Todd Energy Limited Mangahewa-C Hydraulic Fracturing Monitoring Programme

Annual Report

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Executive summary

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 July to October 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-11 and Mangahewa-15 wells. The discharges are authorised by Consent 7971-2.

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

The programme of monitoring implemented by the Council in relation to these hydraulic fracturing activities spanned the 2016-2017 and 2017-2018 monitoring years. Monitoring included a mixture of groundwater, surface water and discharge monitoring components. This is the fifth monitoring report produced by the Council in relation to the hydraulic fracturing activities at the Mangahewa-C wellsite. The four previous reports covered hydraulic fracturing activities spanning July 2011 to June 2016.

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 consent over the reporting period.

For reference, in the 2016-2017 year, consent holders were found to achieve a high level of environmental performance and compliance for 74% of the consents monitored through the Taranaki tailored monitoring programmes, while for another 21% of the consents, a good level of environmental performance and compliance was achieved.

In terms of overall environmental and compliance performance by the consent holder over the last several years, this report shows that the consent holder's performance remains at a high level.

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

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1.1 Compliance monitoring programme reports and the Resource Management Act 1991

1.1.1 Introduction

This report outlines and discusses the results of the monitoring programme implemented by the Taranaki Regional Council (the Council) in relation to the programme of hydraulic fracturing undertaken by Todd Energy Limited (Todd) at their Mangahewa–C wellsite, over the period July to October 2016. The report also assesses Todd's level of environmental performance and compliance with the resource consent held in relation to the activity.

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1.1.2 Structure of this report

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

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

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

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

Section 4 presents recommendations to be implemented for the future monitoring of any hydraulic fracturing activities at the Mangahewa-C wellsite.

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

1.1.3 The Resource Management Act 1991 and monitoring

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

a. the neighbourhood or the wider community around an activity, and may include cultural and social-economic effects;

b. physical effects on the locality, including landscape, amenity and visual effects;

c. ecosystems, including effects on plants, animals, or habitats, whether aquatic or terrestrial;

d. natural and physical resources having special significance (for example recreational, cultural, or aesthetic); and

e. risks to the neighbourhood or environment.

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

1.1.4 Evaluation of environmental and administrative performance

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

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

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

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

Environmental Performance

High: No or inconsequential (short-term duration, less than minor in severity) breaches of consent or regional plan parameters resulting from the activity; no adverse effects of significance noted or likely in the receiving environment. The Council did not record any verified unauthorised incidents involving 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 2016-2017 year, consent holders were found to achieve a high level of environmental performance and compliance for 74% of the consents monitored through the Taranaki tailored monitoring programmes, while for another 21% of the consents, a good level of environmental performance and compliance was achieved.

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).

1.2.1.1 Gel fracturing

Gel fracturing utilises cross-linked gel solutions, which are liquid at the surface but, when mixed, form long-chain polymer bonds and thus become viscous gels. These gels are used to transport the proppant into the

formation. Once in the formation they 'break' back with time, temperature and the aid of gel breaking chemicals into a liquid state and are flowed back to surface, without disturbing the proppant which remains in place and enhances the flow of hydrocarbons back to the surface.

1.2.1.2 Slick water fracturing

Slick water fracturing utilises water based fracturing fluids with friction-reducing additives. The addition of the friction reducers allows the fracturing fluids and proppant to be pumped to the target zone at higher rates and reduced pressures, than when using water alone. The higher rate creates turbulence within the fluid column holding the proppant and enabling its placement into the open fractures and enhancing the flow of hydrocarbons back to the surface. [1]

1.2.1.3 Nitrogen gas fracturing

Nitrogen gas assisted fracturing involves replacing some of the fluid used in the fracturing process with nitrogen gas, which can fracture rock at high pressures much like water. While nitrogen (N^2) is a gas at room temperature, it can be maintained in a liquid state through cooling and pressurisation. Nitrogen assisted 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. [2] More indirectly, a reduction in the volume of water used also reduces the total concentration of chemical additives required and the volume of water returning to the surface that requires subsequent disposal[2].

1.2.2 The Mangahewa-C wellsite and hydraulic fracturing activities

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

Table 1 Summary of hydraulic fracturing details

Well	Fracturing date		Range mid-point injection zones (m TVD)	Formation
	Start	End		
Mangahewa-11	17/11/16	24/11/16	3,436 to 4,562	Kapuni Group
Mangahewa-15	28/11/16	22/12/16	3,586 to 5,414	Kapuni Group

[1] *http://geology.com/energy/hydraulic-fracturing-fluids/*

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

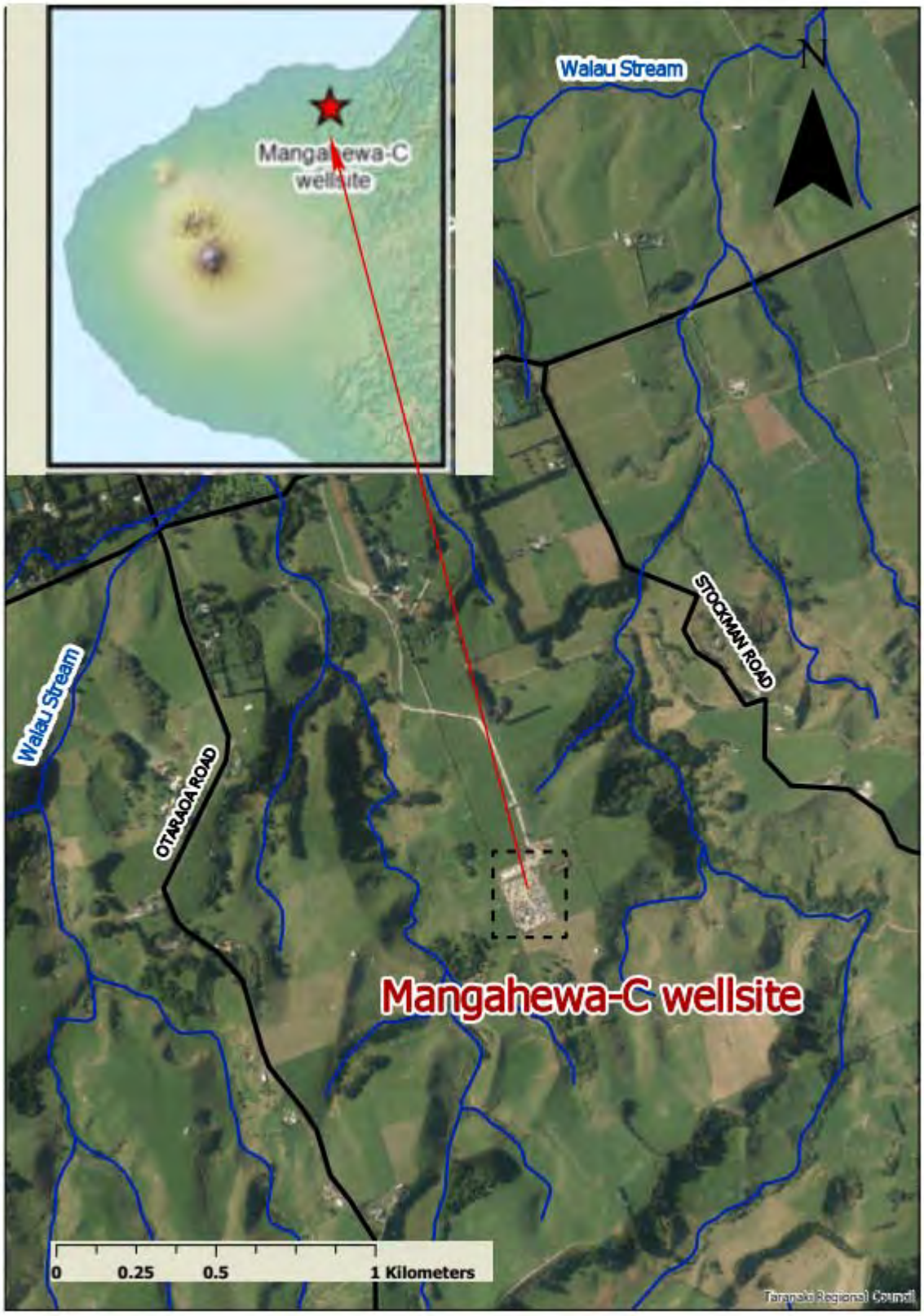

Figure 1 Location map

1.3 Resource consents

1.3.1 Discharges of wastes to land

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

Todd holds discharge permit **7971-2** to cover hydraulic fracturing activities at the Mangahewa-C wellsite. This permit was issued by the Council on 30 June 2014 under Section 87(e) of the RMA. It is due to expire on 1 June 2024.

The consent 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.

This summary of consent conditions may not reflect the full requirements of each condition. The consent conditions in full can be found in the resource consent which is appended to this report (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 for the Mangahewa-C wellsite consisted of four primary components.

1.4.2 Programme liaison and management

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

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

1.4.3 Assessment of data submitted by the consent holder

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

1.4.4 Physiochemical sampling

1.4.4.1 Groundwater

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 in 2013, one of the original sites (GND2258) was replaced with the water supply bore GND2360 (Table 2). 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.

Table 2 Details of groundwater sites included in the monitoring programme

Monitoring site	Distance from wellsite (m)	Total depth (m)	Screened/open interval (m)	Aquifer
GND2254	1,161	37	unknown	Volcanics
GND2255	1,158	4	unknown	Volcanics
GND2256	595	2.4	0-2.4	Volcanics
GND2257	960	5	unknown	Volcanics
GND2360	60	533	Open from 149 m	Matemateaonga

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.

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 31 October 2016 and 31 January 2017 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 and uncontaminated site water were discharged from a skimmer pit into an unnamed tributary of the Waiau Stream (Figure 3).

Table 3 Biomonitoring site details

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

Figure 2 Groundwater monitoring sites

Figure 3 Surface water monitoring sites

2 Results

2.1 Consent holder submitted data

2.1.1 Mangahewa-11 post-fracturing discharge report

The conclusions from the Mangahewa-11 post-fracturing discharge report are summarised as follows:

- A total of five discrete zones were fractured over the period 17 November to 24 November 2016 at depths between 3,435 to 4,562 m TVD.
- A total of 13,144 bbls (2,090 m^3) of liquid was discharged across the five fractured zones. The total proppant weight was 169 tonnes (371,791 lbs).
- By volume, 95.3% of the fluid injected over all five intervals was water, 2.5% was proppant with the remaining 2.1% comprised of chemical additives.
- The Mangahewa-11 well was opened for flow-back following the completion of fracturing operations. In total, 25,628 bbls (4,075 m^3) of fluid was returned from the well over the initial flow-back (clean-up) period.
- The initial flow-back comprised of two separate depth interval flow-backs, 4,033 to 4,096 m TVD and 4,200 to 4,572 m TVD, with both intervals returning more fluid than injected.
- The volume of fluid returned during the initial flow-back (clean-up) was 12,484 bbls (1,985 m^3) greater than the volume of fluid injected.
- Approximately 157 tonnes (346,111 lbs) or 93.1% of proppant remained within the formation after the completion of flow back.
- One screen out occurred while fracturing. Pressure was relieved at the surface and no indication of fluid loss to the annulus was present.
- All return fluid from the Mangahewa-11 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-15 post-fracturing discharge report

The conclusions from the Mangahewa-15 post-fracturing discharge report are summarised as follows:

- A total of eight discrete zones were fractured over nine events during the period 28 November to 22 December 2016, at depths between 3,586 to 4,105 m TVD.
- A total of 18,023 bbls (2,865 m^3) of liquid was discharged across the eight fractured zones. The total proppant weight was 191 tonnes (420,285 lbs).
- By volume, 95.1% of the fluid injected into the upper intervals was water and 1.9% was proppant with the remaining 3.3% comprised of chemical additives.
- By volume, 95.0% of the fluid injected into the lower intervals was water and 2.7% was proppant with the remaining 2.4% comprised of chemical additives.

- The Mangahewa-15 well was opened for flow-back following the completion of fracturing operations. In total, 34,050 bbls (5,514 m^3) of fluid was returned from the well over the three separate flow-back events.
- In total 16,027 bbls more fluid was returned than injected over the eight injection zones.
- Approximately 172 tonnes (380,000 lbs) or 90.4% of proppant remained within the formation after completion of flow back.
- One screen out occurred while fracturing. In response the pressure injection rate was decreased as the pressure increased and injection ceased when the maximum allowable pressure was reached. The discharge point remained at the targeted interval and pressure was relieved at the surface.
- All return fluid from the Mangahewa-15 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 Physiochemical sampling

2.2.1 Groundwater

The hydraulic fracturing activities commenced at the Mangahewa-C wellsite on 17 November 2016 and continued over several weeks until 22 December 2016. Pre-fracturing sampling was undertaken on 21 August 2016. A three month post-fracturing sample was undertaken on 22 February 2017 and a one year post-fracturing sampling was undertaken on 22 November 2017.

The results of the laboratory analysis of samples indicate there have been no significant changes in groundwater composition over the reporting period.

Trace toluene was recorded in the baseline sample taken at GND2360, which is located around 60 m from the wellsite. Trace values can sometimes be attributable to lab margins of error and subsequent samples reported concentrations within expected ranges. Slightly higher levels of conductivity and concentrations of chloride and sodium were recorded in the baseline sample than in subsequent samples. Likely a result of the sampling point utilised to take the sample, which was an onsite storage tank, susceptible to evaporation and other external influences, rather than from the bore itself.

Low concentrations of methane were detected in all samples taken at GND2254 and GND2360 therefore samples were sent to GNS for further analysis. Isotopic analysis of the dissolved methane within the samples analysed indicates that the methane gas is biogenic and were all within the expected ranges for shallow groundwater across Taranaki.

Biogenic methane is produced by the biological breakdown of organic matter in shallow formations and is distinct from thermogenic methane which is produced under high pressures and temperatures in deep hydrocarbon bearing formations.

All samples, with a few minor exceptions discussed above, 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.

A summary of the results for groundwater samples taken in relation to the hydraulic fracturing activities compared to baseline is included in Table 4 and Table 5. The certificates of analysis for the review period are included in Appendix II.

Table 4 Results of groundwater sampling carried out at GND2254, GND2255 and GND2256 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	-	17/04/2012	21/07/2016	22/02/2017	27/11/2017	17/04/2012	21/07/2016	22/02/2017	27/11/2017	17/04/2012	21/07/2016	22/02/2017	27/11/2017
Lab number	TRC	TRC121416	TRC162531	TRC171199	TRC174386	TRC121417	TRC162532	TRC171200	TRC174387	TRC121418	TRC162533	TRC171201	TRC174388
Conductivity	mS/m	27.5	27.4	27.1	27.6	13.0	13.7	14.0	13.3	15.4	18.0	16.5	16.8
pH	pH	8.1	7.9	7.8	8	6.4	6.1	6.6	6.1	6.4	6.1	6.4	6.2
Total alkalinity	g/m^3 $CaCO_3$	132	123	119	119	20	20	21	20	20	21	20	22
Bicarbonate	g/m^3 HCO_3	161	149	144	144	24	25	25	25	24	26	25	27
Total hardness	g/m^3 $CaCO_3$	104	105	95	98	31	30	28	28	39	45	38	38
Calcium	g/m^3	25	25	23	24	6.5	6.5	6.2	6.1	8.6	10.3	8.6	8.7
Chloride	g/m^3	14.4	13.8	12.8	13	24	23	21	22	21	23	20	21
Magnesium	g/m^3	10.5	10.2	9.4	9.2	3.7	3.2	3.1	3.1	4.2	4.7	4.1	3.9
Potassium	g/m^3	2.3	2.5	2.2	2.4	3.5	3.6	3.3	3.2	4.9	5.6	4.7	5.4
Sodium	g/m^3	21	16.2	15.5	16.2	12.6	12.5	12.2	10.3	12.7	12.8	11.4	10.2
Total dissolved solids	g/m^3	181	171	183	158	90	90	101	85	117	127	121	115
Nitrate & nitrite nitrogen	g/m^3 N	0.005	< 0.002	0.003	< 0.002	1.22	1.47	1.52	1.21	4.8	6.1	5.4	4.3
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	0.003	< 0.002	1.22	1.47	1.52	1.21	4.8	6.1	5.4	4.3
Sulphate	g/m^3	<0.5	< 0.5	< 0.5	< 0.5	3.1	3.4	3.5	3.3	4.1	3.9	4.3	4
Barium	mg/kg	0.0146	0.0150	0.0138	0.0143	0.0430	0.0450	0.0420	0.0410	0.0540	0.0690	0.0570	0.0640
Dissolved bromine	g/m^3	0.070	0.046	0.041	0.070	0.100	0.075	0.071	0.110	0.100	0.085	0.072	0.110
Bromide	g/m^3	-	-	-	-	-	-	-	-	-	-	-	-
Dissolved copper	g/m^3	<0.0005	< 0.0005	< 0.0005	< 0.0005	0.0072	0.028	0.129	0.0095	0.0007	< 0.0005	0.0006	< 0.0005

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	-	17/04/2012	21/07/2016	22/02/2017	27/11/2017	17/04/2012	21/07/2016	22/02/2017	27/11/2017	17/04/2012	21/07/2016	22/02/2017	27/11/2017
Lab number	TRC	TRC121416	TRC162531	TRC171199	TRC174386	TRC121417	TRC162532	TRC171200	TRC174387	TRC121418	TRC162533	TRC171201	TRC174388
Dissolved iron	g/m^3	0.32	0.32	0.21	0.3	<0.02	0.07	< 0.02	0.07	<0.02	< 0.02	< 0.02	0.03
Dissolved manganese	g/m^3	0.024	0.030	0.029	0.033	0.003	0.003	0.002	0.004	0.002	0.003	0.005	0.013
Dissolved mercury	g/m^3	-	< 0.00008	< 0.00008	< 0.00008	-	< 0.00008	< 0.00008	< 0.00008	-	< 0.00008	< 0.00008	< 0.00008
Nickel	mg/kg	<0.0005	0.0013	0.0073	< 0.0005	<0.0005	< 0.0005	0.0011	< 0.0005	<0.0005	< 0.0005	< 0.0005	< 0.0005
Dissolved zinc	g/m^3	0.001	0.021	0.024	< 0.001	0.011	0.026	0.230	0.011	0.015	0.021	0.046	0.004
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
Methane	g/m^3	1.54	2.50	1.60	2.40	<0.002	< 0.002	< 0.002	< 0.002	<0.002	0.002	< 0.002	0.008
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	< 0.003	< 0.003	<0.004	< 0.004	< 0.003	< 0.003	<0.0010	< 0.004	< 0.003	< 0.003
Methanol	g/m^3	<2	< 20	< 2	< 2	<2	< 2	< 2	< 2	<2	< 2	< 2	< 2
Ethylene glycol	g/m^3	<4	< 20	< 4	< 4	<4	< 4	< 4	< 4	<4	< 4	< 4	< 4
Propylene glycol	g/m^3	-	< 20	< 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
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
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
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
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
δ13C value*	‰ (-)	-	75.1	-	76.6	-	-	-	-	-	-	-	-

Table 5 Results of groundwater sampling carried out at GND2257 and GND2360 in relation to the Mangahewa-C fracturing event compared to baseline

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	21/07/2016	22/02/2017	27/11/2017	21/10/2013	21/07/2016	22/02/2017	27/11/2017
Lab number	TRC	TRC121419	TRC162534	TRC171202	TRC174389	TRC137897	TRC162535	TRC171203	TRC174390
Conductivity	mS/m	16.1	16.4	16.7	16.5	145.9	39.8	43.1	40.6
pH	pH	6.3	6.1	6.5	6.3	9	9.4	9.1	9.4
Total alkalinity	g/m^3 $CaCO_3$	24	28	29	27	185	160	175	170
Bicarbonate	g/m^3 HCO_3	29	35	35	33	226	159	190	167
Total hardness	g/m^3 $CaCO_3$	39	38	37	38	41	8.2	5.1	5.2
Calcium	g/m^3	8.1	8.0	7.7	7.9	10.2	2.3	1.4	1.5
Chloride	g/m^3	22	21	20	19	350	28	30	23
Magnesium	g/m^3	4.6	4.4	4.4	4.4	3.9	0.61	0.4	0.37
Potassium	g/m^3	2.20	2.10	1.78	2.00	1.36	0.89	0.73	0.71
Sodium	g/m^3	15.5	16.3	15.0	14.9	250.0	95.0	96.0	79.0
Total dissolved solids	g/m^3	118	115	118	120	770	220	250	240
Nitrate & nitrite nitrogen	g/m^3 N	4.5	3.3	4.0	3.9	<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	3.3	4.0	3.9	<0.002	< 0.002	< 0.002	< 0.002
Sulphate	g/m^3	4.4	4.0	4.5	4.4	1.9	2.8	2.2	1.8
Barium	mg/kg	0.0143	0.0168	0.0156	0.0131	0.0250	0.0075	0.0026	0.0029
Dissolved bromine	g/m^3	0.100	0.070	0.063	0.100	-	0.090	0.085	0.100
Bromide	g/m^3	-	-	-	-	1.13	-	-	-
Dissolved copper	g/m^3	0.0125	0.0230	0.0220	0.0086	<0.0005	< 0.0005	< 0.0005	< 0.0005
Dissolved iron	g/m^3	1.82	0.15	0.06	< 0.02	0.14	0.04	0.04	0.03
Dissolved manganese	g/m^3	0.0199	0.0134	0.0047	0.0012	0.0081	0.0033	0.002	0.0024

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
Dissolved mercury	g/m³		< 0.00008	< 0.00008	< 0.00008	<0.00008	< 0.00008	< 0.00008	< 0.00008
Nickel	mg/kg	<0.0005	0.0029	< 0.0005	0.0045	<0.0005	< 0.0005	< 0.0005	< 0.0005
Dissolved zinc	g/m³	0.047	0.134	0.08	0.024	0.0055	0.09	0.0107	0.025
Formaldehyde	g/m³	<0.02	< 0.02	< 0.02	< 0.02	<0.02	< 0.02	< 0.02	< 0.02
Methane	g/m³	<0.002	< 0.002	< 0.002	< 0.002	<11.6	1.83	0.44	1.63
Ethane	g/m³	<0.003	< 0.003	< 0.003	< 0.003	<0.017	0.006	< 0.003	0.005
Ethylene	g/m³	<0.004	< 0.004	< 0.003	< 0.003	<0.003	< 0.004	< 0.003	< 0.003
Methanol	g/m³	<2	< 2	< 2	< 2	<2	< 20	< 2	< 2
Ethylene glycol	g/m³	<4	< 4	< 4	< 4	<4	< 20	< 4	< 4
Propylene glycol	g/m³	-	< 4	< 4	< 4	<4	< 20	< 4	< 4
Hydrocarbons	g/m³	<0.7	< 0.7	< 0.7	< 0.7	<0.7	< 0.7	< 0.7	< 0.7
Benzene	g/m³	<0.0010	< 0.0010	< 0.0010	< 0.0010	<0.0010	< 0.0010	< 0.0010	< 0.0010
Toluene	g/m³	<0.0010	< 0.0010	< 0.0010	< 0.0010	0.001	< 0.0010	< 0.0010	< 0.0010
Ethylbenzene	g/m³	<0.0010	< 0.0010	< 0.0010	< 0.0010	<0.0010	< 0.0010	< 0.0010	< 0.0010
o-Xylene	g/m³	<0.001	< 0.0010	< 0.0010	< 0.0010	<0.0010	< 0.0010	< 0.0010	< 0.0010
m-Xylene	g/m³	<0.002	< 0.002	< 0.002	< 0.002	<0.002	< 0.002	< 0.002	< 0.002
δ13C value*	‰ (-)	-	-	-	-	-	63.6	-	62.9

* A value >-50‰ indicates thermogenic methane, a value <-50‰ indicates biogenic methane.

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-11 and Mangahewa-15 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	GND2271	GND2375
Injection well	-	Mangahewa-11	Mangahewa-15
Lab number	-	TRC170784	TRC171207
Sample date	-	21 Nov 2016	21 Dec 2016
Methanol	g/m^3	< 2	< 2
Benzene	g/m^3	0.0081	0.0100
Ethylbenzene	g/m^3	0.0017	0.0024
Ethylene glycol	g/m^3	7	< 4
Toluene	g/m^3	0.029	0.038
M & p-Xylene	g/m^3	0.010	0.016
o-Xylene	g/m^3	0.0024	0.0031
C7 - C9	g/m^3	0.80	0.65
C10 - C14	g/m^3	105	58
C15 - C36	g/m^3	188	112
Total hydrocarbons	g/m^3	290	171
Propylene glycol	g/m^3	25	16

The results of the analyses carried out on the return fluid samples obtained following the hydraulic fracturing of the Mangahewa-11 and Mangahewa-15 wells are summarised 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	GND2271	GND2375
Location	-	Mangahewa-11	Mangahewa-15
Sample	-	TRC170785	TRC171208
Collected	-	04 Dec 2016	18 Jan 2017
Time	-	07:02	11:25
Conductivity	g/m^3	2,620	4,190
pH	pH units	8.0	7.6
Total alkalinity	g/m^3 $CaCO_3$	4,300	2,800
Total hardness	g/m^3 $CaCO_3$	280	260
Bicarbonate	g/m^3 HCO_3	4,930	3,140
Calcium	g/m^3	94	90
Dissolved calcium	g/m^3	96	86
Chloride	g/m^3	6,900	13,500
Dissolved magnesium	g/m^3	10	11
Total potassium	g/m^3	1,330	3,500
Total sodium	g/m^3	5,700	7,400
Total dissolved solids	g/m^3	15,500	25,000
Nitrate & nitrite nitrogen	g/m^3	53	< 0.2
Nitrite nitrogen	g/m^3	< 0.2	< 0.2
Nitrate nitrogen	g/m^3	240	< 0.90
Sulphate	g/m^3	199	47
Total sulphur	g/m^3	67	16
Total barium	g/m^3	44	197
Total bromine	g/m^3	37	21
Total copper	g/m^3	0.0013	0.0100
Total iron	g/m^3	0.93	3.50
Total manganese	g/m^3	11	11
Total mercury	g/m^3	< 0.00008	0.00015
Total nickel	g/m^3	0.020	0.019
Total zinc	g/m^3	0.036	0.191
Formaldehyde	g/m^3	< 0.02	0.08
Methanol	g/m^3	< 2	< 2
Ethylene glycol	g/m^3	< 4	< 4
Propylene glycol	g/m^3	< 4	< 4
C7-C9	g/m^3	3	101
C10 - C14	g/m^3	32	230

Parameter	Unit	GND2271	GND2375
Location	-	Mangahewa-11	Mangahewa-15
Sample	-	TRC170785	TRC171208
Collected	-	04 Dec 2016	18 Jan 2017
Time	-	07:02	11:25
C15-C36	g/m^3	71	181
Total hydrocarbons	g/m^3	106	510
Benzene	g/m^3	1.4	21.0
Toluene	g/m^3	0.7	71.0
Ethylbenzene	g/m^3	0.07	8.90
M & p-Xylene	g/m^3	0.4	54.0
o-Xylene	g/m^3	0.2	18.7

2.3 Biomonitoring surveys

The Council's standard 'kick-sampling' technique was used at three established sites to collect streambed macroinvertebrates from an unnamed tributary of the Waiau Stream. Samples were processed to provide number of taxa (richness), MCI and $SQMCI_S$ scores for each site.

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

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

Invertebrate metrics at sites 1 and 3 (in the larger unnamed tributary of the Waiau Stream) were relatively similar between sites and between surveys. In contrast, site 2 (in the smaller tributary receiving the wellsite discharges) showed an increase in all three metrics between the pre-HF and post-HF surveys, with the taxa richness and MCI in the post-HF survey similar to those observed at sites 1 and 3. This change is likely a result of sustained higher than usual flow conditions in the period between the two surveys. There was no evidence that the stormwater discharges from the Mangahewa-C wellsite have caused any recent significant adverse effects on the macroinvertebrate communities of these two unnamed tributaries of the Waiau Stream.

Overall, the results of both surveys recorded high MCI and $SQMCI_s$ scores indicating that both unnamed tributaries of the Waiau Stream have good macroinvertebrate community health when compared with other lowland coastal streams at similar altitudes in Taranaki. The biomonitoring report is appended to this report as Appendix IV.

2.4 Investigations, interventions, and incidents

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

The Council operates and maintains a register of all complaints or reported and discovered excursions from acceptable limits and practices, including non-compliance with consents, which may damage the environment. The incident register includes events where the 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 period under review, the Council was not required to undertake significant additional investigations and interventions, or record incidents, in association with Todd's conditions in resource consent or provisions in Regional Plans.

3 Discussion

3.1 Environmental effects of exercise of consents

The Mangahewa-11 and Mangahewa-15 wells were stimulated by hydraulic fracturing between November and December 2016. The wells are located at the Mangahewa-C wellsite.

The monitoring programme carried out by the Council in relation to the fracturing events undertaken included both groundwater and surface water monitoring components. The groundwater monitoring component incorporated pre and post-fracturing sampling at five groundwater monitoring sites in the vicinity of the Mangahewa-C wellsite.

The results of post-fracturing groundwater sampling carried out showed no significant variations in water composition in comparison to pre-fracturing or baseline results. The minor variations in analytes are a result of natural variations in water composition.

Slightly higher levels of conductivity and concentrations of chloride and sodium were noted in the baseline sample of GND2360, likely attributable to the location of the sampling point.

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 year under review is set out in Table 8. An evaluation of environmental performance since 2011 is included in Table 9.

Table 8 Summary of performance for consent 7971-2

Purpose: ***To discharge water based hydraulic fracturing fluids into land at depths greater than 3,290 metres true vertical depth subsea (TVDss) beneath the Mangahewa-C wellsite***		
Condition requirement	**Means of monitoring during period under review**	**Compliance achieved?**
1. Any discharge shall occur below 3,290 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

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?**
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 emailed to consents@trc.govt.nz	Reports received via email	Yes
13. The consent holder shall provide access to a location where samples of hydraulic fracturing fluids and return fluids can be obtained by the Council officers	Access provided	Yes
14. Consent holder to adopt best practicable option at all times	Site inspections, sampling and assessment of consent holder submitted data	Yes
15. No hydrocarbon based hydraulic fracturing fluid shall be discharged	Assessment of consent holder submitted data and sampling of fracturing fluid	Yes
16. Lapse clause	Receive notice of exercise of consent	Yes
17. 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**

N/A = not applicable

Table 9 Evaluation of environmental performance over time

Period	Consent no	High	Good	Improvement required	Poor
2016-2017	7971-2	1			
2015-2017		1			
2014-2016		1			
2013-2015	7971-1 and 7971-2	1			
2011-2013	7971-1	1			
Totals		5			

During the year, Todd demonstrated a high level of environmental and high level of administrative performance with the resource consent as defined in Section 1.1.4. Since 2011 the environmental performance in relation to Consent 7912-1/2 has remained at a high level.

3.3 Recommendations from the previous compliance Report

In the previous compliance report, it was recommended:

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.

These recommendations were implemented.

3.4 Alterations to monitoring programmes of future hydraulic fracturing events

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

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

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

It is proposed that the range of monitoring carried out in relation to the 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.

It should be noted that the proposed programme represents a reasonable and risk-based level of monitoring for the site in question. The Council reserves the right to subsequently adjust the programme

from that initially prepared, should the need arise if potential or actual non-compliance is determined at any time during future monitoring periods.

3.5 Exercise of optional review of consent

Resource consent 7971-2 provides for an optional review of the consent in June 2018. Condition 17 allows the Council to review the consent, for the purpose of:

a. ensuring that the conditions are adequate to deal with any significant adverse effects on the environment arising from the exercise of this consent, which were either not foreseen at the time the application was considered or which it was not appropriate to deal with at the time; and/or

b. further specifying the best practicable option as required by condition 14 and/or

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

Based on the results of monitoring in the year under review, and in previous years as set out in earlier compliance monitoring reports, it is considered that there are no grounds that require a review to be pursued or grounds to exercise the review option.

A recommendation to this effect is presented in Section 4 of this report.

4 Recommendations

1. THAT in the first instance, the range of monitoring carried out during the reporting period in relation to Todd's hydraulic fracturing activities be replicated for any future fracturing events at the Mangahewa-C wellsite.
2. THAT should there be issues with environmental or administrative performance in future periods, monitoring may be adjusted to reflect any additional investigation or intervention as found necessary.
3. THAT the option for a review of resource consents in June 2018, as set out in condition 17 of the consent not be exercised

Glossary of common terms and abbreviations

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

Biomonitoring	Assessing the health of the environment using aquatic organisms.
bbls	Barrel. Unit of measure used in the oil and gas industry (equivalent to approximately 159 litres).
Fresh	Elevated flow in a stream, such as after heavy rainfall.
g/m3	Grams per cubic metre, and equivalent to milligrams per litre (mg/L). In water, this is also equivalent to parts per million (ppm), but the same does not apply to gaseous mixtures.
Incident	An event that is alleged or is found to have occurred that may have actual or potential environmental consequences or may involve non-compliance with a consent or rule in a regional plan. Registration of an incident by the Council does not automatically mean such an outcome had actually occurred.
Intervention	Action/s taken by Council to instruct or direct actions be taken to avoid or reduce the likelihood of an incident occurring.
Investigation	Action taken by Council to establish the circumstances/events surrounding an incident including any allegations of an incident.
L/s	Litres per second.
Macroinvertebrate	An invertebrate that is large enough to be seen without the use of a microscope.
masl	Metres above sea level.
MCI	Macroinvertebrate community index; a numerical indication of the state of biological life in a stream that takes into account the sensitivity of the taxa present to organic pollution in stony habitats.
mS/m	Millisiemens per metre.
m^3	Cubic metre (1,000 litres).
NZTM	New Zealand Transverse Mercator coordinates.
pH	A numerical system for measuring acidity in solutions, with 7 as neutral. Numbers lower than 7 are increasingly acidic and higher than 7 are increasingly alkaline.
Physicochemical	Measurement of both physical properties (e.g. temperature, clarity, density) and chemical determinants (e.g. metals and nutrients) to characterise the state of an environment.
Resource consent	Refer Section 87 of the RMA. Resource consents include land use consents (refer Sections 9 and 13 of the RMA), coastal permits (Sections 12, 14 and 15), water permits (Section 14) and discharge permits (Section 15).
RMA	Resource Management Act 1991 and including all subsequent amendments.
Screen Out	A condition that occurs when the solids carried in a treatment fluid, such as proppant in a fracture fluid, create a bridge across the perforations or similar restricted flow area. This creates a sudden and significant restriction to fluid flow that causes a rapid rise in pump pressure.
SQMCI	Semi quantitative macroinvertebrate community index.
TVDss	True vertical depth sub-sea
Workover	The repair or stimulation of an existing production well for the purpose of restoring, prolonging or enhancing the production of hydrocarbons.

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Todd Energy Limited (2017) Hydraulic Fracturing Todd Mangahewa-C Wellsite Post-Fracturing Discharge Report Mangahewa-11. Doc id.1828892

Todd Energy Limited (2017) Hydraulic Fracturing Todd Mangahewa-C Wellsite Post-Fracturing Discharge Report Mangahewa-15. Doc id. 1828878

Taranaki Regional Council (2015) Mangahewa-C Hydraulic Fracturing Groundwater Monitoring Programme Report 2015-2017. Technical Report 2015-46.

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 consent held by Todd Petroleum Limited

(For a copy of the signed resource consent
please contact the TRC Consents 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}C-CH_4).

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

7. All sampling and analysis shall be undertaken in accordance with a *Sampling and Analysis Plan*, which shall be submitted to the Chief Executive for review and certification before the first sampling is undertaken. The plan shall specify the use of standard protocols recognised to constitute good professional practice including quality control and assurance. An International Accreditation New Zealand (IANZ) accredited laboratory shall be used for all sample analysis. Results shall be provided to the Chief Executive within 30 days of sampling and shall include supporting quality control and assurance information. These results will be used to assess compliance with condition 3.

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

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

9. Any hydraulic fracture discharge shall only occur after the consent holder has provided a comprehensive 'Pre-fracturing discharge report' to the Chief Executive. The report shall be provided at least 14 days before the discharge is proposed to commence and shall detail the hydraulic fracturing programme proposed, including as a minimum:

   (a) the specific well in which each discharge is to occur, the intended fracture interval(s) ('fracture interval' is the discrete subsurface zone to receive a hydraulic fracture treatment), and the duration of the hydraulic fracturing programme;
   (b) the number of discharges proposed and the geographical position (i.e. depth and lateral position) of each intended discharge point;
   (c) the total volume of fracture fluid planned to be pumped down the well, including mini- fracture treatments, and their intended composition, including a list of all contaminants and Material Safety Data Sheets for all the chemicals to be used;
   (d) the monitoring techniques to be used to determine the fate of discharged material;
   (e) the results of the reviews required by condition 14;
   (f) results of modelling showing an assessment of the likely extent and dimensions of the fractures that will be generated by the discharge;
   (g) the preventative and mitigation measures to be in place to ensure the discharge does not cause adverse environmental effects and complies with condition 3;
   (h) the extent and permeability characteristics of the geology above the discharge point to the surface;
   (i) any identified faults within the modeled fracture length plus a margin of 50%, and the potential for adverse environmental effects due to the presence of the identified faults;
   (j) the burst pressure of the well and the anticipated maximum well and discharge pressures and the duration of the pressures; and
   (k) details of the disposal of any returned fluids, including any consents that are relied on to authorise the disposal; and
   (l) details why the contaminants in the discharge and the monitoring techniques used comply with condition 14.

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

10. The consent holder shall notify the Taranaki Regional Council of the date that each discharge is intended to commence by emailing worknotification@trc.govt.nz. Notification also shall identify the 'Pre-fracturing discharge report', required by condition 9, which details the discharge and be given no less than 3 days before the intended discharge date. If any discharge occurs more than 30 days after the notification date, additional notification as specified in this condition is required.

11. Within 90 days of any commencement date as advised under condition 10, the consent holder shall submit a comprehensive 'Post-fracturing discharge report' to the Chief Executive. The report shall, as a minimum, contain:

    (a) date and time of discharge;
    (b) confirmation of the interval(s) where fracturing occurred for that programme, and the geographical position (i.e. depth and lateral position) of the discharge point for each fracture interval;
    (c) the contaminant volumes and composition of fluid discharged into each fracture interval;
    (d) the volume of return fluids from each fracture interval;
    (e) an analysis for the constituents set out in conditions 6(a) to 6(k), in a return fluid sample taken within the first two hours of flow back, for each fracture interval if flowed back individually, or for the well if flowed back with all intervals comingled;
    (f) an estimate of the volume of fluids (and proppant) remaining underground;
    (g) the volume of water produced with the hydrocarbons (produced water) over the period beginning at the start of the hydraulic fracturing programme and ending 50 days after the programme is completed or after that period of production;
    (h) an assessment of the extent and dimensions of the fractures that were generated by the discharge, based on modelling undertaken after the discharge has occurred and other diagnostic techniques, including production analysis, available to determine fracture length, height and containment;
    (i) the results of pressure testing required by condition 8, and the top hole pressure (psi), slurry rate (bpm), surface proppant concentration (lb/gal), bottom hole proppant concentration (lb/gal), and calculated bottom hole pressure (psi), as well as predicted values for each of these parameters; prior to, during and after each hydraulic fracture treatment;
    (j) details of the disposal of any returned fluids, including any consents that are relied on to authorise the disposal;
    (k) details of any incidents where hydraulic fracture fluid is unable to pass through the well perforations (screen outs) that occurred, their likely cause and implications for compliance with conditions 1 and 3; and
    (l) results of the monitoring referred to in condition 9 (d);
    (m) an assessment of the effectiveness of the mitigation measures in place with specific reference to those described in the application for this consent.

    Note: *For programs including multiple hydraulic fracturing discharges, more than one 'Post-fracturing discharge report' may be required in order to meet the specified 90 day deadline.*

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

13. The consent holder shall provide access to a location where the Taranaki Regional Council officers can obtain a sample of the hydraulic fracturing fluids and the return fluids.

14. The consent holder shall at all times adopt the best practicable option, as defined in section 2 of the Resource Management Act 1991, to prevent or minimize any actual or likely adverse effect of the activity on the environment by, as a minimum, ensuring that:

    (a) the discharge is contained within the fracture interval;
    (b) regular reviews of monitoring techniques used to ensure the discharge does not cause adverse environmental effects are undertaken;
    (c) regular reviews are undertaken of the preventative and mitigation measures adopted to ensure the discharge does not cause adverse environmental effects; and
    (d) regular reviews of the chemicals used are undertaken with a view to reducing the toxicity of the chemicals used.

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

16. This consent shall lapse on 30 June 2019, unless the consent is given effect to before the end of that period or the Taranaki Regional Council fixes a longer period pursuant to section 125(1)(b) of the Resource Management Act 1991.

17. The Taranaki Regional Council may review any or all of the conditions of this consent by giving notice of review during the month of June each year, for the purposes of:

    (a) ensuring that the conditions are adequate to deal with any significant adverse effects on the environment arising from the exercise of this consent, which were either not foreseen at the time the application was considered or which it was not appropriate to deal with at the time; and/or

    (b) further specifying the best practicable option as required by condition 14; and/or

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

Signed at Stratford on 30 June 2014

For and on behalf of
Taranaki Regional Council

_____

A D McLay
Director - Resource Management

Appendix II

Certificates of analysis (groundwater)

Hill Laboratories
BETTER TESTING BETTER RESULTS

R J Hill Laboratories Limited
1 Clyde Street
Private Bag 3205
Hamilton 3240, New Zealand

Tel +64 7 858 2000
Fax +64 7 858 2001
Email mail@hill-labs.co.nz
Web www.hill-labs.co.nz

ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1619541 SPv1
Contact:	David Olson	**Date Received:**	22-Jul-2016
	C/- Taranaki Regional Council	**Date Reported:**	08-Aug-2016
	Private Bag 713	**Quote No:**	47915
	Stratford 4352	**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/m³ as $CaCO_3$	123	20	21	28	160
Bicarbonate	g/m³ at 25°C	149	25	26	35	159
Total Hardness	g/m³ 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/m³	171	90	127	115	220
Dissolved Barium	g/m³	0.0150	0.045	0.069	0.0168	0.0075
Dissolved Bromine*	g/m³	0.046	0.075	0.085	0.070	0.090
Dissolved Calcium	g/m³	25	6.5	10.3	8.0	2.3
Dissolved Copper	g/m³	< 0.0005	0.028	< 0.0005	0.023	< 0.0005
Dissolved Iron	g/m³	0.32	0.07	< 0.02	0.15	0.04
Dissolved Magnesium	g/m³	10.2	3.2	4.7	4.4	0.61
Dissolved Manganese	g/m³	0.030	0.0034	0.0029	0.0134	0.0033
Dissolved Mercury	g/m³	< 0.00008	< 0.00008	< 0.00008	< 0.00008	< 0.00008
Dissolved Nickel	g/m³	0.0013	< 0.0005	< 0.0005	0.0029	< 0.0005
Dissolved Potassium	g/m³	2.5	3.6	5.6	2.1	0.89
Dissolved Sodium	g/m³	16.2	12.5	12.8	16.3	95
Dissolved Zinc	g/m³	0.021	0.026	0.021	0.134	0.090
Chloride	g/m³	13.8	23	23	21	28
Nitrite-N	g/m³	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Nitrate-N	g/m³	< 0.002	1.47	6.1	3.3	< 0.002
Nitrate-N + Nitrite-N	g/m³	< 0.002	1.47	6.1	3.3	< 0.002
Sulphate	g/m³	< 0.5	3.4	3.9	4.0	2.8
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	< 20	< 4	< 4	< 4	< 20
Propylene Glycol in Water						
Propylene glycol*	g/m³	< 20	< 4	< 4	< 4	< 20
Methanol in Water - Aqueous Solvents						
Methanol*	g/m³	< 20	< 2	< 2	< 2	< 20
BTEX in Water by Headspace GC-MS						
Benzene	g/m³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Toluene	g/m³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Ethylbenzene	g/m³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
m&p-Xylene	g/m³	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002

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/m³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m³	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Gases in groundwater						
Ethane	g/m³	< 0.003	< 0.003	< 0.003	< 0.003	0.006
Ethylene	g/m³	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
Methane	g/m³	2.5	< 0.002	0.002	< 0.002	1.83
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m³	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
C10 - C14	g/m³	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
C15 - C36	g/m³	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4
Total hydrocarbons (C7 - C36)	g/m³	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7

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/m³	1-5
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	1-5
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m³	1-5
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m³	1-5
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS	0.02 g/m³	1-5
Gases in groundwater	Manual headspace creation and sub-sampling, GC-FID analysis.	0.002 - 0.003 g/m³	1-5
Total Petroleum Hydrocarbons in Water	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734]	0.10 - 0.7 g/m³	1-5
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1-5
Total anions for anion/cation balance check	Calculation: sum of anions as mEquiv/L calculated from Alkalinity (bicarbonate), Chloride and Sulphate. Nitrate-N, Nitrite-N. Fluoride, Dissolved Reactive Phosphorus and Cyanide also included in calculation if available. APHA 1030 E 22nd ed. 2012.	0.07 meq/L	1-5
Total cations for anion/cation balance check	Sum of cations as mEquiv/L calculated from Sodium, Potassium, Calcium and Magnesium. Iron, Manganese, Aluminium, Zinc, Copper, Lithium, Total Ammoniacal-N and pH (H^+) also included in calculation if available. APHA 1030 E 22nd ed. 2012.	0.05 meq/L	1-5
pH	pH meter. APHA 4500-H^+ B 22nd ed. 2012. Note: It is not possible to achieve the APHA Maximum Storage Recommendation for this test (15 min) when samples are analysed upon receipt at the laboratory, and not in the field.	0.1 pH Units	1-5
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (Modified for alk <20) 22nd ed. 2012.	1.0 g/m³ as $CaCO_3$	1-5
Bicarbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO_2 D 22nd ed. 2012.	1.0 g/m³ at 25°C	1-5
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 22nd ed. 2012.	1.0 g/m³ as $CaCO_3$	1-5
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 22nd ed. 2012.	0.1 mS/m	1-5
Total Dissolved Solids (TDS)	Filtration through GF/C (1.2 µm), gravimetric. APHA 2540 C (modified; drying temperature of 103 - 105°C used rather than 180 ± 2°C) 22nd ed. 2012.	10 g/m³	1-5
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.00010 g/m³	1-5

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Dissolved Bromine*	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.005 g/m³	1-5
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m³	1-5
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1-5
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m³	1-5
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m³	1-5
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1-5
Dissolved Mercury	0.45µm filtration, bromine oxidation followed by atomic fluorescence. US EPA Method 245.7, Feb 2005.	0.00008 g/m³	1-5
Dissolved Nickel	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1-5
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m³	1-5
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m³	1-5
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0010 g/m³	1-5
Chloride	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl^- E (modified from continuous flow analysis) 22nd ed. 2012.	0.5 g/m³	1-5
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012 (modified).	0.002 g/m³	1-5
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m³	1-5
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012 (modified).	0.002 g/m³	1-5
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B 22nd ed. 2012.	0.5 g/m³	1-5

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.

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

Hill Laboratories
TRIED, TESTED AND TRUSTED

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ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1728624 SPv1
Contact:	Regan Phipps	**Date Received:**	23-Feb-2017
	C/- Taranaki Regional Council	**Date Reported:**	16-Mar-2017
	Private Bag 713	**Quote No:**	47915
	Stratford 4352	**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/m³ as $CaCO_3$	119	21	20	29	175
Bicarbonate	g/m³ at 25°C	144	25	25	35	190
Total Hardness	g/m³ 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/m³	183	101	121	118	250
Dissolved Barium	g/m³	0.0138	0.042	0.057	0.0156	0.0026
Dissolved Bromine*	g/m³	0.041	0.071	0.072	0.063	0.085
Dissolved Calcium	g/m³	23	6.2	8.6	7.7	1.37
Dissolved Copper	g/m³	< 0.0005	0.129	0.0006	0.022	< 0.0005
Dissolved Iron	g/m³	0.21	< 0.02	< 0.02	0.06	0.04
Dissolved Magnesium	g/m³	9.4	3.1	4.1	4.4	0.40
Dissolved Manganese	g/m³	0.029	0.0020	0.0049	0.0047	0.0020
Dissolved Mercury	g/m³	< 0.00008	< 0.00008	< 0.00008	< 0.00008	< 0.00008
Dissolved Nickel	g/m³	0.0073	0.0011	< 0.0005	< 0.0005	< 0.0005
Dissolved Potassium	g/m³	2.2	3.3	4.7	1.78	0.73
Dissolved Sodium	g/m³	15.5	12.2	11.4	15.0	96
Dissolved Zinc	g/m³	0.024	0.23	0.046	0.080	0.0107
Chloride	g/m³	12.8	21	19.6	19.9	30
Nitrite-N	g/m³	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Nitrate-N	g/m³	0.003	1.52	5.4	4.0	< 0.002
Nitrate-N + Nitrite-N	g/m³	0.003	1.52	5.4	4.0	< 0.002
Sulphate	g/m³	< 0.5	3.5	4.3	4.5	2.2
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	< 4	< 4	< 4	< 4	< 4
Propylene Glycol in Water						
Propylene glycol*	g/m³	< 4	< 4	< 4	< 4	< 4
Methanol in Water - Aqueous Solvents						
Methanol*	g/m³	< 2	< 2	< 2	< 2	< 2
BTEX in Water by Headspace GC-MS						
Benzene	g/m³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Toluene	g/m³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Ethylbenzene	g/m³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
m&p-Xylene	g/m³	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
o-Xylene	g/m³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010

Sample Type: Aqueous						
Sample Name:		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/m³	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Gases in groundwater						
Ethane	g/m³	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
Ethylene	g/m³	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
Methane	g/m³	1.60	< 0.002	< 0.002	< 0.002	0.44
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m³	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
C10 - C14	g/m³	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
C15 - C36	g/m³	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4
Total hydrocarbons (C7 - C36)	g/m³	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7

SUMMARY OF METHODS

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	1-5
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	1-5
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m³	1-5
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m³	1-5
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS	0.02 g/m³	1-5
Gases in groundwater	Manual headspace creation and sub-sampling, GC-FID analysis.	0.002 - 0.003 g/m³	1-5
Total Petroleum Hydrocarbons in Water	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734]	0.10 - 0.7 g/m³	1-5
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1-5
Total anions for anion/cation balance check	Calculation: sum of anions as mEquiv/L calculated from Alkalinity (bicarbonate), Chloride and Sulphate. Nitrate-N, Nitrite-N. Fluoride, Dissolved Reactive Phosphorus and Cyanide also included in calculation if available. APHA 1030 E 22nd ed. 2012.	0.07 meq/L	1-5
Total cations for anion/cation balance check	Sum of cations as mEquiv/L calculated from Sodium, Potassium, Calcium and Magnesium. Iron, Manganese, Aluminium, Zinc, Copper, Lithium, Total Ammoniacal-N and pH (H^+) also included in calculation if available. APHA 1030 E 22nd ed. 2012.	0.05 meq/L	1-5
pH	pH meter. APHA 4500-H^+ B 22nd ed. 2012. Note: It is not possible to achieve the APHA Maximum Storage Recommendation for this test (15 min) when samples are analysed upon receipt at the laboratory, and not in the field.	0.1 pH Units	1-5
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (Modified for alk <20) 22nd ed. 2012.	1.0 g/m³ as $CaCO_3$	1-5
Bicarbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO_2 D 22nd ed. 2012.	1.0 g/m³ at 25°C	1-5
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 22nd ed. 2012.	1.0 g/m³ as $CaCO_3$	1-5
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 22nd ed. 2012.	0.1 mS/m	1-5
Total Dissolved Solids (TDS)	Filtration through GF/C (1.2 µm), gravimetric. APHA 2540 C (modified; drying temperature of 103 - 105°C used rather than 180 ± 2°C) 22nd ed. 2012.	10 g/m³	1-5
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.00010 g/m³	1-5
Dissolved Bromine*	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.005 g/m³	1-5
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m³	1-5
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1-5

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

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.

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

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ANALYSIS REPORT

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

Sample Type: Aqueous

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

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

SUMMARY OF METHODS

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	1-5
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	1-5
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m³	1-5
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m³	1-5
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS	0.02 g/m³	1-5
Gases in groundwater	Manual headspace creation and sub-sampling, GC-FID analysis.	0.002 - 0.003 g/m³	1-5
Total Petroleum Hydrocarbons in Water	Solvent Hexane extraction, GC-FID analysis, Headspace GC-MS FS analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734;26687,3629]	0.06 - 0.7 g/m³	1-5
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1-5
Total anions for anion/cation balance check	Calculation: sum of anions as mEquiv/L calculated from Alkalinity (bicarbonate), Chloride and Sulphate. Nitrate-N, Nitrite-N. Fluoride, Dissolved Reactive Phosphorus and Cyanide also included in calculation if available. APHA 1030 E 22nd ed. 2012.	0.07 meq/L	1-5
Total cations for anion/cation balance check	Sum of cations as mEquiv/L calculated from Sodium, Potassium, Calcium and Magnesium. Iron, Manganese, Aluminium, Zinc, Copper, Lithium, Total Ammoniacal-N and pH (H^+) also included in calculation if available. APHA 1030 E 22nd ed. 2012.	0.05 meq/L	1-5
pH	pH meter. APHA 4500-H^+ B 22nd ed. 2012. Note: It is not possible to achieve the APHA Maximum Storage Recommendation for this test (15 min) when samples are analysed upon receipt at the laboratory, and not in the field.	0.1 pH Units	1-5
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (Modified for alk <20) 22nd ed. 2012.	1.0 g/m³ as $CaCO_3$	1-5
Bicarbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO_2 D 22nd ed. 2012.	1.0 g/m³ at 25°C	1-5
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 22nd ed. 2012.	1.0 g/m³ as $CaCO_3$	1-5
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 22nd ed. 2012.	0.1 mS/m	1-5
Total Dissolved Solids (TDS)	Filtration through GF/C (1.2 µm), gravimetric. APHA 2540 C (modified; drying temperature of 103 - 105°C used rather than 180 ± 2°C) 22nd ed. 2012.	10 g/m³	1-5
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.00010 g/m³	1-5
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m³	1-5
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1-5

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

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

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

Ara Heron BSc (Tech)
Client Services Manager - Environmental

Appendix III

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

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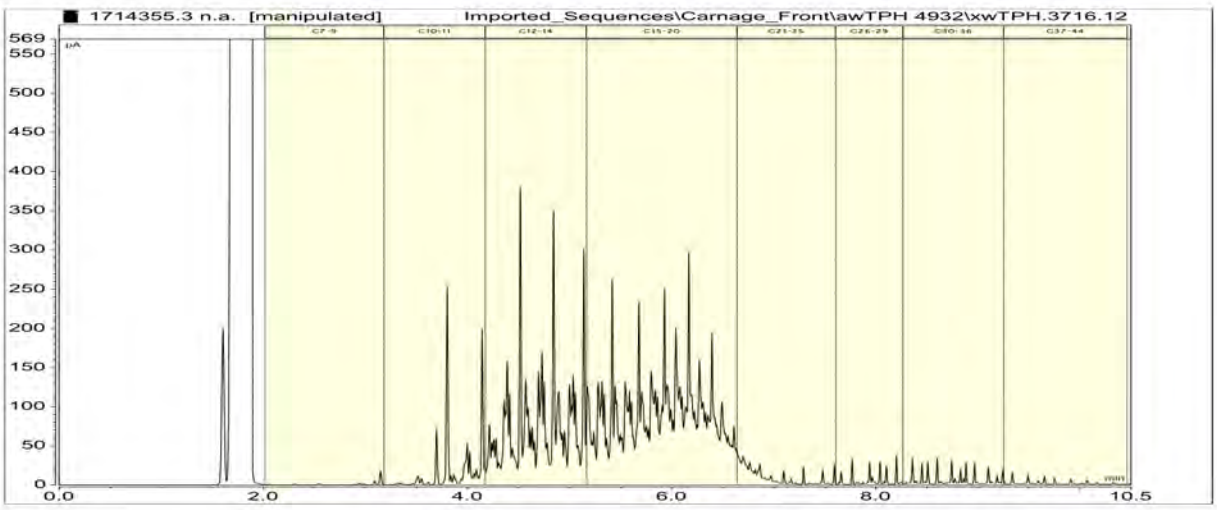
ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1714355 SPv1
Contact:	Regan Phipps	**Date Received:**	26-Jan-2017
	C/- Taranaki Regional Council	**Date Reported:**	13-Feb-2017
	Private Bag 713	**Quote No:**	50522
	Stratford 4352	**Order No:**	62359
		Client Reference:	Mangahewa C11 Frac Fluid
		Submitted By:	David Olson

Sample Type: Aqueous

Sample Name:		GND2271 FF - Composite of GND 2271 FF1 and GND 2271 FF2				
Lab Number:		1714355.3				
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	7	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m³	25	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m³	< 2	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m³	0.0081	-	-	-	-
Toluene	g/m³	0.029	-	-	-	-
Ethylbenzene	g/m³	0.0017	-	-	-	-
m&p-Xylene	g/m³	0.010	-	-	-	-
o-Xylene	g/m³	0.0024	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m³	0.80	-	-	-	-
C10 - C14	g/m³	105	-	-	-	-
C15 - C36	g/m³	188	-	-	-	-
Total hydrocarbons (C7 - C36)	g/m³	290	-	-	-	-

1714355.3
GND2271 FF - Composite of GND 2271 FF1 and GND 2271 FF2
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	3
Propylene Glycol in Water	Direct injection, dual column GC-FID	4 g/m^3	3
Methanol in Water - Aqueous Solvents	Direct injection, dual column GC-FID	1.0 g/m^3	3
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m^3	3
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	3

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

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ANALYSIS REPORT

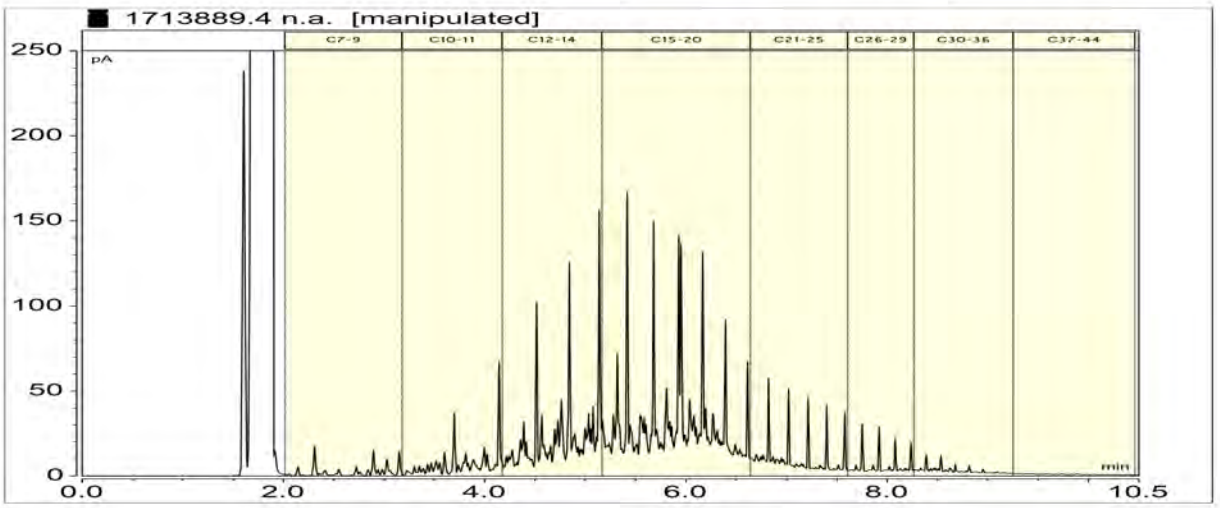
Client:	Taranaki Regional Council	**Lab No:**	1713889 SPv1
Contact:	Regan Phipps	**Date Received:**	26-Jan-2017
	C/- Taranaki Regional Council	**Date Reported:**	14-Feb-2017
	Private Bag 713	**Quote No:**	71307
	Stratford 4352	**Order No:**	62359
		Client Reference:	Mangahewa C11 Return Fluid
		Submitted By:	David Olson

Sample Type: Saline

Sample Name:		GND2271 RF - Composite of GND 2271 RF1, GND 2271 RF2 & GND 2271 RF3				
Lab Number:		1713889.4				
Individual Tests						
pH*	pH Units	8.0	-	-	-	-
Total Alkalinity*	g/m³ as $CaCO_3$	4,300	-	-	-	-
Analysis Temperature for Bicarbonate	°C	23	-	-	-	-
Bicarbonate	g/m³ at Analysis Temperature	4,930	-	-	-	-
Total Hardness*	g/m³ as $CaCO_3$	280	-	-	-	-
Electrical Conductivity (EC)*	mS/m	2,620	-	-	-	-
Total Dissolved Solids (TDS)*	g/m³	15,500	-	-	-	-
Total Barium*	g/m³	44	-	-	-	-
Total Bromine*	g/m³	37	-	-	-	-
Dissolved Calcium*	g/m³	96	-	-	-	-
Total Calcium*	g/m³	94	-	-	-	-
Total Copper*	g/m³	0.0013	-	-	-	-
Total Iron*	g/m³	0.93	-	-	-	-
Dissolved Magnesium*	g/m³	10	-	-	-	-
Total Magnesium*	g/m³	11.0	-	-	-	-
Total Manganese*	g/m³	2.2	-	-	-	-
Total Mercury*	g/m³	< 0.00008	-	-	-	-
Total Nickel*	g/m³	0.020	-	-	-	-
Total Potassium*	g/m³	1,330	-	-	-	-
Total Sodium*	g/m³	5,700	-	-	-	-
Total Sulphur*	g/m³	67	-	-	-	-
Total Zinc*	g/m³	0.036	-	-	-	-
Chloride*	g/m³	6,900	-	-	-	-
Nitrite-N	g/m³	< 0.2	-	-	-	-
Nitrate-N	g/m³	53	-	-	-	-
Nitrate*	g/m³	240	-	-	-	-
Nitrate-N + Nitrite-N	g/m³	53	-	-	-	-
Sulphate*	g/m³	199	-	-	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	< 4	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m³	< 4	-	-	-	-

Sample Type: Saline						
Sample Name:	GND2271 RF - Composite of GND 2271 RF1, GND 2271 RF2 & GND 2271 RF3					
Lab Number:	1713889.4					
Methanol in Water - Aqueous Solvents						
Methanol* g/m³	< 2	-	-	-	-	
BTEX in Water by Headspace GC-MS						
Benzene* g/m³	1.40	-	-	-	-	
Toluene* g/m³	0.69	-	-	-	-	
Ethylbenzene* g/m³	0.073	-	-	-	-	
m&p-Xylene* g/m³	0.36	-	-	-	-	
o-Xylene* g/m³	0.23	-	-	-	-	
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde* g/m³	< 0.02	-	-	-	-	
Total Petroleum Hydrocarbons in Water						
C7 - C9* g/m³	2.8	-	-	-	-	
C10 - C14* g/m³	32	-	-	-	-	
C15 - C36* g/m³	71	-	-	-	-	
Total hydrocarbons (C7 - C36)* g/m³	106	-	-	-	-	

1713889.4
GND2271 RF - Composite of GND 2271 RF1, GND 2271 RF2 & GND 2271 RF3
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: Saline			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	4
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	4
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m³	4
BTEX in Water by Headspace GC-MS*	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m³	4
Formaldehyde in Water by DNPH & LCMSMS*	DNPH derivatisation, extraction, LCMSMS	0.02 g/m³	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/m³	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

Sample Type: Saline			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
pH*	Saline water, pH meter. APHA 4500-H^+ B 22nd ed. 2012. Note: It is not possible to achieve the APHA Maximum Storage Recommendation for this test (15 min) when samples are analysed upon receipt at the laboratory, and not in the field.	0.1 pH Units	4
Total Alkalinity*	Saline water, Titration to pH 4.5.	1.0 g/m³ 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 (HCO3) Titration Method conducted at reported temperature. Subcontracted to Geological & Nuclear Sciences, Wairakei. ASTM Standards D513-82 Vol.11.01 of 1988.	20 g/m³ at Analysis Temperature	4
Total Hardness*	Calculation from Calcium and Magnesium. APHA 2340 B 22nd ed. 2012.	1.0 g/m³ as $CaCO_3$	4
Electrical Conductivity (EC)*	Saline water, Conductivity meter, 25°C. APHA 2510 B 22nd 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) 22nd ed. 2012.	50 g/m³	4
Filtration for dissolved metals analysis*	Sample filtration through 0.45µm membrane filter and preservation with nitric acid. APHA 3030 B 22nd ed. 2012.	-	4
Total Barium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.00063 g/m³	4
Total Bromine*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.11 g/m³	4
Dissolved Calcium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	1.0 g/m³	4
Total Calcium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	1.1 g/m³	4
Total Copper*	Nitric acid digestion, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0011 g/m³	4
Total Iron*	Nitric acid digestion, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0042 g/m³	4
Dissolved Magnesium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.4 g/m³	4
Total Magnesium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.42 g/m³	4
Total Manganese*	Nitric acid digestion, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0011 g/m³	4
Total Mercury*	Bromine Oxidation followed by Atomic Fluorescence. US EPA Method 245.7, Feb 2005.	0.00008 g/m³	4
Total Nickel*	Nitric acid digestion, ICP-MS with universal cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0011 g/m³	4
Total Potassium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	1.1 g/m³	4
Total Sodium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.42 g/m³	4
Total Sulphur*	Nitric acid digestion, ICP-OES (method may not fully account for H_2S due to volatilisation during digestion). All forms of oxidised and organic sulphur will be determined by this method.	0.5 g/m³	4
Total Zinc*	Nitric acid digestion, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0042 g/m³	4
Chloride*	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl^- E (modified from continuous flow analysis) 22nd ed. 2012.	0.5 g/m³	4
Nitrite-N	Saline sample. Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012 (modified).	0.002 g/m³	4
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m³	4
Nitrate*	Calculation from Nitrate-N.	0.010 g/m³	4
Nitrate-N + Nitrite-N	Saline sample. Total oxidised nitrogen. Automated cadmium reduction, Flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012 (modified).	0.002 g/m³	4
Total Sulphate*	Calculation: from total sulphur.	2 g/m³	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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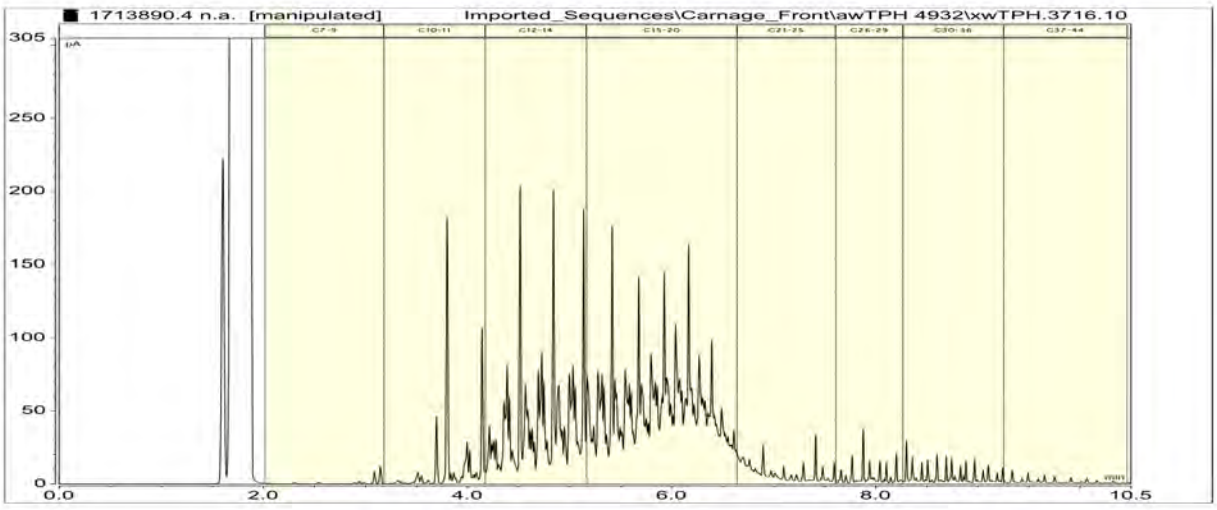
ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1713890 SPv1
Contact:	Regan Phipps	**Date Received:**	26-Jan-2017
	C/- Taranaki Regional Council	**Date Reported:**	13-Feb-2017
	Private Bag 713	**Quote No:**	50522
	Stratford 4352	**Order No:**	62359
		Client Reference:	Mangahewa C15 Frac Fluid
		Submitted By:	David Olson

Sample Type: Aqueous

Sample Name:		GND2375 FF - Composite of GND2375 FF1, GND2375 FF2 and GND2375 FF3				
Lab Number:		1713890.4				
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	< 4	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m³	16	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m³	< 2	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m³	0.0100	-	-	-	-
Toluene	g/m³	0.038	-	-	-	-
Ethylbenzene	g/m³	0.0024	-	-	-	-
m&p-Xylene	g/m³	0.016	-	-	-	-
o-Xylene	g/m³	0.0031	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m³	0.65	-	-	-	-
C10 - C14	g/m³	58	-	-	-	-
C15 - C36	g/m³	112	-	-	-	-
Total hydrocarbons (C7 - C36)	g/m³	171	-	-	-	-

1713890.4
GND2375 FF - Composite of GND2375 FF1, GND2375 FF2 and GND2375 FF3
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	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
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

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

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ANALYSIS REPORT

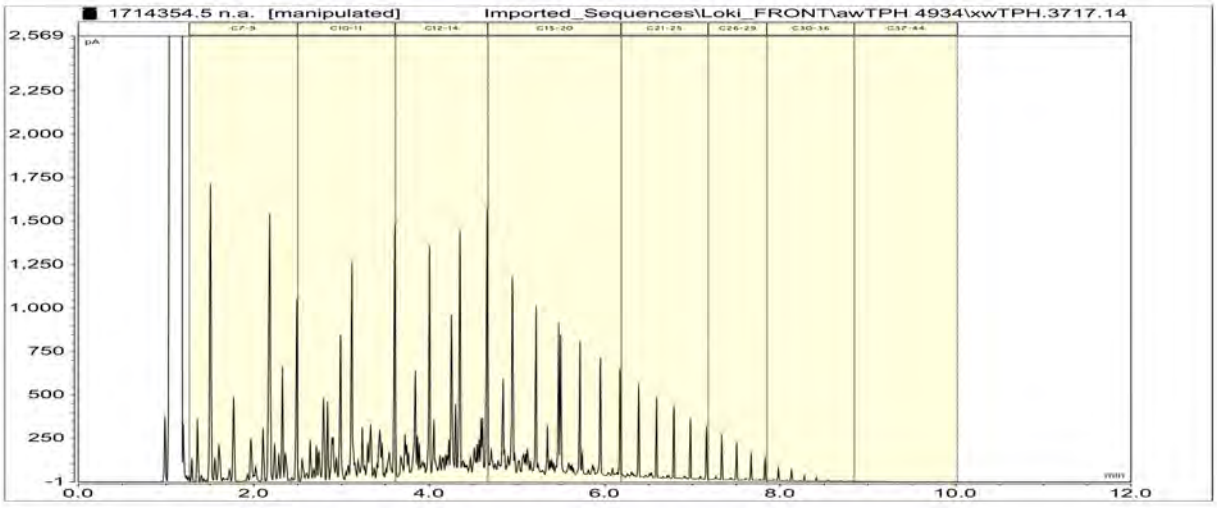
Client:	Taranaki Regional Council	**Lab No:**	1714354 SPv1
Contact:	Regan Phipps	**Date Received:**	26-Jan-2017
	C/- Taranaki Regional Council	**Date Reported:**	14-Feb-2017
	Private Bag 713	**Quote No:**	71307
	Stratford 4352	**Order No:**	62359
		Client Reference:	Mangahewa C15 Return Fluid
		Submitted By:	David Olson

Sample Type: Saline

Sample Name:		GND2375 RF - Composite of GND2375 RF1, GND2375 RF2 & GND2375 RF3 [Aqueous Phase]				
Lab Number:		1714354.5				
Individual Tests						
pH*	pH Units	7.6	-	-	-	-
Total Alkalinity*	g/m³ as $CaCO_3$	2,800	-	-	-	-
Analysis Temperature for Bicarbonate	°C	25	-	-	-	-
Bicarbonate	g/m³ at Analysis Temperature	3,140	-	-	-	-
Total Hardness*	g/m³ as $CaCO_3$	260	-	-	-	-
Electrical Conductivity (EC)*	mS/m	4,190	-	-	-	-
Total Dissolved Solids (TDS)*	g/m³	25,000	-	-	-	-
Total Barium*	g/m³	197	-	-	-	-
Total Bromine*	g/m³	21	-	-	-	-
Dissolved Calcium*	g/m³	86	-	-	-	-
Total Calcium*	g/m³	90	-	-	-	-
Total Copper*	g/m³	0.0100	-	-	-	-
Total Iron*	g/m³	3.5	-	-	-	-
Dissolved Magnesium*	g/m³	11	-	-	-	-
Total Magnesium*	g/m³	11.2	-	-	-	-
Total Manganese*	g/m³	0.79	-	-	-	-
Total Mercury*	g/m³	0.00015	-	-	-	-
Total Nickel*	g/m³	0.019	-	-	-	-
Total Potassium*	g/m³	3,500	-	-	-	-
Total Sodium*	g/m³	7,400	-	-	-	-
Total Sulphur*	g/m³	16	-	-	-	-
Total Zinc*	g/m³	0.191	-	-	-	-
Chloride*	g/m³	13,500	-	-	-	-
Nitrite-N	g/m³	< 0.2	-	-	-	-
Nitrate-N	g/m³	< 0.2	-	-	-	-
Nitrate*	g/m³	< 0.9	-	-	-	-
Nitrate-N + Nitrite-N	g/m³	< 0.2 #1	-	-	-	-
Sulphate*	g/m³	47	-	-	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	< 4	-	-	-	-

Sample Type: Saline						
Sample Name:	GND2375 RF - Composite of GND2375 RF1, GND2375 RF2 & GND2375 RF3 [Aqueous Phase]					
Lab Number:	1714354.5					
Propylene Glycol in Water						
Propylene glycol* g/m³	< 4	-	-	-	-	
Methanol in Water - Aqueous Solvents						
Methanol* g/m³	< 2	-	-	-	-	
BTEX in Water by Headspace GC-MS						
Benzene* g/m³	21	-	-	-	-	
Toluene* g/m³	71	-	-	-	-	
Ethylbenzene* g/m³	8.9	-	-	-	-	
m&p-Xylene* g/m³	54	-	-	-	-	
o-Xylene* g/m³	18.7	-	-	-	-	
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde* g/m³	0.08	-	-	-	-	
Total Petroleum Hydrocarbons in Water						
C7 - C9* g/m³	101	-	-	-	-	
C10 - C14* g/m³	230	-	-	-	-	
C15 - C36* g/m³	181	-	-	-	-	
Total hydrocarbons (C7 - C36)* g/m³	510	-	-	-	-	

1714354.5
GND2375 RF - Composite of GND2375 RF1, GND2375 RF2 & GND2375 RF3 [Aqueous Phase]
Client Chromatogram for TPH by FID



Analyst's Comments

#1 Severe matrix interferences required that a dilution be performed prior to analysis, resulting in a detection limit higher than that normally achieved for the NOxNsal /NO2Nsal 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**
Sample preparation by Non Routine section*	Sample preparation as per test requirement.	-	4
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	5
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	5
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m³	5

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	5
Formaldehyde in Water by DNPH & LCMSMS*	DNPH derivatisation, extraction, LCMSMS	0.02 g/m^3	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	5
Filtration, Unpreserved*	Sample filtration through 0.45µm membrane filter.	-	5
Total Digestion*	Boiling nitric acid digestion. APHA 3030 E 22nd ed. 2012 (modified).	-	5
Total Digestion of Saline Samples*	Nitric acid digestion. APHA 3030 E 22nd ed. 2012 (modified).	-	5
pH*	Saline water, pH meter. APHA 4500-H$^+$ B 22nd ed. 2012. Note: It is not possible to achieve the APHA Maximum Storage Recommendation for this test (15 min) when samples are analysed upon receipt at the laboratory, and not in the field.	0.1 pH Units	5
Total Alkalinity*	Saline water, Titration to pH 4.5.	1.0 g/m^3 as $CaCO_3$	5
Analysis Temperature for Bicarbonate	Temperature at which Bicarbonate titration was conducted as reported by Geological & Nuclear Sciences, Wairakei.	1.0 °C	5
Bicarbonate	Bicarbonate (HCO3) 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	5
Total Hardness*	Calculation from Calcium and Magnesium. APHA 2340 B 22nd ed. 2012.	1.0 g/m^3 as $CaCO_3$	5
Electrical Conductivity (EC)*	Saline water, Conductivity meter, 25°C. APHA 2510 B 22nd ed. 2012.	0.10 mS/m	5
Total Dissolved Solids (TDS)*	Filtration through GF/C (1.2 µm), gravimetric. APHA 2540 C (modified; drying temperature of 103 - 105°C used rather than 180 ± 2°C) 22nd ed. 2012.	50 g/m^3	5
Filtration for dissolved metals analysis*	Sample filtration through 0.45µm membrane filter and preservation with nitric acid. APHA 3030 B 22nd ed. 2012.	-	5
Total Barium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.00063 g/m^3	5
Total Bromine*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.11 g/m^3	5
Dissolved Calcium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	1.0 g/m^3	5
Total Calcium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	1.1 g/m^3	5
Total Copper*	Nitric acid digestion, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0011 g/m^3	5
Total Iron*	Nitric acid digestion, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0042 g/m^3	5
Dissolved Magnesium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.4 g/m^3	5
Total Magnesium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.42 g/m^3	5
Total Manganese*	Nitric acid digestion, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0011 g/m^3	5
Total Mercury*	Bromine Oxidation followed by Atomic Fluorescence. US EPA Method 245.7, Feb 2005.	0.00008 g/m^3	5
Total Nickel*	Nitric acid digestion, ICP-MS with universal cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0011 g/m^3	5
Total Potassium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	1.1 g/m^3	5
Total Sodium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.42 g/m^3	5
Total Sulphur*	Nitric acid digestion, ICP-OES (method may not fully account for H_2S due to volatilisation during digestion). All forms of oxidised and organic sulphur will be determined by this method.	0.5 g/m^3	5
Total Zinc*	Nitric acid digestion, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0042 g/m^3	5
Chloride*	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl$^-$ E (modified from continuous flow analysis) 22nd ed. 2012.	0.5 g/m^3	5
Nitrite-N	Saline sample. Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012 (modified).	0.002 g/m^3	5
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m^3	5
Nitrate*	Calculation from Nitrate-N.	0.010 g/m^3	5

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 22nd ed. 2012 (modified).	0.002 g/m^3	5
Total Sulphate*	Calculation: from total sulphur.	2 g/m^3	5

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

Appendix IV

Biomonitoring reports

To	Job Manager, Jane Harvey
From	Technical Officer, Katie Blakemore
Report No	KB021
Document	1899031
Date	14 Jul 2017

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

Introduction

A pre-hydraulic fracturing (HF) 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 HF activities. A further survey was undertaken following the completion of 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 standard '400ml kick-sampling' technique was used to collect streambed macroinvertebrates from three established sites in two unnamed tributaries of the Waiau Stream on 31 October 2016 and again on 31 January 2017 (Table 1**Error! Reference source not found.**, Figure 1). Site 2 is located in the unnamed tributary receiving the discharge from the wellsite, while sites 1 and 3 are situated in another unnamed tributary, upstream and downstream of the wellsite tributary confluence. The '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).

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

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

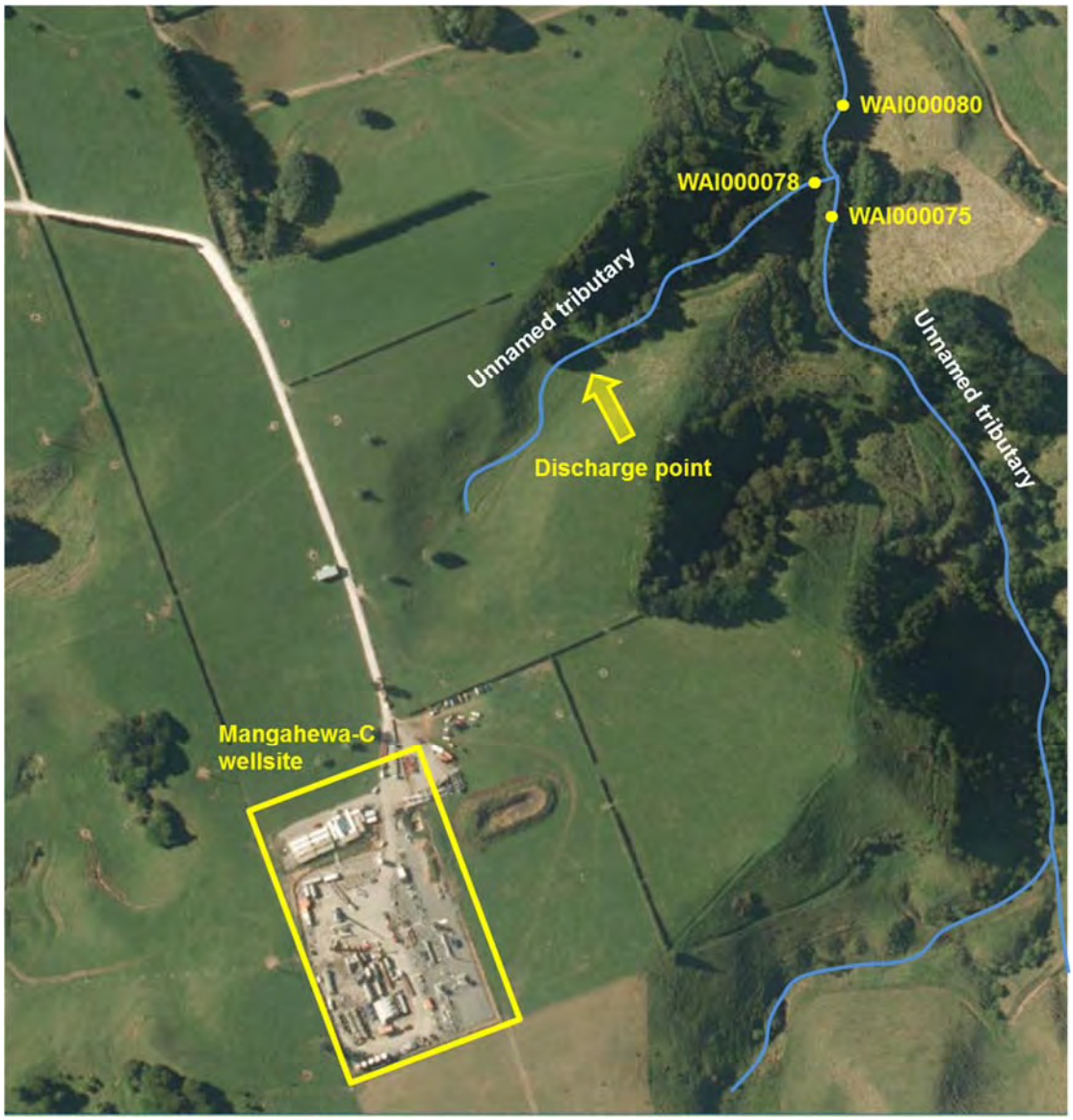

Figure 1 Biomonitoring sites in two unnamed tributaries of the Waiau Stream in relation to the Mangahewa-C wellsite

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 collected 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. More 'sensitive' communities inhabit less polluted waterways. A difference of 11 units or more in MCI values is considered significantly different (Stark 1998). 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; Boothroyd and Stark, 2000) (Table 3).

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

The MCI was designed as a measure of the overall sensitivity of macroinvertebrate communities to the effects of organic pollution. MCI results can also reflect the effects of warm temperatures, slow current speeds and low dissolved oxygen levels, because the taxa capable of tolerating these conditions generally have low sensitivity scores. Usually more 'sensitive' communities (with higher MCI values) inhabit less polluted waterways. The use of this index in non-stony streams is possible if results are related to physical habitat (e.g., good quality muddy/weedy sites tend to produce lower MCI values than good quality stony sites). Weedy stream macroinvertebrate communities tend to be dominated by more 'tolerant' taxa than is the case in stony stream communities. It may therefore require more severe organic pollution to cause a significant decline in MCI value in weedy streams.

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, therefore $SQMCI_s$ values range from 1 to 10. A difference of 0.9 units or more in $SQMCI_s$ is considered significantly different (Stark, 1998).

Results

At the time of the pre-HF survey on 31 October 2016, there was a clear and uncoloured, steady flow at all sites. Water level was moderate at sites 1 and 3, but very low at site 2. Substrate was comprised of predominantly hard clay, with silt, coarse gravel, cobble, boulder and wood/root also present in smaller amounts. Fine gravel was present at sites 1 and 2, and sand was also present at site 1. Water temperatures were 13.4°C, 12.1°C and 13.2°C at sites 1-3 respectively.

Patchy leaves, moss and wood were present on the streambed at site 1, while site 2 recorded patchy leaves and wood, with no moss present. Site 3 recorded patchy moss and wood, while leaves where widespread on

the streambed. No macrophytes or periphyton was present at any of the three sites. Overhanging vegetation and canopy cover provided complete shading at all three sites.

At the time of the post-HF survey on 31 January 2017, there was a clear, uncoloured flow at all sites. Water level was moderate at all sites, with a slow flow at site 1 and a steady flow at sites 2 and 3. Substrate at all sites comprised hard clay, wood/root, coarse gravel and fine gravel. Silt was also present at sites 1 and 3, and sand was present at sites 2 and 3. Bank erosion was noted at site 1. Water temperatures ranged from 15.1 – 15.8°C at the three sites.

Leaves on the streambed were patchy at all three sites, while wood was widespread at site 1, and patchy at site 2 and 3. Macrophytes were present on the stream edges at site 2, but absent at sites 1 and 3. No moss or periphyton was present at any of the three sites. There was partial shading of the streambed from the streambanks and canopy cover at site 1, while sites 2 and 3 had complete shading provided by overhanging vegetation, streambanks and canopy cover at sites 2 and 3.

Macroinvertebrate communities

A summary of previously recorded median scores and ranges for macroinvertebrate indices at control sites in Taranaki Lowland Coastal Streams between 50 and 79 metres above sea level are provided for reference purposes in Table 4.

Table 4 Summary of median and ranges based on previously recorded data from control sites in Taranaki lowland coastal streams between 50 and 79 masl

Metric	Number of samples	Range	Median
Taxa richness	119	0-30	20
MCI	119	60-109	79
$SQMCI_s$	90	1.2-6.7	2.0

Results from all surveys to date at these sites are provided in Table 5.

Table 5 Macroinvertebrate metric results from all surveys to date at sites surveyed in relation to the Mangahewa-C wellsite

Site	Taxa Richness				MCI				$SQMCI_s$			
	26 May 2015	18 Apr 2016	31 Oct 2016	31 Jan 2017	26 May 2015	18 Apr 2016	31 Oct 2016	31 Jan 2017	26 May 2015	18 Apr 2016	31 Oct 2016	31 Jan 2017
WAI000075	14	29	23	25	103	109	108	106	6.7	6.7	5.7	6.3
WAI000078	10	8	9	22	120	100	93	107	6.2	4.7	3.0	5.0
WAI000080	15	20	17	17	91	118	109	108	5.1	6.5	5.2	6.5

The macroinvertebrate communities of the two unnamed tributaries of the Waiau Stream recorded at the time of the pre-HF survey are provided in Table 6, and at the time of the post-HF survey in Table 7.

Table 6 Macroinvertebrate communities of two unnamed tributaries of the Waiau Stream in relation to the Mangahewa-C wellsite, sampled on 31 October 2016

Taxa List	Site Number	MCI score	1	2	3
	Site Code		WAI000075	WAI000078	WAI000080
	Sample Number		FWB16254	FWB16255	FWB16256
NEMERTEA	Nemertea	3	R	-	-
ANNELIDA (WORMS)	Oligochaeta	1	R	A	R
	Lumbricidae	5	C	-	-
MOLLUSCA	*Potamopyrgus*	4	C	C	R
	Sphaeriidae	3	R	-	-
CRUSTACEA	*Paranephrops*	5	R	-	R
EPHEMEROPTERA (MAYFLIES)	*Austroclima*	7	R	-	-
	Coloburiscus	7	C	-	R
	Deleatidium	8	R	-	C
	Neozephlebia	7	R	R	-
	Zephlebia group	7	A	R	A
PLECOPTERA (STONEFLIES)	*Acroperla*	5	R	-	C
COLEOPTERA (BEETLES)	Elmidae	6	R	-	-
	Ptilodactylidae	8	R	-	R
MEGALOPTERA (DOBSONFLIES)	*Archichauliodes*	7	R	-	-
TRICHOPTERA (CADDISFLIES)	*Hydrobiosis*	5	R	-	R
	Hydrobiosella	9	-	-	R
	Hydropsyche (Orthopsyche)	9	R	-	-
	Polyplectropus	6	-	C	-
	Psilochorema	6	-	-	R
	Oeconesidae	5	-	-	R
	Pycnocentria	7	C	-	R
DIPTERA (TRUE FLIES)	Eriopterini	5	R	C	R
	Hexatomini	5	R	R	-
	Polypedilum	3	R	R	A
	Austrosimulium	3	C	-	C
	Tanyderidae	4	C	R	-
ACARINA (MITES)	Acarina	5	-	-	R
No of taxa			23	9	17
MCI			108	93	109
SQMCIs			5.7	3.0	5.2
EPT (taxa)			9	3	9
%EPT (taxa)			39	33	53

'Tolerant' taxa	'Moderately sensitive' taxa	'Highly sensitive' taxa

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

Table 7 Macroinvertebrate communities of two unnamed tributaries of the Waiau Stream in relation to the Mangahewa-C wellsite, sampled on 31 January 2017

Taxa List	Site Number	MCI score	1	2	3
	Site Code		WAI000075	WAI000078	WAI000080
	Sample Number		FWB17014	FWB17015	FWB17016
PLATYHELMINTHES (FLATWORMS)	*Cura*	3	R	-	-
NEMERTEA	Nemertea	3	-	R	-
ANNELIDA (WORMS)	Oligochaeta	1	R	A	R
	Lumbricidae	5	-	-	R
MOLLUSCA	*Potamopyrgus*	4	A	C	C
	Sphaeriidae	3	R	-	-
CRUSTACEA	Paraleptamphopidae	5	R	R	-
	Paranephrops	5	-	R	-
EPHEMEROPTERA (MAYFLIES)	*Austroclima*	7	A	-	C
	Coloburiscus	7	VA	R	C
	Zephlebia group	7	VA	A	VA
PLECOPTERA (STONEFLIES)	*Austroperla*	9	-	C	-
	Spaniocerca	8	R	R	R
COLEOPTERA (BEETLES)	Ptilodactylidae	8	R	R	-
TRICHOPTERA (CADDISFLIES)	*Costachorema*	7	R	-	-
	Hydrobiosis	5	C	-	R
	Hydrobiosella	9	R	-	R
	Hydropsyche (Orthopsyche)	9	C	C	R
	Polyplectropus	6	-	C	-
	Psilochorema	6	-	R	-
	Hudsonema	6	R	-	-
	Oeconesidae	5	R	C	R
	Triplectides	5	C	C	R
DIPTERA (TRUE FLIES)	Eriopterini	5	-	C	R
	Hexatomini	5	R	C	-
	Limonia	6	-	R	-
	Harrisius	6	R	-	-
	Orthocladiinae	2	C	-	-
	Polypedilum	3	A	R	C
	Tanypodinae	5	R	-	-
	Dolichopodidae	3	-	R	-
	Paradixa	4	-	R	-
	Austrosimulium	3	R	-	C
	Tanyderidae	4	R	R	R
ACARINA (MITES)	Acarina	5	C	-	R
No of taxa			25	22	17
MCI			106	107	108
SQMCIs			6.3	5.0	6.5
EPT (taxa)			11	9	9
%EPT (taxa)			44	41	53

'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-HF survey, a moderate taxa richness of 23 taxa was recorded at this 'control' site (Table 6). This was within the previously recorded range for this site (Table 5), and three taxa more than the median score for Taranaki coastal lowland streams at similar altitude (median richness 20 taxa; Table 4). The macroinvertebrate community was characterised by only one taxon, the 'moderately sensitive' mayfly (*Zephlebia*) (Table 6).

The post-HF survey recorded a moderate taxa richness of 25 taxa (Table 7), two taxa more than the pre-HF survey (Table 5). This score was also within the previously recorded range for this site (Table 5). The macroinvertebrate community on this occasion was characterised by five taxa, three 'moderately sensitive' mayflies (*Austroclima*, *Coloburiscus* and *Zephlebia*) and two 'tolerant' taxa [snail (*Potamopyrgus*) and midge (*Polypedilum*)] (Table 7).

A MCI score of 108 units was recorded in the pre-HF survey (Table 6) and a score of 106 units in the post-HF survey. This categorises the site as having 'good' macroinvertebrate community health on both occasions (Table 3). These scores are not significantly different (Stark 1998) from each other, or from any previously recorded score at this site (Table 4). Both scores are significantly higher than the median score for Taranaki coastal lowland streams at similar altitude (median MCI score 79 units; Table 4).

A $SQMCI_s$ score of 5.7 units was recorded in the pre-HF survey (Table 6), and 6.3 units in the post-HF survey (Table 7). These scores are not significantly different (Stark 1998) from each other, but both were significantly higher than median score for Taranaki coastal lowland streams at similar altitude (median $SQMCI_s$ score 2.0 units; Table 4).

Site 2

At the time of the pre-HF survey, a low richness of 9 taxa was recorded at this 'primary impact' site (Table 6), similar to previously recorded richnesses at this site (Table 5).The macroinvertebrate community was characterised by one taxon, the 'tolerant' oligochaete worms.

The post-HF survey recorded a moderate taxa richness of 22 taxa (Table 7). This is a substantial thirteen taxa more than the score recorded in the pre-HF survey, and ten taxa more than the highest previously recorded richness at this site (Table 5). The macroinvertebrate community was characterised by two taxa, the 'moderately sensitive' mayfly (*Zephlebia*) and the 'tolerant' oligochaete worms.

A MCI score of 93 units was recorded in the pre-HF survey (Table 6), the lowest score recorded to date at this site (Table 5). The post-HF survey recorded a MCI score of 107 units (Table 7), which is significantly higher than that recorded in the pre-HF survey. Both scores are significantly higher (Stark 1998) than the median MCI score for Taranaki coastal lowland streams at similar altitude (median MCI score 79 units; Table 4). The recorded scores categorised the macroinvertebrate community health as being 'fair' and 'good' at the time of the pre-HF and post-HF surveys respectively (Table 3).

A $SQMCI_s$ score of 3.0 units was recorded in the pre-HF survey (Table 6). This is the lowest $SQMCI_s$ score recorded to date at this site. The post-HF survey recorded a significantly higher (Stark 1998) $SQMCI_S$ score of 5.0 units. Both scores are significantly higher (Stark 1998) than the median $SQMCI_s$ score for Taranaki coastal lowland streams at similar altitude (median $SQMCI_S$ score 2.0 units; Table 4).

Site 3

At the time of the pre-HF survey, a moderate richness of 17 taxa was recorded (Table 6), similar to previously recorded richnesses at this site (Table 5) and an insubstantial three taxa less than the median richness for sites in Taranaki coastal lowland streams (Table 4). The macroinvertebrate community was characterised by two taxa, the 'moderately sensitive' mayfly (*Zephlebia*) and the 'tolerant' midge (*Polypedilum*).

The post-HF survey recorded a richness of 17 taxa (Table 7), equal to that recorded in the pre-HF survey. The macroinvertebrate community was characterised by only one taxon, the 'moderately sensitive' mayfly (*Zephlebia*).

A MCI score of 109 units was recorded in the pre-HF survey (Table 6), while the post-HF survey recorded a MCI score of 108 units. These scores are not significantly different (Stark 1998) to each other, and both are within the range previously recorded at this site (Table 5). Further, both scores are significantly higher (Stark 1998) than the median score for Taranaki coastal lowland streams at similar altitude (median MCI score 79 units; Table 4). The MCI scores categorised the site as having 'good' macroinvertebrate community health on both sampling occasions (Table 3).

A $SQMCI_S$ score of 5.2 units was recorded in the pre-HF survey, within the range of scores previously recorded at this site. The post-HF survey recorded a $SQMCI_S$ score of 6.5 units, equal to the highest previously recorded score at this site. This score is significantly higher (Stark 1998) than that recorded in the pre-HF survey, while the both the pre-HF and post-HF survey scores are significantly higher than the median score for Taranaki coastal lowland streams at similar altitude (median $SQMCI_s$ score 2.0 units; Table 4).

Discussion and conclusions

The Council's "kick-sampling' technique was used to collect samples from three sites in the two unnamed tributaries of the Waiau 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 also easily influenced by the 'patchiness' of invertebrates on the streambed, and as such must be considered in the context of all three metrics.

Taxa richness varied widely between sites at the time of the pre-HF survey, with site 2 recording a richness that was substantially lower than at either site 1 and 3 (which had similar taxa richnesses to each other). This is consistent with results observed in previous surveys at these sites (Table 5). The most likely explanation for this pattern is due to the location of site 2, which is located in a smaller unnamed tributary of the Waiau Stream than sites 1 and 3, causing it to be more strongly affected by periods of low flow. This is primarily through habitat limitation. In addition, under low flow 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. It is of note, that the water level during the pre-HF survey at site 2 was very low, while sites 1 and 3 recorded moderate water level.

Further, taxa richness at the time of the post-HF survey was similar between all three sites. Sites 1 and 3 recorded a taxa richness similar to that recorded in the pre-HF survey, and to previously recorded taxa richnesses for these sites. In contrast, site 2 recorded a richness of 22 taxa, a substantial twelve taxa higher than any previously recorded score at this site and thirteen taxa more than that recorded in the pre-HF survey. This is because the post-HF survey followed an exceptionally wet spring and early summer period, with 19 freshes of greater than 3x median flow and 12 freshes of greater than 7x median flow recorded

since the pre-HF survey. Water level at this site was recorded as moderate during the post-HF survey, while all previous surveys at this site have recorded the water level as low or very low. This provides evidence that the substantial increase in taxa richness at site 2 between the pre-HF and post-HF survey (and compared to all previous surveys) is most likely related to sustained higher than usual flow conditions at the time of the pre-HF survey. This further supports for lower taxa richness previously observed at site 2 resulting from low flow conditions due to the smaller size of this tributary.

The pre-HF survey recorded MCI scores of 108, 93 and 109 units at sites 1-3 respectively, while the post-HF survey recorded scores of 106, 107 and 108 at these same sites. At the time of the pre-HF survey, the score at site 2 was significantly lower than that at either site 1 or site 3 (which had similar MCI scores to each other). This score was also significantly lower than the score recorded at this site in the post-HF survey. In contrast, the post-HF survey recorded similar MCI scores at all three sites. All recorded MCI scores in both the pre-HF and post-HF surveys were higher than the median score for Taranaki coastal lowland streams at similar altitude.

$SQMCI_s$ scores in the pre-HF survey were similar at sites 1 and 3, while the score recorded at site 2 was significantly lower than that at either site 1 or site 3. This same pattern was recorded in the post – HF survey, with an increase in $SQMCI_s$ score at every site between these two surveys. This increase was significant at sites 2 and 3. The lower $SQMCI_s$ score at site 2 is likely to be influenced by the higher abundance of the 'tolerant' oligochaete worms, which were abundant at site 2, but not at sites 1 or 3 in both surveys. Further, the abundance of the 'moderately sensitive' *Zephlebia* group was lower at site 2 than either site 1 or 3 in both surveys (although this taxon was characteristic at site 2 in the post –HF survey). All recorded $SQMCI_s$ scores in both the pre-HF and post-HF surveys were higher than the median score for Taranaki coastal lowland streams at similar altitude.

Overall, the results of these two surveys show that these two unnamed tributaries of the Waiau Stream have good macroinvertebrate community health when compared with other lowland coastal stream at similar altitude in Taranaki. When the macroinvertebrate community metrics from these two surveys are taken together, an improvement in macroinvertebrate community health is observed at site 2, the 'primary impact' site. This is most likely due to sustained higher than usual flow conditions in this tributary. There is no evidence that stormwater discharges from the Mangahewa-C wellsite have had any recent detrimental impacts on the macroinvertebrate communities of these two unnamed tributaries of the Waiau Stream.

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 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.

Invertebrate metrics at sites 1 and 3 (in the larger unnamed tributary of the Waiau Stream) were relatively similar between sites and between surveys. In contrast, site 2 (in the smaller tributary receiving the wellsite discharges) showed an increase in all three metrics between the pre-HF and post-HF surveys, with the taxa richness and MCI in the post-HF survey similar to those observed at sites 1 and 3. This change is likely a result of sustained higher than usual flow conditions in the period between the two surveys. There was no evidence that the stormwater discharges from the Mangahewa-C wellsite have caused any recent significant adverse effects on the macroinvertebrate communities of these two unnamed tributaries of the Waiau Stream.

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