Environmental Science and Policy Committee

Meeting will be held in the Council Chamber, Level 2, Philip Laing House,
144 Rattray Street, Dunedin

This meeting will be livestreamed to the ORC Official YouTube Channel

Members:
Cr Lloyd McCall (Co-Chair)
Mr Edward Ellison (Co-Chair)
Ms Karen Coutts
Cr Alexa Forbes
Cr Gary Kelliher
Cr Michael Laws
Cr Kevin Malcolm
Cr Tim Mepham
Cr Andrew Noone
Cr Gretchen Robertson
Cr Alan Somerville
Cr Elliot Weir
Cr Kate Wilson

Senior Officer: Richard Saunders, Chief Executive

Meeting Support: Kylie Darragh, Governance Support Officer

20 February 2025 10:45 AM

Agenda Topic | Page

1. WELCOME

2. APOLOGIES

No apologies received at time of publication.

3. PUBLIC FORUM

At the time of publishing no requests to speak had been received.

4. CONFIRMATION OF AGENDA

Note: Any additions must be approved by resolution with an explanation as to why they cannot be delayed until a future meeting.

5. DECLARATION OF INTERESTS

Members are reminded of the need to stand aside from decision-making when a conflict arises between their role as an elected representative and any private or other external interest they might have. The Register of Councillors Pecuniary Interests are published on the ORC website.

6. PRESENTATIONS

At the time of printing no requests to present had been received.

7. CONFIRMATION OF MINUTES 3

That the minutes of the Environmental Science and Policy Meeting of 4 December 2024 be confirmed as a true and accurate record.

7.1 Minutes of Environmental Science and Policy Committee 3

8. OPEN ACTIONS FROM THE RESOLUTIONS OF THE COMMITTEE 10

9. MATTERS FOR CONSIDERATION 11

9.1 Groundwater Hydrology in the Critically Endangered Native Galaxiid Habitat, Kauru River, North Otago 11

This paper summarises the findings of a study (Attachment 1) to understand the relationship between river flows and groundwater behaviour in the lower reach of the Kauru River, Kakanui catchment, North Otago. This section of river provides habitat to the critically endangered lowland long jaw galaxiid.

9.1.1 Assessment of Groundwater - Surface Water Interaction in the Kauru River North Otago 18

9.2 Update on the Groundwater Science Programme 66

This paper updates the Environmental Science and Policy Committee on the groundwater science programme. This includes recent expansions and improvements to the monitoring network, the transition to an online national wells database, technical contributions to the proposed Land and Water Regional Plan, and ongoing efforts to better understand and manage Otago's groundwater resource.

10. CLOSURE

Otago Regional Council

Environmental Science and Policy Committee
MINUTES

Minutes of an ordinary meeting of the Environmental Policy and Science Committee held in the Council Chamber, Level 2 Philip Laing House, 144 Rattray Street, Dunedin on Wednesday 4 December 2024, commencing at 10:00 AM.
https://www.youtube.com/live/43CQWdli2R8?si=-kzPKnSjEzA4EJjh

PRESENT

Mr Edward Ellison	*(Chair)*
Cr Lloyd McCall	*(Co-Chair)*
Ms Karen Coutts	
Cr Alexa Forbes	
Cr Gary Kelliher	
Cr Michael Laws	
Cr Kevin Malcolm	
Cr Tim Mepham	
Cr Andrew Noone	
Cr Gretchen Robertson	
Cr Alan Somerville	
Cr Elliot Weir	
Cr Kate Wilson	

1. WELCOME

Chair Ellison welcomed Councillors, members of the public and staff to the meeting at 9 am. Staff present included Richard Saunders (Chief Executive), Anita Dawe (GM Regional Planning and Transport), Tom Dyer (GM Manager Science and Resilience) Joanna Gilroy (GM Environmental Delivery), Tami Sargeant (GM People and Corporate) Amanda Vercoe (GM Strategy and Customer, Deputy CE) online, Kylie Darragh (Governance Support).

2. APOLOGIES

Noted by the Chair was the absence of Cr Laws.

3. PUBLIC FORUM

No requests to address the Committee under Public Forum were received.

4. CONFIRMATION OF AGENDA

The agenda was confirmed as published.

5. DECLARATIONS OF INTERESTS

Councillors were reminded to advise of any conflict of interest if they arose.

6. PRESENTATIONS

No presentations were held.

7. CONFIRMATION OF MINUTES

Resolution: Cr Somerville Moved, Cr Wilson Seconded

***That** the minutes of the Environmental Science & Policy Committee 26 September 2024 be received and confirmed as a true and accurate record.*

MOTION CARRIED

8. OPEN ACTIONS FROM RESOLUTIONS OF THE COMMITTEE

There are currently no open actions for this committee.

9. MATTERS FOR CONSIDERATION

9.1. Regional Pest Management Plan Review Options

[YouTube 7:58] This report presented options for the potential review of the Otago Regional Pest Management Plan. Murray Boardman, Performance and Delivery Specialist and Libby Caldwell, Manager Environmental Implementation, and Joanna Gilroy, General Manager Environmental Delivery, were present to respond to questions on the report.

At 10:05 am Cr Malcolm moved, and Cr Wilson seconded:
That the committee adjourn for ten minutes break to draft additional recommendations.
MOTION CARRIED

The Committee reconvened at 10:15 am.

Resolution ESP24-112: Cr Robertson Moved, Cr Weir Seconded
That the Environmental Science & Policy Committee:

1. ***Notes*** *this report.*
2. ***Recommends that the Council approves*** *the recommendation of* ***Option 3A*** *to undertake a full review of the Regional Pest Management Plan (RPMP) and* ***provides*** *staff direction as to the year this would be started.*

    a. Notes *that the timing of the recommended option may be dependent on when the current Biosecurity Act is amended by Parliament.*

    b. Notes *that staff will make any necessary adjustments to budgets through the 25/26 Annual Plan process.*

MOTION CARRIED
Cr Mepham voted against the motion.

Additional recommendations were reviewed by the committee and taken separately by division.
Resolution: Cr Malcolm Moved, Cr Noone Seconded
That the Committee:

1. **Recommends** to Council that in addition to commencing the full review of the RPMP staff are requested to engage with the community to identify priorities for new site led programmes for inclusion in the RPMP, with those sites to comply with the site led programme objectives in the existing Otago Pest Management Plan 2019 – 2029.

For:	*Cr Kelliher, Cr Malcolm, Cr Mepham, Cr Noone, Cr Wilson*
Against:	*Cr Forbes, Cr McCall, Cr Robertson, Cr Somerville, Cr Weir, Chair Ellison, Karen Coutts*
Abstained:	*Nil.*

MOTION FAILED

Resolution: Cr Malcolm Moved, Cr Noone Seconded
That the Committee:

2. **Recommends** to Council that staff are instructed to report back to the Committee with an update following an assessment of whether the new site led programmes identified above can be added without the need for a partial review of the plan.

MOTION FAILED

Resolution ESP24-113: Cr Malcolm Moved, Cr Noone Seconded
That the Committee:

3. **Recommends** that staff are requested to correct inconsistencies and errors within the existing Otago Pest Management Plan through the minor changes process outlined in option 1.

MOTION CARRIED
Cr Malcolm voted against the motion.

Resolution: Cr Malcolm Moved, Cr Noone Seconded
That the Committee:

4. **Recommends** to Council that staff encourage consideration of Otago Pest Management Plans objectives and rules as part of the development of Integrated Catchment Action plans.

For:	*Cr Kelliher, Cr Malcolm, Cr Mepham, Cr Noone, Cr Robertson, Cr Wilson*
Against:	*Cr Forbes, Cr McCall, Cr Somerville, Cr Weir, Chair Ellison, Karen Coutts*
Abstained:	*Nil.*

The vote was tied, and the Chair declined to use a casting vote.
MOTION FAILED

9.2. Biodiversity Monitoring Programme Update
[YouTube 1:44:40] This paper highlighted some of the biodiversity work the Environmental Monitoring (EM) team is involved with at the Otago Regional Council. Scott Jarvie, Senior Scientist - Biodiversity, Tom Dyer, Eve Bruhns, Environmental Monitoring Manager, Matt Salmon, Environmental Technician Biodiversity, and Lauren Harrex, Team Leader Monitoring - Ecology/Water Quality, were available to respond to questions on the report.

Resolution ESP24-114: Cr Weir Moved, Cr Wilson Seconded
That *the Committee:*

1. ***Notes*** *this report.*
2. **Notes** that EM teams work on biodiversity will continue as part of established work programmes.

MOTION CARRIED

9.3. Lake Programme update

[YouTube 1:58:08] The purpose of this report was to provide the committee with an update on the lakes programme as a supplement to the regular State of the Environment (SOE) reporting. This included presenting the latest data and performance update from lake buoys currently installed in Lake Hayes, Lake Wānaka, and Lake Whakatipu. Additionally, this report covered recent lake snow monitoring results from Otago lakes and assessed the ecological condition of three key lakes in the Otago region—Hāwea, Whakatipu, and Wānaka—using the Lake Submerged Plant Indicator (LakeSPI) developed by NIWA. Hugo Borges, Senior Scientist - Lakes (online) Ben Mackay, Manager Science, and Tom Dyer, General Manager Science and Resilience were available to respond to questions on the report.

Resolution ESP24-115: Edward Ellison Moved, Cr Wilson Seconded

***That** the Committee:*

1. ***Receives** this report.*

MOTION CARRIED

9.4. Deep Lakes Technical Advisory Group update

[YouTube 2:18:00] The purpose of this paper is to provide and update to Council Committee on the formation and progress of the Otago Deep Water Lakes Technical Advisory Group and share the initial outputs from the Group. Tom Dyer, General Manager Science and Resilience, Hugo Borges, Senior Scientist – Lakes (online), Ben Mackay, Science Manager and Helen Trotter, Scientist - Water Quality, were present to respond to questions on the report. There was an addition to the recommendation.

Resolution ESP24-116: Edward Ellison Moved, Cr Forbes Seconded

That the Committee:

1. ***Notes** this report.*
2. ***Requests** an updated report be prepared for the Committee for mid-2025.*

MOTION CARRIED

9.5. Annual Surface Water Quality Report

[Youtube 2:35:45] This report provides an annual update of water quality and ecosystem health monitoring results from the State of the Environment surface water monitoring network, for the period July 2023 to June 2024. This annual reporting is required by the National Policy Statement – Freshwater Management. Tom Dyer, Ben Mackay and Helen Trotter were available to respond to questions on the report. Helen Trotter demonstrated to the committee the LAWA website and the data maps and ranges and further fact sheets, state trends. (Land and Water Aotearoa).

Resolution ESP24-117: Edward Ellison Moved, Cr Wilson Seconded

That the Committee:

1. ***Notes** this report.*

MOTION CARRIED

Cr McCall left the meeting at 11:52 am
Cr McCall returned to the meeting at 11:53 am

9.6. Estuary SOE update for summer 2023 - 24 monitoring season.
[YouTube 2:56:50] The purpose of this report is to provide the Committee with an annual update on the progress of the state of the environment estuary monitoring programme. The report outlines what monitoring has been completed over the summer monitoring season of 2023/24 and outlines the next steps in the monitoring programme, including the upcoming estuary programme review. Tom Dyer, General Manager Science & Resilience, Ben Mackay, Manager Science, and Sam Thomas, Senior Coastal Scientist, were available to respond to questions on the report.

Resolution ESP24-118: Edward Ellison Moved, Cr Malcolm Seconded
That *the Committee:*

1. ***Receives*** *this report.*
2. ***Notes*** *that the Estuary monitoring programme has been implemented according to the updated estuary monitoring programme plan in 2020 and now has obtained data for every estuary in Otago.*
3. ***Notes that next steps*** *include an estuary monitoring programme review this financial year to ensure the programme is delivering maximum value and to start prioritising areas for investigations and targeted management/restoration where needed.*
4. ***Notes*** *that an SOE report for the state of Otago's estuaries, pulling together current data will be presented to council before the end of FY in June 2025 after the final pieces of data are gathered this summer 2024/25 to inform this report.*

MOTION CARRIED

Cr Noone left the meeting at 12:02 pm.
Cr Noone returned to the meeting at 12:03 pm.
Cr Weir left the meeting at 12:07 pm.
Cr Weir returned to the meeting at 12:11 pm.
Cr Wilson left the meeting at 12:12 pm.
Edward Ellison left the meeting at 12:15 pm.
Cr McCall chaired from 12:16PM

9.7. Blue carbon potential in the Otago Region
[YouTube 3:04:40] This report presented the findings of a recent study by Tidal Research and NIWA into blue carbon habitats within the Otago Region. Blue Carbon is carbon that is stored within marine habitats and ecosystems such as salt marshes, seagrass intertidal sandflats, soft sediment and kelp forests. The study provides information on the importance of the ecosystem services provided by blue carbon habitats and the potential for restoration opportunities throughout the Otago region around estuaries, both currently, and under potential future sea level rise scenarios. Ben Mackay, Manager Science and Sam Thomas Senior Coastal Scientist, were available to respond to questions on the report.

Resolution ESP24-119: Cr Forbes Moved, Cr Noone Seconded
That *the Committee:*

1. ***Receives*** *this report*.
2. ***Notes*** *the opportunity available in the Otago region for the potential to increase blue carbon storage, biodiversity and ecosystem services through restoring salt marsh.*
3. ***Notes*** *that this report is to provide guidance about potential sites for restoration opportunities for landowners and catchment groups, as well as outlining the current benefits of salt marsh restoration and the potential for future credit opportunities.*

MOTION CARRIED
Kelliher and Cr Malcolm voted against the recommendations.

9.8. Regional conservation status of selected fungal taxa in Otago

[YouTube 3:30:50] This paper documents the regional conservation status of selected fungal species (nonlichenised agarics, boletes and russuloid) in the Otago Region. Scott Jarvie, Scientist - Biodiversity, Ben Mackay, Manager Science and Tom Dyer, General Manager Science & Resilience, were available to respond to questions on the report.

Resolution ESP24-120: Cr McCall Moved, Cr Weir Seconded

That *the Committee:*

1. ***Notes*** *this report.*
2. ***Notes*** *that the regional threat assessment for other species groups will continue as part of the terrestrial ecology work programme.*

MOTION CARRIED

10. NOTICES OF MOTION

Nil.

11. RESOLUTION TO EXCLUDE THE PUBLIC

Nil.

12. CLOSURE

There was no further business, Karen Coutts said a karakia and Chair McCall declared the meeting closed at 12:32 pm.

_________________________ ___________________

Chair Date

Meeting Date	Document	Item	Status	Action Required	Assignee/s	Action Taken	Due Date
4-12-2024	Environmental Science and Policy Committee - 4 December 2024	GOV2465 Deep Lakes Technical Advisory Group update	Assigned	ESP24-116 Requests an updated report be prepared for the Committee for mid-2025.	Scientist - Lakes, Team Leader - Land, Water Quality Scientist		30-06-2025

9.1. Groundwater Hydrology in the Critically Endangered Native Galaxiid Habitat, Kauru River, North Otago

Prepared for:	Environmental Science and Policy Commitee
Report No.	GOV2506
Activity:	Governance Report
Author:	Sam Yeo, Groundwater Scientist
Endorsed by:	Tom Dyer, General Manager Science and Resilience
Date:	20 February 2025

PURPOSE

[1] This paper summarises the findings of a study (Attachment 1) to understand the relationship between river flows and groundwater behaviour in the lower reach of the Kauru River, Kakanui catchment, North Otago. This section of river provides habitat to the critically endangered lowland long jaw galaxiid.

EXECUTIVE SUMMARY

[2] The Kauru River in North Otago is a strongly connected groundwater-surface water braided river system that supports the critically endangered lowland long jaw (G. Cobitinis).

[3] The report (appended as Attachment 1) indicates the presence of a highly permeable gravel groundwater system (henceforth named the braid plain aquifer) beneath the riverbed but overlying older relatively low permeability gravel sediments. The wider Kakanui-Kauru Alluvial Aquifer comprises these low permeability sediments and has been found to provide a limited groundwater contribution to the Kauru River system.

[4] The braid plain aquifer groundwater system is tightly coupled to the river. The aquifer is thin and constrained within the lateral limits of the contemporary braid plain. The braid plain aquifer has limited storage capacity which reduces its ability to support surface flows or provide a wetted habitat for burrowing galaxiids during low flow conditions.

[5] These characteristics mean Kauru River is inherently sensitive to changes in flow conditions, water abstraction, gravel abstraction and river engineering works.

[6] Given the limited size and high porosity of the braid plain aquifer, if future management of the Kauru River prioritises protecting the value of galaxiid habitat, the policy may seek to manage water allocation based on groundwater levels, rather than surface flow. Minimising water abstraction during low flows will help maintain natural low flow conditions and the resulting river/groundwater/gravel hydrological system to which the fish have become adapted.

RECOMMENDATION

That the Committee

a) ***Notes*** *this report.*

BACKGROUND

[7] The Kauru River in North Otago (Figure 1) has high in-stream values supporting the critically endangered lowland longjaw galaxias. This threat category places it in the same threat category as the Kākāpō.

[8] The long jaw is found only in the Kauru and Kakanui Rivers occupying a reach of the river where the bed is comprised of loosely packed, high porosity gravels.

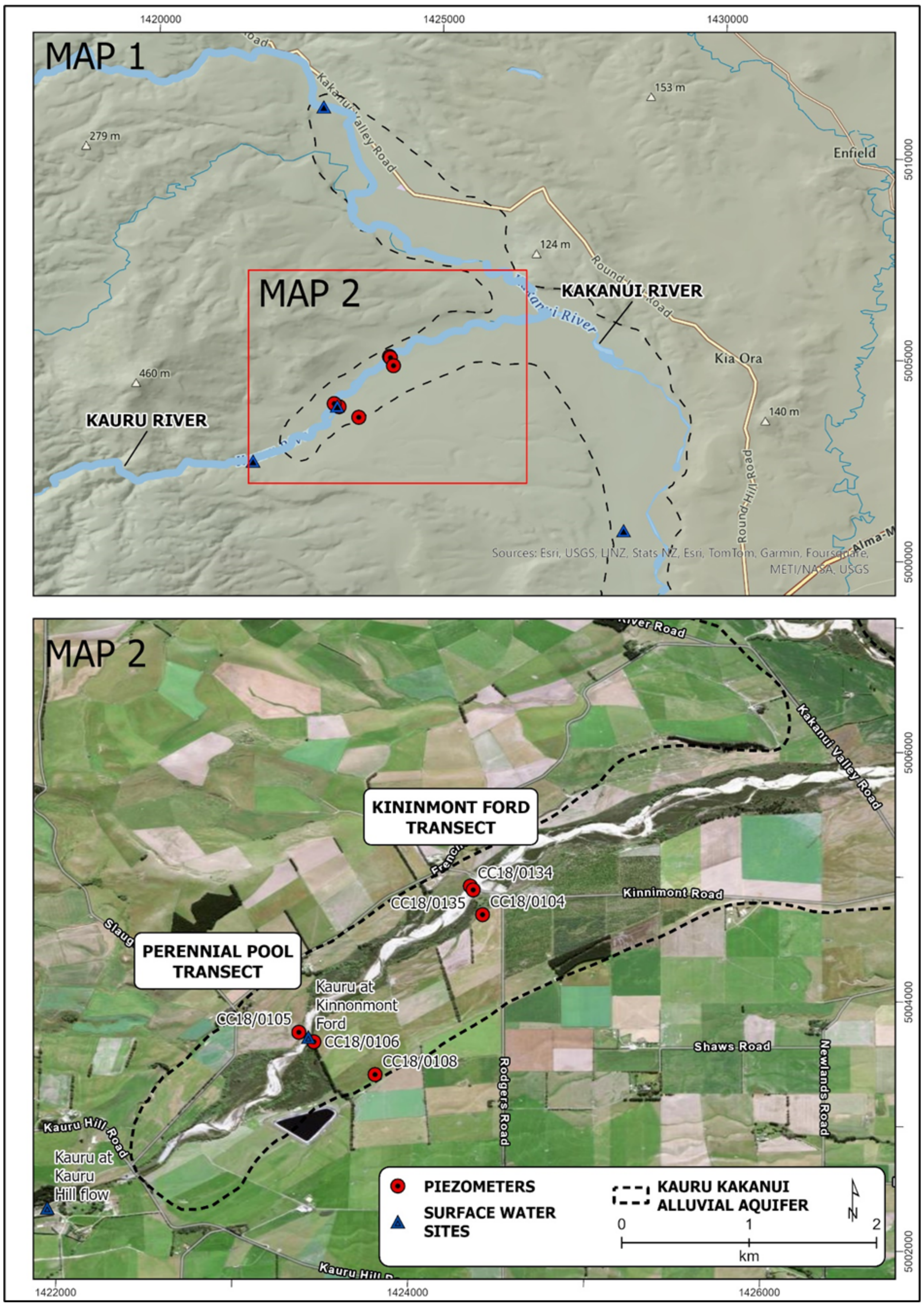

Figure 1. Map showing study area. Map 1 shows the Kauru and Kakanui River locations. Map 2 shows the study area highlighting the piezometer locations at the Perennial Pool bore transect and the downstream Kininmont Ford transect.

[9] Braided gravel-bed rivers are often highly connected to underlying groundwater leading to losing/gaining reaches where water can flow underground and re-emerge

downstream. During low flow periods, the Kauru River often naturally dries in its lower reaches with no surface flow.

[10] When the Kauru River starts to disconnect and form a series of isolated reaches or pools, the galaxiid can burrow into gravels beneath the riverbed where groundwater saturates the underlying gravels and provides a habitat refuge until the river flows are replenished.

[11] Changing flows and water abstraction pose a threat to the availability of this habitat refuge. Lower groundwater levels may deplete the braid plain aquifer, potentially leading to a decrease in habitat extent, or leave it in a depleted state for longer time periods than would naturally occur, resulting in adverse conditions for the fish.

[12] This report (Attachment 1) presents an investigation into the interaction between river flows and groundwater, to inform potential water management strategies tailored to support the galaxias habitat.

DISCUSSION

Conceptual Model

[13] This report introduces a new conceptual model of the Kauru River braid plain based on analysing drilling results (coring), radon-222, and time series data (groundwater levels and temperature) from downhole pressure transducers. Analysis of these datasets identified three main hydrological systems: the braided Kauru River (surface), the Kauru braid plain aquifer (higher surface connectivity groundwater), and the Kauru-Kakanui Alluvial Aquifer (low connectivity groundwater and regional aquifer) (Figure 2).

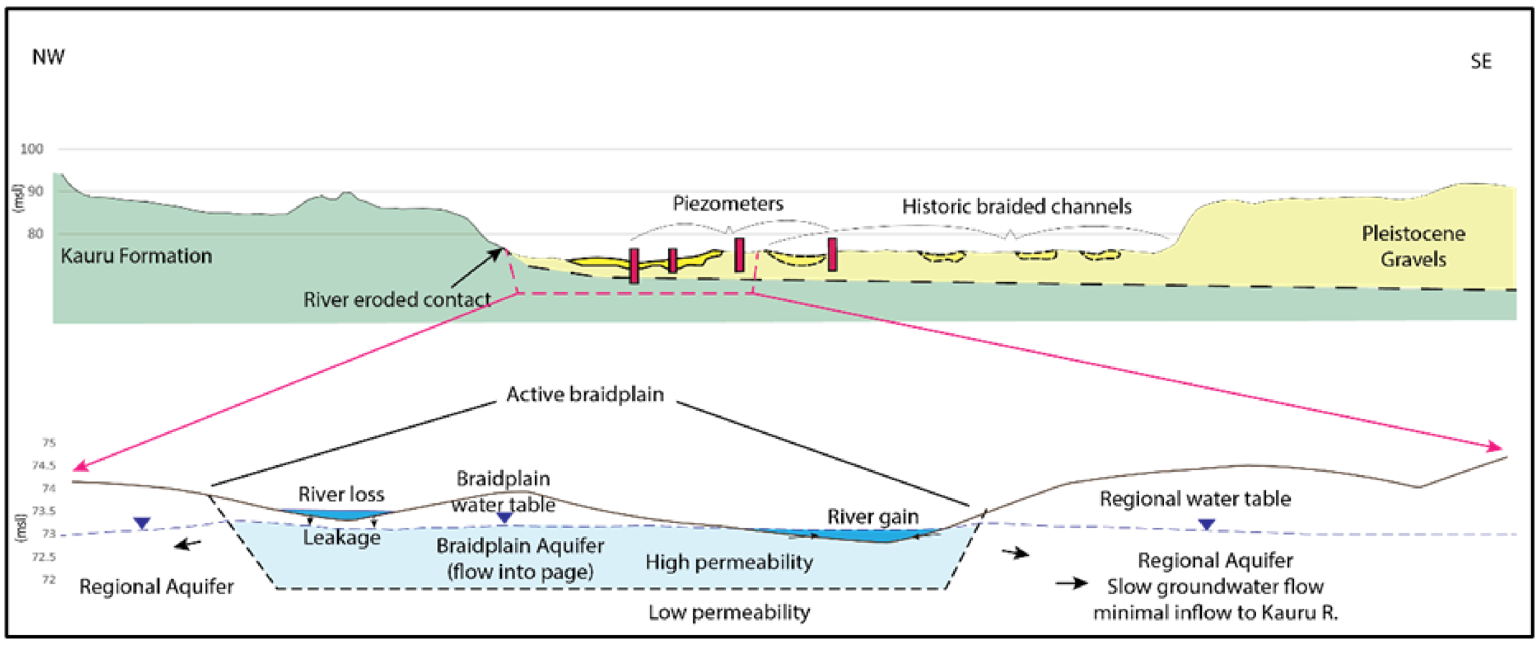

Figure 2. Cross section through the Kauru River and Kininmont Ford crossing highlighting the conceptualisation of the system (horizontal scale is approximately 900m for top image). The green area in the top plot shows the Kauru Formation unit, which is comprised of glauconitic sandstone, siltstones, and mudstones. The lighter yellow is the Pleistocene, silt-bound gravels (low permeability zone in the bottom diagram). The yellow Pleistocene gravels comprise the Kauru-Kakanui Alluvial Aquifer (regional aquifer). The green unit is impermeable geology which could be considered hydrogeological basement that does not host any groundwater. The bottom diagram introduces the concept of the braid plain aquifer and its relationship with the Kauru River and the surrounding low permeability sediments, (modified from Wilson et al., 2024).

[14] The findings from this study show that the river is closely connected to the underlying braid plain aquifer (BPA). The Kauru BPA is found to be very thin, on the order of 1.5-2m

thick, and constrained to the active/contemporary braid plain channel (i.e. the wetted riverbed). The BPA sits within relatively low permeability silt bound gravels which separate the BPA from the Kauru-Kakanui Alluvial Aquifer ("regional aquifer" in Figure 2). Data has shown these low permeability gravels, that make up the wider, Kakanui-Kauru Alluvial regional aquifer system to be poorly connected to the Kauru braided aquifer/river system.

River Flow versus Groundwater relationship

[15] A challenging but key data source for this study was installing piezometers within the active channel (Figure 3) to record groundwater in close proximity to the surface flow.

Figure 3. Photos of drilling into the Kauru riverbed at Kininmont Ford.

[16] Comparison of groundwater levels recorded by bores screened within the BPA gravels and flow in the Kauru River, show a flow rate threshold that determines the stability of groundwater levels in the braid plain aquifer (Figure 4).

[17] Two distinct thresholds create three distinct zones in the flow versus BPA relationship (Figure 2).

1. When flow at Kauru Hill is above 800L/s groundwater levels are stable. Increasingly higher flows (>2 m^3/s) have a limited effect on groundwater levels. In these higher flows the BPA gravels are fully saturated.
2. When flow is between 200L/s and 800L/s, groundwater levels decline suggesting flows in this range are insufficient to maintain full capacity in the braid plain aquifer.
3. When flows fall below 200L/s groundwater levels rapidly decline and surface flow ceases at this site. This is when the braid plain aquifer could be considered depleted.

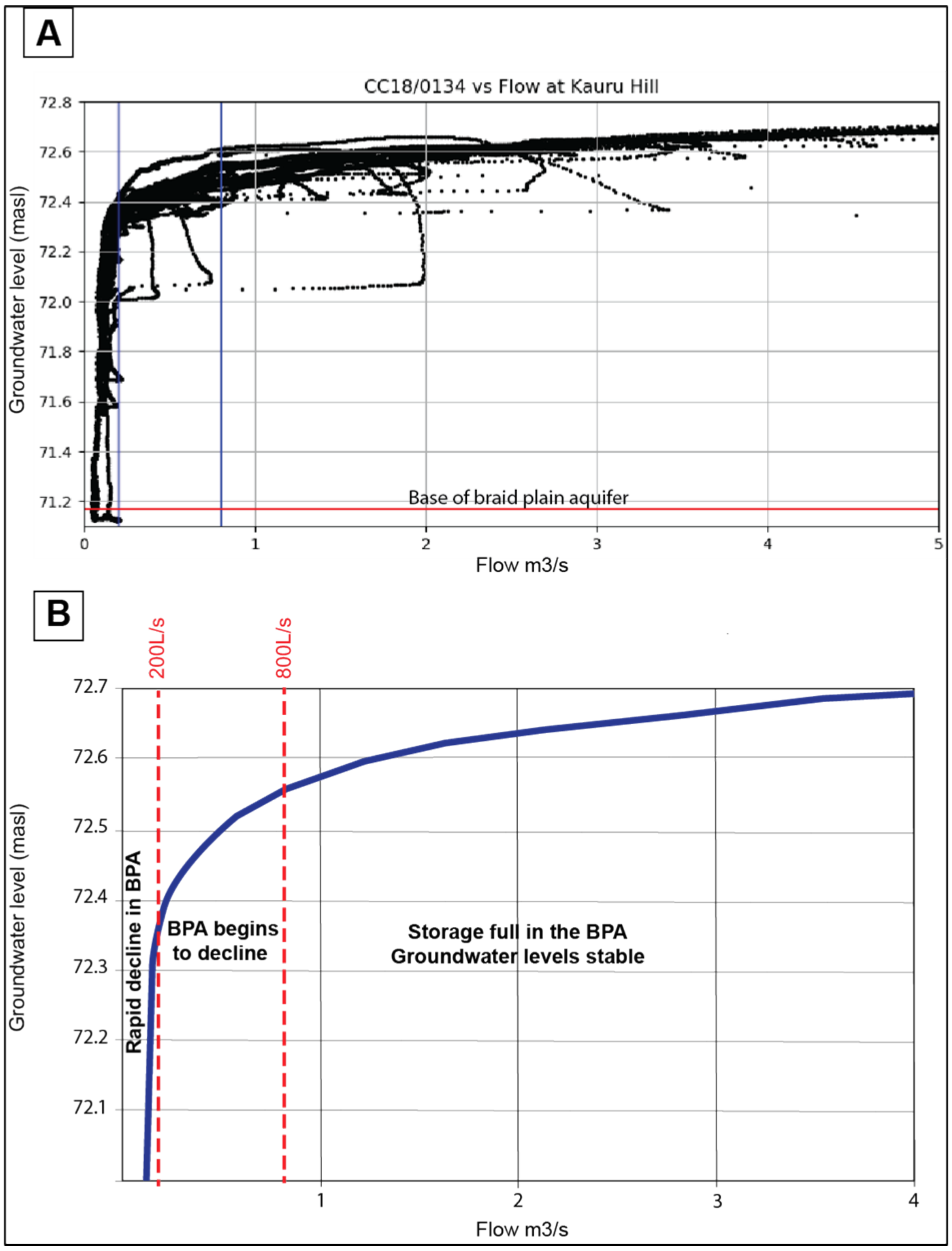

Figure 4. Raw data plot (A) and schematic plot (B) from bore CC18/0134 showing flow divisions based on the bounding relationship between groundwater levels in the braid plain aquifer and Kauru flow. Plot B approximates the upper bound of the data pattern seen in A, delineated by the blue line. The red dashed lines in B show the two flow divisions where there are noticeable changes in slope.

[18] Key study findings indicate that the primary dynamic hydrological interaction occurs between the Kauru River's surface flow and the shallow groundwater in the braid plain aquifer. The underlying silt-bound sediments of the larger Kakanui-Kauru Alluvial Aquifer have minimal impact on the hydrological system at the Kauru River.

[19] The braid plain aquifer is very thin and therefore has low storage potential making it vulnerable to flow losses when surface water begins to decrease below 800L/s.

[20] Groundwater levels start to decline when flows are lower than 800L/s and drop rapidly when flow is below 200 L/s.

Management considerations

[21] These flow thresholds could be key considerations when developing surface abstraction limits, or groundwater takes within the BPA, if protecting galaxiid habit is a management objective.

[22] Due to the characteristics of the losing reach, flow setting optimised to protect galaxiid habitat would require consideration of the relationship between flow and groundwater. This may require minimum flow setting at a level above those typically used in default setting such as relying on retaining a proportion of 7-day MALF flows. Currently the low flow threshold for the Kauru River is based on 250L/s (all primary permits cease) at the Kakanui at Mill Dam flow recorder, downstream of the Kakanui/Kauru confluence.

OPTIONS

[23] This paper is for noting only.

CONSIDERATIONS

Strategic Framework and Policy Considerations

[24] This study aligns with the environmental strategic directions[1,2] The results from this study can be used to inform minimum flow and allocation settings for the Kauru River.

Financial Considerations

[25] This study concludes three years of monitoring and analysis of the findings.

Significance and Engagement

[26] Any future minimum flow derived using the information from this study would be consulted on as part of the planning process. This report highlights thresholds which would affect a key river value and can inform future policy direction.

Legislative and Risk Considerations

[27] Under National Policy Statement for Freshwater Management, we are required to provide for habitats of freshwater threatened species. This study provides key thresholds below which lowland longjaw habitat may decrease.

Climate Change Considerations

[28] Under climate change hydrological system functioning in the Kauru River may change, including the potential for changes to river inflows. The results from this study show a complex relationship between surface water and groundwater and therefore when setting environmental limits in the Kauru River the whole hydrological system should be considered.

Communications Considerations

[29] Technical report to be released to the public and report and recommendations to be communicated to policy.

[1] *Ecosystems are healthy, our water and air are clean, and biodiversity loss is arrested across the region.*

[2] *Our regional plans are effective at ensuring our resources are managed sustainably within biophysical limits in a planned and considered way*

[30] Any future minimum flow derived using the information from this study would be consulted on as part of the planning process and communicated to the relevant stakeholders at the time.

NEXT STEPS

[31] Release the technical, peer reviewed report to policy for consideration of recommendations.

[32] An offer will be made to present the findings of the study to stakeholders in the Kauru / Kakanui area.

ATTACHMENTS

1. ORC Kauru River water manangement recommendation Final [**9.1.1** - 48 pages]

Assessment of groundwater-surface water interaction in the Kauru River, North Otago

Photo courtesy of P. Ravenscroft

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Prepared by Sam Yeo, Groundwater Scientist

Reviewed by Ben Mackey, Science Manager

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Contents

1 Technical Summary 1
1.1 Scope/purpose of project 1
2 Introduction 2
3 Geology 5
3.1 Catchment description 5
3.2 Hydrogeological basement rocks 7
3.3 Sediments 7
4 Galaxiid habitat 7
5 Review of braided river systems and definitions 8
6 Water Allocation in Kauru River catchment 9
6.1 Surface water allocation 10
6.2 Groundwater allocation 10
7 Methods and analysis 11
7.1 Sonic Drilling 11
7.1.1 Borehole construction: 13
7.1.2 Downhole geology in drill core 13
7.2 Assessment of flow and groundwater level data 15
7.2.1 Results 15
7.2.2 Key thresholds 21
7.3 Temperature time-series 22
7.3.1 Temperature results and discussion 23
7.4 Radon-222 23
7.4.1 Methodology 24
7.4.2 Radon-222 concentrations in the Kauru River 24
8 Synthesis and Conceptual model 26
8.1 Introduction 26

8.2 Groundwater-surface water relationship 26
9 Conclusion 31
9.1 Recommendations 31
9.2 Future investigations 32
10 Acknowledgements 33
11 References 33
12 Appendix 1 34

List of Figures

Figure 1. Map of Kauru River study area and wider Kakanui catchment. 2
Figure 2. Images facing both downstream of the Kauru River toward Kakanui confluence and upstream towards Kakanui mountains and upper catchment area for the Kauru River 3
Figure 3. Map showing the sub-basin boundaries (dashed in red) in the Kakanui-Kauru catchment redrawn from Ozanne and Wilson, 2013. 4
Figure 4. Catchment map of Kauru-Kakanui, sub catchments labelled and coloured (Ozanne and Wilson, 2013). 5
Figure 5. Median monthly rainfall for the full record of the Kauru at the Dasher rainfall recorder, located at the toop of the Kauru River catchment. 6
Figure 6. Lowland longjaw distribution within the Kauru and Kakanui Rivers, data sourced from the NZ freshwater fish database 8
Figure 7. Location of consented water takes. All takes are allocated against surface water. 10
Figure 8. Study site with simplified geology layer (MAP 1) from QMap (Forsyth, 2001) and monitoring locations (MAP 2). 12
Figure 9. Drill core photos from piezometer CC18/0134 and CC18/0105. The blue line delineated the geologically young BPA gravel unit. The red boxes indicate silt bound schist-derived gravels, likely emplaced during the Quaternary (Q1a or Q2a). The green 14
Figure 10. Groundwater level time series data from the Kininmont Ford transect 15

Figure 11. Time series comparison between CC18/0105 and CC18/0106 16

Figure 12. Flow data from Kauru at Kauru Hill (x-axis) plotted against groundwater level time-series 17

Figure 13. Plot of FDC (frequency distribution curve) from Kauru at Ewings flow recorder 19

Figure 14. Frequency distribution curves for groundwater levels in the braid plain aquifer 20

Figure 15. Temperature time series 23

Figure 16. Image from Coble (2023) report showing radon concentrations from each sample site 24

Figure 17. Plot from Coble (2023) showing radon and flow relationship 25

Figure 18. Cross section through the Kauru River and Kininmont Ford crossing 28

Figure 19 Schematic plot of CC18/1034 showing flow divisions 30

1 Technical Summary

The Kauru River in North Otago supports the habitat of the critically endangered native galaxiid – *Galaxias Cobitinis.* The Kauru River is strongly connected to underlying groundwater and therefore the purpose of this study was to understand the dynamics of this connection with the goal of using this understanding to protect the native galaxiid habitat.

This report presents a conceptual model of the Kauru ground water systems near the drying reach including the Kauru River, Kauru braid plain aquifer (BPA), and Kakanui-Kauru Alluvial Aquifer. Based on drilling results (coring), radon-222, and time series data (groundwater levels and temperature) from downhole pressure transducers, the BPA hosted within the Kauru River contemporary braidplain is very thin (1.5-2m), sitting above older, and lower permeability, silt-bound gravels. In addition, the outer area of the Kauru-Kakanui alluvial ribbon adjacent to the Kauru River is also predominately comprised of silt bound gravels. Temperature data suggests groundwater movement through these gravels to be low hydraulic conductivity and unlikely to be a considerable contributor to the Kauru River hydrological system. The main groundwater storage component for the Kauru River is found within the underlying braid plain aquifer gravels, constrained within the lateral limits of the contemporary braid plain. The limited storage capacity of the braid plain gravels means, that during low flow conditions, the BPA gravels have a limited ability to support surface flows and provide a wetted habitat for burrowing galaxiids. Therefore, the Kauru River is inherently naturally vulnerable to changes in flow conditions, water abstraction, gravel abstraction and river engineering works.

1.1 Scope/purpose of project

The Kauru River in North Otago has high in-stream values supporting the critically endangered lowland longjaw galaxias (*Galaxias cobitinis*). This threat status puts it in the same category as other endangered species such as the Kākāpō (DOC, 2018). The criteria resulting in this threat status include the species occurring in only one location and having less than 250 mature individuals. Studies carried out by both the Department of Conservation and the Otago Regional Council (DOC, 2004; ORC, 2003) have found this fish occupies habitat conditions comprised of loosely packed, high porosity gravels in Kauru and Kakanui rivers. During periods of low flow, the fish burrow into the substrate, occupying the hyporheic zone (gravel bed reservoir i.e. the braid plain aquifer) until flows are replenished. Changing flow and abstraction conditions pose a threat to the availability of this habitat refuge; lower aquifer levels may deplete the hyporheic zone potentially leading to a decrease in habitat availability. Here we investigate the interaction between river flows and the Kauru-Kakanui aquifer, to inform future water management strategies which may better support the galaxias habitat.

2 Introduction

The Kauru River is a braided river in North Otago, South Island, NZ (Figure 1 and Figure 2). The Kauru River headwaters are in the Kakanui mountains, flowing east - northeast before joining the Kakanui River. The lower reaches of the Kauru River form a steep, braided river system as it exits the steep schist terrain. The Kauru and Kakanui Rivers form an important habitat refuge for the native galaxiid, *galaxias cobitinis.* This species is endemic to these two rivers and has the same threat status as the native Kākāpō or Takahē and is only found in these two river systems (Dunn et al, 2004).

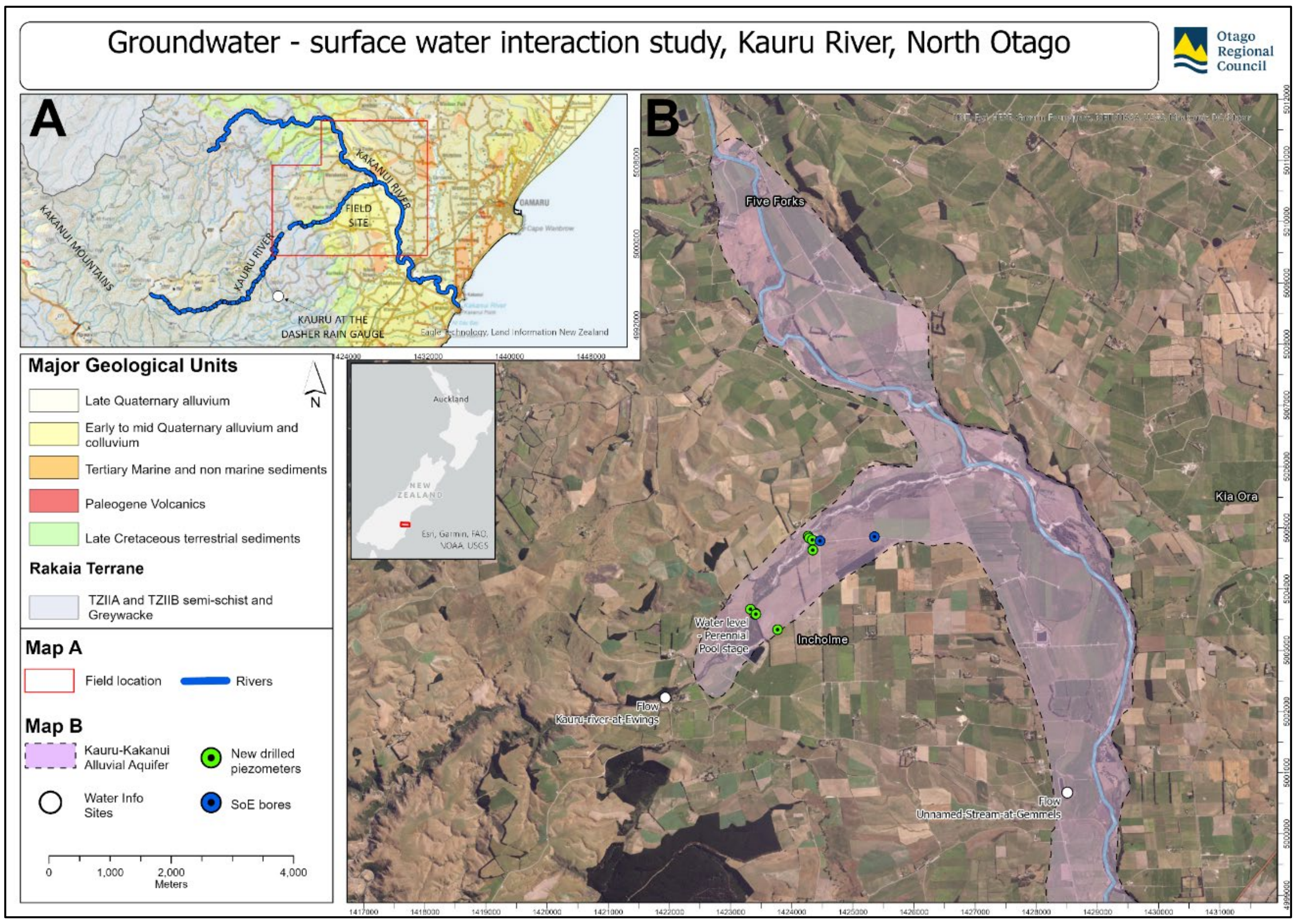


Figure 1. Map of Kauru River study area and wider Kakanui catchment. Geological map is in Map A. Map B shows the field area and monitoring locations. The pink area shows the boundary of the mapped Kakanui-Kauru Alluvial Aquifer in Regional Plan:Water.

The Kakanui and Kauru Rivers have complex underlying groundwater systems. These complex systems lead to losing and gaining reaches (Figure 3) in the Kakanui and Kauru rivers. Groundwater

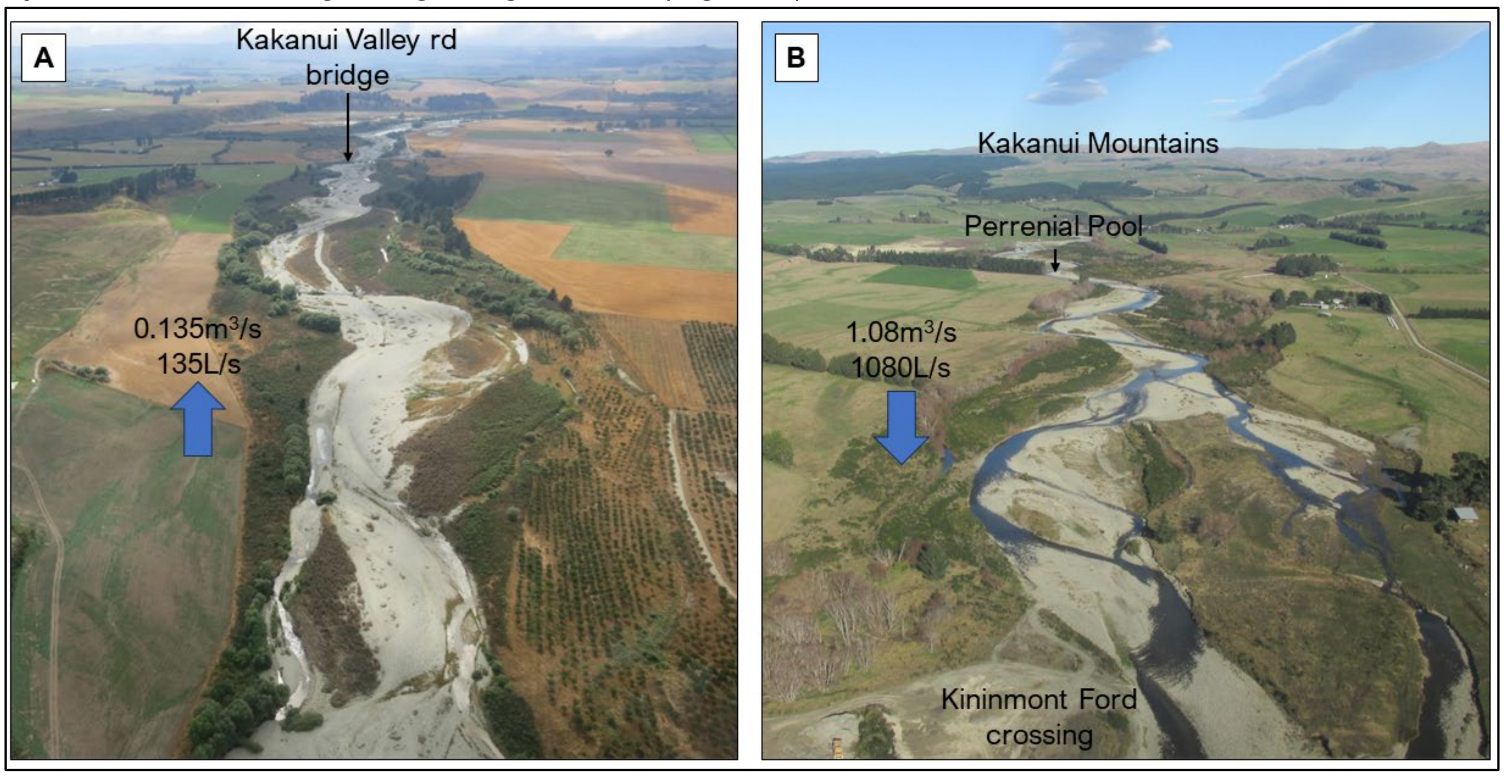


Figure 2. Images facing both downstream of the Kauru River toward Kakanui confluence (A) and upstream towards Kakanui mountains and upper catchment area for the Kauru River (B). Blue arrows denote flow direction and measured flow at Kauru Hill flow recorder at the time the photos were taken.

levels in the Kauru alluvial aquifer change seasonally and with high flow events (Ozanne and Wilson, 2013). Storage in the groundwater is replenished during high flow events and drained during flow recessions (Ozanne and Wilson, 2013). Groundwater levels in both the Kauru and Kakanui riparian aquifers are highly responsive to changes in surface water flows and are generally understood to be thin with limited storage capacity.

The thin nature of the aquifer means that, during summer, the Kauru BPA can drain leading to drying reaches and diminished galaxiid habitat. During these dry periods, the galaxiids become stranded in pools in the drying reaches as the river begins to disconnect. As surface habitat completely dries, smaller galaxiids can burrow into the substrate to occupy the hyporheic zone. They can persist in these sub-optimal conditions, where food is likely limited, for an unknown period of time until rainfall results in aquifer replenishment and surface flow. Surface flows do not occur in the drying reaches until groundwater storage is replenished.

Due to the strong interconnection between the Kakanui and Kauru Rivers and the underlying alluvial ribbon aquifers, the current operative Regional Plan: Water manages all water takes in the alluvial ribbon aquifers as surface water takes. At present, the minimum flow setting for water extraction from the Kauru River is determined downstream in the Kakanui River, specifically at the Mill Dam flow recorder. All primary permits are required to cease when the flow rate reaches $0.25m^3/s$. The protection level provided to the galaxiid habitat by these regulations is currently unknown, however relative to the precautionary default minimum flow guidelines (Hayes et al, 2021), environmental flow settings in the Kauru catchment could be considered permissive.

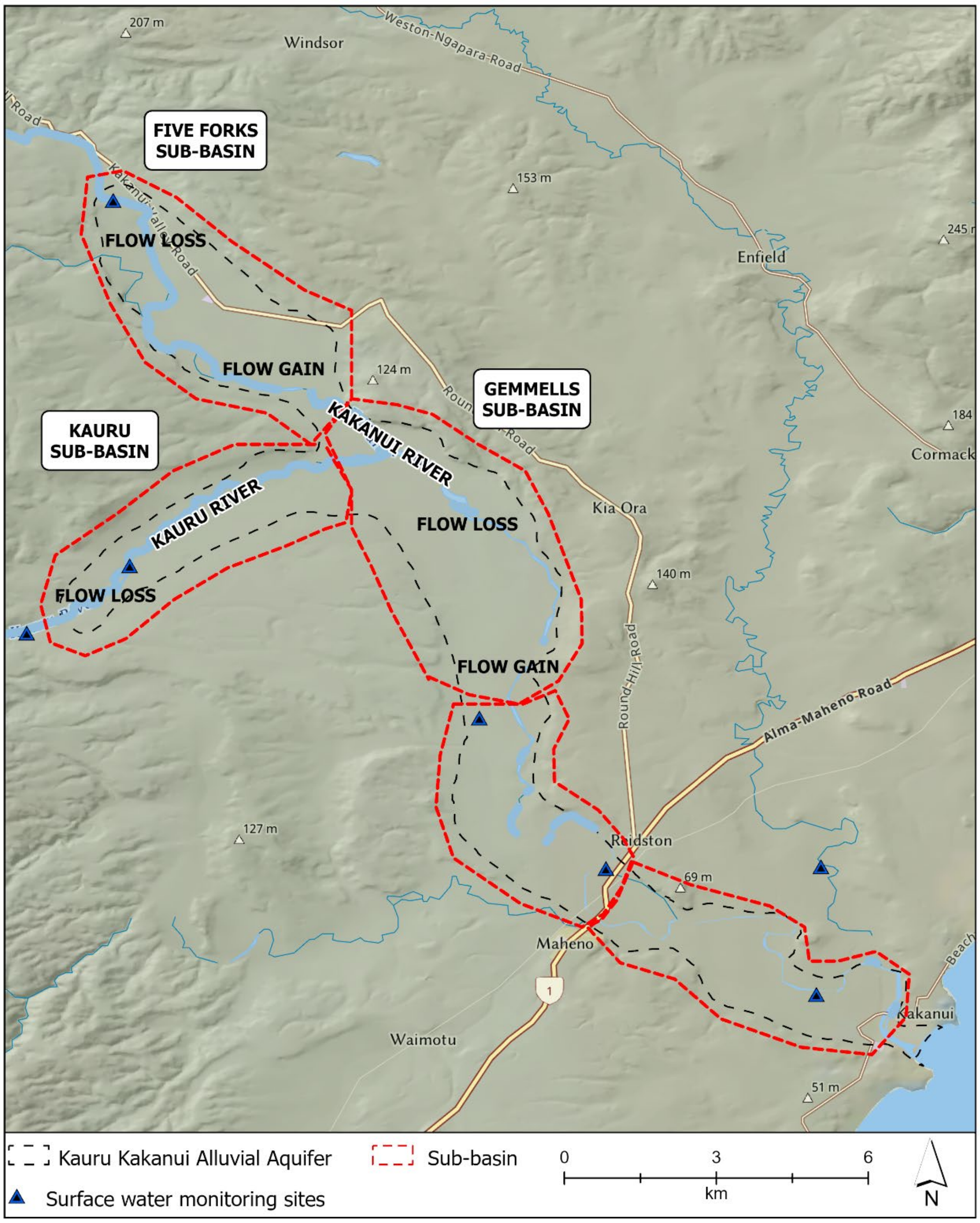


Figure 3. Map showing the sub-basin boundaries (dashed in red) in the Kakanui-Kauru catchment redrawn from Ozanne and Wilson, 2013.

4

3 Geology

3.1 Catchment description

The Kauru River is located in North Otago, South Island, NZ, within the North Otago Freshwater Management Unit. The Kauru River is hosted within the larger 894 km^2 Kakanui catchment with the three major tributaries being the Kauru River (143 km^2), Island Stream (122 km^2) and the Waiareka Creek catchment (213 km^2) (Figure 4).

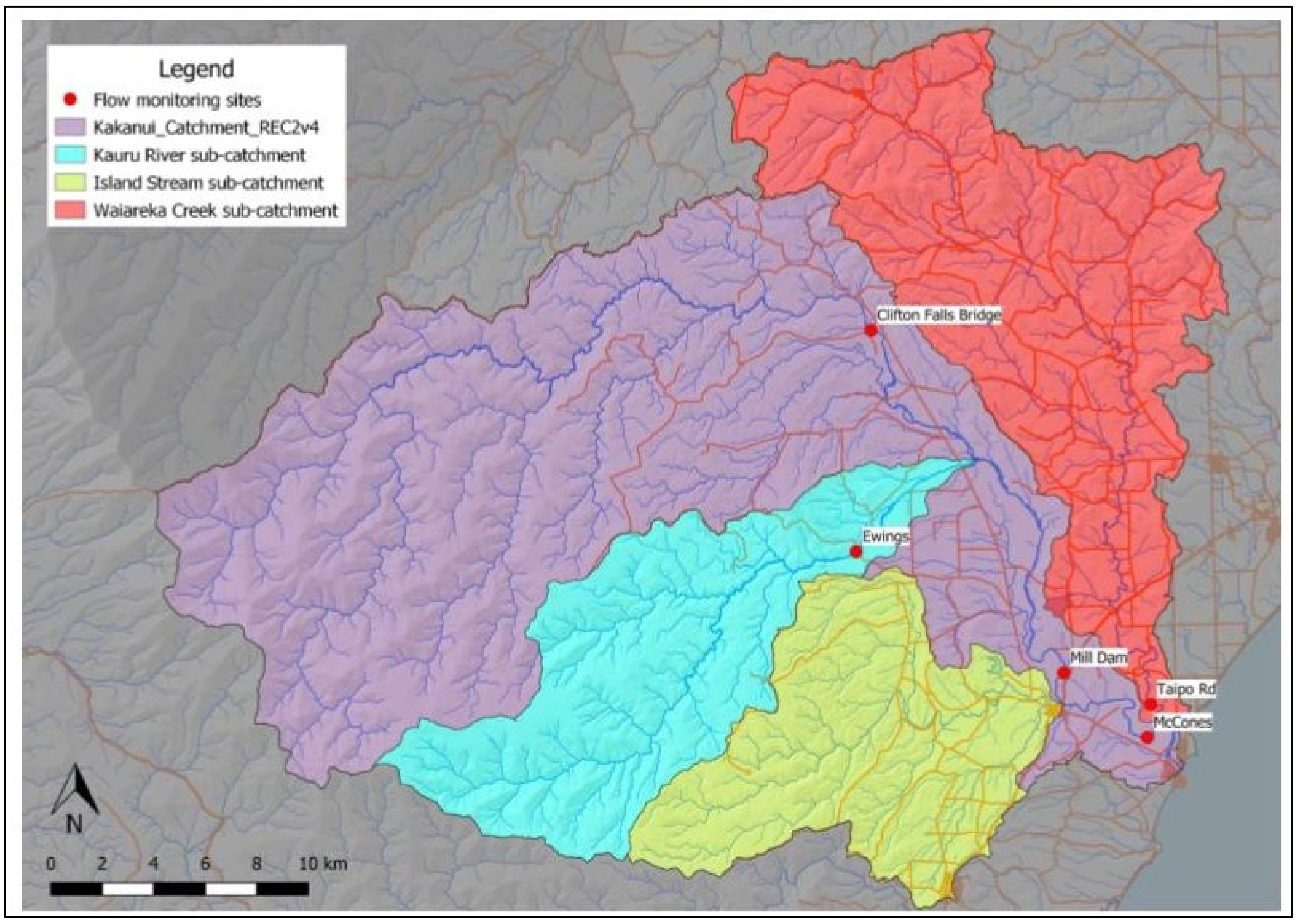


Figure 4. Catchment map of Kauru-Kakanui, sub catchments labelled and coloured (Ozanne and Wilson, 2013).

Annual average rainfall in the catchment is relatively low, with median annual rainfall approximately 550mm/yr, with annual rain days of ~91-100 (growOTAGO®). The wettest months on average are December-January, with the lowest monthly rainfall occurring over the winter months (Figure 5).

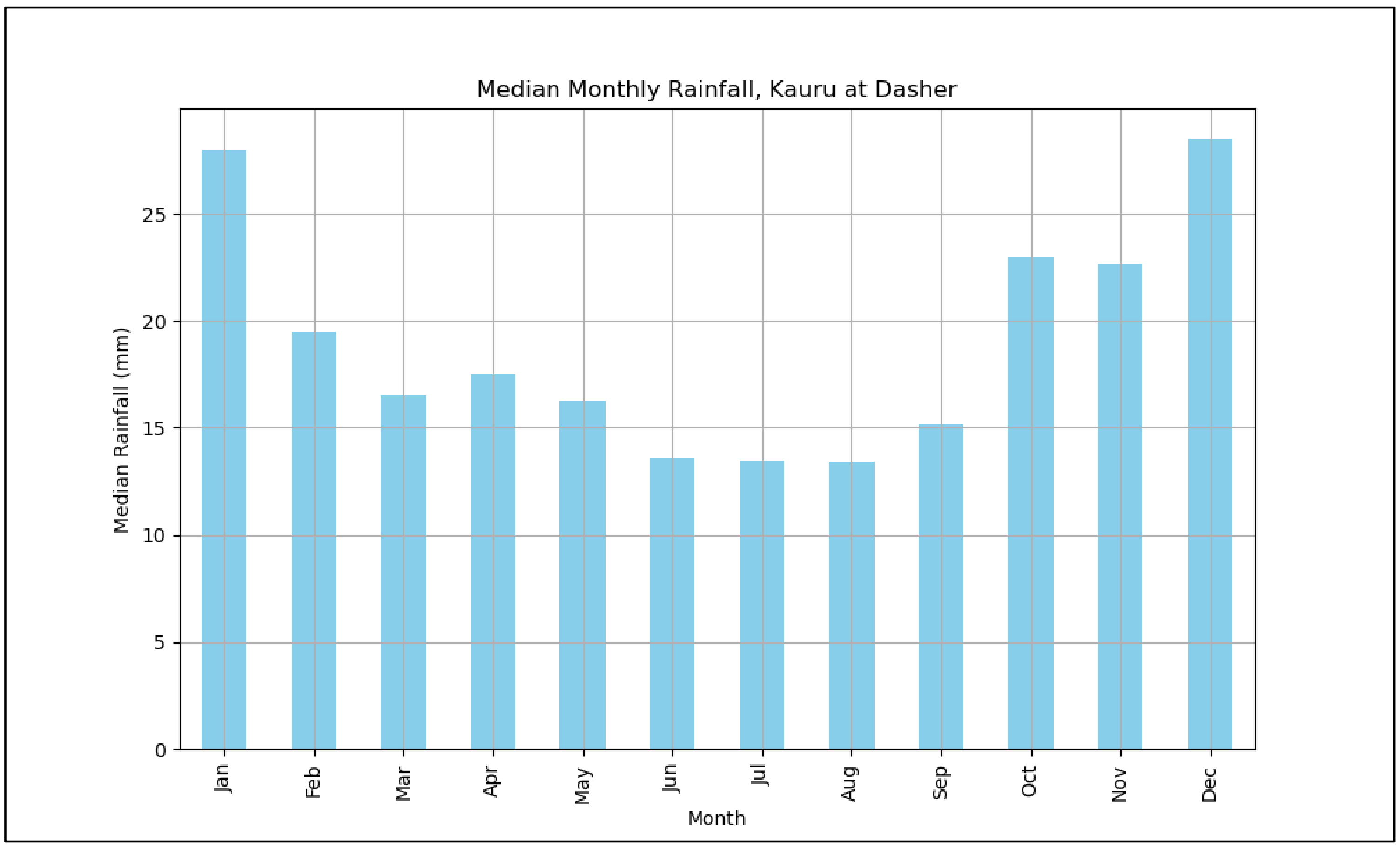


Figure 5. Median monthly rainfall for the full record of the Kauru at the Dasher rainfall recorder, located at the toop of the Kauru River catchment.

The headwaters for the Kauru River are located in the Kakanui mountains, flowing east, northeast to the confluence with the Kakanui River. The Kauru River is ~25 km long, running through steep schist terrain in the upper catchment before flattening into a braided river system in the lower reaches once the river exits the gorge. The study area is in the lowlands section of the river between the flow recorder Kauru at Kauru Hill Rd 700m Upstream (referred to Kauru Hill flow hereafter) at the gorge exit and the confluence with the Kakanui River.

The current understanding of the system is that during low flow conditions (flows < 250L/s), the Kauru River begins to disconnect upstream from the Kakanui confluence to just downstream of the "perennial pool" at the ORC Kininmont Ford stage recorder (Figure 8). The river has been observed to disconnect into a series of pools, which will slowly begin to dry if there is no rainfall for an extended period.

Land use in the upper Kauru River catchment primarily comprises deer, mixed stock, and sheep & beef. The lowlands section is predominately deer, sheep, sheep & beef, livestock support. Land parcels with dairy are found towards the lower reaches near the confluence. There is a small area near Kininmont Ford hosting a pine nut plantation.

3.2 Hydrogeological basement rocks

The upper reaches of the Kauru catchment are dominated by steep schist terrain as part of the Jurassic Rakaia Terrane TZIIB meta sandstones/greywacke and argillite. In the study area, the Kauru River is bound by Late Cretaceous to Paleocene marine greensand unit to the north as part of the Onekakara Group sediments on the true left. The true right of the Kauru is bound by geologically young terrace gravels, comprising predominately Q2 and Q8 Pleistocene gravels (Forsyth, 2001) which are discussed in section 3.3.

The Onekakara Group sediments are a shallow marine micaceous and glauconitic sandstone, siltstone, and mudstone and in the Kauru River area are sub horizontal, dipping ~3 degrees southeast. These form an important impermeable basement for the hydrological system.

3.3 Sediments

In the lower braided reaches river bedload is predominately rounded schist pebbles, with minor sub angular basalt gravels and boulders. There is very little fine-grained sands and silts within the bedload gravels. The gravels are generally clast-supported resulting in overall high porosity sediments. This gravel composition provides the holes and pathways for the fish to burrow into during low flows. Approximately 1.5 to 2m below the clast supported gravels are silt to clay matrix supported schist gravels, with minor basalt. This sediment package sits unconformably above much older Onekakara Group sediments (Forsyth, 2001) and is contiguous with the silt matrix supported gravels comprising the wider ribbon aquifer material. The thickness of these sediments is variable, from the schist basement at the gorge exit to the confluence with the Kakanui, but in general are approximately 10-15m thick. The silt-bound sediments comprise the Q2 alluvial gravel unit, emplaced during the Late Pleistocene.

4 Galaxiid habitat

Sections of the Kauru and Kakanui rivers host the lowland long jaw habitat, which are only found in these two rivers (DoC, 2003). These fish are often subject to extreme fluctuations in their habitat, depending on the flow conditions in the river. The Kauru naturally dries multiple times a year causing many members of the population to become stranded in pools or forced to burrow down into the substrate. This burrowing behaviour was investigated in a DoC led BACI (before and after control impact) study during channel realignment works (DoC, 2003). They found that the riverbed was comprised of poorly sorted, open framework gravels, where interstitial spaces are an important factor in allowing for this burrowing behaviour, where fish can access subsurface flows during low flow conditions.

Longjaws have been found relatively evenly distributed along the lower reaches of the Kauru River and the Kakanui River (Figure 6). They have been observed spawning in relatively cool waters, which are inferred to be areas where groundwater upwelling occurs within the riverbed (Ravenscroft pers comm).

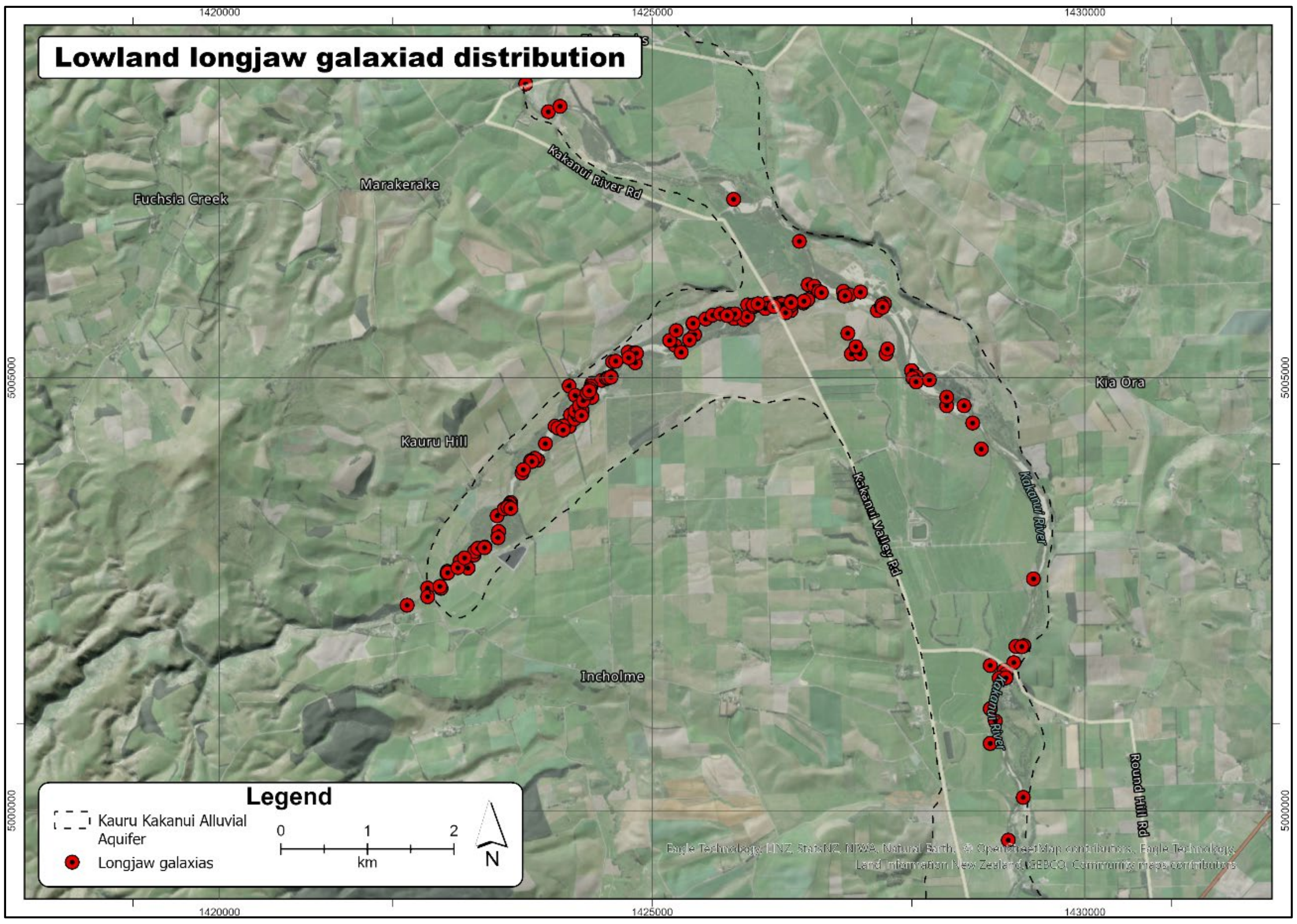


Figure 6. Lowland longjaw distribution within the Kauru and Kakanui Rivers, data sourced from the NZ freshwater fish database.

5 Review of braided river systems and definitions

Surface water interaction with groundwater in braided river systems is complex and can differ along a river section spatially and temporally. Braided rivers usually comprise multiple channels with varying degrees of flow losses and gains along the river stretch.

A recent publication from Wilson et al (2024), conceptualises braided river systems in a New Zealand context, with studies based on 3 different braided river systems, two in the South Island and one in the North Island (Waikirikiri, Wairau, and Ngaruroro rivers respectively).

The proposed conceptualisation from this study suggested that there are two hydrological exchange processes to consider. One is the exchange/interface between the river channel and the braid plain aquifer (hyporheic and/or parafluvial exchange). This exchange occurs between individual river braids and the shallow water table within the riverbed sediments at a point or local scale (i.e., the "braid plain aquifer"). The other is the exchange between the braid plain aquifer (described above) and regional aquifer (i.e. river system to groundwater exchange).

The braid plain aquifer functions as a gravel reservoir which sits immediately below the river surface (Wilson et al, 2024). It is characterised as high transmissivity and is usually formed as a result of winnowing of the gravels from successive flooding events that strip the river gravels of fine sediment, allowing for large interstitial spaces between gravel clasts resulting in high permeability gravels within the active river channel.

From herein the high transmissivity zone hosting the coarse gravels beneath the Kauru River contemporary braid plain is referred to as the BPA.

6 Water Allocation in Kauru River catchment

Overall, there is very little water taken from the Kauru River and the wider Kauru Alluvial Ribbon Aquifer (Figure 7). Landowners within this catchment area have access to the NOIC (North Otago Irrigation Network) water, which is a piped network running water from the Waitaki River across the Waitaki Plains and the lowland Kakanui areas.

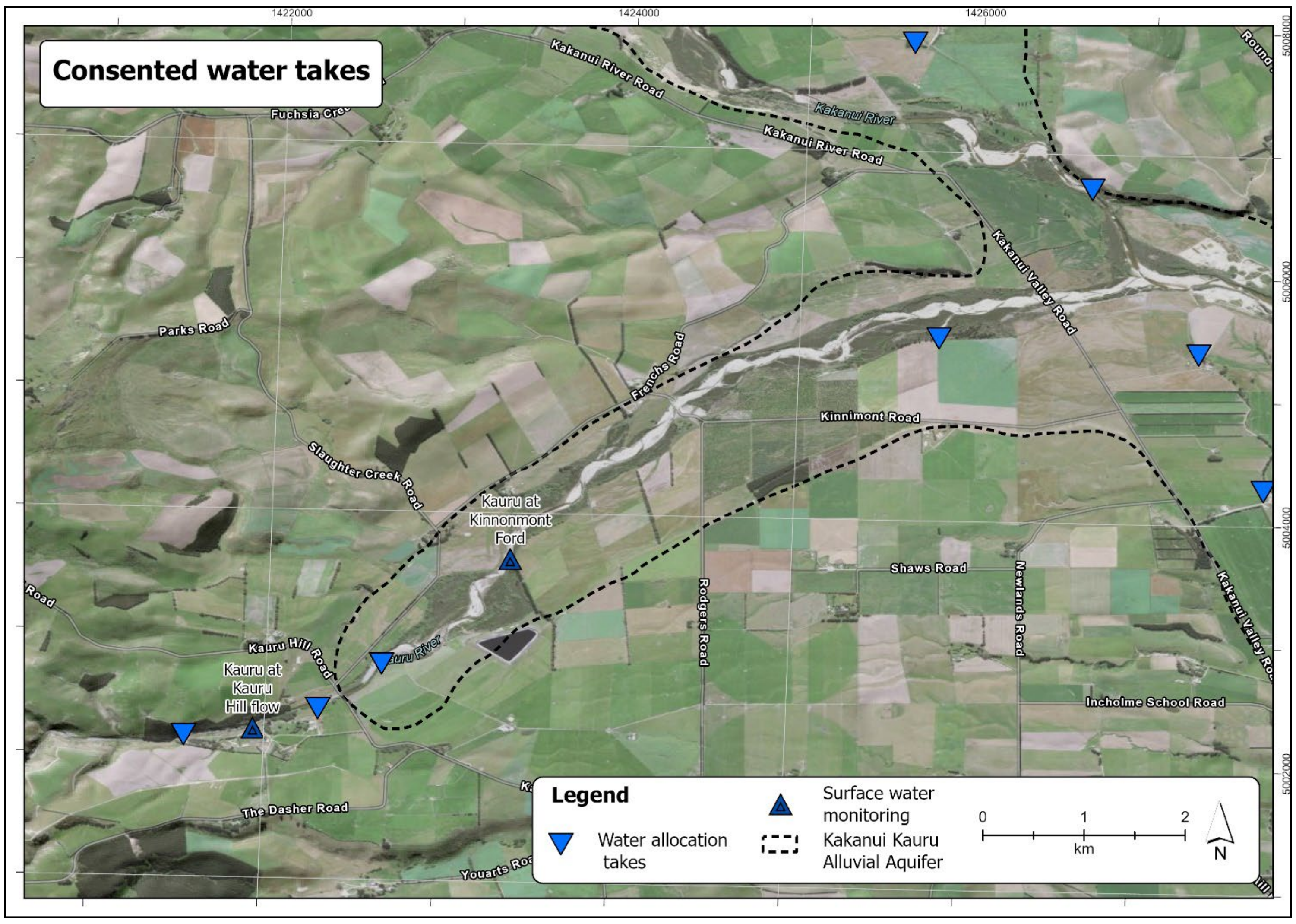


Figure 7. Location of consented water takes. All takes are allocated against surface water.

6.1 Surface water allocation

The Kauru Rural Water Scheme takes ~4-6L/s and is located close to the ORC flow recorder. A smaller take just below the flow recorder can take up to 38L/s, however their actual take is on the order of 2L/s. A downstream surface take that fills the large reservoir seen in Figure 7, could potentially take up to 500L/s, however the consent for this take is rarely exercised, with the landowner indicating they will use NOIC water for irrigation. There is a small surface take at the Kauru-Kakanui confluence for gravel washing.

6.2 Groundwater allocation

In the Kauru River area there is only one groundwater bore with a consented water take. As it is located within an alluvial ribbon aquifer it is allocated against surface water. It is located between Kininmont Ford crossing and the Kakanui confluence and is within 200m of the Kauru River. The consented take is for 38L/s up to 39,000m^3/month and 243,443m^3/year. Due to proximity to the Kauru River it is likely to be largely surface water depleting. The well location appears to be within or very close to the margin of active braid plain and is used to fill a reservoir nearby for irrigation. There is no well log for this bore however a nearby decommissioned bore shows 8.3m of "coarse to cobbly greywacke and basalt gravel", with static water level at 3.2m below ground level.

7 Methods and analysis

Four different approaches were used to inform the conceptual model of the Kauru hydrological system. These were:

1. Drilling using sonic coring methods to obtain intact drill core to determine vertical geology and delineate potential hydrogeological units and contact depths.
2. Assessment of groundwater levels and flow using surface water flow sites and downhole pressure transducers to determine hydrological characteristics and relationships.
3. Assessment of groundwater temperature versus surface water temperature to understand flux between surface water and groundwater.
4. Radon-222 sampling and analysis as an additional line of evidence to quantify gaining and losing reaches from the Kauru Hill flow recorder to the confluence with the Kakanui River.

In this section the methods used, results and interpretations are outlined. This information is then synthesised in section 6.

7.1 Sonic Drilling

In 2022 seven new piezometers (monitored bore holes) were installed in two transects perpendicular to the Kauru River (Figure 8). The upstream transect comprises 3 piezometers (CC18/0105, CC18/0106 and CC18/0108). This transect is located at the "Perennial Pool" and as the name suggests, this is an area where surface flows persist, even during low flow summer conditions. This site also contains a stage recorder (Kauru at Kininmont Ford) immediately downstream from a large surface water take.

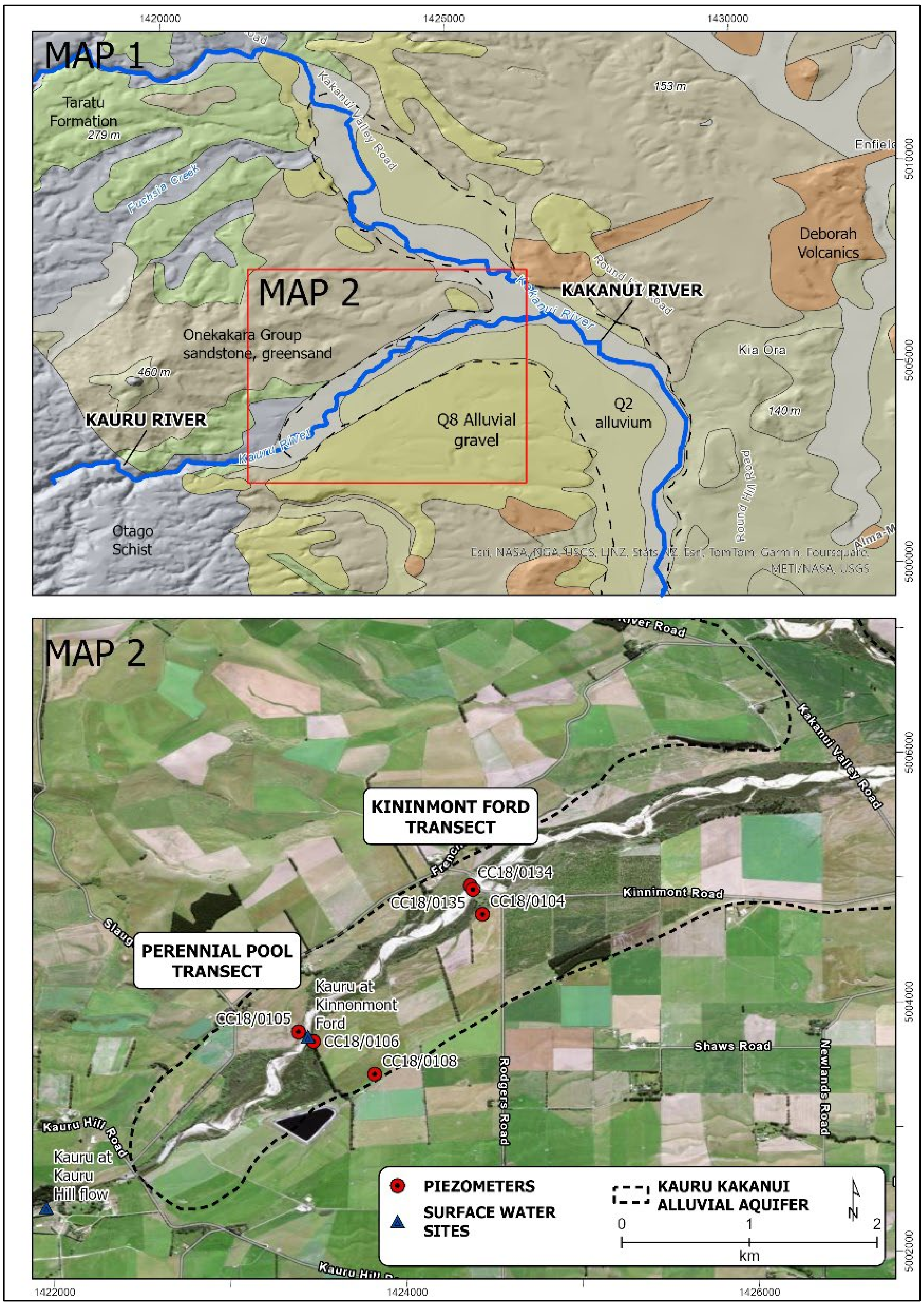


Figure 8. Study site with simplified geology layer (MAP 1) from QMap (Forsyth, 2001) and monitoring locations (MAP 2).

12

The downstream transect is located at Kininmont Ford, which is within a known drying reach and galaxiid refuge zone. At this location, four piezometers were installed. Two (CC18/0102 and CC18/0103) were located within the riverbed and CC18/0104 and CC18/0107 are located in a line above the active braid plain (Figure 8). This was to capture data on what happened to groundwater levels across the riverbed when the river went dry, and to look at the magnitude of the head gradients between all piezometers in the transect.

In July 2022 a series of three successive flood events washed away the riverbed piezometers. These were replaced by CC18/0134 and CC18/0135 in March 2023. All well logs can be found in Appendix 1.

7.1.1 Borehole construction:

Piezometer construction details are listed below (Table 1). The piezometers are constructed using 50mm internal diameter pvc with slotted pvc for the screens. After pvc installation, a gravel pack was installed around the screens followed by a bentonite seal around the overlying casing. An outer 100mm diameter steel casing/toby was installed outside of the pvc and grouted into place using cement. Higher upstands were used in the riverbed piezometers (CC18/0134 and CC18/0135) to increase resistance to flood events, i.e. make them less susceptible to burial during gravel mobilisation during high flows.

Table 1. Piezometer installation details

Well number	Northing	Easting	Elevation	Upstand height (magl)	Depth (mbgl)	Screen from (mbgl)	Screen to (mbgl)	SWL (m below mp)
CC18/0102	5004870	1424263	73.698	0.4	6	3.8	5.8	0.814
CC18/0103	5004842	1424286	73.339	0.5	6	3	6	0.477
CC18/0104	5004801	1424335	75.089	0.6	6	3.7	5.7	2.55
CC18/0105	5003662	1423322	86.494	0.6	3	0.5	2.5	2.182
CC18/0106	5003591	1423414	87.561	0.6	6.2	1.9	4.9	3.22
CC18/0107	5004642	1424344	76.136	0.6	6	3	6	-
CC18/0108	5003343	1423768	90.39	0.6	6	2.8	5.8	4.734
CC18/0134	5004865	1424263	74.635	1	9	5.5	6.5	2.108
CC18/0135	5004854	1424272	74.539	1	3	1	1.5	1.799

7.1.2 Downhole geology in drill core

Examples of geology encountered in the drill core are shown in Figure 9 below. In the boxes the core is arranged from the start of the drill hole on the right-hand side, getting deeper as you move down and towards the left.

From ground surface to approximately 1.5m below ground level (mbgl) the geology comprises schist-derived gravels and cobbles (highlighted in blue). Highlighted in red from ~1.5 mbgl – 6.8 mbgl in

CC18/0134 and 1.5mbgl – 2.2mbgl in CC18/0105 are silt to clay cemented gravels, with minor silt. The gravels are predominately schist-derived with minor subangular basalt. Lastly, sections of core highlighted in green are fine grained silt to clay sediments. CC18/0105 contains a soft clay layer at 2.2mbgl before grading into green coloured silt. CC18/0134 shows orange clay rich matrix supported gravel sediments, grading into a fine-grained blue/grey silt and clay from 7mbgl.

Figure 9. Drill core photos from piezometer CC18/0134 and CC18/0105. The blue line delineated the geologically young BPA gravel unit. The red boxes indicate silt bound schist-derived gravels, likely emplaced during the Quaternary (Q1a or Q2a). The green

The open framework gravels within the blue boxes are interpreted to be recent gravels deposited during the Holocene. These gravels are often mobilised and redistributed during high flow/flood events, a process which winnows out the finer fractions. In addition, this gravel package is restricted to the active braid plain channel and hosts the braid plain aquifer. This has been confirmed through drilling on the terrace above the active braid plain channel.

Underlying the braid plain aquifer gravels is the orange/brown, silt to clay-rich matrix supported gravels, highlighted by the red box in Figure 9. The silt bound sediments are moderately to well consolidated. These are interpreted to be part of the Q2 alluvial gravels mapped in Forsyth (2001) and which make up most of the mapped “alluvial ribbon aquifer” in the Regional Plan: Water.

Lastly the grey to green siltstone/mudstone underlying the orange silty sediments are highlighted by the blue box. CC18/0104 had a distinct green tinge, whereas the CC18/0134 sediments were slightly greyer. The green sediments in CC18/0104 were predominately silt, poorly sorted and well consolidated. The grey silty mud in CC18/0134 was also predominately silt with minor clay and well consolidated with good core recovery. These sediments are inferred to be part of the Onekakara Formation glauconitic sandstones, siltstones and mudstones, that make up much of the higher topography hills to the true left of the Kauru River (Forsyth, 2001).

7.2 Assessment of flow and groundwater level data

To help with understanding the dynamics within the river system and outer alluvial aquifer, time series analysis of groundwater levels was carried out from downhole pressure transducer data.

7.2.1 Results

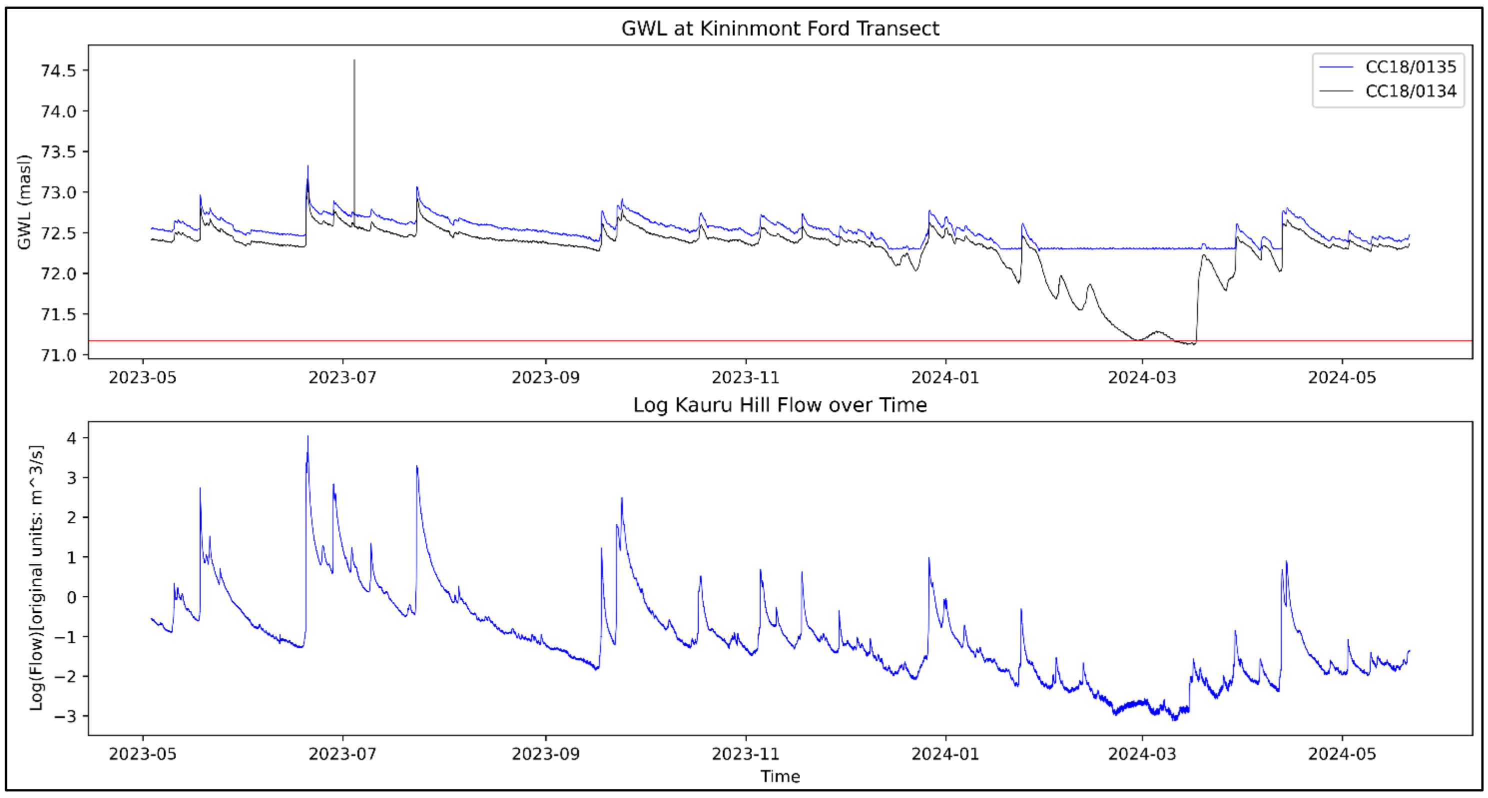


Figure 10. Groundwater level time series data from the Kininmont Ford transect of CC18/0135 (blue line) and CC18/0134 (black line) in the top plot. The red line delineates the base of the BPA gravels at this transect. During March 2024 the groundwater levels in CC18/0135 dropped below the bottom of the well, as it was not screened deep enough. Groundwater levels dropped right down to the base of the braid plain gravels as can be seen in CC18/0134 – the black line, during this same time period. The bottom plot shows log flows from the Kauru at Kauru Hill flow recorder for comparison. *Note: flow has been transformed to log to better illustrate fluctuations in flow.*

Figure 10 compares groundwater levels between CC18/0134 and CC18/0135 in the riverbed at Kininmont Ford. The plot on the bottom panel is flow from Kauru at Kauru Hill (note log scale, y-axis) over the same time period. The data shows a strong, responsive relationship between flow and groundwater level. The plot in the top panel also shows that groundwater levels in CC18/0135 generally sit higher than levels in CC18/0134. The interpretation here is that high flows replenish storage in the BPA, and the storage then gets drained during a recession. In general groundwater levels are lower closer to the channel (because the channel acts as a drainage feature).

In March 2024 well CC18/0135 went dry, likely the well is not deep enough to capture lower groundwater levels. CC18/0134 is deeper and is screened across the BPA and the underlying silt bound gravels. The CC18/0134 plot shows that groundwater levels drop to the bottom of the BPA (horizontal red line on plot) but do not go below into the underlying silt-bound gravel unit.

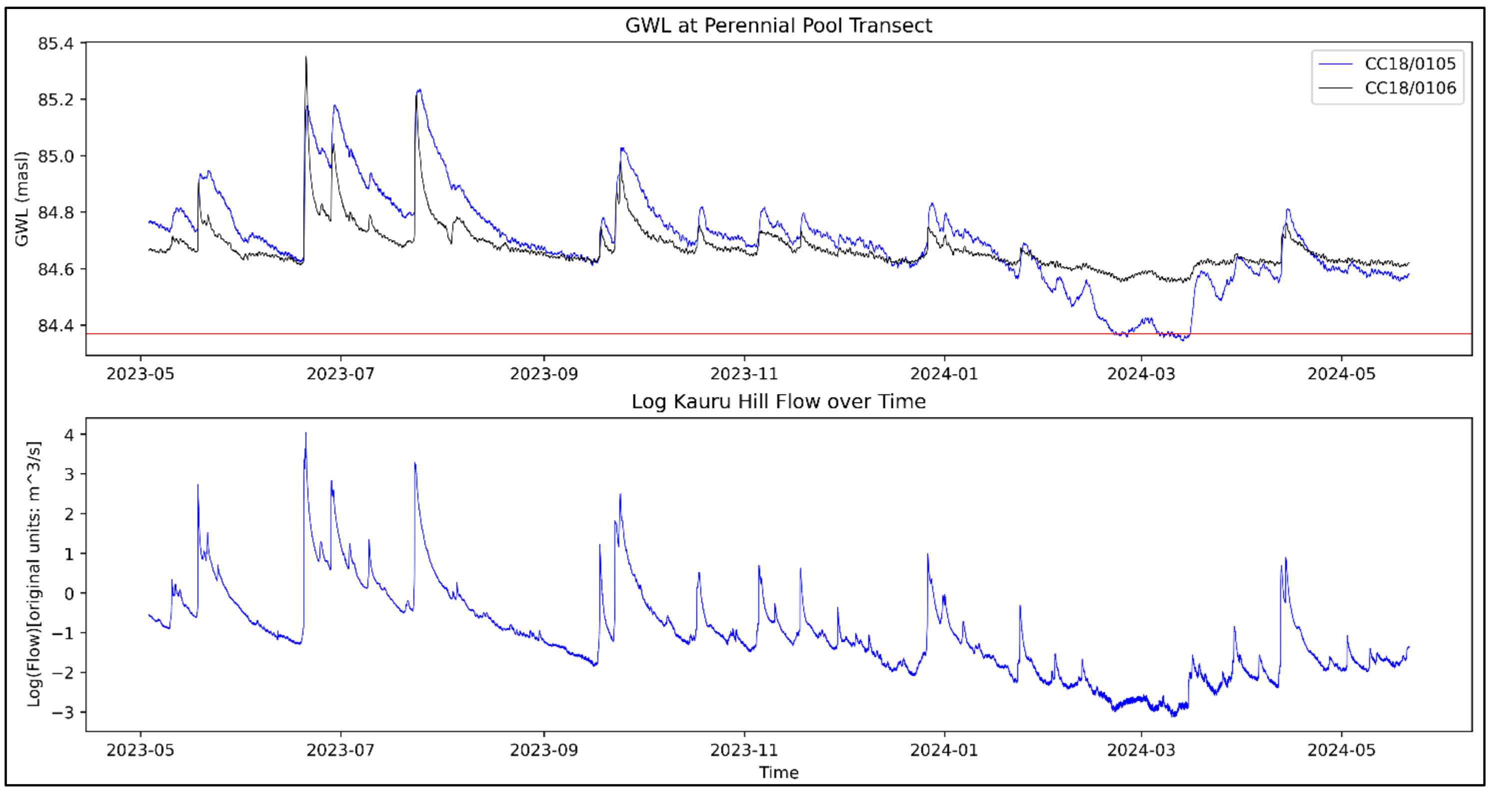
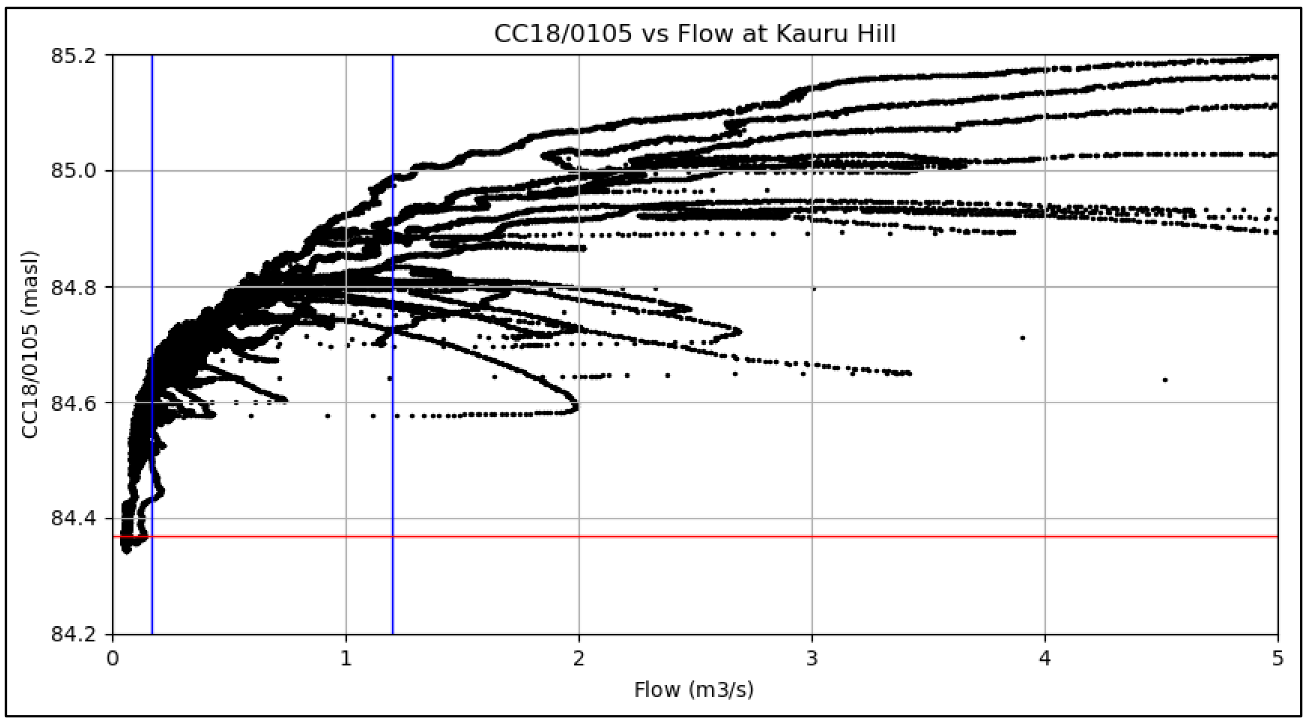


Figure 11. Time series comparison between CC18/0105 and CC18/0106 (top plot) and Kauru flow recorder (bottom plot). The red line delineates the base of the BPA gravels. Both CC18/0105 and CC18/0106 are responsive to changes in river flow. CC18/0105 is screened within the braid plain aquifer gravels, CC18/0106 is screened above the river in the silt bound gravels.

As can be seen in Figure 11, groundwater levels show a relatively rapid response to surface water flows as expected. These wells are located at the perennial pool, with CC18/0105 located on the true left, within the contemporary braid plain and CC18/0106 is located on the true right on a terrace above the river, screened within the silt-bound gravels. Groundwater levels are almost always higher in CC18/0105, meaning there is a strong gradient of groundwater flow away from the river (towards CC18/0106) i.e., groundwater levels are lower away from the river, meaning the river is losing flow to groundwater. In addition, CC18/0105 decreases to lower levels during low flow conditions in response to low river flows and drainage of the BPA during March 2024.

Based on the conceptual understanding of this system (i.e., from bore log data) it appears the CC18/0134 and CC18/0105 are connected to the BPA, i.e., they are screened within the BPA gravels.

Therefore, the groundwater level time-series data can be considered for comparison against surface water flow data as we assume CC18/0134 and CC18/0105 reflect the hydrogeological characteristics of the BPA.



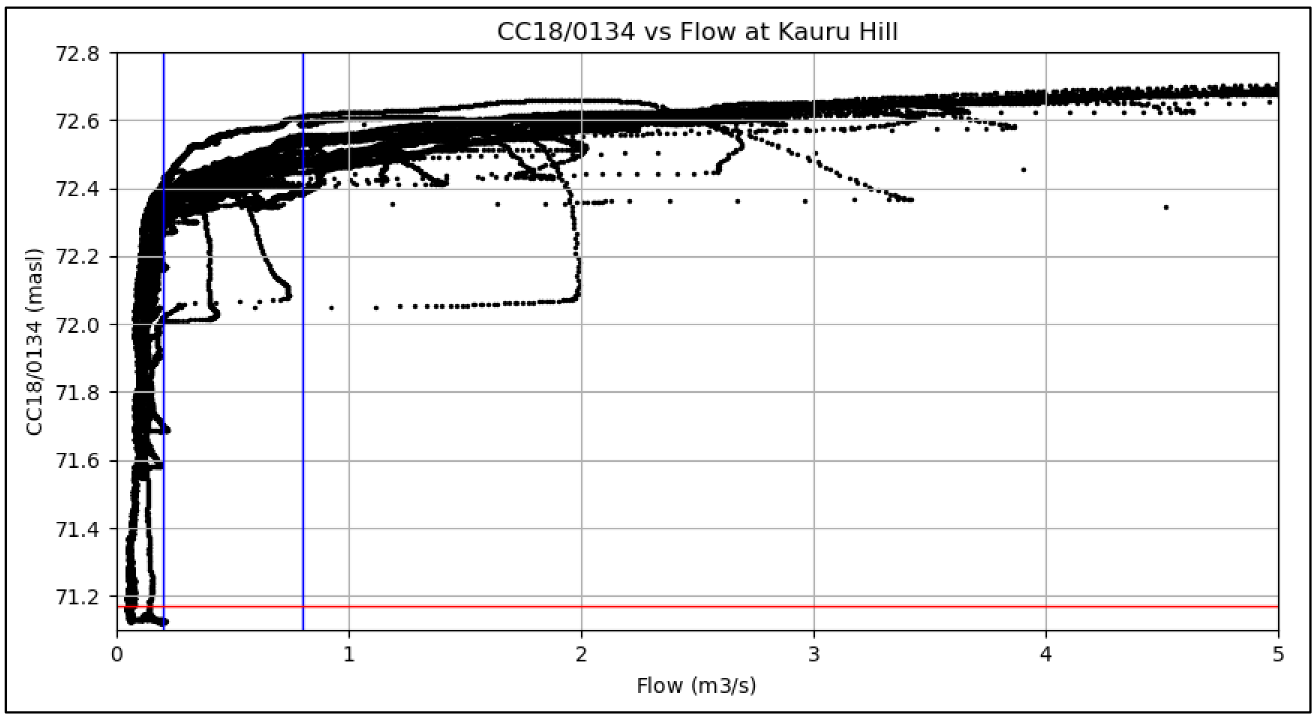


Figure 12. The above plots show flow data from Kauru at Kauru Hill (x-axis) plotted against groundwater level time-series data from CC18/0105 and CC18/0134. The blue lines delineate 3 distinct GWL trend zones in the plotted data. The red lines show the elevation of the base of the BPA gravels. ***Note flows have only been plotted at 5 m^3/or less as the focus of the study is groundwater levels in low flow conditions. At flows above ~5cumecs groundwater levels are relatively stable see*** **Figure 13*.***

Figure 12 compares flow data from the Kauru at Kauru Hill recorder with groundwater levels in wells CC18/0105 and CC18/0134. What can be seen in both wells (that are screened within the braid plain aquifer), is that when flows at at Kauru Hill, are above 800L/s at CC18/0134, the groundwater levels in the braid plain aquifer are relatively stable, and even as flows increase, groundwater levels remain relatively steady (i.e. no significant increase or decrease). This indicates that the braid plain aquifer is fully saturated. However, when flow at Kauru at Kauru Hill drop below 800L/s then groundwater levels begin to decrease within the BPA. The downward curve shows a consistent decline until flow at Kauru at Kauru Hill reach ~200L/s. At 200L/s flow at Kauru at Kauru Hill groundwater levels show a very rapid and steep decline, and the river stops flowing past the groundwater monitoring site. The flow values demarking the divisions between stable groundwater levels and declining to rapidly declining groundwater levels are relatively consistent between the two sites i.e. CC18/0105 at the perennial pool and CC18/0134 at Kininmont Ford. As expected groundwater levels sharply decline at slightly lower flow rates (<200L/s) in the upstream site.

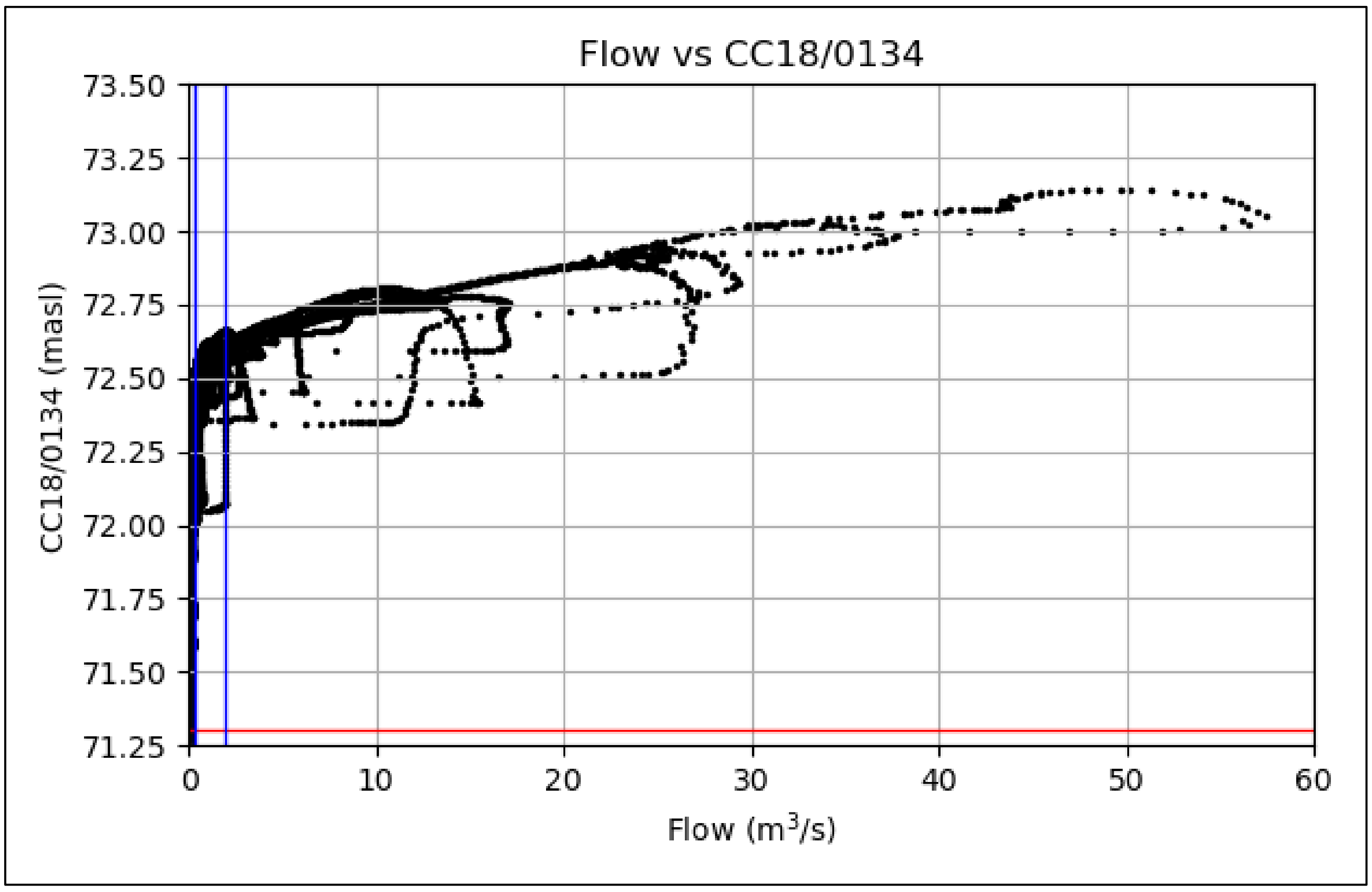


Figure 13. Full record of flow at Kauru Hill versus CC18/0134 groundwater level. Blue lines are the flow thresholds, and the red line is the base of the Kauru BPA, both highlighted in Figure 12.

Figure 13 shows the full span of flow versus groundwater levels in CC18/0134. Levels gradually rise with increasing flows at a relatively shallow gradient until groundwater levels essentially contact the top of the riverbed around 73.12 masl. The notable changes in slope are seen below 5m^3/s (Figure 12).

To test how often the flows in the Kauru River would be expected to drop below 200L/s, we can look at the frequency distribution of flows over the record of the upstream flow recorder were analysed (Figure 14). Flows are below 200 L/s approximately 16% of the time.

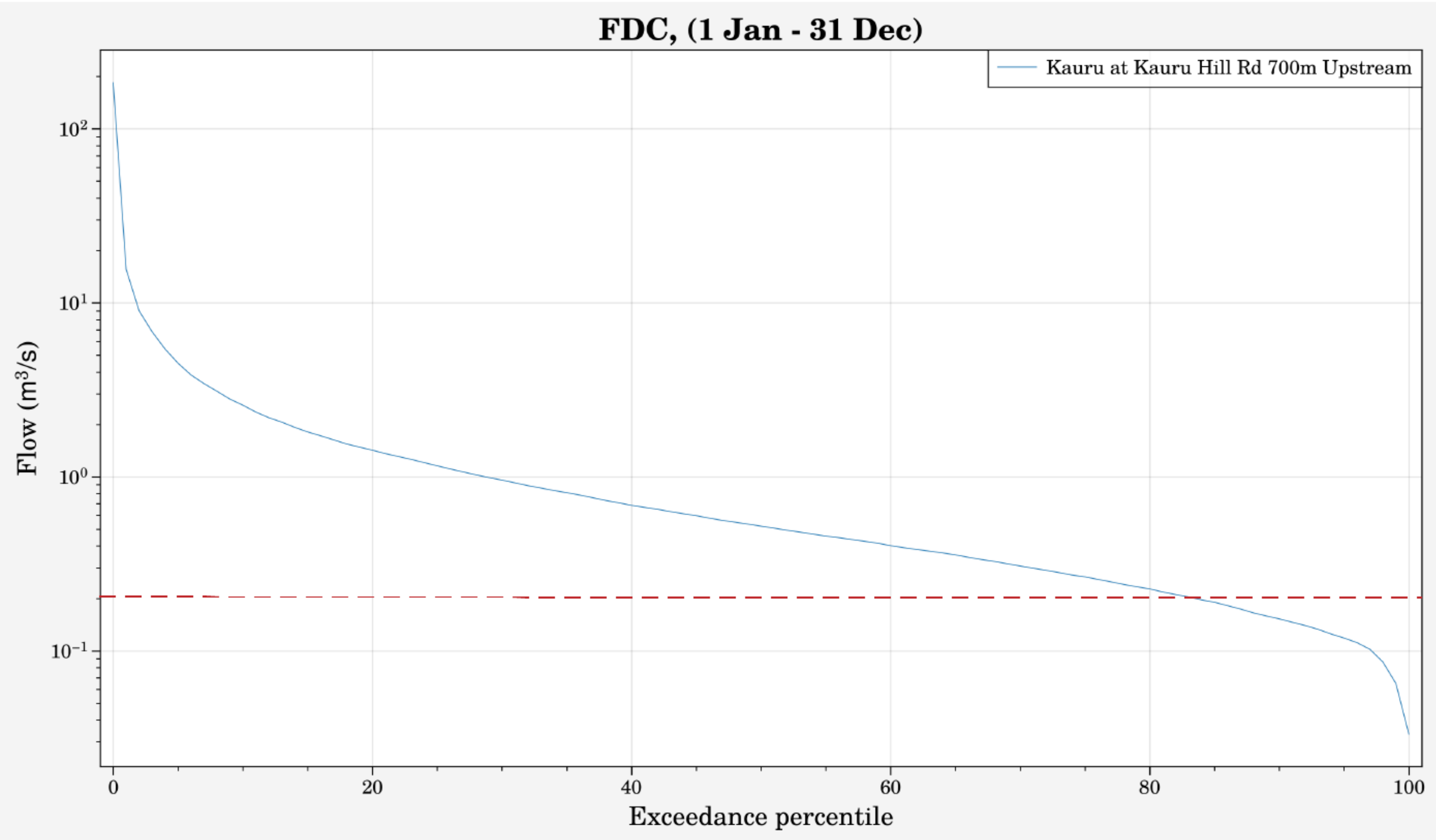


Figure 14. Plot of FDC (frequency distribution curve) from Kauru at Ewings flow recorder for the entire record of the flow recorder. The red dashed line shows the flow at 200L/s, where 84% of the time for the entire flow record, flows in the Kauru River at the flow recorder are above 200L/s.

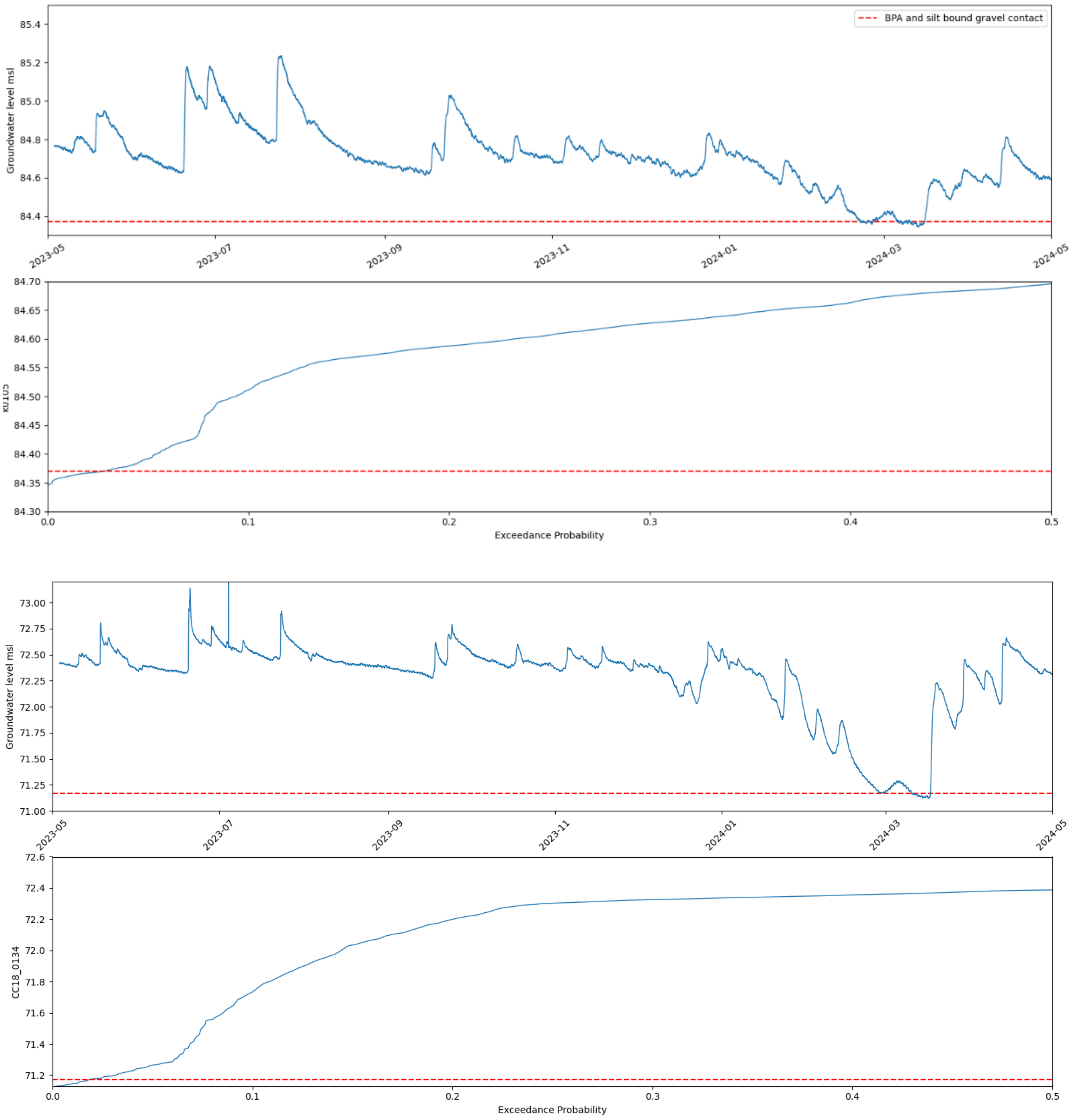


Figure 15. Frequency distribution curves for groundwater levels in the braid plain aquifer piezometers.

Figure 14 shows that 84% of the time, including data back to 2016, that flows in the Kauru River at the flow recorder would be above 200L/s. Alternatively flows in the Kauru River are above 800L/s at the flow recorder for the period 2016-2024 only 35% of the time.

The same frequency curve can be applied to groundwater levels from the riverbed piezometer data (Figure 15).

Based on the frequency distribution plots given above (Figure 15), for the upstream area the groundwater levels in the year 2023-2024 groundwater levels fell below the base of the braid plain aquifer (therefore drained BPA) less than 5% of the time. In addition to this, by looking at the long-term record for the Kauru Hill flow recorder, river flows at the recorder fell below 200L/s only 16% of the time. The time series plots given in Figure 15 are also useful for showing changes in geology. Accurately determining the contact elevation between the braid plain aquifer gravels and the underlying silt-bound gravels has a higher level of uncertainty that looking at the hydrology. In both plots you can see that the contact of the BPA is plotted at the lowest levels of the time series curve and is also found very close to a change in slope of the frequency distribution curves.

7.2.2 Key thresholds

Given that the CC18/0134 and CC18/0105 bores are screened across the braid plain aquifer and are therefore an indication of the groundwater level response in the BPA relative to surface water flows, the following can be determined from Figure 12 (delineated by the blue lines):

1. When flow at Kauru Hill is above 800-900L/s groundwater levels are stable. This means the BPA gravels are fully saturated.
2. When flow is between 200L/s and 800L/s groundwater levels show a declining trend suggesting flows in this range are insufficient to maintain groundwater levels in the BPA at full capacity.
3. When flows fall below 200L/s groundwater levels rapidly decline, this is when the BPA could be considered depleted**.**

The frequency distribution plots show the Kauru River naturally flows below 800L/s much of the time, less so for flows lower than 200L/s. The FDC plots also show that groundwater levels in the braid plain aquifer are above the contact with the braid plain aquifer and underlying sediments much of the time as expected (i.e. above the dashed red lines in Figure 15). In addition, in the FDC for CC18/0134 groundwater levels show a drop and the river begins to pool around 71.2masl, which is just above the red dashed line, i.e. around the base of the BPA as groundwater levels then begin to drop below the BPA into the silt-bound gravels. Similarly, for CC18/0105 surface water begins to pool is around 84.3 masl. These elevations are the approximate contact elevation of the base of the BPA.

The flows and groundwater levels in Figure 12. The above plots show flow data from Kauru at Kauru Hill (x-axis) plotted against groundwater level time-series data from CC18/0105 and CC18/0134. The blue lines delineate 3 distinct GWL trend zones in the plotted data. The red lines show the elevation of the base of the BPA gravels.are both observed flows and levels. A flow naturalisation[1] process was considered to better account for water abstraction. However, the magnitude of water abstracted between the flow recorder and groundwater piezometers is likely to be within the uncertainty of the flow and piezometer measurements. As a result, flow naturalisation would be unlikely to make a significant difference to the flow/groundwater curve. No naturalisation therefore was performed in this reach. Naturalised estimates available for the Kauru Hill flow recorder show 122 L/s versus the observed flows at the Kauru Hill recorder of 119L/s, so only a difference of 3L/s, indicating the Kauru Hill flow recorder is already relatively natural (Lu, 2023). In addition, there are very few takes of any significant size downstream from the flow recorder, the largest of which has not been exercised since 2021.

7.3 Temperature time-series

To further investigate whether the groundwater wells are hosted within the BPA, we can analyse the temperature data to demonstrate that the silt-bound gravels exhibit low groundwater flux. Additionally, we can confirm that wells CC18/0105, CC18/0134 and CC18/0135 are located within the BPA and are closely connected to the Kauru River.

[1] Groundwater level naturalisation described here refers to a correction made to groundwater level data to remove the effects from any taking of water that would have an effect natural groundwater level.

7.3.1 Temperature results and discussion

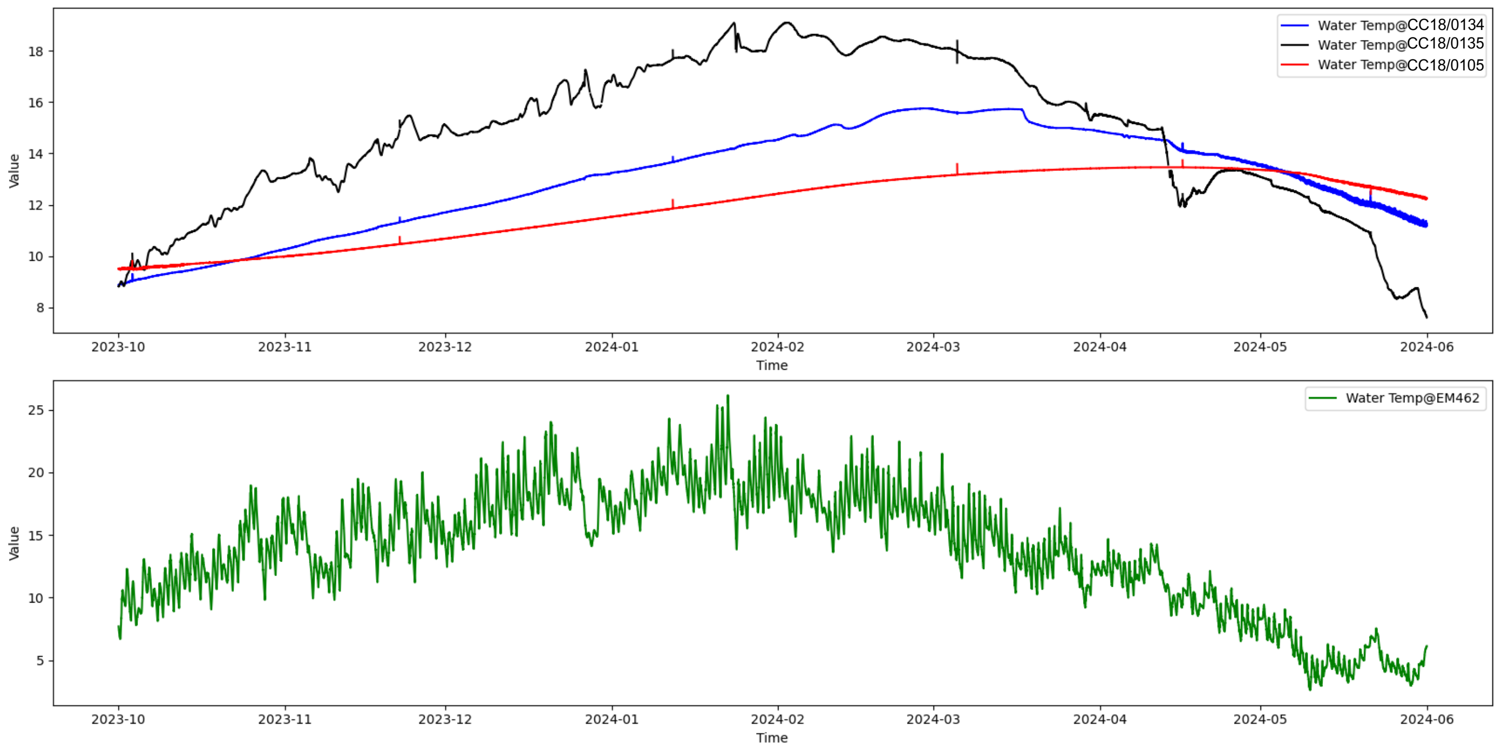


Figure 16. The blue line in the top plot shows the temperature time series from CC18/0134 and the black line delineates CC18/0135, the wells we interpret to be in the BPA. The red line in the top plot is a reflection of the silt bound gravels temperature signature and show a much slower response to river flow (river flow temperature in bottom graph for the perennial pool for comparison).

Temperature data can be considered as distinct from analysis of groundwater level data. The results in this analysis (Figure 16) show that the piezometers that are identified as being within the BPA (CC18/0135 and CC18/0134) show temperature signatures that are in close association to the Kauru River temperatures. The piezometers on the outer edge, outside of the contemporary braid plain, show a delayed temperature response when compared to surface water. This suggests there is a delay in water from surface flows reaching these outer wells, confirming there is attenuation and slow flux of losing surface water as it flows towards these wells. This is in contrast to the groundwater level data that appears to show a relatively rapid response to changes in surface water flows (except for CC18/0108 which shows no connectivity to the Kauru River).

7.4 Radon-222

In 2023 ORC commissioned GNS Science to carry out field planning and interpretation of Radon-222 (^{222}Rn) surveying in the Kauru River by way of an Envirolink grant (Coble, 2023). Radon-222 (hereby referred to as radon) has been developed as a tool by GNS Science as an environmental tracer to help characterise losing and gaining reaches within rivers that have a close association with groundwater. Radon is a naturally occurring radioactive noble gas produced from U-series decay in rocks, that is soluble in water. When groundwater is found within a closed system and it is in contact with uranium rich minerals in the geology, radon can accumulate and enrich groundwater (Coble, 2023). Radon in surface waters is typically negligible as it rapidly degasses to the atmosphere. Therefore, sampling for radon in surface waters can indicate the presence of groundwater influx (i.e., groundwater gaining) based on radon concentrations in the river.

7.4.1 Methodology

Samples were collected on the 14th of March 2023 during a period of relatively low-flow conditions (~0.5 cumecs) with continuous channel flow in the river (i.e. the river flows had not disconnected). A 5.7km stretch of the lower Kauru River was sampled at an average interval of 230m, resulting in 26 sample sites between the Kakanui Bridge and the Kauru Hill bridge.

Samples were collected in 20mL glass vials with metal-lined lids. The sample sites were collected within the main river trace (the river had not disconnected), and small ribbons or braids were avoided.

Due to the short half-life of ^{222}Rn the samples were measured in the laboratory at GNS Science within 2 days of being sampled.

7.4.2 Radon-222 concentrations in the Kauru River

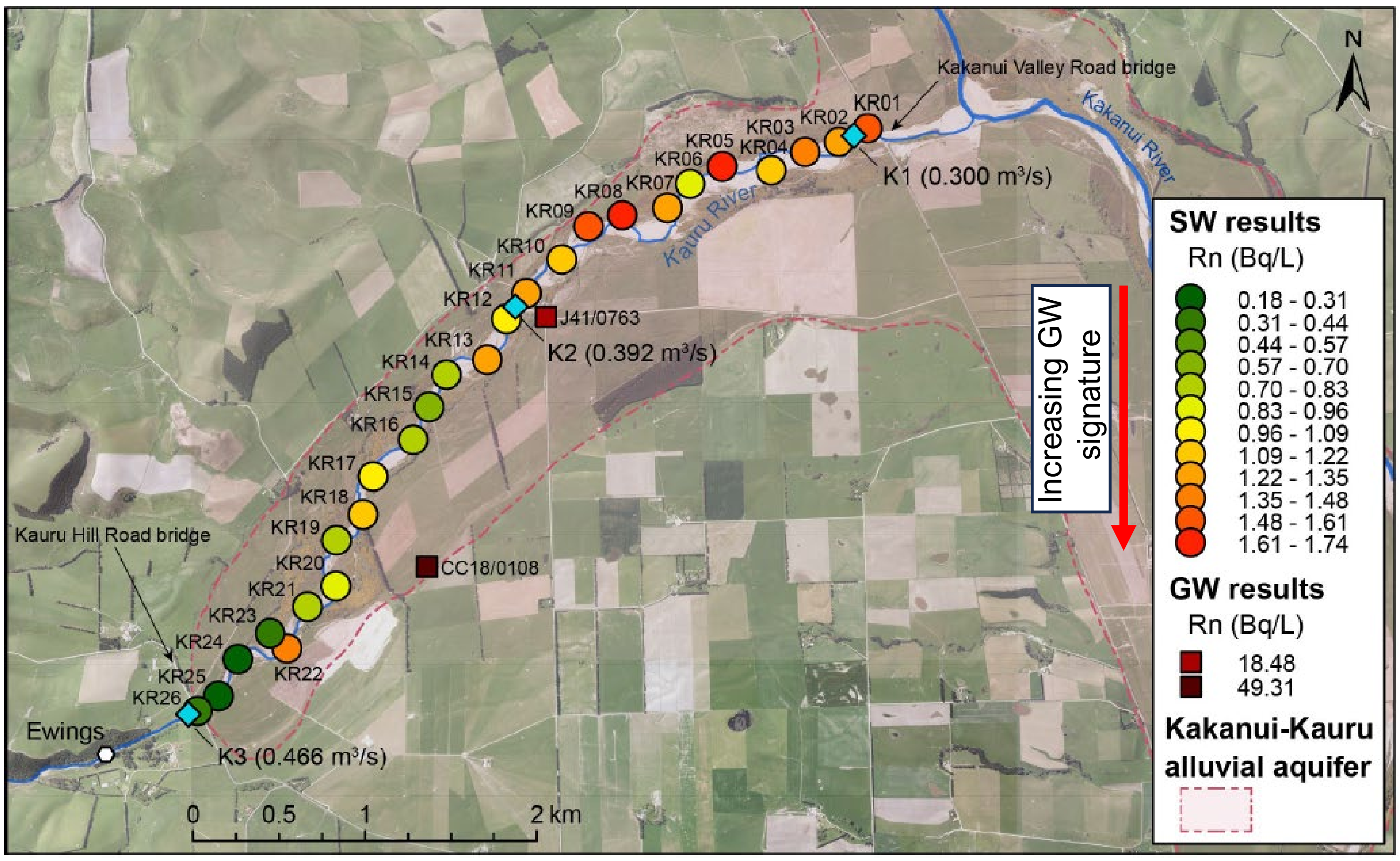


Figure 17. Image from Coble (2023) report showing radon concentrations from each sample site. The data shows that radon concentration increase downstream from the Kauru at Kauru Hill flow recorder to the Kakanui Valley rd bridge (the warmer colour indicate higher groundwater input to surface water). For comparison two groundwater bores were also sampled, which as expected show much higher radon concentrations that surface water sites.

Results from this study (Figure 17) confirm that the lower reaches of the Kauru River are losing to groundwater, where flows decrease by ~35% over the 5.7km from the Kauru Hill bridge to the Kakanui Valley road bridge. Radon concentrations generally increase downstream, suggesting an increase in groundwater discharge to the Kauru River despite the overall reduction in river flows (surface water losing).

Although the Kauru River is losing surface water to the ground at a rate of about 0.03 m³/L/km based on gauging results, radon data suggests that groundwater input to surface water increases downstream (Figure 17 and Figure 18). This can be explained by the river losing water to the adjacent gravels, which prevents the mixing of old water with the BPA. As you move with increasing distance downstream, the samples show increased age because the upstream area has a higher surface flow input compared to downstream. Consequently, the proportion of BPA water in the flow increases downstream, leading to longer residence times and therefore higher Rn concentrations.

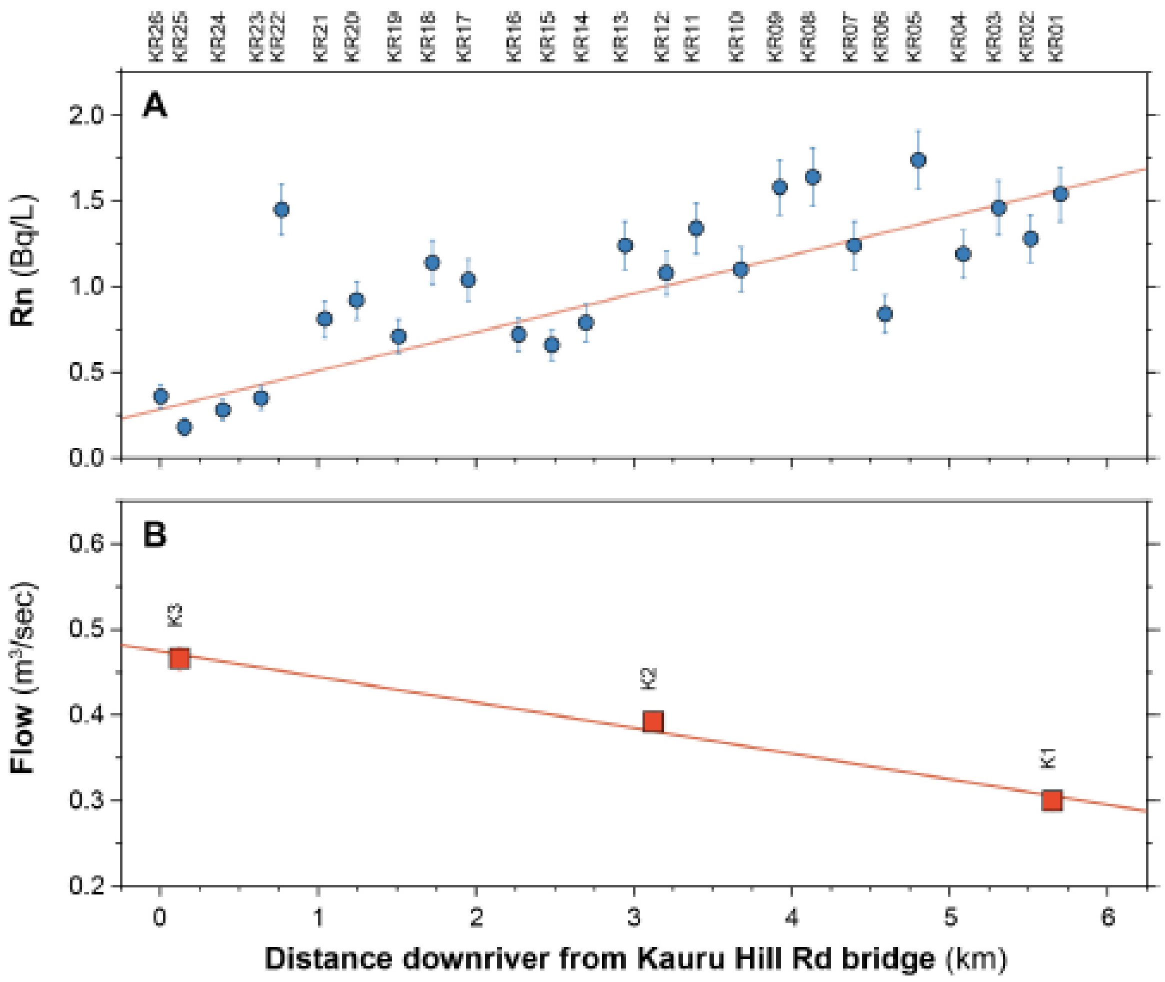


Figure 18. Plot from Coble (2023) showing radon increasing in concentration downstream from the Kauru Hill Bridge towards the confluence with the Kaknui River (A). Conversely the bottom plot (B) shows flow decreasing downstream from the Kauru Hill Bridge to the Kakanui Bridge.

Other aspects to consider in the radon analysis:

1. Flow gauging can be difficult to carry out in braided river systems. There will be different flow velocities along a river depending on whether the gauging is done above or below a riffle bed for example. In addition, only 3 sites were gauged, therefore the magnitude of flow losses has some uncertainty.
2. The GNS report (Coble, 2023) concluded that there was a limited number of sites and noted that the interpretations of the radon results could be strengthened with more groundwater sites, specifically riverbed gravel sites.

Overall, the radon results align with the analysis of the Kauru hydrological regime:

1. Groundwater level results indicate that in low to moderate flow rates, the river is losing water to the surrounding gravels as it flows downstream.
2. The upper reaches of the sampled area are near basement geology (schist), and the BPA is not likely present until further downstream, where the radon results show an increasing input of BPA water.

8 Synthesis and Conceptual model

8.1 Introduction

The hydrological behaviour of the Kauru River, particularly in its lower reaches, presents a complex interaction between surface water and groundwater. This discussion aims to synthesise the findings from groundwater level measurements, flow gauging, radon concentration data, and temperature monitoring to determine the conceptual hydrological model of the Kauru area (presented in Figure 19). This is to better understand the Kauru River and the role of the braid plain aquifer (BPA), and the implications for water/river management and ecological health.

8.2 Groundwater-surface water relationship

The study revealed several key findings:

- **Braid Plain Gravels**: The high porosity gravels beneath the riverbed, that have a thickness of ~1.5-2m and whose extent reaches the edge of the contemporary braid plain, comprise the BPA. The thinness of these gravels significantly affects their ability to contribute to surface water flows, host hyporheic flow beneath the riverbed and provide cooler upwelling areas to support the native fish species and overall river health.

- **Silt bound Gravels**: These gravels exhibit low groundwater flux. While the lower section of the basin is losing water as expected, the volumetric contribution from groundwater within the silt bound gravels is interpreted to be relatively low. The silt bound gravels are relatively shallow throughout the wider Kauru aquifer area, and there are likely low rates of vertical flow from the braid plain aquifer into the underlying silt bound gravels. Temperature data confirms that groundwater response to surface water flows is delayed and attenuated in these gravels. Overall, the silt bound gravels could not be considered a significant contributor to Kauru River flows or the BPA.
- **Hydrogeological Basement**: The schist basement is relatively shallow, particularly upstream from the perennial pool (on the order of <10m bgl). From perennial pool downstream silt bound gravels (based on low conductivity could be considered hydrogeological basement) are relatively shallow at ~1.5m bgl to Kininmont Ford. BPA gravels may thicken downstream to confluence but would need to carry out more drilling to quantify this.
- **River flow versus groundwater relationship**: There is a relationship between flow rates and groundwater levels in the BPA bores (CC18/0134 and CC18/0105). When flow at Kauru Hill is above 800-1000 L/s, the groundwater levels remain stable, indicating that the BPA storage is full. However, when the flow drops below 800 L/s, the groundwater levels begin to decline, and if the flow falls below 200 L/s, the groundwater levels drop rapidly. This suggests that there is a flow rate threshold that affects the stability of groundwater levels in the BPA.

As seen in Figure 19, the Kauru River has a very thin braid plain aquifer, on the order of 1.5-2m thick (potentially slightly thicker downstream from Kininmont Ford, further drilling needed to determine). There is a marginal regional aquifer within the silt bound gravels surrounding and beneath the active braid plain and BPA. The groundwater flux through this older silt bound (Pleistocene) gravels is relatively slow, with limited mixing of older water and surface water (as seen in the radon results) and is therefore unlikely to be a significant contributor to surface water or BPA flows. The lower reaches of the Kauru River can be overall considered losing (surface water lost to ground), which is supported by groundwater level head gradients and flow gauging.

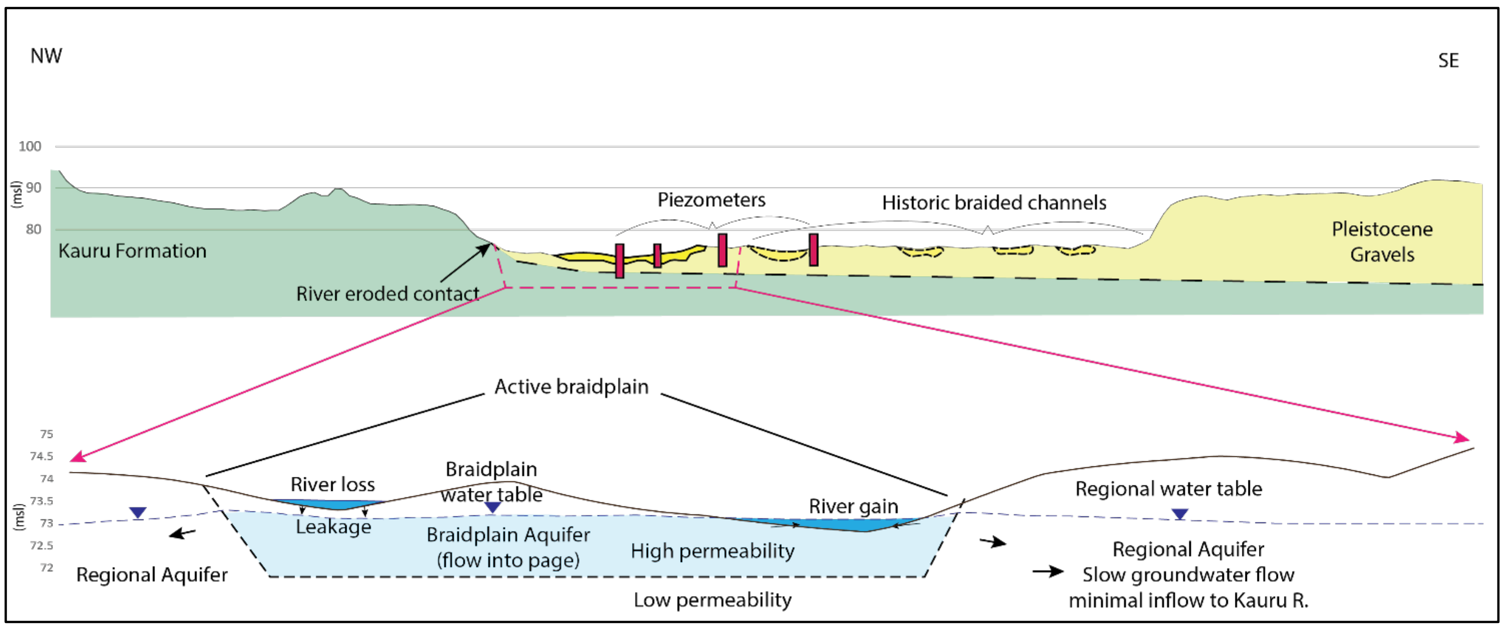


Figure 19. Cross section through the Kauru River and Kininmont Ford crossing highlighting the conceptualisation of the system. The green area in the top plot shows the Kauru Formation unit, which is comprised of glauconitic sandstone, siltstones, and mudstones. The lighter yellow is the Pleistocene, silt-bound gravels (low permeability zone in the bottom diagram). The yellow Pleistocene gravels comprise the Kauru-Kakanui Alluvial Aquifer (regional aquifer). The green unit is impermeable geology which could be considered hydrogeological basement that does not host any groundwater (horizontal extent approximately 1000m across). The bottom diagram introduces the concept of the braid plain aquifer and its relationship with the Kauru River and the surrounding low permeability sediments, (modified from Wilson et al., 2024).

The lower reaches of the Kauru River during low flows will disconnect naturally (in the absence of any water takes). The flow losses calculated in the Lu (2023) report indicate the lower reaches are naturally intermittent and the flow losses can exceed the naturalised MALF at Kauru at Kauru Hill (naturalised MALF being 122L/s). Flow loss to groundwater is also supported by this study from looking at hydrogeological gradients in groundwater head and flow gauging results.

Apart from CC18/0108, all other piezometers in the Kauru ribbon aquifer are responsive to groundwater levels as expected. Temperature data however has revealed that there is a strong connection between the riverbed bores (CC18/0134, CC18/0135 and CC18/0105), where temperature signatures are relatively aligned with surface water temperature. However, the outer piezometers found outside of the active braid plain show a delayed temperature response suggesting attenuation of the temperature signature of surface water flows. This suggests there is a lag in surface water recharge to the outer piezometers (even those near to the river but outside the contemporary braid plain), in addition to confirming slow groundwater flux through the silt bound gravels.

The silt bound gravels comprise the majority of the mapped Kauru-Kakanui Alluvial Aquifer however the results from this study show that the silt bound materials are likely low flux/low transmissivity and provide relatively low groundwater input to the Kauru River. The alluvial aquifer is in general likely a relatively poorly yielding aquifer overall. The gravel bed reservoir beneath the Kauru River and within the active braid plain channel (i.e. the braid plain aquifer) is the main connected hydrological system to the Kauru River. The river and the braid plain aquifer are poorly connected to the outer Kakanui-

Kauru Alluvial Aquifer system. Essentially most of the dynamic hydrological interaction occurs between the river (surface flow) and the shallow BPA (groundwater) The more distal silt-bound gravel aquifers likely have little material effect on the hydrological system near the river.

Therefore, over the 7km stretch of river in the lower reaches, the river loses to groundwater and the potential for aquifer storage in the BPA to support surface flows and/or burrowing fish habitat is low during low flow conditions. This means that any surface water taken during lower flows leaves the river vulnerable to increased rates of drying and rapid movement toward BPA depletion. Conversely, if there is enough rain in the upper catchment boosting river flows in the headwaters, filling of storage in the BPA can occur relatively quickly due to the low volume of the storage reservoir, therefore restoring surface water flows relatively quickly.

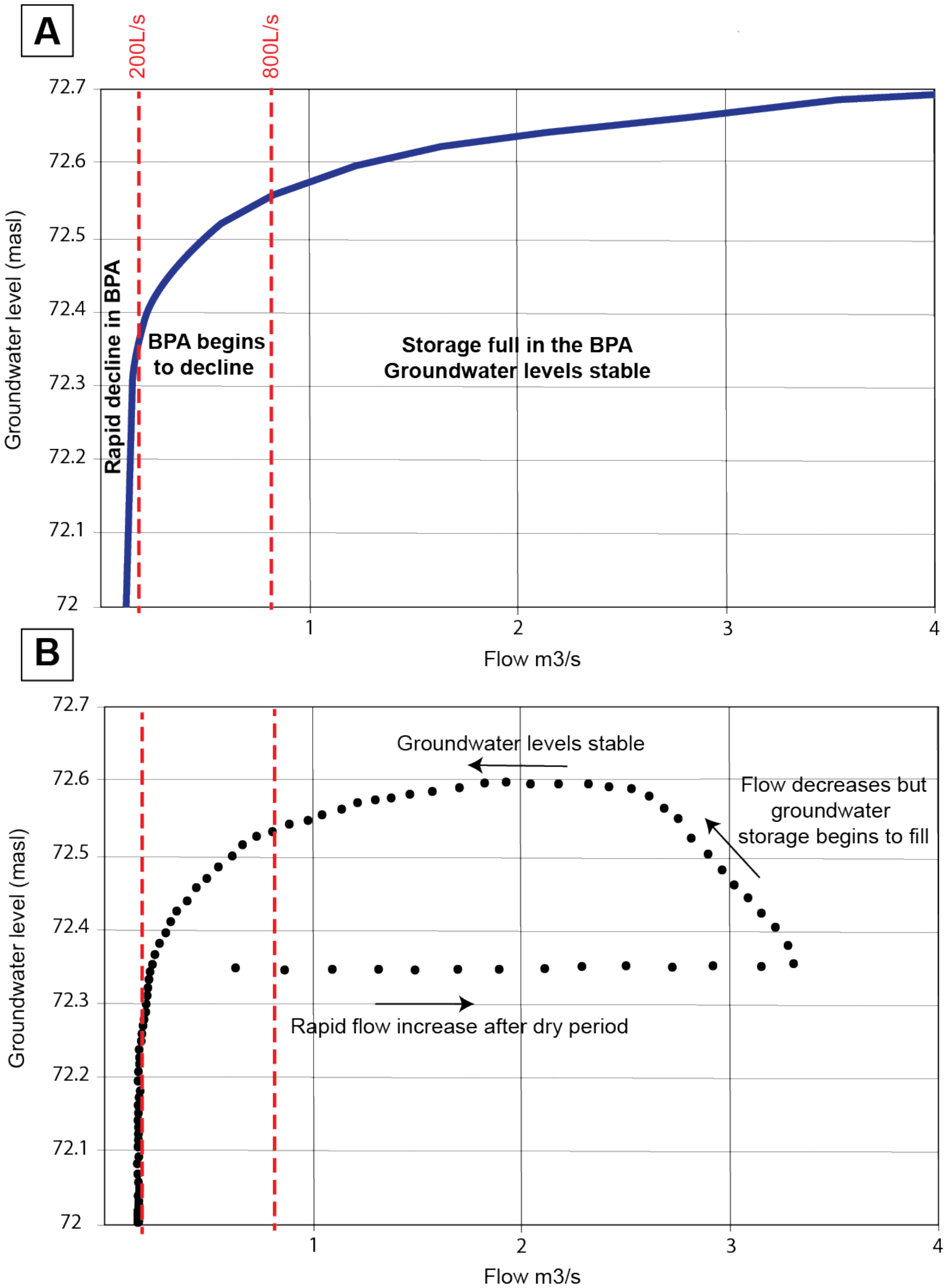


Figure 20 Schematic plot of CC18/1034 showing flow divisions based on the relationship between groundwater level in the BPA and flow at Kauru at Kauru Hill site. Plot A shows the groundwater level/flow relationship during a normal flow recession, where groundwater levels are stable until 800L/s where they begin to decline, then rapidly drop below 200L/s. Plot B shows a rewetting flow scenario, when groundwater levels have been depleted then surface flows rapidly increase. There is generally a lag in groundwater level response until storage refills then groundwater levels respond and then follow the normal flow recession curve. Each dot represents a consistent time interval.

9 Conclusion

Our findings indicate that Kauru River and Kauru BPA is inherently vulnerable to changes in flow conditions, river management practices, and water abstraction from either surface or groundwater within the contemporary braid plain. The limited storage capacity of the braid plain gravels means that during natural low flow conditions, these gravels have a restricted ability to support surface flows or provide a wetted habitat for burrowing galaxiids. In addition, the underlying silt bound gravels are unlikely to be a significant contributor of groundwater to the hydrological system. Given that these galaxiids inhabit only a ~7km stretch of the Kauru River, it is crucial to understand the relationship between river flows and the BPA water levels to ensure the protection of their native habitat.

Flow setting optimised to protect galaxiid habitat in the losing reach would require consideration of the above 800 and 200 L/s thresholds (Figure 20). To optimise galaxiid protection, minimum flows would be set above typical precautionary default guidelines such as 90% of the naturalised 7-day mean annual low flow. In addition, the Kauru River and the BPA should be treated as a connected system, with storage in the gravels an important contributor to surface water flows, or host to burrowing galaxiids. As has been seen in this study, particularly in the drilling core, the BPA is very thin BPA has low storage potential making it vulnerable to flow losses when the surface water begins to decrease below 800L/s. Abstraction below this threshold would decrease galaxiid habitat. Therefore, setting an environmental flow above the precautionary default minimum flow settings would provide for the galaxiid habitat if this is a priority for the Kauru.

9.1 Recommendations

Flow management

The results have shown that the above-ground extent and continuity of the Kauru River is exceptionally sensitive to changes in river inflow, which in turn influences the habitability of the galaxiid refuge zone. As groundwater levels decline when flows are lower than 800L/s, this threshold could be considered when developing surface abstraction limits. There could be a preference for high flow harvesting (above 800L/s at

Kauru at Kauru Hill flow site), rather than taking water when the flows are close to MALF[2], and the BPA is beginning to deplete. The advantage of the thin BPA gravels is that it does not take long for storage to fill in the BPA before surface water flows return.

Gravel abstraction

Due to the thin BPA, and the low transmissivity of the silt-bound gravels beneath, which act as a flow barrier, the Kauru River is exceptionally vulnerable to gravel extraction. If gravel is extracted beneath the riverbed, removing BPA gravels, then this may allow the river to rework sediment to greater depths, reducing the effective transmissivity of the gravel sequence above the silt bound gravels (Wilson et al 2024). In addition, there is potential for dropping of the riverbed in the Kakanui River due to gravel abstraction, which will overall cause a drop in the hydrological drainage elevation for the whole Kauru-Kakanui system. Therefore, gravel abstraction and river engineering within the active braid plain margins in the Kauru River should be carefully considered.

9.2 Future investigations

As has been covered, the BPA is very thin and therefore vulnerable to engineering works and gravel extraction in the contemporary braid plain of the Kauru River. Further analysis of the depth of the BPA downstream of the Kininmont Ford site could be beneficial. Drilling of at least 2-3 more piezometers in the riverbed to determine depth of the BPA and install piezometers screened across the BPA would strengthen our knowledge of the relationship between BPA groundwater levels and flow at Kauru at Kauru Hill. There is a slight gap in the understanding of the conceptual geological model from the Kininmont Ford site and the Kakanui Hill Bridge. This understanding could be strengthened by obtaining drill core samples. In addition, drilling piezometers close to the Kakanui confluence would also help increase our understanding of how Kakanui River flows interact with the Kauru River and underlying Kauru BPA. However, it is unlikely the BPA is significantly thicker towards the Kakanui-Kauru confluence and therefore the flow versus groundwater level relationship is likely to be similar to what has been found in this study.

There is a slight discrepancy in flow threshold values between the upstream (CC18/0105) and downstream (CC18/0134) sites (Figure 12). This difference is within the expected

[2] Mean annual low flow.

uncertainty due to their locations and the accuracy range of the datasets (approximately +/- 10%). More data could be collected by way of more monitoring wells however the implications outlined in this study are unlikely to change.

The fundamental understanding of the losing reach within the Kauru River are not expected to change in the short to medium term (5-10 years).

10 Acknowledgements

Thanks to ORC Environmental monitoring team for help including data collection and QA/QC; local landowners including Murray Rodgers, Bernie Pringle, Jan and Clyde Douglas for all providing land access and allowing bore installations on their respective properties; LINZ for river access agreement; Matt Coble from GNS for the radon survey and analysis; and Scott Wilson from Lincoln Agritech for input and advice throughout the project.

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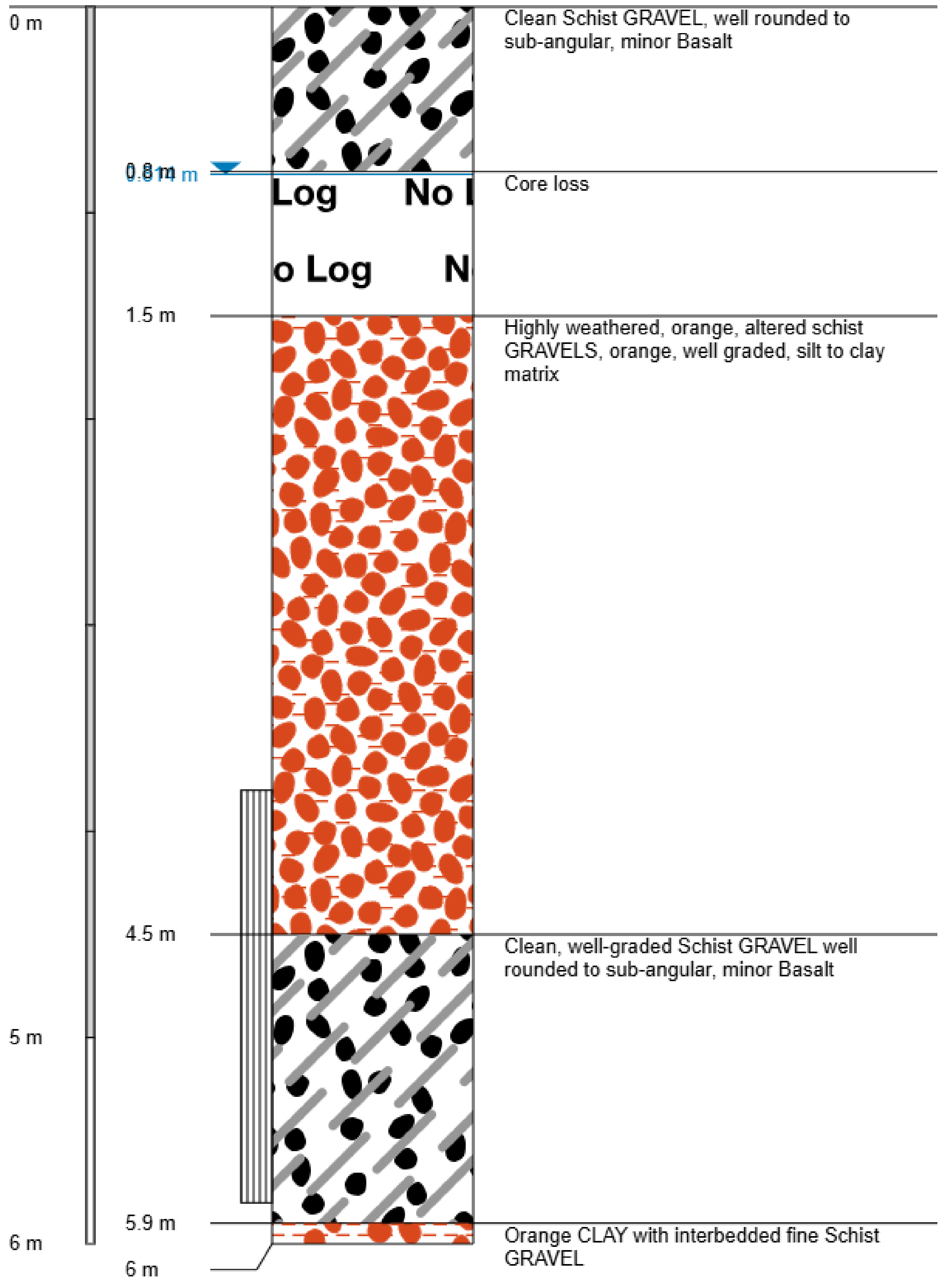
12 Appendix 1

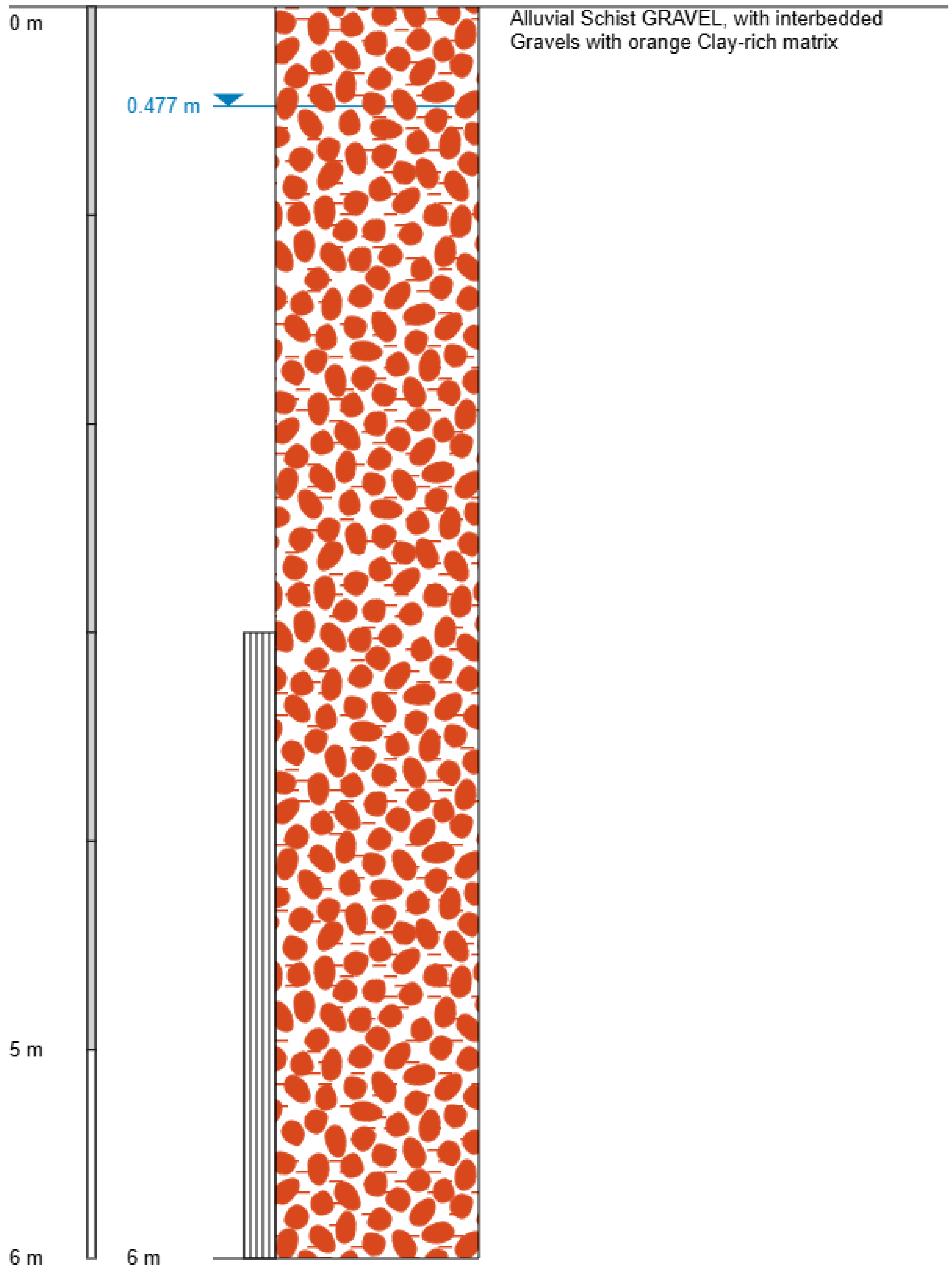
Well logs, accessed through WellsNZ on 28/01/2025 (https://wellsnz.teurukahika.nz/). Note: CC18/0102, CC18/0105, CC18/0106, CC18/0134, CC18/0135 were sampled and stored in core boxes.

Council well number : CC18/0102
Well name : Kakanui River Piezo BH2
Drilling company : Speight Drilling
Drilling date : 23/03/2022
Drilling method : Sonic
Locality : -
Total depth drilled : 6m
NZTM : 1424353 : 5004899



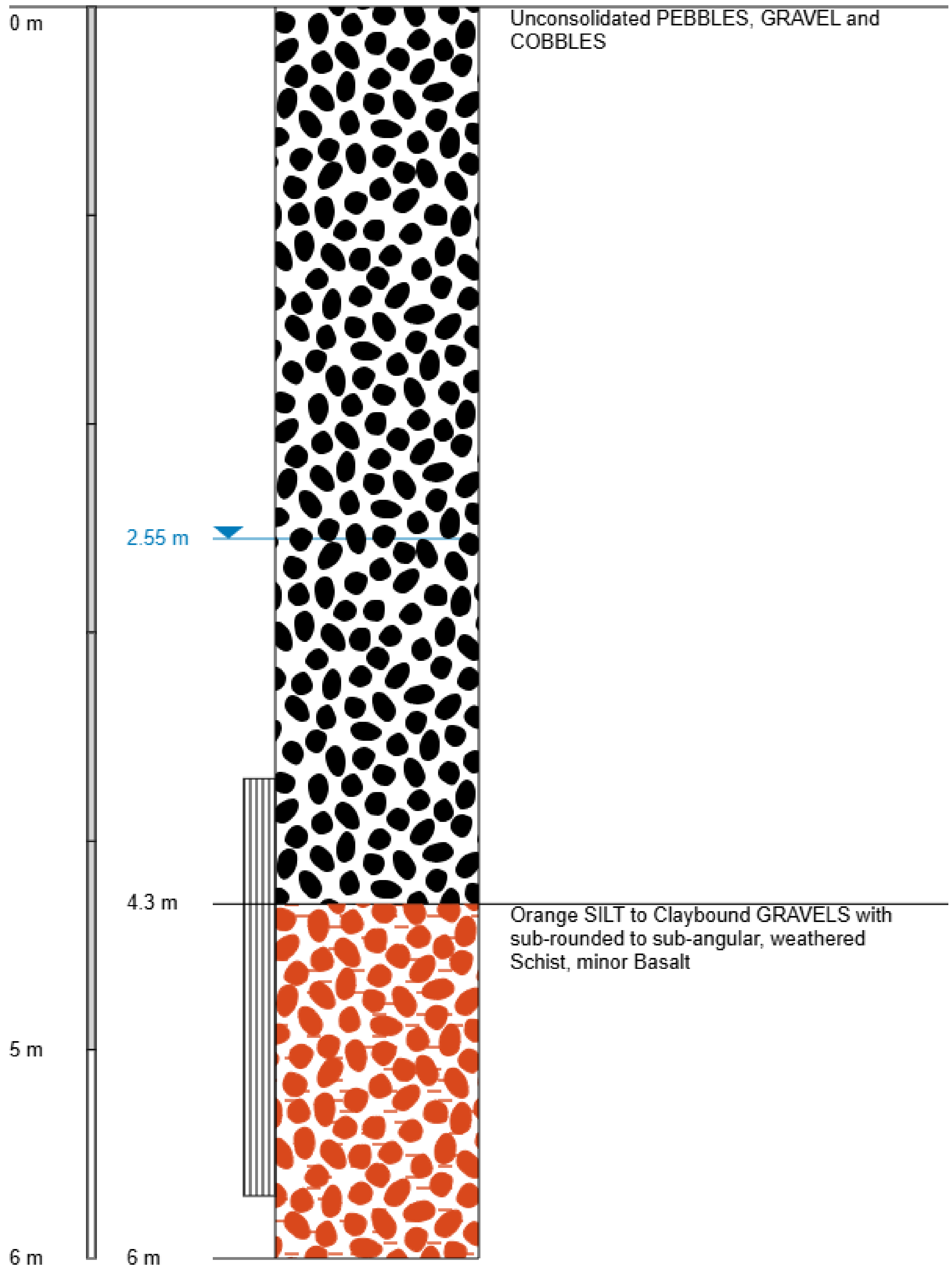
35

Council well number : CC18/0103
Well name : Kakanui River Piezo BH3
Drilling company : Speight Drilling
Drilling date : 23/03/2022
Drilling method : Sonic
Locality : -
Total depth drilled : 6m
NZTM : 1424403 : 5004882



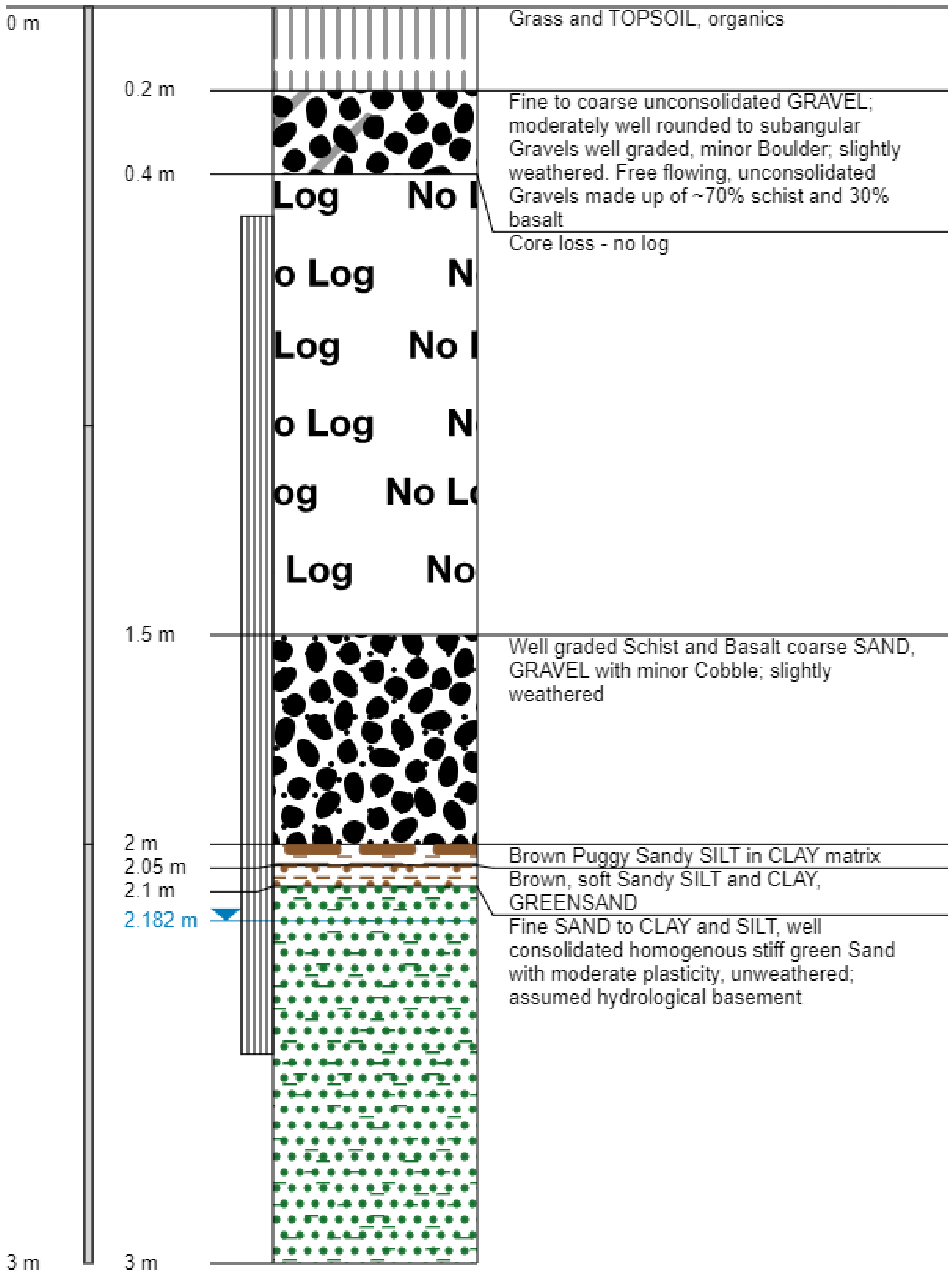
36

Council well number : CC18/0104
Well name : Kakanui River Piezo BH4
Drilling company : Speight Drilling
Drilling date : 23/03/2022
Drilling method : Sonic
Locality : -
Total depth drilled : 6m
NZTM : 1423325 : 5003632



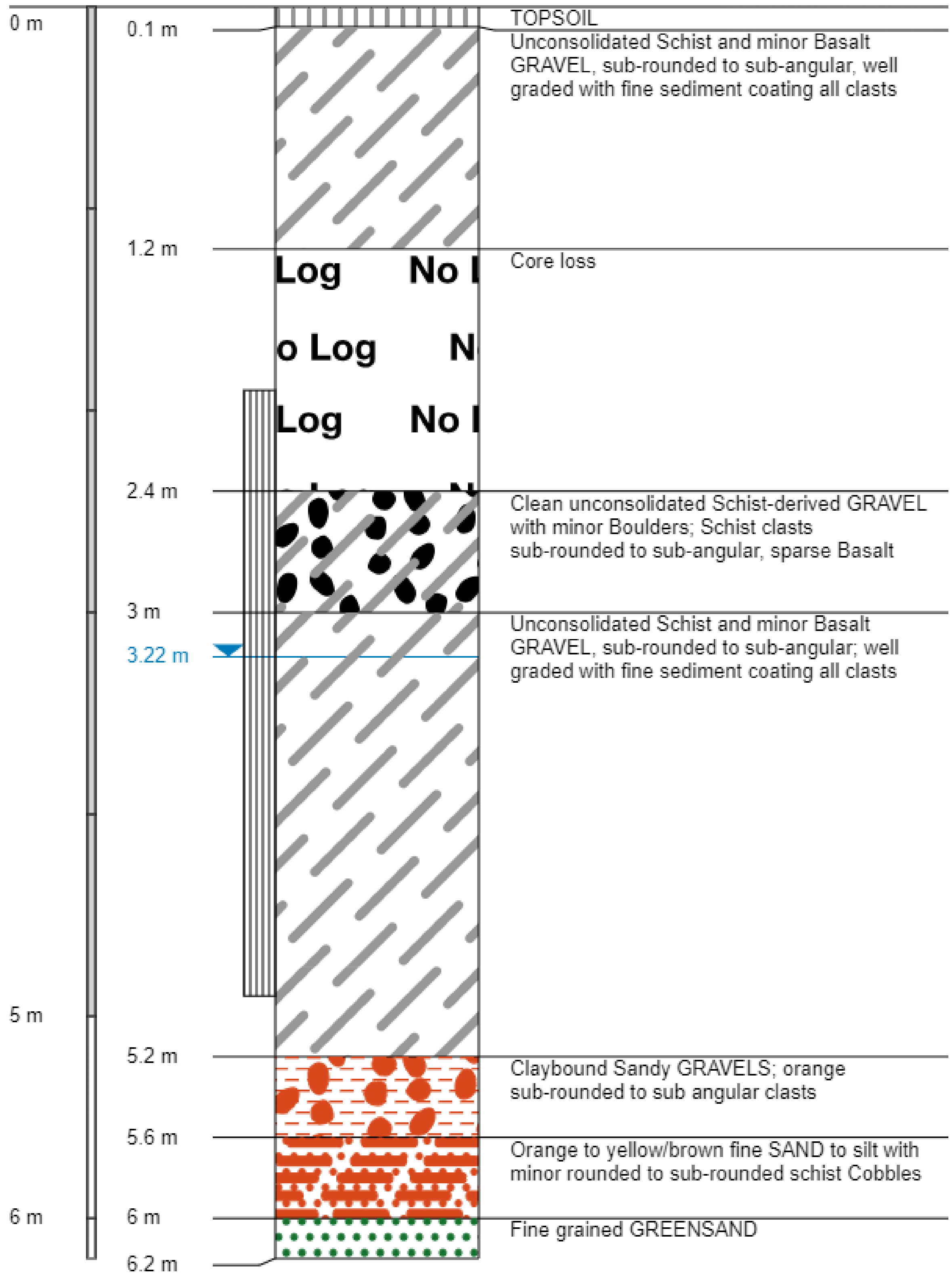
37

Council well number : CC18/0105
Well name : Kakanui River Piezo BH5
Drilling company : Speight Drilling
Drilling date : 23/03/2022
Drilling method : Sonic
Locality : -
Total depth drilled : 3m
NZTM : 1423409 : 5003617



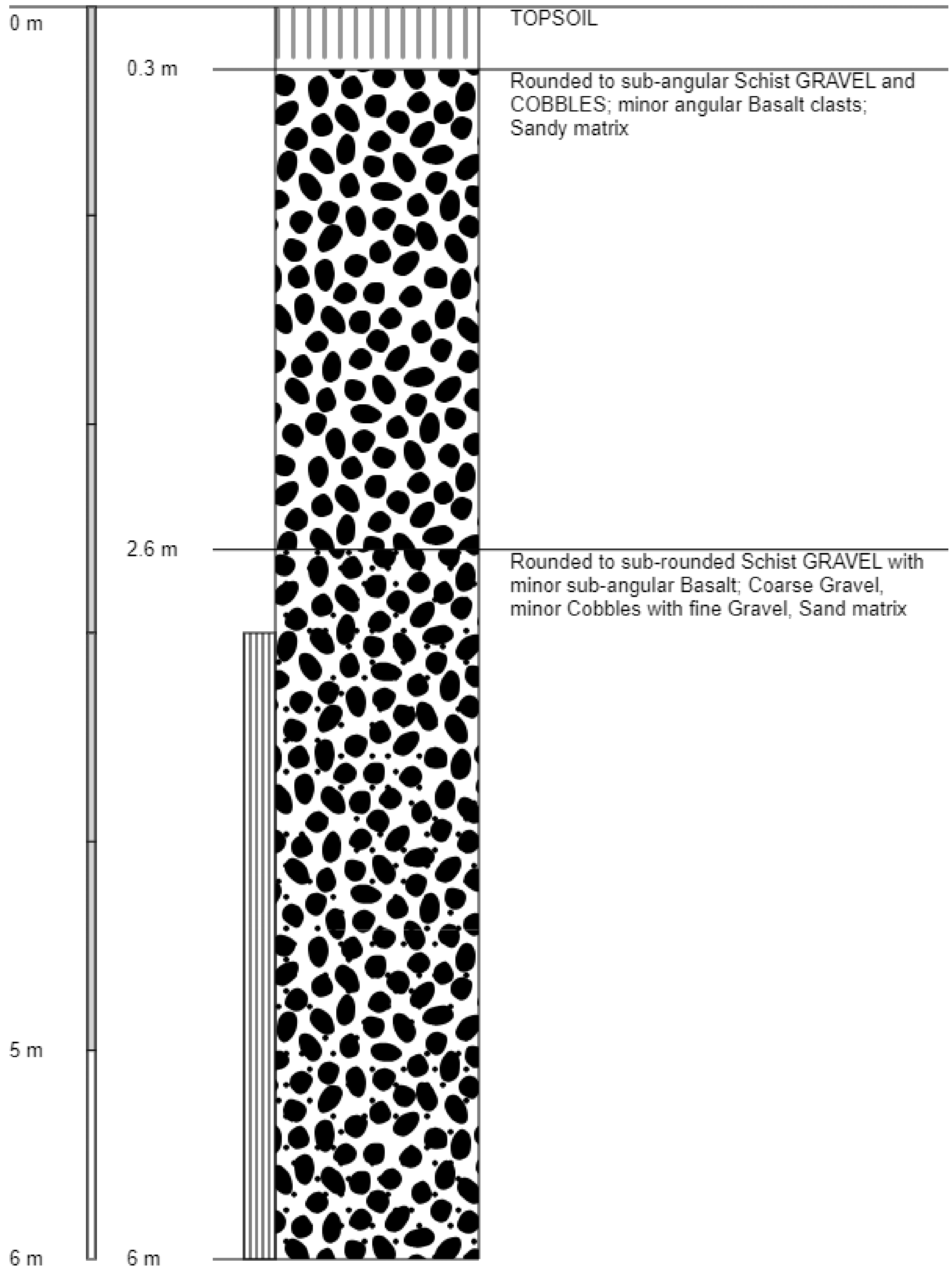
38

Council well number : CC18/0106
Well name : Kakanui River Piezo BH6
Drilling company : Speight Drilling
Drilling date : 23/03/2022
Drilling method : Sonic
Locality : -
Total depth drilled : 6.2m
NZTM : 1423526 : 5003595



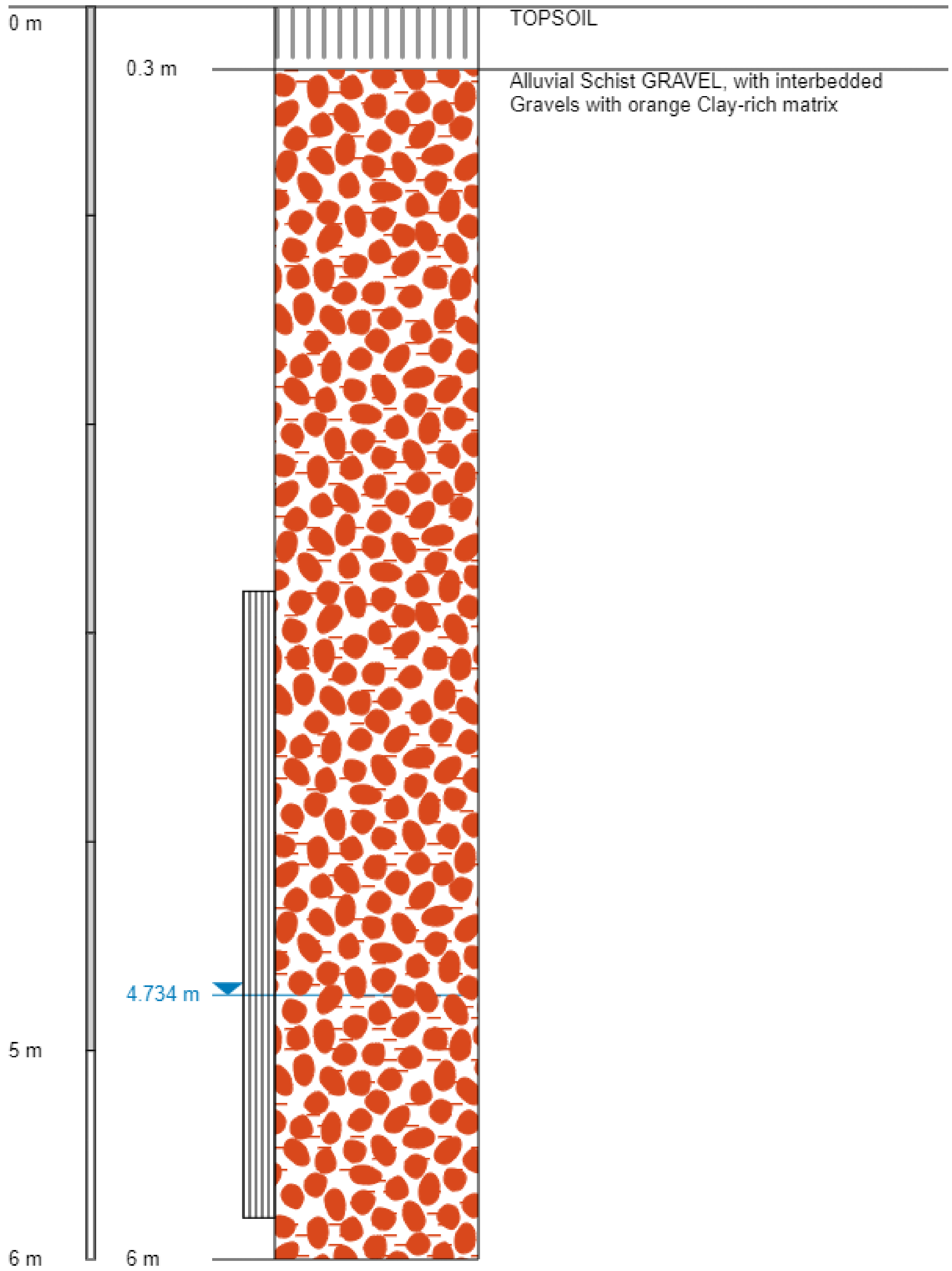
39

Council well number : CC18/0107
Well name : Kakanui River Piezo BH7
Drilling company : Speight Drilling
Drilling date : 23/03/2022
Drilling method : Sonic
Locality : -
Total depth drilled : 6m
NZTM : 1423939 : 5003531



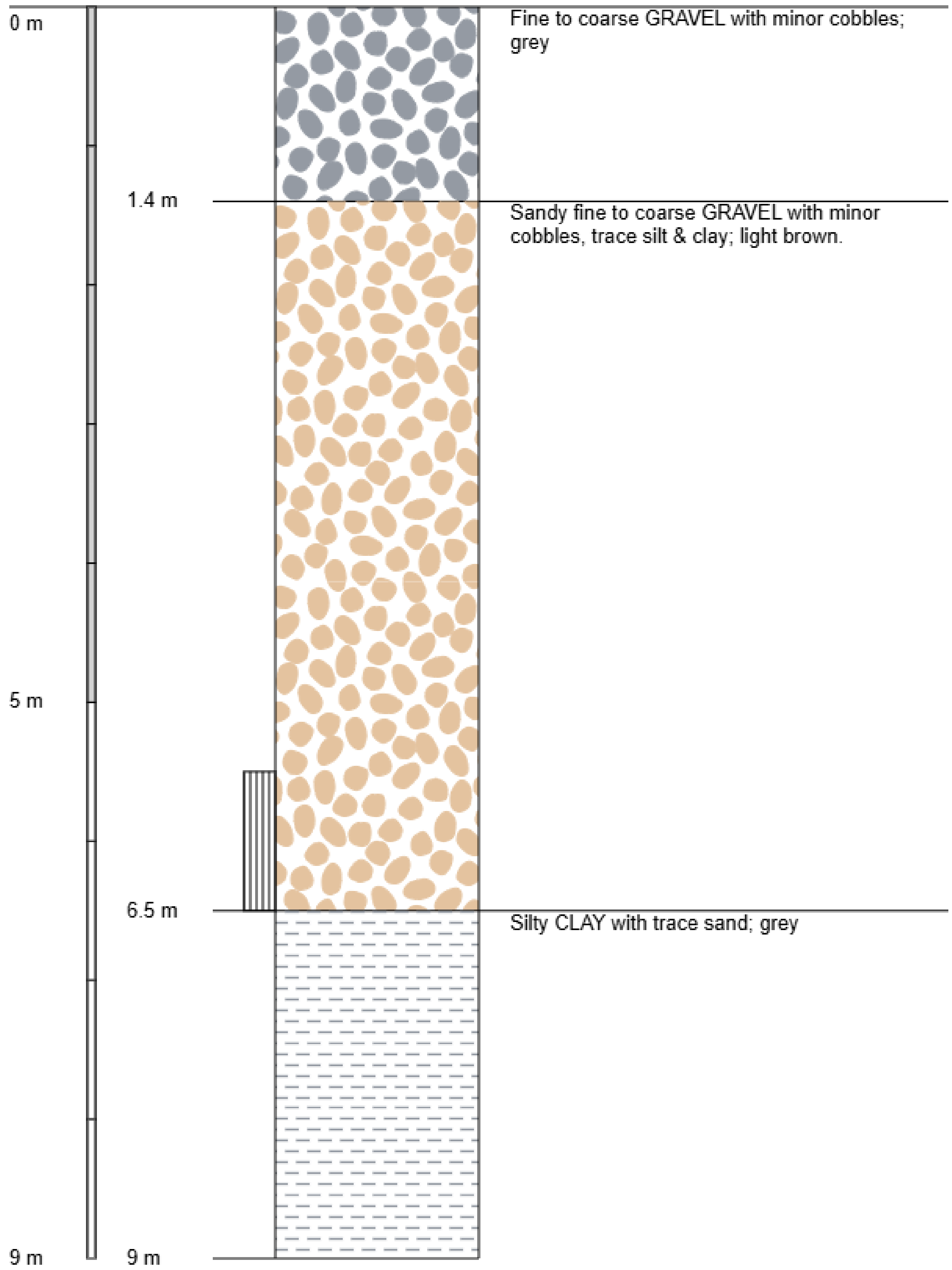
40

Council well number : CC18/0108
Well name : Kakanui River Piezo BH1
Drilling company : Speight Drilling
Drilling date : 23/03/2022
Drilling method : Sonic
Locality : -
Total depth drilled : 6m
NZTM : 1424278 : 5004988

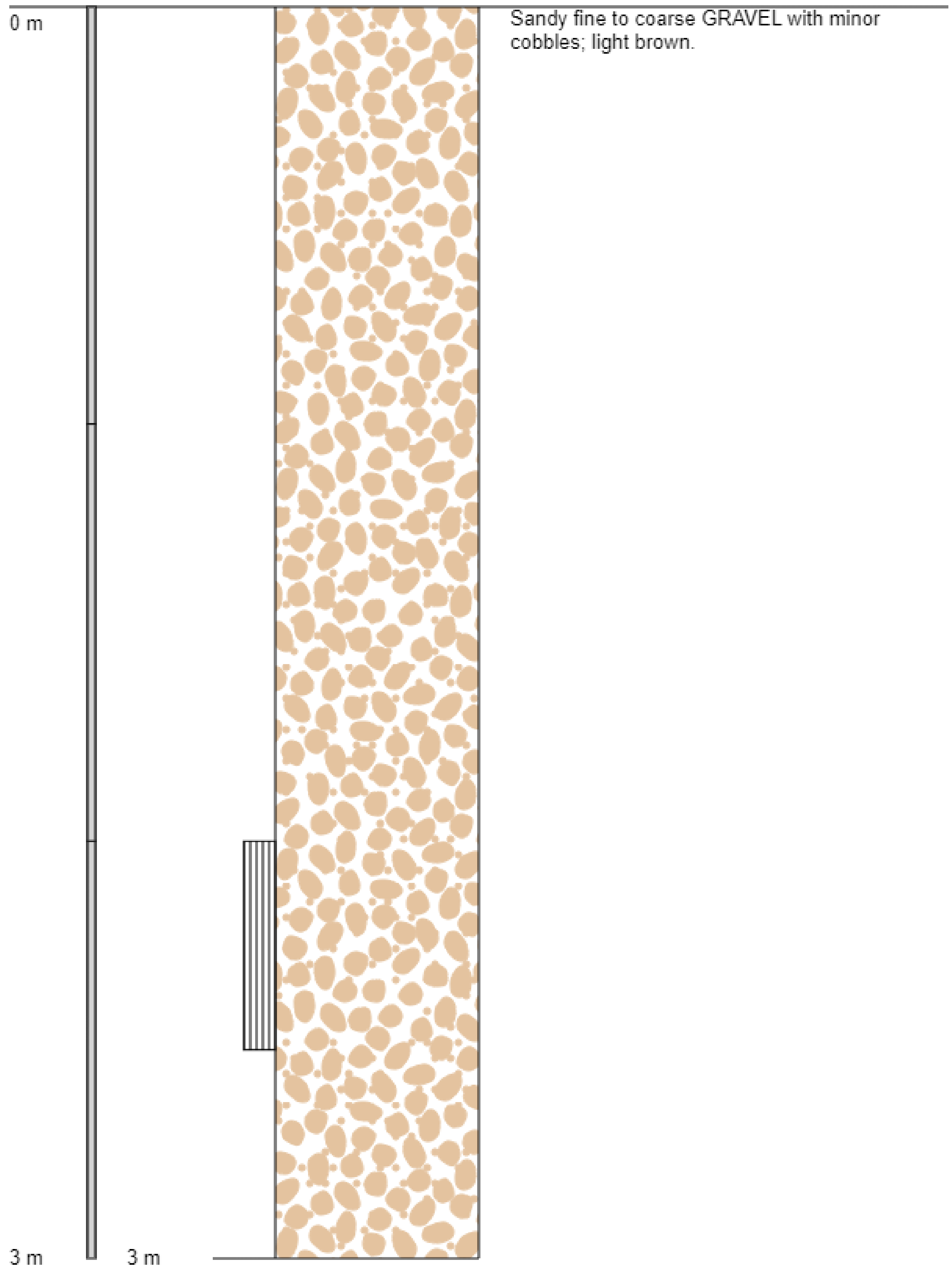


41

Council well number : CC18/0134
Well name : Kauru Redrilled Obs Bore 1
Drilling company : -
Drilling date : 12/04/2023
Drilling method : (unknown)
Locality : Kininmont Road, Incholme
Total depth drilled : 9m
NZTM : 1424263 : 5004865



Council well number : CC18/0135
Well name : Kauru River Bore 2
Drilling company : McMillan Drilling
Drilling date : 13/04/2023
Drilling method : Sonic
Locality : Kininmont Road, Incholme
Total depth drilled : 3m
NZTM : 1424272 : 5004854



9.2. Update on the Groundwater Science Programme

Prepared for:	Environmental Science and Policy Committee
Report No.	GOV2507
Activity:	Governance Report
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Endorsed by:	Tom Dyer, General Manager Science and Resilience
Date:	20 February 2025

PURPOSE

[1] This paper updates the Environmental Science and Policy Committee on the groundwater science programme. This includes recent expansions and improvements to the monitoring network, the transition to an online national wells database, technical contributions to the proposed Land and Water Regional Plan, and ongoing efforts to better understand and manage Otago's groundwater resource.

EXECUTIVE SUMMARY

[2] The groundwater science programme aims to improve the understanding and management of Otago's groundwater. Over the past four years the groundwater State of Environment (SOE) monitoring network was expanded by over 40 sites, most of which are new, purpose-drilled monitoring bores located on public land. The bores are used for monitoring groundwater levels, quality, or both.

[3] Significant improvements were made to the database that holds Otago's well records, with ORC joining the WellsNZ national database initiative. This provides rapid and convenient access to well records held by ORC, including the generation of visual bore logs and stratigraphy.

[4] Groundwater scientists also provided technical input to the development of the Land and Water Regional Plan.

[5] Other ongoing projects include modelling groundwater recharge, bespoke catchment studies, and regional studies including mapping onsite wastewater systems, groundwater nitrate concentrations, aquifer recharge, and groundwater ecosystems.

RECOMMENDATION

That the Committee:

a) ***Notes*** *this report.*

BACKGROUND

[6] Groundwater Science sits within the Land Team within the broader Science unit. Three groundwater scientists work closely with three groundwater technicians within the Environmental Monitoring (EM) team, and other Council teams with a groundwater focus, including Regulatory Data, Policy, Natural Hazards, Compliance, and Consents.

[7] This paper is the first comprehensive groundwater-focussed update to Council since the groundwater quality State of Environment (SOE) report in March 2021. Over the past 4 years, the groundwater programme has focused on expanding the groundwater State of Environment (SOE) network, providing technical input for the Land & Water Regional Plan (LWRP), implementing of a new wells database, updating groundwater models, bespoke catchment studies, and the provision of internal advice regarding groundwater. The team's outputs are used across ORC and the community for various applications including consent applications, policy development, groundwater modelling, catchment management, and regulatory functions.

GROUNDWATER SCIENCE PROGRAMME

[8] This report provides an update on various components of the groundwater science programme and is structured into the following sections:

- Groundwater State of the Environment network improvement
- Proposed Land and Water Regional Plan – technical input
- Wells Database upgrade
- Aquifer specific studies
- Ongoing work

[9] In addition to the initiatives described here, groundwater scientists also provide an array of internal services to various teams across ORC, including reviewing consent applications for taking groundwater and discharges to land, assisting with compliance and investigation queries, and providing scientific advice on groundwater-related natural hazards (e.g. South Dunedin, Clutha Delta Sea level rise project). The groundwater scientists work closely with Regulatory Data officers on recording bore information and water takes. ORC's groundwater scientists actively contribute to the Groundwater Forum (regional councils' Special Interest Group [SIG]) and presented work in the last 4 NZ Hydrological Society conferences.

GROUNDWATER STATE OF THE ENVIRONMENT (SOE) MONITORING NETWORK

[10] The hydrogeological setting for Otago consists of many shallow, unconfined aquifers, typically along river valleys. However, Otago also has some larger semi-confined/confined aquifer systems, where groundwater is confined beneath an impermeable layer. Otago's high number of small aquifers differs from groundwater-dominated regions such as Canterbury and Hawke's Bay, where most groundwater resources are located within a few very large-scale aquifers. This high number of aquifers in Otago and their diversity in type increases the challenges associated with monitoring and managing their levels and quality.

[11] ORC's SOE groundwater monitoring network is currently composed of 104 sites that monitor groundwater levels, quality, or both. The bores are either owned by ORC, privately, or by District or City Councils. Groundwater SOE reports were most recently presented to Council in 2021[1] and 2023[2].

[12] Groundwater level is monitored by down hole pressure transducers. Levels in the sites are also validated during monthly inspections by the Environmental Monitoring (EM) technicians. Groundwater quality is monitored every 3 months by collecting water

[1] https://www.orc.govt.nz/media/9785/otago-groundwater-soe-report-march-2021.pdf
[2]https://www.orc.govt.nz/media/14523/orc-river-lake-groundwater-state-and-trends-2017-2022.pdf

samples and analysing them in an accredited laboratory for over 40 chemical, physical, and biological parameters, including nutrient concentrations and E. coli.

[13] Some groundwater quality results, notably E. coli, nitrate, and dissolved arsenic concentrations, are assessed against the Drinking Water Standards for New Zealand (2022) Most Acceptable Values (MAV)[3]. Some locations show frequent exceedance of the MAV for some parameters - for example elevated dissolved arsenic concentrations in Central Otago, likely due to the local schist geology [4].

[14] It is important to note that the SOE monitoring samples raw, untreated groundwater, at three monthly intervals. This data only serves as background monitoring rather than a real time drinking water quality assessment. If the SOE results exceed the MAV for particular parameters, the team notifies the bore owner (if applicable), Taumata Arowai (water regulator), relevant district/city council, and the Southern District Health Board. We then work collaboratively with these bodies to assess whether further actions are needed.

Network Review and Expansion Rationale

[15] The groundwater SOE network was externally reviewed in 2017 by Pattle Delamore and Partners (PDP)[5]. This review highlighted gaps in the number and distribution of SOE sites, alongside the lack of monitoring in areas of rapid development (e.g. Glenorchy). However, this desktop-based review did not assess any practical considerations for the monitoring bores such as location, condition, and access.

[16] Following discussions and field visits with EM staff, many site-specific limitations were identified. These include poor borehead security, a risk of losing access to privately owned bores, and many of the bores being pumped regularly, which makes them unsuitable for monitoring groundwater levels or pressures. These issues can compromise the data from the bores and become a liability to ORC, e.g. in case of pump failures or well damage during the sampling, or loss of access. Furthermore, long-term records, suitable monitoring bores, and continuity of access are crucial for SOE monitoring. Hence, these limitations highlighted the need to improve the network.

[17] Further impetus for improving the network comes from the increasing importance of numerical models to manage groundwater resources. These models are underpinned by continuous monitoring of groundwater level, which requires suitable SOE bores. The value of continuous groundwater level monitoring from designated SOE bores was highlighted by a recent modelling exercise of the Hawea Aquifer. In this example, continuous water level data from monitoring bores installed between 2014 and 2017 (following recommendations from a previous modelling effort) provided crucial data and enabled transient modelling of the basin[6].

2021-2025 Network expansion

[18] Following the review, the network has been improved and expanded through a staged programme of drilling dedicated monitoring bores. The bores have been located and

[3] https://www.legislation.govt.nz/regulation/public/2022/0168/latest/whole.html
[4] https://www.orc.govt.nz/media/9785/otago-groundwater-soe-report-march-2021.pdf
[5] C03577500R001_GroundwaterReview_Final_v2_29.08.2017.pdf
[6] Hawea Basin Model-Allocation Review_final.pdf

designed to enable groundwater monitoring for decades to come. The bores were placed on public land, usually road reserves, which substantially increases the likelihood of long-term access. To increase efficiency and reduce mobilisation costs, the drilling was undertaken in tranches over smaller areas.

[19] The drilling programme started during the 2021-22 Financial Year in north Otago, with the Maniototo area a focus in 2023-24, and the Dunstan and Earnslceugh aquifers near Alexandra drilled in 2024. The newly drilled bores are shown in Figure 1 and the programme output is summarised in Table 1.

[20] The total capital cost for drilling and installing the 29 groundwater SOE monitoring bores since 2020-21 FY has been $570k (excl. Lower Clutha). In addition to this, each site has set-up and instrumentation costs of $10-14k (depending on well depth and complexity), including installing a concrete pad and cabinet, down-hole sensors, solar power system, logging and telemetry equipment.

[21] Additional bores in the Ettrick and Millers Flat areas are planned for this summer. Other areas targeted for drilling new SOE bores after the 2024-25 Financial Year include the Mangauwera Valley (Hawea basin), Kingston, Strath Taieri, Pomahaka, South Otago fractured rock, and the Tokomairiro areas.

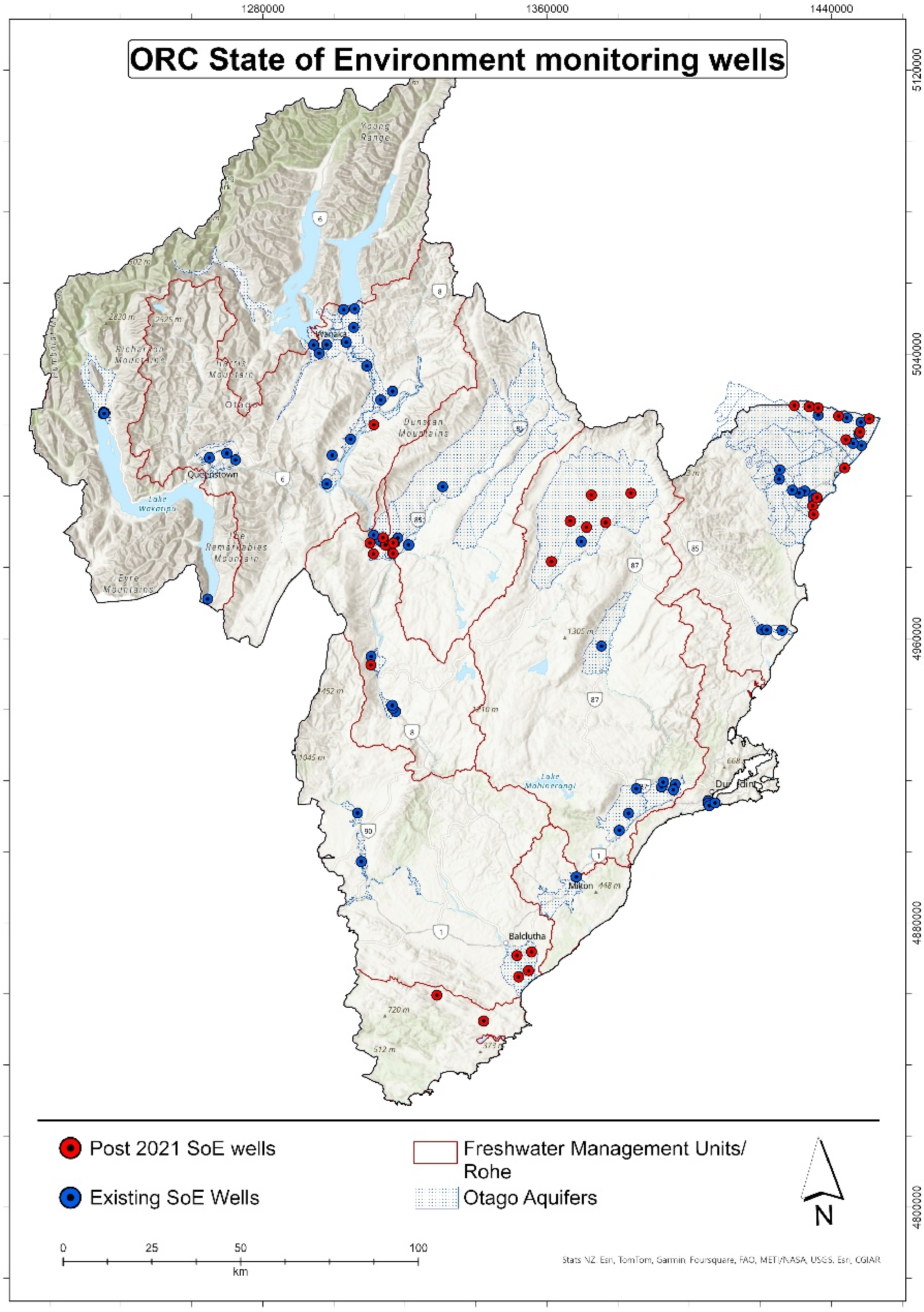

Figure 1: Location of existing and newly drilled monitoring bores in Otago.

Table 1: Summary of SOE bores drilled since the 2020-21 Financial Year

Financial Year	FMU	Area	Number of bores installed
2020-2021	Clutha Mata-Au (Dunstan Rohe)	Bendigo	1
2021-2022	Clutha Mata-Au (lower Clutha Rohe)	Inch Clutha (collaboration with Natural Hazards)	8
2022-23	North Otago	• Lower Waitaki Plains Aquifer • N. Otago Volcanic Aquifer (Kakanui)	8 3
2022-23	Catlins	Owaka Valley	2
2023-24	Taieri	Maniototo	10
2024-25	Clutha Mata-Au (Dunstan Rohe)	Alexandra/Earnscleugh	5
2024-25	Clutha Mata-Au (Roxburgh Rohe) - pending	Ettrick/Millers Flat	Planned 5

Standardised monitoring bore design

[22] Well installation to the ORC specifications is tendered to drilling contractors. Following completion of the drilling, a robust concrete pad is poured around the bore upstand, before the EM team install headworks and monitoring instrumentation in each site, which was enclosed in cabinets (Figure 2). The water level data from the bores (recorded at 15 minute intervals) is telemetered and the data from most sites is available on the ORC web portal.

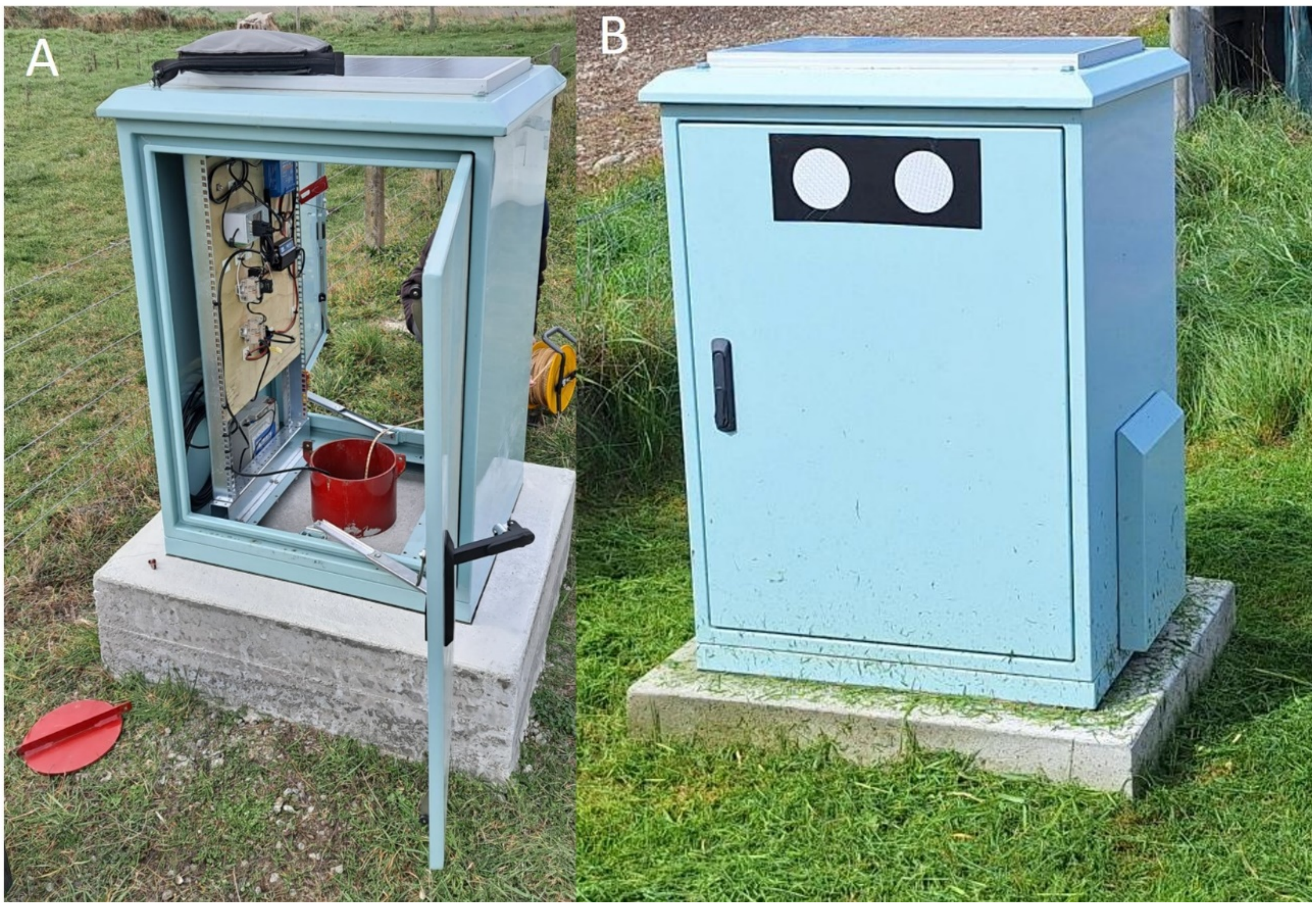

***Figure 2: Images showing examples of a standard bore site installation with concrete pad and monitoring equipment (A) housed in metal, lockable cabinet (B). Photos provided by Nick Boyens and Malc Allan*.**

[23] The Maniototo Aquifer has shallow and deep groundwater resources, which are separated by a fine-grained impermeable silt unit. In this area paired wells were drilled adjacent to each other, respectively targeting the shallow, near surface groundwater and the deeper part of the aquifer. The deeper wells commonly encountered artesian conditions, where the water level is higher than ground level. The headworks design was modified to enable measurement and sampling of these higher pressures, and to withstand the potential effects of freezing in the Maniototo area (Figure 3).

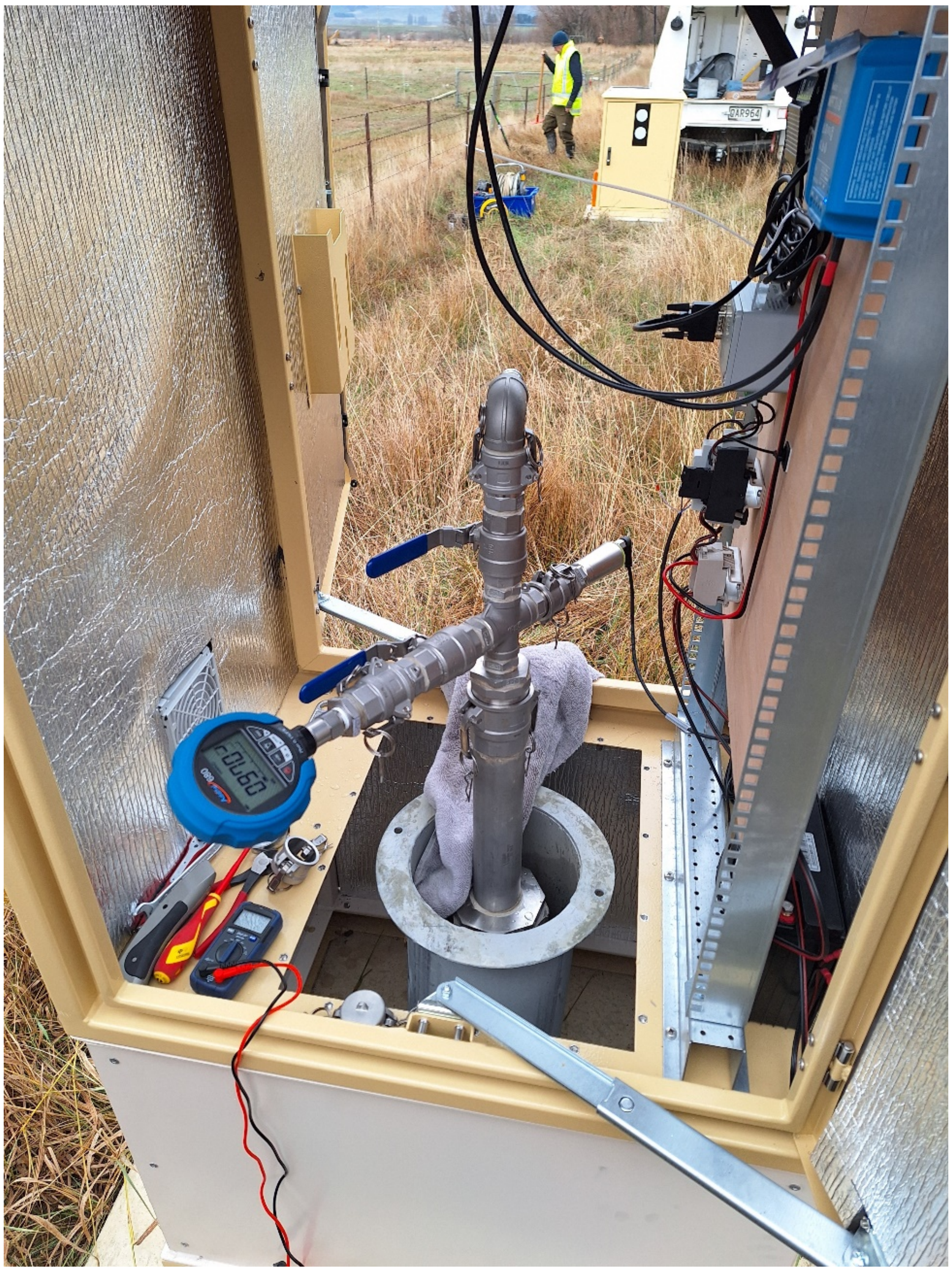

Figure 3: setup for monitoring artesian groundwater in the Maniototo. The headworks are sealed with access points to allow pressure monitoring and sampling. The cabinets are insulated to reduce the effects of freezing.

[24] In addition to drilling new bores, the team successfully secured access to several unused bores owned by district councils. Four QLDC-owned bores in Glenorchy and two CODC-owned bores in Clyde and Roxburgh were added to the network in 2020 and 2023, respectively. It is also planned to add an existing bore to monitor the Papakaio aquifer in North Otago, as described below.

Papakaio Aquifer Monitoring

[25] The Papakaio Aquifer is an extensive, deep confined aquifer south of Oamaru. Groundwater dating using carbon-14 in the 1980s indicated the groundwater age exceeds 20,000 years. However, despite the aquifer size and uniqueness it has not been regularly monitored by ORC. The Otago Catchment Board undertook an exploratory drilling programme to better understand the aquifer during the 1980s. The programme drilled 3 exploratory wells to depths ranging from 60 to 450m. After the project ended, the wells were transferred to the landowners for irrigation and/or stock water, although it was noted that the water quality from the aquifer can be poor and highly corrosive to the steel headworks. Monitoring the Papakaio aquifer has been a priority for some time. However, due to its depth and artesian conditions the costs associated with drilling new monitoring bores in this aquifer would likely be prohibitive.

[26] One deep well (J41/0273) was still operational but unused by the landowner since the expansion of water delivery from the North Otago Irrigation Company. This well is 454 m deep, with a high artesian pressure of 425kPa, equating to a water level of 42m above ground. This is one of the highest groundwater pressures monitored by any regional Council in New Zealand.

[27] Upgrading this existing well, rather than drilling a new one, therefore provides a cost effective opportunity to monitor the Papakaio Aquifer. Following an access agreement with the landowner, this well has been modified to serve as a monitoring well. The modification to the headworks required careful design and installation due to the artesian pressure (Figure 4). It is anticipated that the well will be instrumented for monitoring in early 2025.

Figure 4: Upgraded headworks for monitoring artesian groundwater levels in the Papakaio aquifer in bore J41/0273. The assembly will be enclosed in a lockable cabinet. Photo provided by Nick Boyens.

TECHNICAL GROUNDWATER INPUT TO THE PROPOSED LAND AND WATER REGIONAL PLAN

[28] As part of ORC's effort to develop the new Land & Water Regional Plan (pLWRP), groundwater scientists provided technical input on groundwater allocation, restrictions and trigger wells, and the management of bore interference, surface water depletion, and fractured-rock aquifers. Inputs included reviewing the groundwater provisions in the Regional Plan: Water (RPW), refining of aquifer boundaries, and producing memoranda that outlined current issues and suggested improvements for manging Otago's groundwater. The memoranda were published on the ORC website and were consulted on as part of the LWRP process.

[29] In addition to assisting the Policy team with the provisions, the groundwater scientists also commissioned groundwater model updates for the Hawea and Alexandra Basin aquifers and secured Envirolink Funding for a GNS-led synthesis of groundwater in the

Shag River catchment[7]. External analysis of groundwater quality formed part of the 2017-2022 Otago rivers and lake water quality report[8].

[30] This body of work can be readily adapted to inform future plan iterations.

WELLS DATABASE UPGRADE

[31] Having a fit for purpose and user-friendly database to store Otago's well records is key for managing our groundwater. The ORC Wells Database encompasses data for over 8,000 known wells (Figure 5). This data, dating back to groundwater investigations from the 1980s and before, is continuously updated through the bore consenting and compliance processes.

[32] Until 2023 the ORC maintained an inhouse wells database that was no longer fit for purpose as it lacked a proper user interface, data integrity rules, standardised definitions and had very limited functionality (e.g. it could not produce visual borelogs and well construction reports). The ORC has therefore partnered with three other Regional Councils in a project led by RSHL to develop WellsNZ, a standardised national database system for storing and accessing well information (e.g. location, depth, screen information, bore logs, and many other parameters). This collaborative effort addresses the need to replace aging well database variants across participating councils.

[33] The project went 'live' at ORC with a "soft launch" in January 2024. WellsNZ data is also presented via the Wells layer of OtagoMaps. WellsNZ displays key information including visual borelogs, construction details, aquifer test results, and documents relating to the well. It is also convenient for entering and updating information. Two more councils are expected to join the project in the coming year, and further enhancements are planned for 2025. Integration with the NextGen Iris project is also currently being explored. WellsNZ can be accessed on https://wellsnz.teurukahika.nz/dashboard or through links on Otago Maps.

[34] The WellsNZ database is used externally by drillers, consultants, scientists and others, in addition to four sections within ORC – Compliance, Regulatory Data, Consents, and Science – who collaborate closely to maintain and improve the database. WellsNZ is specifically designed to integrate with existing council office procedures (e.g. uploading reports from newly drilled bores) as well as scientific needs.

[35] Although the introduction of WellsNZ substantially improves ORC's database capabilities, it is key that the information is regularly updated, as some data is several decades old, hence well locations, condition, use, and other details can be inaccurate or unknown. For example, many older well positions were estimated from topographic maps, and can be out by hundreds of meters. Inaccurate or missing well information can lead to knowledge gaps and risks for ORC and groundwater users when conducting groundwater research, assessing groundwater consents, or assisting with compliance queries. Therefore, despite the associated challenges, ORC has been working with drilling companies to visit properties and, with landowner permission, check the locations and condition of groundwater wells to update the WellsNZ database as required.

[7] https://www.orc.govt.nz/media/15652/cr2022-91_synthesis_of_the_groundwater_investigations_in_the_lower_waihemo_shag_river_valley_final.pdf
[8] https://www.orc.govt.nz/media/14523/orc-river-lake-groundwater-state-and-trends-2017-2022.pdf

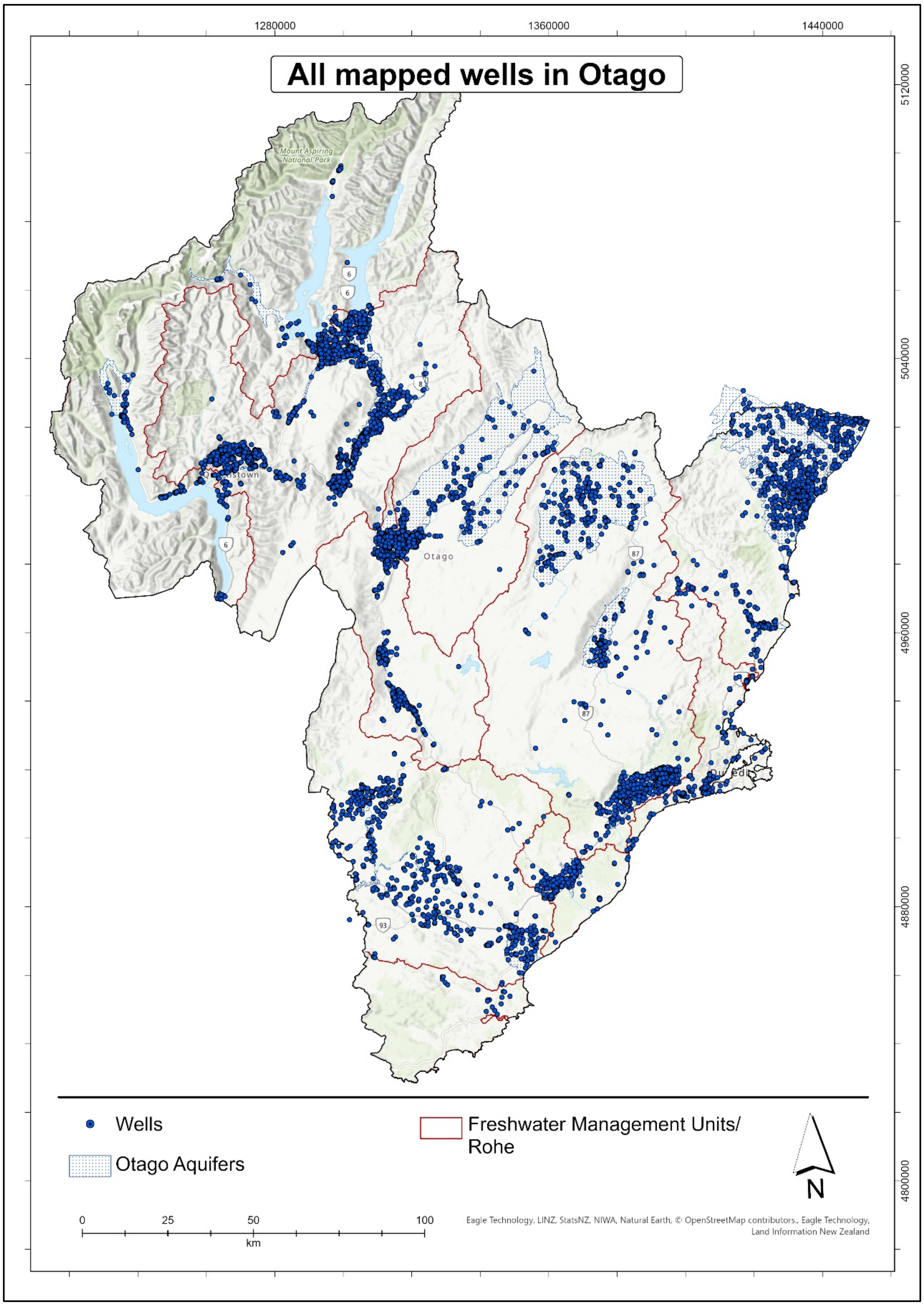

Figure 5: locations of 8,273 bores in the Otago region. Bore locations in WellsNZ are denoted as blue dots. FMU and rohe boundaries are marked in red.

GROUNDWATER-SURFACE WATER INTERACTION STUDIES

[36] A traditional function of the groundwater science team has been to undertake aquifer-specific studies to better understand aquifer properties and improve the management

of local groundwater resources. Two recent investigations have focussed on the interaction between groundwater and surface water at the Taieri Scroll Plain and the lower Kauru River.

Upper Taieri Scroll Plain

[37] The Upper Taieri Scroll Plain holds unique ecological, landscape, and cultural values. However, there is currently little knowledge regarding the influence of groundwater on the Scroll Plain wetlands and the upper Taieri River. An array of 15 bores were installed within the Scroll Plain to better understand the hydrological system through measurements of water levels, temperature, geochemistry, and calculation of groundwater flow fluxes. This work is ongoing and will feed into any future management strategy for this area.

Kauru River study

[38] A study of the interaction between surface and groundwater flow in the Kauru river has been undertaken over the past 3 years, and is presented separately (see paper GOV2506)

ONGOING PROJECTS

Recharge modelling for Otago aquifers

[39] Groundwater recharge is important for sustainable groundwater management and determining how much water can be allocated from aquifers. Aquifers get recharged from sources such as rainfall, surface water losses, and irrigation. Calculating the proportions of these sources is essential for understanding the aquifer's mass balance and allocation volumes. Current recharge information for Otago aquifers is outdated, based on a report from over a decade ago, using the Rushton soil moisture balance model[9].

[40] This project aims to update the recharge estimates for Otago’s aquifers. ORC is commissioning a consultant to integrate the Rushton methodology into a regional recharge model. The project will use recent satellite and climate data, along with statistical methods. The model will provide more up-to-date recharge estimates, helping to sustainably manage Otago’s groundwater resources.

Ettrick Groundwater Model

[41] The South Ettrick Basin aquifer is almost fully allocated, in addition to hosting the Benger Burn River which has high in-stream values. To ensure ORC is sustainably allocating from the Ettrick Aquifer without adversely affecting the Benger Burn through groundwater extraction, a Modflow model is being developed in collaboration with Dr Leanne Morgan from Canterbury University to help address these questions.

Modelling Onsite Wastewater Systems across Otago

[42] Discharge from onsite wastewater management systems (OWMS) can impose significant risks to groundwater and soil quality. However, the locations of many of these systems across Otago are unknown due to their age and a historically permissive consenting approach. This causes a risk to groundwater quality and imposes challenges for ensuring new bores are drilled at adequate distances away from OWMS disposal fields.

[9] Microsoft Word - Land Surface Recharge Report

[43] An internal report modelled the location of OWMS in Otago in 2015[10]. However, many areas in the region have undergone rapid development over the past decade. To address this gap ORC is collaborating with the Environmental Science and Research (ESR) Crown Research Institute (CRI) to estimate the locations of previously undocumented OWMS across Otago. ESR contributes to this project from its Strategic Science and Investment Fund (SSIF), designed to investigate risks associated with onsite wastewater management systems, and ORC is providing data and additional funding.

[44] The locations of OWMS are modelled using spatial datasets of properties, building consents, and drinking and wastewater reticulation networks. In addition to mapping the locations of OWMS across Otago, this project will also model their density and associated loads of nitrogen and phosphorus. This information will be key to ORC's groundwater and soil quality science programmes. The work is expected to be completed before July 2025.

Modelling reference conditions for groundwater nitrate concentrations

[45] Nitrates in drinking water is gaining significant international attention due to potential health risks. With a few well documented exceptions, nitrate concentrations in Otago Groundwater are within the drinking water guidelines[11]. However, nitrate concentrations remain a key focus of the SOE monitoring.

[46] There is increasing national interest in establishing reference conditions for a range of environmental measurements, which involves estimating the water quality or quantity expected in the absence of human activity. In some cases natural conditions can generate high concentrations of parameters such as sediment, nutrients, or bacteria. Understanding groundwater reference or background nitrate concentrations is therefore important to assess the impact of human activities on groundwater nitrate concentrations and their changes over time.

[47] ORC has recently established a project to estimate nitrate reference conditions using the following three methods:

- Hierarchical Cluster Analysis (HCA), which groups groundwater into various facies based on similarities in their water chemistry. These are based on ORC's groundwater quality SOE data, analysed by the Institute for Geological and Nuclear Sciences (GNS) CRI through an EnviroLink grant.
- Groundwater age and its correlation with nitrate concentration. Groundwater age has been sampled across Otago in collaboration with GNS for the past 25 years, and it provides important data for understanding groundwater dynamics and modelling. Additional intensive sampling campaigns in collaboration with GNS have taken place over the past 2-3 years, which will augment previous aging data from across Otago.
- Analysis of the relationship between nitrate concentrations and land-use intensity. This will use modelled nutrient losses from different land uses, which was conducted for the LWRP.

[48] The results of this project will then be combined with the SOE data to help understand the relation of current groundwater nitrate concentrations to natural state and potentially help set future targets for groundwater nitrate concentrations.

[10] groundwater-contamination-risk.pdf
[11] https://www.orc.govt.nz/media/9785/otago-groundwater-soe-report-march-2021.pdf

Stygofauna sampling (with ESR)

[49] Stygofauna are an unusual group of organisms who live in groundwater. There is not a great deal known about them, but documenting stygofauna has been the focus of a recent project led by ESR.

[50] ORC is collaborating with ESR to advance the understanding of Otago's groundwater ecosystems by collecting specimens and water samples from some of our SOE bores. The samples are analysed by ESR using various techniques such as microscope identification and environmental DNA (eDNA).

[51] Although documenting and analysing stygofauna is a relatively new field, sampling the occurrence and diversity of communities that live within groundwater ecosystems will position the region well as the understanding of stygofauna develops. For example, the presence or absence of certain species may develop as an indicator of groundwater health.

[52] To date, samples were collected in Central Otago, North Otago, the Maniototo, and the Catlins, with repeat samples collected from several bores. A selection of the species found in Otago groundwater is shown in Figure 6.

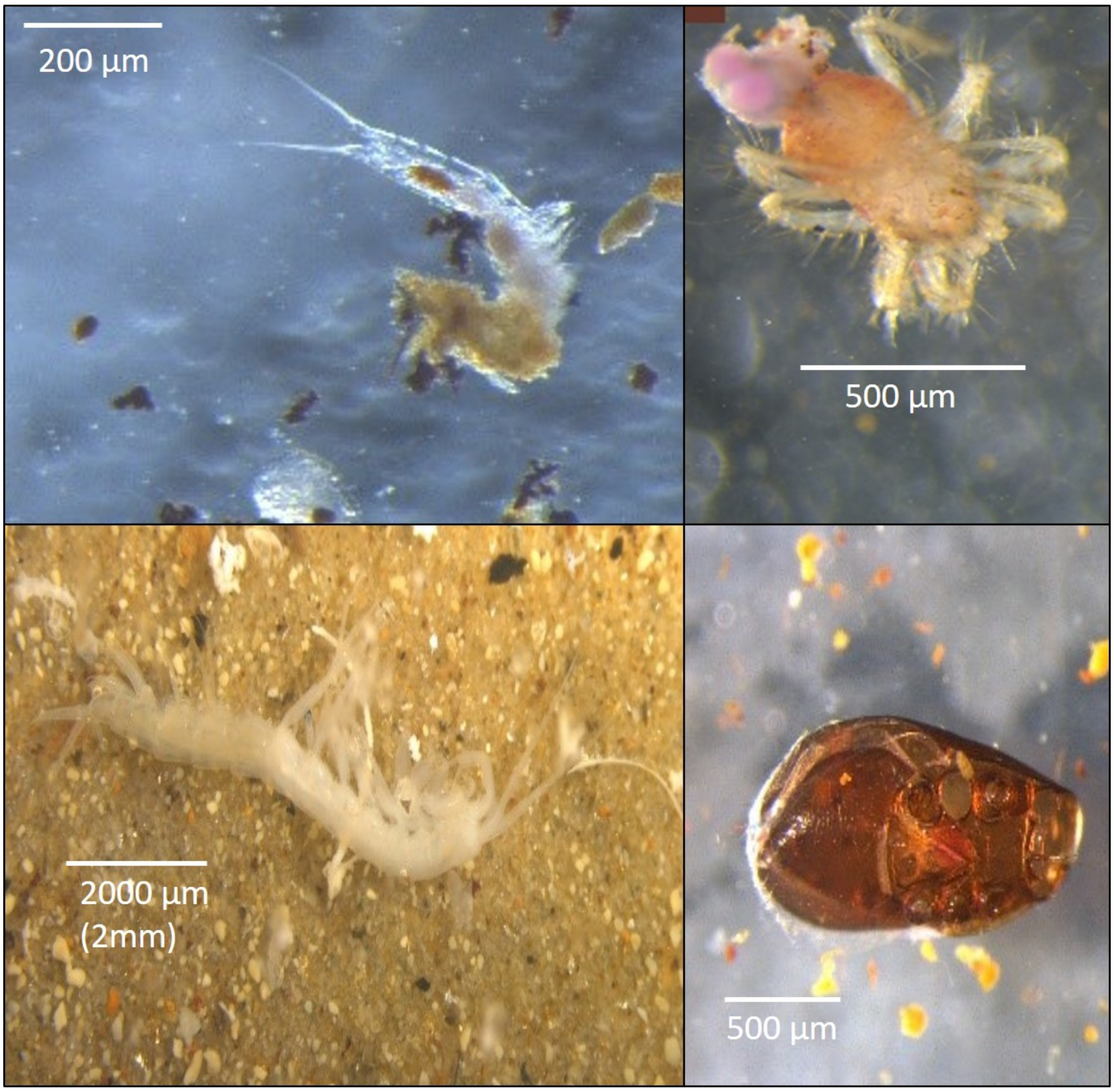

Figure 6: examples of stygofauna collected from ORC's monitoring bores (photos kindly provided by ESR and are displayed with their permission)

OPTIONS

[53] This paper is for noting only

CONSIDERATIONS

Strategic Framework and Policy Considerations

[54] The work described in this paper contributes to advancing ORC's strategic direction particularly the environmental goals:

- Ecosystems are healthy, our water and air are clean, and biodiversity loss is arrested across the region.
- We predict and address emerging environmental issues before they arise.
- Our regional plans are effective at ensuring our resources are managed sustainably within biophysical limits in a planned and considered way.

Financial Considerations

[55] The groundwater programme is a funded and planned work stream within Science budgets.

Significance and Engagement

[56] N/A

Legislative and Risk Considerations

[57] Monitoring and reporting source water quality is a requirement under the Water Services Act 2021 and Water Services (Drinking Water Standards for New Zealand) Regulations 2022.

Climate Change Considerations

[58] The projects described in this paper will help ORC to better understand the impact of climate change on groundwater recharge and levels and help develop better models which will help the region to better adapt to it.

Communications Considerations

[59] This update paper will be shared with relevant stakeholders.

NEXT STEPS

[60] The projects will continue as outlined

ATTACHMENTS

Nil