Shotover WWTP Enforcement

Technical Assessment - Shotover WWTP Compliance

December 2024

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Mott MacDonald
Mason Bros. Building
Level 2, 139 Pakenham
Street West
Wynyard Quarter
Auckland
1010
PO Box 37525
Parnell 1151
New Zealand

T +64 (0)9 375 2400
mottmac.com

Otago Regional Council
70 Stafford St
Dunedin 9054

Shotover WWTP Enforcement

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December 2024

Mott MacDonald New Zealand Limited
Registered in New Zealand no. 3338812

Issue and Revision Record

Revision	Date	Originator	Checker	Approver	Description
A	25 Jul 2024	M Li	D Hume	N Dempsey	Working Draft for discussion with client.
B	29 Jul 2024	M Li	D Hume	N Dempsey	Working Draft for discussion - minor amendment to recommendations.
C	30 Sep 2024	M Li	D Hume	N Dempsey	Update to report following Veolia incident report TEM-419-2
D	3 Dec 2024	D Hume	S Exeter	N Dempsey	Draft – update following DAD report
E	23 Dec 2024	D Hume	S Exeter	N Dempsey	Final

Document reference: 416485 | 002 | E | F416485-RPT-002

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Executive summary

On the 18 March 2024 Otago Regional Council (ORC) issued an abatement notice to Queenstown Lakes District Council (QLDC) in respect of breaches of the resource consent conditions at Shotover wastewater treatment plant (WWTP) due to partially treated wastewater ponding within the disposal field and overflowing through the boundary fence.

ORC has asked Mott MacDonald to review available documents, including incident reports, and provide an opinion on whether the measures proposed by QLDC are an appropriate response to gaining compliance and if not, what further measures would be required. The purpose of this is to inform an Enforcement Order to support QLDC becoming compliant with the resource consent conditions.

There are two key issues at Shotover WWTP. One is the deterioration of the dose and drain (DAD) disposal field which is leading to effluent ponding and surface breakthrough inside and outside of the disposal field perimeter. The second is the deterioration in the quality of the effluent discharged to the disposal field, as evidenced by the elevated effluent concentrations observed in the December 2023 and July 2024 samples.

Two separate incidents led to the plant failures that resulted in non-compliance with the effluent consent, as well as elevated levels of nitrogen and solids carrying over to the disposal field. The first occurred in November 2023 when failures in the dewatering system and the aeration system led to elevated mixed liquor suspended solids (MLSS) in the bioreactor and decreased dissolved oxygen (DO) concentrations. The plant was recovering from this initial incident when, in May 2024, the pre-anoxic and anoxic zone mixers in the bioreactor failed, resulting in loss of nitrification and further loss of solids from the clarifier. QLDC say that all issues have now been resolved, and recent sample results show that the effluent quality is returning to normal levels.

It is evident from the historical sample data that the WWTP has remained compliant since the beginning of 2018 when monthly sampling started, and that the recent compliance issues starting in December 2023 are unusual for this plant and appear to stem from a specific set of events. The explanation of the events and the actions taken by QLDC/Veolia towards resolving the issues would seem to be appropriate, and there is evidence that the quality of the effluent being applied to the disposal fields is returning to normal levels.

The elevated concentrations observed in the WWTP effluent in December 2023 and July 2024 resulted in corresponding elevated concentrations within many of the groundwater bores surrounding the disposal field. However, there was a delayed and disproportionately large response observed in the down gradient bore 8. A possible explanation is that there has been a significant discharge of organic solids (consistent with the loss of biological solids from the WWTP) deposited in the disposal field that have accumulated and then decomposed gradually over time, resulting in a large and delayed input of nutrients into the groundwater. The ammonia and nitrate levels in bore 8 are now recovering back to normal levels. This should continue, provided there is not another breakthrough of solids from the plant.

The Stage 3 upgrade, which will provide further treatment capacity for up to 2048, is currently being constructed and is due for completion at the end of 2025. This will be required to meet tighter discharge consent limits under a new resource consent 2008.238.V2 within 6 months of being commissioned. The Beca review in 2023 concludes that most of the solids entering the disposal field are from the ponds and that the clarifier contributes solids at high flows (200 L/s) but that the Stage 3 upgrade will increase this threshold to 400 L/s and the ponds will be decommissioned at this time. Therefore, provided the Stage 3 upgrade can treat the maximum design flows, the issue of high solids loading to the disposal field will only exist until late 2025. After that the effluent TSS is expected to be much improved.

Mott MacDonald has undertaken a review of the disposal field performance (included in Appendix A).

This report outlines a number of areas that need to be improved to bring the discharge from the Shotover WWTP into compliance. A full list of recommendations is provided in 3.2 at the end of this report. However, as many of these recommendations involve the installation of infrastructure that will take some time to design and install, and in some instances, there are already activities taking place that will overtake these proposed changes, we recognise the need to be pragmatic in what is recommended.

Treatment

- There are clear changes needed to the existing solids treatment system, which we have included in the recommendations.
- We have also demonstrated that the DAD is not suitable for ongoing use if the consent conditions are to be achieved. But we have outlined how performance of the existing DAD can be protected by ensuring low solids effluent is discharged.
- We could therefore recommend a range of solutions to augment the existing treatment plant as discussed in this report. For example, diversion to ponds, filtration and other new assets.
- However, these will have significant cost to the community, and there is already a construction upgrade underway to add a new high quality treatment train (new MLE) to improve effluent quality; this is planned for completion in late 2025.
- Therefore, we recommend a pragmatic approach with the following actions, which are outlined further in Table 3.1:
  - QLDC demonstrates how the design of the new MLE and decommissioning of the existing ponds will consistently achieve the future consent conditions for TSS – median and peak in order protect the existing (and possible future) disposal field.
  - QLDC provides the programme for completion of the new MLE and demonstrates how the new asset will be in place and commissioned before the end of 2025.
  - QLDC includes in the new MLE treatment plant design, facilities to continuously monitor TSS and/or turbidity, and to divert treated effluent flows to either the Calamity Pond and/or a repurposed treatment pond when it exceeds the peak TSS consent condition(s).

1 Introduction

1.1 Background

Queenstown Lakes District Council (QLDC) holds and exercises the Resource Consent (RM13.215.03.V2) to discharge treated wastewater to land from Shotover wastewater treatment plant (WWTP).

Following the major floods that occurred at Shotover Delta in December 2019, the disposal field was underperforming. An abatement notice EN.RMA.21.0025 was issued by Otago Regional Council (ORC) due to the ponding of treated wastewater at the Shotover WWTP on 11 June 2021. The date for compliance with the abatement notice has been extended to 25 May 2024 to allow for investigations and remediation work to be carried out.

On 27 and 28 December 2023, ORC Enforcement Officers carried out inspections, where they saw:

- A substantial flow of wastewater that was not fully treated discharging through the Disposal Field boundary fence from the south-southeast corner of the Disposal Field.
- The wastewater flowed like a small river away from the Disposal Field to where it ponded in an area outside the Disposal Field in the Shotover Delta.
- The wastewater was slightly discoloured, silt laden and smelt of sewage.
- The wastewater is likely to have had entered the Kawarau River.

The ORC Enforcement Officers took samples of the wastewater discharged from the disposal field and found it contained contaminants at a significantly higher levels than the resource consent limits for the annual mean and the 95th percentile (for BOD, TSS, and TN) and the geomean and 90th percentile parameter (for E. Coli.).

It was concluded by the enforcement officers that partially treated wastewater had been discharged from the WWTP to land and had likely entered the receiving water (Kawarau River, Shotover River and/or groundwater), contravening condition 12 of the resource consent. Furthermore, the discharged wastewater had ponded, and groundwater mounding had occurred with surface breakthrough within the disposal field, contravening conditions 20 and 21 of the resource consent (ORC, 18 March 2024).

On the 18 March 2024 ORC issued a further abatement notice EN.RMA.24.0012 to QLDC in respect of these breaches of the resource consent conditions.

1.2 Scope and Methodology

ORC has asked Mott MacDonald to provide an opinion on whether the measures proposed by QLDC are an appropriate response to gaining compliance, and if not, what further measures would be required. The purpose of this report is to inform an Enforcement Order to support QLDC becoming compliant with the resource consent conditions.

Mott MacDonald attended a site visit on 19 September 2024 at Shotover WWTP with ORC, QLDC and Veolia, to gather further information. This followed a meeting between QLDC, Veolia and ORC on 13 August 2024 to discuss the recommendations form the draft report. The findings of the site visit and a review of the Veolia incident report TEM-419-2 which describes an incident on 27 May 2024 in which three of the mixers in the MLE reactor failed, is also incorporated into this report. Following a request to QLDC for further information regarding the specific issues with the dewatering system in late 2023, we have also reviewed an email explanation from Veolia along with the decanter service reports.

Our scope has been extended to include a review of the original DAD design concept and the mitigation measures undertaken to date, to assess potential causes of the ongoing problems and evaluate options to make DAD operations compliant with resource consent requirements, until the long-term effluent disposal solution is constructed by 2028. The review is included in Appendix A.

1.2.1 Assumptions and Exclusions

Key assumptions and exclusions of this report include:

1. The purpose of this report is to inform an Enforcement Order to support QLDC becoming compliant with resource consent RM13.215.03.V2 conditions 12, 20 and 21.
2. Recommendations of options do not include consideration of:
   - Capital and operational costs
   - Potential requirements of other RMA resource consents (and applications) and other regulatory requirements (Building Act etc)
   - Constructability
3. Recommendations of options require further feasibility assessment and design.

2 Information Review and Findings

2.1 Setting the Scene

Originally all of Queenstown's wastewater was treated via oxidation ponds only. In 2017 the Stage 1 plant upgrade works were completed which included the addition of a Modified Ludzack-Ettinger (MLE) treatment train. The MLE process provides treatment to approximately 80% of the wastewater, with the balance of flows being treated within the oxidation ponds. The two effluent streams are blended, before receiving UV disinfection and on to disposal in the dose and drain (DAD) disposal field.

The current disposal field was completed in January 2019 as part of the Stage 2 WWTP upgrades and is located on the Shotover Delta to the south of the existing wastewater treatment plant and ponds.

The Stage 3 upgrade to the WWTP is currently underway, which includes duplication of the MLE reactor system and decommissioning/repurposing of the oxidation ponds. The existing Pond 1 (northern most pond) will be used for improved stormwater management on site, with another area converted to act as a calamity pond in the event the treatment plant is unavailable. The upgrade is programmed to be completed and commissioned in late 2025. The upgrade will be designed to treat the wastewater to a higher standard under a new resource consent 2008.238.V1 by no later than 31 December 2031, or sooner if effluent nitrogen loads reach the trigger level.

Since 2020 the performance of the DAD disposal field has steadily deteriorated, and the field is now unable to operate as designed and consented (QLDC, 30 May 2024). Investigation and remediation work has been ongoing since this time.

Permanent surface water ponding is present across the field and on some occasions, surface water has discharged through the southern end of the field and ponded outside of the fenced field area. The repeated non-conformances with the conditions of the Resource Consent (RM13.215.03.V2) resulted in the ORC issuing an abatement notice. QLDC has applied for and has been granted several abatement notice extensions which have allowed it to investigate the issue, trial various operational interventions to restore performance, undertake internal master planning, confirm a delivery strategy and pathway, and seek funding through Council processes (QLDC, 30 May 2024).

In March 2023, QLDC engaged BECA to carry out an investigation into the viability of the disposal fields and the likely cause of sludge accumulation at the fields. The review concluded that the most likely source of the sludge was the oxidation ponds, and there was also evidence of solids entering the field from the clarifier when high flows are reached (approximately 200L/s- this is typically only during times of high rainfall) (Shotover WWTP Annual Report 2023).

From their investigation, BECA concluded the following key points:

- The disposal field is too small because of the clogging, shallow water table and hydraulic performance limitations.
- The buried nature of the trenches and the plastic baskets make cleaning and maintenance needs difficult to identify and conduct by contractors.
- The site is prone to flood hazards, erosion, and sedimentation from the nearby rivers (it is located within the ORC river training line)

- The disposal field may be able to be remediated to minimise over topping (although at potentially high cost), however is unlikely to meet future demand or provide adequate cycling and scarification.

The upgrade and addition of a second clarifier is estimated to increase the sludge carryover ‘threshold’ from 200L/s to 400L/s (Shotover WWTP Annual Report 2023).

QLDC proposes a new long-term disposal solution for treated effluent from the Shotover WWTP to replace the existing disposal field that is not performing as designed and intended (QLDC, 30 May 2024). Although a specific solution has not been identified in the Project Plan, a proposed delivery pathway has been identified, with a proposed timescale for identification and implementation of the long-term disposal solution by 2028.

In response to the 2024 abatement notice, QLDC and the operators, Veolia have provided several documents describing the recent issues and the actions taken towards resolving the issues.

2.2 Documents Reviewed

The following documents were received from ORC (further references are included in the DAD performance review in Appendix A):

- Abatement Notice - EN.RMA.24.0012 (ORC, 18 March 2024)
- Project Report – Project Shotover Aeration Cleaning, Tube Diffusers Test and Replacement (Veolia, 14 May 2024)
- Project Shotover WWTP Incident Report: November 2023 - April 2024, Rev 3 (Veolia, 15 May 2024)
- Disposal Field Missed/ Undocumented Inspections, Rev 2 (Veolia, 17 May 2024)
- Project Plan - Shotover WWTP Disposal Field Alternative Discharge (v.30.05.2024) (QLDC, 30 May 2024)
- Project Shotover Wastewater Treatment Plant Operations & Maintenance Manual, First Issue (Veolia, June 2024)
- Shotover WWTP Disposal Field End of Month Update (May 2024)
- Shotover WWTP Disposal Field End of Month Update (June 2024)
- Shotover WWTP Annual Report 2020 (LEI, 1 February 2021)
- Shotover WWTP Annual Report 2021 (LEI, 31 January 2022)
- Shotover WWTP Annual Report 2022 (LEI, 30 January 2023)
- Shotover WWTP Annual Report 2023 (Veolia, 31 January 2024)
- Effluent Analytical Report AR-24-NC-021205-01 (Eurofins, 11 June 2024)
- Effluent Analytical Report AR-24-NC-021204-01 (Eurofins, 11 June 2024)
- MLE Activated Sludge Biomass Sample Analysis Report (The Wastewater Specialists, 18 July 2024)
- Shotover WWTP Disposal Field Report, Assistance with Remedial Works (Beca Limited, 15 March 2023)
- Shotover WWTP Disposal “Full” Sizing, and Long List for Medium-Term Options (Beca Limited, 3 July 2023)
- Project Shotover, Wastewater Treatment and Disposal System Environmental Impact Assessment (e3 Scientific, 19 August 2024)
- Shotover WWTP MLE Mixer Incident Investigation Report (Veolia, 28 August 2024)

- Minutes of meeting on 13 August 2024 between QLDC/Veolia and ORC to discuss draft recommendations from Mott MacDonald report.
- GEA Decanter Service Report S64750 – Decanter 1 (20 November 2023)
- GEA Decanter Service Report S64750 – Decanter 2 (20 November 2023)
- Email from Celeste Lado (Veolia) to David Reine (Veolia) – Re: Nov 2023 Centrifuge problems (24 October 2024)
- Updated Shotover WWTP Stage 3 Basis of Design Letter (Beca, 2020)
- Review of Shotover WWTP Enforcement Technical Assessment – Shotover WWTP Compliance (GHD, 10 December 2024) - Technical Memorandum (draft provided on a without prejudice basis).

2.3 Resource consent conditions

QLDC holds and exercises the Resource Consent, RM13.215.03.V2 (dated 9 March 2017/ expires 31 Dec 2031) to discharge treated wastewater to land from the WWTP.

The relevant resource consent conditions referred to by ORC in the abatement notices, are included below (refer to resource consent for full details).

12. The quality of the treated wastewater shall not exceed the following limits prior to discharge:

Table 2.1: Treated effluent discharge limits

Parameter	***95th percentile***	***Annual mean***
BOD_5 (mg/L)	*50*	*30*
TSS (mg/L)	*50*	*30*
Total Nitrogen (mg/L)	*35*	*23*
E. coli (cfu/100ml)	*260 (90th percentile)*	*260 geomean*

Means and percentiles apply to a rolling 12 calendar month period.

14. …the consent holder shall prepare and forward to the Consent Authority an Operations and Maintenance Manual for the treatment and disposal system to ensure its effective and efficient operation at all times. The system shall be operated in accordance with this manual, which may be updated as appropriate. The manual shall include, but not be limited to…

15. The consent holder shall submit a record of complaints and malfunctions to the Consent Authority within two weeks after any complaint or malfunction occurring, together with the details of the remedial measures taken or proposed to be undertaken.

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 100 m^2 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-years mounding trial period following the commencement of this consent.*

Abatement notice EN.RMA.21.0025 (ORC, 27 May 2021) refers to non-compliance with conditions 15 and 20 of the Resource Consent.

Abatement notice EN.RMA.24.0012 (ORC, 18 March 2024) refers to non-compliance with conditions 12, 14, 20 and 21 of the Resource Consent.

Some other conditions that are pertinent to this assessment, but not specifically referred to in the abatement notices, are:

3. The volume of wastewater discharged to the disposal field shall not exceed:

> *(a) an annual average of 11,238 cubic metres per day; and*
>
> *(b) a maximum discharge loading rate averaged over the disposal field area of 1,000 millimetres per calendar day based on the total area of the disposal field.*

4. The recorded daily flow and and total nitrogen concentration of the effluent as monitored in accordance with Conditions 7 and 8 of this consent shall be averaged over the previous 12 month rolling period and when the mass of nitrogen reaches:

> *(a) 73.2 tonnes per year the consent holder shall implement the wastewater treatment plant upgrade process to meet the conditions of Consent 2008.238.V2 within two years; and*
>
> *(b) 75.5 tonnes per year, the consent holder shall have commissioned the upgraded wastewater treatment plant to meet the conditions of Consent 2008.238.V2 (RM13.215.03.V2 shall be surrendered within 6 months of the upgrade being commissioned).*

The Stage 3 upgrade will be designed to treat the wastewater to a higher standard (Table 2.2) under a new resource consent 2008.238.V2 by no later than 31 December 2031 (Condition 19b), or sooner if effluent nitrogen loads reach the above trigger levels. **It is assumed that the Stage 3 upgrade, due to be commissioned by the end of 2025, will be required to meet the higher standard.**

Table 2.2: Stage 3 treated effluent discharge limits

Parameter	90^{th} percentile	Annual mean
BOD_5 (mg/L)	20	10
TSS (mg/L)	20	10
Total Nitrogen (mg/L)	15	10
Total Phosphorus (mg/L)	10	8
E. coli (cfu/100ml)	100 (95^{th} percentile)	10 geomean

Percentiles apply to a rolling 12 calendar month period.

Resource Consent 2008.238.V2 (expires 18 March 2044) permits up to 45,000 m^3/d to be discharged to the disposal field at a maximum discharge loading rate averaged over the land disposal area of 1,330 mm/d based on the total area of the disposal field. We note that this would require an increase in the disposal field area from the existing 28,000 m^2 to 37,240 m^2.

It is understood that the existing disposal field is designed to accept a maximum discharge of up to 430 L/s (37,152 m^3/d), this being the anticipated maximum flow rate for Stage 3 of the proposed development (ORC Staff Recommending Report, 08/03/2017, 2008.238). For comparison, the updated Stage 3 basis of design (Beca, 2020) indicates a maximum daily flow of 383 L/s (33,100 m^3/d) in 2048.

2.4 Key Findings

There are two key issues at Shotover WWTP. One is the deterioration of the disposal field which is leading to effluent ponding and surface breakthrough inside and outside of the disposal field perimeter. This appears to have been a steadily worsening issue since the disposal field was commissioned in 2020. The second is the deterioration in the quality of the effluent discharged to the disposal field, as evidenced by the elevated effluent concentrations observed in the December 2023 sample.

A timeline of the activities undertaken at the Shotover WWTP, relating to both issues, and based on the provided documents is shown below:

Table 2.3: Timeline of Shotover WWTP

Date	Description
Dec-16	Stage 1 commences
Feb-17	Stage 1 fully commissioned: Upgrading the plant, new screening, flow splitter and MLE
9-Jan-19	Stage 2 completed: Discharge to land commenced
Dec-19	Major floods cause the DAD system to underperform
11-Jun-21	Abatement notice issued due to ponding of treated wastewater
Jul-21	Investigation and Remediation work begins Found that adjacent sandy silts infiltrated the fill's voids, decreasing hydraulic conductivity
Dec-21	Pond 2 removed and ground reinstated. (Mentioned in 2022 Annual Report, App G)
Mar-22	22 additional soakage trenches installed (2 per field)
?	Four rapid infiltration basins constructed along the southern boundary to intercept any surface flows (Mentioned in 2023 Annual Report)
Mar-23	BECA investigation on the ponding issues
Jul-23	Veolia assumed operational control of the facility
9-Aug-23	All 8 Piezometers in the bores go offline due to cable fault
Aug-23	Construction of Stage 3 begins: Second clarifier, Second MLE, decommissioned oxidation ponds and replace with calamity ponds. Due to be commissioned 2025.
Sep-23	Piezometers back online
Nov-23	Wastewater quality issues - breach of consent
27-Nov-23	GEA engaged on site to service both centrifuges High vibration and solid gate issues.
18-Dec-23	GEA engaged on site to service both centrifuges
Dec-23	Crack discovered in MLE blowers outlet pipe manifold PACl dosing system installed at outlet of MLE
10-Jan-24	New aerator installed at swing zone of MLE
11-Jan-24	Diffuser grids were inspected and upgraded to improve aeration
Feb-24	Centrifuge high vibration and polymer dosing issues resolved
Mar-24	Centrifuge “Solid Gate” issue resolved
April-24	Aeration grids replaced with new diffusers
May-24	Construction of perimeter bund walls to increase storage capacity of the fields and prevent seepage through the perimeter Excavate areas between constructed tees to locate better draining gravels

Date	Description
	Cameras installed to improve the ability of operators to monitor the field from the plant Creation of additional volume in areas 10 and 11 Expanding the soakage area by clearing out trees and creating new soakage basins
May-24	Catastrophic failure of three MLE mixers (2 pre-anoxic zone, 1 anoxic zone)
Jun-24	Development of 2 large soakage basins in the vicinity of zones 5/6 and 6/7 Installed one camera Completed crude soakage testing in the new basins that indicates 280mm/hr
Mid-June-24	Mechanical surface aerator removed
24-June-24	Effluent ammonia concentration started to increase
July-24	Elevated ammonia and TSS observed in the MLE plant effluent MLE pre-anoxic zone mixers repaired and placed back in service
21-Aug-24	Installation guide rail complete and MLE anoxic zone mixer replaced and put back into service
4-Sep-24	Effluent quality much improved compared with previous month, based on monthly sample result
14-Sep-24	Surface overflow from disposal field, breaching perimeter fence

Further information relating to these events is discussed in the following sections.

2.4.1 Veolia incident report - 15 May 2024

The Veolia incident report (15 May 2024) describes significant operational challenges faced by the operators at Shotover WWTP between November 2023 and April 2024, that severely impacted treatment performance and compliance. The report provides a timeline of the incidents and the corrective actions undertaken by Veolia and QLDC in an effort to restore compliance and operational stability. The following summary is taken directly from the report.

The primary issues are reported to have stemmed from failures in the centrifuge system used for sludge wasting, problems with the polymer dosing system required for dewatering, and deficiencies in the aeration system responsible for providing oxygen to the biological treatment process.

These compounding issues resulted in elevated levels of mixed liquor suspended solids (MLSS) in the bioreactors, decreased dissolved oxygen (DO) concentrations below the required 2 ppm level for effective biological treatment, and increased total suspended solids (TSS) carryover from the clarifier into the final effluent. Consequently, the plant was unable to meet effluent quality standards, and odour complaints from the surrounding community began in early December 2023.

Veolia, who assumed operational control of the facility in July 2023 (the facility had been in operation for 7 years previously) speculates that the root cause of these widespread failures stems from inadequate preventive maintenance practices by the previous facility operator, potentially contributing to the degradation of assets over time.

In November 2023 both centrifuges encountered problems, including 'High vibration' and 'Solid gate' alarms, as well as conveyor screw malfunctions. Ultimately, the centrifuges became inoperable, preventing the removal of waste activated sludge (WAS) from the process and an accumulation of sludge within the plant.

The wasting process was further hindered by problems with the polymer dosing system. Alarms were triggered due to mechanical issues within the dosing system, indicating valve malfunctions. Consequently, the system had to be operated manually.

Additionally, there was low flow of make-up water through the system which slowed down the process of filling the polymer tank and impacted the ability to adjust the polymer dosing rate effectively. During troubleshooting, it was discovered that the dosing system settings were incorrect, leading to additional alarms being raised.

The dissolved oxygen (DO) levels in the wastewater treatment plant became variable and started to decrease rapidly, eventually reaching levels below 0.5 ppm in early December. As a result of the aeration system deficiencies and the subsequent development of anaerobic conditions within the plant, a foul odour began to emanate from the Project Shotover WWTP. This odour issue became apparent to the surrounding community, and the first complaints from residents were received on December 4, 2023.

In December 2023, the root cause of the decreasing DO levels and subsequent odour complaints was found to be linked to issues with the aeration grids and diffusers in the MLE reactor. Initially a large crack was found in the outlet pipe manifold of two of the blowers, that provide air to the MLE, greatly reducing the amount of oxygen travelling to the diffusers. This was repaired on 15th December 2023.

Further inspection conducted on December 20th, 2023, revealed the following problems with the aeration system:

- Sludge buildup on the aeration grids and diffusers - Sludge accumulation can clog or obstruct the diffusers, reducing the effective transfer of oxygen into the wastewater.
- Cracked diffuser connections - Cracks or leaks in the connections between the diffusers and the air supply system were found, this led to air leakage, reducing the amount of oxygen being introduced into the aeration tanks.
- Membranes of the diffusers needed replacement - Over time, diffusers can become worn or damaged. As the diffusers were installed in 2016, the membranes were nearing the end of their lifespan, and thus organised to be replaced.

The issues with the aeration system and low dissolved oxygen (DO) levels led to further consequences. Total Suspended Solids (TSS) within the clarifier began to rise and carry-over into the final effluent, indicating inefficient solid-liquid separation and potential sludge bulking or rising issues.

By the end of December, a Polyaluminum chloride (PACl) dosing system was introduced to aid settlement in the clarifier. Consequently, the plant began to see a reduction in the levels of Total Suspended Solids (TSS) within the clarifier, and the overall quality of the final effluent began to improve.

On 11th January, 16 new diffusers were installed to replace the fouled and damaged diffusers that had contributed to the DO deficiency. Additionally, a temporary Aquaturbo surface aerator was brought online on January 10th to provide supplemental aeration in the swing zone. Consequently, the DO levels increased, and the necessary aerobic conditions were re-established. As a result, the total suspended solids (TSS) concentrations in the clarifier effluent returned to compliance levels by January 20th, and the foul odour that had prompted community complaints had dissipated.

In February 2024, progress was made in resolving the high vibration with the centrifuge and mentioned problems with the polymer dosing system. These improvements helped restore the plant's ability to effectively dewater and waste solids.

In March 2024, the 'Solid Gate' fault affecting one of the centrifuges, an ongoing issue since November 2023, was resolved. This restored the centrifuge's capability to manage solids discharge and prevent the accumulation of excess sludge within the treatment process.

Additionally, a plan was developed to comprehensively overhaul the aeration system, as described in the Veolia aeration grid replacement report (14 May 2024).

As of 15 May 2024, significant progress had been made in restoring operational stability and compliance at the Project Shotover WWTP:

- The health of the biomass has improved and continues to evolve, containing a good diversity and abundance of higher life, based on microbiological monitoring of the biomass by The Wastewater Specialists
- TSS levels had settled to an average of 12.8 ppm from March 1st to April 30th.
- DO levels were averaging 4.7 ppm in May.
- PACl dosing continues to aid solids settling until results stabilise (the plant will be weaned off the PACl after the decommissioning of the surface aerator).
- Intermittent conveyor screw issues during dewatering persist but are being addressed.

The Aquaturbo frequency is being gradually decreased by 1Hz per day to avoid sudden DO drops that could upset the biomass, with the goal of shutting it down by the end of May (note, this was removed in mid-June 2024).

2.4.2 Aeration improvements

In April and May 2024, the diffusers in all 20 aeration grids within the MLE Plant were replaced with new diffusers due to fouling and sub-optimal performance, as described in the Veolia aeration grid replacement report (14 May 2024). The aeration grids were originally installed eight years ago. The report states that testing showed that aeration performance improved following the replacement.

During the testing of the aeration grids, it was discovered that a significant number of the diffusers were blocked with dust. This was hypothesized to have been caused by a perforated filter element on the blower, passing a significant amount of dust to the diffuser grids.

The presence of dust in the process air clearly poses a serious risk to the diffusers.

The following next steps are discussed in the Veolia report:

- Removing the surface aerator in the swing zone by gradually reducing the frequency by 1 Hz per day while maintaining acceptable DO levels, with the goal of shutting it down by the end of May.
- Considering the installation of flow metres for the blowers.
- Considering the installation of triboelectric dust detection probes on the main manifolds to the diffusers to prevent dust fouling, which poses a serious risk to the diffusers.

2.4.3 Dewatering Issues

In November and December 2023, the polymer dosing, dewatering centrifuges, and screw conveyors encountered operational issues.

Following a request to QLDC for further information regarding the specific issues with the dewatering system in late 2023, Veolia provided the following explanation in an email along with GEA Decanter Service Reports for the decanter centrifuges.

The centrifuges experienced vibration issues which caused the high vibration alarm to be engaged. According to the original service reports from GEA, the high vibration was caused by the water flushing valve not opening during shut down. GEA proposed a new flushing valve to be fitted to amend this. However, this issue persisted as the centrifuges received insufficient flushing water during the shut down process. In an email (24 October 2024), Veolia state that this was caused by the failure of the recycled effluent filter, and the subsequent lack of automatic filling for the flushing water tank. The recycled effluent filter has since been repaired and sensors were installed onto the flushing water tank.

The sludge gate had also failed, which was initially thought to be caused by incorrect settings in the GEA servicing report. Veolia also stated the cause to be misalignment between the gate's stop sensor and metal plate, which caused the motor to continuously operate until the thermal overload switch was tripped. This has been resolved by resetting the thermal overload trip and adjusting the mechanical bolt and plate on the gate so that it aligns with the sensor.

According to Veolia, the conveyor screws also experienced malfunction due to a missing liner in conveyor 1, damaged and misaligned liners in conveyors 2 and 3, as well as blockages in chutes and conveyor 3. These issues are being addressed by replacing the liners in conveyors 2 and 3, and replacing conveyor 1. The PLC code of the centrifuges is also being modified to redirect flush water to drain. Blockages have also been reduced with the adjustment of polymer dosage.

The polymer dosing system was found to have incorrect settings which prevented adequate suction of polymer powder. The level sensor had also malfunctioned and was not opening the polymer influent valve. These were amended by replacing the failed level sensor and adjusting the polymer dosing system settings.

The above corrective actions appear to be appropriate. It isn't clear whether these have all been implemented yet. Therefore, we recommend these be included as a requirement in the enforcement notice to ensure they are carried out. Also, it is a requirement of the resource consent 14(d)(i) that the OMM includes contingency plans for system malfunction and breakdowns for each part of the treatment and disposal system. We recommend a specific contingency plan for the dewatering system should be captured in the OMM that considers installing temporary dewatering equipment until the permanent plant is back online. This could have significantly reduced the consequences of the dewatering system failures seen in 2023.

2.4.4 Effluent discharge consent compliance

Treated blended wastewater from the outlet of the UV plant is sampled monthly. QLDC say the effluent samples are 24-hour flow-weighted composite samples (the resource consent only stipulates that the sample shall be representative). The quality of the treated effluent shall not exceed the limits shown in Figure 2.1 - Figure 2.5.

The graphs below summarise the consent compliance since the beginning of 2018, including the period of the recent WWTP failures, up to the sample result on the 4 September 2024. Whilst E. coli approached its 90th percentile limit following the December 2023 sample, it has remained within consent compliance. Total nitrogen has exceeded its annual mean limit. TSS, BOD_5, and Total nitrogen have exceeded their 95th percentile limits, and this will likely continue to remain non-compliant for the next few months due to this being based on a rolling 12-month period.

Figure 2.1: Total Suspended Solids in Shotover WWTP Effluent

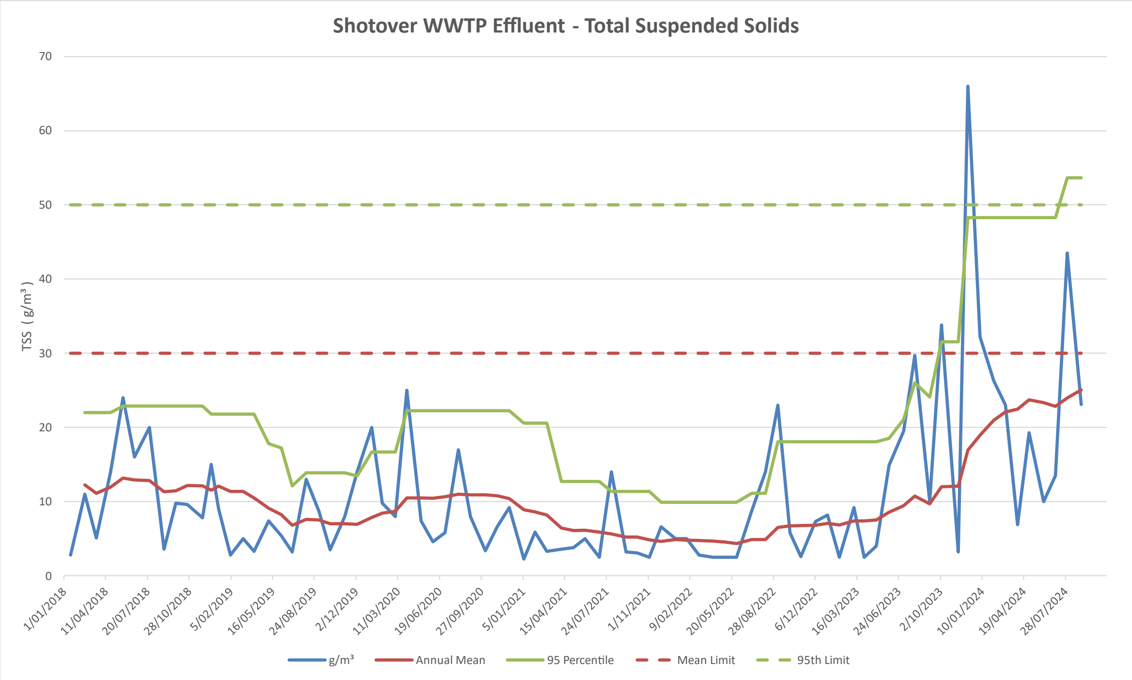


Figure 2.2: BOD_5 in Shotover WWTP Effluent

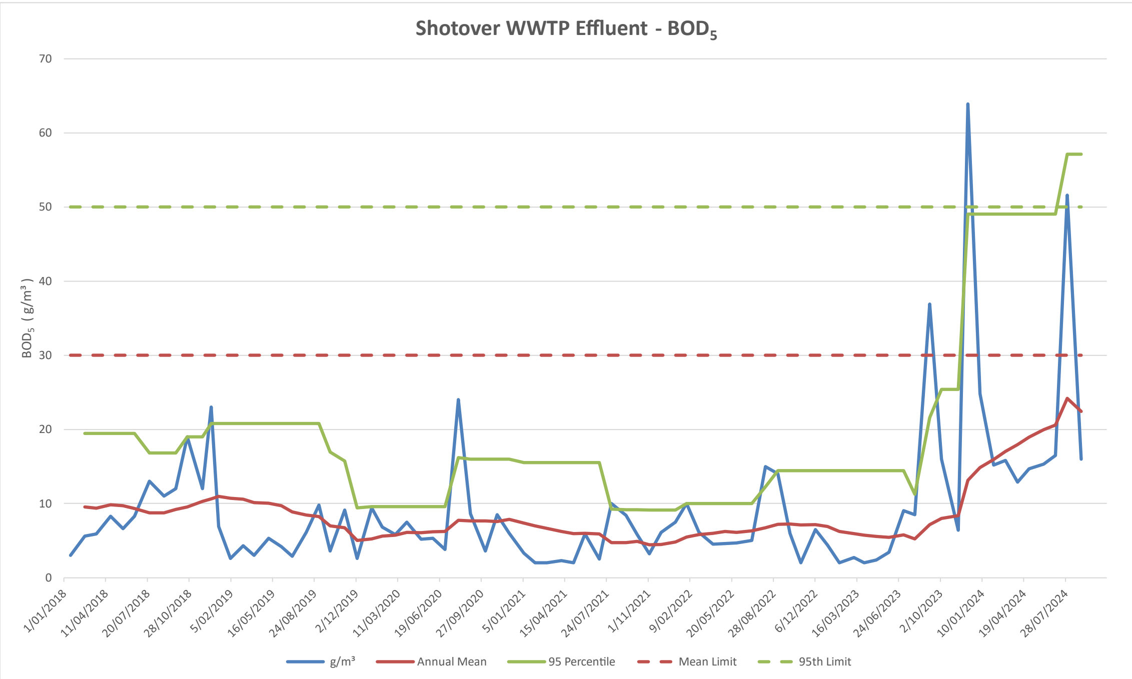


Figure 2.3: Total Nitrogen in Shotover WWTP Effluent

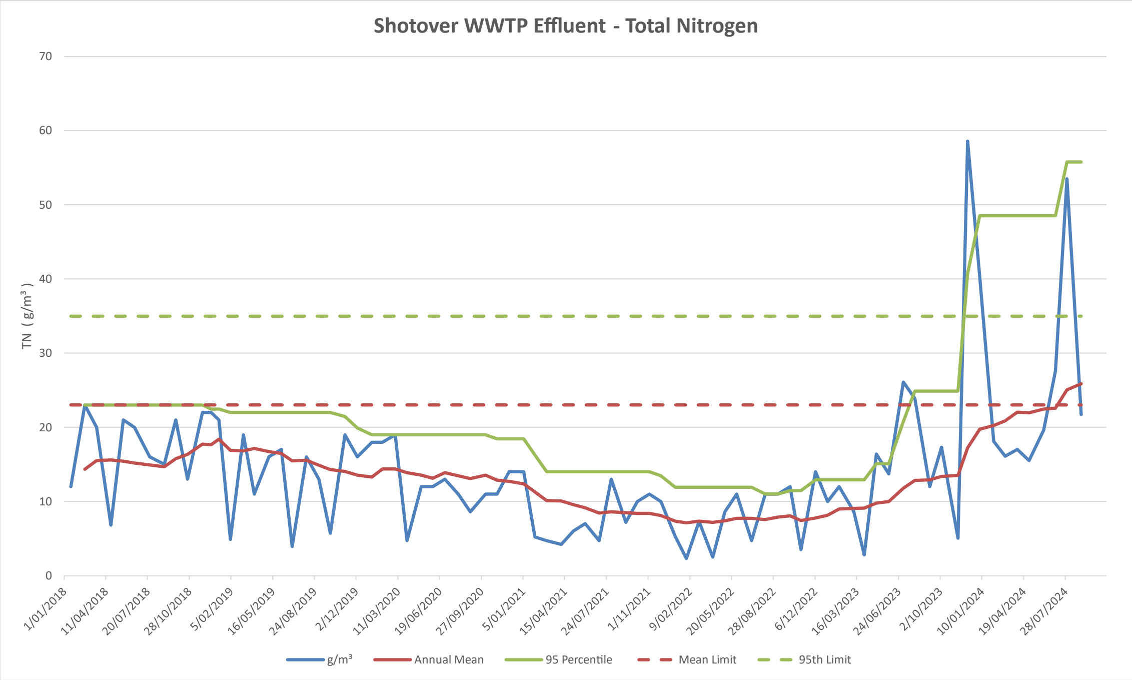


Figure 2.4: E. Coli in Shotover WWTP Effluent

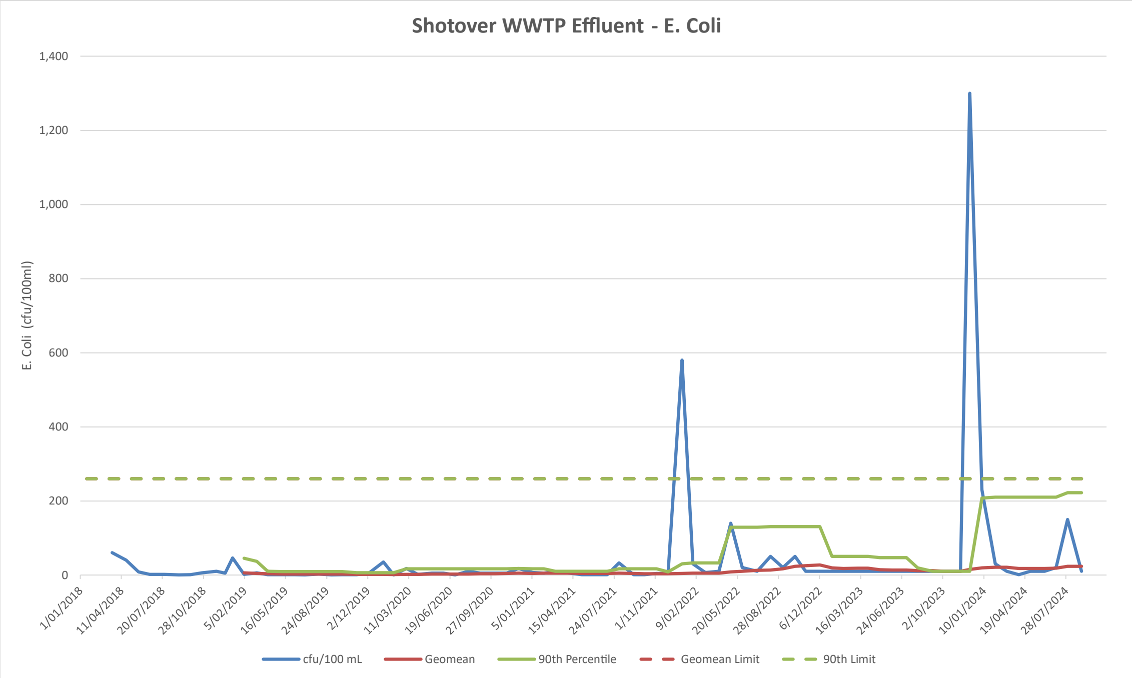
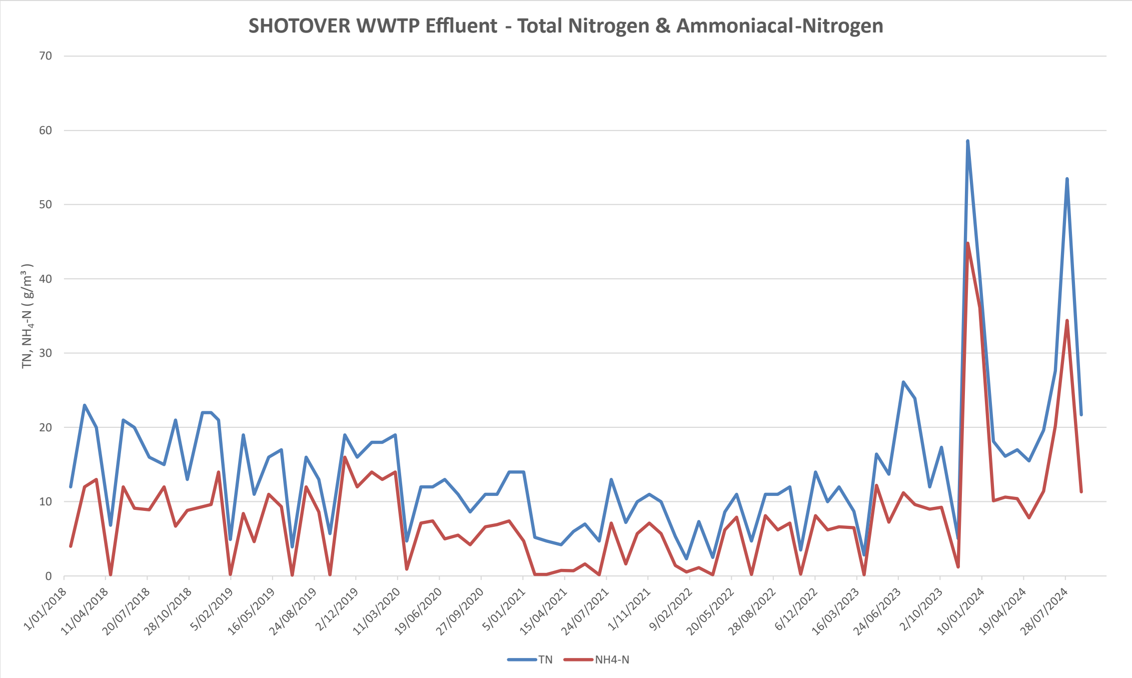


Figure 2.5: Total Nitrogen and Ammonical-Nitrogen in Shotover WWTP Effluent



The results show that there was a high TSS in the effluent from the plant on the 7 December 2023 and 1 August 2024, and that this correlates with the elevated $cBOD_5$, Total Nitrogen, Total Ammoniacal-Nitrogen, and E. coli results. It seems likely that the low DO and the loss of solids from the MLE process contributed to the loss of nitrification and elevated ammonia levels seen in the December 2023 sample.

By the 4 April 2024 the results appeared to be trending downwards towards normal levels again, suggesting the issues had been resolved and the plant was approaching a more stable performance. However, the results from July and August 2024 suggested that this was not the case, as discussed in Section 2.4.6.

It is noted that approximately 20% of the raw wastewater is treated in the oxidation pond. Typically, ammonia removal in oxidation ponds is low. It is not possible to determine from the above graphs what the relative contribution of the pond effluent is to the elevated effluent concentrations. However, anecdotal evidence from the operators is that the recent elevated concentrations are due to the issues with the MLE process.

2.4.5 Disposal field hydraulic loading

Based on the historical flow records and annual reports since 2020, the volume of wastewater discharged to the disposal field has not exceeded the annual average of 11,238 m^3/d permitted under the resource consent, or the maximum discharge loading rate averaged over the disposal field area of 1,000 mm/ per calendar day (refer to condition 3) which equates to 28,000 m^3/d based on the total field area of 28,000 m^2.

2.4.6 July 2024 incident

In July 2024 (w/c 15th July) ORC were notified that the Shotover WWTP MLE process appears to have lost nitrification again. The sample results for August 2024 show TN in the effluent at 53.5 mg/L (up from 27.6 mg/L the previous month) and ammoniacal-nitrogen at 34.4 mg/L (up from 20.2 mg/L the previous month). QLDC and Veolia have postulated an underlying cause for the loss of treatment, and this is discussed in 2.4.7. Mott MacDonald would also make the following observations.

The microbiological report (The Wastewater Specialists, 18 July 2024) observes that the biomass appears to be in reasonable health.

It is understood that the mechanical surface aerator was removed in mid-June, approximately two weeks before ammonia concentrations started to increase. Veolia increased the dissolved oxygen (DO) setpoints in response to this increase in ammonia.

DO concentrations in the aerobic portions of the reactor vary diurnally, dropping to a minimum of ~1 mg/L at peak diurnal load, and increasing to 4+ mg/L during off-peak periods. The DO of ~1 mg/L during the diurnal peak load will reduce the rate of nitrification and may contribute to elevated ammonia concentrations during this time. Normally a plant would be designed for a DO of 1.5 – 2 mg/L to ensure optimum conditions for nitrification. It is not known why the DO under peak diurnal load is operating less than this.

The growth rate of nitrifying bacteria, and the rate of nitrification, reduce significantly at colder temperatures. From a cursory check, a sludge age of 12 days should be adequate to maintain a population of nitrifying bacteria, even at a reactor temperature of 11 – 12.5°C, provided the swing zone is being aerated.

It is evident from the historical sample data that the WWTP has remained compliant since the beginning of 2018 when monthly sampling started, and that the recent compliance issues starting in December 2023 are unusual for this plant and appear to stem from a specific set of events.

2.4.7 MLE Mixer Failure

The Veolia incident investigation report dated 28 August 2024 states that starting on 27 May 2024, two pre-anoxic zone mixers and one anoxic zone mixer at the MLE Bio-Reactor catastrophically failed due to mechanical seals not being replaced in 2022 as per the manufacturer's recommendations under previous QLDC contractor operation.

A loss of treatment was subsequently recognised on 16 July 2024 due to inadequate mixing, resulting in non-compliance with the operating consent, as well as elevated levels of nitrogen and solids carrying over to the disposal field.

On 5 and 27 June 2024, the two pre-anoxic zone mixers were removed, repaired, and refitted for service on 22 July 2024. The mixer guide rail was broken during the attempted retrieval of the anoxic zone mixer, where it was discovered that the mixer was a replacement of the wrong size and there was evidence of improper mixer installation by a previous QLDC contractor. The anoxic zone mixer was retrieved on 29 July 2024. The original mixer of the correct size was found at the bottom of the tank on 20 August when divers were removing parts of the broken mixer guide rail.

A new mixer guide rail was fitted on 21 August 2024 and the correct replacement anoxic zone mixer was put into service.

This incident report says that the treatment process was affected negatively by the lack of mixing, and that after the reintroduction of the pre-anoxic zone mixers, steady improvement in treatment has been realised. The pre-anoxic zone mixers were returned to service on the 22 July and the anoxic zone mixer was reinstated on the 21 August 2024. The most recent sample result on the 4 September 2024 would appear to confirm that effluent quality is improving; however, this is a single result. It is recommended that further, more frequent sample data is obtained from QLDC/Veolia for the period since the mixers were returned to service, to demonstrate a sustained improvement in the effluent quality.

We would agree with the following recommendations made in the incident report to help prevent further mixer failures or mitigate the effects of such failures:

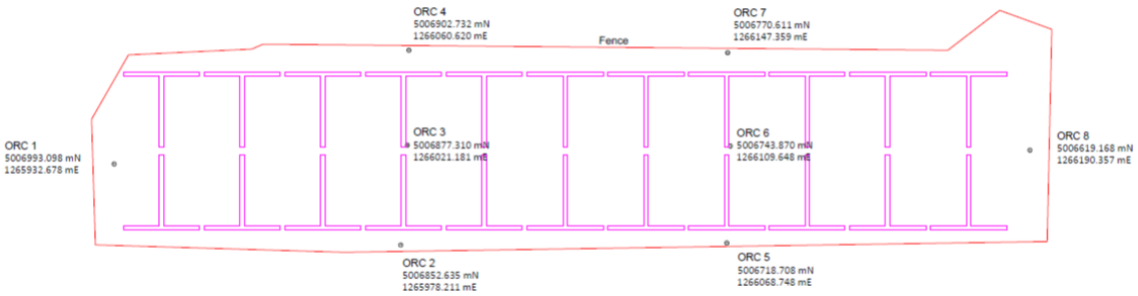
- Mixer PM’s (preventative maintenance) will be set up in the Veolia asset management system (VAMS) to adhere with the manufacturer's recommended maintenance schedule and ensure operational performance.
- More training for those performing operational testing to detect treatment failures earlier. More involvement of Supervisor level personnel in the daily operation of the facility to escalate equipment failures in a more timely fashion.

The incident also highlights the importance of having critical spares in stock. In this case, the anoxic zone mixer was kept in storage on site.

2.4.8 Groundwater bore samples

The effects of discharge are monitored through monthly quality sampling of the 8 groundwater bores located at the disposal field. The up gradient (bore 1) and down gradient (bore 8) are required to be sampled monthly to meet consent compliance; the other bores are sampled monthly for monitoring purposes.

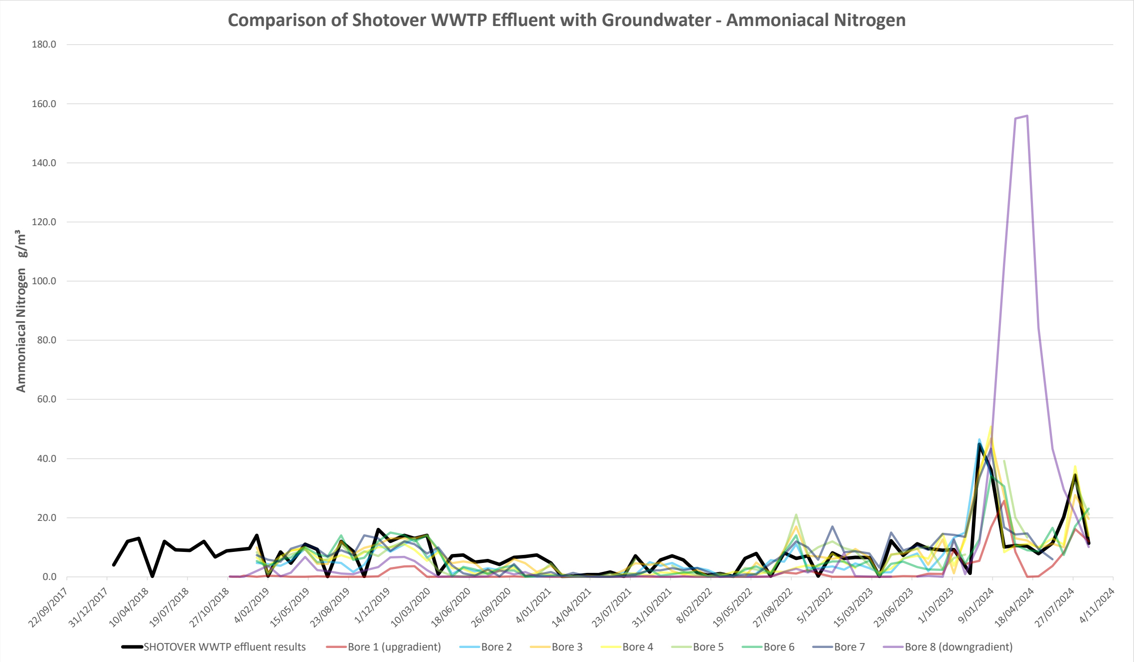
Figure 2.6: Location of the 8 monitoring bores within the disposal field



Source: Project Shotover WWTP O&M Manual

The graphs below are of groundwater sample data from the eight boreholes, compared against the discharge effluent quality of the Shotover WWTP. The nitrate graph (Figure 2.9) shows only the borehole water quality as there is no nitrate data available for the effluent.

Figure 2.7: Ammoniacal Nitrogen in Groundwater Bores and Shotover WWTP Effluent

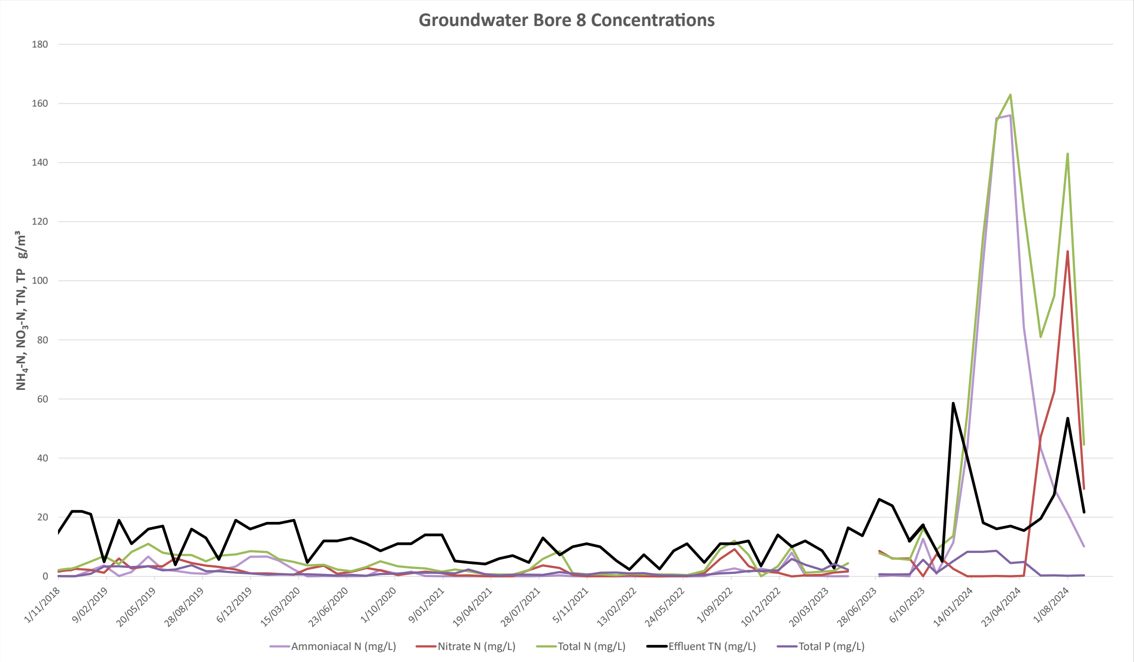


Generally, there is a reasonable correlation between the WWTP effluent concentrations, and the concentrations measured in the groundwater bores.

However, the down gradient bore 8 showed a disproportionate and delayed response to the effluent peak seen in December 2023.

The following shows the concentrations for several parameters in Bore 8 compared with the WWTP effluent.

Figure 2.8: Groundwater Bore 8 Concentrations (Effluent TN shown for comparison)



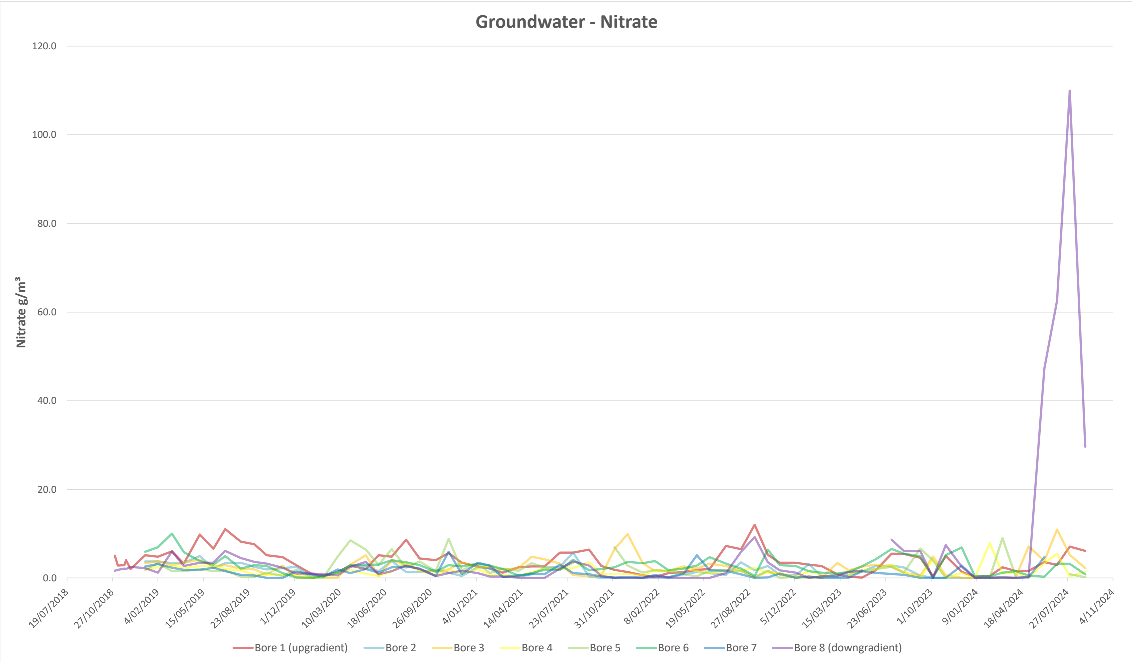
Generally, one would not expect the total nitrogen concentration in the bore to exceed the concentration in the discharged effluent by this magnitude (it is nearly 3 times higher). Nitrogen is converted from one form to another depending on the environmental conditions (eg from ammonia to nitrate, and from nitrate to nitrogen gas) but the total nitrogen is conserved or reduced (for example if ammonia or nitrogen gas is stripped from the liquid phase). For the total nitrogen to increase like this would suggest another source is contributing significant ammonia to the groundwater.

One possible explanation is that there has been a significant discharge of organic solids (consistent with the loss of biological solids from the WWTP) deposited in the disposal field that have accumulated and then decomposed. Organic solids are broken down by microorganisms to produce ammonia. This ammonia can then be biologically converted to nitrate under aerobic conditions, which may be what we are seeing in the June sample (ammonia is decreasing whilst nitrate is increasing).

It is not clear why the same pattern has not been seen in the other bores. The effect seems to be concentrated in the down gradient Bore 8.

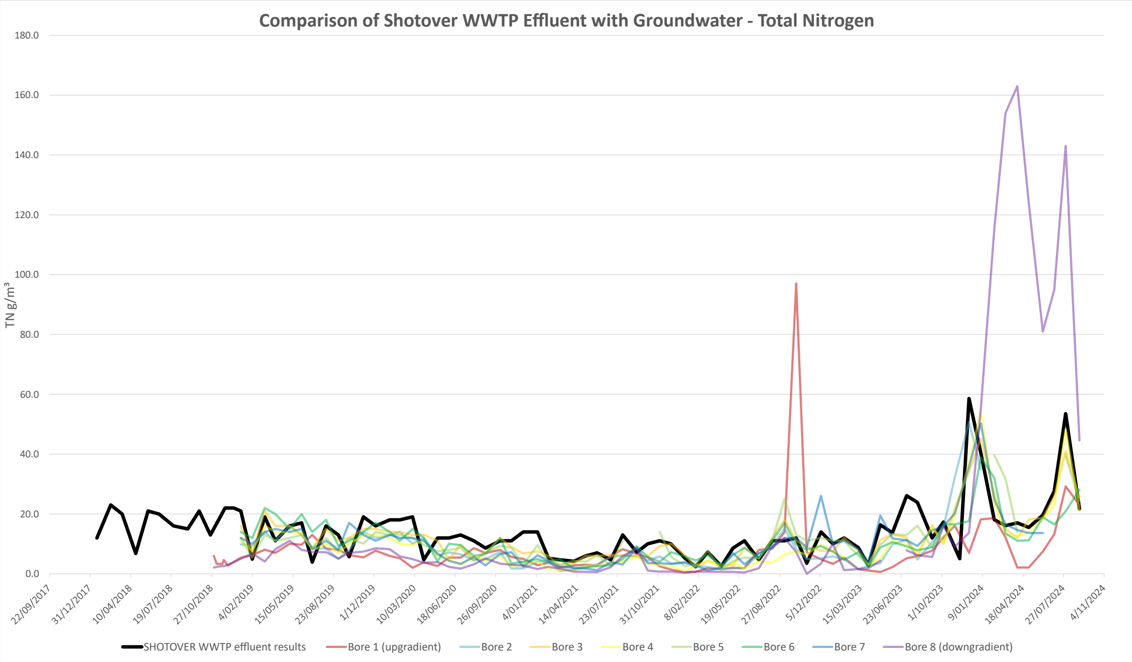
The ammonia in the bore is on a downward trend and it would appear that nitrate levels have also peaked and are now falling. It is expected that this should continue, provided there is not another breakthrough of solids from the plant.

Figure 2.9: Nitrate-Nitrogen in Groundwater Bores



Nitrate-nitrogen levels in the groundwater bores were generally consistent, with the exception of bore 8 which showed a disproportionately high datapoint in June 2024, as discussed previously.

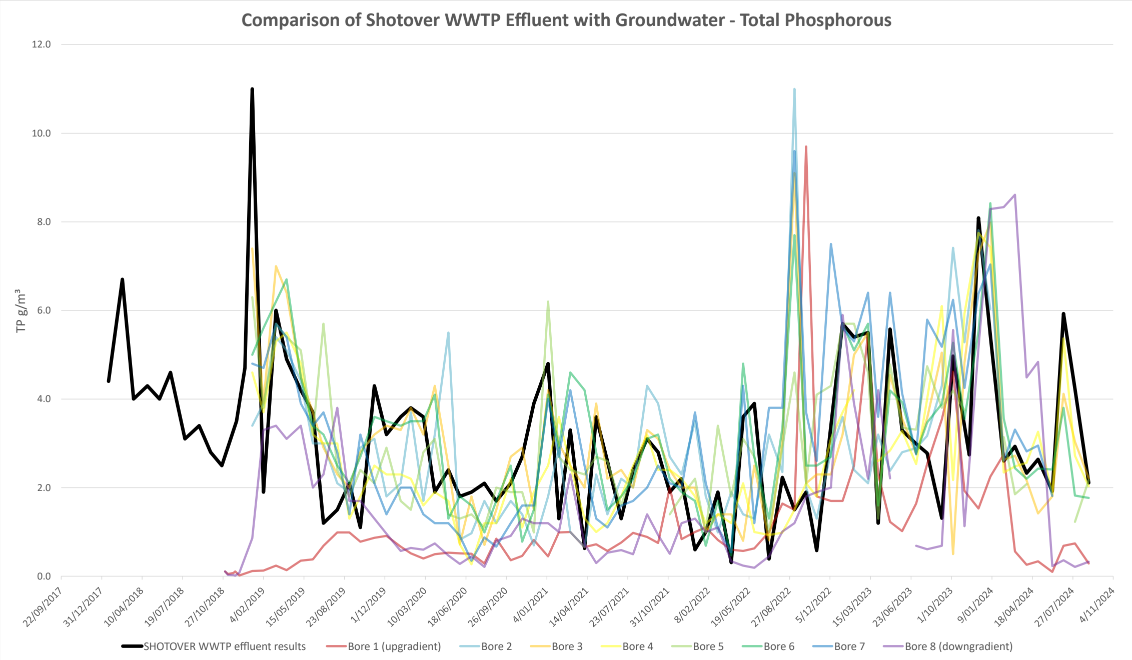
Figure 2.10: Total Nitrogen in Groundwater Bores and Shotover WWTP Effluent



Generally, there is a reasonable correlation between the WWTP effluent total nitrogen concentration, and the concentrations measured in the groundwater bores. As discussed previously, a disproportionately high peak was observed for bore 8 peaking in April 2024 at 163 mg-N/L.

It is noted that there was a peak in total nitrogen seen in the up gradient bore 1 in October 2022 that was not seen by the other groundwater bores. However, the ammoniacal nitrogen sample for bore 1 (Figure 2.7) did not respond in a similar fashion for the same time period, suggesting the datapoint could perhaps have been an outlier.

Figure 2.11: Total Phosphorus in Groundwater Bores and Shotover WWTP Effluent



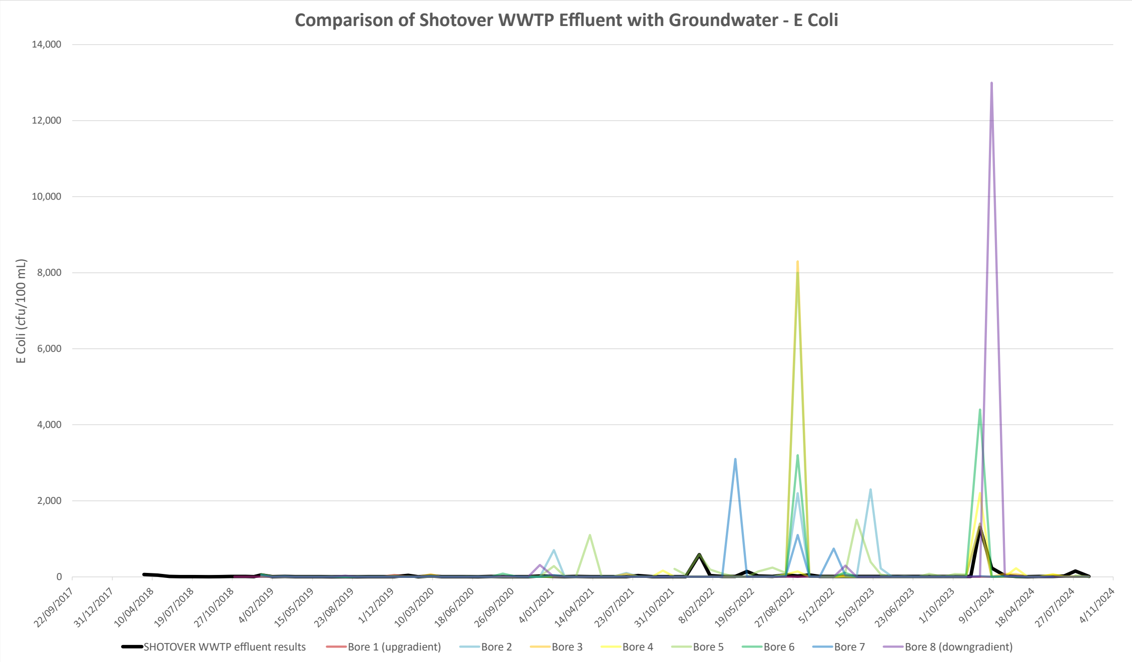
The concentration of total phosphorus in the groundwater samples have had similar concentrations to the Shotover WWTP effluent sampling data, with high levels of variation in 2023. However, there was a disproportionately high peak of total phosphorus recorded for the groundwater samples, specifically bores 2, 3, 4, 6 and 7 in September 2022, as well as a delayed peak from bore 1 in October 2022, that were not reflected in the Shotover WWTP effluent for the same time periods. The reason for this peak is not known.

It is interesting to note that the phosphorus peak seen in bore 8 between January and March 2024 does not vary to the same magnitude as the total nitrogen.

One might expect a more direct correlation between the effluent and the bores where soluble components, such as ammonia, are concerned, as these would be transported through the disposal field relatively quickly compared with particulate components, which would be trapped within the disposal field.

Another consideration is that the effluent and bore samples are only taken monthly, and it is possible that an event might have occurred in between the sample days, followed by a delayed response in the groundwater bores, perhaps more likely in the case of particulate components (that include TSS, E. coli and particulate forms of BOD_5, nitrogen and phosphorus).

Figure 2.12: E. coli in Groundwater Bores and Shotover WWTP Effluent



The E. coli levels in the groundwater samples are shown to have increased variability in the latter half of the sampling period, with a large spike observed in September 2022 for bores 2, 3, 5, 6, and 7. This spike is not reflected in the E. coli level for the Shotover WWTP effluent in the same time period which was found to be 20 cfu/100mL.

It is possible that bacterial growth within the disposal field, as well as contamination by bird droppings etc, could result in levels of E. Coli higher than in the effluent.

The peaks in E. coli concentration observed in the groundwater samples for January 2024 can be correlated to a similar peak in E. coli observed in the Shotover WWTP effluent for January 2024. However, the response in borehole 8 again seems disproportionately large and delayed.

2.4.9 Beca disposal field assessment

Beca have produced the following report relating to the disposal field and providing advice on how best to remediate the site in the short- and long-term:

- Shotover WWTP Disposal Field Report, Assistance with Remedial Works (Beca Limited, 15 March 2023)

The report says that there remain information gaps around the causes and reasons behind the breakouts and reduction in disposal field performance, but suggests that clogging due to solids in the treated wastewater appears to be the main issue. The proximity of the site to the Shotover River and the high hydraulic connection between groundwater and surface water is also suggested to significantly influence the soakage performance of the disposal field. The Mott MacDonald review of the disposal field in Appendix A discusses the disposal field performance.

The Beca report concludes that the primary source of the solids is likely to be the pond, with the clarifier contributing elevated solids only during infrequent high flows, of approx. 200 L/s. The addition of Clarifier 2 with the Stage 3 upgrade should therefore raise this apparent carryover 'threshold' to 400 L/s.

Table 1 in the report suggests that the average TSS concentrations are 37 mg/L in the pond effluent and 4.4 mg/L in the clarifier effluent[1], but that 23% of the flow is to the pond, such that the ratio of pond effluent solids to clarifier effluent solids is around 2.6:1 on a mass basis. The report observes lower UVT (higher TSS) in the combined effluent when the pond pumping station (PS) is above 15 L/s but is inconclusive about the mechanism and suggests that site testing is required to understand this.

The report discusses the following options, comprising short-term and long-term measures to remediate the disposal field. Options 1-3 and 10-12 relate to improvements to the treatment plant to better protect the infiltration trenches from ingress of sludge and biological fines.

1. Implement continuous turbidity monitoring on both pond and clarifier effluent streams. This will provide additional data to more accurately assess the solids issue and provide the operator with the options to address the issue as it occurs, such as:
    a. For the Pond Pump Station
        i. Stopping the pump temporarily to investigate the issue
        ii. Testing if a higher flow from the pump station will alleviate this issue, as the data suggest
    b. For the Clarifier Effluent
        i. Temporarily reducing the flow split to MLE/Clarifier, depending on pond levels
        ii. Attempt to lower the clarifier sludge blanket by increasing the RAS flow
        iii. Consider lowering the clarifier solids load by lowering the Mixed Liquor Suspended Solids (MLSS) through increased wasting. Noting this will require careful planning and risks lowering the sludge age to the point where nitrification becomes compromised.
2. Install the effluent return pipeline from the Pond PS to the QT 1/2 main so any algal biomass can be captured into the process-activated sludge. This has been previously designed with an estimated total cost of $266k.
3. Creation of the treated effluent calamity pond. Note this can only be done after the Stage 3 upgrade works have been commissioned, which may resolve the issue.
4. Consider installing a perimeter bund to prevent overflow from site to surrounding areas and the Shotover River. Then potentially provide overflow pathways to a pump station and to pump back any excess flows to a calamity pond if one is constructed.
5. Consider reshaping the site to maximise infiltration over the total available area within the disposal field, by creating a series of surface basins in the space between the sets of baskets.
6. Clean the current infiltration trenches where there is evidence of significant sediment/algae accumulation/clogging (noting that this will likely reoccur in the short-term).
7. Investigate further the performance and risks of the current disposal field and continue to monitor disposal trench water levels (especially recovery), groundwater levels, water quality and flows and cycling times to achieve better scarification (drying periods)
8. Install surveillance cameras and monitor the extent and frequency of over topping/flooding at the site.
9. Prepare a monitoring and response plan in the event of excessive over topping and flooding at the site.

The report also mentions the following options, but says that these are no longer recommended:

[1] The most recent sample results in September 2024 (based on only 4 samples) indicate an average TSS in the pond effluent of 47 mg/L and in the clarifier effluent of 11 mg/L.

10. Install tertiary filters downstream of the clarifier (short term) or clarifiers (long term). This would help to remove the small number of residual solids from the clarifier effluent stream prior to the disposal field. This is unlikely to be a feasible option in the short term with only one clarifier operating but it may be feasible long term when very high flow rate events become a rarity. This is because generously sized tertiary filters for high flow events would be unlikely to be able to process the shear mass of solids discharged during a clarifier blanket overflow event. It also does not address the main issue which is the solids content from the pond (prior to Stage 3 commissioning). With decommissioning of the pond planned in the future it is important that the solids from the clarifier also be addressed.
11. Creation of an automated divert of clarifier effluent to Pond 3 (not recommended unless Item 1 above regarding turbidity monitoring shows the clarifier to be a significant source of solids).
12. Temporary addition of polymer to the clarifier feed, under very high flow rates, to enhance settling (prior to completion of Stage 3).

Table 2.4 describes each of the above options, in light of the recommended DAD upgrade works in Mott MacDonald's DAD performance review (Appendix A), with recommendations on which should be taken forward.

Table 2.4: Discussion of Beca proposed remediation measures

Option #	Description	Comment	Recommended
1	Implement continuous turbidity monitoring on both pond and clarifier effluent streams.	This should be implemented to understand effluent TSS patterns with flow and provide early warning.	Yes. This should be done in conjunction with an operational response plan for high turbidity and high sludge blanket events.
2	Install the effluent return pipeline from the Pond PS to the QT 1/2 main so any algal biomass can be captured into the process-activated sludge.	In the short term this will introduce greater risk to the MLE process. The oxidation ponds are being decommissioned end of 2025.	No
3	Creation of the treated effluent calamity pond.	It is understood this is part of the Stage 3 upgrade.	Yes
4	Consider installing a perimeter bund to prevent overflow.	This has been implemented. Integrity of bund should be checked.	See Appendix A
	Provide overflow pathways to a pump station and pump back any excess flows to the calamity pond.	Short-term DAD upgrade proposes field influent buffering rather than field effluent storage.	See Appendix A
5	Consider reshaping the site to maximise infiltration over the total available area within the disposal field by creating a series of surface basins in the space.	This has been implemented.	See Appendix A
6	Clean the current infiltration trenches where there is evidence of significant sediment/algae accumulation/clogging.	This is understood to have been implemented.	See Appendix A
7	Investigate further the performance and risks of the current disposal field and continue to monitor disposal trench water levels (especially recovery), groundwater levels, water quality and flows and cycling times to achieve better scarification (drying periods).	This is understood to be ongoing.	See Appendix A

Option #	Description	Comment	Recommended
8	Install surveillance cameras and monitor the extent and frequency of over topping/flooding at the site.	This is understood to have been implemented.	See Appendix A
9	Prepare a monitoring and response plan in the event of excessive over topping and flooding at the site.	This should be done.	See Appendix A
10	Install tertiary filters downstream of the clarifier.	Risk to process should be much reduced once Stage 3 upgrade completed. May offer marginal benefits after this.	No. QLDC to demonstrate ability of Stage 3 upgrade to achieve new discharge consent standard.
11	Creation of an automated divert of clarifier effluent to Pond 3.	This could take up to a year to design and install and ponds will be decommissioned at the end of 2025. Diversion to calamity pond could be considered as part of Stage 3 upgrade.	QLDC to determine whether this is required based on assessment of Stage 3 upgrade ability to achieve new discharge consent standard.
12	Temporary addition of polymer to the clarifier feed under very high flow rates.	This has been done recently. Could be retained as part of operational response plan.	Yes

2.4.9.1 Tertiary effluent filtration

Tertiary effluent filtration 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.

The Mott MacDonald review of the disposal field (Appendix A) concludes that whilst clogging is assessed to have contributed to groundwater mounding, at least locally within the DAD, 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, is not expected to achieve resource consent conditions 20 and 21(i).

The Beca review in 2023 concludes that most of the solids entering the disposal field are from the ponds and that the clarifier contributes solids at high flows (200 L/s) but that the Stage 3 upgrade will increase this threshold to 400 L/s and the ponds will be decommissioned at this time. Therefore, provided the Stage 3 upgrade can treat the maximum design flows, the issue of high solids loading to the disposal field will only exist until late 2025. After that the effluent TSS is expected to be much improved. Installation of tertiary filtration is expected to take roughly one year, and will therefore not provide a solution to elevated TSS in the short term. It would potentially extend the life of the disposal field after the Stage 3 upgrade, but as this only needs to operate until the long-term solution is implemented by 2028, the benefits of tertiary filtration are considered marginal. It is recommended that a condition of the enforcement order be that the Stage 3 upgrade is completed by the end of 2025 and that the long-term solution is completed by the end of 2028.

It is therefore not recommended to install tertiary effluent filtration.

3 Conclusion & Recommendations

3.1 Discussion & Conclusion

The Veolia incident report (15 May 2024) describes significant operational challenges faced by the operators at Shotover WWTP between November 2023 and April 2024, that severely impacted treatment performance and compliance. The report provides a timeline of the incidents and the corrective actions undertaken by Veolia and QLDC to restore compliance and operational stability.

The operational challenges described by Veolia appear to be the result of multiple inter-related and unrelated failures. The issues with the centrifuges and polymer dosing, whilst not obviously related to the diffuser fouling, caused elevated mixed liquor in the reactor, which exacerbated the low DO. This in turn caused anaerobic conditions and settleability issues which resulted in loss of suspended solids from the clarifiers. Replacement of the diffusers and resolution of the dewatering issues appear to have resolved many of the plant performance issues.

By May 2024, Veolia reported that significant progress had been made in restoring operational stability and compliance at the plant. However, in July 2024 ORC were notified that the MLE process appeared to have lost nitrification, with elevated concentrations of ammonia and nitrogen in the effluent compared with the previous month. An incident report in August 2024 describes the catastrophic failure of two MLE pre-anoxic zone mixers and one anoxic zone mixer in May 2024. This incident caused inadequate mixing in the MLE plant and lead to the subsequent loss of treatment in July 2024. Mixing was resumed partially on 22 July with the two pre-anoxic mixers repaired and put into service. However, due to the damaged mixer guide rails also requiring replacement, it was not until 21 August that the replacement anoxic zone mixer was installed and resumed service. Veolia claim in the incident report that effluent quality has since improved. The most recent sample result on the 4 September 2024 would appear to confirm that effluent quality is improving; however, this is a single result. It is recommended that further, more frequent sample data is obtained from QLDC/Veolia for the period since the mixers were returned to service, to demonstrate a sustained improvement in the effluent quality.

The microbiological report (The Wastewater Specialists, 18 July 2024) also suggests several potential causes for the loss of nitrification in July 2024, including lower than ideal DO concentrations in the reactor under peak load conditions, and relatively low temperatures that might be inhibiting nitrification. However, it seems likely these comments were made without knowledge of the failed mixer, since no mention is made of this in the report. QLDC/Veolia have stated the replacement of the aeration diffuser grid seems to have been successful, and that the DO appears to be adequate. However, they believe they will be able to make more informed decisions once the plant operation has stabilised following reinstatement of the mixers.

It is evident from the historical sample data that the WWTP has remained compliant since the beginning of 2018 when monthly sampling started, and that the recent compliance issues starting in December 2023 are unusual for this plant and appear to stem from a specific set of events. The loss of the pre-anoxic and anoxic mixers in May 2024 appears to coincide with the onset of treatment issues and would seem a likely contributing factor.

The Stage 3 upgrade, which will provide further treatment capacity for up to 2048, is currently being constructed and is due for completion at the end of 2025. Therefore, the existing reactor and clarifier and ponds 2 & 3 (pond 1 is currently being decommissioned) will continue to provide treatment until this time. Therefore, it is recommended that the capacity of the existing treatment plant be confirmed and compared with current influent flows to inform operators when the influent flows are exceeding the plant's capacity. This should feed into an appropriate operational response plan.

It is evident that the elevated concentrations observed in the WWTP effluent in December 2023 resulted in corresponding elevated concentrations within many of the groundwater bores surrounding the disposal field.

There was a delayed and disproportionately large response observed in the down gradient bore 8. For example, in the case of total nitrogen the concentration in the bore reached a peak concentration of nearly 3 times that in the discharged effluent and occurring 3 to 4 months later.

A possible explanation is that there has been a significant discharge of organic solids deposited in the disposal field (consistent with the loss of biological solids from the WWTP) that have accumulated and then decomposed gradually over time, resulting in a large and delayed input of nutrients into the groundwater.

It is not clear why the same pattern has not been seen in the other bores. The effect seems to be concentrated in the down gradient bore 8. If further investigation of this is required to determine a link, we recommend a hydrogeological investigation of the information. It is not known what impact these elevated concentrations might have on ground water supplies in the area. We recommend that any potential impact should be investigated.

The ammonia in bore 8 is on a downward trend and the nitrate has peaked and is now falling. This should continue, provided there is not another breakthrough of solids from the plant. The remediation work that QLDC/Veolia have been doing to restore the operational stability of the MLE process should help to reduce the risk of recurrence.

3.2 Recommendations

The Veolia incident reports (15 May 2024 and 28 August 2024) describe significant operational challenges faced by the operators at Shotover WWTP between November 2023 and August 2024, that severely impacted treatment performance and compliance, along with the corrective actions undertaken in an effort to restore compliance and operational stability. Based on these findings, the following recommendations are made to inform an Enforcement Order to support QLDC becoming compliant with the resource consent conditions.

1. According to Veolia, the conveyor screws experienced malfunction due to a missing liner in conveyor 1, damaged and misaligned liners in conveyors 2 and 3, as well as blockages in chutes and conveyor 3. These issues are being addressed by replacing the liners in conveyors 2 and 3, and replacing conveyor 1. The PLC code of the centrifuges is also being modified to redirect flush water to drain. It isn't clear whether these have all been implemented yet. Therefore, we recommend these be included as a requirement in the enforcement notice to ensure they are carried out.
2. It is a requirement of the resource consent 14(d)(i) that the OMM includes contingency plans for system malfunction and breakdowns for each part of the treatment and disposal system. We recommend a specific contingency plan for the dewatering system should be captured in the OMM that considers installing temporary dewatering equipment until the permanent plant is back online. This could have significantly reduced the consequences of the dewatering system failures seen in 2023.
3. Section 9.5 of the OMM (preventative maintenance tasks and schedules) should be updated to include specific monitoring of the integrity of the blower inlet filter. This should include checking the condition of the inlet filters and recording the differential pressure shown by the PDI's on the inlet filters. Table 6.8.5. of the OMM includes monitoring of blower header

pressure and DO, including troubleshooting of high and low values, including fouling of diffusers, air line leaks, blocked air filters. These actions are presumably prompted by SCADA alarms. This should be updated to include routine monitoring of trends in the aeration manifold pressure that could indicate a more progressive problem. The trends should be provided in the annual report to ORC with an explanation of any deviations from normal values.

4. The Stage 3 upgrade, which will provide further treatment capacity for up to year 2048, is currently being constructed and is due for completion at the end of 2025. Therefore, the existing reactor and clarifier and ponds 2 & 3 (pond 1 is currently being decommissioned) will continue to provide treatment until this time. Therefore, QLDC should demonstrate the maximum hydraulic and solids loading capacity of the existing MLE clarifier based on actual measured mixed liquor settleability to understand at what flow rate the clarifier is expected to lose its sludge blanket. Specific operating procedures should be prepared showing how the operator will know when the plant capacity is being exceeded and what the response should be.
5. Loss of sludge blanket from the MLE clarifier occurs at high flows and can lead to non-compliance with the TSS and BOD consent conditions but will also lead to high solids being sent to the disposal field with risk of blockages. Therefore, timely response to this occurrence is required. This requires a means of detection and a response plan. Online turbidity can be used as a proxy for TSS once a relationship has been established on site and may be used to detect a high TSS concentration. This will address the detection part, however an appropriate response plan must also be developed. Therefore, it is recommended that continuous turbidity monitoring be implemented on both pond and clarifier effluent streams. This will provide additional data to more accurately assess the solids issue and provide the operator with the options to address the issue as it occurs.
6. Proper training for operators carrying out operational testing is key to early detection of treatment failures, and appropriate involvement of Supervisor level personnel in the daily operation of the facility to escalate equipment failures in a timely fashion. This was a lesson identified in the recent Veolia incident report. It is recommended that a training plan be developed for new operators covering identification of and response to operational and performance issues.
7. It is recommended that QLDC/Veolia provide a plan for failure of critical equipment, including identifying critical equipment, reviewing installed redundancy, identifying equipment lead times, reviewing holding of spares, identifying options for temporary hire plant.
8. Installation of tertiary filtration after the clarifiers would be expected to take roughly one year, and will therefore not provide a solution to elevated TSS in the short term. It would potentially extend the life of the disposal field after the Stage 3 upgrade, but as this only needs to operate until the long-term solution is implemented by 2028, the benefits of tertiary filtration are considered marginal. Therefore, tertiary filtration is not recommended. However, it is important that any upgrade to the disposal field (discussed below) consider how the storage cells will be cleaned, which has been an issue with the existing design.
9. It is recommended that:
   a. routine effluent sampling should be increased from once a month (as stipulated in the resource consent) to once a fortnight, with the data being made available to ORC within a specified time period such as two weeks.
   b. in addition to the combined effluent, the routine effluent sampling should include separate sampling of the effluent from the oxidation pond and MLE process to understand the contribution of each.
   c. there should be a requirement for the consent holder to perform more frequent sampling following a process upset, that results in elevated effluent concentrations. This should be

at least 3 times a week until the process returns to stable operation. This would give ORC more visibility of how the process and the effluent quality is trending following an upset.

10. The details of the ongoing remedial work of the disposal field and associated performance should continue to be shared with ORC on a monthly basis. This should consider providing ORC with access to the 'live' progress tracker, discussed in Section 1.5 of the O&M manual, which is updated weekly by Veolia.
11. It is recommended that QLDC/Veolia provide a Monitoring and Response Plan in the event of excessive over topping and flooding at the disposal field site.
12. It is not known what impact the elevated groundwater contaminant concentrations in the disposal field (as discussed in 2.4.8) might have on ground water supplies in the area. We recommend that any potential impact on public health should be investigated.
13. Whilst the primary aim of the recent remedial work has apparently been to achieve faster drainage of the disposal field it is not known what impact this will have on the quality of the groundwater and the river water. Therefore, it is recommended that the monthly reporting to ORC should continue to include groundwater levels, as well as sampling of the quality of the groundwater bores, and the upstream and downstream river. This would allow ORC to seek interpretation of the sample data. Further recommendations have been provided by e3 Scientific in this regard (e3 Scientific, 19 August 2024).
14. It is not known whether the remedial works that have been carried out, which includes expanding the disposal field and constructing soakage basins, is allowed under the existing resource consent. It is recommended that this be confirmed by ORC.
15. Mott MacDonald has undertaken a review of the existing disposal field performance (included in Appendix A).

The main recommendations to be included in the enforcement notice are summarised in Table 3.1 below. For convenience the relevant consent conditions are repeated below and are cross-referenced in the table.

12. The quality of the treated wastewater shall not exceed the following limits prior to discharge:

Parameter	***95^{th} percentile***	***Annual mean***
BOD_5 (mg/L)	*50*	*30*
TSS (mg/L)	*50*	*30*
Total Nitrogen (mg/L)	*35*	*23*
E. coli (cfu/100ml)	*260 (90^{th} percentile)*	*260 geomean*

Means and percentiles apply to a rolling 12 calendar month period.

14. …the consent holder shall prepare and forward to the Consent Authority an Operations and Maintenance Manual for the treatment and disposal system to ensure its effective and efficient operation at all times. The system shall be operated in accordance with this manual, which may be updated as appropriate. The manual shall include, but not be limited to…

15. The consent holder shall submit a record of complaints and malfunctions to the Consent Authority within two weeks after any complaint or malfunction occurring, together with the details of the remedial measures taken or proposed to be undertaken.

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 100 m^2 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-years mounding trial period following the commencement of this consent.*

Compliance with the effluent quality in Condition 12 requires that the process and associated mechanical equipment is operating effectively. As has been seen at the plant, plant breakdowns can quickly lead to deteriorating effluent quality. For this reason, recommendations that lead to improved reliability of plant operation and maintenance have been associated with Condition 12.

This report outlines a number of areas that need to be improved to bring the discharge from the Shotover WWTP into compliance. However, as many of these recommendations involve the installation of infrastructure that will take some time to design and install, and in some instances, there are already activities taking place that will overtake these proposed changes, we recognise the need to be pragmatic in what is recommended.

Treatment

- There are clear changes needed to the existing solids treatment system, which we have recommended below.
- We have also demonstrated that the DAD is not suitable for ongoing use if the consent conditions are to be achieved. But we have outlined how performance of the existing DAD can be protected by ensuring low solids effluent is discharged.
- We could therefore recommend a range of solutions to augment the existing treatment plant as discussed in this report. For example, diversion to ponds, filtration and other new assets.
- However, these will have significant cost to the community, and there is already a construction upgrade underway to add a new high quality treatment train (new MLE) to improve effluent quality; this is planned for completion in late 2025.
- Therefore, we recommend a pragmatic approach with the following actions, which are outlined further in the table below:
  - QLDC demonstrates how the design of the new MLE and decommissioning of the existing ponds will consistently achieve the future consent conditions for TSS – median and peak in order protect the existing (and possible future) disposal field.
  - QLDC provides the programme for completion of the new MLE, and demonstrates how the new asset will be in place and commissioned before the end of 2025.
  - QLDC includes in the new MLE treatment plant design, facilities to continuously monitor TSS and/or turbidity, and to divert treated effluent flows to either the Calamity Pond and/or a repurposed treatment pond when it exceeds the peak TSS consent condition(s).

Disposal Field, see Appendix A

Table 3.1: Recommendation Table

Consent condition	Commentary / Explanation / Recommendation Details	Recommended Action
Immediate Treatment Requirements		
12: WWTP Treated Wastewater Limits	According to Veolia, the conveyor screws experienced malfunction due to a missing liner in conveyor 1, damaged and misaligned liners in conveyors 2 and 3, as well as blockages in chutes and conveyor 3. These issues are being addressed by replacing the liners in conveyors 2 and 3, and replacing conveyor 1. The PLC code of the centrifuges is also being modified to redirect flush water to drain. It isn't clear whether these	QLDC to implement the stated repairs on the sludge conveyors 1, 2 & 3 and amendment of PLC code to redirect flush water from centrifuges to drain. To be completed by an agreed date.

Consent condition	Commentary / Explanation / Recommendation Details	Recommended Action
	have all been implemented yet. Therefore, we recommend these be included as a requirement in the enforcement notice to ensure they are carried out.	
12: WWTP Treated Wastewater Limits	Section 9.5 of the OMM (preventative maintenance tasks and schedules) should be updated to include specific monitoring of the integrity of the blower inlet filter. This should include checking the condition of the inlet filters and recording the differential pressure shown by the PDI's on the inlet filters. Table 6.8.5. of the OMM includes monitoring of blower header pressure and DO, including troubleshooting of high and low values, including fouling of diffusers, air line leaks, blocked air filters. These actions are presumably prompted by SCADA alarms. This should be updated to include routine monitoring of trends in the aeration manifold pressure that could indicate a more progressive problem. The trends should be provided in the annual report to ORC with an explanation of any deviations from normal values.	QLDC to update Section 9.5 of the OMM (preventative maintenance tasks and schedules) to include specific monitoring of the integrity of the blower inlet filter. This should include checking the condition of the inlet filters and recording the differential pressure shown by the PDI's on the inlet filters. QLDC to update Table 6.8.5. of the OMM to include routine monitoring of trends in the aeration manifold pressure. QLDC to provide the trends in the annual report to ORC with an explanation of any deviations from normal values.
12: WWTP Treated Wastewater Limits	The Stage 3 upgrade, which will provide further treatment capacity for up to 2048, is currently being constructed and is due for completion at the end of 2025. Therefore, the existing reactor and clarifier and ponds 2 & 3 (pond 1 is currently being decommissioned) will continue to provide treatment until this time. Therefore, QLDC should demonstrate the maximum hydraulic and solids loading capacity of the existing MLE clarifier based on actual measured mixed liquor settleability to understand at what flow rate the clarifier is expected to lose its sludge blanket. Specific operating procedures should be prepared showing how the operator will know when the plant capacity is being exceeded and what the response should be.	QLDC to demonstrate the maximum hydraulic and solids loading capacity of the existing MLE clarifier based on actual measured mixed liquor settleability to understand at what flow rate the clarifier is expected to lose its sludge blanket. QLDC to prepare specific operating procedures showing how the operator will know when the plant capacity is being exceeded and what the response will be.
12: WWTP Treated Wastewater Limits	Loss of sludge blanket from the MLE clarifier occurs at high flows and can lead to non-compliance with the TSS and BOD consent conditions but will also lead to high solids being sent to the disposal field with risk of blockages. Therefore, timely response to this occurrence is required. This requires a means of detection and a response plan (see also conditions 14 and 15). Online turbidity can be used as a proxy for TSS once a relationship has been established on site and may be used to detect a high TSS concentration. This will address the detection part; however, an appropriate response plan must also be developed. Therefore, it is recommended that continuous turbidity monitoring be implemented on both pond and clarifier effluent streams. This will provide additional data to more accurately assess the solids issue and provide the operator with the options to address the issue as it occurs.	QLDC to implement continuous turbidity monitoring on both pond and clarifier effluent streams, with output linked to response plan (refer to previous recommendation).
12: WWTP Treated Wastewater Limits	Proper training for operators carrying out operational testing is key to early detection of treatment failures, and appropriate involvement of Supervisor level personnel in the daily operation of the facility to escalate equipment failures in a timely fashion. This	QLDC to prepare operator training plan covering identification of and response to operational and performance issues.

Consent condition	Commentary / Explanation / Recommendation Details	Recommended Action
	was a lesson identified in the recent Veolia incident report. It is recommended that a training plan be developed for new operators covering identification of and response to operational and performance issues.	
12: WWTP Treated Wastewater Limits	It is recommended that QLDC/Veolia provide a plan for failure of critical equipment, including identifying critical equipment, reviewing installed redundancy, identifying equipment lead times, reviewing holding of spares, identifying options for temporary hire plant.	QLDC to provide a plan for failure of critical equipment, including identifying critical equipment, reviewing installed redundancy, identifying lead times, reviewing holding of spares, identifying options for temporary hire plant.
12: WWTP Treated Wastewater Limits	It is recommended that: a) routine effluent sampling should be increased from once a month (as stipulated in the resource consent) to once a fortnight, with the data being made available to ORC within a specified time period such as two weeks. b) in addition to the combined effluent, the routine effluent sampling should include separate sampling of the effluent from the oxidation pond and MLE process to understand the contribution of each. c) there should be a requirement for the consent holder to perform more frequent sampling following a process upset, that results in elevated effluent concentrations. This should be at least 3 times a week until the process returns to stable operation. This would give ORC more visibility of how the process and the effluent quality is trending following an upset.	QLDC to increase routine effluent sampling from once a month (as stipulated in the resource consent) to once a fortnight, with the data being made available to ORC within two weeks. Routine sampling to include combined effluent and individual effluents from oxidation pond and MLE process. QLDC to perform more frequent sampling following a process upset, that results in elevated effluent concentrations. This should be at least 3 times a week until the process returns to stable operation.
14(d)(i): OMM	It is a requirement of the resource consent 14(d)(i) that the OMM includes contingency plans for system malfunction and breakdowns for each part of the treatment and disposal system.	QLDC to prepare a specific contingency plan for the dewatering system in the OMM that considers installing temporary dewatering equipment until the permanent plant is back online. OMM to be updated accordingly based on any new actions implemented.
15: Record of complaints and malfunctions	Complaints and malfunctions matter.	Not assessed.
Long-Term Treatment Solution		
12: WWTP Treated Wastewater Limits	This report has discussed a range of solutions to augment the existing treatment plant. For example, diversion to ponds, filtration and other new assets. These additions will have significant cost to the community, and there is already a construction upgrade underway to add a new high quality treatment train (new MLE) to improve effluent quality; this is planned for completion in late 2025. Therefore, we recommend a pragmatic approach with the following actions, to ensure that the new treatment plant achieves the conditions required to optimise current and future disposal field performance.	QLDC to demonstrate how the design of the new MLE and decommissioning of the existing ponds will consistently achieve the future consent conditions for TSS – median and peak in order protect the existing (and possible future) disposal field. QLDC to provide the programme for completion of the new MLE and demonstrate how the new asset

Consent condition	Commentary / Explanation / Recommendation Details	Recommended Action
		will be in place and commissioned before the end of 2025. QLDC to include in the new MLE treatment plant design, facilities to continuously monitor TSS and/or turbidity, and to divert treated effluent flows to either the Calamity Pond and/or a repurposed treatment pond when it exceeds the peak TSS consent condition(s).

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A. DAD performance review

Shotover WWTP Enforcement

Dose and drain disposal field - Performance review

December 2024

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Mott MacDonald
Mason Bros. Building
Level 2, 139 Pakenham
Street West
Wynyard Quarter
Auckland
1010
PO Box 37525
Parnell 1151
New Zealand

T +64 (0)9 375 2400
mottmac.com

Otago Regional Council
70 Stafford Street
Dunedin 9054

Shotover WWTP Enforcement

Dose and drain disposal field - Performance review

December 2024

Mott MacDonald New Zealand Limited
Registered in New Zealand no. 3338812

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	23/12/2024	TZ	MR & SE	ND	Final – updated following GHD response

Document reference: 705416485 | 03 | 0 | F416485-RPT-003

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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.

The draft report, issued 03 December 2024, has been updated following the technical options review provided by GHD (GHD, 2024).

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. At the time of this report, it is reported by Queenstown Lakes District Council (QLDC) that the DAD is permanently ponding and a steady surface overflow discharge is occurring.

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 11,238m^3 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 100m^2 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.

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 28,000m^2. 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 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).

At the time of this report, the following mitigation measures and design adaptations have been undertaken and represent the current DAD state (GHD, 2024):

- 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

DAD	Dimension
Dosage trench width (including gravel trenches on side)	4m
Dosage trench area	3,212m^2
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 37,150m^3/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 8,679m^3/d and 9,995m^3/d from 2020 to 2023, with recorded maximum daily discharges between 14,643m^3 and 19,402m^3.

The measured Total Suspended Solids (TSS) in the effluent varied between 4.6g/m^3 (2021) and 17g/m^3 (2023) in the same timeframe, averaging around 9 – 10g/m^3.

The predicted maximum daily flow in 2028, when the current DAD will be decommissioned is 24,600m^3/d, with a predicted average daily flow of 14,300m^3/d (Beca, 2020).

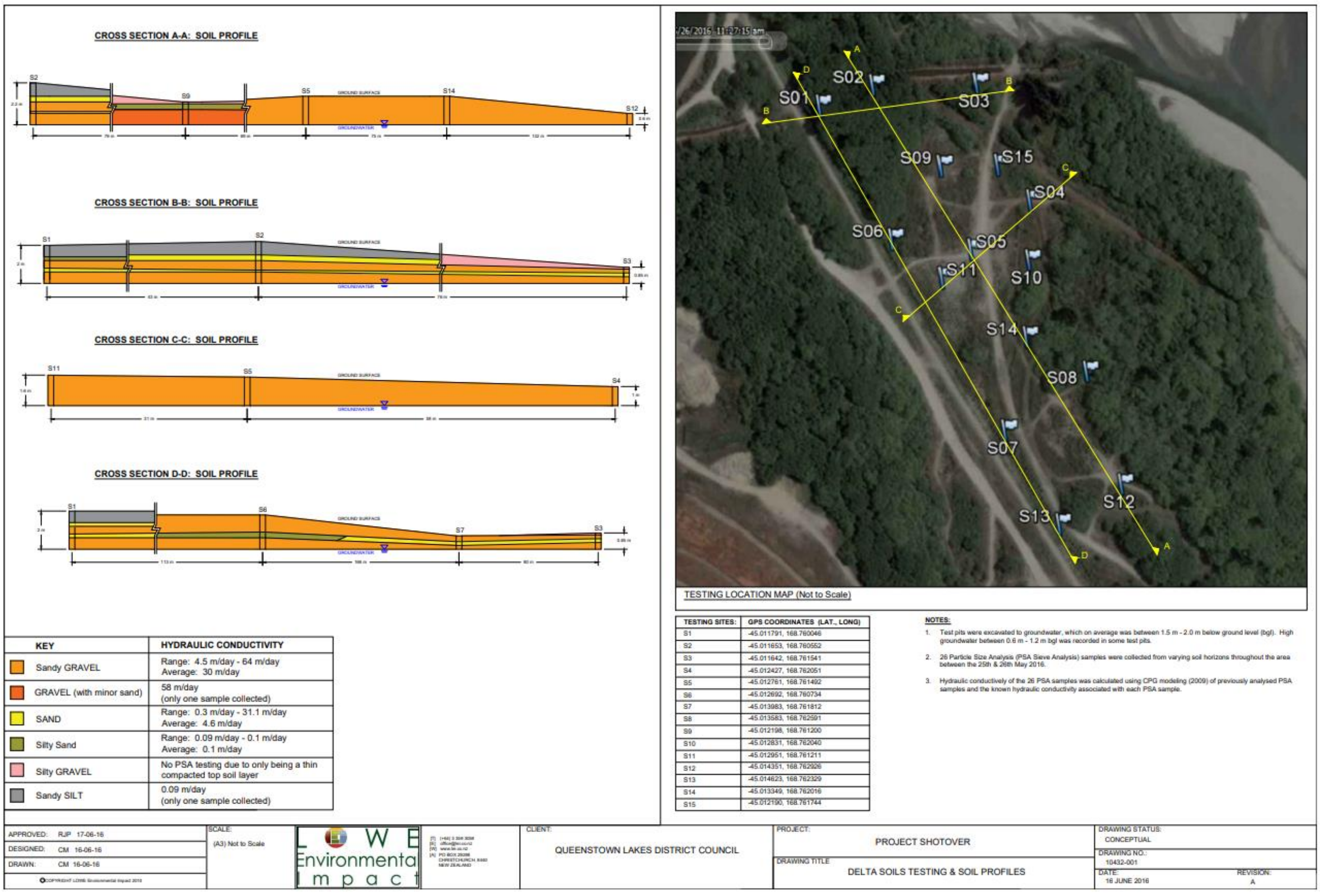
3 Geology and hydrogeology

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 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 Sy	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 12,000m^3/d – 13,000m^3/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 14,000m^3/d, correlating to less than 40% of the design infiltration rate of 37,150m^3/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 equivalates 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 28,000m^2 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 6,424m^2 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 14,000m^3/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.

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.

The raised limitation by GHD is understood. 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 100,000m^3 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 in 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 (GHD, 2024):

- 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 disproportionally 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 summarises and evaluates options to achieve resource consent conditions 20 and 21(i) as described above:

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 requirements 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 disproportionally 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 disproportionally 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.

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

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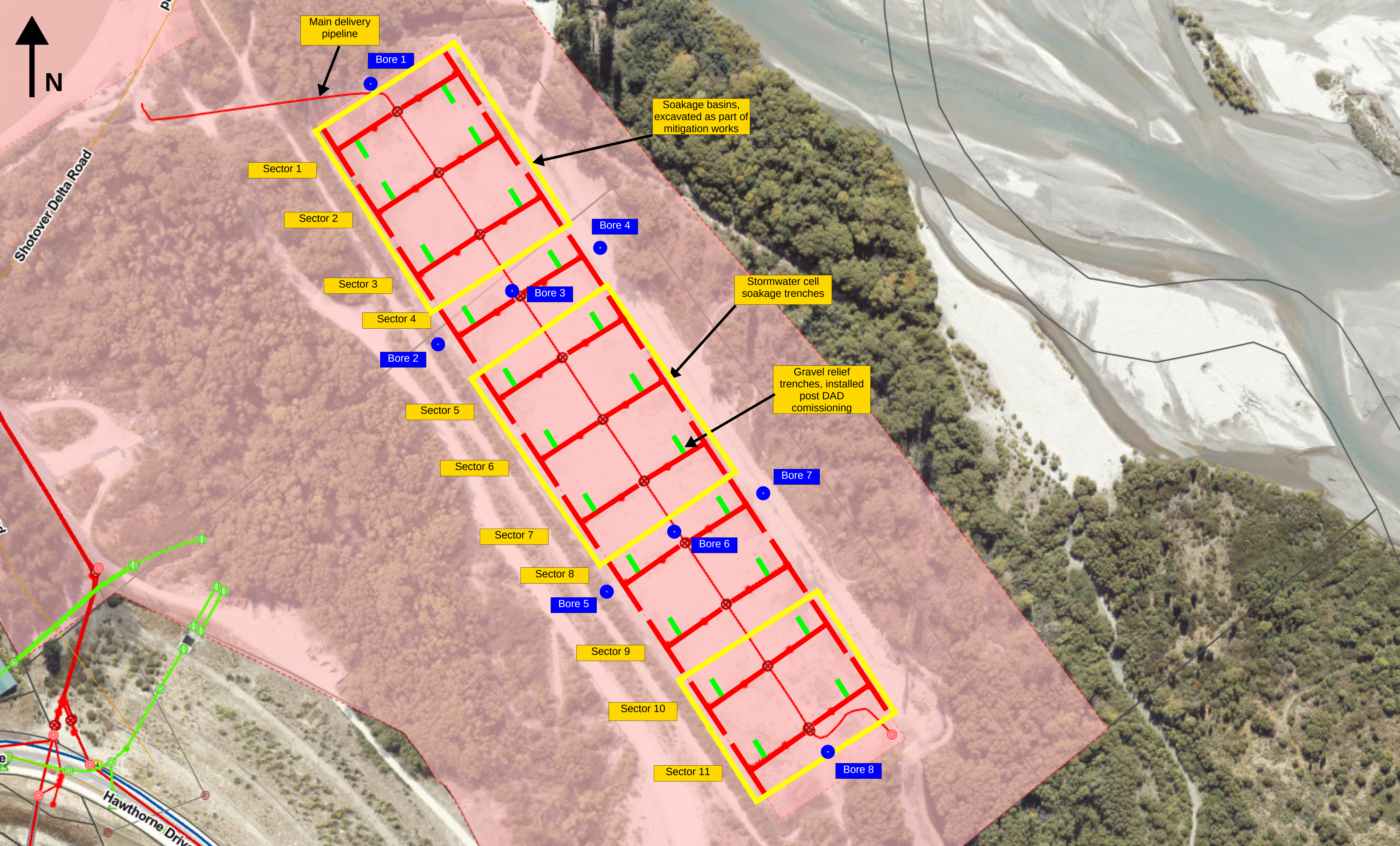
Appendix

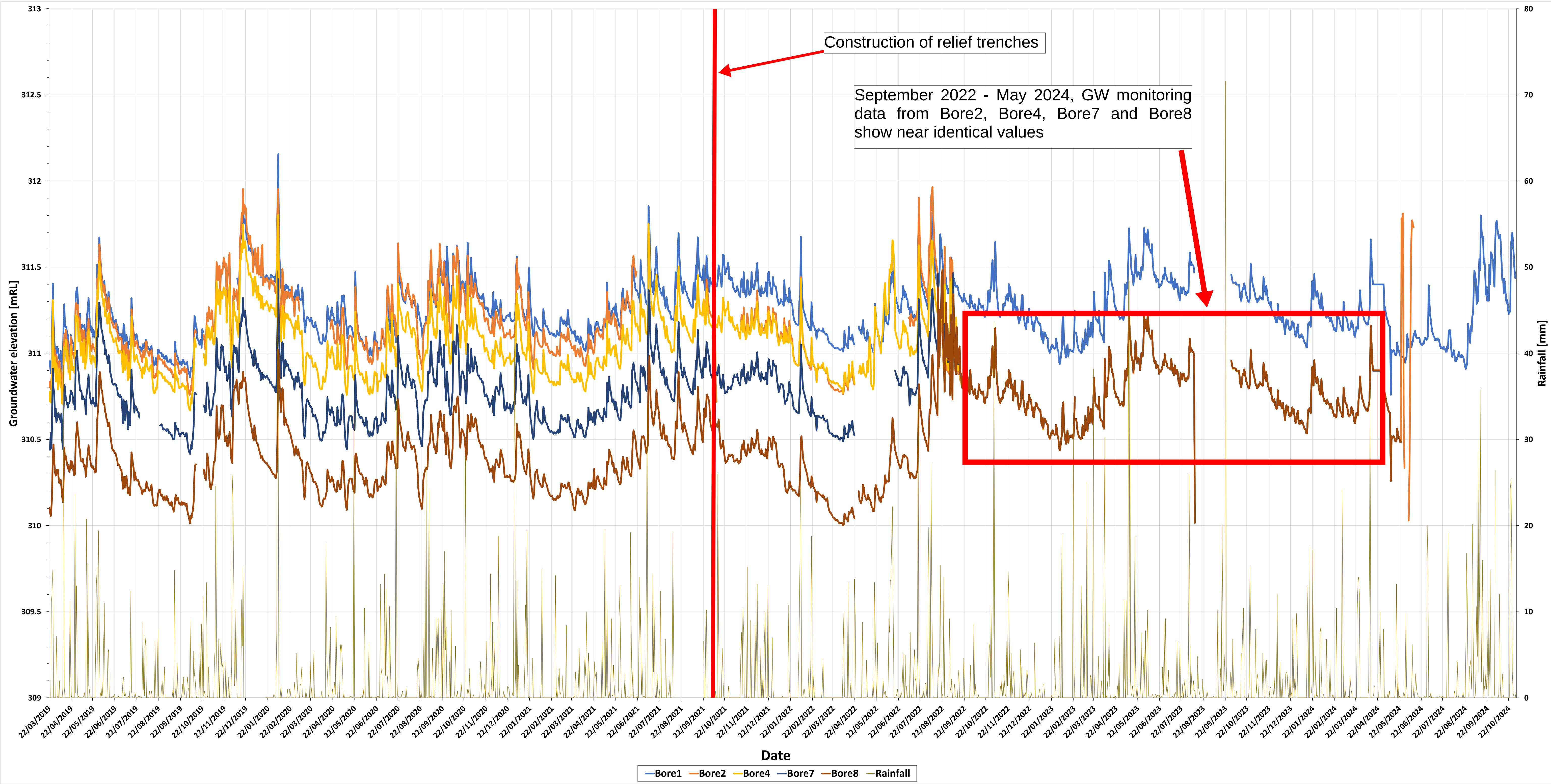
A. Schematic DAD design drawing



N
Main delivery pipeline
Bore 1
Soakage basins, excavated as part of mitigation works
Sector 1
Sector 2
Bore 4
Sector 3
Bore 3
Stormwater cell soakage trenches
Sector 4
Bore 2
Gravel relief trenches, installed post DAD comissioning
Sector 5
Sector 6
Bore 7
Sector 7
Bore 6
Sector 8
Bore 5
Sector 9
Sector 10
Sector 11
Bore 8
Shotover Delta Road
Hawthorne Drive

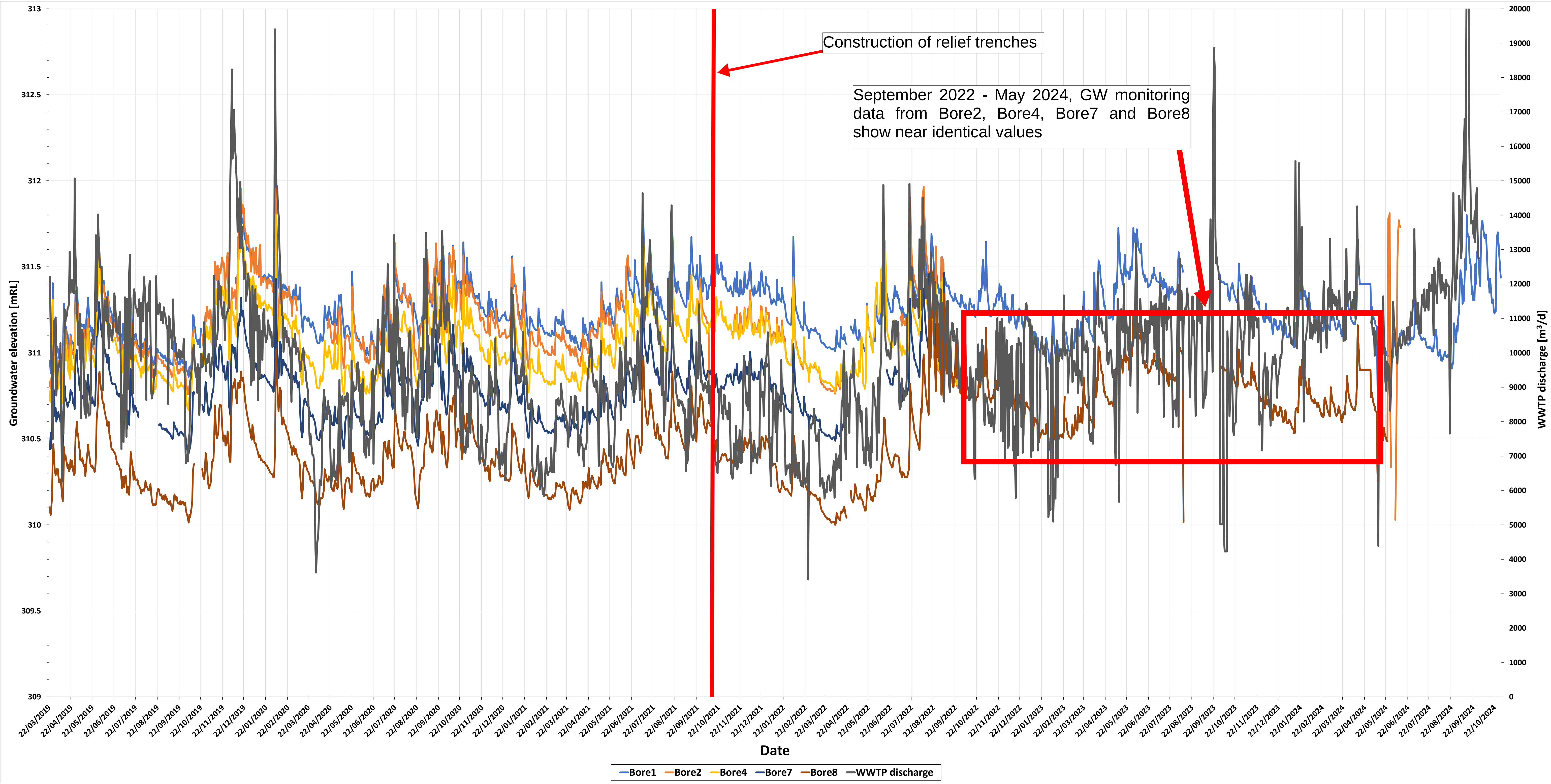
B. Groundwater monitoring plots

B.1 Groundwater monitoring bores outside DAD vs. rainfall



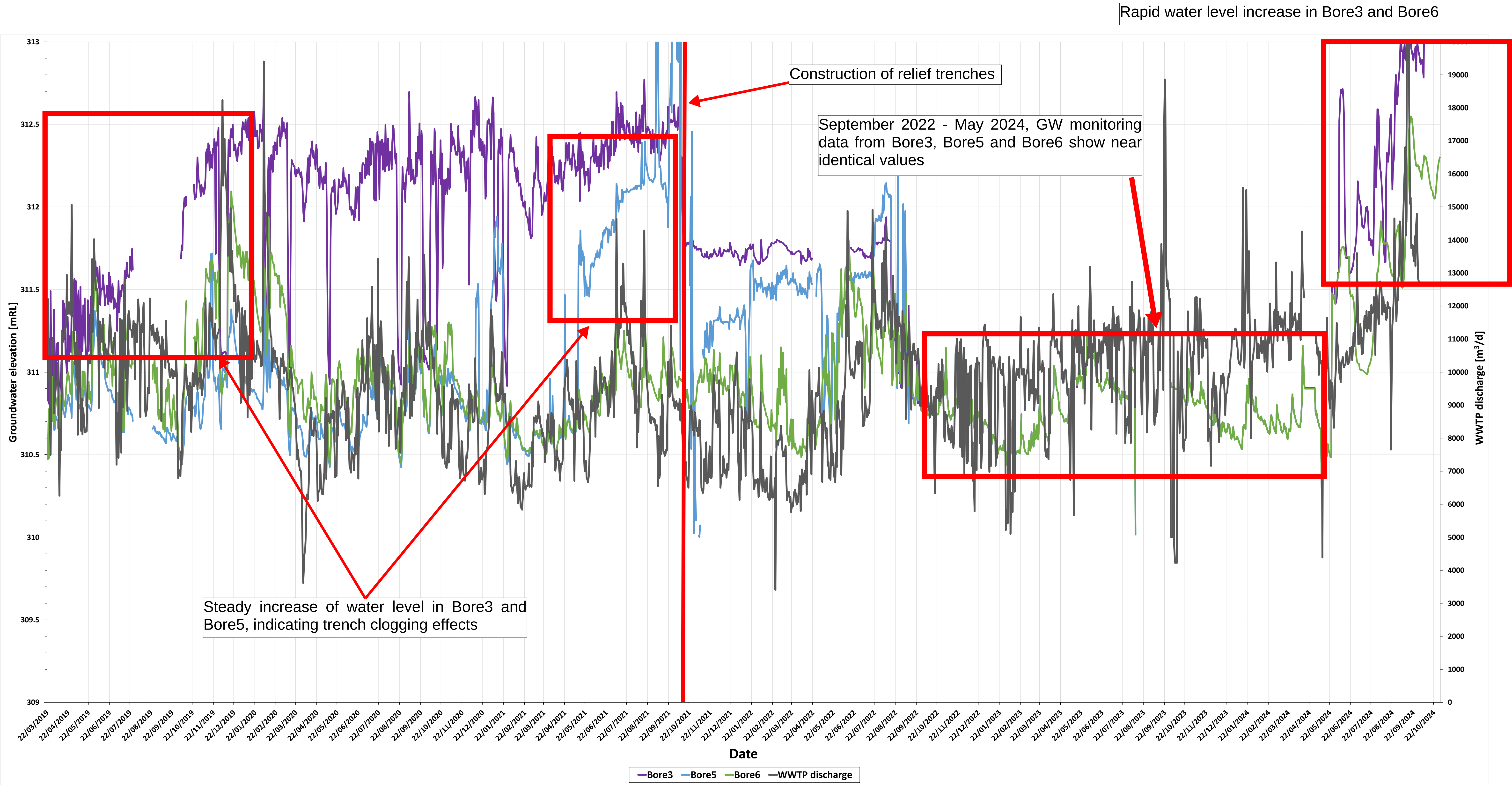
Construction of relief trenches
September 2022 - May 2024, GW monitoring data from Bore2, Bore4, Bore7 and Bore8 show near identical values
Groundwater elevation [mRL]
Rainfall [mm]
Date
Bore1
Bore2
Bore4
Bore7
Bore8
Rainfall

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



Construction of relief trenches
September 2022 - May 2024, GW monitoring data from Bore2, Bore4, Bore7 and Bore8 show near identical values
Groundwater elevation [mRL]
WWTP discharge [m3/d]
Date
Bore1
Bore2
Bore4
Bore7
Bore8
WWTP discharge

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



Rapid water level increase in Bore3 and Bore6
Construction of relief trenches
September 2022 - May 2024, GW monitoring data from Bore3, Bore5 and Bore6 show near identical values
Steady increase of water level in Bore3 and Bore5, indicating trench clogging effects
Groundwater elevation [mRL]
WWTP discharge [m3/d]
Date
Bore3
Bore5
Bore6
WWTP discharge

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