

Tag Oil Limited  
Cheal-C Hydraulic Fracturing  
Monitoring Programme Report  
2013-2015

Technical Report 2015-04

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## Executive summary

Tag Oil Limited (TAG) operate the Cheal-C wellsite, located at 127 Brookes Road, Stratford. The wellsite lies within the Waingongoro catchment and contains a hydrocarbon producing well and associated infrastructure.

TAG hold resource consent 9397-1, authorising the discharge of contaminants associated with hydraulic fracturing activities into land at depths greater than 3,700 m TVDss beneath the Cheal-C wellsite. The consent was issued by Taranaki Regional Council (the Council) on 19 September 2013 and contains 16 special conditions which set out the requirements that TAG must satisfy.

The following report for the period March 2014 to May 2015 outlines and discusses the results of the monitoring programme implemented by the Council in relation to the programme of hydraulic fracturing undertaken by TAG, within their Cheal-C wellsite. The report also assesses TAG's level of environmental performance and compliance with the resource consent held in relation to the activity.

**During the monitoring period being reported, TAG demonstrated a high level of environmental performance.**

The programme of hydraulic fracturing undertaken by TAG at Cheal-C included the fracturing of one well; Cardiff-3. The hydraulic fracturing of this well took place on 24 March 2014.

The programme of monitoring implemented by the Council in relation to these activities spanned the 2013-2014 and 2014-2015 monitoring periods. The programme included the analysis of samples taken from groundwater sites surrounding the wellsite. Samples of groundwater were obtained prior to hydraulic fracturing being undertaken to provide a baseline reference of groundwater composition, with a further round of sampling carried out post hydraulic fracturing for comparison with baseline results.

In addition, samples of the both the hydraulic fracturing fluid and the formation fluids produced back to the wellhead immediately following the fracturing event were obtained for analysis.

The monitoring programme also incorporated a surface water component, whereby biomonitoring surveys were undertaken in surface water bodies surrounding the wellsite. In order to provide a baseline reference for stream health, surveys were undertaken prior to hydraulic fracturing. Additional surveys were then carried out post hydraulic fracturing to determine whether the activity had resulted in any adverse effects on stream health.

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

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

For reference, in the 2012-2013 year, 35% 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 59% demonstrated a good level of environmental performance and compliance with their consents. In the 2013-2014 year, 60% of consent holders achieved a high level of environmental performance and compliance with their consents, while another 29% demonstrated a good level of environmental performance and compliance.

This report includes recommendations for the 2015-2016 year.

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# **1. Introduction**

## **1.1 Compliance monitoring programme reports and the Resource Management Act 1991**

### **1.1.1 Introduction**

The following 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 TAG Petroleum Limited (TAG) at their Cheal-C wellsite, 127 Brookes Road, Stratford over the period March 2014 to May 2015. The wellsite is located in the Waingongoro catchment. The report also assesses TAG's level of environmental performance and compliance with the resource consents held in relation to the activity.

The programme of hydraulic fracturing undertaken by TAG at the Cheal-C wellsite included the fracturing of one well; Cardiff-3.

The programme of monitoring implemented by the Council in relation to this activity spanned the 2013-2014 and 2014-2015 monitoring periods and included groundwater, surface water and discharge monitoring components. This is the first monitoring report produced by the Council in relation to the hydraulic fracturing activities at the Cheal-C wellsite.

### **1.1.2 Structure of this report**

Section 1 of this report is a background section. It sets out general information about compliance monitoring under the *Resource Management Act 1991* (RMA) and the Council's obligations and general approach to monitoring sites through annual programmes, the resource consents held by TAG for discharges into land associated with hydraulic fracturing in the Waingongoro catchment, a description of the activities undertaken under these consents, and the nature of the monitoring programme in place for the period under review.

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 2015-2016 monitoring year.

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

### **1.1.3 The Resource Management Act 1991 and monitoring**

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

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

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

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

Events that were beyond the control of the consent holder and unforeseeable (i.e. 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 compliance**

- **High** The administrative requirements of the resource consent were met, or any failure to do this had trivial consequences and was addressed promptly and co-operatively.
- **Good** Perhaps some administrative requirements of the resource consent were not met at a particular time, however these were 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 consent 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 consent. Significant intervention by the Council was required. Typically there were grounds for an infringement notice.

For reference, in the 2012-2013 year, 35% 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 59% demonstrated a good level of environmental performance and compliance with their consents. In the 2013-2014 year, 60% of consent holders achieved a high level of environmental performance and compliance with their consents, while another 29% demonstrated a good level of environmental performance and compliance.

## **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 'traditional' production techniques.

The process of hydraulic fracturing involves the pumping of fluids (consisting of freshwater and a small volume of chemicals) 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 is assisted by the use of cross-linked gels. These are solutions, which are liquid at the surface but, when mixed, form long-chain polymer bonds and thus become gels that transport the proppant into the formation. Once in the formation these gels 'break' back with time and temperature to a liquid state and are flowed back to surface without disturbing the proppant wedge. With continued flow, fluids pumped as part of hydraulic fracturing process, formation fluids and hydrocarbons are drawn to the surface.

### **1.2.2 Cheal-C wellsite history**

The Cheal-C wellsite has been subject to a lease since the early 1990's. It is located within the rural environment, and the predominant land use surrounding the site is pastoral farming and dairy runoff. A number of wellsites and pipelines associated with hydrocarbon exploration, production, and processing are located within a 10km radius of the site, this includes the Cheal A and Cheal B wellsites, the Waihapa wellsites and the Waihapa production station. The topography of the surrounding land is gently rolling farmland that tends to be dissected by small to medium sized streams that radiate out from Mount Taranaki.

Hydraulic fracturing took place in the Cardiff-3 well on 24 March 2014. The location of the wellsite is illustrated in Figure 1. Well construction schematics for the Cardiff-3 well are included in Appendix I.

An outline of the hydraulic fracturing activity carried out by TAG at the Cheal-C wellsite during the period being reported is provided below in Table 1.

**Table 1** Summary of hydraulic fracturing activity (2013-2014)

Well	Wellsite	Consent	Date	Injection zone (m TVDss)	Formation
Cardiff-3	Cheal-C	9397-1	24/03/2014	4731.5 – 4737.5	K3E

## 1.3 Resource consent

### 1.3.1 Discharges onto and into land

Section 15(1)(b) of the RMA stipulates 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.

TAG holds resource consent **9397-1**, authorising the discharge of contaminants into land at the Cheal-C wellsite. The consent was issued by the Council on 19 September 2013, under Section 87(e) of the RMA. This is the consent under which Cardiff-3 was fractured. Consent 9397-1 contains 16 special conditions which set out the requirements that TAG must satisfy.

Condition 1 stipulates the minimum depth below which the injection of hydraulic fracturing fluids must occur.

Condition 2 stipulates the date after which no hydraulic fracturing fluids shall be discharged into the reservoir.

Condition 3 requires the consent holder to ensure that the exercising of the consent does not result in any contaminants reaching any useable freshwater (ground or surface water).

Conditions 4, 5, 6 and 7 relate to fresh water monitoring requirements, to allow compliance with condition 2 to be assessed.

Condition 8 requires the consent holder to carry out pressure testing of equipment prior to discharging.

Condition 9 requires the consent holder to submit a pre-fracturing discharge report prior to any discharge occurring.

Condition 10 is a notification requirement.

Condition 11 requires the consent holder to submit a post-fracturing discharge report after the completion of the hydraulic fracturing programme for each well.

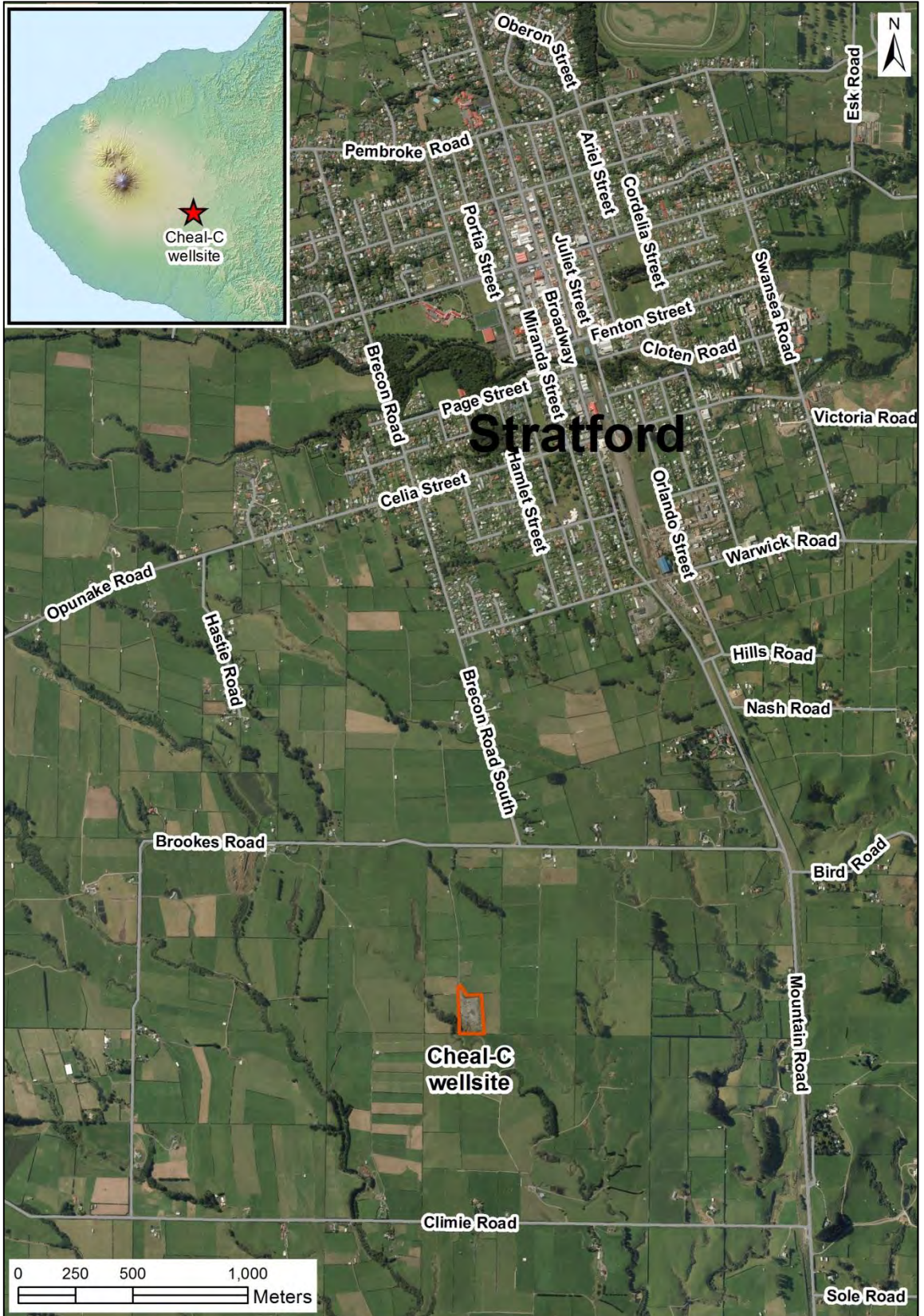
Condition 12 stipulates how the reports required by conditions 9 and 11 are to be submitted.

Condition 13 requires the consent holder to allow the Council access to a location where samples of hydraulic fracturing and return fluids can be obtained.

Condition 14 requires the consent holder to use best practicable options.

Condition 15 relates to the composition of the fracturing fluid.

Consent 16 is a review provision.



**Figure 1** Location of Cheal-C wellsite where hydraulic fracturing occurred during the period under review

## **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, and the effects arising, within the Taranaki region and report upon these.

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 Cardiff-3 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 consent reviews or renewals;
- renewals;
- new consents;
- advice on the Council's environmental management strategies and content of regional plans; and
- consultation on associated matters.

### **1.4.3 Review of consent holder submitted data**

As required by the conditions of consent 9397-1, TAG submitted pre and post-fracturing discharge reports to the Council for the well fractured during the period under review. Pre-fracturing discharge reports provide an outline of the proposed fracturing operations in relation to the 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 resource consents.

### **1.4.4 Chemical sampling**

The primary component of the monitoring programme implemented by the Council was the collection and analysis of samples from an existing groundwater well and a specifically installed groundwater monitoring bore in the vicinity of the Cheal-C wellsite.

In order to select suitable sites for sampling, the Council carried out a well survey in the vicinity of the Cheal-C wellsite to identify existing groundwater abstractions. The survey was undertaken within a defined 'areas of review' which extended 1 km radially from the wellsite. One existing groundwater site was identified for inclusion in the monitoring programme, GND2274. As well as this, a monitoring bore at the Cheal-C wellsite, GND2246, was specifically installed by TAG for the purposes of groundwater monitoring in relation to the planned hydraulic fracturing. The design



and location of the monitoring bore was discussed and agreed with Council staff prior to installation. The details of the monitoring sites are included in Table 2 and its proximity to the wellsite is illustrated in Figure 2.

**Table 2** Details of groundwater sites included in the monitoring programme

Hydraulically fractured well	Monitoring site	Distance from fractured well (m)	Total depth (m)	Screened interval (m)	Aquifer
Cardiff-3	GND2446	65.43	41.2	21-41.2	Volcanics
	GND2274	775	18	Unknown	Volcanics

Samples of groundwater were obtained before fracturing to provide a baseline reference of groundwater composition, with a further round of sampling carried out post-fracturing for comparison with baseline results.

All samples were transported to Hill Laboratories Limited for analysis following standard chain of custody procedures.

In addition to the sampling of local groundwater, samples of both the hydraulic fracturing fluid and the reservoir fluids produced back to the wellhead immediately following each fracturing event (return fluids) were obtained for analysis at Hill Laboratories Limited.

#### 1.4.5 Biomonitoring surveys

Biomonitoring surveys are carried out to assess whether any stormwater discharges from the Cheal-C wellsite during the course of fracturing operations had resulted in any detrimental effects upon the biological communities within the receiving waters.

Biological surveys were performed pre and post-fracturing in the vicinity of the wellsite. Surveys were carried out in an unnamed tributary of the Mangawharawhara Stream, which receives stormwater discharge locations of the Cheal-C wellsite. The stream also has high amenity and community value. The surveys were undertaken to assess whether potential discharges from the site during fracturing operations had resulted in any detrimental effects on biological communities within the stream.

The details of each biomonitoring site included in the survey are presented in Table 3 and their proximity to the wellsite is illustrated in Figure 2 and Figure 3.

**Table 3** Details of biomonitoring sites included in the monitoring programme

Site code	GPS reference (NZTM)	Location	Sampling method used
MWW000217	E 1710311 N 5641604	25 m upstream of stream discharge point	Kick sweep
MWW000219	E 1710315 N 5641542	40 m downstream of stream discharge point	Vegetation sweep
MWW000221	E 1710348 N 5641498	50 m downstream of MWW000219	Kick sweep



**Figure 2** Location of groundwater sampling sites in relation to Cardiff-3 well (GND2449)



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

## 2. Results

### 2.1 Consent holder submitted data

#### 2.1.1 Cardiff-3 post-fracturing discharge report

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

- One discrete zone was fractured on 24 March 2014, at depths between 4,731.5 and 4,737.5 m TVDss.
- A total of 2,403 barrels (bbls) (382 m<sup>3</sup>) of liquid was discharged across the fractured zone. The total proppant weight was 71.2 tonnes.
- By volume, 82.38% of the fluid injected was water, 14.8% was proppant and 2.82% was chemicals.
- Pressure testing of the tubing and well head equipment was carried out prior to fracturing commencing. The maximum pressure exerted during the fracturing programme remained below the successfully tested levels at all times.
- Approximately 2,403 bbls of frac fluid was pumped into the Cardiff-3 well during the fracture. At the end of the fracture treatment the well was opened to flow through surface test equipment. The well flowed back with the aid of the nitrogen that was pumped into the tail of the fracture, and over the following 3-4 days the well flow began to die away. Coil tubing was run and circulated both water and nitrogen to clean out proppant from the perforations. 9,140 bbls (1453 m<sup>3</sup>) of liquid (frac fluid & clean-out fluid) was injected and 4,943 bbls (786 m<sup>3</sup>) was returned to the surface, leaving 4,198 bbls (667 m<sup>3</sup>) in the formation. However, this is mostly attributed to water used during the coil tubing clean out post fracture. TAG estimates that a total recovery of water used during the hydraulic fracturing job of at least 37.6% or 904 bbls (144 m<sup>3</sup>). It is estimated that out of 71.2 tonnes of proppant injected, 5.25 tonnes were recovered at the surface, leaving 65.95 tonnes in the formation.
- Coil cleanings were dispatched to Cheal production station. Post-frac fluids that returned to the surface during the flowback of the hydraulic fracturing operation were disposed of by deep well injection at the Waihapa production station as per consent 4094-2.
- It is considered that the mitigation measures implemented by TAG were effective in ensuring there were no adverse environmental effects associated with fracturing operations.

## **2.2 Chemical sampling**

### **2.2.1 Cardiff-3 groundwater sampling survey**

Two sites were sampled to monitor the effects of the hydraulic fracturing of the Cardiff-3 well on local groundwater resources.

The results of the laboratory analysis of samples from site GND2274 indicate a slight decrease in electrical conductivity, dissolved bromine and nitrate concentrations. There was a slight increase in pH and total dissolved solids. The changes in concentrations of these analytes are a result of natural variations in water composition and are unrelated to hydraulic fracturing activities. There were no traces of substances associated with hydraulic fracturing fluids, or hydrocarbons relating to fracturing activities in any of the post-fracturing samples obtained.

There was no dissolved methane detected in any samples taken from GND2274.

The results of the laboratory analysis of samples from site GND2446 indicate a slight decrease in electrical conductivity, pH and total alkalinity. There was a slight increase in dissolved iron. The changes in concentrations of these analytes are a result of natural variations in water composition and are unrelated to hydraulic fracturing activities. Formaldehyde was detected in very low concentrations in the one year post-frac sample at GND2446. The result was within the margin of error for formaldehyde measurement.

Dissolved methane was detected in all samples taken from GND2446. Concentrations were within the expected ranges for shallow groundwater across Taranaki. The methane/ethane ratios indicate that the gas is biogenic in origin and not derived from deep gas reservoirs, as shown in Section 2.2.2.

A full summary of results for all groundwater samples taken in relation to hydraulic fracturing of the Cardiff-3 well is included below in Table 4. The certificates of analysis are included in Appendix III.

**Table 4** Results of groundwater sampling carried out in the vicinity of the Cardiff-3 well

Parameter	Unit	GND2274			GND2446		
		Pre-frac	Post-frac		Pre-frac	Post-frac	
Sample date	-	13 Mar 2014	23 Jun 2014	02 Mar 2015	17 Mar 2014	12 Jun 2014	02 Mar 2015
lab number	-	TRC149567	TRC1410367	TRC151155	TRC149566	TRC1410389	TRC151154
Total alkalinity	g/m <sup>3</sup> CaCO <sub>3</sub>	29	28	29	97	115	84
Barium	mg/kg	0.036	0.039	0.035	0.025	0.038	0.0192
Benzene	g/m <sup>3</sup>	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Dissolved bromine	g/m <sup>3</sup>	0.052	0.047	0.042	0.050	0.047	0.040
Calcium	g/m <sup>3</sup>	9.8	9.7	10.4	8.7	10.7	8.9
Chloride	g/m <sup>3</sup>	11.7	10.6	11.6	11.0	11.9	11.5
Electrical conductivity	mS/m@20°C	12.6	11.8	12.0	22.5	27	20.1
Dissolved copper	g/m <sup>3</sup>	0.021	0.036	0.0177	0.0017	<0.0005	<0.0005
Ethylbenzene	g/m <sup>3</sup>	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Ethane	g/m <sup>3</sup>	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Ethylene	g/m <sup>3</sup>	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Dissolved iron	g/m <sup>3</sup>	<0.02	<0.02	0.12	13.4	17.9	13.9
Formaldehyde	g/m <sup>3</sup>	<0.02	<0.02	<0.02	<0.02	<0.02	0.02
Ethylene glycol	g/m <sup>3</sup>	<4	<4	<4	<4	<4	<4
Hydrocarbons	g/m <sup>3</sup>	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7
Bicarbonate	g/m <sup>3</sup> HCO <sub>3</sub>	35.4	34.2	35	118.3	140.3	103
Total hardness	g/m <sup>3</sup> CaCO <sub>3</sub>	32	31	35	38	47	38
Dissolved mercury	g/m <sup>3</sup>	<0.00008	<0.00008	<0.00008	<0.00008	<0.00008	<0.00008
Potassium	g/m <sup>3</sup>	3.3	3.0	3.6	10.4	12.8	9.9
Methanol	g/m <sup>3</sup>	<2	<2	<2	<2	<2	<2
Methane	g/m <sup>3</sup>	<0.002	<0.002	<0.002	13.7	23	11.6
Magnesium	g/m <sup>3</sup>	1.92	1.76	2.1	3.8	5.0	3.8
Dissolved manganese	g/m <sup>3</sup>	0.0023	0.0024	0.0077	0.41	0.36	0.42
Sodium	g/m <sup>3</sup>	8.3	8.3	9.8	22	25	24
Nickel	mg/kg	<0.0005	<0.0005	0.0011	<0.0005	<0.0005	<0.0005
Nitrate & nitrite nitrogen	g/m <sup>3</sup> N	1.61	1.48	0.84	<0.002	0.8	<0.2
Nitrite	g/m <sup>3</sup> N	<0.002	<0.002	<0.002	<0.002	<0.2	<0.2
Nitrate	g/m <sup>3</sup> N	1.61	1.48	0.84	<0.002	0.7	<0.2
pH	pH	6.4	6.6	6.6	7.1	6.8	6.6
Propylene glycol	g/m <sup>3</sup>	<4	<4	<4	<4	<4	<4
Sulphate	g/m <sup>3</sup>	5.8	5.0	9.4	<0.5	<0.5	<0.5
Sum of Anions	meq/l	1.14	1.07	1.16	2.3	2.7	2.0
Sum of Cations	meq/l	1.09	1.07	1.22	2.5	3.0	2.5
Total dissolved solids	g/m <sup>3</sup>	90	92	95	170	199	167
Temperature	Deg.C	14.3	11.5	15.2	16.9	12.8	14.7
Toluene	g/m <sup>3</sup>	<0.0010	<0.0010	<0.0010	0.0046	<0.0010	<0.0010
m-Xylene	g/m <sup>3</sup>	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
o-Xylene	g/m <sup>3</sup>	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Dissolved zinc	g/m <sup>3</sup>	0.0078	0.0165	0.041	0.0163	0.0047	0.0032

## 2.2.2 Carbon isotope analysis

During the period being reported, one groundwater sample was sent to GNS Science for carbon isotope analysis in their National Isotope Centre. The isotopic analysis is used to calculate a delta carbon13 ( $\delta^{13}\text{C}$ ) value for a given sample, which is then used to determine the origin of the gas. Generally, a  $\delta^{13}\text{C}$  value that exceeds  $-50\text{‰}$  indicates biogenic methane, and a  $\delta^{13}\text{C}$  value less than  $-50\text{‰}$  indicates thermogenic methane. The higher or lower the  $\delta^{13}\text{C}$  values, the stronger the isotopic signature. A  $\delta^{13}\text{C}$  value in the vicinity of  $-50\text{‰}$  can indicate a mixture of both biogenic and thermogenic methane. Results of analyses undertaken in the period being reported are compared with previous results in Table 3 below.

**Table 5** Results of  $\delta^{13}\text{C}$  carbon isotope analysis

Site	Date	Result
GND2446	4 August 2014	$-80.2\text{‰}$

Table 5 shows that the methane gas present in GND2446 is strongly biogenic. It is important to note that the results were issued from the analysing laboratory with an uncertainty of measurement of  $\pm 10\text{‰}$

## 2.2.3 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 Cardiff-3 well for the March 2014 fracturing event are summarised below in Table 6. The certificates of analysis are included in Appendix IV.

Due to the viscosity of the sample of the fluid samples obtained, the range of analyses that were able to be performed on each sample were limited. The samples taken were gel like in composition, as opposed to a liquid. While the fracturing fluid is predominantly comprised of water, specialised additives are used to increase the viscosity of the fluid in order to suspend the proppant prior to injection.

Due to the volume of water used in the fracturing fluid mixture, all additives included in the mixture are highly dilute.

A composite sample of return fluids from Cardiff-3 was submitted for analysis. 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 that 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.

**Table 6** Results of hydraulic fracturing fluid sampling

Parameter	Unit	Cardiff-3
Sample date	-	24 Mar 2014
Lab number	-	TRC149607
Benzene	g/m <sup>3</sup>	<0.0010
Ethylbenzene	g/m <sup>3</sup>	0.0025
Ethylene glycol	g/m <sup>3</sup>	620
Hydrocarbons	g/m <sup>3</sup>	76
Methanol	g/m <sup>3</sup>	<2
Propylene glycol	g/m <sup>3</sup>	<4
Toluene	g/m <sup>3</sup>	0.0024
o-Xylene	g/m <sup>3</sup>	0.0026
m-Xylene	g/m <sup>3</sup>	0.006

The results of the analyses carried out on the return fluid sample obtained following the hydraulic fracturing of the Cardiff-3 well are summarised below in Table 7 and the certificates of analysis is included in Appendix IV. The relatively high levels of salinity (sodium and chloride) in the sample indicate that the composite samples prepared contained a greater proportion of saline reservoir fluids than fluids introduced during fracturing activities. The presence of BTEX compounds are indicative of fluids being drawn from a hydrocarbon bearing reservoir.

**Table 7** Results of hydraulic fracturing return fluid sampling

Parameter	Unit	Cardiff-3
Sample date	-	24 Mar 2014
Lab number	-	TRC149611
Benzene	g/m <sup>3</sup>	1.60
Ethylbenzene	g/m <sup>3</sup>	0.192
Ethylene glycol	g/m <sup>3</sup>	75
Hydrocarbons	g/m <sup>3</sup>	500
Methanol	g/m <sup>3</sup>	3
Propylene glycol	g/m <sup>3</sup>	<4
Toluene	g/m <sup>3</sup>	2.7
o-Xylene	g/m <sup>3</sup>	0.50
m-Xylene	g/m <sup>3</sup>	1.27
Total alkalinity	g/m <sup>3</sup> CaCO <sub>3</sub>	1940
Barium	mg/kg	6.0
Dissolved bromine	g/m <sup>3</sup>	2.7
Calcium	g/m <sup>3</sup>	14
Chloride	g/m <sup>3</sup>	1370
Electrical conductivity	mS/m@20°C	775
Dissolved copper	g/m <sup>3</sup>	0.033



Parameter	Unit	Cardiff-3
Ethane	g/m <sup>3</sup>	0.43
Ethylene	g/m <sup>3</sup>	<0.003
Dissolved iron	g/m <sup>3</sup>	42
Formaldehyde	g/m <sup>3</sup>	1.7
Bicarbonate	g/m <sup>3</sup> HCO <sub>3</sub>	1991
Total hardness	g/m <sup>3</sup> CaCO <sub>3</sub>	45
Potassium	g/m <sup>3</sup>	99
Methane	g/m <sup>3</sup>	1.54
Magnesium	g/m <sup>3</sup>	3
Dissolved manganese	g/m <sup>3</sup>	3.2
Sodium	g/m <sup>3</sup>	1640
Nickel	mg/kg	0.03
Nitrate + nitrite nitrogen	g/m <sup>3</sup> N	0.013
Nitrite	g/m <sup>3</sup> N	0.011
Nitrate	g/m <sup>3</sup> N	<0.002
pH	pH	7.4
Dissolved sulphur	g/m <sup>3</sup>	11
Sulphate	g/m <sup>3</sup>	34
Total dissolved solids	g/m <sup>3</sup>	7800
Dissolved zinc	g/m <sup>3</sup>	0.47

### 2.3 Biomonitoring survey

A combination of the Council's standard 'kick sweep' and 'vegetation sweep' sampling techniques was used to collect streambed macroinvertebrates from the unnamed tributary of the Mangawharawhara stream in relation to fracturing at the Cheal-C wellsite. The intention of these surveys was to determine the health of the macroinvertebrate communities prior to fracturing, which then allowed a comparison with the health of macroinvertebrate communities once fracturing had been completed. Samples were processed to provide number of taxa (richness), MCI and SQMCI<sub>5</sub> scores for each site.

The MCI is a measure of the overall sensitivity of the macroinvertebrate community to the effects of organic pollution in stony streams. It is based on the presence/absence of taxa with varying degrees of sensitivity to environmental conditions. The SQMCI<sub>5</sub> 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<sub>5</sub> between sites indicate the degree of adverse effects (if any) of the discharges being monitored.

Taxa richness was low to moderate. The macroinvertebrate communities of the stream contained slightly more 'sensitive' than 'tolerant' taxa. A total of 16 taxa was found through the reach of the stream surveyed, with 5 of these taxa (31%) found at all three sites and 3 taxa (19%), found at any two of these sites. The number of taxa recorded in

abundance increased at MWW000219, downstream of the skimmer pit discharge, and was the same as the control site at MWW000221.

A comparison of the pre-hydraulic fracturing and post-hydraulic fracturing survey results showed a significant increase in MCI and SQMCI<sub>s</sub> scores at MWW000217, but no significant changes at MWW000219 and MWW000221. Slight variations in MCI and SQMCI<sub>s</sub> scores and taxa richness, particularly at MWW000219 compared with MWW000217 and MWW000221 are considered to be due to habitat variability rather than a change in water quality.

The MCI scores recorded in this survey indicated that the stream communities were of poor to fair health (TRC, 2014), slightly worse than the biological health recorded at 'control' sites in similar streams at a comparative altitude elsewhere in the region. This, in part, can be attributed to the habitat which was limited by very low and slow flows. There was no indication from the results of the two surveys that the discharge from the Cheal C wellsite has impacted on the biological communities of the unnamed tributary of the Mangawharawhara Stream.

A full report on the biomonitoring carried out in the vicinity of the wellsite is included in Appendix V.

## **2.4 Investigations, interventions, and incidents**

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

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

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

During the period under review, there was no requirement for the Council to undertake any significant additional investigations and/or interventions, or record incidents, in association with the conditions in TAG's resource consent or provisions in Regional Plans relating to this site.

### **3. Discussion**

#### **3.1 Environmental effects of hydraulic fracturing on useable freshwater resources**

The primary objective of the monitoring programme implemented by the Council was to assess whether the hydraulic fracturing activities undertaken by TAG during the period being reported had resulted in any adverse effects on useable freshwater resources. As defined in the conditions of the relevant resource consent, useable freshwater includes both groundwater and surface water systems.

To assess the level of environmental performance and compliance by TAG during the period being reported, the monitoring programme implemented by the Council included both groundwater and surface water monitoring components. The groundwater monitoring component of the programme included the sampling of groundwater at selected sites in the vicinity of the Cheal-C wellsite. The surface water monitoring component of the programme comprised biomonitoring surveys being carried out in surface water systems adjacent to the wellsite. Both groundwater and surface water systems were surveyed prior to any hydraulic fracturing occurring to determine baseline conditions, allowing comparisons to be made with post-fracturing results.

The results of post-fracturing groundwater sampling carried out in the vicinity of the Cardiff-3 well showed only very minor variations in water composition in comparison to baseline results. The minor variations in some analytes are a result of natural variations in water composition and unrelated to fracturing activities. Methane was detected in low concentrations but within the expected range for shallow groundwater in Taranaki. The methane/ethane ratios for this well indicate that the methane gas is biogenic in origin and not derived from deep gas reservoirs. Formaldehyde was detected at the laboratory's lower limit of detection ( $0.02 \text{ g/m}^3$ ) following post-fracturing sampling at site GND2446. Pre-fracturing analysis at the same site returned a formaldehyde concentrations of  $<0.2 \text{ g/m}^3$ . The margin of error associated with the laboratory test for formaldehyde is  $0.014 \text{ mg/L}$  and it therefore cannot be conclusively confirmed that formaldehyde was in fact present in the sample obtained. No traces of any other substances associated with hydraulic fracturing fluids, or hydrocarbons relating to fracturing activities were present in the groundwater during any of the post-fracturing sampling events, indicating that there had been no adverse effects on groundwater as a result of fracturing activities.

The result of the biomonitoring survey undertaken suggests that hydraulic fracturing operations did not result in adverse effects on local surface water resources, with community indices in line with reference sites of similar altitude.

In summary, the monitoring carried out by the Council during the 2013-2014 and 2014-2015 monitoring periods indicates that the hydraulic fracturing activities undertaken by TAG over the period being reported had no 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 Table 8.

**Table 8** Summary of performance for Consent 9397-1: To discharge contaminants associated with hydraulic fracturing activities into land at depths greater than 3,140 mTVD beneath the Cheal-C wellsite.

Condition requirement	Means of monitoring during period under review	Compliance achieved?
1. Any discharge shall occur below 3,700 mTVD	Assessment of consent holder submitted data	Yes
2. No discharge of hydraulic fracturing fluids after 1 June 2015	Assessment of consent holder submitted data and site inspections	N/A
3. 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
4. Consent holder shall undertake sampling programme	Development and certification of a monitoring programme	Yes
5. A dedicated groundwater monitoring well may need to be installed	Development and certification of a monitoring programme	Yes
6. Sampling programme shall follow recognised field procedures and be analysed for a specified range of chemical parameters	Development and certification of a monitoring programme and assessment of results	Yes
7. All sampling to be carried out in accordance with a certified sampling and analysis plan	Development and certification of a sampling and analysis plan	Yes
8. Well and equipment pressure testing to be carried out prior to any hydraulic fracturing programme commencing	Assessment of consent holder submitted data	Yes
9. A pre-fracturing discharge report is to be provided to the Council 14 days prior to discharge	Pre-fracturing discharge report received	Yes
10. Consent holder shall notify the Council of hydraulic fracturing discharge	Notification received	Yes
11. A post-fracturing discharge report is to be provided to the Council within 60 days after the hydraulic fracturing programme is completed	Post-fracturing discharge report received	Yes
12. The reports outlined in conditions 9 and 11 must be emailed to consents@trc.govt.nz	Reports received via email	Yes

13. The consent holder shall provide access to a location where samples of hydraulic fracturing fluids and return fluids can be obtained by the Council officers	Access provided	Yes
14. Consent holder to adopt best practicable option at all times	Site inspections, sampling and assessment of consent holder submitted data	Yes
15. No hydrocarbon based hydraulic fracturing fluid shall be discharged	Assessment of consent holder submitted data and sampling of fracturing fluid	Yes
16. Notice of Council to review consent	No provision for review during period	N/A
Overall assessment of environmental performance and compliance in respect of this consent		High
Overall assessment of administrative performance and compliance in respect of this consent		High

During the 2013-2014 and 2014-2015 monitoring periods, TAG demonstrated a high level of environmental performance and administrative performance and compliance with its resource consent as defined in Section 1.1.4.

### 3.3 Alterations to monitoring programmes for 2015-2016

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 the obligations of the RMA in terms of monitoring emissions/discharges and effects, and subsequently reporting to the regional community. The Council also takes into account the scope of assessments required at the time of renewal of permits, and the need to maintain a sound understanding of industrial processes within Taranaki emitting to the atmosphere/discharging to the environment.

It is proposed that for 2015-2016 year, no further monitoring be carried out in relation to previously undertaken hydraulic fracturing events at the Cheal-C wellsite. Monitoring should recommence however if any further fracturing is undertaken at the site.

### 3.4 Exercise of optional review of consent

Resource consent 9397-1 provides for an optional review of the consent on an annual basis, with the next optional review date being June 2015. Condition 16 of this consent allows the Council to review consent conditions to ensure they 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. The Council can also review the consent in order to further specify the best practicable option and/or to ensure that hydraulic fracturing operations appropriately take into account any best practice guidance published by a recognised industry association or environmental regulator.

Following an assessment of the current consent conditions and the results of monitoring undertaken over the period under review, it is considered that there are no grounds that require a review to be pursued or grounds to exercise the review option.

#### **4. Recommendations**

1. THAT no further monitoring be carried out in relation to previously undertaken hydraulic fracturing events at the Cheal-C wellsite. Monitoring should recommence however if any further fracturing is undertaken at the site.
2. THAT the option for a review of resource consents in June 2015, as set out in condition 16 of consent 9397-1, 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.

## Glossary of common terms and abbreviations

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

Biomonitoring	Assessing the health of the environment using aquatic organisms.
bbls	Barrel. Unit of measure used in the oil and gas industry (equivalent to approximately 159 litres).
Fresh	Elevated flow in a stream, such as after heavy rainfall.
g/m <sup>3</sup>	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.
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 <sup>3</sup>	Cubic metre (1,000 litres).
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. The scale is logarithmic i.e. a change of 1 represents a ten-fold change in strength. For example, a pH of 4 is ten times more acidic than a pH of 5.
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	<i>Resource Management Act 1991</i> and including all subsequent amendments.
SQMCI	Semi quantitative macroinvertebrate community index.

## Bibliography and references

Tag Oil Limited (2014) Cardiff-3 Pre-Fracturing Discharge Report

Tag Oil Limited (2014) Cardiff-3 Post-Fracturing Discharge Report

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 (2014) Biomonitoring of an unnamed tributary of the Mangawharawhara Stream following hydraulic fracturing by Tag Oil Ltd at the Cheal-C wellsite, March 2014. Report BT016.

Taranaki Regional Council (2014) Hydraulic Fracturing – Cheal-C Wellsite Water Quality Monitoring Programme



## **Appendix I**

### **Well construction schematic**



#### GENERAL WELL DATA

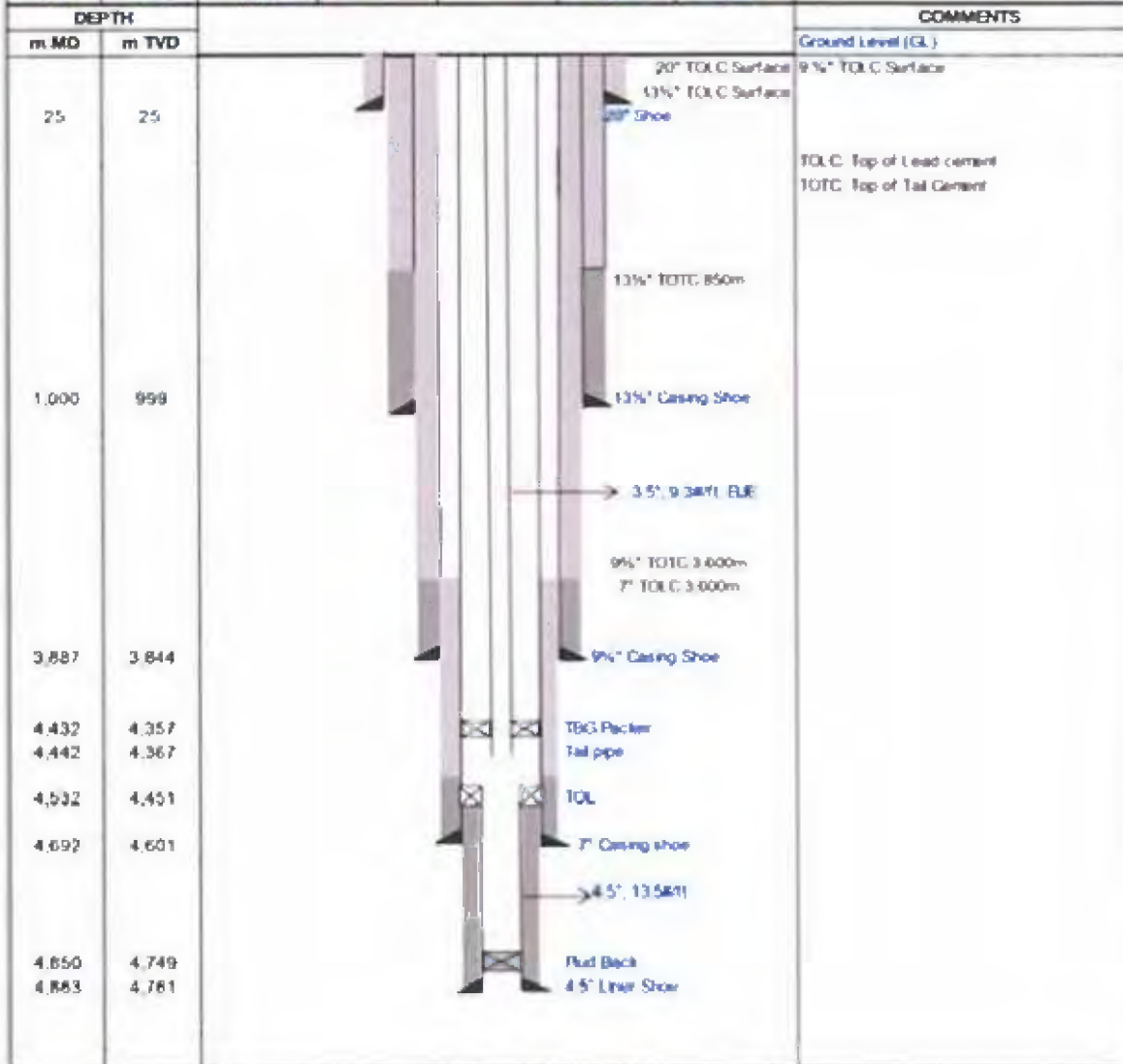
Well: Conventional Casing Design  
 Primary Target: Kapuni Formations  
 Secondary Target: None  
 Surface Location: 6,203,386.5 N, 2,620,422.5 E  
 TD Location: 6,203,711.4 N, 2,620,701.1 E

Profile: S Shape  
 KOP: 210, 2553m  
 Max Inc.: 15'  
 Well TD: 4692 m MD BRT  
 4601 m TVD BRT

Rig: Rig 43  
 Type: Land Rig  
 Contractor: OGD  
 RTE - GL: 9.47m  
 GL - MSL: 293.3m

#### CASING DATA

SIZE (in)	WEIGHT (Rwt)	GRADE	COUPLING	DEPTH (m MD BRT)		TOC (m)	REMARKS
				Top	Bottom		
20"	94	K55	BTC	GL	25	0	
13 3/8"	68	N80	BTC	GL	1,500	0	
9 5/8"	47	P110	BTC	GL	650	0	
9 5/8"	47	G65	JFE Bear	GL	3,900	0	
7"	32	P110	JFE Bear	GL	4,602	3,600	
4 1/2"	13.5	P110			4,883	4,500	





## **Appendix II**

### **Resource consent held by TAG**



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

Name of  
Consent Holder:                      Cheal Petroleum Limited  
   P O Box 402  
   NEW PLYMOUTH 4340

Decision Date:                        19 September 2013

Commencement Date:                19 September 2013

**Conditions of Consent**

Consent Granted:                      To discharge contaminants associated with hydraulic  
   fracturing activities into land at depths greater than 3,700  
   mTVDss beneath the Cardiff-3 well located at the Cheal-C  
   wellsite

Expiry Date:                            1 June 2021

Review Date(s):                        June Annually

Site Location:                          Cheal-C wellsite, 127 Brookes Road, Stratford  
   (Property owner: V Hancock)

Legal Description:                      Sec 13 Blk V Ngaere SD (Discharge source & site)

Grid Reference (NZTM)                1710351E-5641664N

Catchment:                                Waingongoro

Tributary:                                 Mangawharawhara

*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 3700 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 into the reservoir after 1 June 2016.
3. The consent holder shall ensure that the exercise of this consent does not result in contaminants reaching any useable fresh water (groundwater or surface water). Usable fresh groundwater is defined as any groundwater having a Total Dissolved Solids concentration of less than 1000 mg/l.
4. The consent holder shall undertake a programme of sampling and testing that monitors the effects of the exercise of this consent on fresh water resources to assess compliance with condition 3 (the 'Monitoring Programme'). The Monitoring Programme shall be certified by the Chief Executive, Taranaki Regional Council ('the Chief Executive'), before this consent is exercised, and shall include:
  - (a) the location of the discharge point(s);
  - (b) the location of sampling sites; and
  - (c) sampling frequency with reference to a hydraulic fracturing programme.
5. Depending on the suitability of existing bores within 500 metres of the wellsite for obtaining a representative groundwater sample, it may be necessary for the Monitoring Programme to include installation of, and sampling from, a monitoring bore. The bore would be of a depth, location and design determined after consultation with the Chief Executive, Taranaki Regional Council and installed in accordance with NZS 4411:2001.
6. All water samples taken for monitoring purposes shall be taken in accordance with recognised field procedures and analysed for:
  - (a) pH;
  - (b) conductivity;
  - (c) total dissolved solids;
  - (d) major ions (Ca, Mg, K, Na, total alkalinity, bromide, chloride, nitrate-nitrogen, and sulphate);
  - (e) trace metals (barium, copper, iron, manganese, nickel, and zinc);
  - (f) total petroleum hydrocarbons;
  - (g) formaldehyde;
  - (h) dissolved methane and ethane gas;
  - (i) methanol;
  - (j) glycols;
  - (k) benzene, toluene, ethylbenzene, and xylenes (BTEX); and
  - (l) carbon-13 composition of any dissolved methane gas discovered ( $^{13}\text{C-CH}_4$ ).



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

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

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

8. The consent holder shall undertake well and equipment pressure testing prior to any hydraulic fracture programme on a given well to ensure any discharge will not affect the integrity of the well and hydraulic fracturing equipment.
9. Any hydraulic fracture discharge shall only occur after the consent holder has provided a comprehensive 'Pre-fracturing discharge report' to the Chief Executive. The report shall be provided at least 14 days before the discharge is proposed to commence and shall detail the hydraulic fracturing programme proposed, including as a minimum:
  - (a) the specific well in which each discharge is to occur, the intended fracture interval(s) ('fracture interval' is the discrete subsurface zone to receive a hydraulic fracture treatment), and the duration of the hydraulic fracturing programme;
  - (b) the number of discharges proposed and the geographical position (i.e. depth and lateral position) of each intended discharge point;
  - (c) the total volume of fracture fluid planned to be pumped down the well, including mini- fracture treatments, and their intended composition, including a list of all contaminants and Material Safety Data Sheets for all the chemicals to be used;
  - (d) the results of the reviews required by condition 14;
  - (e) results of modelling showing an assessment of the likely extent and dimensions of the fractures that will be generated by the discharge;
  - (f) the preventative and mitigation measures to be in place to ensure the discharge does not cause adverse environmental effects and complies with condition 3;
  - (g) the extent and permeability characteristics of the geology above the discharge point to the surface;
  - (h) any identified faults within the modeled fracture length plus a margin of 50%, and the potential for adverse environmental effects due to the presence of the identified faults;
  - (i) the burst pressure of the well and the anticipated maximum well and discharge pressures and the duration of the pressures; and
  - (j) details of the disposal of any returned fluids, including any consents that are relied on to authorise the disposal.

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

10. The consent holder shall notify the Taranaki Regional Council of each discharge by emailing [worknotification@trc.govt.nz](mailto:worknotification@trc.govt.nz). Notification shall include the date that the discharge is to occur and identify the 'Pre-fracturing discharge report', required by condition 9, which details the discharge. Where practicable and reasonable notice shall be given between 3 days and 14 days before the discharge occurs, but in any event 24 hours notice shall be given.
11. At the conclusion of a hydraulic fracturing programme on a given well, the consent holder shall submit a comprehensive 'Post-fracturing discharge report' to the Chief Executive. The report shall be provided within 60 days after the programme is completed and, as a minimum, shall contain:
  - (a) 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;
  - (b) the contaminant volumes and compositions discharged into each fracture interval;
  - (c) the volume of return fluids from each fracture interval;
  - (d) an analysis for the constituents set out in conditions 6(a) to 6(k), in a return fluid sample taken within the first two hours of flow back, for each fracture interval if flowed back individually, or for the well if flowed back with all intervals comingled;
  - (e) an estimate of the volume of fluids (and proppant) remaining underground;
  - (f) the volume of water produced with the hydrocarbons (produced water) over the period beginning at the start of the hydraulic fracturing programme and ending 50 days after the programme is completed or after that period of production;
  - (g) 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;
  - (h) the results of pressure testing required by condition 8, and the top hole pressure (psi), slurry rate (bpm), surface proppant concentration (lb/gal), bottom hole proppant concentration (lb/gal), and calculated bottom hole pressure (psi), as well as predicted values for each of these parameters; prior to, during and after each hydraulic fracture treatment;
  - (i) details of the disposal of any returned fluids, including any consents that are relied on to authorise the disposal;
  - (j) details of any incidents where hydraulic fracture fluid is unable to pass through the well perforations (screen outs) that occurred, their likely cause and implications for compliance with conditions 1 and 3; and
  - (k) an assessment of the effectiveness of the mitigation measures in place with specific reference to those described in the application for this consent.
12. The reports described in conditions 9 and 11 shall be emailed to [consents@trc.govt.nz](mailto:consents@trc.govt.nz) with a reference to the number of this consent.
13. The consent holder shall provide access to a location where the Taranaki Regional Council officers can obtain a sample of the hydraulic fracturing fluids and the return fluids.

Consent 9397-1

14. The consent holder shall at all times adopt the best practicable option, as defined in section 2 of the Resource Management Act 1991, to prevent or minimize any actual or likely adverse effect of the activity on the environment by, as a minimum, ensuring that:
  - (a) the discharge is contained within the fracture interval;
  - (b) regular reviews are undertaken of the preventative and mitigation measures adopted to ensure the discharge does not cause adverse environmental effects; and
  - (c) regular reviews of the chemicals used are undertaken with a view to reducing the toxicity of the chemicals used.
15. The fracture fluid shall be comprised of no less than 91% water and proppant by volume.
16. The Taranaki Regional Council may review any or all of the conditions of this consent by giving notice of review during the month of June each year, for the purposes of:
  - (a) ensuring that the conditions are adequate to deal with any significant adverse effects on the environment arising from the exercise of this consent, which were either not foreseen at the time the application was considered or which it was not appropriate to deal with at the time; and/or
  - (b) further specifying the best practicable option as required by condition 14; and/or
  - (c) ensuring hydraulic fracturing operations appropriately take into account any best practice guidance published by a recognised industry association or environmental regulator.

Signed at Stratford on 19 September 2013

For and on behalf of  
Taranaki Regional Council



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**Director-Resource Management**



## **Appendix III**

### **Certificates of analysis (Groundwater)**





## ANALYSIS REPORT

<b>Client:</b>	Taranaki Regional Council	<b>Lab No:</b>	1392623	SPV1
<b>Contact:</b>	Regan Phipps C/- Taranaki Regional Council Private Bag 713 STRATFORD 4352	<b>Date Registered:</b>	04-Mar-2015	
		<b>Date Reported:</b>	12-Mar-2015	
		<b>Quote No:</b>	47915	
		<b>Order No:</b>		
		<b>Client Reference:</b>		
		<b>Submitted By:</b>	R McDonnell	

### Sample Type: Aqueous

<b>Sample Name:</b>	GND2274 02-Mar-2015 10:58 am	GND2446 02-Mar-2015 3:17 pm			
<b>Lab Number:</b>	1392623.1	1392623.2			

#### Individual Tests

Sum of Anions	meq/L	1.16	2.0	-	-	-
Sum of Cations	meq/L	1.22	2.5	-	-	-
pH	pH Units	6.6	6.9	-	-	-
Total Alkalinity	g/m <sup>3</sup> as CaCO <sub>3</sub>	29	84	-	-	-
Bicarbonate	g/m <sup>3</sup> at 25°C	35	103	-	-	-
Total Hardness	g/m <sup>3</sup> as CaCO <sub>3</sub>	35	38	-	-	-
Electrical Conductivity (EC)	mS/m	12.0	20.1	-	-	-
Total Dissolved Solids (TDS)	g/m <sup>3</sup>	95	167	-	-	-
Dissolved Barium	g/m <sup>3</sup>	0.035	0.0192	-	-	-
Dissolved Bromine*	g/m <sup>3</sup>	0.042	0.040	-	-	-
Dissolved Calcium	g/m <sup>3</sup>	10.4	8.9	-	-	-
Dissolved Copper	g/m <sup>3</sup>	0.0177	< 0.0005	-	-	-
Dissolved Iron	g/m <sup>3</sup>	0.12	13.9	-	-	-
Dissolved Magnesium	g/m <sup>3</sup>	2.1	3.8	-	-	-
Dissolved Manganese	g/m <sup>3</sup>	0.0077	0.42	-	-	-
Dissolved Mercury	g/m <sup>3</sup>	< 0.00008	< 0.00008	-	-	-
Dissolved Nickel	g/m <sup>3</sup>	0.0011	< 0.0005	-	-	-
Dissolved Potassium	g/m <sup>3</sup>	3.6	9.9	-	-	-
Dissolved Sodium	g/m <sup>3</sup>	9.8	24	-	-	-
Dissolved Zinc	g/m <sup>3</sup>	0.041	0.0032	-	-	-
Chloride	g/m <sup>3</sup>	11.6	11.5	-	-	-
Nitrite-N	g/m <sup>3</sup>	< 0.002	< 0.2 #1	-	-	-
Nitrate-N	g/m <sup>3</sup>	0.84	< 0.2	-	-	-
Nitrate-N + Nitrite-N	g/m <sup>3</sup>	0.84	< 0.2 #1	-	-	-
Sulphate	g/m <sup>3</sup>	9.4	< 0.5	-	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m <sup>3</sup>	< 4	< 4	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m <sup>3</sup>	< 4	< 4	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m <sup>3</sup>	< 2	< 2	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m <sup>3</sup>	< 0.0010	< 0.0010	-	-	-
Toluene	g/m <sup>3</sup>	< 0.0010	< 0.0010	-	-	-
Ethylbenzene	g/m <sup>3</sup>	< 0.0010	< 0.0010	-	-	-
m&p-Xylene	g/m <sup>3</sup>	< 0.002	< 0.002	-	-	-



This Laboratory is accredited by International Accreditation New Zealand (IANZ), which represents New Zealand in the International Laboratory Accreditation Cooperation (ILAC). Through the ILAC Mutual Recognition Arrangement (ILAC-MRA) this accreditation is internationally recognised.

The tests reported herein have been performed in accordance with the terms of accreditation, with the exception of tests marked \*, which are not accredited.

Sample Type: Aqueous						
<b>Sample Name:</b>	GND2274 02-Mar-2015 10:58 am	GND2446 02-Mar-2015 3:17 pm				
<b>Lab Number:</b>	1392623.1	1392623.2				
BTEX in Water by Headspace GC-MS						
o-Xylene	g/m <sup>3</sup>	< 0.0010	< 0.0010	-	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m <sup>3</sup>	< 0.02	0.02	-	-	-
Gases in groundwater						
Ethane	g/m <sup>3</sup>	< 0.003	< 0.003	-	-	-
Ethylene	g/m <sup>3</sup>	< 0.003	< 0.003	-	-	-
Methane	g/m <sup>3</sup>	< 0.002	11.6	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m <sup>3</sup>	< 0.10	< 0.10	-	-	-
C10 - C14	g/m <sup>3</sup>	< 0.2	< 0.2	-	-	-
C15 - C36	g/m <sup>3</sup>	< 0.4	< 0.4	-	-	-
Total hydrocarbons (C7 - C36)	g/m <sup>3</sup>	< 0.7	< 0.7	-	-	-

### Analyst's Comments

#1 Severe matrix interferences required that a dilution be performed prior to analysis of this sample, resulting in a detection limit higher than that normally achieved for the NO<sub>2</sub>N, NO<sub>3</sub>N and NO<sub>x</sub>N 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: Aqueous			
Test	Method Description	Default Detection Limit	Sample No
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m <sup>3</sup>	1-2
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m <sup>3</sup>	1-2
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m <sup>3</sup>	1-2
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m <sup>3</sup>	1-2
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS	0.02 g/m <sup>3</sup>	1-2
Gases in groundwater	Manual headspace creation and sub-sampling, GC-FID analysis.	0.002 - 0.003 g/m <sup>3</sup>	1-2
Total Petroleum Hydrocarbons in Water	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734]	0.10 - 0.7 g/m <sup>3</sup>	1-2
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1-2
Total anions for anion/cation balance check	Calculation: sum of anions as mEq/L calculated from Alkalinity (bicarbonate), Chloride and Sulphate. Nitrate-N, Nitrite-N. Fluoride, Dissolved Reactive Phosphorus and Cyanide also included in calculation if available. APHA 1030 E 22 <sup>nd</sup> ed. 2012.	0.07 meq/L	1-2
Total cations for anion/cation balance check	Sum of cations as mEq/L calculated from Sodium, Potassium, Calcium and Magnesium. Iron, Manganese, Aluminium, Zinc, Copper, Lithium, Total Ammoniacal-N and pH (H <sup>+</sup> ) also included in calculation if available. APHA 1030 E 22 <sup>nd</sup> ed. 2012.	0.05 meq/L	1-2
pH	pH meter. APHA 4500-H <sup>+</sup> B 22 <sup>nd</sup> ed. 2012.	0.1 pH Units	1-2
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (Modified for alk <20) 22 <sup>nd</sup> ed. 2012.	1.0 g/m <sup>3</sup> as CaCO <sub>3</sub>	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 <sub>2</sub> D 22 <sup>nd</sup> ed. 2012.	1.0 g/m <sup>3</sup> at 25°C	1-2
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 22 <sup>nd</sup> ed. 2012.	1.0 g/m <sup>3</sup> as CaCO <sub>3</sub>	1-2
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 22 <sup>nd</sup> ed. 2012.	0.1 mS/m	1-2
Total Dissolved Solids (TDS)	Filtration through GF/C (1.2 µm), gravimetric. APHA 2540 C (modified; drying temperature of 103 - 105°C used rather than 180 ± 2°C) 22 <sup>nd</sup> ed. 2012.	10 g/m <sup>3</sup>	1-2
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.00010 g/m <sup>3</sup>	1-2



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

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





## ANALYSIS REPORT

<b>Client:</b>	Taranaki Regional Council	<b>Lab No:</b>	1287029	SPV1
<b>Contact:</b>	Regan Phipps C/- Taranaki Regional Council Private Bag 713 STRATFORD 4352	<b>Date Registered:</b>	13-Jun-2014	
		<b>Date Reported:</b>	24-Jun-2014	
		<b>Quote No:</b>	47915	
		<b>Order No:</b>		
		<b>Client Reference:</b>	Cheal C - Post HF GW	
		<b>Submitted By:</b>	Regan Phipps	

### Sample Type: Aqueous

<b>Sample Name:</b>	GND2446 12-Jun-2014 3:15 pm				
<b>Lab Number:</b>	1287029.1				

#### Individual Tests

Sum of Anions	meq/L	2.7	-	-	-	-
Sum of Cations	meq/L	3.0	-	-	-	-
pH	pH Units	6.8	-	-	-	-
Total Alkalinity	g/m <sup>3</sup> as CaCO <sub>3</sub>	115	-	-	-	-
Bicarbonate	g/m <sup>3</sup> at 25°C	140	-	-	-	-
Total Hardness	g/m <sup>3</sup> as CaCO <sub>3</sub>	47	-	-	-	-
Electrical Conductivity (EC)	mS/m	27.0	-	-	-	-
Total Dissolved Solids (TDS)	g/m <sup>3</sup>	199	-	-	-	-
Dissolved Barium	g/m <sup>3</sup>	0.038	-	-	-	-
Dissolved Bromine*	g/m <sup>3</sup>	0.047	-	-	-	-
Dissolved Calcium	g/m <sup>3</sup>	10.7	-	-	-	-
Dissolved Copper	g/m <sup>3</sup>	< 0.0005	-	-	-	-
Dissolved Iron	g/m <sup>3</sup>	17.9	-	-	-	-
Dissolved Magnesium	g/m <sup>3</sup>	5.0	-	-	-	-
Dissolved Manganese	g/m <sup>3</sup>	0.36	-	-	-	-
Dissolved Mercury	g/m <sup>3</sup>	< 0.00008	-	-	-	-
Dissolved Nickel	g/m <sup>3</sup>	< 0.0005	-	-	-	-
Dissolved Potassium	g/m <sup>3</sup>	12.8	-	-	-	-
Dissolved Sodium	g/m <sup>3</sup>	25	-	-	-	-
Dissolved Zinc	g/m <sup>3</sup>	0.0047	-	-	-	-
Chloride	g/m <sup>3</sup>	11.9	-	-	-	-
Nitrite-N	g/m <sup>3</sup>	< 0.2	-	-	-	-
Nitrate-N	g/m <sup>3</sup>	0.7	-	-	-	-
Nitrate-N + Nitrite-N	g/m <sup>3</sup>	0.8 #1	-	-	-	-
Sulphate	g/m <sup>3</sup>	< 0.5	-	-	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m <sup>3</sup>	< 4	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m <sup>3</sup>	< 4	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m <sup>3</sup>	< 2	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m <sup>3</sup>	< 0.0010	-	-	-	-
Toluene	g/m <sup>3</sup>	< 0.0010	-	-	-	-
Ethylbenzene	g/m <sup>3</sup>	< 0.0010	-	-	-	-
m&p-Xylene	g/m <sup>3</sup>	< 0.002	-	-	-	-



This Laboratory is accredited by International Accreditation New Zealand (IANZ), which represents New Zealand in the International Laboratory Accreditation Cooperation (ILAC). Through the ILAC Mutual Recognition Arrangement (ILAC-MRA) this accreditation is internationally recognised.

The tests reported herein have been performed in accordance with the terms of accreditation, with the exception of tests marked \*, which are not accredited.

Sample Type: Aqueous						
<b>Sample Name:</b>	GND2446 12-Jun-2014 3:15 pm					
<b>Lab Number:</b>	1287029.1					
BTEX in Water by Headspace GC-MS						
o-Xylene	g/m <sup>3</sup>	< 0.0010	-	-	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m <sup>3</sup>	< 0.02	-	-	-	-
Gases in groundwater						
Ethane	g/m <sup>3</sup>	< 0.003	-	-	-	-
Ethylene	g/m <sup>3</sup>	< 0.003	-	-	-	-
Methane	g/m <sup>3</sup>	23	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m <sup>3</sup>	< 0.10	-	-	-	-
C10 - C14	g/m <sup>3</sup>	< 0.2	-	-	-	-
C15 - C36	g/m <sup>3</sup>	< 0.4	-	-	-	-
Total hydrocarbons (C7 - C36)	g/m <sup>3</sup>	< 0.7	-	-	-	-

### Analyst's Comments

#1 Severe matrix interferences required that a dilution be performed prior to analysis, resulting in a detection limit higher than that normally achieved for the NOxN /NO2N 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: Aqueous			
Test	Method Description	Default Detection Limit	Sample No
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m <sup>3</sup>	1
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m <sup>3</sup>	1
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m <sup>3</sup>	1
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m <sup>3</sup>	1
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS	0.02 g/m <sup>3</sup>	1
Gases in groundwater	Manual headspace creation and sub-sampling, GC-FID analysis.	0.002 - 0.003 g/m <sup>3</sup>	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 <sup>3</sup>	1
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1
Total anions for anion/cation balance check	Calculation: sum of anions as mEq/L.	0.07 meq/L	1
Total cations for anion/cation balance check	Calculation: sum of cations as mEq/L.	0.05 meq/L	1
pH	pH meter. APHA 4500-H+ B 22 <sup>nd</sup> ed. 2012.	0.1 pH Units	1
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (Modified for alk <20) 22 <sup>nd</sup> ed. 2012.	1.0 g/m <sup>3</sup> as CaCO <sub>3</sub>	1
Bicarbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO <sub>2</sub> D 22 <sup>nd</sup> ed. 2012.	1.0 g/m <sup>3</sup> at 25°C	1
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 22 <sup>nd</sup> ed. 2012.	1.0 g/m <sup>3</sup> as CaCO <sub>3</sub>	1
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 22 <sup>nd</sup> ed. 2012.	0.1 mS/m	1
Total Dissolved Solids (TDS)	Filtration through GF/C (1.2 µm), gravimetric. APHA 2540 C (modified; drying temperature of 103 - 105°C used rather than 180 ± 2°C) 22 <sup>nd</sup> ed. 2012.	10 g/m <sup>3</sup>	1
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.00010 g/m <sup>3</sup>	1
Dissolved Bromine*	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.005 g/m <sup>3</sup>	1
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.05 g/m <sup>3</sup>	1

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

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

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

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Martin Cowell - BSc  
Client Services Manager - Environmental Division





## ANALYSIS REPORT

<b>Client:</b>	Taranaki Regional Council	<b>Lab No:</b>	1249264	SPV1
<b>Contact:</b>	Regan Phipps C/- Taranaki Regional Council Private Bag 713 STRATFORD 4352	<b>Date Registered:</b>	18-Mar-2014	
		<b>Date Reported:</b>	27-Mar-2014	
		<b>Quote No:</b>	47915	
		<b>Order No:</b>		
		<b>Client Reference:</b>	Cheal C Pre HF GW	
		<b>Submitted By:</b>	Regan Phipps	

### Sample Type: Aqueous

<b>Sample Name:</b>	GND2446 17-Mar-2014 11:55 am				
<b>Lab Number:</b>	1249264.1				

#### Individual Tests

Sum of Anions	meq/L	2.3	-	-	-	-
Sum of Cations	meq/L	2.5	-	-	-	-
pH	pH Units	7.1	-	-	-	-
Total Alkalinity	g/m <sup>3</sup> as CaCO <sub>3</sub>	97	-	-	-	-
Bicarbonate	g/m <sup>3</sup> at 25°C	118	-	-	-	-
Total Hardness	g/m <sup>3</sup> as CaCO <sub>3</sub>	38	-	-	-	-
Electrical Conductivity (EC)	mS/m	22.5	-	-	-	-
Total Dissolved Solids (TDS)	g/m <sup>3</sup>	170	-	-	-	-
Dissolved Barium	g/m <sup>3</sup>	0.025	-	-	-	-
Dissolved Bromine*	g/m <sup>3</sup>	0.050	-	-	-	-
Dissolved Calcium	g/m <sup>3</sup>	8.7	-	-	-	-
Dissolved Copper	g/m <sup>3</sup>	0.0017	-	-	-	-
Dissolved Iron	g/m <sup>3</sup>	13.4	-	-	-	-
Dissolved Magnesium	g/m <sup>3</sup>	3.8	-	-	-	-
Dissolved Manganese	g/m <sup>3</sup>	0.41	-	-	-	-
Dissolved Mercury	g/m <sup>3</sup>	< 0.00008	-	-	-	-
Dissolved Nickel	g/m <sup>3</sup>	< 0.0005	-	-	-	-
Dissolved Potassium	g/m <sup>3</sup>	10.4	-	-	-	-
Dissolved Sodium	g/m <sup>3</sup>	22	-	-	-	-
Dissolved Zinc	g/m <sup>3</sup>	0.0163	-	-	-	-
Chloride	g/m <sup>3</sup>	11.0	-	-	-	-
Nitrite-N	g/m <sup>3</sup>	< 0.002	-	-	-	-
Nitrate-N	g/m <sup>3</sup>	< 0.002	-	-	-	-
Nitrate-N + Nitrite-N	g/m <sup>3</sup>	< 0.002	-	-	-	-
Sulphate	g/m <sup>3</sup>	< 0.5	-	-	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m <sup>3</sup>	< 4	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m <sup>3</sup>	< 4	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m <sup>3</sup>	< 2	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m <sup>3</sup>	< 0.0010	-	-	-	-
Toluene	g/m <sup>3</sup>	0.0046	-	-	-	-
Ethylbenzene	g/m <sup>3</sup>	< 0.0010	-	-	-	-
m&p-Xylene	g/m <sup>3</sup>	< 0.002	-	-	-	-



This Laboratory is accredited by International Accreditation New Zealand (IANZ), which represents New Zealand in the International Laboratory Accreditation Cooperation (ILAC). Through the ILAC Mutual Recognition Arrangement (ILAC-MRA) this accreditation is internationally recognised.

The tests reported herein have been performed in accordance with the terms of accreditation, with the exception of tests marked \*, which are not accredited.

Sample Type: Aqueous						
<b>Sample Name:</b>	GND2446 17-Mar-2014 11:55 am					
<b>Lab Number:</b>	1249264.1					
BTEX in Water by Headspace GC-MS						
o-Xylene	g/m <sup>3</sup>	< 0.0010	-	-	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m <sup>3</sup>	< 0.02	-	-	-	-
Gases in groundwater						
Ethane	g/m <sup>3</sup>	< 0.003	-	-	-	-
Ethylene	g/m <sup>3</sup>	< 0.003	-	-	-	-
Methane	g/m <sup>3</sup>	13.7	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m <sup>3</sup>	< 0.10	-	-	-	-
C10 - C14	g/m <sup>3</sup>	< 0.2	-	-	-	-
C15 - C36	g/m <sup>3</sup>	< 0.4	-	-	-	-
Total hydrocarbons (C7 - C36)	g/m <sup>3</sup>	< 0.7	-	-	-	-

## SUMMARY OF METHODS

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

Sample Type: Aqueous			
Test	Method Description	Default Detection Limit	Sample No
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m <sup>3</sup>	1
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m <sup>3</sup>	1
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m <sup>3</sup>	1
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m <sup>3</sup>	1
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS	0.02 g/m <sup>3</sup>	1
Gases in groundwater	Manual headspace creation and sub-sampling, GC-FID analysis.	0.002 - 0.003 g/m <sup>3</sup>	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 <sup>3</sup>	1
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1
Total anions for anion/cation balance check	Calculation: sum of anions as mEq/L.	0.07 meq/L	1
Total cations for anion/cation balance check	Calculation: sum of cations as mEq/L.	0.05 meq/L	1
pH	pH meter. APHA 4500-H+ B 22 <sup>nd</sup> ed. 2012.	0.1 pH Units	1
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (Modified for alk <20) 22 <sup>nd</sup> ed. 2012.	1.0 g/m <sup>3</sup> as CaCO <sub>3</sub>	1
Bicarbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO <sub>2</sub> D 22 <sup>nd</sup> ed. 2012.	1.0 g/m <sup>3</sup> at 25°C	1
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 22 <sup>nd</sup> ed. 2012.	1.0 g/m <sup>3</sup> as CaCO <sub>3</sub>	1
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 22 <sup>nd</sup> ed. 2012.	0.1 mS/m	1
Total Dissolved Solids (TDS)	Filtration through GF/C (1.2 µm), gravimetric. APHA 2540 C (modified; drying temperature of 103 - 105°C used rather than 180 ± 2°C) 22 <sup>nd</sup> ed. 2012.	10 g/m <sup>3</sup>	1
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.00010 g/m <sup>3</sup>	1
Dissolved Bromine*	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.005 g/m <sup>3</sup>	1
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.05 g/m <sup>3</sup>	1
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.0005 g/m <sup>3</sup>	1
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.02 g/m <sup>3</sup>	1
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.02 g/m <sup>3</sup>	1



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

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

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

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



# ANALYSIS REPORT

Page 1 of 3

<b>Client:</b>	Taranaki Regional Council	<b>Lab No:</b>	1248042	SPV1
<b>Contact:</b>	Regan Phipps C/- Taranaki Regional Council Private Bag 713 STRATFORD 4352	<b>Date Registered:</b>	14-Mar-2014	
		<b>Date Reported:</b>	24-Mar-2014	
		<b>Quote No:</b>	47915	
		<b>Order No:</b>		
		<b>Client Reference:</b>	Cheal C Pre HF GW	
		<b>Submitted By:</b>	R McDonnell	

## Sample Type: Aqueous

<b>Sample Name:</b>	GND2274 13-Mar-2014 10:30 am				
<b>Lab Number:</b>	1248042.1				

### Individual Tests

Sum of Anions	meq/L	1.14	-	-	-	-
Sum of Cations	meq/L	1.09	-	-	-	-
pH	pH Units	6.4	-	-	-	-
Total Alkalinity	g/m <sup>3</sup> as CaCO <sub>3</sub>	29	-	-	-	-
Bicarbonate	g/m <sup>3</sup> at 25°C	35	-	-	-	-
Total Hardness	g/m <sup>3</sup> as CaCO <sub>3</sub>	32	-	-	-	-
Electrical Conductivity (EC)	mS/m	12.6	-	-	-	-
Total Dissolved Solids (TDS)	g/m <sup>3</sup>	90	-	-	-	-
Dissolved Barium	g/m <sup>3</sup>	0.036	-	-	-	-
Dissolved Bromine*	g/m <sup>3</sup>	0.052	-	-	-	-
Dissolved Calcium	g/m <sup>3</sup>	9.8	-	-	-	-
Dissolved Copper	g/m <sup>3</sup>	0.021	-	-	-	-
Dissolved Iron	g/m <sup>3</sup>	< 0.02	-	-	-	-
Dissolved Magnesium	g/m <sup>3</sup>	1.92	-	-	-	-
Dissolved Manganese	g/m <sup>3</sup>	0.0023	-	-	-	-
Dissolved Mercury	g/m <sup>3</sup>	< 0.00008	-	-	-	-
Dissolved Nickel	g/m <sup>3</sup>	< 0.0005	-	-	-	-
Dissolved Potassium	g/m <sup>3</sup>	3.3	-	-	-	-
Dissolved Sodium	g/m <sup>3</sup>	8.3	-	-	-	-
Dissolved Zinc	g/m <sup>3</sup>	0.0078	-	-	-	-
Chloride	g/m <sup>3</sup>	11.7	-	-	-	-
Nitrite-N	g/m <sup>3</sup>	< 0.002	-	-	-	-
Nitrate-N	g/m <sup>3</sup>	1.61	-	-	-	-
Nitrate-N + Nitrite-N	g/m <sup>3</sup>	1.61	-	-	-	-
Sulphate	g/m <sup>3</sup>	5.8	-	-	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m <sup>3</sup>	< 4	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m <sup>3</sup>	< 4	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m <sup>3</sup>	< 2	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m <sup>3</sup>	< 0.0010	-	-	-	-
Toluene	g/m <sup>3</sup>	< 0.0010	-	-	-	-
Ethylbenzene	g/m <sup>3</sup>	< 0.0010	-	-	-	-
m&p-Xylene	g/m <sup>3</sup>	< 0.002	-	-	-	-

Sample Type: Aqueous						
<b>Sample Name:</b>	GND2274 13-Mar-2014 10:30 am					
<b>Lab Number:</b>	1248042.1					
BTEX in Water by Headspace GC-MS						
o-Xylene	g/m <sup>3</sup>	< 0.0010	-	-	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m <sup>3</sup>	< 0.02	-	-	-	-
Gases in groundwater						
Ethane	g/m <sup>3</sup>	< 0.003	-	-	-	-
Ethylene	g/m <sup>3</sup>	< 0.003	-	-	-	-
Methane	g/m <sup>3</sup>	< 0.002	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m <sup>3</sup>	< 0.10	-	-	-	-
C10 - C14	g/m <sup>3</sup>	< 0.2	-	-	-	-
C15 - C36	g/m <sup>3</sup>	< 0.4	-	-	-	-
Total hydrocarbons (C7 - C36)	g/m <sup>3</sup>	< 0.7	-	-	-	-

## SUMMARY OF METHODS

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

Sample Type: Aqueous			
Test	Method Description	Default Detection Limit	Sample No
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m <sup>3</sup>	1
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m <sup>3</sup>	1
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m <sup>3</sup>	1
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m <sup>3</sup>	1
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS	0.02 g/m <sup>3</sup>	1
Gases in groundwater	Manual headspace creation and sub-sampling, GC-FID analysis.	0.002 - 0.003 g/m <sup>3</sup>	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 <sup>3</sup>	1
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1
Total anions for anion/cation balance check	Calculation: sum of anions as mEq/L.	0.07 meq/L	1
Total cations for anion/cation balance check	Calculation: sum of cations as mEq/L.	0.05 meq/L	1
pH	pH meter. APHA 4500-H+ B 22 <sup>nd</sup> ed. 2012.	0.1 pH Units	1
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (Modified for alk <20) 22 <sup>nd</sup> ed. 2012.	1.0 g/m <sup>3</sup> as CaCO <sub>3</sub>	1
Bicarbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO <sub>2</sub> D 22 <sup>nd</sup> ed. 2012.	1.0 g/m <sup>3</sup> at 25°C	1
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 22 <sup>nd</sup> ed. 2012.	1.0 g/m <sup>3</sup> as CaCO <sub>3</sub>	1
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 22 <sup>nd</sup> ed. 2012.	0.1 mS/m	1
Total Dissolved Solids (TDS)	Filtration through GF/C (1.2 µm), gravimetric. APHA 2540 C (modified; drying temperature of 103 - 105°C used rather than 180 ± 2°C) 22 <sup>nd</sup> ed. 2012.	10 g/m <sup>3</sup>	1
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.00010 g/m <sup>3</sup>	1
Dissolved Bromine*	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.005 g/m <sup>3</sup>	1
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.05 g/m <sup>3</sup>	1
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.0005 g/m <sup>3</sup>	1
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.02 g/m <sup>3</sup>	1
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.02 g/m <sup>3</sup>	1

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

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

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

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



# ANALYSIS REPORT

Page 1 of 3

<b>Client:</b>	Taranaki Regional Council	<b>Lab No:</b>	1290693	SPV1
<b>Contact:</b>	Regan Phipps C/- Taranaki Regional Council Private Bag 713 STRATFORD 4352	<b>Date Registered:</b>	24-Jun-2014	
		<b>Date Reported:</b>	02-Jul-2014	
		<b>Quote No:</b>	47915	
		<b>Order No:</b>		
		<b>Client Reference:</b>	Cleal C Post HF GW	
		<b>Submitted By:</b>	Regan Phipps	

## Sample Type: Aqueous

<b>Sample Name:</b>	GND2274 23-Jun-2014 8:45 am				
<b>Lab Number:</b>	1290693.1				
Individual Tests					
Sum of Anions	meq/L	1.07	-	-	-
Sum of Cations	meq/L	1.07	-	-	-
pH	pH Units	6.6	-	-	-
Total Alkalinity	g/m <sup>3</sup> as CaCO <sub>3</sub>	28	-	-	-
Bicarbonate	g/m <sup>3</sup> at 25°C	34	-	-	-
Total Hardness	g/m <sup>3</sup> as CaCO <sub>3</sub>	31	-	-	-
Electrical Conductivity (EC)	mS/m	11.8	-	-	-
Total Dissolved Solids (TDS)	g/m <sup>3</sup>	92	-	-	-
Dissolved Barium	g/m <sup>3</sup>	0.039	-	-	-
Dissolved Bromine*	g/m <sup>3</sup>	0.047	-	-	-
Dissolved Calcium	g/m <sup>3</sup>	9.7	-	-	-
Dissolved Copper	g/m <sup>3</sup>	0.036	-	-	-
Dissolved Iron	g/m <sup>3</sup>	< 0.02	-	-	-
Dissolved Magnesium	g/m <sup>3</sup>	1.76	-	-	-
Dissolved Manganese	g/m <sup>3</sup>	0.0024	-	-	-
Dissolved Mercury	g/m <sup>3</sup>	< 0.00008	-	-	-
Dissolved Nickel	g/m <sup>3</sup>	< 0.0005	-	-	-
Dissolved Potassium	g/m <sup>3</sup>	3.0	-	-	-
Dissolved Sodium	g/m <sup>3</sup>	8.3	-	-	-
Dissolved Zinc	g/m <sup>3</sup>	0.0165	-	-	-
Chloride	g/m <sup>3</sup>	10.6	-	-	-
Nitrite-N	g/m <sup>3</sup>	< 0.002	-	-	-
Nitrate-N	g/m <sup>3</sup>	1.48	-	-	-
Nitrate-N + Nitrite-N	g/m <sup>3</sup>	1.48	-	-	-
Sulphate	g/m <sup>3</sup>	5.0	-	-	-
Ethylene Glycol in Water					
Ethylene glycol*	g/m <sup>3</sup>	< 4	-	-	-
Propylene Glycol in Water					
Propylene glycol*	g/m <sup>3</sup>	< 4	-	-	-
Methanol in Water - Aqueous Solvents					
Methanol*	g/m <sup>3</sup>	< 2	-	-	-
BTEX in Water by Headspace GC-MS					
Benzene	g/m <sup>3</sup>	< 0.0010	-	-	-
Toluene	g/m <sup>3</sup>	< 0.0010	-	-	-
Ethylbenzene	g/m <sup>3</sup>	< 0.0010	-	-	-
m&p-Xylene	g/m <sup>3</sup>	< 0.002	-	-	-

Sample Type: Aqueous						
<b>Sample Name:</b>	GND2274 23-Jun-2014 8:45 am					
<b>Lab Number:</b>	1290693.1					
BTEX in Water by Headspace GC-MS						
o-Xylene	g/m <sup>3</sup>	< 0.0010	-	-	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m <sup>3</sup>	< 0.02	-	-	-	-
Gases in groundwater						
Ethane	g/m <sup>3</sup>	< 0.003	-	-	-	-
Ethylene	g/m <sup>3</sup>	< 0.003	-	-	-	-
Methane	g/m <sup>3</sup>	< 0.002	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m <sup>3</sup>	< 0.10	-	-	-	-
C10 - C14	g/m <sup>3</sup>	< 0.2	-	-	-	-
C15 - C36	g/m <sup>3</sup>	< 0.4	-	-	-	-
Total hydrocarbons (C7 - C36)	g/m <sup>3</sup>	< 0.7	-	-	-	-

## SUMMARY OF METHODS

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

Sample Type: Aqueous			
Test	Method Description	Default Detection Limit	Sample No
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m <sup>3</sup>	1
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m <sup>3</sup>	1
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m <sup>3</sup>	1
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m <sup>3</sup>	1
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS	0.02 g/m <sup>3</sup>	1
Gases in groundwater	Manual headspace creation and sub-sampling, GC-FID analysis.	0.002 - 0.003 g/m <sup>3</sup>	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 <sup>3</sup>	1
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1
Total anions for anion/cation balance check	Calculation: sum of anions as mEq/L.	0.07 meq/L	1
Total cations for anion/cation balance check	Calculation: sum of cations as mEq/L.	0.05 meq/L	1
pH	pH meter. APHA 4500-H+ B 22 <sup>nd</sup> ed. 2012.	0.1 pH Units	1
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (Modified for alk <20) 22 <sup>nd</sup> ed. 2012.	1.0 g/m <sup>3</sup> as CaCO <sub>3</sub>	1
Bicarbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO <sub>2</sub> D 22 <sup>nd</sup> ed. 2012.	1.0 g/m <sup>3</sup> at 25°C	1
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 22 <sup>nd</sup> ed. 2012.	1.0 g/m <sup>3</sup> as CaCO <sub>3</sub>	1
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 22 <sup>nd</sup> ed. 2012.	0.1 mS/m	1
Total Dissolved Solids (TDS)	Filtration through GF/C (1.2 µm), gravimetric. APHA 2540 C (modified; drying temperature of 103 - 105°C used rather than 180 ± 2°C) 22 <sup>nd</sup> ed. 2012.	10 g/m <sup>3</sup>	1
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.00010 g/m <sup>3</sup>	1
Dissolved Bromine*	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.005 g/m <sup>3</sup>	1
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.05 g/m <sup>3</sup>	1
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.0005 g/m <sup>3</sup>	1
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.02 g/m <sup>3</sup>	1
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.02 g/m <sup>3</sup>	1



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

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

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

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



**STABLE ISOTOPE RESULTS**

Rachel McDonnell  
47 Cloten Road  
Stratford  
Taranaki 4352  
New Zealand



<b>Project Title</b>	Cheal C	<b>Invoice</b>	<b>Taranaki Regional Council</b>
<b>SIL Order No.:</b>		<b>Attn:</b>	<b>Rachel</b>
<b>Client Ref.:</b>			<b>Private Bag 713</b>
<b>Date Received:</b>	11/08/2014		<b>Stratford</b>
<b>Date Measured:</b>			<b>4352</b>
<b>Approved By:</b>			<b>New Zealand</b>
<b>Date Reported:</b>	22/08/2014		
<b>Sample Type:</b>	other C-bearing material		

SIL ID	External ID	$\delta^{13}C$ Value	Analysis Type	State or Province	Latitude	Longitude	Collection Date/Time (Start)	Other Info
G-1402591	GND2446	-80.2	C13	Taranaki	-39.36783333	174.2813889	05/08/2014 13:28	Water



## **Appendix IV**

### **Certificates of analysis (Hydraulic fracturing and return fluid)**



# ANALYSIS REPORT

Page 1 of 2

<b>Client:</b>	Taranaki Regional Council	<b>Lab No:</b>	1253339	SPV1
<b>Contact:</b>	Regan Phipps C/- Taranaki Regional Council Private Bag 713 STRATFORD 4352	<b>Date Registered:</b>	26-Mar-2014	
		<b>Date Reported:</b>	04-Apr-2014	
		<b>Quote No:</b>	50522	
		<b>Order No:</b>		
		<b>Client Reference:</b>	Cheal C HF Fluid	
		<b>Submitted By:</b>	Regan Phipps	

## Sample Type: Aqueous

<b>Sample Name:</b>	GND2449 24-Mar-2014 12:00 pm				
<b>Lab Number:</b>	1253339.1				
Ethylene Glycol in Water					
Ethylene glycol*	g/m <sup>3</sup>	620	-	-	-
Propylene Glycol in Water					
Propylene glycol*	g/m <sup>3</sup>	< 4	-	-	-
Methanol in Water - Aqueous Solvents					
Methanol*	g/m <sup>3</sup>	< 2	-	-	-
BTEX in Water by Headspace GC-MS					
Benzene	g/m <sup>3</sup>	< 0.0010	-	-	-
Toluene	g/m <sup>3</sup>	0.0024	-	-	-
Ethylbenzene	g/m <sup>3</sup>	0.0025	-	-	-
m&p-Xylene	g/m <sup>3</sup>	0.006	-	-	-
o-Xylene	g/m <sup>3</sup>	0.0026	-	-	-
Total Petroleum Hydrocarbons in Water					
C7 - C9	g/m <sup>3</sup>	0.78	-	-	-
C10 - C14	g/m <sup>3</sup>	24	-	-	-
C15 - C36	g/m <sup>3</sup>	51	-	-	-
Total hydrocarbons (C7 - C36)	g/m <sup>3</sup>	76	-	-	-

## Analyst's Comments

Appendix No.1 - Total Petroleum Hydrocarbon Chromatograms

## 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 <sup>3</sup>	1
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m <sup>3</sup>	1
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m <sup>3</sup>	1
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m <sup>3</sup>	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 <sup>3</sup>	1

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

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

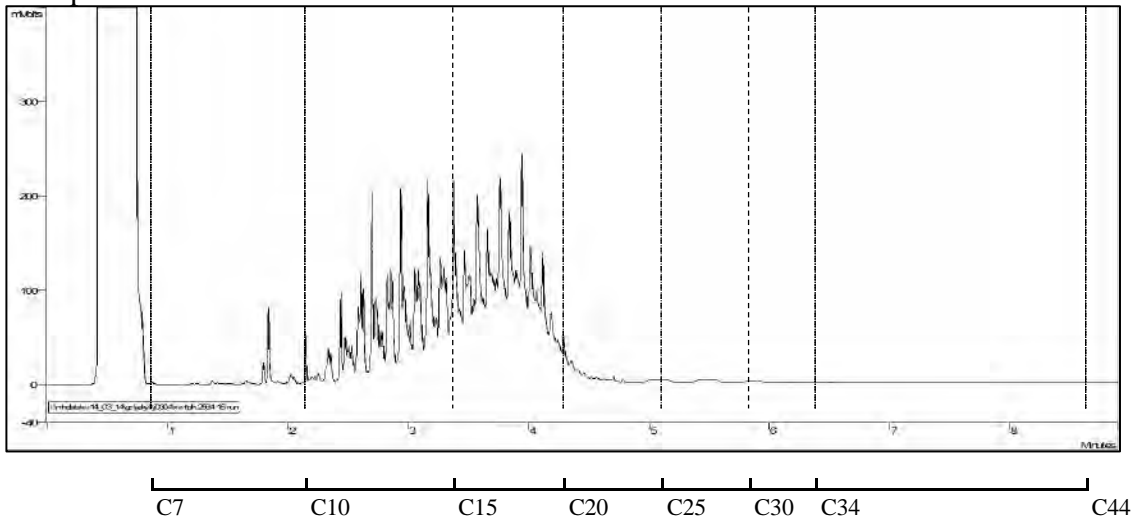
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A handwritten signature in blue ink, consisting of several overlapping, stylized strokes.

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



Sample : 1253339.1





# ANALYSIS REPORT

Page 1 of 3

<b>Client:</b>	Taranaki Regional Council	<b>Lab No:</b>	1254061	SPV1
<b>Contact:</b>	Regan Phipps C/- Taranaki Regional Council Private Bag 713 STRATFORD 4352	<b>Date Registered:</b>	27-Mar-2014	
		<b>Date Reported:</b>	14-Apr-2014	
		<b>Quote No:</b>	49265	
		<b>Order No:</b>		
		<b>Client Reference:</b>	Cheal C Return Fluid	
		<b>Submitted By:</b>	Regan Phipps	

## Sample Type: Saline

<b>Sample Name:</b>	GND2449 24-Mar-2014 10:01 pm				
<b>Lab Number:</b>	1254061.1				

### Individual Tests

pH*	pH Units	7.4	-	-	-	-
Total Alkalinity*	g/m <sup>3</sup> as CaCO <sub>3</sub>	1,940	-	-	-	-
Analysis Temperature for Bicarbonate	°C	22	-	-	-	-
Bicarbonate	g/m <sup>3</sup> at Analysis Temperature	1,991	-	-	-	-
Total Hardness*	g/m <sup>3</sup> as CaCO <sub>3</sub>	45	-	-	-	-
Electrical Conductivity (EC)*	mS/m	775	-	-	-	-
Total Dissolved Solids (TDS)*	g/m <sup>3</sup>	7,800	-	-	-	-
Dissolved Barium*	g/m <sup>3</sup>	6.0	-	-	-	-
Dissolved Bromine*	g/m <sup>3</sup>	2.7	-	-	-	-
Dissolved Calcium*	g/m <sup>3</sup>	14	-	-	-	-
Dissolved Copper*	g/m <sup>3</sup>	0.033	-	-	-	-
Dissolved Iron*	g/m <sup>3</sup>	42	-	-	-	-
Dissolved Magnesium*	g/m <sup>3</sup>	3	-	-	-	-
Dissolved Manganese*	g/m <sup>3</sup>	3.2	-	-	-	-
Total Mercury*	g/m <sup>3</sup>	< 0.011	-	-	-	-
Dissolved Nickel*	g/m <sup>3</sup>	0.03	-	-	-	-
Dissolved Potassium*	g/m <sup>3</sup>	99	-	-	-	-
Dissolved Sodium*	g/m <sup>3</sup>	1,640	-	-	-	-
Dissolved Sulphur*	g/m <sup>3</sup>	11	-	-	-	-
Dissolved Zinc*	g/m <sup>3</sup>	0.47	-	-	-	-
Chloride*	g/m <sup>3</sup>	1,370	-	-	-	-
Nitrite-N	g/m <sup>3</sup>	0.011	-	-	-	-
Nitrate-N	g/m <sup>3</sup>	< 0.002	-	-	-	-
Nitrate*	g/m <sup>3</sup>	< 0.010	-	-	-	-
Nitrate-N + Nitrite-N	g/m <sup>3</sup>	0.013	-	-	-	-
Sulphate*	g/m <sup>3</sup>	34	-	-	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m <sup>3</sup>	75	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m <sup>3</sup>	< 4	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m <sup>3</sup>	3	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene*	g/m <sup>3</sup>	1.60	-	-	-	-
Toluene*	g/m <sup>3</sup>	2.7	-	-	-	-
Ethylbenzene*	g/m <sup>3</sup>	0.192	-	-	-	-

Sample Type: Saline						
<b>Sample Name:</b>	GND2449					
	24-Mar-2014					
	10:01 pm					
<b>Lab Number:</b>	1254061.1					
BTEX in Water by Headspace GC-MS						
m&p-Xylene*	g/m <sup>3</sup>	1.27	-	-	-	-
o-Xylene*	g/m <sup>3</sup>	0.50	-	-	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde*	g/m <sup>3</sup>	1.7	-	-	-	-
Gases in groundwater						
Ethane*	g/m <sup>3</sup>	0.43	-	-	-	-
Ethylene*	g/m <sup>3</sup>	< 0.003	-	-	-	-
Methane*	g/m <sup>3</sup>	1.54	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9*	g/m <sup>3</sup>	16.8	-	-	-	-
C10 - C14*	g/m <sup>3</sup>	143	-	-	-	-
C15 - C36*	g/m <sup>3</sup>	340	-	-	-	-
Total hydrocarbons (C7 - C36)*	g/m <sup>3</sup>	500	-	-	-	-

### Analyst's Comments

Appendix No.1 - Total Petroleum Hydrocarbon Chromatograms

## SUMMARY OF METHODS

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

Sample Type: Saline			
Test	Method Description	Default Detection Limit	Sample No
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m <sup>3</sup>	1
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m <sup>3</sup>	1
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m <sup>3</sup>	1
BTEX in Water by Headspace GC-MS*	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m <sup>3</sup>	1
Formaldehyde in Water by DNPH & LCMSMS*	DNPH derivatisation, extraction, LCMSMS	0.02 g/m <sup>3</sup>	1
Gases in groundwater*	Manual headspace creation and sub-sampling, GC-FID analysis.	0.002 - 0.003 g/m <sup>3</sup>	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 <sup>3</sup>	1
Filtration, Unpreserved*	Sample filtration through 0.45µm membrane filter.	-	1
Total Digestion of Saline Samples*	Nitric acid digestion. APHA 3030 E 22 <sup>nd</sup> ed. 2012 (modified).	-	1
pH*	pH meter. APHA 4500-H+ B 22 <sup>nd</sup> ed. 2012.	0.1 pH Units	1
Total Alkalinity*	Saline water, Titration to pH 4.5.	1.0 g/m <sup>3</sup> as CaCO <sub>3</sub>	1
Analysis Temperature for Bicarbonate	Temperature at which Bicarbonate titration was conducted as reported by Geological & Nuclear Sciences, Wairakei.	1.0 °C	1
Bicarbonate	Bicarbonate (HCO <sub>3</sub> ) Titration Method conducted at reported temperature. Subcontracted to Geological & Nuclear Sciences, Wairakei. ASTM Standards D513-82 Vol.11.01 of 1988.	20 g/m <sup>3</sup> at Analysis Temperature	1
Total Hardness*	Calculation from Calcium and Magnesium. APHA 2340 B 22 <sup>nd</sup> ed. 2012.	1.0 g/m <sup>3</sup> as CaCO <sub>3</sub>	1
Electrical Conductivity (EC)*	Conductivity meter, 25°C. APHA 2510 B 22 <sup>nd</sup> ed. 2012.	0.1 mS/m	1
Total Dissolved Solids (TDS)*	Filtration through GF/C (1.2 µm), gravimetric. APHA 2540 C (modified; drying temperature of 103 - 105°C used rather than 180 ± 2°C) 22 <sup>nd</sup> ed. 2012.	50 g/m <sup>3</sup>	1
Filtration for dissolved metals analysis*	Sample filtration through 0.45µm membrane filter and preservation with nitric acid. APHA 3030 B 22 <sup>nd</sup> ed. 2012.	-	1
Dissolved Barium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.0006 g/m <sup>3</sup>	1
Dissolved Bromine*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.10 g/m <sup>3</sup>	1
Dissolved Calcium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	1.0 g/m <sup>3</sup>	1
Dissolved Copper*	Filtered sample, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.0010 g/m <sup>3</sup>	1

Sample Type: Saline			
Test	Method Description	Default Detection Limit	Sample No
Dissolved Iron*	Filtered sample, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.004 g/m <sup>3</sup>	1
Dissolved Magnesium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.4 g/m <sup>3</sup>	1
Dissolved Manganese*	Filtered sample, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.0010 g/m <sup>3</sup>	1
Total Mercury*	Nitric acid digestion, ICP-MS, screen level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.0021 g/m <sup>3</sup>	1
Dissolved Nickel*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.006 g/m <sup>3</sup>	1
Dissolved Potassium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	1.0 g/m <sup>3</sup>	1
Dissolved Sodium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.4 g/m <sup>3</sup>	1
Dissolved Sulphur*	Filtered sample, ICP-OES.	0.10 g/m <sup>3</sup>	1
Dissolved Zinc*	Filtered sample, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.004 g/m <sup>3</sup>	1
Chloride*	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl E (modified from continuous flow analysis) 22 <sup>nd</sup> ed. 2012.	0.5 g/m <sup>3</sup>	1
Nitrite-N	Saline sample. Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO <sub>2</sub> <sup>-</sup> I 22 <sup>nd</sup> ed. 2012.	0.002 g/m <sup>3</sup>	1
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO <sub>2</sub> N. In-House.	0.0010 g/m <sup>3</sup>	1
Nitrate*	Calculation from Nitrate-N.	0.010 g/m <sup>3</sup>	1
Nitrate-N + Nitrite-N	Saline sample. Total oxidised nitrogen. Automated cadmium reduction, Flow injection analyser. APHA 4500-NO <sub>3</sub> <sup>-</sup> I 22 <sup>nd</sup> ed. 2012.	0.002 g/m <sup>3</sup>	1
Soluble Sulphate*	Calculation: from dissolved sulphur.	2 g/m <sup>3</sup>	1

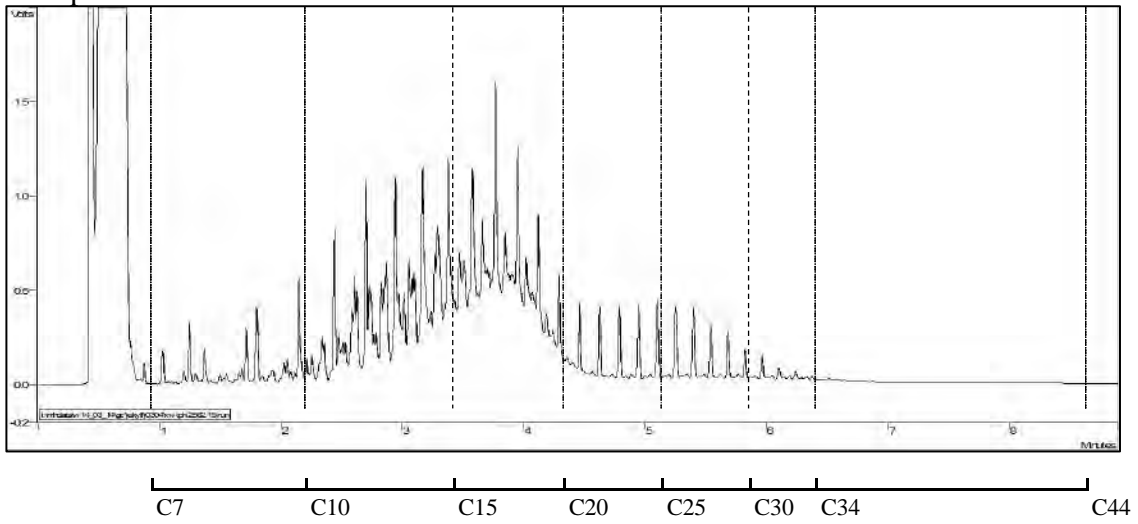
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Graham Corban MSc Tech (Hons)  
Client Services Manager - Environmental Division

Sample : 1254061.1



**Appendix V**  
**Biomonitoring report**





To Job Manager; Callum MacKenzie  
From Freshwater Biologist; Brooke Thomas  
Document 1369887  
Date 03 July 2014

## **Biomonitoring of an unnamed tributary of the Mangawharawhara Stream following hydraulic fracturing by Tag Oil Ltd Ltd at Cheal C wellsite, March 2014**

### **Introduction**

This biological survey was performed following hydraulic fracturing of the Cheal C well to determine whether or not treated stormwater and uncontaminated site and production water discharges onto land, in the vicinity of the unnamed tributary of the Mangawharawhara Stream had any effects upon the macroinvertebrate communities of the stream. A survey was also conducted prior to hydraulic fracturing, to provide baseline data on the macroinvertebrate community of this stream (Thomas, 2014).

### **Methods**

The Cheal C wellsite stormwater and site production water was discharged from a skimmer pit on to land within the vicinity of the unnamed tributary of the Mangawharawhara Stream (Figure 1). This survey was undertaken on 31 March 2013 at three established sites ; 25 m upstream of the Cheal C wellsite discharge (site 1), 50 m downstream of the Cheal C wellsite discharge (site 2) and 100 m downstream of the Cheal C wellsite discharge (site 3) (Table 1 and Figure 1).

Two different sampling techniques were used to collect streambed macroinvertebrates from the unnamed tributary of the Mangawharawhara Stream, downstream of the stormwater discharges from the Cheal C well site. The Council's 'vegetation sweep' technique was used at site 2 and a combination of the 'kick-sampling' and 'vegetation sweep' sampling techniques were used at sites 1 and 3 (Table 1). The 'kick-sampling' and 'vegetation sweep' techniques are very similar to Protocol C1 (hard-bottomed, semi-quantitative) and C2 (soft-bottomed, semi-quantitative) of the New Zealand Macroinvertebrate Working Group (NZMWG) protocols for macroinvertebrate samples in wadeable streams (Stark et al, 2001).

Table 1: Biomonitoring sites and sampling methods used in the unnamed tributary of the Mangawharawhara Stream related to the Cheal C wellsite

Site no.	Site code	Grid reference (NZTM)	Location	Sampling method	Altitude m asl
1	MWWW000217	1710311E-5641604N	25 m u/s of Cheal C wellsite discharge	Kick- sweep	300
2	MWWW000219	1710315E-5641542N	50m d/s of Cheal C wellsite discharge	Vegetation sweep	300
3	MWWW000221	1710348E-5641498N	100m d/s of Cheal C wellsite discharge	Kick- sweep	300



Figure 1 Biomonitoring sites in the unnamed tributary of the Mangawharawhara Stream in relation to the Cheal 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 NZMVG protocols of sampling macroinvertebrates in wadeable streams (Stark et al, 2001). Macroinvertebrate taxa found in each sample were recorded as:

R (rare)	= less than 5 individuals;
C (common)	= 5-19 individuals;
A (abundant)	= estimated 20-99 individuals;
VA (very abundant)	= estimated 100-499 individuals;
XA (extremely abundant)	= estimated 500 individuals or more.

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. More 'sensitive' communities inhabit less polluted waterways.

A semi-quantitative MCI value (SQMCI<sub>s</sub>) has also been calculated for the taxa present at each site by multiplying each taxon score by a loading factor (related to its abundance), totalling these products, and dividing by the sum of the loading factors (Stark, 1998 and 1999). The loading factors were 1 for rare (R), 5 for common (C), 20 for abundant (A), 100 for very abundant (VA) and 500 for extremely abundant (XA). Unlike the MCI, the SQMCI<sub>s</sub> score 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 this mid morning survey the water temperatures in the unnamed tributary of the Mangawharawhara Stream ranged from 11.7 to 12.2 °C. A very low and very slow flow of clear, uncoloured water was recorded at all three sites. Substrate was comprised of silt at site 2 and site 3 and of silt and wood and root at site 1. Patchy mats of periphyton were recorded at site 1, and no periphyton was recorded at site 2 and site 3. Macrophytes were recorded growing on the edges of the stream at site 1 and site 3 and on the edges and bed of the stream at site 2. Site 1 and site 2 were partially shaded by overhanging vegetation, whereas site 3 was completely shaded.

### Macroinvertebrate communities

Table 2 summarises the results of the current macroinvertebrate survey following hydraulic fracturing (HF) of the Cheal C well, along with results from the survey carried out 07 March 2014 prior to hydraulic fracturing. Comparative data for sites in similar streams in the region are presented in Table 3. The macroinvertebrate fauna recorded by the current survey are presented in Table 4.

Table 2: Number of taxa, MCI and SQMCI<sub>s</sub> values for the unnamed tributary of the Mangawharawhara Stream prior to and following hydraulic fracturing of Cheal C well

Site No.	Site Code	No of taxa		MCI value		SQMCI <sub>s</sub> value	
		Pre-HF (Mar 07 2014)	Post-HF (Mar 31 2014)	Pre-HF (Mar 07 2014)	Post-HF (Mar 31 2014)	Pre-HF (Mar 07 2014)	Post-HF (Mar 31 2014)
1	MWW000217	10	7	64	77	1.8	2.9
2	MWW000219	16	15	80	80	4.9	5.0
3	MWW000221	10	7	76	71	1.8	1.8

Table 3: Range and median number of taxa, MCI values and SQMCI<sub>s</sub> scores for ring plain streams rising outside of the National Park at altitudes 300-349 m asl ((TRC, 1999 (updated 2013)).

	No. of taxa	MCI value	SQMCI <sub>s</sub> value
No. Samples	44	44	25
Range	9-34	76-129	1.5-7.4
Median	23	100	4

Table 4: Macroinvertebrate fauna of unnamed tributary of the Mangawharawhara Stream in relation to the Cheal C post-HF survey sampled 31 March 2014

Taxa List	Site Number	MCI score	Site 1	Site 2	Site 3
	Site Code		MWW000217	MWW000219	MWW000221
	Sample Number		FWB14189	FWB14190	FWB14191
ANNELIDA (WORMS)	Oligochaeta	1	VA	R	VA
CRUSTACEA	Ostracoda	1	A	R	A
	<i>Paracalliope</i>	5	VA	XA	A
	<i>Paranephrops</i>	5	-	R	-
EPHEMEROPTERA (MAYFLIES)	<i>Zephlebia group</i>	7	R	A	-
ODONATA (DRAGONFLIES)	<i>Xanthocnemis</i>	4	-	R	-
HEMIPTERA (BUGS)	<i>Microvelia</i>	3	-	R	-
TRICHOPTERA (CADDISFLIES)	<i>Polypsectropus</i>	6	-	A	-
	<i>Psilochorema</i>	6	-	R	-
	<i>Tripletides</i>	5	-	R	R
DIPTERA (TRUE FLIES)	<i>Paralimnophila</i>	6	R	-	R
	Orthoclaadiinae	2	R	A	A
	<i>Polypedilum</i>	3	-	R	-
	Tanypodinae	5	C	R	C
	<i>Paradixa</i>	4	-	C	-
	Empididae	3	-	R	-
No of taxa			7	15	7
MCI			77	80	71
SQMCI <sub>s</sub>			2.9	5.0	1.8
EPT (taxa)			1	4	1
%EPT (taxa)			14	27	14
'Tolerant' taxa		'Moderately sensitive' taxa	'Highly sensitive' taxa		

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

### Site 1- 25 m upstream of Cheal C wellsite discharge

A low community richness of seven taxa was found at site 1 (Table 2 and Table 4), three taxa fewer than what was recorded in the pre-HF survey and sixteen taxa less than the median richness found at similar sites elsewhere in the region (Table 3). The macroinvertebrate community contained a significant proportion of 'moderately sensitive' taxa (57%), which was reflected in the MCI score of 77 units. This result represented a significant increase from that recorded in the pre-HF survey (64 MCI units) but was significantly lower (Stark, 1998) than the median MCI score for 'control' sites in similar streams at comparative altitudes (Table 3).

The community at this site was characterised by two 'tolerant' taxa, (oligochaete worms and seed shrimp (Ostracoda)); and one 'sensitive' taxon, (amphipod (*Paracalliope*)).

The numerical dominance of 'tolerant' taxa resulted in a SQMCI<sub>s</sub> score of 2.9 units, which was significantly higher (by 1.1 units) than what was recorded in the pre-HF survey, but was significantly lower (by 1.1 units) than the median score for 'control' sites in similar streams at this altitude (Table 3).

### **Site 2- 50 m downstream of Cheal C wellsite discharge**

A moderate community richness of fifteen taxa was found at site 2 (Table 2 and Table 4), eight taxa more than found at site 1, one taxon less than what was recorded in the pre-HF survey and eight taxa less than the median richness found at similar sites (Table 3). The macroinvertebrate community contained a larger proportion of 'tolerant' taxa (53%), which was reflected in the MCI score of 80 units; the same as what was recorded during the pre-HF survey and an insignificant three units higher than at the upstream 'control' site. This MCI score was significantly lower (Stark, 1998) than the median MCI score for 'control' sites in similar streams at comparative altitudes (Table 3).

The community at this site was characterised by three 'sensitive' taxa (amphipod (*Paracalliope*), caddisfly (*Polyplectropus*) and mayfly (*Zephlebia* group)), and one 'tolerant' taxon (orthoclad midges).

The numerical dominance of several 'sensitive' taxa resulted in a SQMCI<sub>s</sub> score of 5.0 units, which was slightly higher (by 0.1 unit) than what was recorded in the pre-HF survey, and significantly higher (by 1.0 unit) than the median score for 'control' sites in similar streams at this altitude (Table 3). Similarly to the pre-HF survey an increase (2.1 units) in SQMCI<sub>s</sub> score was recorded between sites 1 and 2. This can be attributed to an increase in macrophyte cover both on the edges of the stream and the streambed providing habitat for increased abundances of sensitive taxa.

### **Site 3- 100 m downstream of Cheal C wellsite discharge**

A low community richness of seven taxa was found at site 3 (Table 2 and Table 4), three taxa less than recorded in the pre-HF survey and sixteen taxa fewer than the median richness found at similar sites elsewhere in the region (Table 3). The macroinvertebrate community was comprised of a larger proportion of 'sensitive' taxa (57%), which was reflected in the MCI score of 71 units; an insignificant 5 units fewer than the pre-HF survey. This score was a significant 29 units fewer (Stark, 1998) than the median MCI score for 'control' sites in similar streams at comparative altitudes (Table 3).

The community at this site was characterised by three 'tolerant' taxa (oligochaete worms, orthoclad midges and seed shrimp (Ostracoda)); and one 'sensitive' taxon, (amphipod (*Paracalliope*)).

The SQMCI<sub>s</sub> score of 1.8 units recorded at site 3 in this survey was the same SQMCI<sub>s</sub> score in the pre-HF survey and was 2.2 units fewer than the median score for 'control' sites in similar streams at this altitude elsewhere the region (TRC, 1998 (updated 2012)).

## **Summary and Conclusions**

The Councils 'vegetation sweep' and a combination of the 'vegetation sweep' and 'kick-sampling' techniques were used at three sites to collect streambed macroinvertebrates from the unnamed tributary of the Mangawharawhara Stream. This has provided data to compare with baseline data for the assessment of skimmer pit discharge effects from the Cheal C wellsite on the macroinvertebrate communities of this stream. Samples were processed to provide number of taxa (richness), MCI, and SQMCI<sub>s</sub> scores for each site.

The MCI is a measure of the overall sensitivity of the macroinvertebrate community to the effects of organic pollution in stony streams. It is based on the presence/absence of taxa with varying degrees of sensitivity to environmental conditions. The SQMCI<sub>s</sub> 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<sub>s</sub> between sites may indicate the degree of adverse effects (if any) of the discharge being monitored.

This March 2014 survey of three sites, upstream and downstream of the skimmer pit discharge point to land near the stream, was undertaken following hydraulic fracturing at the Cheal C wellsite. Taxa richness's were low to moderate. The macroinvertebrate communities of the stream contained slightly more 'sensitive' than 'tolerant' taxa. A total of 16 taxa was found through the reach of the stream surveyed, with 5 of these taxa (31%) found at all three sites and 3 taxa (19%), found at any two of these sites. The number of taxa recorded in abundance increased at site 2, downstream of the skimmer pit discharge, and was the same as the control site at site 3.

A comparison of the pre-HF and post-HF survey results showed a significant increase in MCI and SQMCI<sub>s</sub> scores at site 1, but no significant changes at site 2 and site 3. Slight variations in MCI and SQMCI<sub>s</sub> scores and taxa richness, particularly at site 2 compared with site 1 and site 3 are considered to be due to habitat variability rather than a change in water quality.

The MCI scores recorded in this survey indicated that the stream communities were of poor to fair 'health' (TRC, 2014), slightly worse than the biological health recorded at 'control' sites in similar streams at a comparative altitude elsewhere in the region. This, in part, can be attributed to the habitat which was limited by very low and slow flows. There was no indication from the results of the two surveys that the discharge from the Cheal C wellsite has impacted on the biological communities of the unnamed tributary of the Mangawharawhara Stream.

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