

BEFORE THE ENVIRONMENT COURT
AT CHRISTCHURCH

I MUA I TE KOOTI TAIAO O AOTEAROA
ŌTAUTAHU ROHE

ENV-2024-CHC-

IN THE MATTER	of the Resource Management Act 1991
AND	in the matter of an application for an enforcement order or orders under section 316 of the Act
BETWEEN	OTAGO REGIONAL COUNCIL
	Applicant
AND	QUEENSTOWN LAKES DISTRICT COUNCIL
	Respondent

AFFIDAVIT OF T [REDACTED] ZAEGE

Affirmed 24 December 2024

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Solicitor: K J Logan	

AFFIDAVIT OF T [REDACTED] ZAEGE

I, T [REDACTED] ZAEGE of Auckland, Senior Engineering Geologist solemnly and sincerely affirm:

Qualifications and Experience

1. I hold a Master of Science degree in Applied Geoscience, obtained from Karlsruhe Institute of Technology in 2016.
2. I am a engineering geologist and hydrogeologist with eight years' experience. I have worked in this role in New Zealand and Germany. I am a Senior Engineering Geologist with Mott MacDonald, responsible for conducting geotechnical and hydrogeological investigations and assessments, including dewatering and settlement effects reports, construction monitoring and quality assurance as well as seepage evaluations.
3. I **attach** my curriculum vitae as Exhibit "A".

Code of Conduct

4. I confirm that I have read the Code of Conduct for Expert Witnesses as contained in the Environment Court's Practice Note of 2023 and agree to comply with it. I have complied with the Practice Note when preparing my affidavit, and will do so if and when I give oral evidence.
5. The data, information, facts and assumptions I have considered in forming my opinions are set out in my evidence to follow. The reasons for the opinions expressed are also set out in the evidence to follow.
6. Unless I state otherwise, this evidence is within my sphere of expertise and I have not omitted to consider material facts known to me that might alter or detract from the opinions that I express.

Material Considered

7. In preparing my evidence have considered the following documents:
 - 7.1. Beca. (2023). Shotover WWTP Disposal field report.

- 7.2. e3 Scientific. (2024). Project Shotover, Wastewater treatment and disposal system - Environmental Impact Assessment.
- 7.3. Heron, D. (2014). Geological map of New Zealand 1:250,000.
- 7.4. Hoon Y Jeong, S.-C. J. (February 2018). A review on clogging mechanisms and managements in aquifer storage and recovery (ASR) applications. Geosciences Journal.
- 7.5. Lowe Environmental Impact. (2016). Shotover Wastewater Treatment Plant - Variation to discharge of treated sewage to land and landuse consent conditions and assessment of environmental effects.
- 7.6. Lowe Environmental Impact. (2020 - 2023). Shotover Wastewater Treatment Plant - Annual report.
- 7.7. Mott MacDonald. (2024). Shotover WWTP Enforcement - Technical Assessment - Shotover WWTP.
- 7.8. Otago Regional Council. (2017). Decision on Resource Consent Application No. RM16.116 Variation to RM13.215.03, 2008.238, 2008.242 and 2008.243.
- 7.9. Potts, R. (2018). DAD - an innovative dose and drain land dispersal system.
- 7.10. QLDC. (2024). Shotover WWTP Effluent Disposal Field - Update June 2024.
- 7.11. QLDC. (August 2024). Shotover WWTP effluent disposal field - Update.
- 7.12. Vermaas, Lane. (n.d.). Shotover delta dose and drain effluent disposal system.
- 7.13. WSP. (2022). Memorandum - *Post trench mitigation water level assessment*.
- 7.14. Review of Shotover WWTP Enforcement Technical Assessment – Shotover WWTP Compliance (GHD Technical Memorandum, dated 10 December 2024, provided on a without prejudice base).

- 7.15. Draft Shotover Wastewater Disposal - Short term improvement option (GHD Memorandum dated 16 December 2024, provided on a without prejudice basis).

Scope of Evidence

8. The scope of this evidence relates to the following matters:
- 8.1. Review of initial design of the Dose and Drain Disposal Field (the **DAD**) to which treated wastewater is discharged from the Shotover Wastewater Treatment Plant (**WWTP**).
 - 8.2. Review of modifications to the DAD undertaken to date.
 - 8.3. Assessment of geological and hydrogeological design parameters of the DAD.
 - 8.4. Review of hydraulic performance of the DAD under given effluent inflows and geological setting.
 - 8.5. Recommendations for design adaptations the DAD to handle inflow under resource conditions, including projected future inflow.
 - 8.6. Providing a report summarising the conducted assessments of the DAD and recommendations.

Report

9. I **attach** my report "Shotover WWTP Enforcement, Dose and Drain Disposal Field – Performance Review" as Exhibit "**B**". I confirm the contents of the report are trust and correct.

Conclusion

10. Having reviewed the referenced information, the following is concluded:
- 10.1. The DAD infiltration rate is significantly lower than designed for due to the hydrogeological setting and continuing clogging of soil underlying the DAD, thereby causing ponding and overflowing into the environment.

- 10.2. Inspecting and excavating potentially clogged soil requires draining the ponded effluent into the surrounding area / river and diverting effluent flow from the WWTP for extended periods until remediation works are done. Even with the removal of clogged soil, ponding is likely to continue due to the naturally shallow groundwater table. Therefore, temporarily draining and excavating is not recommended.
- 10.3. The appearance of wastewater ponding and flowpaths in the Shotover Delta area could be improved by filling the ponded areas and flowpaths with aggregate.
- 10.4. Backfilling the DAD is expected to exacerbate ponding if no extensive ancillary measures are taken, such as limiting effluent inflow or increasing the depth of the DAD. However, the naturally low infiltration rate is likely to favor recurring clogging and thereby necessitating frequent cleaning measures.
- 10.5. Ponding is therefore likely to continue if the DAD is backfilled. We recommend considering a partial deviation from resource consent conditions (20) and (21) by permitting surface ponding. However, any ponding that leads to an overflow needs to be in a controlled manner with additional measures undertaken to manage overflows e.g. minimise overflows and safely conceal or bury any overflow channels where possible.
- 10.6. For the future DAD operation until a permanent solution is implemented, focus should be given to limiting overflow discharge into the surrounding area and river.
- 10.7. I recommend undertaking measures to limit the effluent inflow into the DAD as outlined in my report attached as **Exhibit B**, thus minimizing potential perimeter bund breaches and overflow.
- 10.8. Measures should be undertaken to strengthen the perimeter bund to prevent uncontrolled overflow.
- 10.9. If overflow cannot be prevented, it should occur in a controlled manner and within buried channels but kept to a minimum.

- 10.10. The environmental impact of the deviation from resource consent should continuously monitored via regular groundwater and river water sampling.
- 10.11. I recommend the development and implementation of a long-term disposal field solution within 2 years. This is likely to require the replacement of the DAD with an alternative disposal system.
- 10.12. The assumptions, assessments and conclusions drawn to support the aforementioned recommendations are outlined in the report provided as 'Exhibit B'.

Affirmed at Auckland this 24th day
of December 2024 before me:

) [Redacted]
) [Redacted]
T [Redacted] Zaege

A Solicitor of the High Court of New Zealand

[Redacted]

M.B. Burnell, JP
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Justice of the Peace for New Zealand

14/ [Redacted] Burnell

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24/12/2024

[Handwritten signatures]

"A"

This is the exhibit marked "A" referred to in the affidavit of Tobias Maximilian Zaege affirmed at Auckland this 24th day of December 2024.

NAME

Before me:

M.B. Burnell

Margaret Beatrice Burnell

T. [REDACTED] ZAEGE

Justice of the Peace

M.B. Burnell, JP

#94292

AUCKLAND

Justice of the Peace for New Zealand

24/12/2024

Profession	Engineering Geologist
Specialisation	Transport
Position in Group	Senior
Year of joining Group	2023

KEY QUALIFICATIONS

Eight years of experience as engineering geologist and hydrogeologist. Expertise in planning and undertaking site investigations (hydraulic testing, soil probing, core logging) and on-site monitoring of earthworks, foundational design, soil stability analyses, groundwater management and hydrogeological assessments such as drawdown and permeability evaluations as well as well design. Further work involved the assessment of contaminated soils and structural vibration monitoring.

EDUCATION AND PROFESSIONAL STATUS

MSc Applied Geosciences, Karlsruhe Institute of Technology, 2016

BSc Geosciences, Technical University of Munich & Ludwig-Maximilians University Munich, 2013

EXPERIENCE RECORD

2023 – present	MOTT MACDONALD NEW ZEALAND LIMITED Senior Engineering Geologist
2016 - 2023	Sakosta GmbH
2018 - 2023	Project Manager
2017 – 2018	Junior-Project Manager
2016 – 2017	Trainee Geotechnics and Contaminated Land

Isabella Road WWTP and pipeline, Auckland: Geotechnical and hydrogeological advisor to support the resource consent application under the Auckland Unitary Plan (AUP) / Resource Management Act (RMA). Scope of work included modelling the required groundwater drawdown for the proposed pipeline and wastewater treatment plant and evaluating the associated drawdown and settlement effects on sensitive structures and wetlands nearby. Based on the results, monitoring and mitigation measures were proposed to address potential negative impacts on affected structures. Additionally, a compliance assessment of the proposed construction against AUP Standards was conducted.

Rotorua WWTP, Rotorua: Geotechnical and hydrogeological advice to Rotorua Lakes Council for the proposed wastewater treatment plant. A hydrogeological assessment was conducted to evaluate possible causes and mitigation measures of a flooded sheet piled excavation. This included assessments of groundwater influx rates and hydraulic heave calculations. Additionally, a geotechnical risk assessment was conducted for the proposed re-purpose of an existing pump station to accommodate a replacement WWTP.

T.B. B.S.

Oruarangi Stormwater Treatment Wetland, Auckland, New Zealand: Technical advice for the resource consent application for a proposed stormwater treatment wetland under the Auckland Unitary Plan. The dewatering and ground settlement effects associated with the groundwater drawdown and construction were assessed. A 2D-hydrogeological ground model was established in Seep/W and the change in groundwater level over time modelled. Based on the computed drawdown curve and associated change in porewater pressure, the consolidation settlement was calculated. Additionally, settlement effects from excavation were calculated. Based on these results, a risk assessment for nearby structures was undertaken and mitigation measures against excessive ground movement proposed.

Snells Beach WWTP – Overflow management system, Auckland, New Zealand: Geotechnical investigations comprising hand augers, piezometer installation and slug testing to derive and interpret a geotechnical ground model and design parameters for an overflow management system. The collected data was used to assess ground bearing strength, slope stability and hydrogeological implications for the proposed development.

Mill Flat Road Bridge Renewal, Auckland, New Zealand: Conducting and interpreting geotechnical investigations for a bridge renewal and highway widening. Investigations comprised machine boreholes, hand augers, test pits, piezometer installation and CPT-tests. The collected data was used to establish a geotechnical ground model and derive geotechnical parameters. The results are used for slope stability assessments, preliminary highway design as well as preliminary pile design. The on-site support required coordination between multiple drilling rigs as well as traffic management. As the current bridge is temporary, the results for the permanent replacement needed to be delivered fast while maintaining high level of reliability.

Baroota Reservoir, South Australia: Hydrogeological advisor for the assessment of dewatering effects of Baroota Reservoir. As part of the ongoing de-commissioning assessment of Baroota Reservoir in South Australia, the effects of dewatering the reservoir on local groundwater table were evaluated. Five cross-sections covering the reservoir and surrounding region were prepared and transient two-dimensional seepage models created. The models estimated the reduction and extent of groundwater table with lowering the water table in the reservoir. To create realistic conditions, the effects of rainfall recharge were included in the model. The model supports the decision process by allowing an estimation of effects for nearby agriculture.

Siemens-Tower Munich Germany: Project lead as geotechnical and hydrogeological advisor. Geotechnical and hydrogeological assessment for the refurbishment and extension of existing building including a 5 sub-level parking garage and horizontal geothermal well. Site investigation and geotechnical assessment of a proposed 16 m deep parking garage adjacent to an existing office tower. Geotechnical parameters and a settlement analysis was conducted for the proposed parking garage. Additionally we assisted in planning of the retaining walls (combination of sheet piles and bored piles). The refurbished building was going to be heated by geothermal groundwater use. A hydrogeological assessment of the aquifer was conducted by installing a 25 m deep observation well and conducting hydraulic pump tests. Based on the results a hydrogeological ground model for the area was developed and the geothermal potential was assessed. The maximum potential extraction of groundwater was calculated to avoid interference with existing wells in the area. Ultimately a 23 m deep horizontal well with two 25 m long lateral lines was planned. As part of the planning process, the groundwater chemistry was assessed for potential contaminants and well clogging.

Tyrolit GmbH, Munich, Germany: Geotechnical and hydrogeological project lead for the geotechnical design of an office building and associated stormwater disposal field as well as groundwater supply. The scope of work included geotechnical investigations comprising machine boreholes to identify underlying ground conditions, installing a monitoring well and conducting a hydraulic pump test to assess hydrogeological properties. Additionally, infiltration testing was undertaken for the subsequent design of a buried stormwater disposal field. Based on the gathered ground information, a concept for stormwater disposal comprising buried soakage cells was developed and implemented. The design considers 1% ARI-rainfall events and potential stormwater contamination.

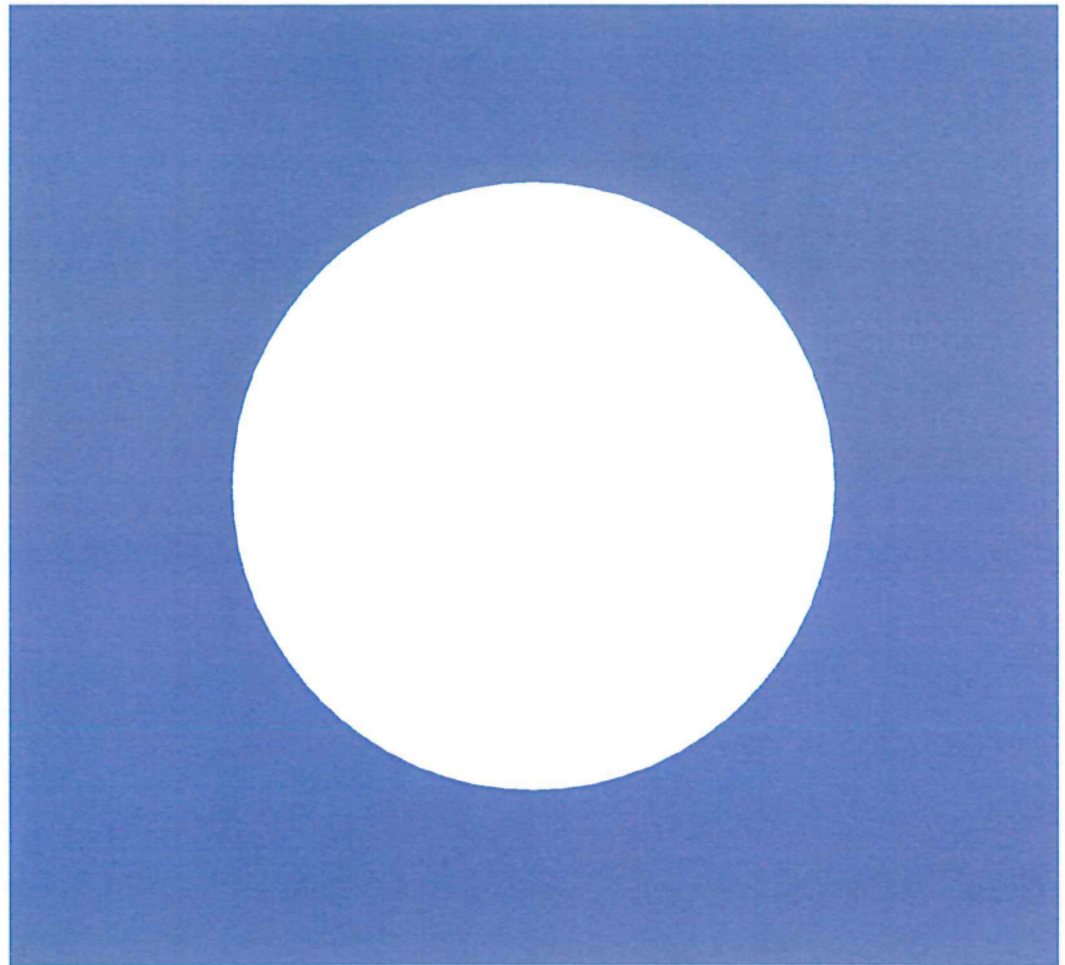


Alexisquartier Munich, Germany: Geotechnical project lead for the geotechnical, hydrogeological and soil contaminant investigations and assessments of a 110.000 sqm refilled quarry for the subsequent building of +20 residential buildings and +400 apartments. The existing landfill was heavily contaminated with predominantly PAH and MOH and posed a heterogenous, unconsolidated and settlement-sensitive subgrade. After conducting various geotechnical investigations and settlement analysis, a foundation method of bored piles combined with reinforced gravel rafts was developed. There was fear, that the earthworks could mobilise soil contaminants, causing them to leach into the groundwater. Multiple observation wells were therefore constructed, and the groundwater chemistry was monitored on a fortnightly basis.

Project Horus Sentilo, Machtlfinger Strasse, Munich, Germany: Geotechnical and hydrogeological project lead for the planned development of multiple residential and office buildings on a 45,000 m² large compound. The proposed development included up to 15 story buildings and a 5-level, up to 15 m deep parking garage. The compound is split in two by a subway tunnel. Extra care had to be given to the retaining walls for the garage surrounding the tunnel. The geotechnical assessment included ground investigations via boreholes and DCPs, development of geotechnical parameters and a settlement and ground bearing capacity analysis. As part of the project shallow geothermal groundwater use was intended. With sparse information on the groundwater conditions a 25 m deep observation well was constructed, and the groundwater levels measured on a regular basis. Additionally, a hydraulic pump test was conducted to assess the relevant hydrological parameters. Heating and cooling of the proposed new buildings required ~80 m³/h of groundwater extraction. The aquifer was assessed to be highly permeable but thin. With limited space for multiple vertical wells, a horizontal extraction well with two 40 m long lateral lines was ultimately planned. The assessments were supported by 3D-flow and temperature modelling. As part of the planning process, the groundwater chemistry was assessed for potential contaminants and well clogging.

LANGUAGE CAPABILITY

English : Spoken – fluent; written - fluent; reading - fluent
German : Mother tongue



Shotover WWTP Enforcement

Dose and drain disposal field - Performance
review

December 2024

This is the exhibit marked "B" referred to in the affidavit of T [REDACTED] Zaege
affirmed at Auckland this 24th day of December 2024.

Before me:

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Shotover WWTP Enforcement

Dose and drain disposal field - Performance
review

December 2024

A handwritten signature in black ink, appearing to be 'TC' followed by a stylized flourish.

Issue and Revision Record

Revision	Date	Originator	Checker	Approver	Description
A	25/11/2024	TZ	SE	DH	Working Draft – issued to client
B	03/12/2024	TZ	MR & SE	DH	Draft – issued to client
C	20/12/2024	TZ	MR & SE	ND	Final – updated following GHD response
D	23/12/2024	TZ	MR & SE	ND	Final – Revised based on Client feedback
E	24/12/2024	TZ	MR & SE	ND	Final – Revised based on Client feedback

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1 Introduction

1.1 Appointment

Otago Regional Council (ORC) has commissioned Mott MacDonald New Zealand Limited (Mott MacDonald) to undertake a performance review of the existing dose and drain disposal field of the Shotover wastewater treatment plant (WWTP) in Queenstown, Otago and evaluate options to return operation under resource consent conditions. Mott MacDonald has undertaken this work in accordance with the variation provided via email on 18 October 2024 to ORC.

1.2 Background

The Shotover WWTP utilises a dose and drain disposal field (DAD) as a final treatment stage before effluent is released into the environment. While initially performing as intended, a decline in performance was observed from 2020 onwards. The declining performance manifests as:

- Over-topping of the installed drainage trenches and surface ponding, and
- Effluent discharge through the DADs perimeter bund, notably on the southern edge.

A variety of possible causes for the ongoing issues have been stated in previous reports, including:

- Reduction of infiltration capacity of the installed drainage trenches due to clogging as a consequence of solids in the effluent
- Shallow groundwater table resulting in groundwater mounding to surface level
- Fine soil particles entering the DAD and its drainage trenches along the outer perimeter and from silt layers capping the site
- Insufficient drying time of soakage areas within the DAD after dosing intervals.

No definitive cause of the recurring ponding and perimeter breaches could yet be confirmed.

Various approaches have been undertaken, and are still ongoing, to mitigate the observed issues. Mitigation efforts undertaken include:

- Clearing the existing dosage trenches of accumulated sludge by water jetting
- Installing additional trenches to increase infiltration capacity
- Constructing a perimeter bund around the DAD to stop effluent breaches, and
- Expanding soakage areas by excavating extensive areas within the DAD.

The mitigation efforts initially succeeded in reducing the number of ponding and effluent perimeter breaches but have not remediated the situation altogether.

To provide data to assess the potential adverse effects of the surface ponding and perimeter breaching of effluent on the environment, monthly groundwater quality monitoring has been implemented and is ongoing at the time of writing this report.

1.3 Purpose of this report

The purpose of this report is to:

- review and evaluate the original DAD design concept, its input parameters and undertaken mitigation measures to date to assess potential causes of the ongoing problems and
- evaluate options to make DAD operations compliant with resource consent requirements.

It is understood the DAD will be decommissioned in 2028 and replaced by a permanent effluent disposal system.

1.4 Scope and limitations

1.4.1 Scope of review

The following was undertaken as part of the performance review:

- Review of initial design and undertaken modifications to date
- Assessment of geological and hydrogeological design parameters
- Review of hydraulic performance under given effluent inflows and geological setting
- Recommendations for design adaptations to handle inflow under resource conditions, including projected future inflow
- Providing a report summarising the conducted assessments and recommendations

1.4.2 Assumptions and limitations

The scope of this report is limited to a performance review of the existing 'Dose and Drain' disposal area. All the information provided in this report is obtained from various publicly available information sources, from the client and from previous projects in similar geology and location. It must be appreciated that the actual conditions may vary from the shown data. There may be special conditions pertaining to this site that have not yet been disclosed and not been considered in this report.

The following limitations apply to this review:

- Uncertainties and gaps in the groundwater monitoring data means there is uncertainty in the assessed natural groundwater levels and the potential impact of effluent discharge.
- There is uncertainty over the achievable infiltration rate across the site, as previous investigations relied on particle size analysis (PSA) assessments and no in-situ infiltration testing has been undertaken.
- No monitoring data is provided on groundwater levels outside the DAD from ORC bores, creating uncertainty about natural groundwater levels and flow conditions.

Due to the gaps in data and lack of in-situ testing, groundwater mounding and water level rises due to dosing cannot be predicted with certainty. More assessments and monitoring will be required to inform detailed design of proposed mitigation measures.

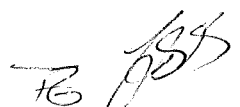
1.5 Resource consent conditions

The resource consent discharge permit (Otago Regional Council, 2017) allowed for the operation of the DAD. Relevant resource consent conditions for this performance review are as follows:

3. The volume of wastewater discharged to the disposal field shall not exceed:
 - a) An annual average of 11,238m³ per day; and
 - b) A maximum discharge loading rate averaged over the disposal field area of 1,000mm per calendar day based on the total area of the disposal field
20. No ponding or surface run-off of treated wastewater shall occur as a result of the exercise of this consent
21. Mounding of groundwater:

- (i) Above the ground surface shall not occur in cumulative area greater than 100m² over the entire disposal area for more than 48-hours in any one event.
 - (ii) As a result of the exercise of this consent shall not result in surface breakthrough after the initial 5 year mounding trial period following the commencement of this consent.
22. In accordance with Sections 128 and 129 of the Resource Management Act 1991 Condition 20 and 21 shall be reviewed after a 5-year trial period for the purpose of dealing with any mounding issues, such as reassessing the area of acceptable mounding, testing the quality of mounded water to determine risk, or assessing the need for fencing and/or signage.

The DAD currently operates in breach of conditions 20 and 21. Therefore, ORC has issued an abatement notice.

Handwritten signature and initials, possibly 'FS' and '76', in the bottom right corner.

2 DAD Overview

2.1 Setting

The DAD is part of the Shotover WWTP. It is situated roughly 50m south-east of the WWTPs oxidation ponds and roughly 50m west of the Shotover River delta. An aerial image is presented in Figure 2-1 below. The overall area of the DAD is 28,000m². The finished ground surface of the DAD varied between roughly 313mRL in the north and 312mRL in the south after construction finished but has been altered following the undertaken remediation works.

The adjacent Shotover River flows in a north to south direction to the east of the WWTP. The Shotover River terminates into Kawarau River roughly 600m south of the DAD.

Figure 2-1: Aerial overview of the Shotover WWTP.



Source: Queenstown Lakes District Council – Spatial Data Hub.

2.2 DAD design and mitigation works

The DAD is the final effluent treatment stage of the Shotover WWTP. It receives 80% of its total inflow from the treatment plants MLE reactor and 20% from the plant's oxidation ponds (Beca, 2023). The effluent is dispersed within dosage trenches where it infiltrates into the existing

EG

ground before mixing with groundwater and being transported away with natural groundwater flow.

Originally, the DAD comprised of eleven individual soakage sectors, each consisting of one pair of t-shape arranged storage cells. The storage cell pairs are stepped down in 100mm increments, starting from 311.5mRL embedment depth in the north to 310.5mRL in the south (Potts, 2018). Each storage cell was embedded in 0.5m of gravel and surrounded on both sides by 1.0m wide trenches of high-void gravel to increase infiltration rate and side-wall dispersal. A geocloth was placed on top of the cells and accompanying trenches (Lowe Environmental Impact, 2016). The number of sectors active at any time depends on amount of inflow coming from the WWTP. Each sector is dosed for a set amount of time, then switched off to allow for drying. At maximum flow rate, all sectors can be dosed simultaneously. The current dosing and drying intervals are unknown.

Groundwater mounding during dosing was estimated to potentially raise the static groundwater table by 0.98m to 1.39m in the DAD centre and 0.83m to 1.17m at its edges, depending on average daily flow. To accommodate the effects, the surface level of the DAD was raised by 1.5 – 3.0m to a final level of roughly 313 - 312mRL. Based on investigation data of that time, the storage cells were placed roughly 1m above assumed average groundwater level.

In 2021, as part of the undertaken mitigation efforts, relief trenches have been added to the storage cells to further increase infiltration area. The natural ground along the trench length was excavated, backfilled with gravel and wrapped in geocloth to prevent accumulation of fine particles (WSP, 2022).

- Excavation of the DAD base and operation as a large soakage basin, undertaken to increase infiltration surface area.
- Construction of a bund to allow ponding higher than the DAD design level, thus creating additional storage capacity and increasing the vertical hydraulic gradient to aid infiltration.
- Construction of an overflow relief at the eastern extent to create storage and a controlled effluent discharge to a historical river channel.

It is noted, that the release of discharge occurs during periods when overtopping of the DAD would otherwise risk scouring and failure of the embankment.

To monitor groundwater levels during DAD operation, a total of eight piezometers are installed across the site, labelled Bore 1 to Bore 8. Additionally, the dosage trenches and relief trenches are equipped with multiple monitoring wells each to observe water level rise during dosing.

A schematic drawing of the DAD is presented in Appendix A.

Key dimensions of the DAD are presented in Table 2-1 below.

Table 2-1: Key DAD dimensions.

DAD	Dimension
Available area	28,000m ²
Number of dosing trenches	22 (11 pairs)
Dosage trench length	73m
Combined length of dosage trenches	1,606m
Dosage trench width	2m
Dosage trench width (including gravel trenches on side)	4m
Dosage trench area	3,212m ²

DAD	Dimension
Dosage trench area (including gravel trenches on side)	6,424m ²
Depth of storage cells	1mbgl 311.5mRL (north) – 310.5mRL (south)

2.3 Effluent inflow

The DAD was sized based on a design infiltration rate of 5m/d, which includes a factor of safety of 2 from the assessed possible infiltration rate to account for TSS:BOS in the effluent. It was designed to accommodate a peak effluent inflow / dosage rate of up to 430l/s or 37,150m³/d (Potts, 2018). This corresponds to a maximum infiltration rate of roughly 40l/s per soakage sector (Lowe Environmental Impact, 2016).

According to the provided annual WWTP reports (Lowe Environmental Impact, 2020 - 2023), the average effluent discharge varied between 8,679m³/d and 9,995m³/d from 2020 to 2023, with recorded maximum daily discharges between 14,643m³ and 19,402m³.

The measured Total Suspended Solids (TSS) in the effluent varied between 4.6g/m³ (2021) and 17g/m³ (2023) in the same timeframe, averaging around 9 – 10g/m³.

The predicted maximum daily flow in 2028, when the current DAD will be replaced by a permanent solution is 24,600m³/d, with a predicted average daily flow of 14,300m³/d (Beca, 2020).

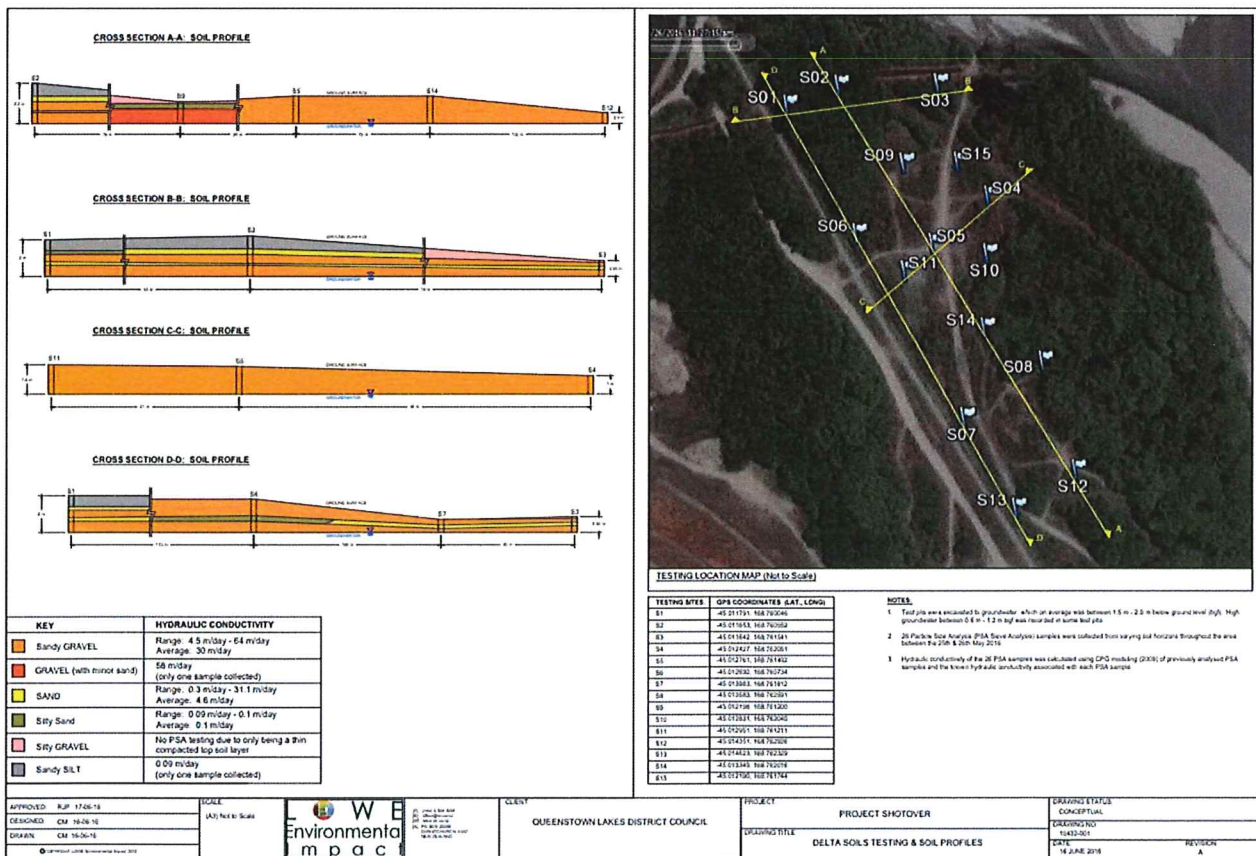
3 Geology and hydrogeology

3.1 Geology

According to the 1:250,000 geological map of New Zealand (Heron, 2014), the site is located within Holocene river deposits comprising loose, commonly angular, boulders, gravel, sand and silt forming alluvial fans.

As part of the DAD design report (Lowe Environmental Impact, 2016) a total of fifteen test pits have been dug to groundwater level, ranging between 0.5m and 2.2m below ground level (mbgl). The encountered ground generally comprised gravel to sandy gravel with thin layers of sand and silty sand interbedded. At higher elevations in the north, a maximum 0.6m thick capping layer comprising sandy silt (silty gravel in the northeast) was encountered. Conceptual ground models (Lowe Environmental Impact, 2016) are presented in Figure 3-1. The deltaic sediments extend to roughly 15mbgl (Lowe Environmental Impact, 2016).

Figure 3-1: Conceptual ground models at the DAD (Lowe Environmental Impact, 2016).



3.2 Hydrogeology

3.2.1 Hydrogeological design parameters

The saturated hydraulic conductivity of the existing soils was assessed by conducting particle size analyses (PSA) of a total of 26 samples and evaluating them against a previously

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concluded relationship between particle size and conductivity as part of a report by CPG NZ Ltd (CPG). In the CPG report, soil samples were collected across the river delta and conductivity testing as well as particles size assessments (PSA) undertaken. The results indicated a saturated hydraulic conductivity k_{sat} of the delta material between 10m/d and 100m/d.

The PSA assessment results for each encountered layer are given in Figure 3-1, they range between 4.5m/d and 64m/d for the sandy gravels. Encountered sand and silty sand layers show average hydraulic conductivities of 4.6m/d and 0.1m/d respectively. It must be noted that no infiltration testing was undertaken as part of the DAD design. The PSA results were used to predict infiltration (Lowe Environmental Impact, 2020 - 2023).

The following hydrogeological parameters were presented as part of the DAD design (Lowe Environmental Impact, 2016), Table 3-1:

Table 3-1: Hydrogeological parameters (Lowe Environmental Impact, 2016).

Parameter	Value	Investigation method
Saturated vertical hydraulic conductivity k_{sat}	10m/d assumed across the DAD field	PSA correlations
Groundwater depth	1.2 – 2.0mbgl, average 1.5mbgl	Test pits
Transmissivity T	5,000m ² /d (e3 Scientific, 2024)	Pumping test*
Saturated horizontal permeability $k_{sat,h}$	400m/d (Lowe Environmental Impact, 2016) 350m/d (e3 Scientific, 2024)	Pumping test*
Specific yield S_y	0.1 – 0.25	Literature recommendations
Saturated aquifer thickness	15m	Report by Duffill Watts (2008)**

*test procedure and interpretation are not provided in reviewed reports

**report was not reviewed, values are provided in (Lowe Environmental Impact, 2016)

3.2.2 Groundwater levels and gradient

Groundwater levels have been monitored in Bores 1 – 8, starting from the commissioning of the DAD in 2019. With the exception of Bores 3 and 6, all piezometers are located outside the dosage area and storage cells. The monitoring records from the piezometers outside the DAD were plotted against rainfall data and WWTP discharge, see Appendix B.1 and B.2, to try to identify natural groundwater levels without the influence of groundwater mounding. Bores 3, 5 and 6 have been identified to show a stark response to dosing (WSP, 2022). Their data has therefore been omitted from the plot. Note, no groundwater monitoring data is available between August and September 2023 for all bores as well as starting from June 2024 onwards for bores 2, 4, 5, 7 and 8.

Overall, the measured groundwater levels between bores are aligned approximately parallel and show a strong correlation to rainfall events and dry periods. Rising groundwater levels align with heavy rainfall events i.e. indicating a fast response of the aquifer. Between individual groundwater bores, differences in response are limited to roughly 0.2m.

As the WWTP effluent discharge also corresponds with rainfall events, a similar trend between discharge and groundwater level can be observe, however, in a subdued and non-uniform manner. Notably, starting from September 2022, groundwater level and effluent discharge appear less correlated.

The available data indicates the groundwater level being primarily influenced by precipitation. No discernible influence of groundwater mounding due to dosing can be observed. As soakage sectors are dosed at intervals, a time delay / lag between groundwater peaks would be expected but has not been observed. This could be possibly due to groundwater mounds dispersing quickly or the bores being outside the zone of influence.

Starting from Summer 2021, groundwater levels in Bore 2 and 4 become closer in measured level yet increased in difference compared to Bore 1. This could be an effect of the ongoing mitigation works, such as the installation of relief trenches. However with longer term data missing, a definitive trend cannot be identified. Also, from August 2022, the difference in groundwater level between Bore 7 and Bore 8 is measured at mostly less than 1mm. Given the distance between bores, the integrity of the provided data is doubted and will be disregarded.

To evaluate natural groundwater levels across the DAD, the monitoring data from Bore 1, 2, 7 and 8 pre-July 2021 is used, providing roughly 2.5 years of data.

The following groundwater levels can be summarised, Table 3-2.

Table 3-2: Assessed groundwater levels.

Bore No.	Average groundwater level [mRL]	Highest measured groundwater level [mRL]	Average high groundwater level* [mRL]	Lowest measured groundwater level [mRL]	Embedment depth of nearest storage cell [mRL]
1	311.2	312.2	311.5	310.8	311.5 (Sector 1)
2	311.1	312.1	311.5	310.0	311.2 (Sector 4)
7	310.7	311.4	311.0	310.0	310.8 (Sector 8)
8	310.3	311.1	310.6	310.0	310.5 (Sector 11)

*calculated as the highest groundwater level for each month of measurement divided by the number of months.

As the groundwater levels were measured during DAD operation, an impact from effluent discharge and groundwater mounding cannot be fully excluded nor can it be confirmed, whether the groundwater table in the observed bores is generally elevated by the discharge or if it represents the natural groundwater level.

No assessment of hydraulic gradient can be found in the design report (Lowe Environmental Impact, 2016). As part of this review, a high-level estimation at average groundwater levels was undertaken, indicating regional groundwater flow from north to south, roughly parallel with Shotover River. Due to the ongoing DAD dosing, locally disturbed flow patterns can be expected.

An assessment of existing piezometers outside the zone of influence would be required to fully assess natural groundwater levels, gradient and fluctuations.

4 Performance review

It was reported that the undertaken mitigation measures improved the DADs performance, yet breaches of resource consent are still ongoing. In September 2024 effluent overflowing and breaching the perimeter bund was observed (Mott MacDonald, 2024). As of December 2024, effluent is permanently ponded in the DAD with little infiltration noted. Overflowing effluent is steadily discharging through an outlet in the perimeter bund and openly flowing towards the Shotover River.

Groundwater monitoring data for bores located within the DAD, Bore 3 and 6, and previously identified bore to show a response to the dosing, Bore 5, is plotted against WWTP discharge in Appendix B.3. Provided an assumed ground level of approximately 312mRL in the centre of the DAD, surface ponding is observed to occur frequently and for extended periods of time in proximity to Bore 3 until the construction of relief trenches in fall 2021. Data from Bore 5 and 6 also indicate water level rising above surface, albeit to a lesser extent. Notably, a drastic rise in groundwater level is observed starting from May 2024 in Bore 3 and 6, frequently breaking surface level. It has to be noted, from September 2022 to May 2024, groundwater monitoring data from these bores show near identical values. The integrity of the data is questioned and will not be assessed going forward.

The following sections aim to assess likely causes of the experienced problems as well as evaluate options to bring DAD operation back under resource consent conditions until decommissioning in 2028.

4.1 Infiltration rate and clogging

4.1.1 Infiltration rate

4.1.1.1 Background

As stated in Section 3.2, the saturated hydraulic conductivity of the existing soils was determined by comparing PSA results with a pre-established hydraulic conductivity correlation from soil samples collected across the delta. Based on the results, a possible infiltration rate of 10m/d (5m/d including FOS = 2) was predicted. This approach is susceptible for overestimation of the possible infiltration rate as:

- Site specific conditions such as soil layering and compaction are not adequately considered
 - While the existing gravels are of high saturated hydraulic conductivity, interbedded silt or fine sand layers can reduce infiltration rate locally if present under the installed dosage trenches. A blanket infiltration rate does not consider such effects.
- Vertical hydraulic gradient is not considered
 - Infiltration rate is a product of saturated hydraulic conductivity and hydraulic gradient, with the hydraulic gradient predominantly governed by gravity and capillary suction (Massman, 2003). If the freeboard between bottom of storage cells and groundwater table is reduced, e.g. by groundwater mounding, the soils vertical hydraulic gradient and thereby infiltration rate is lowered.
- Possible infiltration rate may be significantly reduced under unsaturated conditions
 - Permeability testing and PSA assessments, as applied here, estimate the saturated hydraulic conductivity. Previously, each soakage sector underwent a drying period before being dosed again, allowing groundwater mounds to disperse. This maintained a freeboard between groundwater table and bottom of storage cells, resulting in at least

temporary unsaturated conditions. Particularly in sands and gravels, permeability can be reduced by multiple orders of magnitude if unsaturated.

4.1.1.2 Data review

It has been noted, that surface ponding has occurred at a significantly lower dosage rates than the design infiltration rate of 5m/d.

As part of the undertaken remediation works, a crude soakage test was conducted in June 2024 (QLDC, 2024). The results indicate an infiltration rate of roughly 280mm/hr or 6.72m/d. There are however no details provided on test methodology and location.

A performance review was undertaken two months after construction of the relief trenches in 2021. Key observations can be summarised as follows:

- Most sectors operate effectively at effluent inflow rates of 12,000m³/d – 13,000m³/d, correlating to 1.9 m/d – 2.0m/d, assuming equal distribution of effluent. However, localised surface ponding is observed, indicating infiltration capacities of less than 2.0m/d in certain areas.
- Groundwater rising to less than 0.2mbgl or breaking surface is considered reflective of wastewater flows exceeding 14,000m³/d, correlating to less than 40% of the design infiltration rate of 37,150m³/d across the site.
- The average specific capacity of trenches should be monitored continuously to evaluate drops in performance.
- Poor performance of sectors is localised and depending on dosage rate. Particularly, sectors in the centre of the DAD have shown lower infiltration rates.

4.1.1.3 Summary

Based on the presented information, it is concluded that the existing gravels may be of high saturated hydraulic conductivity, however the possible infiltration rate was likely overestimated by not considering effects as noted in Section 4.1.1.1. The available data suggests possible infiltration rates can be as low as 2.0m/d.

The undertaken excavation of soakage basins has significantly increased the available infiltration area, thus mitigating effects of locally present low conductivity layers. Silt layers capping the site and surrounding the dosage trenches are understood to have been removed by the excavation. Low conductivity layers might still be present underneath soakage basins and need to be investigated.

The applied factor of safety to the assumed infiltration rate of 10m/d is understood to only account for TSS loading of the effluent, not a decrease in hydraulic conductivity from groundwater mounding / hydraulic gradient or unsaturated flow conditions. For any future design changes or mitigation efforts, it is crucial to assess these effects, e.g. by conducting soakage testing and transient groundwater mounding studies.

4.1.2 Clogging

4.1.2.1 Monitoring data

The monitoring data for Bore 3, located in the centre of sector 4, shows a steady increase in groundwater levels, which does not correlate to the groundwater levels measured in neighbouring bores or the effluent discharge. The data indicates a steady decline in infiltration capacity starting from the commissioning of the DAD until a plateau is reached. In September 2021 when the relief trenches were installed, a rapid drop in groundwater level is observable.

No equivalent rise in groundwater level after commissioning is observable in Bore 6, located in the centre of sector 8. The groundwater level mostly follows the trend of bores located outside



the dosage zone. A disproportionate increase in groundwater level can be observed from April 2021 until September 2021. From September, when the relief trenches were installed, groundwater level drops, but can still be considered elevated. Note, from roughly August 2022, monitoring data from Bore 3, 5 and 6 show near identical values. The integrity of the data is questioned and an assessment of effects not possible.

Notably, from June 2024, Bore 3 and 6 show a rapid increase in groundwater level, which could be related to the recent excavation of soakage basins in sectors nearby or the growth of biofilm across the soakage basing floor. The cause cannot be confirmed at the time of this report and should be investigated via additional groundwater monitoring and an investigation of the basin floor.

4.1.2.2 Potential causes of clogging

The DAD is located within a flood hazard area (<https://gis-qldc.hub.arcgis.com>). Previous flooding events are indicated by the encountered silt and silty sand layer with the gravels and capping the site in the north.

During the remedial works in 2021, blinding layers of silty sand containing a biofilm were encountered along the soakage trenches (Lowe Environmental Impact, 2020 - 2023). It was concluded, the layer originates from the pre-existing silt capping layer, which has migrated into the open void space of the gravel trenches accompanying the storage cells. The trench water levels were observed as being between 1.5m and 1.8m higher than the adjacent groundwater level, which approximately corresponds to the observed rise in water level in Bore 3.

In addition to fine soil particles migrating into the DAD, a reduction of infiltration capacity from TSS in the effluent accumulating in the storage cells and trenches has been listed as a potential cause of clogging. The average effluent loading equvalates to roughly 10mg/l TSS and up to 40t of dry solids passing through the oxidation ponds towards the DAD per year (Beca, 2023). There are however no estimations or records of actual sludge volume being cleaned out or excavated as part of the remediation works.

4.1.2.3 Summary

Based on the provided data, it can be concluded that clogging and an associated reduction in infiltration capacity is a contributing factor in groundwater level rise and over-topping. The observed surface ponding near Bore 3 seems to be primarily caused by clogging on top of a high groundwater table. The accumulation of fine soil particles in the surrounding trenches is considered the major contributing factor. The contribution from TSS accumulating cannot be quantified and the amount and extent of clogging is yet to be verified.

As no groundwater level data is available from other sectors within the DAD, it cannot be confirmed whether observed surface ponding is due to clogging, shallow groundwater table or a naturally lower infiltration capacity.

The proportions of clogging due to fine soil particle entering and TSS sedimentation are not quantifiable. Additionally, the ongoing remediation works and lack of robust groundwater monitoring data from within the DAD create uncertainty on ongoing clogging processes. The initial DAD design is understood to have favoured the accumulation of fine particles and TSS by confining the dosage area to narrow trenches where effluent ponded and particles could accumulate. The high void gravel trenches would have provided pore volume for migrating silt and TSS to settle and hinder infiltration. Additionally, as the storage cells were buried, access and cleaning were limited.

With the excavation of soakage basins it is presumed pre-existing silt capping layers and silt layers surrounding the dosage trenches have been largely removed. This decreases the likelihood of future silt accumulation, yet precautions still need to be undertaken to prevent fine particles moving in from the side, e.g. by covering the perimeter in geocloth.



It was concluded that TSS in the effluent mainly originates from the plant's oxidation ponds (Beca, 2023). As these will be decommissioned in the near future, TSS influx is likely to decrease. Additionally, the currently ongoing Stage 3 upgrade of the WWTP is further going to decrease TSS in the effluent (Lowe Environmental Impact, 2016).

Overall, due to the undertaken excavation and projected decrease in effluent TSS content, accumulation of particles and associated clogging is expected to become less frequent. However, over time, effects can still become noticeable. Options to clear accumulated sludge should be included in future mitigation works.

4.2 Groundwater mounding and groundwater table

4.2.1 Data review

The design report (Lowe Environmental Impact, 2016) accounts for the assessed groundwater mounding but no records of a factor of safety applied to the design groundwater level accounting for seasonal fluctuations and wet weather events could be found. Due to climate change, the number and intensity of extreme weather events, such as heavy rainfall is likely to increase, leading to strong and rapid fluctuations in groundwater table. We are unsure if climate change effects have been considered in the assessments or design. Additionally, no assessment of the regional hydraulic gradient seems to have been undertaken.

The available groundwater monitoring data indicates that the groundwater table strongly and rapidly responds to rainfall events. Average groundwater levels are likely higher by multiple decimetres than identified during test pitting in the hydrogeological assessment (Lowe Environmental Impact, 2016).

A groundwater mounding assessment based on Hantush (1967) was done as part of the DAD design (Lowe Environmental Impact, 2016) using the hydrogeological input parameters as presented in Table 3-1. The estimated groundwater mound in the centre of the DAD was estimated between 0.98m and 1.56m, mounding at the edge of the field was estimated at 0.83m to 1.32m, depending on applied specific yield of 0.1 to 0.25. It was noted, that based on the design surface ponding was unlikely but not impossible, especially during wet weather events.

The conducted mounding assessment assumed an even dosing and infiltration across the entire site of 28,000m² at the assumed average design flow and an analysis period of 1 year. It has to be noted, that the input parameters differ significantly from the actual design, where 11 sectors with a combined area of roughly 6,424m² are dosed at 2-hour intervals. An adjusted groundwater mounding assessment would have been required to evaluate groundwater mounding effects more accurately in the past.

However, with the excavation of large soakage basins, the previous groundwater mounding assessment more closely resembles the current situation so that the results will be applied as described below.

4.2.2 Groundwater mounding evaluation

As shown in Table 3-2, the freeboard between assumed natural groundwater and bottom of storage cells vary between -0.7m and 1.2m, depending on soakage sector and groundwater level. At times of elevated groundwater, the storage cells are likely to be at least partially flooded. In this case, the cells storage capacity is reduced and groundwater dispersal is controlled by the regional horizontal hydraulic gradient, which is yet to be confirmed.

Applying the estimated design groundwater mounds as described above, over-topping and surface ponding across the site is possible even at average flow conditions.

This is confirmed by an undertaken high-level groundwater mounding assessment (Beca, 2023), which indicates over-topping to potentially occur at flows exceeding 14,000m³/d even if the entire site is used.

4.2.3 Summary

The review of groundwater data suggests that the groundwater table across the site is likely higher on average than assumed in the design stage. The reduction of freeboard between groundwater table and bottom of storage cells, up to partial flooding during times of high groundwater table, reduces the storage capacity of installed cells and contributes to groundwater mounds over-topping. This is a systemic issue closely relating to the hydrogeological conditions at the site. Mitigation measures are limited to an increase in infiltration area, which is being undertaken, or severely limiting the dosage rate of the DAD. A detailed transient groundwater mounding assessment accounting for groundwater table fluctuations, horizontal hydraulic gradient and considering effects on infiltration rate would be required to quantify the dosage regulation.

4.3 Dosing and drying interval

The applied dosing duration for each sector was given as two hours (Beca, 2023) before the next sector is dosed and the previous one taken offline. At times of higher flow, multiple sectors operate at once. This results in maximum drying times at low flow conditions for each sector of roughly 20 hours. If insufficient time is given between doses, groundwater mounds might not be fully dispersed and the soil at least partially saturated. This can further reduce the storage cells capacity. However, saturated hydraulic conductivity governs infiltration in this case, increasing the potential soakage rate. Further investigation is needed to adequately assess effects. In general, changing dosing routine from intervals per sector to a permanent dosing across the site is considered preferable, as it reduces the risk of clogging.

Note, following the recent remediation works, dosing and drying periods are unknown.

4.4 Summary

Based on the conducted performance review, the following can be summarised:

- Previous surface ponding incidents are likely due to a combination of:
 - Limited available area of infiltration from dosage trenches
 - Overestimation of possible infiltration rate
 - Shallow groundwater table reducing storage cell capacity.
- Groundwater table is variable with strong, rapid reactions to rainfall events. Short- and long-term fluctuations do not seem to have been included in the DAD design.
- Shallow groundwater table causes the dosage trenches and soakage sectors to be temporarily flooded, hydraulically limiting the storage capacity.
- Groundwater mounding and associated surface ponding is expected to be an ongoing issue, especially at elevated groundwater levels following rainfall events.
- TSS concentrations in the effluent are expected to decrease, lowering future risk of clogging
- Infiltration capacity of the existing soils is potentially lowered by the accumulation of biofilm
- Excavation of soakage basins reduced the risk of clogging and allowed for easier cleaning of accumulating sludge while increasing the infiltration area.
- Locally present silt or silty sand layers underneath or surrounding the dosage trenches, unsaturated flow conditions and groundwater mounding reduce the possible infiltration rate below the design value.
- Permanent dosing of the field is considered favourable.
- Additional excavation of low conductivity material is likely to increase infiltration capacity yet will not stop over-topping as it is related to the shallow groundwater table.



- Gaps in groundwater monitoring data create uncertainties in conducted cause-and-effect-assessments. It is recommended to review the provided groundwater data for integrity and re-calibrate the measurements as required to allow adequate groundwater level assessments and support mitigation design.

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5 Options & Discussion

Based on the provided data and undertaken performance review, it is concluded that surface ponding is primarily a consequence of the shallow groundwater table and lower than presumed infiltration rate. Clogging of trenches is a contributing factor but surface ponding is likely to continue even if TSS and silt sedimentation is reduced.

Under the current field size limitations, dosage rate and ground levels we conclude that surface ponding is, at the least, over periods of time, unavoidable across the site, with ponding likely to extend across larger areas, especially where infiltration capacity is lower.

The contribution from clogging is likely to decrease with proposed WWTP upgrades and undertaken excavations but options for cleaning need to be included going forward.

Breaches of resource conditions 20 and 21(i) are assessed to be continuing under the current setting. The following options are considered for operations to fulfil resource consent conditions (20 and 21(i)) until 2028 when it is expected the DAD will be decommissioned and replaced by a permanent solution. The expected peak and average flows as described in Section 2.3 will be used for the options.

5.1 Options

5.1.1 Option 1: Increasing DAD area

Groundwater mounding is largely governed by the applied dosing rate and duration over a given area. As per our conducted performance review and considering groundwater level fluctuations, including contingencies for future climate change related severe weather events, groundwater mounding would need to be reduced to approximately less than 0.5m across the site. This could be achieved by reducing the applied dosage rate per area by increasing the size of the DAD.

This option includes expanding the current DAD by clearing and excavating adjacent land, followed by installation of stormwater cells and backfilling the site to comply with resource conditions. Additionally, the currently excavated soakage basins in the DAD will need to be backfilled as well. During backfilling of the DAD, it is recommended to install additional storage cells, to increase effluent dispersal and add infiltration area.

The required extension needs to consider groundwater fluctuations by conducting further monitoring, undertaking infiltration tests to understand infiltration capacities of the existing ground and undertaking a detailed transient groundwater mounding assessment in order to adequately size the extension and embedment depths of storage cells.

As burying the storage cells is going to limit the available infiltration area per site, the installation of additional storage cells would be recommended in combination with protective measures against silt migration. Further, a bund against surface runoff should be installed to accommodate over-topping during extreme weather events.

Clogging of trenches over time can become an issue. Options for trench cleaning or an additional freeboard should be considered when sizing the field.

Overall, assuming detailed investigations and hydrogeological assessments confirm feasibility, a DAD extension in size is a viable option to meet resource consent conditions 20 and 21(i). Expanding the DAD means that construction can be integrated whilst the current WWTP still operates. Notable downsides to this method include:

- An extensive area would be required to accommodate the additional DAD area. This could conflict with the planned permanent solution.
- Investigation, design and construction time will take time, therefore limiting the operational time from commissioning to expected decommission in 2028, lowering cost-benefit value.
- Clogging from TSS sedimentation is estimated to decrease in the future yet is still understood to potentially reduce infiltration capacity over time. Re-burying the storage cells hinders access and cleaning potential, therefore increasing the risk of recurring surface ponding over time and further need to control effluent inflow.
- As the DAD is expected to extend into surrounding areas, potentially a new resource consent or S127 RMA variation may be required, requiring time and resources. Vegetation clearance and other activities may also require consents.

If this option is pursued, infiltration design modifications beyond a mere spatial extension should be considered. The time requirements for additional investigations, construction and design must be considered.

5.1.2 Option 2: Limiting effluent inflow

This option sees the DAD backfilled and returned to its original design and surface level but reducing the potential of surface ponding by limiting the inflow of effluent, especially during times of elevated groundwater tables following rainfall events. Before backfilling commences, it would be recommended to add additional storage cells and dispersal pipelines to increase infiltration area and effluent distribution.

An assessment of sustainable discharge rates would have to be conducted, taking future developments into account. Additionally, groundwater levels and clogging would have to be closely monitored and options provided to adjust effluent discharge if performance drop of the DAD is identified.

As evident from the provided data, effluent discharge is highly variable and closely related to rainfall intensity. Merely reducing WWTP discharge in response to changing groundwater levels is not considered feasible. Additional effluent storage would have to be created to temporarily withhold effluent from being dispersed in the DAD. Possible storage options are e.g. construction of bulk storage liquid tanks or using the existing oxidation ponds after their decommissioning. An assessment will be required to determine the maximum discharge flow rate as determined by the infiltration capacity beyond which the field will pond, and the associated storage volume needed. Analogue to Option 1, infiltration testing and groundwater mounding assessments need to be undertaken as part of the design.

Further, the existing perimeter bund should be checked for integrity and upgraded as required to prevent effluent breaches.

Issues with this option include:

- Clogging from TSS sedimentation is estimated to decrease in the future yet is still understood to potentially reduce infiltration capacity over time. Re-burying the storage cells hinders access and cleaning potential, therefore increasing the risk of recurring surface ponding over time and further need to control effluent inflow.
- Potential for algae growth if temporary storage is left uncovered. This could potentially negate any benefits from future TSS reduction in the effluent. Covering the temporary storage should be considered in the design stage.
- Prior to re-commissioning as temporary storage, the oxidation ponds would have to be emptied, cleaned and equipped with lining (if not already).

A trial period would be recommended to establish an effluent discharge to water level rise correlation. Additionally, a feasibility study is recommended, to determine suitability of possible storage options.

As of now, this option is considered cost-effective and comparatively fast to implement. Provided thorough hydrogeological assessments, it is considered a robust method of bringing operations back under resource consent.

The Stage 3 works to the WWTP may require use of the oxidation ponds leaving no buffer storage available. Further ponding may be mitigated but not avoided / eliminated. However, option two should not be disqualified without further assessment of:

- Duration until Pond 2 or 3 become available
- Option to use other means of temporary storage on site, e.g. construction of bulk storage liquid tanks
- Option to temporarily halt flow within the WWTP

5.1.3 Option 3: Raising depth of DAD bed

This option aims to prevent any over-topping and ponding due to groundwater mounding by first backfilling the excavated soakage basins and then raising the surface level at the DAD by multiple metres to store and contain mounding groundwater. The installed storage cells would remain in place to disperse effluent, and it is recommended to add additional storage cells to aid in effluent dispersal and infiltration.

A retaining structure would have to be built around the platform to stabilise the elevated material. The structure would also prevent any water rising beyond ground level from laterally dispersing into the environment. No adjustment of effluent discharge would be required, but sufficient freeboard between groundwater table and elevated ground level needs to be determined to permanently stop ponding and effluent breaches, returning the DAD to operate under resource consent.

The required level raise needs to consider groundwater fluctuations by conducting further monitoring and undertaking a detailed transient groundwater mounding assessment in order to adequately determine the required freeboard.

However, this option comes with several limitations:

- Even though sedimentation from TSS in the effluent and fine particles migrating into the DAD is considered to decrease in the future, accumulation over time is still possible. Re-burying the storage cells, in this case under potentially multiple metres of backfill, hinders access and proper cleaning options.
- Investigation, design and construction will take time, therefore limiting the operational time from commissioning to expected decommission in 2028, lowering cost-benefit value.
- This option would require backfill material in excess of 100,000m³ and prolonged construction, including design and build of the required retaining structure

This option is considered a resilient method to return operation under resource consent, as both surface ponding and effluent breaches can be controlled structurally, but requires large volumes of backfill and construction of permanent retaining walls.

In addition to the limitations outlined above, backfilling may give rise to the following concerns:

- The gain in storage capacity by backfilling and raising the DAD is not proportional with height increase.
- The additional height in wastewater due to level increase from reduced storage capacity increases the difference in vertical gradient between DAD and surrounding area.



- As overflowing effluent is currently daylighting in a pre-existing river channel, any increase in hydraulic gradient is likely to proportionally increase surface discharge and create a permanent surface flow path.

These concerns are addressed by noting the need for additional structural reinforcement and the associated construction and material requirements. The raised limitation of potentially increased surface discharge cannot be considered in the preferred options as this is occurring in breach of resource consent conditions and needs to be addressed regardless of preferred remediation options.

5.1.4 Option 4: Tertiary effluent filtration

Tertiary effluent infiltration involves adding a unit process such as sand filters or disc filters in between oxidation ponds / MLE clarifier and the DAD to further reduce effluent TSS and prevent clogging.

At least locally within the DAD, clogging is assessed to have contributed to groundwater mounding. However, proportions of clogging being caused by migrating silt particles or effluent derived TSS are not quantifiable using the existing data. It is further concluded that surface ponding and effluent breaches are largely due to shallow groundwater table. Therefore, tertiary filtration without additional DAD upgrades as listed above, are not expected to achieve resource consent.

The experienced clogging effects are understood to have been pronounced by the confined nature of the installed storage cells and limited access for cleaning. These are likely to recur, should the site be backfilled. Tertiary filtration will reduce TSS in the effluent, therefore making clogging less likely. It is reported though that clogging of alluvial formations can occur at TSS concentrations as low as 0.5mg/l to 1.0mg/l (Hoon Y Jeong, February 2018). It is not expected TSS concentration can be lowered enough to prevent clogging altogether, potentially making cleaning necessary despite additional filtration measures. Installation of tertiary filtration is expected to take roughly one year, significantly reducing any cost-benefit prior to switching to a permanent effluent disposal in 2028.

It is therefore not recommended to install additional tertiary effluent filtration. We recommend improving clogging prevention during operations, e.g. by permanently dosing the field instead of abrupt discharges and including cleaning options of trenches before backfilling.

5.1.5 Backfilling the DAD and biofouling

Each of the aforementioned options includes backfilling the DAD at least to its original level to prevent surface ponding.

The following implications are outlined by backfilling the DAD:

- Backfilling the DAD bears no improvement on the treated wastewater discharge from the DAD
- Backfilling results in significant loss in storage capacity
- The potential for DAD overflows increases as the reduction in storage capacity results in increased wastewater level responses

It is understood, that backfilling the DAD disproportionately reduces storage capacity of the field compared to any undertaken ponding and overflow mitigation measures, such as limiting effluent inflow and raising the depth of the DAD bed. Additionally, the option to adequately clean soils affected by clogging will be severely limited. It is likely, that the DAD will react more rapidly and strongly following heavy rainfall events if the DAD is backfilled and temporary ponding is reoccurring as a consequence.

However, backfilling is essential if DAD operation is to return under resource consent.

The reduction in storage capacity is addressed by recommending installation of additional storage cells. Due to the stated extensive clogging, options to excavate affected soils, e.g. under temporarily draining the DAD, should be considered moving forward.

The practical implications of backfilling the DAD are considered in the presented options and will be included in the final recommendations, see Section 5.3.

5.2 Discussion

Based on the undertaken performance review, the breaches of resource consent conditions 20 and 21(i) are primarily due to a shallow, highly fluctuating groundwater table, locally reduced infiltration capacity and clogging effects. Recent mitigation works have highlighted that surface ponding is systemic to the sites hydrogeological conditions and cannot be remediated without extensive construction works or operational changes.

The following Table 5-1 summarises and evaluates options to achieve resource consent conditions 20 and 21(i) as described above:

Table 5-1: Summary of remediation options.

Option #	Option	Advantages	Limitations	Evaluation / Comments
1	Increasing DAD area into adjacent land	Increase in infiltration area Low risk of surface ponding Construction can be incorporated in day to day operation No adjustment to effluent discharge volume required	Requires sizeable area adjacent to DAD Potential conflict with permanent solution Potentially new resource consent required	Third placed option, as high construction requirement and implications for adjacent land.
2	Limiting effluent inflow	Limited additional construction required Decommissioned oxidation ponds could be re-used	No additional infiltration area created Additional testing of infiltration rate required to determine sustainable constant inflow System potentially needs adjustment if drop in infiltration capacity is identified	Preferred option, as simplest implementation
3	Raising depth of DAD bed	Provides structural protection against effluent breaches Low risk of surface ponding after construction finishes No adjustment to effluent discharge required	Significant construction time and cost required Access to storage cells and pipelines is hindered	Second ranked option, due to required construction.
4	Tertiary effluent filtration	Reduces potential for clogging Reduces trench cleaning requirements during operation	Construction times reduces cost-benefit Clogging still likely to continue after commissioning Limited impact on surface ponding	Not recommended as ponding would still occur
5	Backfilling the DAD (to be done regardless of preferred option)	Ponding can be mitigated if used in combination with other options	Will disproportionately reduce storage capacity and may not prevent	Not recommended as ponding is likely to continue

Option #	Option	Advantages	Limitations	Evaluation / Comments
			ponding and effluent overflow altogether	

5.3 Recommendations

Returning the DAD operation under resource consent conditions (20) and (21) will require backfilling the DAD at least to its original level in combination with one of the outlined options above. Limiting effluent inflow into the DAD was identified as the preferred option as it provides the simplest implementation.

However, backfilling the DAD disproportionately reduces the fields storage capacity and is likely not going to prevent ponding altogether as the system is highly reactive to rapid changes in water level, especially following heavy rainfall events. Temporary ponding and associated overflow are therefore likely, even if the outlined options are proceeded with. The proposed remedial activities to improve the DAD performance will ultimately not be a permanent solution due to the inherent flaws of the DAD design.

The following is therefore recommended, under consideration that a long-term solution is currently being developed:

- Inspecting and excavating potentially clogged soil requires draining the ponded effluent into the surrounding area / river and diverting effluent flow from the WWTP for extended periods until remediation works are done. Even with the removal of clogged soil, ponding is likely to continue due to the naturally shallow groundwater table. Therefore, temporarily draining and excavating is not recommended.
- Consider a partial deviation from resource consent conditions (20) and (21) by permitting surface ponding. However, any ponding that leads to an overflow needs to be in a controlled manner with additional measures undertaken to manage overflows e.g. minimise overflows and safely conceal or bury any overflow channels where possible.
- For the future DAD operation until a permanent solution is implemented, focus should be given to limiting overflow discharge into the surrounding area and river. Therefore, options should be sought to limit the effluent inflow into the DAD, thereby minimising the potential for overflow.
- Measures should be undertaken to strengthen the perimeter bund to prevent uncontrolled overflow. If overflow cannot be prevented, it should occur in a controlled manner and within buried channels but kept to a minimum.
- The occurring overflow and infiltration within the field should be measured regularly to identify performance degradation of the DAD.
- The appearance of wastewater ponding and flowpaths in the Shotover Delta area could be improved by filling the ponded areas and flowpaths with aggregate.
- The environmental impact of the deviation from resource consent should continuously monitored via regular groundwater and river water sampling.
- The development and implementation of a long-term disposal field should be advanced. QLDC is to provide a programme for the earliest design, consent, and installation of a new disposal system and share progress on the programme at regular intervals.

Regardless of chosen option, the following additional assessments are recommended:

- Conduct extensive infiltration testing under unsaturated conditions to determine possible infiltration rates.
- Check provided groundwater monitoring data for integrity.

- Continue groundwater monitoring both outside of and within the DAD to evaluate groundwater mounding and effects of clogging.
- Conduct a transient groundwater mounding and regional hydraulic gradient assessment to inform sustainable discharge and mounding values.

It is concluded though that if returning DAD operation under resource consent conditions is sought, backfilling the DAD to prevent ponding is required but not recommended due to the inherent hydrogeological conditions.

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6 Conclusion

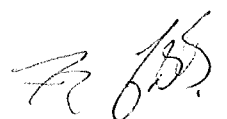
The undertaken performance review has identified key issues with the DAD, which are predominantly a consequence of the hydrogeological setting and its design choice. A deviation from resource consent conditions should be sought, as returning DAD operation under the conditions is not considered feasible. Focus should be given to preventing overflow discharge into the environment.

7 References

- Beca. (2020). Updated Shotover WWTP Stage 3 Basis of Design Letter.
- Beca. (2023). *Shotover WWTP Disposal field report*.
- e3 Scientific. (2024). *Project Shotover, Wastewater treatment and disposal system - Environmental Impact Assessment*.
- Heron, D. (2014). Geological map of New Zealand 1:250,000.
- Hoon Y Jeong, S.-C. J. (February 2018). *A review on clogging mechanisms and managements in aquifer storage and recovery (ASR) applications*. Geosciences Journal.
- Lowe Environmental Impact. (2016). *Shotover Wastewater Treatment Plant - Variation to discharge of treated sewage to land and landuse consent conditions and assessment of environmental effects*.
- Lowe Environmental Impact. (2020 - 2023). *Shotover Wastewater Treatment Plant - Annual report*.
- Massman, J. W. (2003). *A design manual for sizing infiltration ponds*.
- Mott MacDonald. (2024). *Shotover WWTP Enforcement - Technical Assessment - Shotover WWTP*.
- Otago Regional Council. (2017). *Discharge Permit - Consent No. 2008.238.V1*.
- Potts, R. (2018). *DAD - an innovative dose and drain land dispersal system*.
- QLDC. (2024). *Shotover WWTP Effluent Disposal Field - Update June 2024*.
- QLDC. (August 2024). *Shotover WWTP effluent disposal field - Update*.
- Vermaas, Lane. (n.d.). *Shotover delta dose and drain effluent disposal system*.
- WSP. (2022). *Memorandum - Post trench mitigation water level assessment*.

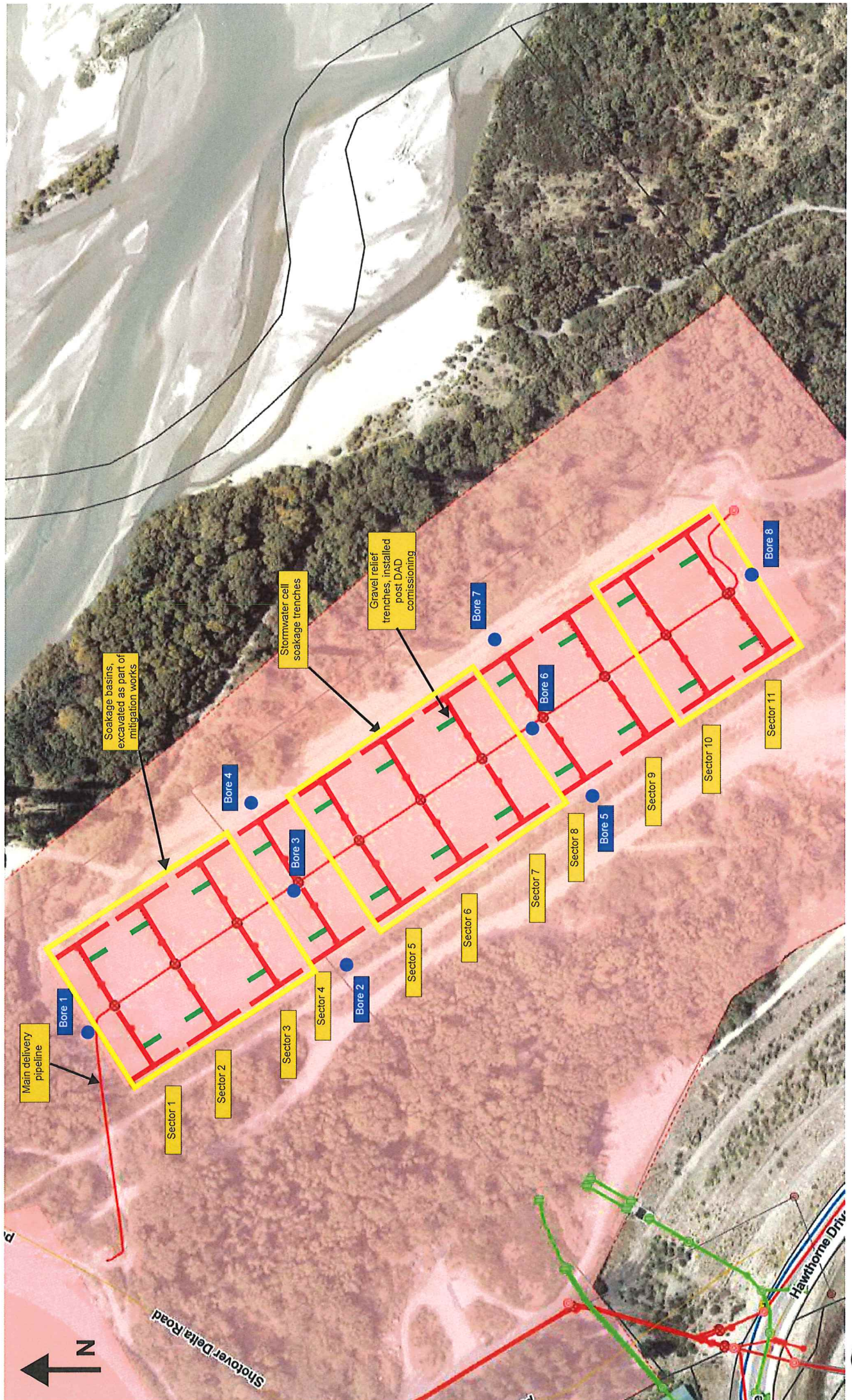


A. Schematic DAD design drawing

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Appendix

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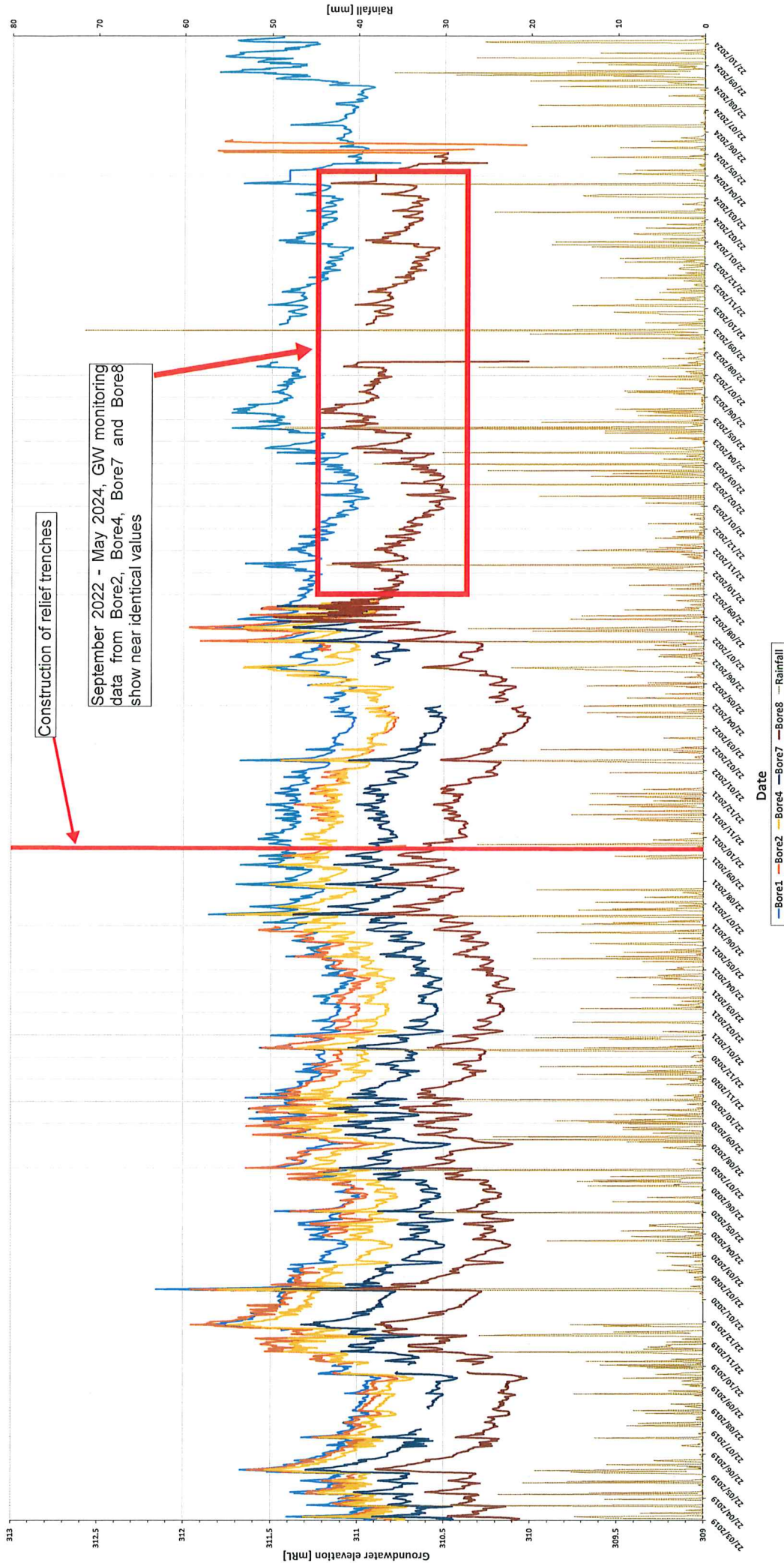
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B. Groundwater monitoring plots

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B.1 Groundwater monitoring bores outside DAD vs. rainfall

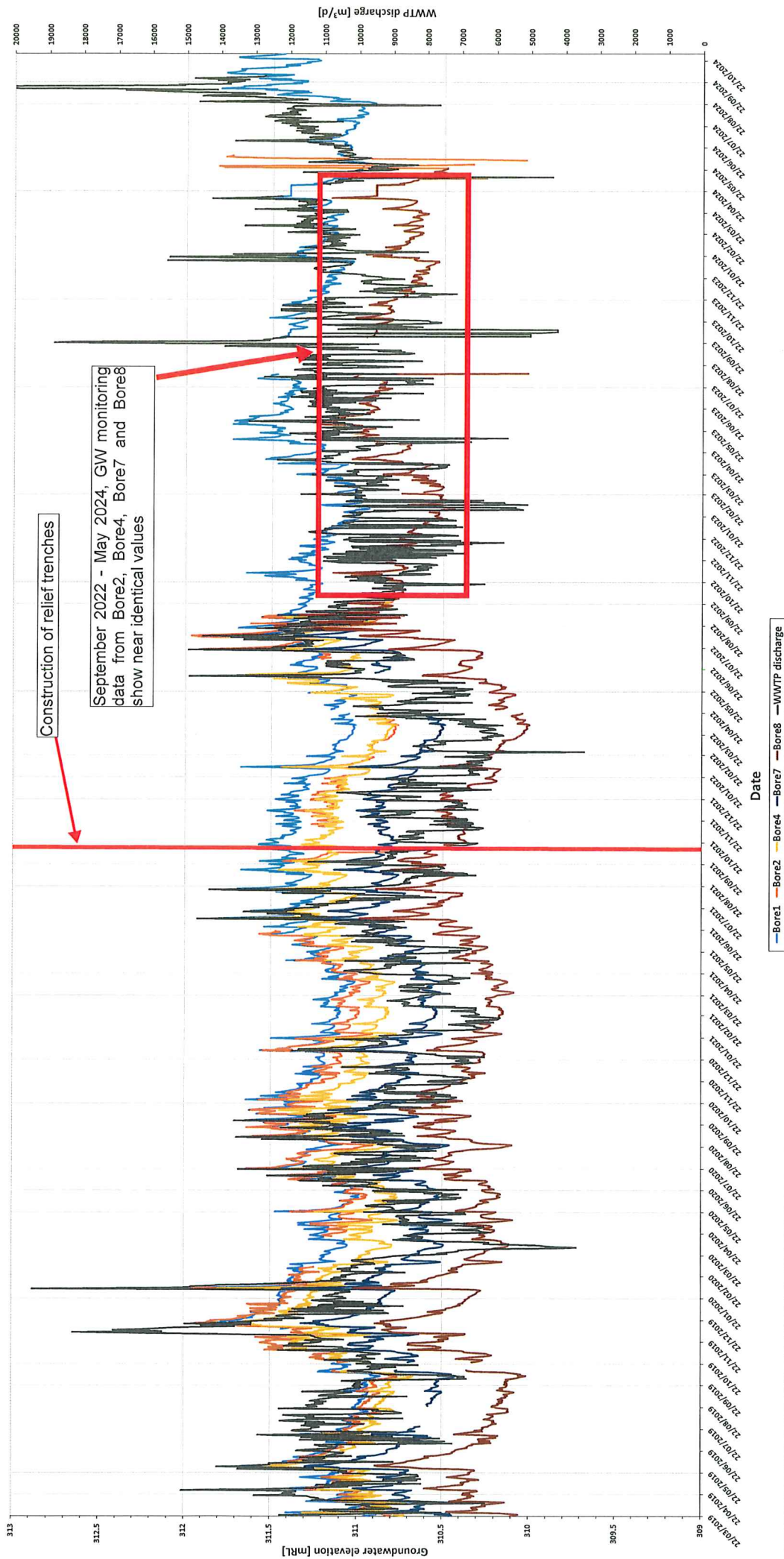
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B.2 Groundwater monitoring bores outside DAD vs. WWTP discharge

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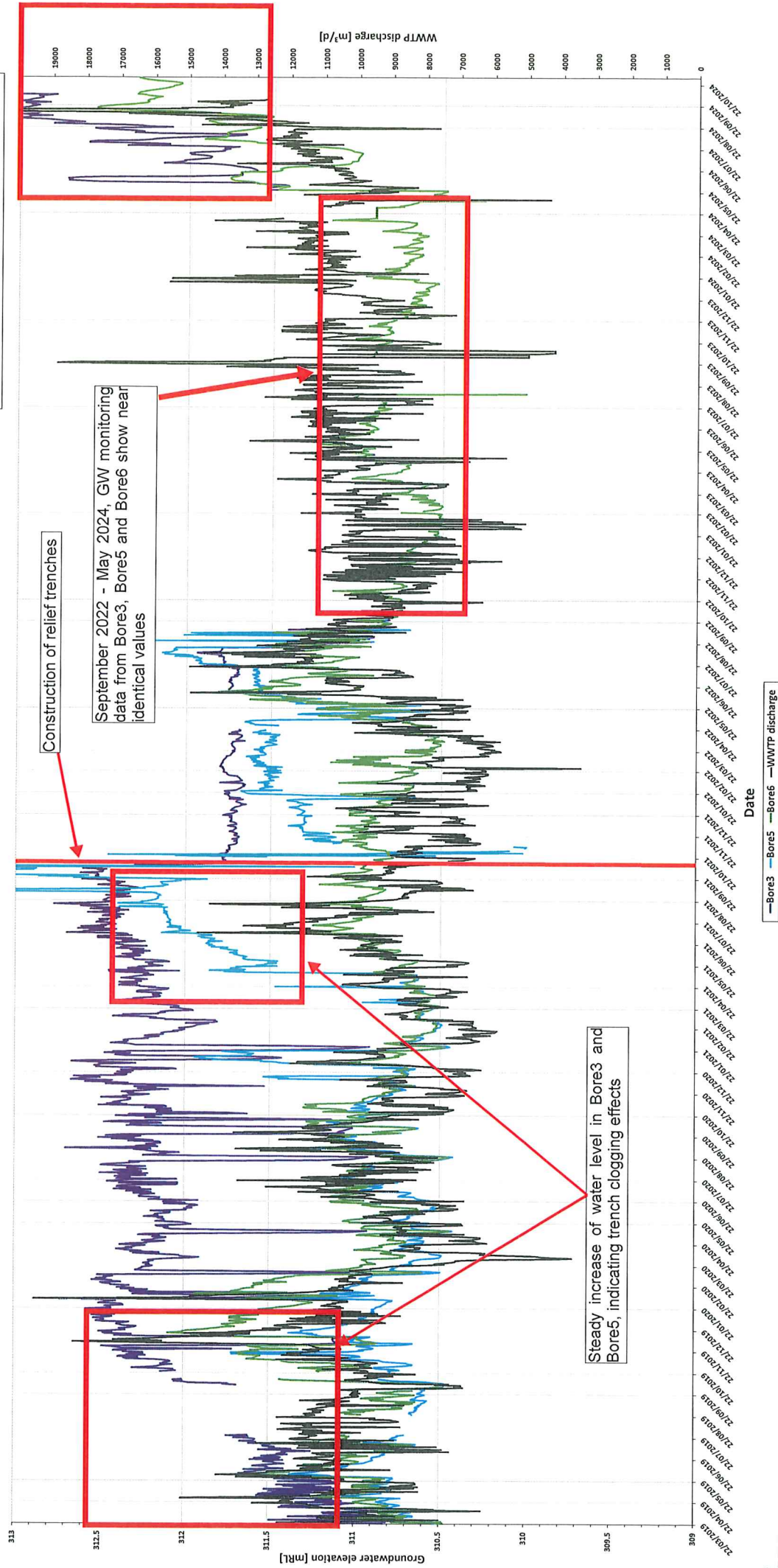


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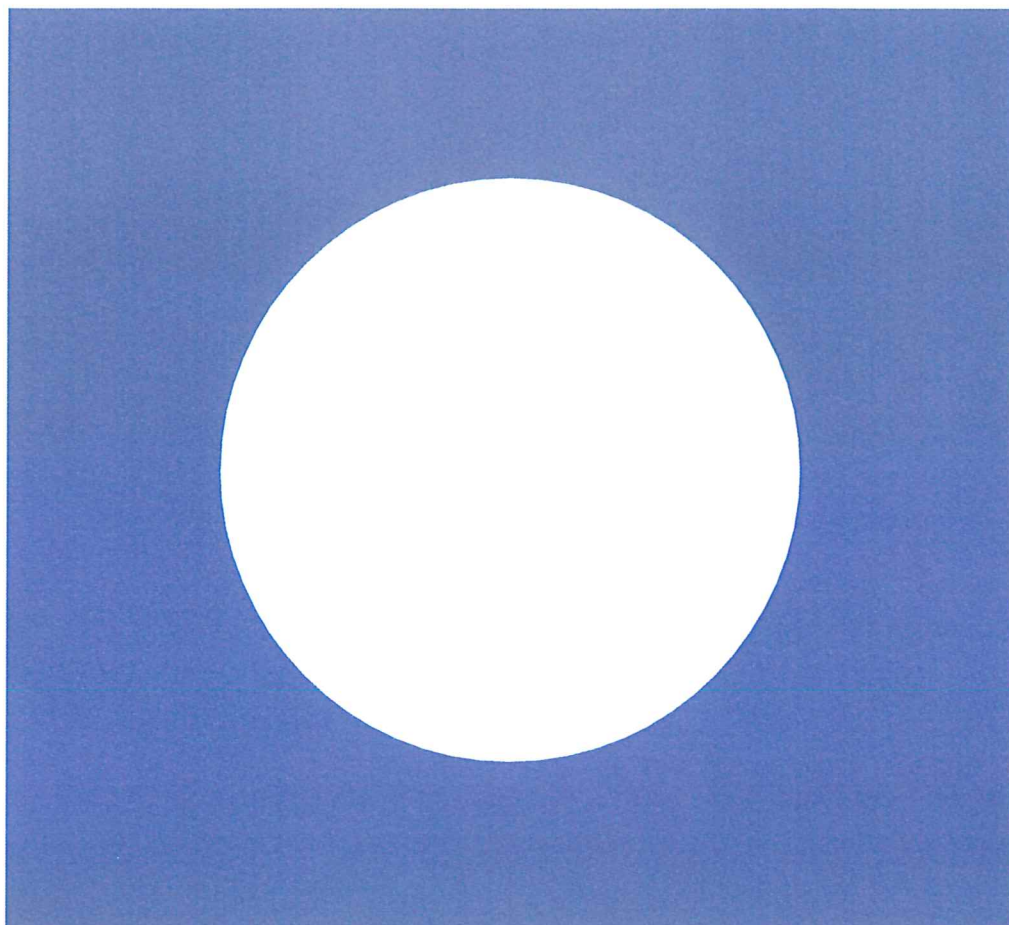
B.3 Groundwater monitoring bores inside DAD vs. WWTP discharge

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Rapid water level increase in Bore3 and Bore6



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