

Todd Energy Limited
Mangahewa-C Hydraulic Fracturing
Monitoring Programme Report
2015-2017

Technical Report 2017-3

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Executive summary

This report for the period July 2015 to June 2017 outlines and discusses the results of the monitoring programme implemented by the Taranaki Regional Council (the Council) in relation to hydraulic fracturing activities conducted by Todd Energy Limited (Todd) at their Mangahewa-C wellsite. The wellsite is located on Tikorangi Road East, Tikorangi and lies within the Waiau Catchment. This report also assesses Todd's level of environmental performance and compliance with the resource consents held in relation to the activity.

Todd hold resource consent 7971-2, authorising the discharge of water based hydraulic fracturing fluids into land at depths greater than 3,290 metres true vertical depth subsea (TVDss) beneath the Mangahewa-C wellsite. This consent was issued by the Council on 30 June 2014, replacing consent 7971-1 which was issued on 20 January 2012. Consent 7971-2 contains a total of 17 special conditions which set out the requirements that Todd must satisfy.

The programme of hydraulic fracturing undertaken by Todd at Mangahewa-C discussed in this report included the fracturing of two wells. The wells targeted for stimulation were Mangahewa-12ST2, and Mangahewa-14ST1. The hydraulic fracturing of these wells took place between January and April 2016.

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

The programme of monitoring implemented by the Council in relation to hydraulic fracturing activities at the Mangahewa-C wellsite was initiated in 2011. This report details the results of monitoring conducted during the 2015–2016 and the 2016-2017 monitoring years in relation to activities carried out in January to April 2016. Previous reports published by the Council cover the results of monitoring undertaken for HF activities prior to this period.

The programme of monitoring implemented by the Council during the period being reported included pre and post discharge groundwater sampling. Biomonitoring surveys were also carried out to assess the impact of any site discharges during the fracturing programme on unnamed tributaries of 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.

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 consents 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 2015-2016 year, 71% of consent holders achieved a high level of environmental performance and compliance with their consents, while another 24% demonstrated a good level of environmental performance and compliance.

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

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1. Introduction

1.1. Compliance monitoring programme reports and the Resource Management Act 1991

1.1.1. Introduction

This report outlines and discusses the results of the monitoring programme implemented by the Taranaki Regional Council (the Council) in relation to the programme of hydraulic fracturing undertaken by Todd Energy Limited (Todd) at their Mangahewa–C wellsite, over the period January to April 2016. 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 their Mangahewa-C wellsite included the hydraulic fracturing of two wells. The wells targeted for stimulation were the Mangahewa-12ST2 and Mangahewa-14ST1 wells.

The programme of monitoring implemented by the Council in relation to these hydraulic fracturing activities spanned the 2015-2016 and 2016-2017 monitoring years. Monitoring included a mixture of groundwater, surface water and discharge monitoring components. This is the fourth monitoring report produced by the Council in relation to the hydraulic fracturing activities at the Mangahewa-C wellsite. The other three reports covered previous hydraulic fracturing activities spanning July 2011 to June 2015.

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 in the Company’s site/catchment.

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 regarding future monitoring at the site.

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

1.1.3. The Resource Management Act 1991 and monitoring

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

- a. the neighbourhood or the wider community around an activity, and may include cultural and social-economic effects;
- b. physical effects on the locality, including landscape, amenity and visual effects;
- c. ecosystems, including effects on plants, animals, or habitats, whether aquatic or terrestrial;
- d. natural and physical resources having special significance (for example recreational, cultural, or aesthetic); and
- e. risks to the neighbourhood or environment.

In drafting and reviewing conditions on discharge permits, and in implementing monitoring programmes, the Council is recognising the comprehensive meaning of 'effects' 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 consent holders, this report also assigns a rating as to each Company's 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 significant 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 in response to unauthorised incident reports, 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 in response to unauthorised incident reports. 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 in response to unauthorised incident reports. 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 2015-2016 year, 71% of consent holders in Taranaki monitored through tailored compliance monitoring programmes achieved a high level of environmental performance and compliance with their consents, while another 24% demonstrated a good level of environmental performance and compliance with their consents

1.2. Process description

1.2.1. Hydraulic fracturing

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

The process of hydraulic fracturing involves the pumping of fluids and a proppant (medium-grained sand or small ceramic pellets) down a well, through a perforated section of the well casing, and into the target reservoir. The fluid mixture is pumped at a pressure that exceeds the fracture strength of the reservoir rock in order to create fractures. Once fractures have been initiated, pumping continues in order to force the fluid and proppant into the fractures created. The proppant is designed to keep the fractures open when the pumping is stopped. The placement of proppant into the fractures can be assisted by the use of cross-linked gels (gel fracking) or turbulent flow (slick-water fracking).

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.

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

Nitrogen gas assisted fracturing

Nitrogen gas assisted fracturing involves replacing some of the fluid used in the fracturing process with nitrogen gas, which can fracture rock at high pressures much like water. While nitrogen (N²) is a gas at room temperature, it can be maintained in a liquid state through cooling and pressurisation. Nitrogen assisted fracking 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. 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 disposal².

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 activity during the reporting period

Well	Fracturing date		Range mid point injection zones (m TVD)	Formation
	Start	End		
Mangahewa 14ST1	19/01/16	17/02/16	3,462 to 4,637	Kapuni Group
Mangahewa 12ST2	21/02/16	04/02/16	3,444 to 4,750	Kapuni Group

¹ <http://geology.com/energy/hydraulic-fracturing-fluids/>

1.3. Resource consents

1.3.1. Discharges onto and into land

Sections 15(1)(b) of the RMA stipulate that no person may discharge any contaminant onto or into land, which may result in that contaminant (or any other contaminant emanating as a result of natural processes from that contaminant) entering water, unless the activity is expressly allowed for by a resource consent, a rule in a regional plan, or by national regulations.

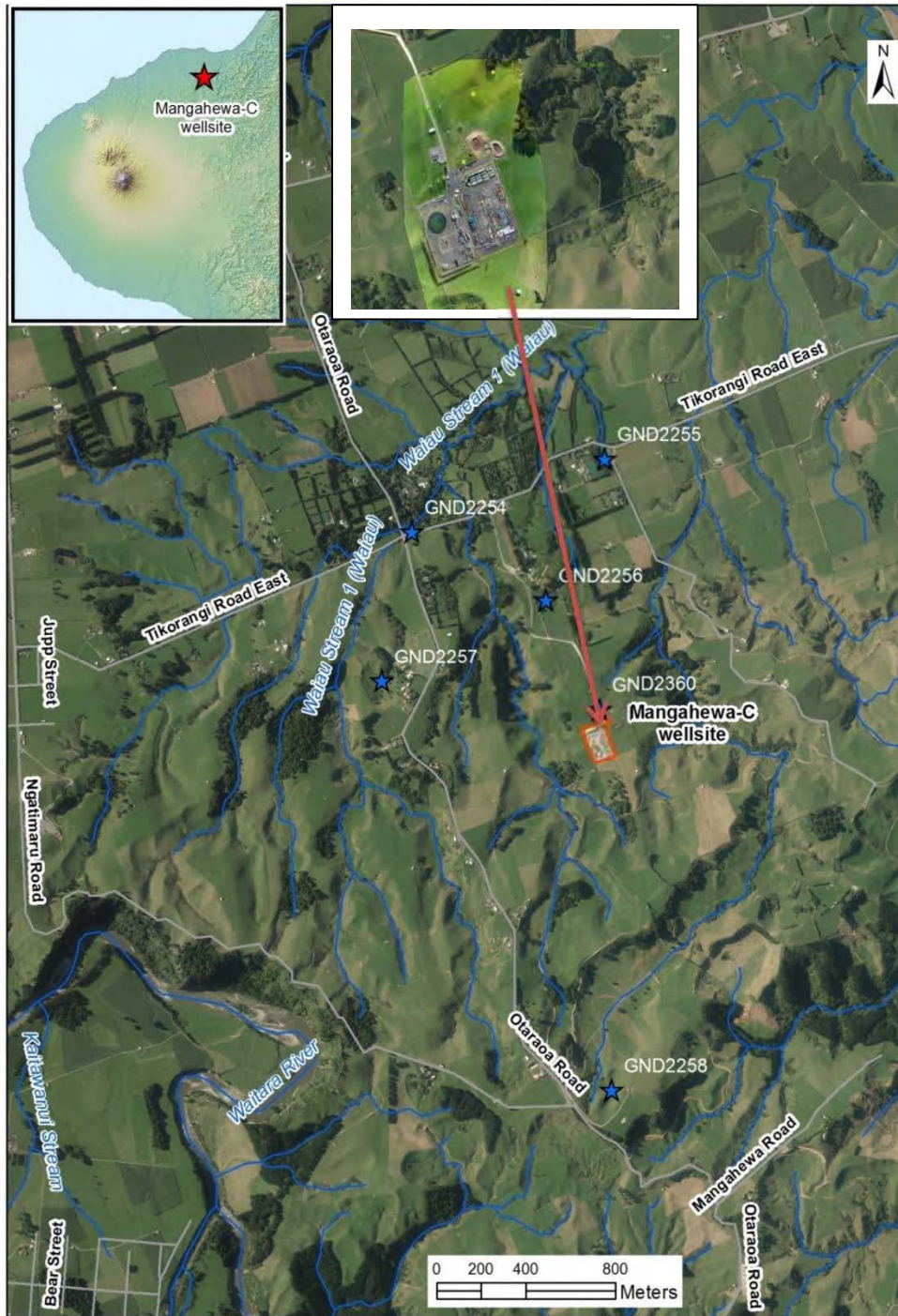


Figure 1 Location map

The current consent 7971-2 has 17 special conditions, as summarised below:

- Condition 1 stipulates the minimum depth below which the injection of hydraulic fracturing fluids must occur;
- Condition 2 stipulates the date before which discharge of hydraulic fracturing fluids must occur;
- Condition 3 requires the consent holder to ensure that the exercising of the consent does not result in any contaminants reaching any useable freshwater (ground or surface water);
- Conditions 4, 5, 6 and 7 relate to fresh water monitoring requirements, to allow compliance with condition 3 to be assessed;
- Condition 8 requires the consent holder to carry out pressure testing of equipment prior to discharging;
- Condition 9 requires the consent holder to submit a pre-fracturing discharge report prior to any discharge occurring;
- Condition 10 is a notification requirement;
- Condition 11 requires the consent holder to submit a post-fracturing discharge report after the completion of the hydraulic fracturing programme for each well;
- Condition 12 stipulates how the reports required by conditions 9 and 11 are to be submitted;
- Condition 13 requires the consent holder to allow the Council access to a location where samples of hydraulic fracturing and return fluids can be obtained;
- Condition 14 requires the consent holder to adopt best practicable options;
- Condition 15 relates to the composition of the fracturing fluid;
- Condition 16 is a lapse clause; and
- Condition 17 is a review provision.

A Copy of the consent valid during the reporting period is included in Appendix I.

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 implemented in relation to the hydraulic fracturing of the Mangahewa-C wells 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 consent holder

As required by the conditions of consents 7971-2, Todd submitted pre and post-fracturing discharge reports to the Council for each well fractured during the period under review. Pre-fracturing discharge reports provide an outline of the proposed fracturing operations in relation to each well, while post-fracturing reports confirm details of what actually occurred. The specific range of information required in each report is stipulated in the conditions of the consent.

1.4.4. Physicochemical sampling

1.4.4.1. Groundwater

In order to select suitable sites for sampling, a well survey was carried out in the vicinity of the Mangahewa-C wellsite to identify any existing groundwater abstractions in the area. The survey was undertaken in April 2012 within a defined area which extended 1 km radially from the wellsite. A total of five groundwater abstraction sites were then selected for inclusion in the monitoring programme. More recently one of the original sites GND2258 was replaced with the water supply bore at the Mangahewa wellsite (GND2360). The sampling sites have been 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.

The details of all groundwater sites that were sampled over the course of the reporting period are included in Table 2. Their location and proximity to the Mangahewa-C wellsite is illustrated in Figure 2.

Table 2 Details of groundwater sites included in the monitoring programme

Monitoring site	Distance from wellsite (m)	Total depth (m)	Screened interval (m)	Aquifer
GND2254	1,161	37	N/A	Volcanics
GND2255	1,158	4	N/A	Volcanics
GND2256	595	2.4	N/A	Volcanics
GND2257	960	5	N/A	Volcanics
GND2360	60	533	Open from 149 m	Unknown

Samples of groundwater were obtained pre-fracturing to provide a baseline reference of groundwater composition, with further rounds of sampling carried out three months and one year after the cessation of activities.

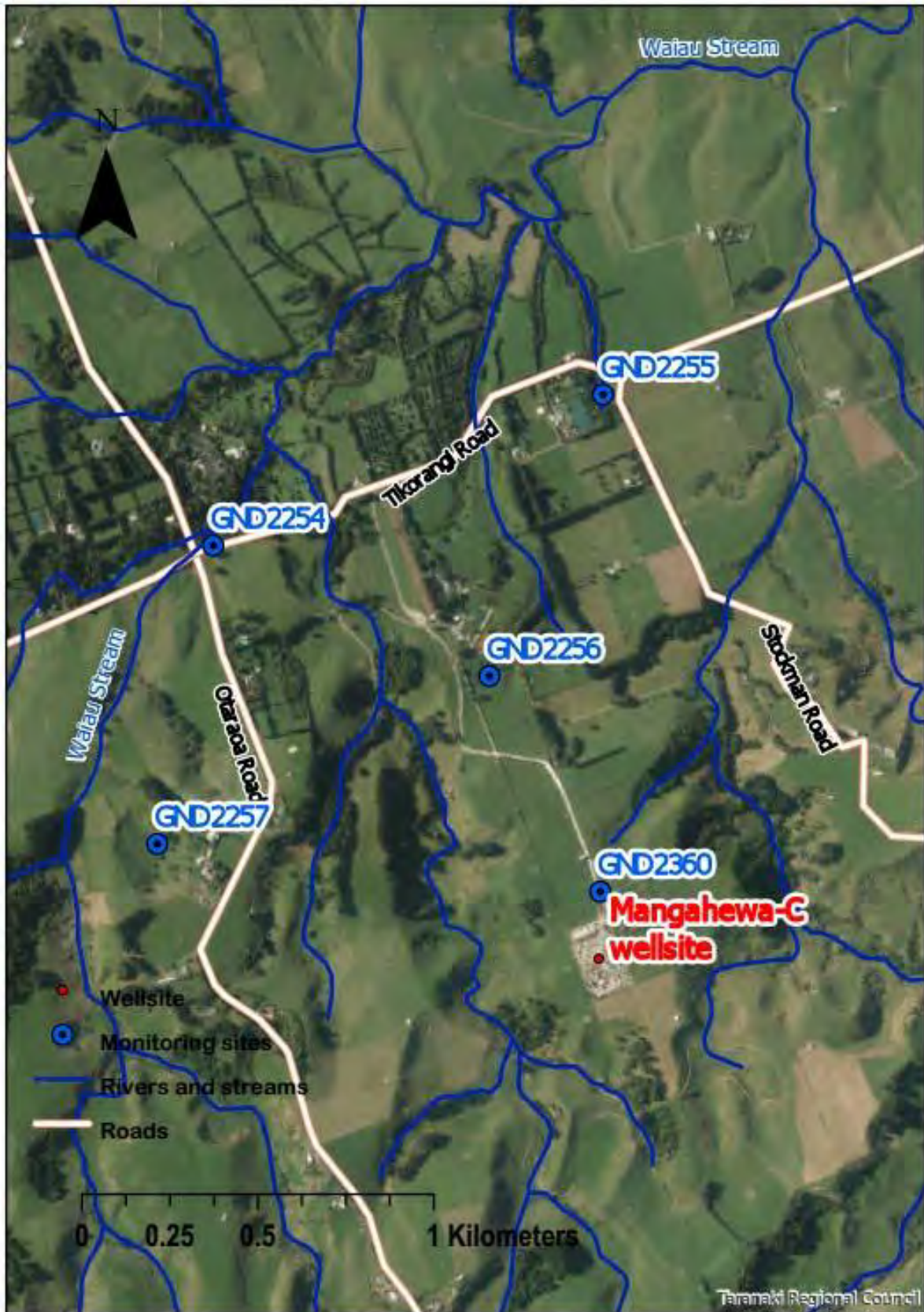


Figure 2 Groundwater monitoring sites at Mangahewa-C

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 hydraulic fracturing fluid were obtained from storage tanks on-site.

Samples of return fluids for each well 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 Limited for analysis following standard chain of custody procedures.

1.4.5. Surface water quality monitoring

1.4.5.1. Biomonitoring surveys

Macroinvertebrate surveys were carried out on 26 May 2015 and 18 April 2016 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. The wellsite treated stormwater, uncontaminated site water and production water were discharged from a skimmer pit into an unnamed tributary of the Waiau Stream (Figure 3).

Taxa richness is the most robust index when determining whether a macroinvertebrate community has been exposed to toxic discharges. When exposed to toxic discharges, macroinvertebrates may die and be swept downstream or may deliberately drift downstream as an avoidance mechanism (catastrophic drift). The Macroinvertebrate Index (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 Semi-quantitative Macroinvertebrate Index (SQMCI) takes into account taxa abundances as well as sensitivity to pollution. It may indicate subtle changes in communities, and therefore be the more relevant index if non-organic impacts are occurring. Significant differences in either MCI or SQMCI between sites indicate the degree of adverse effects (if any) of the discharges being monitored.

The details of each biomonitoring site included in the surveys are presented in Table 3. Their location and proximity to the Mangahewa-C wellsite is illustrated in Figure 3.

Table 3 Details of biomonitoring sites included in the monitoring programme

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



Figure 3 Location of biomonitoring sites in relation to the Mangahewa-C wellsite

2. Results

2.1. Consent holder submitted data

2.1.1. Mangahewa-14ST1 post-fracturing discharge report

The conclusions from the Mangahewa-14ST1 post-fracturing discharge report are summarised as follows:

- A total of nine discrete zones were fractured over the period 19 January to 17 February 2016 at depths between 3,462 to 4,637 m TVD.
- A total of 33,988 bbls (5,404 m³) of liquid and 93,697 m³ of nitrogen was discharged across the nine fractured zones. The total proppant weight was 247 tonnes (545,512 lbs).
- By volume, 94.31% of the fluid injected was water, 1.30% was proppant, and 2.53% was nitrogen with the remaining 1.85% comprised of chemical additives.
- The Mangahewa-14ST1 well was opened for flow-back following the completion of fracturing operations. In total, 36,821 bbls (5,854 m³) of fluid was returned from the well over the initial flow-back period.
- The initial flow-back comprised of two separate depth intervals flow-backs, 3,462 to 4,348 m TVD and 3,950 to 4,637 m TVD, with both intervals returning more fluid than injected.
- The volume of fluid returned during the flow-back was 2,833 bbls greater than the volume of fluid injected.
- Approximately 244 tonnes (538,982 lbs) or 98.9% of proppant remained within the formation after the completion of flow back.
- Nitrogen dissipates in to the formation and is returned over time as part of the gas produced.
- No screen outs occurred while fracturing.
- All return fluid from the Mangahewa-14ST1 fracturing operations was disposed of by deep well injection, via the McKee-A injection well under consent 4182-2, the McKee B injection well under consent 5052-2 and Tuhua-B injection well under consent 1315-1.
- The Christmas tree, tubing string, casing strings and wellhead maintained full integrity throughout the treatment.
- Pressure testing of the tubing and well head equipment was carried out prior to fracturing commencing. When threshold pressures were imminent, measures were taken to reduce the pressure and when threshold pressures were reached, pumping ceased.
- It is considered that the mitigation measures implemented by Todd were effective in ensuring there were no adverse environmental effects associated with fracturing operations.

2.1.2. Mangahewa-12ST2 post-fracturing discharge report

The conclusions from the Mangahewa-12ST2 post-fracturing discharge report are summarised as follows:

- A total of thirteen discrete zones were fractured over the period 21 February to 4 April 2016, at depths between 3,444 to 4,750 m TVD.
- A total of 41,849 bbls (6,653 m³) of liquid was discharged across the thirteen fractured zones. The total proppant weight was 319 tonnes (703,399 lbs).
- By volume, 96.66% of the fluid injected was water and 1.42% was proppant with the remaining 0.2% comprised of chemical additives.

- The Mangahewa-12ST2 well was opened for flow-back following the completion of fracturing operations. In total, 44,597 bbls (7,090 m³) of fluid was returned from the well over the initial flow-back period.
- The initial flow-back comprised of three separate depth intervals flow-backs, 3,444 to 4,290 m TVD, 3,640 to 4,504 m TVD and 3,995 to 4,750 m TVD, with the first two returning more fluid than injected and the third interval less fluid than injected.
- Approximately 3,143 bbls (499 m³) or 14% of the fluids injected (22,799 bbls) remained in the formation upon completion of flow-back in the third interval. Additional fluid is likely to be returned back to the surface as the well produces.
- Approximately 316 tonnes (697,100 lbs) or 99.1% of proppant remained within the formation after the completion of flow back.
- No screen outs occurred while fracturing.
- All return fluid from the Mangahewa-12ST2 fracturing operations was disposed of by deep well injection, via the McKee-A injection well under consent 4182-2, the McKee B injection well under consent 5052-2 and Tuhua-B injection well under consent 1315-1.
- The Christmas tree, tubing string, casing strings and wellhead maintained full integrity throughout the treatment.
- Pressure testing of the tubing and well head equipment was carried out prior to fracturing commencing. When threshold pressures were imminent, measures were taken to reduce the pressure and when threshold pressures were reached, pumping ceased.
- It is considered that the mitigation measures implemented by Todd were effective in ensuring there were no adverse environmental effects associated with fracturing operations.

2.2. Physicochemical sampling

2.2.1. Groundwater

The recent hydraulic fracturing activities commenced at Mangahewa-C (wells MHW-12ST2 and MHW14ST1) in January 2016. Pre-fracturing sampling was undertaken on 31 July 2015 at five sites GND2254, GND2255, GND2256, GND2257 and GND2360. Hydraulic fracturing continued over several months until April 2016. A three month post-fracturing sample was undertaken on 21 July 2016 at all five sites. The one year post-fracturing sampling was undertaken at all five sites on 22 February 2017 (Table 4).

Table 4 Groundwater sampling undertaken over the reporting period

Well	Fracturing date		Pre-fracturing sample date	3 month post-fracturing sample date	One year post-fracturing sample date
	Start	End			
Mangahewa 14ST1	19/01/2016	17/02/2016	31/07/2015	21/07/2016	22/02/2017
Mangahewa 12ST2	21/02/2016	01/04/2016			

The results of the laboratory analysis of samples from all sites indicate there have been no significant changes in groundwater composition over the period. A comparison of these results to baseline samples taken in 2012 and 2013 indicate there have been no significant changes since monitoring commenced. Slightly higher salinities and trace toluene were recorded in the baseline sample taken at GND2360, which is located on the Mangahewa-C wellsite. However, all subsequent samples at this site have reported concentrations within expected ranges.

All 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.

Low concentrations of methane were detected in the samples taken at GND2254 and GND2360. The methane can be further analysed to determine whether the source is biogenic or thermogenic, with a concentration of $>-50\text{‰}$ indicating thermogenic methane and a value $<-50\text{‰}$ indicating biogenic methane. The samples taken from both bores were sent to GNS for isotopic analysis. The analysis of the dissolved methane within the samples analysed by GNS indicates the methane gas is neither strongly biogenic, nor strongly thermogenic, but potentially of mixed origin. Concentrations from all samples were all within the expected ranges for shallow groundwater across Taranaki.

A summary of results for groundwater samples taken in relation to the hydraulic fracturing activities during the reporting period 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-C fracturing event compared to baseline

Parameter	Unit	GND2254				GND2255				GND2256			
		Baseline	Pre-frac	3 mth post-frac	1 year post-frac	Baseline	Pre-frac	3 mth post-frac	1 year post-frac	Baseline	Pre-frac	3 mth post-frac	1 year post-frac
Sample date		17/04/12	29/07/15	21/07/16	22/02/17	17/04/12	29/07/15	21/07/16	22/02/17	17/04/12	31/07/15	21/07/16	22/02/17
Lab number	TRC	121416	152420	162531	171199	121417	152419	162532	1711200	121418	152422	162533	171201
Total alkalinity	g/m ³ CaCO ₃	132	125	123	119	20	20	20	21	20	20	21	20
Barium	mg/kg	0.0146	0.0148	0.015	0.0138	0.043	0.045	0.045	0.042	0.054	0.066	0.069	0.057
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
Dissolved bromine	g/m ³	0.07	NR*	0.046	0.041	0.1	NR*	0.075	0.071	0.1	NR*	0.085	0.072
Bromide	g/m ³	NR*	0.048	NR*	NR*	NR*	0.082	NR*	NR*	NR*	0.091	NR*	NR*
Calcium	g/m ³	25	24	25	23	6.5	6.1	6.5	6.2	8.6	10.8	10.3	8.6
Chloride	g/m ³	14.4	13.7	13.8	12.8	24.0	23.0	23.0	21.0	21.0	23.0	23.0	19.6
Conductivity	mS/m	27.5	27.6	27.4	27.1	13.0	13.6	13.7	14.0	15.4	18.2	18.0	16.5
Dissolved copper	g/m ³	<0.0005	<0.0005	< 0.0005	< 0.0005	0.0072	0.019	0.028	0.129	0.0007	<0.0005	< 0.0005	0.0006
Ethylbenzene	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
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
Ethylene	g/m ³	<0.004	<0.004	< 0.004	< 0.003	<0.004	<0.004	< 0.004	< 0.003	<0.0010	<0.004	< 0.004	< 0.003
Dissolved iron	g/m ³	0.32	0.31	0.32	0.21	<0.02	<0.02	0.07	< 0.02	<0.02	<0.02	< 0.02	< 0.02
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
Ethylene glycol	g/m ³	<4	<4	< 20	< 4	<4	<4	< 4	< 4	<4	<4	< 4	< 4
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

Parameter	Unit	GND2254				GND2255				GND2256			
		Baseline	Pre-frac	3 mth post-frac	1 year post-frac	Baseline	Pre-frac	3 mth post-frac	1 year post-frac	Baseline	Pre-frac	3 mth post-frac	1 year post-frac
Sample date		17/04/12	29/07/15	21/07/16	22/02/17	17/04/12	29/07/15	21/07/16	22/02/17	17/04/12	31/07/15	21/07/16	22/02/17
Lab number	TRC	121416	152420	162531	171199	121417	152419	162532	1711200	121418	152422	162533	171201
Bicarbonate	g/m ³ HCO ₃	161.04	151	149	144	24.4	24	25	25	24.4	24	26	25
Total hardness	g/m ³ CaCO ₃	104	103	105	95	31	28	30	28	39	49	45	38
Dissolved mercury	g/m ³	NR**	<0.00008	<0.00008	<0.00008	NR**	<0.00008	< 0.00008	<0.00008	NR**	<0.00008	< 0.00008	<0.00008
Potassium	g/m ³	2.3	2.2	2.5	2.2	3.5	3.2	3.6	3.3	4.9	5.6	5.6	4.7
Methanol	g/m ³	<2	<2	< 20	< 2	<2	<2	< 2	< 2	<2	<2	< 2	< 2
Methane	g/m ³	1.54	3.1	2.5	1.6	<0.002	<0.002	< 0.002	< 0.002	<0.002	<0.002	0.002	< 0.002
Magnesium	g/m ³	10.5	10.4	10.2	9.4	3.7	3.1	3.2	3.1	4.2	5.4	4.7	4.1
Dissolved manganese	g/m ³	0.024	0.029	0.03	0.029	0.0029	0.002	0.0034	0.002	0.0023	0.0019	0.0029	0.0049
Sodium	g/m ³	21	16.5	16.2	15.5	12.6	11.8	12.5	12.2	12.7	13.6	12.8	11.4
Nickel	mg/kg	<0.0005	<0.0005	0.0013	0.0073	<0.0005	<0.0005	< 0.0005	0.0011	<0.0005	<0.0005	< 0.0005	< 0.0005
Nitrate & nitrite nitrogen	g/m ³ N	0.005	<0.002	< 0.002	0.003	1.22	1.69	1.47	1.52	4.8	6.2	6.1	5.4
Nitrite nitrogen	g/m ³ N	0.003	<0.002	< 0.002	< 0.002	0.003	<0.002	< 0.002	< 0.002	<0.002	<0.002	< 0.002	< 0.002
Nitrate nitrogen	g/m ³ N	<0.002	<0.002	< 0.002	0.003	1.22	1.69	1.47	1.52	4.8	6.2	6.1	5.4
pH	pH	8.1	8	7.9	7.8	6.4	6.1	6.1	6.6	6.4	6.3	6.1	6.4
Sulphate	g/m ³	<0.5	<0.5	< 0.5	< 0.5	3.1	3.9	3.4	3.5	4.1	3.9	3.9	4.3

Parameter	Unit	GND2254				GND2255				GND2256			
		Baseline	Pre-frac	3 mth post-frac	1 year post-frac	Baseline	Pre-frac	3 mth post-frac	1 year post-frac	Baseline	Pre-frac	3 mth post-frac	1 year post-frac
Sample date		17/04/12	29/07/15	21/07/16	22/02/17	17/04/12	29/07/15	21/07/16	22/02/17	17/04/12	31/07/15	21/07/16	22/02/17
Lab number	TRC	121416	152420	162531	171199	121417	152419	162532	1711200	121418	152422	162533	171201
Total dissolved solids	g/m ³	181	178	171	183	90	105	90	101	117	120	127	121
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
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
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
Dissolved zinc	g/m ³	0.0012	<0.0010	0.021	0.024	0.0112	0.0084	0.026	0.23	0.0151	0.0044	0.021	0.046
Propylene glycol	g/m ³	NR	<4	< 20	< 4	NR	<4	< 4	< 4	NR	<4	< 4	< 4
δ13C value*	‰ (-)	N/A	75.8	75.1	BDL	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Note: N/A = not applicable; * =Since 2013 δ13C has been analysed when methane levels are >1 g/m³; BDL = below detection limit; NR* =results analysed and reported as either bromine or bromide; NR = Parameter was not analysed.

Parameter	Unit	GND2257				GND2360			
		Baseline	Pre-frac	3 mth post-frac	1 year post-frac	Baseline	Pre-frac	3 mth post-frac	1 year post-frac
Sample date		17/04/2012	31/07/2015	21/07/2016	22/02/2017	21/10/2013	29/07/2015	21/07/2016	22/02/2017
Lab number	TRC	121419	152421	162534	171202	137897	152418	162535	171203
Total alkalinity	g/m ³ CaCO ₃	24	24	28	29	185	172	160	175
Barium	mg/kg	0.0143	0.0148	0.0168	0.0156	0.025	0.0043	0.0075	0.0026
Benzene	g/m ³	<0.0010	<0.0010	< 0.0010	< 0.0010	<0.0010	<0.0010	< 0.0010	< 0.0010
Dissolved bromine	g/m ³	0.1	NR*	0.07	0.063	NR*	NR*	0.09	0.085
Bromide	g/m ³	NR*	0.08	NR*	NR*	1.13	0.33	NR*	NR*
Calcium	g/m ³	8.1	7.6	8	7.7	10.2	2.6	2.3	1.37
Chloride	g/m ³	22	21	21	19.9	350	81	28	30
Conductivity	mS/m	16.1	16.1	16.4	16.7	145.9	60.1	39.8	43.1
Dissolved copper	g/m ³	0.0125	0.0103	0.023	0.022	<0.0005	<0.0005	< 0.0005	< 0.0005
Ethylbenzene	g/m ³	<0.0010	<0.0010	< 0.0010	< 0.0010	<0.0010	<0.0010	< 0.0010	< 0.0010
Ethane	g/m ³	<0.003	<0.003	< 0.003	< 0.003	<0.017	<0.003	0.006	< 0.003
Ethylene	g/m ³	<0.004	<0.004	< 0.004	< 0.003	<0.003	<0.004	< 0.004	< 0.003
Dissolved iron	g/m ³	1.82	1.06	0.15	0.06	0.14	0.12	0.04	0.04
Formaldehyde	g/m ³	<0.02	<0.02	< 0.02	< 0.02	<0.02	<0.02	< 0.02	< 0.02
Ethylene glycol	g/m ³	<4	<4	< 4	< 4	<4	<4	< 20	< 4
Hydrocarbons	g/m ³	<0.7	<0.7	< 0.7	< 0.7	<0.7	<0.7	< 0.7	< 0.7
Bicarbonate	g/m ³ HCO ₃	29.3	29	35	35	225.7	180	159	190
Total hardness	g/m ³	39	37	38	37	41	10.2	8.2	5.1

Parameter	Unit	GND2257				GND2360			
		Baseline	Pre-frac	3 mth post-frac	1 year post-frac	Baseline	Pre-frac	3 mth post-frac	1 year post-frac
Sample date		17/04/2012	31/07/2015	21/07/2016	22/02/2017	21/10/2013	29/07/2015	21/07/2016	22/02/2017
Lab number	TRC	121419	152421	162534	171202	137897	152418	162535	171203
	CaCO ₃								
Dissolved mercury	g/m ³	NR	<0.00008	< 0.00008	< 0.00008	<0.00008	<0.00008	< 0.00008	< 0.00008
Potassium	g/m ³	2.2	2	2.1	1.78	1.36	0.87	0.89	0.73
Methanol	g/m ³	<2	<2	< 2	< 2	<2	<2	< 20	< 2
Methane	g/m ³	<0.002	<0.002	< 0.002	< 0.002	<11.6	1.68	1.83	0.44
Magnesium	g/m ³	4.6	4.4	4.4	4.4	3.9	0.92	0.61	0.4
Dissolved manganese	g/m ³	0.0199	0.0143	0.0134	0.0047	0.0081	0.0051	0.0033	0.002
Sodium	g/m ³	15.5	15.9	16.3	15	250	131	95	96
Nickel	mg/kg	<0.0005	<0.0005	0.0029	< 0.0005	<0.0005	<0.0005	< 0.0005	< 0.0005
Nitrate & nitrite nitrogen	g/m ³ N	4.5	3.2	3.3	4	<0.002	<0.002	< 0.002	< 0.002
Nitrite nitrogen	g/m ³ N	0.005	<0.002	< 0.002	< 0.002	<0.002	<0.002	< 0.002	< 0.002
Nitrate nitrogen	g/m ³ N	4.5	3.2	3.3	4	<0.002	<0.002	< 0.002	< 0.002
pH	pH	6.3	6.7	6.1	6.5	9	9.2	9.4	9.1
Sulphate	g/m ³	4.4	4.6	4	4.5	1.9	2.4	2.8	2.2
Total dissolved solids	g/m ³	118	107	115	118	770	350	220	250
Toluene	g/m ³	<0.0010	<0.0010	< 0.0010	< 0.0010	0.001	<0.0010	< 0.0010	< 0.0010
o-Xylene	g/m ³	<0.001	<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

Parameter	Unit	GND2257				GND2360			
		Baseline	Pre-frac	3 mth post-frac	1 year post-frac	Baseline	Pre-frac	3 mth post-frac	1 year post-frac
Sample date		17/04/2012	31/07/2015	21/07/2016	22/02/2017	21/10/2013	29/07/2015	21/07/2016	22/02/2017
Lab number	TRC	121419	152421	162534	171202	137897	152418	162535	171203
Dissolved zinc	g/m ³	0.047	0.049	0.134	0.08	0.0055	0.0112	0.09	0.0107
Propylene glycol	g/m ³	NR	<4	< 4	< 4	<4	<4	< 20	< 4
δ13C value*	‰ (-)	N/A	N/A	N/A	N/A	N/A	63	63.6	N/A

Note: N/A = not applicable; * =Since 2013 δ13C has been analysed when methane levels are >1 g/m³; BDL = below detection limit; NR* =results analysed and reported as either bromine or bromide; NR = Parameter was not analysed.

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-12ST2 and Mangahewa-14ST1 wells are shown below in Table 6. The certificates of analysis are included in Appendix III.

Table 6 Results of hydraulic fracturing fluid sampling

Parameter	Unit	Mangahewa-14ST1		Mangahewa-12ST2
		GND2374		GND2368
Sample date	-	20/01/2016	17/02/2016	05/03/2016
Lab number	-	TRC160449	TRC161601	TRC161695
Benzene	g/m ³	0.0062	0.0017	<0.0010
Ethylbenzene	g/m ³	<0.0010	<0.0010	<0.0010
Ethylene glycol	g/m ³	<4	<4	<4
Total hydrocarbons	g/m ³	67	52	<70
Methanol	g/m ³	<2	<2	<2
Propylene glycol	g/m ³	73	<4	<4
Toluene	g/m ³	<0.0010	0.0033	0.0051
o-Xylene	g/m ³	<0.0010	<0.0010	<0.0010
m-Xylene	g/m ³	<0.002	<0.002	0.002

The results of the analyses carried out on the return fluid samples obtained following the hydraulic fracturing of the Mangahewa-12ST2 and Mangahewa-14ST1 wells are summarised below in Table 7 and certificates of analysis are included in Appendix III. Return fluid samples generally contain a composite of samples collected at different intervals during the flow back period. 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 fluids introduced during fracturing activities (comprised predominantly of freshwater).

Table 7 Results of hydraulic fracturing return fluid sampling

Parameter	Unit	Mangahewa-14ST1	Mangahewa-12ST2	
		GND2374	GND2368	
Sample date		26/02/2016	16/03/2016	12/04/2016
Lab number		TRC161679	TRC161694	TRC161680
Total alkalinity	g/m ³ CaCO ₃	1,360	960	1,590
Barium	mg/kg	146	230	68
Benzene	g/m ³	13.0	3.0	15.8
Bromide	g/m ³	10.1	18.6	16.6
Calcium	g/m ³	155	210	130
Chloride	g/m ³	10,800	14,300	10,900
Conductivity	mS/m	4,340	<0.10	3,670
Dissolved copper	g/m ³	0.021	0.0081	0.151
Ethylbenzene	g/m ³	2.4	0.75	7.4
Dissolved iron	g/m ³	17.8	1.75	13.0
Formaldehyde	g/m ³	3.3	0.19	0.25
Ethylene glycol	g/m ³	<40	<4	<4
Hydrocarbons	g/m ³	2,100	400	1,310
Bicarbonate	g/m ³ HCO ₃	1,659	1,274	1,600
Total hardness	g/m ³ CaCO ₃	450	640	400
Dissolved mercury	g/m ³	<0.011	<0.011	<0.011
Potassium	g/m ³	7,700	4,700	4,600
Methanol	g/m ³	<20	<2	<20
Magnesium	g/m ³	15	29	19
Dissolved manganese	g/m ³	2.7	3.6	2.3
Sodium	g/m ³	4,700	6,900	5,400
Nickel	mg/kg	0.16	<0.03	0.12
Nitrate & nitrite nitrogen	g/m ³ N	<0.2	<0.2	<0.2
Nitrite nitrogen	g/m ³ N	<0.2	<0.2	<0.2
Nitrate nitrogen	g/m ³ N	<0.2	<0.2	<0.2
pH	pH	7.5	7.7	7.6
Propylene glycol	g/m ³	<40	<4	<4
Dissolved sulphur	g/m ³	38	11	48

Parameter	Unit	Mangahewa-14ST1	Mangahewa-12ST2	
		GND2374	GND2368	
Sample date		26/02/2016	16/03/2016	12/04/2016
Lab number		TRC161679	TRC161694	TRC161680
Sulphate	g/m ³	115	33	143
Total dissolved solids	g/m ³	28,000	29,000	24,000
Toluene	g/m ³	27.0	6.7	44.0
o-Xylene	g/m ³	5.5	2.2	14.7
m-Xylene	g/m ³	16.6	5.6	44.0
Dissolved zinc	g/m ³	5.40	0.16	0.23

2.3. Biomonitoring surveys

Macroinvertebrate surveys were carried out on 26 May 2015 (pre-fracturing) and 18 April 2016 (post fracturing), to determine if stormwater discharges from the wellsite had significant adverse effects on the stream macroinvertebrate communities. The surveys each included sampling and three separate sites (Figure 3).

The macroinvertebrate surveys were undertaken using the Council's 'kick sampling' and 'vegetation sweep' techniques at three sites in two unnamed tributaries of the Waiau Stream. These surveys recorded high MCI and SQMCI_s scores for lowland coastal streams at similar altitude.

Taxa richness varied widely between the two surveys, with substantial increases at sites 1 and 3, and a decrease at site 2. There was also a significant decrease in MCI and SQMCI_s scores at site 2, but no concurrent reductions at sites 1 and 3. These changes were found to be due to the extremely low flow conditions at the time of the post wellsite activity survey. There was no evidence that the stormwater discharges from the Mangahewa-C wellsite caused any significant adverse effects on the macroinvertebrate communities of these two unnamed tributaries of the Waiau Stream.

The full report on the biomonitoring carried out in the vicinity of the wellsite and undertaken in 2015 and 2016 is included in Appendix IV.

2.4. Investigations, interventions, and incidents

The monitoring programme for the reporting period was based on what was considered to be an appropriate level of monitoring, review of data, and liaison with the consent holder. 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 company 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 reporting period, the Council was not required to undertake significant additional investigations and interventions, or record incidents, in association with Todd's conditions in the resource consents or provisions in regional plans.

3. Discussion

3.1. Environmental effects of hydraulic fracturing on useable freshwater resources

A total of two wells were stimulated by hydraulic fracturing at the Mangahewa-C wellsite between January and April 2016.

Monitoring carried out by the Council in relation to the fracturing events 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 local 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 most analytes are a result of natural variations in water composition.

The surface water monitoring component of the programme comprised of two biomonitoring surveys of two unnamed tributaries of the Waiau Stream pre and post-fracturing of the wells.

The results of the biomonitoring surveys undertaken in relation to the Mangahewa-C fracturing event indicate that site activities had no adverse effects on local surface water resources.

In summary, the monitoring carried out by the Council during the period being reported indicates 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 period under review is set out in Tables 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 mTVDss	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
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	Reports received via email	Yes

Purpose: <i>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</i>		
Condition requirement	Means of monitoring during period under review	Compliance achieved?
emailed to consents@trc.govt.nz		
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. Notice of Council to review consent	No provision for review during period	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

During the reporting period, the Company demonstrated a high level of environmental and high level of administrative performance with the resource consents as defined in Section 1.1.4.

3.3. Recommendations from the 2014-2016 Biennial Report

In the 2014-2016 Monitoring Report, it was recommended:

1. THAT for the forthcoming 2015/2016 monitoring period, one one-year-post-fracturing groundwater sampling round is carried out. After that, it is recommended that no further monitoring be carried out in relation to the hydraulic fracturing events at the Mangahewa-C wellsite. Monitoring should recommence however if any further fracturing is undertaken at the site.
2. THAT the option for a review of the resource consent in June 2015, as set out in condition 17 of consent 7971-2, is not exercised, on the grounds that the current conditions of the consents are adequate to ensure that any significant adverse effects on the environment are avoided.

These recommendations were implemented.

3.4. Alterations to monitoring 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 made available by previous authorities,
- its relevance under the RMA;
- its obligations to monitor emissions/discharges and effects under the RMA; and

- report 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 emitting to the atmosphere/discharging to the environment.

It is proposed that the range of monitoring carried out in relation to the Company's hydraulic fracturing activities be replicated for any future fracturing events at the Mangahewa-C wellsite.

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

3.5. Exercise of optional review of consent

The next optional review dates for consents 7971-2 is provided for in June 2017.

The Council may serve notice of its intention to review, amend, delete or add to the conditions of this resource consent. A review may be required for the purpose of ensuring that the conditions are adequate to deal with any adverse effects on the environment arising from the exercise of this resource 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.

Based on the results of monitoring carried out in the period under review, and in previous years as set out in earlier compliance monitoring reports, it is considered that there are no grounds to require a consent review to be pursued or grounds to exercise the review options. A recommendation to this effect is presented in Section 4 of this report.

4. Recommendations

1. THAT the range of monitoring carried out during the reporting period in relation to the Company's hydraulic fracturing activities be replicated for any future fracturing events at the Mangahewa-C wellsite.
2. THAT the Council notes there is no requirement at this time for a consent review to be pursued or grounds to exercise the review options.

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).
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.
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
Workover	The repair or stimulation of an existing production well for the purpose of restoring, prolonging or enhancing the production of hydrocarbons.

Bibliography and references

- Stark JD, (1998). SQMCI: a biotic index for freshwater macroinvertebrate coded abundance data. *New Zealand Journal of Marine and Freshwater Research* 32(1): 55-66.
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- Taranaki Regional Council (2016) Sampling and Analysis Plan Mangahewa-C Groundwater Monitoring Programme.
- Todd Energy Limited (2016) Hydraulic Fracturing Todd Mangahewa-14ST1 Post-Fracturing Discharge Report.
- Todd Energy Limited (2016) Hydraulic Fracturing Todd Mangahewa-12ST2 Post-Fracturing Discharge Report.
- Todd Energy Limited (2015) Hydraulic Fracturing Todd Mangahewa-C Wellsite Pre-Fracturing Discharge Report – Mangahewa-14ST1.
- Todd Energy Limited (2015) Hydraulic Fracturing Todd Mangahewa-C Wellsite Pre-Fracturing Discharge Report – Mangahewa-12ST2.
- Taranaki Regional Council (2015) Mangahewa-C Hydraulic Fracturing Groundwater Monitoring Programme Report 2014-2016. Technical Report 2015-46.
- Taranaki Regional Council (2015) Mangahewa-C Hydraulic Fracturing Groundwater Monitoring Programme Report 2013-2015. Technical Report 2015-05.
- Taranaki Regional Council (2013) Mangahewa-C Hydraulic Fracturing Groundwater Monitoring Programme Report 2011-2013. Technical Report 2013-15.

Appendix I
Resource consents held by
Todd Company Limited
(For a copy of the signed resource consent
please contact the TRC consent department)

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 ($^{13}\text{C-CH}_4$).

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.*

Consent 7971-2.0

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.

Consent 7971-2.0

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.

Consent 7971-2.0

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)

ANALYSIS REPORT

Page 1 of 3

Client:	Taranaki Regional Council	Lab No:	1457586	SPV1
Contact:	Regan Phipps C/- Taranaki Regional Council Private Bag 713 STRATFORD 4352	Date Registered:	01-Aug-2015	
		Date Reported:	10-Aug-2015	
		Quote No:	47915	
		Order No:		
		Client Reference:	Mangahewa C - 1yr Post HF	
		Submitted By:	R McDonnell	

Sample Type: Aqueous

Sample Name:		GND2257	GND2256			
Lab Number:		31-Jul-2015 9:36 am	31-Jul-2015 11:23 am			
Individual Tests						
Sum of Anions	meq/L	1.38	1.58	-	-	-
Sum of Cations	meq/L	1.52	1.72	-	-	-
pH	pH Units	6.7	6.3	-	-	-
Total Alkalinity	g/m ³ as CaCO ₃	24	20	-	-	-
Bicarbonate	g/m ³ at 25°C	29	24	-	-	-
Total Hardness	g/m ³ as CaCO ₃	37	49	-	-	-
Electrical Conductivity (EC)	mS/m	16.1	18.2	-	-	-
Total Dissolved Solids (TDS)	g/m ³	107	120	-	-	-
Dissolved Barium	g/m ³	0.0148	0.066	-	-	-
Dissolved Bromine*	g/m ³	0.080	0.091	-	-	-
Dissolved Calcium	g/m ³	7.6	10.8	-	-	-
Dissolved Copper	g/m ³	0.0103	< 0.0005	-	-	-
Dissolved Iron	g/m ³	1.06	< 0.02	-	-	-
Dissolved Magnesium	g/m ³	4.4	5.4	-	-	-
Dissolved Manganese	g/m ³	0.0143	0.0019	-	-	-
Dissolved Mercury	g/m ³	< 0.00008	< 0.00008	-	-	-
Dissolved Nickel	g/m ³	< 0.0005	< 0.0005	-	-	-
Dissolved Potassium	g/m ³	2.0	5.6	-	-	-
Dissolved Sodium	g/m ³	15.9	13.6	-	-	-
Dissolved Zinc	g/m ³	0.049	0.0044	-	-	-
Chloride	g/m ³	21	23	-	-	-
Nitrite-N	g/m ³	< 0.002	< 0.002	-	-	-
Nitrate-N	g/m ³	3.2	6.2	-	-	-
Nitrate-N + Nitrite-N	g/m ³	3.2	6.2	-	-	-
Sulphate	g/m ³	4.6	3.9	-	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m ³	< 4	< 4	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m ³	< 4	< 4	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m ³	< 2	< 2	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m ³	< 0.0010	< 0.0010	-	-	-
Toluene	g/m ³	< 0.0010	< 0.0010	-	-	-
Ethylbenzene	g/m ³	< 0.0010	< 0.0010	-	-	-
m&p-Xylene	g/m ³	< 0.002	< 0.002	-	-	-

Sample Type: Aqueous						
Sample Name:	GND2257 31-Jul-2015 9:36 am	GND2256 31-Jul-2015 11:23 am				
Lab Number:	1457586.1	1457586.2				
BTEX in Water by Headspace GC-MS						
o-Xylene	g/m ³	< 0.0010	< 0.0010	-	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m ³	< 0.02	< 0.02	-	-	-
Gases in groundwater						
Ethane	g/m ³	< 0.003	< 0.003	-	-	-
Ethylene	g/m ³	< 0.004	< 0.004	-	-	-
Methane	g/m ³	< 0.002	< 0.002	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m ³	< 0.10	< 0.10	-	-	-
C10 - C14	g/m ³	< 0.2	< 0.2	-	-	-
C15 - C36	g/m ³	< 0.4	< 0.4	-	-	-
Total hydrocarbons (C7 - C36)	g/m ³	< 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/m ³	1-2
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m ³	1-2
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m ³	1-2
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m ³	1-2
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS	0.02 g/m ³	1-2
Gases in groundwater	Manual headspace creation and sub-sampling, GC-FID analysis.	0.002 - 0.003 g/m ³	1-2
Total Petroleum Hydrocarbons in Water	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734]	0.10 - 0.7 g/m ³	1-2
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1-2
Total anions for anion/cation balance check	Calculation: sum of anions as mEq/L calculated from Alkalinity (bicarbonate), Chloride and Sulphate. Nitrate-N, Nitrite-N. Fluoride, Dissolved Reactive Phosphorus and Cyanide also included in calculation if available. APHA 1030 E 22 nd ed. 2012.	0.07 meq/L	1-2
Total cations for anion/cation balance check	Sum of cations as mEq/L calculated from Sodium, Potassium, Calcium and Magnesium. Iron, Manganese, Aluminium, Zinc, Copper, Lithium, Total Ammoniacal-N and pH (H ⁺) also included in calculation if available. APHA 1030 E 22 nd ed. 2012.	0.05 meq/L	1-2
pH	pH meter. APHA 4500-H ⁺ B 22 nd 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	1-2
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (Modified for alk <20) 22 nd ed. 2012.	1.0 g/m ³ as CaCO ₃	1-2
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 22 nd ed. 2012.	1.0 g/m ³ at 25°C	1-2
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 22 nd ed. 2012.	1.0 g/m ³ as CaCO ₃	1-2
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 22 nd ed. 2012.	0.1 mS/m	1-2
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) 22 nd ed. 2012.	10 g/m ³	1-2
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.00010 g/m ³	1-2
Dissolved Bromine*	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.005 g/m ³	1-2

Sample Type: Aqueous			
Test	Method Description	Default Detection Limit	Sample No
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.05 g/m ³	1-2
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.0005 g/m ³	1-2
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.02 g/m ³	1-2
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.02 g/m ³	1-2
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.0005 g/m ³	1-2
Dissolved Mercury	0.45µm filtration, bromine oxidation followed by atomic fluorescence. US EPA Method 245.7, Feb 2005.	0.00008 g/m ³	1-2
Dissolved Nickel	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.0005 g/m ³	1-2
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.05 g/m ³	1-2
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.02 g/m ³	1-2
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.0010 g/m ³	1-2
Chloride	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl E (modified from continuous flow analysis) 22 nd ed. 2012.	0.5 g/m ³	1-2
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO ₂ ⁻ I 22 nd ed. 2012 (modified).	0.002 g/m ³	1-2
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO ₂ N. In-House.	0.0010 g/m ³	1-2
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO ₃ ⁻ I 22 nd ed. 2012 (modified).	0.002 g/m ³	1-2
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B 22 nd ed. 2012.	0.5 g/m ³	1-2

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.

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



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

ANALYSIS REPORT

Page 1 of 3

Client:	Taranaki Regional Council	Lab No:	1619541	SPV1
Contact:	David Olson C/- Taranaki Regional Council Private Bag 713 Stratford 4352	Date Received:	22-Jul-2016	
		Date Reported:	08-Aug-2016	
		Quote No:	47915	
		Order No:		
		Client Reference:	MHW c 3 Month Post Frac	
		Submitted By:	David Olson	

Sample Type: Aqueous

Sample Name:	GND 2254 21-Jul-2016 2:50 pm	GND 2255 21-Jul-2016 10:45 am	GND 2256 21-Jul-2016 12:05 pm	GND 2257 21-Jul-2016 1:50 pm	GND 2360 21-Jul-2016 9:20 am	
Lab Number:	1619541.1	1619541.2	1619541.3	1619541.4	1619541.5	
Individual Tests						
Sum of Anions	meq/L	2.9	1.22	1.59	1.49	4.1
Sum of Cations	meq/L	2.9	1.23	1.60	1.54	4.3
pH	pH Units	7.9	6.1	6.1	6.1	9.4
Total Alkalinity	g/m ³ as CaCO ₃	123	20	21	28	160
Bicarbonate	g/m ³ at 25°C	149	25	26	35	159
Total Hardness	g/m ³ as CaCO ₃	105	30	45	38	8.2
Electrical Conductivity (EC)	mS/m	27.4	13.7	18.0	16.4	39.8
Total Dissolved Solids (TDS)	g/m ³	171	90	127	115	220
Dissolved Barium	g/m ³	0.0150	0.045	0.069	0.0168	0.0075
Dissolved Bromine*	g/m ³	0.046	0.075	0.085	0.070	0.090
Dissolved Calcium	g/m ³	25	6.5	10.3	8.0	2.3
Dissolved Copper	g/m ³	< 0.0005	0.028	< 0.0005	0.023	< 0.0005
Dissolved Iron	g/m ³	0.32	0.07	< 0.02	0.15	0.04
Dissolved Magnesium	g/m ³	10.2	3.2	4.7	4.4	0.61
Dissolved Manganese	g/m ³	0.030	0.0034	0.0029	0.0134	0.0033
Dissolved Mercury	g/m ³	< 0.00008	< 0.00008	< 0.00008	< 0.00008	< 0.00008
Dissolved Nickel	g/m ³	0.0013	< 0.0005	< 0.0005	0.0029	< 0.0005
Dissolved Potassium	g/m ³	2.5	3.6	5.6	2.1	0.89
Dissolved Sodium	g/m ³	16.2	12.5	12.8	16.3	95
Dissolved Zinc	g/m ³	0.021	0.026	0.021	0.134	0.090
Chloride	g/m ³	13.8	23	23	21	28
Nitrite-N	g/m ³	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Nitrate-N	g/m ³	< 0.002	1.47	6.1	3.3	< 0.002
Nitrate-N + Nitrite-N	g/m ³	< 0.002	1.47	6.1	3.3	< 0.002
Sulphate	g/m ³	< 0.5	3.4	3.9	4.0	2.8
Ethylene Glycol in Water						
Ethylene glycol*	g/m ³	< 20	< 4	< 4	< 4	< 20
Propylene Glycol in Water						
Propylene glycol*	g/m ³	< 20	< 4	< 4	< 4	< 20
Methanol in Water - Aqueous Solvents						
Methanol*	g/m ³	< 20	< 2	< 2	< 2	< 20
BTEX in Water by Headspace GC-MS						
Benzene	g/m ³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Toluene	g/m ³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Ethylbenzene	g/m ³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
m&p-Xylene	g/m ³	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002

Sample Type: Aqueous						
Sample Name:	GND 2254 21-Jul-2016 2:50 pm	GND 2255 21-Jul-2016 10:45 am	GND 2256 21-Jul-2016 12:05 pm	GND 2257 21-Jul-2016 1:50 pm	GND 2360 21-Jul-2016 9:20 am	
Lab Number:	1619541.1	1619541.2	1619541.3	1619541.4	1619541.5	
BTEX in Water by Headspace GC-MS						
o-Xylene	g/m ³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m ³	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Gases in groundwater						
Ethane	g/m ³	< 0.003	< 0.003	< 0.003	< 0.003	0.006
Ethylene	g/m ³	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
Methane	g/m ³	2.5	< 0.002	0.002	< 0.002	1.83
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m ³	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
C10 - C14	g/m ³	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
C15 - C36	g/m ³	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4
Total hydrocarbons (C7 - C36)	g/m ³	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7

Analyst's Comments

It was noted that Security Seals were applied and intact on receipt at the laboratory.

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	1-5
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m ³	1-5
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m ³	1-5
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m ³	1-5
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS	0.02 g/m ³	1-5
Gases in groundwater	Manual headspace creation and sub-sampling, GC-FID analysis.	0.002 - 0.003 g/m ³	1-5
Total Petroleum Hydrocarbons in Water	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734]	0.10 - 0.7 g/m ³	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 mEq/L calculated from Alkalinity (bicarbonate), Chloride and Sulphate. Nitrate-N, Nitrite-N. Fluoride, Dissolved Reactive Phosphorus and Cyanide also included in calculation if available. APHA 1030 E 22 nd ed. 2012.	0.07 meq/L	1-5
Total cations for anion/cation balance check	Sum of cations as mEq/L calculated from Sodium, Potassium, Calcium and Magnesium. Iron, Manganese, Aluminium, Zinc, Copper, Lithium, Total Ammoniacal-N and pH (H ⁺) also included in calculation if available. APHA 1030 E 22 nd ed. 2012.	0.05 meq/L	1-5
pH	pH meter. APHA 4500-H ⁺ B 22 nd 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) 22 nd ed. 2012.	1.0 g/m ³ 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 22 nd ed. 2012.	1.0 g/m ³ at 25°C	1-5
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 22 nd ed. 2012.	1.0 g/m ³ as CaCO ₃	1-5
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 22 nd 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) 22 nd ed. 2012.	10 g/m ³	1-5
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.00010 g/m ³	1-5

Sample Type: Aqueous			
Test	Method Description	Default Detection Limit	Sample No
Dissolved Bromine*	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.005 g/m ³	1-5
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.05 g/m ³	1-5
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.0005 g/m ³	1-5
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.02 g/m ³	1-5
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.02 g/m ³	1-5
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.0005 g/m ³	1-5
Dissolved Mercury	0.45µm filtration, bromine oxidation followed by atomic fluorescence. US EPA Method 245.7, Feb 2005.	0.00008 g/m ³	1-5
Dissolved Nickel	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.0005 g/m ³	1-5
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.05 g/m ³	1-5
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.02 g/m ³	1-5
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.0010 g/m ³	1-5
Chloride	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl ⁻ E (modified from continuous flow analysis) 22 nd ed. 2012.	0.5 g/m ³	1-5
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO ₂ ⁻ I 22 nd ed. 2012 (modified).	0.002 g/m ³	1-5
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO ₂ N. In-House.	0.0010 g/m ³	1-5
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO ₃ ⁻ I 22 nd ed. 2012 (modified).	0.002 g/m ³	1-5
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B 22 nd ed. 2012.	0.5 g/m ³	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.

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Peter Robinson MSc (Hons), PhD, FNZIC
Client Services Manager - Environmental



ANALYSIS REPORT

Client:	Taranaki Regional Council	Lab No:	1728624	SPV1
Contact:	Regan Phipps C/- Taranaki Regional Council Private Bag 713 Stratford 4352	Date Received:	23-Feb-2017	
		Date Reported:	16-Mar-2017	
		Quote No:	47915	
		Order No:		
		Client Reference:	MHWC 3 Month Post Frac GW	
		Submitted By:	David Olson	

Sample Type: Aqueous

Sample Name:	GND2254 22-Feb-2017 11:46 am	GND2255 22-Feb-2017 3:31 pm	GND2256 22-Feb-2017 2:35 pm	GND2257 22-Feb-2017 1:14 pm	GND2360 22-Feb-2017 10:22 am
Lab Number:	1728624.1	1728624.2	1728624.3	1728624.4	1728624.5

Individual Tests						
Sum of Anions	meq/L	2.8	1.20	1.43	1.51	4.4
Sum of Cations	meq/L	2.6	1.19	1.39	1.45	4.3
pH	pH Units	7.8	6.6	6.4	6.5	9.1
Total Alkalinity	g/m ³ as CaCO ₃	119	21	20	29	175
Bicarbonate	g/m ³ at 25°C	144	25	25	35	190
Total Hardness	g/m ³ as CaCO ₃	95	28	38	37	5.1
Electrical Conductivity (EC)	mS/m	27.1	14.0	16.5	16.7	43.1
Total Dissolved Solids (TDS)	g/m ³	183	101	121	118	250
Dissolved Barium	g/m ³	0.0138	0.042	0.057	0.0156	0.0026
Dissolved Bromine*	g/m ³	0.041	0.071	0.072	0.063	0.085
Dissolved Calcium	g/m ³	23	6.2	8.6	7.7	1.37
Dissolved Copper	g/m ³	< 0.0005	0.129	0.0006	0.022	< 0.0005
Dissolved Iron	g/m ³	0.21	< 0.02	< 0.02	0.06	0.04
Dissolved Magnesium	g/m ³	9.4	3.1	4.1	4.4	0.40
Dissolved Manganese	g/m ³	0.029	0.0020	0.0049	0.0047	0.0020
Dissolved Mercury	g/m ³	< 0.00008	< 0.00008	< 0.00008	< 0.00008	< 0.00008
Dissolved Nickel	g/m ³	0.0073	0.0011	< 0.0005	< 0.0005	< 0.0005
Dissolved Potassium	g/m ³	2.2	3.3	4.7	1.78	0.73
Dissolved Sodium	g/m ³	15.5	12.2	11.4	15.0	96
Dissolved Zinc	g/m ³	0.024	0.23	0.046	0.080	0.0107
Chloride	g/m ³	12.8	21	19.6	19.9	30
Nitrite-N	g/m ³	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Nitrate-N	g/m ³	0.003	1.52	5.4	4.0	< 0.002
Nitrate-N + Nitrite-N	g/m ³	0.003	1.52	5.4	4.0	< 0.002
Sulphate	g/m ³	< 0.5	3.5	4.3	4.5	2.2
Ethylene Glycol in Water						
Ethylene glycol*	g/m ³	< 4	< 4	< 4	< 4	< 4
Propylene Glycol in Water						
Propylene glycol*	g/m ³	< 4	< 4	< 4	< 4	< 4
Methanol in Water - Aqueous Solvents						
Methanol*	g/m ³	< 2	< 2	< 2	< 2	< 2
BTEX in Water by Headspace GC-MS						
Benzene	g/m ³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Toluene	g/m ³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Ethylbenzene	g/m ³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
m&p-Xylene	g/m ³	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
o-Xylene	g/m ³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010



Sample Type: Aqueous						
Sample Name:	GND2254 22-Feb-2017 11:46 am	GND2255 22-Feb-2017 3:31 pm	GND2256 22-Feb-2017 2:35 pm	GND2257 22-Feb-2017 1:14 pm	GND2360 22-Feb-2017 10:22 am	
Lab Number:	1728624.1	1728624.2	1728624.3	1728624.4	1728624.5	
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m ³	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Gases in groundwater						
Ethane	g/m ³	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
Ethylene	g/m ³	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
Methane	g/m ³	1.60	< 0.002	< 0.002	< 0.002	0.44
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m ³	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
C10 - C14	g/m ³	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
C15 - C36	g/m ³	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4
Total hydrocarbons (C7 - C36)	g/m ³	< 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/m ³	1-5
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m ³	1-5
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m ³	1-5
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m ³	1-5
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS	0.02 g/m ³	1-5
Gases in groundwater	Manual headspace creation and sub-sampling, GC-FID analysis.	0.002 - 0.003 g/m ³	1-5
Total Petroleum Hydrocarbons in Water	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734]	0.10 - 0.7 g/m ³	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 mEq/L calculated from Alkalinity (bicarbonate), Chloride and Sulphate. Nitrate-N, Nitrite-N. Fluoride, Dissolved Reactive Phosphorus and Cyanide also included in calculation if available. APHA 1030 E 22 nd ed. 2012.	0.07 meq/L	1-5
Total cations for anion/cation balance check	Sum of cations as mEq/L calculated from Sodium, Potassium, Calcium and Magnesium. Iron, Manganese, Aluminium, Zinc, Copper, Lithium, Total Ammoniacal-N and pH (H ⁺) also included in calculation if available. APHA 1030 E 22 nd ed. 2012.	0.05 meq/L	1-5
pH	pH meter. APHA 4500-H ⁺ B 22 nd 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) 22 nd ed. 2012.	1.0 g/m ³ 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 22 nd ed. 2012.	1.0 g/m ³ at 25°C	1-5
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 22 nd ed. 2012.	1.0 g/m ³ as CaCO ₃	1-5
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 22 nd 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) 22 nd ed. 2012.	10 g/m ³	1-5
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.00010 g/m ³	1-5
Dissolved Bromine*	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.005 g/m ³	1-5
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.05 g/m ³	1-5
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.0005 g/m ³	1-5

Sample Type: Aqueous			
Test	Method Description	Default Detection Limit	Sample No
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.02 g/m ³	1-5
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.02 g/m ³	1-5
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.0005 g/m ³	1-5
Dissolved Mercury	0.45µm filtration, bromine oxidation followed by atomic fluorescence. US EPA Method 245.7, Feb 2005.	0.00008 g/m ³	1-5
Dissolved Nickel	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.0005 g/m ³	1-5
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.05 g/m ³	1-5
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.02 g/m ³	1-5
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.0010 g/m ³	1-5
Chloride	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl E (modified from continuous flow analysis) 22 nd ed. 2012.	0.5 g/m ³	1-5
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO ₂ ⁻ I 22 nd ed. 2012 (modified).	0.002 g/m ³	1-5
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO ₂ N. In-House.	0.0010 g/m ³	1-5
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO ₃ ⁻ I 22 nd ed. 2012 (modified).	0.002 g/m ³	1-5
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B 22 nd ed. 2012.	0.5 g/m ³	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.

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

Appendix III
Certificates of analysis
(hydraulic fracturing fluids and return flow fluids)

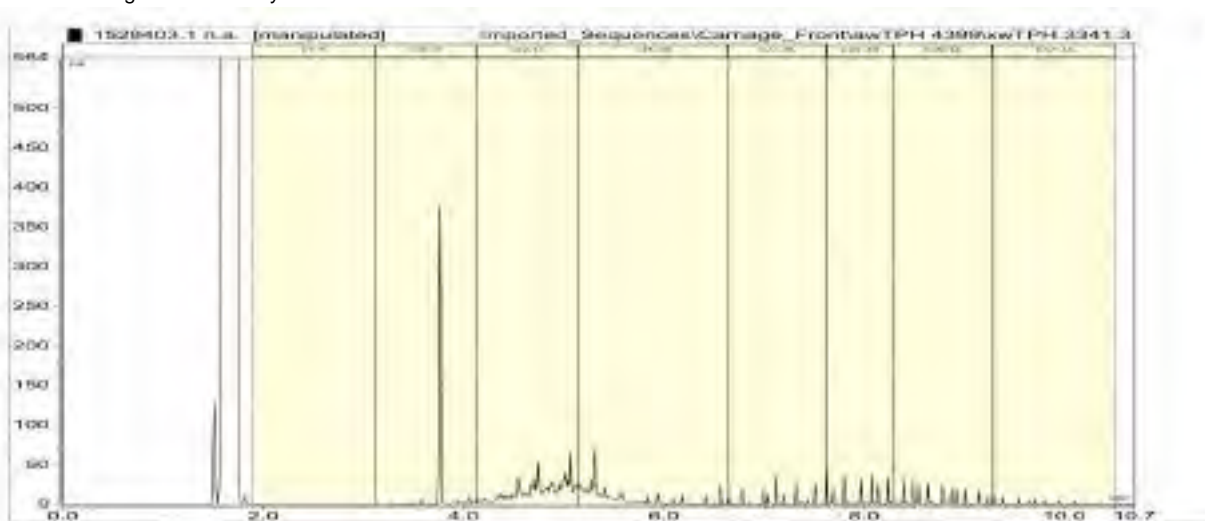
ANALYSIS REPORT

Client:	Taranaki Regional Council	Lab No:	1528403	SPV1
Contact:	Regan Phipps C/- Taranaki Regional Council Private Bag 713 STRATFORD 4352	Date Registered:	23-Jan-2016	
		Date Reported:	03-Feb-2016	
		Quote No:	50522	
		Order No:		
		Client Reference:	Manwahewa - C14 HF Fluid	
		Submitted By:	David Olson	

Sample Type: Aqueous

Sample Name:	GND 2374 20-Jan-2016 12:00 pm					
Lab Number:	1528403.1					
Ethylene Glycol in Water						
Ethylene glycol*	g/m ³	< 4	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m ³	73	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m ³	< 2	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m ³	0.0062	-	-	-	-
Toluene	g/m ³	< 0.0010	-	-	-	-
Ethylbenzene	g/m ³	< 0.0010	-	-	-	-
m&p-Xylene	g/m ³	< 0.002	-	-	-	-
o-Xylene	g/m ³	< 0.0010	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m ³	< 0.15	-	-	-	-
C10 - C14	g/m ³	39	-	-	-	-
C15 - C36	g/m ³	28	-	-	-	-
Total hydrocarbons (C7 - C36)	g/m ³	67	-	-	-	-

1528403.1
 GND 2374 20-Jan-2016 12:00 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.

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	1
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m ³	1
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m ³	1
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m ³	1
Total Petroleum Hydrocarbons in Water*	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734]	0.10 - 0.7 g/m ³	1

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

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Ara Heron BSc (Tech)
Client Services Manager - Environmental Division

ANALYSIS REPORT

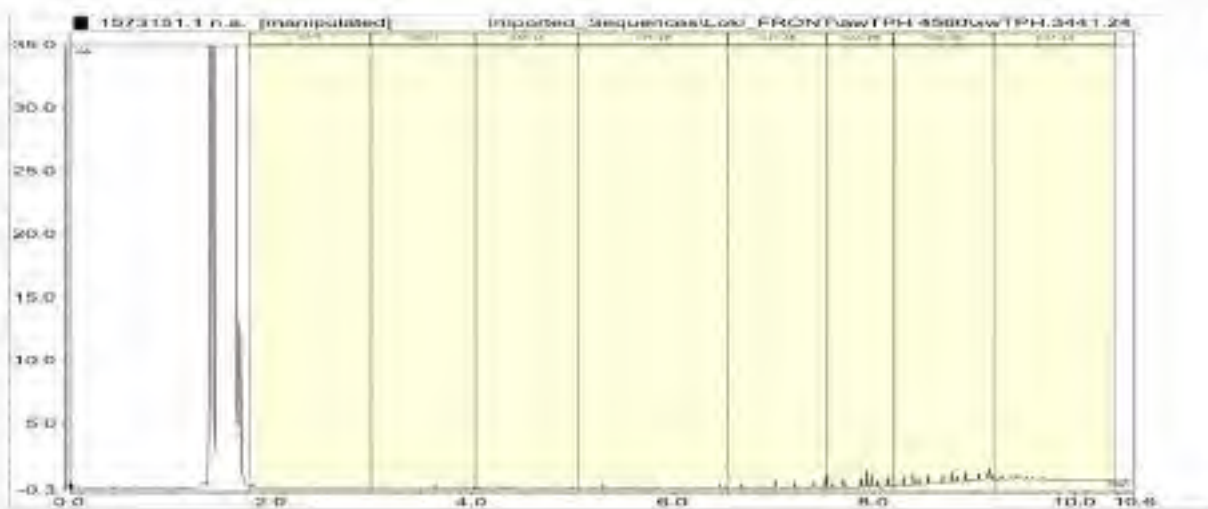
Page 1 of 2

Client:	Taranaki Regional Council	Lab No:	1573151	SPV1
Contact:	Regan Phipps C/- Taranaki Regional Council Private Bag 713 Stratford 4352	Date Registered:	23-Apr-2016	
		Date Reported:	06-May-2016	
		Quote No:	50522	
		Order No:		
		Client Reference:	MHWC 15ST2 Frac Fluid March 2016	
		Submitted By:	David Olson	

Sample Type: Aqueous

Sample Name:	MHWC 125T				
	05-Mar-2016				
Lab Number:	1573151.1				
Ethylene Glycol in Water					
Ethylene glycol*	g/m ³	< 4	-	-	-
Propylene Glycol in Water					
Propylene glycol*	g/m ³	< 4	-	-	-
Methanol in Water - Aqueous Solvents					
Methanol*	g/m ³	< 2	-	-	-
BTEX in Water by Headspace GC-MS					
Benzene	g/m ³	< 0.0010	-	-	-
Toluene	g/m ³	0.0051	-	-	-
Ethylbenzene	g/m ³	< 0.0010	-	-	-
m&p-Xylene	g/m ³	0.002	-	-	-
o-Xylene	g/m ³	< 0.0010	-	-	-
Total Petroleum Hydrocarbons in Water					
C7 - C9	g/m ³	< 8	-	-	-
C10 - C14	g/m ³	< 20	-	-	-
C15 - C36	g/m ³	< 40	-	-	-
Total hydrocarbons (C7 - C36)	g/m ³	< 70	-	-	-

1573151.1
MHWC 125T 05-Mar-2016
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	1
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m ³	1
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m ³	1
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m ³	1
Total Petroleum Hydrocarbons in Water*	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734]	0.10 - 0.7 g/m ³	1

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

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

ANALYSIS REPORT

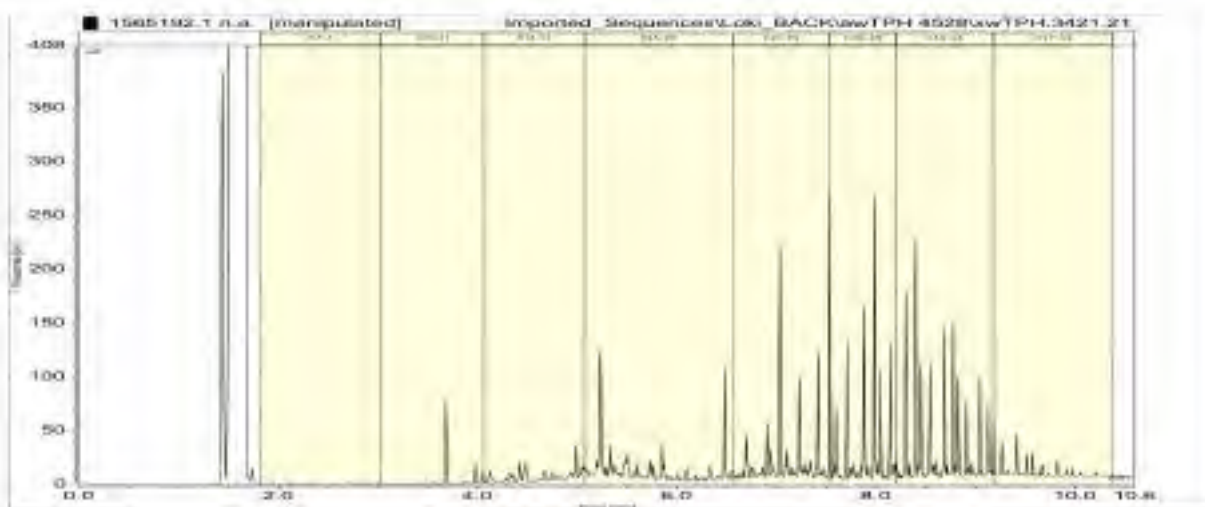
Page 1 of 2

Client:	Taranaki Regional Council	Lab No:	1565192	SPV1
Contact:	Regan Phipps C/- Taranaki Regional Council Private Bag 713 Stratford 4352	Date Registered:	11-Apr-2016	
		Date Reported:	20-Apr-2016	
		Quote No:	50522	
		Order No:		
		Client Reference:	Mangahewa - C 14-ST HF Fluid	
		Submitted By:	David Olson	

Sample Type: Aqueous

Sample Name:	GND2374 Mangahewa 14ST 17-Feb-2016 12:00 pm				
Lab Number:	1565192.1				
Ethylene Glycol in Water					
Ethylene glycol*	g/m ³	< 4	-	-	-
Propylene Glycol in Water					
Propylene glycol*	g/m ³	< 4	-	-	-
Methanol in Water - Aqueous Solvents					
Methanol*	g/m ³	< 2	-	-	-
BTEX in Water by Headspace GC-MS					
Benzene	g/m ³	0.0017	-	-	-
Toluene	g/m ³	0.0033	-	-	-
Ethylbenzene	g/m ³	< 0.0010	-	-	-
m&p-Xylene	g/m ³	< 0.002	-	-	-
o-Xylene	g/m ³	< 0.0010	-	-	-
Total Petroleum Hydrocarbons in Water					
C7 - C9	g/m ³	< 0.10	-	-	-
C10 - C14	g/m ³	5.6	-	-	-
C15 - C36	g/m ³	46	-	-	-
Total hydrocarbons (C7 - C36)	g/m ³	52	-	-	-

1565192.1
GND2374 Mangahewa 14ST 17-Feb-2016 12:00 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.

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	1
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m ³	1
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m ³	1
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m ³	1
Total Petroleum Hydrocarbons in Water*	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734]	0.10 - 0.7 g/m ³	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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Ara Heron BSc (Tech)
Client Services Manager - Environmental Division

ANALYSIS REPORT

Page 1 of 4

Client:	Taranaki Regional Council	Lab No:	1573003	SPV1
Contact:	Regan Phipps C/- Taranaki Regional Council Private Bag 713 Stratford 4352	Date Registered:	23-Apr-2016	
		Date Reported:	10-May-2016	
		Quote No:	71307	
		Order No:		
		Client Reference:	MHW-C 12ST2 Return Fluid April 2016 (D)	
		Submitted By:	David Olson	

Sample Type: Saline

Sample Name:	Composite of MHCW 12ST2-012, MHCW 12ST2-050 and MHCW 12ST2-087				
Lab Number:	1573003.4				

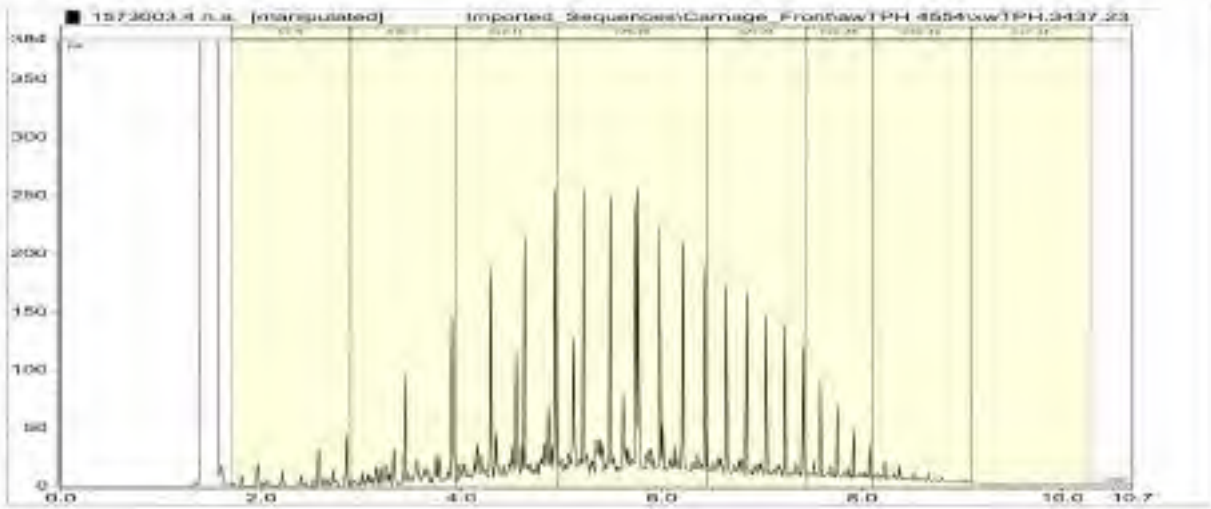
Individual Tests

pH*	pH Units	7.7	-	-	-	-
Total Alkalinity*	g/m ³ as CaCO ₃	960	-	-	-	-
Analysis Temperature for Bicarbonate	°C	24	-	-	-	-
Bicarbonate	g/m ³ at Analysis Temperature	1,274	-	-	-	-
Total Hardness*	g/m ³ as CaCO ₃	640	-	-	-	-
Electrical Conductivity (EC)*	mS/m	< 0.10	-	-	-	-
Total Dissolved Solids (TDS)*	g/m ³	29,000	-	-	-	-
Total Barium*	g/m ³	230	-	-	-	-
Total Bromine*	g/m ³	18.6	-	-	-	-
Dissolved Calcium*	g/m ³	210	-	-	-	-
Total Calcium*	g/m ³	310	-	-	-	-
Total Copper*	g/m ³	0.0081	-	-	-	-
Total Iron*	g/m ³	1.75	-	-	-	-
Dissolved Magnesium*	g/m ³	29 #1	-	-	-	-
Total Magnesium*	g/m ³	26 #1	-	-	-	-
Total Manganese*	g/m ³	3.6	-	-	-	-
Total Mercury*	g/m ³	< 0.011	-	-	-	-
Total Nickel*	g/m ³	< 0.03	-	-	-	-
Total Potassium*	g/m ³	4,700	-	-	-	-
Total Sodium*	g/m ³	6,900	-	-	-	-
Total Sulphur*	g/m ³	11	-	-	-	-
Total Zinc*	g/m ³	0.155	-	-	-	-
Chloride*	g/m ³	14,300	-	-	-	-
Nitrite-N	g/m ³	< 0.2 #2	-	-	-	-
Nitrate-N	g/m ³	< 0.2	-	-	-	-
Nitrate*	g/m ³	< 0.9	-	-	-	-
Nitrate-N + Nitrite-N	g/m ³	< 0.2 #2	-	-	-	-
Sulphate*	g/m ³	33	-	-	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m ³	< 4	-	-	-	-

Sample Type: Saline

Sample Name:	Composite of MHC 12ST2-012, MHC 12ST2-050 and MHC 12ST2-087				
Lab Number:	1573003.4				
Propylene Glycol in Water					
Propylene glycol*	g/m ³	< 4	-	-	-
Methanol in Water - Aqueous Solvents					
Methanol*	g/m ³	< 2	-	-	-
BTEX in Water by Headspace GC-MS					
Benzene*	g/m ³	3.0	-	-	-
Toluene*	g/m ³	6.7	-	-	-
Ethylbenzene*	g/m ³	0.75	-	-	-
m&p-Xylene*	g/m ³	5.6	-	-	-
o-Xylene*	g/m ³	2.2	-	-	-
Formaldehyde in Water by DNPH & LCMSMS					
Formaldehyde*	g/m ³	0.19	-	-	-
Total Petroleum Hydrocarbons in Water					
C7 - C9*	g/m ³	14.2	-	-	-
C10 - C14*	g/m ³	132	-	-	-
C15 - C36*	g/m ³	260	-	-	-
Total hydrocarbons (C7 - C36)*	g/m ³	400	-	-	-

1573003.4
 Composite of MHC 12ST2-012, MHC 12ST2-050 and MHC 12ST2-087
 Client Chromatogram for TPH by FID



Analyst's Comments

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

#2 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 NO_xNsal analysis.

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	4
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m ³	4
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m ³	4

Sample Type: Saline			
Test	Method Description	Default Detection Limit	Sample No
BTEX in Water by Headspace GC-MS*	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m ³	4
Formaldehyde in Water by DNPH & LCMSMS*	DNPH derivatisation, extraction, LCMSMS	0.02 g/m ³	4
Total Petroleum Hydrocarbons in Water*	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734]	0.10 - 0.7 g/m ³	4
Filtration, Unpreserved*	Sample filtration through 0.45µm membrane filter.	-	4
Total Digestion*	Boiling nitric acid digestion. APHA 3030 E 22nd ed. 2012 (modified).	-	4
Total Digestion of Saline Samples*	Nitric acid digestion. APHA 3030 E 22nd ed. 2012 (modified).	-	4
pH*	pH meter. APHA 4500-H ⁺ B 22 nd 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	4
Total Alkalinity*	Saline water, Titration to pH 4.5.	1.0 g/m ³ as CaCO ₃	4
Analysis Temperature for Bicarbonate	Temperature at which Bicarbonate titration was conducted as reported by Geological & Nuclear Sciences, Wairakei.	1.0 °C	4
Bicarbonate	Bicarbonate (HCO ₃) Titration Method conducted at reported temperature. Subcontracted to Geological & Nuclear Sciences, Wairakei. ASTM Standards D513-82 Vol.11.01 of 1988.	20 g/m ³ at Analysis Temperature	4
Total Hardness*	Calculation from Calcium and Magnesium. APHA 2340 B 22 nd ed. 2012.	1.0 g/m ³ as CaCO ₃	4
Electrical Conductivity (EC)*	Saline water, Conductivity meter, 25°C. APHA 2510 B 22 ^d ed. 2012.	0.10 mS/m	4
Total Dissolved Solids (TDS)*	Filtration through GF/C (1.2 µm), gravimetric. APHA 2540 C (modified; drying temperature of 103 - 105°C used rather than 180 ± 2°C) 22 nd ed. 2012.	50 g/m ³	4
Filtration for dissolved metals analysis*	Sample filtration through 0.45µm membrane filter and preservation with nitric acid. APHA 3030 B 22 ^d ed. 2012.	-	4
Total Barium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22 nd ed. 2012.	0.00063 g/m ³	4
Total Bromine*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22 nd ed. 2012.	0.11 g/m ³	4
Dissolved Calcium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22 nd ed. 2012.	1.0 g/m ³	4
Total Calcium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22 nd ed. 2012.	1.1 g/m ³	4
Total Copper*	Nitric acid digestion, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22 nd ed. 2012.	0.0011 g/m ³	4
Total Iron*	Nitric acid digestion, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22 nd ed. 2012.	0.0042 g/m ³	4
Dissolved Magnesium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22 nd ed. 2012.	0.4 g/m ³	4
Total Magnesium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22 nd ed. 2012.	0.42 g/m ³	4
Total Manganese*	Nitric acid digestion, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22 nd ed. 2012.	0.0011 g/m ³	4
Total Mercury*	Nitric acid digestion, ICP-MS, screen level. APHA 3125 B 22 ^d ed. 2012.	0.0021 g/m ³	4
Total Nickel*	Nitric acid digestion, ICP-MS with universal cell, ultratrace. APHA 3125 B 22 nd ed. 2012.	0.0011 g/m ³	4
Total Potassium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22 nd ed. 2012.	1.1 g/m ³	4
Total Sodium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22 nd ed. 2012.	0.42 g/m ³	4
Total Sulphur*	Nitric acid digestion, ICP-OES (method may not fully account for H ₂ S due to volatilisation during digestion). All forms of oxidised and organic sulphur will be determined by this method.	0.5 g/m ³	4
Total Zinc*	Nitric acid digestion, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22 nd ed. 2012.	0.0042 g/m ³	4
Chloride*	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl ⁻ E (modified from continuous flow analysis) 22 nd ed. 2012.	0.5 g/m ³	4
Nitrite-N	Saline sample. Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO ₂ ⁻ I 22 nd ed. 2012 (modified).	0.002 g/m ³	4
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO ₂ N. In-House.	0.0010 g/m ³	4
Nitrate*	Calculation from Nitrate-N.	0.010 g/m ³	4

Sample Type: Saline			
Test	Method Description	Default Detection Limit	Sample No
Nitrate-N + Nitrite-N	Saline sample. Total oxidised nitrogen. Automated cadmium reduction, Flow injection analyser. APHA 4500-NO ₃ ⁻ I 22 nd ed. 2012 (modified).	0.002 g/m ³	4
Total Sulphate*	Calculation: from total sulphur.	2 g/m ³	4

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Peter Robinson MSc (Hons), PhD, FNZIC
Client Services Manager - Environmental Division

ANALYSIS REPORT

Page 1 of 4

Client:	Taranaki Regional Council	Lab No:	1565190	SPV1
Contact:	Regan Phipps C/- Taranaki Regional Council Private Bag 713 Stratford 4352	Date Registered:	11-Apr-2016	
		Date Reported:	10-May-2016	
		Quote No:	71307	
		Order No:		
		Client Reference:	Mangahewa -C 14ST Return Fluid	
		Submitted By:	David Olson	

Sample Type: Saline

Sample Name:	Composite of MHW 145T1 - 011, MHW 145T1 - 076 & MHW 145T1 - 126				
Lab Number:	1565190.4				
Individual Tests					
pH*	pH Units	7.5	-	-	-
Total Alkalinity*	g/m ³ as CaCO ₃	1,360	-	-	-
Total Hardness*	g/m ³ as CaCO ₃	450	-	-	-
Electrical Conductivity (EC)*	mS/m	4,340	-	-	-
Total Dissolved Solids (TDS)*	g/m ³	28,000	-	-	-
Total Barium*	g/m ³	146	-	-	-
Total Bromine*	g/m ³	10.1	-	-	-
Dissolved Calcium*	g/m ³	155	-	-	-
Total Calcium*	g/m ³	111	-	-	-
Total Copper*	g/m ³	0.021	-	-	-
Total Iron*	g/m ³	17.8	-	-	-
Dissolved Magnesium*	g/m ³	15	-	-	-
Total Magnesium*	g/m ³	13.7	-	-	-
Total Manganese*	g/m ³	2.7	-	-	-
Total Mercury*	g/m ³	< 0.011	-	-	-
Total Nickel*	g/m ³	0.16	-	-	-
Total Potassium*	g/m ³	7,700	-	-	-
Total Sodium*	g/m ³	4,700	-	-	-
Total Sulphur*	g/m ³	38	-	-	-
Total Zinc*	g/m ³	5.4	-	-	-
Chloride*	g/m ³	10,800	-	-	-
Nitrite-N	g/m ³	< 0.2 #1	-	-	-
Nitrate-N	g/m ³	< 0.2	-	-	-
Nitrate*	g/m ³	< 0.9	-	-	-
Nitrate-N + Nitrite-N	g/m ³	0.2 #1	-	-	-
Sulphate*	g/m ³	115	-	-	-
Ethylene Glycol in Water					
Ethylene glycol*	g/m ³	< 40	-	-	-
Propylene Glycol in Water					
Propylene glycol*	g/m ³	< 40	-	-	-
Methanol in Water - Aqueous Solvents					
Methanol*	g/m ³	< 20	-	-	-

Sample Type: Saline

Sample Name:	Composite of MHW 145T1 - 011, MHW 145T1 - 076 & MHW 145T1 - 126				
Lab Number:	1565190.4				

BTEX in Water by Headspace GC-MS

Benzene*	g/m ³	13.0	-	-	-	-
Toluene*	g/m ³	27	-	-	-	-
Ethylbenzene*	g/m ³	2.4	-	-	-	-
m&p-Xylene*	g/m ³	16.6	-	-	-	-
o-Xylene*	g/m ³	5.5	-	-	-	-

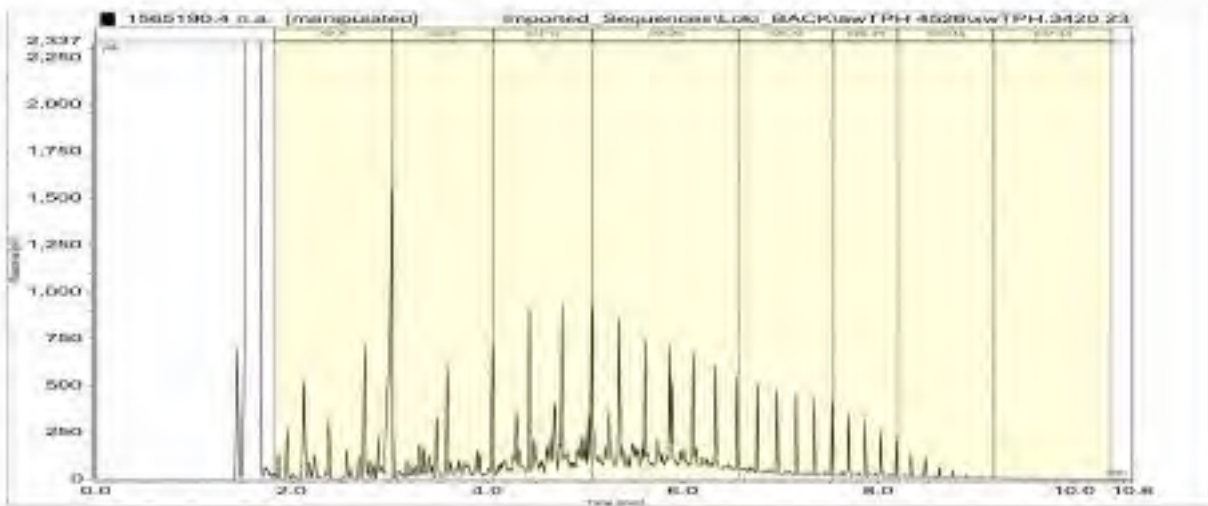
Formaldehyde in Water by DNPH & LCMSMS

Formaldehyde*	g/m ³	3.3	-	-	-	-
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Total Petroleum Hydrocarbons in Water

C7 - C9*	g/m ³	520	-	-	-	-
C10 - C14*	g/m ³	730	-	-	-	-
C15 - C36*	g/m ³	870	-	-	-	-
Total hydrocarbons (C7 - C36)*	g/m ³	2,100	-	-	-	-

1565190.4
 Composite of MHW 145T1 - 011, MHW 145T1 - 076 & MHW 145T1 - 126
 Client Chromatogram for TPH by FID



Analyst's Comments

A sub-sample for bicarbonate analysis was not sent to GNS in the correct time frame required for the testing [QOWQ 61564].

#1 Severe matrix interferences required that a dilution be performed prior to analysis of this sample, resulting in a detection limit higher than that normally achieved for the NO2Nsal, NO3Nsal and NOxNsal analysis.

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	4
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m ³	4
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m ³	4
BTEX in Water by Headspace GC-MS*	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m ³	4
Formaldehyde in Water by DNPH & LCMSMS*	DNPH derivatisation, extraction, LCMSMS	0.02 g/m ³	4
Total Petroleum Hydrocarbons in Water*	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734]	0.10 - 0.7 g/m ³	4

Sample Type: Saline			
Test	Method Description	Default Detection Limit	Sample No
Filtration, Unpreserved*	Sample filtration through 0.45µm membrane filter.	-	4
Total Digestion*	Boiling nitric acid digestion. APHA 3030 E 22nd ed. 2012 (modified).	-	4
Total Digestion of Saline Samples*	Nitric acid digestion. APHA 3030 E 22nd ed. 2012 (modified).	-	4
pH*	pH meter. APHA 4500-H ⁺ B 22 nd 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	4
Total Alkalinity*	Saline water, Titration to pH 4.5.	1.0 g/m ³ as CaCO ₃	4
Total Hardness*	Calculation from Calcium and Magnesium. APHA 2340 B 22 nd ed. 2012.	1.0 g/m ³ as CaCO ₃	4
Electrical Conductivity (EC)*	Conductivity meter, 25°C. APHA 2510 B 22 nd ed. 2012.	0.1 mS/m	4
Total Dissolved Solids (TDS)*	Filtration through GF/C (1.2 µm), gravimetric. APHA 2540 C (modified; drying temperature of 103 - 105°C used rather than 180 ± 2°C) 22 nd ed. 2012.	50 g/m ³	4
Filtration for dissolved metals analysis*	Sample filtration through 0.45µm membrane filter and preservation with nitric acid. APHA 3030 B 22 nd ed. 2012.	-	4
Total Barium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22 nd ed. 2012.	0.00063 g/m ³	4
Total Bromine*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22 nd ed. 2012.	0.11 g/m ³	4
Dissolved Calcium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22 nd ed. 2012.	1.0 g/m ³	4
Total Calcium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22 nd ed. 2012.	1.1 g/m ³	4
Total Copper*	Nitric acid digestion, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22 nd ed. 2012.	0.0011 g/m ³	4
Total Iron*	Nitric acid digestion, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22 nd ed. 2012.	0.0042 g/m ³	4
Dissolved Magnesium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22 nd ed. 2012.	0.4 g/m ³	4
Total Magnesium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22 nd ed. 2012.	0.42 g/m ³	4
Total Manganese*	Nitric acid digestion, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22 nd ed. 2012.	0.0011 g/m ³	4
Total Mercury*	Nitric acid digestion, ICP-MS, screen level. APHA 3125 B 22 nd ed. 2012.	0.0021 g/m ³	4
Total Nickel*	Nitric acid digestion, ICP-MS with universal cell, ultratrace. APHA 3125 B 22 nd ed. 2012.	0.0011 g/m ³	4
Total Potassium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22 nd ed. 2012.	1.1 g/m ³	4
Total Sodium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22 nd ed. 2012.	0.42 g/m ³	4
Total Sulphur*	Nitric acid digestion, ICP-OES (method may not fully account for H ₂ S due to volatilisation during digestion). All forms of oxidised and organic sulphur will be determined by this method.	0.5 g/m ³	4
Total Zinc*	Nitric acid digestion, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22 nd ed. 2012.	0.0042 g/m ³	4
Chloride*	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl ⁻ E (modified from continuous flow analysis) 22 nd ed. 2012.	0.5 g/m ³	4
Nitrite-N	Saline sample. Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO ₂ ⁻ I 22 nd ed. 2012 (modified).	0.002 g/m ³	4
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO ₂ N. In-House.	0.0010 g/m ³	4
Nitrate*	Calculation from Nitrate-N.	0.010 g/m ³	4
Nitrate-N + Nitrite-N	Saline sample. Total oxidised nitrogen. Automated cadmium reduction, Flow injection analyser. APHA 4500-NO ₃ ⁻ I 22 nd ed. 2012 (modified).	0.002 g/m ³	4
Total Sulphate*	Calculation: from total sulphur.	2 g/m ³	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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A handwritten signature in blue ink, appearing to read "Peter Robinson", is written over a light yellow rectangular background.

Peter Robinson MSc (Hons), PhD, FNZIC
Client Services Manager - Environmental Division

ANALYSIS REPORT

Page 1 of 4

Client:	Taranaki Regional Council	Lab No:	1573002	SPV1
Contact:	Regan Phipps C/- Taranaki Regional Council Private Bag 713 Stratford 4352	Date Registered:	23-Apr-2016	
		Date Reported:	10-May-2016	
		Quote No:	71307	
		Order No:		
		Client Reference:	HMWE 21st Return Fluid April 2016 (5)	
		Submitted By:	David Olson	

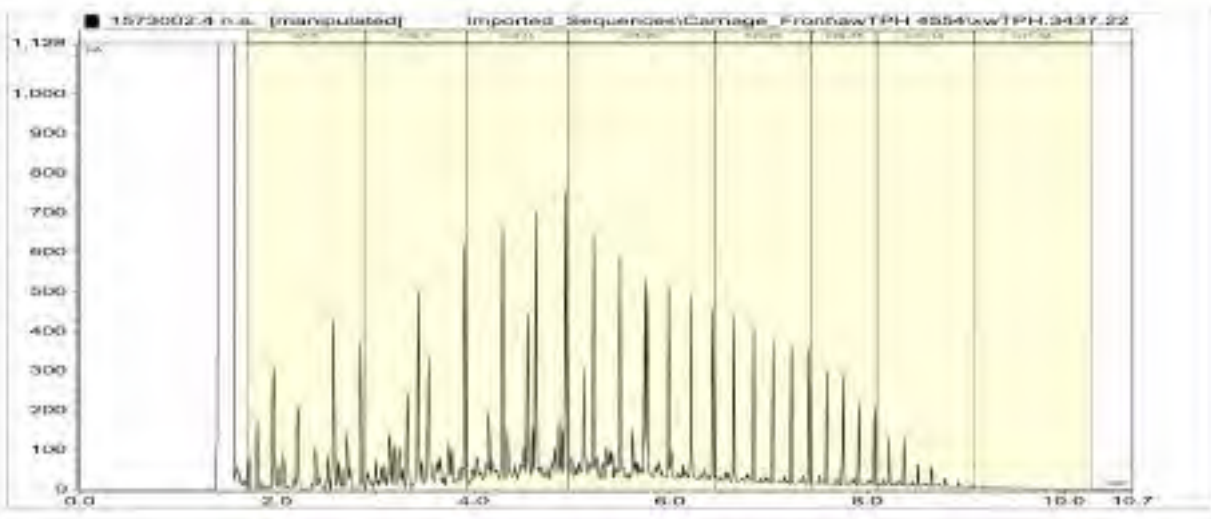
Sample Type: Saline

Sample Name:	Composite MHW12 ST-2 (188), MHW12 ST-2 (220) and MHW12 ST-2 (245)				
Lab Number:	1573002.4				
Individual Tests					
pH*	pH Units	7.6	-	-	-
Total Alkalinity*	g/m ³ as CaCO ₃	1,590	-	-	-
Analysis Temperature for Bicarbonate	°C	24	-	-	-
Bicarbonate	g/m ³ at Analysis Temperature	1,600	-	-	-
Total Hardness*	g/m ³ as CaCO ₃	400	-	-	-
Electrical Conductivity (EC)*	mS/m	3,670	-	-	-
Total Dissolved Solids (TDS)*	g/m ³	24,000	-	-	-
Total Barium*	g/m ³	68	-	-	-
Total Bromine*	g/m ³	16.6	-	-	-
Dissolved Calcium*	g/m ³	130	-	-	-
Total Calcium*	g/m ³	185	-	-	-
Total Copper*	g/m ³	0.151	-	-	-
Total Iron*	g/m ³	13.0	-	-	-
Dissolved Magnesium*	g/m ³	19	-	-	-
Total Magnesium*	g/m ³	17.2	-	-	-
Total Manganese*	g/m ³	2.3	-	-	-
Total Mercury*	g/m ³	< 0.011	-	-	-
Total Nickel*	g/m ³	0.12	-	-	-
Total Potassium*	g/m ³	4,600	-	-	-
Total Sodium*	g/m ³	5,400	-	-	-
Total Sulphur*	g/m ³	48	-	-	-
Total Zinc*	g/m ³	0.23	-	-	-
Chloride*	g/m ³	10,900	-	-	-
Nitrite-N	g/m ³	< 0.2 #1	-	-	-
Nitrate-N	g/m ³	< 0.2	-	-	-
Nitrate*	g/m ³	< 0.9	-	-	-
Nitrate-N + Nitrite-N	g/m ³	< 0.2 #1	-	-	-
Sulphate*	g/m ³	143	-	-	-
Ethylene Glycol in Water					
Ethylene glycol*	g/m ³	< 4	-	-	-

Sample Type: Saline

Sample Name:	Composite MHW12 ST-2 (188), MHW12 ST-2 (220) and MHW12 ST-2 (245)					
Lab Number:	1573002.4					
Propylene Glycol in Water						
Propylene glycol*	g/m ³	< 4	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m ³	< 20	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene*	g/m ³	15.8	-	-	-	-
Toluene*	g/m ³	44	-	-	-	-
Ethylbenzene*	g/m ³	7.4	-	-	-	-
m&p-Xylene*	g/m ³	44	-	-	-	-
o-Xylene*	g/m ³	14.7	-	-	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde*	g/m ³	0.25	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9*	g/m ³	200	-	-	-	-
C10 - C14*	g/m ³	540	-	-	-	-
C15 - C36*	g/m ³	570	-	-	-	-
Total hydrocarbons (C7 - C36)*	g/m ³	1,310	-	-	-	-

1573002.4
 Composite MHW12 ST-2 (188), MHW12 ST-2 (220) and MHW12 ST-2 (245)
 Client Chromatogram for TPH by FID



Analyst's Comments

#1 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.

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	4
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m ³	4
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m ³	4
BTEX in Water by Headspace GC-MS*	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m ³	4
Formaldehyde in Water by DNPH & LCMSMS*	DNPH derivatisation, extraction, LCMSMS	0.02 g/m ³	4

Sample Type: Saline			
Test	Method Description	Default Detection Limit	Sample No
Total Petroleum Hydrocarbons in Water*	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734]	0.10 - 0.7 g/m ³	4
Filtration, Unpreserved*	Sample filtration through 0.45µm membrane filter.	-	4
Total Digestion*	Boiling nitric acid digestion. APHA 3030 E 22nd ed. 2012 (modified).	-	4
Total Digestion of Saline Samples*	Nitric acid digestion. APHA 3030 E 22nd ed. 2012 (modified).	-	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.	0.1 pH Units	4
Total Alkalinity*	Saline water, Titration to pH 4.5.	1.0 g/m ³ as CaCO ₃	4
Analysis Temperature for Bicarbonate	Temperature at which Bicarbonate titration was conducted as reported by Geological & Nuclear Sciences, Wairakei.	1.0 °C	4
Bicarbonate	Bicarbonate (HCO ₃) Titration Method conducted at reported temperature. Subcontracted to Geological & Nuclear Sciences, Wairakei. ASTM Standards D513-82 Vol.11.01 of 1988.	20 g/m ³ at Analysis Temperature	4
Total Hardness*	Calculation from Calcium and Magnesium. APHA 2340 B 22 nd ed. 2012.	1.0 g/m ³ as CaCO ₃	4
Electrical Conductivity (EC)*	Conductivity meter, 25°C. APHA 2510 B 22 nd ed. 2012.	0.1 mS/m	4
Total Dissolved Solids (TDS)*	Filtration through GF/C (1.2 µm), gravimetric. APHA 2540 C (modified; drying temperature of 103 - 105°C used rather than 180 ± 2°C) 22 nd ed. 2012.	50 g/m ³	4
Filtration for dissolved metals analysis*	Sample filtration through 0.45µm membrane filter and preservation with nitric acid. APHA 3030 B 22 nd ed. 2012.	-	4
Total Barium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22 nd ed. 2012.	0.00063 g/m ³	4
Total Bromine*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22 nd ed. 2012.	0.11 g/m ³	4
Dissolved Calcium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22 nd ed. 2012.	1.0 g/m ³	4
Total Calcium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22 nd ed. 2012.	1.1 g/m ³	4
Total Copper*	Nitric acid digestion, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22 nd ed. 2012.	0.0011 g/m ³	4
Total Iron*	Nitric acid digestion, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22 nd ed. 2012.	0.0042 g/m ³	4
Dissolved Magnesium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22 nd ed. 2012.	0.4 g/m ³	4
Total Magnesium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22 nd ed. 2012.	0.42 g/m ³	4
Total Manganese*	Nitric acid digestion, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22 nd ed. 2012.	0.0011 g/m ³	4
Total Mercury*	Nitric acid digestion, ICP-MS, screen level. APHA 3125 B 22 nd ed. 2012.	0.0021 g/m ³	4
Total Nickel*	Nitric acid digestion, ICP-MS with universal cell, ultratrace. APHA 3125 B 22 nd ed. 2012.	0.0011 g/m ³	4
Total Potassium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22 nd ed. 2012.	1.1 g/m ³	4
Total Sodium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22 nd ed. 2012.	0.42 g/m ³	4
Total Sulphur*	Nitric acid digestion, ICP-OES (method may not fully account for H ₂ S due to volatilisation during digestion). All forms of oxidised and organic sulphur will be determined by this method.	0.5 g/m ³	4
Total Zinc*	Nitric acid digestion, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22 nd ed. 2012.	0.0042 g/m ³	4
Chloride*	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl E (modified from continuous flow analysis) 22 nd ed. 2012.	0.5 g/m ³	4
Nitrite-N	Saline sample. Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO ₂ -I 22 nd ed. 2012 (modified).	0.002 g/m ³	4
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO ₂ N. In-House.	0.0010 g/m ³	4
Nitrate*	Calculation from Nitrate-N.	0.010 g/m ³	4
Nitrate-N + Nitrite-N	Saline sample. Total oxidised nitrogen. Automated cadmium reduction, Flow injection analyser. APHA 4500-NO ₃ -I 22 nd ed. 2012 (modified).	0.002 g/m ³	4
Total Sulphate*	Calculation: from total sulphur.	2 g/m ³	4

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A handwritten signature in blue ink, appearing to read 'Peter Robinson', is written over a light yellow rectangular background.

Peter Robinson MSc (Hons), PhD, FNZIC
Client Services Manager - Environmental Division

Appendix IV
Biomonitoring report

To Callum MacKenzie, Scientific Officer
Jane Harvey, Scientific Officer - Groundwater Resources
From Katie Blakemore, Technical Officer
Document 1678381
Report No KB005
Date 3 May 2016

Biomonitoring of two unnamed tributaries of the Waiau Stream in relation to drilling and hydraulic fracturing activities at the Mangahewa-C wellsite

Introduction

A pre-drill biological survey was carried out near the Mangahewa-C wellsite, to provide baseline data on the health of the macroinvertebrate communities of two unnamed tributaries of the Waiau Stream prior to the commencement of drilling activities. A further survey was undertaken following the completion of drilling and hydraulic fracturing to determine whether stormwater discharges onto land and water have caused significant adverse effects on the macroinvertebrate communities of two unnamed tributaries of the Waiau Stream.

Methods

The pre-drill survey was completed on 26 May 2015. Three sites were established at the time of the survey (Table 1, Figure 1). A 'control' site (Site 1) was situated in an unnamed tributary of the Waiau Stream, approximately 20m upstream of the confluence with another unnamed tributary which receives the stormwater discharges from the Mangahewa-C wellsite. A 'primary impact' site (Site 2) was situated in the tributary receiving the discharge, approximately 110m downstream of the discharge point and 10m upstream of the confluence with the other unnamed tributary. A 'secondary impact' site (Site 3) was situated 20m downstream of the confluence with the tributary receiving the discharge. A subsequent survey was carried out on 18 April 2016, following the completion of drilling and hydraulic fracturing (hereafter referred to as the post wellsite activity survey).

Table 1 Biomonitoring sites in two unnamed tributaries of the Waiau Stream in relation to the Mangahewa-C wellsite

Site number	Site code	Grid reference (NZTM)	Location	Altitude (masl)
1	WAI000075	E1713722 N5677105	20m u/s of confluence with tributary receiving wellsite discharge	70
2	WAI000078	E1713717 N5677129	110m d/s wellsite discharge, 10m u/s of confluence	70
3	WAI000080	E1713730 N5677170	20m d/s of confluence with tributary receiving wellsite discharge	70

The standard '400 ml kick-sampling' technique was used to collect streambed macroinvertebrates. This 'kick-sampling' technique is very similar to Protocol C1 (hard-bottomed, semi-quantitative) of the New Zealand Macroinvertebrate Working Group (NZMWG) protocols for macroinvertebrate samples in wadeable streams (Stark et al, 2001).



Figure 1 Biomonitoring sites in two unnamed tributaries of the Waiiau Stream in relation to the Mangahewa-C wellsite

Samples were preserved with Kahle’s Fluid for later sorting and identification under a stereomicroscope according to Taranaki Regional Council methodology using protocol P1 of NZMWG protocols for sampling macroinvertebrates in wadeable streams (Stark et al. 2001). Macroinvertebrate taxa abundances found in each sample were recorded based on the categories in Table 2.

Table 2 Macroinvertebrate abundance categories

Abundance category	Number of individuals
R (rare)	1-4
C (common)	5-19
A (abundant)	20-99
VA (very abundant)	100-499
XA (extremely abundant)	>499

Stark (1985) developed a scoring system for macroinvertebrate taxa according to their sensitivity to organic pollution in stony New Zealand streams. Highly 'sensitive' taxa were assigned the highest scores of 9 or 10, while the most 'tolerant' forms scored 1. Sensitivity scores for certain taxa have been modified in accordance with Taranaki experience. By averaging the scores obtained from a list of taxa taken from one site and multiplying by a scaling factor of 20, a Macroinvertebrate Community Index (MCI) value was obtained. The MCI is a measure of the overall sensitivity of macroinvertebrate communities to the effects of organic pollution. A gradation of biological water quality conditions based upon MCI ranges which has been adapted for Taranaki streams and rivers (TRC, 2013) from Stark's classification (Stark, 1985 and Boothroyd and Stark, 2000) (Table 3). More 'sensitive' communities inhabit less polluted waterways. A difference of 11 units or more in MCI values is considered significantly different (Stark 1998).

Table 3 Macroinvertebrate community health based on MCI ranges which has been adapted for Taranaki streams and rivers (TRC, 2013) from Stark's classification (Stark, 1985 and Boothroyd and Stark, 2000)

Grading	MCI
Excellent	>140
Very Good	120-140
Good	100-119
Fair	80-99
Poor	60-79
Very Poor	<60

A semi-quantitative MCI value (SQMCI_s) has also been calculated for the taxa present at each site by multiplying each taxon score by a loading factor (related to its abundance), totalling these products, and dividing by the sum of the loading factors (Stark, 1998 and 1999). The loading factors were 1 for rare (R), 5 for common (C), 20 for abundant (A), 100 for very abundant (VA) and 500 for extremely abundant (XA). Unlike the MCI, the SQMCI_s is not multiplied by a scaling factor of 20, so that its corresponding range of values is 20x lower. Macroinvertebrate community health grades can also be assigned from the SQMCI_s, although these have not been modified for Taranaki.

Results and discussion

Site Habitat and Hydrology

At the time of the pre-drill survey there was a clear uncoloured flow at all sites. Sites 1 and 3 had a moderate, steady flow while site 2 had a low, slow flow. Substrate was composed of sand, silt, fine gravels, and coarse gravels at all sites, with wood substrate also present at site 1 and cobble also present at site 2. Water temperatures were in the range 12.6 -12.8 °C at all sites.

Site 1 had patches of leaves and wood, and macrophytes on the edges only, but no moss. Sites 2 and 3 had patches of leaves and wood, but no moss or macrophytes present. There was no periphyton present at any sites.

At the time of the post wellsite activity survey there was a clear uncoloured flow at all sites. Water levels were very low at all sites, while water velocity was steady at sites 1 and 3, and very slow/still at site 2. This represents a reduction in flow to that noted in the pre-drill survey.

Site 1 and site 3 had patches of leaves and wood, but no moss or macrophytes present, while site 2 had no moss, widespread leaves, patchy wood and no macrophytes on the streambed. There was no periphyton present at any sites.

Macroinvertebrate communities

A summary of previously recorded median scores and ranges for macroinvertebrate indices in Taranaki lowland coastal streams between 50 and 79 metres above sea level, together with results recorded in the current surveys are provided in Table 4.

Table 4 Summary of medians and ranges based on previously recorded data from Taranaki lowland coastal streams between 50-79m above sea level (TRC 2015), together with results recorded in the current surveys

	Median	Range	Pre-drill survey			Post wellsite activity survey		
			WAI000075	WAI000078	WAI000080	WAI000075	WAI000078	WAI000080
Number of taxa	20	0-30	14	10	15	29	8	20
MCI	78	60-100	103	120	91	109	100	118
SQMCI _s	4.0	1.4-6.2	6.7	6.2	5.1	6.7	4.7	6.5

The macroinvertebrate communities of the two unnamed tributaries of the Waiau Stream recorded during of the pre-drill survey are provided in Table 5, and at during the post wellsite activity survey are provided in Table 6.

Table 5 Macroinvertebrate communities of two unnamed tributaries of the Waiau Stream in relation to the Mangahewa-C wellsite, sampled on 26 May 2015

Taxa List	Site Number	MCI score	1	2	3
	Site Code		WAI000075	WAI000078	WAI000080
	Sample Number		FWB15237	FWB15238	FWB15239
ANNELIDA (WORMS)	Oligochaeta	1	R	C	C
MOLLUSCA	<i>Potamopyrgus</i>	4	C	C	A
	Sphaeriidae	3	-	-	R
CRUSTACEA	Ostracoda	1	-	-	R
	Paraleptamphopidae	5	-	R	R
EPHEMEROPTERA (MAYFLIES)	<i>Coloburiscus</i>	7	C	R	C
	<i>Zephlebia group</i>	7	VA	A	A
PLECOPTERA (STONEFLIES)	<i>Acroperla</i>	5	-	-	R
	<i>Austroperla</i>	9	-	R	-
	<i>Megaleptoperla</i>	9	R	-	-
	<i>Spaniocerca</i>	8	-	C	-
	<i>Microvelia</i>	3	R	-	-
TRICHOPTERA (CADDISFLIES)	<i>Hydrobiosis</i>	5	R	-	-
	<i>Hydropsyche (Orthopsyche)</i>	9	C	C	-
	Oeconesidae	5	-	-	R
	<i>Pycnocentria</i>	7	R	R	R
	<i>Tripletides</i>	5	C	-	C
DIPTERA (TRUE FLIES)	Eriopterini	5	-	-	R
	<i>Zelandotipula</i>	6	R	-	-
	<i>Polypedilum</i>	3	R	R	-
	Tanypodinae	5	-	-	R
	Ceratopogonidae	3	R	-	-
<i>Austrosimulium</i>	3	R	-	R	
ACARINA (MITES)	Acarina	5	-	-	R
No of taxa			14	10	15
MCI			103	120	91
SQMCI			6.7	6.2	5.1
EPT (taxa)			7	6	6
%EPT (taxa)			50	60	40
'Tolerant' taxa		'Moderately sensitive' taxa	'Highly sensitive' taxa		

R = Rare C = Common A = Abundant VA = Very Abundant XA = Extremely Abundant

Table 6 Macroinvertebrate communities of two unnamed tributaries of the Mangaoraka Stream in relation to the Mangahewa-C wellsite, sampled on 18 April 2016

Taxa List	Site Number	MCI score	1	2	3
	Site Code		WAI000075	WAI000078	WAI000080
	Sample Number		FWB16201	FWB16202	FWB16203
NEMERTEA	Nemertea	3	-	R	-
ANNELIDA (WORMS)	Oligochaeta	1	A	-	C
MOLLUSCA	<i>Potamopyrgus</i>	4	C	A	C
CRUSTACEA	Copepoda	5	R	R	-
	Ostracoda	1	R	-	-
	<i>Paracalliope</i>	5	C	-	-
	Paraleptamphopidae	5	-	C	-
	<i>Paranephrops</i>	5	R	R	-
EPHEMEROPTERA (MAYFLIES)	<i>Austroclima</i>	7	A	-	C
	<i>Coloburiscus</i>	7	VA	-	A
	<i>Deleatidium</i>	8	VA	-	A
	<i>Zephlebia</i> group	7	VA	C	A
PLECOPTERA (STONEFLIES)	<i>Austroperla</i>	9	-	-	R
	<i>Megaleptoperla</i>	9	R	-	-
ODONATA (DRAGONFLIES)	<i>Procordulia</i>	5	-	R	-
COLEOPTERA (BEETLES)	Elmidae	6	R	-	C
	Scirtidae	8	R	-	R
MEGALOPTERA (DOBSONFLIES)	<i>Archichauliodes</i>	7	R	-	R
TRICHOPTERA (CADDISFLIES)	Ecnomidae/Psychomyiidae	6	R	-	R
	<i>Hydrobiosis</i>	5	C	-	R
	<i>Hydrobiosella</i>	9	R	-	-
	<i>Hydropsyche</i> (<i>Orthopsyche</i>)	9	C	-	R
	<i>Polypsectropus</i>	6	R	R	-
	<i>Psilochorema</i>	6	R	-	R
	<i>Pycnocentria</i>	7	R	-	R
	<i>Eriopterini</i>	5	R	-	-
DIPTERA (TRUE FLIES)	Hexatomini	5	C	-	R
	<i>Limonia</i>	6	-	-	R
	Orthoclaadiinae	2	R	-	-
	<i>Polypedilum</i>	3	R	-	R
	Empididae	3	R	-	-
	<i>Austrosimulium</i>	3	C	-	R
	Tanyderidae	4	R	-	R
ACARINA (MITES)	Acarina	5	R	-	-
No of taxa			29	8	20
MCI			109	100	118
SQMCIs			6.7	4.7	6.5
EPT (taxa)			12	2	10
%EPT (taxa)			41	25	50
'Tolerant' taxa		'Moderately sensitive' taxa	'Highly sensitive' taxa		

R = Rare C = Common A = Abundant VA = Very Abundant XA = Extremely Abundant

Site 1

At the time of the pre-drill survey, a moderately low taxa richness of 14 taxa was recorded. This is lower than the median taxa richness (20 taxa; Table 4) that is recorded for sites in similar Taranaki lowland coastal streams at this altitude. The community was characterised by one taxon on this occasion, the 'moderately sensitive' mayfly *Zephlebia* group which was very abundant (Table 5). The post wellsite activity survey recorded a high taxa richness of 29 taxa, substantially higher than the 14 taxa recorded in the pre-drill survey and the median score (median taxa richness 20 taxa) for similar sites at this altitudinal range (TRC 2015). In addition, this is only one taxon less than the maximum recorded taxa richness for similar sites at this altitude (Table 4). The macroinvertebrate community was characterised by five taxa on this occasion, one 'highly sensitive' mayfly (*Deleatidium*), three 'moderately sensitive' mayflies (*Austroclima*, *Coloburiscus* and *Zephlebia* group) and one 'tolerant' taxon (oligochaete worms) (Table 6).

A MCI score of 103 units was recorded in the pre-drill survey and a score of 109 in the post wellsite activity survey (Tables 5 and 6). This categorises the site as having 'good' macroinvertebrate community health on both occasions (Table 3), and was higher than the maximum MCI score previously recorded for similar sites at this altitudinal range (maximum MCI score 100 units; Table 4). There is no significant difference between the scores found in the pre-drill and post wellsite activity surveys (Stark 1998).

A SQMCI_s score of 6.7 units was recorded in both surveys (Tables 5 and 6), higher than the maximum recorded score for similar sites in this altitudinal range (maximum SQMCI_s score 6.2 units; Table 4).

The pre-drill survey recorded seven EPT (Ephemeroptera, Plecoptera and Trichoptera) taxa, and a percentage of EPT taxa of 50%. The post wellsite activity survey recorded twelve EPT taxa and a percentage of EPT taxa of 41%.

Site 2

Low taxa richness was recorded at this site on both sampling occasions, with 10 taxa found in the pre-drill survey (Table 5) and 8 taxa in the post wellsite activity survey (Table 6). This is substantially lower than the median taxa richness of 20 taxa for sites at a similar altitude in lowland coastal streams (Table 4). The macroinvertebrate community was characterised by one taxon, the 'moderately sensitive' mayfly *Zephlebia* group in the pre-drill survey (Table 5). The post wellsite activity survey macroinvertebrate community was characterised by only a different taxon, the 'tolerant snail' *Potamopyrgus* (Table 6).

The pre-drill survey recorded a MCI score of 120 (Table 5), which categorises the site as having 'very good' ecological health (Table 3). This is significantly higher than the maximum previously recorded score for a lowland coastal stream at similar altitude (maximum recorded MCI score 100 units; Table 4) and is the highest recorded MCI score for a Taranaki lowland coastal stream at similar altitude. It is also the highest MCI score recorded in either survey. The post wellsite activity survey recorded a MCI score of 100 units (Table 6), categorising the site as having 'good' macroinvertebrate community health (Table 3). This is significantly higher (Stark 1998) than the median score for these streams (median MCI 78; units, Table 4), but is significantly lower (Stark 1998) than the score recorded in the pre-drill survey.

The recorded SQMCI_s score at this site was 6.2 units during the pre-drill survey (Table 5), equal to the maximum previously recorded SQMCI_s score for lowland coastal streams at similar altitude and significantly higher than the median (median SQMCI_s score 4.0 units; Table 4). The post wellsite activity SQMCI_s score was 4.7 (Table 6), significantly lower (Stark 1998) than at the time of the pre-drill survey, but similar to the median score for Taranaki lowland coastal streams at this altitude (Table 4).

The pre-drill survey recorded six EPT taxa, and a percentage of EPT taxa of 60%. The post wellsite activity survey recorded two EPT taxa, and a percentage of EPT taxa of 25%.

Site 3

A moderately low macroinvertebrate taxonomic richness of 15 taxa was recorded at the time of the pre-drill survey at site 3 (Table 5). The macroinvertebrate community was characterised by two abundant taxa, the 'moderately sensitive' mayfly *Zephlebia* group and the 'tolerant' snail *Potamopyrgus* (Table 5). The post wellsite activity survey recorded a moderate taxa richness of 20 taxa, with three characteristic taxa, one 'highly sensitive' mayfly (*Deleatidium*) and two 'moderately sensitive' mayflies (*Coloburiscus* and *Zephlebia* group) (Table 6).

The pre-drill survey recorded a MCI score of 91 (Table 5), categorising the site as having 'fair' macroinvertebrate community health (Table 3). The post wellsite activity survey recorded a MCI score of 118 (Table 6), significantly higher (Stark 1998) than the pre-drill survey. This score categorises the site as having 'good' macroinvertebrate community health at this time (Table 3). Both scores are significantly higher (Stark 1998) than the median score for Taranaki lowland coastal streams at similar altitude (median MCI score 78 units; Table 4).

The SQMCI_s score recorded in the pre-drill survey was 5.1 units (Table 5), while the post wellsite activity survey recorded a score of 6.5 units (Table 6). This shows a significant improvement (Stark 1998) between the pre-drill and post wellsite activity surveys. Both scores are significantly higher than the median score for similar sites in Taranaki lowland coastal streams at a similar altitude (median SQMCI_s score 4.0; Table 4).

The pre-drill survey recorded six EPT taxa, and a percentage of EPT taxa of 40%. The post wellsite activity survey recorded ten EPT taxa and a percentage of EPT taxa of 50%.

Discussion and conclusions

The Council's "kick-sampling" technique was used to collect samples from three sites in the two unnamed tributaries of the Waiiau Stream on two occasions. This has provided data to assess the impact of the stormwater discharge to land and water from the Mangahewa-C wellsite on the macroinvertebrate communities of the tributaries. Samples were processed to provide taxa richness, MCI and SQMCI_s scores for each site.

Taxa richness is a valuable macroinvertebrate community metric when determining whether a community has been exposed to a toxic discharge, as macroinvertebrates will either drift downstream to avoid the discharge or may be killed. This would result in reduced taxa richness at the downstream sites. In contrast, the MCI and SQMCI_s scores are a measure of community tolerance to organic pollution, although they can also provide an indication of more subtle influences caused by a poor quality discharge. As the SQMCI_s score takes into

account relative abundances of the taxa found in the sample, it provides additional insight to that provided by the MCI score. However, it is also easily influenced by the 'patchiness' of invertebrates on the stream bed, and as such must be considered in the context of all three metrics.

Taxa richnesses showed a wide variation between sites and sampling occasions. On both occasions, sites 1 and 3 (which are situated in the same unnamed tributary of the Waiau Stream) had higher taxa richnesses than site 2 (situated in a smaller unnamed tributary of the Waiau Stream). At site 1, taxa richness more than doubled from 14 to 29 taxa between the pre-drill and post wellsite activity surveys. At site 3, taxa richness increased slightly from 15 to 20 taxa, while site 2 showed a slight decrease from 10 to 8 taxa. The reduced richness at site 2 compared to sites 1 and 3 is likely to be due to the smaller size of this tributary, causing it to be more strongly affected by periods of low flow primarily through habitat limitation. At the time of the post wellsite activity there was extremely low flow in this tributary, which had a very small amount of flow between pools. Under these conditions, organisms are more likely to experience extremes of variables such as water temperature, conductivity and dissolved oxygen levels. There is also less dilution of any discharges that may occur. Therefore organisms which cannot tolerate these conditions may die or deliberately drift downstream to avoid the unfavourable conditions (catastrophic drift), thus reducing taxa richness. The low flow conditions also reduce the area of habitat available, directly impacting the organisms present. This is further supported by the changes in EPT (Ephemeroptera, Plecoptera, and Trichoptera) taxa richness and percentage of EPT taxa at site 2 between the two surveys. EPT taxa (mayflies, stoneflies and caddisflies) are widely known to be sensitive to environmental conditions including dissolved oxygen levels. The decrease in EPT taxa richness from 6 taxa to 2 taxa and percentage of EPT taxa from 60% to 25% between the pre-drill and post wellsite activity surveys respectively (Table 4 and 5) further supports any changes being related to the extremely low flow conditions experienced at the time of the post wellsite activity survey.

The pre-drill survey found MCI scores of 103, 120 and 91 at sites 1-3 respectively, while the post wellsite activity survey recorded scores of 109, 100 and 118 at these sites. At the time of the pre-drill survey, site 2 had a significantly higher MCI score than sites 1 and 3, and site 3 had a significantly lower MCI score than sites 1 and 2. In contrast the post wellsite activity survey found that the MCI score at site 1 was not significantly different from either site 2 or site 3, but site 2 had a significantly lower MCI score than site 3. Site 1 had similar MCI scores on both survey occasions, while site 2 had a significant decrease in MCI score between the two surveys, and site 3 had a significant increase in MCI score between the two surveys. These results indicate that any stormwater discharges are not having a significant adverse effect on the macroinvertebrate communities of the two unnamed tributaries of the Waiau Stream. A decrease in MCI at both sites 2 and 3 would indicate that discharges from the Mangahewa-C are having an adverse impact on the macroinvertebrate communities of the two tributaries of the Waiau Stream. The increase in MCI score at site 3 shows that this is not the case, and the decrease in MCI score at site 2 between these two surveys provides further evidence that differences in macroinvertebrate communities between sites and between the two surveys is due to habitat differences caused by the very low flow conditions at the time of the post wellsite activity survey. Furthermore, all recorded MCI scores were higher than the median MCI, and all samples except one equaled or exceeded the highest previously recorded MCI score, for lowland coastal streams at similar altitude.

SQMCI_s scores in the pre-drill survey were 6.7, 6.2 and 5.1, and in the post wellsite activity survey were 6.7, 4.7 and 6.5 for sites 1-3 respectively. These scores are all higher than the

median SQMCI_s score, and four of these scores equaled or exceeded the highest previously recorded SQMCI_s score, for lowland coastal streams at similar altitude. This and the similar results for MCI indicate that these two unnamed tributaries of the Waiau Stream have good macroinvertebrate community health.

These results show the two unnamed tributaries of the Waiau Stream sampled in relation to the Mangahewa-C wellsite have good macroinvertebrate community health for Taranaki lowland coastal streams. Taken together, the changes in macroinvertebrate community metrics show that any changes in macroinvertebrate communities between the pre-drill and post wellsite surveys are most likely to be the effect of extremely low flow conditions at the time of the post wellsite activity survey, and are most likely unrelated to any stormwater discharges from the Mangahewa-C wellsite.

Summary

Two macroinvertebrate surveys were carried out at three sites in two unnamed tributaries of the Waiau Stream, near the Mangahewa-C wellsite prior to and following drilling and hydraulic fracturing activities, to determine if stormwater discharges from the wellsite had significant adverse effects on the stream macroinvertebrate communities. These surveys recorded high MCI and SQMCI_s scores for lowland coastal streams at similar altitude.

Taxa richness varied widely between the two surveys, with substantial increases at sites 1 and 3, and a decrease at site 2. There was also a significant decrease in MCI and SQMCI_s scores at site 2, but no concurrent reductions at sites 1 and 3. These changes were found to be due to the extremely low flow conditions at the time of the post wellsite activity survey. There was no evidence that the stormwater discharges from the Mangahewa-C wellsite caused any significant adverse effects on the macroinvertebrate communities of these two unnamed tributaries of the Waiau Stream.

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