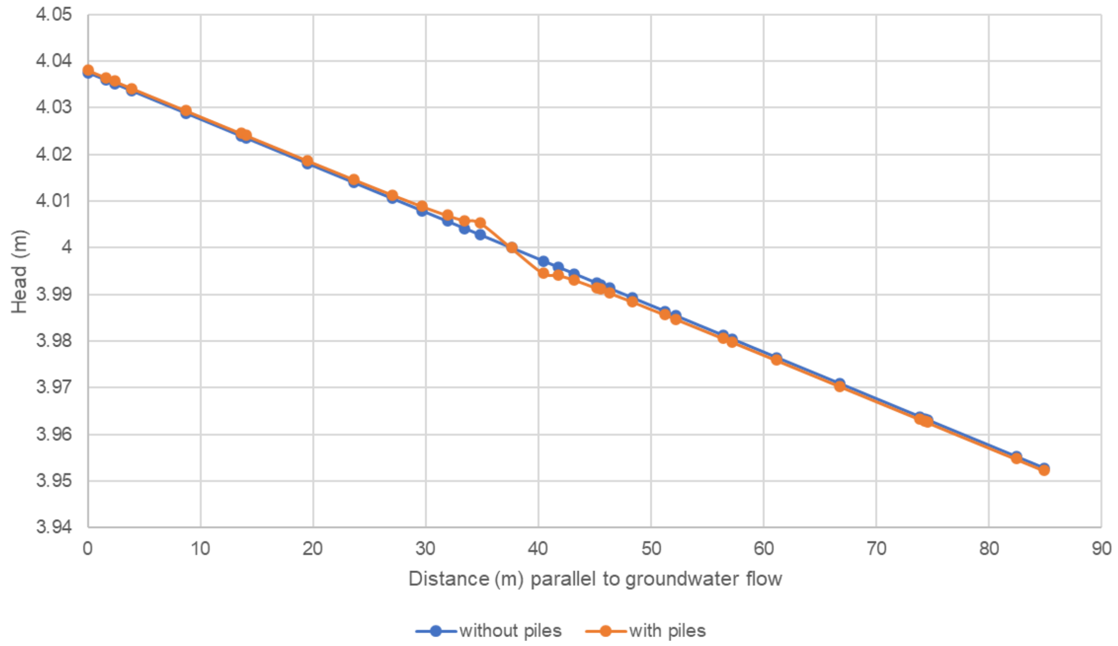


Figure B10 Groundwater head pre and post development

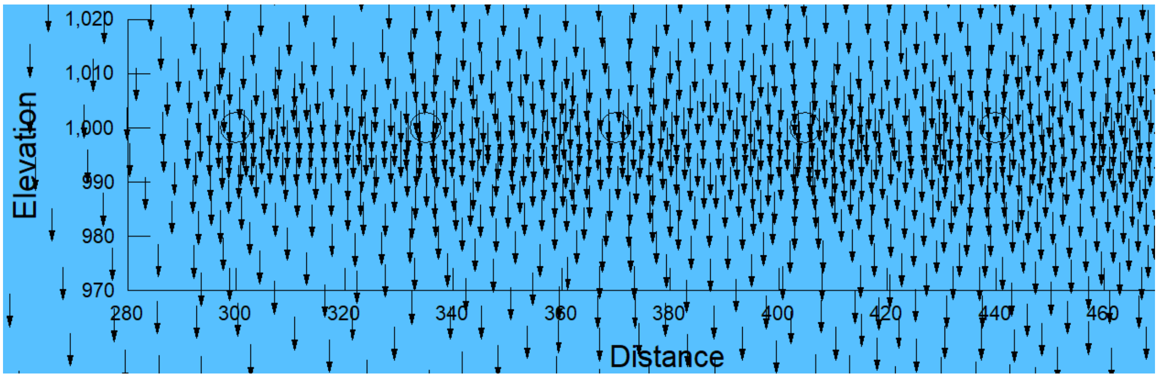


Figure B11 Groundwater flow vectors before pile construction

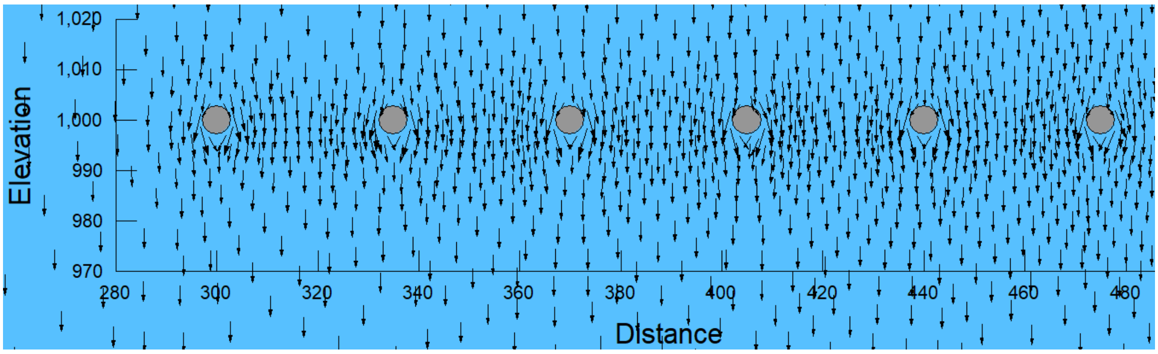


Figure B12 Groundwater flow vectors after pile construction

1.7 Groundwater Modelling Summary

The groundwater assessment as part of this application, describes the groundwater modelling undertaken to understand the groundwater impacts associated with the proposed riverbed excavation and piling. The SEEP/W modelling results indicate:

- The proposed river works under conservative assumptions are expected to result in river inflows increasing at all sections between 0.1 and 0.4 m^3/day per metre river length.

- Even when conservative assumptions are applied i.e. negative hydraulic gradient caused by pumping the Waterloo wellfield and removal of the confining layer (aquitard) the increase of inflows in to the river is small ranging from 0.2 to 1.2 m^3/day per metre river length.

- Modelling results indicate that the proposed lowering of the riverbed will not result in reduced yield in the Waiwhetu aquifer due to groundwater losses from Waiwhetu to the river. Under very conservative assumptions the proposed works are estimated to result in groundwater exchange from Waiwhetu to the Taita in the order of 71 m^3/day to 210 m^3/day across the full length of the proposal, which includes the potential recharge losses from Taita. This represents a very small percentage of the total aquifer volume and pumped daily rates from Waterloo wellfield.

- These small “groundwater losses” from the shallow Taita alluvium to the river are likely to be reduced with time’ as fines and gravels will be re-deposited.

- Under river “flood conditions with simultaneous high pumping at the Waterloo well field, “river losses” to groundwater are expected to increase by up to 0.4 m^3/day per linear m when compared to the existing state. Most of the river losses are expected to be to the Taita Alluvium with only 61 m^3/day and up to 85 m^3/day additional flow expected to reach Waiwhetu. This additional inflow rate is very small when compared to the Waiwhetu aquifer volumes of water and therefore no significant change in the Waiwhetu water quality properties (turbidity, pH, DO, hardness) is expected at the Waterloo bore field.

- Flow paths and aquifer groundwater velocities are not expected to change because of the proposed river works. Travel times and natural attenuation reduction is likely, from the proposed riverbed excavation and the removal of the silty layer. Quantifying though this change with reasonable confidence is extremely difficult, given the lack of tracer studies in the Waiwhetu aquifer and particularly in the vicinity of the Hutt River. Additional inflows to the aquifer from the proposed excavations in the riverbed, are estimated to be very small and the increase in risk is considered small. This risk is expected to decrease with time, as fine material is redeposited in the riverbed. Water quality monitoring should be undertaken to manage any contamination risk in case of a flood event.

- A small drawdown of the groundwater level in the order of 0.25 m within 75 m from the excavation is estimated. This change is small and within the seasonal range of groundwater levels (1-2 m in the shallow Taita Alluvium) and no adverse effects are expected on groundwater levels and groundwater flow direction from the proposed works. For a 300 m river section, shallow drawdowns can be larger and up to 0.50 m at some 100 m from the riverbed reducing to 0.25 m approximately 200 m from the excavation. In all cases considered the effects on the Waiwhetu aquifer water levels are very small (less than 1 cm).

- The placement of piles creates a very small mounding effect (<0.01 m) immediately upgradient of each pile. The introduction of the piles causes groundwater to flow around each pile before resuming flow in the normal flow direction. The effects of piling to the artesian aquifer flow conditions are considered unlikely to be significant if constructed properly and according to the construction methodology (subject to be finalised and approved by GWRC following drilling at pile location).

Appendix C – Groundwater Users

The bore data set available on GWRC open data was filtered to only include bores within the Lower Hutt area with a listed water use (i.e. not water level observation, geological research, etc.). These filtered results returned 14 bores, including one deep well (R27/0320, 114.6 m depth) and one with no bore or associated consent details (Bore 1188). Of the eight bores within the Waterloo Borefield, six did not have a water use listed on their bore details but were known to be associated with consent WGN970036 and were added to the bore search results. Nine additional bores without a listed water-use were added as they were associated with an active water take resource consent listed in Table C2. The bores are summarised in Table C1.

Table C1. Filtered GWRC bore search results

Bore ID	Use	Well Type	Drill date	Water Use Consent #	Depth (m)	Diameter (mm)	Screen Top (m)	Screen Bottom (m)	Aquifer Type	X	Y
R27/1183	Air Conditioning	Bore	1983-03-0	WGN120019	25	300	17.92	24.4	-	1763084	5438691
BQ32/0015	-	Bore	1983-03-0	WGN120019	24.4	300				1763113	5438751
R27/1232	Aquifer Testing / Public Supply	Bore	1974-11-2	-	39.7	200	32.92	35.96	Flowing Artesian	1758743	5434126
BQ32/0271	Commercial	Bore	-	WGN170342	25	150	0	16.38	-	1758905	5434821
R27/1265	Fire	Bore	1986-02-0	-	48.3	300	37	48	Flowing Artesian	1756998	5434516
R27/6862	Fire	Bore	1989-01-0	-	35	0	0	0	Flowing Artesian	1757797	5435257
R27/4003	Industrial	Bore	1958-01-0	WGN070154 (expired)	37.5	0	0	0	Flowing Artesian	1757878	5434116
R27/6908	Industrial	Bore	1997-05-0		29	150	26	29	Flowing Artesian	1760391	5432981
R27/1235	Irrigation	Bore	1978-01-0	WGN170263	32.8	0	0	0	Flowing Artesian	1758903	5434186
BQ32/0024	Public Supply	Bore	2012-06-0	WGN120153	38.8	150	36.3	38.8	Flowing Artesian	1759627	5435949
R27/6390	Small Community Public Supply	Bore	2003-04-1	WGN130127	24	100	21	24	Flowing Artesian	1761033	5434646
R27/0001	Public Supply	Bore	-	WGN970036	40	0	25	40	Flowing Artesian	1760194	5435923
R27/1180	Purpose Drilled for Public supply	Bore	1988-01-0	WGN970036	39	0	0	0	Flowing Artesian	1760435	5435698

R27/4063	-		1978-01-0	WGN970036	39.8	-	-	-	-	1759943	5436062
R27/4064	-	-	1978-01-0	WGN970036	38.98	-	-	-	-	1760086	5435986
R27/1179	-	-	1988-01-0	WGN970036	39	-	-	-	-	1760215	5435701
R27/1181	-	-	1976-01-0	WGN970036	39.3	-	-	-	-	1760578	5435866
R27/4057	-	-	1980-01-0	WGN970036	39	-	-	-	-	1760354	5435896
R27/4058	-	-	1980-01-0	WGN970036	39.2	-	-	-	-	1760478	5435836
R27/1234	-	-	1990-01-0	WGN170093	34.6	-	-	-	Flowing Artesian	1757695	5435142
R27/1167	-	-	1962-01-0	WGN160011	*35.7*	-	-	-	-	1758613	5434191
R27/1168	-	-	1956-01-0	WNG160011	*33.5*	-	-	-	-	1758578	5434191
R27/1141	-	-	-	WGN170078	*32.9*	-	-	-	-	1760573	5433535
BQ32/0287	-	Bore	-	WGN170078	*32.9*	-	-	-	-	1760569	5433534
R27/6333	-	-	1975-01-0	WGN180089	*0.2*	-	-	-	-	1762053	5437886
R27/7214	-	-	-	WGN180214	-	-	-	-	-	1760948	5437406
R27/7232	-	Bore	-	WGN180214	-	-	-	-	-	1760954	5,437,446
- Indicates no data											

The consents database was filtered to include only water takes within the Lower Hutt area which were listed as active or granted. Temporary takes for dewatering were excluded from the search. These filtered results returned 15 consents (Table C2). Some are specifically noted in the description to extract from the Waiwhetu Artesian Aquifer.

Table C2. Filtered GWRC groundwater take results

X	Y	Consent ID	Purpose	Commenced	Expires
1759979 1758578	5436086 5434186	WGN970036	To take water from the Waiwhetu Artesian Aquifer (Waterloo and Gear Island Bores)	12/08/1998	12/08/2033
1758978	5433886	WGN160011	To take and use groundwater from the Lower Hutt Category B Groundwater Management Unit using two existing bores (R27/1167 and R27/1168) for industrial or commercial purposes. (Upper Waiwhetu Aquifer)	18/02/2016	12/08/2033
1761033	*5434674*	*WGN130127*	*To take and use groundwater from an existing bore (wells number R27/6390) located in the Lower Hutt Groundwater Zone, for health, cultural, drinking water and emergency supply purposes. (Upper Waiwhetu Aquifer)*	*06/05/2013*	*05/11/2029*
1761231	5436750	WGN000020	Abstraction of water from the Waiwhetu Aquifer for an emergency potable water supply	23/08/1999	23/08/2034
1759033	5433807	WGN040360	To take and use water from the Waiwhetu Artesian Aquifer.	09/03/2007	09/03/2022
1763179	*5438686*	*WGN120019*	*To take and use groundwater from bore R27/1183 or BQ32/0015 for the air conditioning system at Avalon Studio. (Upper Waiwhetu Aquifer)*	*25/08/2011*	*25/08/2021*
1757716	5434375	WGN090243	To take water from R27/7345 for untreated public water supply *	13/02/2009	13/02/2029
1759955	5436227	WGN190104	Water permit and discharge permit to take groundwater and divert groundwater	08/02/2019	08/02/2024
1760578	5433536	WGN170078	To take and use groundwater from existing bores (R27/1141 and BQ32/0287) from the Lower Hutt Category B Groundwater Management Unit for industrial purposes. (Upper Waiwhetu Aquifer)	03/11/2016	12/08/2033
1757691	5435142	WGN170093	To take and use groundwater from existing bore (R27/1234) from the Lower Hutt Category B Groundwater Management Unit for industrial purposes. (Upper Waiwhetu Aquifer)	09/01/2017	12/08/2033
1759039	*5433892*	*WGN170263*	*To take and use water from an existing bore (R27/1235) located within the Lower Hutt Category B Groundwater Management Unit for the irrigation of a golf course.*	*15/05/2017*	*12/08/2033*
1758908	*5434820*	*WGN170342*	*To take and use groundwater from bore BQ32/0271 located in the Lower Hutt Category B Groundwater Management Unit, for amenity irrigation purposes.*	*12/08/2017*	*12/08/2033*

1760948	5437406	WGN180214	To take and use water from existing bores (R27/7214 and R27/7232) for irrigation of a golf course.	09/03/2018	09/03/2028
1762053	5437886	WGN180089	To take and use groundwater from an existing bore (Wells Number: R27/6333) located in the Lower Hutt Groundwater Zone to replenish a duck pond.	17/01/2018	12/08/2033
1759626	*5435948*	*WGN120153*	*To take and use groundwater from bore BQ32/0024 located in the Lower Hutt Groundwater Zone for untreated public water and emergency supply (Upper Waiwhetu Aquifer)*	*14/09/2012*	*13/02/2029*
Italics indicate description which notes an extraction bore identified in the bore search (had water use listed). * Bore R27/7345 details could not be identified in the wells database					

The categories (Category A, B or C) referred to in the description of some of the listed GWRC water take consents refer to the degree of hydraulic connectivity between groundwater and surface water. Defining these categories helps differentiate groundwater abstractions that have potential to result in direct and immediate effects on surface water from those where there is a lag or lack of effect of pumping on surface water. This aids in management of the water resources. (http://www.gw.govt.nz/assets/Plans--Publications/Regional-Plan-Review/Proposed-Plan/ConjunctivewatermanagementrecommendationsfortheHuttValley.PDF)

Category A refers to abstractions from an aquifer exhibits direct connectivity with surface water.

Category B represents a high hydraulic connectivity where abstractions may result in significant impacts on surface water but where pumping regulation does not always provide an effective option for mitigating these effects. Category B reflects the transition between a direct and indirect stream depletion effect.

Category C reflects a lower degree of connectivity and applies to takes where pumping regulations do not effectively mitigate any contributions a take may have to overall baseflow reduction

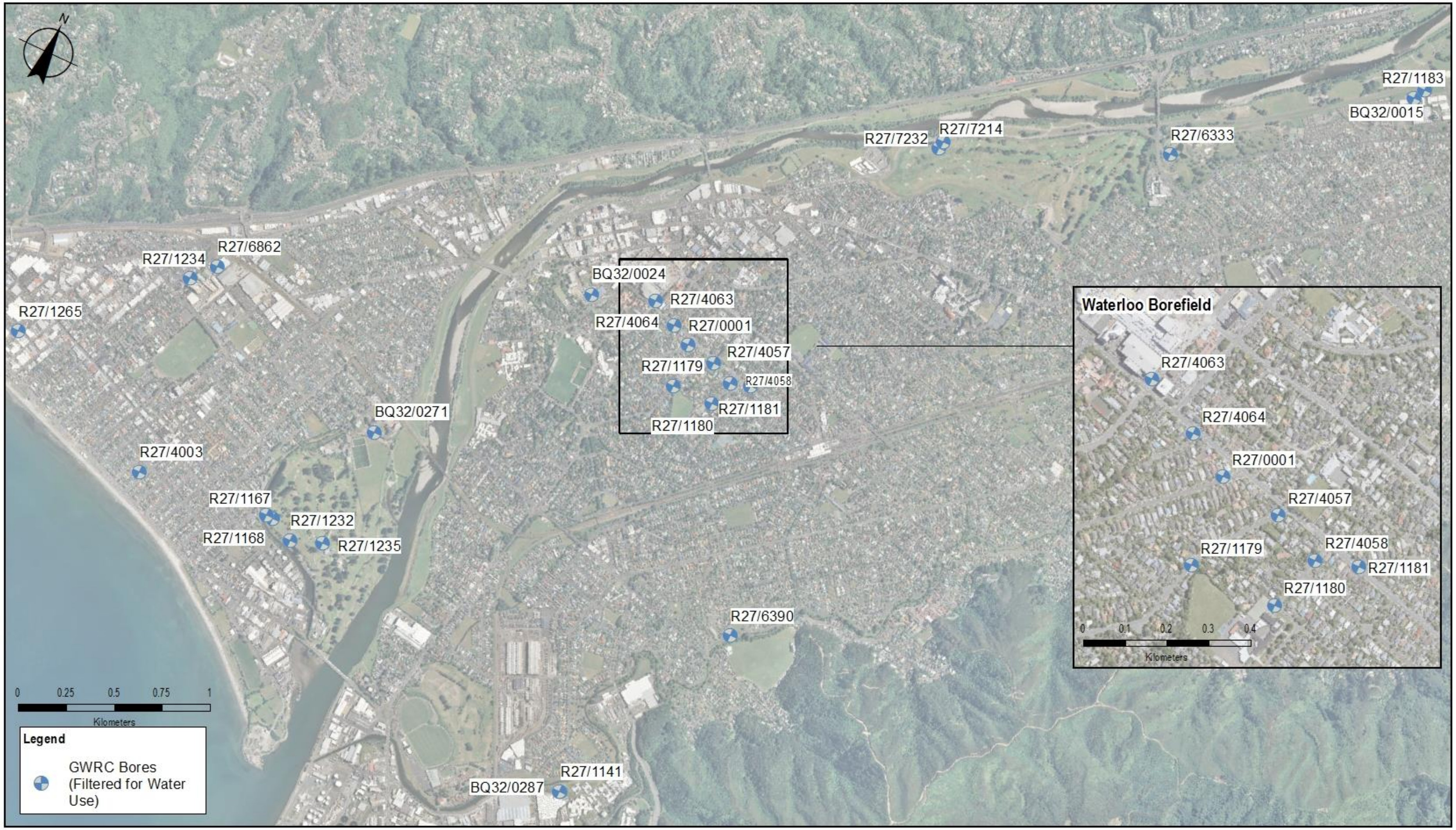


Figure E1. GWRC Water Use Bore Search Results

Appendix D – Draft Groundwater Management Plan

RIVERLINK PROJECT - DRAFT GMP

DRAFT Groundwater Management Plan

1 Introduction

1.1 Scope and purpose of Groundwater Management Plan

This Groundwater Management Plan (GMP) forms part of a comprehensive suite of environmental controls within the Construction Environmental Management Plan (CEMP) for the Riverlink Project (“the Project”).

The GMP addresses the potential effects on groundwater levels associated with both the construction and long-term operation of the Project, and identifies the minimum standards that must be complied with as well as best practicable options for groundwater management for the Project. It is intended as a framework for the development of groundwater level management practices and procedures to minimise the potential impact on the environment, and to achieve compliance with resource consent conditions.

The purpose of this Groundwater Management Plan (GMP) is to set out the most practicable options for groundwater monitoring and management, to set out procedures to avoid or mitigate changes in groundwater levels and to ensure that existing bore owners have priority to abstract water from their existing water supply bores and to protect the integrity of those supplies (in terms of both quality and quantity of supply).

This management plan, and any updates to it, is to be submitted to Greater Wellington Regional Council (GWRC) for certification.

The potential for effects on the environment can be quantified by recording changes in groundwater levels in piezometers installed in proximity to the works, and responding with suitable actions, if trigger levels are reached

The GMP will be updated, with the necessary approval, throughout the course of the Project to reflect material changes associated with construction techniques, a better understanding of ground conditions, and/or the longer data records in areas where construction has yet to commence. The effects of changes to the Project as a result of the detailed design process will also need to be considered. Approval from the Greater Wellington Regional Council (GWRC) will be required for any relevant revisions of a material nature to the GMP.

1.2 Project description

The Project is the design, construction, operation and maintenance of Riverlink. Key components of the project are as follows:

a. Upgrade and raising of existing and construction of new stopbanks on both sides of Te Awa Kairangi/Hutt River between Ewen Bridge and Mills Street.

b. Instream works between the Kennedy Good and Ewen Bridges to re-align, deepen and widen the active river channel.

c. The replacement of the two signalised at-grade intersections of SH2/Harbour View Road/Melling Link and SH2/Tirohanga Road with a new grade separated interchange.

d. Construction of an approximately 220 m long and up to 7 span road bridge with a direct connection across the River from the new interchange to Queens Drive.

e. Removal of the existing Melling Bridge.

f. Changes to local roads.

g. Changes to the Melling Line rail network and supporting infrastructure.

h. Construction of an approximately 175 m long and 3 span pedestrian/cycle bridge over the River.

i. Creation of six new development areas to integrate urban development with the infrastructure works, ranging in between 1,000 m^2 to 5,930 m^2 in area, and up to 5 stories in height along Daly Street, Queens Drive and Rutherford Street.

j. Construction of walking promenades located along the stopbank between Margaret Street and High Street. This includes new steps and ramps to facilitate access between the CBD and the promenade.

k. Associated works including construction and installation of culverts, stormwater management systems, signage, lighting, network utility relocations, landscape and street furniture, pedestrian/cycle connections and landscaping within the project area.

The project area is shown in Figure 1

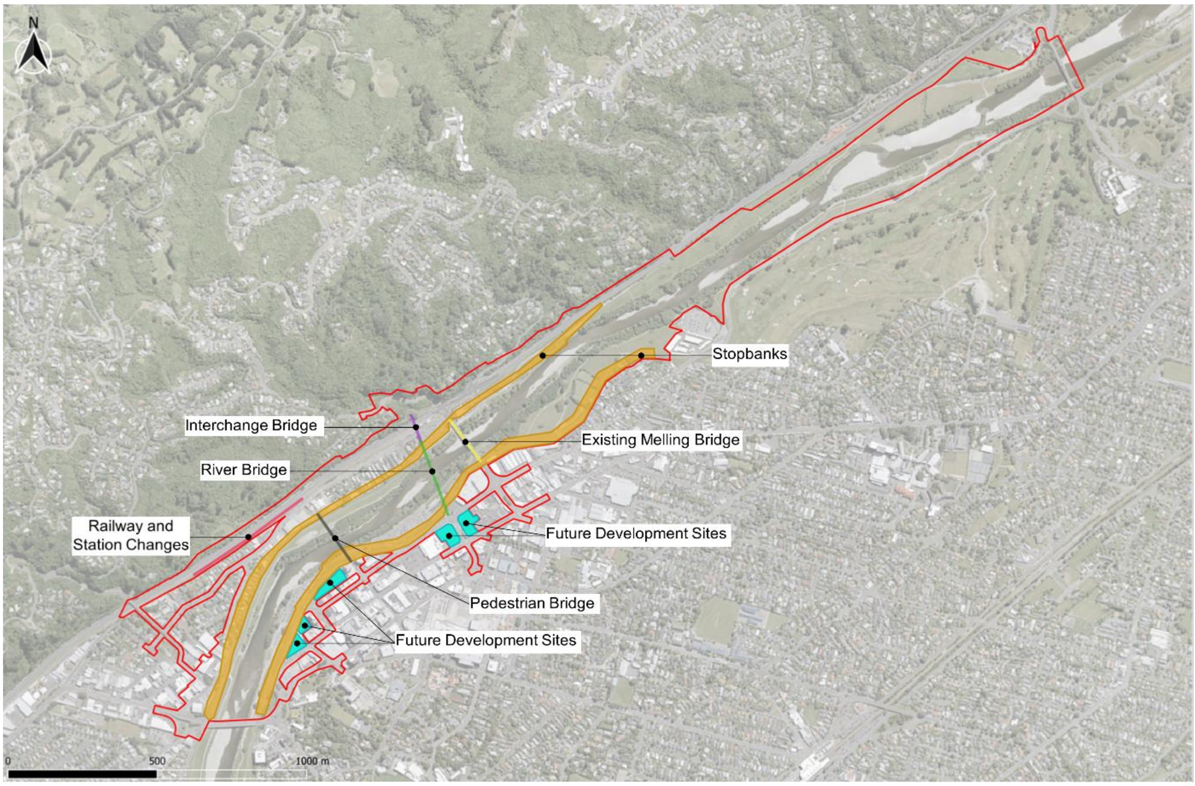


Figure 1: Project location plan

2 Managing groundwater - roles and responsibilities

Roles and responsibilities for the Project are described in the CEMP. Contact details of specific roles and responsibilities relating to managing groundwater are include in the table below.

Table 1: Contact details of specific project roles

Name	Role & Organisation	Contact Number	Email Address
	Project Director		

	Project Manager		
	Environmental Protection Officer, GWRC		
	Environmental Manager		
	Project Manager Site Contractor		
	Site Supervisor, Site Contractor		

The Project team will monitor the effects on the groundwater regime and wetlands by comparing the results of monitoring with modelled values.

If groundwater effects beyond those estimated to occur, then the Project team will pass on the findings and coordinate any discussions with GWRC. The Project team will implement measures to limit groundwater drawdown, minimise effects on surface water bodies with the agreement of GWRC. This will include consideration of actual geology encountered as compared with modelled geology and updating the relevant assessments if necessary.

All personnel working on the Project, including Project team employees and subcontractors, have the responsibility to follow the requirements of this GMP.

3 Monitoring requirements

This section details the monitoring programme for the measurement of groundwater levels pre, during, and post construction.

Differences between modelled and measured changes in groundwater level can be expected and will need to be considered in terms of the actual geological sequence encountered compared with that modelled and the impact this might have (if any) on potential effects.

3.1 Groundwater level monitoring

Monitoring (if not telemetered online) will be undertaken by a specifically identified and trained team. Review and reporting of the collected monitoring data will be undertaken by a suitability qualified and trained hydrogeologist/geohydrologist with more than 10 years' experience.

Groundwater levels will be recorded in monitoring bores that will include piezometers already installed in the Project area, piezometers proposed in this document (Draft – GMP), as well as new bores drilled specifically to allow monitoring of water levels in proximity to proposed structures of Project (e.g. following Detailed Design stage). The GMP will be updated to include additional monitoring required.

3.1.1 Location of existing groundwater monitoring piezometers (June 2021)

Groundwater level monitoring piezometers (standpipes and vibrating wire) have been established at five locations near the Project area as shown in Figure 2 below.

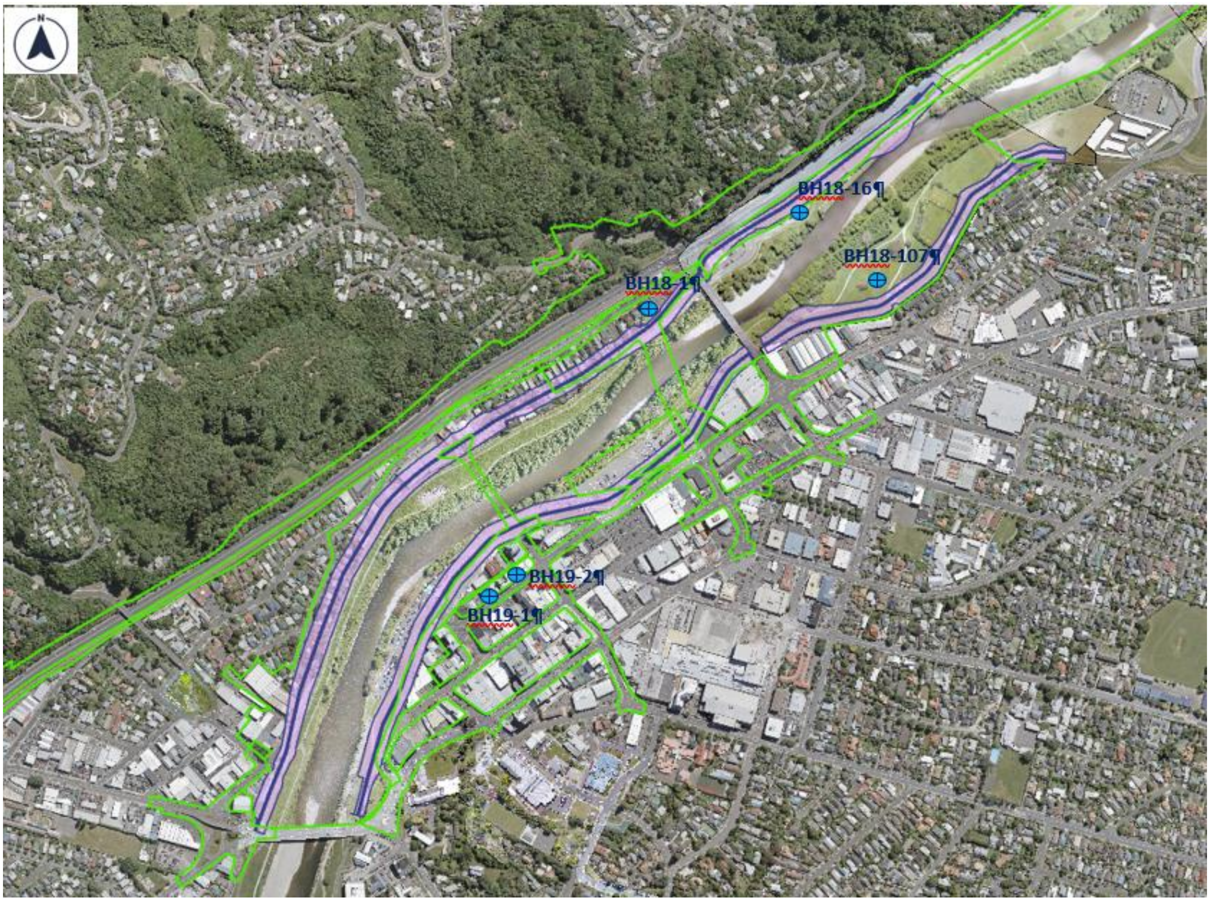


Figure 2 Location of Project's existing piezometers

3.1.2 Construction details of existing groundwater monitoring piezometers

Instrumentation details for groundwater monitoring installed currently (June 2021), at the Project area, is summarised in Table 2. Groundwater level monitoring in the existing piezometers is continuous through online telemetry that has been established by GWRC since September 2020.

Table 2 Groundwater level monitoring piezometer details

ID	Type	Ground surface elevation[1] RL (m)	Screen / vibrating wire installation depth (m bgl)	Geological unit	Monitoring
BH18-1	Vibrating Wire Piezometer	7.89	17	Taita Alluvium	Online telemetry installed

ID	Type	Ground surface elevation[1] RL (m)	Screen / vibrating wire installation depth (m bgl)	Geological unit	Monitoring
BH18-107	Standpipe Piezometer	6.5	3.0 – 4.0	Taita Alluvium	Online telemetry installed
BH18 -16	Standpipe Piezometer	6.5	4.5 – 7.5	Taita Alluvium	Online telemetry installed
BH19-1	Vibrating Wire Piezometer	5.0	11, 15 and 24	Taita Alluvium, and Waiwhetu Aquifer	Online telemetry installed
BH19-2	Standpipe Piezometer	4.5	7.5 – 11.5	Taita Alluvium	Online telemetry installed
[1] Elevation based on Hutt City LiDAR 2016 in terms of Wellington 1953 vertical datum					

3.1.3 Proposed (new) deep piezometers (to be installed prior to riverworks and piling activities)

In addition to the existing deep piezometers (listed in Table 2) four additional deep piezometers shall be installed prior to riverbed excavations. Two of the proposed piezometers shall be installed prior to piling activities approximately 50 m and 100 -150 m from the location of the Melling Bridge and be screened in the upper Waiwhetu gravels. The final location of the piezometers will depend on land access restrictions and existing services. These shall monitor the following groundwater attributes using sensors:

a) turbidity/conductivity;
b) temperature; and
c) pressure (head).

Furthermore, the piezometers will be used to monitor other groundwater quality attributes like pH, Dissolved Oxygen and hardness.

Approximate location of proposed piezometers is shown in Figure 3.

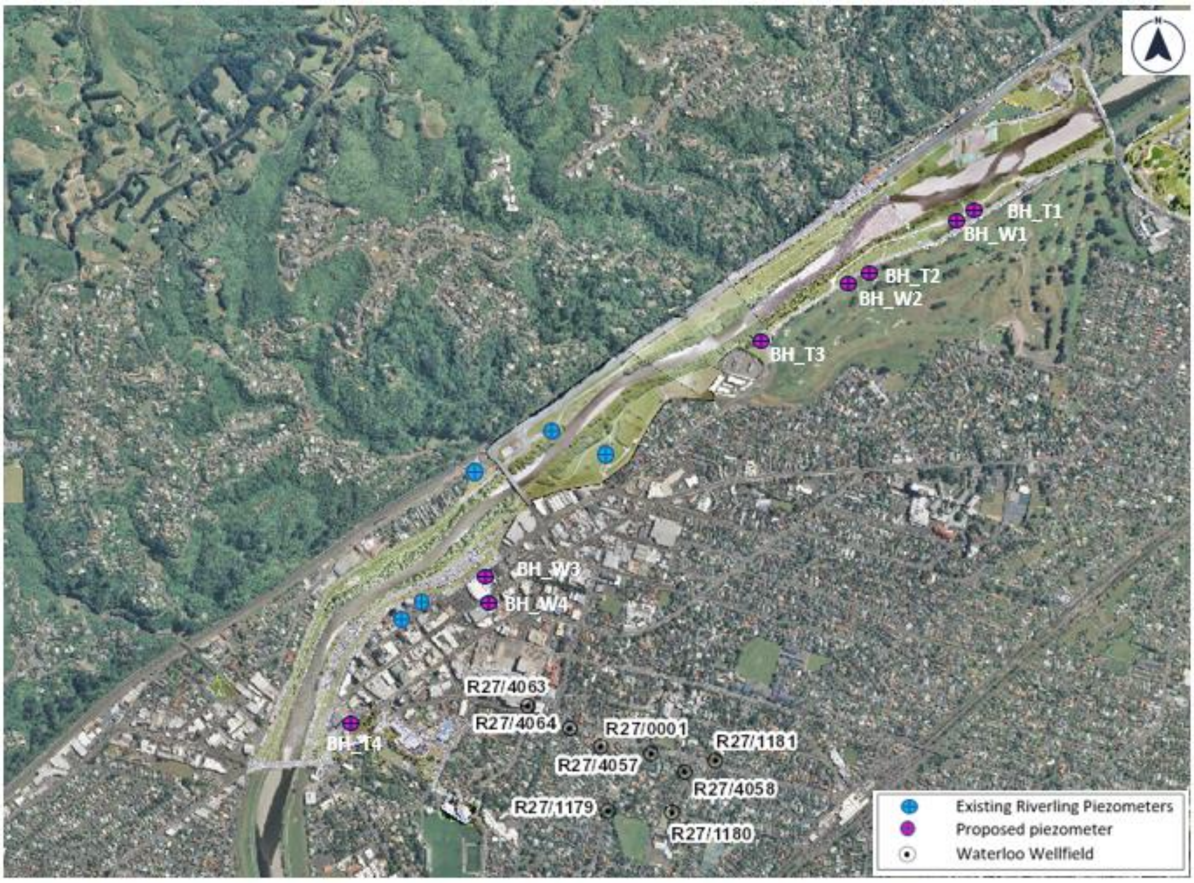


Figure 3 Location of proposed shallow and deep standpipe piezometers

Construction details of proposed piezometers will be confirmed after drilling.

Table 3 Construction details of proposed deep groundwater monitoring piezometers

ID (TBC)	Type	Ground surface elevation RL (m)	Screen installation depth (m bgl)	Geological unit	Monitoring
BH_W1	Standpipe Piezometer	TBC	TBC	Upper Waiwhetu Gravels	using sensor – online telemetry
BH_W2	Standpipe Piezometer	TBC	TBC	Upper Waiwhetu Gravels	using sensor – online telemetry
BH_W3	Standpipe Piezometer	TBC	TBC	Upper Waiwhetu Gravels	using sensor – online telemetry
BH_W4	Standpipe Piezometer	TBC	TBC	Upper Waiwhetu Gravels	using sensor – online telemetry

3.1.4 Proposed (new) shallow piezometers (to be installed prior to riverworks and piling activities)

In addition to the existing shallow piezometers (listed in Table 2) four additional shallow piezometers shall be installed prior to riverbed excavations near the river corridor and be screened in the Taita Alluvium. Approximate locations are shown in Figure 3. These shall monitor the following groundwater attributes using sensors:

a) turbidity/conductivity;

b) temperature; and

c) pressure (head).

Table 4 Construction details of proposed (new) shallow piezometers

ID (TBC)	Type	Ground surface elevation RL (m)	Screen installation depth (m bgl)	Geological unit
BH_T1	Standpipe Piezometer	TBC	TBC	Taita Alluvium
BH_T2	Standpipe Piezometer	TBC	TBC	Taita Alluvium
BH_T3	Standpipe Piezometer	TBC	TBC	Taita Alluvium
BH_T4	Standpipe Piezometer	TBC	TBC	Taita Alluvium

Furthermore, the piezometers will be used to monitor other groundwater quality attributes like pH, Dissolved Oxygen and hardness.

3.1.5 Construction of additional piezometers at specific sites

Additional shallow piezometers (screened in Taita Alluvium) are expected to be installed following detailed design near the location of deep excavations (e.g. for the construction of new stormwater Pump Stations or utilities relocations).

3.1.6 Monitoring frequency at specific sites (shallow piezometers for dewatering activities)

This section should be completed if deemed necessary at Detailed Design stage and following any site-specific Dewatering Assessment of effects if applicable.

3.2 Groundwater Quality Monitoring

Shallow groundwater quality monitoring shall be undertaken in the following standpipe piezometers using sensors if feasible.

Monitoring shall include:

- turbidity, conductivity, temperature
- pH, Dissolved Oxygen, Hardness and Ecoli

Table 5 Groundwater Quality Monitoring Piezometers

ID	Type	Ground surface elevation[1] RL (m)	Screen installation depth (m bgl)	Geological unit
BH18-107	Standpipe Piezometer	6.5	3.0 – 4.0	Taita Alluvium
BH18 -16	Standpipe Piezometer	6.5	4.5 – 7.5	Taita Alluvium
BH19-2	Standpipe Piezometer	4.5	7.5 – 11.5	Taita Alluvium
BH_T1	Standpipe Piezometer	TBC	TBC	Taita Alluvium
BH_T2	Standpipe Piezometer	TBC	TBC	Taita Alluvium
BH_T3	Standpipe Piezometer	TBC	TBC	Taita Alluvium
BH_T4	Standpipe Piezometer	TBC	TBC	Taita Alluvium
BH_W1	Standpipe Piezometer	TBC	TBC	Upper Waiwhetu Gravels
BH_W2	Standpipe Piezometer	TBC	TBC	Upper Waiwhetu Gravels
BH_W3	Standpipe Piezometer	TBC	TBC	Upper Waiwhetu Gravels
BH_W4	Standpipe Piezometer	TBC	TBC	Upper Waiwhetu Gravels

3.3 Monitoring Frequency

Monitoring in shallow piezometers (screened in the Taita Alluvium) must commence at least one month before any riverbed excavations. Testing for the constituents that can't be monitored through sensors sampling and testing should be undertaken weekly for a month before any riverbed excavations and weekly during riverbed excavations. Monitoring can cease one month after such activities have been completed.

The monitoring in piezometers screened in the upper Waiwhetu Gravels must commence at least one month before any drilling activity is to take place in the Waiwhetu aquifer, including pile driving. Similar to the shallow piezometers testing for the constituents that can't be monitored through sensors sampling and testing should be undertaken at weekly for a month before any drilling or piling activity and weekly during drilling and pilling. Monitoring can cease one month after such activities have been completed.

4 Groundwater alert levels and action levels

4.1 Monitoring of groundwater levels

The natural variation of groundwater levels in each piezometer is established using all data collected from that piezometer over the pre-construction period. This data should be used to identify natural groundwater level variations and groundwater monitoring trigger levels.

The purpose of the **Alert** level is to initiate a check of changes in water level and compare them with modelled levels and if exceeded, increase the frequency of data collection.

The purpose of the **Action** level is to avoid the occurrence of adverse effects that might result from groundwater drawdown (or mounding) in excess of modelled levels.

Trigger levels for each individual piezometer should be set as a reduction below the lowest recorded naturally occurring low level before construction starts.

Recommendations for amendments to the monitoring program and the adopted trigger levels should be submitted for approval to GWRC.

Alert and alarm levels for shallow piezometers in proximity to a temporary construction water abstraction site (dewatering) can be calculated as:

Alert Level	Lowest recorded level – (predicted drawdown) or Lowest recorded level – 0.5 m, whichever is the greater
Action Level	A further 0.2 m variation

Trigger levels should be calculated following site-specific Dewatering Assessment of effects.

Table 6 Groundwater Trigger Levels in piezometers installed at specific sites to monitor dewatering effects

Piezometer ID	Low Trigger Levels		Coordinates (NZMG)	
	Alert	Action	Easting	Northing
BHXX			TBC	TBC
BHXX			TBC	TBC

4.2 Monitoring of groundwater quality

Alert and alarm turbidity levels for both shallow and deep piezometers listed in Table 5 are defined below:

	Turbidity	pH	Hardness ($CaCO_3$)
Alert Level	2.5 NTU	TBD - 0.5 below the minimum (from baseline data)	100 mg/L
Action Level	5 NTU	TBD – 0.75 below the minimum (from baseline data)	200 mg/L

5 Alert or action trigger response / Mitigation measures

5.1 During construction

Where an **Alert trigger** level is exceeded, the Project team's Project Manager and the Consenting Authority (Greater Wellington Regional Council) will be notified by the Environmental Management Team, in writing, within 3 working days with details of actions to be undertaken.

Actions are outlined below:

- Review groundwater level data daily (for telemetered piezometers)
- Review turbidity levels hourly

Where an **Action trigger** level for a monitoring bore is exceeded, activities that have the potential to cause adverse effects (such as increasing drawdown and or turbidity spikes) **will be ceased.** The following people will be notified:

- The Project and Site Managers;
- The Consenting Authority (Greater Wellington Regional Council); and
- The Environmental Management Team.

Works may recommence without mitigation once groundwater levels and or turbidity levels return to sub-Action levels. Alternatively, works may recommence if written notice is received from the Consenting Authority (Greater Wellington Regional Council) indicating that they are satisfied that damage to buildings, structures and services, or impacts on surface water bodies or on the water quality of other groundwater users are unlikely.

6 Reporting Requirements

Data collected in monitoring will be collated, plotted, evaluated and reported. Groundwater data

An annual report will be prepared and submitted to the Manager (Greater Wellington Regional Council) by XXXX each year that describes:

- Groundwater monitoring undertaken since commencement of the works
- Actual and potential effects arising from the groundwater level changes
- Any remedial or mitigation measures that have been implemented
- Any changes to proposed remedial or mitigation measures

- And changes proposed to construction methods that might influence groundwater levels
- Any changes proposed for the future monitoring programme or to alert levels.

The GMP will be amended to address and such approved changes and certified by the Manager (GWRC) before being implemented.

7 Review procedures

This section describes how the GMP will be reviewed, including considering the environmental controls and procedures to make sure that they are still applicable to the activities being carried out.

The GMP will be reviewed by the Project team after confirmation of the resource consent conditions and will be revised in accordance with these conditions. The GMP will be updated, with the necessary approval, throughout the course of the Project to reflect material changes associated with changes to construction techniques or the natural environment. Approval from GWRC will be required for any relevant revisions of a material nature to the GMP.

A management review of the GMP will be undertaken at least every six months by the Project team Project Management team. The management review will be organised by the Environmental Manager and the Project team will be informed of any changes to this Plan through the regular Project communications processes. The review will take into consideration:

- Significant changes to construction activities or methods;
- Significant change in the volume or nature of groundwater encountered;
- Key changes to roles and responsibilities within the Project;
- Changes in industry best practice standards or recommended pollution controls;
- Changes in legal or other requirements (social and environmental legal requirements, the Project's partners objectives and relevant policies, plans, standards, specifications and guidelines);
- Results of monitoring, inspection and maintenance programmes, logs of incidents, corrective actions, internal or external assessments; and

Reasons for making changes to the GMP will be documented. A copy of the original GMP document and subsequent versions will be kept for the Project records and marked as obsolete. Each new/updated version of the GMP documentation will be issued with a version number and date to eliminate obsolete GMP documentation being used.

Appendix E – Turbidity Data - Waterloo Wellfield

Table E1 Turbidity data summary– Waterloo wellfield for the monitoring period 01/04/2020 - 27/04/2021

Well	**% of turbidity readings <0.1 NTU**	**% of turbidity readings >0.1 and <1.0 NTU**	**% of turbidity readings >1.0 NTU**
Waterloo Wellfield	99.72	0.27	<0.003
Bloomfield	98.18	1.72	0.100
Colin Grove VSD	98.26	1.63	0.109
Hautana	95.55	4.43	0.020
Mahoe	90.25	6.82	2.935
Penrose	81.45	17.32	1.236
Penrose VSD	98.83	1.07	0.099
Willoughby	73.75	25.54	0.713
Willoughby VSD	87.89	7.96	4.152

Turbidity data plotted in this Appendix were provided by Wellington Water Limited (WWL)

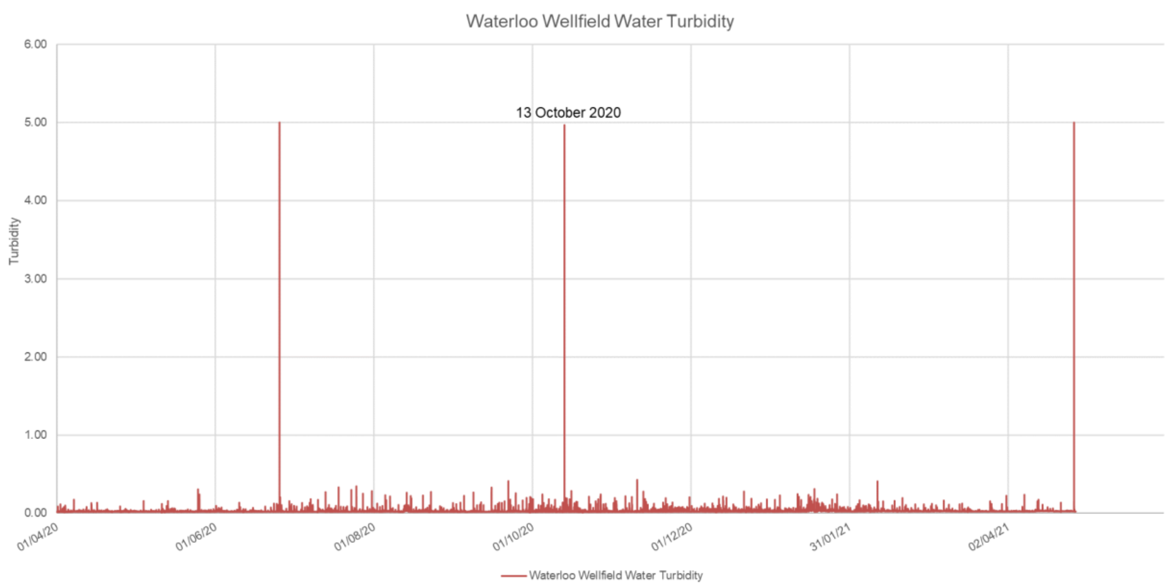


Figure E1. Waterloo Wellfield (overall) turbidity data recorded (01/04/2020 - 27/04/2021)

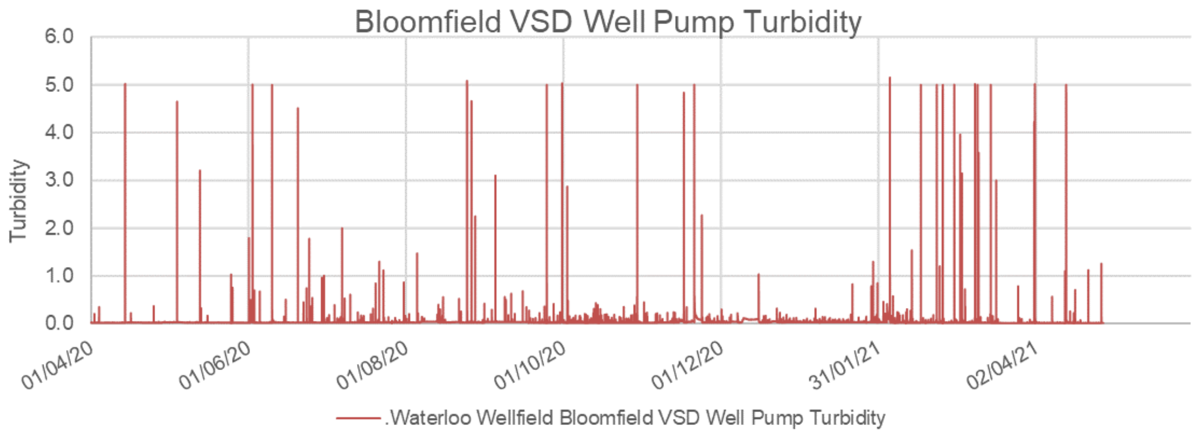


Figure E2. Bloomfield well turbidity data recorded (01/04/2020 - 27/04/2021)

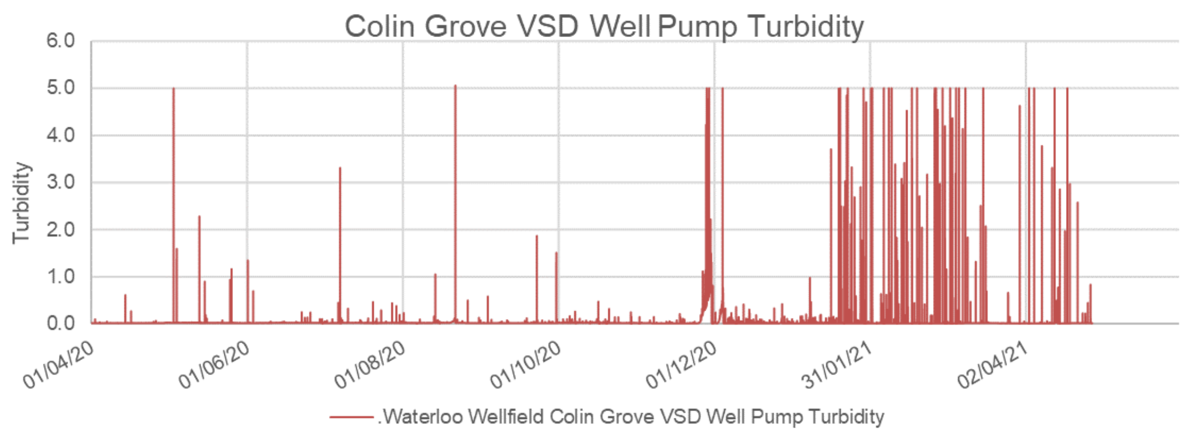


Figure E3. Colin Grove VSD well turbidity data recorded (01/04/2020 - 27/04/2021)

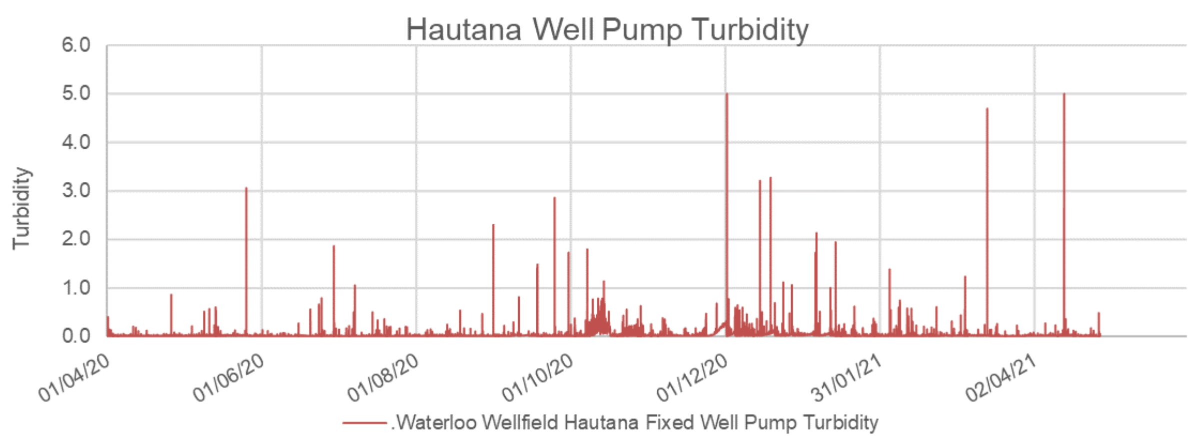


Figure E4. Hautana well turbidity data recorded (01/04/2020 - 27/04/2021)

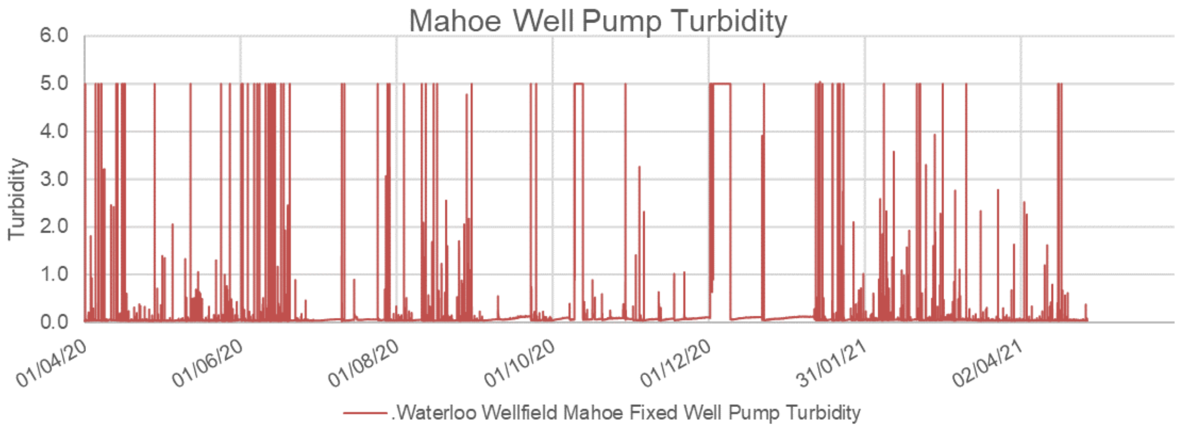


Figure E5. Mahoe well turbidity data recorded (01/04/2020 - 27/04/2021)

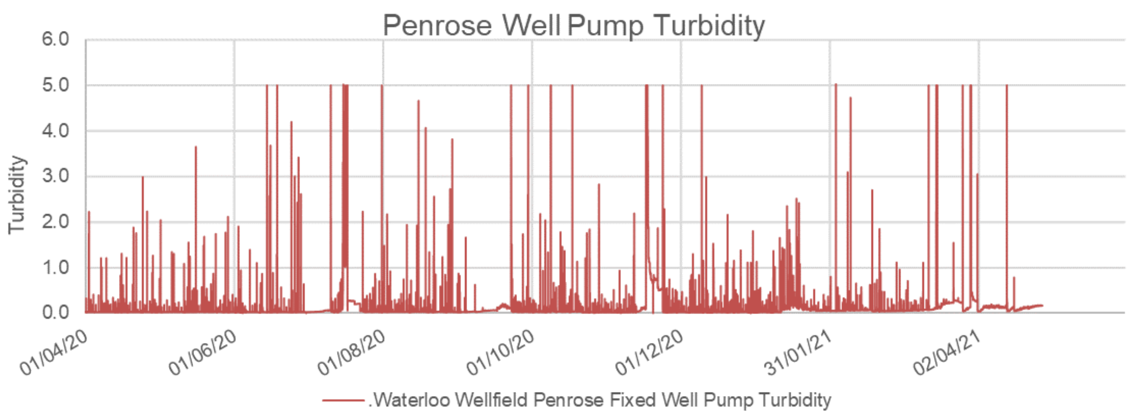


Figure E6. Penrose well turbidity data recorded (01/04/2020 - 27/04/2021)

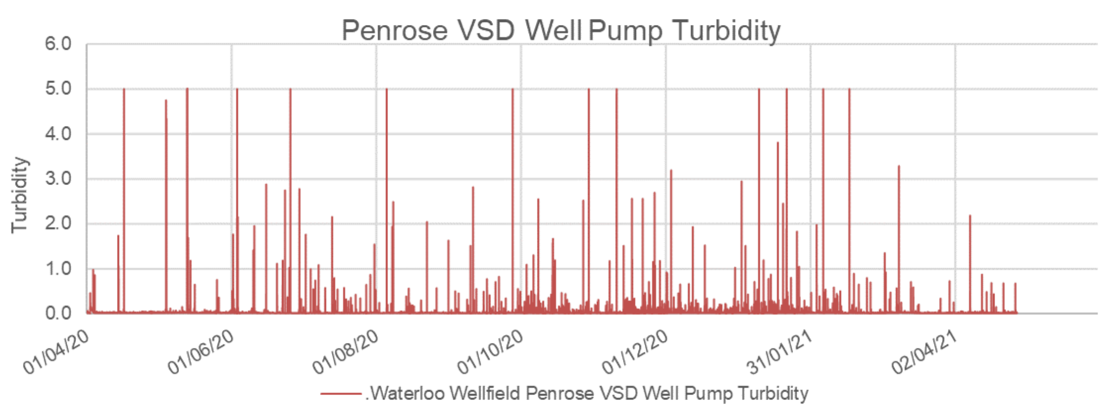


Figure E7. Penrose VSD well turbidity data recorded (01/04/2020 - 27/04/2021)

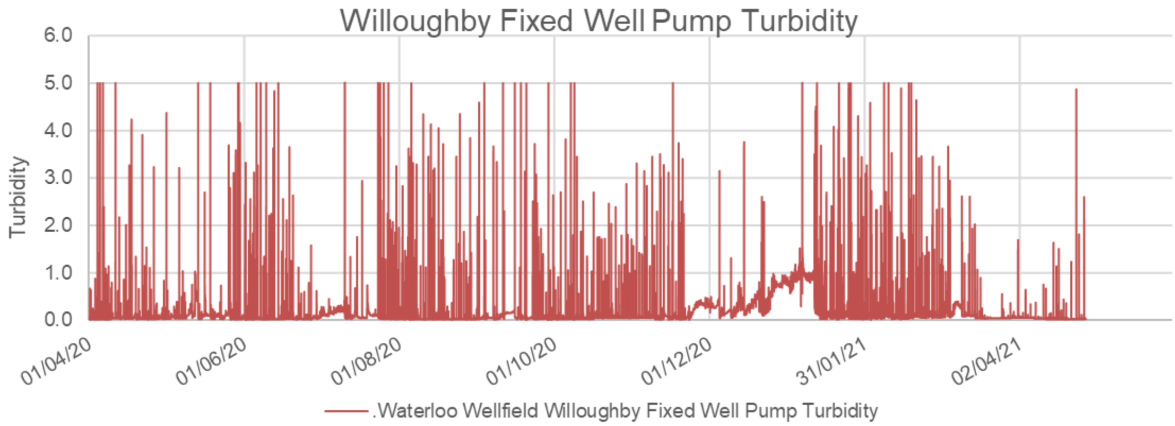


Figure E8. Willoughby well turbidity data recorded (01/04/2020 - 27/04/2021)

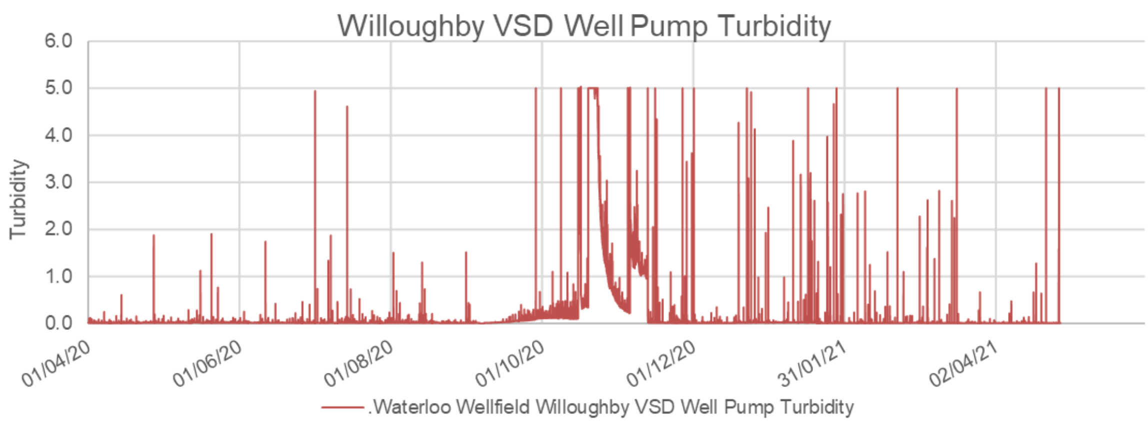


Figure E9. Willoughby VSD well turbidity data recorded (01/04/2020 - 27/04/2021)

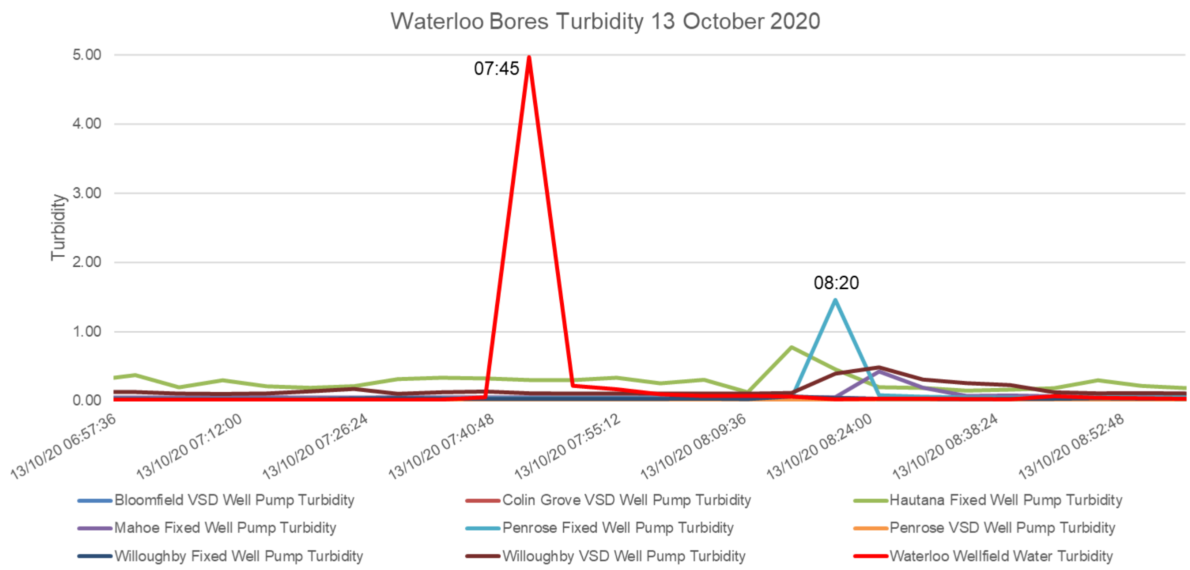


Figure E10. Turbidity spike recorded on October 13, 2020, at the Waterloo Wellfield

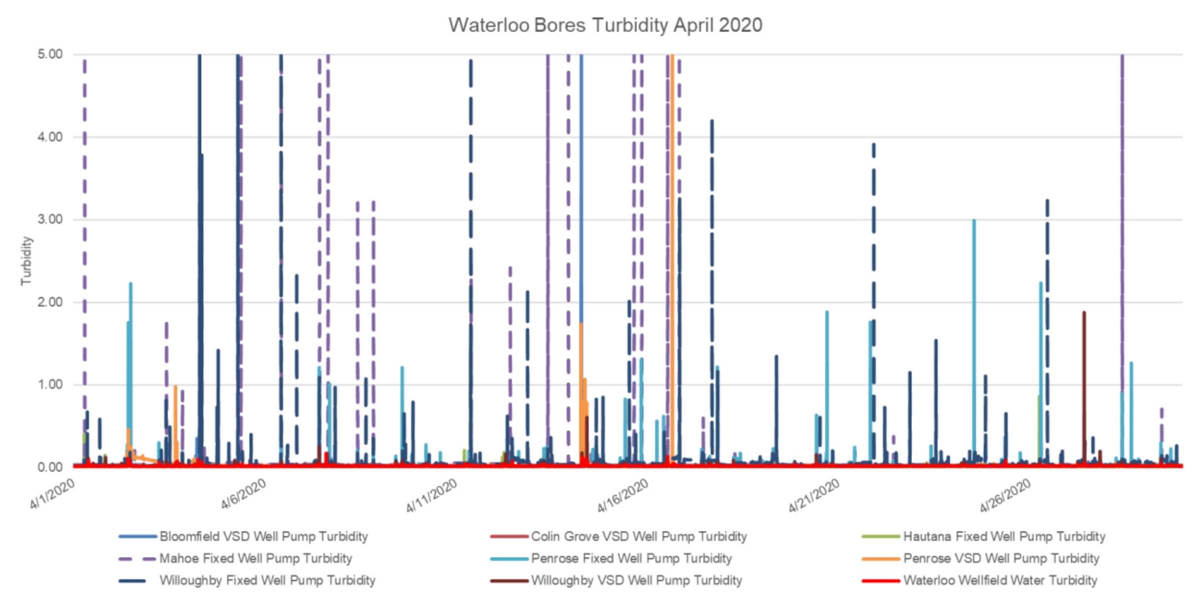


Figure E11. Turbidity data for all wells during April 2020

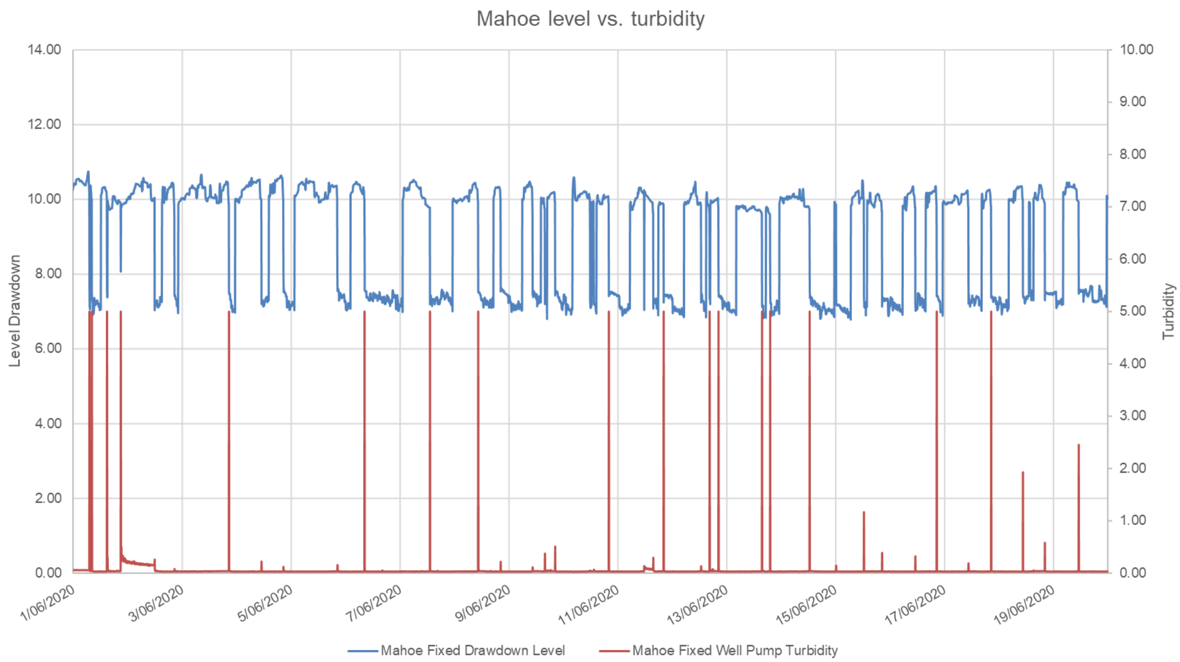


Figure E12. Mahoe well groundwater level drawdown vs. turbidity data (June 2020)

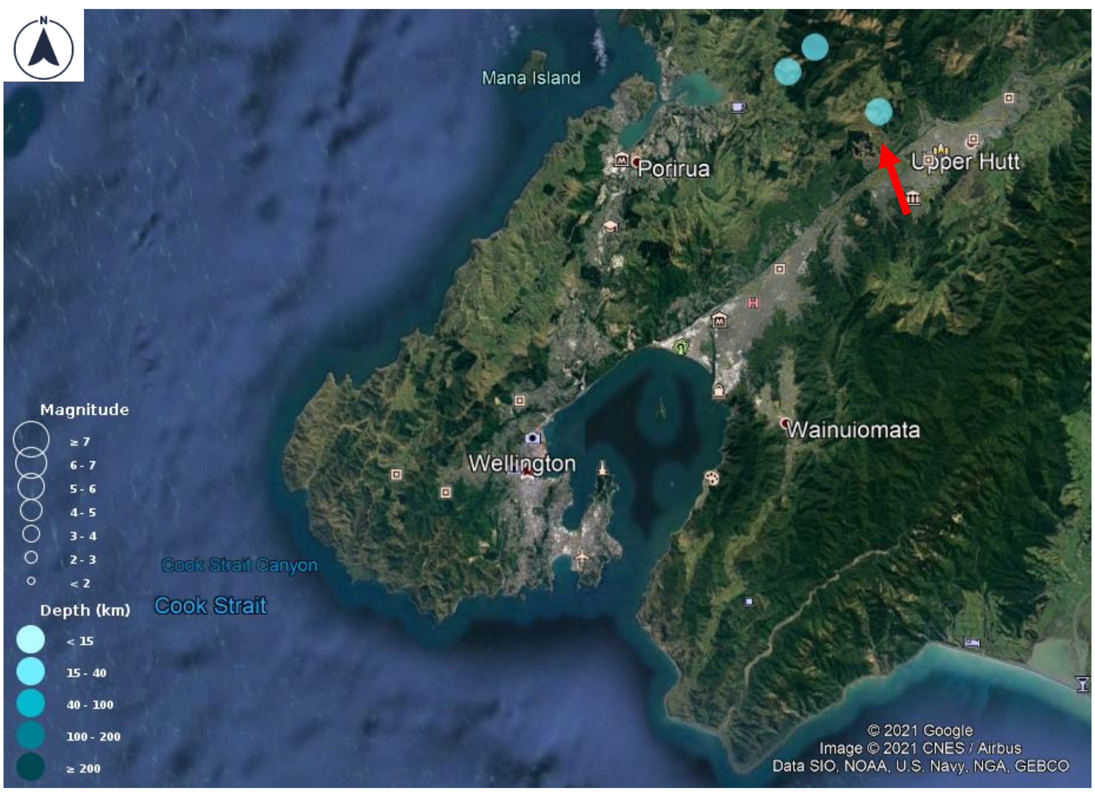


Figure E13: Location of 2021 Jan 02 Earthquake, M4.2 (data from https://www.geonet.org.nz/data/types/eq_catalogue)

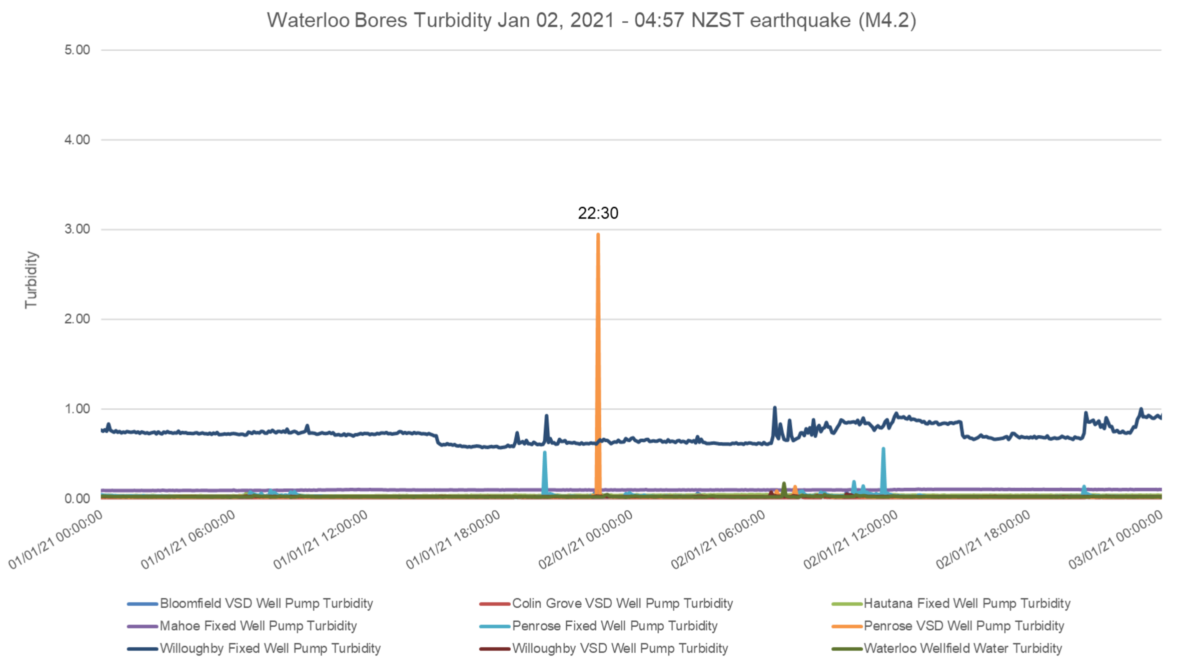


Figure E14. Turbidity data Jan 01 – Jan 03, 2021, M4.2 earthquake recorded on Jan 2 at 04:57 NZST

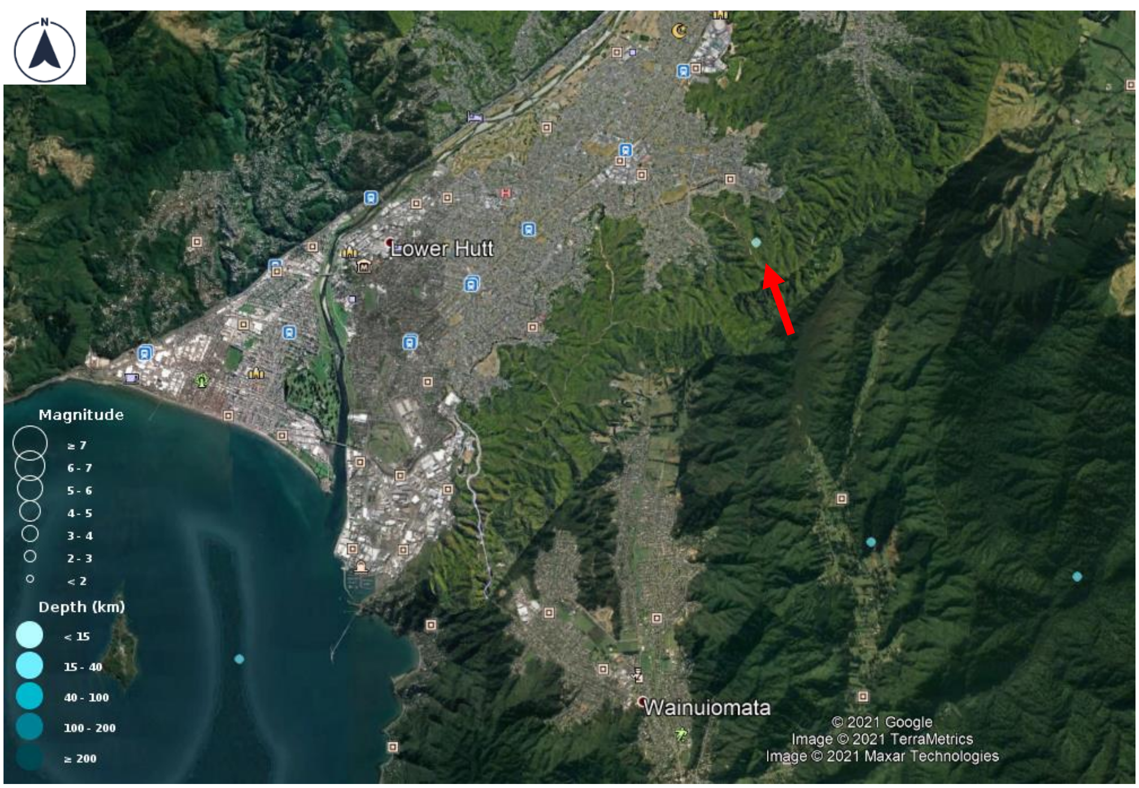


Figure E15 Location of 2020 November 14 Earthquake, M1.65 (data from https://www.geonet.org.nz/data/types/eq_catalogue)

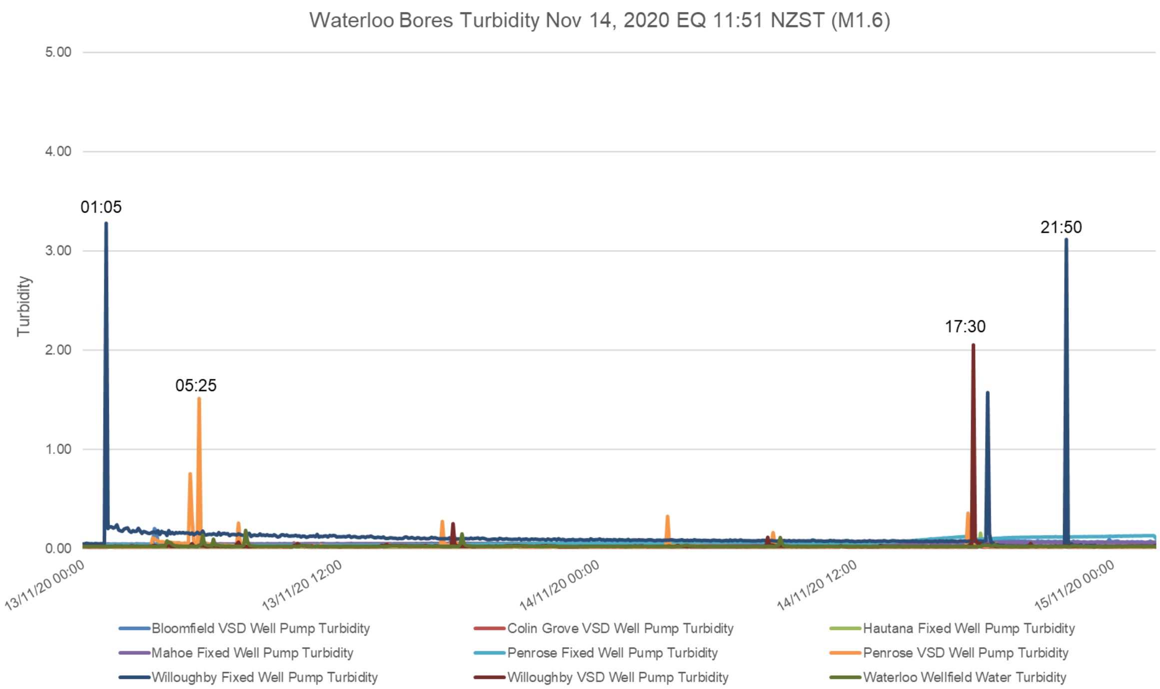


Figure E16 Turbidity around Nov 14, 2020, M4.3 earthquake

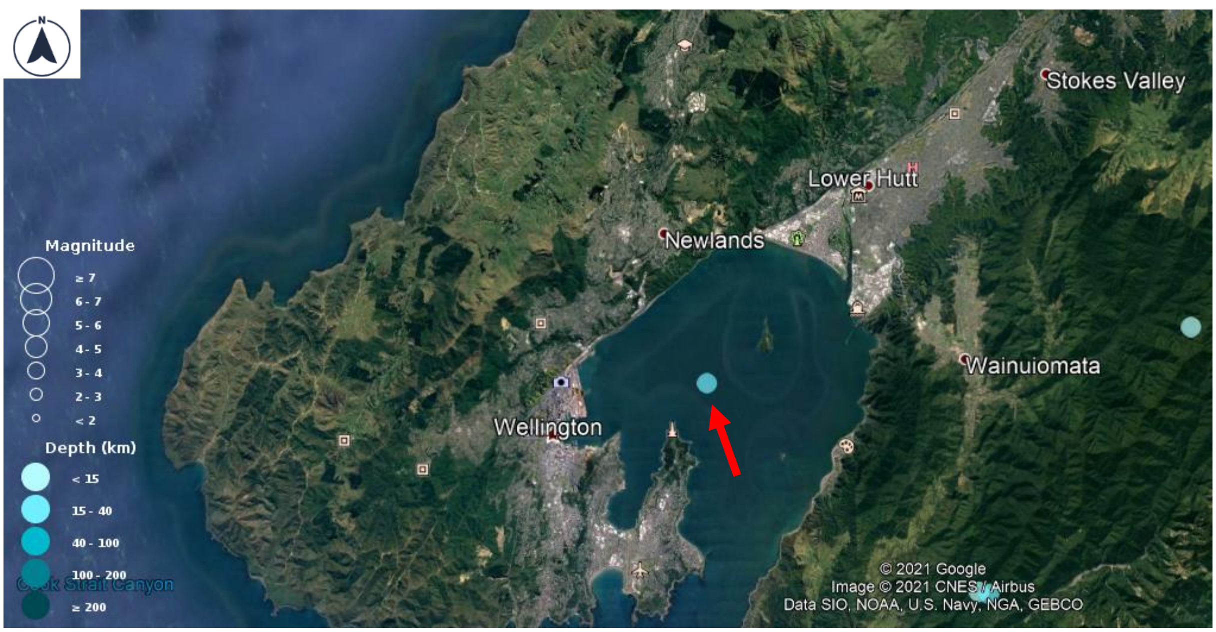


Figure E17 Location of 2020 October 08 Earthquake, M3.6 (data from https://www.geonet.org.nz/data/types/eq_catalogue)

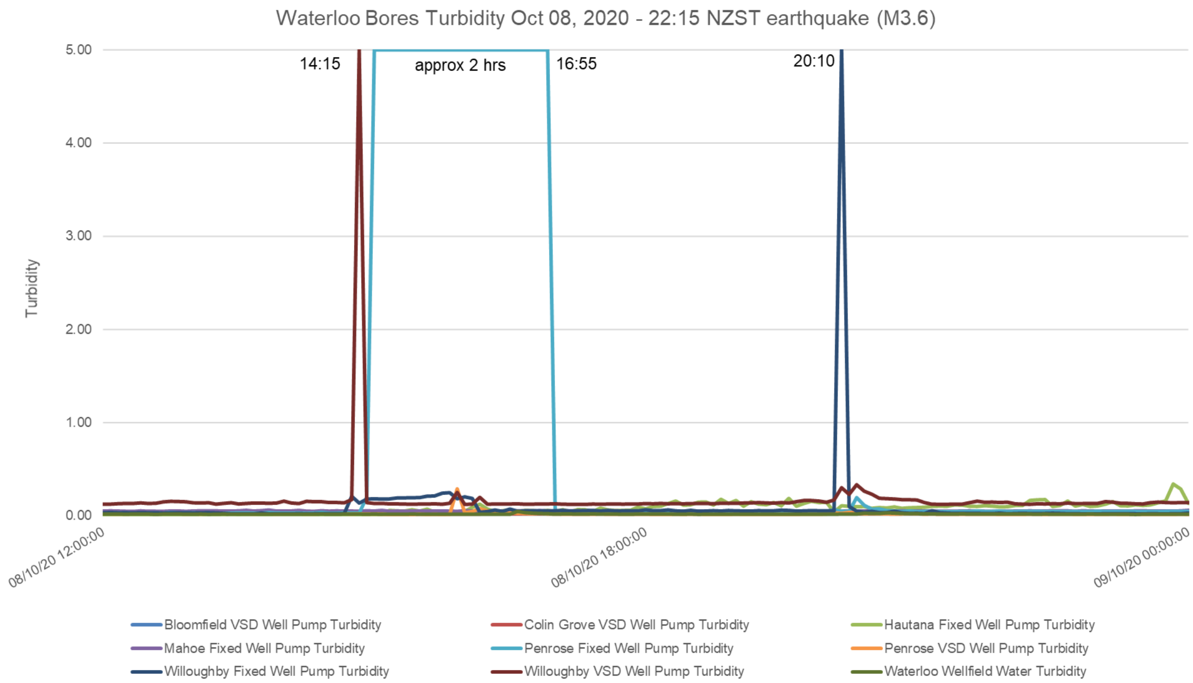


Figure E18. Turbidity data Oct 08 – Oct 09, 2020, M3.6 earthquake recorded on Oct 08 2020 at 22:15 NZST

Appendix F References

References

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