Greymouth Petroleum Limited
Kowhai-C Hydraulic Fracturing
Monitoring Programme Report
2015-2017

Technical Report 2017-04

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Executive summary

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

GPL hold resource consent 10139-1, authorising the discharge of water based hydraulic fracturing fluids into land at depths greater than 3,400 metres true vertical depth subsea (TVDss) beneath the Kowhai-C wellsite. This consent was issued by the Council on 30 July 2015, replacing consent 9480-1 which was issued on 22 February 2013. Consent 10139-1 contains a total of 20 special conditions which set out the requirements that GPL must satisfy.

The programme of hydraulic fracturing undertaken by GPL at Kowhai-C discussed in this report included the fracturing of one well. The well targeted for stimulation was Kowhai-3. The hydraulic fracturing of the well took place on 27 April 2016.

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

The programme of monitoring implemented by the Council in relation to hydraulic fracturing activities at the Kowhai-C wellsite was initiated in 2013. This report details the results of monitoring conducted during the 2015–2016 and the 2016-2017 monitoring years in relation to the activities carried out in April 2016. A previous report published by the Council cover the results of monitoring undertaken for HF activities over the period 2013-2015.

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 the Parahaki Stream and an unnamed tributary 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 GPL 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 GPL in relation to these activities or provisions in regional plans, during the period under review.

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

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

This report includes recommendations for the future monitoring of any hydraulic fracturing activities at the Kowhai-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 Greymouth Petroleum Limited (GPL) at their Kowhai–C wellsite during April 2016. The report also assesses GPL's level of environmental performance and compliance with the resource consent held in relation to the activity.

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

The programme of monitoring implemented by the Council in relation to the hydraulic fracturing activities spanned the 2015-2016 and 2016-2017 monitoring years. Monitoring included a mixture of groundwater, surface water and discharge monitoring components. This is the second monitoring report produced by the Council in relation to the hydraulic fracturing activities at the Kowhai-C wellsite. The other report covered the hydraulic fracturing activities spanning the period July 2013 to June 2015.

1.1.2. Structure of this report

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

- the nature of the monitoring programme in place for the period under review; and
- a description of the activities and operations conducted in the Company's site/catchment.

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

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

Section 4 presents recommendations to be implemented in the 2017 - onwards monitoring period.

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

1.1.3. The Resource Management Act 1991 and monitoring

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

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

In drafting and reviewing conditions on discharge permits, and in implementing monitoring programmes, the Council is recognising the comprehensive meaning of 'effects' inasmuch as is appropriate for each activity. Monitoring programmes are not only based on existing permit conditions, but also on the

obligations of the RMA to assess the effects of the exercise of consents. In accordance with Section 35 of the RMA, the Council undertakes compliance monitoring for consents and rules in regional plans, and maintains an overview of the performance of resource users and consent holders. Compliance monitoring, including both activity and impact monitoring, enables the Council to continually re-evaluate its approach and that of consent holders to resource management and, ultimately, through the refinement of methods and considered responsible resource utilisation, to move closer to achieving sustainable development of the region's resources.

1.1.4. Evaluation of environmental and administrative performance

Besides discussing the various details of the performance and extent of compliance by the consent holders, this report also assigns a rating as to each Company's environmental and administrative performance during the period under review.

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

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

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

Environmental Performance

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

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

For example:

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

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

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

Administrative performance

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

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

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

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

For reference, in the 2015-2016 year, 71% of consent holders in Taranaki monitored through tailored compliance monitoring programmes achieved a high level of environmental performance and compliance with their consents, while another 24% demonstrated a good level of environmental performance and compliance with their consents

1.2. Process description

1.2.1. Hydraulic fracturing

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

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

Gel fracturing

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

Slick water fracturing

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

Nitrogen gas assisted fracturing

Nitrogen gas assisted fracturing involves replacing some of the fluid used in the fracturing process with nitrogen gas, which can fracture rock at high pressures much like water. While nitrogen (N^2) is a gas at room temperature, it can be maintained in a liquid state through cooling and pressurisation. Nitrogen assisted fracturing is extremely beneficial from a production standpoint as inevitably during the fracturing process some of the water pumped down the well remains underground in the rock formation, which can block some of the small pores inhibiting hydrocarbon recovery. Nitrogen gas achieves the same purpose as water but returns more easily to the surface. [2] More indirectly, a reduction in the volume of water used also reduces the total concentration of chemical additives required and the volume of water returning to the surface that requires subsequent disposal[2].

1.2.2. The Kowhai-C wellsite and hydraulic fracturing activities

The Kowhai-C wellsite is located at 492 Otaraoa Road, 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 GPL at the Kowhai-C wellsite during the period being reported is provided below in Table 1.

Table 1 Summary of hydraulic fracturing activity during the reporting period

Well	Fracturing date		Range mid point injection zones (M TVD)	Formation
	Start	End		
Kowhai-3	27/04/2016	27/04/2016	3,492 to 3,495	Kapuni Group

1.3. Resource consents

1.3.1. Discharges onto and into land

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

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

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

Figure 1 Location map

The current consent 10139-1 has twenty 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 stipulates actions to be taken if a nearby seismic event higher than a magnitude 3.0 occurs;
- Condition 4 stipulates the investigation and reporting requirements if a nearby seismic event higher than magnitude 3.0 occurs;
- Condition 5 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 6, 7, 8 and 9 relate to fresh water monitoring requirements, to allow compliance with condition 5 to be assessed;
- Condition 10 requires the consent holder to carry out pressure testing of equipment prior to discharging;
- Condition 11 requires the consent holder to submit a pre-fracturing discharge report prior to any discharge occurring;
- Condition 12 is a notification requirement;
- Condition 13 requires the consent holder to submit a post-fracturing discharge report after the completion of the hydraulic fracturing programme for each well;
- Condition 14 relates to the submittal of interim post fracturing reports which may be required in order to meet the 90-day submittal deadline;
- Condition 15 stipulates how the reports required by conditions 11, 13 and 14 are to be submitted;
- Condition 16 requires the consent holder to allow the Council access to a location where samples of hydraulic fracturing and return fluids can be obtained;
- Condition 17 requires the consent holder to adopt best practicable options;
- Condition 18 relates to the composition of the fracturing fluid;
- Condition 19 is a lapse clause; and
- Condition 20 is a review provision.

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

1.4. Monitoring programme

1.4.1. Introduction

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

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

The monitoring programme implemented in relation to the hydraulic fracturing of the Kowhai-C well 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 reviews;
- renewals;
- new consents;
- advice on the Council's environmental management strategies and content of regional plans; and
- consultation on associated matters.

1.4.3. Assessment of data submitted by consent holder

As required by the conditions of consent 10139-1, GPL submitted a pre and post-fracturing discharge report to the Council in relation to the Kowhai-3 fracturing event. Pre-fracturing discharge reports provide an outline of the proposed fracturing operations in relation to each well, while post-fracturing reports confirm details of what actually occurred. The specific range of information required in each report is stipulated in the conditions of the consent.

1.4.4. Physicochemical sampling

1.4.4.1. Groundwater

In order to select suitable sites for sampling, a well survey was carried out under the previous consent (9480-1) in the vicinity of the Kowhai-C wellsite to identify any existing groundwater abstractions in the area. Consent 10139-1 was issued 30 July 2015 and replaced consent 9480-1 which was issued on 22 July 2013. Consent 9480-1 was due to expire on 1 June 2020 with no discharge of HF fluids allowed into the reservoir after 1 June 2015.

Following the survey a total of four groundwater sampling sites were selected for inclusion in the Monitoring Programme. The sampling sites were selected based on their proximity to the Kowhai-C wellsite, and their individual construction and usage characteristics. The selection of sampling sites was designed to provide a sample set representative of groundwater in use, or which could be accessed for use, in the immediate area surrounding the Kowhai-C wellsite. One site GND2318 was removed from the programme due to unsafe access. More recently another site (GND2432) has also been removed from the programme due to ongoing access issues. The remaining two sites GND2434 and GND2433 are both very shallow and are located around 500 m from the wellsite These two sites on their own, due to both their distance from the wellsite and depth, do not provide a good sample set representative of groundwater in use, or which could be accessed for use, in the vicinity of the site. Therefore, GPL will be required to install a site specific monitoring bore in order to improve the monitoring network before they undertake any further fracturing activities at the site.

The details of all groundwater sites that were sampled over the course of the reporting period are included in Table 2. Their location and proximity to the Kowhai-C wellsite is illustrated in Figure 1

Table 2 Details of groundwater monitoring sites

Site code	Type	Distance from wellsite (m)	Depth (m)
GND2318*	Spring	450	N/A
GND2432*	Bore	640	180
GND2433	Well	575	2.0

Site code	Type	Distance from wellsite (m)	Depth (m)
GND2434	Spring	480	N/A

*Note * No longer part of the monitoring programme*

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 the fracturing event (return fluids) were obtained for analysis.

Samples of hydraulic fracturing fluid were obtained from storage tanks on-site. While the fracturing fluid is predominantly comprised of water, specialised additives are used to either increase the viscosity (gel fracturing) or turbulence (slick-water fracturing) of the fluid in order to suspend the proppant prior to injection.

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

All samples were transported to Hill Laboratories 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 15 April 2016 and 9 May 2016 at the Kowhai-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 the Parahaki Stream and an unnamed tributary of the Waiau Stream. The wellsite treated stormwater, uncontaminated site water and production water were discharged from a skimmer pit into an unnamed tributary of the Waiau Stream (Figure 1).

Taxa richness is the most robust index when determining whether a macroinvertebrate community has been exposed to toxic discharges. When exposed to toxic discharges, macroinvertebrates may die and be swept downstream or may deliberately drift downstream as an avoidance mechanism (catastrophic drift). The Macroinvertebrate Index (MCI) is a measure of the overall sensitivity of the macroinvertebrate community to the effects of organic pollution in stony streams. It is based on the presence/absence of taxa with varying degrees of sensitivity to environmental conditions. The Semi-quantitative Macroinvertebrate Index (SQMCI) takes into account taxa abundances as well as sensitivity to pollution. It may indicate subtle changes in communities, and therefore be the more relevant index if non-organic impacts are occurring. Significant

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

The details of each biomonitoring site included in the surveys are presented in Table 3. Their location and proximity to the Kowhai-C wellsite is illustrated in Figure 1.

Table 3 Details of biomonitoring sites included in the monitoring programme

Site No.	Site code	Grid reference (NZTM)	Location	Altitude (m asl)
1	WAI000070	1172016E-5678534N	10 m d/s of pond	79
2	PRH000010	1711471E-5678890N	20 m u/s Inland North Road	79

2. Results

2.1. Consent holder submitted data

2.1.1. Kowhai-3 post-fracturing discharge report

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

- One zone was fractured on 27 April 2016 at depths between 3,492 to 3,495 m TVD;
- A total of 1,612 bbls (256 m^3) of liquid and 62,026 lbs of proppant was discharged across the fractured zone;
- The Kowhai-3 well was opened for flow-back following the completion of fracturing operations. In total, 784 bbls (125 m^3) of fluid were returned from the well over the initial flow-back period. It is estimated that approximately 828 bbls of the fluids injected remained in the formation. Additional fluid is likely to returned back to the surface as the well produces;
- Approximately 62,026 lbs or 100% of proppant remained within the formation after the completion of flow back;
- No screen outs occurred while fracturing;
- All return fluid from the Kowhai-3 fracturing operations was disposed of by deep well injection, at the Turangi Production Station under consent 9272-2 and the Kaimiro-G wellsite well under consent 9470-1;
- 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; and
- It is considered that the mitigation measures implemented by GPL were effective in ensuring there were no adverse environmental effects associated with fracturing operations.

2.2. Physicochemical sampling

2.2.1. Groundwater

The recent hydraulic fracturing activities occurred at Kowhai-C (Kowhai-3 well) on 27 April 2016. Pre-fracturing sampling was undertaken on 17 July 2015 at three sites GND2432, GND2433 and GND2434. Three month post-fracturing sampling was undertaken on 19 and 20 July 2016 at two sites (GND2434 and GND2433 respectively). The one year post-fracturing sampling was undertaken on 4 May 2017 at two sites (GND2433 and GND2434) (Table 4).

Table 4 Groundwater sampling undertaken over the reporting period

Well	TRC sampling id	Fracturing date		Pre-fracturing sample date	3 month post-fracturing sample date	One year post-fracturing sample date
		Start	End			
Kowhai-3	GND2436	27/04/2016	27/04/2016	17/07/2015	19 - 20/07/2016	04/05/2017

The results of the laboratory analysis of samples from all sites indicate there have been no significant changes in groundwater composition over the review period. A comparison of these results to the baseline samples taken in 2014 and discussed in the 2013-2015 monitoring report also indicates there have been no significant changes since monitoring commenced. This is demonstrated by the relatively narrow ranges between analyte concentrations over time. The subtle variation in analyte concentrations at each site are a result of natural seasonal fluctuation and sampling variability.

Low concentrations of methane were detected in the pre-fracturing sample taken at GND2432 during July 2015. This sample was sent to GNS for further analysis. Isotopic analysis of the dissolved methane within the sample analysed by GNS indicates the methane gas is biogenic. Concentrations from all samples were all within the expected ranges for shallow groundwater across Taranaki.

A summary of results for all groundwater samples taken in relation to the hydraulic fracturing undertaken at the Kowhai-C wellsite for the recent hydraulic fracturing event is included in Table 5. The certificates of analysis are included in Appendix II.

Table 5 Results of groundwater sampling carried out in relation to the Kowhai-C fracturing event

Parameters	Units	GND2432	GND2434	GND2433	GND2434	GND2433	GND2433	GND2434
Sample id	-	TRC152333	TRC152334	TRC152335	TRC162546	TRC162547	TRC171794	TRC171795
Date	-	17-Jul-15	17-Jul-15	17-Jul-15	19-Jul-16	20-Jul-16	04-May-17	04-May-17
Time	-	8:15	8:40	9:00	12:25	8:30	8:45	9:30
Period	-	Pre-frac sample			Post-frac sample (3 mth)		Post-frac sample (1 yr)	
Field Parameters								
Dissolved oxygen	g/m^3	0.68	4.83	7.35	8.8	5.74	6.48	6.24
Dissolved oxygen	%	6.2	47.2	72.7	89.5	58.6	65	63.1
Electrical conductivity	mS/m	87.9	16.48	10.97	22.1	11.9	8.66	14.55
pH	pH	6.78	6.95	6.72	7.24	6.46	5.96	5.78
Specific conductance	mS/m	-	-	-	-	-	10.59	17.8
Temperature	°C	10.5	14	14.6	15.4	15.4	15.5	15.4
Laboratory Parameters								
Alkalinity	g/m^3 $CaCO_3$	510	25	23	25	23	23	27
Bicarbonate	g/m^3 at 25°C	630	30	28	30	28	28	32
Electrical conductivity	mS/m@25C	93.2	15.8	11	20.3	10.6	11.1	19.3
Hardness	g/m^3 $CaCO_3$	390	47	33	52	33	34	54
pH	pH	7	5.7	6	6.3	6.2	6.2	6
Total dissolved solids	g/m^3	530	110	71	130	74	85	125
Chloride	g/m^3	13.6	17.9	9.5	25	8.9	10.1	23
Nitrogen	g/m^3 N	<0.002	1.75	0.42	4.3	0.42	0.46	2.9
Nitrite	g/m^3 N	<0.002	<0.002	<0.002	< 0.002	< 0.002	< 0.002	< 0.002
Nitrate	g/m^3 N	<0.002	1.75	0.42	4.3	0.42	0.46	2.9
Sulphate	g/m^3	<0.5	12.1	10.9	14.8	11.8	11.4	14.4
Dissolved bromine	g/m^3	0.1	0.09	0.057	0.092	0.041	0.054	0.116
Dissolved calcium	g/m^3	91	12.9	9.8	15.1	9.7	10	15
Dissolved magnesium	g/m^3	40	3.6	2.2	3.5	2.1	2.1	4
Dissolved potassium	g/m^3	14.4	2.7	1.45	8.1	1.22	1.42	4.2

Parameters	Units	GND2432	GND2434	GND2433	GND2434	GND2433	GND2433	GND2434
Sample id	-	**TRC152333**	**TRC152334**	**TRC152335**	**TRC162546**	**TRC162547**	**TRC171794**	**TRC171795**
Date	-	**17-Jul-15**	**17-Jul-15**	**17-Jul-15**	**19-Jul-16**	**20-Jul-16**	**04-May-17**	**04-May-17**
Time	-	**8:15**	**8:40**	**9:00**	**12:25**	**8:30**	**8:45**	**9:30**
Period	-	**Pre-frac sample**			**Post-frac sample (3 mth)**		**Post-frac sample (1 yr)**	
Dissolved Sodium	g/m^3	47	10.4	7.2	12.8	6.6	6.8	11.3
Dissolved barium	g/m^3	0.04	0.024	0.0159	0.051	0.0164	0.0172	0.043
Dissolved copper	g/m^3	<0.0005	0.0006	<0.0005	0.0006	< 0.0005	0.0007	0.0008
Dissolved iron	g/m^3	19.4	0.02	<0.02	< 0.02	< 0.02	< 0.02	< 0.02
Dissolved manganese	g/m^3	0.173	0.0151	0.0034	0.0025	0.0027	0.004	0.0166
Dissolved mercury	g/m^3	<0.00008	<0.00008	<0.00008	< 0.00008	< 0.00008	< 0.00008	< 0.00008
Dissolved nickel	g/m^3	<0.0005	<0.0005	<0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Dissolved zinc	g/m^3	1.64	0.0164	0.0098	0.012	0.0059	0.0068	0.0142
Ethane gas	g/m^3	<0.003	<0.003	<0.003	< 0.003	< 0.003	< 0.003	< 0.003
Ethylene gas	g/m^3	<0.003	<0.003	<0.003	< 0.004	< 0.004	< 0.004	< 0.004
Methane gas	g/m^3	29	0.017	<0.002	< 0.002	< 0.002	< 0.002	0.003
Benzene	g/m^3	<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
Ethylene glycol	g/m^3	<4	<4	<4	< 4	< 4	< 4	< 4
Formaldehyde	g/m^3	0.04	<0.02	<0.02	< 0.02	< 0.02	< 0.02	< 0.02
Hydrocarbon c7-c9	g/m^3	-	-	-	< 0.10	< 0.10	< 0.06	< 0.06
Hydrocarbon c10-c14	g/m^3	-	-	-	< 0.2	< 0.2	< 0.2	< 0.2
Hydrocarbon c15-c36	g/m^3	-	-	-	< 0.4	< 0.4	< 0.4	< 0.4
Hydrocarbons -total	g/m^3	<0.7	<0.7	<0.7	< 0.7	< 0.7	< 0.7	< 0.7
Methanol	g/m^3	<2	<2	<2	< 2	< 2	< 2	< 2
Propylene glycol	g/m^3	<4	<4	<4	< 4	< 4	< 4	< 4
Toluene	g/m^3	<0.0010	<0.0010	<0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Xylene-m	g/m^3	<0.002	<0.002	<0.002	< 0.002	< 0.002	< 0.002	< 0.002
Xylene-o	g/m^3	<0.0010	<0.0010	<0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010

Parameters	Units	GND2432	GND2434	GND2433	GND2434	GND2433	GND2433	GND2434
Sample id	-	TRC152333	TRC152334	TRC152335	TRC162546	TRC162547	TRC171794	TRC171795
Date	-	17-Jul-15	17-Jul-15	17-Jul-15	19-Jul-16	20-Jul-16	04-May-17	04-May-17
Time	-	8:15	8:40	9:00	12:25	8:30	8:45	9:30
Period	-	Pre-frac sample			Post-frac sample (3 mth)		Post-frac sample (1 yr)	
C^{13} isotope in methane	0/000	-65.6	N/R	-	-	-	-	-

** A value <-50‰ indicates thermogenic methane, a value >-50‰ indicates biogenic methane, – value not provided, N/R = Not required*

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 Kowhai-C well 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	Hydraulic Fracturing Fluid
Sample date	-	**27 April 2016**
Lab number	-	**TRC162058**
Benzene	g/m^3	0.0055
Ethylbenzene	g/m^3	<0.0010
Ethylene glycol	g/m^3	<4
Hydrocarbons- total	g/m^3	18,400
Methanol	g/m^3	<2
Propylene glycol	g/m^3	<4
Toluene	g/m^3	0.0078
Xylene-m	g/m^3	<0.002
Xylene-o	g/m^3	0.0018

The results of the analyses carried out on the return fluid samples obtained following the hydraulic fracturing of the Kowhai-C well are summarised below in Table 7 and certificates of analysis are included in Appendix III. Return fluid samples generally contain a composite of samples collected at different intervals during the flow back period. The relatively high levels of chloride, sodium and hydrocarbons in each sample indicate that the composite samples prepared contained a greater proportion of reservoir fluids than fluids introduced during fracturing activities (comprised predominantly of freshwater).

Table 7 Results of hydraulic fracturing return fluid sampling

Parameter	Unit	Kowhai-3*	Parameter	Unit	Kowhai-3*
Lab number		**TRC161852**	**Lab number**		**TRC161852**
Total barium	g/m^3	5	Alkalinity	g/m^3 $CaCO_3$	2,200
Total copper	g/m^3	0.058	Bicarbonate	g/m^3 HCO_3	2,177
Total iron	g/m^3	1.77	Conductivity	mS/m	857
Total manganese	g/m^3	1.65	Hardness	g/m^3 $CaCO_3$	65
Total mercury	g/m^3	<0.0021	pH	pH	7.7
Total nickel	mg/kg	0.095	Total dissolved solids	g/m^3	7,700
Total zinc	g/m^3	0.47	Chloride	g/m^3	1,210
Benzene	g/m^3	3.8	Nitrate	g/m^3 N	0.04
Ethylbenzene	g/m^3	0.027	Nitrite	g/m^3 N	<0.02
Ethylene glycol	g/m^3	<4	Nitrogen	g/m^3 N	0.06
Formaldehyde	g/m^3	1.42	Sulphate	g/m^3	210
Hydrocarbons	g/m^3	450	Total bromine	g/m^3	10.3
Methanol	g/m^3	<2	Total calcium	g/m^3	22
Propylene glycol	g/m^3	<4	Total magnesium	g/m^3	4.2

Parameter	Unit	Kowhai-3*	Parameter	Unit	Kowhai-3*
Lab number		**TRC161852**	**Lab number**		**TRC161852**
Toluene	g/m^3	1.21	Total potassium	g/m^3	370
Xylene-m	g/m^3	0.13	Total sodium	g/m^3	1,700
Xylene-o	g/m^3	0.065	Total sulphur	g/m^3	69
*Note * TRC id for the Kowhai-3 production well is GND2436*					

2.3. Biomonitoring surveys

Two macroinvertebrate surveys were carried out on 15 April 2016 and 9 May 2016 to determine if discharges from the wellsite had significant adverse effects on the stream macroinvertebrate communities.

The macroinvertebrate surveys were undertaken using the Council's 'kick sampling' and 'vegetation sweep' techniques at one site in the Parahaki Stream and one site in an unnamed tributary of the Waiau Stream. The unnamed tributary of the Waiau Stream showed a significant decrease in MCI score between the two sampling occasions, which was attributable to the presence of one rare, 'highly sensitive' taxon in the pre-HF survey but not the post-HF survey, coupled with a low taxa richness. The taxa richness and $SQMCI_s$ scores at this site did not change significantly between these two surveys. The Parahaki Stream showed no significant changes in taxa richness, MCI score or $SQMCI_s$ score between the pre-HF and post-HF surveys. The lower than previously recorded taxa richness's and $SQMCI_s$ scores in the current surveys at both sites can be attributed to very low flow conditions resulting in habitat limitation at the time of these surveys. The MCI and $SQMCI_s$ scores recorded at both sites were high in comparison to other lowland coastal streams at similar altitude.

Overall, the results of these current surveys provide no evidence that the discharges from the Kowhai-C wellsite have had any significant impacts on the macroinvertebrate communities of the unnamed tributary of the Waiau Stream or of the Parahaki Stream.

The full report on the biomonitoring carried out in the vicinity of the wellsite undertaken in relation to the April 2016 activities is included in Appendix IV.

2.4. Investigations, interventions, and incidents

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

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

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

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

3. Discussion

3.1. Environmental effects of hydraulic fracturing on useable freshwater resources

One well (Kowhai-3) was stimulated by hydraulic fracturing at the Kowhai-C wellsite in April 2016.

Monitoring carried out by the Council in relation to the fracturing event undertaken in April 2016 included both groundwater and surface water monitoring components. Groundwater monitoring incorporated pre-fracturing sampling of three monitoring sites and post-fracturing sampling of two monitoring sites in the vicinity of the Kowhai-C wellsite.

The results of post-fracturing groundwater sampling carried out showed only very minor variations in water composition in comparison to pre-fracturing results. The minor variations in most analytes are a result of natural variations in water composition.

The surface water monitoring component of the programme comprised of two biomonitoring surveys (pre and post-fracturing) of one site in the Parahaki Stream and one site in an unnamed tributary of the Waiau Stream.

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

No complaints were received or further investigations required by the Council.

In summary, the monitoring carried out by the Council during the period being reported indicates that the hydraulic fracturing activities undertaken by GPL at the Kowhai-C wellsite has had no significant adverse effects on local groundwater or surface water resources.

3.2. Evaluation of performance

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

Table 8 Summary of performance for Consent 10139-1

Purpose: *To discharge contaminants in association with hydraulic fracturing activities into land at depths greater than 3,400 m TVD beneath the Kowhai-C wellsite*		
Condition requirement	**Means of monitoring during period under review**	**Compliance achieved?**
1. Any discharge shall occur below 3,400 m TVD	Assessment of consent holder submitted data	Yes
2. No discharge of hydraulic fracturing fluids after 1 June 2025	Assessment of consent holder submitted data and site inspections	N/A
3. Hydraulic activities to cease if a nearby seismic event of Magnitude 3.0 or above is recorded	Assessment of consent holder submitted data	N/A
4. Consent holder shall investigate and report on any recorded seismic events of magnitude 3.0 or higher occur nearby during hydraulic fracturing activities	Assessment of consent holder submitted data	N/A
5. Exercise of consent shall not result in any contaminants reaching any useable freshwater (groundwater or surface water)	Results of groundwater and surface water monitoring	Yes
6. Consent holder shall undertake sampling programme	Development and certification of a monitoring programme	Yes
7. If no suitable groundwater monitoring bore within 500 m of the wellsite, a monitoring well will need to be installed	Development and certification of a monitoring programme	N/A
8. Sampling programme shall follow recognised field procedures and be analysed for a specified range of chemical parameters	Development and certification of a monitoring programme and assessment of results	Yes
9. All sampling to be carried out in accordance with a certified sampling and analysis plan	Development and certification of a sampling and analysis plan	Yes
10. Well and equipment pressure testing to be carried out prior to any hydraulic fracturing programme commencing	Assessment of consent holder submitted data	Yes
11. A pre-fracturing discharge report is to be provided to the Council 14 days prior to discharge	Pre-fracturing discharge report received	Yes
12. Consent holder shall notify the Council of hydraulic fracturing discharge	Notification received	Yes

Purpose: *To discharge contaminants in association with hydraulic fracturing activities into land at depths greater than 3,400 m TVD beneath the Kowhai-C wellsite*		
Condition requirement	**Means of monitoring during period under review**	**Compliance achieved?**
13. A post-fracturing discharge report is to be provided to the Council within 90 days after the hydraulic fracturing programme has commenced	Post-fracturing discharge report received	Yes
14. Interim post fracturing reports are to be provided if necessary to meet the 90 day deadline	Interim post-fracturing discharge reports received	N/A
15. The reports outlined in conditions 11, 13 and 14 must be emailed to consents@trc.govt.nz	Reports received via email	Yes
16. The consent holder shall provide access to a location where samples of hydraulic fracturing fluids and return fluids can be obtained by the Council officers	Access provided	Yes
17. Consent holder to adopt best practicable option at all times	Site inspections, sampling and assessment of consent holder submitted data	Yes
18. Composition of fluids to be no less than 95% water and proppant by volume	Assessment of consent holder submitted data	*Yes
19. No hydrocarbon based hydraulic fracturing fluid shall be discharged	Assessment of consent holder submitted data and sampling of fracturing fluid	Yes
20. 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 Overall assessment of administrative performance and compliance in respect of this consent		**High** **High**

Note - *Volumes provided in mass percentage not volume percentage

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

3.3. Recommendations from the 2013-2015 Monitoring Report

In the 2013-2015 Monitoring Report, it was recommended:

1. THAT during the 2015-2016 monitoring year, a further round of groundwater sampling be carried out across all sites previously surveyed to assess for any delayed effects on local groundwater resources as a result of fracturing events at the Kowhai-C wellsite.
2. THAT following the assessment of the results of the groundwater sampling recommended above, a review be undertaken to determine if any further monitoring is warranted, or whether the programmes can be discontinued, provided no further fracturing occurs at the Kowhai-C wellsite.

3. THAT the option for a review of resource consents in June 2015, as set out in condition 16 of consent 9480-1, is not exercised, on the grounds that the current conditions of the consent are adequate to ensure that any significant adverse effects on the environment are avoided.

These recommendations were implemented.

3.4. Alterations to monitoring of future hydraulic fracturing events

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

- the extent of information made available by previous authorities,
- its relevance under the RMA;
- its obligations to monitor emissions/discharges and effects under the RMA; and
- report to the regional community.

The Council also takes into account the scope of assessments required at the time of renewal of permits, and the need to maintain a sound understanding of industrial processes within Taranaki emitting to the atmosphere/discharging to the environment.

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

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

3.5. Exercise of optional review of consent

The next optional review dates for consents 10139-1 is provided for in June 2017.

The Council may serve notice of its intention to review, amend, delete or add to the conditions of this resource consent. A review may be required for the purpose of ensuring that the conditions are adequate to deal with any adverse effects on the environment arising from the exercise of this resource consent, which were either not foreseen at the time the application was considered or which it was not appropriate to deal with at the time.

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

4. Recommendations

1. THAT the range of monitoring carried out during the reporting period in relation to the Company's hydraulic fracturing activities be replicated for any future fracturing events at the Kowhai-C wellsite.
2. That GPL install a site specific monitoring bore to improve the monitoring network prior to any future hydraulic fracturing activities, given the current site access issues.
3. THAT the Council notes there is no requirement at this time for a consent review to be pursued or grounds to exercise the review options.

Glossary of common terms and abbreviations

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

Biomonitoring	Assessing the health of the environment using aquatic organisms.
Bbls	Barrel. Unit of measure used in the oil and gas industry (equivalent to approximately 159 litres).
Fresh	Elevated flow in a stream, such as after heavy rainfall.
g/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.
Macroinvertebrate	An invertebrate that is large enough to be seen without the use of a microscope.
M asl	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).
M TVD	Metres total vertical depth.
pH	A numerical system for measuring acidity in solutions, with 7 as neutral. Numbers lower than 7 are increasingly acidic and higher than 7 are increasingly alkaline.
Physicochemical	Measurement of both physical properties (e.g. temperature, clarity, density) and chemical determinants (e.g. metals and nutrients) to characterise the state of an environment.
Resource consent	Refer Section 87 of the RMA. Resource consents include land use consents (refer Sections 9 and 13 of the RMA), coastal permits (Sections 12, 14 and 15), water permits (Section 14) and discharge permits (Section 15).
RMA	Resource Management Act 1991 and including all subsequent amendments.
Screen Out	A condition that occurs when the solids carried in a treatment fluid, such as proppant in a fracture fluid, create a bridge across the perforations or similar restricted flow area. This creates a sudden and significant restriction to fluid flow that causes a rapid rise in pump pressure.
SQMCI	Semi quantitative macroinvertebrate community index.
TVDss	True vertical depth sub-sea
Workover	The repair or stimulation of an existing production well for the purpose of restoring, prolonging or enhancing the production of hydrocarbons.

Bibliography and references

Stark JD, (1998). SQMCI: a biotic index for freshwater macroinvertebrate coded abundance data. *New Zealand Journal of Marine and Freshwater Research 32(1)*: 55-66.

Taranaki Regional Council, (2016). Biomonitoring of an unnamed tributary of the Waiau Stream and of the Parahaki Stream in relation to hydraulic fracturing at the Kowhai-C wellsite, May 2016. Report KB006.

Taranaki Regional Council (2017) Greymouth Petroleum Limited Kowhai-C Wellsite Water Quality Monitoring Programme, doc id 1850015.

Taranaki Regional Council (2016) Greymouth Petroleum Limited Kowhai-C Wellsite Water Quality Monitoring Programme, doc id 1732570.

Greymouth Petroleum Limited (2016) Kowhai-3 Post-Fracturing Discharge Report. Doc id 1720341.

Greymouth Petroleum Limited (2015) Kowhai-3 Pre-Fracturing Discharge Report. Doc id 1674853.

Taranaki Regional Council (2015) Kowhai-C Hydraulic Fracturing Groundwater Monitoring Programme Report 2013-2015. Technical Report 2014-110.

Appendix I
Resource consents held by Greymouth Petroleum Limited

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

Discharge Permit

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

Name of Consent Holder:	Petrochem Limited PO Box 3394 New Plymouth 4341
Decision Date:	30 July 2015
Commencement Date:	30 July 2015

Conditions of Consent

Consent Granted:	To discharge water based hydraulic fracturing fluids into land at depths greater than 3,400 mTVDss beneath the Kowhai-C wellsite
Expiry Date:	1 June 2030
Review Date(s):	June Annually
Site Location:	Kowhai-C wellsite, 492 Otaraoa Road, Tikorangi
Legal Description:	Lot 2 DP 6166 Blk VI Waitara SD (Discharge source & site)
Grid Reference (NZTM)	1711761E-5678397N
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 3,400 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 2025.

3. If the GeoNet seismic monitoring network records a seismic event higher than a Modified Mercalli intensity of magnitude 3.0 within 5 km of the geographical position (in 3 dimensions) of any hydraulic fracturing discharge, then:

   (a) if a hydraulic fracturing discharge is currently being undertaken it shall cease immediately and not recommence; or

   (b) if a hydraulic fracturing discharge has occurred within the previous 72 hours no further hydraulic fracturing discharges shall occur.

4. Following the occurrence of any seismic event described in special condition 3 the consent holder shall investigate and report to the Chief Executive, Taranaki Regional Council on the likelihood of the seismic event being induced by the exercise of this consent. Hydraulic fracturing discharges may only then continue once the Chief Executive, Taranaki Regional Council has considered the report and concluded that the environmental risk of recommencing hydraulic fracturing is acceptable and has advised the consent holder accordingly.

5. The consent holder shall ensure that the exercise of this consent does not result in contaminants reaching any useable fresh water (groundwater or surface water). Usable fresh groundwater is defined as any groundwater having a Total Dissolved Solids concentration of less than 1,000 mg/l.

6. The consent holder shall undertake a programme of sampling and testing that monitors the effects of the exercise of this consent on fresh water resources to assess compliance with condition 5 (the 'Monitoring Programme'). The Monitoring Programme shall be certified by the Chief Executive, Taranaki Regional Council ('the Chief Executive'), before this consent is exercised, and shall include:

   (a) the location of the discharge point(s);
   (b) the location of sampling sites; and
   (c) sampling frequency with reference to a hydraulic fracturing programme.

7. 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.

8. All water samples taken for monitoring purposes shall be taken in accordance with recognised field procedures and analysed for:

   (a) pH;
   (b) conductivity;
   (c) total dissolved solids;
   (d) major ions (Ca, Mg, K, Na, total alkalinity, bromide, chloride, nitrate-nitrogen, and sulphate);
   (e) trace metals (barium, copper, iron, manganese, nickel, and zinc);
   (f) total petroleum hydrocarbons;
   (g) formaldehyde;
   (h) dissolved methane and ethane gas;
   (i) methanol;
   (j) glycols;
   (k) benzene, toluene, ethylbenzene, and xylenes (BTEX); and
   (l) carbon-13 composition of any dissolved methane gas discovered (^{13}C-CH_4).

   Note: *The samples required, under conditions 7 and 9 could be taken and analysed by the Taranaki Regional Council or other contracted party on behalf of the consent holder.*

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

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

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

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

    (a) the specific well in which each discharge is to occur, the intended fracture interval(s) ('fracture interval' is the discrete subsurface zone to receive a hydraulic fracture treatment), and the duration of the hydraulic fracturing programme;
    (b) the number of discharges proposed and the geographical position (i.e. depth and lateral position) of each intended discharge point;
    (c) the total volume of fracture fluid planned to be pumped down the well, including mini-fracture treatments, and their intended composition, including a list of all contaminants and Material Safety Data Sheets for all the chemicals to be used;
    (d) the monitoring techniques to be used to determine the fate of discharged material;
    (e) the results of the reviews required by condition 17;
    (f) results of modelling showing an assessment of the likely extent and dimensions of the fractures that will be generated by the discharge;
    (g) the preventative and mitigation measures to be in place to ensure the discharge does not cause adverse environmental effects and complies with condition 5;
    (h) the extent and permeability characteristics of the geology above the discharge point to the surface;
    (i) any identified faults within the modelled 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 casing 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 17.

    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.

12. The consent holder shall notify the Taranaki Regional Council of the date that each discharge is intended to commence by emailing worknotification@trc.govt.nz. Notification also shall identify the 'Pre-fracturing Discharge Report', required by condition 0, which details the discharge and be given no less than 3 days before the intended discharge date. If any discharge occurs more than 30 days after the notification date, additional notification as specified in this condition is required.

13. Subject to condition 14, within 90 days of any commencement date as advised under condition 12, the consent holder shall submit a comprehensive 'Post-fracturing Discharge Report' to the Chief Executive. The report shall, as a minimum, contain:

    (a) date and time of discharge;
    (b) confirmation of the interval(s) where fracturing occurred for that programme, and the geographical position (i.e., depth and lateral position) of the discharge point for each fracture interval;
    (c) the contaminant volumes and composition of fluid discharged into each fracture interval;
    (d) the volume of return fluids from each fracture interval;
    (e) an analysis for the constituents set out in conditions 8(a) to 8(k), in a return fluid sample taken within the first two hours of flow back, for each fracture interval if flowed back individually, or for the well if flowed back with all intervals comingled;
    (f) an estimate of the volume of fluids (and proppant) remaining underground;
    (g) the volume of water produced with the hydrocarbons (produced water) over the period beginning at the start of the hydraulic fracturing programme and ending 30 days after the programme is completed or after that period of production;
    (h) an assessment of the extent and dimensions of the fractures that were generated by the discharge, based on modelling undertaken after the discharge has occurred and other diagnostic techniques, including production analysis, available to determine fracture length, height and containment;
    (i) the results of pressure testing required by condition 10 and the top-hole pressure (psi), slurry rate (bpm), surface proppant concentration (lb/gal), bottom hole proppant concentration (lb/gal), and calculated bottom hole pressure (psi), as well as predicted values for each of these parameters; prior to, during and after each hydraulic fracture treatment;
    (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 5; and
    (l) results of the monitoring referred to in condition 11 (d); and
    (m) an assessment of the effectiveness of the mitigation measures in place with specific reference to those described in the application for this consent.

14. On occasions, including for programs involving multiple hydraulic fracturing discharges, more than one 'Post-fracturing discharge report' may be required in order to meet the 90-day deadline from commencement required by condition 13. In these situations the consent holder shall submit an 'Interim Post-fracturing Discharge Report', which includes all the information that is available, to the Chief Executive within 90 days and a final Post-fracturing report as soon as practicable but within 90 days of the interim report.

15. The reports described in conditions 0 and 13 shall be emailed to consents@trc.govt.nz with a reference to the number of this consent.

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

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

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

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

19. This consent shall lapse on 1 June 2022, unless the consent is given effect to before the end of that period or the Taranaki Regional Council fixes a longer period pursuant to section 125(1)(b) of the Resource Management Act 1991.

20. The Taranaki Regional Council may review any or all of the conditions of this consent by giving notice of review:

    a) during the month of June each year, and/or
    b) within 30 days of receiving any investigation and report in accordance with special condition 4 above;

    for the purposes of:

    (a) ensuring that the conditions are adequate to deal with any significant adverse effects on the environment arising from the exercise of this consent, which were either not foreseen at the time the application was considered or which it was not appropriate to deal with at the time; and/or
    (b) further specifying the best practicable option as required by condition 17; and/or
    (c) ensuring hydraulic fracturing operations appropriately take into account any best practice guidance published by a recognised industry association or environmental regulator.

Signed at Stratford on 30 July 2015

For and on behalf of
Taranaki Regional Council

_____

A D McLay
Director - Resource Management

Appendix II
Certificates of analysis (groundwater)

Hill Laboratories
TRIED, TESTED AND TRUSTED

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Hamilton 3240 New Zealand

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E mail@hill-labs.co.nz
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ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1770922 SPv1
Contact:	David Olson	**Date Received:**	06-May-2017
	C/- Taranaki Regional Council	**Date Reported:**	16-May-2017
	Private Bag 713	**Quote No:**	47915
	Stratford 4352	**Order No:**	64192
		Client Reference:	GPL Kowhai-C 1 year post frac SW
		Submitted By:	David Olson

Sample Type: Aqueous

Sample Name:		GND 2433 04-May-2017 8:45 am	GND 2434 04-May-2017 9:30 am			
Lab Number:		1770922.1	1770922.2			
Individual Tests						
Sum of Anions	meq/L	1.01	1.70	-	-	-
Sum of Cations	meq/L	1.00	1.67	-	-	-
pH	pH Units	6.2	6.0	-	-	-
Total Alkalinity	g/m³ as $CaCO_3$	23	27	-	-	-
Bicarbonate	g/m³ at 25°C	28	32	-	-	-
Total Hardness	g/m³ as $CaCO_3$	34	54	-	-	-
Electrical Conductivity (EC)	mS/m	11.1	19.3	-	-	-
Total Dissolved Solids (TDS)	g/m³	85	125	-	-	-
Dissolved Barium	g/m³	0.0172	0.043	-	-	-
Dissolved Bromine*	g/m³	0.054	0.116	-	-	-
Dissolved Calcium	g/m³	10.0	15.0	-	-	-
Dissolved Copper	g/m³	0.0007	0.0008	-	-	-
Dissolved Iron	g/m³	< 0.02	< 0.02	-	-	-
Dissolved Magnesium	g/m³	2.1	4.0	-	-	-
Dissolved Manganese	g/m³	0.0040	0.0166	-	-	-
Dissolved Mercury	g/m³	< 0.00008	< 0.00008	-	-	-
Dissolved Nickel	g/m³	< 0.0005	< 0.0005	-	-	-
Dissolved Potassium	g/m³	1.42	4.2	-	-	-
Dissolved Sodium	g/m³	6.8	11.3	-	-	-
Dissolved Zinc	g/m³	0.0068	0.0142	-	-	-
Chloride	g/m³	10.1	23	-	-	-
Nitrite-N	g/m³	< 0.002	< 0.002	-	-	-
Nitrate-N	g/m³	0.46	2.9	-	-	-
Nitrate-N + Nitrite-N	g/m³	0.46	2.9	-	-	-
Sulphate	g/m³	11.4	14.4	-	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	< 4	< 4	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m³	< 4	< 4	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m³	< 2	< 2	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m³	< 0.0010	< 0.0010	-	-	-
Toluene	g/m³	< 0.0010	< 0.0010	-	-	-
Ethylbenzene	g/m³	< 0.0010	< 0.0010	-	-	-
m&p-Xylene	g/m³	< 0.002	< 0.002	-	-	-
o-Xylene	g/m³	< 0.0010	< 0.0010	-	-	-

Sample Type: Aqueous						
Sample Name:		GND 2433 04-May-2017 8:45 am	GND 2434 04-May-2017 9:30 am			
Lab Number:		1770922.1	1770922.2			
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m³	< 0.02	< 0.02	-	-	-
Gases in groundwater						
Ethane	g/m³	< 0.003	< 0.003	-	-	-
Ethylene	g/m³	< 0.004	< 0.004	-	-	-
Methane	g/m³	< 0.002	0.003	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m³	< 0.06	< 0.06	-	-	-
C10 - C14	g/m³	< 0.2	< 0.2	-	-	-
C15 - C36	g/m³	< 0.4	< 0.4	-	-	-
Total hydrocarbons (C7 - C36)	g/m³	< 0.7	< 0.7	-	-	-

Analyst's Comments

Samples 1-2 Comment:
Please note that the TPH C7 - C9 band was analysed by the head space/GCMS method, with all other TPH bands analysed by hexane solvent extraction/GC/FID.

SUMMARY OF METHODS

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

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	1-2
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	1-2
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m³	1-2
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m³	1-2
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS	0.02 g/m³	1-2
Gases in groundwater	Manual headspace creation and sub-sampling, GC-FID analysis.	0.002 - 0.003 g/m³	1-2
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	1-2
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1-2
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	1-2
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	1-2
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	1-2
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 $CaCO_3$	1-2
Bicarbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO_2 D 22nd ed. 2012.	1.0 g/m³ at 25°C	1-2
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 22nd ed. 2012.	1.0 g/m³ as $CaCO_3$	1-2
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 22nd ed. 2012.	0.1 mS/m	1-2
Total Dissolved Solids (TDS)	Filtration through GF/C (1.2 µm), gravimetric. APHA 2540 C (modified; drying temperature of 103 - 105°C used rather than 180 ± 2°C) 22nd ed. 2012.	10 g/m³	1-2

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.00010 g/m³	1-2
Dissolved Bromine*	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.005 g/m³	1-2
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m³	1-2
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1-2
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m³	1-2
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m³	1-2
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1-2
Dissolved Mercury	0.45µm filtration, bromine oxidation followed by atomic fluorescence. US EPA Method 245.7, Feb 2005.	0.00008 g/m³	1-2
Dissolved Nickel	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1-2
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m³	1-2
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m³	1-2
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0010 g/m³	1-2
Chloride	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl^- E (modified from continuous flow analysis) 22nd ed. 2012.	0.5 g/m³	1-2
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012 (modified).	0.002 g/m³	1-2
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m³	1-2
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	1-2
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B 22nd ed. 2012.	0.5 g/m³	1-2
C7 - C9	Head Space, GCMS analysis.	0.06 g/m³	1-2
C10 - C14	Solvent extraction, GC-FID analysis. US EPA 8015B/NZ OIEWG.	0.2 g/m³	1-2
C15 - C36	Solvent extraction, GC-FID analysis. US EPA 8015B/NZ OIEWG.	0.4 g/m³	1-2
Total hydrocarbons (C7 - C36)	Solvent extraction, GC-FID analysis and Headspace, GC-MS FS analysis for C7-C9 carbon band.	0.7 g/m³	1-2

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

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

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

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BETTER TESTING BETTER RESULTS

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ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1452032	SPv1
Contact:	Regan Phipps	**Date Registered:**	18-Jul-2015	
	C/- Taranaki Regional Council	**Date Reported:**	24-Jul-2015	
	Private Bag 713	**Quote No:**	47915	
	STRATFORD 4352	**Order No:**		
		Client Reference:	Kowhai C - 1 yr Post HF	
		Submitted By:	Regan Phipps	

Sample Type: Aqueous

Sample Name:		GND2432 17-Jul-2015 8:15 am	GND2434 17-Jul-2015 8:40 am	GND2433 17-Jul-2015 9:00 am		
Lab Number:		1452032.1	1452032.2	1452032.3		
Individual Tests						
Sum of Anions	meq/L	10.7	1.38	0.98	-	-
Sum of Cations	meq/L	11.0	1.47	1.02	-	-
pH	pH Units	7.0	5.7	6.0	-	-
Total Alkalinity	g/m³ as $CaCO_3$	510	25	23	-	-
Bicarbonate	g/m³ at 25°C	630 #1	30	28	-	-
Total Hardness	g/m³ as $CaCO_3$	390	47	33	-	-
Electrical Conductivity (EC)	mS/m	93.2	15.8	11.0	-	-
Total Dissolved Solids (TDS)	g/m³	530 #1	110	71	-	-
Dissolved Barium	g/m³	0.040	0.024	0.0159	-	-
Dissolved Bromine*	g/m³	0.10	0.090	0.057	-	-
Dissolved Calcium	g/m³	91	12.9	9.8	-	-
Dissolved Copper	g/m³	< 0.0005	0.0006	< 0.0005	-	-
Dissolved Iron	g/m³	19.4	0.02	< 0.02	-	-
Dissolved Magnesium	g/m³	40	3.6	2.2	-	-
Dissolved Manganese	g/m³	0.173	0.0151	0.0034	-	-
Dissolved Mercury	g/m³	< 0.00008	< 0.00008	< 0.00008	-	-
Dissolved Nickel	g/m³	< 0.0005	< 0.0005	< 0.0005	-	-
Dissolved Potassium	g/m³	14.4	2.7	1.45	-	-
Dissolved Sodium	g/m³	47	10.4	7.2	-	-
Dissolved Zinc	g/m³	1.64	0.0164	0.0098	-	-
Chloride	g/m³	13.6	17.9	9.5	-	-
Nitrite-N	g/m³	< 0.002	< 0.002	< 0.002	-	-
Nitrate-N	g/m³	< 0.002	1.75	0.42	-	-
Nitrate-N + Nitrite-N	g/m³	< 0.002	1.75	0.42	-	-
Sulphate	g/m³	< 0.5	12.1	10.9	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	< 4	< 4	< 4	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m³	< 4	< 4	< 4	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m³	< 2	< 2	< 2	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m³	< 0.0010	< 0.0010	< 0.0010	-	-
Toluene	g/m³	< 0.0010	< 0.0010	< 0.0010	-	-
Ethylbenzene	g/m³	< 0.0010	< 0.0010	< 0.0010	-	-
m&p-Xylene	g/m³	< 0.002	< 0.002	< 0.002	-	-

Sample Type: Aqueous						
Sample Name:		GND2432 17-Jul-2015 8:15 am	GND2434 17-Jul-2015 8:40 am	GND2433 17-Jul-2015 9:00 am		
Lab Number:		1452032.1	1452032.2	1452032.3		
BTEX in Water by Headspace GC-MS						
o-Xylene	g/m³	< 0.0010	< 0.0010	< 0.0010	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m³	0.04	< 0.02	< 0.02	-	-
Gases in groundwater						
Ethane	g/m³	< 0.003	< 0.003	< 0.003	-	-
Ethylene	g/m³	< 0.003	< 0.003	< 0.003	-	-
Methane	g/m³	29	0.017	< 0.002	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m³	< 0.10	< 0.10	< 0.10	-	-
C10 - C14	g/m³	< 0.2	< 0.2	< 0.2	-	-
C15 - C36	g/m³	< 0.4	< 0.4	< 0.4	-	-
Total hydrocarbons (C7 - C36)	g/m³	< 0.7	< 0.7	< 0.7	-	-

Analyst's Comments

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

SUMMARY OF METHODS

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

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	1-3
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	1-3
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m³	1-3
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m³	1-3
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS	0.02 g/m³	1-3
Gases in groundwater	Manual headspace creation and sub-sampling, GC-FID analysis.	0.002 - 0.003 g/m³	1-3
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/m³	1-3
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1-3
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	1-3
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	1-3
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	1-3
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 $CaCO_3$	1-3
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	1-3
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 22nd ed. 2012.	1.0 g/m³ as $CaCO_3$	1-3
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 22nd ed. 2012.	0.1 mS/m	1-3
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	1-3

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.00010 g/m³	1-3
Dissolved Bromine*	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.005 g/m³	1-3
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m³	1-3
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1-3
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m³	1-3
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m³	1-3
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1-3
Dissolved Mercury	0.45µm filtration, bromine oxidation followed by atomic fluorescence. US EPA Method 245.7, Feb 2005.	0.00008 g/m³	1-3
Dissolved Nickel	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1-3
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m³	1-3
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m³	1-3
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0010 g/m³	1-3
Chloride	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl^- E (modified from continuous flow analysis) 22nd ed. 2012.	0.5 g/m³	1-3
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012 (modified).	0.002 g/m³	1-3
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m³	1-3
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	1-3
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B 22nd ed. 2012.	0.5 g/m³	1-3

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.

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

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ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1618870 SPv1
Contact:	David Olson	**Date Received:**	21-Jul-2016
	C/- Taranaki Regional Council	**Date Reported:**	08-Aug-2016
	Private Bag 713	**Quote No:**	47915
	Stratford 4352	**Order No:**	
		Client Reference:	Kowhai C Post FRAC 3 Months
		Submitted By:	David Olson

Sample Type: Aqueous

Sample Name:		GND2433 20-Jul-2016 8:30 am	GND2434 19-Jul-2016 12:15 pm			
Lab Number:		1618870.1	1618870.2			
Individual Tests						
Sum of Anions	meq/L	0.99	1.82	-	-	-
Sum of Cations	meq/L	0.98	1.81	-	-	-
pH	pH Units	6.2	6.3	-	-	-
Total Alkalinity	g/m³ as $CaCO_3$	23	25	-	-	-
Bicarbonate	g/m³ at 25°C	28	30	-	-	-
Total Hardness	g/m³ as $CaCO_3$	33	52	-	-	-
Electrical Conductivity (EC)	mS/m	10.6	20.3	-	-	-
Total Dissolved Solids (TDS)	g/m³	74	130	-	-	-
Dissolved Barium	g/m³	0.0164	0.051	-	-	-
Dissolved Bromine*	g/m³	0.041	0.092	-	-	-
Dissolved Calcium	g/m³	9.7	15.1	-	-	-
Dissolved Copper	g/m³	< 0.0005	0.0006	-	-	-
Dissolved Iron	g/m³	< 0.02	< 0.02	-	-	-
Dissolved Magnesium	g/m³	2.1	3.5	-	-	-
Dissolved Manganese	g/m³	0.0027	0.0025	-	-	-
Dissolved Mercury	g/m³	< 0.00008	< 0.00008	-	-	-
Dissolved Nickel	g/m³	< 0.0005	< 0.0005	-	-	-
Dissolved Potassium	g/m³	1.22	8.1	-	-	-
Dissolved Sodium	g/m³	6.6	12.8	-	-	-
Dissolved Zinc	g/m³	0.0059	0.0120	-	-	-
Chloride	g/m³	8.9	25	-	-	-
Nitrite-N	g/m³	< 0.002	< 0.002	-	-	-
Nitrate-N	g/m³	0.42	4.3	-	-	-
Nitrate-N + Nitrite-N	g/m³	0.42	4.3	-	-	-
Sulphate	g/m³	11.8	14.8	-	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	< 4	< 4	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m³	< 4	< 4	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m³	< 2	< 2	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m³	< 0.0010	< 0.0010	-	-	-
Toluene	g/m³	< 0.0010	< 0.0010	-	-	-
Ethylbenzene	g/m³	< 0.0010	< 0.0010	-	-	-
m&p-Xylene	g/m³	< 0.002	< 0.002	-	-	-

Sample Type: Aqueous						
Sample Name:		GND2433 20-Jul-2016 8:30 am	GND2434 19-Jul-2016 12:15 pm			
Lab Number:		1618870.1	1618870.2			
BTEX in Water by Headspace GC-MS						
o-Xylene	g/m³	< 0.0010	< 0.0010	-	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m³	< 0.02	< 0.02	-	-	-
Gases in groundwater						
Ethane	g/m³	< 0.003	< 0.003	-	-	-
Ethylene	g/m³	< 0.004	< 0.004	-	-	-
Methane	g/m³	< 0.002	< 0.002	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m³	< 0.10	< 0.10	-	-	-
C10 - C14	g/m³	< 0.2	< 0.2	-	-	-
C15 - C36	g/m³	< 0.4	< 0.4	-	-	-
Total hydrocarbons (C7 - C36)	g/m³	< 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	1-2
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	1-2
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m³	1-2
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m³	1-2
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS	0.02 g/m³	1-2
Gases in groundwater	Manual headspace creation and sub-sampling, GC-FID analysis.	0.002 - 0.003 g/m³	1-2
Total Petroleum Hydrocarbons in Water	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734]	0.10 - 0.7 g/m³	1-2
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1-2
Total anions for anion/cation balance check	Calculation: sum of anions as 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	1-2
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	1-2
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	1-2
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 $CaCO_3$	1-2
Bicarbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO_2 D 22nd ed. 2012.	1.0 g/m³ at 25°C	1-2
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 22nd ed. 2012.	1.0 g/m³ as $CaCO_3$	1-2
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 22nd ed. 2012.	0.1 mS/m	1-2
Total Dissolved Solids (TDS)	Filtration through GF/C (1.2 µm), gravimetric. APHA 2540 C (modified; drying temperature of 103 - 105°C used rather than 180 ± 2°C) 22nd ed. 2012.	10 g/m³	1-2
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.00010 g/m³	1-2
Dissolved Bromine*	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.005 g/m³	1-2

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m³	1-2
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1-2
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m³	1-2
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m³	1-2
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1-2
Dissolved Mercury	0.45µm filtration, bromine oxidation followed by atomic fluorescence. US EPA Method 245.7, Feb 2005.	0.00008 g/m³	1-2
Dissolved Nickel	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1-2
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m³	1-2
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m³	1-2
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0010 g/m³	1-2
Chloride	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl^- E (modified from continuous flow analysis) 22nd ed. 2012.	0.5 g/m³	1-2
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012 (modified).	0.002 g/m³	1-2
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m³	1-2
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	1-2
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B 22nd ed. 2012.	0.5 g/m³	1-2

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

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

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

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

Hill Laboratories
BETTER TESTING BETTER RESULTS

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Hamilton 3240, New Zealand

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

ANALYSIS REPORT

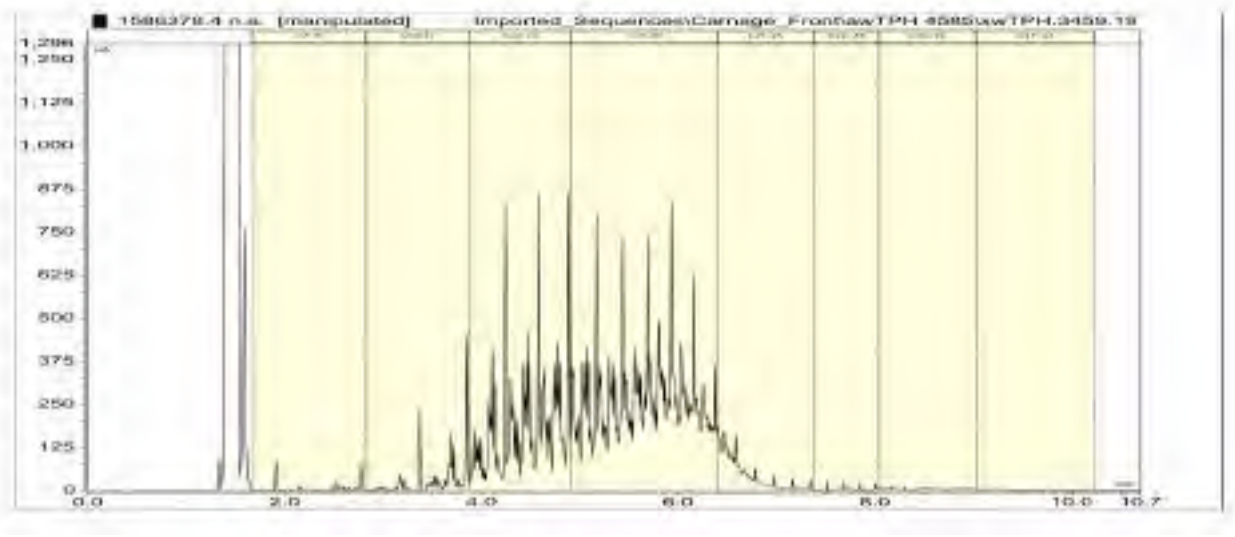
Client:	Taranaki Regional Council	**Lab No:**	1586378 SPv1
Contact:	Regan Phipps	**Date Registered:**	19-May-2016
	C/- Taranaki Regional Council	**Date Reported:**	31-May-2016
	Private Bag 713	**Quote No:**	71307
	Stratford 4352	**Order No:**	
		Client Reference:	GPL Kowhai-C Frac Return Fluid
		Submitted By:	David Olson

Sample Type: Saline

Sample Name:		Composite of Kowhai -C K3 #2, Kowhai -C K3 and Kowhai -C K3 #46				
Lab Number:		1586378.4				
Individual Tests						
pH*	pH Units	7.7	-	-	-	-
Total Alkalinity*	g/m³ as $CaCO_3$	2,200	-	-	-	-
Analysis Temperature for Bicarbonate	°C	23	-	-	-	-
Bicarbonate	g/m³ at Analysis Temperature	2,177	-	-	-	-
Total Hardness*	g/m³ as $CaCO_3$	65	-	-	-	-
Electrical Conductivity (EC)*	mS/m	857	-	-	-	-
Total Dissolved Solids (TDS)*	g/m³	7,700	-	-	-	-
Total Barium*	g/m³	5.0	-	-	-	-
Total Bromine*	g/m³	10.3	-	-	-	-
Dissolved Calcium*	g/m³	20	-	-	-	-
Total Calcium*	g/m³	22	-	-	-	-
Total Copper*	g/m³	0.058	-	-	-	-
Total Iron*	g/m³	1.77	-	-	-	-
Dissolved Magnesium*	g/m³	3.6	-	-	-	-
Total Magnesium*	g/m³	4.2	-	-	-	-
Total Manganese*	g/m³	1.65	-	-	-	-
Total Mercury*	g/m³	< 0.0021	-	-	-	-
Total Nickel*	g/m³	0.095	-	-	-	-
Total Potassium*	g/m³	370	-	-	-	-
Total Sodium*	g/m³	1,700	-	-	-	-
Total Sulphur*	g/m³	69	-	-	-	-
Total Zinc*	g/m³	0.47	-	-	-	-
Chloride*	g/m³	1,210	-	-	-	-
Nitrite-N	g/m³	< 0.02 #1	-	-	-	-
Nitrate-N	g/m³	0.04	-	-	-	-
Nitrate*	g/m³	0.19	-	-	-	-
Nitrate-N + Nitrite-N	g/m³	0.06 #1	-	-	-	-
Sulphate*	g/m³	210	-	-	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	< 4	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m³	< 4	-	-	-	-

Sample Type: Saline						
Sample Name:	Composite of Kowhai -C K3 #2, Kowhai -C K3 and Kowhai -C K3 #46					
Lab Number:	1586378.4					
Methanol in Water - Aqueous Solvents						
Methanol* g/m³	< 2	-	-	-	-	
BTEX in Water by Headspace GC-MS						
Benzene* g/m³	3.8	-	-	-	-	
Toluene* g/m³	1.21	-	-	-	-	
Ethylbenzene* g/m³	0.027	-	-	-	-	
m&p-Xylene* g/m³	0.13	-	-	-	-	
o-Xylene* g/m³	0.065	-	-	-	-	
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde* g/m³	1.42	-	-	-	-	
Total Petroleum Hydrocarbons in Water						
C7 - C9* g/m³	4.6	-	-	-	-	
C10 - C14* g/m³	158	-	-	-	-	
C15 - C36* g/m³	290	-	-	-	-	
Total hydrocarbons (C7 - C36)* g/m³	450	-	-	-	-	

1586378.4
Composite of Kowhai -C K3 #2, Kowhai -C K3 and Kowhai -C K3 #46
Client Chromatogram for TPH by FID



Analyst's Comments

#1 Due to the nature of this sample a dilution was performed prior to analysis, resulting in a detection limit higher than that normally achieved for the 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**
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

Sample Type: Saline			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Total Digestion*	Boiling nitric acid digestion. APHA 3030 E 22nd ed. 2012 (modified).	-	4
Total Digestion of Saline Samples*	Nitric acid digestion. APHA 3030 E 22nd ed. 2012 (modified).	-	4
pH*	pH meter. APHA 4500-H^+ B 22nd ed. 2012. Note: It is not possible to achieve the APHA Maximum Storage Recommendation for this test (15 min) when samples are analysed upon receipt at the laboratory, and not in the field.	0.1 pH Units	4
Total Alkalinity*	Saline water, Titration to pH 4.5.	1.0 g/m^3 as $CaCO_3$	4
Analysis Temperature for Bicarbonate	Temperature at which Bicarbonate titration was conducted as reported by Geological & Nuclear Sciences, Wairakei.	1.0 °C	4
Bicarbonate	Bicarbonate (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	4
Total Hardness*	Calculation from Calcium and Magnesium. APHA 2340 B 22nd ed. 2012.	1.0 g/m^3 as $CaCO_3$	4
Electrical Conductivity (EC)*	Conductivity meter, 25°C. APHA 2510 B 22nd ed. 2012.	0.1 mS/m	4
Total Dissolved Solids (TDS)*	Filtration through GF/C (1.2 µm), gravimetric. APHA 2540 C (modified; drying temperature of 103 - 105°C used rather than 180 ± 2°C) 22nd ed. 2012.	50 g/m^3	4
Filtration for dissolved metals analysis*	Sample filtration through 0.45µm membrane filter and preservation with nitric acid. APHA 3030 B 22nd ed. 2012.	-	4
Total Barium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.00063 g/m^3	4
Total Bromine*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.11 g/m^3	4
Dissolved Calcium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	1.0 g/m^3	4
Total Calcium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	1.1 g/m^3	4
Total Copper*	Nitric acid digestion, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0011 g/m^3	4
Total Iron*	Nitric acid digestion, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0042 g/m^3	4
Dissolved Magnesium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.4 g/m^3	4
Total Magnesium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.42 g/m^3	4
Total Manganese*	Nitric acid digestion, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0011 g/m^3	4
Total Mercury*	Nitric acid digestion, ICP-MS, screen level. APHA 3125 B 22nd ed. 2012.	0.0021 g/m^3	4
Total Nickel*	Nitric acid digestion, ICP-MS with universal cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0011 g/m^3	4
Total Potassium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	1.1 g/m^3	4
Total Sodium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.42 g/m^3	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/m^3	4
Total Zinc*	Nitric acid digestion, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0042 g/m^3	4
Chloride*	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl^- E (modified from continuous flow analysis) 22nd ed. 2012.	0.5 g/m^3	4
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	4
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m^3	4
Nitrate*	Calculation from Nitrate-N.	0.010 g/m^3	4
Nitrate-N + Nitrite-N	Saline sample. Total oxidised nitrogen. Automated cadmium reduction, Flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012 (modified).	0.002 g/m^3	4
Total Sulphate*	Calculation: from total sulphur.	2 g/m^3	4

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

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

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

Ara Heron BSc (Tech)
Client Services Manager - Environmental

Hill Laboratories
BETTER TESTING BETTER RESULTS

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

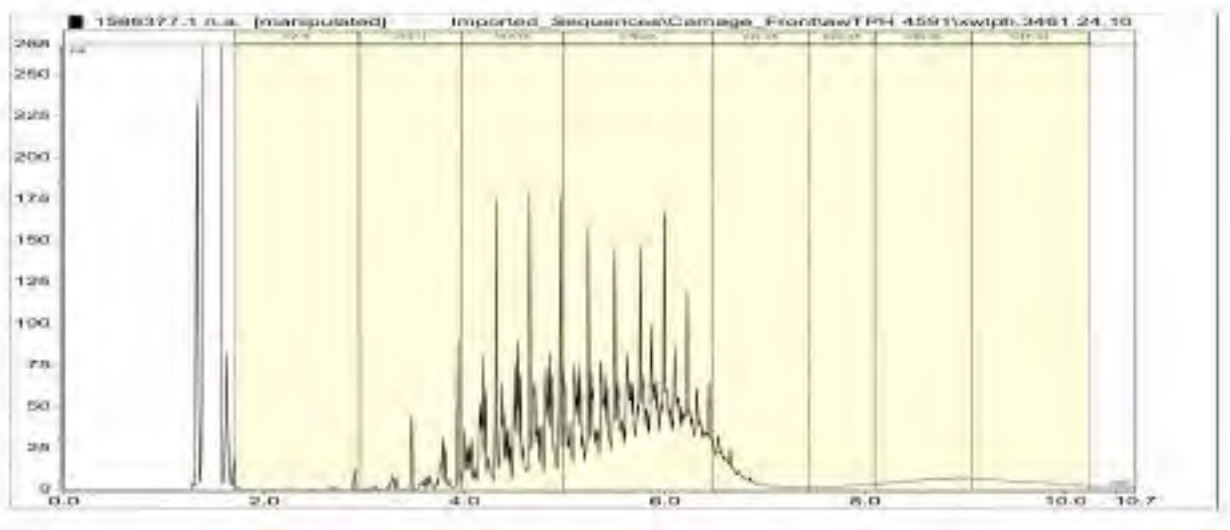
ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1586377	SPv1
Contact:	Regan Phipps	**Date Registered:**	19-May-2016	
	C/- Taranaki Regional Council	**Date Reported:**	03-Jun-2016	
	Private Bag 713	**Quote No:**	50522	
	Stratford 4352	**Order No:**		
		Client Reference:	GPL Kowhai-C Frac Fluid April 2016	
		Submitted By:	David Olson	

Sample Type: Aqueous

Sample Name:		Kowhai-C K3 FF 27-Apr-2016				
Lab Number:		1586377.1				
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	< 4	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m³	< 4	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m³	< 2	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m³	0.0055	-	-	-	-
Toluene	g/m³	0.0078	-	-	-	-
Ethylbenzene	g/m³	< 0.0010	-	-	-	-
m&p-Xylene	g/m³	< 0.002	-	-	-	-
o-Xylene	g/m³	0.0018	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m³	63	-	-	-	-
C10 - C14	g/m³	6,100	-	-	-	-
C15 - C36	g/m³	12,200	-	-	-	-
Total hydrocarbons (C7 - C36)	g/m³	18,400	-	-	-	-

1586377.1
Kowhai-C K3 FF 27-Apr-2016
Client Chromatogram for TPH by FID



SUMMARY OF METHODS

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

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m^3	1
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m^3	1
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m^3	1
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m^3	1
Total Petroleum Hydrocarbons in Water*	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734]	0.10 - 0.7 g/m^3	1

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

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 IV
Biomonitoring report

To	Jane Harvey, Scientific Officer - Groundwater Resources
From	Katie Blakemore, Technical Officer
Report No	KB006
Document	1688230
Date	23 May 2016

Biomonitoring of an unnamed tributary of the Waiau Stream and of the Parahaki Stream in relation to hydraulic fracturing at the Kowhai-C wellsite, May 2016

Introduction

A biological survey was performed prior to hydraulic fracturing (HF) at the Kowhai-C wellsite, to provide recent baseline data on the macroinvertebrate communities of the unnamed tributary of the Waiau stream and of the Parahaki Stream. A further biological survey were performed following HF at the Kowhai-C wellsite, to determine whether or not treated stormwater and uncontaminated site and production water discharges, in the vicinity of the Waiau Stream had any effects upon the macroinvertebrate communities of the Waiau and Parahaki streams.

Methods

Kowhai-C wellsite treated stormwater and site production water was discharged on to land within the vicinity of the unnamed tributary of the Waiau Stream (Figure 1). This pre-HF survey of the unnamed tributary of the Waiau Stream was undertaken on 15 April 2016 at one established site (Table 1); 10 metres downstream of an access culvert and pond (site 1). A post-HF survey was undertaken at the same site on 9 May 2016. No upstream site was established as the position of the Kowhai-C discharge was directly above the headwaters of the unnamed tributary of the Waiau Stream. Only one site was sampled below the discharge point due to limited accessibility.

A pre-HF survey of the Parahaki Stream was also carried out on 15 April 2016 at one established site (Table 1); 20 metres upstream of Inland North Road (site 2). A post-Hf survey was also undertaken at this site on 9 May 2016. The Parahaki Stream is valued by the local community for its watercress. Although not in the direct vicinity of the Kowhai-C discharge, this biological survey was deemed necessary to determine whether or not hydraulic fracturing activities of the Kowhai-C wellsite had any detrimental effect upon macroinvertebrate communities of this valued stream.

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

Table 1 Biomonitoring site details of sites monitored in relation to the Kowhai C wellsite including the unnamed tributary of the Waiau Stream and the Parahaki Stream

Site No.	Site code	Grid reference (NZTM)	Location	Altitude (m asl)
1	WAI000070	1172016E-5678534N	10m d/s of pond	79
2	PRH000010	1711471E-5678890N	20m u/s Inland North Road	79

Figure 1 Biomonitoring sites in the unnamed tributary of the Waiau Stream and the Parahaki Stream in relation to the Kowhai-C wellsite

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

Table 2 Macroinvertebrate abundance categories

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

Stark (1985) developed a scoring system for macroinvertebrate taxa according to their sensitivity to organic pollution in stony New Zealand streams. Highly 'sensitive' taxa were assigned the highest scores of 9 or 10, while the most 'tolerant' forms scored 1. Sensitivity scores for certain taxa have been modified in accordance with Taranaki experience. By averaging the scores obtained from a list of taxa taken from one site and multiplying by a scaling factor of 20, a Macroinvertebrate Community Index (MCI) value was obtained. The MCI is a measure of the overall sensitivity of macroinvertebrate communities to the effects of organic pollution. However, other physical variables such as sedimentation, temperatures, water velocity, and dissolved oxygen levels may also affect the MCI values because the taxa that are able to tolerate extremes in these variables generally have lower sensitivity scores. More 'sensitive' communities inhabit less polluted waterways. 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). A difference of eleven or more MCI units is considered significant (Stark 1998).

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

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

A semi-quantitative MCI value (SQMCIs) 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 SQMCIs is not multiplied by a scaling factor of 20, so that its corresponding range of values is 20x lower.

Results and discussion

At the time of the pre-HF survey of the unnamed tributary of the Waiau Stream a very low, very slow/still, uncoloured flow was recorded. A water temperature of 13.6 °C was recorded at this site which was partially shaded by overhanging vegetation. Patches of leaves and wood were present on the streambed, while no periphyton, moss or macrophytes were recorded. The substrate comprised predominantly silt with minor amounts of wood and root. Iron oxide and sediment were visible on the streambed.

The post-HF survey recorded very similar conditions in the unnamed tributary of the Waiau Stream as the pre-HF survey. Flows were again very low, very slow/still and uncoloured. Water temperature was a significantly higher 17.3 °C. Patches of wood were present, and leaves were widespread on the streambed. The substrate comprised predominantly silt, with minor amounts of coarse gravel, hard clay and wood and root. Iron oxide and deposited sediment were visible on the streambed.

The pre-HF survey of the Parahaki Stream recorded a very low, very slow/still, cloudy flow which was brown due to suspended sediment in the water column. Water temperature was 15.6 °C at this site which was partially shaded by overhanging vegetation. Patches of leaves and wood were recorded on the streambed, as were macrophytes (predominantly watercress) and small patches of filamentous periphyton. Moss and periphyton mats were not recorded. Substrate comprised sand and silt, with deposited sediment visible on the streambed.

The post-HF survey of the Parahaki Stream recorded a very low, slow, cloudy flow which was brown due to suspended sediment. Water temperature was a slightly higher 16.2 °C in this survey. Patches of leaves and wood were recorded on the streambed, as were macrophytes (predominantly watercress). No periphyton or moss was recorded. Substrate comprised sand and silt, with minor amounts of fine gravel present. Deposited sediment was visible on the streambed.

Macroinvertebrate communities

A summary of previous macroinvertebrate survey results at these two sites, together with results of the current pre-HF and post-HF surveys are provided in Table 4. Comparative data for sites in similar streams are presented in Table 5.

Table 4 Number of taxa, MCI and SQMCI$_s$ in the unnamed tributary of the Waiau Stream (site 1) and the Parahaki Stream (site 2) in previous and current surveys in relation to the Kowhai-C wellsite

Site No.	Site Code	Number of taxa					MCI					SQMCI$_s$				
		Pre-drill (6 Sep & 17 Dec 13)	Post-drill (20 Feb 14)	Post-HF (5 Aug 14)	Pre-HF (15 Apr 16)	Post-HF (9 May 16)	Pre-drill (6 Sep & 17 Dec 13)	Post-drill (20 Feb 14)	Post-HF (5 Aug 14)	Pre-HF (15 Apr 16)	Post-HF (9 May 16)	Pre-drill (6 Sep & 17 Dec 13)	Post-drill (20 Feb 14)	Post-HF (5 Aug 14)	Pre-HF (15 Apr 16)	Post-HF (9 May 16)
1	WAI000070	25	10	18	8	5	83	70	74	83	68	2.7	1.7	3.2	1.3	1.6
2	PRH000010	22	15	15	11	7	76	72	73	73	77	4.1	3.2	4.0	1.5	1.5

Table 5 Range and median number of taxa, MCI scores and $SQMCI_s$ scores for control sites at altitudes between 50 and 79 m asl in Taranaki lowland coastal streams (TRC 2015)

	Number of Taxa	MCI Score	$SQMCI_s$ Score
Number of samples	111	111	82
Range	0-30	60-103	1.4-6.7
Median	20	79	4.0

Macroinvertebrate communities recorded in the current surveys are presented for the unnamed tributary of the Waiau Stream in Table 6 and the Parahaki Stream in Table 7.

Table 6 Macroinvertebrate communities of the unnamed tributary of the Waiau Stream recorded in the pre-HF survey on 15 April 2016 and the post-HF survey on 9 May 2016

Taxa List	Site Number	MCI score	Pre-HF	Post HF
	Site Code		WAI000070	WAI000070
	Sample Number		FWB16199	FWB16208
ANNELIDA (WORMS)	Oligochaeta	1	A	A
MOLLUSCA	*Potamopyrgus*	4	R	R
CRUSTACEA	Copepoda	5	R	-
	Ostracoda	1	VA	A
HEMIPTERA (BUGS)	*Microvelia*	3	R	-
COLEOPTERA (BEETLES)	Scirtidae	8	R	-
DIPTERA (TRUE FLIES)	*Paralimnophila*	6	R	R
ACARINA (MITES)	Acarina	5	C	C
		No of taxa	8	5
		MCI	83	68
		SQMCIs	1.3	1.6
		EPT (taxa)	0	0
		%EPT (taxa)	0	0
'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 the Parahaki Stream recorded in the pre-HF survey on 15 April 2016 and the post-HF survey on 9 May 2016

Taxa List	Site Number	MCI score	Pre-HF	Post-HF
	Site Code		PRH000010	PRH000010
	Sample Number		FWB16200	FWB16209
COELENTERATA	Coelenterata	3	R	-
PLATYHELMINTHES (FLATWORMS)	*Cura*	3	R	-
ANNELIDA (WORMS)	Oligochaeta	1	C	A
MOLLUSCA	*Potamopyrgus*	4	R	C
CRUSTACEA	Copepoda	5	R	-
	Ostracoda	1	VA	VA
	Paracalliope	5	C	C
DIPTERA (TRUE FLIES)	*Paralimnophila*	6	R	R
	Orthocladiinae	2	R	-
	Tanypodinae	5	R	R
ACARINA (MITES)	Acarina	5	C	C
		No of taxa	11	7
		MCI	73	77
		SQMCIs	1.5	1.5
		EPT (taxa)	0	0
		%EPT (taxa)	0	0
'Tolerant' taxa	'Moderately sensitive' taxa		'Highly sensitive' taxa	

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

Site 1 – 10 metres downstream of pond (unnamed tributary of Waiau Stream)

A low taxa richness of eight taxa was found at site 1 in this pre-HF survey (Table 6), two taxa less than the minimum previously recorded taxa richness for this site (Table 4). The post-HF survey recorded a slightly lower taxa richness of five taxa (Table 6). Both these results are lower than the median taxa richness for 'control' sites in similar streams (Table 5). The macroinvertebrate community on both occasions was characterised by two 'tolerant' taxa [seed shrimps (Ostracoda) and oligochaete worms].

A MCI score of 83 was recorded in this pre-HF survey (Table 6), categorising the site as having 'fair' macroinvertebrate community health (Table 3). This is equal to the highest previously recorded MCI score at this site (Table 4) and is similar to the median MCI score for 'control' sites in similar streams (Table 5). The post-HF survey recorded a significantly lower MCI score of 68 (Table 6, Stark 1998), categorising the site as having 'poor' macroinvertebrate community health at this time (Table 3) This score is significantly lower than the median score for 'control' sites in similar streams (Table 5) but is similar to previously recorded MCI scores at this site (Table 4).The recorded $SQMCI_s$ score in the pre-HF survey was 1.3 (Table 6), which is the lowest recorded $SQMCI_s$ score for this site (Table 4). An insignificantly higher $SQMCI_s$ score of 1.6 was recorded in the post-HF survey (Table 6, Stark 1998). These $SQMCI_s$ scores are significantly lower than the median score for 'control' sites in similar streams (Table 5).

Site 2 – 20 metres upstream of Inland North Road (Parahaki Stream)

A low taxa richness of eleven taxa was found at this site in the pre-HF survey (Table 7), four taxa less than the minimum previously recorded taxa richness at this site (Table 4). The post-

HF survey recorded a slightly lower taxa richness of seven taxa (Table 7). Both of these taxa richnesses are lower than the median taxa richness for 'control' sites in similar streams. The macroinvertebrate community was characterised by one 'tolerant' taxon, ostracod seed shrimps, at the time of the pre-HF survey. The macroinvertebrate community of the post-HF survey was characterised by two 'tolerant' taxa [seed shrimps (Ostracoda) and oligochaete worms].

A MCI score of 73 was recorded in the pre-HF survey, while the post-HF survey recorded a MCI score of 77 (Table 7). These scores are not significantly different from each other or from any previously recorded MCI score for this site (Table 4), and categorise the site as having 'poor' macroinvertebrate community health (Table 3). These MCI scores are also similar to the median MCI score for 'control' sites in similar streams (Table 5). Both the pre-HF and post-HF surveys recorded a $SQMCI_s$ score of 1.5 (Table 7). This is significantly lower than all previously recorded $SQMCI_s$ scores for this site, and the median $SQMCI_s$ score for 'control' sites in similar streams (Table 5).

Discussion and conclusions

The Councils 'kick sampling' technique was used to collect streambed macroinvertebrates from an unnamed tributary of the Waiau Stream and a combination of the Council's 'kick sampling' and 'vegetation sweep' techniques were used to collect streambed macroinvertebrates from the Parahaki Stream. Samples were collected before and after HF at the Kowhai-C wellsite. This has provided data to compare with existing data for the assessment of hydraulic fracturing and skimmer pit discharge effects from the Kowhai-C wellsite on the macroinvertebrate communities of these streams. Samples were processed to provide number of taxa (richness), MCI, and $SQMCI_S$ scores for each site.

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

Taxa richnesses recorded at both sites 1 and 2 in these two surveys were low compared to previous surveys and to the median score for 'control' sites in similar streams. Both surveys recorded a high proportion of 'tolerant' taxa, and all characteristic taxa were classed as 'tolerant' at both sites. Recorded MCI scores for both sites were generally similar to the median score for 'control' sites in similar streams, with the exception of site 1 in the post-HF survey which recorded a significantly lower than median score. MCI scores at site 1 showed a significant decrease between the pre-HF and post-HF surveys. The higher MCI score recorded at site 1 in the pre-HF survey was primarily due to the presence of the rare 'highly sensitive' beetle, *Scirtidae*, which was not recorded in the post-HF surveys. The MCI score was disproportionately affected by the presence of this one taxon due to the low taxa richness in this sample. This score categorised the site as having 'fair' macroinvertebrate community

health, while all other samples categorised the sites as having 'poor' macroinvertebrate community health. $SQMCI_s$ scores were significantly lower than previously recorded $SQMCI_s$ scores at these sites, and lower than the median for 'control' sites in similar streams. This reflects the high abundances of 'tolerant' taxa found in these surveys. There were no significant differences in $SQMCI_s$ score between the pre-HF and post-HF survey for either site 1 or site 2. This lack of significant change in $SQMCI_s$ scores compared to MCI scores at site 1 reflects the relative abundances of taxa, and is less influenced by the presence of a particular taxon (the rare 'highly sensitive' scirtid beetle).

The current surveys were undertaken during a period of extremely low flow conditions. This is evidenced by the ostracod seed shrimps which were a characteristic taxon at both sites 1 and 2 in both surveys. This taxon is usually abundant in low flow conditions, that do not generally favour more 'sensitive' taxa. This indicates that the primary influence on the macroinvertebrate communities during these surveys was habitat limitation caused by the low flow conditions.

The results of these current surveys provide no evidence that the discharges from the Kowhai-C wellsite have had any significant impacts on the macroinvertebrate communities of the unnamed tributary of the Waiau Stream or of the Parahaki Stream. The lower than previously recorded taxa richnesses and $SQMCI_s$ scores in the current surveys at both sites can be attributed to very low flow conditions at the time of these surveys.

Summary

Two macroinvertebrate surveys were carried out at one site in an unnamed tributary of the Waiau Stream and one site in the Parahaki Stream, near the Kowhai-C wellsite prior to and following hydraulic fracturing, to determine if discharges from the wellsite had significant adverse effects on the stream macroinvertebrate communities.

The unnamed tributary of the Waiau Stream showed a significant decrease in MCI score between the two sampling occasions, which was attributable to the presence of one rare, 'highly sensitive' taxon in the pre-HF survey but not the post-HF survey, coupled with a low taxa richness. The taxa richness and $SQMCI_s$ scores at this site did not change significantly between these two surveys. The Parahaki Stream showed no significant changes in taxa richness, MCI score or $SQMCI_s$ score between the pre-HF and post-HF surveys. The lower than previously recorded taxa richnesses and $SQMCI_s$ scores in the current surveys at both sites can be attributed to very low flow conditions resulting in habitat limitation at the time of these surveys. Overall, the results of these current surveys provide no evidence that the discharges from the Kowhai-C wellsite have had any significant impacts on the macroinvertebrate communities of the unnamed tributary of the Waiau Stream or of the Parahaki Stream.

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