

Waikouaiti Metals Sampling Plan

DOCUMENT CONTROL

Date	Version	Author	Change Details	Approved By
03/02/2021	1		Initial draft for Public Health South	John McAndrew
11/02/2021	2		Added previous sample points and references for distribution. Address comments from PHU & ORC Added additional sampling and monitoring	John McAndrew

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1. PURPOSE OF METALS SAMPLING PLAN

The purpose of this plan is to define the plan, protocols and locations for additional monitoring of heavy metals in the drinking water distribution system, following the recent detection of elevated lead levels.

This sampling plan may be adapted to adjust to any changes recommended through results of monitoring, or as advised by Public Health South (PHU) or ESR (Institute of Environmental Science and Research).

A separate Response Plan provides a clear outline of how DCC will respond to recent elevated lead results in the Waikouaiti drinking water supply.

2. PROJECT MANAGEMENT APPROACH

The Response Plan sets out a project management approach that defines roles and responsibilities of all project team members going forward, methods for change management, methods for communication between parties, internal documentation processes and expectations for public health messaging.

3. WATER SAMPLING

Sampling & Analysis Provider

Sampling and analysis is provided by Eurofins laboratories unless stated otherwise.

Sample Locations for Waikouaiti Water Supply (WAI015)

Sample Point Description	SID ^{1,2}
New Dedicated Sampling Tap: Waikouaiti SS - 192 Main Rd ³ Replaces: TAB Waikouaiti (customer side)	DZWK01-01 DCCDZ-WK-01
New Dedicated Sampling Tap: Karitane SS - 99 Stornoway St ³ Replaces: Karitane Bowls (customer side)	DZWK02-01 DCCDZ-WK-02
New Dedicated Sampling Tap: Waikouaiti SS - 210 Edinburgh St ³ Replaces: Waikouaiti Golf Club (customer side)	DZWK04-01 DCCDZ-WK-04
Catchment - Waikouaiti River - Pump Station Replaced: Waikouaiti Pumping Main	CAWK02-01 DCCCA-SW-13
Waikouaiti WTP - Raw Water Reservoir Feed to Plant Replaced: Waikouaiti Pre-treatment	DWWK14-01 DCCPO-14
Waikouaiti WTP - Containerised Plant Filtrate	DWWK45-01
Waikouaiti WTP - Post Treated Water Reservoir Replaced: Waikouaiti Post Treatment	DWWK56-01 DCCPO-18
Waikouaiti WTP - Tube Settler Supernatant	DWWK60-02
Waikouaiti WTP - Waikouaiti River - Upstream	DWWK67-03
Waikouaiti WTP - Settling Ponds Sediment	DWWK65-50
Waikouaiti WTP - Raw Water Reservoir Sediment	DWWK14-50
Waikouaiti WTP - Treated Water Reservoir Sediment	DWWK56-50

1: Eurofins hold sample point sheets with GPS coordinates and maps for each location (in addition to H&S information). A summary plan is provided in Appendix A.

2: The MoH source code for the Waikouaiti River is S00156 and should be referenced on all results from CAWK02-01, DWWK14-01, DWWK67-03. The MoH plant code is TP00250 and should be referenced on all results from DWWK45-01, DWWK56-01, DWWK60-02. The MoH network code is WAI015WK and should be referenced on all results from DZWK01-01, DZWK02-01, DZWK04-01.

3: New Dedicated Sampling Taps will be used from 04/02/2021 – these are all supply side (as opposed to customer side).

Parameters

Lab analysis: Total and Dissolved Metals (Cd, Zn, Cu, Ni, Pb, Fe, Ca, Mg, Mn, Al, As, Hg), Alkalinity (no air gap sample), Dissolved inorganic carbon, Chloride, sulphate, total dissolved and suspended solids.

Field samples: Dissolved Oxygen, pH

Network and Post Treated Water Reservoir ONLY: Free and Total Chlorine

Sampling Protocol - Network Sample Points

1. Test Total and free chlorine, DO and pH. Only sample enough water to do these tests and turn off tap in between tests.
2. Sample metals, alkalinity, DIC, chloride, sulphate.
3. Begin 2-minute flush
4. At 2-minute mark, lower flow and collect a second round of samples
5. Sample metals, alkalinity, DIC, chloride, sulphate
6. Test total and free chlorine, DO and pH. Only sample enough water to do these tests and turn off tap in between tests.
7. Turn tap off.

This protocol requires two sets of samples for every distribution sampling point (first flush and flushed). To achieve confidence that the new sampling taps are not contributing to metals this method will be altered once five results are received back and analysed. Five pre-flush and flushed samples will be compared to see if results make sense (lower chlorine in first flush, similar metals content, etc). This will help determine the contribution of the sampling taps to metals in the water samples, if any. If the results are nominal, we will cease first-flush samples, as there will no longer be sufficient reasoning for taking these as long as the first flush is long enough. This also will reduce the burden on the lab which is currently at capacity. The timing of the flush has been conservatively estimated using a distance of 20 m. No sampling line is more than 20 m in Dunedin's whole network. Using this distance and the diameter of the stainless steel sampling tubing (10 mm), the volume in the line can be calculated. A minimum of 0.1 L/sec shall be used for 2 minutes. This conservatively flushes the line 6 times and will undoubtedly be representative of water in the network.

Eurofins sample protocols (and training records) are provided in Appendix A.

Sampling Protocol - Catchment and Treatment Plant Sample Points

8. Begin 2-minute flush (as required)
9. Collect samples DO, pH (free and total chlorine for post treated water reservoir)
10. Sample metals, alkalinity, DIC, chloride, sulphate
11. DO and pH.
12. Turn tap off.

Sampling Protocol – Reservoir Sediments

Samples to be collected by DCC during reservoir drains / inspections (protocol TBC) and provided to the laboratory to be analysed for the same metals as in water. DCC will provide a protocol for analysis for these sediment samples.

Sampling Frequency

All samples to be collected daily until further notice with the exception of Raw Water Reservoir and Treated Water Reservoir Sediment samples (notionally 2 off per tank on an as required basis).

Blank Requirements

The following blanks are required.

Duplicate type	Frequency	Purpose	Comments
Blind duplicate	One duplicate per 5 samples	A blind duplicate is an un-labelled sample (except to label as "duplicate 1", "duplicate 2"...) that is analysed by the primary laboratory to test the "repeatability" of laboratory analysis. The sampler simply collects a second sample at a location, labels it as a duplicate and sends it to the laboratory	Eurofins to provide batch number and sample point to DCC.
Trip blank	One trip blank per consignment	A trip blank is simply a sample of "Type 1" water supplied by the laboratory that is decanted into the appropriate sample container. Trip blanks are used to identify whether there has been cross-contamination during transport of the samples.	If Type 1 water is not available, bottled water can be substituted (although will have trace minerals etc)
Inter-lab duplicate	one per consignment	A blind duplicate that is sent to a secondary laboratory to check that the primary and secondary laboratory results are comparable.	To be provided to Hill Laboratories

Reporting

Values which exceed MAV will send an automated alert to DCC.

Analysis and reporting to be provided ASAP. Typically this is 48 hours, however, Friday and weekend samples will take longer due to logistics.

Verification

13. Automatic verification of any sample that exceeds MAV - including retest of held sample.
14. Keep samples for minimum of 3 weeks.

4. RAW WATER AUTOSAMPLER

Sampling & Analysis Provider

Sampling by DCC. Analysis by Otago University

Locations

Raw Water Intake (Pump Station Discharge)

Parameters

Initially lead only (total and soluble).

Sample Collection

Samples to be provided by DCC and delivered to University of Otago. Chain of Custody form to be filled out and signed by sampler and upon delivery to lab.

Sample Frequency

24 samples per day. No. of days per week is TBC but notionally Monday – Thursday.

Blank Requirements

Trip Blank as described above.

Reporting

Analysis and reporting to be provided ASAP.

5. RIVER WATER QUALITY

Sampling & Analysis Provider

Sampling by T&T with analysis by Hills Laboratories.

Locations

As defined in the Catchment Risk Assessment methodology (see appendix C). This will include river and sediment samples.

Parameters

As defined in the Catchment Risk Assessment methodology.

Sample Collection

Samples to be provided by T&T and delivered to Hills Lab.

Sample Frequency

As defined in the Catchment Risk Assessment methodology.

Blank Requirements

None.

Reporting

Analysis and reporting to be provided ASAP.

6. CONTINUOUS MONITORING

A number of continuous analysers are already installed at the treatment plant including parameters. A number of additional analysers have been proposed and are at various stages of installation. The table below provides a summary of continuous monitoring.

Description	Tag	Existing / Proposed
Dosed pH	S108_PHT0_002_PH	Existing
5 min chlorine	S108_CLT6_001_CL	Existing
Ex-tank chlorine	S108_CLT6_002_CL	Existing
Ex-tank pH	S108_PHT6_002_PH	Existing
Raw pH	S108_PHT0_001_PH	Existing
River Turbidity	S073_processturbidity_river	Existing
Raw Colour	S108_COT0_001_CO	Existing
Filtered Colour	S108_COT6_001_CO	Existing
Water Level at Waikouaiti Pump Station	S073_river_level	Existing
Waikouaiti river Pump flow Rate	S073_flowrate_river	Existing
Treated water flow	S108_flowrate_treated	Existing
Filtered pH	S108_PHT6_001_PH	Existing
Rainfall	S108_rainfall	Existing
Treated reservoir level	S108_reservoir_level_treated	Existing
Raw reservoir level	S108_reservoir_level_raw	Existing
Raw water temperature	S108_TIT0_001_TT	Existing
Raw water turbidity	S108_TUT0_001_TU	Existing
Filtered water conductivity	S108_CNT6_001_CN	Existing
Raw water flow	S108_FIT0_001_flow	Existing
River flow rate	S073_flowrate_river	Existing
River pH (at Raw Water PS)	TBC	Proposed (expected week beginning 15th Feb)

River Conductivity (at Raw Water PS)	TBC	Existing (since 10/02/21)
River Lead (at Raw Water PS)	TBC	Proposed (expected late March 2021)

7. RESPONSE TO ELEVATED LEVELS

When a result is received that is elevated compared to baseline levels, more testing will be considered. This will be addressed at the time, as the timing and location of the sample, as well as the other determinants measured in all the samples on the same day, are important in determining frequency and locations of extra sampling (not mentioned in this plan). Eurofins should be prepared to execute this extra sampling in a timely fashion and have a plan to address these types of responses.

8. OTHER SAMPLING/TESTS DCC IS CONSIDERING UNDERTAKING (TO BE UPDATED IN NEXT VERSION)

- Pipe scale analysis of different sections of pipe in different areas of the network (University of Otago)
- Isotoping of sediment and/or water samples (possibly St isotope tracing)
- XRD (x-ray diffraction) analysis and speciation analysis of sediment, old membranes, pipe scale.
- SEM (scanning electron microscopy) of membranes

9. OTHER SAMPLING THAT MAY BE TAKEN BY OTHER PARTIES (TO BE UPDATED IN NEXT VERSION)

- Food: Shellfish, flounder, mahinga kai
- Sludge, soil, sediment, water tests in conjunction with DCC

APPENDIX A: EUROFINS PROTOCOLS AND TRAINING RECORDS

APPENDIX B: SAMPLE POINT LOCATIONS

APPENDIX C: CATCMENT RISK ASSESSMENT SAMPLING PLAN



DZWK01-01 - Waikouaiti SS - 192 Main Rd

DZWK02-01 - Karitane SS - 99 Stornoway St

DZWK04-01 - Waikouaiti SS - 210 Edinburgh St



CAWK02-01 - Waikouaiti River - Pump Station

DWWK67-03 - Waikouaiti River - Upstream

WBP00024

DWWK45-01 - Containerised Plant Filtrate

DWWK60-02 - Tube Settler Supernatant

DWWK14-50 - Raw Water Reservoir Sediment

DWWK14-01 - Raw Water Reservoir Feed to Plant

DWWK56-01 - Post Treated Water Reservoir

DWWK56-50 - Treated Water Reservoir Sediment

DWWK45-01 - Containerised Plant Filtrate

DWWK14-50 - Raw Water Reservoir Sediment

DWWK60-02 - Tube Settler Supernatant

DWWK14-01 - Raw Water Reservoir Feed to Plant

DWWK56-01 - Post Treated Water Reservoir

DWWK56-50 - Treated Water Reservoir Sediment

WMR37015

WMR37019

WMT40939

WSL41645

Mountain Rd

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Water Supply Process Scientist
3 Waters Plant Operations
Dunedin City Council
50 The Octagon
Dunedin

Cc
Tom Dyer, 3 Waters Group Manager
John McAndrew, Plant Operations Manager

14th July 2021

Investigation of Lead Test Results in Water Samples for Dunedin City Council

Eurofins ELS Ltd (Eurofins) has undertaken an investigation of lead test results in water samples that have been provided to Dunedin City Council (DCC) by Eurofins from October 2020 to February 2021.

Water Sampling and Testing

This report follows our response on the 8th June 2021 to your review questions raised on 3rd June 2021 regarding the high lead results from testing completed on samples collected from Waikouaiti Golf club.

Eurofins commenced sampling at Waikouaiti Golf Club on 9th October 2020 using a sampling point not previously used before. This sample point and the sampling points at TAB Waikouiti and Karitane Bowls returned 79 positive lead results during the first four months of sampling.

Two samples were collected from each sampling point on each visit; the first was prior to flushing the tap and the second was collected after a standard flush time of two minutes.

Of the 108 samples collected from these three locations between 9 October 2020 and 1 February 2021, only 29 recorded levels less than the laboratory detection limit. Results ranged from 0.5 ppb to 394 ppb. Between the dates 9th October 2020 to 21st February 2021 of the 108 samples taken 79 had quantifiable amounts of lead and of these 79 there were 7 samples above the MAV of 10ppb. Both unflushed and flushed samples recorded positive lead levels during this time, with ten flushed samples recording higher levels than the unflushed samples. The results from the Waikouaiti Golf Club, TAB Waikouiti and Karitane Bowls sampling points are tabulated below.

Table 1: Lead results from the three sites

Sampling Date	Site Name	Pre/Post	ppb
09-10-20	Waikouaiti Golf Club - Pre-flush	Pre	1.5
09-10-20	Waikouaiti Golf Club	Post	12.1
09-10-20	TAB Waikouaiti - Pre-flush	Pre	1
09-10-20	TAB Waikouaiti	Post	0.6
09-10-20	Karitane Bowls - Pre-flush	Pre	1.7
09-10-20	Karitane Bowls	Post	0.5
16-10-20	Waikouaiti Golf Club - Pre-flush	Pre	0.8
16-10-20	Waikouaiti Golf Club	Post	3.9
16-10-20	TAB Waikouaiti - Pre-flush	Pre	<0.5

16-10-20	TAB Waikouaiti	Post	<0.5
16-10-20	Karitane Bowls - Pre-flush	Pre	2.8
16-10-20	Karitane Bowls	Post	<0.5
21-10-20	Waikouaiti Golf Club - Pre-flush	Pre	<0.5
21-10-20	Waikouaiti Golf Club	Post	0.8
21-10-20	TAB Waikouaiti - Pre-flush	Pre	0.5
21-10-20	TAB Waikouaiti	Post	<0.5
21-10-20	Karitane Bowls - Pre-flush	Pre	8.1
21-10-20	Karitane Bowls	Post	<0.5
30-10-20	Waikouaiti Golf Club - Pre-flush	Pre	3.4
30-10-20	Waikouaiti Golf Club	Post	0.6
30-10-20	TAB Waikouaiti - Pre-flush	Pre	8.3
30-10-20	TAB Waikouaiti	Post	<0.5
30-10-20	Karitane Bowls - Pre-flush	Pre	17.2
30-10-20	Karitane Bowls	Post	<0.5
05-11-20	Waikouaiti Golf Club - Pre-flush	Pre	0.9
05-11-20	Waikouaiti Golf Club	Post	0.7
05-11-20	TAB Waikouaiti - Pre-flush	Pre	2.5
05-11-20	TAB Waikouaiti	Post	<0.5
05-11-20	Karitane Bowls - Pre-flush	Pre	4.9
05-11-20	Karitane Bowls	Post	<0.5
12-11-20	Waikouaiti Golf Club - Pre-flush	Pre	2.1
12-11-20	Waikouaiti Golf Club	Post	0.9
12-11-20	TAB Waikouaiti - Pre-flush	Pre	2.1
12-11-20	TAB Waikouaiti	Post	<0.5
12-11-20	Karitane Bowls - Pre-flush	Pre	9.3
12-11-20	Karitane Bowls	Post	<0.5
20-11-20	Waikouaiti Golf Club - Pre-flush	Pre	1.3
20-11-20	Waikouaiti Golf Club	Post	1
20-11-20	TAB Waikouaiti - Pre-flush	Pre	1.5
20-11-20	TAB Waikouaiti	Post	<0.5
20-11-20	Karitane Bowls - Pre-flush	Pre	6.1
20-11-20	Karitane Bowls	Post	<0.5
27-11-20	Waikouaiti Golf Club - Pre-flush	Pre	3.3
27-11-20	Waikouaiti Golf Club	Post	0.7
27-11-20	TAB Waikouaiti - Pre-flush	Pre	1.7
27-11-20	TAB Waikouaiti	Post	<0.5
27-11-20	Karitane Bowls - Pre-flush	Pre	4.6
27-11-20	Karitane Bowls	Post	<0.5
04-12-20	Waikouaiti Golf Club - Pre-flush	Pre	8.1
04-12-20	Waikouaiti Golf Club	Post	2.5
04-12-20	TAB Waikouaiti - Pre-flush	Pre	1.2
04-12-20	TAB Waikouaiti	Post	0.5
04-12-20	Karitane Bowls - Pre-flush	Pre	5.3
04-12-20	Karitane Bowls	Post	<0.5

08-12-20	Waikouaiti Golf Club - Pre-flush	Pre	16.8
08-12-20	Waikouaiti Golf Club	Post	394
08-12-20	TAB Waikouaiti - Pre-flush	Pre	0.9
08-12-20	TAB Waikouaiti	Post	0.7
08-12-20	Karitane Bowls - Pre-flush	Pre	2.4
08-12-20	Karitane Bowls	Post	72
18-12-20	Waikouaiti Golf Club - Pre-flush	Pre	4
18-12-20	Waikouaiti Golf Club	Post	8.5
18-12-20	TAB Waikouaiti - Pre-flush	Pre	0.9
18-12-20	TAB Waikouaiti	Post	<0.5
18-12-20	Karitane Bowls - Pre-flush	Pre	2.9
18-12-20	Karitane Bowls	Post	<0.5
22-12-20	Waikouaiti Golf Club - Pre-flush	Pre	0.9
22-12-20	Waikouaiti Golf Club	Post	0.9
22-12-20	TAB Waikouaiti - Pre-flush	Pre	2.2
22-12-20	TAB Waikouaiti	Post	0.9
22-12-20	Karitane Bowls - Pre-flush	Pre	7.7
22-12-20	Karitane Bowls	Post	0.5
31-12-20	Waikouaiti Golf Club - Pre-flush	Pre	26.6
31-12-20	Waikouaiti Golf Club	Post	5.5
31-12-20	TAB Waikouaiti - Pre-flush	Pre	0.7
31-12-20	TAB Waikouaiti	Post	<0.5
31-12-20	Karitane Bowls - Pre-flush	Pre	4.2
31-12-20	Karitane Bowls	Post	<0.5
07-01-21	Waikouaiti Golf Club - Pre-flush	Pre	3.6
07-01-21	Waikouaiti Golf Club	Post	17.8
07-01-21	TAB Waikouaiti - Pre-flush	Pre	1.3
07-01-21	TAB Waikouaiti	Post	<0.5
07-01-21	Karitane Bowls - Pre-flush	Pre	8.7
07-01-21	Karitane Bowls	Post	<0.5
12-01-21	Waikouaiti Golf Club - Pre-flush	Pre	1.6
12-01-21	Waikouaiti Golf Club	Post	6.4
12-01-21	TAB Waikouaiti - Pre-flush	Pre	1.1
12-01-21	TAB Waikouaiti	Post	<0.5
12-01-21	Karitane Bowls - Pre-flush	Pre	5.1
12-01-21	Karitane Bowls	Post	0.5
20-01-21	Waikouaiti Golf Club - Pre-flush	Pre	1.7
20-01-21	Waikouaiti Golf Club	Post	5.7
20-01-21	TAB Waikouaiti - Pre-flush	Pre	2.1
20-01-21	TAB Waikouaiti	Post	<0.5
20-01-21	Karitane Bowls - Pre-flush	Pre	3.5
20-01-21	Karitane Bowls	Post	0.5
28-01-21	Waikouaiti Golf Club - Pre-flush	Pre	1.3
28-01-21	Waikouaiti Golf Club	Post	<0.5
28-01-21	TAB Waikouaiti - Pre-flush	Pre	1.2

28-01-21	TAB Waikouaiti	Post	<0.5
28-01-21	Karitane Bowls - Pre-flush	Pre	9.5
28-01-21	Karitane Bowls	Post	<0.5
01-02-21	Waikouaiti Golf Club - Pre-flush	Pre	3.7
01-02-21	Waikouaiti Golf Club	Post	4.4
01-02-21	TAB Waikouaiti - Pre-flush	Pre	1.6
01-02-21	TAB Waikouaiti	Post	<0.5
01-02-21	Karitane Bowls - Pre-flush	Pre	2.7
01-02-21	Karitane Bowls	Post	0.8

The sample with the lead content at 394 ppb was sampled on 8th of December 2020 and tested on 9th December 2020 in duplicate. The results were 394 and 392 ppb. This sample also had high copper and Zinc levels and the laboratory had to reanalyse a third time with a 1 in 10 dilution on 12th December 2020. The lead result from this analysis was 370 ppb and confirmed the original high lead results. All three lead results were within the method repeatability and reproducibility.

There is clear evidence of high Lead levels based on the multiple positive lead results across multiple samples and multiple sampling points. The sample with the highest lead result at 394 ppb was tested twice before the result was released to DCC.

The sampling from Waikouaiti Golf Club, TAB Waikouiti and Karitane Bowls sampling points was stopped on instructions given by DCC on 4th February 2021. Eurofins was instructed by DCC to take samples from the Waikouaiti SS - 210 Edinburgh St, Karitane SS - 99 Stornoway St and Waikouaiti SS - 192 Main Rd sampling points instead of the original three sites.

Internal Audit

An internal audit led by the Quality & Compliance team of Eurofins was undertaken in February 2021, as part of our Quality Management Systems requirement for regular technical audits. The audit team considered sampler training, sampling procedures, sample location, Dunedin laboratory responsibility, transportation of samples to the metal testing laboratory in Wellington, sample storage prior to testing, metals testing process, test method, interlaboratory comparison programme, and reporting of results.

A summary of the findings from the audit follows;

Sampler training

The sampling staff were fully trained and signed off to level 2 (trained to be able to work unsupervised) or higher. The samplers are also observed sampling on periodic basis by senior staff as part of their ongoing refresher training and competency assessments.

Sampling procedures

Please be aware that there is not currently a National level regulatory guideline for sampling of water. Eurofins follows a proprietary sampling procedure developed from experience and expertise across all six water testing laboratories in New Zealand unless the customer requests otherwise.

DCC provided Eurofins with a procedure for collecting flushed and unflushed water samples for chemistry testing, which includes flush time and bottle filling order. This procedure was modified twice by DCC between February 2021 and March 2021. This procedure and subsequent updates were always followed by Eurofins' samplers.

Sampler location

All Eurofins vehicles used for sampling are tracked by GPS. Data has been reviewed and confirms the vehicles the samplers used were at the correct locations.

Dunedin laboratory responsibility

The Eurofins Dunedin laboratory was responsible for preparing sample bottles, including the addition of preservatives as required for each test, collection of the samples from the prescribed location, performance of the microbiological and short holding-time tests, and the packaging and delivery of specialised tests to Eurofins Wellington. All samples requiring metals testing were sent to the Wellington lab.

Transport of samples to the metals testing Lab in Wellington

All weekday samples were delivered overnight by a courier service for perishables to Wellington.

Sample storage prior to testing

Samples after registration were stored chilled until the testing commenced on the same day at the Dunedin lab for micro biological and time sensitive tests. The samples for metals testing were stored at ambient temperature and shipped to Wellington for testing by overnight courier.

Metals testing process

The testing method was carried out according to documented test methods by trained lab analysts. There was no evidence of deviation from the documented test methods. The Quality Control samples produced results within the specified limits.

Test method

The test method used by Eurofins is accredited to ISO17025 by International Accreditation New Zealand (IANZ).

Interlaboratory Comparison Programme

Eurofins participates in an Interlaboratory Comparison Programme (ILCP) provided by Global Proficiency Ltd, as mandated by the Ministry of Health and IANZ, the accreditation body for water testing labs. There have been no failures reported for lead ILCP rounds from 2017 to 2021. The December 2020 ILCP round samples were tested in the same month as the DCC high lead sample was tested. We completed and passed ILCP round samples testing in December 2020 and March 2021 ILCP. The lab has completed the June and July ILCP round and are awaiting report from the ILCP provider. There are no outstanding corrective or preventative actions arising from the ILCP comparison program.

Reporting of results

The results were generated by trained staff and a Key Technical Person (KTP) reviewed the test data and signed off the results for reporting purposes. The test report was then emailed to DCC staff.

There are no outstanding corrective or preventative actions from the Internal Audit. The Internal Audit will be reviewed by IANZ as part of their Annual Review in August 2021.

Conclusion

There is clear evidence of high Lead levels in the water samples (as detailed above). The results reported to DCC came from multiple samples taken from multiple sampling points from October 2020 to February 2021 and provide a sound basis to confirm the high metal readings. There is no evidence of any deficiency in the sampling and testing methods used by Eurofins that would contribute to these results.

Next Steps

We propose that we meet at the earliest opportunity to further discuss our findings with you. We remain committed to work closely with DCC to provide Sampling and Testing Services to assist with your compliance requirements.

If you require any further information, please do not hesitate to contact me.

Kind Regards,



Pathik Vyas
Quality & Compliance Director
Eurofins Food & Water Testing New Zealand
Email: pathikvyas@eurofins.com

Vertically Cast, Cast Iron Pipes

Pipe Condition and

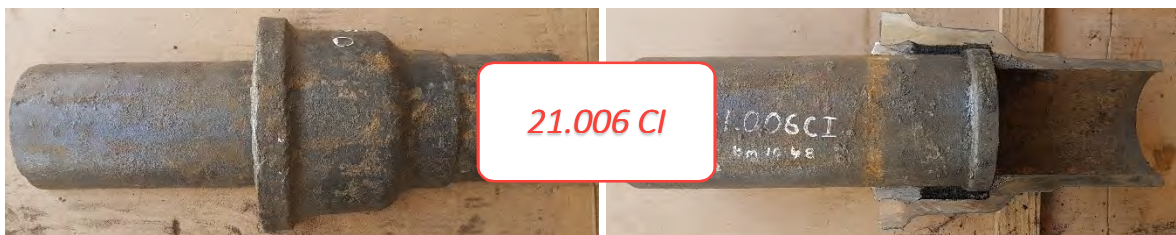
Lead Joint Integrity Assessment

Water Supply – Waikouaiti Township

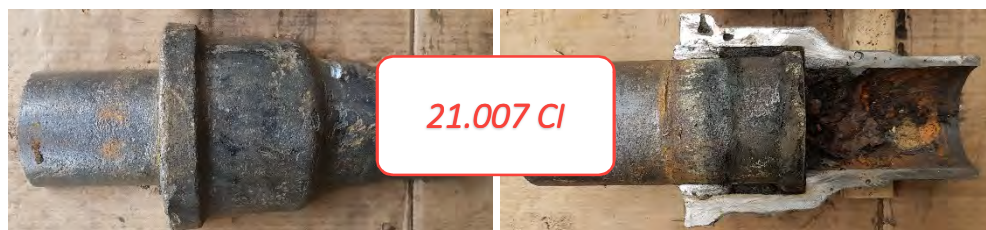
18 February 2021

CONFIDENTIAL

4" (DN 100), Cast Iron Pipe with Run-Lead Joint – 111 Edinburgh Street



3" (DN 75), Cast Iron Pipe with Run-Lead Joint – Perth Street



Contact Details

Adam Wheeldon

WSP
12 Moorhouse Avenue
Christchurch 8011
+64 3 363 5400
+6427 298 8278
adam.wheeldon@wsp.com

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Prepared for: Dave Dewhirst
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Prepared by



Adam Wheeldon
Technical Principal Pipe
Condition Management

Reviewed by



John Black
Principal Engineer - Water

Approved for release by



Dave Gardiner
Technical Director - Water



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Disclaimers and Limitations

This report (**'Report'**) has been prepared by WSP exclusively for Dunedin City Council (**'Client'**) in relation to the 4" (DN 100) and 3" (DN 75) cast iron pipe samples recovered for condition and joint integrity assessment (**'Purpose'**) and in accordance with the email from Dunedin CC's Dave Dewhirst on 4 February 2021 confirming the assessment is carried out under the Minor Emergency Work terms of engagement. The findings in this Report are based on and are subject to the assumptions specified in the Report. WSP accepts no liability whatsoever for any reliance on or use of this Report, in whole or in part, for any use or purpose other than the Purpose or any use or reliance on the Report by any third party.

In preparing the Report, WSP has relied upon data, pipe sample recovery forms, online GIS, and other information (**'Client Data'**) provided by or on behalf of the Client. Except as otherwise stated in the Report, WSP has not verified the accuracy or completeness of the Client Data. To the extent that the statements, opinions, facts, information, conclusions and/or recommendations in this Report are based in whole or part on the Client Data, those conclusions are contingent upon the accuracy and completeness of the Client Data. WSP will not be liable in relation to incorrect conclusions or findings in the Report should any Client Data be incorrect or have been concealed, withheld, misrepresented or otherwise not fully disclosed to WSP.

Executive Summary

Overview

This report has been prepared by WSP New Zealand Ltd (WSP) for Dunedin City Council (Dunedin CC), to document our findings and recommendations based on the two Cast Iron (CI) pipe samples received for condition and lead joint integrity assessment.

The pipe samples were recovered from the Waikouaiti water supply network (Edinburgh and Perth Streets) on the 4 February 2021 as part of Dunedin CC investigation into the recent elevated levels of lead found in water samples. The pipe samples were received by WSP on 10 February 2021.

Two complete pipe joints were recovered from Waikouaiti for the purpose of:

- Confirming lead has been used in making the joints.
- Gaining a better understanding of the joints and whether lead joints may be contributing to the recently elevated lead levels.
- Determining a remaining service life.

Conclusions and Recommendations

Our conclusions and recommendations are based on our knowledge of cast iron pipes with run-lead joints and our observations and investigations of the pipe joint samples provided are presented below:

Our Conclusions

- The original water supply in Waikouaiti was established in approximately 1913 (report in the Otago Daily Times (issue 15365), dated 31 January 1912 of a pipe supply tender being let).
- Both pipe samples assessed had run-lead spigot and socket joints. This was the predominant jointing method for jointing CI pipes of this age.
- It is likely that all the CI water mains in Waikouaiti were installed at the same time and have lead joints. We cannot comment on the Karitane reticulation as we have not seen a pipe joint sample.
- We believe that it is **extremely unlikely** that the two joints recovered contributed to lead in the drinking water supply.
 - Assuming all the lead-run joints in the network are similarly constructed (and this is a reasonable assumption based on our experience testing such joints) then we believe that it is also **unlikely** that the lead detected in the water supply has come from lead-run joints.
- Regarding the two spigot and socket run-lead joints inspected:
 - These joints were still providing a watertight seal.
 - The interior surface of the pipe spigots showed some minor corrosion pits, however, Full Wall Graphitisation (FWG) has not occurred and the lead was not in contact with the water supply.
 - The spigots had been inserted to the root of the socket and the hemp rope was tightly packed in by caulking. This provides both a barrier between the lead and water supply as well as preventing the lead (from) entering the pipe during the jointing process.
 - At the boundary between the lead and hemp rope in the socket, the hemp was still firmly bonded in the lead and there was no visual sign of deterioration of the lead.
- General Comments:

- The reported operating pressure for these streets range from ~92 m to 122 m (up to 1,200 kPa), which is up to an approximate 36 % overload on the designed maximum pressure for Class C, CI pipes.
- The reported installation years are 1932 (for 21.006 CI) and 1965 (for 21.007 CI). Based on the physical characteristics and condition of the pipes we believe an installation year of 1912 or 1913 to be realistic, and for this report we have used the installed year to be 1913.
- The installation year of 1913, pre-dates the earliest cast iron pipe standard by approximately four years.
- Edinburgh Street pipe sample (21:006 CI):
 - This pipe sample is a **4" (DN 100) CI, Equiv. to Class C (PN 9)** pipe with a spigot and socket, run-lead joint.
 - One blow-out failure a "gushing leak" was repaired on this main in 2015.
 - This pipe and joint sample has been assessed as **Grade 5 – Very Poor Condition**.
 - FWG is likely in the barrel of the pipe now, a 'gushing leak' has already occurred in 2015.
 - The pipe manufacturer is unknown.
- Perth Street pipe sample (21.007 CI):
 - This pipe sample is a **3" (DN 75) CI, Equiv. to Class C (PN9)** pipe with a spigot and socket run-lead joint.
 - This pipe and joint sample has been assessed as **Grade 5 – Very Poor Condition**.
 - FWG is likely to have occurred in the late 1990's or early 2000's where the pipe wall is thinnest.
 - The pipe manufacturer is unknown.

Our Recommendations

- The old cast iron water mains in Waikouaiti are programmed for renewal within the next five years, unless occasional, and the increasing frequency in failures (easily repaired) and service complaints can be tolerated. In which case, renewal could be delayed until failure frequency causes concern, possibly 10 years, maybe more.
- The year installed for both piped assets is updated in Council's GIS to 1913.
- The original cast iron water mains in Waikouaiti are assigned as **Grade 5 – Very Poor Condition**.
- Since the only way to be sure of the dynamic range of operating pressures is to log the pressure in the water main, the pressure is logged at 1 second intervals over at least 24 hours during a peak demand period.

1 Introduction and Background

1.1 Introduction

This report has been prepared by WSP New Zealand Ltd (WSP) for Dunedin City Council (Dunedin CC), to document our findings and recommendations based on the two Cast Iron (CI) pipe samples received for condition and lead joint integrity assessment.

Dunedin CC want to identify the possible sources of lead found in the Waikouaiti and Karitane water supplies. Two complete joints were recovered from Waikouaiti for the purpose of:

- Confirming lead has been used in making the joints.
- Gaining a better understanding of the joints and whether lead joints may be contributing to the recently elevated lead levels.
- Determining a remaining service life.

1.2 Background

The pipe samples were recovered by City Care from the Waikouaiti water supply network (Edinburgh and Perth Streets) on the 4 February 2021 as part of Dunedin CC investigation into the recent elevated levels of lead found in water samples. The joint samples were received by WSP on 10 February 2021.

The two pipe samples have been given the follow unique WSP pipe sample numbers:

- 21.006 CI (complete joint of 4" [DN 100] cast iron pipe)
- 21.007 CI (complete joint of 3" [DN 75] cast iron pipe)

2 Pipe Sample Recovery, Service Details and Pipeline Installation Summary

2.1 Pipe Sample Locations

The two pipe samples were recovered from 111 Edinburgh Street and Perth Street in Waikouaiti, refer to Figure 2-1.



Figure 2-1 Reported recovery locations of the pipe samples

2.2 Pipe Sample Recovery and Service Details

The pipe sample recovery details, service and installation summaries are presented in Table 2-1 to Table 2-4.

Table 2-1 : Pipe Sample 21.006 CI Details

Pipe Sample Number	21.006 CI	Asset ID	Not Reported
Address	111 Edinburgh Road, Waikouaiti	Geocoded NZTM (geocoded by WSP)	E 1419445 N 9478340
Material	Cast Iron (Vertically Cast)	Pipe Sample Length (mm)	497
Diameter (DN)	4" (DN 100)	Pipe Sample Recovery Date	4 February 2021
Manufacturer	Unknown	Pipe Samples Received	10 February 2021
Pipe Sample Type	Pipe and joint	Pressure Class	Equiv. to Class C
Coating	Bitumen Dipped Composite	Lining	Bitumen Dipped Composite

Table 2-2 : Pipe Sample 21.006 CI Reported Service and Installation Details

Installation Year	Reported 1932 <i>WSP Est. 1913</i>	Factory Test Pressure	600' Ft head of Water (≈182 m Head of Water)
Pipe Purpose	Water reticulation	Design Pressure (½ Factory Test Pressure)	300' Ft head of Water (≈91 m Head of Water)
Reported Maximum Operating Pressure	1,200 kPa (≈122 m Head of Water)	Percentage of Pressure Class	~136%

Design convention and prudent engineering meant that the maximum design pressure for Class C pipes was 300 Ft head of water (half of the factory test pressure).

Depth of Cover	0.5 m	Groundwater Depth	Reported 'N/A'
Bedding Material	Clay	Ground Surface	Sealed Shoulder

The bedding sample provided was damp, consisted of Light grey to blue clay (high plasticity) with flecks of red sand. Fine roots were present.

Table 2-3 : Pipe Sample 21.007 CI Details

Pipe Sample Number	21.007 CI	Asset ID	Not Reported
Address	Perth Street, Waikouaiti	Geocoded NZTM (geocoded by WSP)	E 1419125 N 4948005
Material	Cast Iron (Vertically Cast)	Pipe Sample Length (mm)	347
Diameter (DN)	3" (DN 75)	Pipe Sample Recovery Date	4 February 2021
Manufacturer	Unknown	Pipe Samples Received	10 February 2021
Pipe Sample Type	Pipe and joint	Pressure Class	Equiv. to Class C
Coating	Bitumen Dipped Composite	Lining	Bitumen Dipped Composite

Table 2-4 : Pipe Sample 21.006 CI Reported Installation Details

Installation Year	Reported 1965 <i>WSP Est. 1913</i>	Factory Test Pressure	600' Ft head of Water (≈182 m Head of Water)
Pipe Purpose	Water reticulation	Design Pressure (½ Factory Test Pressure)	300' Ft head of Water (≈91 m Head of Water)
Reported Maximum Operating Pressure	1,200 kPa (≈122 m Head of Water)	Percentage of Pressure Class	~136%

Design convention and prudent engineering meant that the maximum design pressure for Class C pipes was 300 Ft head of water (half of the factory test pressure).

Depth of Cover	0.6 m	Groundwater Depth	Reported 'N/A'
Bedding Material	Clay	Ground Surface	Grass Berm

The bedding sample provided was dry, consisted of Light grey, slightly plastic clay with flecks of red sand. Fine roots were present

2.3 Reported Installation Details

The reported installation years were 1932 (21.006 CI) and 1965 (21.007 CI).

Having searched Papers Past, an article from the Otago Daily Times (issue 15365), dated 31 January 1912 reports that a Waikouaiti Borough Council Tender for Contract 1a 'supply and delivery of cast iron pipe and accessories for the town reticulation' was awarded to Briscoe and Co (Ltd) of Dunedin, refer to Figure 2-2.

It is reasonable to assume once the tender was awarded that the works would commence without delay.

Based on this article and the profile of the spigot and socket being similar to cast iron pipes manufactured in the early 1900's, we believe an installation year of 1912 or 1913 to be realistic. For this report, we have assumed the year installed to be 1913.

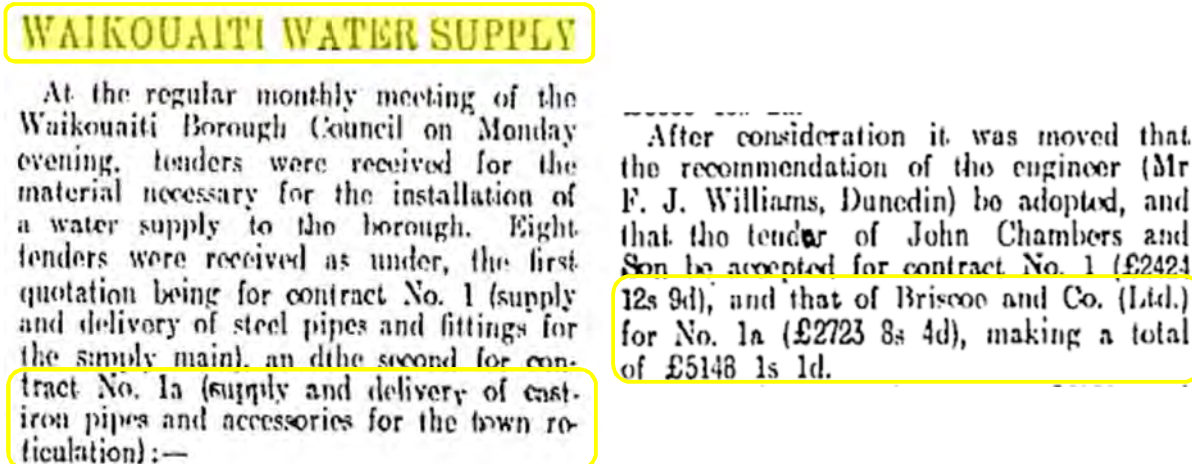


Figure 2-2 Extracts from Otago Daily Times (issue 15365), dated 31 January 1912

3 Pipeline Failure History

3.1 Edinburgh Street:

Only one pipeline failure has been reported by Dunedin CC on the 4" cast iron water main, this was recorded as 'Leak Gushing' in February 2015 and approximately 1 m of pipe was replaced, see Figure 3-1.



Figure 3-1 Repair to the 'Leak' that occurred in February 2015, photo courtesy Dunedin CC

The location of this failure was reported as approximately 85 m south of where pipe sample 21.006 CI was recovered.

3.2 Perth Street:

No failures have been reported on the 3" cast iron water main in Perth Street.

4 Dimensions

Measurements of each pipe sample were made of the spigot and socket ends. The wall thickness was also measured, refer to Table 4-1.

The estimated installation year of 1913 for these two samples predates the earliest standard (BS 78:1917) by approximately four years. However, this CI pipe standard was first promoted in 1903 and formalised industry practice dating back to the mid 1800's.

Table 4-1 : 4" (DN 100) and 3" (DN 75), Class C (Vertically Cast), Cast Iron Pipe Dimensions Summary

Manufacturing Standard & Sample No.	OD (mm)	Wall Thickness / Range (mm)
BS 78:1917	4.8" $\pm$ 0.0625" (4.74" to 4.86") 121.9 $\pm$ 1.6 (120.3 to 123.5)	0.4" (10.16 mm) Minimum Requirement $\frac{9}{10}$ (0.36" / 9.14 mm)
21.006 CI Spigot End	121.90	10.48 (9.66 to 11.42)
21.006 CI Socket End	120.50	10.68 (9.98 to 11.17)
Standards Comments: The wall thickness exceeds the minimum requirements of the 1917 standard for a 4" (DN 100) Class C pipe.		
BS 78:1917	3.76" $\pm$ 0.0625" (3.70" to 3.81") 95.5 $\pm$ 1.6 (93.9 to 97.1)	0.38" (9.65 mm) Minimum Requirement $\frac{9}{10}$ (0.34" / 8.69 mm)
21.007 CI Spigot End	97.0	9.31 (8.06 to 10.30)
21.007 CI Socket End	97.1	8.64 (7.14 to 9.86)
Standards Comments: The wall thickness is up to 1.55 mm less than the minimum requirements of the 1917 standard for a 3" (DN 75) Class C pipe. This is not uncommon for a vertically cast, cast iron pipe wall thickness to be uneven circumferentially, as when the core was inserted into the mould, it was often off-centre.		

5 Spigot and Socket Run-Lead Joints

5.1 Joint Assembly

No visible deflection was observed during inspection of the two joints. From our observations and dismantling of the joints, we believe that each joint was made with good workmanship.

The standard of workmanship in making the joints was similar and likely reflects how the cast iron pipe joints were made.

The top half (as-laid) of the socket was cut longitudinally at the approximate spring line of the pipe and removed so the joint assembly could be clearly seen, as shown in Figure 5-1 (21.006 CI) and Figure 5-2 (21.007 CI).

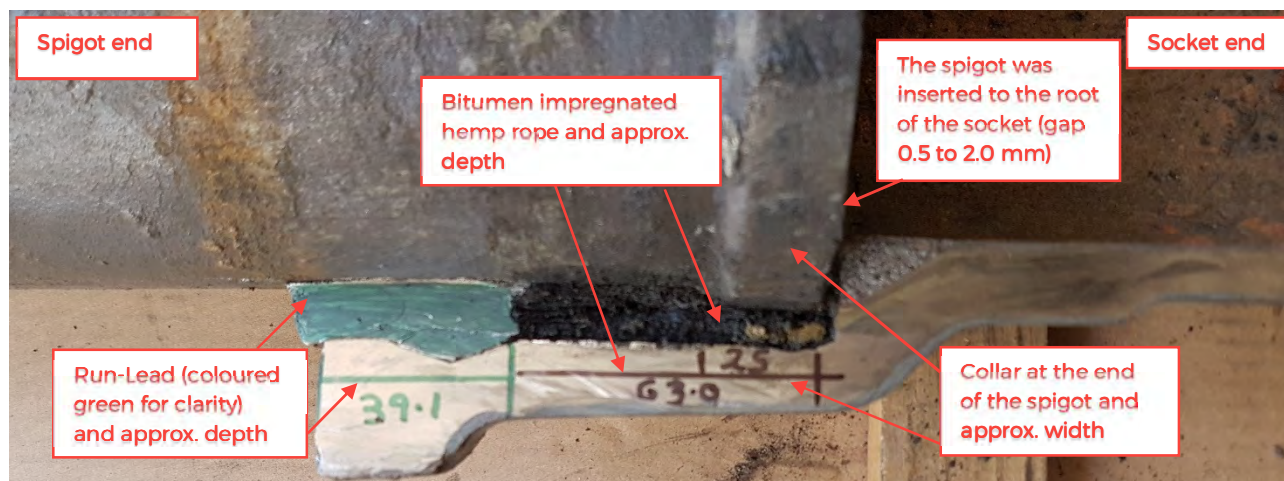


Figure 5-1 longitudinal section view of pipe sample 21.006 CI run-lead joint assembly

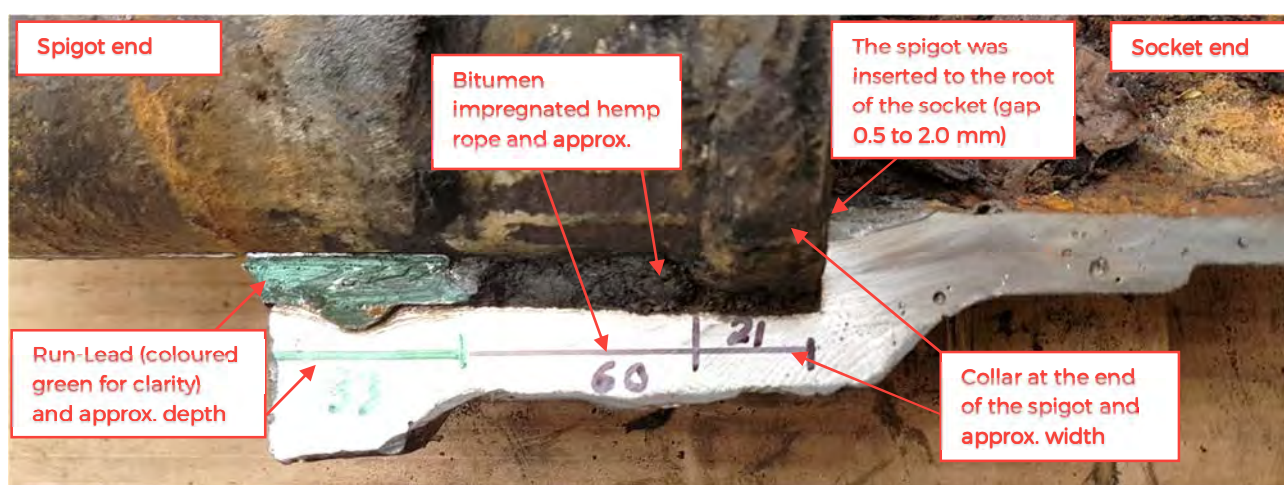


Figure 5-2 longitudinal section view of pipe sample 21.007 CI run-lead joint assembly

Refer to Appendix A and B for additional joint details such as the casting, coating, lining, tuberculation and graphitisation of the iron, etc.

5.2 Likelihood of the Lead Joint being in Contact with the Water Supply

When a run-lead joint was made, bitumen impregnated hemp rope (or caulking oakum) was packed tightly into the root of the socket using caulking tools. This was to prevent the lead running into the pipe and forming puddle inside the pipe.

It is **remotely** possible that a joint on the cast iron water mains in Waikouaiti may have a 'lead puddle' in the pipe due to the hemp rope not being sufficiently packed prior to the pouring the molten lead.

However, based on our observations of these two samples and our experience with cast iron pipes, we believe it is extreme unlikely that the lead in these cast iron pipe joints has contributed to the recently recorded elevated lead levels in the water supply.

After the pipe samples were sand blasted to white metal, attention was given to the spigots, with focus on the exterior and interior surfaces within the socket.

- There was minimal corrosion pitting under the lead and where the bitumen impregnated hemp rope was tightly packed.
- The bitumen composite lining was still providing limited corrosion protection to the interior surface of the cast iron. Some corrosion pits with graphitised iron were present, refer to Appendix A, photo A12 and Appendix B, photo B12.

- FWG has not occurred and the lead has not been exposed to the water supply

5.3 Joint Conclusions

The lead joints recovered have been made to a satisfactory standard of workmanship. Assuming the other joints are similarly well made, which is a reasonable assumption, the only ways that the lead could be exposed to the water supply are:

- The pipe spigot end must completely corrode through and the flake graphite must disintegrate to allow the water to contact the lead. (This is not possible as the pipe would have burst under the [high] water pressure.
- Water must have found its way through the bitumen impregnated hemp packing and come into contact with the lead and then found its way out again. There would be no movement of water in either direction to allow this to happen. In addition, the corrosion tuberculation that forms in a cast iron pipe effectively seals the small gap between the pipe spigot end and socket.

6 Pipe Sample Visual Appearance, Corrosion Pit and Deterioration Depth Measurements

6.1 Pipe Sample Observations – 21.006 CI

Tables 6-1 and 6-2 give details of our observations and examination of the two pipe samples.

Table 6-1 : Exterior and Interior Observations

Pipe Exterior	Pipe Interior
• A factory applied bitumen dipped coating still covered ~95 % of the surface area, see Appendix A, photo A2. • We estimate that FWG of the cast iron could occur with the next two to five years, refer to Section 6.2. • The coating was no longer providing corrosion protection to approximately 90 % of the exterior surface and corrosion pits were up to ~3.7 mm deep, see Appendix A, photo A11. • No FWG had occurred. • Manufacturers marks were present on the socket 'S O' and '? W W' see Appendix A, photos A3 and A4.	• A factory applied bitumen dipped lining still covered ~90 % of the surface area, see Appendix A, photo A10. • Tuberculation was present and the reduction in bore was up to 25%, see Appendix A, photos A5 and A6. • The lining was no longer providing corrosion protection to approximately 60 % of the interior surface and corrosion pits were up to ~5.7 mm deep, see Appendix A, photo A12.

Pipe Sample Observations – 21.007 CI

Table 6-2 : Exterior and Interior Observations

Pipe Exterior	Pipe Interior
- A factory applied bitumen dipped coating still covered ~95 % of the surface area, see Appendix B, photo B2. - Sand blasting revealed FWG of the cast iron that likely occurred in the late-1990's or early-2000's, see Appendix B, photos B11 and B12. - The coating was no longer providing corrosion protection to approximately 60 % of the exterior surface and corrosion pits were up to ~3.1 mm deep, see Appendix B, photo B11. - Manufacturers marks were present on the socket 'O XX' and 'W W W', see Appendix B, photos B3 and B4.	- A factory applied bitumen dipped lining still covered ~95 % of the surface area, see Appendix B photo B10. - Tuberculation was present and the reduction in bore was up to 40% in places, see Appendix B, photos B5 and B6. - The lining was no longer providing corrosion protection to approximately 80 % of the interior surface and corrosion pits were up to ~6.2 mm deep, see Appendix B, photo B12.

6.2 Cast Iron Corrosion Pit Depth Measurements and Corrosion Rates

Corrosion pit depth measurements were taken after each pipe sample had been sand blasted to white metal. The maximum internal and external corrosion pit depth measurements and estimated annual corrosion rates are presented in Table 6-3.

We have assumed that the bitumen dipped composite provided up to 10 years corrosion protection to the cast iron pipes before corrosion of the cast iron started.

Table 6-3: Maximum internal and external corrosion pit depths measured and estimated annual corrosion rate

Pipe Sample No.	Min. Wall Thickness (mm)	Max. Ext. Corrosion Depth (mm)	Max. Int. Corrosion Depth (mm)	Max. Combined Depth (mm)	Max. Combined Corrosion Rate (mm /yr)
21.006 CI	9.66	3.74	5.70	9.44	0.096
21.007 CI	7.14	3.12	6.22	9.34	0.095

For pipe sample **21.006 CI**, we estimate that if the deepest corrosion pits were to align, **FWG** of the cast iron could occur within **the next two to five years** where the pipe wall is thinnest (~9.7 mm).

FWG has already occurred at one location on pipe sample **21.007 CI** (see Appendix B, photos B11 and B12). We estimate that FWG of the cast iron may have occurred in the **late-1990's** or **early-2000's**.

Firmly bound graphitisation (as in this case) generally has sufficient strength to resist internal pressure for many years. It should be noted that graphitised cast iron can withstand steady internal pressure for many years before the area of graphitisation becomes large enough to allow blow-out to occur.

Without knowing the cause, or any details of the 2015 “gushing leak”, it is reasonable to assume that it may have been a blow-out at an area of extreme graphitisation or unusually thin pipe wall.

7 Condition Assessment Results and Interpretation

7.1 Condition Grade and Assessed Pipe Class

Our condition assessment and assessed condition grade of the two-cast iron pipe sample are presented in Table 7-1.

Table 7-1: Pipe Sample Condition Grades and Pipe Class

Pipe Sample Number	Pipe Class	Condition Grade
21.006 CI	Equiv. Class C (PN 9)	Grade 5 – Very Poor Condition
21.007 CI	Equiv. Class C (PN 9)	Grade 5 – Very Poor Condition

7.2 Useful Remaining Life

These pipes are near the end of their useful remaining life.

Based on our experience with vertically cast CI pipes, the condition of these pipe samples, and if they reflect the condition of most of these 1913 cast iron pipes in Waikouaiti, we believe that they could remain in service for 10 years, maybe more, if the occasional leak or blow-out (easily repaired) can be tolerated.

A reasonable useful life for CI pipes ($\leq$ DN 150) installed correctly is 80 years, however, if these pipe samples reflects the condition of the pipeline, a useful life of 100 years or more is likely. However, there are other lifetime reducing factors that also need to be considered, especially for smaller diameter cast iron pipes:

- Cast iron pipes with rigid joints (particularly 4" and 3" diameter (DN 100 and DN 75) are highly vulnerable to earthquake shaking, liquefaction-imposed forces which can cause deflection at joints and beam failure (broken back) which can also be caused by heavy traffic loading or third-party interference. As the graphitisation develops, the risk of failure from imposed forces increases.
- Minor joint deflection will cause the lead joints to leak slowly.
- Water quality complaints from consumers; red or discoloured water from the tuberculated pipe interior.
- Corrosion tuberculation reduces the hydraulic capacity (fire flow – particularly in the 3" (DN 75) water main.
- The graphite remaining in the pipe wall can usually withstand normal operation pressures.

The reported operating pressure ranges from ~92 to ~122 m head (1,200 kPa), represents up to a ~36 % overload on the designed pressure of Class C, CI pipes and this also adds a little to the risk profile.

8 Repair and Renewal Planning

Cast iron pipes in the condition of the pipe samples assessed, with the minimum measured wall thickness of ~9.7 and ~7.1 mm for the 4" and 3" diameter pipes respectively, are likely to have limited areas of FWG for the last ~20 years. However, this does not translate directly into blow-out failure.

The consequence of failure for these water mains should be determined and taken into consideration for the prioritisation of the renewal planning. Provided a few bursts, failures or public complaints can be tolerated the renewal of these water main could be delayed 10 years, maybe more.

Appendix A – 21.006 CI



Photo A1

- Pipe Sample 21.006 CI as received on 10 February 2021.
- Top of pipe 'as laid' indicated by two grooves cut into the spigot end (yellow arrow).
- Surface corrosion and rusty clay is visible.

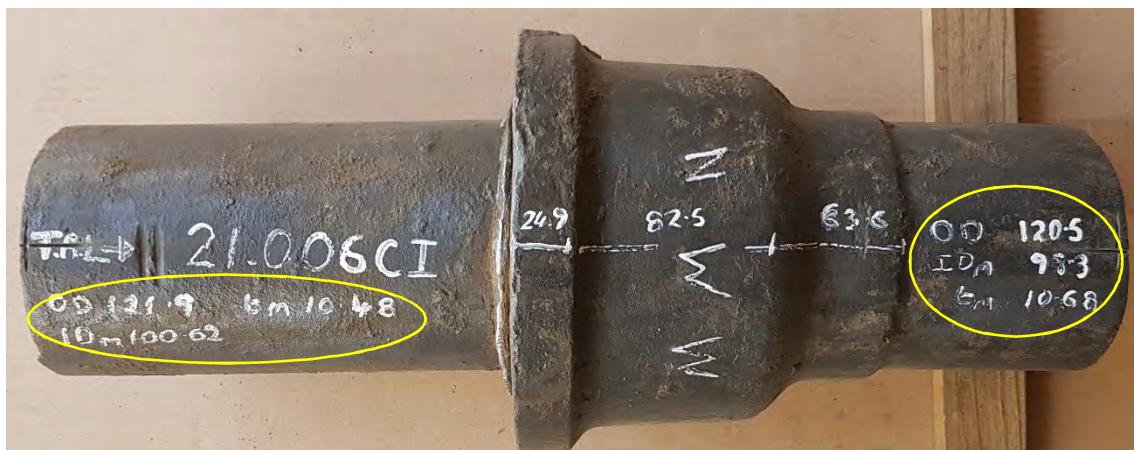
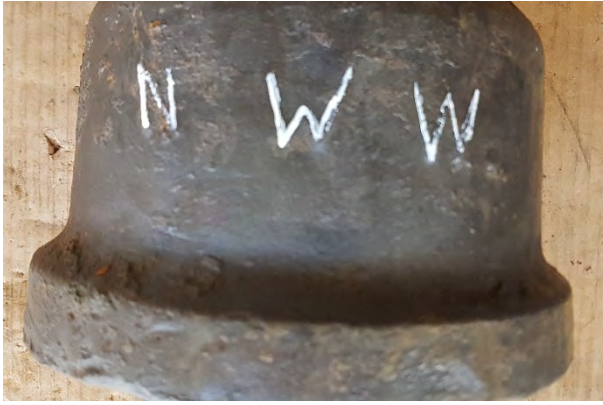


Photo A2

- After cleaning with a power wire brush in preparation for examination and measurements.
- The OD, mean ID and wall thickness's are annotated at each end of the pipe sample (yellow ellipses).
- The external bitumen coating covered ~95% of the pipe sample.
- Some manufacturers markers were visible on the pipe socket and are marked with a white pen for clarity, refer to photo A3 and A4 for details.



Photos A3 and A4

- Manufacturers markings on the socket were marked with a white pen for clarity. The markings are of unknown meaning, however, they are like those also present on pipe sample 21.007 CI, refer to Appendix B, photos B3 and B4.



Photo A5

- Internal view of the pipe sample.
- Some minor tuberculation nodules were present at the far end of the sample (it is likely that the tuberculation at the near end was dislodged during sample recovery).
- We estimate a 25% effective reduction in the bore.



Photos A6 and A7

- The pipe was cut longitudinally at the approximate spring line and the top half of the spigot (as-laid) was exposed

Photo A6 (left)

- Shows the bitumen impregnated hemp rope (red arrow), the run-lead (green arrow) and tuberculation in the socket (yellow arrow).
- The spigot had been fully inserted to the root of the socket.

Photo A7 (right)

- The lead and bitumen impregnated hemp rope was removed from the spigot and the depth of each is shown (red and green dimensions).
- The collar at the end of the spigot is shown at the yellow arrow.



Photo A8

- Exterior view – pipe sample cut in half longitudinally (along the spring line of the pipe as-laid).
- The bitumen dipped composite coating is still visible and covered ~95 % of the pipe sample.
- Pre-sandblasting, some corrosion pits were visible.
- The approximate depths of lead and bitumen impregnated hemp rope and the collar at the end of the spigot are marked with a white paint pen for clarity.
- Manufacturers marking on the socket 'N W W' are highlighted in white pen for clarity.



Photo A9

- Interior view of the pipe sample prior to the tuberculation being removed.
- A short section of tuberculation had been removed at each end to allow measurement of the wall thickness (yellow arrows).
- The lead between the spigot and socket is shown (green arrow).



Photo A10

- Interior view of the pipe sample after the tuberculation was removed with a power wire brush.
- The bitumen dipped composite is still visible and covered ~90% of the pipe sample however, some graphitisation of the iron is visible.
- The lead between the spigot and socket is shown (green arrow).



Photo A11

- Pipe exterior, after sandblasting to white metal.
- Corrosion pits up to 3.74 mm deep are visible (yellow ellipse).
- Approximately 90 % of the surface area is pitted.
- The approx. extent of the lead and bitumen impregnated hemp rope is marked and annotated on the spigot end.



Photo A12

- Pipe interior, after sandblasting to white metal.
- Corrosion pits up to 5.7 mm deep are visible (yellow ellipse).
- Approximately 60 % of the surface area is pitted.

Appendix B – 21.007 CI



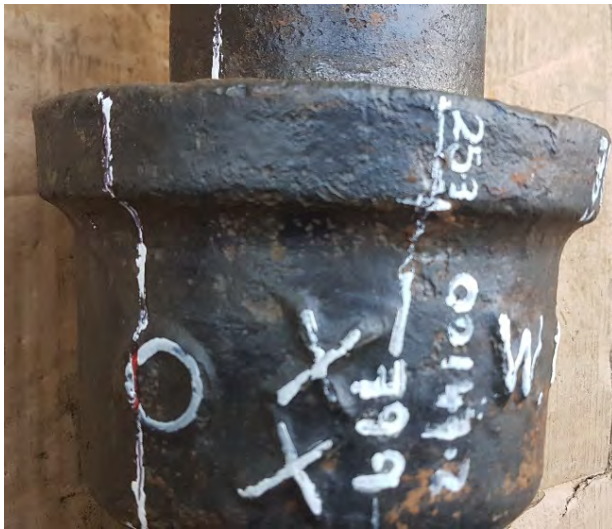
Photo B1

- Pipe Sample 21.007 CI as received on 10 February 2021.
- Top of pipe 'as laid' indicated by two grooves cut into the socket end (yellow arrow).
- Surface corrosion and rusty clay is visible.



Photo B2

- After cleaning with a power wire brush in preparation for examination and measurements.
- The OD, mean ID and wall thickness's are annotated at each end of the pipe sample (yellow ellipses).
- The external bitumen coating covered ~95% of the pipe sample.
- Some manufacturers markers were visible on the pipe socket and are marked with a white pen for clarity, refer to photo B3 and B4 for details.



Photos B3 and B4

- Manufacturers markings on the socket were marked with a white pen for clarity. The markings are of unknown meaning, however, they are like those present on pipe sample 21.006 CI, refer to Appendix A, photos A3 and A4.



Photo B5

- Internal view of the pipe sample.
- Some significant tuberculation nodules were present.
- There is up to 40% effective reduction of the bore in places.



Photos B6 and B7

- The pipe was cut longitudinally at the approximate spring line and the top half of the spigot (as-laid) was exposed

Photo B6 (left)

- Shows the bitumen impregnated hemp rope (red arrow), the run-lead (green arrow) and tuberculation in the socket (yellow arrow).
- The spigot had been fully inserted to the root of the socket.

Photo B7 (right)

- The lead and bitumen impregnated hemp rope was removed from the spigot and the depth of each is shown (dimensions marked on the socket).
- The collar at the end of the spigot is shown at the yellow arrow



Photo B8

- Exterior view – pipe sample cut in half longitudinally (along the spring line of the pipe as-laid).
- The bitumen dipped composite coating is still visible and covered ~95 % of the pipe sample.
- Pre-sandblasting, some corrosion pits were visible.
- The approximate depths of lead and bitumen impregnated hemp rope and the collar at the end of the spigot are marked with a white paint pen for clarity. Manufacturers marking on the socket 'XX' and 'W W W' are highlighted in white pen for clarity.



Photo B9

- Interior view of the pipe sample prior to the tuberculation being removed.
- A short section of tuberculation had been removed at each end to allow measurement of the wall thickness (yellow arrows).
- The lead between the spigot and socket is shown (green arrow).

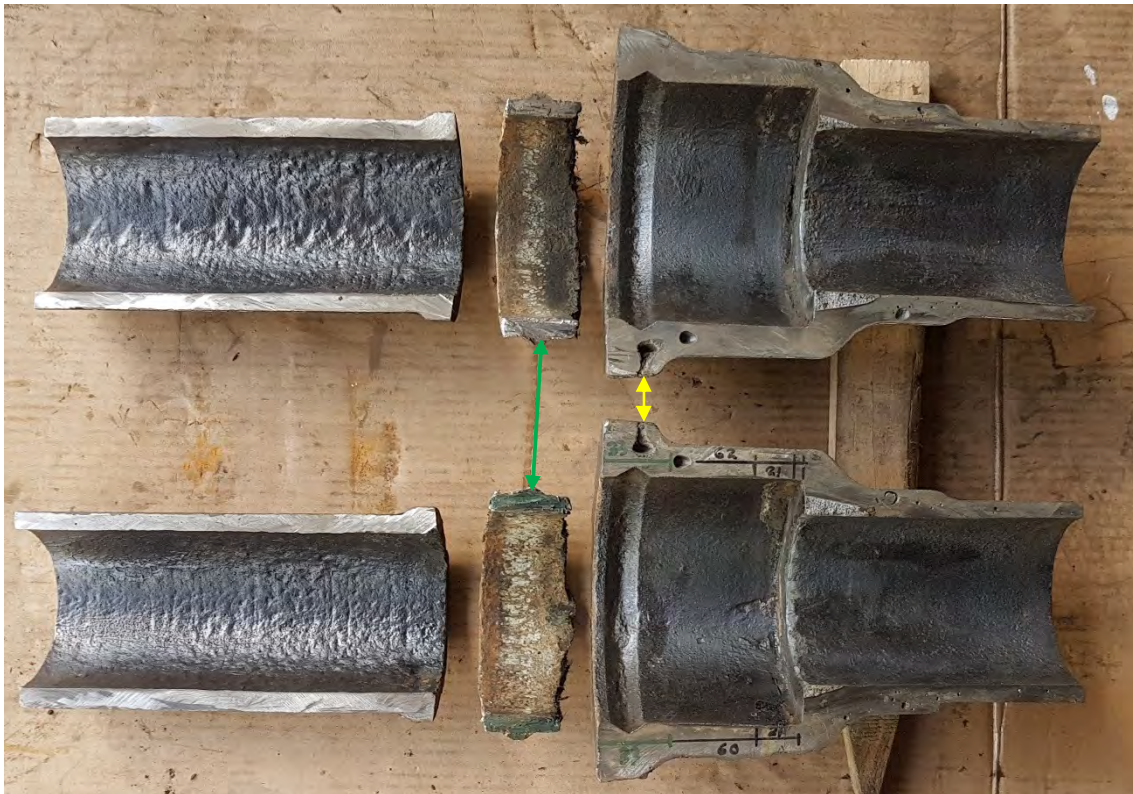


Photo B10

- Interior view of the pipe sample after the tuberculation was removed with a power wire brush.
- The bitumen dipped composite is still visible and covered ~95% of the pipe sample however, some graphitisation of the iron is visible.
- The lead between the spigot and socket is shown (green arrow).
- Porosity is present in the socket. This porosity was deepest at the mouth of the socket, the larger of the two voids (yellow arrow) had a combined depth of ≈ 12.3 mm.

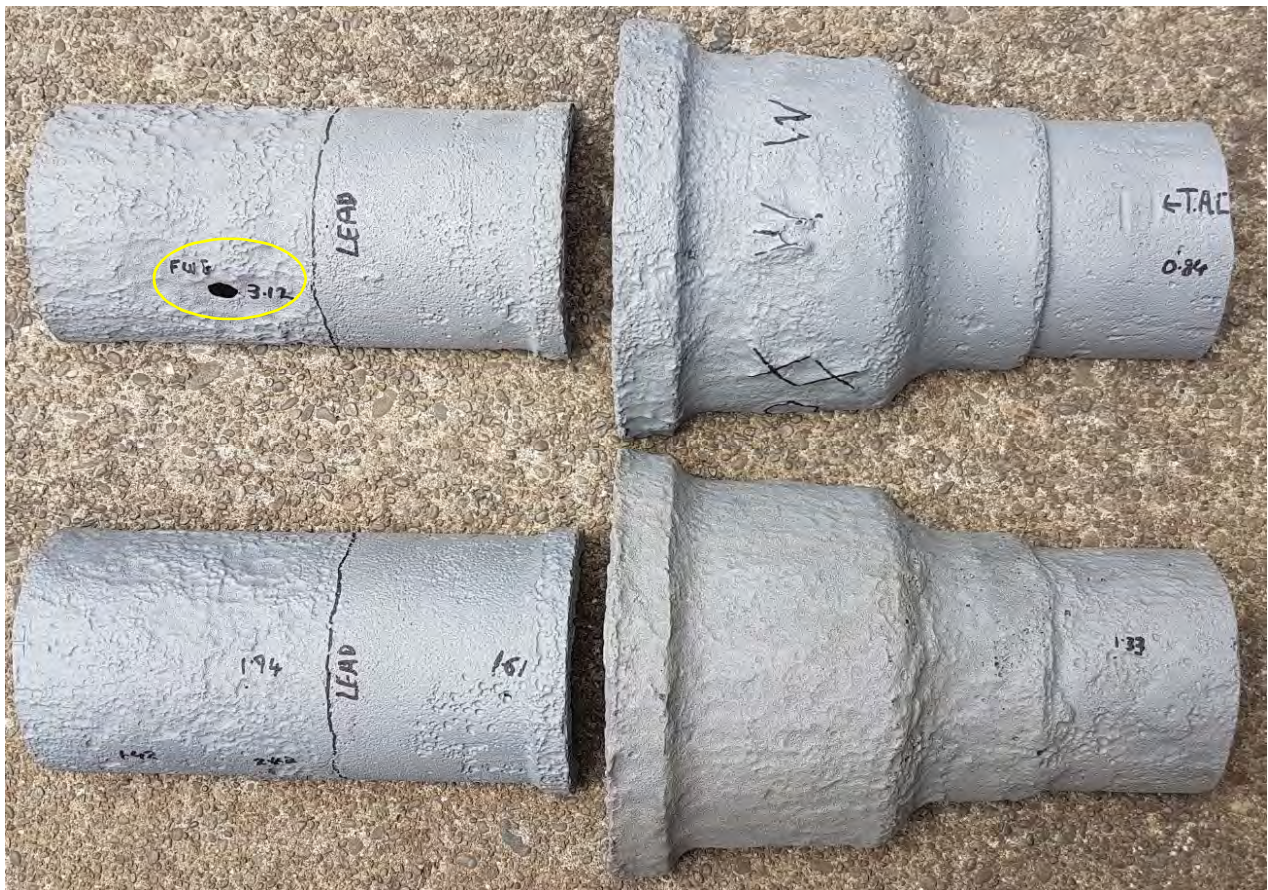


Photo B11

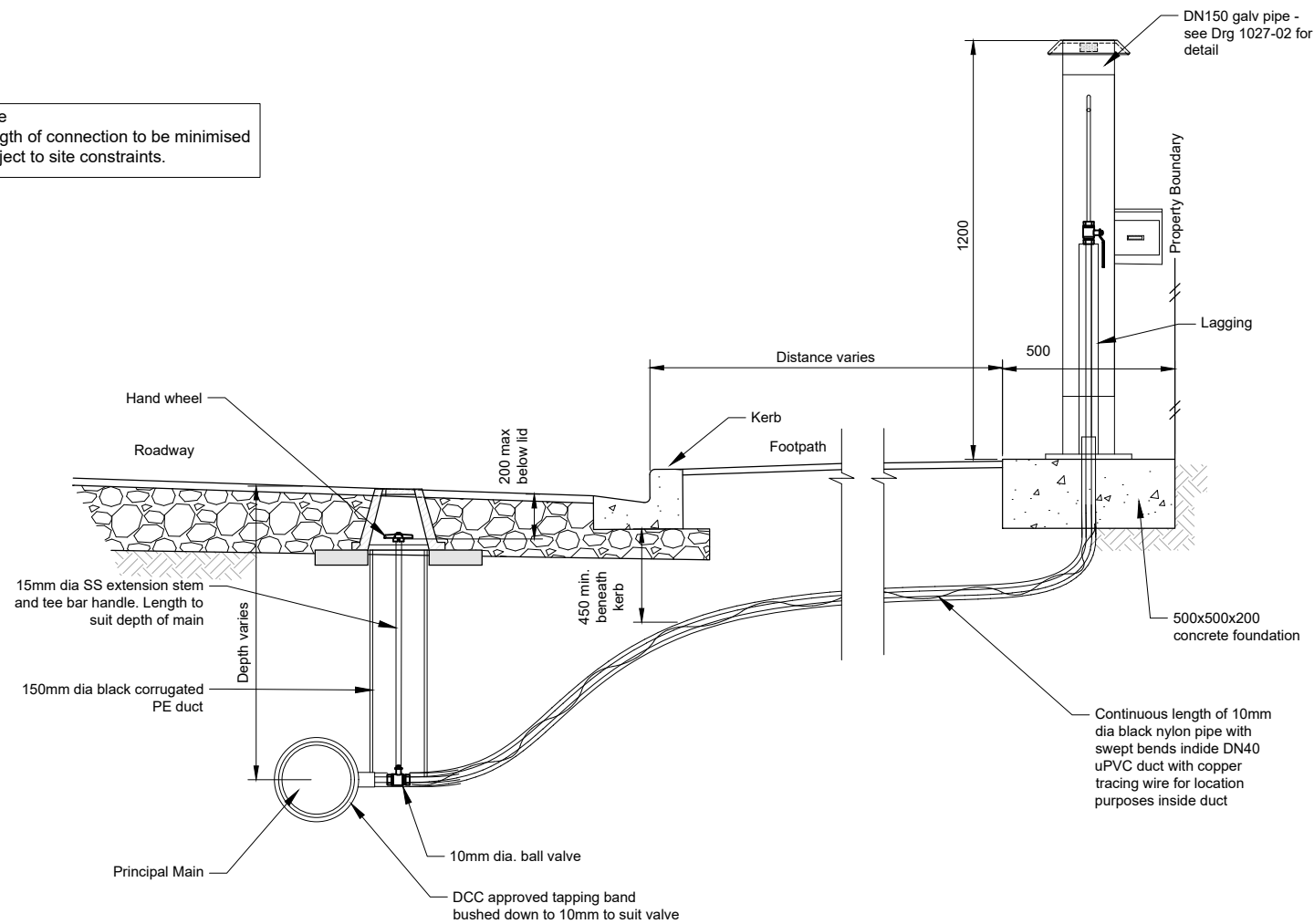
- Pipe exterior, after sandblasting to white metal.
- Corrosion pits up to 3.12 mm deep are visible and FWG has occurred, from combined external and internal corrosion (yellow ellipse).
- Approximately 60 % of the surface area is pitted.
- The approx. extent of the lead is marked and annotated on the spigot end.



Photo B12

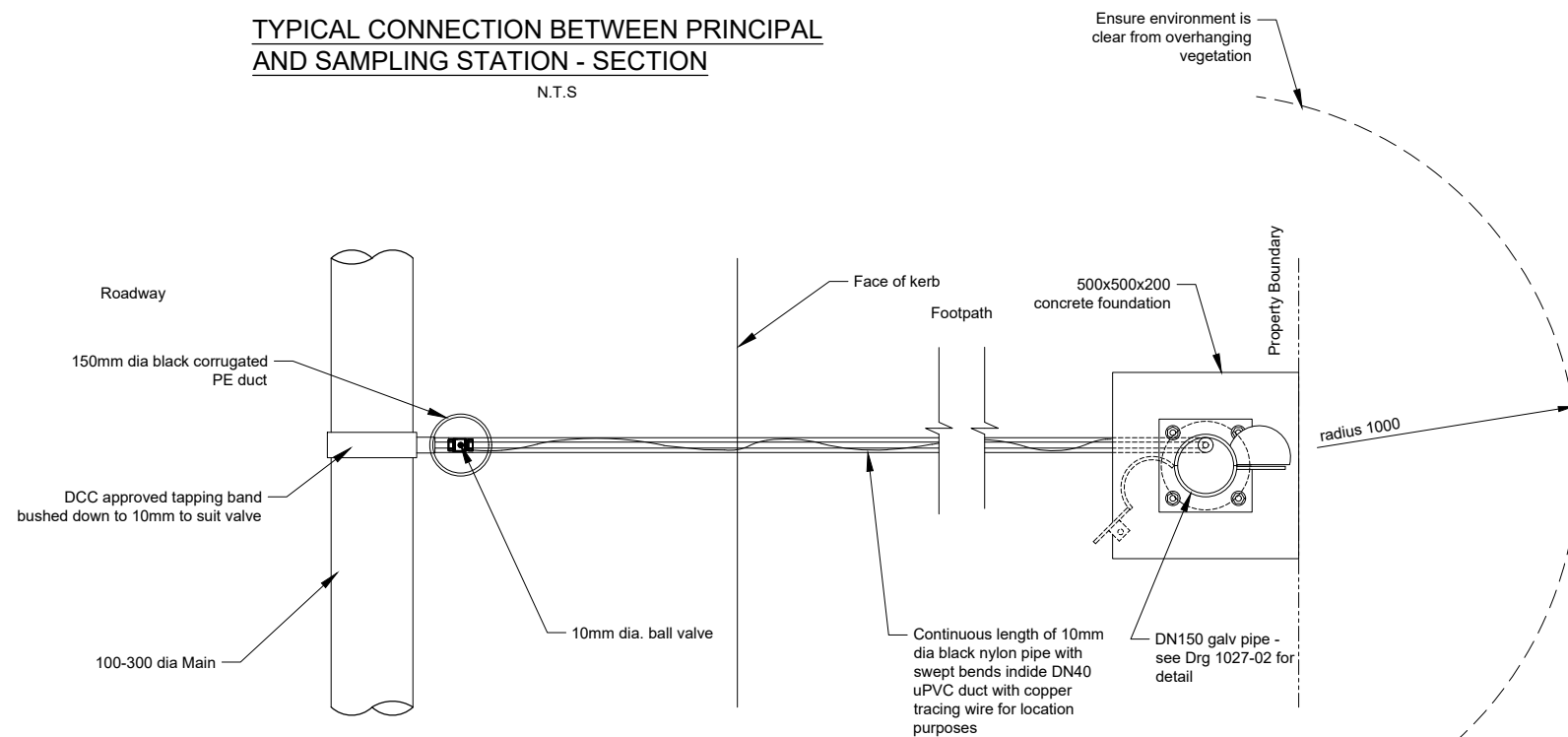
- Pipe interior, after sandblasting to white metal.
- Corrosion pits up to 6.22 mm deep are visible and FWG has occurred, from combined external and internal corrosion (yellow ellipse).
- Approximately 80 % of the surface area is pitted.

Note
Length of connection to be minimised
subject to site constraints.



**TYPICAL CONNECTION BETWEEN PRINCIPAL
AND SAMPLING STATION - SECTION**

N.T.S



TYPICAL SAMPLING POINT CONNECTION - PLAN

N.T.S

Draft No. 3

7/06/19

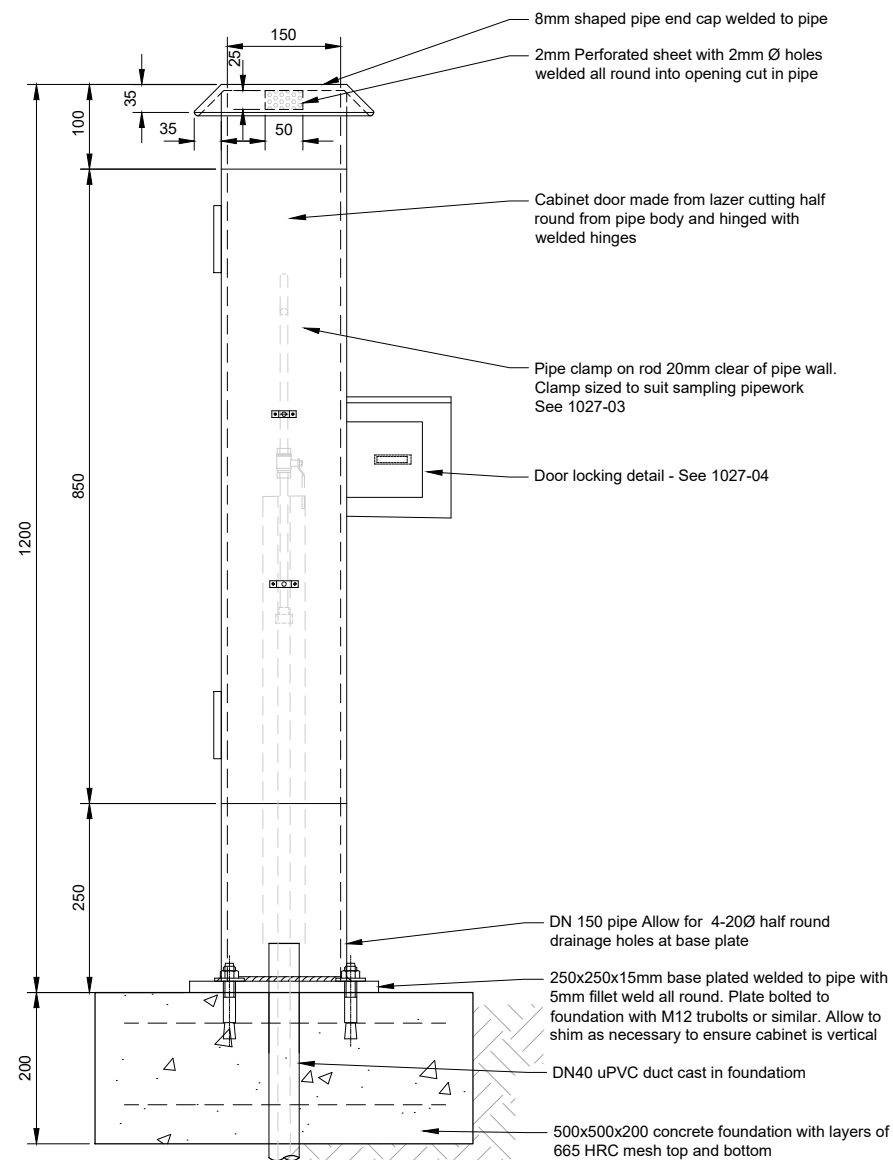
DESIGNED	3 Waters Management Team
DRAWN	
TRACED	
CHECKED	
APPROVED	

SCALE (A1)	NTS	(A3)	###
FOR ISSUE			
DRAWING STATUS	STANDARDS		
NOTE: CONTRACTOR SHALL VERIFY ALL DIMENSIONS ON SITE BEFORE COMMENCING WORK			

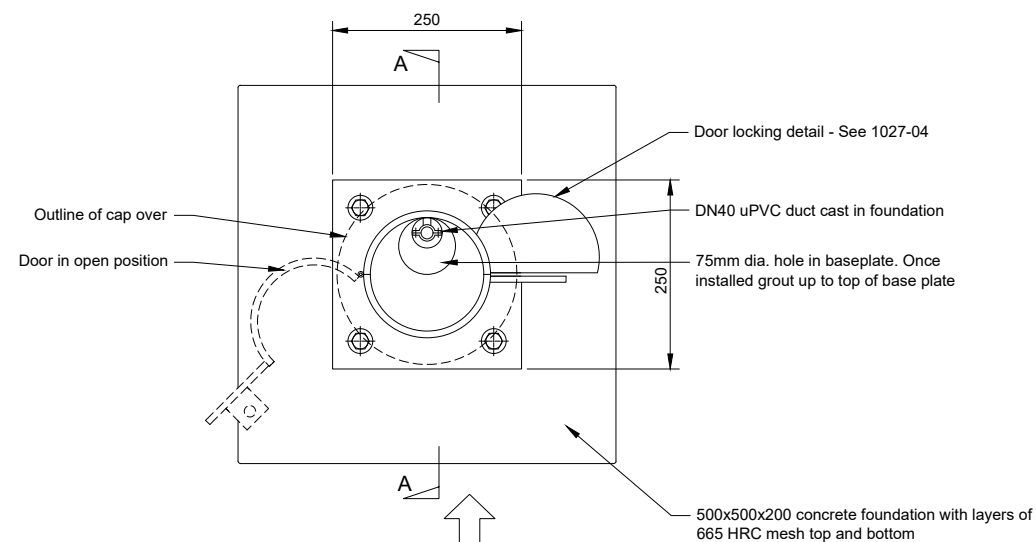


Water Quality Sampling Station General Arrangement

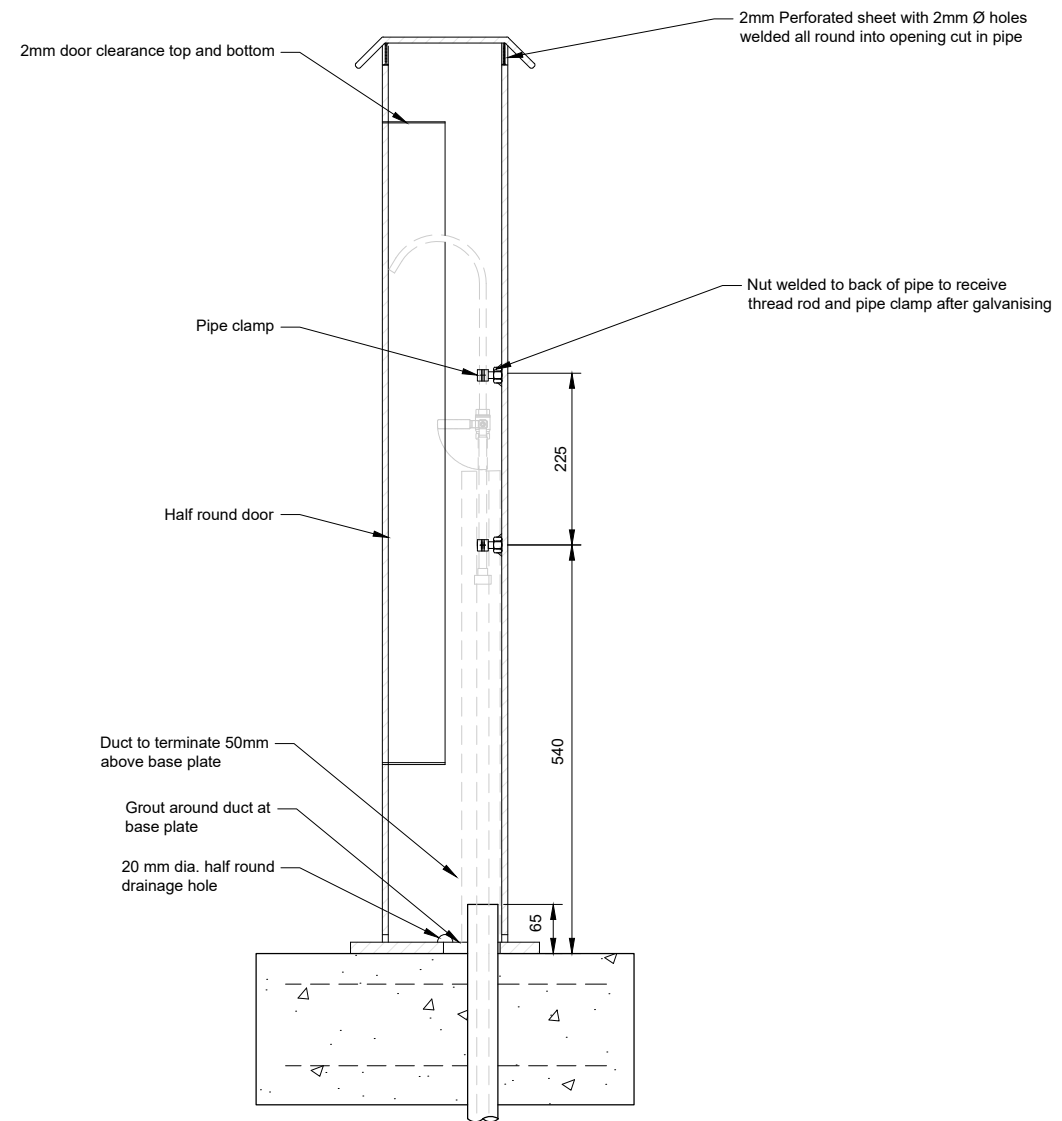
DRAWING No	1027-01
SHEET No	01 of 4
ISSUE	A B C D E F G H I J
DATE ISSUED	####



VIEW 1



PLAN



SECTION A-A

- Note
1. Metalwork to be hot dipped galvanised after fabrication
 2. Door clearance 2mm top and bottom
 3. Pipe to be 150 nominal internal dia.

Draft No. 3

7/06/19

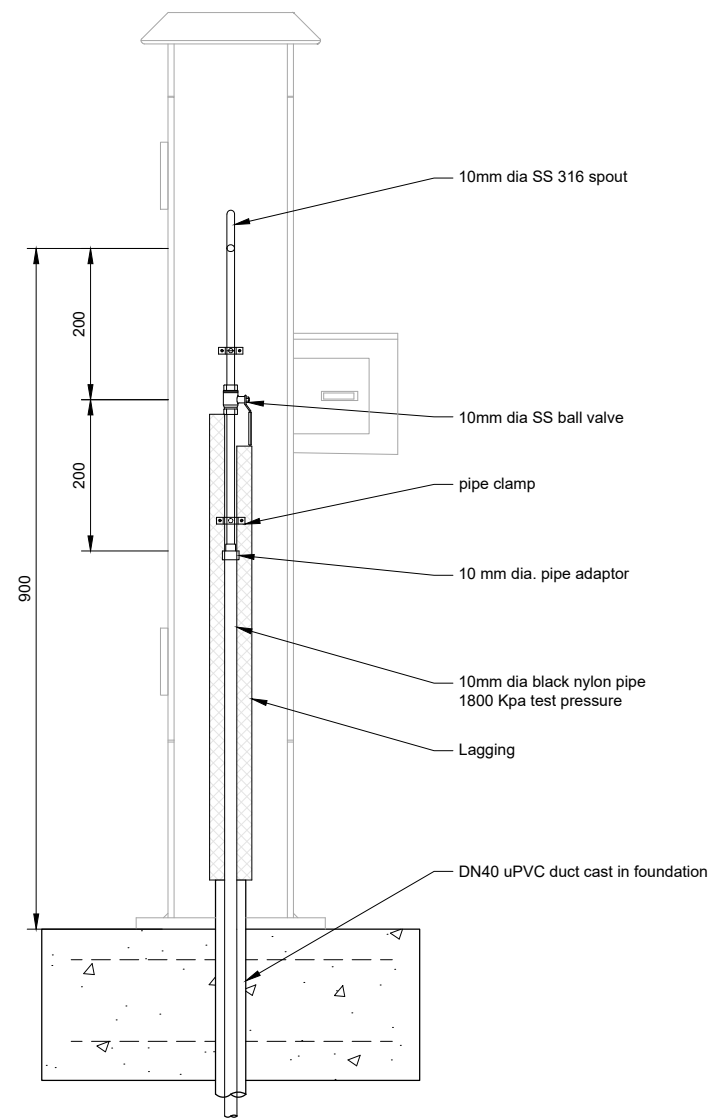
DESIGNED	3 Waters Management Team	SCALE (A1) NTS (A3) NTS
DRAWN		FOR ISSUE
TRACED		DRAWING STATUS STANDARDS
CHECKED		NOTE: CONTRACTOR SHALL VERIFY ALL DIMENSIONS ON SITE BEFORE COMMENCING WORK
APPROVED		

3 WATERS

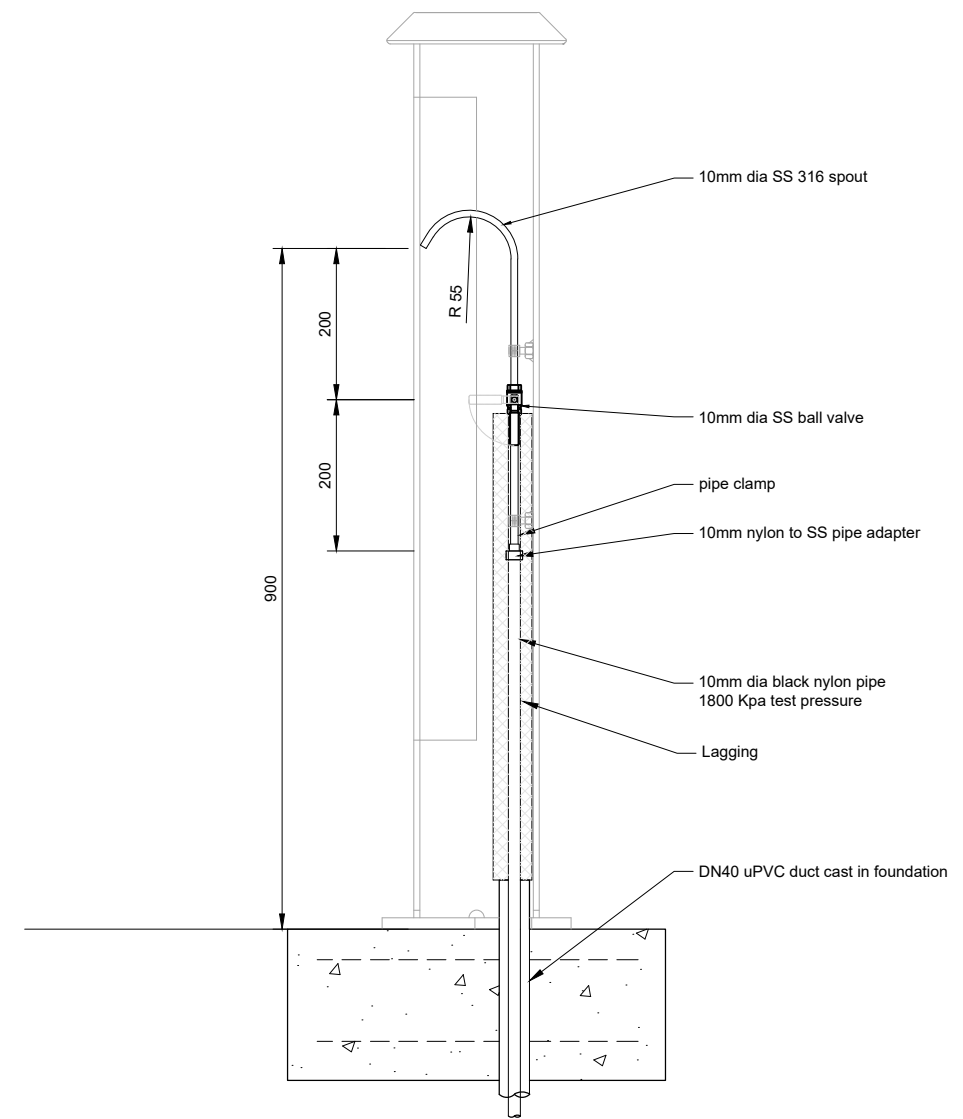


Water Quality Sampling Station Cabinet Fabrication Details

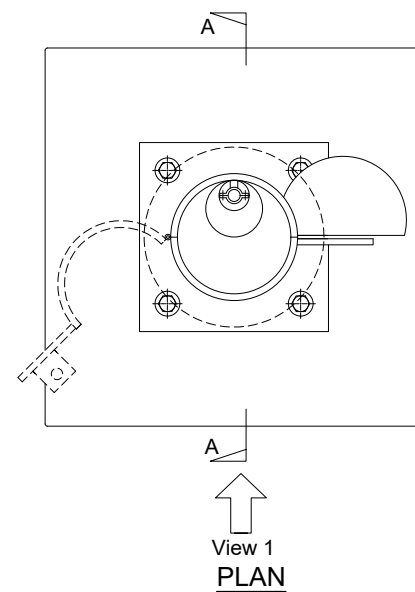
DRAWING No	1027-02
SHEET No	02 of 4
ISSUE	A B C D E F G H I J
DATE ISSUED	####



VIEW 1



SECTION A-A



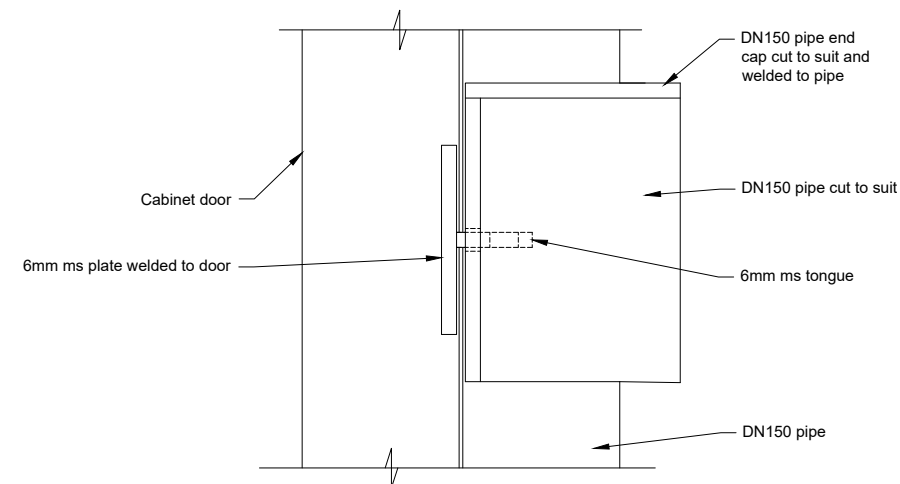
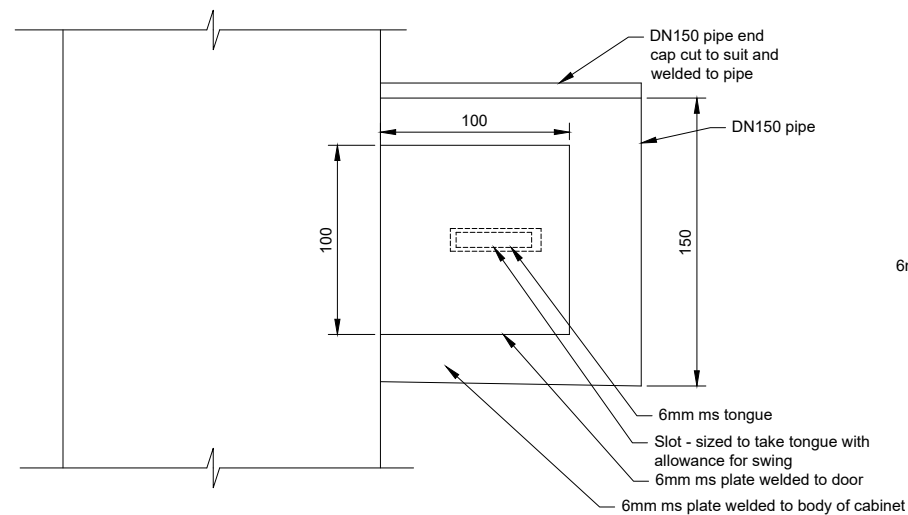
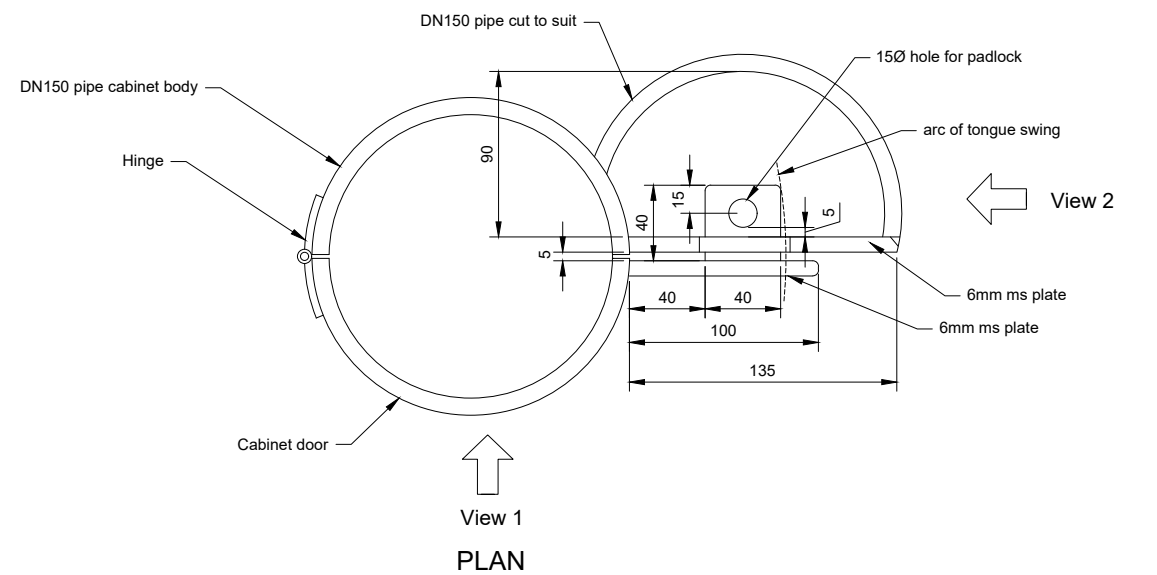
Note

1. Outside of Sampling Station to be labelled or engraved "DCC WATER"
2. Label to be fixed to inside of door with the following
 - (i) Asset No. and Sample Tap No.
 - (ii) Flushing Time _____ Minutes
3. Fire resistant lagging is required as ball valve and spout will be flamed prior to sampling.
4. SS ball valve to have no rubber parts susceptible to heat.

Draft No. 3

7/06/19

DESIGNED	3 Waters Management Team	SCALE (A1) NTS (A3) NTS	3 WATERS	 DUNEDIN kaunihera CITY COUNCIL a-rōhe o ōtepoti	Water Quality Sampling Station Internal Pipe Work	DRAWING No	1027-03
DRAWN		FOR ISSUE				SHEET No	03 of 4
TRACED		DRAWING STATUS As Built				ISSUE	A B C D E F G H I J
CHECKED		NOTE: CONTRACTOR SHALL VERIFY ALL DIMENSIONS ON SITE BEFORE COMMENCING WORK				DATE ISSUED	####
APPROVED							



- Note
1. Metalwork to be hot dipped galvanised after fabrication
 2. Door clearance 2mm top and bottom
 3. Pipe to be 150 nominal internal dia

Draft No. 3
7/06/19

DESIGNED	3 Waters Management Team	SCALE (A1) NTS (A3) NTS	3 WATERS	Water Quality Sampling Station Vandal Cover and Lock Protection Details	DRAWING No 1027-04									
DRAWN		FOR ISSUE	 DUNEDIN CITY COUNCIL kaunihera a-rohe o ōtēpoti		SHEET No 04 of 4									
TRACED		DRAWING STATUS STANDARDS			ISSUE A B C D E F G H I J									
CHECKED		NOTE: CONTRACTOR SHALL VERIFY ALL DIMENSIONS ON SITE BEFORE COMMENCING WORK			DATE ISSUED ####									
APPROVED														

Purpose

To describe the requirements for the provision of water quality sampling points and taps.

Regulation & Guidance

- The Drinking Water Standards of New Zealand 2005 (Revised 2018)

General Requirements

The overall objectives are:

- To obtain water samples of the same composition as the water in the main, tank or system from which they have been taken.
- To ensure that the sample does not degrade, suffer contamination or change in temperature in the sample line.

Scope

Principles guiding site selection.

Sample points for raw, partially and fully treated water.

All new structures and works under the control of the DCC.

All repairs to or replacement of existing sampling facilities including taps.

Contents

1. Principles for Tap Location
2. Detailed Aspects of Tap Sites
3. Tappings for Sample points
4. Sampling Lines
5. Sample taps
6. Length & flushing times
7. Sample pumps
8. Recirculation
9. Site Start up & Periods When Shut down
10. Disposal of flushing water
11. Identification
12. Security
13. References
14. Revision history

1. Principles for Tap Location

The following factors shall be considered when choosing a suitable location.

- The selection of sites which will provide as clear a picture as practical, of the prevailing water quality variations across the raw and treated water networks, having regard to regulatory as well as customer requirements.
- Health and Safety including ease of access to the sample point, the avoidance of restricted areas and routes of access that may be hazardous for sampling staff.
- Sample tap height: Ideally sample taps should be positioned at around 1 metre above ground level.
- Upstream mixing.
- Avoiding sample at points of low turnover.
- Gravity feeds: Where possible sampling points should be gravity or “pressurised” main fed. Pumped systems shall be avoided.
- The potential for backflow to be avoided.
- Changes in flow at the sampling point should be avoided wherever practicable.
- The need to avoid fire hazards (note taps are sterilised by flaming).

2. Detailed Aspects of Tap Sites

- Sample take off points shall be located such that they are supplied with water representative of the point in the process or within the structure to be sampled.
- Upstream process mixing requirements shall be complete at the point of sampling.
- Sampling points shall not be from a dead leg of pipework, balancing main between two structures or anywhere with atypical or transient turnover.
- Sample points shall be located such that they are under positive pressure at all times. Where a risk of backflow exists, including when the works is not in supply, a double check valve shall be provided.
- If pumps have to be used to sample tanks, they shall draw water from a location away from the tank wall to avoid dead areas of flow.
- Sample taps shall be located in a secure building, cabinet or pillar protected from frost, wind and environmental contamination.
- The sample cabinets and pillars shall be free draining to take the full flow from the tap.
- The sample cabinets shall provide sufficient space for filling bottles.
- Sample cabinets shall be securely fixed to cast in-situ concrete foundations. Ideally a 1 metre wide concrete path around the cabinet to facilitate sampler access.
- Sample cabinets, pillars and taps shall be sited in a way that minimises risk of contamination of the sample by surrounding vegetation. Any hedges, trees and vegetation shall be pruned back such that there is clear space around the cabinet or pillar.

3. Tappings for Sampling Points

- Dedicated tapping must be made for sample taps.
- Redundant fittings including ferrules and tappings, shall be removed when making new tappings or replacing or refurbishing existing sampling arrangements.
- Tappings shall sample the water from the horizontal centre line of the main, i.e. at 90° or 270°, where there is expected to be minimum change in the velocity of the water. Tappings shall not be placed at the top or bottom of the main unless this unavoidable and this must be agreed by the **Regulatory Compliance Officer?**.
- For large diameter mains (>300mm dia.) where no upstream mixing and there are concerns over getting representative samples provision shall be considered for a lance to ensure that samples derive from the centre of the pipe. Lances shall be stainless steel and capable of being withdrawn. Where lances are used to sample the centre of the pipe they can be fitted at the most convenient point for withdrawal (typically the top of the pipe)
- Tappings on a water treatment plant that feed a sample tap must be in a chamber. The chamber must be of suitable size to allow replacement and facilitate renewal of the sample line which must be ducted to the sample tap below ground or inaccessible portion). **Subject to DCC H & S controls and operational security rules, the main valve chambers at the Mt Grand & Southern may be suitable. We need to think about sample points at other locations within the treatment plants. Purpose built sampling chambers & buildings will probably be required at the smaller WTPs.**
- Tappings on service reservoir that feed a sample tap shall be 10mm ID and where possible, installed at a location where the static pressure is between 5 to 10m. The sampling line to the tap shall be ducted. Where sample lances are required, the tapping point shall be in a drained chamber to facilitate renewal of the sample line. **(Subject to DCC H & S controls and operational security it may be feasible to house the tapping point in the main valve chamber of some of some reservoirs, particularly where walk in access is available).**
- DCC 3Waters Sketches 1 & 2 as well as Image 1 indicate the details for Sampling points/Water Quality Monitoring and shall be followed.

4. Sampling lines

- All materials in contact with water shall comply with the DCC 3 Waters Approved Materials list.
- Sample lines shall be sized to achieve maximum flushing flow velocities. As rule, 10mm black nylon pipe used to link the tapping to the sample tap assembly. Black Nylon is to used for reasons of biochemical stability.
- The sample lines shall be installed in a duct when installed below ground. As guide, the duct should be a minimum 40mm ID.
- In water treatment plants or valve chambers, or where the sample line is exposed to natural light (e.g. a valve house with skylights) the sample line shall be insulated with proprietary plumbing product.

5. Sample taps

- Sampling taps shall be quarter turn 316 stainless steel or Nickel plated. Brass, bronze, galvanised, or non-metallic bodied taps shall not be used.
- The sample tap assembly pipework shall be 6mm ID 316 stainless steel tubing downstream of the sample tap.
- The number of bends and joints used in the installation should be minimised.
- In distribution zone situations, where the pressure is greater than 100 metres head, a PRV may be required.

6. Length & Flushing times

- Sample lines should be as short as practical, with the minimum number of joints as possible. As a general rule, the sample line length should be less than 10 metres.
- Flow at the tap shall be sufficient to fill a 1 litre sample bottle in less than 30 seconds in all normal operating conditions.
- The flow at the tap shall be sufficient to flush the line in less than 2.5 minutes. A flush is defined as volume of water equating to three times the volume of the sample line. In all cases, the required flush time shall be clearly displayed above the sample tap and on the sample tap tag. *(Need to think about GIS asset number convention).*
- Some sample lines, such as those for raw water, can be prone to deposition. Facilities should be provided to enable flushing of these lines in excess of the minimum specified above.
- In all cases, the location and design of the sampling facility, must be agreed with the *Regulatory Compliance Officer, relevant Operational Manager and the Laboratory Services Contractor.*

7. Sample pumps

- Sample pumps shall only be considered where all other options have been ruled out on grounds of practicality of achieving a representative sample.
- Pumps must be of a type and specification suitable for the application and manufactured of materials suitable for being in contact with drinking water.
- Pumps shall be suitably sized for the intended application and the installation must be able to deliver a smooth, pulse and splash free flow within the acceptable range described in section 6 above.
- Pumps shall be installed so as to facilitate maintenance or replacement, particularly any components likely to deteriorate in use.
- The installation and connecting pipework must be capable of being disinfected and flushed.
- Pump installations shall be located within a building, cabinet or pillar protected from damage, and designed to facilitate sampling.

- Where mains power is unavailable, a solar-battery or portable 12V-24V battery may be used.

8. Recirculation

- Recirculation lines shall not be used for sampling purposes.

9. Site Start Up and Periods When Shut Down

- Consideration must be given to protecting and inhibiting sampling under circumstances where the main or process may drain down.
- Manual compliance samples taken by Sampling staff should be representative of water in network. *For distribution zone sampling is there a process whereby the laboratory services contractor is notified when specific sampling taps are unavailable when mains maintenance work is being carried out? At water treatment plants how is the laboratory services contractor notified when the WTP is off line?*

10. Disposal of Flushing Water

- Taps shall be able to be run to waste at a rate that does not limit the ability to adequately flush the tap.
- Cabinets & pillars shall be designed and located to avoid splashing.

11. Identification

Sample taps shall be permanently labelled with:

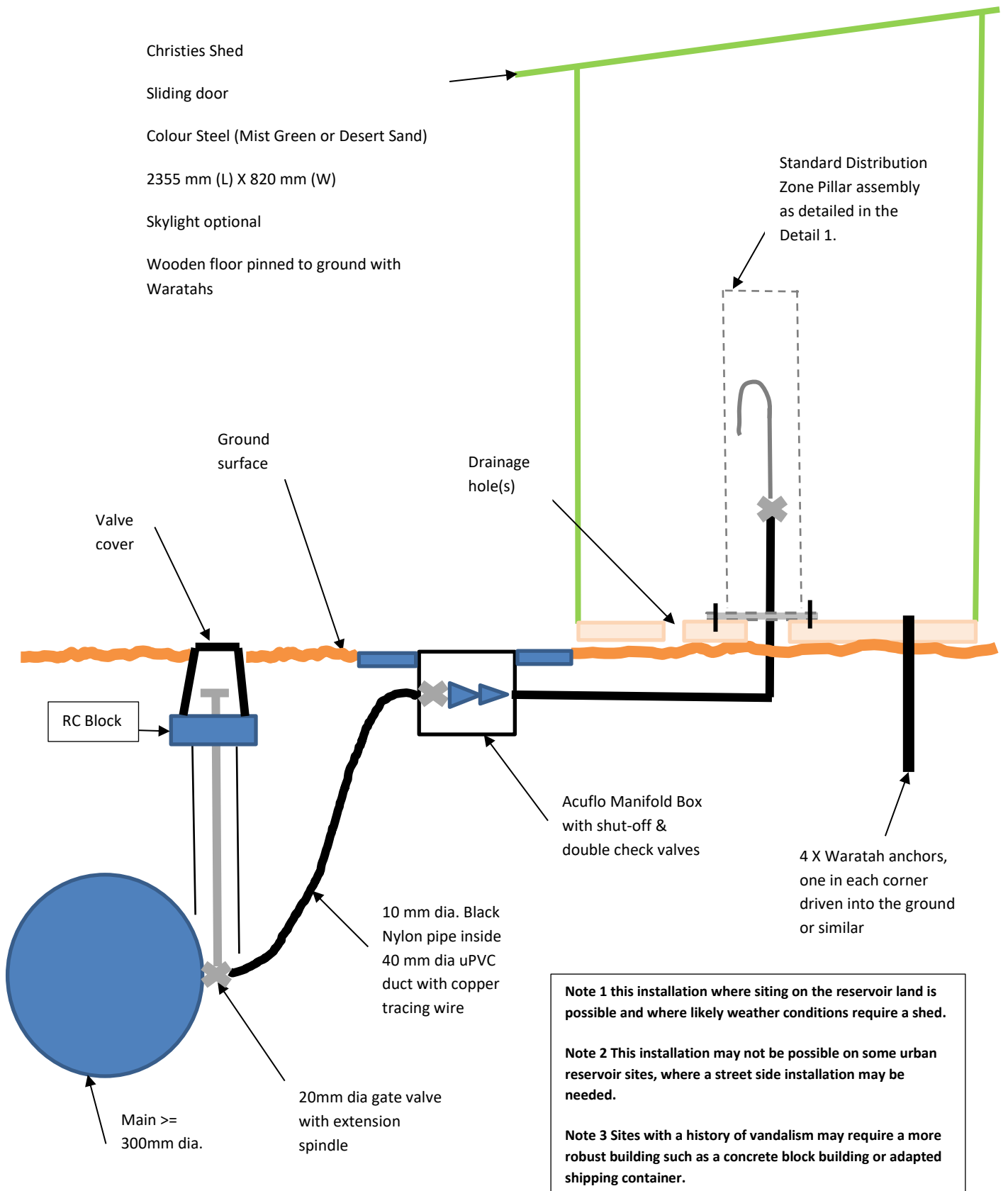
- Sample location name. *What is the currently naming convention? GIS?*
- Water quality site name. *Are unique site names registered in WINZ?*
- Required flushing time
- Where tapping points are buried a concrete slab (300mm X 300mm X 50mm) with "TP" on its shall be placed over the tapping point well.

12. Security

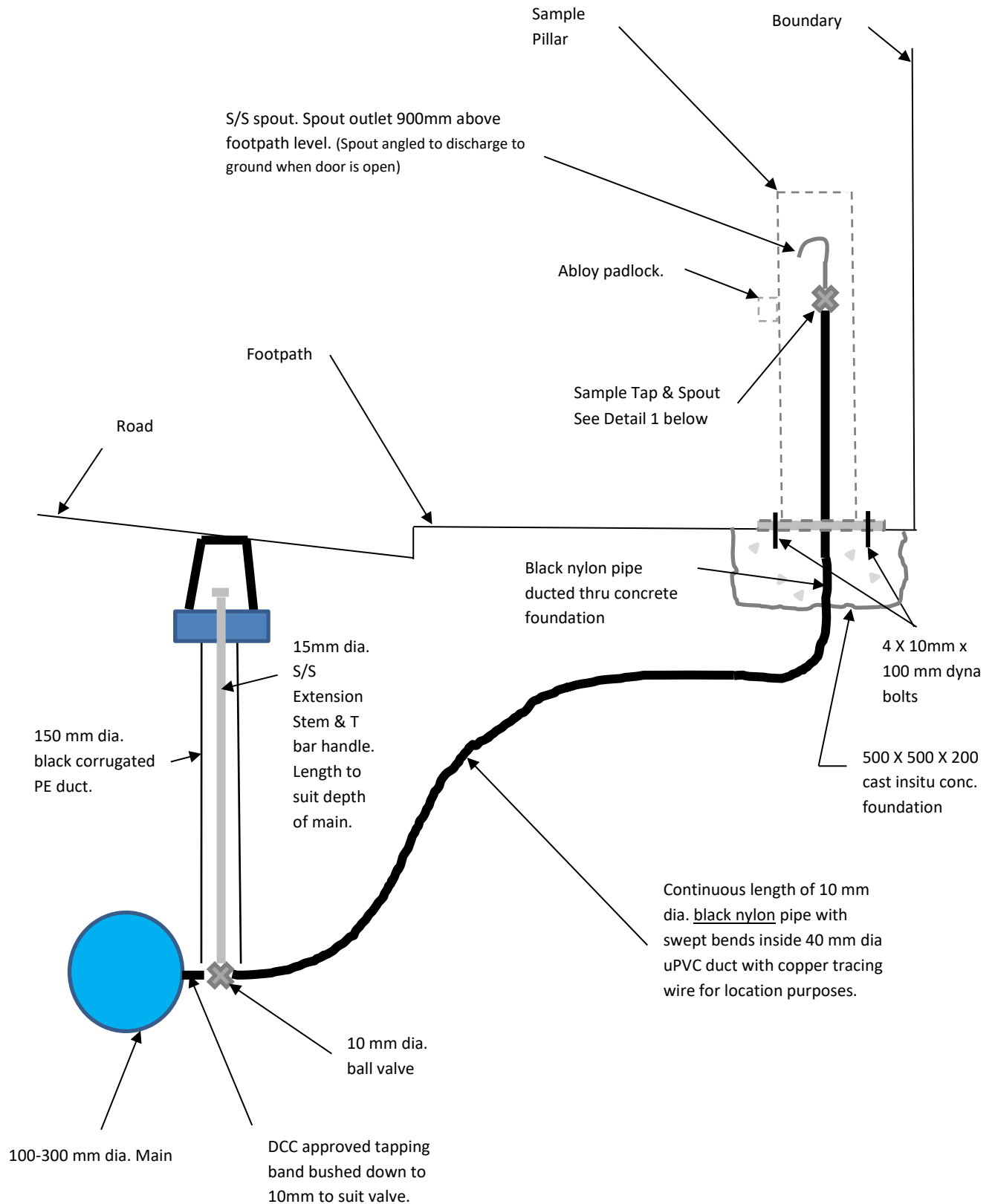
- Sample taps at Water Treatment Plants, Service Reservoirs and Distribution zone sites shall be located in a secure building, cabinet or pillar fitted with the current 3 Waters lock.
- New or replacement sample cabinets or pillars shall conform to the current approved design.

- Sample line ducting to secure sample cabinets shall also be secure tamperproof and designed to prevent direct access to the body of water e.g. service reservoir.
- Insert reference to standard pillar drawing.
- In some rural situations, the sampling pillar may need to be protected by a shed and fence as protection against cattle.

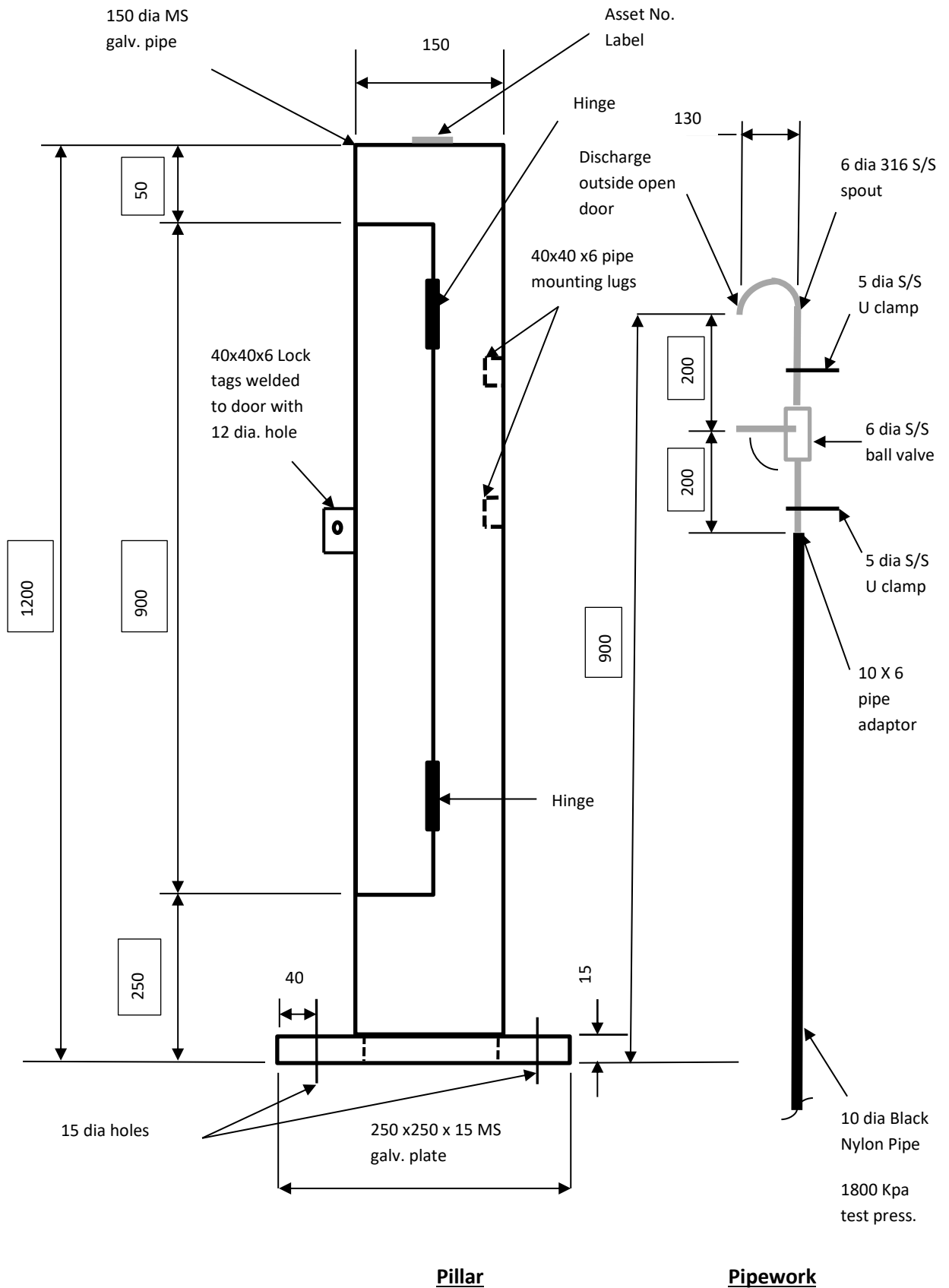
Sketch 1) - Standard Service Reservoir Sampling Point



Sketch 2) - Standard Distribution Zone Sampling Point



Detail 1 - Standard Sampling Pillar & Spout



Detail 2 - Standard Sampling Pillar – Service Reservoir

Insert detailed dimensioned drawing of installed Sampling Pillar with shed

Image 3 - Standard Sampling Pillar – Service Reservoir

Insert image of installed Sampling Pillar without shed

Image 4 - Standard Sampling Pillar – Water Treatment Plant

Insert images of installed Sampling Tap

Image 5 - Standard Sampling Pillar – Raw Water Pipelines

Insert images of installed Sampling Tap



Waikouaiti River Catchment Risk Assessment

Prepared for
Dunedin City Council

Prepared by
Tonkin & Taylor Ltd

Date
March 2021

Job Number
1016715



Exceptional thinking together

www.tonkintaylor.co.nz

Document Control

Title: Waikouaiti River Catchment Risk Assessment					
Date	Version	Description	Prepared by:	Reviewed by:	Authorised by:
10 Mar 21	0	Initial Desktop CRA DRAFT	CRSS	TPC	TPC
15 Mar 21	1	Final CRA report	CRSS	TPC	TPC

Distribution:

Dunedin City Council

1 electronic copy

Tonkin & Taylor Ltd (FILE)

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Executive summary

Background:

Lead has exceeded the Drinking Water Standards for New Zealand (DWSNS) Maximum Acceptable Value (MAV) within Dunedin City Council's (DCC) Waikouaiti/Karitane water supply network (isolated events) and (on one occasion only) within the DCC raw water reservoir at the Water Treatment Plant (total lead 0.05 mg/L). DCC has concluded that the MAV exceedance events within the network are likely from lead pipe joints. The raw water reservoir exceedance event remains unexplained. There are limited possible sources of lead between the intake and the reservoir (the delivery main is a concrete-lined steel pipe). An environmental source of lead and, or changing water conditions that affect lead partitioning (i.e., the balance between particulate and dissolved fractions of lead), or laboratory error are possible explanations for the MAV exceedance in the reservoir.

Objective and summary of scope:

The objective of this assessment was to assess the Waikouaiti River as a potential source of lead detected within the Karitane/Waikouaiti water supply system, particularly the lead that was detected within the raw water reservoir. The scope of the investigation included completion of the following:

- Review of existing water, sediment, and Mahika Kai tissue sampling undertaken within the Waikouaiti catchment and estuary, including:
 - Raw water quality data collected by DCC at its water treatment plant (WTP),
 - Environmental compliance monitoring data collected by Oceana Gold (OG),
 - Environmental monitoring undertaken by Otago Regional Council, and
 - Mahika kai sampling undertaken by Te Rūnanga o Ngāi Tahu
- Desktop review of aerial photographs, discharge consent information, Hazardous Activities and Industries List (HAIL) site registries, and field notes collected by ORC during an aerial survey of the catchment.
- Targeted sampling of water and sediment at and around the WTP and in the wider Waikouaiti River catchment, undertaken in February 2021.

Summary of findings:

Our review of available water and sediment quality data, including the recent sampling undertaken as part of this investigation showed the following:

- Key water chemistry parameters, such as sulfate, hardness, alkalinity, calcium, magnesium and potassium within the OG dataset show a seasonal trend in water chemistry at the upper reaches of the river, with higher concentrations in summer, and lower concentrations in winter. This was particularly pronounced in the summer of 2019, which showed a significant spike in concentrations of all inorganic parameters. The 2019 spike is also evident in the WTP raw water monitoring data for sulfate (other parameters were not measured).
- Only dissolved lead has been tested by OG continuously, and it has been infrequently collected (particularly prior to 2018). The data shows times when dissolved lead has been slightly elevated (complicated by intermittent analysis), up to 0.017 mg/L in February 2000 at NBWR Redbank Road. The results are generally an order of magnitude below the DWSNZ MAV (which relates to total fraction rather than dissolved), but it is possible that total lead concentrations could have been higher between sampling rounds.
- A single extremely low pH event (pH 3.5) is shown in the OG monitoring data in September 2019 at an upstream location (NBWR Ross Ford). However, low pH was not

recorded approximately 7 km downstream (NB01) on the same day, so is likely to be an equipment issue.

- All water quality samples collected from the river and tributaries on 16/17 February 2021 were at or below laboratory detection levels for total and dissolved lead.
- Inorganic parameters (such as sulfate, alkalinity, hardness) all decline from the upper catchment to the lower catchment. Based on these parameters, water corrosivity appears to increase from scale-forming in the upper reaches, to being slightly corrosive at the WTP intake.
- Lead levels within sediment appear to generally decline from the upper river to the lower river, from approximately 11 mg/kg in the upper catchment to around 5 mg/kg near to the WTP intake. However, all results are within expected background concentrations.
- The concentrations of lead in soil collected from the former slash fire area (11-15 mg/kg) were within expected background concentrations, but slightly higher than lead concentrations in the lower river and estuary sediments, which are generally around 5mg/kg.
- Lead concentrations in the raw water reservoir sediment (17.3 mg/kg) and sediment from the filter backwash settling ponds (13-17 mg/kg) were all within the expected background concentration, but slightly higher than samples from the lower portion of the river.
- Lead concentrations in sediment at the filter backwash discharge point (10 mg/kg) and within the tributary downstream of the discharge (5-12 mg/kg) were also within background ranges, but slightly higher than the river sediment in the lower portion of the river.
- Mahika Kai sampling results appear to show a slight elevation of lead within bivalve biota relative to limited available baseline data. However, results were considered inconclusive, without further specialist input to bioaccumulation processes and a more comprehensive baseline comparison. All sampling results were below Food Safety Australia New Zealand maximum wet weight values for fish and molluscs.

Conclusions:

- Based on water quality sampling and sediment data from the river and the estuary, there are unlikely to be sustained elevated discharges of lead within the river catchment. Alongside laboratory error or sample contamination, short-term “pulse(s)” of elevated lead are the most-likely explanations for the elevated lead results from the raw water reservoir in January 2021 and the recent spike of 0.034 mg/L.
- Discharges from OG were qualitatively assessed as medium risk, based on the limited compliance data set available. Note that this qualitative assessment does not consider catastrophic events (e.g., tailings dam failure) or non-compliant behaviour.
Key water chemistry parameters decline from the upper to lower catchment. These spatial changes may arise from discharges related to OG’s activities, which are diluted by increasing inputs to the river moving downstream. The changes in water chemistry may affect lead partitioning as the water moves down-river, and could influence lead partitioning in the source/raw water to the WTP. Compliance data shows historical events where elevated dissolved lead has been present in the upper catchment, highlighting that such events can occur from time to time.
- A simple mass balance conducted shows that – based on the very limited data that we have – there is no evidence to indicate that under worst case calculations, discharges from Oceana Gold could lead to concentrations of lead at the water intake that have been experienced. However, the very small data set is only representative of a small fraction of the overall long term picture and does not account for more complex catchment and chemical processes.

- The discharges from the WTP were qualitatively assessed as medium risk. Lead concentrations in sediment/sludge at the former slash fire, in the raw water reservoir and from the filter backwash ponds were all within expected background ranges for lead in soil, but about 2-3 times higher than concentrations in the river sediment. Although not conclusive, the results do highlight the possibility that lead from these areas (or pulses from an upstream source) could be entering the water supply, either as particulate or dissolved phase (depending on water chemistry/corrosivity conditions). The results may also simply be a function of finer sediment within these areas providing greater surface area for the adsorption of lead.
- Potential discharges from the fly dump near Eldorado Station were qualitatively assessed as medium risk. A conservative assessment was made, on the basis that the contents and volume of the dump was still poorly defined. If high-concentration sources of lead are present within the dump, these could be mobilised during high rainfall/flood events such as the January 2021 event.

Recommendations:

- Continue to monitor raw water for lead (total and dissolved) at high-frequency, along with periodic sampling of sediment for lead (including event-based sampling also).
- Further discussion with OG to establish whether further environmental monitoring data may be available.
- In order to further assess and understand the sources, fate and transport of key contaminants in the river, a series of co-ordinated, monitoring exercises are conducted, involving continuous water sampling and/or monitoring for parameters including metals, pH and turbidity at several locations along the length of the river. Critical locations would be upstream and downstream of major discharges and tributaries, coordinated with sampling at the WTP described above. Ideally the exercise would be conducted over several different weather and river flow conditions, and would involve co-ordination with major consent holders, and additional sampling of their discharges. Flow measurements and/or calculations for the discharges and the river at various points would also be required. Analysis of data from such an exercise would then be used to develop an enhanced understanding of the potential sources of contaminant and to feed into any more detailed fate and transport modelling exercise that might subsequently be undertaken.
- Further physical/visual inspection of the Eldorado Station fly dump to better define the nature, contents, volume and distribution of wastes. If significant sources of lead are identified, potential of these could be assessed using fate and transport modelling.
- Further assessment of the relevance of the Mahika Kai sampling results, respective to relationship between background lead concentrations in the catchment and bioaccumulation processes. This is specialist work, outside of T+T expertise.

1 Introduction

Following the contamination of the Waikouaiti and Karitane drinking water supply with lead, Tonkin and Taylor (T+T) has been engaged by Dunedin City Council (DCC) to provide a range of technical support services during initial responses and investigation planning.

As part of our inputs to the investigation response, T+T has completed an initial screening level catchment risk assessment and a fieldwork programme to investigate potential sources of lead, and potential contributing factors to water corrosivity. This document provides a summary of an initial screening level catchment risk assessment (CRA) and preliminary source water sampling completed in February 2021.

We have completed this work in general accordance with our scope of work, provided to DCC via email on 9 February 2021.

2 Background

The Waikouaiti water supply sources raw surface water from the Waikouaiti River. Water is treated at the nearby Waikouaiti Water Treatment Plant (WTP) before being supplied to the Waikouaiti and Karitane communities.

Elevated lead was found within the reticulated network during routine sampling in July 2020, then again in December 2020 and January 2021. Elevated lead was also found within the raw water reservoir in January 2021 and tube settlers (within the WTP) in February 2021. DCC's current interpretation of these results is that there is likely to be a source of lead within the reticulated network (a section of cast iron pipe, with lead joints) and potentially lead contamination in the source water. Variations in the corrosivity of the raw water may also be contributing to lead concentration trends in the network.

A full investigation programme has been launched to determine the source(s) of lead contamination and the likely impact to community health. As part of the programme, DCC is investigating potential sources of lead in the catchment, as well as potential sources that could have contributed to changes in the raw water corrosivity. This report provides a summary of the results of investigations completed to date to assess potential sources of contamination within source water to the Waikouaiti WTP.

3 Catchment Investigation Scope

The objective of this assessment was to assess the Waikouaiti River as a potential source of lead detected within the Karitane/Waikouaiti water supply system, particularly the raw water reservoir. The intention was then to use this information to complete further targeted assessments focused towards higher risk sources of contamination.

The scope of the investigation included completion of the following:

- Review of existing water and sediment quality sampling undertaken within the river and Waikouaiti estuary, including:
 - raw water quality data collected by DCC at its WTP,
 - compliance monitoring data collected by Oceana Gold (OG),
 - environmental monitoring undertaken by Otago Regional Council (ORC), and
 - Mahika Kai sampling undertaken by Te Rūnanga o Ngāi Tahu.
- Desktop review of aerial photographs, discharge consent information, Hazardous Activities and Industries List (HAIL) site registries, field noted collect by ORC during an aerial survey of the catchment.
- Targeted sampling of water and sediment within the vicinity of the WTP and in the wider Waikouaiti River catchment
- Once potential contaminant sources have been identified, completion of a qualitative assessment of the likelihood and consequence of contamination mobilising from each of the potential sources. From this process, preparation of a table of potential sources, with assigned qualitative risk (ranging from Very low to Very High).
- Preparation of this preliminary catchment investigation report

4 Catchment description

The Waikouaiti River comprises two main branches (the North and South branches). The North Branch headwaters start at approximately 32 km inland to the west of Karitane, and generally flow eastwards to its confluence with the South Branch, some 10.5 km upstream from the coast. From the confluence, the river flows out to the coast, where it discharges to the Waikouaiti Estuary. The South Branch extends from the confluence to the south-west approximately 18 km to its headwaters. The total catchment area of the River is approximately 42,000 ha.

The WTP intake is located 9 km upstream of the coast, and approximately 1.5 km downstream of the north/south branch confluence (see Figure 1).



Figure 1: Surface water extraction point along the Waikouaiti River with northern and southern branches of the river west of the extraction point.

4.1 Hydrology

Based on data available from the ORC website and the NIWA River Maps portal¹, river flows within the vicinity of the WTP intake are generally in the range of 1-5 m³/s, with a median flow of around 2- 3 m³/s. The North Branch has a median flow of around 2 m³/s, with much higher flows in the winter season than the summer/irrigation season. The South Branch has a median flow of about 0.8 m³/s and shows little seasonal difference. Both branches produce large floods at irregular intervals (as shown by the January 2021 flood depicted in Figure 2).

ORC data from the last 180 days shows a significant peak in flow within the Waikouaiti River in early January in excess of 550 m³/s, then sharply declining over several days. The flow peak coincides with a significant rainfall event around the same time and precedes the detection of lead in the raw water reservoir on 22 January 2021. The measured river flows and rainfall are shown on Figures 2 and 3 below.

¹ <https://shiny.niwa.co.nz/nzrivermaps> - New Zealand River Maps is an interactive web-based application for exploring national-scale predictions of a suite of river environmental variables, including water quality, hydrology, bed sediment size, invertebrate metrics, fish presence, bed sediment cover and water allocation.

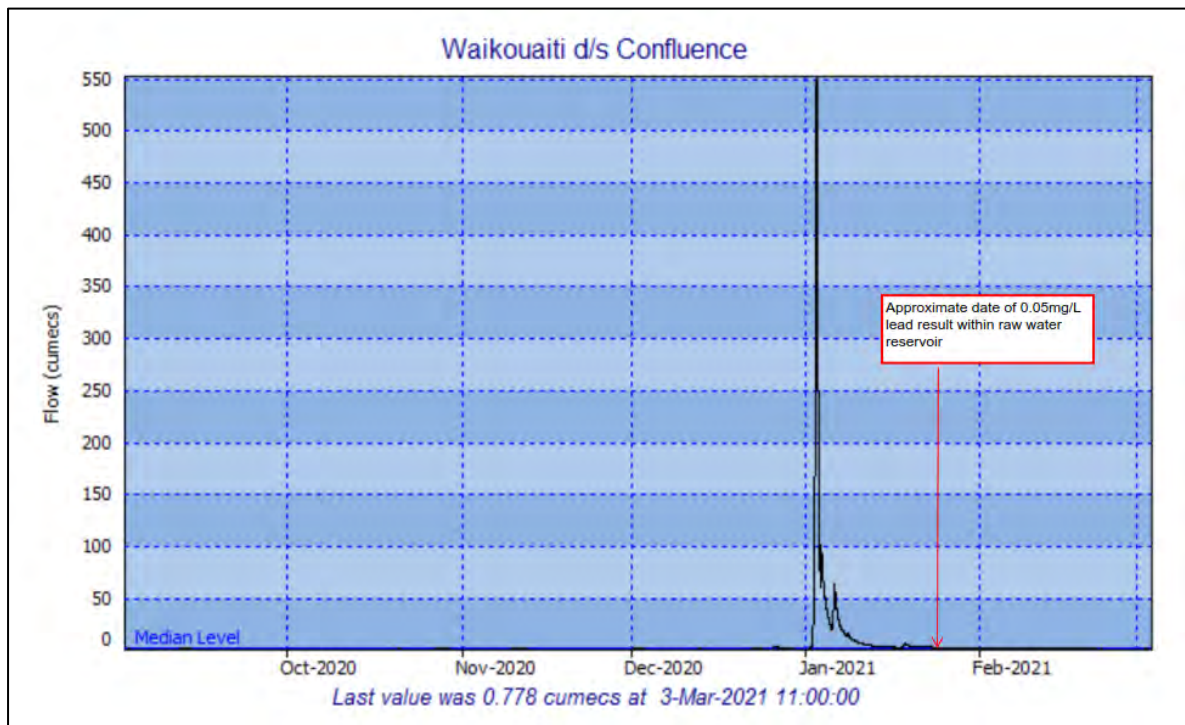


Figure 2: Measured flows within the Waikouaiti River, 200m downstream of the WTP intake (Source: ORC).

Last 180 days rainfall in mm/day

[Show Alerts in Graph](#)

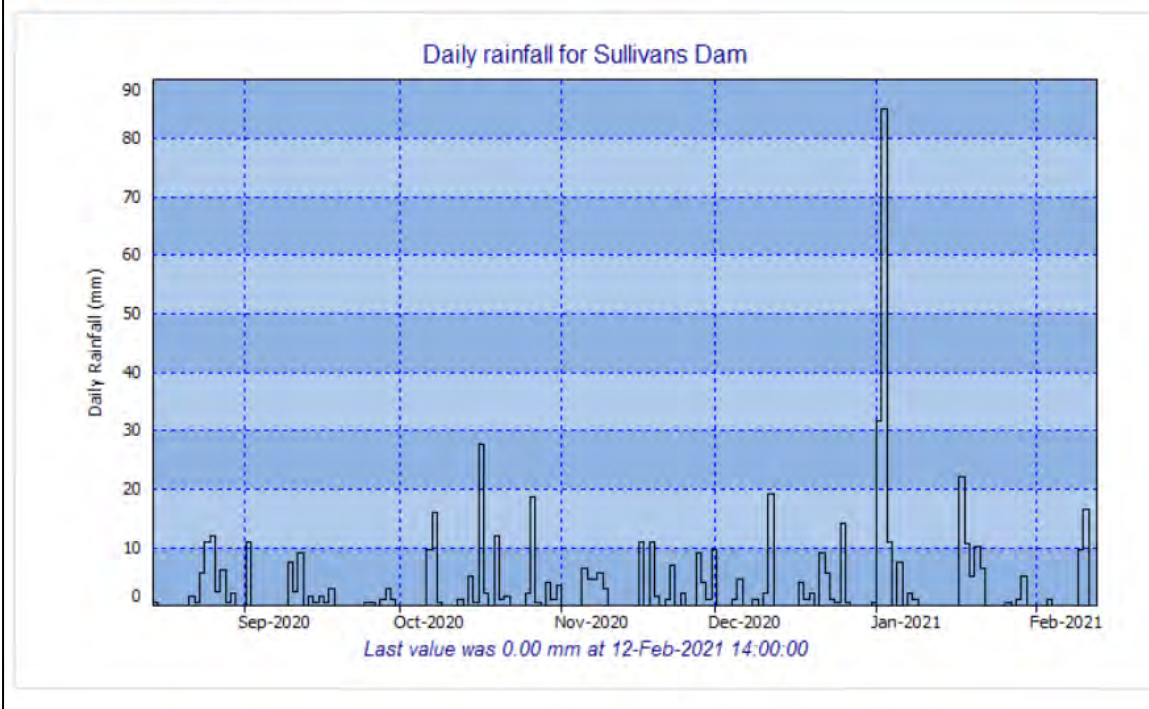


Figure 3: Measured rainfall at Sullivan's Dam (Source: ORC).

4.2 Geology

The Otago Schist basement rocks make up the geology of the Waikouaiti River (see Figure 4²). ORC report that there are limited groundwater systems aside from fractured schist rock drainage. Published background concentrations report a median and 95% quartile of lead concentrations within schist of 10.79 and 39.23 mg/kg respectively³.

ORC have advised that the sole contrast to that is the Hyde – Macrae’s Shear Zone found at Macrae’s Flat⁴ (see Figure 4), that contains sulfides characterised by a higher density of galena (a lead sulfide, PbS mineral). The sulfides have been disturbed by open cast and underground gold mining within the upper reaches of the north branch in recent geological history. The likelihood of acid mine drainage within the catchment is relatively low, on the basis of relatively high calcite in the schist, which neutralises acid from pyrite in schist-hosted gold deposits⁵. However, schist-hosted gold deposits can yield waters with very high arsenic and antimony.

Otherwise, the rest of the catchment is considered to essentially be fully stabilised with respect to geochemical reactions. Apart from the Macrae’s mine, land used within the catchment is generally low-intensity farming, with some areas of exotic and native forest.

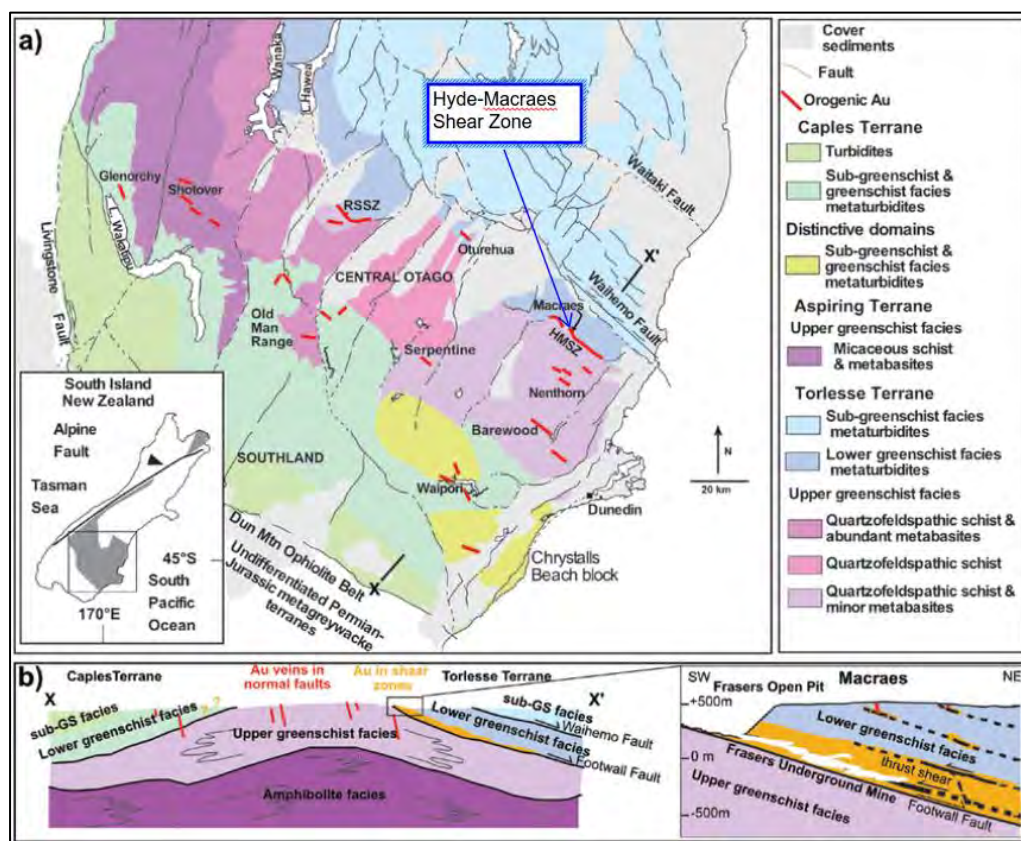


Figure 4: Summary of regional geology, showing the location of the Hyde-Macraes shear zone (Source: Mackenzie and Craw, 2017²).

² Doug Mackenzie & Dave Craw, February 2017. Geophysical signals and exploration for orogenic gold on the low-grade margins of the Otago Schist. Conference paper at Gold 17 conference, Rotorua, New Zealand.

³ Background soil concentrations of selected trace elements and organic contaminants in New Zealand; prepared by Landcare Research and GNS Science; November 2015; reference LC2440.

⁴ Pers. Comms., Jens Rekker, Senior Scientist – Catchment Modelling, Otago Regional Council; email received 4 February 2021.

⁵ Dave Craw & James Pope (2017) Time-series monitoring of water-rock interactions in mine wastes, Macraes gold mine, New Zealand, New Zealand Journal of Geology and Geophysics, 60:3 159-175.

5 Summary of available water and sediment quality information

5.1 Dunedin City Council water quality data

We have reviewed laboratory analysis of treatment and network water samples provided to T+T by DCC⁶. Pre-flush samples were collected by DCC from sample taps at a number of locations across the reticulated network, then a post-flush sample following a period of flushing. Using this method, the impact of plumbosolvency within the sampling tap and immediate network can be differentiated from contamination coming from further away in the network.

Acid soluble lead results for network sampling points are depicted in Figure 5. These indicate a peak in lead concentrations on 8 December 2020 at both Waikouaiti Golf Club and Karitane Bowls Club. Note that this lead spike is approximately an order of magnitude higher at Waikouaiti Golf Club than at Karitane Bowls Club.

We note that pre-flush concentrations at this time at both sampling points are lower than the post-flush concentrations. Lead concentrations at the Waikouaiti Golden Fleece Hotel (TAB) are all below the Maximum Acceptable Value (MAV) for total lead of 0.01 mg/L stipulated in the Drinking Water Standards for New Zealand⁷ (DWSNZ).

⁶ File 'Waikouaiti_RawData_110221_400days.csv' provided via email on 11 February 2021 by [REDACTED], Water Supply Process Scientist, DCC.

⁷ Ministry of Health. 2018. Drinking-water Standards for New Zealand 2005 (revised 2018). Wellington: Ministry of Health.

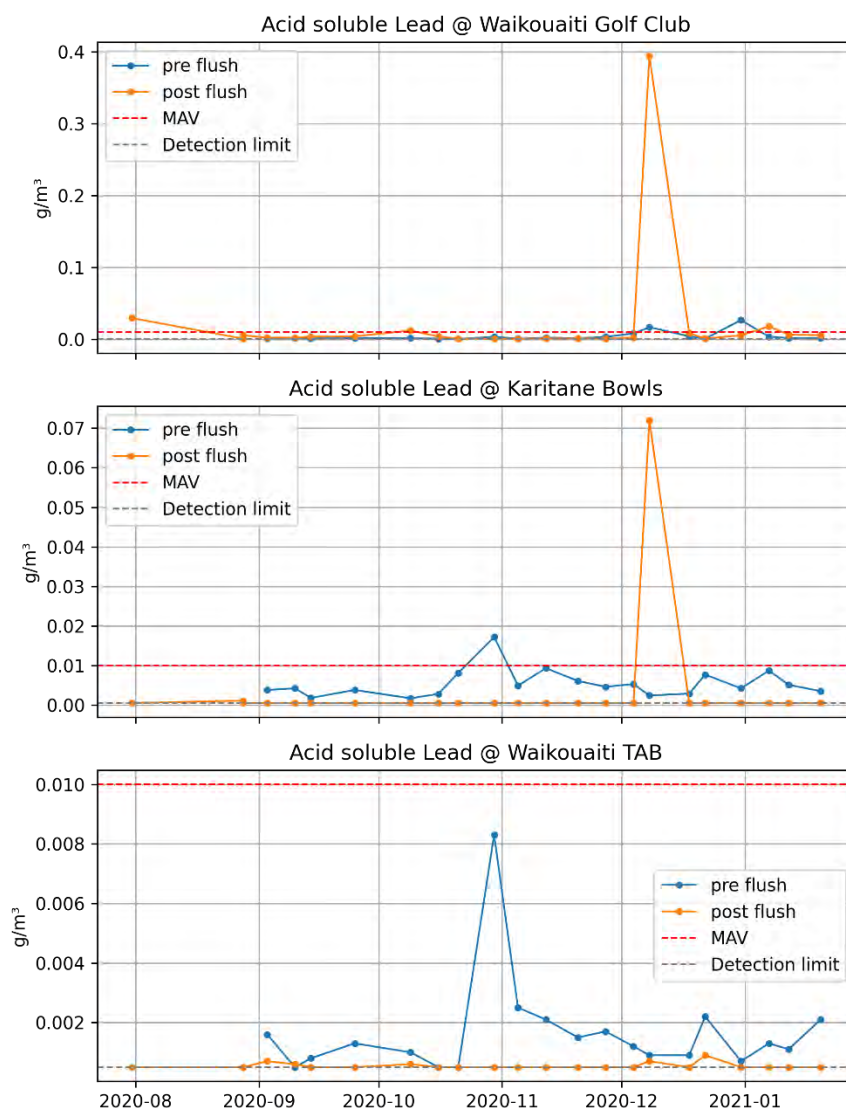


Figure 5: Acid soluble lead concentrations in network water samples. Note y-axis limits vary between sample locations.

Intermittent analysis for total lead has been undertaken from the raw water reservoir since July 2020. Results have generally shown lead levels below, or close to laboratory detection limits, except for a single spike of 0.05 mg/L (total) on 20 January 2021. The spike exceeded the DWSNZ MAV of 0.01 mg/L (Figure 6 below). Corresponding samples collected from the treated water reservoir analysed for acid soluble lead during the same time period has not shown any elevated lead post-treatment. This result indicates that the lead within raw water may have been removed by the WTP.

Anecdotally from DCC we understand that recent two-hourly sampling from raw water has shown a 0.034 mg/kg suspended solids concentration in acid-soluble lead⁸. However, we have not yet received formal test results and have not been able to determine the environmental conditions during which sampling occurred.

⁸ Multiple files 'TE21xxx_River water samples_xx0221.csv' provided via email on 4 March 2021 by John McAndrew, Plant Operations Manager (3 Waters), DCC.

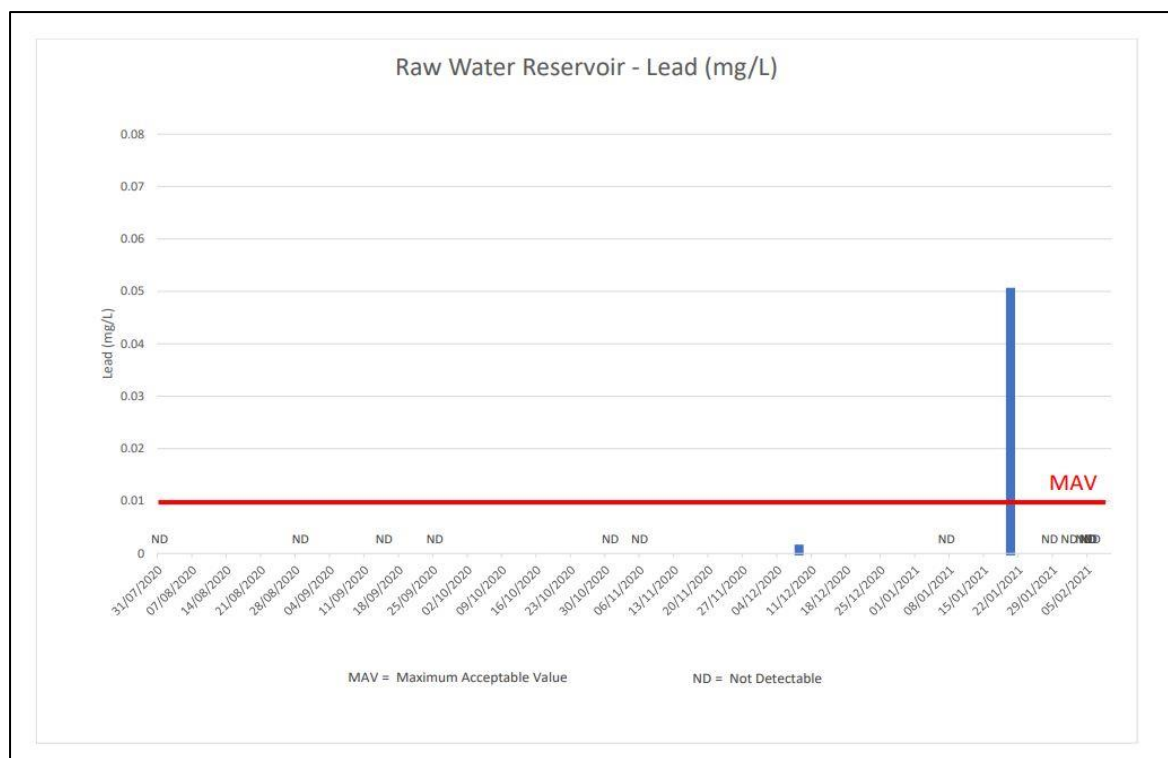


Figure 6: Summary of total lead in water collected from the raw water reservoir (source: DCC).

5.2 Dunedin City Council SCADA data

SCADA data from the Waikouaiti WTP provided to T+T by DCC⁹ has been included in Appendix B1. These figures show rolling daily mean, maximum and minimum values for each parameter. Also shown on these plots are the times of elevated lead samples collected at Waikouaiti Golf Club and Karitane Bowls Club. The lag time between the treatment of raw water and the sampling points has been estimated by DCC to be 40-100 hours¹⁰.

Comparisons between various pre- and post-treatment water quality parameters and the elevated lead events at Waikouaiti Golf Club and Karitane Bowls Club show no obvious relationship between raw/treated water quality and the lead events. However, the large rainfall/flood event in late January does appear to have resulted in an increase to raw/treated water colour and a decline in post-treatment electrical conductivity.

5.3 Oceana Gold water quality data

Oceana Gold (OG) run a significant mining operation of approximately 900 ha within the upper reaches of the Waikouaiti River. The site represents approximately 2% of the total Waikouaiti River catchment area. OG holds numerous consents to discharge stormwater and sediment from the site to local surface water features, including the Waikouaiti River and its tributaries (Refer Appendix A). Because of the size and scale of the operation, we expect that OG generally discharges a “baseflow” of water during normal conditions and significant volumes of stormwater to the Waikouaiti River during rainfall and flood events to manage site conditions. Temporal changes to discharge volume and quality to the Waikouaiti River are likely highly influenced by changes to the site operation and the site “water balance”.

⁹ File ‘Waikouaiti 5min Historical water data 01-01-20 through 04-02-21.xlsx’ provided via email on 4 February 2021 by John McAndrew, Plant Operations Manager (3 Waters), DCC.

¹⁰ Pers. Comms. [REDACTED], Water Supply Process Scientist, DCC.

OG undertakes a programme of surface water quality monitoring at various sites within the upper Waikouaiti River catchment as conditions of consent. Monitoring data undertaken by OG and kept on record by ORC has been provided to T+T by DCC¹¹. Sampling site locations have been included in Appendix A. The dataset of available sampling results generally spans at least 10 years (often >15 years) of quarterly or monthly data. Water quality data undertaken by OG has been plotted in Appendix B2.

Key water chemistry parameters, such as sulfate, hardness, alkalinity, calcium, magnesium and potassium within the OG dataset show a seasonal trend, with higher concentrations in summer, and lower concentrations in winter. This suggests that analyte concentrations are diluted during autumn/winter by rainfall and associated discharges into the Waikouaiti River. This was particularly pronounced in the summer of 2019, which showed a significant spike in concentrations of all inorganic parameters. The 2019 spike is also evident in the WTP raw water monitoring data for sulfate.

Dissolved lead has been tested by OG, and it has been infrequently collected (particularly prior to 2018). The data show dissolved lead is occasionally slightly elevated (complicated by intermittent analysis), up to 0.017 mg/L in February 2000 (NBWR Redbank Road). The average dissolved lead value is 0.003 mg/L, an order of magnitude below the DWSNZ MAV (which relates to total fraction rather than dissolved), but it is possible that total lead concentrations could have been higher in between sampling rounds.

pH in the OG samples is typically between 7.2 and 8 pH units, with the exception of a single extremely low pH of 3.5 detected in September 2019 at a single location. (NBWR Ross Ford). However, low pH was not recorded at the downstream location at the same time, so it is possible that the result is anomalous.

Because of the frequency of data collection from the OG monitoring sites, and an apparent lack of event-based monitoring data, it is difficult to determine the quality of discharges from the site at anything above a relatively coarse-scale, particularly during rainfall events (such as the January 2021 flood).

5.4 Waikouaiti Estuary – ORC monitoring

Otago Regional Council undertook a programme of environmental sampling and ecological assessment within the Waikouaiti Estuary in 2016/17¹², including one site within the Waikouaiti River, downstream of the WTP. The programme included sediment sampling at all sites and analysis for a range of contaminants, including heavy metals. The 2016/17 study was augmented by results from a similar (but limited) study completed in 2006¹³.

Sediment quality results depicted in Figure 10 show relatively low levels of lead within the estuary sediments (below published background³). These results indicate that there is unlikely to be long-term/ chronic discharge of elevated lead levels from the Waikouaiti River, but does not provide substantial evidence that short-term “pulses” of contamination are not occurring.

¹¹ File ‘*Oceana Gold WQ Sites - data corrected.xlsx*’ provided via email on 8 March 2021 by [REDACTED], Water Supply Process Scientist, DCC.

¹² Robertson, B.M., Robertson, B.P., and Stevens, L.M. 2017. Waikouaiti Estuary: Fine Scale Monitoring 2016/17. Report prepared by Wriggle Coastal Management for Otago Regional Council.

¹³ Stewart B. 2007. Mapping of the Waikouaiti and Shag River Estuaries: Otago Regional Council State of the Environment Report. Prepared for the ORC by Ryder Consulting Ltd. pp. 55.



Figure 9: Location of sampling sites within the Waikouaiti River and Estuary. Sediment samples were collected at the Yellow sites and the 2016 sites (Robertson et al., 2017, Fig. 1).

Year Site	RPD cm	Salinity ppt	TOC	Mud %	Sand %	Gravel %	Cd	Cr	Cu	Ni	Pb	Zn mg/kg	As	Hg	TN	TP
2016 A	3	34	0.50	11.9	74.6	13.5	0.0257	6.4	5.0	6.9	4.4	26.7	7.9	0.0125	700	487
2016 B	5	28	0.20	8.0	79.0	13.0	<0.010	3.9	3.4	4.5	2.8	18.0	4.0	<0.010	<500	683
2016 C	0	25	0.41	30.9	68.9	0.3	0.0487	5.3	3.3	3.9	3.5	22.0	4.1	0.011	633	463
2006 D/S	3	NA	NA	10.7	75.5	13.7	0.02	6.4	4.6	6.0	4.21	26.3	6.2	NA	700	466
2006 U/S	5	NA	NA	8.7	73.4	17.9	0.01	5.1	4.8	5.9	4.28	26.3	6.7	NA	600	417

Figure 10: Sediment quality results from Robertson et al., 2017 (lead values highlighted).

5.5 WTP sediment – ORC sampling

Otago Regional Council collected two sediment samples¹⁴ from the Waikouaiti river, located within the immediate proximity of the WTP intake. Analysis showed lead levels at 4.9 and 5.3 mg/kg, which is below the median published background level for lead in Otago schist.

¹⁴ Eurofins ELS Ltd, 15 February 2021. Analytical Report 21/5953. Client: Ryder Environmental Ltd.

5.6 Mahika Kai sampling

Aquatic organisms take up heavy metals from surrounding environments which accumulate in their body tissues. This is particularly true for suspension-feeding organisms such as bivalves (e.g., freshwater mussels, pipi and tuatua). Because of this, aquatic organisms often provide an indicator of long-term sediment and water quality within a catchment.

Te Rūnanga o Ngāi Tahu iwi group undertake a programme of sampling and analysis of key customary food sources (Mahika Kai) along with cultural and ecological monitoring sites along the lower portion of the Waikouaiti River and Estuary (sites shown on Figure 11 below). Following the lead exceedance event, Te Rūnanga o Ngāi Tahu iwi group have undertaken sampling and analysis of key Mahika Kai, including eel, flounder, trout, pipi and cockle to check for bioaccumulation of lead at a subset of the long-term monitoring sites¹⁵.



Figure 11: Routine Mahika Kai sampling sites visited during the Te Rūnanga o Ngāi Tahu iwi group programme. Note – not all sites were sampled during the February 2021 sampling event.

The results show lead levels within the flesh of eels and trout found within the river and Waikouaiti Estuary up to 0.033 mg/kg (wet weight), which is consistent with other published results from similar

¹⁵ Need data reference

studies elsewhere in New Zealand¹⁶ and well below the NZ Food Standards¹⁷ of 0.5 mg/kg (wet weight) for fish. Lead levels found within gut contents of eel and liver of trout collected from the Waikouaiti River show relatively high concentrations compared to flesh samples collected from the same organism (up to 0.52 mg/kg found in a gut-sample collected from an eel). However, a relevant published comparison could not be identified to determine the significance of this result.

Lead levels found within cockle, pipi and mussels collected from the Waikouaiti Estuary appear to be higher than published concentrations for cockles by 1-2 orders of magnitude. However, the reported values are still below the NZ food standard maximum level of 2 mg/kg (wet weight) for molluscs.

Table 1: Summary of February 2021 Mahika Kai sampling results for lead.

Bioata	Site	Flesh (mg/kg - wet weight)	Liver (mg/kg - wet weight)	Gut contents (mg/kg - wet weight)	Published ranges in flesh (mg/kg - wet weight)	Maximum level FSANZ (mg/kg - wet weight)
Trout	Rookery	<0.010	<0.010	-	Not detected	0.5 (Fish)
	Orbells	0.017	0.34	-		
	Confluence	<0.010	<0.010	-		
Eel	Eldorado	0.033	-	-	Mean 0.014 Max 0.048	
	Rookery	<0.010	-	0.52		
	Orbells	<0.010	-	-		
	Confluence	<0.010	-	0.031		
	North Branch	<0.010	-	-		
Flounder	Rookery	0.013	-	-	N/A	
	Orbells	<0.010	-	-		
Cockles	Ohinepouwera	0.045	-	-	Mean 0.006 ¹ Max 0.007	2 (Molluscs)
Pipi	Ohinepouwera	0.106	-	-		
Green Lipped Mussel	Wharf Pillar	0.12	-	-		
	Wharf Pillar	0.136	-	-		

Note 1: Published range for cockle assumed to be also indicative of expected pipi and mussel ranges also.

These results generally indicate that there may be some minor bioaccumulation of lead within the tissue of biota within estuary, particularly within bivalves such as mussel, pipi and cockles. However, these results could also be attributed to differences in background sediment-lead concentrations between the published reference and the Waikouaiti catchment. As such, the results are considered to be inconclusive, without further specialist input to bioaccumulation processes and a more comprehensive baseline comparison.

The Mahika Kai sampling does not provide any indication of whether significant “pulses” of lead contamination may be occurring within the river.

¹⁶ J. Cavanagh and N. Ward (Landcare Research), March 2014. Contaminants in estuarine and riverine sediments and biota in Southland. Prepared for Environment Southland, Invercargill, New Zealand.

¹⁷ Food Standards Australia New Zealand, April 2017. Australia New Zealand Food Standards Code – Schedule 19 – Maximum levels of contaminants and natural toxicants. Accessed at <https://www.legislation.gov.au/Details/F2017C00333>.

5.7 February 2021 Sediment and Surface Water Sampling

Field sampling within the Waikouaiti River catchment was undertaken by T+T on 16 and 17 February 2021. The sampling plan (prepared prior to the fieldwork) is provided in Appendix D and described the methods and analysis undertaken. Sampling was completed at the following sampling sites:

- 14 sites along the Waikouaiti river and its tributaries, where samples of sediment and surface water were collected.
- 1 sample of water/sediment at the discharge point for the WTP filter back wash
- 2 soil samples collected from the former slash fire are, to the west of the WTP.
- Sediment/sludge and water samples collected from each of the 5 filter backwash and raw water reservoir drain settling ponds within the WTP site.
- 1 sludge sample collected from the raw water reservoir.

At each site, field parameters of pH, electrical conductivity, ORP and DO were collected from surface water.

Water quality samples were analysed for a range of inorganic parameters, including heavy metals and standard water chemistry parameters (refer Appendix D1 for tabulated field data). Sediment and soil samples were analysed for a suite of heavy metals, and sulfate.

5.7.1 Field Parameter Results

Field readings of water quality parameters collected during sampling show a general declining trend in electrical conductivity from the upper reaches down to the Eldorado Station, approximately 20 km upstream of the WTP intake. From the Eldorado station to the WTP intake, electrical conductivity (EC) is generally stable at approximately 200 $\mu\text{S}/\text{cm}$. This trend is consistent with the results from analysis of inorganic parameters presented in the next section. pH, redox potential and dissolved oxygen all appear to be relatively consistent across all of the sites sampled (refer Appendix D1 for tabulated field data).

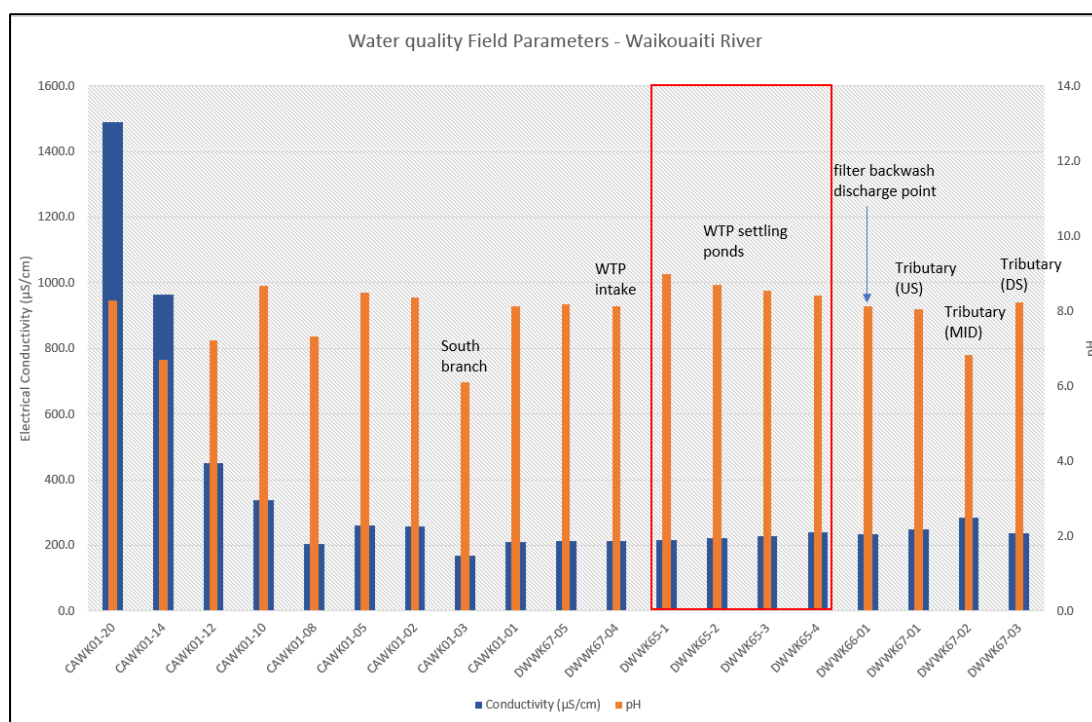


Figure 12: Summary of key field parameters.

5.7.2 Laboratory results

Lead

Total and dissolved lead within water samples collected at all sites were generally at, or below laboratory detection limits. Lead in sediments, sludge and soil at all sites range from 2.63 - 17.3 mg/kg (refer Figure 13 below), which is within published background concentrations for Otago Schist³.

Although the sediment-lead results are all with background levels, results from areas associated with the WTP and the slash-fire area generally appear to be higher than those from the river sediments. However, this could be associated with a qualitative difference in particle size between these two areas: a visual inspection indicated that river sediments generally appear coarser than sediments at the WTP and slash-fire area). A slightly decreasing trend in sediment-lead is observable from the upper river to the lower river.

These results indicate that chronic discharges of elevated lead are unlikely to be occurring within the catchment. However, slightly higher lead associated with the WTP could be attributed to an accumulation of short-term “pulses” of lead being captured within raw water and treatment infrastructure, or to the difference in particle size distributions in the different sediment samples.

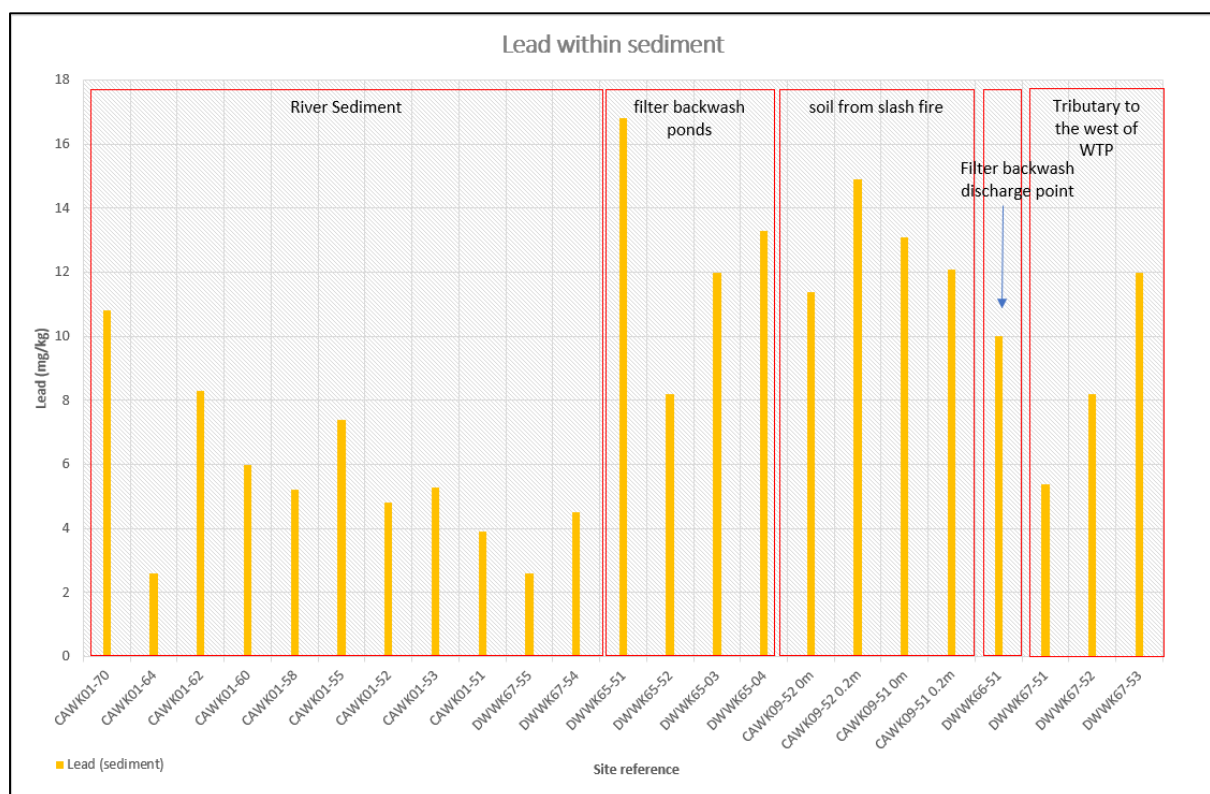


Figure 13: Summary of sediment-lead and soil-lead results for the Waikouaiti River, WTP site and slash fire area.

Water chemistry

Inorganic parameters appear to generally decline from upstream to downstream (refer Figure 14 below). This suggests that inputs of elevated inorganics near the headwaters of the river are being gradually diluted by compounding inputs to the river moving downstream. Given the sample locations, the most likely explanation is discharges from the OG site, either direct, or as groundwater baseflow to the river. Results from the small tributary to the west of the WTP show elevated turbidity, which could be resulting from recent DCC activities (raw water reservoir drainage), or upstream activities.

pH within the river appears to be relatively spatially consistent, and is above neutral.

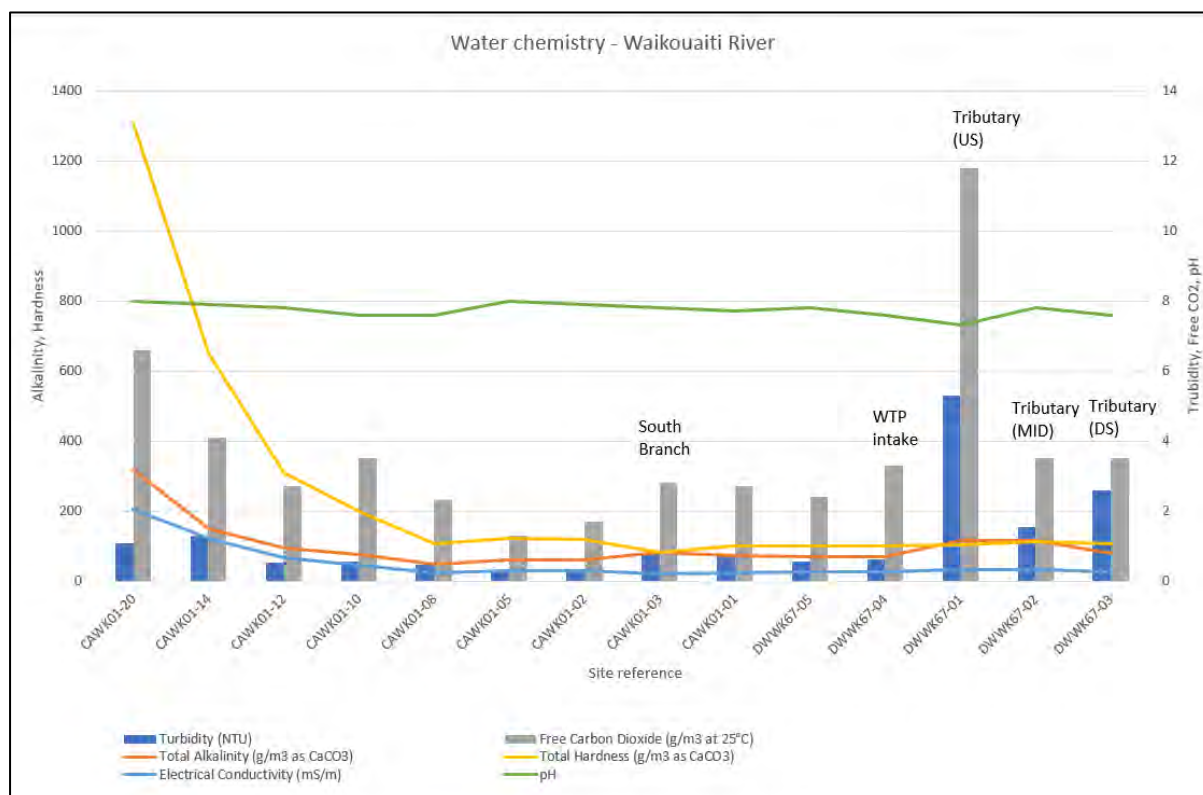


Figure 14: Summary of inorganic water chemistry.

The water quality results also show a declining spatial trend in sulfate, both within river water and sediment. Relatively low water-sulfate, but relatedly high sediment-sulfate concentrations are shown in the WTP settling ponds and the tributary (Figure 15).

Sulfate present within the upper reaches of the river is predominantly present in the dissolved phase, as opposed to the WTP settling ponds and at the filter backwash discharge point, where sulfate is predominantly found in the sediment, rather than in the water. Similar to the slight observed elevations in lead within the WTP sediment, it is possible that sulfate is being accumulated in the sediments of the settling ponds, raw water reservoir and at the WTP filter backwash discharge from “pulses” of sediment coming down the river.

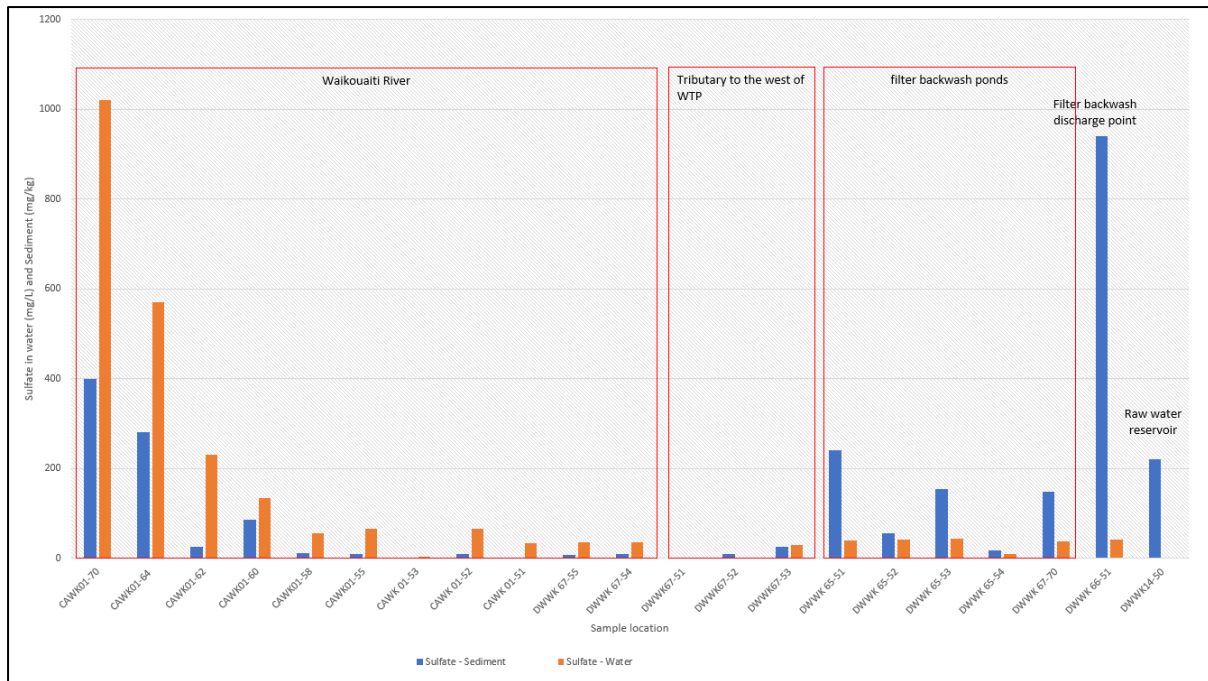


Figure 15: Summary of water-sulfate and sediment-sulfate results.

Many factors contribute to corrosivity, including elevated concentrations of chloride, pH out of neutral range, elevated concentrations of dissolved and suspended solids, and lower alkalinity. The potential for water to be corrosive is measured by three different indexes: the Langelier Saturation Index (LSI), the Potential to Promote Galvanic Corrosion (PPGC), and the Larson Ratio (LR).

- The **LSI** is a measure of the balance between pH and calcium carbonate (CaCO_3)—as the LSI value becomes more negative, the water is increasingly under-saturated with CaCO_3 and therefore has a greater corrosion potential.
- The **PPGC** is based on the ratio of chloride to sulfate (CSMR); the higher the PPGC, the greater the potential for galvanic corrosion of lead in the plumbing system.
- The **LR** is defined as defined as the sum of equivalents of chloride and sulfate divided by equivalents of bicarbonate. The LR indicates the corrosivity of water to iron and steel.

Consequently, The LSI and the PPGC were calculated to provide an indication of the potential for spatial changes in source water corrosivity.

Samples were classified as 'potentially corrosive' if the LSI was less than -0.5 , 'indeterminate' if the average LSI was greater than or equal to -0.5 and less than or equal to 0.5 , and 'scale forming' if the average LSI was greater than 0.5 .

A three-tier classification system was adopted for the PPGC (low, moderate and high corrosion potential) PPGC:

- If $\text{CSMR} < 0.2$, then PPGC is low;
- If $0.2 \leq \text{CSMR} \leq 0.5$, then PPGC is moderate;
- If $\text{CSMR} > 0.5$ and alkalinity ≥ 50 , then PPGC is moderate; and
- If $\text{CSMR} > 0.5$ and alkalinity < 50 , then PPGC is high.

This method has been used in similar studies completed by the USGS¹⁸.

The results depicted in Figure 16 generally show low corrosivity/scale-forming waters within the upper reaches of the river, transitioning to slightly indeterminate/low PPGC nearer to the WTP intake. Water sampled from the small tributary to the west of the WTP and from the WTP settling ponds shows moderate PPGC, but is limited by relatively high alkalinity (of around 100 mg/L as CaCO₃).

These results show that although there appears to be a spatial trend of increasing corrosivity downstream, source water corrosivity at the WTP intake is still relatively low. However, these results must be interpreted as a single moment in time. Significant discharges within the catchment, or treatment processes may cause temporal changes to raw or treated water corrosivity.

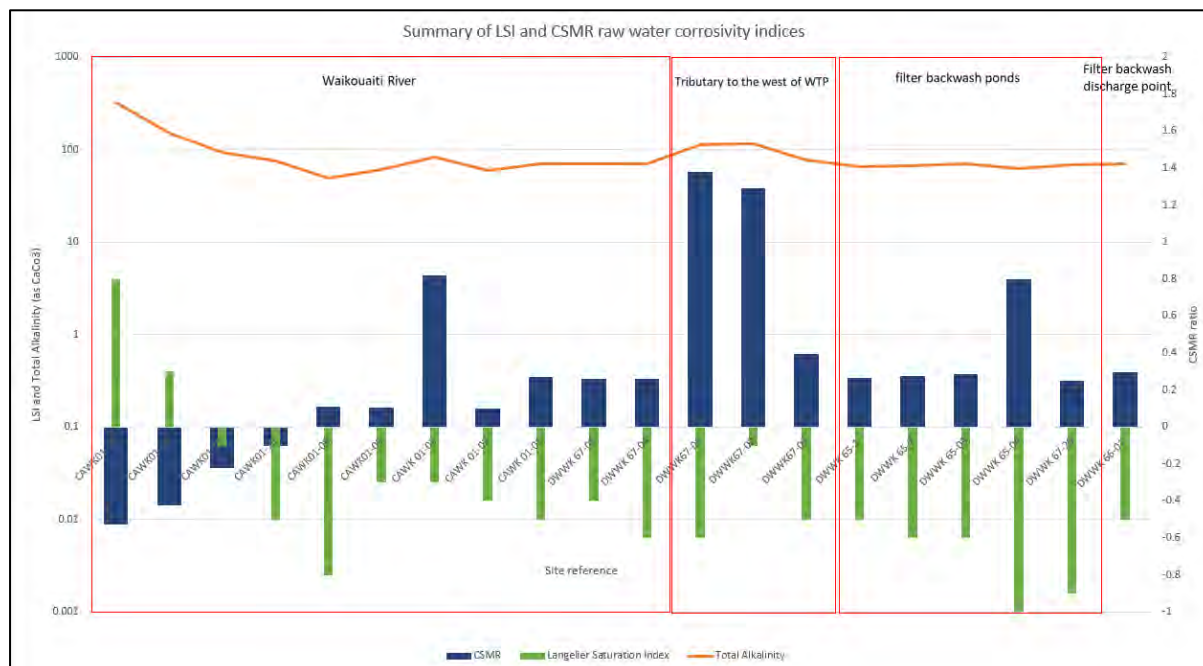


Figure 16: Summary of Langelier Saturation Index (LSI) and the ratio of chloride to sulfate (CSMR) results.

5.8 Surface water mass balance calculations

T+T was engaged to undertake surface water mass balance calculations based on existing information. This modelling is described in the letter report attached in Appendix E.

The simple mass balance conducted shows that – based on the very limited data that we have – there is no evidence to indicate that under worst case calculations, discharges from Oceana Gold could lead to concentrations of lead at the water intake that have been experienced. However, the very small data set is only representative of a small fraction of the overall long term picture and does not account for more complex catchment and chemical processes.

5.9 Summary and conclusions from available data

The historic, and recent data can be summarised as follows:

¹⁸ US Geological Survey; *Potential Corrosivity of Untreated Groundwater in the United States*; Scientific Investigations Report 2016-5092

- Elevated lead concentrations above the MAV were reported in the distribution network (Waikouaiti Golf Club and Karitane Bowls Club) on 8 December 2020. The cause of these elevated concentrations is still unexplained.
- A single exceedance of the MAV for lead occurred in the raw water reservoir in late January 2021. The exceedance followed a significant rainfall event and flooding conditions in the river, which occurred earlier in January. A very recent spike in raw-water lead has not yet been investigated.
- Monitoring for lead completed by OG in the upper river catchment shows some isolated events where dissolved lead has been elevated. However, the data is relatively low-frequency, so may not have highlighted short-term events, particularly those associated with climatic events.
- Lead within sediments of the river, within the WTP settling ponds and at the former slash fire is within expected background concentrations. Some minor spatial trends may be present which may be explained by:
 - an accumulation of lead within sediments of the raw water reservoir and WTP settling ponds, possibly from “pulses” of sediment entering the supply from the river.
 - Differences in particle grain sizes between the river sediments and finer sediments found in the raw water reservoir, settling ponds and slash-fire soil.
- Concentrations of lead within Mahika Kai may be slightly elevated for some biota, but without a more comprehensive baseline comparison and specialist advice relating to bioaccumulation, the results are currently inconclusive. All sampling results were below Food Safety Australia New Zealand maximum wet weight values for fish and molluscs.
- Inorganic parameters decline from the upper to lower river, indicating spatial changes to water chemistry. This is complicated by long-term seasonal trends in water chemistry that are observable in the upper catchment from the OG data. Water chemistry at the WTP intake is likely being influenced by discharges within the upper catchment.
- Although there appears to be a spatial trend of increasing corrosivity downstream, source water corrosivity at the WTP intake is still relatively low. However, given the influence that the upper catchment has on water quality at the WTP intake, the possibility of short-term changes to corrosivity could not be excluded.

Broadly, we conclude the following:

- Results indicate that there is unlikely to be a significant chronic discharge of lead within the Waikouaiti River catchment. However, the potential for short-term pulses of lead could not be ruled-out. The recent spike of lead observed in raw water needs further assessment, but suggests that raw water impacts from lead may not be limited to “extreme” weather events such as the January 2021 flood event.
- Sediment-lead concentrations found in the river, WTP ponds and the raw water reservoir are within published background levels.
- Based on available data, this leaves the following potential causes for the event:
 - A significant pulse of dissolved lead entering the supply – possibly associated in some way to the early January 2021 flood event.
 - A significant pulse of sediment entering the supply (or a combination of both particulate/dissolved lead) - possibly associated in some way to the early January 2021 flood event.
 - Laboratory or sampling error relating to the 20 January 2021 sample, although the more recent second spike in lead reduces the likelihood of this explanation.

6 Potential Sources of Contamination

Following a review of available data, we have concluded that the most-likely scenario is that a short-term pulse of lead contamination caused the January 2021 MAV exceedance in raw water, likely associated with a flood event earlier in the month. A preliminary desktop review of potential sources of contamination has been undertaken to identify and qualitatively assess the risk posed by individual activities identified within the catchment. This assessment has focused on identifying potential sources of lead, or factors that may have influenced raw water corrosivity to have caused the elevated lead events reported in raw water, or the reticulated network.

Given that dilution is expected to occur during transport between the source of contamination and the WTP intake, a relatively large source (volume or concentration) of contamination would be required to cause the observed impacts to raw water. The further upstream the contamination source is located from the WTP intake, the greater the contaminant load would be required to increase concentrations in the river downstream of the confluence of North and South branches of the river.

For this reason, the CRA has focused on identifying either a very large source, or a very close source to the WTP intake. Relatively small potential sources of contamination (such as dwellings and implement sheds located <50 m from waterways) have been omitted.

6.1 Aerial photograph review

A review of aerial photography flown in 2018/2019 indicates that land use within the catchment is predominantly rural/pastoral, with some areas of native and exotic forestry. The review identified that relatively large areas of farmland sometimes appear to have been “worked” (presumably for re-seeding or planting feed crops).

The review identified the Eldorado farm stockyards and shearing shed, located directly adjacent to the stream channel at a bend in the North Branch, some 20 km upstream of the WTP intake.

Notes taken during by ORC during an aerial inspection of the catchment using a helicopter on 3 February 2021 indicate that a fly dump is located >25 km upstream of the WTP intake on a cliff above a tributary of the North Branch (see photo below and location on Photograph 1 below). Given the size and location of the fly dump above the tributary, it is likely that wastes are able to mobilise to surface water, and subsequently into the Waikouaiti River, particularly during significant rainfall or flooding events.

The aerial inspection also describes recent forestry harvesting, spraying and “blue containers” located near the river at the Bucklands Crossing, located approximately 4.5 km upstream of the WTP intake. An Otago Daily Times article from November 2019 also reports a 10 ha forest fire at Bucklands crossing¹⁹.

Anecdotal accounts from DCC staff also describe a fire during early 2020. Forestry slash located on the hillside above a small tributary that enters the Waikouaiti River about 125 m upstream of the intake. Residual ash from the fire may have elevated lead concentrations. See Figure 17 in Section 6.4 below for approximate extent.

¹⁹ Otago Daily Times, 9 November 2019. “Crews continue to battle Bucklands Crossing Blaze”, accessed at <https://www.odt.co.nz/star-news/star-national/crews-continue-battle-buckland-crossing-blaze>.



Photograph 1: aerial view of the fly dump. Photo taken by ORC on 3 February 2021.

6.2 Discharge consents

Current discharge consents issued by ORC within the catchment were collated and available information from the ORC online portal was reviewed (generally only brief notes were available). The review identified that there are very few consented discharges to the Waikouaiti River and associated tributaries, except for discharges from the OG site and consented discharges from the WTP associated with filter backwashing.

As described earlier in Section 5.3, the OG site is located within the upper reaches of the Waikouaiti River (North Branch) and holds numerous resource consents that allow for the discharge of water, silt and sediment to water associated with its mining operation. Of these, nineteen are located within the Waikouaiti River's headwaters, including consents that allow for direct discharges of significant volumes of water to the Waikouaiti River and its tributaries. Given the size and scale of the mining operation and observable ponds/lakes at the site, there is the potential for the discharge of significant volumes of contaminated water to the Waikouaiti River.

The WTP filter backwash discharge consent allows DCC to discharge up to 30 L/s of settled filter backwash to the Waikouaiti, up to a maximum of 120 m³/day. Filter backwash is settled in three ponds located adjacent to the WTP. From the ponds, settled backwash is discharged to the top of a small gully, located north-west of the WTP. A small stream at the base of the gully discharges to the

Waikouaiti River, approximately 125 m upstream of the WTP intake. The total flow path between the discharge and the WTP intake is approximately 420 m, some of which is over dry land (between the discharge point and the stream below). Depending on contaminant loadings, volume and duration of the discharge, this may pose a risk to the raw water supply.

In addition to the WTP filter backwash discharge, the WTP also has a discharge/run to waste for draining the raw water reservoirs. This water discharges into a natural swale immediately to the west of the WTP, which flows to a small pond, then on to the north-west where it eventually discharge at the same location as the filter backwash. During significant discharge events, local soil/sediment may be entrained by the discharge and carried into the Waikouaiti River upstream of the WTP intake. Depending on contaminant loadings within the sediments, this may pose a risk to the raw water supply.

6.3 Contaminated sites

The ORC HAIL database was reviewed to identify known potentially contaminated sites in the catchment. Three sites were identified within the catchment upstream of the WTP intake:

- Cherry Farm closed landfill, indicated to be located directly adjacent to the WTP (on its eastern boundary).
- Macrae's mine (OG), located within the Waikouaiti River North Branch headwaters.
- Macrae's mine (OG) – Golden Bar pit, located within the Waikouaiti River North Branch headwaters.

6.3.1 Cherry Farm Closed Landfill

According to the HAIL entry for the Cherry Farm Closed Landfill:

"the Site stopped receiving waste 20 - 50 years ago - replaced by system at Olbell Bridge (Area 1836). Unknown wastes were disposed at landfill (possibly hospital waste although there was an incinerator). Controls inadequate - capped with local substrate."

ORC have completed a review of available reporting for the Cherry Farm former landfill site, including a review of historical aerial imagery (review provided in Appendix B). The review concluded that the landfill is likely to be located immediately to the east of the WTP (as shown in Figure 17 below). However, the exact location, extent and contents of the landfill are still highly uncertain. Historical correspondence between Otago Regional Hospital and Waikouaiti County Council indicates that the landfill received waste from the Otago Hospital (likely waste water treatment plant sludge).

Not mentioned in the ORC summary is a reference to the presence of offal pits within a 2011 geotechnical report²⁰. The report states:

A number of offal pits are located within the Water treatment plant and these were used to dump waste cooking from the hospital and later animal carcasses. These are located to the north of the building on the DCC land."

If used to dispose organic material only, the offal pits likely pose a relatively low risk of contamination to the Waikouaiti River. However, in practice offal pits are often used to dispose a wide range of waste materials.

Depending on the size, and contents the landfill site itself may be a contamination source, through leaching to the Waikouaiti River near the WTP intake.

²⁰ TL Survey Services; 4th October 2011; Request for further information: 42 Mountain Track Road, Merton, Otago.SUB 2011-108 & LUC2011-367; reference 09070

6.3.2 Macrae's Mine (OG) site

The OG site, and associated potential for contamination is described in Sections 5.3 and 6.2.

6.4 Summary of potential contaminant sources

A number of potential contaminant sources have been identified relatively close to the WTP intake that may have the capacity to deliver elevated lead to the Waikouaiti River, including the following:

- Ash deposited by the 2020 slash fire,
- Groundwater contamination from the Cherry Farm landfill (including offal pits) reaching the river,
- Filter backwash and raw water reservoir discharges from the WTP,
- Waste and vehicles located adjacent to the small tributary entering the Waikouaiti immediately upstream of the WTP intake.

Beyond the immediate vicinity of the WTP intake, the following potential contamination sources were identified:

- Unknown "blue containers" located next to the river at Bucklands Crossing,
- Ash associated with the 2019 forest fire at Bucklands Crossing,
- Pesticide or other chemical storage The Eldorado Farm stockyards and shearing sheds,
- General soil disturbance during farming (reseeding/cropping) and forestry harvesting widespread across the catchment,
- A relatively large fly dump located on a tributary near Eldorado Farm (location and contents to be confirmed),
- Macrae's mine various discharges from overburden and tailings pile drainage/dams that enter the upper reaches of the North Branch,
- Recreational activities (such as shooting using lead shot) within or adjacent to the river that may deposit lead into the waterway.

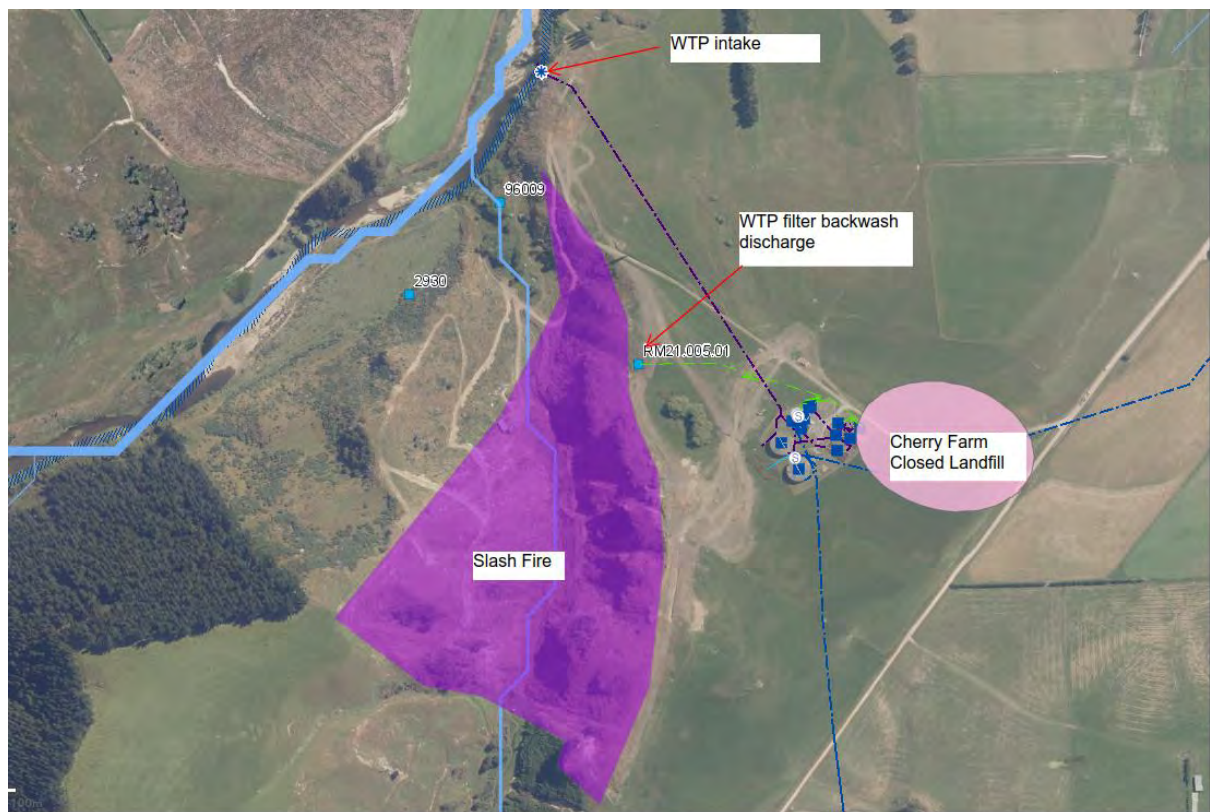


Figure 17: Summary of potential contaminant sources within the vicinity of the WTP

7 Qualitative assessment of potential contaminant sources

The table overleaf provides a description of each potential contamination source, along with a qualitative assessment of risk in terms of potential to have caused elevated lead within the supply.

Qualitative assessment of contaminant source risk

A Potential contaminant source	B Location in the catchment and description of the source	C Potential contaminants	D Contaminant pathway	E Consequence of the hazardous event	Likelihood of hazardous event occurring	G Maximum (unmitigated) risk	H Uncertainty	I Comments
Macrae's Mine (Oceana Gold) – various discharges to the Waikouaiti River and tributaries	The mine straddles the northern branch catchment boundary, more than 50 km upstream of the WTP intake. The mine site covers an area of approximately 900 ha, within a total upgradient catchment above the WTP intake of approximately 37,000 ha (approximately 2.5% of this catchment).	Heavy metals, particularly arsenic and antimony (these readily dissolve at neutral pH). Lead concentrations in Otago Schist is generally <20 ppm. However, Macrae's shear zone likely has elevated lead sulfide (PbS) mineral in the rock, which may be a higher concentration source of lead or sulfate. Capacity to cause large changes in water chemistry/raw water corrosivity. Impacts to pH (acid mine drainage) and alkalinity due to rock weathering less likely in schist due to calcite.	Mobilisation of particulate or dissolved lead within direct discharges to the river, or sediment discharges, then mobilising down-river to the WTP intake. If a significant failure of a tailings dam occurred, a "pulse" of metal-laden sediment and water could discharge down the river	Major	Rare	Medium	Estimate. Monthly compliance data shows some historical events where dissolved lead has been elevated. Monitoring and investigation data also show likely impacts from the site on water chemistry that reach the WTP intake (e.g., sulfate)	The site holds significant volumes of potentially contaminated material (water and tailings), so is assessed as having the potential to cause pulses of contamination. Preliminary fate and transport modelling may provide further insight into the potential impact of discharges from the site on raw water quality.
Fly Dump - Appears to be domestic and farm refuse, although contents largely unknown	Located on a tributary near Eldorado (approximately 20 km upstream of the WTP intake). Description of the dump contents is limited, so some uncertainty about the content of the site	Various possible contaminants, depending on the contents. Possible low-volume source of heavy metals, including lead	Mobilising of leachate or contaminated sediment down-slope and into the tributary, then into the main river, then transport in the river (either dissolved or adsorbed to sediment) to the WTP intake. Likely relatively high dilution pathway	Moderate	Unlikely	Medium	Uncertain - conservative assessment assuming a relatively large volume of contaminated material	Further visual inspection should be undertaken to confirm the contents of the site.
Eldorado Farm Stockyards and shearing shed	Located directly adjacent to the river on the North branch, approximately 20 km upstream of the WTP intake	Relatively low volumes of agrichemicals (<1,000 L) that may contain lead, such as pesticides. Storage of relatively low volumes of fertiliser (no significant outdoor storage visible)	Direct discharge to the river via overland flow, or leaching to ground, then subsurface flow to the river, then transport down-river to the WTP intake	Insignificant	Unlikely	Very Low	Uncertain. Assessment based on typical stockyards/shearing shed operations. No verification undertaken	
Agriculture - Fertiliser application	Most of the land use in catchments of both branches is predominantly low-density pastoral, from directly adjacent to the WTP intake, up to the upper river reaches	Nitrogen, ammonia (urea), phosphorus and relatively low levels of heavy metals (lead). Some accumulation may occur from repeated applications, but application rates expected to be relatively low and infrequent due to non-intensive land use.	Pastoral runoff during rainfall and transport downstream to the intake	Minor	Unlikely	Low	Estimate.	

Agriculture - Pesticide application		Heavy metals within pesticide products, but likely at relatively low application rates	Pastoral runoff and transport downstream to the intake	Minor	Unlikely	Low	Estimate.	
Agriculture - Soil disturbance (mobilising soil)		Heavy metals, but at background soil concentrations (which is relatively low for lead)	Soil erosion and generation of river sediment, then transport downstream in the river to the WTP intake	Minor	Unlikely	Low	Estimate.	
Forestry - pesticide application	The closest forestry block is a small plot, located approximately 600 m upstream of the WTP intake. Otherwise, forestry on the North branch is relatively small and isolated plots, largely located in the lower catchment, within 5-10 km of the WTP intake	Heavy metals(including lead) in pesticides.	Direct runoff, or adsorption to sediment, then mobilisation to the river. Contaminant concentrations likely constrained by relatively low application rates and plant uptake	Minor	Unlikely	Low	Estimate.	
Forestry - Harvesting/clearance	Relatively large blocks of exotic forestry are observable within the South-branch catchment.	Heavy metals (including lead) adsorbed to sediment/soil. Contributor to turbidity, which may increase corrosivity	Mobilisation of sediment to the river. Concentrations are likely limited by relatively low background concentrations of lead in soils	Minor	Unlikely	Low	Estimate. Soil expected to be at background concentrations	
Recreational activities (water sports in the river)	Possible that shooting (such as duck shooting) occurs directly adjacent to the WTP intake and within the immediate catchment. However, the shooting would have to be intense and very close to the WTP intake to deposit enough lead into the river to impact the supply.	Lead (other contaminants/recreational activities other than shooting not considered relevant)	Accumulation of lead shot within river sediments and mobilisation to the intake	Insignificant	Unlikely	Very Low	Estimate.	No targeted sampling recommended at this stage
Slash Fire	The fire occurred on the hillside behind a small tributary that flows into the Waikouaiti River 125 m upstream of the WTP intake.	Heavy metal(including lead) accumulation from plant uptake, then deposition as ash. Ash is likely to increase pH and alkalinity, which may reduce raw water corrosivity.	Runoff of dissolved contaminants, or contaminated sediment	Minor	unlikely	Low	Estimate – two data points available suggest that lead levels within soil are within published background levels	Targeted sampling upstream, below and downstream of the slash fire area and upstream/downstream of the tributary/main river confluence should be considered in sampling plan, including sediment and water quality

WTP Filter backwash discharge	The filter backwash is discharged to a small tributary that flows into the Waikouaiti River 125 m upstream of the WTP intake. The total flow path between the discharge and the WTP intake is approximately 420 m, with significant dilution likely occurring where the tributary enters the main river.	Heavy metals (including lead), possible high TDS	Indirect discharge of sediment-laden water or water with high particulate lead to the river via some overland flow into the tributary, then into the main river channel. Some capacity for dilution.	Moderate	Possible	Medium	Estimate. Sampling results from the settling ponds and filter backwash discharge location show relatively low sediment and water lead concentrations.
WTP reservoir discharges	The reservoir overflow and run-to-waste is discharged to a small swale that flows into a small pond, then to tributary of the Waikouaiti River 125 m upstream of the WTP intake. The total flow path between the discharge and the WTP intake is approximately 600 m, with dilution likely occurring where the tributary enters the main river.	Heavy metals (including lead), possible high total dissolved solids (TDS)	Indirect discharge of sediment-laden water or water with high dissolved lead to the river via some overland flow into the tributary, then into the main river channel. Some capacity for dilution.	Moderate	Possible	Medium	Estimate. Sampling results from the reservoir sediment and the settling pond show relatively low sediment and water lead concentrations.
Cherry Farm landfill - buried refuse	Location uncertain. The ORC HAIL database shows the landfill as directly adjacent to the WTP (west)	A range of potential contaminants are possible, depending on the contents of the landfill. Heavy metals are often associated with landfill leachate, particularly from hospital disposal sites (anecdotally the landfill received waste from the hospital). Low pH is also often associated with landfill leachate, which may impact raw water corrosivity. High TDS and chloride	Leachate discharge to the river or tributary through groundwater flow	Moderate	Rare	Low	Estimate. Landfill location, construction and contents not well defined. However, if occurring, leachate discharge from the landfill would be a chronic impact, which was not found during recent sampling.
Cherry Farm landfill - ash dump	Location uncertain. Anecdotally, incinerator ash was dumped in a nearby gully, which may be one of the small gullies to the east of the WTP. These gullies drain to the same small tributary as the slash fire hillside and the WTP filter backwash discharge.	Heavy metals are often concentrated in ash, so high concentrations of lead are possible, particularly given the source of refuse may have been from the hospital. Ash is likely to increase pH and alkalinity, which may reduce raw water corrosivity.	Ash-dump leachate discharge to the river or tributary through groundwater flow	Moderate	Rare	Low	Estimate. Ash dump location and extent not well defined. However, if occurring, leachate discharge from the ash dump would be a chronic impact, which was not found during recent sampling.

8 Conclusions and recommendations

Summary of findings:

Our review of available water and sediment quality data, including the recent sampling undertaken as part of this investigation showed the following:

- Key water chemistry parameters, such as sulfate, hardness, alkalinity, calcium, magnesium and potassium within the OG dataset show a seasonal trend in water chemistry at the upper reaches of the river, with higher concentrations in summer, and lower concentrations in winter. This was particularly pronounced in the summer of 2019, which showed a significant spike in concentrations of all inorganic parameters. The 2019 spike is also evident in the WTP raw water monitoring data for sulfate (other parameters were not measured).
- Only dissolved lead has been tested by OG continuously, and it has been infrequently collected (particularly prior to 2018). The dataset includes some samples with elevated dissolved lead, including a value of 0.017 mg/L in February 2000 (NBWR Redbank Road). More recently, dissolved lead has been occasionally slightly elevated (complicated by intermittent analysis), up to approximately 0.0025 mg/L. The average dissolved lead results are an order of magnitude below the DWSNZ MAV (which relates to total fraction rather than dissolved), but it is possible that total lead concentrations could have been higher between sampling events.
- A single extremely low pH event (pH 3.5) is shown in the OG monitoring data in September 2019 at an upstream location (NBWR Ross Ford). However, low pH was not recorded at the downstream location at the same time, so is likely to be an equipment issue.
- All water quality samples collected from the river and tributaries on 16/17 February 2021 were at or below laboratory detection levels for total and dissolved lead.
- Inorganic parameters (such as sulfate, alkalinity, hardness) all decline from the upper catchment to the lower catchment. Based on these parameters, water corrosivity appears to increase from scale-forming in the upper reaches, to being slightly corrosive at the WTP intake.
- Lead levels within sediment appear to generally decline from the upper river to the lower river, from approximately 11 mg/kg in the upper catchment to around 5 mg/kg near to the WTP intake. However, all results are within expected background concentrations.
- The concentrations of lead in soil collected from the former slash fire area (11-15 mg/kg) were within expected background concentrations, but slightly higher than lead concentrations in the lower river and estuary sediments, which are generally around 5mg/kg.
- Lead concentrations in the raw water reservoir sediment (17.3 mg/kg) and sediment from the filter backwash settling ponds (13-17 mg/kg) were all within the expected background concentration, but slightly higher than samples from the lower portion of the river.
- Lead concentrations in sediment at the filter backwash discharge point (10 mg/kg) and within the tributary downstream of the discharge (5-12 mg/kg) were also within background ranges, but slightly higher than the river sediment in the lower portion of the river.
- Mahika Kai sampling results appear to show a slight elevation of lead within bivalve biota relative to limited available baseline data. However, results were considered inconclusive, without further specialist input to bioaccumulation processes and a more comprehensive baseline comparison. All sampling results were below Food Safety Australia New Zealand maximum wet weight values for fish and molluscs.

Conclusions:

- Based on water quality sampling and sediment data from the river and the estuary, there are unlikely to be sustained elevated discharges of lead within the river catchment. Alongside laboratory error (which is now looking less likely), short-term “pulse(s)” of elevated lead are the most-likely explanations for the elevated lead results from the raw water reservoir in January 2021 and the recent spike of 0.034 mg/L.
- Discharges from OG were qualitatively assessed as medium risk, based on the limited compliance data set available. Note that this qualitative assessment does not consider catastrophic events (e.g., tailings dam failure) or non-compliant behaviour.
Key water chemistry parameters decline from the upper to lower catchment. These spatial changes may arise from discharges related to OG’s activities, which are diluted by increasing inputs to the river moving downstream. The changes in water chemistry may affect lead partitioning as the water moves down-river, and could influence lead partitioning in the source/raw water to the WTP. Compliance data shows historical events where elevated dissolved lead has been present in the upper catchment, highlighting that such events can occur from time to time.
- A simple surface water mass balance conducted shows that – based on the very limited data that we have – there is no evidence to indicate that under worst case calculations, discharges from Oceana Gold could lead to concentrations of lead at the water intake that have been experienced. However, the very small data set is only representative of a small fraction of the overall long-term picture and does not account for more complex catchment and chemical processes.
- The discharges from the WTP were qualitatively assessed as medium risk. Lead concentrations in sediment/sludge at the former slash fire, in the raw water reservoir and from the filter backwash ponds were all within expected background ranges for lead in soil, but about two to three times higher than concentrations in the river sediment. Although not conclusive, the results do highlight the possibility that lead from these areas (or pulses from an upstream source) could be entering the water supply, either as particulate or dissolved phase (depending on water chemistry/corrosivity conditions). The results may also simply be a function of finer sediment within these areas providing greater surface area for adsorption of lead.
- Potential discharges from the fly dump near Eldorado Station were qualitatively assessed as medium risk. A conservative assessment was made, on the basis that the contents and volume of the dump was still poorly defined. If high-concentration sources of lead are present within the dump, these could be mobilised during high rainfall/flood events such as the January 2021 event.

Recommendations:

- Continue to monitor raw water for lead (total and dissolved) at high-frequency, along with periodic sampling of sediment for lead (including event-based sampling also).
- Further discussion with OG to establish whether further environmental monitoring data may be available.
- In order to further assess and understand the sources, fate and transport of key contaminants in the river, a series of co-ordinated, monitoring exercises are conducted, involving continuous water sampling and/or monitoring for parameters including metals, pH and turbidity at several locations along the length of the river. Critical locations would be upstream and downstream of major discharges and tributaries, coordinated with sampling at the WTP described above. Ideally the exercise would be conducted over several different weather and river flow conditions, and would involve co-ordination with major consent holders, and

additional sampling of their discharges. Flow measurements and/or calculations for the discharges and the river at various points would also be required. Analysis of data from such an exercise would then be used to develop an enhanced understanding of the potential sources of contaminant and to feed into any more detailed fate and transport modelling exercise that might subsequently be undertaken.

- Further physical inspection of the Eldorado Station fly dump to better define the nature, contents, volume and distribution of wastes. If significant sources of lead are identified, potential of these could be assessed using fate and transport modelling.

Further assessment of the relevance of the Mahika Kai sampling results, respective to relationship between background lead concentrations in the catchment and bioaccumulation processes. This is specialist work, outside of T+T expertise.

9 Applicability

This report has been prepared for the exclusive use of our client Dunedin City Council, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

Tonkin & Taylor Ltd

Report prepared by:

Authorised for Tonkin & Taylor Ltd by:

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Chris Shanks

Senior Environmental Scientist

.....
Tony Cussins

Project Director

CRSS

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Appendix A: Summary of Oceana Gold Mine Discharge Consents and sampling locations

- Oceana Gold Macrae's Mine Discharge Consents
- Oceana Gold Macrae's Mine sampling locations

Consent Numer	Consent Type	Consent status	Consent holder	Consent expiry date	District Authority	Purpose Activity
2002.763	Discharge to Water Permit	Current	Oceana Gold (New Zealand) Limited	30/11/2037	Waitaki District	To discharge water into Golden Bar Pit for the purpose of establishing long-term drainage patterns after completion of mining operations at the Golden Bar development area
2002.759	Discharge to Water Permit	Current	Oceana Gold (New Zealand) Limited	30/11/2037	Waitaki District	To discharge to water up to 30,000 cubic metres per day of water from the Clydesdale silt pond to Clydesdale Creek for the purpose of releasing surface water runoff.
RM10.351.10.V2	Discharge to Water Permit	Current	Oceana Gold (New Zealand) Limited	1/10/2046	Waitaki District	To discharge contaminants to water from the base and toe of the Frasers Waste Rock Stack for the purpose of waste rock disposal
RM10.351.08	Discharge to Water Permit	Current	Oceana Gold (New Zealand) Limited	1/10/2046	Waitaki District	To discharge silt and sediment to water for the purpose of extending the Frasers Waste Rock Stack
RM10.351.11.V1	Discharge to Water Permit	Current	Oceana Gold (New Zealand) Limited	1/10/2046	Waitaki District	To discharge water from silt ponds to tributaries of the North Branch of the Waikouaiti River and Murphys Creek for the purpose of operating silt ponds associated with the Frasers Waste Rock Stack
RM13.452.04	Discharge to Water Permit	Current	Oceana Gold (New Zealand) Limited	10/04/2049	Waitaki District	To to discharge water from a dam for the purpose of augmenting instream flows
RM13.452.01	Discharge to Water Permit	Current	Oceana Gold (New Zealand) Limited	10/04/2024	Waitaki District	To discharge silt and sediment to water for the purpose of constructing a dam
RM10.351.26.V2	Discharge to Water Permit	Current	Oceana Gold (New Zealand) Limited	1/10/2046	Waitaki District	To discharge contaminated water from the Top Tipperary Tailings Storage Facility silt pond/tailings seepage sump to the Frasers Underground mine workings for the purpose of draining the Top Tipperary Tailings Storage Facility
RM10.351.23	Discharge to Water Permit	Current	Oceana Gold (New Zealand) Limited	1/10/2022	Waitaki District	To discharge silt and sediment to water for the purpose of constructing the Top Tipperary Tailings Storage Facility silt pond/tailings seepage sump.
RM10.351.20.V1	Discharge to Water Permit	Current	Oceana Gold (New Zealand) Limited	1/10/2022	Waitaki District	To discharge water from silt ponds to unnamed tributaries of Tipperary Creek, Cranky Jims Creek and the North Branch of the Waikouaiti River for the purpose of operating temporary silt ponds associated with the construction of the Top Tipperary Tailings Storage Facility
RM10.351.13	Discharge to Water Permit	Current	Oceana Gold (New Zealand) Limited	1/10/2022	Waitaki District	To discharge silt and sediment to Tipperary Creek, Cranky Jims Creek and their respective unnamed tributaries for the purpose of the construction of the Top Tipperary Tailings Storage Facility
RM10.351.17.V3	Discharge to Water Permit	Current	Oceana Gold (New Zealand) Limited	1/10/2046	Waitaki District	To discharge mine tailings and contaminants from mine tailings to water for purpose of disposing of mine process tailings
96815A_V1	Discharge to Water Permit	Current	Oceana Gold (New Zealand) Limited	31/08/2032	Waitaki District	To discharge water from the North Branch Waikouaiti River and its tributaries into open cut pits for the purpose of managing surface water runoff for Innes Mills and Frasers Pits on completion of those pits, and post mining rehabilitation in the vicinity of Macraes Flat at the site shown on Map A annexed.
RM10.351.40.V1	Discharge to Water Permit	Current	Oceana Gold (New Zealand) Limited	1/10/2022	Waitaki District	To discharge water to the Frasers Pit Silt Pond for the purpose of dewatering the Frasers Underground Mine and the associated decline
RM10.351.43.V1	Discharge to Water Permit	Current	Oceana Gold (New Zealand) Limited	1/10/2046	Waitaki District	To discharge water containing contaminants to water in open pits and Frasers Underground mine for the purpose of disposal of water and the creation of lakes (the Golden Point - Round Hill Pit Lake and the Frasers - Innes Mills Pit Lake)
RM19.288.01	Discharge to Water Permit	Current	Oceana Gold (New Zealand) Limited	1/10/2024	Dunedin City	To discharge tailings water to Innes Mills West Pit in a manner that may enter water for the purpose of compliance with tailing storage threshold
96814_V1	Discharge to Water Permit	Current	Oceana Gold (New Zealand) Limited	31/08/2032	Waitaki District	To discharge water into the North Branch Waikouaiti River from rehabilitated open cut pits known as Innes Mills Pit and Frasers Pit for the purposes of establishing long-term drainage patterns after completion of mining operations at Macraes Flat at the site shown on Map A annexed.
RM19.315.01	Discharge to Water Permit	Current	Oceana Gold (New Zealand) Limited	8/01/2022	Waitaki District	To discharge earth and mining waste rock to land in a manner that may enter water
2007.583	Discharge to Water Permit	Current	Oceana Gold (New Zealand) Limited	15/07/2043	Waitaki District	To discharge water from Frasers Pit into the North Branch of the Waikouaiti River and Murphys Creek for the purpose of disposal of water accumulating within Frasers Pit during and following rainfall events. Locations of activities: Direct discharge into North Branch of the Waikouaiti River: Approximately 270 metres south east of the intersection of Macraes Road and Gifford Road, Macraes Flat; Discharge from Frasers West Silt Pond: Approximately 540 metres east of the intersection of Macraes Road and Red Bank Road, Macraes Flat; Direct discharge into Murphys Creek: Approximately 2.4 kilometres south east of the intersection of Macraes Road and Gifford Road, Macraes Flat; Discharge from Murphys Creek Silt Pond: Approximately 2.8 kilometres south east of the intersection of Macraes Road and Gifford Road, Macraes Flat.

RM10.351.16.V3	Discharge to Water Permit	Current	Oceana Gold (New Zealand) Limited	1/10/2046	Waitaki District	To discharge mine tailings and contaminants from mine tailings to land for purpose of disposing of mine process tailings in the Top Tipperary Tailings Storage Facility
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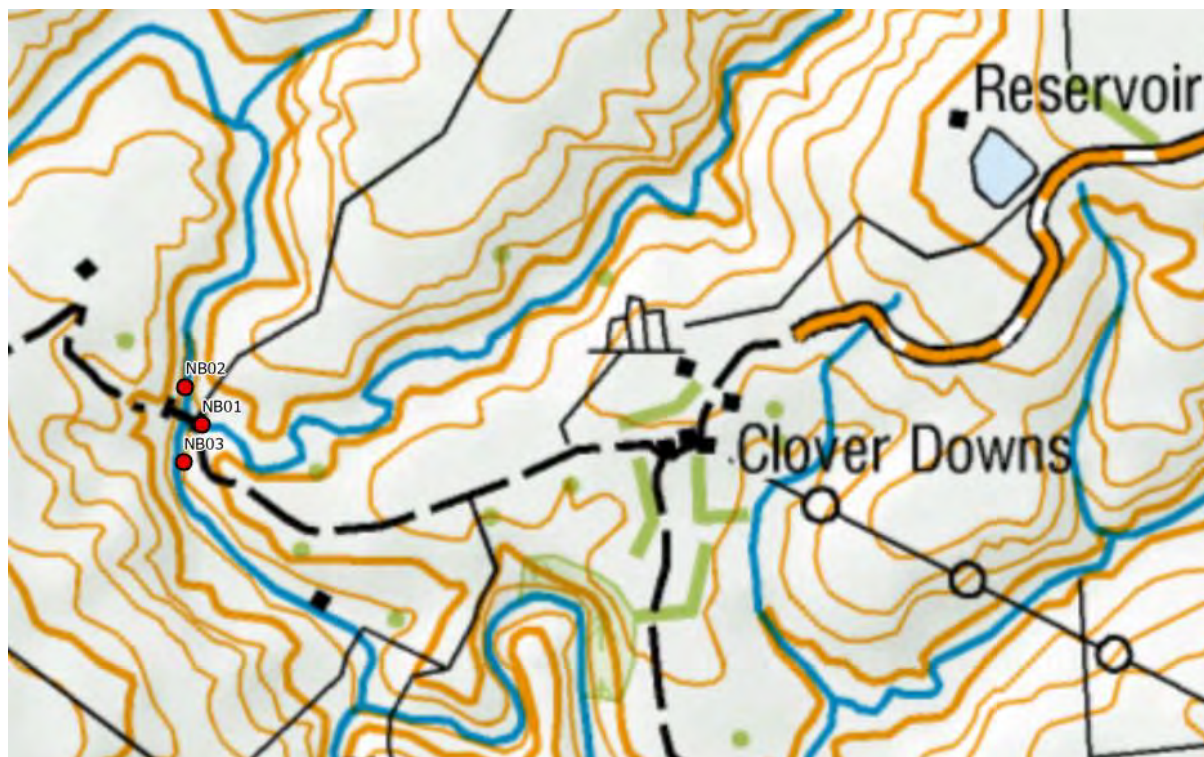
OceanaGold Monitoring Sites

North Branch Waikouaiti River Compliance Points

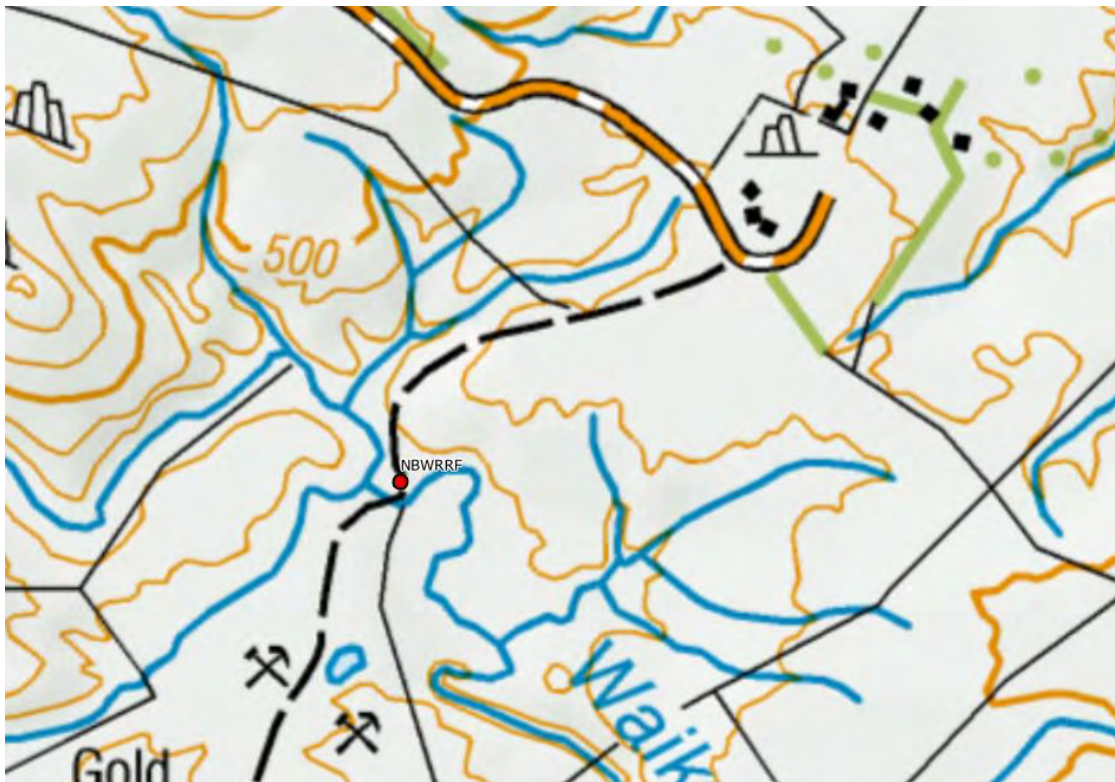
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NB02 – NZTM E1405805.18 N4964676.34

NB03 – NZTM E1405802.59 N4964562.04



NBWRRF – NZTM E1401020.5 N4967165.83



Murphy's Creek Compliance Points

MC01 – NZTM E1403023.45 N4969560.46

MC02 – NZTM E1405418.05 N4966923.66



Sampling Locations Outlined on Field Investigation Scope

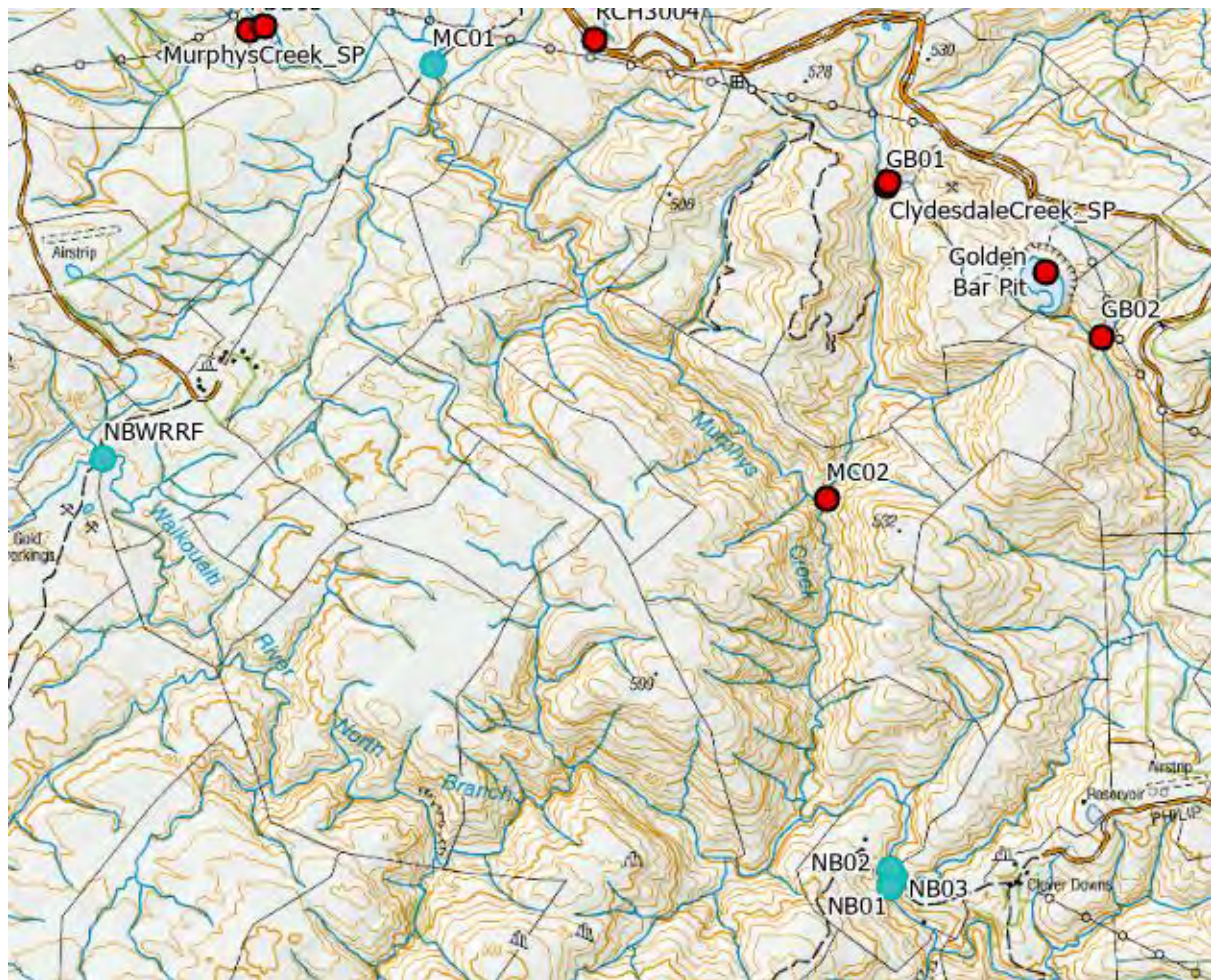


Figure 1 Areas outlined in the DCC field investigation scope highlight in blue

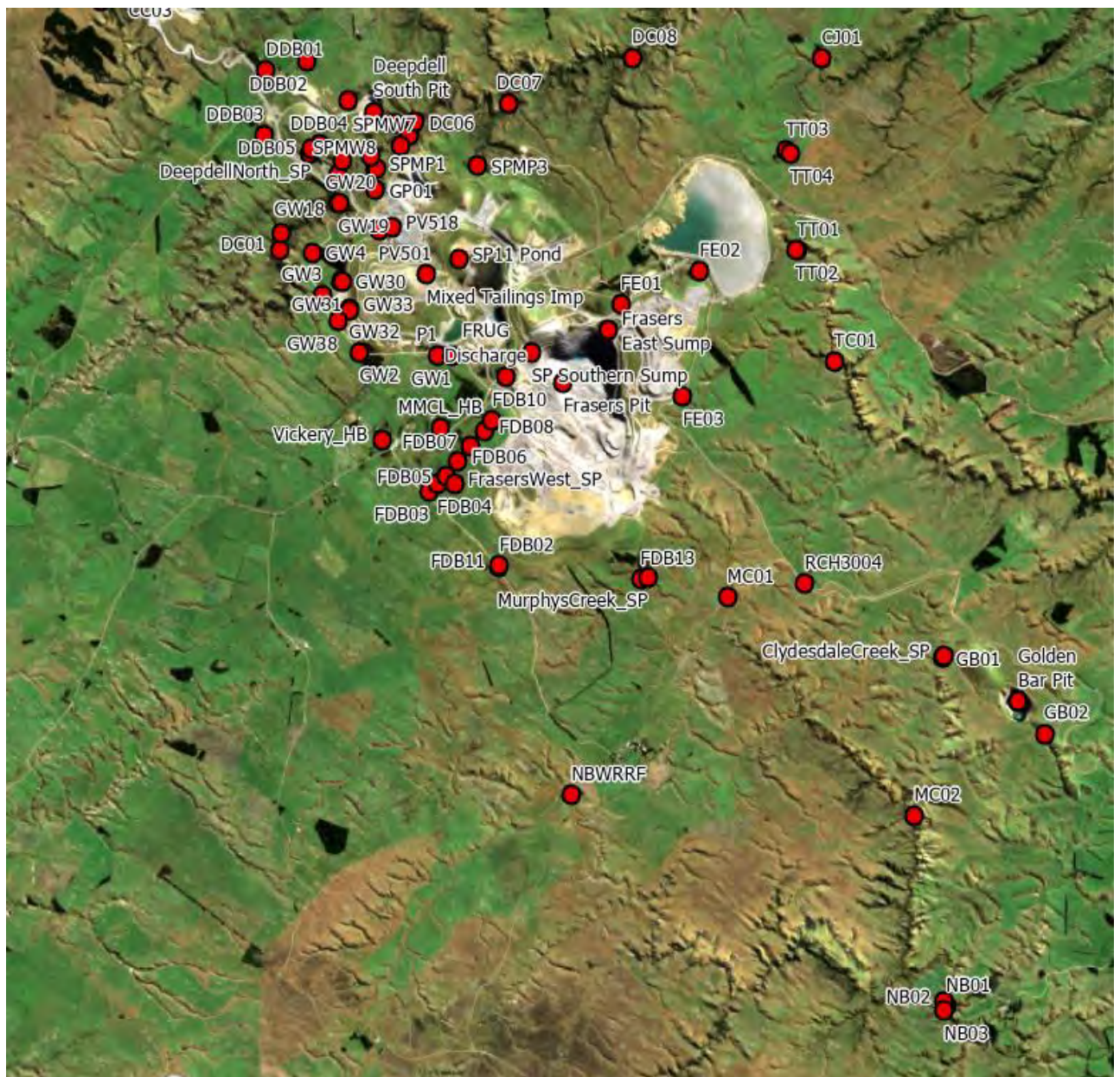


Figure 2 NZ Imagery Map overview – OceanaGold sampling locations outlined as red dots

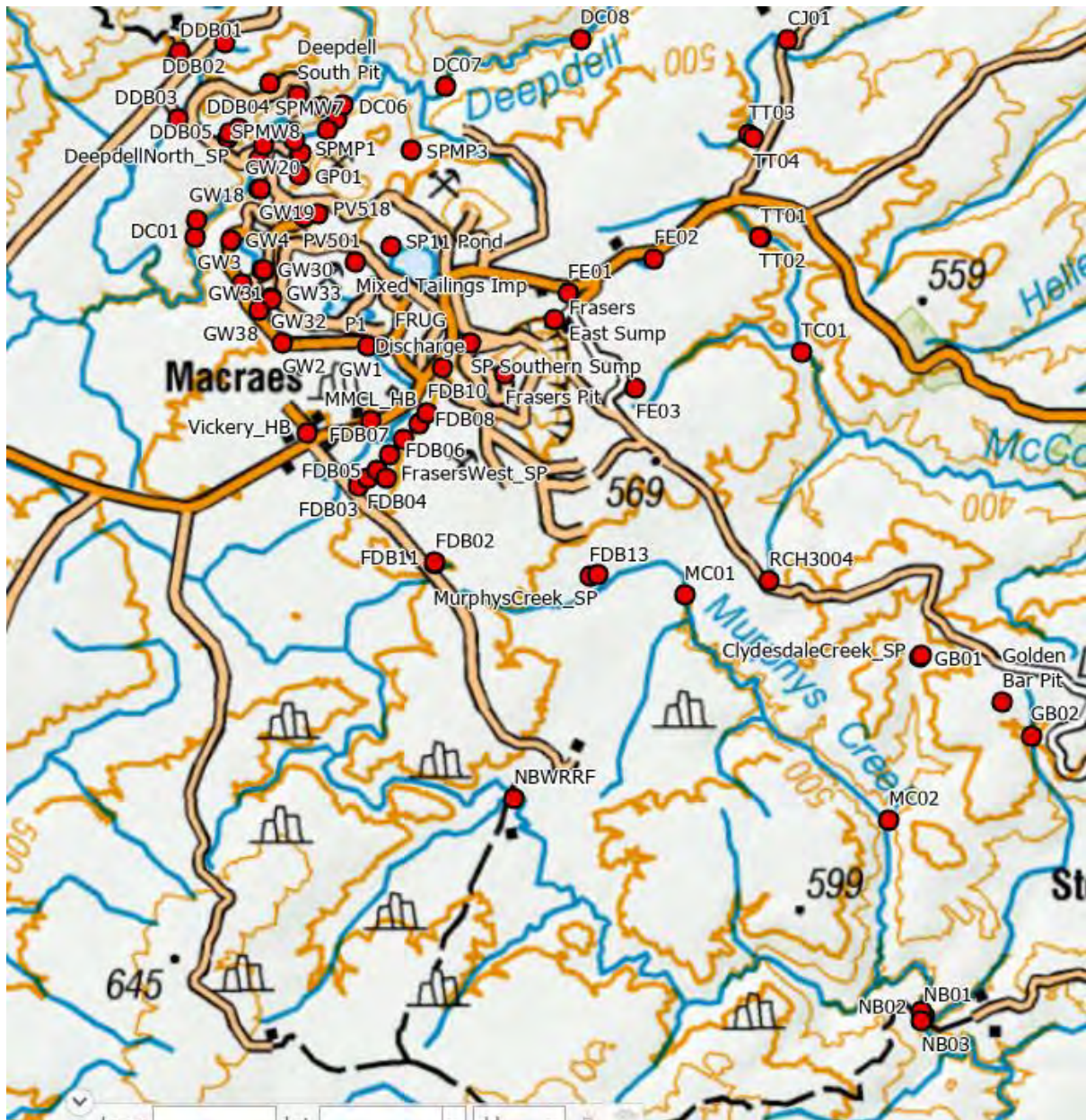
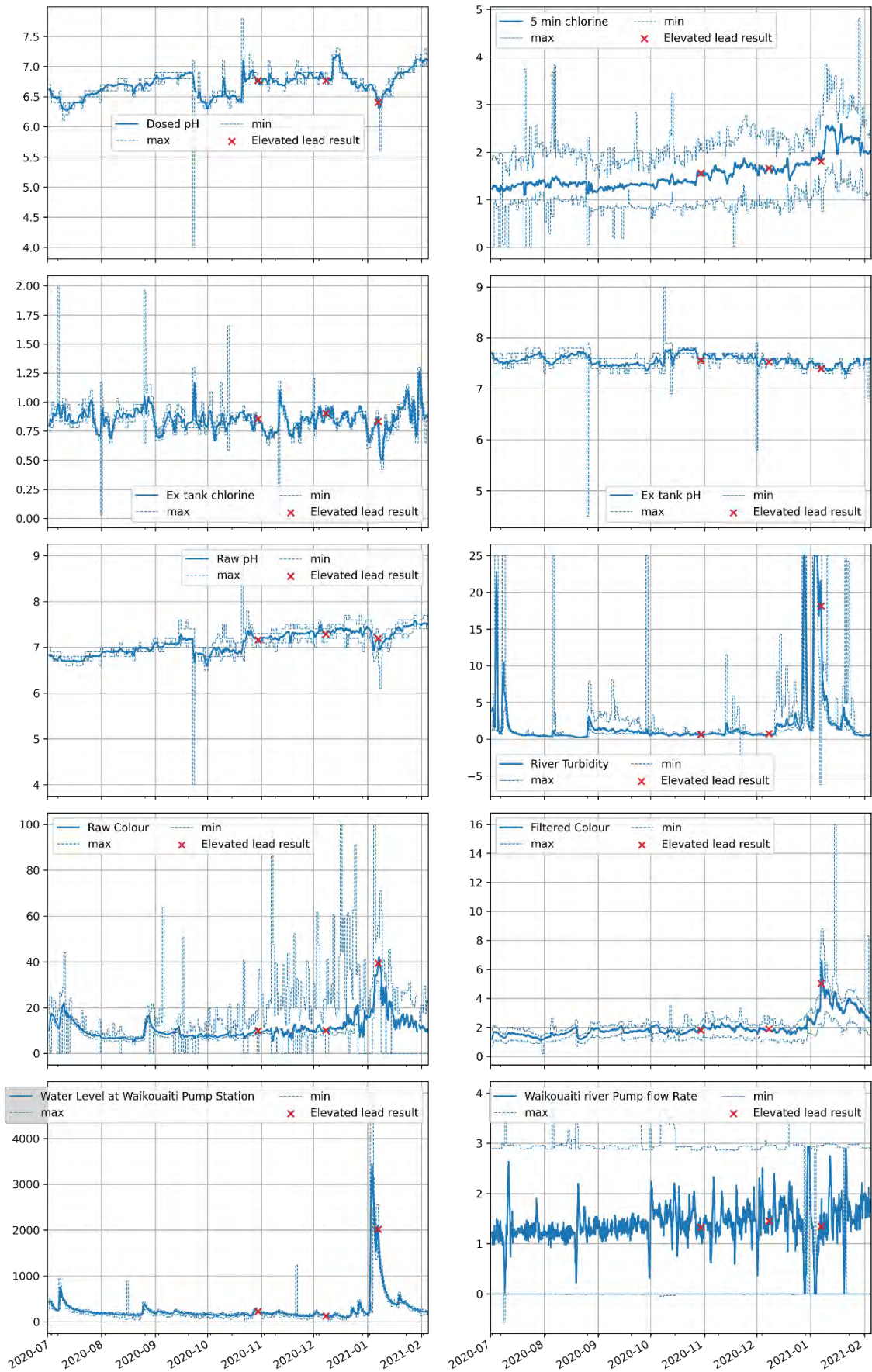


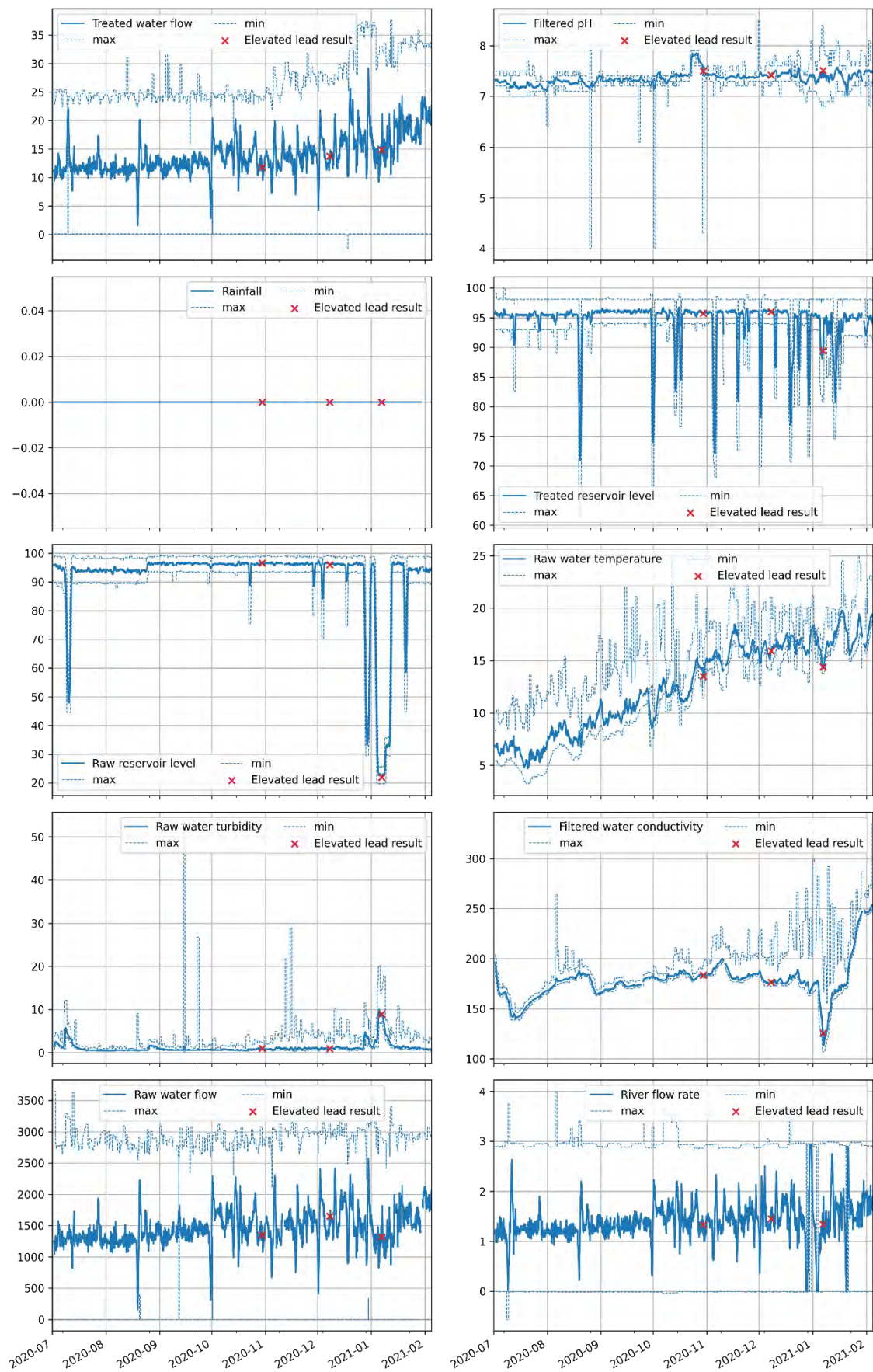
Figure 3 Topography Map Overview – OceanaGold sampling locations outlined as red dots

Appendix B: Water Quality Data

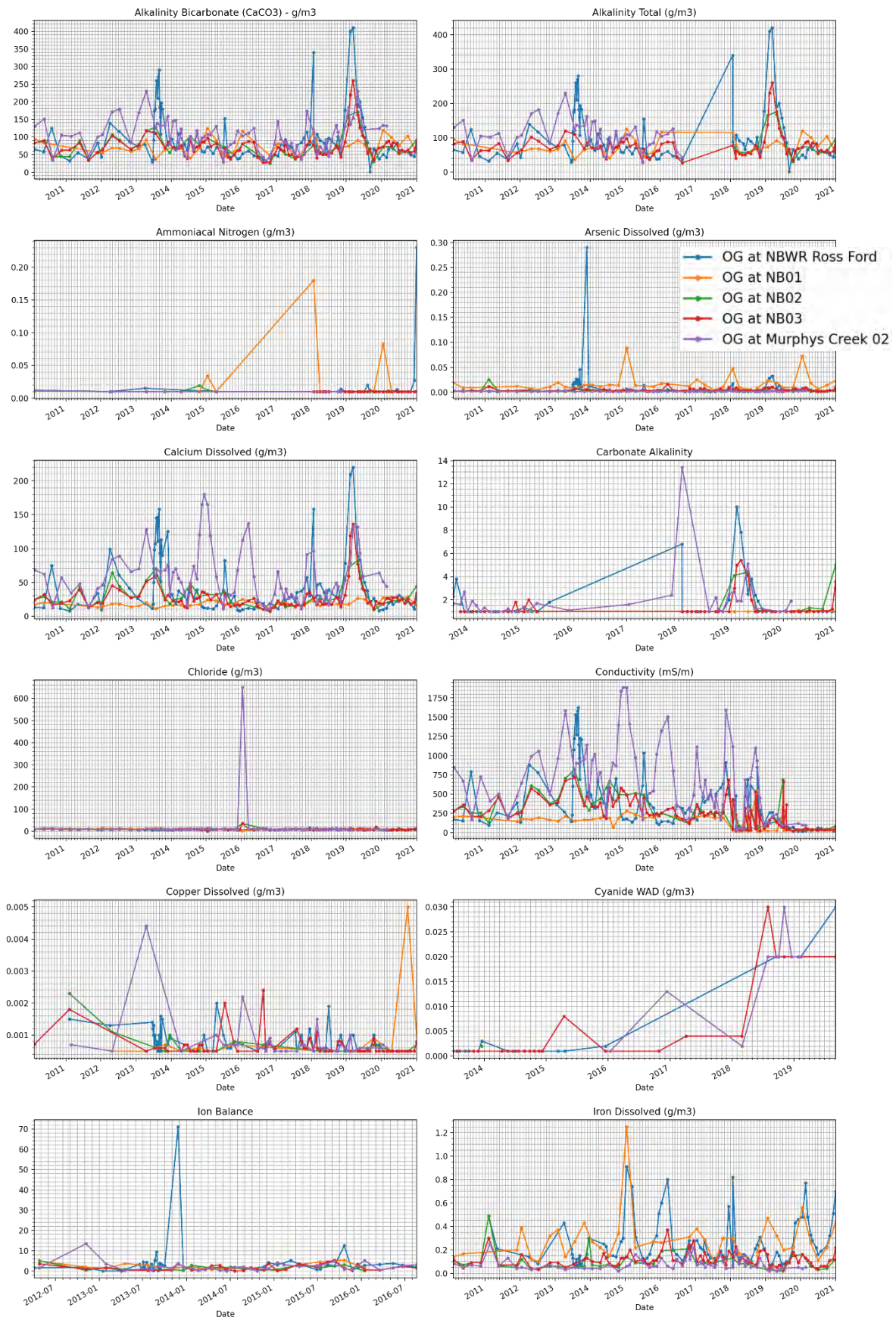
- **Dunedin City Council SCADA data**
- **Oceana water quality data**
- **T+T Field sampling data**

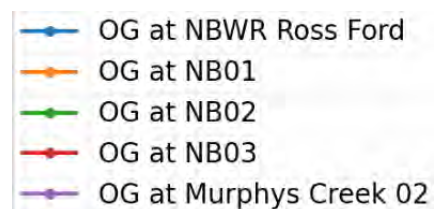
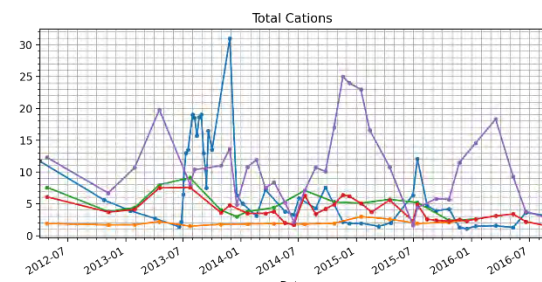
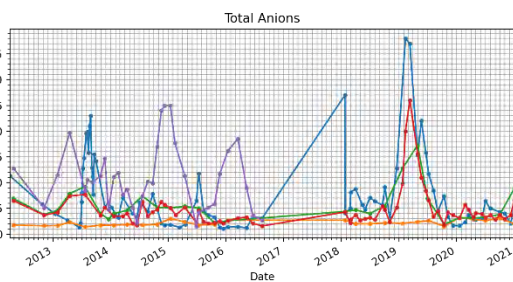
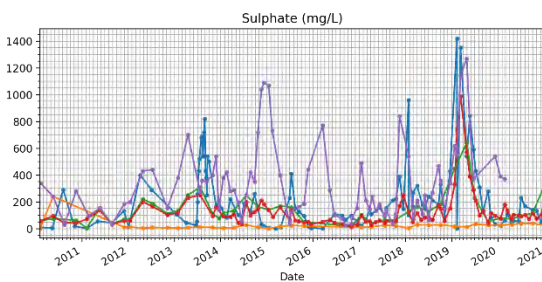
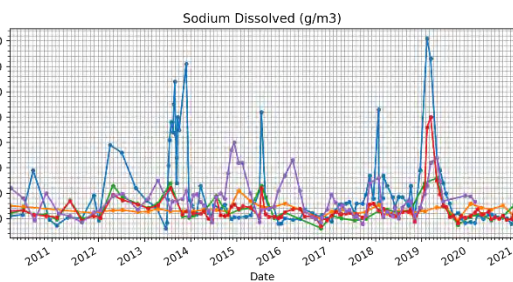
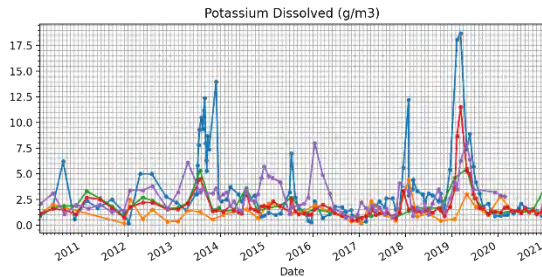
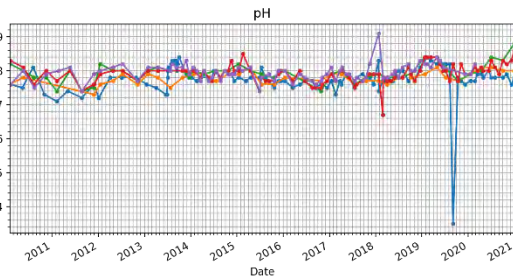
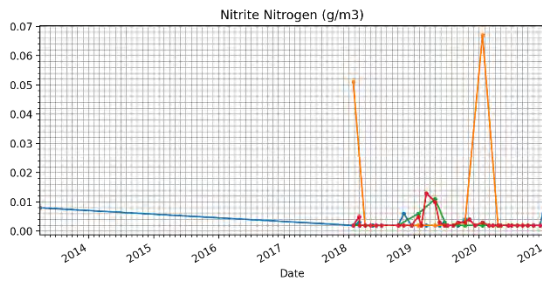
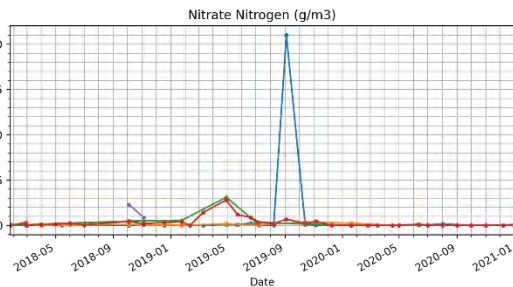
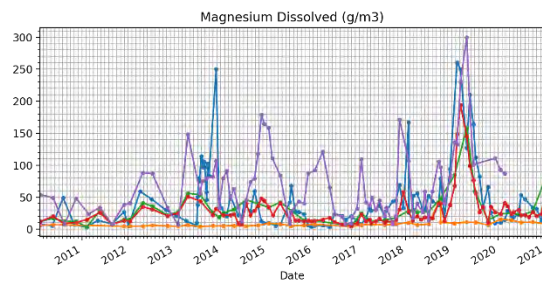
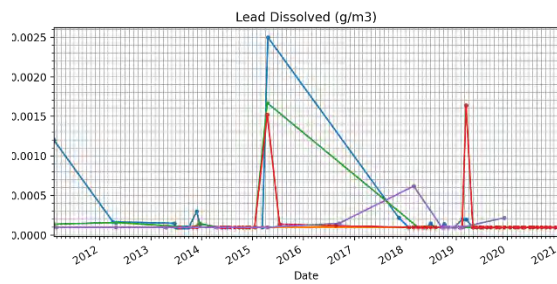
B1 Dunedin City Council SCADA data

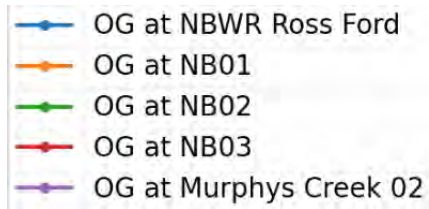
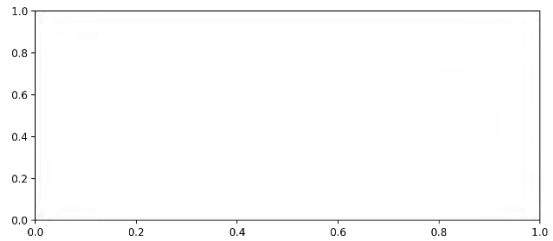
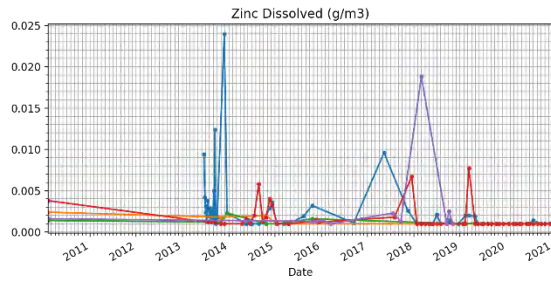
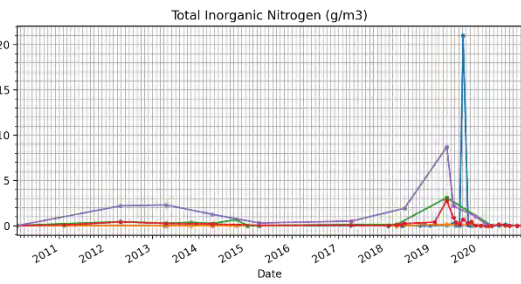
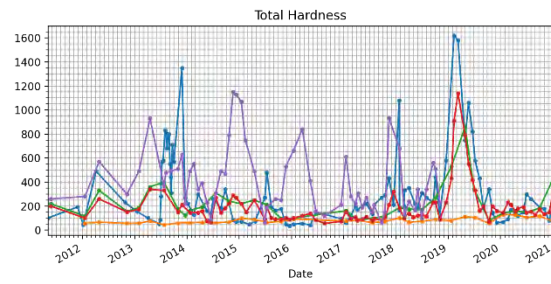




B2 Oceana water quality data







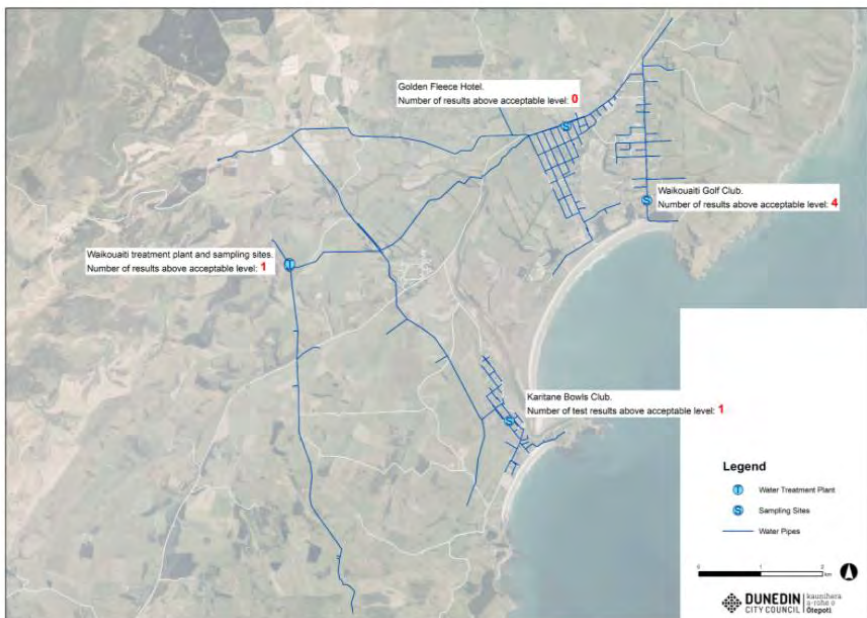
B3 T+T Field Sampling Data

Water quality parameters

Location	Water Sample Name	Sediment Sample Name	Date	pH	Lab pH	Oxidation and reduction potential (mV)	Sulfate (mg/L)	Cl (mg/L)	CSMR	Lead (sediment, mg/kg)	Langelier Saturation Index (for corresponding water samples)	Comments
Farm track off Golden Bar Rd	CAWK01-20	CAWK01-70	17/02/2021	8.29	8	158.5	1,020	9	0.01	10.8	0.8	Anoxic odour
Red Bank Road Crossing	CAWK01-14	CAWK01-64	17/02/2021	6.71	7.9	232.0	570	8.2	0.01	2.6	0.3	
Oceana Sampling Point	CAWK01-12	CAWK01-62	17/02/2021	7.23	7.8	208.2	230	8.3	0.04	8.3	-0.1	
Aignes Road Crossing	CAWK01-10	CAWK01-60	17/02/2021	8.66	7.6	146.7	135	8.4	0.06	6	-0.5	Very low turbidity
Eldorado Road Crossing	CAWK01-08	CAWK01-58	17/02/2021	7.32	7.6	184.6	55	9.2	0.17	5.2	-0.8	
Ramrock Road Bridge/ Bucklands Crossing Reserve	CAWK01-05	CAWK01-55	17/02/2021	8.50	8	122.8	66	10.8	0.16	7.4	-0.3	
North branch upstream of confluence with south branch	CAWK01-02	CAWK01-52	16/02/2021	8.35	-	155.0	-	-	-	4.8	-0.4	
Upstream of south branch confluence with north branch	CAWK01-03	CAWK01-53	16/02/2021	6.09	-	231.2	-	-	-	5.3	-0.3	
Downstream of South Branch	CAWK01-01	CAWK01-51	16/02/2021	8.13	-	167.3	-	-	-	3.9	-0.5	
Upstream of confluence with unnamed tributary	DWWK67-05	DWWK67-55	16/02/2021	8.18	-	170.2	-	-	-	2.6	-0.4	
20m upstream of intake	DWWK67-04	DWWK67-54	16/02/2021	8.13	-	164.6	-	-	-	4.5	-0.6	
WTP1	DWWK65-01	DWWK65-51	16/02/2021	8.98	-	162.2	-	-	-	16.8	-0.5	
WTP2	DWWK65-02	DWWK65-52	16/02/2021	8.71	-	165.0	-	-	-	8.2	-0.6	
WTP3	DWWK65-03	DWWK65-03	16/02/2021	8.55	-	164.4	-	-	-	12.0	-0.6	
WTP4	DWWK65-04	DWWK65-04	16/02/2021	8.42	-	157.2	-	-	-	13.3	-1	
Slash soil 1 - surface	-	CAWK09-52 0m	16/02/2021	-	-	-	-	-	-	11.4	-	
Slash soil 1 - 0.2m	-	CAWK09-52 0.2m	16/02/2021	-	-	-	-	-	-	14.9	-	
Slash soil 2 - surface	-	CAWK09-51 0m	16/02/2021	-	-	-	-	-	-	13.1	-	
Slash soil 2 - 0.2	-	CAWK09-51 0.2m	16/02/2021	-	-	-	-	-	-	12.1	-	
Backwash outflow point	DWWK66-01	DWWK66-51	16/02/2021	8.12	-	167.8	-	-	-	10	-0.5	
Top of unnamed tributary	DWWK67-01	DWWK67-51	17/02/2021	8.05	7.3	77.4	0.5	29	58.00	5.4	-0.6	Variable parameters- not settling
Unnamed tributary at track crossing- mid reach	DWWK67-02	DWWK67-52	16/02/2021	6.83	7.8	209.9	0.9	34	37.78	8.2	-0.1	
Unnamed tributary at track crossing- lower reach	DWWK67-03	DWWK67-53	16/02/2021	8.23	7.6	115.6	30	18.7	0.62	12	-0.5	

Appendix C: Otago Regional Council – Cherry Farm Landfill summary sheet

JOB SHEET / FILE NOTE

Our Reference:	IN21.0110	
File:	Click or tap here to enter text.	
Author:	Joon van der Linde	
Date:	17/02/2021	
Subject:	Review of the Cherry Farm Former Landfill as part of an investigation to determine the source of elevated lead levels detected in the Waikouaiti and Karitane drinking water supply.	
Purpose:	To determine a possible link between the former Cherry Farm Landfill and elevated lead levels detected within the Waikouaiti/Karitane drinking water supply system. Waikouaiti-Karitane water sampling sites  Source: https://www.dunedin.govt.nz/news-and-events/public-notices/alerts/water-notice/water-sampling-results-for-waikouaiti-karitane	
HAIL.00654.01 – Cherry Farm Former Landfill Classification	HAIL.00654.01 HAIL Status: <i>Verified HAIL</i>	Information has been provided confirming, more likely than not, that an activity or industry described in the HAIL is being or has been undertaken on the site.
	HAIL.00654.01 Contamination Status: <i>Not Investigated</i>	The soils at the site have not been subject to investigation (soil sampling & analysis). Contamination may have occurred but should not be assumed to have occurred.
	HAIL Summary: The site stopped receiving waste 20 – 50 years ago – replaced by system at Orbell Bridge (Area 1836). Unknown wastes were disposed at landfill (possibly hospital waste although there was an incinerator). Controls inadequate – capped with local substrate.	

Potential risks to Human Health:	The risk of landfill leachate contaminating the Waikouaiti/Karitane drinking water supply.
	 Figure A: The location of the Waikouaiti Water treatment plant in relation to the general location of the former Cherry Farm Landfill as depicted in the ORC HAIL Database.  Figure B: The location of the Waikouaiti Water treatment plant and associated infrastructure in relation to the general location of the former Cherry Farm Landfill as depicted in the ORC HAIL Database.

6.1. Site plan

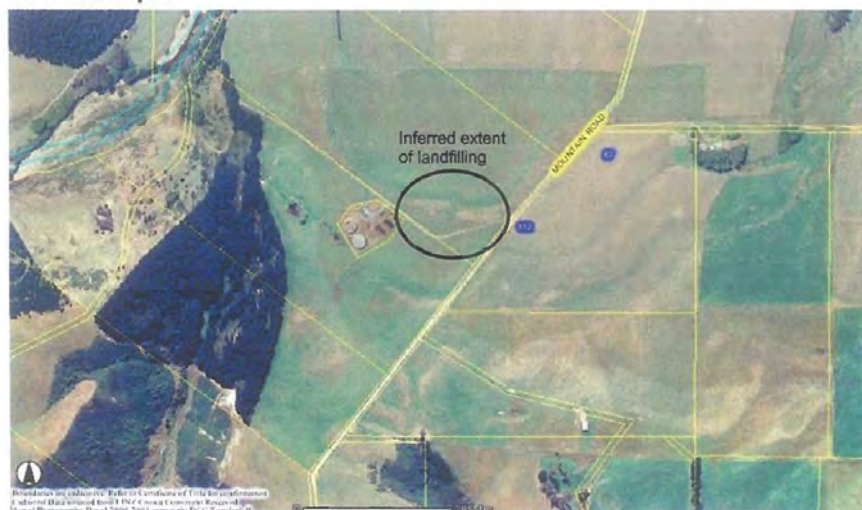


Figure 1: The approximate location of the former Cherry Farm Landfill as documented in the **2005 DCC Closed Landfill Audit Report**.



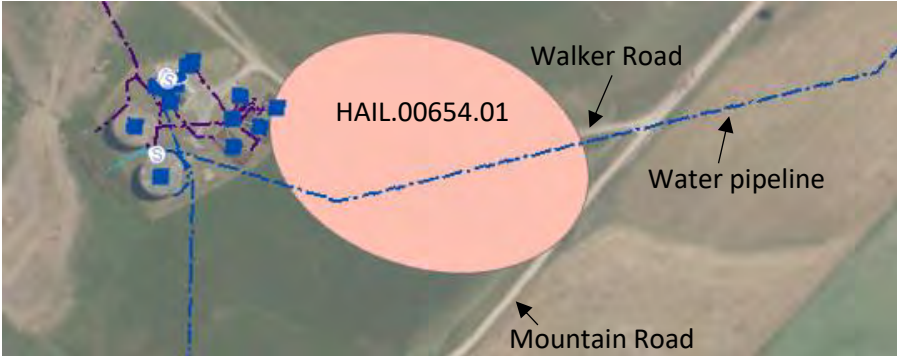
Figure 6.2 Cherry Farm landfill (in red square, panoramic view)

Figure 2: The view towards the water treatment plant. The possible location of the landfill is indicated on the slope to the right side of Walker Road, according to the 2005 DCC Closed landfill report.

Keypoints sourced from the 2005 DCC Closed Landfill Audit Report:

The vegetated landfill cap is intact and forms a mound that is “not obvious to the eye” (the mound blends in seamlessly with its surroundings). Figure 6.2 extracted from the report depict the general location of the landfill. The location on the above image implies that the footprint of the landfill does not extend beyond the access road (Walker Road) leading to the water treatment plant. The document also states that are no obvious drains or leachate collection structures.

1956 Retrolens Aerial Photo extract of the study area	 Figure 3: The Retrolens aerial photo extract above does not show visible indicators including exposed fill material within the general landfill footprint as described in the 2005 DCC Closed Landfill Audit Report. Surface disturbances resembling vehicle tracks are visible in the area between Mountain Road and Walker Road.
Letter dated 31/08/2011 from Sarah Valk Otago Regional Council – Resource Planner - Liaison	Key Points: • It was reported that the site stopped receiving waste 30 - 60 years ago (Now 40 – 70 years ago). • Unknown wastes were disposed of at the landfill. • The site was capped with local substrate, in accordance with accepted practice at the time. • The area of inferred filling was found to be covered in pasture and the cover intact. • The exact location of the landfill is unknown, but its inferred location appears to be more likely on Section 16. • Residual risks are more likely to be geotechnical related.
Geotechnical Assessment for the proposed Subdivision, Stage 2 (Mountain Track Road) GTR A42 dated 04/10/2011.	Key Points: • The purpose of the investigation was to identify a suitable building platform, that was not situated on or near any possible contaminated land. • The soil profile related to the land earmarked for development on Lot 5 indicated that no disturbance had occurred and it was not located on any landfill or contaminated land. • The site identified by the ORC and DCC as a landfill did not show any evidence of disturbance , however further subsurface investigation would be required to confirm this. • <i>Note: The image resolution of the scanned image contained in Appendix I, drafted by Survey Services fails to clearly indicated the general location of the landfill site.</i>

Conclusions:	The image below depicts the location of the Waikouaiti Water Treatment Plant and associated infrastructure, in relation to HAIL.00654.01 which indicate the general location of the former Cherry Farm Landfill Site . It is worth noting that the location as depicted in the HAIL Database, is not based on official survey plans.  Based on the available information relating to the location of the former Cherry Farm Landfill, it is probable that the landfill footprint does not extend beyond Walker Road. However, it cannot be confirmed that the water pipeline is buried outside the former landfill footprint.		
Supporting Information:	Otago Hospital Board Letter - 1974 DCC Closed Landfill Report -2005 Otago Regional Council Letter – 2011 Geotechnical Assessment – 2011 http://www.mapspast.org.nz/ Retrolens https://www.dunedin.govt.nz/news-and-events/public-notice/alerts/water-notice/water-sampling-results-for-waikouaiti-karitane		
Signed	Joon van der Linde 	Date / Time	17/02/2021

Appendix D: Fieldwork Sampling Plan

- Sampling location plans
- Laboratory certificates of analysis

D1 Sampling location plans



All Waikouaiti River sampling locations



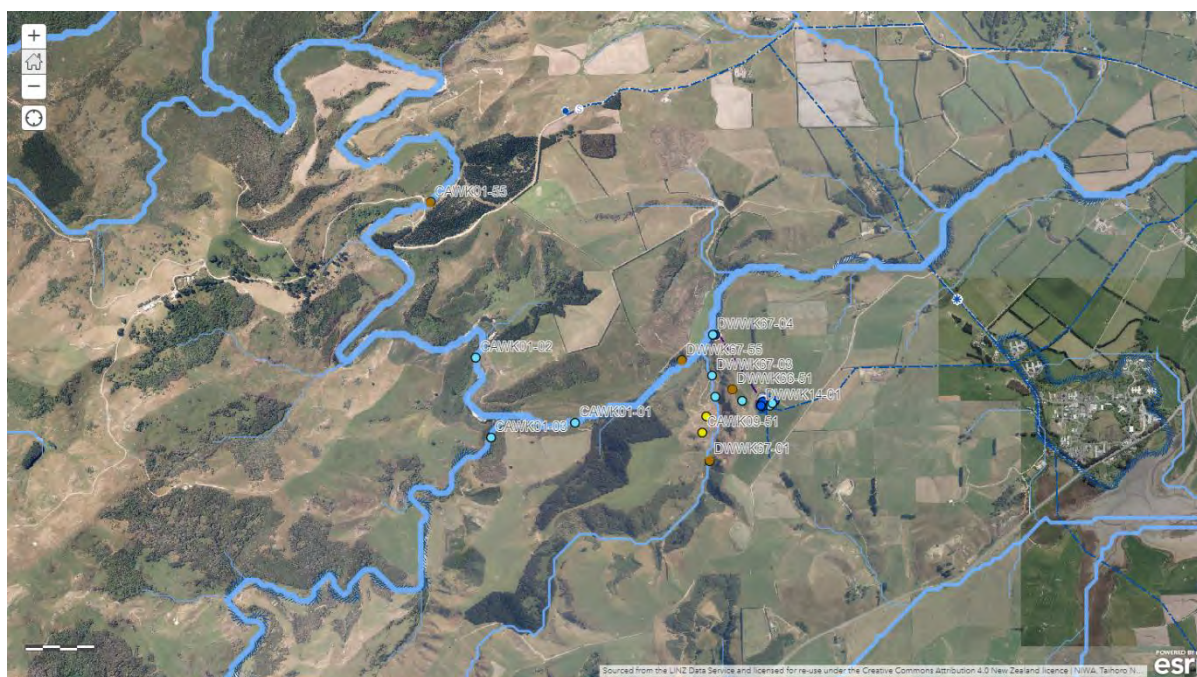
CAWK01-12, CAWK01-62 OG location NB02



CAWK01-14, CAWK01-64 OG location NBWRRF (Ross River Ford)



CAWK01-20, CAWK01-70 OG location MC01 (Murphy's Creek)



Lower Waikouaiti River sample locations



Wider WTP and gully sample locations



Certificate of Analysis

Page 1 of 6

Client:	Tonkin & Taylor	Lab No:	2531414	SPv5
Contact:	Natalie O'Rourke C/- Tonkin & Taylor PO Box 5271 Auckland 1141	Date Received:	18-Feb-2021	
		Date Reported:	25-Feb-2021	
		Quote No:	109816	
		Order No:	1016715	
		Client Reference:	1016715	
		Submitted By:	Lucy Hine	

Sample Type: Soil

Sample Name:		CAWK09-52-0m 16-Feb-2021 4:30 pm	CAWK09-52-0.2 m 16-Feb-2021 4:30 pm	CAWK09-51-0m 17-Feb-2021 3:25 pm	CAWK09-51-0.2 m 17-Feb-2021 3:25 pm	
Lab Number:		2531414.6	2531414.7	2531414.29	2531414.30	
Individual Tests						
Sulphate*	mg/kg dry wt	20	12	17	19	-
Heavy Metals, Screen Level						
Total Recoverable Arsenic	mg/kg dry wt	8	10	10	11	-
Total Recoverable Cadmium	mg/kg dry wt	0.16	< 0.10	< 0.10	< 0.10	-
Total Recoverable Chromium	mg/kg dry wt	7	5	4	4	-
Total Recoverable Copper	mg/kg dry wt	11	11	7	9	-
Total Recoverable Lead	mg/kg dry wt	11.4	14.9	13.1	12.1	-
Total Recoverable Nickel	mg/kg dry wt	9	9	3	3	-
Total Recoverable Zinc	mg/kg dry wt	72	47	23	24	-

Sample Type: Sediment

Sample Name:	DWWK67-53 16-Feb-2021 4:00 pm	DWWK67-52 16-Feb-2021 4:30 pm	CAWK01-60 17-Feb-2021 8:30 am	CAWK01-64 17-Feb-2021 11:15 am	CAWK01-70 17-Feb-2021 10:20 am	
	Lab Number:	2531414.1	2531414.4	2531414.10	2531414.14	2531414.16
Individual Tests						
Sulphate*	mg/kg dry wt	25	9	85	280	400
Heavy metal screen level As,Cd,Cr,Cu,Ni,Pb,Zn						
Total Recoverable Arsenic	mg/kg dry wt	9	7	14	4	58
Total Recoverable Cadmium	mg/kg dry wt	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
Total Recoverable Chromium	mg/kg dry wt	8	5	9	4	5
Total Recoverable Copper	mg/kg dry wt	11	9	11	4	10
Total Recoverable Lead	mg/kg dry wt	12.0	8.2	6.0	2.6	10.8
Total Recoverable Nickel	mg/kg dry wt	10	9	9	4	10
Total Recoverable Zinc	mg/kg dry wt	45	42	34	14	42

Sample Name:	CAWK01-62 17-Feb-2021 9:30 am	CAWK01-58 17-Feb-2021 1:15 pm	CAWK01-55 17-Feb-2021 2:00 pm	DWWK67-51 17-Feb-2021 3:00 pm		
Lab Number:	2531414.18	2531414.23	2531414.26	2531414.27		
Individual Tests						
Sulphate*	mg/kg dry wt	26	12	9	< 3	-
Heavy metal screen level As,Cd,Cr,Cu,Ni,Pb,Zn						
Total Recoverable Arsenic	mg/kg dry wt	10	6	6	5	-
Total Recoverable Cadmium	mg/kg dry wt	< 0.10	< 0.10	< 0.10	< 0.10	-
Total Recoverable Chromium	mg/kg dry wt	8	5	5	6	-
Total Recoverable Copper	mg/kg dry wt	13	8	11	5	-
Total Recoverable Lead	mg/kg dry wt	8.3	5.2	7.4	5.4	-
Total Recoverable Nickel	mg/kg dry wt	11	8	8	5	-



This Laboratory is accredited by International Accreditation New Zealand (IANZ), which represents New Zealand in the International Laboratory Accreditation Cooperation (ILAC). Through the ILAC Mutual Recognition Arrangement (ILAC-MRA) this accreditation is internationally recognised. The tests reported herein have been performed in accordance with the terms of accreditation, with the exception of tests marked * or any comments and interpretations, which are not accredited.

Sample Type: Sediment						
Sample Name:		CAWK01-62 17-Feb-2021 9:30 am	CAWK01-58 17-Feb-2021 1:15 pm	CAWK01-55 17-Feb-2021 2:00 pm	DWWK67-51 17-Feb-2021 3:00 pm	
Lab Number:		2531414.18	2531414.23	2531414.26	2531414.27	
Heavy metal screen level As,Cd,Cr,Cu,Ni,Pb,Zn						
Total Recoverable Zinc		mg/kg dry wt	37	28	30	21
						-
Sample Type: Aqueous						
Sample Name:		DWWK67-03 16-Feb-2021 4:00 pm	DWWK67-02 16-Feb-2021 4:30 pm	CAWK01-10 17-Feb-2021 8:30 am	CAWK01-14 17-Feb-2021 11:15 am	CAWK01-20 17-Feb-2021 10:20 am
Lab Number:		2531414.2	2531414.5	2531414.9	2531414.13	2531414.15
Individual Tests						
Sum of Anions	meq/L	2.7	3.3	4.5	15.0	28
Sum of Cations	meq/L	2.8	3.4	4.7	14.2	27
Turbidity	NTU	2.6	1.55	0.54	1.30	1.09
pH	pH Units	7.6	7.8	7.6	7.9	8.0
Total Alkalinity	g/m ³ as CaCO ₃	78	116	75	149	320
Carbonate	g/m ³ at 25°C	< 1.0	< 1.0	< 1.0	< 1.0	1.7
Bicarbonate	g/m ³ at 25°C	94	141	91	181	390
Free Carbon Dioxide	g/m ³ at 25°C	3.5	3.5	3.5	4.1	6.6
Langelier Saturation Index		-0.5	-0.1	-0.5	0.3	0.8
Total Hardness	g/m ³ as CaCO ₃	105	113	200	650	1,310
Electrical Conductivity (EC)	mS/m	27.1	32.4	45.5	121.7	206
Total Dissolved Solids (TDS)	g/m ³	171	200	310	1,020	1,960
Sample Temperature*	°C	20.0	20.0	20.0	20.0	20.0
Dissolved Calcium	g/m ³	22	26	27	70	93
Dissolved Magnesium	g/m ³	12.1	11.5	33	114	260
Dissolved Potassium	g/m ³	1.62	1.05	2.1	5.4	6.4
Dissolved Sodium	g/m ³	15.2	25	12.8	26	26
Chloride	g/m ³	18.7	34	8.4	8.2	9
Nitrite-N	g/m ³	< 0.002	< 0.002	< 0.002	< 0.002	0.004
Nitrate-N	g/m ³	0.010	0.003	0.006	0.005	3.0
Nitrate-N + Nitrite-N	g/m ³	0.010	0.004	0.006	0.006	3.0
Sulphate	g/m ³	30	0.9	135	570	1,020
Heavy metals, dissolved, trace As,Cd,Cr,Cu,Ni,Pb,Zn						
Dissolved Arsenic	g/m ³	< 0.0010	< 0.0010	0.0025	0.0047	0.0016
Dissolved Cadmium	g/m ³	< 0.00005	< 0.00005	< 0.00005	< 0.00005	< 0.00005
Dissolved Chromium	g/m ³	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Dissolved Copper	g/m ³	< 0.0005	< 0.0005	0.0007 #1	< 0.0005	< 0.0005
Dissolved Lead	g/m ³	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010
Dissolved Nickel	g/m ³	< 0.0005	< 0.0005	0.0009	0.0018	0.0026 #1
Dissolved Zinc	g/m ³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Heavy metals, totals, trace As,Cd,Cr,Cu,Ni,Pb,Zn						
Total Arsenic	g/m ³	< 0.0011	< 0.0011	0.0028	0.0060	0.0018
Total Cadmium	g/m ³	< 0.000053	< 0.000053	< 0.000053	< 0.000053	< 0.000053
Total Chromium	g/m ³	< 0.00053	< 0.00053	< 0.00053	< 0.00053	< 0.00053
Total Copper	g/m ³	< 0.00053	< 0.00053	< 0.00053	< 0.00053	< 0.00053
Total Lead	g/m ³	0.00013	< 0.00011	< 0.00011	< 0.00011	< 0.00011
Total Nickel	g/m ³	< 0.00053	< 0.00053	0.00100	0.00177	0.0025
Total Zinc	g/m ³	< 0.0011	< 0.0011	< 0.0011	< 0.0011	0.0017
Sample Name:		CAWK01-12 17-Feb-2021 9:30 am	CAWK01-08 17-Feb-2021 1:15 pm	CAWK01-05 17-Feb-2021 2:00 pm	DWWK67-01 17-Feb-2021 3:00 pm	
Lab Number:		2531414.17	2531414.24	2531414.25	2531414.28	
Individual Tests						
Sum of Anions	meq/L	6.9	2.4	2.9	3.1	-
Sum of Cations	meq/L	6.9	2.5	3.0	3.1	-
Turbidity	NTU	0.52	0.46	0.30	5.3	-
pH	pH Units	7.8	7.6	8.0	7.3	-

Sample Type: Aqueous						
Sample Name:		CAWK01-12 17-Feb-2021 9:30 am	CAWK01-08 17-Feb-2021 1:15 pm	CAWK01-05 17-Feb-2021 2:00 pm	DWWK67-01 17-Feb-2021 3:00 pm	
Lab Number:		2531414.17	2531414.24	2531414.25	2531414.28	
Individual Tests						
Total Alkalinity	g/m ³ as CaCO ₃	93	49	61	114	-
Carbonate	g/m ³ at 25°C	< 1.0	< 1.0	< 1.0	< 1.0	-
Bicarbonate	g/m ³ at 25°C	112	60	73	139	-
Free Carbon Dioxide	g/m ³ at 25°C	2.7	2.3	1.3	11.8	-
Langelier Saturation Index		-0.1	-0.8	-0.3	-0.6	-
Total Hardness	g/m ³ as CaCO ₃	310	105	122	103	-
Electrical Conductivity (EC)	mS/m	65.6	24.4	29.3	30.9	-
Total Dissolved Solids (TDS)	g/m ³	560	153	188	182	-
Sample Temperature*	°C	20.0	20.0	20.0	20.0	-
Dissolved Calcium	g/m ³	40	16.9	21	25	-
Dissolved Magnesium	g/m ³	51	15.2	16.9	10.0	-
Dissolved Potassium	g/m ³	2.7	1.44	1.79	1.03	-
Dissolved Sodium	g/m ³	15.0	8.7	11.3	23	-
Chloride	g/m ³	8.3	9.2	10.8	29	-
Nitrite-N	g/m ³	< 0.002	< 0.002	< 0.002	< 0.002	-
Nitrate-N	g/m ³	0.003	0.015	0.002	0.004	-
Nitrate-N + Nitrite-N	g/m ³	0.004	0.016	0.003	0.005	-
Sulphate	g/m ³	230	55	66	0.5	-
Heavy metals, dissolved, trace As,Cd,Cr,Cu,Ni,Pb,Zn						
Dissolved Arsenic	g/m ³	0.0015 #1	0.0024 #1	0.0012	< 0.0010	-
Dissolved Cadmium	g/m ³	< 0.00005	< 0.00005	< 0.00005	< 0.00005	-
Dissolved Chromium	g/m ³	< 0.0005	< 0.0005	< 0.0005	< 0.0005	-
Dissolved Copper	g/m ³	< 0.0005	< 0.0005	0.0006 #1	< 0.0005	-
Dissolved Lead	g/m ³	< 0.00010	< 0.00010	< 0.00010	< 0.00010	-
Dissolved Nickel	g/m ³	0.0010	0.0006 #1	< 0.0005	0.0006	-
Dissolved Zinc	g/m ³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	-
Heavy metals, totals, trace As,Cd,Cr,Cu,Ni,Pb,Zn						
Total Arsenic	g/m ³	0.0015	0.0023	0.0013	< 0.0011	-
Total Cadmium	g/m ³	< 0.000053	< 0.000053	< 0.000053	< 0.000053	-
Total Chromium	g/m ³	< 0.00053	< 0.00053	< 0.00053	< 0.00053	-
Total Copper	g/m ³	0.00053	0.00064	0.00058	< 0.00053	-
Total Lead	g/m ³	< 0.00011	< 0.00011	< 0.00011	< 0.00011	-
Total Nickel	g/m ³	0.00107	0.00060	0.00060	0.00057	-
Total Zinc	g/m ³	< 0.0011	< 0.0011	< 0.0011	< 0.0011	-

Analyst's Comments

#1 It has been noted that the result for the dissolved fraction was greater than that for the total fraction, but within analytical variation of the methods.

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively simple matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis. A detection limit range indicates the lowest and highest detection limits in the associated suite of analytes. A full listing of compounds and detection limits are available from the laboratory upon request. Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Soil			
Test	Method Description	Default Detection Limit	Sample No
Heavy Metals, Screen Level	Dried sample, < 2mm fraction. Nitric/Hydrochloric acid digestion US EPA 200.2. Complies with NES Regulations. ICP-MS screen level, interference removal by Kinetic Energy Discrimination if required.	0.10 - 4 mg/kg dry wt	6-7, 29-30
Sample Type: Sediment			
Test	Method Description	Default Detection Limit	Sample No
Environmental Solids Sample Drying*	Air dried at 35°C Used for sample preparation. May contain a residual moisture content of 2-5%.	-	1, 4, 6-7, 10, 14, 16, 18, 23, 26-27, 29-30

Sample Type: Sediment			
Test	Method Description	Default Detection Limit	Sample No
Environmental Solids Sample Preparation	Air dried at 35°C and sieved, <2mm fraction. Used for sample preparation May contain a residual moisture content of 2-5%.	-	1, 4, 10, 14, 16, 18, 23, 26-27, 29-30
Heavy metal screen level As,Cd,Cr,Cu,Ni,Pb,Zn	Dried sample, <2mm fraction. Nitric/Hydrochloric acid digestion, ICP-MS, screen level.	0.10 - 4 mg/kg dry wt	1, 4, 10, 14, 16, 18, 23, 26-27
0.02M potassium dihydrogen ortho-phosphate extraction*	(1:5) ratio of sample (g):0.02M potassium dihydrogen ortho-phosphate extractant (mL), analysis by Ion Chromatography. In House.	-	1, 4, 6-7, 10, 14, 16, 18, 23, 26-27, 29-30
Total Recoverable digestion	Nitric / hydrochloric acid digestion. US EPA 200.2.	-	1, 4, 10, 14, 16, 18, 23, 26-27
Sulphate*	Ion Chromatography determination of a potassium phosphate extract of an environmental solid.	3 mg/kg dry wt	1, 4, 6-7, 10, 14, 16, 18, 23, 26-27, 29-30

Sample Type: Aqueous			
Test	Method Description	Default Detection Limit	Sample No
Heavy metals, dissolved, trace As,Cd,Cr,Cu,Ni,Pb,Zn	0.45µm Filtration, ICP-MS, trace level. APHA 3125 B 23 rd ed. 2017.	0.00005 - 0.0010 g/m ³	2, 5, 9, 13, 15, 17, 24-25, 28
Heavy metals, totals, trace As,Cd,Cr,Cu,Ni,Pb,Zn	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23 rd ed. 2017 / US EPA 200.8.	0.000053 - 0.0011 g/m ³	2, 5, 9, 13, 15, 17, 24-25, 28
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	2, 5, 9, 13, 15, 17, 24-25, 28
Total Digestion	Nitric acid digestion. APHA 3030 E (modified) 23 rd ed. 2017.	-	2, 5, 9, 13, 15, 17, 24-25, 28
Total anions for anion/cation balance check	Calculation: sum of anions as mEq/L calculated from Alkalinity (bicarbonate), Chloride and Sulphate. Nitrate-N, Nitrite-N. Fluoride, Dissolved Reactive Phosphorus and Cyanide also included in calculation if available. APHA 1030 E 23 rd ed. 2017.	0.07 meq/L	2, 5, 9, 13, 15, 17, 24-25, 28
Total cations for anion/cation balance check	Sum of cations as mEq/L calculated from Sodium, Potassium, Calcium and Magnesium. Iron, Manganese, Aluminium, Zinc, Copper, Lithium, Total Ammoniacal-N and pH (H ⁺) also included in calculation if available. APHA 1030 E 23 rd ed. 2017.	0.05 meq/L	2, 5, 9, 13, 15, 17, 24-25, 28
Turbidity	Analysis by Turbidity meter. APHA 2130 B 23 rd ed. 2017 (modified).	0.05 NTU	2, 5, 9, 13, 15, 17, 24-25, 28
pH	pH meter. APHA 4500-H ⁺ B 23 rd ed. 2017. Note: It is not possible to achieve the APHA Maximum Storage Recommendation for this test (15 min) when samples are analysed upon receipt at the laboratory, and not in the field. Samples and Standards are analysed at an equivalent laboratory temperature (typically 18 to 22 °C). Temperature compensation is used.	0.1 pH Units	2, 5, 9, 13, 15, 17, 24-25, 28
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (modified for Alkalinity <20) 23 rd ed. 2017.	1.0 g/m ³ as CaCO ₃	2, 5, 9, 13, 15, 17, 24-25, 28
Carbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO ₂ D 23 rd ed. 2017.	1.0 g/m ³ at 25°C	2, 5, 9, 13, 15, 17, 24-25, 28
Bicarbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO ₂ D 23 rd ed. 2017.	1.0 g/m ³ at 25°C	2, 5, 9, 13, 15, 17, 24-25, 28
Free Carbon Dioxide	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO ₂ D 23 rd ed. 2017.	1.0 g/m ³ at 25°C	2, 5, 9, 13, 15, 17, 24-25, 28

Sample Type: Aqueous			
Test	Method Description	Default Detection Limit	Sample No
Langelier Saturation Index	Calculation: from pH, Total Alkalinity, Ionic Strength, Temperature* and Calcium. This calculation assumes that; 1) the calcium carbonate is in the form of calcite, 2) the effects associated with calcium ion pairs are negligible and 3) and the effect of alkalinity contributed or consumed by species other than HCO_3^-, CO_3^{2-}, OH^- and H^+ is not significant. *Note: For accurate calculation of the Langelier Saturation Index (LSI), the sample temperature should be taken using a calibrated thermometer at the time of sampling and recorded on the paperwork submitted with the sample. If a sample temperature is not supplied, a nominal temperature of 20°C will show in the results table above and be used in the calculation. In this case, please interpret the LSI result with caution. APHA 2330 B 23rd ed. 2017.	-	2, 5, 9, 13, 15, 17, 24-25, 28
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 23 rd ed. 2017.	1.0 g/m ³ as CaCO_3	2, 5, 9, 13, 15, 17, 24-25, 28
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 23 rd ed. 2017.	0.1 mS/m	2, 5, 9, 13, 15, 17, 24-25, 28
Total Dissolved Solids (TDS)	Filtration through GF/C (1.2 µm), gravimetric. APHA 2540 C (modified; drying temperature of 103 - 105°C used rather than 180 ± 2°C) 23 rd ed. 2017.	10 g/m ³	2, 5, 9, 13, 15, 17, 24-25, 28
Sample Temperature*	A nominal sample temperature of 20°C has been assumed by the laboratory.	0.1 °C	2, 5, 9, 13, 15, 17, 24-25, 28
Filtration for dissolved metals analysis	Sample filtration through 0.45µm membrane filter and preservation with nitric acid. APHA 3030 B 23 rd ed. 2017.	-	2, 5, 9, 13, 15, 17, 24-25, 28
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 23 rd ed. 2017.	0.05 g/m ³	2, 5, 9, 13, 15, 17, 24-25, 28
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 23 rd ed. 2017.	0.02 g/m ³	2, 5, 9, 13, 15, 17, 24-25, 28
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 23 rd ed. 2017.	0.05 g/m ³	2, 5, 9, 13, 15, 17, 24-25, 28
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 23 rd ed. 2017.	0.02 g/m ³	2, 5, 9, 13, 15, 17, 24-25, 28
Chloride	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 23 rd ed. 2017.	0.5 g/m ³	2, 5, 9, 13, 15, 17, 24-25, 28
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500- NO_3^- I (modified) 23 rd ed. 2017.	0.002 g/m ³	2, 5, 9, 13, 15, 17, 24-25, 28
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO_2N . In-House.	0.0010 g/m ³	2, 5, 9, 13, 15, 17, 24-25, 28
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500- NO_3^- I (modified) 23 rd ed. 2017.	0.002 g/m ³	2, 5, 9, 13, 15, 17, 24-25, 28
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 23 rd ed. 2017.	0.5 g/m ³	2, 5, 9, 13, 15, 17, 24-25, 28

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Testing was completed between 18-Feb-2021 and 25-Feb-2021. For completion dates of individual analyses please contact the laboratory.

Samples are held at the laboratory after reporting for a length of time based on the stability of the samples and analytes being tested (considering any preservation used), and the storage space available. Once the storage period is completed, the samples are discarded unless otherwise agreed with the customer. Extended storage times may incur additional charges.

This certificate of analysis must not be reproduced, except in full, without the written consent of the signatory.

A handwritten signature in blue ink, consisting of a large stylized 'K' followed by the name 'Harrison' in a cursive script.

Kim Harrison MSc
Client Services Manager - Environmental



Certificate of Analysis

Page 1 of 7

Client:	Tonkin & Taylor	Lab No:	2530174	SPv4
Contact:	Natalie O'Rourke C/- Tonkin & Taylor PO Box 5271 Auckland 1141	Date Received:	17-Feb-2021	
		Date Reported:	25-Feb-2021	
		Quote No:	109816	
		Order No:	1016715	
		Client Reference:	1016715	
		Submitted By:	Lewis Black	

Sample Type: Sediment

Sample Name:	DWWK 67-70 16-Feb-2021 9:45 am	DWWK 65-53 16-Feb-2021 10:00 am	DWWK 65-52 16-Feb-2021 11:55 am	DWWK 65-51 16-Feb-2021 12:00 pm	DWWK 65-54 16-Feb-2021 12:10 pm
Lab Number:	2530174.6	2530174.7	2530174.10	2530174.11	2530174.12

Individual Tests

Sulphate*	mg/kg dry wt	148	155	55	240	18
Heavy metal screen level As,Cd,Cr,Cu,Ni,Pb,Zn						
Total Recoverable Arsenic	mg/kg dry wt	< 4	15	11	31	9
Total Recoverable Cadmium	mg/kg dry wt	< 0.19	< 0.10	0.29	0.15	< 0.10
Total Recoverable Chromium	mg/kg dry wt	6	2	< 2	5	14
Total Recoverable Copper	mg/kg dry wt	4	12	11	20	17
Total Recoverable Lead	mg/kg dry wt	7.7	6.0	10.4	16.8	13.3
Total Recoverable Nickel	mg/kg dry wt	< 4	8	5	11	11
Total Recoverable Zinc	mg/kg dry wt	33	35	210	89	48

Sample Name:	DWWK 66-51 16-Feb-2021 12:20 pm	DWWK 67-54 16-Feb-2021 1:20 pm	DWWK 67-54 b 16-Feb-2021 1:35 pm	CAWK 01-53 16-Feb-2021	DUPLICATE S1 16-Feb-2021
Lab Number:	2530174.15	2530174.16	2530174.17	2530174.18	2530174.25

Individual Tests

Sulphate*	mg/kg dry wt	940	10	15	< 3	4
Heavy metal screen level As,Cd,Cr,Cu,Ni,Pb,Zn						
Total Recoverable Arsenic	mg/kg dry wt	10	5	5	4	5
Total Recoverable Cadmium	mg/kg dry wt	0.4	< 0.10	< 0.10	< 0.10	< 0.10
Total Recoverable Chromium	mg/kg dry wt	10	5	5	4	3
Total Recoverable Copper	mg/kg dry wt	21	7	8	8	5
Total Recoverable Lead	mg/kg dry wt	10.0	4.3	4.5	5.3	3.5
Total Recoverable Nickel	mg/kg dry wt	9	7	7	7	5
Total Recoverable Zinc	mg/kg dry wt	92	27	28	26	17

Sample Name:	DWWK 67-55 16-Feb-2021 1:55 pm	CAWK 01-51 16-Feb-2021 2:20 pm	CAWK 01-52 16-Feb-2021 3:30 pm		
Lab Number:	2530174.26	2530174.28	2530174.30		

Individual Tests

Sulphate*	mg/kg dry wt	7	< 3	10	-	-
Heavy metal screen level As,Cd,Cr,Cu,Ni,Pb,Zn						
Total Recoverable Arsenic	mg/kg dry wt	4	6	6	-	-
Total Recoverable Cadmium	mg/kg dry wt	< 0.10	< 0.10	< 0.10	-	-
Total Recoverable Chromium	mg/kg dry wt	3	4	5	-	-
Total Recoverable Copper	mg/kg dry wt	5	6	9	-	-
Total Recoverable Lead	mg/kg dry wt	2.6	3.9	4.8	-	-
Total Recoverable Nickel	mg/kg dry wt	4	7	8	-	-
Total Recoverable Zinc	mg/kg dry wt	18	21	25	-	-



This Laboratory is accredited by International Accreditation New Zealand (IANZ), which represents New Zealand in the International Laboratory Accreditation Cooperation (ILAC). Through the ILAC Mutual Recognition Arrangement (ILAC-MRA) this accreditation is internationally recognised. The tests reported herein have been performed in accordance with the terms of accreditation, with the exception of tests marked * or any comments and interpretations, which are not accredited.

Sample Type: Sludge						
Sample Name:	DWWK 14-50 16-Feb-2021 11:30 am					
Lab Number:	2530174.8					
Individual Tests						
Sulphate*	mg/kg dry wt	220	-	-	-	-
Heavy metal screen level As,Cd,Cr,Cu,Ni,Pb,Zn						
Total Recoverable Arsenic	mg/kg dry wt	50	-	-	-	-
Total Recoverable Cadmium	mg/kg dry wt	0.19	-	-	-	-
Total Recoverable Chromium	mg/kg dry wt	13	-	-	-	-
Total Recoverable Copper	mg/kg dry wt	28	-	-	-	-
Total Recoverable Lead	mg/kg dry wt	17.3	-	-	-	-
Total Recoverable Nickel	mg/kg dry wt	25	-	-	-	-
Total Recoverable Zinc	mg/kg dry wt	110	-	-	-	-

Sample Type: Aqueous						
Sample Name:	DWWK 65-03 16-Feb-2021 9:50 am	DWWK 65-2 16-Feb-2021 9:55 am	DWWK 65-04 16-Feb-2021 10:00 am	DWWK 65-1 16-Feb-2021 10:05 am	DWWK 67-20 16-Feb-2021 9:45 am	
Lab Number:	2530174.1	2530174.2	2530174.3	2530174.4	2530174.5	
Individual Tests						
Sum of Anions	meq/L	2.8	2.6	2.6	2.5	2.5
Sum of Cations	meq/L	2.7	2.6	2.6	2.6	2.5
Turbidity	NTU	0.54	0.66	0.85	0.63	28
pH	pH Units	7.7	7.6	7.4	7.7	7.3
Total Alkalinity	g/m ³ as CaCO ₃	71	67	63	66	68
Carbonate	g/m ³ at 25°C	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Bicarbonate	g/m ³ at 25°C	86	82	77	80	83
Free Carbon Dioxide	g/m ³ at 25°C	3.0	3.1	4.7	2.5	6.8
Langelier Saturation Index		-0.6	-0.6	-1.0	-0.5	-0.9
Total Hardness	g/m ³ as CaCO ₃	103	103	60	103	101
Electrical Conductivity (EC)	mS/m	28.6	27.5	28.5	25.7	25.3
Total Dissolved Solids (TDS)	g/m ³	177	167	163	178	160
Sample Temperature*	°C	20.0	20.0	20.0	20.0	20.0
Dissolved Calcium	g/m ³	19.9	20	13.4	20	20
Dissolved Magnesium	g/m ³	12.8	12.8	6.5	12.7	12.3
Dissolved Potassium	g/m ³	1.58	1.58	2.0	1.62	1.77
Dissolved Sodium	g/m ³	14.4	12.0	32	10.7	11.0
Chloride	g/m ³	16.2	14.6	41	13.7	11.9
Nitrite-N	g/m ³	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Nitrate-N	g/m ³	0.005	0.022	0.005	0.026	0.008
Nitrate-N + Nitrite-N	g/m ³	0.005	0.022	0.005	0.027	0.009
Sulphate	g/m ³	43	41	10.3	40	38
Heavy metals, dissolved, trace As,Cd,Cr,Cu,Ni,Pb,Zn						
Dissolved Arsenic	g/m ³	< 0.0010	< 0.0010	0.0011 #1	< 0.0010	< 0.0010
Dissolved Cadmium	g/m ³	< 0.00005	< 0.00005	< 0.00005	< 0.00005	< 0.00005
Dissolved Chromium	g/m ³	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Dissolved Copper	g/m ³	0.0005	< 0.0005	0.0008	< 0.0005	< 0.0005
Dissolved Lead	g/m ³	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010
Dissolved Nickel	g/m ³	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Dissolved Zinc	g/m ³	< 0.0010	< 0.0010	< 0.0010	0.0046 #1	< 0.0010
Heavy metals, totals, trace As,Cd,Cr,Cu,Ni,Pb,Zn						
Total Arsenic	g/m ³	< 0.0011	< 0.0011	< 0.0011	< 0.0011	< 0.0011
Total Cadmium	g/m ³	< 0.000053	< 0.000053	< 0.000053	< 0.000053	< 0.000053
Total Chromium	g/m ³	< 0.00053	< 0.00053	< 0.00053	< 0.00053	0.00075
Total Copper	g/m ³	0.00060	< 0.00053	0.00085	< 0.00053	0.00092
Total Lead	g/m ³	< 0.00011	< 0.00011	< 0.00011	< 0.00011	0.00088
Total Nickel	g/m ³	< 0.00053	< 0.00053	< 0.00053	< 0.00053	0.00085
Total Zinc	g/m ³	< 0.0011	< 0.0011	< 0.0011	< 0.0011	0.0036

Sample Type: Aqueous						
Sample Name:		DWWK 67-04 16-Feb-2021 10:45 am	DUPLICATE 1 16-Feb-2021 10:45 am	DWWK 66-01 16-Feb-2021 12:20 pm	CAWK 01-03 16-Feb-2021	CAWK 01-02 16-Feb-2021
Lab Number:		2530174.9	2530174.13	2530174.14	2530174.19	2530174.20
Individual Tests						
Sum of Anions	meq/L	2.5	2.4	2.7	2.1	2.8
Sum of Cations	meq/L	2.5	2.5	2.8	2.1	2.9
Turbidity	NTU	0.61	0.61	10.0	0.81	0.30
pH	pH Units	7.6	7.6	7.7	7.8	7.9
Total Alkalinity	g/m ³ as CaCO ₃	70	69	70	83	60
Carbonate	g/m ³ at 25°C	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Bicarbonate	g/m ³ at 25°C	85	84	84	100	73
Free Carbon Dioxide	g/m ³ at 25°C	3.3	3.2	2.7	2.8	1.7
Langelier Saturation Index		-0.6	-0.6	-0.5	-0.3	-0.4
Total Hardness	g/m ³ as CaCO ₃	100	102	105	83	118
Electrical Conductivity (EC)	mS/m	25.0	24.9	27.6	20.3	29.1
Total Dissolved Solids (TDS)	g/m ³	141	155	171	112	175
Sample Temperature*	°C	20.0	20.0	20.0	20.0	20.0
Dissolved Calcium	g/m ³	20	21	21	21	20
Dissolved Magnesium	g/m ³	12.1	12.2	12.9	7.4	16.5
Dissolved Potassium	g/m ³	1.57	1.58	1.73	1.40	1.72
Dissolved Sodium	g/m ³	10.5	10.3	14.5	10.1	10.7
Chloride	g/m ³	11.7	12.0	16.0	13.0	10.2
Nitrite-N	g/m ³	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Nitrate-N	g/m ³	0.029	0.028	0.008	0.009	0.010
Nitrate-N + Nitrite-N	g/m ³	0.030	0.029	0.009	0.010	0.010
Sulphate	g/m ³	35	34	41	3.0	65
Heavy metals, dissolved, trace As,Cd,Cr,Cu,Ni,Pb,Zn						
Dissolved Arsenic	g/m ³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	0.0011
Dissolved Cadmium	g/m ³	< 0.00005	< 0.00005	< 0.00005	< 0.00005	< 0.00005
Dissolved Chromium	g/m ³	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Dissolved Copper	g/m ³	< 0.0005	< 0.0005	0.0009	< 0.0005	0.0006
Dissolved Lead	g/m ³	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010
Dissolved Nickel	g/m ³	< 0.0005	< 0.0005	< 0.0005	< 0.0005	0.0005
Dissolved Zinc	g/m ³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Heavy metals, totals, trace As,Cd,Cr,Cu,Ni,Pb,Zn						
Total Arsenic	g/m ³	< 0.0011	< 0.0011	< 0.0011	< 0.0011	0.0013
Total Cadmium	g/m ³	< 0.000053	< 0.000053	< 0.000053	< 0.000053	< 0.000053
Total Chromium	g/m ³	< 0.00053	< 0.00053	< 0.00053	< 0.00053	< 0.00053
Total Copper	g/m ³	0.00054	< 0.00053	0.00168	< 0.00053	0.00067
Total Lead	g/m ³	< 0.00011	< 0.00011	< 0.00011	< 0.00011	< 0.00011
Total Nickel	g/m ³	< 0.00053	0.00056	0.00055	< 0.00053	0.00056
Total Zinc	g/m ³	< 0.0011	< 0.0011	< 0.0011	< 0.0011	< 0.0011
Sample Name:		DUPLICATE 2 16-Feb-2021	DWWK 67-05 16-Feb-2021 1:55 pm	CAWK 01-01 16-Feb-2021 2:21 pm		
Lab Number:		2530174.21	2530174.27	2530174.29		
Individual Tests						
Sum of Anions	meq/L	2.8	2.5	2.4	-	-
Sum of Cations	meq/L	3.0	2.5	2.5	-	-
Turbidity	NTU	0.29	0.57	0.72	-	-
pH	pH Units	7.8	7.8	7.7	-	-
Total Alkalinity	g/m ³ as CaCO ₃	60	70	71	-	-
Carbonate	g/m ³ at 25°C	< 1.0	< 1.0	< 1.0	-	-
Bicarbonate	g/m ³ at 25°C	73	85	86	-	-
Free Carbon Dioxide	g/m ³ at 25°C	1.8	2.4	2.7	-	-
Langelier Saturation Index		-0.5	-0.4	-0.5	-	-
Total Hardness	g/m ³ as CaCO ₃	122	100	100	-	-
Electrical Conductivity (EC)	mS/m	29.3	24.7	24.5	-	-

Sample Type: Aqueous						
Sample Name:		DUPLICATE 2 16-Feb-2021	DWWK 67-05 16-Feb-2021 1:55 pm	CAWK 01-01 16-Feb-2021 2:21 pm		
Lab Number:		2530174.21	2530174.27	2530174.29		
Individual Tests						
Total Dissolved Solids (TDS)	g/m ³	190	162	145	-	-
Sample Temperature*	°C	20.0	20.0	20.0	-	-
Dissolved Calcium	g/m ³	21	20	20	-	-
Dissolved Magnesium	g/m ³	17.0	12.0	12.1	-	-
Dissolved Potassium	g/m ³	1.76	1.54	1.56	-	-
Dissolved Sodium	g/m ³	11.0	10.1	10.3	-	-
Chloride	g/m ³	10.8	11.6	11.4	-	-
Nitrite-N	g/m ³	< 0.002	< 0.002	< 0.002	-	-
Nitrate-N	g/m ³	0.006	0.019	0.045	-	-
Nitrate-N + Nitrite-N	g/m ³	0.007	0.020	0.046	-	-
Sulphate	g/m ³	64	35	33	-	-
Heavy metals, dissolved, trace As,Cd,Cr,Cu,Ni,Pb,Zn						
Dissolved Arsenic	g/m ³	0.0011	< 0.0010	< 0.0010	-	-
Dissolved Cadmium	g/m ³	< 0.00005	< 0.00005	< 0.00005	-	-
Dissolved Chromium	g/m ³	< 0.0005	< 0.0005	< 0.0005	-	-
Dissolved Copper	g/m ³	0.0006	< 0.0005	0.0005	-	-
Dissolved Lead	g/m ³	< 0.00010	< 0.00010	< 0.00010	-	-
Dissolved Nickel	g/m ³	0.0005	< 0.0005	< 0.0005	-	-
Dissolved Zinc	g/m ³	< 0.0010	< 0.0010	< 0.0010	-	-
Heavy metals, totals, trace As,Cd,Cr,Cu,Ni,Pb,Zn						
Total Arsenic	g/m ³	0.0013	< 0.0011	< 0.0011	-	-
Total Cadmium	g/m ³	< 0.000053	< 0.000053	< 0.000053	-	-
Total Chromium	g/m ³	< 0.00053	< 0.00053	< 0.00053	-	-
Total Copper	g/m ³	0.00067	< 0.00053	< 0.00053	-	-
Total Lead	g/m ³	< 0.00011	< 0.00011	< 0.00011	-	-
Total Nickel	g/m ³	0.00056	< 0.00053	< 0.00053	-	-
Total Zinc	g/m ³	< 0.0011	< 0.0011	< 0.0011	-	-

Analyst's Comments

#1 It has been noted that the result for the dissolved fraction was greater than that for the total fraction, but within analytical variation of the methods.

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively simple matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis. A detection limit range indicates the lowest and highest detection limits in the associated suite of analytes. A full listing of compounds and detection limits are available from the laboratory upon request. Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Sediment			
Test	Method Description	Default Detection Limit	Sample No
Environmental Solids Sample Drying*	Air dried at 35°C Used for sample preparation. May contain a residual moisture content of 2-5%.	-	6-8, 10-12, 15-18, 25-26, 28, 30
Environmental Solids Sample Preparation	Air dried at 35°C and sieved, <2mm fraction. Used for sample preparation May contain a residual moisture content of 2-5%.	-	6-8, 10-12, 15-18, 25-26, 28, 30
Heavy metal screen level As,Cd,Cr,Cu,Ni,Pb,Zn	Dried sample, <2mm fraction. Nitric/Hydrochloric acid digestion, ICP-MS, screen level.	0.10 - 4 mg/kg dry wt	6-8, 10-12, 15-18, 25-26, 28, 30
0.02M potassium dihydrogen ortho-phosphate extraction*	(1:5) ratio of sample (g):0.02M potassium dihydrogen ortho-phosphate extractant (mL), analysis by Ion Chromatography. In House.	-	6-8, 10-12, 15-18, 25-26, 28, 30
Total Recoverable digestion	Nitric / hydrochloric acid digestion. US EPA 200.2.	-	6-8, 10-12, 15-18, 25-26, 28, 30

Sample Type: Sediment			
Test	Method Description	Default Detection Limit	Sample No
Sulphate*	Ion Chromatography determination of a potassium phosphate extract of an environmental solid.	3 mg/kg dry wt	6-8, 10-12, 15-18, 25-26, 28, 30
Sample Type: Aqueous			
Test	Method Description	Default Detection Limit	Sample No
Heavy metals, dissolved, trace As,Cd,Cr,Cu,Ni,Pb,Zn	0.45µm Filtration, ICP-MS, trace level. APHA 3125 B 23 rd ed. 2017.	0.00005 - 0.0010 g/m ³	1-5, 9, 13-14, 19-21, 27, 29
Heavy metals, totals, trace As,Cd,Cr,Cu,Ni,Pb,Zn	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23 rd ed. 2017 / US EPA 200.8.	0.000053 - 0.0011 g/m ³	1-5, 9, 13-14, 19-21, 27, 29
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1-5, 9, 13-14, 19-21, 27, 29
Total Digestion	Nitric acid digestion. APHA 3030 E (modified) 23 rd ed. 2017.	-	1-5, 9, 13-14, 19-21, 27, 29
Total anions for anion/cation balance check	Calculation: sum of anions as mEq/L calculated from Alkalinity (bicarbonate), Chloride and Sulphate. Nitrate-N, Nitrite-N. Fluoride, Dissolved Reactive Phosphorus and Cyanide also included in calculation if available. APHA 1030 E 23 rd ed. 2017.	0.07 meq/L	1-5, 9, 13-14, 19-21, 27, 29
Total cations for anion/cation balance check	Sum of cations as mEq/L calculated from Sodium, Potassium, Calcium and Magnesium. Iron, Manganese, Aluminium, Zinc, Copper, Lithium, Total Ammoniacal-N and pH (H ⁺) also included in calculation if available. APHA 1030 E 23 rd ed. 2017.	0.05 meq/L	1-5, 9, 13-14, 19-21, 27, 29
Turbidity	Analysis by Turbidity meter. APHA 2130 B 23 rd ed. 2017 (modified).	0.05 NTU	1-5, 9, 13-14, 19-21, 27, 29
pH	pH meter. APHA 4500-H ⁺ B 23 rd ed. 2017. Note: It is not possible to achieve the APHA Maximum Storage Recommendation for this test (15 min) when samples are analysed upon receipt at the laboratory, and not in the field. Samples and Standards are analysed at an equivalent laboratory temperature (typically 18 to 22 °C). Temperature compensation is used.	0.1 pH Units	1-5, 9, 13-14, 19-21, 27, 29
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (modified for Alkalinity <20) 23 rd ed. 2017.	1.0 g/m ³ as CaCO ₃	1-5, 9, 13-14, 19-21, 27, 29
Carbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO ₂ D 23 rd ed. 2017.	1.0 g/m ³ at 25°C	1-5, 9, 13-14, 19-21, 27, 29
Bicarbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO ₂ D 23 rd ed. 2017.	1.0 g/m ³ at 25°C	1-5, 9, 13-14, 19-21, 27, 29
Free Carbon Dioxide	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO ₂ D 23 rd ed. 2017.	1.0 g/m ³ at 25°C	1-5, 9, 13-14, 19-21, 27, 29

Sample Type: Aqueous			
Test	Method Description	Default Detection Limit	Sample No
Langelier Saturation Index	Calculation: from pH, Total Alkalinity, Ionic Strength, Temperature* and Calcium. This calculation assumes that; 1) the calcium carbonate is in the form of calcite, 2) the effects associated with calcium ion pairs are negligible and 3) and the effect of alkalinity contributed or consumed by species other than HCO_3^-, CO_3^{2-}, OH^- and H^+ is not significant. *Note: For accurate calculation of the Langelier Saturation Index (LSI), the sample temperature should be taken using a calibrated thermometer at the time of sampling and recorded on the paperwork submitted with the sample. If a sample temperature is not supplied, a nominal temperature of 20°C will show in the results table above and be used in the calculation. In this case, please interpret the LSI result with caution. APHA 2330 B 23rd ed. 2017.	-	1-5, 9, 13-14, 19-21, 27, 29
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 23 rd ed. 2017.	1.0 g/m ³ as CaCO_3	1-5, 9, 13-14, 19-21, 27, 29
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 23 rd ed. 2017.	0.1 mS/m	1-5, 9, 13-14, 19-21, 27, 29
Total Dissolved Solids (TDS)	Filtration through GF/C (1.2 µm), gravimetric. APHA 2540 C (modified; drying temperature of 103 - 105°C used rather than 180 ± 2°C) 23 rd ed. 2017.	10 g/m ³	1-5, 9, 13-14, 19-21, 27, 29
Sample Temperature*	A nominal sample temperature of 20°C has been assumed by the laboratory.	0.1 °C	1-5, 9, 13-14, 19-21, 27, 29
Filtration for dissolved metals analysis	Sample filtration through 0.45µm membrane filter and preservation with nitric acid. APHA 3030 B 23 rd ed. 2017.	-	1-5, 9, 13-14, 19-21, 27, 29
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 23 rd ed. 2017.	0.05 g/m ³	1-5, 9, 13-14, 19-21, 27, 29
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 23 rd ed. 2017.	0.02 g/m ³	1-5, 9, 13-14, 19-21, 27, 29
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 23 rd ed. 2017.	0.05 g/m ³	1-5, 9, 13-14, 19-21, 27, 29
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 23 rd ed. 2017.	0.02 g/m ³	1-5, 9, 13-14, 19-21, 27, 29
Chloride	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 23 rd ed. 2017.	0.5 g/m ³	1-5, 9, 13-14, 19-21, 27, 29
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500- NO_3^- I (modified) 23 rd ed. 2017.	0.002 g/m ³	1-5, 9, 13-14, 19-21, 27, 29
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO_2N . In-House.	0.0010 g/m ³	1-5, 9, 13-14, 19-21, 27, 29
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500- NO_3^- I (modified) 23 rd ed. 2017.	0.002 g/m ³	1-5, 9, 13-14, 19-21, 27, 29
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 23 rd ed. 2017.	0.5 g/m ³	1-5, 9, 13-14, 19-21, 27, 29

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Testing was completed between 17-Feb-2021 and 25-Feb-2021. For completion dates of individual analyses please contact the laboratory.

Samples are held at the laboratory after reporting for a length of time based on the stability of the samples and analytes being tested (considering any preservation used), and the storage space available. Once the storage period is completed, the samples are discarded unless otherwise agreed with the customer. Extended storage times may incur additional charges.

This certificate of analysis must not be reproduced, except in full, without the written consent of the signatory.

A handwritten signature in blue ink, consisting of a large 'K' followed by the name 'Harrison' in a cursive script.

Kim Harrison MSc
Client Services Manager - Environmental

Appendix E: Surface water mass balance calculations letter report

Dunedin City Council
Delivered via email

Attention: Simon Drew

Dear Simon

Waikouaiti River - Surface water mass balance calculations

1 Purpose and objective

This report describes the surface water mass balances undertaken to establish whether landuse activities and the operation of the Oceania Gold site might be a significant source of lead in the Waikouaiti River catchment, and in particular a risk to the Waikouaiti water treatment plant (WTP) raw water.

The river reach of interest is shown below.

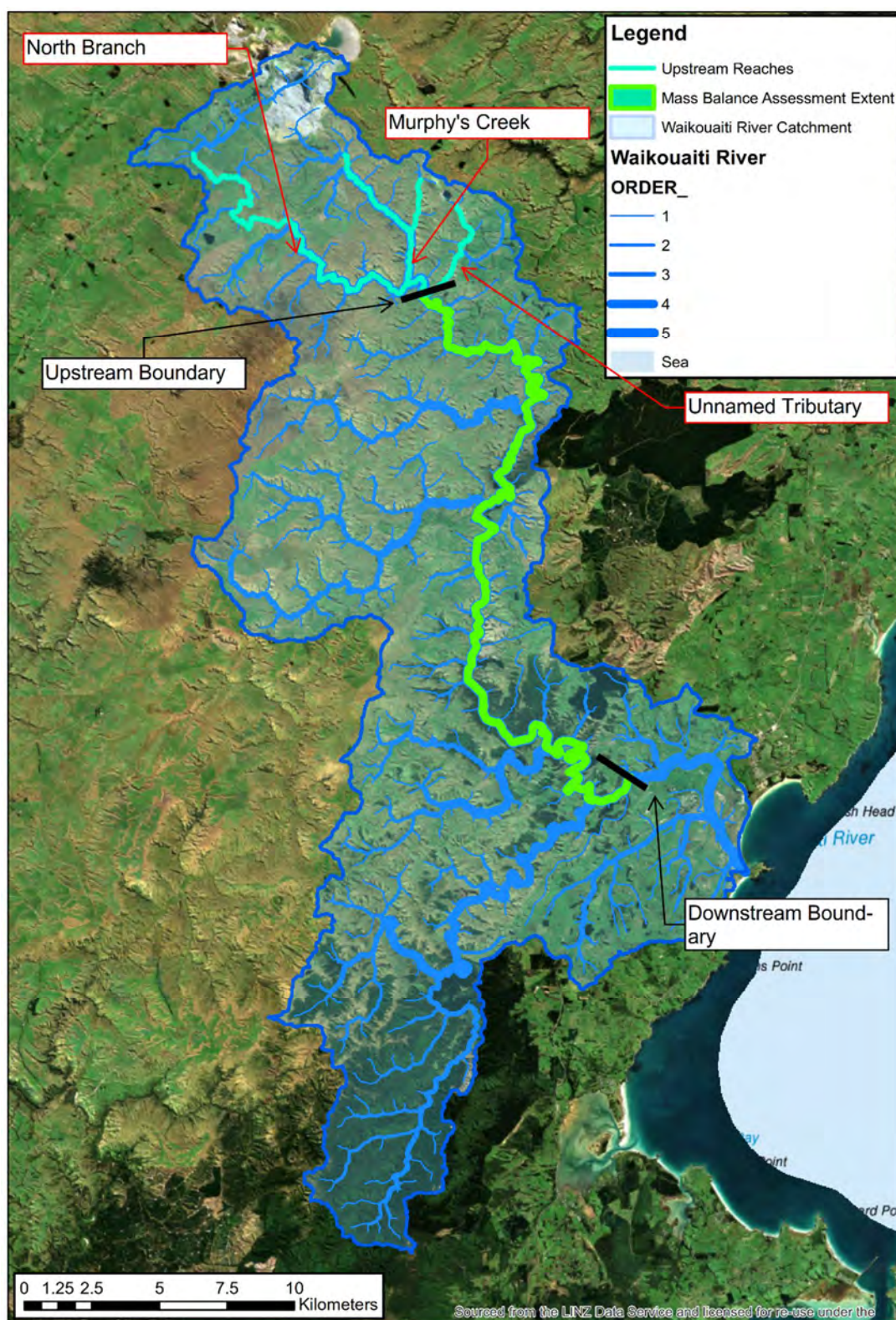


Figure 1.1: Waikouaiti River reach used for mass balances

2 Methodology

To obtain an estimate of the water quality that could be expected at the Waikouaiti WTP intake, a simplified set of QUAL2Kw¹ mass balance equations was configured and solved for the Waikouaiti River. The equations and boundary conditions were schematised and configured based upon best available data and information. Based upon available water quality and hydrological data a series of scenarios were developed to assess the impact of lead discharges from the headwaters of the Waikouaiti River catchment, these are detailed further in section 2.5.

2.1 Model description

QUAL2Kw is a stream water quality modelling framework developed by the Washington Department of Ecology and Tufts University for rivers and streams. In particular, the model can account for the effects of point and non-point source discharges on the river water quality. The model is spreadsheet-based and allows for steady-state, one-dimensional calculation of a range of water quality parameters.

2.2 Model assumptions

The following model assumptions were adopted:

- Lead was treated as conservative (i.e., no settlement, adsorption, or changes in fraction downstream)
- No other sources of lead from non-point or point sources downstream of the unnamed tributary inflow
- A steady state condition was assumed
- The model is one-dimensional

For the purposes of our preliminary assessment and paucity of data we considered these assumptions appropriate.

2.3 Model Limitations

It is noted that the model is based on 109 data points (NB01 and NB02) over a seventeen-year period as provided by Dunedin City Council. This implies that the model is representative of only a very small percentage of time and water quality chemistry in the river. Outputs and findings based on these should therefore be treated with an appropriate degree of caution. Even a longer grab sample record may not be sufficient if it does not capture specific events or is not associated with a specific point on the flow hydrograph.

Continuous simulation of water quality would be the preferred approach but would not be appropriate in this case due to the paucity of available data.

2.4 Catchment schematisation and Data Sources

The Waikouaiti River was divided into 60 segments with a point discharge into segment 2. The upstream boundary was defined as the confluence of the North Branch and Murphy's Creek. The downstream boundary is defined as the raw water intake for the Waikouaiti WTP. Between the unnamed tributary (point discharge) and the WTP abstraction, tributary flows were added as non-point source inflows. Non-point source discharges were assumed to be lead free since the analysis was focused on the potential effect of the Oceana Gold discharge(s) only (see Figure 2.1).

¹ QUAL2Kw has been developed under a collaboration agreement between the USEPA and Tufts University and is used mainly to assist in Total Maximum Daily Load (TMDL) analysis.

2.4.1 Data sources

2.4.2 Flow data

Flows to define the hydrological boundary conditions and Conservative scenarios were sourced from NIWA's New Zealand River Maps² while flood flows for the Median and 'Best case' scenarios were sourced from NIWA's New Zealand Flood Statistics Maps³. The values used are tabulated below.

Table 2.1: Flows used for mass balance scenarios

Scenario	Flows (m ³ /s)		
	Headwater (Murphy's Creek + North Branch) (NZ Segment 14249307)	Unnamed tributary (NZ Segments 14248354)	Non-point discharge (NZ Segments 14249307 and 14261605)
Conservative (low flow) scenarios	• 0.0885¹ • 0.1317²	• 0.0060¹ • 0.0102²	• 0.1710¹ • 0.3345²
Median case scenario	0.3345	0.0241	1.1533
'Best case' (high flow) scenarios	• 41.96³ • 79.69⁴	• 8.23³ • 15.33⁴	• 88.04³ • 152.31⁴

1 1 in 5-year low flow

2 Mean Annual Low Flow (MALF)

3 Mean Annual Flood (MAF)

4 5-year ARI flood event

2.4.3 Water quality data

Water quality data in an upstream river where Oceania Gold activities are present were supplied by Dunedin City Council. These data indicated a highest lead concentration of 0.017 mg/L (dissolved) and the lowest pH of 3.5. The pH of 3.5 has been disputed by Oceania Gold and has been treated with caution in this analysis and subsequent conclusions. Apart from the one 3.5 pH value, all other pH measurements were above 6.5.

A constant lead concentration of 0.002 mg/L was used for the headwater stream input. The boundary concentration of 0.017 mg/L is considered conservative since it represents the worst measurement in the catchment of the unnamed tributary and was likely to be diluted when entering the unnamed tributary before eventual discharge to the Waikouaiti River.

² [NZ River Maps \(niwa.co.nz\)](https://niwa.co.nz)

³ [ArcGIS - NZ Flood Statistics Henderson Collins V2 Layer](#)

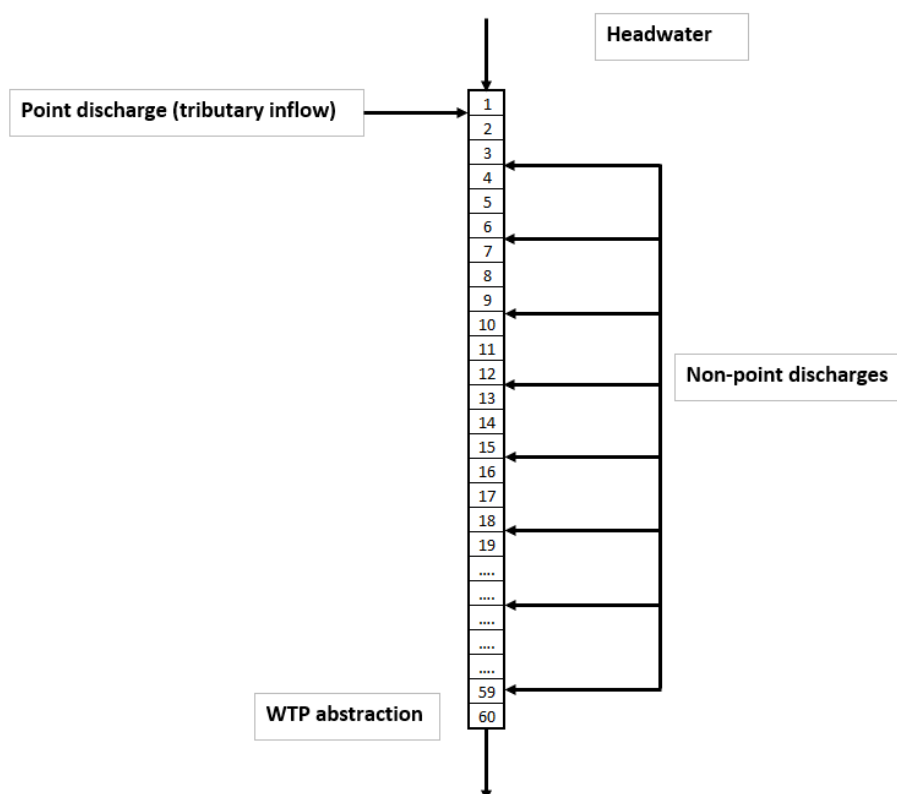


Figure 2.1: QUAL2Kw Schematisation for the Waikouaiti River

2.5 Simulation matrix

To cover a range of both flow conditions and lead concentrations discharging from the upper catchment, several scenarios were constructed. These are as listed in the table below.

Table 2.2: Scenarios defined for mass balance simulations.

Scenario	Description	
	Flow in system	Water quality in Unnamed tributary
Conservative (low flow) scenarios	1 in 5-year low flow in system - Mean Annual Low Flow (MALF) in system	Highest lead concentration and lowest pH on record for the unnamed tributary
Median case scenario	Median flows in system	Highest lead concentration on record for the unnamed tributary
'Best case' (high flow) scenarios	- Mean Annual Flood (MAF) event 5-year Average Recurrence Interval (ARI) flood event	Highest lead concentration on record for the unnamed tributary

3 Simulation outputs

Results for the Conservative scenarios showed that lead concentrations at the WTP abstraction point were approximately 0.001 mg/L, well below the Maximum Acceptable Value (MAV) of 0.01 mg/L for lead. The pH of 3.5 also recovers within the first 10 km downstream of the Unnamed tributary discharge to above 7 (See Appendix A).

For the Median and 'Best case' scenarios the lead concentration at the WTP abstraction point remained at about 0.0017 mg/L, also well below the MAV value for lead.

A summary of results is presented below. It is noted that slightly higher lead concentrations at the WTP abstraction for the 'Best case' scenario is due to a higher mass loading (lead concentration x flowrate) from the upstream boundary conditions.

Table 3.1: Summary of results for the scenarios

	Conservative scenarios	Median case scenario	'Best case' scenarios
Headwater lead concentration	0.002	0.002	0.002
Unnamed Tributary concentration	0.017	0.017	0.017
WTP abstraction concentration	· 0.0011¹ · 0.0009²	0.0007	· 0.0016³ · 0.0017⁴

1 1 in 5-year low flow

2 MALF

3 MAF

4 5-year ARI flood event

4 Conclusions

The simple mass balance conducted shows that – based on the very limited data that we have - there is no evidence to indicate that under worst case calculations, discharges from Oceania Gold could lead to concentrations of lead at the water intake that have been experienced. However, the very small data set is only representative of a small fraction of the overall long-term picture and does not account for more complex catchment and chemical processes.

5 Recommendations

Based on the results and conclusions it is recommended that more frequent monitoring of lead (both dissolved and total) and pH is undertaken at the existing compliance sites for a range of different flow conditions so that a more complete picture of the discharge water quality can be formed. If high lead concentrations occur regularly in the frequent sampling programme, then a more detailed modelling study can be undertaken.

6 Applicability

This report has been prepared for the exclusive use of our client Dunedin City Council, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

COVID-19 impacts: The derived rates are based on information and data obtained prior to COVID-19 being declared a pandemic by the World Health Organisation. New Zealand subsequently entering COVID-19 Alert Level 4 “lockdown” plus the global economic impacts of COVID-19 will have an impact on the construction industry in at least the immediate and medium-term future. The significance and extent of COVID-19 impacts are uncertain at this time but likely to impact both labour and materials rates.

We have not made any attempt to allow for the impact of COVID-19 in this estimate and recommend you seek specialist economic advice on what budgetary allowances you should make for escalation and changed construction costs post COVID-19.

Tonkin & Taylor Ltd

Environmental and Engineering Consultants

Report prepared by:



Wageed Kamish
Senior Water Resources Engineer

Authorised for Tonkin & Taylor Ltd by:



Tony Cussins
Project Director

WKAM

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Appendix A: Simulation outputs

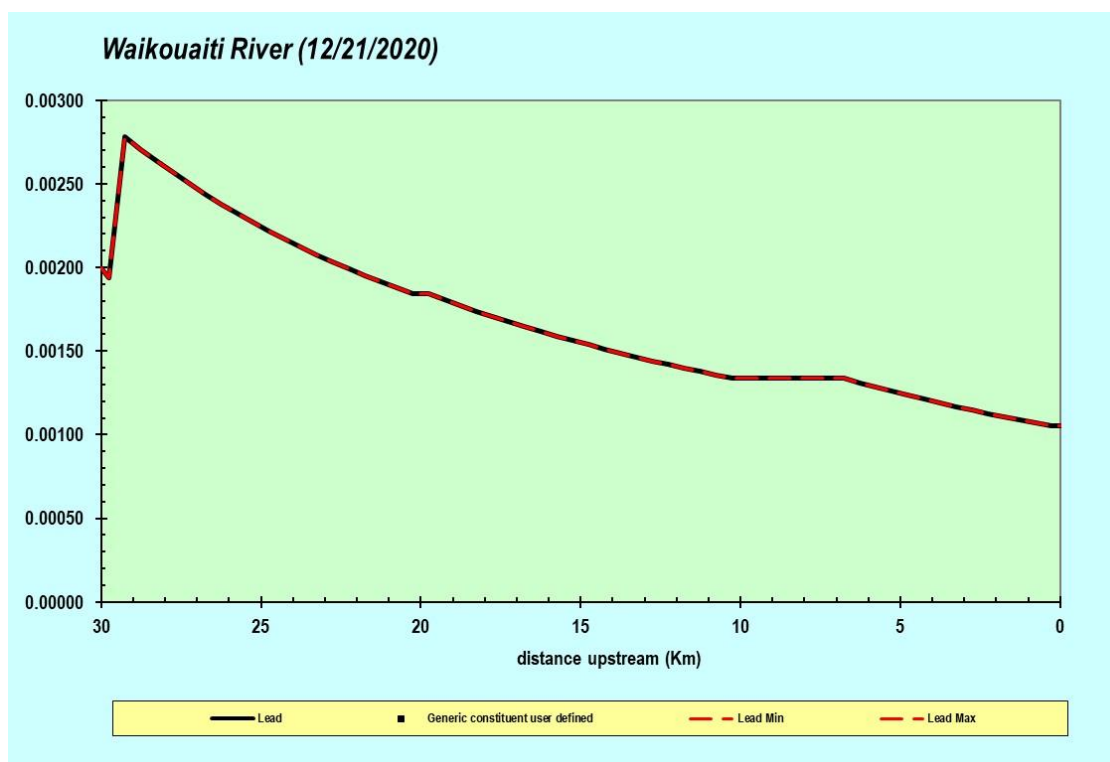


Figure Appendix A.1: Conservative case scenario (1 in 5year low flow) – Lead concentration (mg/L) in the Waikouaiti River

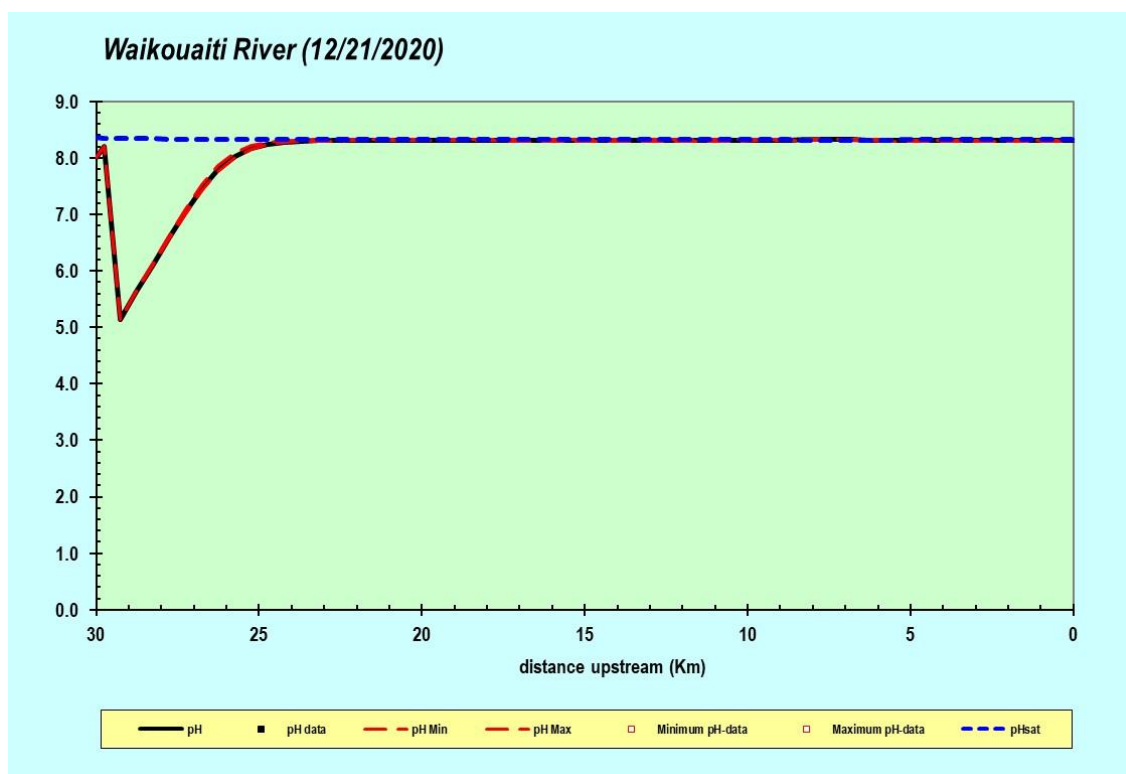


Figure Appendix A.2: Conservative case scenario (1 in 5year low flow) – pH in the Waikouaiti River

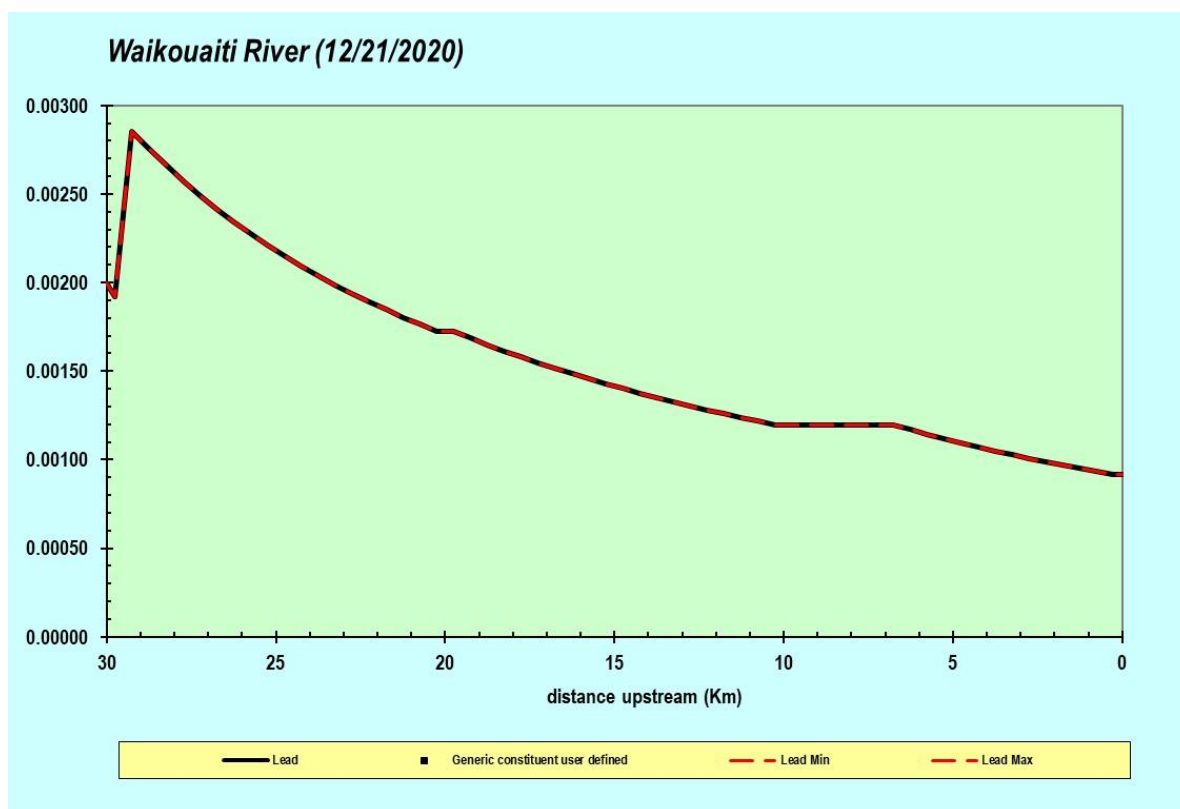


Figure Appendix A.3: Conservative case scenario (MALF) – Lead concentration (mg/L) in the Waikouaiti River

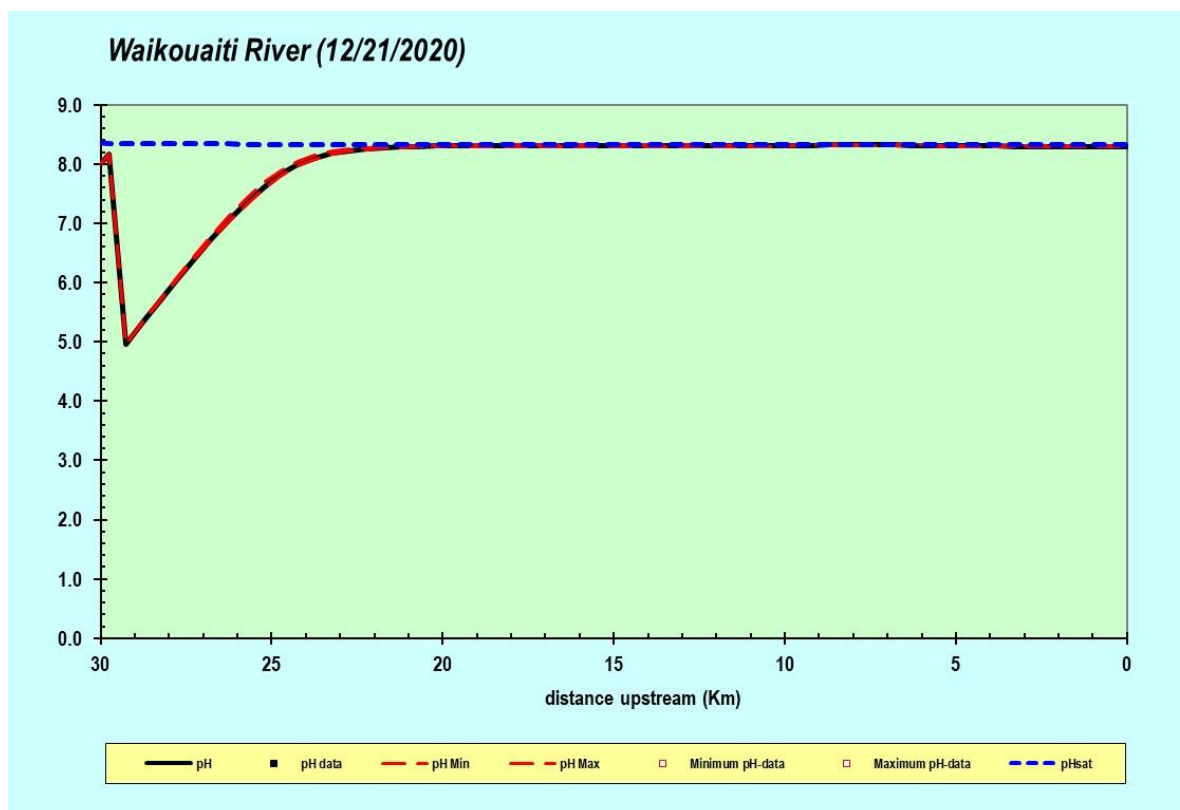


Figure Appendix A.4: Conservative case scenario (MALF) – pH in the Waikouaiti River

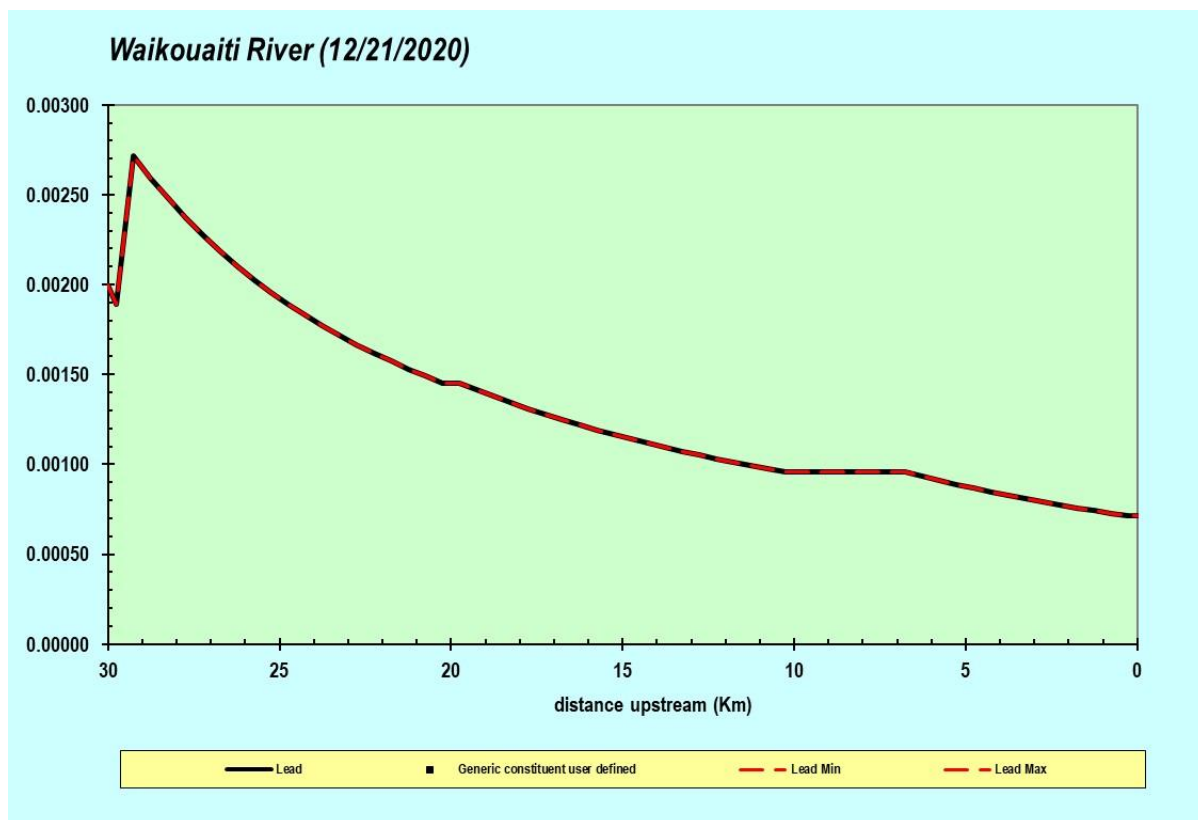


Figure Appendix A.5: Median case scenario – Lead concentration (mg/L) in the Waikouaiti River

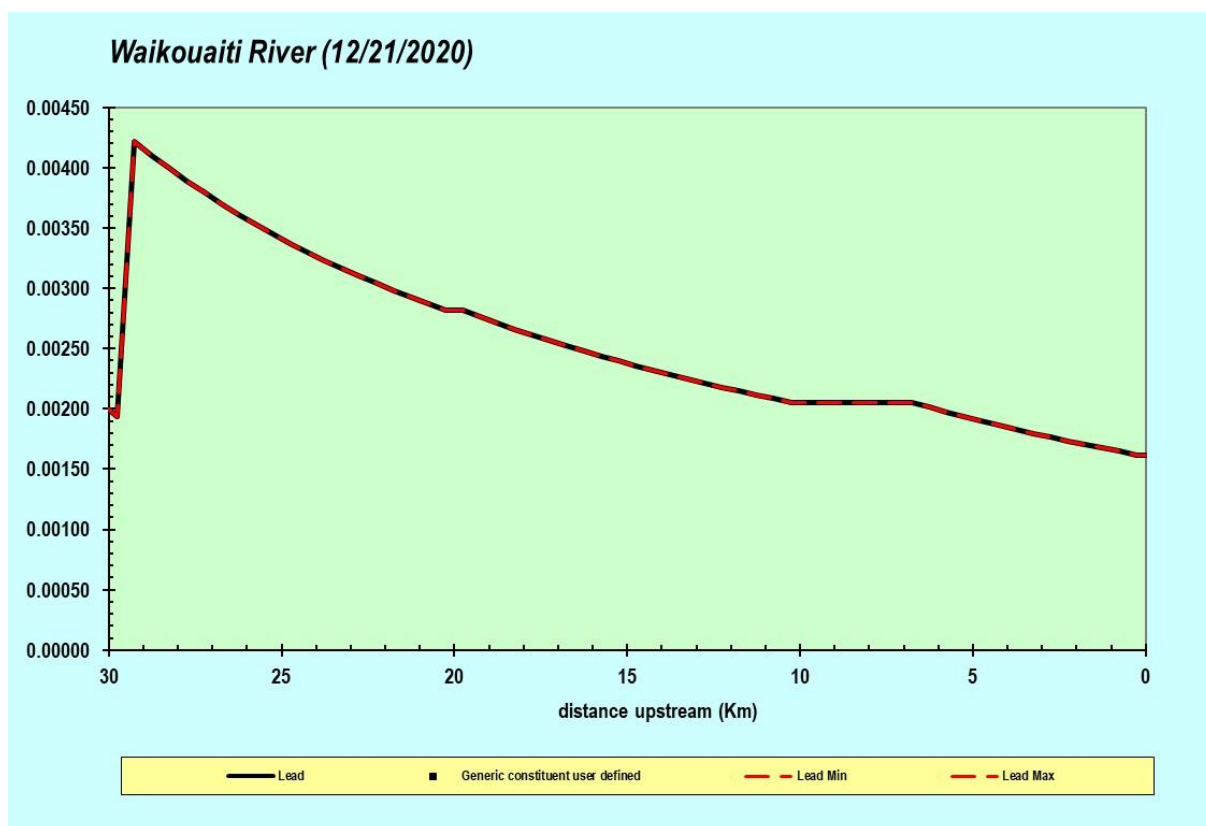


Figure Appendix A.6: 'Best case' scenario (MAF) – Lead concentration (mg/L) in the Waikouaiti River

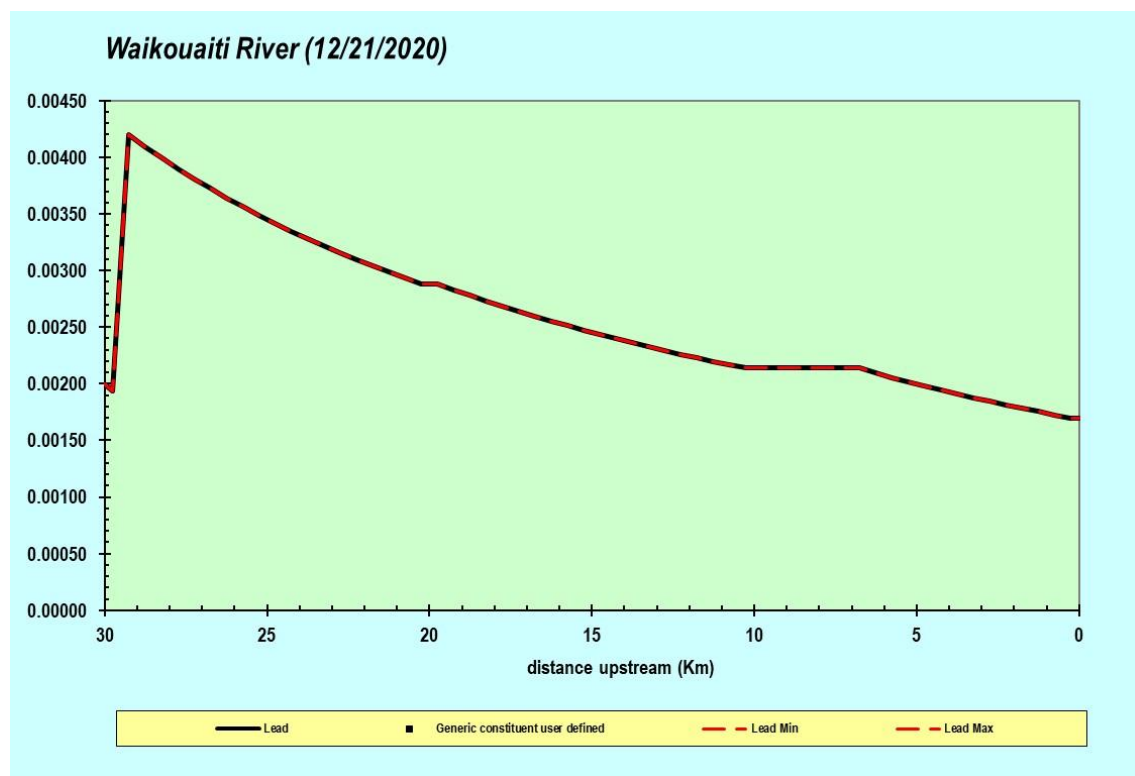
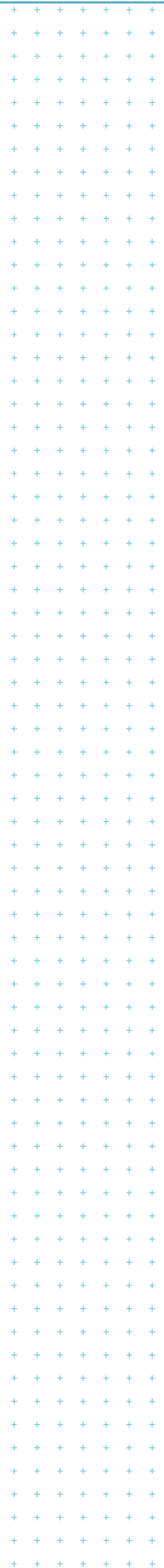
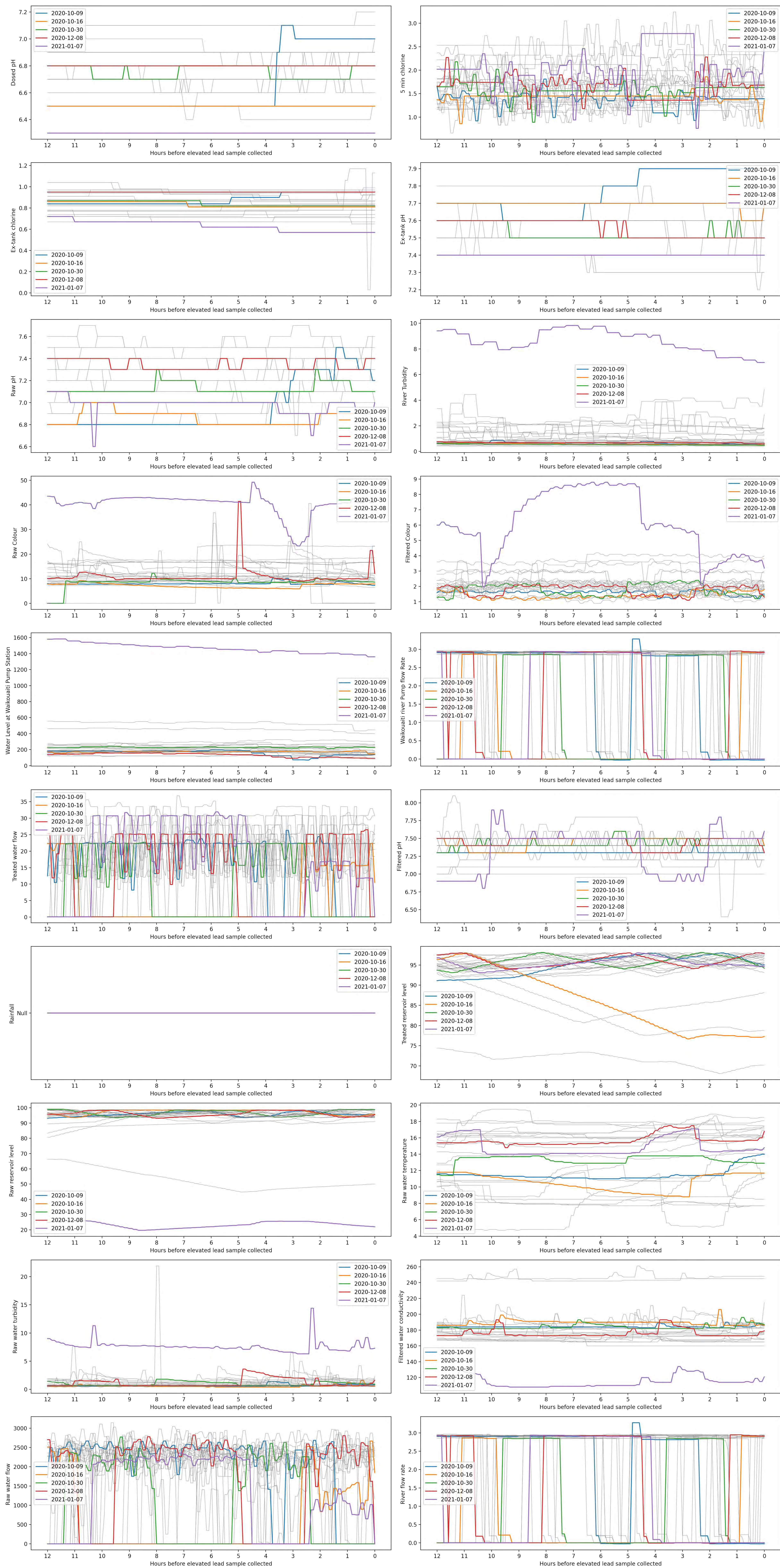
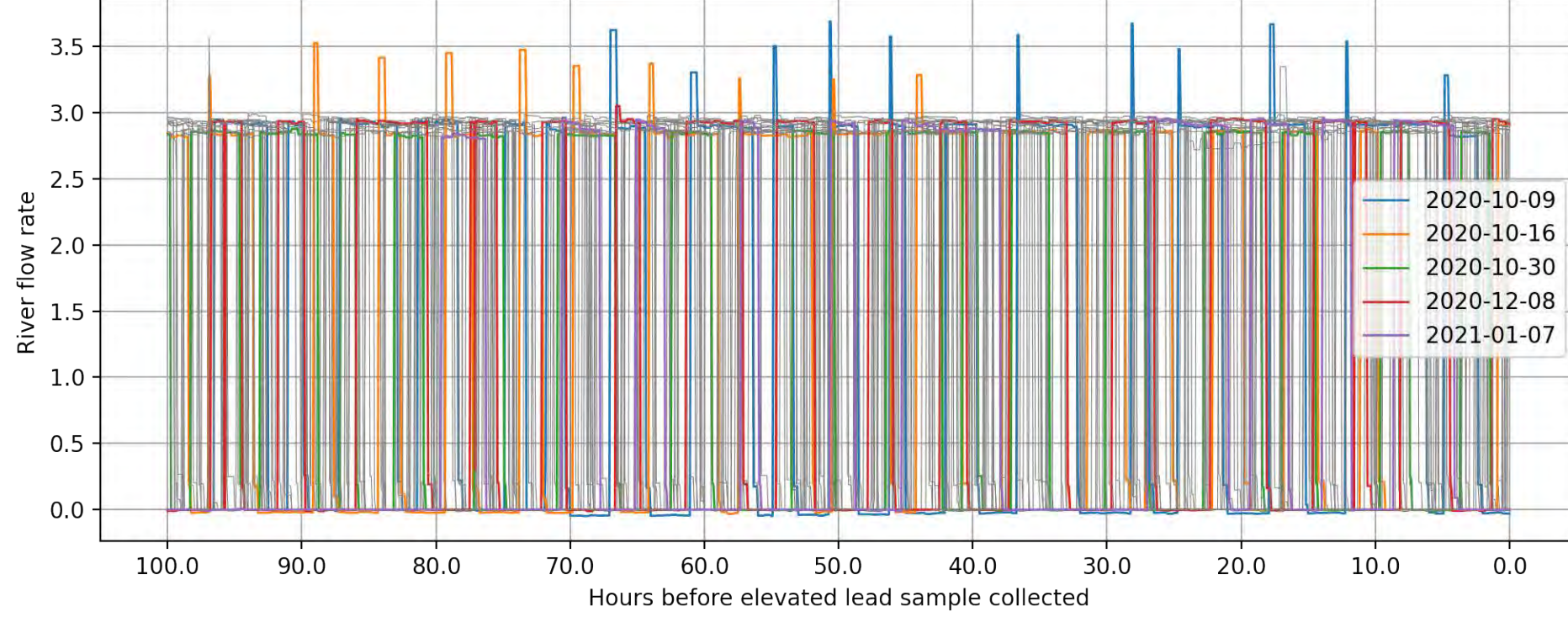
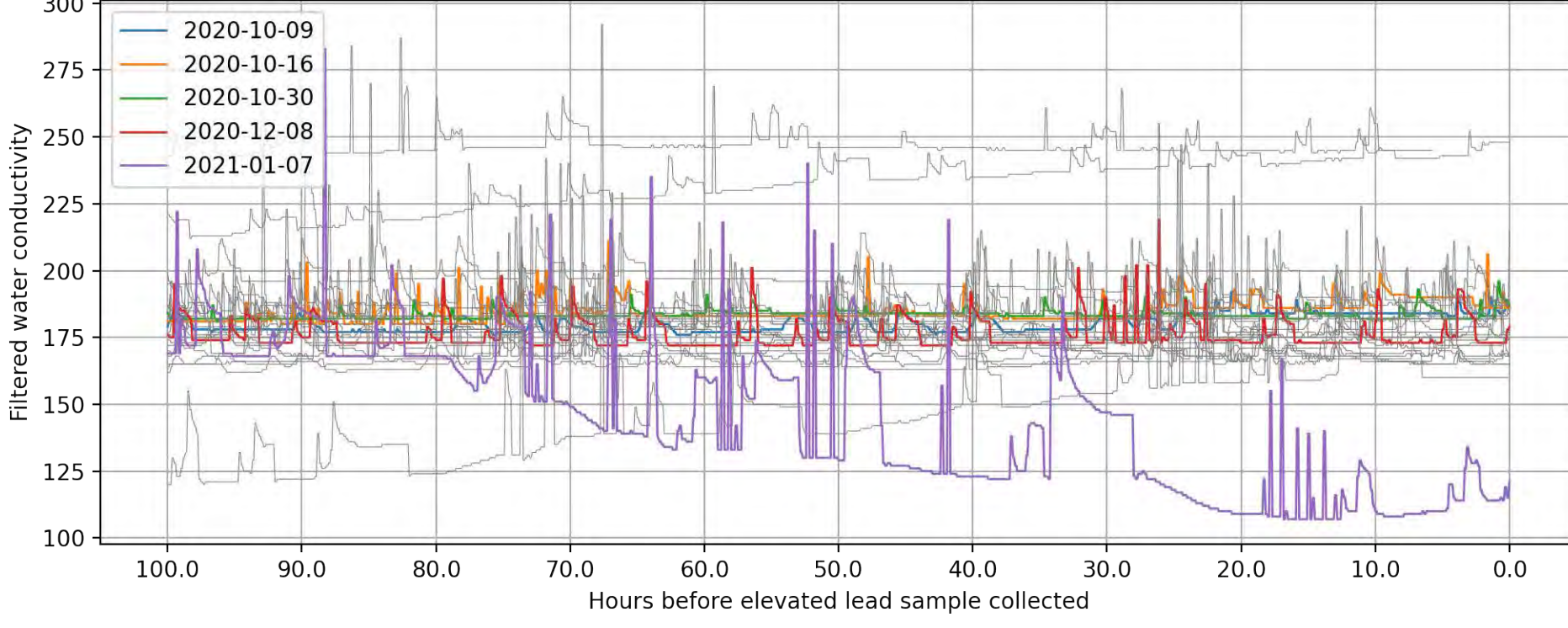
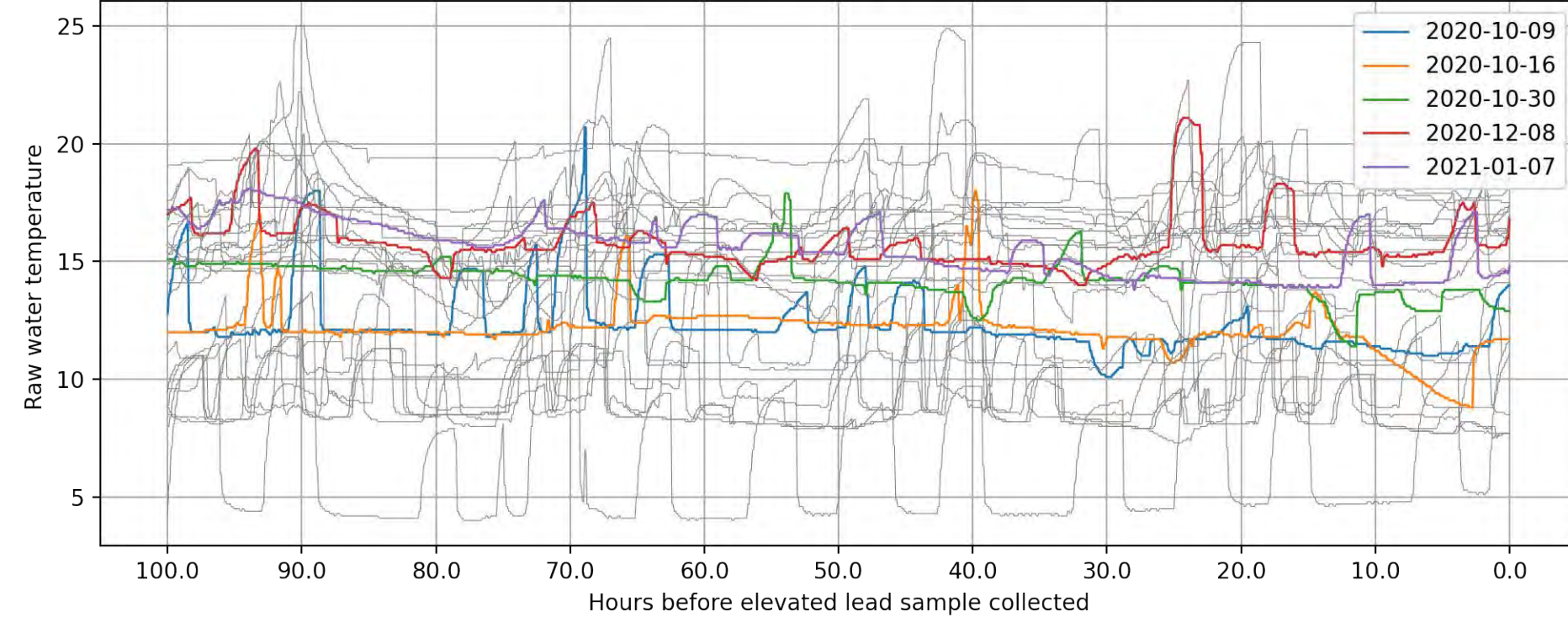
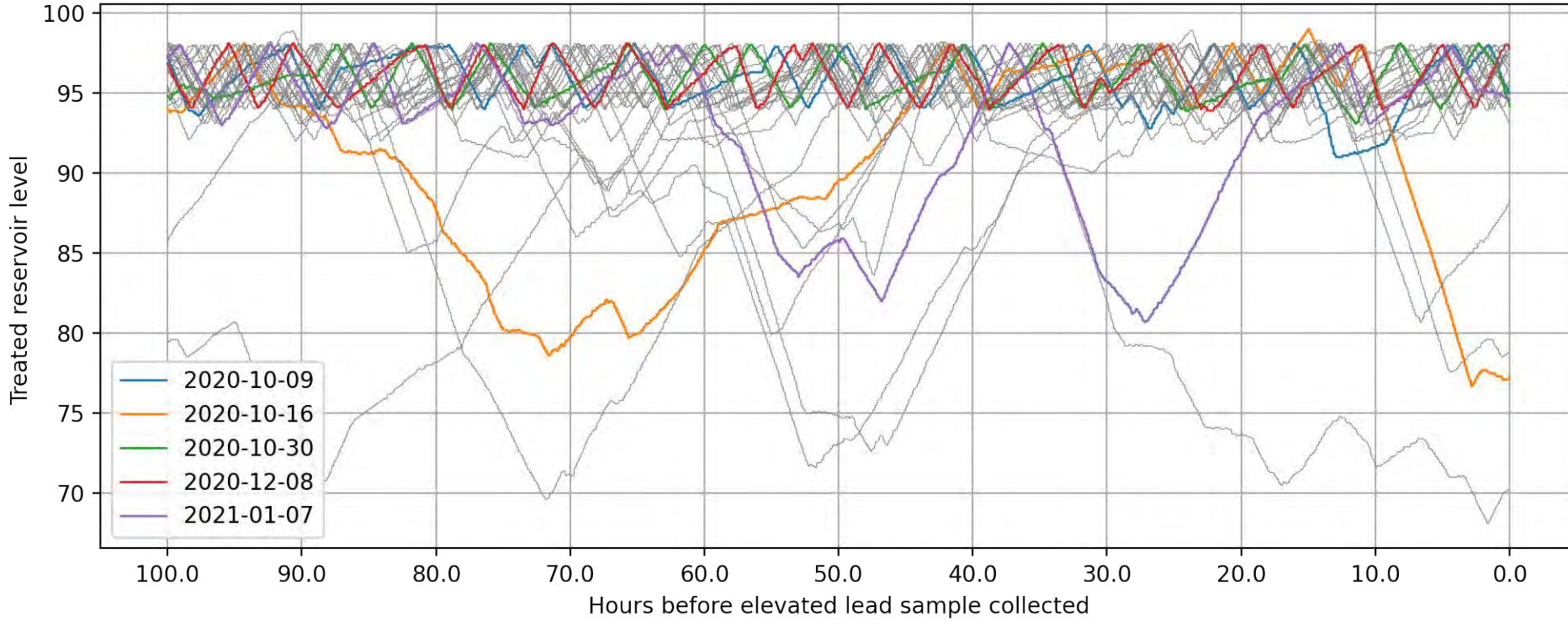
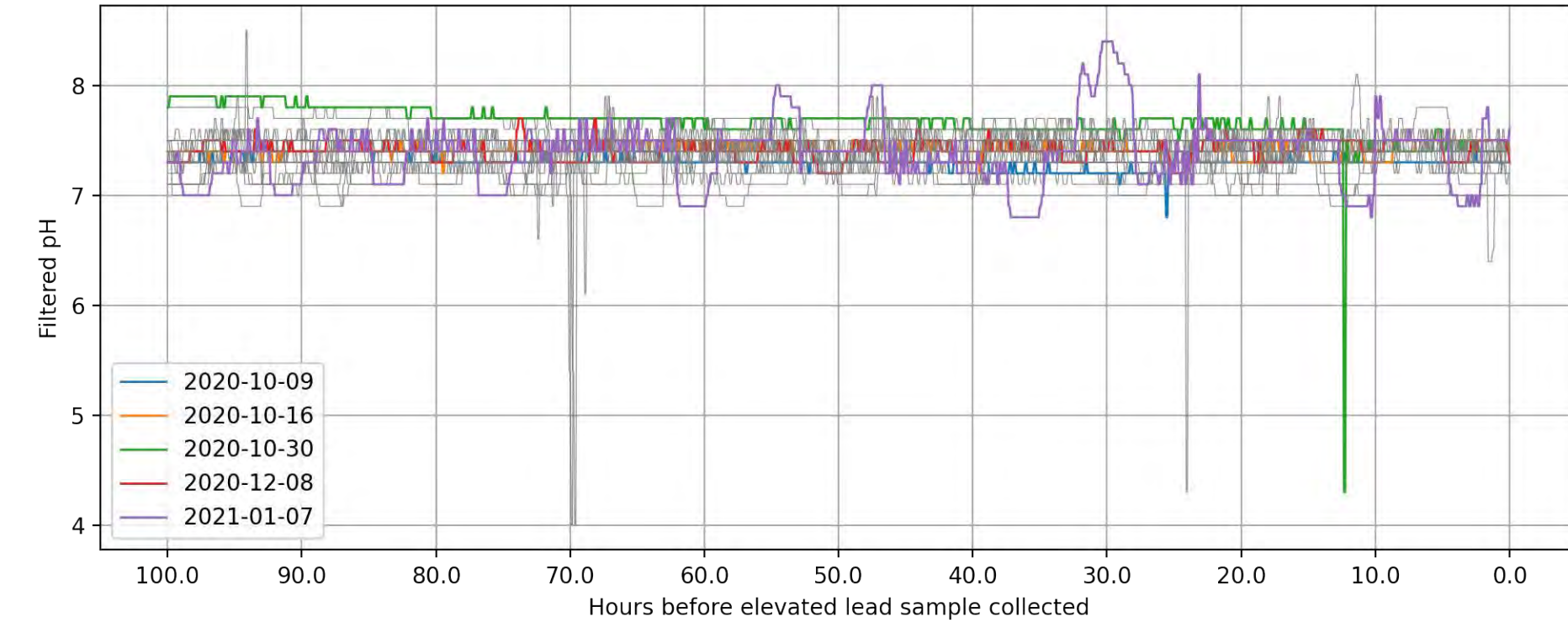
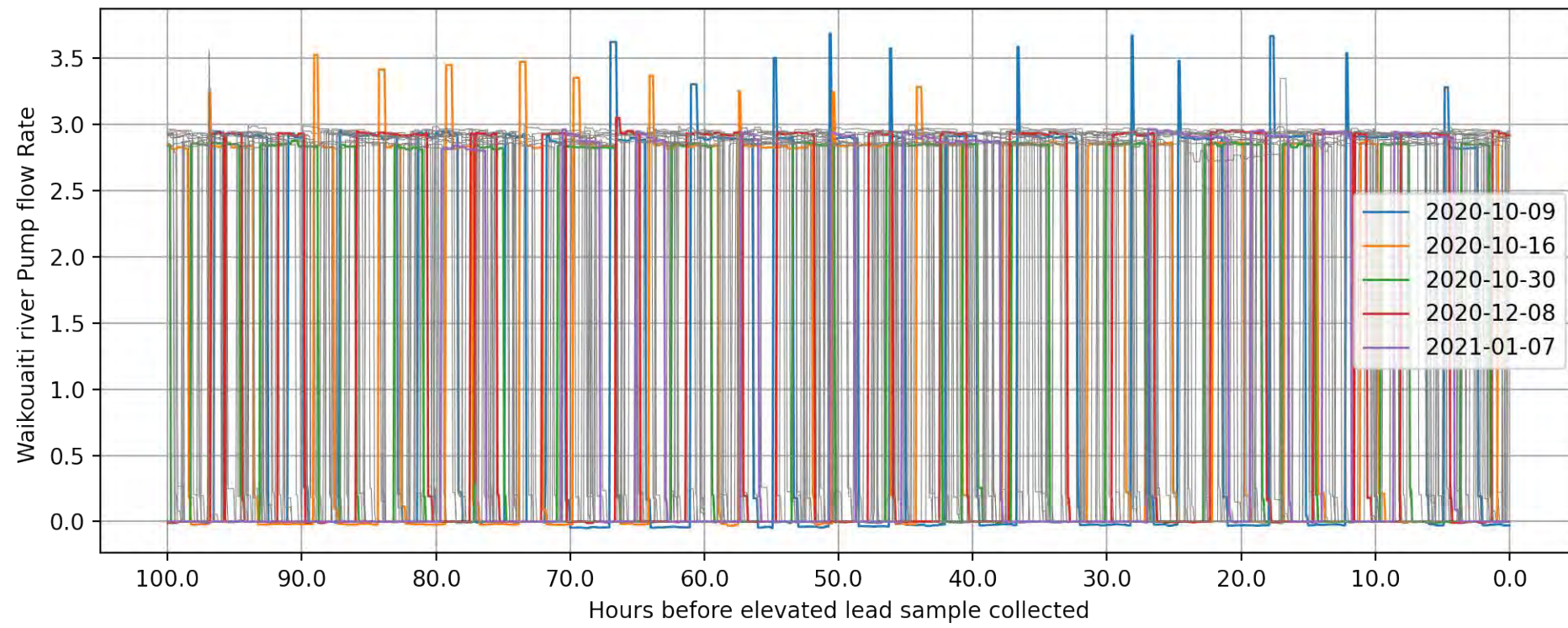
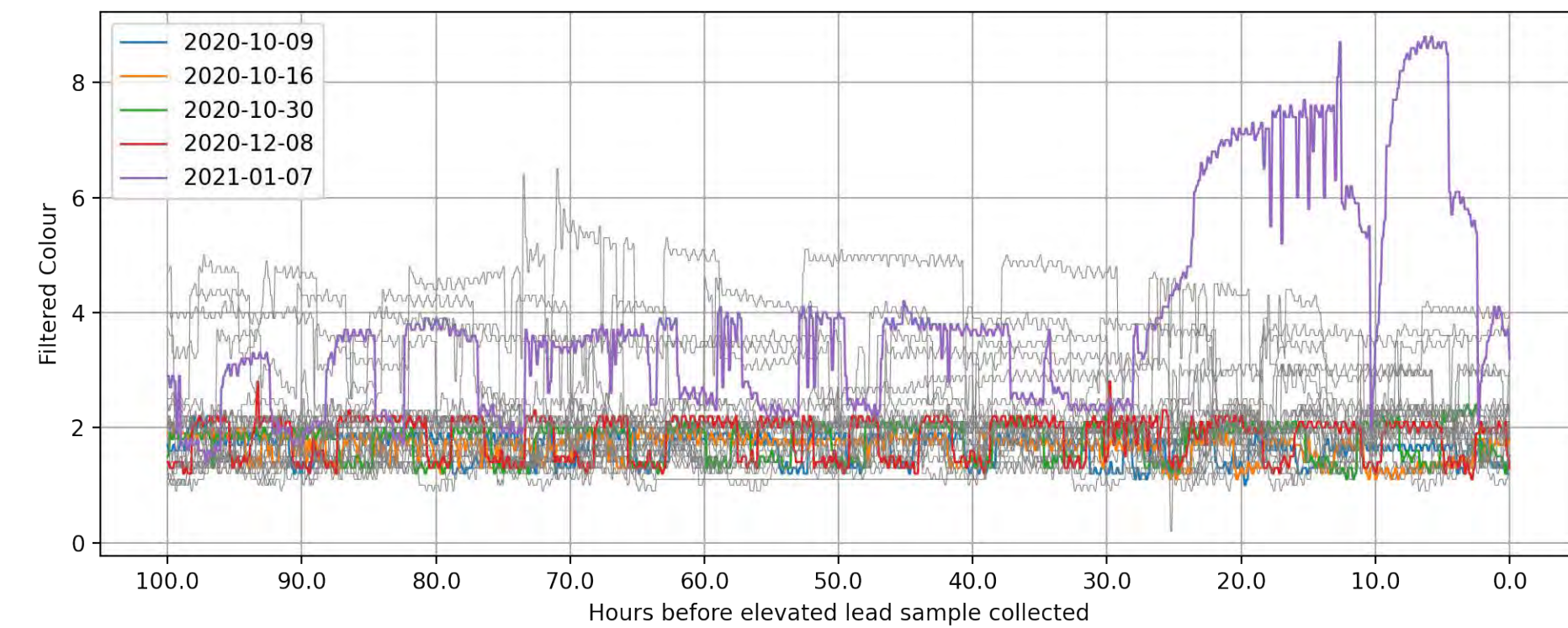
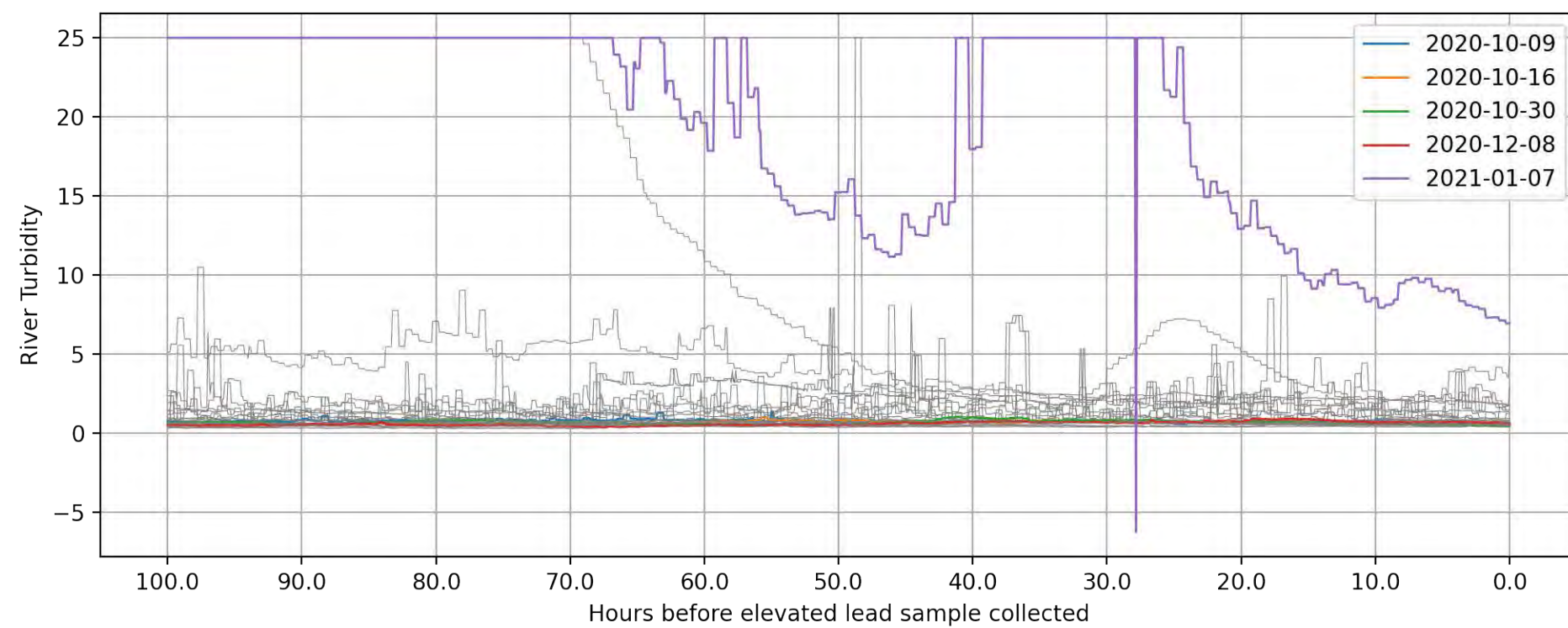
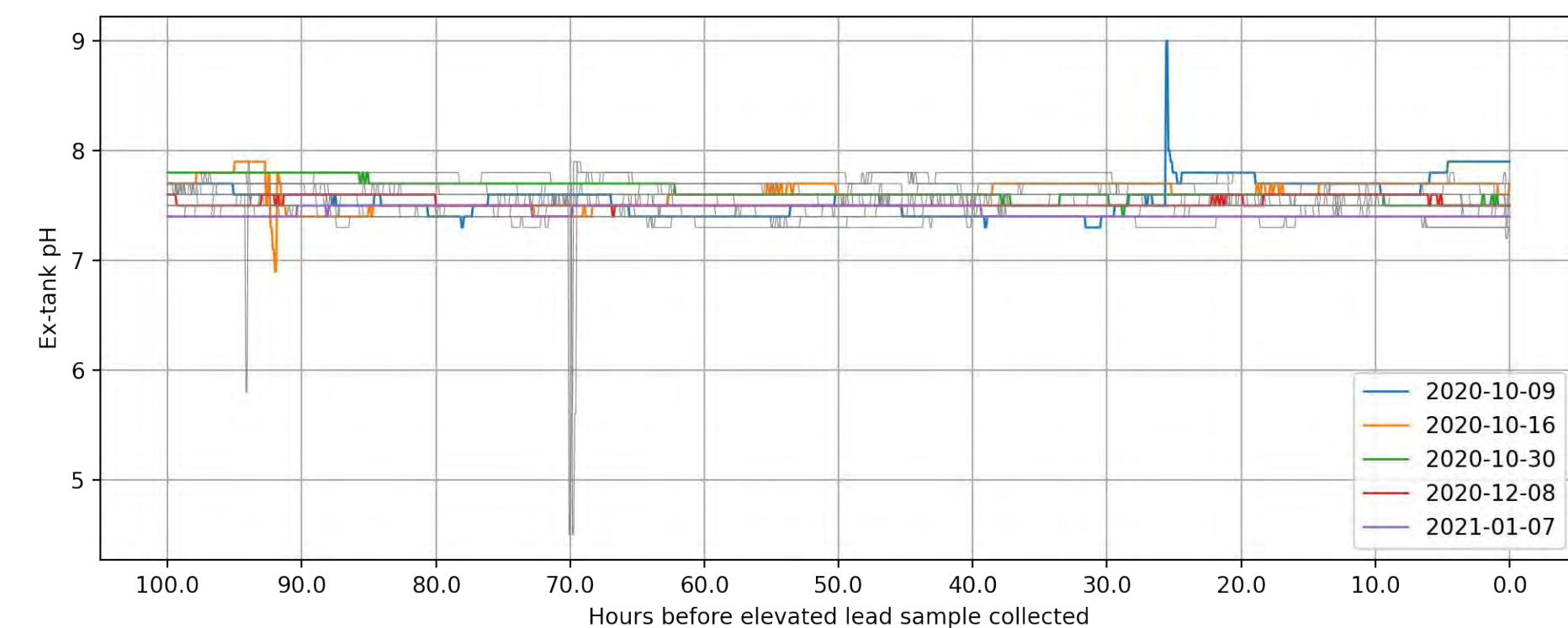
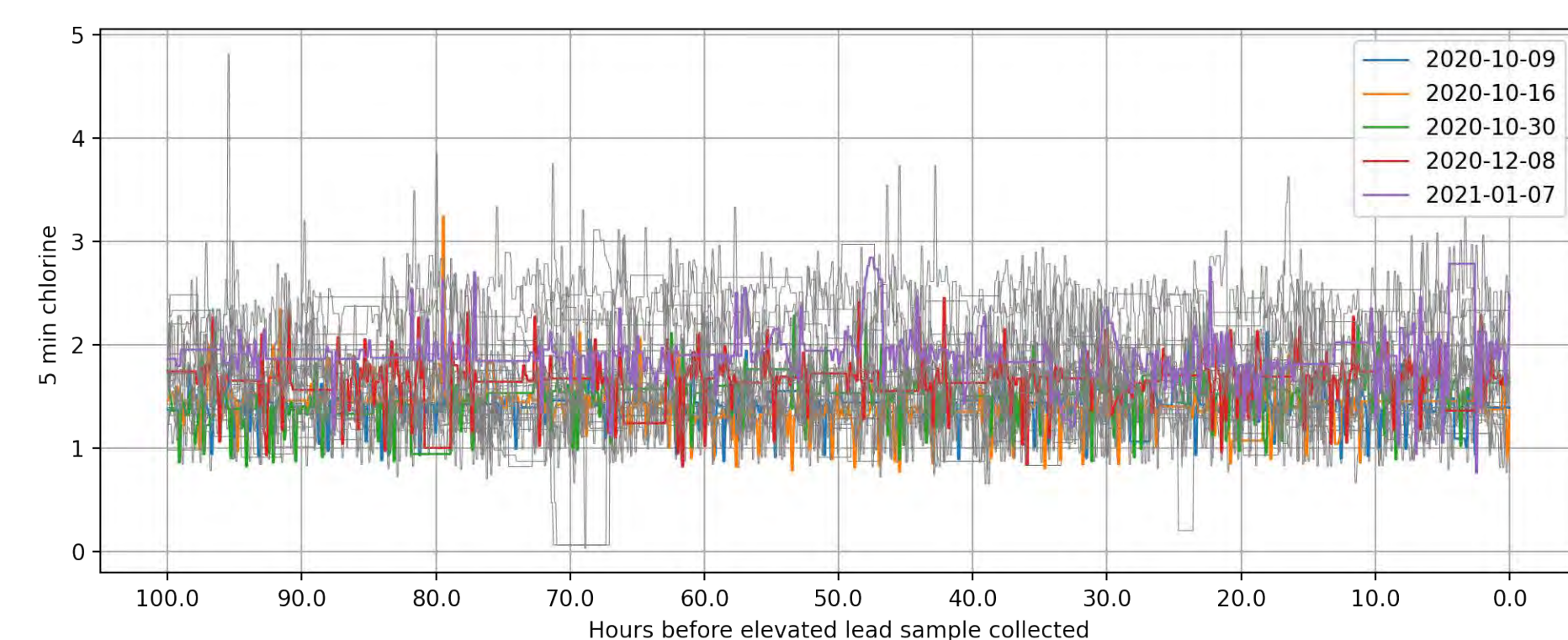
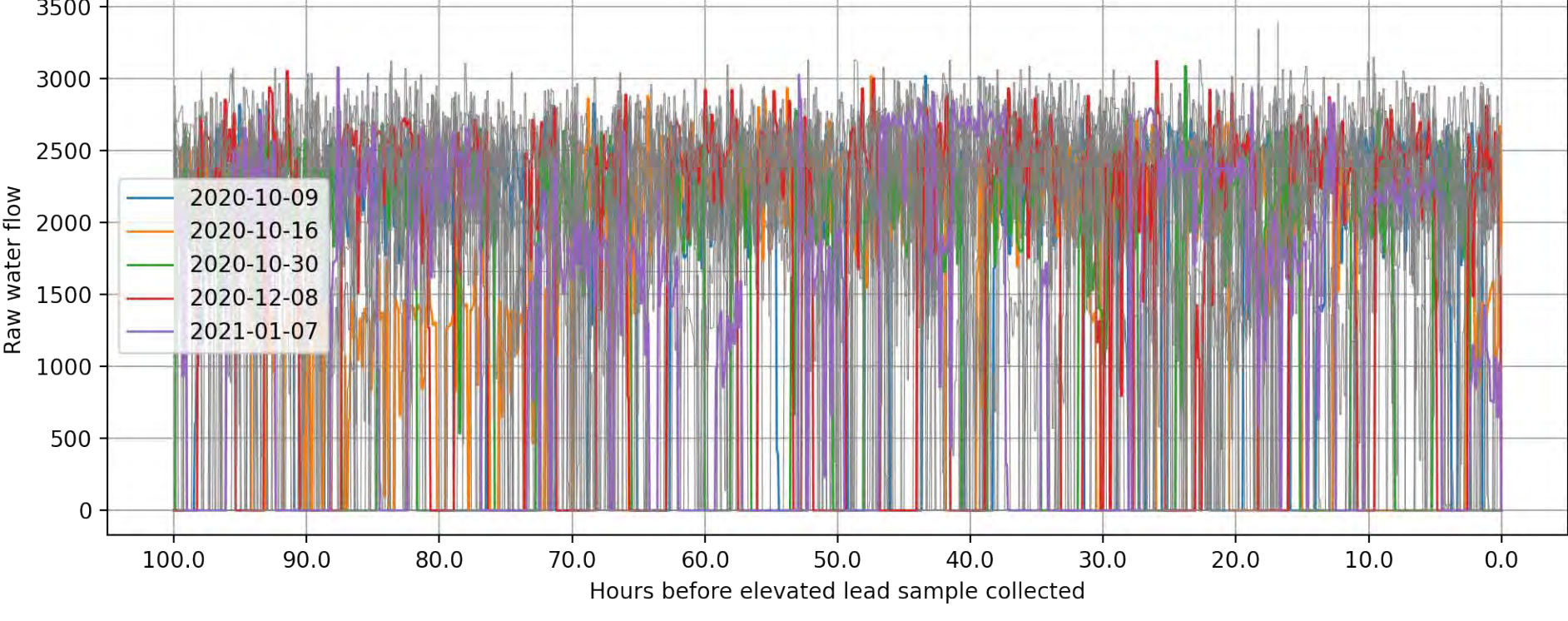
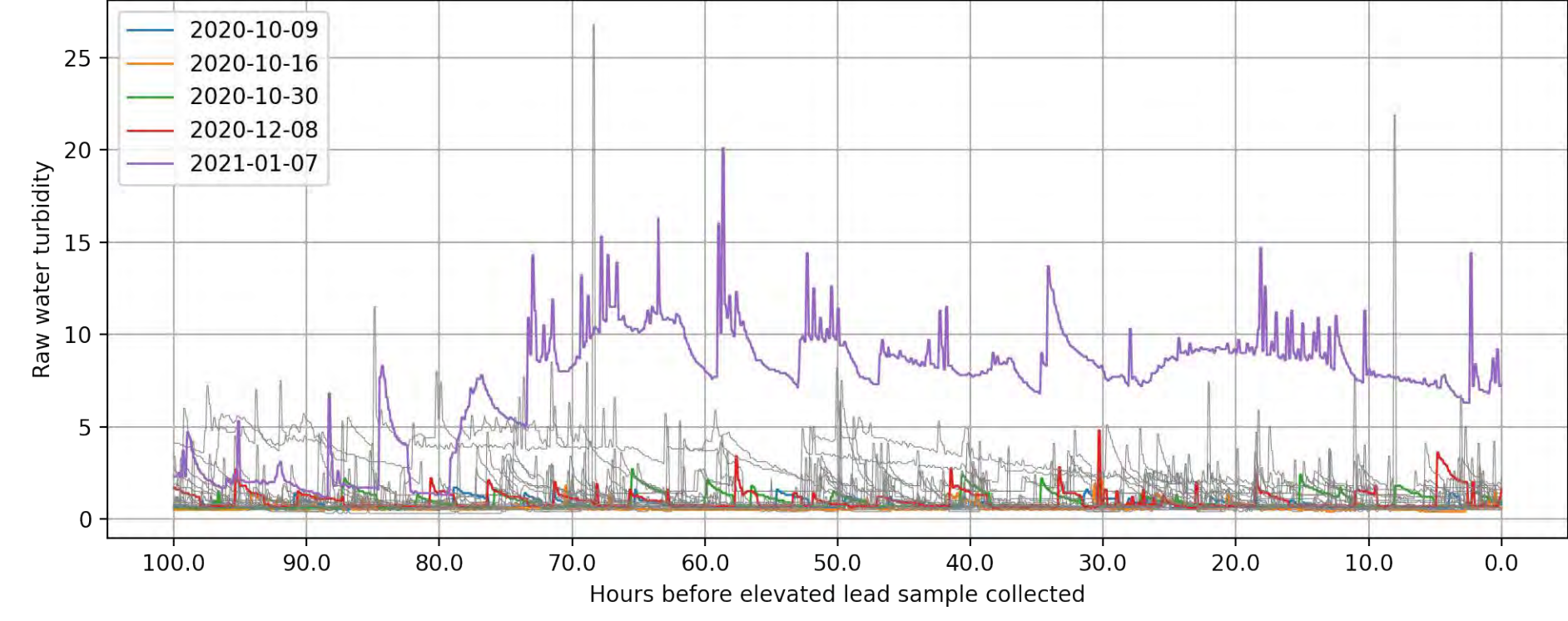
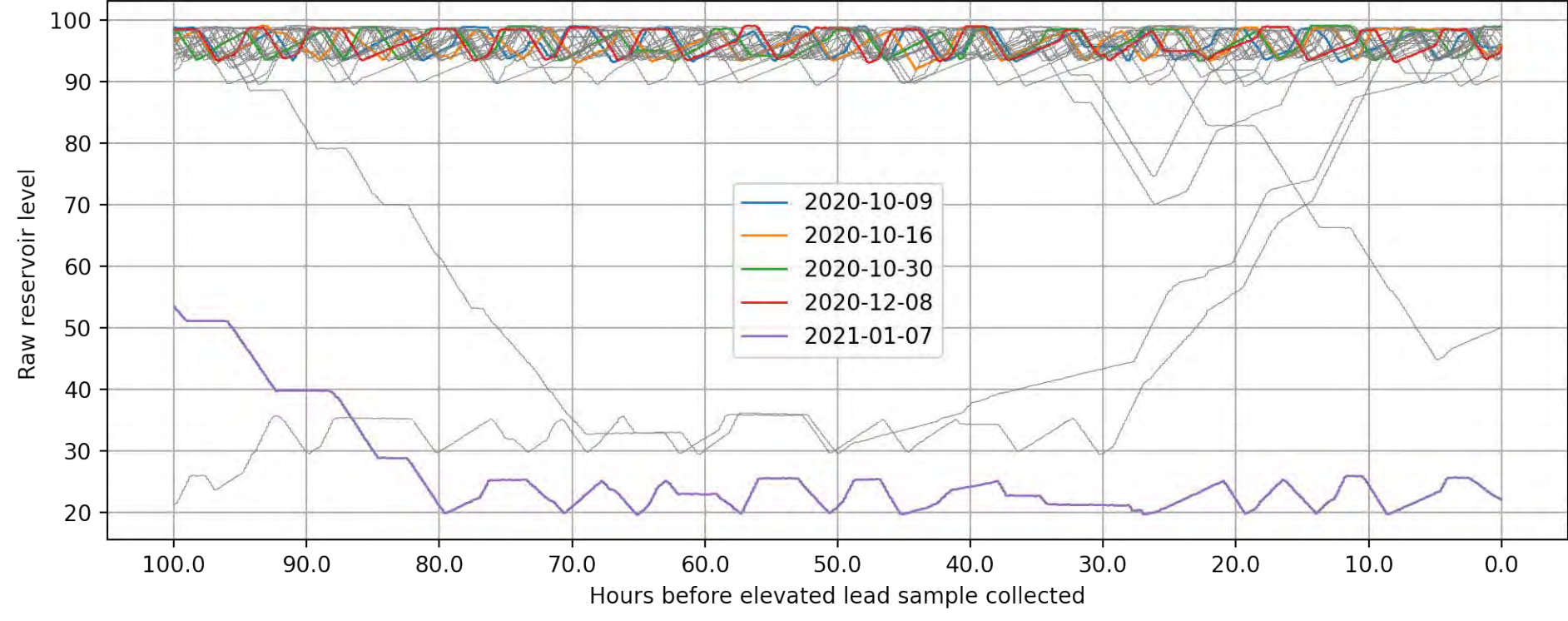
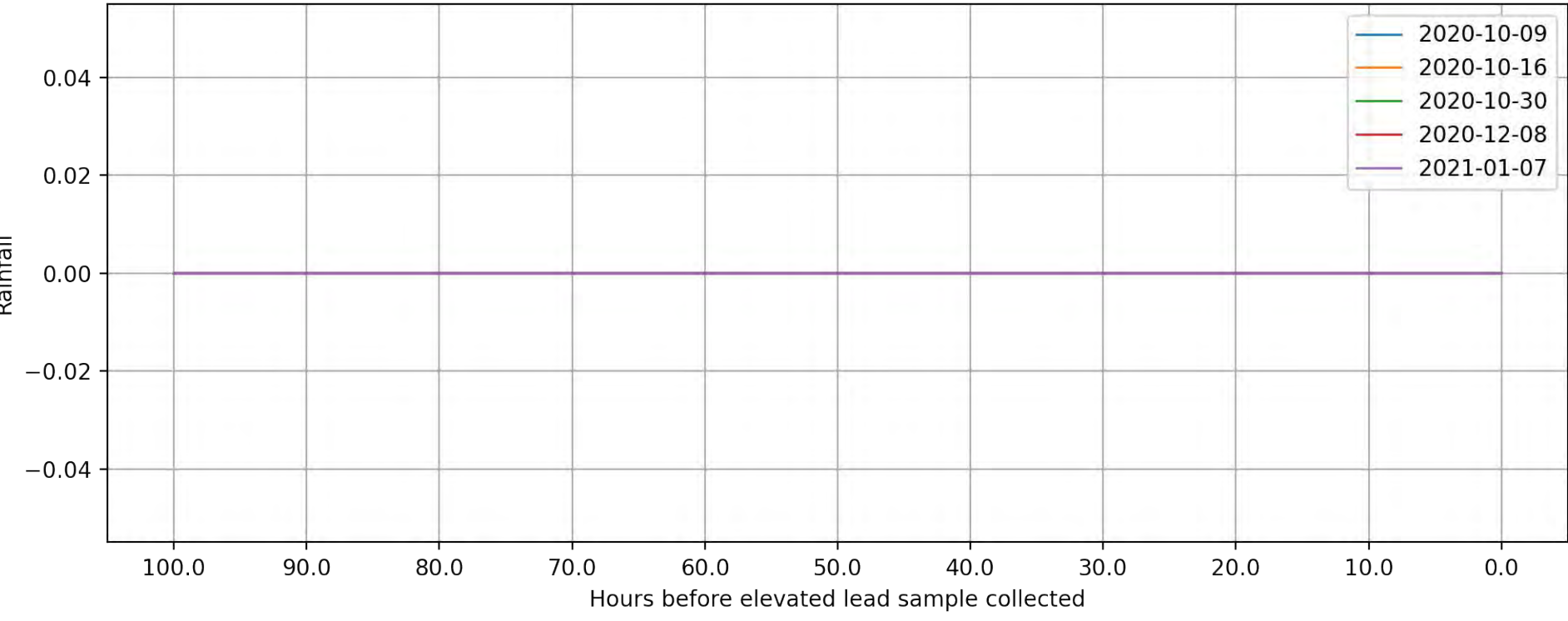
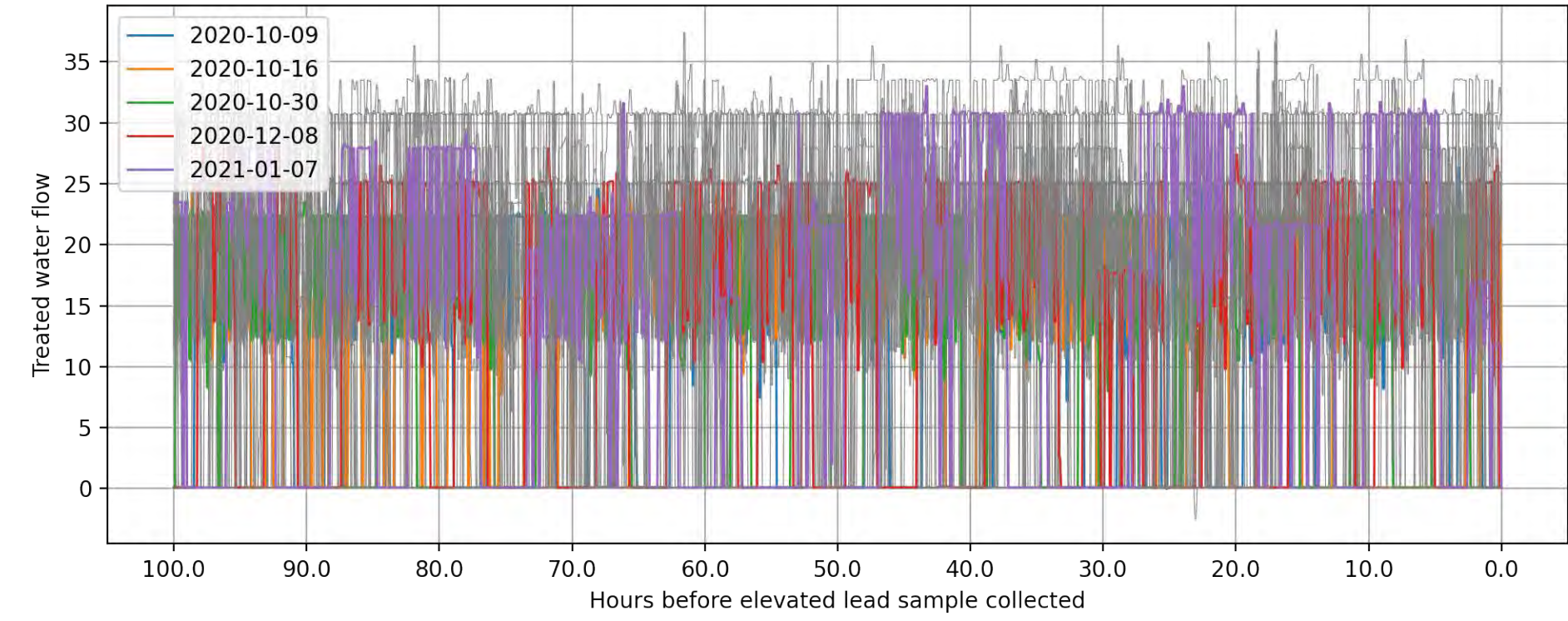
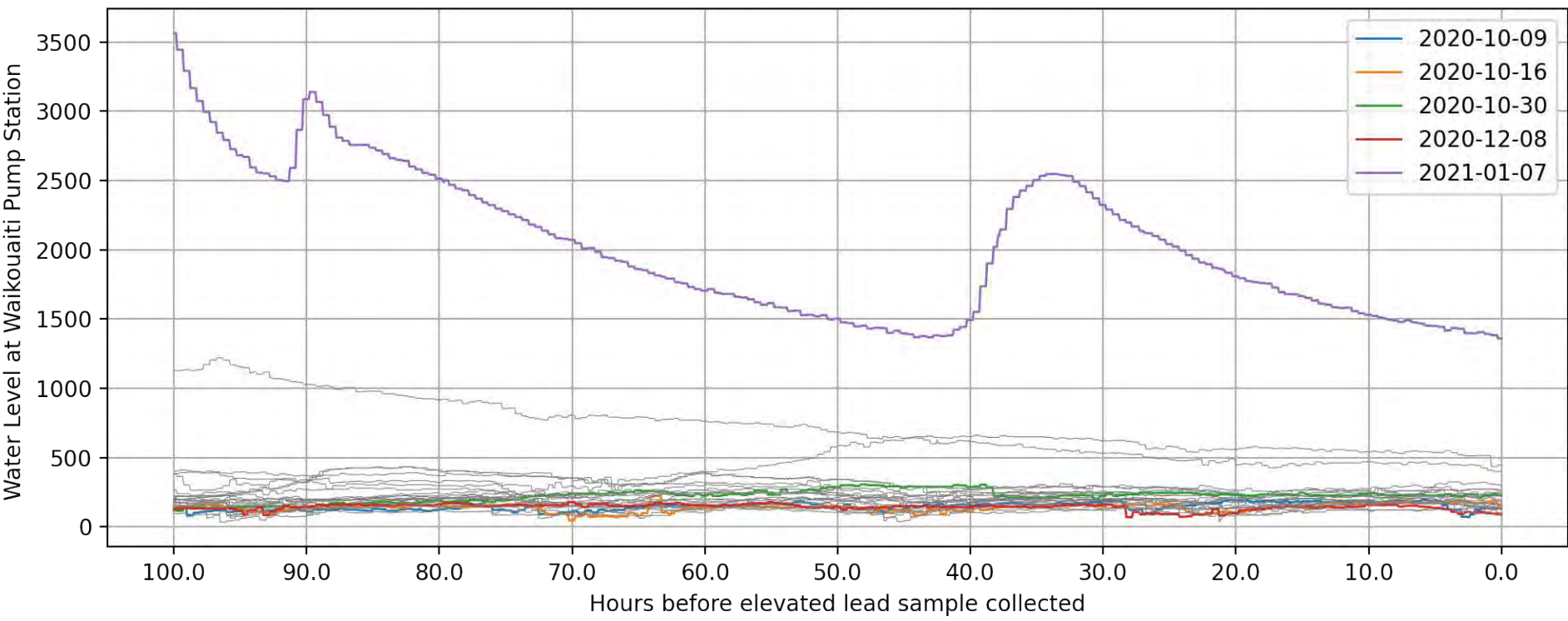
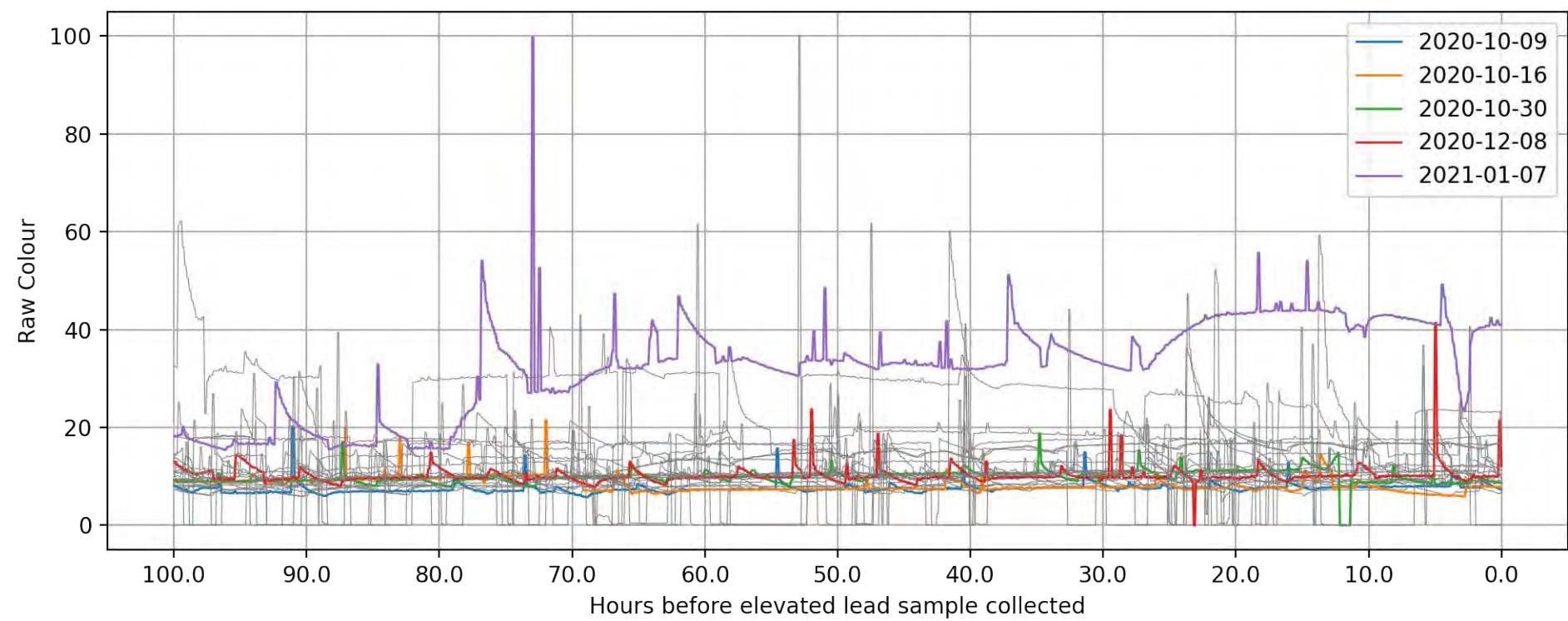
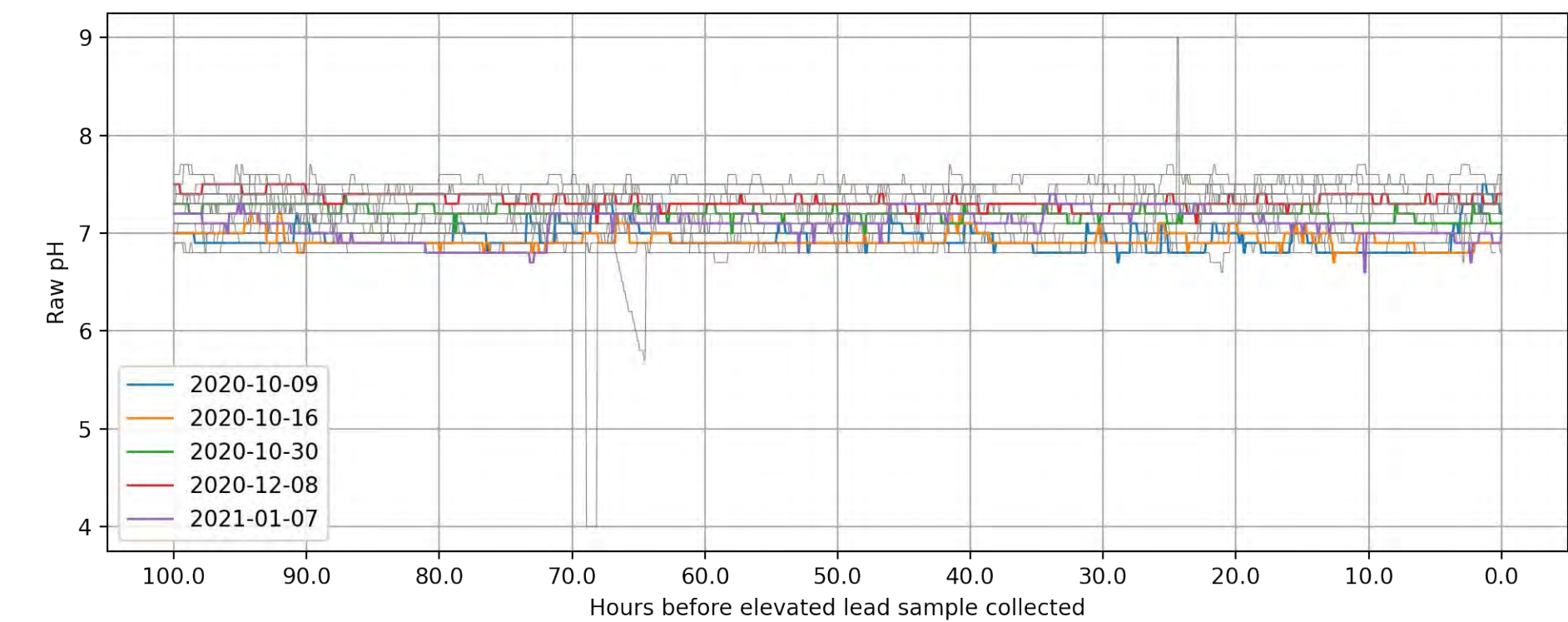
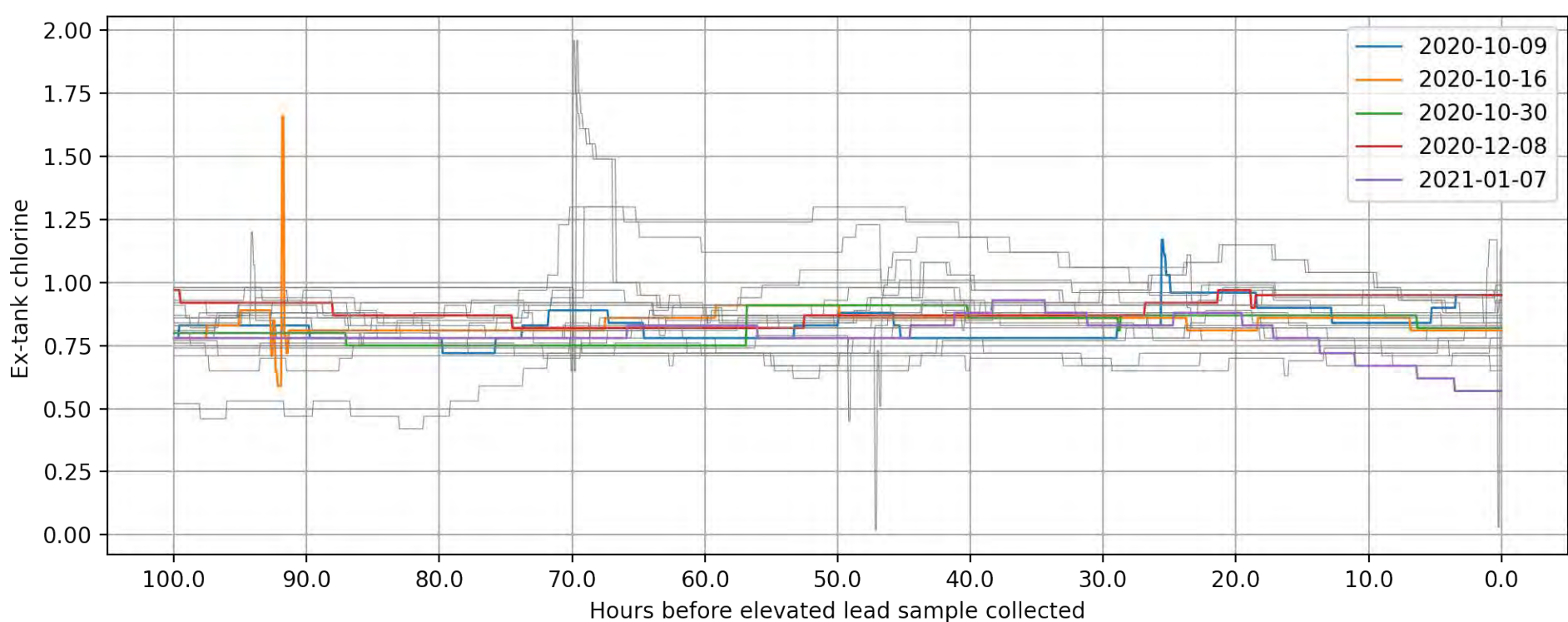
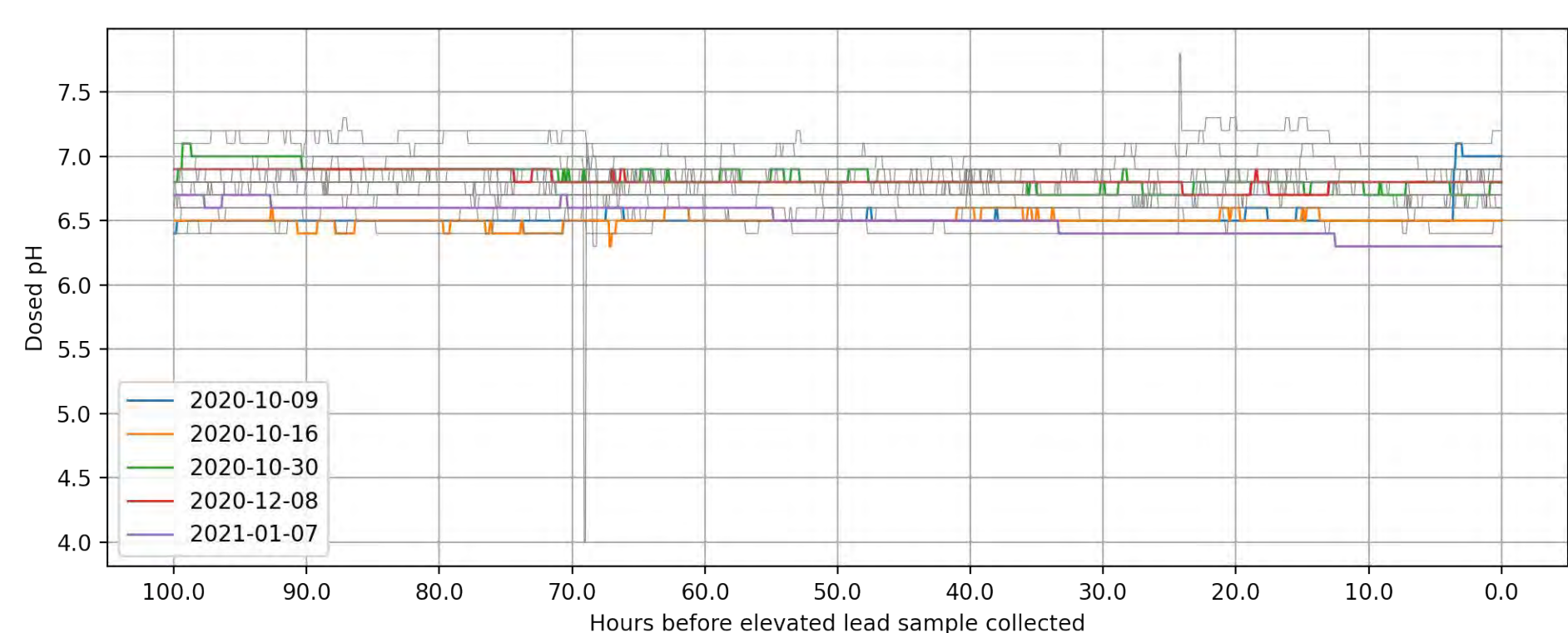


Figure Appendix A.7: 'Best case' scenario (5yr ARI flood) – Lead concentration (mg/L) in the Waikouaiti River







Impact of Sulphate from McCraes Mine on Raw Water Quality

