

Greymouth Petroleum Acquisition
Company Ltd

Ngatoro-E Hydraulic Fracturing

Monitoring Programme Report

2022/23

Technical Report 2024-84



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Executive summary

Greymouth Petroleum Acquisition Company Ltd (the Company) operates the Ngatoro-E hydrocarbon exploration site (wellsite) located on Dudley Road, Inglewood located in the Waitara catchment. This report outlines and discusses the results of the monitoring programme implemented by the Council in relation to hydraulic fracturing activities conducted by the Company at the wellsite on 17 March 2022. The report also details the results of the monitoring undertaken and assesses the environmental effects of the Company's activities.

The programme of hydraulic fracturing undertaken by the Company at the Ngatoro-E wellsite included the hydraulic fracturing of one well. The well targeted for stimulation was Ngatoro-17.

During the monitoring period, the Company demonstrated an overall high level of environmental and a high level of administrative performance.

The programme of monitoring implemented by the Council in relation to this hydraulic fracturing activity was undertaken during the 2022/23 monitoring year. Monitoring included pre and post-discharge groundwater sampling in relation to discharges at the Ngatoro-E wellsite. In order to characterise the discharges and to determine compliance with consent conditions samples of hydraulic fracturing fluids, and fluids returning to the wellhead post-fracturing, were also collected by the Company and results of the physicochemical analysis undertaken were provided to the Council. This is the second monitoring report produced by the Council in relation to the hydraulic fracturing activities at the Ngatoro-E wellsite.

The monitoring carried out by the Council indicates that the hydraulic fracturing activities undertaken by the Company had no significant adverse effects on local groundwater or surface water resources. There were no unauthorised incidents recording non-compliance in respect of the resource consent held by the Company in relation to these activities or provisions in regional plans, during the period under review.

For reference, in the 2022/23 year, consent holders were found to achieve a high level of environmental performance and compliance for 878 (87%) of a total of 1007 consents monitored through the Taranaki tailored monitoring programmes, while for another 96 (10%) of the consents a good level of environmental performance and compliance was achieved. A further 27 (3%) of consents monitored required improvement in their performance, while the remaining one (<1%) achieved a rating of poor.

This report includes recommendations for the future monitoring of any hydraulic fracturing activities at the Ngatoro-E wellsite.

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1. Introduction

1.1 Compliance monitoring programme reports and the Resource Management Act 1991

1.1.1 Introduction

This report outlines and discusses the results of the monitoring programme implemented by Taranaki Regional Council (the Council) in relation to the programme of hydraulic fracturing undertaken by Greymouth Petroleum Acquisition Company Ltd (the Company) at the Ngatoro-E wellsite, on 17 March 2022. The report also assesses the Company's level of environmental performance and compliance with the resource consent held in relation to the activity.

The programme of hydraulic fracturing undertaken by the Company at the Ngatoro-E wellsite included the hydraulic fracturing of one well. The well targeted for stimulation was Ngatoro-17.

The programme of monitoring implemented by the Council in relation to this hydraulic fracturing activity was undertaken during the 2022/23 monitoring year. Monitoring included a mixture of groundwater, surface water and discharge monitoring components. This is the second monitoring report produced by the Council in relation to hydraulic fracturing activities at the Ngatoro-E wellsite.

1.1.2 Structure of this report

Section 1 of this report is a background section. It sets out general information about:

- consent compliance monitoring under the *Resource Management Act 1991* (RMA) and the Council's obligations;
- the Council's approach to monitoring sites through compliance monitoring programmes;
- the resource consents held by the Company;
- the nature of the monitoring programme in place for the period under review; and
- a description of the activities and operations conducted at the Ngatoro-E wellsite.

Section 2 presents the results of monitoring during the period under review, including scientific and technical data.

Section 3 discusses the results, their interpretations, and their significance for the environment.

Section 4 presents recommendations to be implemented in the 2024-2025 monitoring year.

A glossary of common abbreviations and scientific terms, and a bibliography, are presented at the end of the report.

1.1.3 The Resource Management Act 1991 and monitoring

The RMA primarily addresses environmental 'effects' which are defined as positive or adverse, temporary or permanent, past, present or future, or cumulative. Effects may arise in relation to:

- a. the neighbourhood or the wider community around an activity, and may include cultural and social-economic effects;
- b. physical effects on the locality, including landscape, amenity and visual effects;
- c. ecosystems, including effects on plants, animals, or habitats, whether aquatic or terrestrial;

- d. natural and physical resources having special significance (for example recreational, cultural, or aesthetic); and
- e. risks to the neighbourhood or environment.

In drafting and reviewing conditions on discharge permits, and in implementing monitoring programmes, the Council is recognising the comprehensive meaning of 'effects' in as much as is appropriate for each activity. Monitoring programmes are not only based on existing permit conditions, but also on the obligations of the RMA to assess the effects of the exercise of consents. In accordance with Section 35 of the RMA, the Council undertakes compliance monitoring for consents and rules in regional plans, and maintains an overview of the performance of resource users and consent holders. Compliance monitoring, including both activity and impact monitoring, enables the Council to continually re-evaluate its approach and that of consent holders to resource management and, ultimately, through the refinement of methods and considered responsible resource utilisation, to move closer to achieving sustainable development of the region's resources.

1.1.4 Evaluation of environmental performance

Besides discussing the various details of the performance and extent of compliance by the consent holders, this report also assigns a rating as to each Company's environmental and administrative performance during the period under review. The rating categories are high, good, improvement required and poor for both environmental and administrative performance. The interpretations for these ratings are found in Appendix II.

For reference, in the 2022/23 year, consent holders were found to achieve a high level of environmental performance and compliance for 878 (87%) of a total of 1007 consents monitored through the Taranaki tailored monitoring programmes, while for another 96 (10%) of the consents a good level of environmental performance and compliance was achieved. A further 27 (3%) of consents monitored required improvement in their performance, while the remaining one (<1%) achieved a rating of poor.¹

1.2 Process description

1.2.1 Hydraulic fracturing

Hydraulic fracturing is a reservoir stimulation technique used to increase the flow of hydrocarbons to the surface. The primary objective of hydraulic fracturing is to increase the permeability of the target reservoir by creating numerous small, interconnected fractures, thus increasing the flow of hydrocarbons from the formation to a given well. The process of hydraulic fracturing has enabled companies to produce hydrocarbons at economically viable rates from extremely low permeability reservoirs and those that have become depleted using conventional production techniques.

The process of hydraulic fracturing involves the pumping of fluids and a proppant (medium-grained sand or small ceramic pellets) down a well, through a perforated section of the well casing, and into the target reservoir. The fluid mixture is pumped at a pressure that exceeds the fracture strength of the reservoir rock in order to create fractures. Once fractures have been initiated, pumping continues in order to force the fluid and proppant into the fractures created. The proppant is designed to keep the fractures open when the

¹ The Council has used these compliance grading criteria for more than 20 years. They align closely with the 4 compliance grades in the MfE Best Practice Guidelines for Compliance, Monitoring and Enforcement, 2018

pumping is stopped. The placement of proppant into the fractures can be assisted by the use of cross-linked gels (gel fracturing), turbulent flow (slick-water fracturing), or the use of nitrogen gas.

1.2.1.1 Gel fracturing

Gel fracturing utilises cross-linked gel solutions, which are liquid at the surface but, when mixed, form long-chain polymer bonds and thus become viscous gels. These gels are used to transport the proppant into the formation. Once in the formation they 'break' back with time, temperature and the aid of gel breaking chemicals into a liquid state and are flowed back to surface, without disturbing the proppant which remains in place and enhances the flow of hydrocarbons back to the surface.

1.2.1.2 Slick water fracturing

Slick water fracturing utilises water based fracturing fluids with friction-reducing additives. The addition of the friction reducers allows the fracturing fluids and proppant to be pumped to the target zone at higher rates and reduced pressures, than when using water alone. The higher rate creates turbulence within the fluid column holding the proppant and enabling its placement into the open fractures and enhancing the flow of hydrocarbons back to the surface.

1.2.1.3 Nitrogen gas fracturing

Nitrogen gas assisted fracturing involves replacing some of the fluid used in the fracturing process with nitrogen gas, which can fracture rock at high pressures much like water. While nitrogen (N₂) is a gas at room temperature, it can be maintained in a liquid state through cooling and pressurisation. Nitrogen assisted fracturing can be beneficial from a production standpoint as inevitably during the fracturing process some of the water pumped down the well remains underground in the rock formation, which can block some of the small pores, inhibiting hydrocarbon recovery. The use of nitrogen gas reduces the amount of water required for each fracturing event. This also reduces the total concentration of chemical additives required and the volume of water returning to the surface that requires subsequent disposal.

1.2.2 The Ngatoro-E wellsite and hydraulic fracturing activities

The Ngatoro-E is located on Dudley Road, Inglewood and lies within the Waitara catchment. The area surrounding the site is rural in nature and farming and forestry activities co-exist with active petroleum exploration and production operations. The location of the wellsite is illustrated in Figure 1. A summary of the hydraulic fracturing activities carried out by the Company at the Ngatoro-E wellsite during the period being reported is provided below in Table 1.

Table 1 Summary of hydraulic fracturing details

Well	Bore id.	Date range	Mid-point injection intervals (mTVDss)	Formation
Ngatoro-17	GND2469	17 March 2022	3,396-3,418	Upper Mangahewa



Figure 1 Location map

1.3 Resource consents

The Company holds one resource consent the details of which are summarised in Table 2 below. Summaries of the conditions attached to the permit are set out in Section 3 of this report.

A summary of the various consent types issued by the Council is included in Appendix I, as are copies of all permits held by the Company during the period under review.

Table 2 Resource consents held by the Company during the period under review

Consent number	Purpose	Granted	Review	Expires
9744-2	To discharge water based hydraulic fracturing fluids into land at depths greater than 3,375mTVDss beneath the Ngatoro-E wellsite	22 August 2018	June 2024	01 June 2033

1.4 Monitoring programme

1.4.1 Introduction

Section 35 of the RMA sets obligations upon the Council to gather information, monitor and conduct research on the exercise of resource consents within the Taranaki region. The Council is also required to assess the effects arising from the exercising of these consents and report upon them.

The Council may therefore make and record measurements of physical and chemical parameters, take samples for analysis, carry out surveys and inspections, conduct investigations and seek information from consent holders.

The monitoring programme for the Ngatoro-E wellsite consisted of four primary components.

1.4.2 Programme liaison and management

There is generally a significant investment of time and resources by the Council in:

- ongoing liaison with resource consent holders over consent conditions and their interpretation and application;
- discussion over monitoring requirements;
- preparation for any consent reviews, renewals or new consent applications;
- advice on the Council's environmental management strategies and content of regional plans; and
- consultation on associated matters.

1.4.3 Assessment of data submitted by the consent holder

As required by the conditions of consent 9744-2, the Company submitted pre and post fracturing discharge reports to the Council for each well fractured during the period under review. Pre-fracturing discharge reports provide an outline of the proposed fracturing operations in relation to each well, while post fracturing reports confirm details of what actually occurred. The specific range of information required in each report is stipulated in the conditions of the consent.

1.4.4 Physicochemical sampling

1.4.4.1 Groundwater

As a general principle, all existing bores or wells within a 1 km radius of a hydraulic fracturing activity are assessed for their suitability for sampling (or otherwise) and included in the monitoring programme for the wellsite.

As there were no suitable monitoring sites identified, consent conditions required the Company to install a site specific monitoring bore. The new bore installed by the Company is the sole groundwater monitoring site included in the monitoring programme. A summary of bore details are included in Table 3 below.

Samples of groundwater were obtained pre-fracturing to provide a baseline reference of groundwater composition and a further two rounds of sampling were carried out during and following completion of the activities.

Groundwater samples are collected following standard groundwater sampling methodologies and generally in accordance with the National Environmental Monitoring Standards (NEMS) for discrete groundwater quality sampling (2019). All samples were transported to Hill Laboratories Ltd (Hills) for analysis following standard chain of custody procedures.

Table 3 Details of groundwater sites included in the monitoring programme

Monitoring site	Easting (NZTM)	Northing (NZTM)	Distance from wellsite (m)	Total depth (m)	Screened/open interval (m)	Aquifer
GND2469	1701320	5659291	On-site	41.5	28.5-40.5	Marine terraces north

1.4.4.2 Hydraulic fracturing and return fluids

In addition to the sampling of local groundwater, representative samples of the hydraulic fracturing fluid and reservoir fluids produced back to the wellhead immediately following each fracturing event (return fluids) are obtained for analysis.

A samples of return fluid was collected during the flow-back period. Return fluids are comprised of a mixture of hydraulic fracturing fluids and formation fluids produced from the target reservoir, following the completion of the hydraulic fracturing process. The relative concentrations of each contributing fluid type change as the volume of fluid produced from the well increases. Immediately following the opening of the well post fracturing, a high proportion of the fluid returning to the wellhead is fluid injected during the hydraulic fracturing process. As the volume of fluid produced from the well increases, the proportion of hydraulic fracturing fluid reduces in relation to formation fluids. The individual samples of return fluid are generally combined in a composite sample for laboratory analysis. Composites are designed to provide a representative sample of fluids returning to the wellhead over the entire flow-back period.

All samples are collected and sent by the Company to Hills for analysis. Results are provided to the Council on request or in the post fracturing report provided following each fracturing event.

1.4.5 Surface water quality monitoring

The site is located in the Waitara catchment with the Ngatoroit Stream located approximately 120 m from the eastern boundary of the wellsite.

Surveys are conducted at these sites, at times where environmental conditions allow, both pre and post-fracturing any hydraulic fracturing event.

The details of surface water monitoring sites are summarised in Table 4 and the locations in relation to the wellsite are shown on Figure1.

The results of these surveys will be reported on as part of the wider wellsite monitoring programme and have not been included in this report. Details of the surface water sites can be found in Table 4.

Table 4 Details of surface water sites included in the monitoring programme

Site code	Eastings	Northings	Distance from wellsite (m)
NGI000174	1701506	5659250	30m upstream of discharge tributary confluence
NGI000178	1701596	5659355	110m downstream of wellsite discharge location
NGI000180	1701631	5659464	220m downstream of wellsite discharge location

2. Results

2.1 Consent holder submitted data

The conclusions from the Ngatoro-E post fracturing discharge report is summarised as follows:

- One zone was hydraulically fractured on 17 March 2022 at mid-point depths between 3,395 to 3,418m TVDss.
- A total of 1,475bbls (234.5m³) of liquid was discharged into the one fractured unit. The total proppant weight was 43.6 tonnes (96,182lbs).
- All of the fluid injected was returned from the well over the flow-back period with any remaining fluid expected to be returned during subsequent operations.
- A total of 43.6 tonnes (96,182lbs) of proppant was estimated to have remained within the formation following flow-back.
- No screen outs occurred during hydraulic fracturing of the Ngatoro-17 well.
- All return fluid from the Ngatoro-17 fracturing operations were disposed of at the Company's Kaimiro-G wellsite under the Company's deep well injection consent.
- Pressure testing was undertaken of all surface equipment, including flow lines and the wellhead, prior to injection.
- There was no escape of fluids during hydraulic fracturing operations.

2.2 Physicochemical sampling

2.2.1 Groundwater

Hydraulic fracturing activities occurred at the Ngatoro-E wellsite on 17 March 2022. A pre-fracturing baseline sample was collected on 18 November 2021. A 3 month post fracturing sample was collected on 30 June 2022 and the 12 month post fracturing sample was collected on 14 April 2023.

Overall, samples demonstrate relatively narrow ranges in analyte concentrations over time. The subtle variation in analyte concentrations are a result of natural seasonal fluctuation and sampling variability. The results of the laboratory analysis indicate there have been no significant changes in groundwater composition over the period monitored.

A summary of the results for groundwater samples taken in relation to the hydraulic fracturing activities compared to baseline is included in Table 5. The certificates of analysis for the review period are included in Appendix III.

Table 5 Results of groundwater sampling carried out in relation to the Ngatoro-17 fracturing events

Sample date	unit	18/11/2021	30/06/2022	14/04/2023
Sample time	-	08:35	12:03	12:37
Sample id. TRC	-	TRC213808	TRC226927	TRC2311844
pH	pH	7.7	7.9	8.1
Temperature	°C	14.2	13.5	15.8
Total alkalinity	g/m ³ CaCO ₃	140	143	142
Bicarbonate	g/m ³ HCO ₃	171	173	171
Total hardness	g/m ³ CaCO ₃	96	100	99
Electrical conductivity	µS/cm	337	3.9	345
Total dissolved solids	g/m ³	260	240	230
Dissolved calcium	g/m ³	13.6	13.8	14.2
Chloride	g/m ³	5.0	5.6	4.8
Dissolved magnesium	g/m ³	15.0	16.0	15.4
Dissolved potassium	g/m ³	5.7	5.8	5.6
Dissolved sodium	g/m ³	39	37	38
Nitrite	g/m ³ N	< 0.002	< 0.002	<0.002
Nitrate	g/m ³ N	< 0.002	0.004	0.004
Nitrate & nitrite	g/m ³ N	< 0.002	0.004	0.004
Sulphate	g/m ³	29	31	30
Dissolved barium	g/m ³	0.008	0.009	0.011
Bromide	g/m ³	< 0.05	< 0.05	<0.05
Dissolved copper	g/m ³	< 0.0005	< 0.0005	<0.0005
Dissolved iron	g/m ³	0.51	0.76	0.77
Dissolved manganese	g/m ³	15.0	0.37	0.40
Dissolved mercury	g/m ³	< 0.00008	< 0.00008	<0.00008
Dissolved Nickel	g/m ³	< 0.0005	< 0.0005	<0.0005
Dissolved zinc	g/m ³	< 0.0010	< 0.0010	0.0018
Ethylene glycol	g/m ³	< 4	< 4	<4
Propylene glycol	g/m ³	< 4	< 4	<4
Methanol	g/m ³	< 2	< 2	<2
Benzene	g/m ³	< 0.0010	< 0.0010	<0.0010
Toluene	g/m ³	0.0011	<0.0010	0.0014
Ethylbenzene	g/m ³	< 0.0010	< 0.0010	<0.0010
m-Xylene	g/m ³	< 0.002	< 0.002	<0.002
o-Xylene	g/m ³	< 0.0010	< 0.0010	<0.0010
Formaldehyde	g/m ³	< 0.02	0.02	<0.02
Ethane	g/m ³	< 0.003	< 0.003	<0.003
Ethylene	g/m ³	< 0.004	< 0.004	<0.004
Methane	g/m ³	0.015	0.018	0.015
C7-C9 hydrocarbons	g/m ³	< 0.10	< 0.10	<0.10
C10-C14 hydrocarbons	g/m ³	< 0.2	< 0.2	<0.2
C15-C36 hydrocarbons	g/m ³	< 0.4	< 0.4	<0.4
Total hydrocarbons	g/m ³	< 0.7	< 0.7	<0.7

2.2.2 Hydraulic fracturing and return fluids

The results of the analyses carried out on samples of the hydraulic fracturing fluid used in the stimulation of the Ngatoro-17 well is shown below in Table 6. The certificates of analysis are included in Appendix IV.

The results of the analyses carried out on the return fluid samples obtained following the hydraulic fracturing of the Ngatoro-17 well is summarised below in Table 7. The certificates of analysis are included in Appendix IV. The results demonstrate the variability of groundwater composition and hydrocarbon concentrations during flow-back. The relatively high levels of chloride, sodium and hydrocarbons in each sample indicate that the composite samples prepared contained a greater proportion of reservoir fluids than hydraulic fracturing fluids introduced during the fracturing activities, which are comprised predominantly of freshwater.

Table 6 Results of hydraulic fracturing fluid sampling

Well	Unit	Ngatoro-17
Parameter	Range	
Ethylene glycol*	g/m ³	710
Propylene Glycol *	g/m ³	<2
Methanol*	g/m ³	<2
Benzene	g/m ³	0.0060
Toluene	g/m ³	0.031
Ethylbenzene	g/m ³	0.0028
m&p-Xylene	g/m ³	0.017
o-Xylene	g/m ³	0.0058
C7-C9	g/m ³	< 0.15
C10-C14	g/m ³	< 0.4
C15-C36	g/m ³	5.4
Total hydrocarbons	g/m ³	5.8

*Note * Depending on the viscosity of the sample received at the laboratory, samples may require dilution prior to analysis, which results in higher detection limits.*

Table 7 Results of hydraulic fracturing return fluid sampling

Well	Unit	Ngatoro-17
Parameter	Range	
pH	pH	7.1
Total Alkalinity	g/m ³ as CaCO ₃	1,740
Total Hardness	g/m ³ as CaCO ₃	500
Electrical Conductivity	mS/m	2,970
Total Dissolved Solids	g/m ³	20,000
Dissolved Barium	g/m ³	47
Dissolved Bromine	g/m ³	23
Dissolved Calcium	g/m ³	162
Dissolved Copper	g/m ³	0.22
Dissolved Iron	g/m ³	11.3
Dissolved Magnesium	g/m ³	23
Dissolved Manganese	g/m ³	4.3
Total Nickel	g/m ³	0.087

Well	Unit	Ngatoro-17
Parameter	Range	
Total Potassium	g/m ³	250
Total Sodium	g/m ³	6,900
Total Sulphur	g/m ³	8
Total Zinc	g/m ³	0.88
Chloride	g/m ³	10,300
Nitrite	g/m ³ N	< 0.10
Nitrate	g/m ³ N	< 0.5
Nitrate + Nitrite	g/m ³ N	< 0.10
Sulphate	g/m ³	23
Ethylene glycol	g/m ³	< 80
Propylene glycol	g/m ³	< 20
Methanol	g/m ³	< 20
Benzene	g/m ³	3.6
Toluene	g/m ³	2.1
Ethylbenzene	g/m ³	0.090
m&p-Xylene	g/m ³	0.54
o-Xylene	g/m ³	0.26
Formaldehyde	g/m ³	0.16
C7-C9	g/m ³	3.0
C10-C14	g/m ³	15.2
C15-C36	g/m ³	39
Total hydrocarbons	g/m ³	58

*Note * Depending on the viscosity of the sample received at the laboratory, samples may require dilution prior to analysis, which results in higher detection limit.*

2.3 Incidents, investigations, and interventions

The monitoring programme for the year was based on what was considered to be an appropriate level of monitoring, review of data, and liaison with the Company. During the year matters may arise which require additional activity by the Council, for example provision of advice and information, or investigation of potential or actual causes of non-compliance or failure to maintain good practices. A pro-active approach, that in the first instance avoids issues occurring, is favoured.

For all significant compliance issues, as well as complaints from the public, the Council maintains a database record. The record includes events where the individual/organisation concerned has itself notified the Council. Details of any investigation and corrective action taken are recorded for non-compliant events.

Complaints may be alleged to be associated with a particular site. If there is potentially an issue of legal liability, the Council must be able to prove by investigation that the identified individual/organisation is indeed the source of the incident (or that the allegation cannot be proven).

During the period under review, the Council was not required to undertake significant additional investigations and interventions, or record incidents, in association with the Company's conditions in resource consents or provisions in Regional Plans.

3. Discussion

3.1 Environmental effects of exercise of consents

One well, Ngatoro-17, was stimulated by hydraulic fracturing at the Ngatoro-E wellsite on 17 March 2022.

The monitoring programme carried out by the Council in relation to the fracturing events undertaken included pre and post fracturing sampling at one groundwater monitoring site in the vicinity of Ngatoro-E wellsite. The results of post fracturing groundwater sampling carried out generally showed only very minor variations in water composition in comparison to baseline results. The minor variations in analytes are a result of natural variations in water composition.

There was no surface water monitoring undertaken in relation to hydraulic fracturing activities at the wellsite.

In summary, the monitoring carried out by the Council during the period being reported indicated that the hydraulic fracturing activities undertaken by the Company at the Ngatoro-E wellsite have had no significant adverse effects on local groundwater or surface water resources.

3.2 Evaluation of performance

A tabular summary of the consent holder's compliance record for the year under review is set out in Table 8.

Table 8 Summary of performance for consent 9744-2

Purpose: To discharge water based hydraulic fracturing fluids into land at depths greater than 3,375 metres true vertical depth subsea (TVDss) beneath the Ngatoro-E wellsite		
Condition requirement	Means of monitoring during period under review	Compliance achieved?
1. Any discharge shall occur below 3,375m TVDss	Assessment of consent holder submitted data	Yes
2. No discharge shall occur after 1 June 2028	Assessment of consent holder submitted data	N/A
3. Monitoring and reporting of seismic events within 5km of any discharge location	Notification and post fracturing report	N/A
4. Actions to be taken following the occurrence of any event described in condition 3	Notification under condition 3	N/A
5. Exercise of consent shall not result in any contaminants reaching any useable freshwater	Results of groundwater monitoring	Yes
6. Consent holder shall undertake sampling programme	Development and certification of a monitoring programme	Yes
7. If no suitable bores exist within 500m of the wellsite, a monitoring bore may need to be installed	Inspection of bores	Yes
8. Sampling programme shall follow recognised field procedures and be analysed for a specified range of chemical parameters	Development and certification of a monitoring programme and assessment of results	Yes
9. All sampling to be carried out in accordance with a certified Sampling and Analysis Plan	Development and certification of a Sampling and Analysis Plan	Yes
10. Well and equipment pressure testing to be carried out prior to any hydraulic	Assessment of consent holder submitted data	Yes

Purpose: To discharge water based hydraulic fracturing fluids into land at depths greater than 3,375 metres true vertical depth subsea (TVDss) beneath the Ngatoro-E wellsite		
Condition requirement	Means of monitoring during period under review	Compliance achieved?
fracturing programme commencing		
11. A pre-fracturing discharge report is to be provided to the Council 14 days prior to discharge	Pre-fracturing discharge report received	Yes
12. Consent holder shall notify the Council of hydraulic fracturing discharge	Notification received	Yes
13. A post fracturing discharge report is to be provided to the Council within 90 days of any commencement	Post fracturing discharge report received	Yes
14. For programs including multiple hydraulic fracturing discharges, more than one 'Post-fracturing discharge report' may be required	Reports received	N/A
15. Reports in condition 11 and 13 emailed to consents@trc.govt.nz commencement of any hydraulic fracturing	Reports received via email	Yes
16. The consent holder shall provide access to a location where samples of hydraulic fracturing fluids and return fluids can be obtained by the Council officers	Access provided	Yes
17. Consent holder to adopt best practicable option at all times	Site inspections, sampling and assessment of consent holder submitted data	Yes
18. Fracture fluid comprised of no less than 95% water and proppant by volume	Assessment of consent holder submitted data and sampling of fracturing fluid	Yes
19. Lapse clause	Receive notice of exercise of consent	Yes
20. Review condition	N/A	N/A
Overall assessment of environmental performance and compliance in respect of this consent		High
Overall assessment of administrative performance and compliance in respect of this consent		High

N/A = not applicable

Table 9 Evaluation of environmental performance over time

Year	Consent numbers	High	Good	Improvement req	Poor
2014/15	9744-1	1	-	-	-
2022/23	9744-1	1	-	-	-

During the monitoring period, the Company demonstrated a high level of environmental and high level of administrative performance with the resource consent as defined in Appendix II.

3.3 Recommendations from the 2014/15 Annual Report

In the 2014/15 Annual Report, it was recommended:

1. THAT a one year post-fracturing groundwater sample is collected from GND2469 in April 2016.
2. Following the post-fracturing sampling event in April 2016, the monitoring programme should be discontinued, unless further fracturing is undertaken at the site.
3. THAT the option for a review of resource consents in June 2016, as set out in condition 16 of consent 9744-1, is not exercised, on the grounds that the current conditions of the consent are adequate to ensure that any significant adverse effects on the environment are avoided.

3.4 Alterations to monitoring programmes for future hydraulic fracturing activities

In designing and implementing the monitoring programmes for air/water discharges in the region, the Council has taken into account:

- the extent of information already made available through monitoring or other means to date;
- its relevance under the RMA;
- the Council's obligations to monitor consented activities and their effects under the RMA;
- the record of administrative and environmental performances of the consent holder; and
- reporting to the regional community.

The Council also takes into account the scope of assessments required at the time of renewal of permits, and the need to maintain a sound understanding of industrial processes within Taranaki exercising resource consents.

It is proposed that the range of monitoring carried out in relation to the hydraulic fracturing activities undertaken by the Company be replicated for any future fracturing events at the Ngatoro-E wellsite.

Recommendations to this effect are included in Section 4 of this report.

It should be noted that the proposed programme represents a reasonable and risk-based level of monitoring for the site in question. The Council reserves the right to subsequently adjust the programme from that initially prepared, should the need arise if potential or actual non-compliance is determined at any time during future monitoring periods.

4. Recommendations

1. THAT in the first instance, the range of monitoring carried out during the reporting period in relation to the Company's hydraulic fracturing activities be replicated for any future fracturing events at the Ngatoro-E wellsite.
2. THAT should there be issues with environmental or administrative performance in future periods, monitoring may be adjusted to reflect any additional investigation or intervention as found necessary.
3. THAT the option for a review of resource consents in June 2024, as set out in condition 20 of the consent not be exercised.

Glossary of common terms and abbreviations

The following abbreviations and terms may be used within this report:

Biomonitoring	Assessing the health of the environment using aquatic organisms.
bbls	Barrel. Unit of measure used in the oil and gas industry (equivalent to approximately 159L).
Conductivity	An indication of the level of dissolved salts in a sample, usually measured at 25°C and expressed in $\mu\text{S}/\text{cm}$.
DO	Dissolved oxygen.
E.coli	Escherichia coli, an indicator of the possible presence of faecal material and pathological micro-organisms. Usually expressed as colony forming units per 100 millilitre sample.
EPT	Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly) which are macroinvertebrates sensitive to pollution.
Fresh	Elevated flow in a stream, such as after heavy rainfall.
g/m^3	Grams per cubic metre, and equivalent to milligrams per litre (mg/L). In water, this is also equivalent to parts per million (ppm), but the same does not apply to gaseous mixtures.
Incident	An event that is alleged or is found to have occurred that may have actual or potential environmental consequences or may involve non-compliance with a consent or rule in a regional plan. Registration of an incident by the Council does not automatically mean such an outcome had actually occurred.
Intervention	Action/s taken by Council to instruct or direct actions be taken to avoid or reduce the likelihood of an incident occurring.
Investigation	Action taken by Council to establish the circumstances/events surrounding an incident including any allegations of an incident.
L/s	Litres per second.
Macroinvertebrate	An invertebrate that is large enough to be seen without the use of a microscope.
masl	Metres above sea level.
MCI	Macroinvertebrate community index; a numerical indication of the state of biological life in a stream that takes into account the sensitivity of the taxa present to organic pollution in stony habitats.
mS/m	Millisiemens per metre.
m^3	Cubic metre (1,000L).
NZTM	New Zealand Transverse Mercator coordinates.
pH	A numerical system for measuring acidity in solutions, with 7 as neutral. Numbers lower than 7 are increasingly acidic and higher than 7 are increasingly alkaline.
Physicochemical	Measurement of both physical properties (e.g. temperature, clarity, density) and chemical determinants (e.g. metals and nutrients) to characterise the state of an environment.
Resource consent	Refer Section 87 of the RMA. Resource consents include land use consents (refer Sections 9 and 13 of the RMA), coastal permits (Sections 12, 14 and 15), water permits (Section 14) and discharge permits (Section 15).
RMA	Resource Management Act 1991 and including all subsequent amendments.

Screen Out	A condition that occurs when the solids carried in a treatment fluid, such as proppant in a fracture fluid, create a bridge across the perforations or similar restricted flow area. This creates a sudden and significant restriction to fluid flow that causes a rapid rise in pump pressure.
SQMCI	Semi quantitative macroinvertebrate community index.
TVDss	True vertical depth sub-sea.
µS/cm	Microsiemens per centimetre.
Workover	The repair or stimulation of an existing production well for the purpose of restoring, prolonging or enhancing the production of hydrocarbons.

For further information on analytical methods, contact a manager within the Environment Quality Department.

Bibliography and references

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Greymouth Petroleum Ltd (2021): *Ngatoro-E wellsite water quality monitoring programme*. Frodo number #2911107

Greymouth Petroleum Ltd (2021): *Ngatoro-17 Pre-Stimulation Discharge Report, November 2021*. Frodo number #1278414

Greymouth Petroleum Ltd (2022): *Ngatoro-17 Post-Stimulation Discharge Report, May 2022*. Frodo number #3101070

Taranaki Regional Council (2015): *Greymouth Petroleum Limited Ngatoro-E Hydraulic Fracturing Monitoring Programme Annual Report 2014-2015*. Technical report 2015-31

Appendix I

Resource consents held by Greymouth Petroleum Acquisition Ltd

(For a copy of the signed resource consent
please contact the TRC Consents department)

Water abstraction permits

Section 14 of the RMA stipulates that no person may take, use, dam or divert any water, unless the activity is expressly allowed for by a resource consent or a rule in a regional plan, or it falls within some particular categories set out in Section 14. Permits authorising the abstraction of water are issued by the Council under Section 87(d) of the RMA.

Water discharge permits

Section 15(1)(a) of the RMA stipulates that no person may discharge any contaminant into water, unless the activity is expressly allowed for by a resource consent or a rule in a regional plan, or by national regulations. Permits authorising discharges to water are issued by the Council under Section 87(e) of the RMA.

Air discharge permits

Section 15(1)(c) of the RMA stipulates that no person may discharge any contaminant from any industrial or trade premises into air, unless the activity is expressly allowed for by a resource consent, a rule in a regional plan, or by national regulations. Permits authorising discharges to air are issued by the Council under Section 87(e) of the RMA.

Discharges of wastes to land

Sections 15(1)(b) and (d) of the RMA stipulate that no person may discharge any contaminant onto land if it may then enter water, or from any industrial or trade premises onto land under any circumstances, unless the activity is expressly allowed for by a resource consent, a rule in a regional plan, or by national regulations. Permits authorising the discharge of wastes to land are issued by the Council under Section 87(e) of the RMA.

Land use permits

Section 13(1)(a) of the RMA stipulates that no person may in relation to the bed of any lake or river use, erect, reconstruct, place, alter, extend, remove, or demolish any structure or part of any structure in, on, under, or over the bed, unless the activity is expressly allowed for by a resource consent, a rule in a regional plan, or by national regulations. Land use permits are issued by the Council under Section 87(a) of the RMA.

Coastal permits

Section 12(1)(b) of the RMA stipulates that no person may erect, reconstruct, place, alter, extend, remove, or demolish any structure that is fixed in, on, under, or over any foreshore or seabed, unless the activity is expressly allowed for by a resource consent, a rule in a regional plan, or by national regulations. Coastal permits are issued by the Council under Section 87(c) of the RMA.

Discharge Permit
Pursuant to the Resource Management Act 1991
a resource consent is hereby granted by the
Taranaki Regional Council

Name of
Consent Holder: Greymouth Petroleum Acquisition Company Limited
PO Box 3394
New Plymouth 4341

Decision Date: 22 August 2018

Commencement Date: 22 August 2018

Conditions of Consent

Consent Granted: To discharge water based hydraulic fracturing fluids into land at depths greater than 3,375 mTVDss beneath the Ngatoro-E wellsite

Expiry Date: 1 June 2033

Review Date(s): June annually and in accordance with special condition 20

Site Location: Ngatoro-E wellsite, 561 Dudley Road Upper, Inglewood
(Property owner: GD & VK Robinson)

Grid Reference (NZTM) 1701337E-5659269N

Catchment: Waitara

Tributary: Manganui
Ngatoro
Ngatoro-iti

*For General, Standard and Special conditions
pertaining to this consent please see reverse side of this document*

General condition

- a. The consent holder shall pay to the Taranaki Regional Council all the administration, monitoring and supervision costs of this consent, fixed in accordance with section 36 of the Resource Management Act 1991.

Special conditions

1. The discharge point shall be deeper than 3,375 mTVDss.
Note: mTVDss = metres true vertical depth subsea, i.e. the true vertical depth in metres below mean sea level.
2. There shall be no discharge of hydraulic fracturing fluids after 1 June 2028.
3. If the GeoNet seismic monitoring network records a seismic event higher than a Modified Mercalli intensity of magnitude 3 within 5 km of the geographical position (in 3 dimensions) of any hydraulic fracturing discharge, then:
 - (a) if a hydraulic fracturing discharge is currently being undertaken it shall cease immediately and not recommence; or
 - (b) if a hydraulic fracturing discharge has occurred within the previous 72 hours no further hydraulic fracturing discharges shall occur.
4. Following the occurrence of any seismic event described in special condition 3 the consent holder shall immediately notify the Chief Executive, Taranaki Regional Council and investigate and report on the likelihood of the seismic event being induced by the exercise of this consent. Hydraulic fracturing discharges may only then continue once the Chief Executive, Taranaki Regional Council has considered the report and concluded that the environmental risk of recommencing hydraulic fracturing is acceptable and has advised the consent holder accordingly.
5. The consent holder shall ensure that the exercise of this consent does not result in contaminants reaching any useable fresh water (groundwater or surface water). Usable fresh groundwater is defined as any groundwater having a Total Dissolved Solids concentration of less than 1,000 mg/l.
6. The consent holder shall undertake a programme of sampling and testing that monitors the effects of the exercise of this consent on fresh water resources to assess compliance with condition 5 (the 'Monitoring Programme'). The Monitoring Programme shall be certified by the Chief Executive, Taranaki Regional Council ('the Chief Executive'), before this consent is exercised, and shall include:
 - (a) the location of the discharge point(s);
 - (b) the location of sampling sites; and
 - (c) sampling frequency with reference to a hydraulic fracturing programme.

7. Representative groundwater sampling is required to be undertaken at a minimum of one suitable site within 500 metres of the wellsite. If no suitable groundwater monitoring sites can be identified it will be necessary to install at least one monitoring bore of a depth, location and design determined after consultation with the Chief Executive, Taranaki Regional Council and installed in accordance with NZS 4411:2001.
8. All water samples taken for monitoring purposes shall be taken in accordance with recognised field procedures and analysed for:
 - (a) pH;
 - (b) conductivity;
 - (c) total dissolved solids;
 - (d) major ions (Ca, Mg, K, Na, total alkalinity, bromide, chloride, nitrate-nitrogen, and sulphate);
 - (e) trace metals (barium, copper, iron, manganese, nickel, and zinc);
 - (f) total petroleum hydrocarbons;
 - (g) formaldehyde;
 - (h) dissolved methane and ethane gas;
 - (i) methanol;
 - (j) glycols;
 - (k) benzene, toluene, ethylbenzene, and xylenes (BTEX); and
 - (l) carbon-13 composition of any dissolved methane gas discovered ($^{13}\text{C-CH}_4$).

Note: The samples required, under conditions of this consent could be taken and analysed by the Taranaki Regional Council or other contracted party on behalf of the consent holder.

9. All sampling and analysis shall be undertaken in accordance with a *Sampling and Analysis Plan*, which shall be submitted to the Chief Executive for review and certification before the first sampling is undertaken. The plan shall specify the use of standard protocols recognised to constitute good professional practice including quality control and assurance. An International Accreditation New Zealand (IANZ) accredited laboratory shall be used for all sample analysis. Results shall be provided to the Chief Executive within 30 days of sampling and shall include supporting quality control and assurance information. These results will be used to assess compliance with condition 5.

Note: The Sampling and Analysis Plan may be combined with the Monitoring Programme required by condition 6.

10. The consent holder shall undertake well and equipment pressure testing prior to any hydraulic fracture programme on a given well to ensure any discharge will not affect the integrity of the well and hydraulic fracturing equipment.

11. Any hydraulic fracture discharge shall only occur after the consent holder has provided a comprehensive 'Pre-fracturing Discharge Report' to the Chief Executive. The report shall be provided at least 14 days before the discharge is proposed to commence and shall detail the hydraulic fracturing programme proposed, including as a minimum:
- (a) the specific well in which each discharge is to occur, the intended fracture interval(s) ('fracture interval' is the discrete subsurface zone to receive a hydraulic fracture treatment), and the duration of the hydraulic fracturing programme;
 - (b) the number of discharges proposed and the geographical position (i.e. depth and lateral position) of each intended discharge point;
 - (c) the total volume of fracture fluid planned to be pumped down the well, including mini-fracture treatments, and their intended composition, including a list of all contaminants and Material Safety Data Sheets for all the chemicals to be used;
 - (d) the monitoring techniques to be used to determine the fate of discharged material;
 - (e) the results of the reviews required by condition 17;
 - (f) results of modelling showing an assessment of the likely extent and dimensions of the fractures that will be generated by the discharge;
 - (g) the preventative and mitigation measures to be in place to ensure the discharge does not cause adverse environmental effects and complies with condition 5;
 - (h) the extent and permeability characteristics of the geology above the discharge point to the surface;
 - (i) a map of any identified faults within 10 km of the injection location;
 - (j) an annotated seismic profile showing the locations of any identified faults (active or inactive) within 2 km of the injection location, and a discussion regarding the potential for adverse environmental effects due to the presence of any identified faults;
 - (k) an assessment of the integrity of the well;
 - (l) the burst pressure of the well casing and the anticipated maximum well and discharge pressures and the duration of the pressures;
 - (m) details of the disposal of any returned fluids, including any consents that are relied on to authorise the disposal; and
 - (n) details why the contaminants in the discharge and the monitoring techniques used comply with condition 17.

Note: For further information regarding the level of detail required to adequately comply with the requirements of the pre-fracturing report contact the Taranaki Regional Council.

12. The consent holder shall notify the Taranaki Regional Council of the date that each discharge is intended to commence by emailing worknotification@trc.govt.nz. Notification also shall identify the 'Pre-fracturing Discharge Report', required by condition 11, which details the discharge and be given no less than 3 days before the intended discharge date. If any discharge occurs more than 30 days after the notification date, additional notification as specified in this condition is required.

13. Subject to condition 14, within 90 days of any commencement date as advised under condition 12, the consent holder shall submit a comprehensive 'Post-fracturing Discharge Report' to the Chief Executive. The report shall, as a minimum, contain:
- (a) date and time of discharge;
 - (b) confirmation of the interval(s) where fracturing occurred for that programme, and the geographical position (i.e., depth and lateral position) of the discharge point for each fracture interval;
 - (c) the contaminant volumes and composition of fluid discharged into each fracture interval;
 - (d) the volume of return fluids from each fracture interval;
 - (e) an analysis for the constituents set out in conditions 8(a) to 8(k), in a return fluid sample taken within the first two hours of flow back, for each fracture interval if flowed back individually, or for the well if flowed back with all intervals comingled;
 - (f) an estimate of the volume of fluids (and proppant) remaining underground;
 - (g) the volume of water produced with the hydrocarbons (produced water) over the period beginning at the start of the hydraulic fracturing programme and ending 30 days after the programme is completed or after that period of production;
 - (h) an assessment of the extent and dimensions of the fractures that were generated by the discharge, based on modelling undertaken after the discharge has occurred and other diagnostic techniques, including production analysis, available to determine fracture length, height and containment;
 - (i) the results of the seismic monitoring required by condition 3;
 - (j) the results of pressure testing required by condition 10 and the top-hole pressure (psi), slurry rate (bpm), surface proppant concentration (lb/ gal), bottom hole proppant concentration (lb/ gal), and calculated bottom hole pressure (psi), as well as predicted values for each of these parameters; prior to, during and after each hydraulic fracture treatment;
 - (k) details of the disposal of any returned fluids, including any consents that are relied on to authorise the disposal;
 - (l) details of any incidents where hydraulic fracture fluid is unable to pass through the well perforations (screen outs) that occurred, their likely cause and implications for compliance with conditions 1 and 5;
 - (m) results of the monitoring referred to in condition 11(d); and
 - (n) an assessment of the effectiveness of the mitigation measures in place with specific reference to those described in the application for this consent.

Note: Further information regarding the level of detail required to adequately comply with the requirements of the post-fracturing report can be found on the Taranaki Regional Council website.

14. For programs including multiple hydraulic fracturing discharges, more than one 'Post-fracturing discharge report' may be required in order to meet the specified 90-day deadline from each commencement date. In these situations the consent holder shall submit a subsequent 'Post-fracturing Discharge Report' to the Chief Executive within 90 days of the previous report submitted.
15. The reports described in conditions 11 and 13 shall be emailed to consents@trc.govt.nz with a reference to the number of this consent.

Consent 9744-2.0

16. The consent holder shall provide access to a location where the Taranaki Regional Council officers can obtain a sample of the hydraulic fracturing fluids and the return fluids.
17. The consent holder shall at all times adopt the best practicable option, as defined in section 2 of the Resource Management Act 1991, to prevent or minimize any actual or likely adverse effect of the activity on the environment by, as a minimum, ensuring that:
 - (a) the discharge is contained within the fracture interval;
 - (b) regular reviews of monitoring techniques used to ensure the discharge does not cause adverse environmental effects are undertaken;
 - (c) regular reviews are undertaken of the preventative and mitigation measures adopted to ensure the discharge does not cause adverse environmental effects; and
 - (d) regular reviews of the chemicals used are undertaken with a view to reducing the toxicity of the chemicals used.
18. The fracture fluid shall be comprised of no less than 95% water and proppant by volume.
19. This consent shall lapse on 30 September 2023, unless the consent is given effect to before the end of that period or the Taranaki Regional Council fixes a longer period pursuant to section 125(1)(b) of the Resource Management Act 1991.
20. The Taranaki Regional Council may review any or all of the conditions of this consent by giving notice of review:
 - a) during the month of June each year, and/or
 - b) within 30 days of receiving any notification and/or report in accordance with special condition 4 above;for the purposes of:
 - (a) ensuring that the conditions are adequate to deal with any significant adverse effects on the environment arising from the exercise of this consent, which were either not foreseen at the time the application was considered or which it was not appropriate to deal with at the time; and/or
 - (b) further specifying the best practicable option as required by condition 17; and/or
 - (c) ensuring hydraulic fracturing operations appropriately take into account any best practice guidance published by a recognised industry association or environmental regulator.

Signed at Stratford on 22 August 2018

For and on behalf of
Taranaki Regional Council



A D McLay
Director - Resource Management

Appendix II

Categories used to evaluate environmental and administrative performance

Categories used to evaluate environmental and administrative performance

Environmental performance is concerned with actual or likely effects on the receiving environment from the activities during the monitoring year. Administrative performance is concerned with the Company's approach to demonstrating consent compliance in site operations and management including the timely provision of information to Council (such as contingency plans and water take data) in accordance with consent conditions.

Events that were beyond the control of the consent holder and unforeseeable (that is a defence under the provisions of the RMA can be established) may be excluded with regard to the performance rating applied. For example loss of data due to a flood destroying deployed field equipment.

The categories used by the Council for this monitoring period, and their interpretation, are as follows:

Environmental Performance

High: No or inconsequential (short-term duration, less than minor in severity) breaches of consent or regional plan parameters resulting from the activity; no adverse effects of significance noted or likely in the receiving environment. The Council did not record any verified unauthorised incidents involving environmental impacts and was not obliged to issue any abatement notices or infringement notices in relation to such impacts.

Good: Likely or actual adverse effects of activities on the receiving environment were negligible or minor at most. There were some such issues noted during monitoring, from self-reports, or during investigations of incidents reported to the Council by a third party but these items were not critical, and follow-up inspections showed they have been dealt with. These minor issues were resolved positively, co-operatively, and quickly. The Council was not obliged to issue any abatement notices or infringement notices in relation to the minor non-compliant effects however, abatement notices may have been issued to mitigate an identified potential for an environmental effect to occur.

For example:

- High suspended solid values recorded in discharge samples however, the discharge was to land or to receiving waters that were in high flow at the time;
- Strong odour beyond boundary but no residential properties or other recipient nearby.

Improvement required: Likely or actual adverse effects of activities on the receiving environment were more than minor, but not substantial. There were some issues noted during monitoring, from self-reports, or during investigations of incidents reported to the Council by a third party. Cumulative adverse effects of a persistent minor non-compliant activity could elevate a minor issue to this level. Abatement notices and infringement notices may have been issued in respect of effects.

Poor: Likely or actual adverse effects of activities on the receiving environment were significant. There were some items noted during monitoring, from self-reports, or during investigations of incidents reported to the Council by a third party. Cumulative adverse effects of a persistent moderate non-compliant activity could elevate an 'improvement required' issue to this level. Typically there were grounds for either a prosecution or an infringement notice in respect of effects.

Administrative performance

High: The administrative requirements of the resource consents were met, or any failure to do this had trivial consequences and were addressed promptly and co-operatively.

Good: Perhaps some administrative requirements of the resource consents were not met at a particular time however, this was addressed without repeated interventions from the Council staff. Alternatively adequate reason was provided for matters such as the no or late provision of information, interpretation of 'best practical option' for avoiding potential effects, etc.

Improvement required: Repeated interventions to meet the administrative requirements of the resource consents were made by Council staff. These matters took some time to resolve, or remained unresolved at the end of the period under review. The Council may have issued an abatement notice to attain compliance.

Poor: Material failings to meet the administrative requirements of the resource consents. Significant intervention by the Council was required. Typically there were grounds for an infringement notice.

Appendix III

Certificates of analysis (groundwater)



Certificate of Analysis

Page 1 of 3

Client:	Taranaki Regional Council	Lab No:	3242332	SPV1
Contact:	Jane Harvey	Date Received:	15-Apr-2023	
	C/- Taranaki Regional Council	Date Reported:	24-Apr-2023	
	Private Bag 713	Quote No:	47915	
	Stratford 4352	Order No:	4500007241	
		Client Reference:	#8467 - Ngatoro-E 1 year post frac	
		Submitted By:	Josh Dowsing	

Sample Type: Aqueous

Sample Name:		TRC2311844 (GND2469) 14-Apr-2023 12:37 pm	
Lab Number:		3242332.1	
Individual Tests			
Sum of Anions	meq/L	3.6	
Sum of Cations	meq/L	3.8	
pH	pH Units	8.1	
Total Alkalinity	g/m³ as CaCO₃	142	
Bicarbonate	g/m³ at 25°C	171	
Total Hardness	g/m³ as CaCO₃	99	
Electrical Conductivity (EC)	mS/m	34.5	
Total Dissolved Solids (TDS)	g/m³	230	
Sample Temperature*†	°C	15.8	
Dissolved Barium	g/m³	0.011	
Dissolved Calcium	g/m³	14.2	
Dissolved Copper	g/m³	< 0.0005	
Dissolved Iron	g/m³	0.77	
Dissolved Magnesium	g/m³	15.4	
Dissolved Manganese	g/m³	0.40	
Dissolved Mercury	g/m³	< 0.00008	
Dissolved Nickel	g/m³	< 0.0005	
Dissolved Potassium	g/m³	5.6	
Dissolved Sodium	g/m³	38	
Dissolved Zinc	g/m³	0.0018	
Bromide	g/m³	< 0.05	
Chloride	g/m³	4.8	
Nitrite-N	g/m³	< 0.002	
Nitrate-N	g/m³	0.004	
Nitrate-N + Nitrite-N	g/m³	0.004	
Sulphate	g/m³	30	
Ethylene Glycol in Water*			
Ethylene glycol*	g/m³	< 4	
Propylene Glycol in Water*			
Propylene glycol*	g/m³	< 4	
Methanol in Water - Aqueous Solvents*			
Methanol*	g/m³	< 2	
BTEX in Water by Headspace GC-MS			
Benzene	g/m³	< 0.0010	
Toluene	g/m³	0.0014	
Ethylbenzene	g/m³	< 0.0010	
m&p-Xylene	g/m³	< 0.002	
o-Xylene	g/m³	< 0.0010	



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: Aqueous		
Sample Name:	TRC2311844 (GND2469) 14-Apr-2023 12:37 pm	
Lab Number:	3242332.1	
Formaldehyde in Water by DNPH & LCMSMS		
Formaldehyde	g/m³	< 0.02
Gases in groundwater		
Ethane	g/m³	< 0.003
Ethylene	g/m³	< 0.004
Methane	g/m³	0.015
Total Petroleum Hydrocarbons in Water		
C7 - C9	g/m³	< 0.10
C10 - C14	g/m³	< 0.2
C15 - C36	g/m³	< 0.4
Total hydrocarbons (C7 - C36)	g/m³	< 0.7

Analyst's Comments

† Customer supplied data. Please note: Hill Laboratories cannot be held responsible for the validity of this customer supplied data, or any subsequent calculations that rely on this information.

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: Aqueous			
Test	Method Description	Default Detection Limit	Sample No
Individual Tests			
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1
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
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
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
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
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
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 23 rd ed. 2017.	1.0 g/m ³ as CaCO ₃	1
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 23 rd ed. 2017.	0.1 mS/m	1
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
Sample Temperature*	Temperature of the sample at the time of sampling, supplied by customer.	0.1 °C	1
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 23 rd ed. 2017.	0.005 g/m ³	1
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 23 rd ed. 2017.	0.05 g/m ³	1
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 23 rd ed. 2017.	0.0005 g/m ³	1
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 23 rd ed. 2017.	0.02 g/m ³	1
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 23 rd ed. 2017.	0.02 g/m ³	1

Sample Type: Aqueous			
Test	Method Description	Default Detection Limit	Sample No
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 23 rd ed. 2017.	0.0005 g/m ³	1
Dissolved Mercury	0.45µm filtration, bromine oxidation followed by atomic fluorescence. US EPA Method 245.7, Feb 2005.	0.00008 g/m ³	1
Dissolved Nickel	Filtered sample, ICP-MS, trace level. APHA 3125 B 23 rd ed. 2017.	0.0005 g/m ³	1
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 23 rd ed. 2017.	0.05 g/m ³	1
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 23 rd ed. 2017.	0.02 g/m ³	1
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 23 rd ed. 2017.	0.0010 g/m ³	1
Bromide	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 23 rd ed. 2017.	0.05 g/m ³	1
Chloride	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 23 rd ed. 2017.	0.5 g/m ³	1
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
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO ₂ N. In-House.	0.0010 g/m ³	1
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
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 23 rd ed. 2017.	0.5 g/m ³	1
Ethylene Glycol in Water*	Direct injection, dual column GC-FID.	4 g/m ³	1
Propylene Glycol in Water*	Direct injection, dual column GC-FID.	4 g/m ³	1
Methanol in Water - Aqueous Solvents*	GC-FID analysis. In-house.	1.0 g/m ³	1
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis. In-house based on US EPA 8260 and 5021.	0.0010 - 0.002 g/m ³	1
Formaldehyde in Water by DNPH & LCMSMS	Derivatisation, SPE extraction, LC-MS/MS analysis. In-house based on US EPA 8315A.	0.02 g/m ³	1
Gases in groundwater	Headspace GC-FID analysis. In-house.	0.002 - 0.003 g/m ³	1
Total Petroleum Hydrocarbons in Water			
C7 - C9	Solvent extraction, GC-FID analysis. In-house based on US EPA 8015.	0.10 g/m ³	1
C10 - C14	Solvent extraction, GC-FID analysis. In-house based on US EPA 8015.	0.2 g/m ³	1
C15 - C36	Solvent extraction, GC-FID analysis. In-house based on US EPA 8015.	0.4 g/m ³	1
Total hydrocarbons (C7 - C36)	Calculation: Sum of carbon bands from C7 to C36. In-house based on US EPA 8015.	0.7 g/m ³	1

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

Testing was completed between 18-Apr-2023 and 24-Apr-2023. 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.

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Ara Heron BSc (Tech)
Client Services Manager - Environmental



Certificate of Analysis

Page 1 of 3

Client:	Taranaki Regional Council	Lab No:	3024539	SPv1
Contact:	Jane Harvey	Date Received:	01-Jul-2022	
	C/- Taranaki Regional Council	Date Reported:	11-Jul-2022	
	Private Bag 713	Quote No:	47915	
	Stratford 4352	Order No:	4500002828	
		Client Reference:	#7657 - Greymouth Ngatoro-E GW June 2022	
		Submitted By:	Adele Bittner	

Interim Report

This is an interim report, prepared before all test results are completed. As all final Q.C. checks may not have been possible, it is not regarded as an official certificate of analysis. The final, official report will be issued upon completion of all tests.

Sample Type: Aqueous						
Sample Name:	TRC226927 (GND2469) 30-Jun-2022 12:03 pm					
Lab Number:	3024539.1					
Individual Tests						
Sum of Anions	meq/L	3.7	-	-	-	-
Sum of Cations	meq/L	3.8	-	-	-	-
pH	pH Units	7.9	-	-	-	-
Total Alkalinity	g/m ³ as CaCO ₃	143	-	-	-	-
Bicarbonate	g/m ³ at 25°C	173	-	-	-	-
Total Hardness	g/m ³ as CaCO ₃	100	-	-	-	-
Electrical Conductivity (EC)	mS/m	33.9	-	-	-	-
Total Dissolved Solids (TDS)	g/m ³	240	-	-	-	-
Sample Temperature†	°C	13.5	-	-	-	-
Dissolved Barium	g/m ³	0.009	-	-	-	-
Dissolved Calcium	g/m ³	13.8	-	-	-	-
Dissolved Copper	g/m ³	< 0.0005	-	-	-	-
Dissolved Iron	g/m ³	0.76	-	-	-	-
Dissolved Magnesium	g/m ³	16.0	-	-	-	-
Dissolved Manganese	g/m ³	0.37	-	-	-	-
Dissolved Mercury	g/m ³	< 0.00008	-	-	-	-
Dissolved Nickel	g/m ³	< 0.0005	-	-	-	-
Dissolved Potassium	g/m ³	5.8	-	-	-	-
Dissolved Sodium	g/m ³	37	-	-	-	-
Dissolved Zinc	g/m ³	< 0.0010	-	-	-	-
Bromide	g/m ³	< 0.05	-	-	-	-
Chloride	g/m ³	5.6	-	-	-	-
Nitrite-N	g/m ³	< 0.002	-	-	-	-
Nitrate-N	g/m ³	0.004	-	-	-	-
Nitrate-N + Nitrite-N	g/m ³	0.004	-	-	-	-
Sulphate	g/m ³	31	-	-	-	-
Ethylene Glycol in Water						
Ethylene glycol	g/m ³	< 4	-	-	-	-
Propylene Glycol in Water						
Propylene glycol	g/m ³	< 4	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol	g/m ³	In Progress	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m ³	< 0.0010	-	-	-	-
Toluene	g/m ³	< 0.0010	-	-	-	-
Ethylbenzene	g/m ³	< 0.0010	-	-	-	-

Sample Type: Aqueous						
Sample Name:		TRC226927 (GND2469) 30-Jun-2022 12:03 pm				
Lab Number:		3024539.1				
BTEX in Water by Headspace GC-MS						
m&p-Xylene	g/m ³	< 0.002	-	-	-	-
o-Xylene	g/m ³	< 0.0010	-	-	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m ³	In Progress	-	-	-	-
Gases in groundwater						
Ethane	g/m ³	< 0.003	-	-	-	-
Ethylene	g/m ³	< 0.004	-	-	-	-
Methane	g/m ³	0.018	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m ³	< 0.10	-	-	-	-
C10 - C14	g/m ³	< 0.2	-	-	-	-
C15 - C36	g/m ³	< 0.4	-	-	-	-
Total hydrocarbons (C7 - C36)	g/m ³	< 0.7	-	-	-	-

Analyst's Comments

† Customer supplied data. Please note: Hill Laboratories cannot be held responsible for the validity of this customer supplied data, or any subsequent calculations that rely on this information.

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: Aqueous			
Test	Method Description	Default Detection Limit	Sample No
Individual Tests			
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1
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
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
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
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
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
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 23 rd ed. 2017.	1.0 g/m ³ as CaCO ₃	1
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 23 rd ed. 2017.	0.1 mS/m	1
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
Sample Temperature	Temperature of the sample at the time of sampling, supplied by customer.	0.1 °C	1
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 23 rd ed. 2017.	0.005 g/m ³	1
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 23 rd ed. 2017.	0.05 g/m ³	1

Sample Type: Aqueous			
Test	Method Description	Default Detection Limit	Sample No
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 23 rd ed. 2017.	0.0005 g/m ³	1
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 23 rd ed. 2017.	0.02 g/m ³	1
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 23 rd ed. 2017.	0.02 g/m ³	1
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 23 rd ed. 2017.	0.0005 g/m ³	1
Dissolved Mercury	0.45µm filtration, bromine oxidation followed by atomic fluorescence. US EPA Method 245.7, Feb 2005.	0.00008 g/m ³	1
Dissolved Nickel	Filtered sample, ICP-MS, trace level. APHA 3125 B 23 rd ed. 2017.	0.0005 g/m ³	1
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 23 rd ed. 2017.	0.05 g/m ³	1
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 23 rd ed. 2017.	0.02 g/m ³	1
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 23 rd ed. 2017.	0.0010 g/m ³	1
Bromide	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 23 rd ed. 2017.	0.05 g/m ³	1
Chloride	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 23 rd ed. 2017.	0.5 g/m ³	1
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
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO ₂ N. In-House.	0.0010 g/m ³	1
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
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 23 rd ed. 2017.	0.5 g/m ³	1
Ethylene Glycol in Water	Direct injection, dual column GC-FID.	4 g/m ³	1
Propylene Glycol in Water	Direct injection, dual column GC-FID.	4 g/m ³	1
Methanol in Water - Aqueous Solvents	GC-FID analysis. In-house.	1.0 g/m ³	1
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis. In-house based on US EPA 8260 and 5021.	0.0010 - 0.002 g/m ³	1
Formaldehyde in Water by DNPH & LCMSMS	Derivatisation, SPE extraction, LC-MS/MS analysis. In-house based on US EPA 8315A.	0.02 g/m ³	1
Gases in groundwater	Headspace GC-FID analysis. In-house.	0.002 - 0.003 g/m ³	1
Total Petroleum Hydrocarbons in Water			
C7 - C9	Solvent extraction, GC-FID analysis. In-house based on US EPA 8015.	0.10 g/m ³	1
C10 - C14	Solvent extraction, GC-FID analysis. In-house based on US EPA 8015.	0.2 g/m ³	1
C15 - C36	Solvent extraction, GC-FID analysis. In-house based on US EPA 8015.	0.4 g/m ³	1
Total hydrocarbons (C7 - C36)	Calculation: Sum of carbon bands from C7 to C36. In-house based on US EPA 8015.	0.7 g/m ³	1

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

Testing was completed between 01-Jul-2022 and 08-Jul-2022. 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.

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Carole Rodgers-Carroll BA, NZCS
Client Services Manager - Environmental



Certificate of Analysis

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Client:	Taranaki Regional Council	Lab No:	2772421	SPv1
Contact:	Jane Harvey	Date Received:	19-Nov-2021	
	C/- Taranaki Regional Council	Date Reported:	26-Nov-2021	
	Private Bag 713	Quote No:	47915	
	Stratford 4352	Order No:	4500002828	
		Client Reference:	#7169 - Greymouth Ngatoro-E Pre-Frac GW	
		Submitted By:	Sarah Larkin	

Sample Type: Aqueous

Sample Name:	TRC213808 (GND2469) 18-Nov-2021 8:35 am				
Lab Number:	2772421.1				
Individual Tests					
Sum of Anions	meq/L	3.6	-	-	-
Sum of Cations	meq/L	3.8	-	-	-
pH	pH Units	7.7	-	-	-
Total Alkalinity	g/m ³ as CaCO ₃	140	-	-	-
Bicarbonate	g/m ³ at 25°C	171	-	-	-
Total Hardness	g/m ³ as CaCO ₃	96	-	-	-
Electrical Conductivity (EC)	mS/m	33.7	-	-	-
Total Dissolved Solids (TDS)	g/m ³	260	-	-	-
Sample Temperature*†	°C	14.2	-	-	-
Dissolved Barium	g/m ³	0.008	-	-	-
Dissolved Calcium	g/m ³	13.6	-	-	-
Dissolved Copper	g/m ³	< 0.0005	-	-	-
Dissolved Iron	g/m ³	0.51	-	-	-
Dissolved Magnesium	g/m ³	15.0	-	-	-
Dissolved Manganese	g/m ³	0.38	-	-	-
Dissolved Mercury	g/m ³	< 0.00008	-	-	-
Dissolved Nickel	g/m ³	< 0.0005	-	-	-
Dissolved Potassium	g/m ³	5.7	-	-	-
Dissolved Sodium	g/m ³	39	-	-	-
Dissolved Zinc	g/m ³	< 0.0010	-	-	-
Bromide	g/m ³	< 0.05	-	-	-
Chloride	g/m ³	5.0	-	-	-
Nitrite-N	g/m ³	< 0.002	-	-	-
Nitrate-N	g/m ³	< 0.002	-	-	-
Nitrate-N + Nitrite-N	g/m ³	< 0.002	-	-	-
Sulphate	g/m ³	29	-	-	-
Ethylene Glycol in Water*					
Ethylene glycol*	g/m ³	< 4	-	-	-
Propylene Glycol in Water*					
Propylene glycol*	g/m ³	< 4	-	-	-
Methanol in Water - Aqueous Solvents*					
Methanol*	g/m ³	< 2	-	-	-



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: Aqueous						
Sample Name:		TRC213808 (GND2469) 18-Nov-2021 8:35 am				
Lab Number:		2772421.1				
BTEX in Water by Headspace GC-MS						
Benzene	g/m ³	< 0.0010	-	-	-	-
Toluene	g/m ³	0.0011	-	-	-	-
Ethylbenzene	g/m ³	< 0.0010	-	-	-	-
m&p-Xylene	g/m ³	< 0.002	-	-	-	-
o-Xylene	g/m ³	< 0.0010	-	-	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m ³	< 0.02	-	-	-	-
Gases in groundwater						
Ethane	g/m ³	< 0.003	-	-	-	-
Ethylene	g/m ³	< 0.004	-	-	-	-
Methane	g/m ³	0.015	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m ³	< 0.10	-	-	-	-
C10 - C14	g/m ³	< 0.2	-	-	-	-
C15 - C36	g/m ³	< 0.4	-	-	-	-
Total hydrocarbons (C7 - C36)	g/m ³	< 0.7	-	-	-	-

Analyst's Comments

† Customer supplied data. Please note: Hill Laboratories cannot be held responsible for the validity of this customer supplied data, or any subsequent calculations that rely on this information.

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: Aqueous			
Test	Method Description	Default Detection Limit	Sample No
Individual Tests			
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1
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
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
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
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
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
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 23 rd ed. 2017.	1.0 g/m ³ as CaCO ₃	1
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 23 rd ed. 2017.	0.1 mS/m	1
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
Sample Temperature*	Temperature of the sample at the time of sampling, supplied by customer.	0.1 °C	1

Sample Type: Aqueous			
Test	Method Description	Default Detection Limit	Sample No
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 23 rd ed. 2017.	0.005 g/m ³	1
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 23 rd ed. 2017.	0.05 g/m ³	1
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 23 rd ed. 2017.	0.0005 g/m ³	1
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 23 rd ed. 2017.	0.02 g/m ³	1
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 23 rd ed. 2017.	0.02 g/m ³	1
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 23 rd ed. 2017.	0.0005 g/m ³	1
Dissolved Mercury	0.45µm filtration, bromine oxidation followed by atomic fluorescence. US EPA Method 245.7, Feb 2005.	0.00008 g/m ³	1
Dissolved Nickel	Filtered sample, ICP-MS, trace level. APHA 3125 B 23 rd ed. 2017.	0.0005 g/m ³	1
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 23 rd ed. 2017.	0.05 g/m ³	1
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 23 rd ed. 2017.	0.02 g/m ³	1
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 23 rd ed. 2017.	0.0010 g/m ³	1
Bromide	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 23 rd ed. 2017.	0.05 g/m ³	1
Chloride	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 23 rd ed. 2017.	0.5 g/m ³	1
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
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO ₂ N. In-House.	0.0010 g/m ³	1
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
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 23 rd ed. 2017.	0.5 g/m ³	1
Ethylene Glycol in Water*	Direct injection, dual column GC-FID.	4 g/m ³	1
Propylene Glycol in Water*	Direct injection, dual column GC-FID.	4 g/m ³	1
Methanol in Water - Aqueous Solvents*	GC-FID analysis. In-house.	1.0 g/m ³	1
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis. In-house based on US EPA 8260 and 5021.	0.0010 - 0.002 g/m ³	1
Formaldehyde in Water by DNPH & LCMSMS	Derivatisation, SPE extraction, LC-MS/MS analysis. In-house based on US EPA 8315A.	0.02 g/m ³	1
Gases in groundwater	Headspace GC-FID analysis. In-house.	0.002 - 0.003 g/m ³	1
Total Petroleum Hydrocarbons in Water			
C7 - C9	Solvent extraction, GC-FID analysis. In-house based on US EPA 8015.	0.10 g/m ³	1
C10 - C14	Solvent extraction, GC-FID analysis. In-house based on US EPA 8015.	0.2 g/m ³	1
C15 - C36	Solvent extraction, GC-FID analysis. In-house based on US EPA 8015.	0.4 g/m ³	1
Total hydrocarbons (C7 - C36)	Calculation: Sum of carbon bands from C7 to C36. In-house based on US EPA 8015.	0.7 g/m ³	1

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

Testing was completed between 22-Nov-2021 and 26-Nov-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.

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Graham Corban MSc Tech (Hons)
Client Services Manager - Environmental

Appendix IV

Certificates of analysis
(hydraulic fracturing fluids)



Certificate of Analysis

Page 1 of 2

Client:	Greymouth Petroleum Limited	Lab No:	2937153	SPV1
Contact:	Fiona Campbell	Date Received:	30-Mar-2022	
	C/- Greymouth Petroleum Limited	Date Reported:	08-Apr-2022	
	14 Connett Road West	Quote No:	85159	
	Bell Block	Order No:	255275	
	New Plymouth 4312	Client Reference:	Hydraulic fracturing fluid testing	
		Submitted By:	Fiona Campbell	

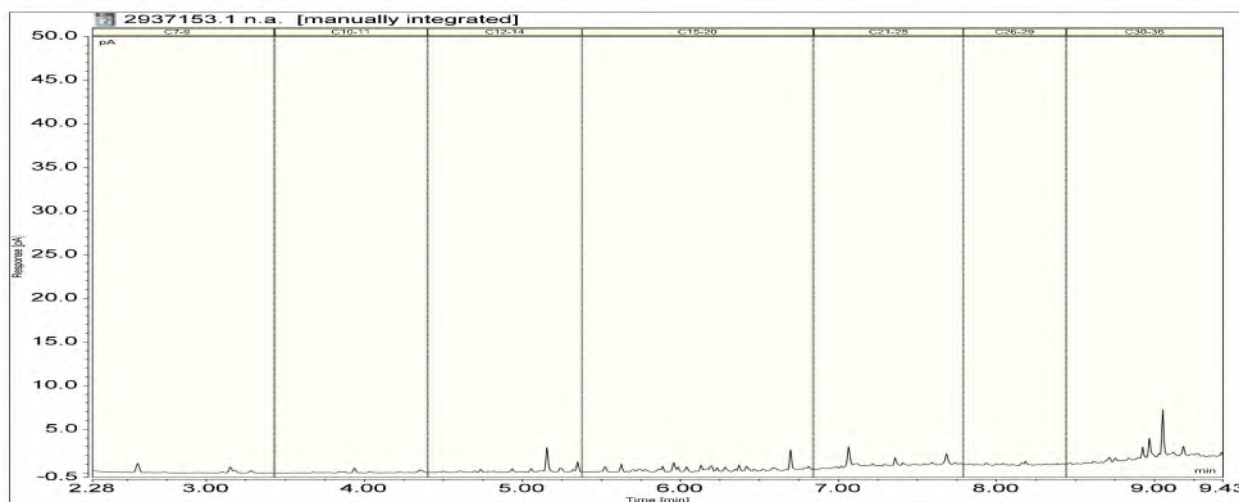
Sample Type: Aqueous

Sample Name:	Ngatao 17 Stim 1 Prepumped HF Fluid 16-Mar-2022				
Lab Number:	2937153.1				
Ethylene Glycol in Water*					
Ethylene glycol*	g/m ³	710	-	-	-
Propylene Glycol in Water*					
Propylene glycol*	g/m ³	< 20	-	-	-
Methanol in Water - Aqueous Solvents*					
Methanol*	g/m ³	< 20	-	-	-
BTEX in Water by Headspace GC-MS					
Benzene	g/m ³	0.0060	-	-	-
Toluene	g/m ³	0.031	-	-	-
Ethylbenzene	g/m ³	0.0028	-	-	-
m&p-Xylene	g/m ³	0.017	-	-	-
o-Xylene	g/m ³	0.0058	-	-	-
Total Petroleum Hydrocarbons in Water					
C7 - C9	g/m ³	< 0.15	-	-	-
C10 - C14	g/m ³	< 0.4	-	-	-
C15 - C36	g/m ³	5.4	-	-	-
Total hydrocarbons (C7 - C36)	g/m ³	5.8	-	-	-

2937153.1

Ngatao 17 Stim 1 Prepumped HF Fluid 16-Mar-2022

Client Chromatogram for TPH by FID



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.

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: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Individual Tests			
Ethylene Glycol in Water*	Direct injection, dual column GC-FID.	4 g/m ³	1
Propylene Glycol in Water*	Direct injection, dual column GC-FID.	4 g/m ³	1
Methanol in Water - Aqueous Solvents*	GC-FID analysis. In-house.	1.0 g/m ³	1
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis. In-house based on US EPA 8260 and 5021.	0.0010 - 0.002 g/m ³	1
Total Petroleum Hydrocarbons in Water			
C7 - C9	Solvent extraction, GC-FID analysis. In-house based on US EPA 8015.	0.10 g/m ³	1
C10 - C14	Solvent extraction, GC-FID analysis. In-house based on US EPA 8015.	0.2 g/m ³	1
C15 - C36	Solvent extraction, GC-FID analysis. In-house based on US EPA 8015.	0.4 g/m ³	1
Total hydrocarbons (C7 - C36)	Calculation: Sum of carbon bands from C7 to C36. In-house based on US EPA 8015.	0.7 g/m ³	1

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

Testing was completed between 01-Apr-2022 and 08-Apr-2022. 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.

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Ara Heron BSc (Tech)
Client Services Manager - Environmental



Certificate of Analysis

Page 1 of 4

Client:	Greymouth Petroleum Limited	Lab No:	2939072	SPv1
Contact:	Fiona Campbell	Date Received:	31-Mar-2022	
	C/- Greymouth Petroleum Limited	Date Reported:	11-Apr-2022	
	14 Connett Road West	Quote No:	81870	
	Bell Block	Order No:	255275	
	New Plymouth 4312	Client Reference:	Return Fluid Composite	
		Submitted By:	Fiona Campbell	

Sample Type: Saline

Sample Name:		Composite of Nga 17 Return HF Fluid Start, Nga 17 Return HF Fluid Middle & Nga 17 Return HF Fluid End				
Lab Number:		2939072.4				
Individual Tests						
pH*	pH Units	7.1	-	-	-	-
Total Alkalinity*	g/m³ as CaCO₃	1,740	-	-	-	-
Total Hardness*	g/m³ as CaCO₃	500	-	-	-	-
Electrical Conductivity (EC)*	mS/m	2,970	-	-	-	-
Total Dissolved Solids (TDS)*	g/m³	20,000	-	-	-	-
Dissolved Barium	g/m³	47	-	-	-	-
Dissolved Bromine	g/m³	23	-	-	-	-
Dissolved Calcium	g/m³	162	-	-	-	-
Dissolved Copper	g/m³	0.22	-	-	-	-
Dissolved Iron	g/m³	11.3	-	-	-	-
Dissolved Magnesium	g/m³	23	-	-	-	-
Dissolved Manganese	g/m³	4.3	-	-	-	-
Total Nickel	g/m³	0.087	-	-	-	-
Total Potassium	g/m³	250	-	-	-	-
Total Sodium	g/m³	6,900	-	-	-	-
Total Sulphur*	g/m³	8	-	-	-	-
Total Zinc	g/m³	0.88	-	-	-	-
Chloride*	g/m³	10,300	-	-	-	-
Nitrite-N	g/m³	< 0.10	-	-	-	-
Nitrate-N	g/m³	< 0.10	-	-	-	-
Nitrate*	g/m³	< 0.5	-	-	-	-
Nitrate-N + Nitrite-N	g/m³	< 0.10	-	-	-	-
Sulphate*	g/m³	23	-	-	-	-
Ethylene Glycol in Water*						
Ethylene glycol*	g/m³	< 80 #1	-	-	-	-
Propylene Glycol in Water*						
Propylene glycol*	g/m³	< 20	-	-	-	-
Methanol in Water - Aqueous Solvents*						
Methanol*	g/m³	< 20	-	-	-	-



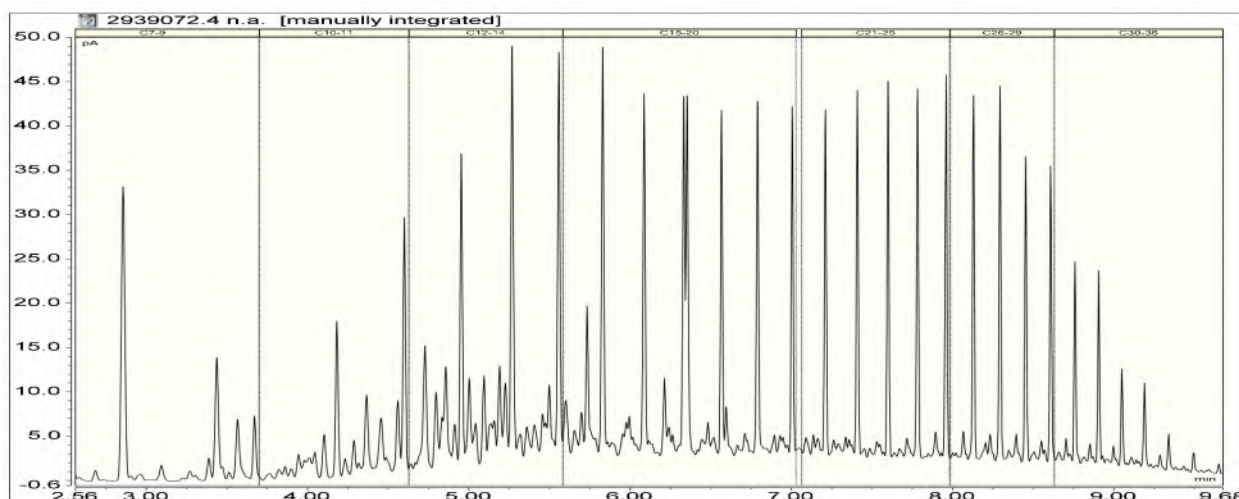
This Laboratory is accredited by International Accreditation New Zealand (IANZ), which represents New Zealand in the International Laboratory Accreditation Cooperation (ILAC). Through the ILAC Mutual Recognition Arrangement (ILAC-MRA) this accreditation is internationally recognised. The tests reported 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: Saline						
Sample Name:		Composite of Nga 17 Return HF Fluid Start, Nga 17 Return HF Fluid Middle & Nga 17 Return HF Fluid End				
Lab Number:		2939072.4				
BTEX in Water by Headspace GC-MS*						
Benzene*	g/m³	3.6	-	-	-	-
Toluene*	g/m³	2.1	-	-	-	-
Ethylbenzene*	g/m³	0.090	-	-	-	-
m&p-Xylene*	g/m³	0.54	-	-	-	-
o-Xylene*	g/m³	0.26	-	-	-	-
Formaldehyde in Water by DNPH & LCMSMS*						
Formaldehyde*	g/m³	0.16	-	-	-	-
Total Petroleum Hydrocarbons in Water*						
C7 - C9*	g/m³	3.0	-	-	-	-
C10 - C14*	g/m³	15.2	-	-	-	-
C15 - C36*	g/m³	39	-	-	-	-
Total hydrocarbons (C7 - C36)*	g/m³	58	-	-	-	-

2939072.4

Composite of Nga 17 Return HF Fluid Start, Nga 17 Return HF Fluid Middle & Nga 17 Return HF Fluid End

Client Chromatogram for TPH by FID



Analyst's Comments

#1 Due to some interference found in the chromatography, the detection limit was raised. Hence the higher detection limit reported.

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: Saline			
Test	Method Description	Default Detection Limit	Sample No
Individual Tests			
Filtration, Unpreserved*	Sample filtration through 0.45µm membrane filter.	-	4
Total Digestion*	Boiling nitric acid digestion. APHA 3030 E (modified) 23 rd ed. 2017.	-	4
Total Digestion of Saline Samples*	Nitric acid digestion. APHA 3030 E (modified) 23 rd ed. 2017.	-	4

Sample Type: Saline			
Test	Method Description	Default Detection Limit	Sample No
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	4
Total Alkalinity*	Saline water, Titration to pH 4.5.	1.0 g/m ³ as CaCO ₃	4
Total Hardness*	Calculation from Calcium and Magnesium. APHA 2340 B 23 rd ed. 2017.	1.0 g/m ³ as CaCO ₃	4
Electrical Conductivity (EC)*	Conductivity meter, 25°C. APHA 2510 B 23 rd ed. 2017.	0.1 mS/m	4
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.	50 g/m ³	4
Filtration for dissolved metals analysis*	Sample filtration through 0.45µm membrane filter and preservation with nitric acid. APHA 3030 B 23 rd ed. 2017.	-	4
Dissolved Barium	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 23 rd ed. 2017.	0.0006 g/m ³	4
Dissolved Bromine	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 23 rd ed. 2017.	0.10 g/m ³	4
Dissolved Calcium	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 23 rd ed. 2017.	1.0 g/m ³	4
Dissolved Copper	Filtered sample, ICP-MS, ultratrace. APHA 3125 B 23 rd ed. 2017.	0.0010 g/m ³	4
Dissolved Iron	Filtered sample, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 23 rd ed. 2017.	0.004 g/m ³	4
Dissolved Magnesium	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 23 rd ed. 2017.	0.4 g/m ³	4
Dissolved Manganese	Filtered sample, ICP-MS, ultratrace. APHA 3125 B 23 rd ed. 2017.	0.0010 g/m ³	4
Total Nickel	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 23 rd ed. 2017.	0.0070 g/m ³	4
Total Potassium	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 23 rd ed. 2017.	1.1 g/m ³	4
Total Sodium	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 23 rd ed. 2017.	0.42 g/m ³	4
Total Sulphur*	Nitric acid digestion, ICP-OES (method may not fully account for H ₂ S due to volatilisation during digestion). All forms of oxidised and organic sulphur will be determined by this method. APHA 3120 B 23 rd ed. 2017.	0.5 g/m ³	4
Total Zinc	Nitric acid digestion, ICP-MS, ultratrace. APHA 3125 B 23 rd ed. 2017.	0.0042 g/m ³	4
Chloride*	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 23 rd ed. 2017.	0.5 g/m ³	4
Nitrite-N	Saline sample. Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO ₂ ⁻ I (modified) 23 rd ed. 2017.	0.0010 g/m ³	4
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO ₂ N. In-House.	0.0010 g/m ³	4
Nitrate*	Calculation from Nitrate-N.	0.005 g/m ³	4
Nitrate-N + Nitrite-N	Saline sample. Total oxidised nitrogen. Automated cadmium reduction, Flow injection analyser. APHA 4500-NO ₃ ⁻ I (modified) 23 rd ed. 2017.	0.0010 g/m ³	4
Total Sulphate*	Calculation: from total sulphur.	2 g/m ³	4
Ethylene Glycol in Water*	Direct injection, dual column GC-FID.	4 g/m ³	4
Propylene Glycol in Water*	Direct injection, dual column GC-FID.	4 g/m ³	4
Methanol in Water - Aqueous Solvents*	GC-FID analysis. In-house.	1.0 g/m ³	4
BTEX in Water by Headspace GC-MS*	Headspace GC-MS analysis. In-house based on US EPA 8260 and 5021.	0.0010 - 0.002 g/m ³	4
Formaldehyde in Water by DNPH & LCMSMS*	Derivatisation, SPE extraction, LC-MS/MS analysis. In-house based on US EPA 8315A.	0.02 g/m ³	4
Total Petroleum Hydrocarbons in Water			
C7 - C9*	Solvent extraction, GC-FID analysis. In-house based on US EPA 8015.	0.10 g/m ³	4
C10 - C14*	Solvent extraction, GC-FID analysis. In-house based on US EPA 8015.	0.2 g/m ³	4
C15 - C36*	Solvent extraction, GC-FID analysis. In-house based on US EPA 8015.	0.4 g/m ³	4

Sample Type: Saline			
Test	Method Description	Default Detection Limit	Sample No
Total hydrocarbons (C7 - C36)*	Calculation: Sum of carbon bands from C7 to C36. In-house based on US EPA 8015.	0.7 g/m ³	4

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

Testing was completed between 01-Apr-2022 and 11-Apr-2022. For completion dates of individual analyses please contact the laboratory.

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Ara Heron BSc (Tech)
Client Services Manager - Environmental