Todd Energy Ltd
Mangahewa-C Hydraulic Fracturing Monitoring Programme 2018-2019

Technical Report 20-36

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Executive summary

Todd Energy Ltd (Todd) operates the Mangahewa-C hydrocarbon exploration site located on Tikorangi Road, Tikorangi. This report outlines and discusses the results of the monitoring programme implemented by the Council in relation to hydraulic fracturing activities conducted by Todd at the wellsite over the period 27 June 2018 to 10 July 2018. 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 Todd at the Mangahewa-C wellsite included the hydraulic fracturing of one well. The well targeted for stimulation was the Mangahewa-3 well.

During the monitoring period, Todd demonstrated an overall high level of environmental performance.

The programme of monitoring implemented by the Council in relation to these hydraulic fracturing activities spanned the 2017-2018 and 2018-2019 monitoring years. Monitoring included pre and post discharge groundwater sampling. Biomonitoring surveys were also carried out to assess the impact of any site discharges during the hydraulic fracturing programme on the Waiau Stream. Samples of hydraulic fracturing fluids, and fluids returning to the wellhead post fracturing, were also obtained for physicochemical analysis in order to characterise the discharges and to determine compliance with consent conditions.

This is the sixth monitoring report produced by the Council in relation to the hydraulic fracturing activities at the Mangahewa-C wellsite.

The monitoring carried out by the Council indicates that the hydraulic fracturing activities undertaken by Todd 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 Todd in relation to these activities or provisions in regional plans, during the period under review.

Todd demonstrated a high level of environmental and administrative performance and compliance with the resource consents over the reporting period.

For reference, in the 2018-2019 year, consent holders were found to achieve a high level of environmental performance and compliance for 83% of the consents monitored through the Taranaki tailored monitoring programmes, while for another 13% of the consents, a good level of environmental performance and compliance was achieved.

For reference, in the 2019-2020 year, consent holders were found to achieve a high level of environmental performance and compliance for 81% of the consents monitored through the Taranaki tailored monitoring programmes, while for another 17% of the consents, a good level of environmental performance and compliance was achieved.

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

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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 the Taranaki Regional Council (the Council) in relation to the programme of hydraulic fracturing undertaken by Todd Energy Ltd (Todd) at the Mangahewa-C wellsite, over the period 27 June 2018 to 10 July 2018. The report also assesses Todd's level of environmental performance and compliance with the resource consent held in relation to the activity.

The programme of hydraulic fracturing undertaken by Todd at the Mangahewa-C wellsite included the hydraulic fracturing of one well. The well targeted for stimulation was the Mangahewa-3 well.

The programme of monitoring implemented by the Council in relation to these hydraulic fracturing activities spanned the 2017-2018 and 2018-2019 monitoring years. Monitoring included a mixture of groundwater, surface water and discharge monitoring components. This is the sixth monitoring report produced by the Council in relation to hydraulic fracturing activities at the Mangahewa-C wellsite. The previous five reports covered hydraulic fracturing activities spanning the period July 2011 to June 2018.

1.1.2 Structure of this report

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

- the nature of the monitoring programme in place for the period under review; and
- a description of the activities and operations conducted at Mangahewa-C.

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 for the future monitoring of any hydraulic fracturing activities at the Mangahewa-C wellsite.

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 Resource Management Act 1991 (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' inasmuch 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 and administrative performance

Besides discussing the various details of the performance and extent of compliance by the Company, this report also assigns them a rating for their environmental and administrative performance during the period under review.

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.

For reference, in the 2018-2019 year, consent holders were found to achieve a high level of environmental performance and compliance for 83% of the consents monitored through the Taranaki tailored monitoring programmes, while for another 13% of the consents, a good level of environmental performance and compliance was achieved.[1]

For reference, in the 2019-2020 year, consent holders were found to achieve a high level of environmental performance and compliance for 81% of the consents monitored through the Taranaki tailored monitoring programmes, while for another 17% of the consents, a good level of environmental performance and compliance was achieved. [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

[1] The Council has used these compliance grading criteria for 15 years. They align closely with the 4 compliance grades in the MfE Best Practice Guidelines for Compliance, Monitoring and Enforcement, 2018

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 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 (N_2) is a gas at room temperature, it can be maintained in a liquid state through cooling and pressurisation. Nitrogen assisted fracturing is extremely 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. Nitrogen gas achieves the same purpose as water but returns more easily to the surface.[2] More indirectly, a reduction in the volume of water used also reduces the total concentration of chemical additives required and the volume of water returning to the surface that requires subsequent disposal.[2]

1.2.2 The Mangahewa-C wellsite and hydraulic fracturing activities

The Mangahewa-C wellsite is located on Tikorangi Road East, Tikorangi and lies within the Waiau 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 Todd at the Mangahewa-C 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 (m TVDss)	Formation
Mangahewa-3	GND2822	27/06/2018-29/06/2018	4044.6, 3971.1, 3931.8, 3805.5	Mangahewa
		07/07/2018-10/07/2018	3792.1, 3673.8, 3618.6, 3479.5	

[2] *http://frackwire.com/nitrogen-gas-fracking*

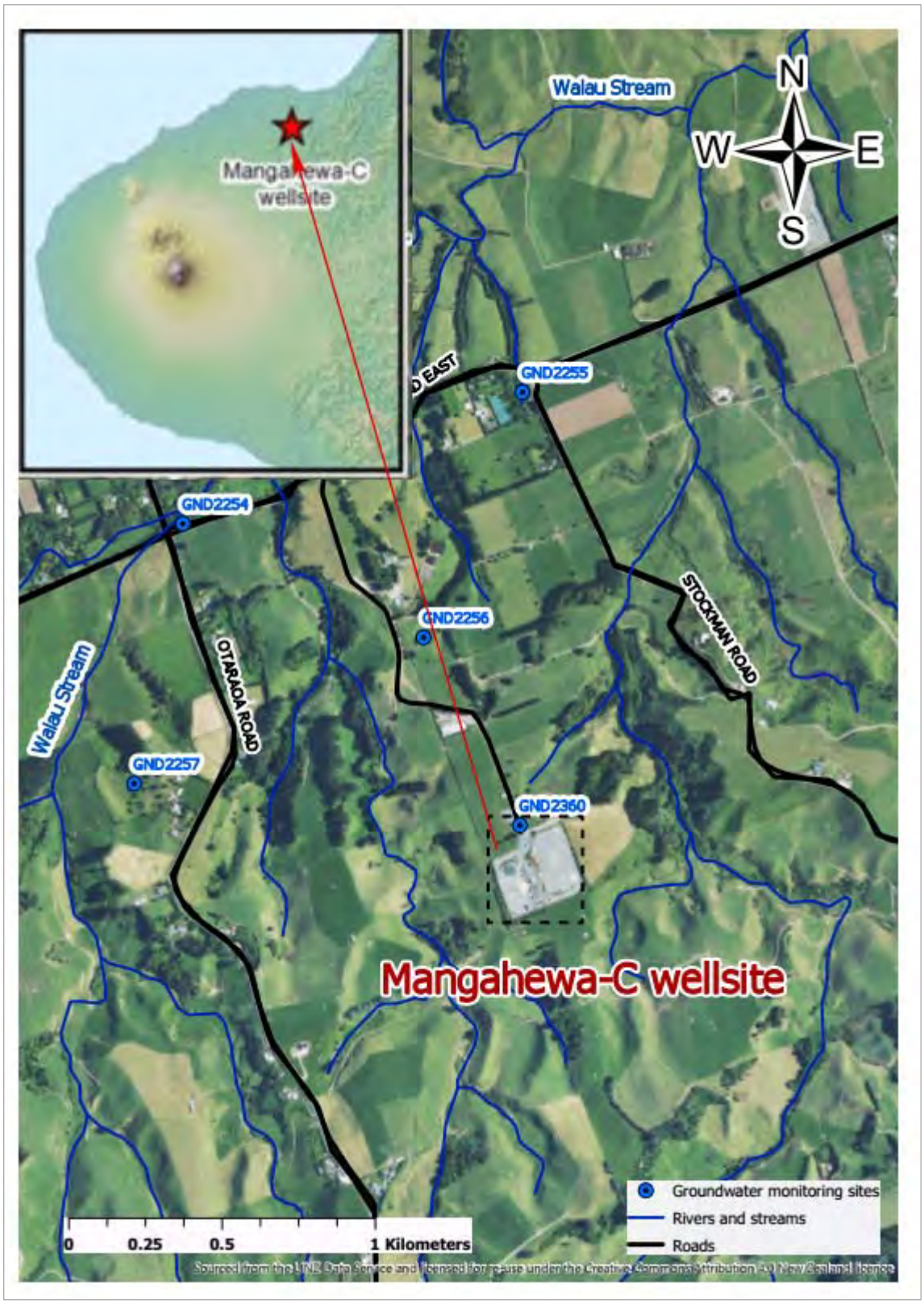

Figure 1 Location map

1.3 Resource consents

1.3.1 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.

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 Appendix I, as is a copy of the permit held by the Company during the period under review.

Table 2 resource consent held by the Company during the period under review

Consent number	Purpose of consent	Granted	Next review	Expires
7971-2	To discharge water based hydraulic fracturing fluids into land at depths greater than 3,290 m TVDss beneath the Mangahewa-C wellsite	30/06/2014	June 2021	01/06/2024

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 Mangahewa-C 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;
- in 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 10356-1, Todd submitted pre and post fracturing discharge reports to the Council for the 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 Physiochemical sampling

1.4.4.1 Groundwater

As a generally accepted rule, 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.

The survey of existing sites resulted in a total of five groundwater abstraction sites being selected for inclusion in the monitoring programme. More recently in 2013, one of the original sites (GND2258) was replaced with the water supply bore GND2360. A summary of bore details is included in Table 3 and the bore locations are illustrated in Figure 1. The sampling sites were selected based on their proximity to the Mangahewa-C wellsite and their individual construction and usage characteristics. The site selection is designed to provide a sample set representative of groundwater abstractions in the area surrounding the site.

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
GND2254	1712606	5677572	1,161	37	unknown	Volcanics
GND2255	1713472	5677892	1,158	4	unknown	Volcanics
GND2256	1713212	5677276	595	2.4	0-2.4	Volcanics
GND2257	1712473	5676917	960	5	unknown	Volcanics
GND2360	1713450	5676798	60	533	Open from 149 m	Matemateaonga

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 following completion of the activities.

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) were obtained for analysis.

Samples of return fluids were collected at regular intervals 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 were transported to Hill Laboratories Ltd (Hills) for analysis following standard chain of custody procedures.

1.4.5 Surface water quality monitoring

The headwaters of two unnamed tributaries of the Waiau Stream initiate close to the Mangahewa-C wellsite. One to the north east of the site and the other to the south east (Figure 1). Stormwater and uncontaminated site water are discharged into the north eastern tributary.

Details of the three sites selected to monitor downstream of the site and the estimated location of groundwater/subsurface drainage from the discharge area are included in Table 4. The locations are illustrated in Figure 2.

Table 4 Surface water monitoring site details

Site number	Site code	Eastings (NZTM)	Northings (NZTM)	Location	Altitude (masl)
1	WAI000075	1713722	5677105	20 m u/s of confluence with tributary receiving wellsite discharge	70
2	WAI000078	1713717	5677129	110 m d/s wellsite discharge, 10m u/s of confluence	70
3	WAI000080	1713730	5677170	20 m d/s of confluence with tributary receiving wellsite discharge	70

1.4.5.1 Biomonitoring surveys

Biomonitoring surveys are undertaken to determine whether discharges related to hydraulic fracturing and/or drilling activities at the wellsite have had any detrimental impacts on the macroinvertebrate communities of the unnamed tributary of the Waiau Stream. Samples are processed to provide number of taxa (richness), MCI and $SQMCI_S$ scores, and EPT taxa for each site.

The MCI is a measure of the overall sensitivity of the macroinvertebrate community to the effects of organic pollution in stony streams. It is based on the presence/absence of taxa with varying degrees of sensitivity to environmental conditions. The $SQMCI_S$ takes into account taxa abundance as well as sensitivity to pollution, and may reveal more subtle changes in communities. It may be the more appropriate index if non-organic impacts are occurring.

Significant differences in either the MCI or the $SQMCI_S$ between sites indicate the degree of adverse effects (if any) of the discharges being monitored.

Macroinvertebrate surveys were carried out on 11 June 2018 and 10 September 2018 at the Mangahewa-C wellsite to determine whether discharges relating to hydraulic fracturing and/or drilling activities undertaken during the reporting period at the wellsite had caused a detrimental effect upon the macroinvertebrate communities of two unnamed tributaries of the Waiau Stream.

Figure 2 Surface water monitoring sites

2 Results

2.1 Consent holder submitted data

2.1.1 Mangahewa-3 post fracturing discharge report

The conclusions from the Mangahewa-3 post fracturing discharge report are summarised as follows:

- A total of eight zones were fractured over the period 27 June to 10 July 2018 at mid-point depths between 3,480 to 4,045 m TVDss.
- A total of 14,218 bbls (2,260 m^3) of liquid was discharged across the eight fractured zones. The total proppant weight was 220.4 tonnes (485,868 lbs).
- The Mangahewa-3 well was opened for flow-back following the completion of the first four zones and then again following completion of the second four zones. In total 17,713 bbls (2,816 m^3) of fluid was returned from the well over the two flow-back periods.
- A total of 218.1 tonnes (480,902 lbs) of proppant was estimated to have remained within the formation following flow back.
- No screen outs occurred during hydraulic fracturing of the Mangahewa-3 well.
- All return fluid from the Mangahewa-3 fracturing operations was disposed of by deep well injection, at the McKee-A, McKee-B and Tuhua-B wellsites.
- 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.
- It is considered that the mitigation measures implemented by Todd were effective in reducing the potential for any adverse environmental effects associated with fracturing operations.

2.2 Physiochemical sampling

2.2.1 Groundwater

Hydraulic fracturing activities commenced at the Mangahewa-C wellsite on 27 June 2018 and continued until 10 July 2018. A pre-fracturing baseline sample was collected on 27 November 2017. Post fracturing samples were collected five months and 12 months following commencement of the activities on 5 November 2018 and 28 June 2019. The five month and 12 month post fracturing samples could not be collected from GND2360, located on the Mangahewa-C wellsite as there is no direct access to the water column and the bore was not connected to a power supply. Following discussions with Todd the bore was reconnected to a power supply and a post fracturing sample was taken on 8 August 2019. The post fracturing results indicate the sample taken contained a higher concentration of dissolved solids, which is an indication that the bore was not purged for a long enough period to remove all the standing water prior to sampling.

Low or trace concentrations of methane were recorded in the groundwater samples collected at GND2254, GND2255 and GND2360, and commonly occurs as a result of biogenic processes in groundwater across the region. Carbon 13 isotope analysis of the methane indicates a biogenic source. Overall, samples demonstrate relatively narrow ranges between analyte concentrations over time. The subtle variation in analyte concentrations at each site 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 II.

Table 5 Results of groundwater sampling carried out in relation to the Mangahewa-3 fracturing event

Parameter	Bore id	GND2254			GND2255			GND2256			GND2257			GND2360	
Sample date	**Unit**	**27/11/17**	**5/11/18**	**21/06/19**	**27/11/17**	**5/11/18**	**21/06/19**	**27/11/17**	**5/11/18**	**21/06/19**	**27/11/17**	**5/11/18**	**21/06/19**	**27/11/17**	**08/08/19**
Sample time	-	**12:55**	**09:00**	**13:30**	**12:15**	**09:50**	**14:00**	**13:54**	**12:20**	**14:25**	**14:35**	**10:35**	**15:00**	**08:40**	**11:10**
Sample id. TRC	-	**174386**	**184502**	**192469**	**174387**	**184498**	**192465**	**174388**	**184500**	**192467**	**174389**	**184501**	**192468**	**174390**	**192466**
pH	pH	8.0	8.0	8.1	6.1	5.9	6.2	6.2	6.0	6.4	6.3	6.1	6.4	9.4	9.1
Temperature	°C	15.5	14.9	15	16.2	15.5	14.8	15.9	19.2	13.7	17.5	15.1	12.7	16.8	17.1
Total alkalinity	g/m^3 $CaCO_3$	119	120	121	20	21	21	22	22	23	27	26	29	170	189
Bicarbonate	g/m^3 HCO_3	144	145	146	25	25	25	27	27	29	33	32	35	167	200
Total hardness	g/m^3 $CaCO_3$	98	100	94	28	29	30	38	39	40	38	38	38	5.2	46
Electrical conductivity	mS/m	27.6	27	26.9	13.3	12.7	13.7	16.8	16.4	16.1	16.5	16.6	17	40.6	128.7
Total dissolved solids	g/m^3	158	160	168	85	78	91	115	104	116	120	102	115	240	690
Dissolved calcium	g/m^3	24	23	22	6.1	6.2	6.4	8.7	8.5	9.1	7.9	7.6	7.8	1.45	11.5
Chloride	g/m^3	13	12.6	13.7	22	19	21	21	19.5	19.3	19	21	21	23	280
Dissolved magnesium	g/m^3	9.2	10.6	9.4	3.1	3.4	3.4	3.9	4.3	4.3	4.4	4.6	4.5	0.4	4.2
Dissolved potassium	g/m^3	2.4	2.3	2.3	3.2	2.9	3.2	5.4	6.0	3.6	2.0	2.0	2.0	0.7	1.4
Dissolved sodium	g/m^3	16.2	15.2	15.1	10.3	10.7	11.8	10.2	10.4	11.3	14.9	15.1	16.5	79.0	270.0
Nitrite	g/m^3 N	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	0.003	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Nitrate	g/m^3 N	< 0.002	0.003	0.002	1.21	1.17	1.88	4.3	4.4	4.4	3.9	3.8	3.9	< 0.002	< 0.002
Nitrate & nitrite	g/m^3 N	< 0.002	0.003	0.002	1.21	1.17	1.88	4.3	4.4	4.4	3.9	3.8	3.9	< 0.002	0.002
Sulphate	g/m^3	< 0.5	< 0.5	< 0.5	3.3	2.6	3.1	4.0	3.8	3.7	4.4	4.7	3.8	1.8	1.8
Dissolved barium	mg/kg	0.0143	0.014	0.014	0.041	0.038	0.042	0.064	0.074	0.047	0.0131	0.014	0.015	0.0029	0.027
Bromide	g/m^3	0.07	0.08	0.08	0.11	0.11	0.11	0.11	0.12	0.11	0.10	0.11	0.11	0.10	1.11
Dissolved copper	g/m^3	< 0.0005	< 0.0005	< 0.0005	0.0095	0.054	0.061	< 0.0005	0.004	0.0042	0.0086	0.0184	0.02	< 0.0005	< 0.0005
Dissolved iron	g/m^3	0.30	0.28	0.30	0.07	0.06	0.08	0.03	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	0.03	0.17
Dissolved manganese	g/m^3	0.033	0.032	0.035	0.004	0.007	0.003	0.013	0.011	0.010	0.001	0.003	0.005	0.002	0.012
Dissolved mercury	g/m^3	< 0.00008	< 0.00008	< 0.00008	< 0.00008	< 0.00008	< 0.00008	< 0.00008	< 0.00008	< 0.00008	< 0.00008	< 0.00008	< 0.00008	< 0.00008	< 0.00008
Dissolved Nickel	mg/kg	< 0.0005	0.0021	0.0006	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	0.0045	0.0007	0.0008	< 0.0005	< 0.0005
Dissolved zinc	g/m^3	< 0.001	0.012	0.002	0.011	0.041	0.037	0.004	0.023	0.021	0.024	0.045	0.090	0.025	0.014
Ethylene glycol	g/m^3	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
Propylene glycol	g/m^3	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
Methanol	g/m^3	< 2	< 2	< 5	< 2	< 2	< 5	< 2	< 2	< 5	< 2	< 2	< 5	< 2	< 2
Benzene	g/m^3	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Toluene	g/m^3	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Ethylbenzene	g/m^3	< 0.0010	0.0012	0.0016	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
m-Xylene	g/m^3	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002

Parameter	Bore id	GND2254			GND2255			GND2256			GND2257			GND2360	
Sample date	**Unit**	**27/11/17**	**5/11/18**	**21/06/19**	**27/11/17**	**5/11/18**	**21/06/19**	**27/11/17**	**5/11/18**	**21/06/19**	**27/11/17**	**5/11/18**	**21/06/19**	**27/11/17**	**08/08/19**
Sample time	**-**	**12:55**	**09:00**	**13:30**	**12:15**	**09:50**	**14:00**	**13:54**	**12:20**	**14:25**	**14:35**	**10:35**	**15:00**	**08:40**	**11:10**
Sample id. TRC	**-**	**174386**	**184502**	**192469**	**174387**	**184498**	**192465**	**174388**	**184500**	**192467**	**174389**	**184501**	**192468**	**174390**	**192466**
o-Xylene	g/m^3	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Formaldehyde	g/m^3	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Ethane	g/m^3	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	0.005	0.013
Ethylene	g/m^3	< 0.003	< 0.004	< 0.004	< 0.003	< 0.004	< 0.004	< 0.003	< 0.004	< 0.004	< 0.003	< 0.004	< 0.004	< 0.003	< 0.004
Methane	g/m^3	2.4	2.4	2.7	< 0.002	0.006	0.003	0.008	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	1.6	6.8
C7-C9 hydrocarbons	g/m^3	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06
C10-C14 hydrocarbons	g/m^3	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
C15-C36 hydrocarbons	g/m^3	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	0.6	< 0.4	< 0.4
Total hydrocarbons	g/m^3	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7
δ13C value	‰ (-)	-76.6	-74.1	-76.1	-	-	-	-	-	-	-	-	-	-62.9	-61.7

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 treatment of the Mangahewa-3 well are shown below in Table 6. The certificates of analysis are included in Appendix III.

The results of the analyses carried out on the return fluid samples obtained following the hydraulic fracturing of the Mangahewa-3 well are summarised below in Table 7 and certificates of analysis are included in Appendix III. The results demonstrate the variability of groundwater composition and hydrocarbon concentrations during flowback. 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

Parameter	Bore id	GND2822			
Sample date	-	28 Jun 2018	07 Jul 2018	08 Jul 2018	10 Jul 2018
Sample id.	Unit	TRC182869	TRC183131	TRC183130	TRC183132
Ethylene glycol*	g/m^3	21	330	< 4	< 4
Propylene glycol*	g/m^3	< 4	< 4	< 4	< 4
Methanol	g/m^3	< 2	< 2	< 2	< 2
Benzene	g/m^3	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Toluene	g/m^3	0.0011	0.0011	< 0.0010	0.0022
Ethylbenzene	g/m^3	< 0.0010	< 0.0010	< 0.0010	< 0.0010
m-Xylene	g/m^3	< 0.002	< 0.002	< 0.002	< 0.002
o-Xylene	g/m^3	< 0.0010	< 0.0010	< 0.0010	< 0.0010
C7-C9 hydrocarbons	g/m^3	< 0.06	< 0.06	0.06	< 0.06
C10-C14 hydrocarbons	g/m^3	420	< 1.0	5.4	520
C15-C36 hydrocarbons	g/m^3	45	9	5	42
Total hydrocarbons	g/m^3	470	9	11	560

*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, in comparison to groundwater seen in some parameters.*

Table 7 Results of hydraulic fracturing return fluid sampling

Parameter	Bore id	GND2822	
Sample date	Unit	03/07/2018	20/07/2018
Sample id.	-	TRC182870	TRC183133
pH	pH	7.3	7.8
Total alkalinity	g/m^3 $CaCO_3$	1,230	1,740
Bicarbonate	g/m^3 HCO_3	1,226	-
Total hardness	g/m^3 $CaCO_3$	700	500

Parameter	Bore id	GND2822	
Sample date	Unit	03/07/2018	20/07/2018
Sample id.	-	TRC182870	TRC183133
Electrical conductivity	mS/m	4,740	4,260
Total dissolved solids	g/m^3	34,000	-
Total barium	g/m^3	137	123
Bromide	g/m^3	38	40
Total calcium	g/m^3	240	158
Total copper	g/m^3	0.025	< 0.005
Total iron	g/m^3	10.7	0.7
Total magnesium	g/m^3	24	25
Total manganese	g/m^3	5.4	3.1
Total Nickel	g/m^3	0.06	< 0.03
Total potassium	g/m^3	7,600	3,100
Total sodium	g/m^3	5,900	7,300
Total sulphur	g/m^3	87	37
Total zinc	g/m^3	0.082	0.026
Chloride	g/m^3	13,400	13,700
Nitrite nitrogen	g/m^3 N	< 0.10	< 0.010
Nitrate nitrogen	g/m^3 N	< 0.10	< 0.010
Nitrate & nitrite nitrogen	g/m^3 N	< 0.10	< 0.010
Sulphate	g/m^3	260	111
Ethylene glycol*	g/m^3	< 40	< 4
Propylene glycol*	g/m^3	< 40	< 4
Methanol	g/m^3	< 2	< 2
Benzene	g/m^3	61	15
Toluene	g/m^3	330	21
Ethylbenzene	g/m^3	98.0	1.2
m-Xylene	g/m^3	680	7
o-Xylene	g/m^3	210.0	2.5
Formaldehyde	g/m^3	< 0.2	< 8.0
C7-C9 hydrocarbons	g/m^3	4,100	40
C10-C14 hydrocarbons	g/m^3	3,800	34
C15-C36 hydrocarbons	g/m^3	3,900	24
Total hydrocarbons	g/m^3	11,900	98

*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, in comparison to groundwater seen in some parameters.*

2.3 Biomonitoring surveys

Two macroinvertebrate surveys were carried out at three sites in two unnamed tributaries of the Waiau Stream, near the Mangahewa-C wellsite. Surveys were carried out pre and post fracturing of the Mangahewa-3 well to enable a comparison to be made and determine if discharges from the wellsite have had any significant adverse effects on the stream macroinvertebrate communities. These surveys recorded high MCI and SQMCI scores when compared to the results from other lowland coastal streams at similar altitude.

MCI and SQMCI scores were similar between all three sites in the pre-fracturing survey, while site 2 in the receiving tributary recorded a lower taxa richness than sites 1 and 3 in the larger tributary. In the post fracturing survey, all three metrics increased in a downstream direction. Site 1 showed a significant decrease in all three metrics between the two surveys, which can be directly attributed to sediment deposition caused by a blocked culvert downstream. Site 2 showed a significant improvement in MCI score, but taxa richness and SQMCI score remained similar, and site 3 showed a significant improvement in all three metrics.

There was no evidence that discharges from the Mangahewa-C wellsite had caused any recent significant adverse effects on the macroinvertebrate communities of these two unnamed tributaries of the Waiau Stream.

A copy of the biomonitoring report for the site is available from the Council upon request.

2.4 Investigations, interventions, and incidents

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 Todd. 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.

The Council operates and maintains a register of all complaints or reported and discovered excursions from acceptable limits and practices, including non-compliance with consents, which may damage the environment. The incident register includes events where the consent holder concerned has itself notified the Council. The register contains details of any investigation and corrective action taken.

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 company 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 Todd's conditions in resource consents or provisions in Regional Plans.

3 Discussion

3.1 Environmental effects of exercise of consents

One well (Mangahewa-3) was stimulated by hydraulic fracturing at the Mangahewa-C wellsite during the period 27 June to 10 July 2018.

The monitoring programme carried out by the Council in relation to the fracturing events undertaken included both groundwater and surface water monitoring components.

The groundwater monitoring component incorporated pre and post fracturing sampling at five groundwater monitoring sites in the vicinity of the Mangahewa-C wellsite. The results of post fracturing groundwater sampling carried out 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.

The surface water monitoring component of the programme comprised of two biomonitoring surveys in two unnamed tributaries of the Waiau Stream. There was no evidence that any discharges from the wellsite had caused any recent significant adverse effects on the macroinvertebrate communities of the two unnamed tributaries.

In summary, the monitoring carried out by the Council during the period being reported indicated that the hydraulic fracturing activities undertaken by Todd at the Mangahewa-C wellsite has 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 and Table 9.

Table 8 Summary of performance for consent 7971-2

Purpose: ***To discharge water based hydraulic fracturing fluids into land at depths greater than 3,290 metres true vertical depth subsea (TVDss) beneath the Mangahewa-C wellsite***		
Condition requirement	**Means of monitoring during period under review**	**Compliance achieved?**
1. Any discharge shall occur below 3,290 m TVDss	Assessment of consent holder submitted data	Yes
2. No discharge shall occur after 1 June 2019	Assessment of consent holder submitted data	N/A
3. Exercise of consent shall not result in any contaminants reaching any useable freshwater	Results of groundwater monitoring	Yes
4. Consent holder shall undertake sampling programme	Development and certification of a monitoring programme	Yes
5. If no suitable bores exist within 500 m of the wellsite, a monitoring bore may need to be installed	Inspection of bores	Yes
6. 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

Purpose: *To discharge water based hydraulic fracturing fluids into land at depths greater than 3,290 metres true vertical depth subsea (TVDss) beneath the Mangahewa-C wellsite*		
Condition requirement	**Means of monitoring during period under review**	**Compliance achieved?**
7. 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
8. Well and equipment pressure testing to be carried out prior to any hydraulic fracturing programme commencing	Assessment of consent holder submitted data	Yes
9. A pre-fracturing discharge report is to be provided to the Council 14 days prior to discharge	Pre-fracturing discharge report received	Yes
10. Consent holder shall notify the Council of hydraulic fracturing discharge	Notification received	Yes
11. A post fracturing discharge report is to be provided to the Council within 90 days of any commencement	Post fracturing discharge report received	Yes
12. The reports outlined in conditions 9 and 11 must be emailed to consents@trc.govt.nz	Reports received via email	Yes
13. 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
14. Consent holder to adopt best practicable option at all times	Site inspections, sampling and assessment of consent holder submitted data	Yes
15. No hydrocarbon based hydraulic fracturing fluid shall be discharged	Assessment of consent holder submitted data and sampling of fracturing fluid	Yes
16. Lapse clause	Receive notice of exercise of consent	Yes
17. 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

Period	Consent no	High	Good	Improvement required	Poor
2017-2018	7971-2	1	-	-	-
2016-2017		1	-	-	-
2015-2017		1	-	-	-
2014-2016		1	-	-	-

Period	Consent no	High	Good	Improvement required	Poor
2013-2015	7971-1 and 7971-2	1	-	-	-
2011-2013	7971-1	1	-	-	-
Totals	-	6	-	-	-

During the monitoring period, Todd demonstrated a high level of environmental and high level of administrative performance with the resource consent as defined in Section 1.1.4. Since 2011 the environmental performance in relation to the consent has remained at a high level.

3.3 Alterations to monitoring programmes of future hydraulic fracturing events

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.

Condition 2 of the consent 7971-2 prohibits any further hydraulic fracturing activities after 1 June 2019 to enable additional monitoring to be undertaken for five years prior to the consent expiring. If the consent is renewed, it is proposed that the range of monitoring carried out in relation to the hydraulic fracturing activities undertaken by Todd be replicated for any future fracturing events at the Mangahewa-C 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.

3.4 Exercise of optional review of consent

Resource consent 7971-2 provides for an optional review of the consent in June 2021. Condition 17 allows the Council to review the consent, for the purpose 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 14; and/or

c. ensuring hydraulic fracturing operations appropriately take into account any best practice guidance published by a recognised industry association or environmental regulator.

Based on the results of monitoring in the year under review, it is considered that there are no grounds that require a review to be pursued or grounds to exercise the review option.

4 Recommendations

1. THAT in the first instance, the range of monitoring carried out during the reporting period in relation to Todd's hydraulic fracturing activities be replicated for any future fracturing events at the Mangahewa-C 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 2021, as set out in condition 17 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 159 litres).
Conductivity	Conductivity, an indication of the level of dissolved salts in a sample, usually measured at 25°C and expressed in µS/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 (1,000 litres).
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 Science Services Manager.

Bibliography and references

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Todd Energy Ltd (2017) Biomonitoring of unnamed tributaries of the Waiau Stream in relation to hydraulic fracturing activities at the Mangahewa-C wellsite. October 2018. Frodo number #2130885.

Todd Energy Ltd (2018) Hydraulic fracturing - Todd Mangahewa-C wellsite Post fracturing Discharge Report Mangahewa-3. September 2018. Frodo number #2121072.

Todd Energy Ltd (2018) Hydraulic fracturing - Todd Mangahewa-C wellsite Pre-fracturing Discharge Report Mangahewa-3. May 2018. Frodo number #2375781.

Todd Energy Ltd (2017) Sampling and analysis plan - Mangahewa-C groundwater monitoring programme September 2016. Frodo number #1750864.

Appendix I

Resource consent held by Todd Energy 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:	Todd Energy Limited PO Box 802 NEW PLYMOUTH 4340
Decision Date:	30 June 2014
Commencement Date:	30 June 2014

Conditions of Consent

Consent Granted:	To discharge water based hydraulic fracturing fluids into land at depths greater than 3290 mTVDss beneath the Mangahewa-C wellsite
Expiry Date:	01 June 2024
Review Date(s):	June annually
Site Location:	Mangahewa-C wellsite, Tikorangi Road, Waitara (Property owner: PG & BM Bourke)
Legal Description:	Lot 9 DP 408656 (Discharge source & site)
Grid Reference (NZTM)	1713435E-5676634N
Catchment:	Waiau

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 3290 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 2019.

3. 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 1000 mg/l.

4. 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 3 (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.

5. Depending on the suitability of existing bores within 500 metres of the wellsite for obtaining a representative groundwater sample, it may be necessary for the Monitoring Programme to include installation of, and sampling from, at least one monitoring bore. The bore(s) would be of a depth, location and design determined after consultation with the Chief Executive, Taranaki Regional Council and installed in accordance with NZS 4411:2001.

6. 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);
   (l) carbon-13 composition of any dissolved methane gas discovered (^{13}C-CH_4).

   Note: *The samples required, under conditions 4 and 6 could be taken and analysed by the Taranaki Regional Council or other contracted party on behalf of the consent holder.*

7. 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 3.

   Note: *The Sampling and Analysis Plan may be combined with the Monitoring Programme required by* condition 4.

8. 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.

9. 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 14;
   (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 3;
   (h) the extent and permeability characteristics of the geology above the discharge point to the surface;
   (i) any identified faults within the modeled fracture length plus a margin of 50%, and the potential for adverse environmental effects due to the presence of the identified faults;
   (j) the burst pressure of the well and the anticipated maximum well and discharge pressures and the duration of the pressures; and
   (k) details of the disposal of any returned fluids, including any consents that are relied on to authorise the disposal; and
   (l) details why the contaminants in the discharge and the monitoring techniques used comply with condition 14.

   Note: *For the avoidance of doubt, the information provided with a resource consent application would usually be sufficient to constitute a 'Pre-fracturing discharge report' for any imminent hydraulic fracturing discharge. The Pre-fracturing discharge report provided for any later discharge may refer to the resource consent application or earlier Pre-fracturing discharge reports noting any differences.*

10. 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 9, 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.

11. Within 90 days of any commencement date as advised under condition 10, 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 6(a) to 6(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 50 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 pressure testing required by condition 8, 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;
    (j) details of the disposal of any returned fluids, including any consents that are relied on to authorise the disposal;
    (k) 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 3; and
    (l) results of the monitoring referred to in condition 9 (d);
    (m) an assessment of the effectiveness of the mitigation measures in place with specific reference to those described in the application for this consent.

    Note: *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.*

12. The reports described in conditions 9 and 11 shall be emailed to consents@trc.govt.nz with a reference to the number of this consent.

13. 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.

14. 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.

15. The fracture fluid shall be comprised of no less than 95% water and proppant by volume.

16. This consent shall lapse on 30 June 2019, 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.

17. The Taranaki Regional Council may review any or all of the conditions of this consent by giving notice of review during the month of June each year, 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 14; 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 30 June 2014

For and on behalf of
Taranaki Regional Council

_____

A D McLay
Director - Resource Management

Appendix II

Certificates of analysis (groundwater)

Hill Laboratories
TRIED, TESTED AND TRUSTED

R J Hill Laboratories Limited
28 Duke Street Frankton 3204
Private Bag 3205
Hamilton 3240 New Zealand

T 0508 HILL LAB (44 555 22)
T +64 7 858 2000
E mail@hill-labs.co.nz
W www.hill-laboratories.com

Certificate of Analysis

Client:	Taranaki Regional Council	**Lab No:**	2197186 SPv1
Contact:	Jane Harvey	**Date Received:**	22-Jun-2019
	C/- Taranaki Regional Council	**Date Reported:**	01-Jul-2019
	Private Bag 713	**Quote No:**	47915
	Stratford 4352	**Order No:**	72831
		Client Reference:	#5136 - MHW C 1 Year Post Frac Groundwater
		Submitted By:	Sarah Larkin

Sample Type: Aqueous

Sample Name:		TRC192465 (GND2255) 21-Jun-2019 2:00 pm	TRC192467 (GND2256) 21-Jun-2019 2:25 pm	TRC192468 (GND2257) 21-Jun-2019 3:00 pm	TRC192469 (GND2254) 21-Jun-2019 1:30 pm	
Lab Number:		2197186.1	2197186.2	2197186.3	2197186.4	
Individual Tests						
Sum of Anions	meq/L	1.20	1.40	1.52	2.8	-
Sum of Cations	meq/L	1.20	1.39	1.53	2.6	-
pH	pH Units	6.2	6.4	6.4	8.1	-
Total Alkalinity	g/m³ as $CaCO_3$	21	23	29	121	-
Bicarbonate	g/m³ at 25°C	25	29	35	146	-
Total Hardness	g/m³ as $CaCO_3$	30	40	38	94	-
Electrical Conductivity (EC)	mS/m	13.7	16.1	17.0	26.9	-
Total Dissolved Solids (TDS)	g/m³	91	116	115	168	-
Sample Temperature*	°C	14.8	13.7	12.7	15.0	-
Dissolved Barium	g/m³	0.042	0.047	0.015	0.014	-
Dissolved Calcium	g/m³	6.4	9.1	7.8	22	-
Dissolved Copper	g/m³	0.061	0.0042	0.020	< 0.0005	-
Dissolved Iron	g/m³	0.08	< 0.02	< 0.02	0.30	-
Dissolved Magnesium	g/m³	3.4	4.3	4.5	9.4	-
Dissolved Manganese	g/m³	0.0032	0.0099	0.0047	0.035	-
Dissolved Mercury	g/m³	< 0.00008	< 0.00008	< 0.00008	< 0.00008	-
Dissolved Nickel	g/m³	< 0.0005	< 0.0005	0.0008	0.0006	-
Dissolved Potassium	g/m³	3.2	3.6	1.98	2.3	-
Dissolved Sodium	g/m³	11.8	11.3	16.5	15.1	-
Dissolved Zinc	g/m³	0.037	0.021	0.090	0.0015	-
Bromide	g/m³	0.11	0.11	0.11	0.08	-
Chloride	g/m³	21	19.3	21	13.7	-
Nitrite-N	g/m³	< 0.002	0.003	< 0.002	< 0.002	-
Nitrate-N	g/m³	1.88	4.4	3.9	0.002	-
Nitrate-N + Nitrite-N	g/m³	1.88	4.4	3.9	0.002	-
Sulphate	g/m³	3.1	3.7	3.8	< 0.5	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	< 4	< 4	< 4	< 4	-
Propylene Glycol in Water						
Propylene glycol*	g/m³	< 4	< 4	< 4	< 4	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m³	< 5	< 5	< 5	< 5	-

Sample Type: Aqueous						
Sample Name:		TRC192465 (GND2255) 21-Jun-2019 2:00 pm	TRC192467 (GND2256) 21-Jun-2019 2:25 pm	TRC192468 (GND2257) 21-Jun-2019 3:00 pm	TRC192469 (GND2254) 21-Jun-2019 1:30 pm	
Lab Number:		2197186.1	2197186.2	2197186.3	2197186.4	
BTEX in Water by Headspace GC-MS						
Benzene	g/m³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	-
Toluene	g/m³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	-
Ethylbenzene	g/m³	< 0.0010	< 0.0010	< 0.0010	0.0016	-
m&p-Xylene	g/m³	< 0.002	< 0.002	< 0.002	< 0.002	-
o-Xylene	g/m³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m³	< 0.02	< 0.02	< 0.02	< 0.02	-
Gases in groundwater						
Ethane	g/m³	< 0.003	< 0.003	< 0.003	< 0.003	-
Ethylene	g/m³	< 0.004	< 0.004	< 0.004	< 0.004	-
Methane	g/m³	0.003	< 0.002	< 0.002	2.7	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m³	< 0.06	< 0.06	< 0.06	< 0.06	-
C10 - C14	g/m³	< 0.2	< 0.2	< 0.2	< 0.2	-
C15 - C36	g/m³	< 0.4	< 0.4	0.6	< 0.4	-
Total hydrocarbons (C7 - C36)	g/m³	< 0.7	< 0.7	< 0.7	< 0.7	-

2197186.3
TRC192468 (GND2257) 21-Jun-2019 3:00 pm
Client Chromatogram for TPH by FID

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 clean 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.
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**
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	1-4
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	1-4
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m³	1-4
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m³	1-4
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS	0.02 g/m³	1-4
Gases in groundwater	Manual headspace creation and sub-sampling, GC-FID analysis.	0.002 - 0.003 g/m³	1-4
Total Petroleum Hydrocarbons in Water	Solvent Hexane extraction, GC-FID analysis, Headspace GC-MS FS analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734;26687,3629]	0.06 - 0.7 g/m³	1-4

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1-4
Total anions for anion/cation balance check	Calculation: sum of anions as mEquiv/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 23rd ed. 2017.	0.07 meq/L	1-4
Total cations for anion/cation balance check	Sum of cations as mEquiv/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 23rd ed. 2017.	0.05 meq/L	1-4
pH	pH meter. APHA 4500-H^+ B 23rd 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	1-4
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (modified for Alkalinity <20) 23rd ed. 2017.	1.0 g/m³ as $CaCO_3$	1-4
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 23rd ed. 2017.	1.0 g/m³ at 25°C	1-4
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 23rd ed. 2017.	1.0 g/m³ as $CaCO_3$	1-4
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 23rd ed. 2017.	0.1 mS/m	1-4
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) 23rd ed. 2017.	10 g/m³	1-4
Sample Temperature*	Supplied by customer, otherwise 20°C.	0.1 °C	1-4
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.005 g/m³	1-4
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.05 g/m³	1-4
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.0005 g/m³	1-4
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.02 g/m³	1-4
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.02 g/m³	1-4
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.0005 g/m³	1-4
Dissolved Mercury	0.45µm filtration, bromine oxidation followed by atomic fluorescence. US EPA Method 245.7, Feb 2005.	0.00008 g/m³	1-4
Dissolved Nickel	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.0005 g/m³	1-4
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.05 g/m³	1-4
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.02 g/m³	1-4
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.0010 g/m³	1-4
Bromide	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 23rd ed. 2017.	0.05 g/m³	1-4
Chloride	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 23rd ed. 2017.	0.5 g/m³	1-4
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I (modified) 23rd ed. 2017.	0.002 g/m³	1-4
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m³	1-4
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I (modified) 23rd ed. 2017.	0.002 g/m³	1-4
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 23rd ed. 2017.	0.5 g/m³	1-4
C7 - C9	Head Space, GCMS analysis.	0.06 g/m³	1-4

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

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

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

Ara Heron BSc (Tech)
Client Services Manager - Environmental

Hill Laboratories
TRIED, TESTED AND TRUSTED

R J Hill Laboratories Limited
28 Duke Street Frankton 3204
Private Bag 3205
Hamilton 3240 New Zealand

T 0508 HILL LAB (44 555 22)
T +64 7 858 2000
E mail@hill-labs.co.nz
W www.hill-laboratories.com

Certificate of Analysis

Client:	Taranaki Regional Council	**Lab No:**	2075697 SPv1
Contact:	Jane Harvey	**Date Received:**	06-Nov-2018
	C/- Taranaki Regional Council	**Date Reported:**	13-Nov-2018
	Private Bag 713	**Quote No:**	47915
	Stratford 4352	**Order No:**	72831
		Client Reference:	Todd MHWC 3 month post frac Groundwater
		Submitted By:	Sarah Larkin

Sample Type: Aqueous

Sample Name:		TRC184498 (GND2255) 05-Nov-2018 9:50 am	TRC184500 (GND2256) 05-Nov-2018 12:20 pm	TRC184501 (GND2257) 05-Nov-2018 10:35 am	TRC184502 (GND2254) 05-Nov-2018 9:00 am	
Lab Number:		2075697.1	2075697.2	2075697.3	2075697.4	
Individual Tests						
Sum of Anions	meq/L	1.09	1.39	1.48	2.8	-
Sum of Cations	meq/L	1.13	1.39	1.47	2.7	-
pH	pH Units	5.9	6.0	6.1	8.0	-
Total Alkalinity	g/m³ as $CaCO_3$	21	22	26	120	-
Bicarbonate	g/m³ at 25°C	25	27	32	145	-
Total Hardness	g/m³ as $CaCO_3$	29	39	38	100	-
Electrical Conductivity (EC)	mS/m	12.7	16.4	16.6	27.0	-
Total Dissolved Solids (TDS)	g/m³	78	104	102	160	-
Sample Temperature*	°C	15.5	19.2	15.1	14.9	-
Dissolved Barium	g/m³	0.038	0.074	0.014	0.014	-
Dissolved Calcium	g/m³	6.2	8.5	7.6	23	-
Dissolved Copper	g/m³	0.054	0.0040	0.0184	< 0.0005	-
Dissolved Iron	g/m³	0.06	< 0.02	< 0.02	0.28	-
Dissolved Magnesium	g/m³	3.4	4.3	4.6	10.6	-
Dissolved Manganese	g/m³	0.0074	0.0108	0.0025	0.032	-
Dissolved Mercury	g/m³	< 0.00008	< 0.00008	< 0.00008	< 0.00008	-
Dissolved Nickel	g/m³	< 0.0005	< 0.0005	0.0007	0.0021	-
Dissolved Potassium	g/m³	2.9	6.0	2.0	2.3	-
Dissolved Sodium	g/m³	10.7	10.4	15.1	15.2	-
Dissolved Zinc	g/m³	0.041	0.023	0.045	0.0120	-
Bromide	g/m³	0.11	0.12	0.11	0.08	-
Chloride	g/m³	19.0	19.5	21	12.6	-
Nitrite-N	g/m³	< 0.002	< 0.002	< 0.002	< 0.002	-
Nitrate-N	g/m³	1.17	4.4	3.8	0.003	-
Nitrate-N + Nitrite-N	g/m³	1.17	4.4	3.8	0.003	-
Sulphate	g/m³	2.6	3.8	4.7	< 0.5	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	< 4	< 4	< 4	< 4	-
Propylene Glycol in Water						
Propylene glycol*	g/m³	< 4	< 4	< 4	< 4	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m³	< 2	< 2	< 2	< 2	-

Sample Type: Aqueous						
Sample Name:		TRC184498 (GND2255) 05-Nov-2018 9:50 am	TRC184500 (GND2256) 05-Nov-2018 12:20 pm	TRC184501 (GND2257) 05-Nov-2018 10:35 am	TRC184502 (GND2254) 05-Nov-2018 9:00 am	
Lab Number:		2075697.1	2075697.2	2075697.3	2075697.4	
BTEX in Water by Headspace GC-MS						
Benzene	g/m³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	-
Toluene	g/m³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	-
Ethylbenzene	g/m³	< 0.0010	< 0.0010	< 0.0010	0.0012	-
m&p-Xylene	g/m³	< 0.002	< 0.002	< 0.002	< 0.002	-
o-Xylene	g/m³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m³	< 0.02	< 0.02	< 0.02	< 0.02	-
Gases in groundwater						
Ethane	g/m³	< 0.003	< 0.003	< 0.003	< 0.003	-
Ethylene	g/m³	< 0.004	< 0.004	< 0.004	< 0.004	-
Methane	g/m³	0.006	< 0.002	< 0.002	2.4	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m³	< 0.06	< 0.06	< 0.06	< 0.06	-
C10 - C14	g/m³	< 0.2	< 0.2	< 0.2	< 0.2	-
C15 - C36	g/m³	< 0.4	< 0.4	< 0.4	< 0.4	-
Total hydrocarbons (C7 - C36)	g/m³	< 0.7	< 0.7	< 0.7	< 0.7	-

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 clean 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.
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**
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	1-4
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	1-4
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m³	1-4
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m³	1-4
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS	0.02 g/m³	1-4
Gases in groundwater	Manual headspace creation and sub-sampling, GC-FID analysis.	0.002 - 0.003 g/m³	1-4
Total Petroleum Hydrocarbons in Water	Solvent Hexane extraction, GC-FID analysis, Headspace GC-MS FS analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734;26687,3629]	0.06 - 0.7 g/m³	1-4
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1-4
Total anions for anion/cation balance check	Calculation: sum of anions as mEquiv/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 22nd ed. 2012.	0.07 meq/L	1-4
Total cations for anion/cation balance check	Sum of cations as mEquiv/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 22nd ed. 2012.	0.05 meq/L	1-4
pH	pH meter. APHA 4500-H^+ B 22nd ed. 2012. 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	1-4
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (Modified for alk <20) 22nd ed. 2012.	1.0 g/m³ as $CaCO_3$	1-4
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 22nd ed. 2012.	1.0 g/m³ at 25°C	1-4

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 22nd ed. 2012.	1.0 g/m³ as $CaCO_3$	1-4
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 22nd ed. 2012.	0.1 mS/m	1-4
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) 22nd ed. 2012.	10 g/m³	1-4
Sample Temperature*	Supplied by customer, otherwise 20°C.	0.1 °C	1-4
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.005 g/m³	1-4
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m³	1-4
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1-4
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m³	1-4
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m³	1-4
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1-4
Dissolved Mercury	0.45µm filtration, bromine oxidation followed by atomic fluorescence. US EPA Method 245.7, Feb 2005.	0.00008 g/m³	1-4
Dissolved Nickel	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1-4
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m³	1-4
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m³	1-4
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0010 g/m³	1-4
Bromide	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 22nd ed. 2012.	0.05 g/m³	1-4
Chloride	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 22nd ed. 2012.	0.5 g/m³	1-4
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012 (modified).	0.002 g/m³	1-4
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m³	1-4
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012 (modified).	0.002 g/m³	1-4
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 22nd ed. 2012.	0.5 g/m³	1-4
C7 - C9	Head Space, GCMS analysis.	0.06 g/m³	1-4

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

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

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Client Services Manager - Environmental

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Certificate of Analysis

Client:	Taranaki Regional Council	**Lab No:**	2221700 SPv1
Contact:	Jane Harvey	**Date Received:**	09-Aug-2019
	C/- Taranaki Regional Council	**Date Reported:**	16-Aug-2019
	Private Bag 713	**Quote No:**	47915
	Stratford 4352	**Order No:**	72831
		Client Reference:	#5136 MHWC 1 Year PF GW
		Submitted By:	Sarah Larkin

Sample Type: Aqueous

Sample Name:		TRC192466 GND2360 08-Aug-2019 11:10 am				
Lab Number:		2221700.1				
Individual Tests						
Sum of Anions	meq/L	11.8	-	-	-	-
Sum of Cations	meq/L	12.5	-	-	-	-
pH	pH Units	9.1	-	-	-	-
Total Alkalinity	g/m³ as $CaCO_3$	189	-	-	-	-
Bicarbonate	g/m³ at 25°C	200 #1	-	-	-	-
Total Hardness	g/m³ as $CaCO_3$	46	-	-	-	-
Electrical Conductivity (EC)	mS/m	128.7	-	-	-	-
Total Dissolved Solids (TDS)	g/m³	690 #1	-	-	-	-
Sample Temperature*	°C	17.1	-	-	-	-
Dissolved Barium	g/m³	0.027	-	-	-	-
Dissolved Calcium	g/m³	11.5	-	-	-	-
Dissolved Copper	g/m³	< 0.0005	-	-	-	-
Dissolved Iron	g/m³	0.17	-	-	-	-
Dissolved Magnesium	g/m³	4.2	-	-	-	-
Dissolved Manganese	g/m³	0.0120	-	-	-	-
Dissolved Mercury	g/m³	< 0.00008	-	-	-	-
Dissolved Nickel	g/m³	< 0.0005	-	-	-	-
Dissolved Potassium	g/m³	1.37	-	-	-	-
Dissolved Sodium	g/m³	270	-	-	-	-
Dissolved Zinc	g/m³	0.0141	-	-	-	-
Bromide	g/m³	1.11	-	-	-	-
Chloride	g/m³	280	-	-	-	-
Nitrite-N	g/m³	< 0.002	-	-	-	-
Nitrate-N	g/m³	< 0.002	-	-	-	-
Nitrate-N + Nitrite-N	g/m³	0.002	-	-	-	-
Sulphate	g/m³	1.8	-	-	-	-
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	-	-	-	-

Sample Type: Aqueous						
Sample Name:		TRC192466 GND2360 08-Aug-2019 11:10 am				
Lab Number:		2221700.1				
BTEX in Water by Headspace GC-MS						
Benzene	g/m³	< 0.0010	-	-	-	-
Toluene	g/m³	< 0.0010	-	-	-	-
Ethylbenzene	g/m³	< 0.0010	-	-	-	-
m&p-Xylene	g/m³	< 0.002	-	-	-	-
o-Xylene	g/m³	< 0.0010	-	-	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m³	< 0.02	-	-	-	-
Gases in groundwater						
Ethane	g/m³	0.013	-	-	-	-
Ethylene	g/m³	< 0.004	-	-	-	-
Methane	g/m³	6.8	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m³	< 0.06	-	-	-	-
C10 - C14	g/m³	< 0.2	-	-	-	-
C15 - C36	g/m³	< 0.4	-	-	-	-
Total hydrocarbons (C7 - C36)	g/m³	< 0.7	-	-	-	-

Analyst's Comments

#1 Please note that the calculation used to determine the carbonate and bicarbonate content is only valid when the total dissolved solids (TDS) content is <500mg/L. It was observed that the TDS content of this sample is >500mg/L, therefore these results should be treated as indicative only.

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 clean 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.
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**
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	1
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	1
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m³	1
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m³	1
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS	0.02 g/m³	1
Gases in groundwater	Manual headspace creation and sub-sampling, GC-FID analysis.	0.002 - 0.003 g/m³	1
Total Petroleum Hydrocarbons in Water	Solvent Hexane extraction, GC-FID analysis, Headspace GC-MS FS analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734;26687,3629]	0.06 - 0.7 g/m³	1
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1
Total anions for anion/cation balance check	Calculation: sum of anions as mEquiv/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 23rd ed. 2017.	0.07 meq/L	1
Total cations for anion/cation balance check	Sum of cations as mEquiv/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 23rd ed. 2017.	0.05 meq/L	1
pH	pH meter. APHA 4500-H^+ B 23rd 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

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (modified for Alkalinity <20) 23rd ed. 2017.	1.0 g/m³ 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 23rd ed. 2017.	1.0 g/m³ at 25°C	1
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 23rd ed. 2017.	1.0 g/m³ as $CaCO_3$	1
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 23rd 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) 23rd ed. 2017.	10 g/m³	1
Sample Temperature*	Supplied by customer, otherwise 20°C.	0.1 °C	1
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.005 g/m³	1
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.05 g/m³	1
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.0005 g/m³	1
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.02 g/m³	1
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.02 g/m³	1
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.0005 g/m³	1
Dissolved Mercury	0.45µm filtration, bromine oxidation followed by atomic fluorescence. US EPA Method 245.7, Feb 2005.	0.00008 g/m³	1
Dissolved Nickel	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.0005 g/m³	1
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.05 g/m³	1
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.02 g/m³	1
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.0010 g/m³	1
Bromide	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 23rd ed. 2017.	0.05 g/m³	1
Chloride	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 23rd ed. 2017.	0.5 g/m³	1
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I (modified) 23rd ed. 2017.	0.002 g/m³	1
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m³	1
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I (modified) 23rd ed. 2017.	0.002 g/m³	1
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 23rd ed. 2017.	0.5 g/m³	1
C7 - C9	Head Space, GCMS analysis.	0.06 g/m³	1

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

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

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ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1884669 SPv1
Contact:	David Olson	**Date Received:**	28-Nov-2017
	C/- Taranaki Regional Council	**Date Reported:**	06-Dec-2017
	Private Bag 713	**Quote No:**	47915
	Stratford 4352	**Order No:**	68398
		Client Reference:	TODD MHWC 1 YEAR POST FRAC GW
		Submitted By:	David Olson

Sample Type: Aqueous

Sample Name:		GND 2360 27-Nov-2017 9:40 am	GND 2254 27-Nov-2017 1:55 pm	GND 2255 27-Nov-2017 1:15 pm	GND 2256 27-Nov-2017 2:55 pm	GND 2257 27-Nov-2017 3:35 pm
Lab Number:		1884669.1	1884669.2	1884669.3	1884669.4	1884669.5
Individual Tests						
Sum of Anions	meq/L	4.1	2.8	1.17	1.41	1.45
Sum of Cations	meq/L	3.6	2.7	1.10	1.34	1.46
pH	pH Units	9.4	8.0	6.1	6.2	6.3
Total Alkalinity	g/m³ as $CaCO_3$	170	119	20	22	27
Bicarbonate	g/m³ at 25°C	167	144	25	27	33
Total Hardness	g/m³ as $CaCO_3$	5.2	98	28	38	38
Electrical Conductivity (EC)	mS/m	40.6	27.6	13.3	16.8	16.5
Total Dissolved Solids (TDS)	g/m³	240	158	85	115	120
Dissolved Barium	g/m³	0.0029	0.0143	0.041	0.064	0.0131
Dissolved Calcium	g/m³	1.45	24	6.1	8.7	7.9
Dissolved Copper	g/m³	< 0.0005	< 0.0005	0.0095	< 0.0005	0.0086
Dissolved Iron	g/m³	0.03	0.30	0.07	0.03	< 0.02
Dissolved Magnesium	g/m³	0.37	9.2	3.1	3.9	4.4
Dissolved Manganese	g/m³	0.0024	0.033	0.0043	0.0130	0.0012
Dissolved Mercury	g/m³	< 0.00008	< 0.00008	< 0.00008	< 0.00008	< 0.00008
Dissolved Nickel	g/m³	< 0.0005	< 0.0005	< 0.0005	< 0.0005	0.0045
Dissolved Potassium	g/m³	0.71	2.4	3.2	5.4	2.0
Dissolved Sodium	g/m³	79	16.2	10.3	10.2	14.9
Dissolved Zinc	g/m³	0.025	< 0.0010	0.0108	0.0039	0.024
Bromide	g/m³	0.10	0.07	0.11	0.11	0.10
Chloride	g/m³	23	13.0	22	21	19.0
Nitrite-N	g/m³	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Nitrate-N	g/m³	< 0.002	< 0.002	1.21	4.3	3.9
Nitrate-N + Nitrite-N	g/m³	< 0.002	< 0.002	1.21	4.3	3.9
Sulphate	g/m³	1.8	< 0.5	3.3	4.0	4.4
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	< 4	< 4	< 4	< 4	< 4
Propylene Glycol in Water						
Propylene glycol*	g/m³	< 4	< 4	< 4	< 4	< 4
Methanol in Water - Aqueous Solvents						
Methanol*	g/m³	< 2	< 2	< 2	< 2	< 2
BTEX in Water by Headspace GC-MS						
Benzene	g/m³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Toluene	g/m³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Ethylbenzene	g/m³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
m&p-Xylene	g/m³	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
o-Xylene	g/m³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010

Sample Type: Aqueous						
Sample Name:		GND 2360 27-Nov-2017 9:40 am	GND 2254 27-Nov-2017 1:55 pm	GND 2255 27-Nov-2017 1:15 pm	GND 2256 27-Nov-2017 2:55 pm	GND 2257 27-Nov-2017 3:35 pm
Lab Number:		1884669.1	1884669.2	1884669.3	1884669.4	1884669.5
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m³	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Gases in groundwater						
Ethane	g/m³	0.005	< 0.003	< 0.003	< 0.003	< 0.003
Ethylene	g/m³	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
Methane	g/m³	1.63	2.4	< 0.002	0.008	< 0.002
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m³	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06
C10 - C14	g/m³	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
C15 - C36	g/m³	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4
Total hydrocarbons (C7 - C36)	g/m³	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7

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 clean 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.

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	1-5
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	1-5
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m³	1-5
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m³	1-5
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS	0.02 g/m³	1-5
Gases in groundwater	Manual headspace creation and sub-sampling, GC-FID analysis.	0.002 - 0.003 g/m³	1-5
Total Petroleum Hydrocarbons in Water	Solvent Hexane extraction, GC-FID analysis, Headspace GC-MS FS analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734;26687,3629]	0.06 - 0.7 g/m³	1-5
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1-5
Total anions for anion/cation balance check	Calculation: sum of anions as mEquiv/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 22nd ed. 2012.	0.07 meq/L	1-5
Total cations for anion/cation balance check	Sum of cations as mEquiv/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 22nd ed. 2012.	0.05 meq/L	1-5
pH	pH meter. APHA 4500-H^+ B 22nd ed. 2012. 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.	0.1 pH Units	1-5
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (Modified for alk <20) 22nd ed. 2012.	1.0 g/m³ as $CaCO_3$	1-5
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 22nd ed. 2012.	1.0 g/m³ at 25°C	1-5
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 22nd ed. 2012.	1.0 g/m³ as $CaCO_3$	1-5
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 22nd ed. 2012.	0.1 mS/m	1-5
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) 22nd ed. 2012.	10 g/m³	1-5
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.00010 g/m³	1-5
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m³	1-5
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1-5

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m³	1-5
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m³	1-5
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1-5
Dissolved Mercury	0.45µm filtration, bromine oxidation followed by atomic fluorescence. US EPA Method 245.7, Feb 2005.	0.00008 g/m³	1-5
Dissolved Nickel	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1-5
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m³	1-5
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m³	1-5
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0010 g/m³	1-5
Bromide	Filtered sample. Ion Chromatography. APHA 4110 B 22nd ed. 2012.	0.05 g/m³	1-5
Chloride	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl^- E (modified from continuous flow analysis) 22nd ed. 2012.	0.5 g/m³	1-5
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012 (modified).	0.002 g/m³	1-5
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m³	1-5
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012 (modified).	0.002 g/m³	1-5
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B 22nd ed. 2012.	0.5 g/m³	1-5
C7 - C9	Head Space, GCMS analysis.	0.06 g/m³	1-5

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

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

Ara Heron BSc (Tech)
Client Services Manager - Environmental

Appendix III

Certificates of analysis (hydraulic fracturing fluids)

Hill Laboratories
TRIED, TESTED AND TRUSTED

R J Hill Laboratories Limited
28 Duke Street Frankton 3204
Private Bag 3205
Hamilton 3240 New Zealand

T 0508 HILL LAB (44 555 22)
T +64 7 858 2000
E mail@hill-labs.co.nz
W www.hill-laboratories.com

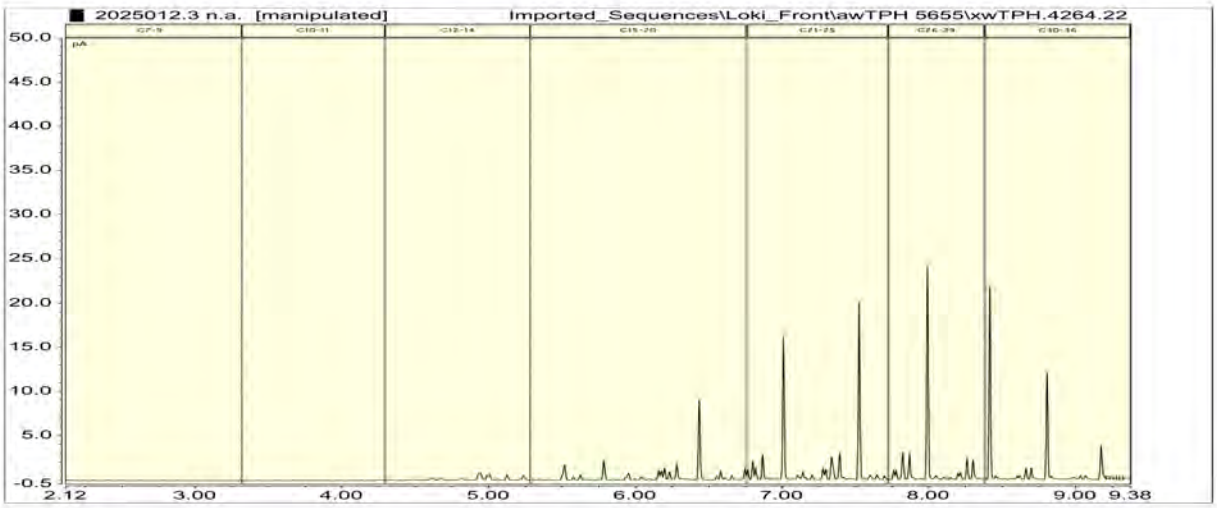
Certificate of Analysis

Client:	Taranaki Regional Council	**Lab No:**	2025012	SPv1
Contact:	Jane Harvey	**Date Received:**	02-Aug-2018	
	C/- Taranaki Regional Council	**Date Reported:**	16-Aug-2018	
	Private Bag 713	**Quote No:**	50522	
	Stratford 4352	**Order No:**	72831	
		Client Reference:	Hydraulic fracturing fluid testing	
		Add. Client Ref:	340300 3 82 MHWC03 FF	
		Submitted By:	Sarah Larkin	

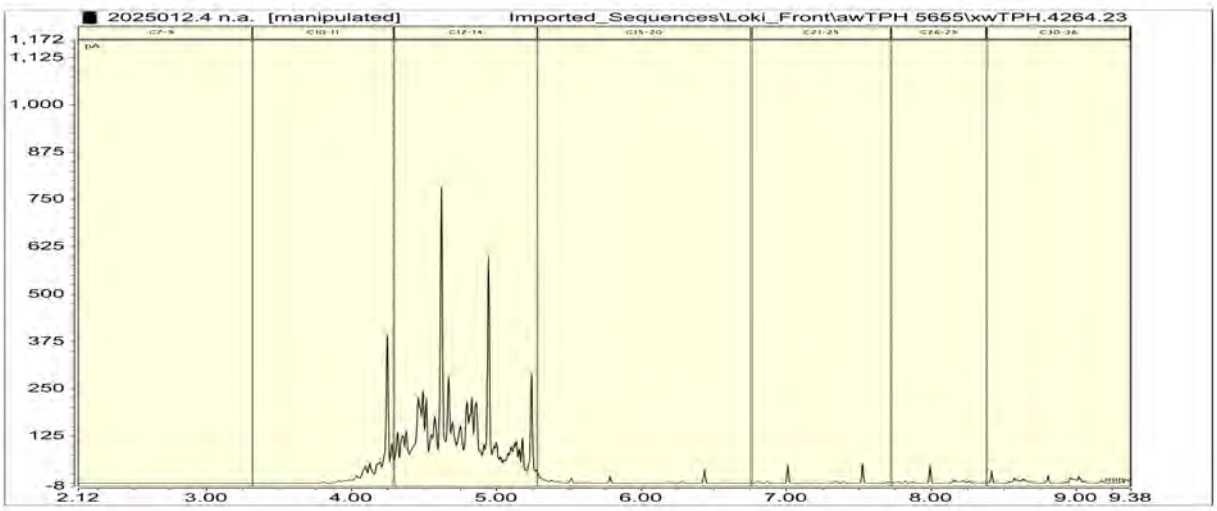
Sample Type: Aqueous

Sample Name:		GND2822 Zone 5 FF 183131 07-Jul-2018	GND2822 Zone 8 FF 183132 10-Jul-2018	GND2822 Zone 6 FF 183130 and GND2822 Zone 7 FF 183130		
Lab Number:		2025012.3	2025012.4	2025012.5		
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	330	< 4	< 4	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m³	< 4	< 4	< 4	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m³	< 2	< 2	< 2	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m³	< 0.0010	< 0.0010	< 0.0010	-	-
Toluene	g/m³	0.0011	0.0022	< 0.0010	-	-
Ethylbenzene	g/m³	< 0.0010	< 0.0010	< 0.0010	-	-
m&p-Xylene	g/m³	< 0.002	< 0.002	< 0.002	-	-
o-Xylene	g/m³	< 0.0010	< 0.0010	< 0.0010	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m³	< 0.06	< 0.06	0.06	-	-
C10 - C14	g/m³	< 1.0	520	5.4	-	-
C15 - C36	g/m³	9	42	5	-	-
Total hydrocarbons (C7 - C36)	g/m³	9	560	11	-	-

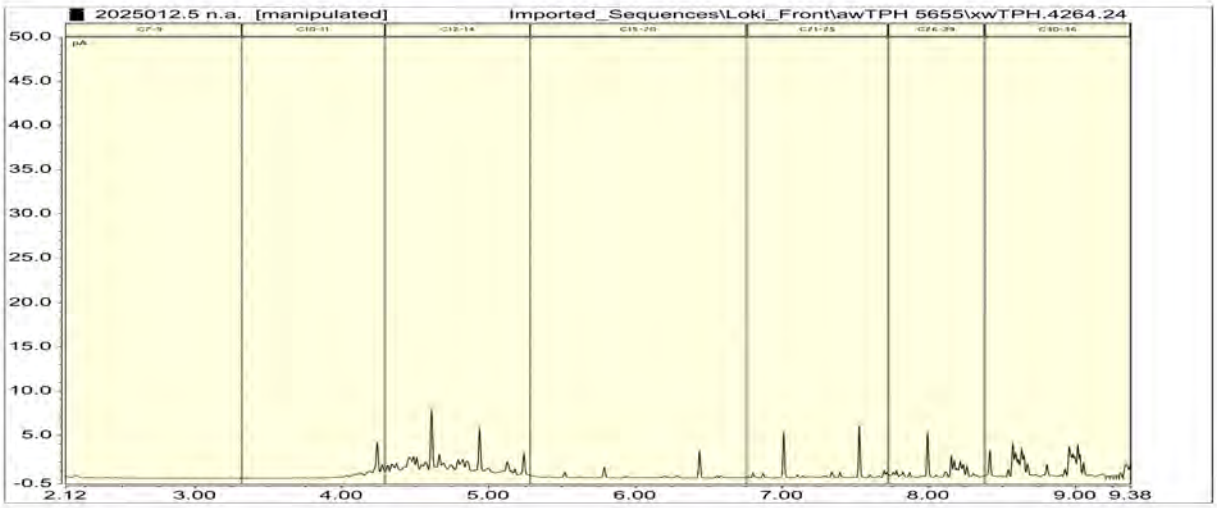
2025012.3
GND2822 Zone 5 FF 183131 07-Jul-2018
Client Chromatogram for TPH by FID



2025012.4
GND2822 Zone 8 FF 183132 10-Jul-2018
Client Chromatogram for TPH by FID



2025012.5
GND2822 Zone 6 FF 183130 and GND2822 Zone 7 FF 183130
Client Chromatogram for TPH by FID



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 clean 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.

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	3-5
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	3-5
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m³	3-5
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m³	3-5
Total Petroleum Hydrocarbons in Water*	Solvent Hexane extraction, GC-FID analysis, Headspace GC-MS FS analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734;26687,3629]	0.06 - 0.7 g/m³	3-5
C7 - C9	Head Space, GCMS analysis.	0.06 g/m³	3-5

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

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

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

Ara Heron BSc (Tech)
Client Services Manager - Environmental

Hill Laboratories
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R J Hill Laboratories Limited
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Private Bag 3205
Hamilton 3240 New Zealand

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T +64 7 858 2000
E mail@hill-labs.co.nz
W www.hill-laboratories.com

Certificate of Analysis

Client:	Taranaki Regional Council	**Lab No:**	2025011 SPv1
Contact:	Jane Harvey C/- Taranaki Regional Council Private Bag 713 Stratford 4352	**Date Received:**	02-Aug-2018
		Date Reported:	17-Aug-2018
		Quote No:	71307
		Order No:	72831
		Client Reference:	Return Fluid Composite
		Add. Client Ref:	340300382 MHWC03 RF
		Submitted By:	Sarah Larkin

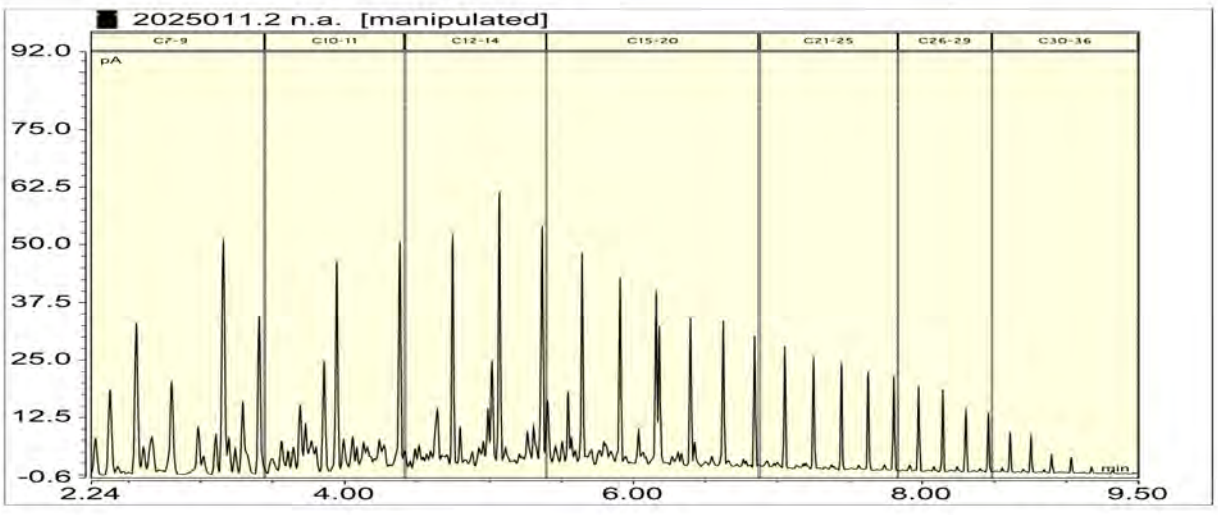
Sample Type: Saline

		Sample Name:	GND2822 RF 183133 [water fraction]				
		Lab Number:	2025011.3				
Individual Tests							
pH*	pH Units		7.8	-	-	-	-
Total Alkalinity*	g/m³ as $CaCO_3$		1,740	-	-	-	-
Total Hardness*	g/m³ as $CaCO_3$		500	-	-	-	-
Electrical Conductivity (EC)*	mS/m		4,260	-	-	-	-
Total Barium*	g/m³		123	-	-	-	-
Total Calcium*	g/m³		158	-	-	-	-
Total Copper*	g/m³		< 0.0053	-	-	-	-
Total Iron*	g/m³		0.69	-	-	-	-
Total Magnesium*	g/m³		25	-	-	-	-
Total Manganese*	g/m³		3.1	-	-	-	-
Total Mercury*	g/m³		< 0.0003	-	-	-	-
Total Nickel*	g/m³		< 0.03	-	-	-	-
Total Potassium*	g/m³		3,100	-	-	-	-
Total Sodium*	g/m³		7,300	-	-	-	-
Total Sulphur*	g/m³		37	-	-	-	-
Total Zinc*	g/m³		0.026	-	-	-	-
Bromide*	g/m³		40	-	-	-	-
Chloride*	g/m³		13,700	-	-	-	-
Nitrite-N	g/m³		< 0.010 #4	-	-	-	-
Nitrate-N	g/m³		< 0.010	-	-	-	-
Nitrate*	g/m³		< 0.05	-	-	-	-
Nitrate-N + Nitrite-N	g/m³		< 0.010 #4	-	-	-	-
Sulphate*	g/m³		111	-	-	-	-
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		14.5	-	-	-	-
Toluene*	g/m³		21	-	-	-	-
Ethylbenzene*	g/m³		1.15	-	-	-	-
m&p-Xylene*	g/m³		7.0	-	-	-	-
o-Xylene*	g/m³		2.5	-	-	-	-

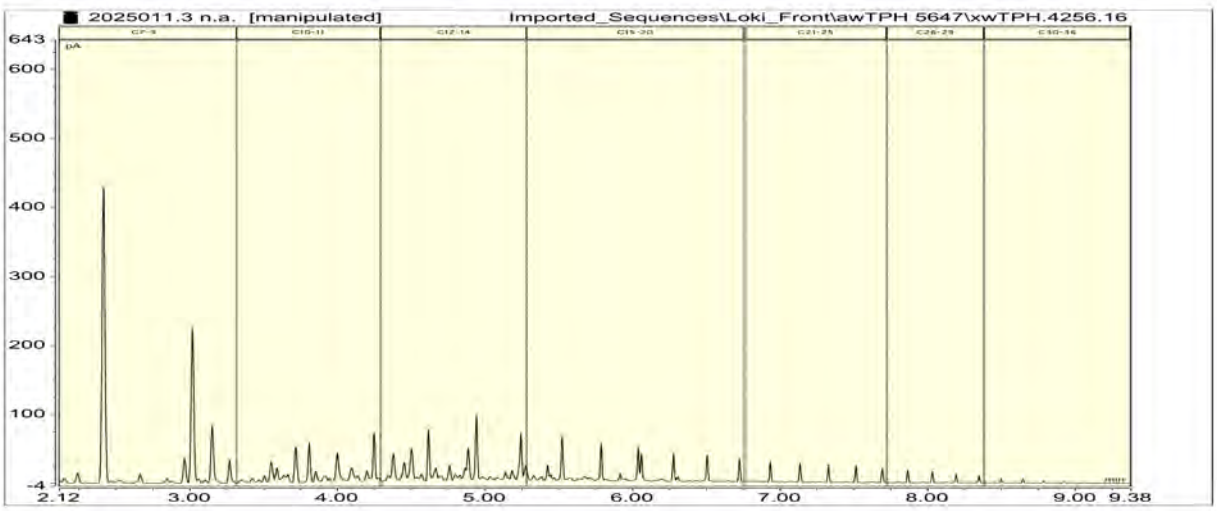
Sample Type: Saline						
Sample Name:		GND2822 RF 183133 [water fraction]				
Lab Number:		2025011.3				
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde*	g/m³	< 8	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m³	40	-	-	-	-
C10 - C14*	g/m³	34	-	-	-	-
C15 - C36*	g/m³	24	-	-	-	-
Total hydrocarbons (C7 - C36)	g/m³	98	-	-	-	-

Sample Type: Oil						
Sample Name:		GND2822 RF 183133 [oil fraction]				
Lab Number:		2025011.2				
Individual Tests						
Total Barium*	mg/kg as rcvd	3.0 #1	-	-	-	-
Total Calcium*	mg/kg as rcvd	152 #2	-	-	-	-
Total Copper*	mg/kg as rcvd	< 1.0	-	-	-	-
Total Iron*	mg/kg as rcvd	< 20	-	-	-	-
Total Manganese*	mg/kg as rcvd	< 0.5	-	-	-	-
Total Nickel*	mg/kg as rcvd	< 1.0	-	-	-	-
Total Potassium*	mg/kg as rcvd	< 50	-	-	-	-
Total Sodium*	mg/kg as rcvd	48 #3	-	-	-	-
Total Sulphur*	g/100g as rcvd	0.030	-	-	-	-
Total Zinc*	mg/kg as rcvd	< 5	-	-	-	-
Chloride*	mg/kg as rcvd	75	-	-	-	-
Free Product GC Scan by FID						
Free Product*	mL/100mL	100	-	-	-	-
BTEX in Oil by Headspace GC-MS						
Benzene*	mg/kg as rcvd	4,500	-	-	-	-
Toluene*	mg/kg as rcvd	30,000	-	-	-	-
Ethylbenzene*	mg/kg as rcvd	5,600	-	-	-	-
m&p-Xylene*	mg/kg as rcvd	35,000	-	-	-	-
o-Xylene*	mg/kg as rcvd	10,500	-	-	-	-

2025011.2
GND2822 RF 183133 [oil fraction]
Client Chromatogram for GC Scan



2025011.3
GND2822 RF 183133 [water fraction]
Client Chromatogram for TPH by FID



Analyst's Comments

#1 It should be noted that the replicate analyses performed on this sample as part of our in-house Quality Assurance procedures showed greater variation than would normally be expected. This may reflect the heterogeneity of the sample.

#2 It should be noted that the blanks contained an elevated level of calcium (138mg/kg c.f. detection limit of 50mg/kg). This has not been corrected for on the sample concentration. This should be kept in mind when interpreting these results.

It should be noted that the replicate analyses performed on this sample as part of our in-house Quality Assurance procedures showed greater variation than would normally be expected. This may reflect the heterogeneity of the sample.

#3 It should be noted that the blanks contained an elevated level of sodium (29mg/kg c.f. detection limit of 20mg/kg). This has not been corrected for on the sample concentration. This should be kept in mind when interpreting these results.

#4 Due to the nature of this sample a dilution was performed prior to analysis, resulting in a detection limit higher than that normally achieved for the NO2Nsal, NO3Nsal and NOxNsal analysis.

Appendix No.1 - Total Sulphur Report 2025011

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 clean 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.

Sample Type: Saline

Test	Method Description	Default Detection Limit	Sample No
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m^3	3
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m^3	3
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m^3	3
BTEX in Water by Headspace GC-MS*	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m^3	3
Formaldehyde in Water by DNPH & LCMSMS*	DNPH derivatisation, extraction, LCMSMS	0.02 g/m^3	3
Total Petroleum Hydrocarbons in Water*	Solvent Hexane extraction, GC-FID analysis, Headspace GC-MS FS analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734;26687,3629]	0.06 - 0.7 g/m^3	3
Filtration, Unpreserved*	Sample filtration through 0.45µm membrane filter.	-	3
Total Digestion*	Boiling nitric acid digestion. APHA 3030 E 22nd ed. 2012 (modified).	-	3
Total Digestion of Saline Samples*	Nitric acid digestion. APHA 3030 E 22nd ed. 2012 (modified).	-	3
pH*	Saline water, pH meter. APHA 4500-H$^+$ B 22nd ed. 2012. 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	3
Total Alkalinity*	Saline water, Titration to pH 4.5.	1.0 g/m^3 as $CaCO_3$	3

Sample Type: Saline			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Total Hardness*	Calculation from Calcium and Magnesium. APHA 2340 B 22nd ed. 2012.	1.0 g/m³ as $CaCO_3$	3
Electrical Conductivity (EC)*	Saline water, Conductivity meter, 25°C. APHA 2510 B 22nd ed. 2012.	0.10 mS/m	3
Total Barium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.00063 g/m³	3
Total Calcium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	1.1 g/m³	3
Total Copper*	Nitric acid digestion, ICP-MS, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0011 g/m³	3
Total Iron*	Nitric acid digestion, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0042 g/m³	3
Total Magnesium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.42 g/m³	3
Total Manganese*	Nitric acid digestion, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0011 g/m³	3
Total Mercury*	Bromine Oxidation followed by Atomic Fluorescence. US EPA Method 245.7, Feb 2005.	0.00008 g/m³	3
Total Nickel*	Nitric acid digestion, ICP-MS with universal cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.007 g/m³	3
Total Potassium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	1.1 g/m³	3
Total Sodium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.42 g/m³	3
Total Sulphur*	Nitric acid digestion, ICP-OES (method may not fully account for H_2S due to volatilisation during digestion). All forms of oxidised and organic sulphur will be determined by this method. APHA 3120 23rd ed. 2017.	0.5 g/m³	3
Total Zinc*	Nitric acid digestion, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0042 g/m³	3
Bromide*	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 22nd ed. 2012.	0.05 g/m³	3
Chloride*	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 22nd ed. 2012.	0.5 g/m³	3
Nitrite-N	Saline sample. Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO3- I 22nd ed. 2012 (modified).	0.0010 g/m³	3
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m³	3
Nitrate*	Calculation from Nitrate-N.	0.010 g/m³	3
Nitrate-N + Nitrite-N	Saline sample. Total oxidised nitrogen. Automated cadmium reduction, Flow injection analyser. APHA 4500-NO3- I 22nd ed. 2012 (modified).	0.0010 g/m³	3
Total Sulphate*	Calculation: from total sulphur.	2 g/m³	3
C7 - C9	Head Space, GCMS analysis.	0.06 g/m³	3

Sample Type: Oil			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Client Chromatogram for GC Scan*	.	-	2
Free Product GC Scan by FID*	Dilution of free product in organic solvent	1.0 mL/100mL	2
Volume of Free Product present in TPH Water samples*	Volumes estimated using Measuring Cylinder.	1.0 mL/100mL	2
BTEX in Oil by Headspace GC-MS*	Solvent dilution, Headspace GC-MS analysis [KBIs:5782,26687,3629]	0 mg/kg as rcvd	2
Ashing and Aqua Regia digest	Ashing in Muffle furnace, Aqua Regia (HNO_3/HCl) digestion.	-	2
Total Barium*	Aqua Regia Digestion, ICP-MS.	0.2 mg/kg as rcvd	2
Total Calcium*	Aqua Regia Digestion, ICP-MS.	50 mg/kg as rcvd	2
Total Copper*	Aqua Regia Digestion, ICP-MS.	1.0 mg/kg as rcvd	2
Total Iron*	Aqua Regia Digestion, ICP-MS.	20 mg/kg as rcvd	2
Total Manganese*	Aqua Regia Digestion, ICP-MS.	0.5 mg/kg as rcvd	2
Total Nickel*	Aqua Regia Digestion, ICP-MS.	1.0 mg/kg as rcvd	2
Total Potassium*	Aqua Regia Digestion, ICP-MS.	50 mg/kg as rcvd	2
Total Sodium*	Aqua Regia Digestion, ICP-MS.	20 mg/kg as rcvd	2
Total Sulphur (Sub CRL)*	LECO SC-144 Sulphur Determinator, high temperature furnace, infra-red detector. Subcontracted to CRL Energy. ASTM 4239.	0.010 g/100g as rcvd	2
Total Zinc*	Aqua Regia Digestion, ICP-MS.	2 mg/kg as rcvd	2

Sample Type: Oil			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Chloride in Oil / Water Emulsion*	Extraction of chloride using acid / alcohol mix. Back titration of silver nitrate against potassium thiocyanate. In-House method based on Vogel's Inorganic Analysis.	70 mg/kg as rcvd	2

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

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

Ara Heron BSc (Tech)
Client Services Manager - Environmental

CRL Energy Ltd

REPORT OF ANALYSIS

Customer: Hill Laboratories **Date Received:** 7-Aug-18

Description: Samples supplied by client

Order # 150506

Customer Reference: **2025011.2**

CRL Energy Ltd Reference: **112/441**

Analysis - As Received Basis

Ash (ISO 1171)	w/w %	
Sulphur (ASTM D4239)	w/w %	0.03

Date of Issue: 14-Aug-18

Signature: ___

Ben Rumsey
Research Officer

THIS REPORT MUST NOT BE QUOTED EXCEPT IN FULL

Distribution:
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CRL Energy Ltd, PO Box 31-244,Lower Hutt

Hill Laboratories
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E mail@hill-labs.co.nz
W www.hill-laboratories.com

Certificate of Analysis

Client:	Taranaki Regional Council	**Lab No:**	2025011 SPv1
Contact:	Jane Harvey C/- Taranaki Regional Council Private Bag 713 Stratford 4352	**Date Received:**	02-Aug-2018
		Date Reported:	17-Aug-2018
		Quote No:	71307
		Order No:	72831
		Client Reference:	Return Fluid Composite
		Add. Client Ref:	340300382 MHWC03 RF
		Submitted By:	Sarah Larkin

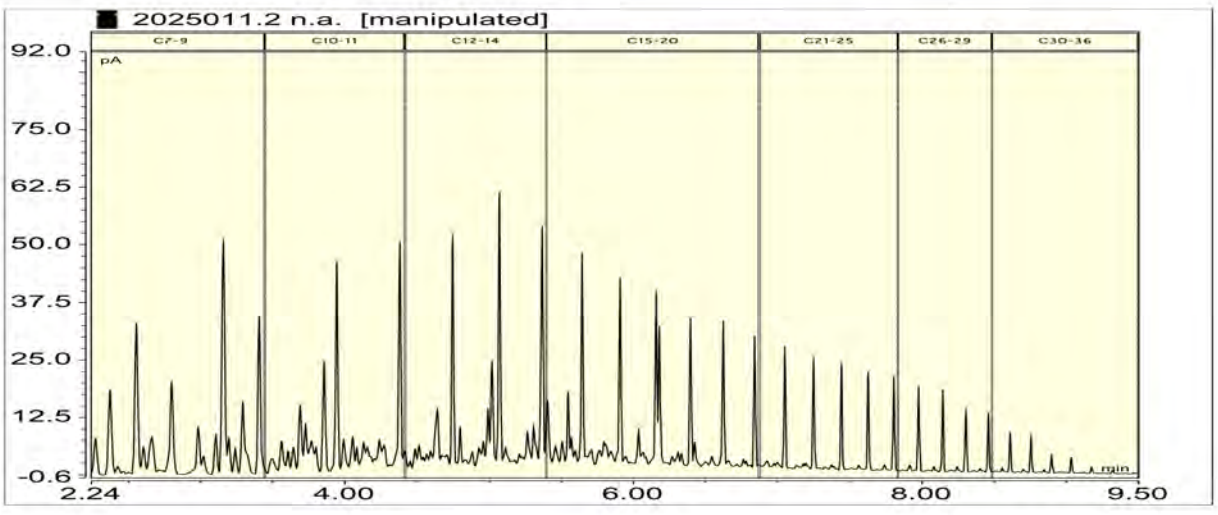
Sample Type: Saline

		Sample Name:	GND2822 RF 183133 [water fraction]				
		Lab Number:	2025011.3				
Individual Tests							
pH*	pH Units		7.8	-	-	-	-
Total Alkalinity*	g/m³ as $CaCO_3$		1,740	-	-	-	-
Total Hardness*	g/m³ as $CaCO_3$		500	-	-	-	-
Electrical Conductivity (EC)*	mS/m		4,260	-	-	-	-
Total Barium*	g/m³		123	-	-	-	-
Total Calcium*	g/m³		158	-	-	-	-
Total Copper*	g/m³		< 0.0053	-	-	-	-
Total Iron*	g/m³		0.69	-	-	-	-
Total Magnesium*	g/m³		25	-	-	-	-
Total Manganese*	g/m³		3.1	-	-	-	-
Total Mercury*	g/m³		< 0.0003	-	-	-	-
Total Nickel*	g/m³		< 0.03	-	-	-	-
Total Potassium*	g/m³		3,100	-	-	-	-
Total Sodium*	g/m³		7,300	-	-	-	-
Total Sulphur*	g/m³		37	-	-	-	-
Total Zinc*	g/m³		0.026	-	-	-	-
Bromide*	g/m³		40	-	-	-	-
Chloride*	g/m³		13,700	-	-	-	-
Nitrite-N	g/m³		< 0.010 #4	-	-	-	-
Nitrate-N	g/m³		< 0.010	-	-	-	-
Nitrate*	g/m³		< 0.05	-	-	-	-
Nitrate-N + Nitrite-N	g/m³		< 0.010 #4	-	-	-	-
Sulphate*	g/m³		111	-	-	-	-
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		14.5	-	-	-	-
Toluene*	g/m³		21	-	-	-	-
Ethylbenzene*	g/m³		1.15	-	-	-	-
m&p-Xylene*	g/m³		7.0	-	-	-	-
o-Xylene*	g/m³		2.5	-	-	-	-

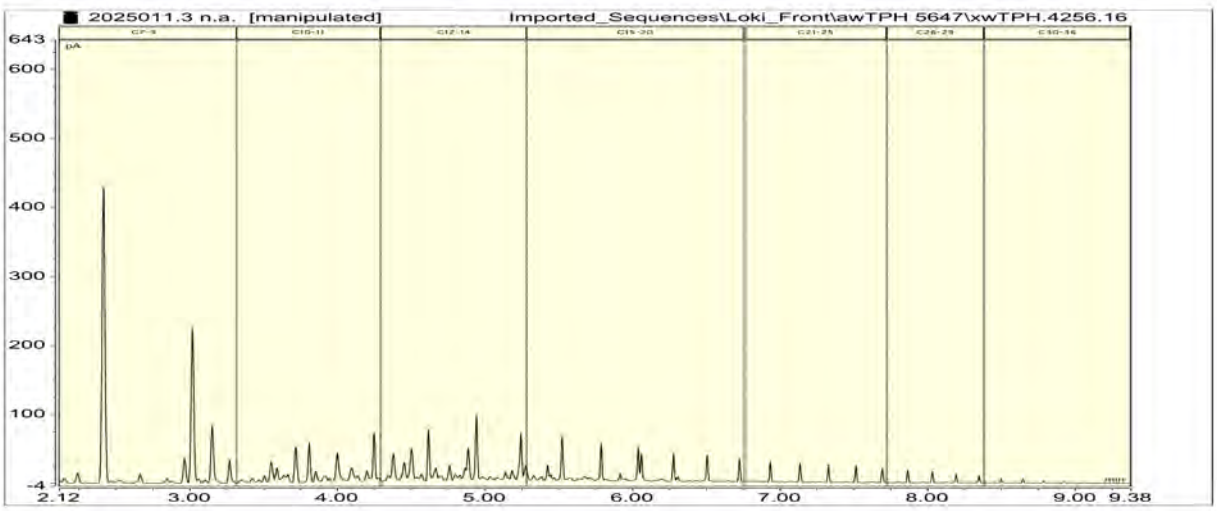
Sample Type: Saline						
Sample Name:		GND2822 RF 183133 [water fraction]				
Lab Number:		2025011.3				
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde*	g/m³	< 8	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m³	40	-	-	-	-
C10 - C14*	g/m³	34	-	-	-	-
C15 - C36*	g/m³	24	-	-	-	-
Total hydrocarbons (C7 - C36)	g/m³	98	-	-	-	-

Sample Type: Oil						
Sample Name:		GND2822 RF 183133 [oil fraction]				
Lab Number:		2025011.2				
Individual Tests						
Total Barium*	mg/kg as rcvd	3.0 #1	-	-	-	-
Total Calcium*	mg/kg as rcvd	152 #2	-	-	-	-
Total Copper*	mg/kg as rcvd	< 1.0	-	-	-	-
Total Iron*	mg/kg as rcvd	< 20	-	-	-	-
Total Manganese*	mg/kg as rcvd	< 0.5	-	-	-	-
Total Nickel*	mg/kg as rcvd	< 1.0	-	-	-	-
Total Potassium*	mg/kg as rcvd	< 50	-	-	-	-
Total Sodium*	mg/kg as rcvd	48 #3	-	-	-	-
Total Sulphur*	g/100g as rcvd	0.030	-	-	-	-
Total Zinc*	mg/kg as rcvd	< 5	-	-	-	-
Chloride*	mg/kg as rcvd	75	-	-	-	-
Free Product GC Scan by FID						
Free Product*	mL/100mL	100	-	-	-	-
BTEX in Oil by Headspace GC-MS						
Benzene*	mg/kg as rcvd	4,500	-	-	-	-
Toluene*	mg/kg as rcvd	30,000	-	-	-	-
Ethylbenzene*	mg/kg as rcvd	5,600	-	-	-	-
m&p-Xylene*	mg/kg as rcvd	35,000	-	-	-	-
o-Xylene*	mg/kg as rcvd	10,500	-	-	-	-

2025011.2
GND2822 RF 183133 [oil fraction]
Client Chromatogram for GC Scan



2025011.3
GND2822 RF 183133 [water fraction]
Client Chromatogram for TPH by FID



Analyst's Comments

#1 It should be noted that the replicate analyses performed on this sample as part of our in-house Quality Assurance procedures showed greater variation than would normally be expected. This may reflect the heterogeneity of the sample.

#2 It should be noted that the blanks contained an elevated level of calcium (138mg/kg c.f. detection limit of 50mg/kg). This has not been corrected for on the sample concentration. This should be kept in mind when interpreting these results.

It should be noted that the replicate analyses performed on this sample as part of our in-house Quality Assurance procedures showed greater variation than would normally be expected. This may reflect the heterogeneity of the sample.

#3 It should be noted that the blanks contained an elevated level of sodium (29mg/kg c.f. detection limit of 20mg/kg). This has not been corrected for on the sample concentration. This should be kept in mind when interpreting these results.

#4 Due to the nature of this sample a dilution was performed prior to analysis, resulting in a detection limit higher than that normally achieved for the NO2Nsal, NO3Nsal and NOxNsal analysis.

Appendix No.1 - Total Sulphur Report 2025011

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 clean 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.

Sample Type: Saline

Test	Method Description	Default Detection Limit	Sample No
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m^3	3
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m^3	3
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m^3	3
BTEX in Water by Headspace GC-MS*	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m^3	3
Formaldehyde in Water by DNPH & LCMSMS*	DNPH derivatisation, extraction, LCMSMS	0.02 g/m^3	3
Total Petroleum Hydrocarbons in Water*	Solvent Hexane extraction, GC-FID analysis, Headspace GC-MS FS analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734;26687,3629]	0.06 - 0.7 g/m^3	3
Filtration, Unpreserved*	Sample filtration through 0.45µm membrane filter.	-	3
Total Digestion*	Boiling nitric acid digestion. APHA 3030 E 22nd ed. 2012 (modified).	-	3
Total Digestion of Saline Samples*	Nitric acid digestion. APHA 3030 E 22nd ed. 2012 (modified).	-	3
pH*	Saline water, pH meter. APHA 4500-H$^+$ B 22nd ed. 2012. 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	3
Total Alkalinity*	Saline water, Titration to pH 4.5.	1.0 g/m^3 as $CaCO_3$	3

Sample Type: Saline			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Total Hardness*	Calculation from Calcium and Magnesium. APHA 2340 B 22nd ed. 2012.	1.0 g/m³ as $CaCO_3$	3
Electrical Conductivity (EC)*	Saline water, Conductivity meter, 25°C. APHA 2510 B 22nd ed. 2012.	0.10 mS/m	3
Total Barium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.00063 g/m³	3
Total Calcium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	1.1 g/m³	3
Total Copper*	Nitric acid digestion, ICP-MS, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0011 g/m³	3
Total Iron*	Nitric acid digestion, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0042 g/m³	3
Total Magnesium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.42 g/m³	3
Total Manganese*	Nitric acid digestion, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0011 g/m³	3
Total Mercury*	Bromine Oxidation followed by Atomic Fluorescence. US EPA Method 245.7, Feb 2005.	0.00008 g/m³	3
Total Nickel*	Nitric acid digestion, ICP-MS with universal cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.007 g/m³	3
Total Potassium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	1.1 g/m³	3
Total Sodium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.42 g/m³	3
Total Sulphur*	Nitric acid digestion, ICP-OES (method may not fully account for H_2S due to volatilisation during digestion). All forms of oxidised and organic sulphur will be determined by this method. APHA 3120 23rd ed. 2017.	0.5 g/m³	3
Total Zinc*	Nitric acid digestion, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0042 g/m³	3
Bromide*	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 22nd ed. 2012.	0.05 g/m³	3
Chloride*	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 22nd ed. 2012.	0.5 g/m³	3
Nitrite-N	Saline sample. Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO3- I 22nd ed. 2012 (modified).	0.0010 g/m³	3
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m³	3
Nitrate*	Calculation from Nitrate-N.	0.010 g/m³	3
Nitrate-N + Nitrite-N	Saline sample. Total oxidised nitrogen. Automated cadmium reduction, Flow injection analyser. APHA 4500-NO3- I 22nd ed. 2012 (modified).	0.0010 g/m³	3
Total Sulphate*	Calculation: from total sulphur.	2 g/m³	3
C7 - C9	Head Space, GCMS analysis.	0.06 g/m³	3

Sample Type: Oil			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Client Chromatogram for GC Scan*	.	-	2
Free Product GC Scan by FID*	Dilution of free product in organic solvent	1.0 mL/100mL	2
Volume of Free Product present in TPH Water samples*	Volumes estimated using Measuring Cylinder.	1.0 mL/100mL	2
BTEX in Oil by Headspace GC-MS*	Solvent dilution, Headspace GC-MS analysis [KBIs:5782,26687,3629]	0 mg/kg as rcvd	2
Ashing and Aqua Regia digest	Ashing in Muffle furnace, Aqua Regia (HNO_3/HCl) digestion.	-	2
Total Barium*	Aqua Regia Digestion, ICP-MS.	0.2 mg/kg as rcvd	2
Total Calcium*	Aqua Regia Digestion, ICP-MS.	50 mg/kg as rcvd	2
Total Copper*	Aqua Regia Digestion, ICP-MS.	1.0 mg/kg as rcvd	2
Total Iron*	Aqua Regia Digestion, ICP-MS.	20 mg/kg as rcvd	2
Total Manganese*	Aqua Regia Digestion, ICP-MS.	0.5 mg/kg as rcvd	2
Total Nickel*	Aqua Regia Digestion, ICP-MS.	1.0 mg/kg as rcvd	2
Total Potassium*	Aqua Regia Digestion, ICP-MS.	50 mg/kg as rcvd	2
Total Sodium*	Aqua Regia Digestion, ICP-MS.	20 mg/kg as rcvd	2
Total Sulphur (Sub CRL)*	LECO SC-144 Sulphur Determinator, high temperature furnace, infra-red detector. Subcontracted to CRL Energy. ASTM 4239.	0.010 g/100g as rcvd	2
Total Zinc*	Aqua Regia Digestion, ICP-MS.	2 mg/kg as rcvd	2

Sample Type: Oil			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Chloride in Oil / Water Emulsion*	Extraction of chloride using acid / alcohol mix. Back titration of silver nitrate against potassium thiocyanate. In-House method based on Vogel's Inorganic Analysis.	70 mg/kg as rcvd	2

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

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

Ara Heron BSc (Tech)
Client Services Manager - Environmental

CRL Energy Ltd

REPORT OF ANALYSIS

Customer: Hill Laboratories **Date Received:** 7-Aug-18

Description: Samples supplied by client

Order # 150506

Customer Reference: **2025011.2**

CRL Energy Ltd Reference: **112/441**

Analysis - As Received Basis

Ash (ISO 1171)	w/w %	
Sulphur (ASTM D4239)	w/w %	0.03

Date of Issue: 14-Aug-18

Signature: ___

Ben Rumsey
Research Officer

THIS REPORT MUST NOT BE QUOTED EXCEPT IN FULL

Distribution:
Hill Laboratories, 1 Clyde Street, Hamilton
CRL Energy Ltd, PO Box 31-244,Lower Hutt

Hill Laboratories
TRIED, TESTED AND TRUSTED

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Private Bag 3205
Hamilton 3240 New Zealand

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T +64 7 858 2000
E mail@hill-labs.co.nz
W www.hill-laboratories.com

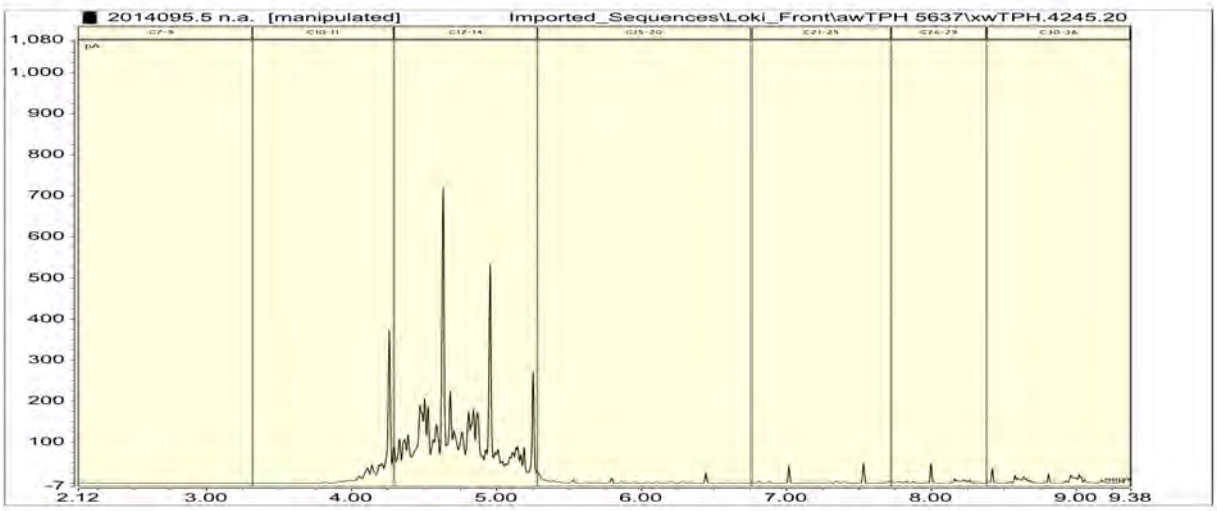
Certificate of Analysis

Client:	Taranaki Regional Council	**Lab No:**	2014095 SPv1
Contact:	Jane Harvey	**Date Received:**	12-Jul-2018
	C/- Taranaki Regional Council	**Date Reported:**	26-Jul-2018
	Private Bag 713	**Quote No:**	50522
	Stratford 4352	**Order No:**	72831
		Client Reference:	Hydraulic fracturing fluid testing
		Add. Client Ref:	340300-382 MHWC-03 FF
		Submitted By:	Sarah Larkin

Sample Type: Aqueous

Sample Name:		GND2822 FF 182869 Zone1, GND2822 FF 182869 Zone2, GND2822 FF 182869 Zone3 and GND2822 FF 182869 Zone4 28-Jun-2018				
Lab Number:		2014095.5				
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	21	-	-	-	-
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	0.0011	-	-	-	-
Ethylbenzene	g/m³	< 0.0010	-	-	-	-
m&p-Xylene	g/m³	< 0.002	-	-	-	-
o-Xylene	g/m³	< 0.0010	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m³	< 0.06	-	-	-	-
C10 - C14	g/m³	420	-	-	-	-
C15 - C36	g/m³	45	-	-	-	-
Total hydrocarbons (C7 - C36)	g/m³	470	-	-	-	-

2014095.5
GND2822 FF 182869 Zone1, GND2822 FF 182869 Zone2, GND2822 FF 182869 Zone3 and GND2822 FF 182869 Zone4 28-Jun-2018
Client Chromatogram for TPH by FID



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 clean 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.

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m^3	5
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m^3	5
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m^3	5
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m^3	5
Total Petroleum Hydrocarbons in Water*	Solvent Hexane extraction, GC-FID analysis, Headspace GC-MS FS analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734;26687,3629]	0.06 - 0.7 g/m^3	5
C7 - C9	Head Space, GCMS analysis.	0.06 g/m^3	5

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