

Todd Energy Limited  
Mangahewa-D Hydraulic Fracturing  
Monitoring Programme Report  
2011-2014

Technical Report 2014-107

ISSN: 1178-1467 (Online)  
Document: 1465837 (Word)  
Document: 1500245 (Pdf)

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June 2015



## Executive summary

This report for the period July 2011 to June 2014 outlines and discusses the results of the monitoring programme implemented by the Taranaki Regional Council (the Council) in relation to the programme of hydraulic fracturing undertaken by Todd Energy Limited (Todd), within their Mangahewa-D wellsite. The reports also assess Todd's level of environmental performance and compliance with the resource consents held in relation to the activity.

Todd operate the Mangahewa-D wellsite, located at Rimutauteka Road, Inglewood. The wellsite lies within the Waitara catchment and contains a number of hydrocarbon producing wells and associated infrastructure.

Todd hold resource consent 7912-2, authorising the discharge of water based hydraulic fracturing fluids into land at depths greater than 3,325 m TVDss beneath the Mangahewa-D wellsite. This replaced resource consent 7912-1, which authorised the same activity. The three hydraulic fracturing events discussed in this report were carried out under consent 7912-1. The consents were issued by the Council on 9 September 2011 (7912-1) and 30 June 2014 (7912-2). Consent 7912-1 contained a total of 14 special conditions which set out the requirements that Todd must satisfy.

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

The programme of hydraulic fracturing undertaken by Todd at Mangahewa-D included the fracturing of three wells. The wells targeted for stimulation included Mangahewa-04, Mangahewa-07 and Mangahewa-16. The hydraulic fracturing of these wells took place between October 2011 and May 2014.

The programme of monitoring implemented by the Council in relation to these activities spanned the 2011-2012, 2012-2013 and 2013-2014 monitoring periods. The programme included the analysis of samples taken from groundwater sites both surrounding and within 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. The monitoring programme was not in place for the fracturing of Mangahewa-04 as it was not required by the consent in place at the time, but was implemented prior to the fracturing of the Mangahewa-07 and Mangahewa-16 wells.

Samples of both the hydraulic fracturing fluid and the formation fluids produced back to the wellhead immediately following the fracturing of the Mangahewa-07 and Mangahewa-16 wells were also obtained for analysis.

The monitoring programme also incorporated a surface water component, whereby biomonitoring surveys were undertaken in an unnamed tributary of the Manganui River. The unnamed tributary receives stormwater discharges from the Mangahewa-D 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 biomonitoring of surface water bodies was only introduced as a standard component of hydraulic fracturing

monitoring programmes in 2013, and therefore surveys were only carried out in relation to the fracturing of the Mangahewa-16 well.

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

Todd demonstrated a high level of environmental and good level of administrative performance and compliance with the resource consents 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 2014-2015 year.

Note: This report relates specifically to the Council's monitoring of hydraulic fracturing activities at the Mangahewa-D wellsite over the 2011-2014 period. A separate monitoring report has been prepared by the Council in relation to the monitoring of general activities at the Mangahewa-D wellsite.

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# **1. Introduction**

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

### **1.1.1 Introduction**

This report outlines and discusses the results of the monitoring programme implemented by the Taranaki Regional Council (the Council) in relation to the programme of hydraulic fracturing undertaken by Todd Energy Limited (Todd) at their Mangahewa-D wellsite, over the period November 2011 to June 2014. The report also assesses Todd's level of environmental performance and compliance with the resource consent held in relation to the activity.

The programme of hydraulic fracturing undertaken by Todd at their Mangahewa-D wellsite has included the hydraulic fracturing of three wells. The wells targeted for stimulation were Mangahewa-04, Mangahewa-07 and Mangahewa-16.

The programme of monitoring implemented by the Council in relation to these hydraulic fracturing activities spanned the 2011-2012, 2012-2013 and 2013-2014 monitoring periods. Monitoring has included a mixture of 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 Mangahewa-D 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 Todd for discharges into land associated with hydraulic fracturing in the Waitara 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 interpretation and significance for the environment.

Section 4 presents recommendations to be implemented in the 2014-2015 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 Todd’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 consents were met, or any failure to do this had trivial consequences and were addressed promptly and co-operatively.
- **Good** Perhaps some administrative requirements of the resource consents were not met at a particular time, however 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 consents were made by Council staff. These matters took some time to resolve, or remained unresolved at the end of the period under review. The Council may have issued an abatement notice to attain compliance.
- **Poor** Material failings to meet the administrative requirements of the resource consents. Significant intervention by the Council was required. Typically there were grounds for an infringement notice.

For reference, in the 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, together with formation fluids and hydrocarbons, are drawn to the surface.

## 1.2.2 The Mangahewa-D wellsite and hydraulic fracturing activities

The Mangahewa-D wellsite is located in the Waitara catchment on Rimutauteka Road, New Plymouth and lies within the Waitara catchment. The area surrounding the site is rural in nature, where farming and forestry activities co-exist with active petroleum exploration and production operations. The location of the wellsite is illustrated in Figure 1.

A summary of all hydraulic fracturing activities carried out by Todd at the Mangahewa-D wellsite during the period being reported is provided below in Table 1.

**Table 1** Summary of hydraulic fracturing activity (2011-2014)

Well	Drill date	Fracturing date		Injection zone (m TVDss)	Formation
		Start	End		
Mangahewa-04	Aug to Sept 2009	17/10/11	21/11/11	4,006 to 4,052	Kapuni Group
Mangahewa-07	May to Jul 2012	01/11/12	12/11/12	3,861 to 4,057	Kapuni Group
Mangahewa-16	Feb to Mar 2014	11/05/14	02/06/14	3,330 to 4,029	Kapuni Group

Well construction schematics for each well are included in Appendix I.

## 1.3 Resource consents

### 1.3.1 Discharges onto and into land

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

Todd were originally granted consent 7912-1, authorising discharge of contaminants into land in relation to hydraulic fracturing at the Mangahewa-D wellsite, on 9 September 2011. The original version of consent 7912-1 contained a total of 11 special conditions which set out the requirements that Todd must satisfy. The hydraulic fracturing of the Mangahewa-04 well was undertaken under this version of the consent.

Prior to the hydraulic fracturing of the Mangahewa-07 well, Todd voluntarily chose to vary consent 7912-1 to align the special conditions of the consent with the standard set of conditions being applied to hydraulic fracturing consents by the Council at that time. The standard conditions being imposed by the Council had evolved significantly since the issuing of the original version of consent 7912-1, to reflect international best practice. The revised conditions included requirements for the sampling and analysis of groundwater in the vicinity of the wellsite. The hydraulic fracturing of the Mangahewa-16 well was also carried out under the revised version of consent 7912-1.

Todd applied for a renewal of consent 7912-1 on 29 November 2013 and consent 7912-2 was subsequently issued by the Council on 30 June 2014. Consent 7912-2 contains a total of 17 special conditions which set out the requirements that Todd must satisfy.

All consents were issued by the Council under Section 87(e) of the RMA.



**Figure 1** Location of Mangahewa-D wellsite

The special conditions attached to each consent are summarised below:

**Consent 7912-1**

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

Condition 2 required the consent holder to ensure that the exercising of the consent did not result in any contaminants reaching any useable freshwater (ground or surface water).

Conditions 3, 4 and 5 related to fresh water monitoring requirements, to allow compliance with condition 2 to be assessed (*added through variation to consent on 14 November 2012*).

Condition 6 required the consent holder to carry out pressure testing of equipment prior to discharging.

Condition 7 required the consent holder to submit a pre-fracturing discharge report prior to any discharge occurring.

Condition 8 was a notification requirement.

Condition 9 required the consent holder to submit a post-fracturing discharge report after the completion of the hydraulic fracturing programme for each well.

Condition 10 stipulated how the reports required by conditions 7 and 9 are to be submitted.

Condition 11 required the consent holder to allow the Council access to a location where samples of hydraulic fracturing and return fluids can be obtained.

Condition 12 required the consent holder to adopt best practicable options.

Condition 13 related to the composition of the fracturing fluid.

Consent 14 was a review provision.

**Consent 7912-2**

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

Condition 2 stipulates the date before which discharge of hydraulic fracturing fluids must occur.

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

Conditions 4, 5, 6 and 7 relate to fresh water monitoring requirements, to allow compliance with condition 3 to be assessed.

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

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

Condition 10 is a notification requirement.

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

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

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

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

Condition 15 relates to the composition of the fracturing fluid.

Condition 16 is a lapse clause.

Condition 17 is a review provision.

Copies of each permit are included in Appendix II.

## **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 range of monitoring carried out by the Council in relation to hydraulic fracturing activities at the Mangahewa-D wellsite has increased since the initial fracturing of the Mangahewa-04 well in 2011. Increases in monitoring reflect the evolution in standard conditions being applied to hydraulic fracturing consents over the period being reported. The evolution of consent conditions and associated monitoring requirements mean that the range of monitoring carried by the Council in relation to each of the hydraulic fracturing events being reported on differs.

At the time of the Mangahewa-04 fracturing event, there were requirements stipulated in consent 7912-1 regarding groundwater or surface water monitoring. Monitoring of this event included an assessment of pre and post-fracturing discharge reports and site inspections during fracturing operations. The fracturing of the Mangahewa-04 well was



undertaken by Todd in compliance with the resource consent in place for the activity at the time.

As discussed in section 1.3.1, prior to the fracturing of the Mangahewa-07 well in November 2012, Todd voluntarily chose to vary consent 7912-1 to align the special conditions of the consent with the standard set of conditions being applied by the Council at that time. The standard conditions being imposed by the Council had evolved significantly since the issuing of the original version of consent 7912-1, to reflect international best practice. The revised conditions included requirements for the sampling and analysis of groundwater in the vicinity of the wellsite.

The range of monitoring carried out by the Council in relation to hydraulic fracturing activities continued to develop over the period following the completion of the Mangahewa-07 fracturing programme. Most significant was the inclusion of biomonitors surveys in all hydraulic fracturing monitoring programmes from 2013. Biomonitors surveys were incorporated into all programmes in order to more comprehensively assess the potential impacts of hydraulic fracturing on local surface water systems.

As a result of the continual evolution of monitoring requirements associated with hydraulic fracturing activities, the programme of monitoring implemented in relation to the fracturing of the Managhewa-16 well, undertaken between May and June 2014, was the most comprehensive to date and included both groundwater and surface water monitoring components.

Table 2 provides a summary of the range of monitoring carried out in relation to each hydraulic fracturing event being reported on.

**Table 2** Summary of monitoring carried out in relation to hydraulic fracturing events at the Mangahewa-D wellsite (2011-2014)

Well	Fracturing date		Assessment of pre and post-fracturing reports	Site inspections during fracturing event	Hydraulic fracturing and return fluid sampling	Groundwater sampling and assessment	Surface water sampling and assessment
	Start	End					
Mangahewa-04	17/10/11	21/11/11	Yes	Yes	No	No	No
Mangahewa-07	01/11/12	12/11/12	Yes	Yes	Yes	Yes	No
Mangahewa-16	11/05/14	02/06/14	Yes	Yes	Yes	Yes	Yes

#### 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 Reviews of consent holder submitted data**

As required by the conditions of consents 7912-1, Todd submitted pre and post-fracturing discharge reports to the Council for each well fractured during the period under review. Pre-fracturing discharge reports provide an outline of the proposed fracturing operations in relation to each well, while post-fracturing reports confirm details of what actually occurred. The specific range of information required in each report is stipulated in the conditions of the consent.

### **1.4.4 Physicochemical sampling**

#### **1.4.4.1 Groundwater**

In order to select suitable sites for sampling, the Council carried out a well survey in the vicinity of the Mangahewa-D wellsite to identify any existing groundwater abstractions in the area. The surveys were undertaken within a defined 'area of review' which extended 1 km radially from the wellsite.

One shallow well (GND2305) was identified on the opposite side of the Manganui River to the wellsite, as were two springs, one on the opposite side of the Manganui River to the wellsite (GND2304) and one located on the true right bank of the Manganui River (GND2306).

Unfortunately, the spring discharge GND2306 was only found to flow intermittently and therefore samples could not always be obtained when required. Several visits were undertaken in an attempt to take samples from the spring, often unsuccessfully. In addition, following a review of sampling locations at the end of the 2013 year, it was decided that sampling from GND2304 and GND2305 would be discontinued as they were deemed to be hydraulically disconnected from shallow groundwater underlying the Mangahewa-D wellsite by the Manganui River.

Given the lack of suitable monitoring sites for groundwater sampling, a request was made to Todd to install a suitable monitoring well in the vicinity of the Mangahewa-D wellsite. The well (GND2459) was installed in April 2014, prior to the fracturing of the Mangahewa-16 well. GND2459 is now the sole groundwater sampling location incorporated in the monitoring programme for this site.

The details of all groundwater sites that have been sampled over the course of the period being reported are included in Table 3. Their location and proximity to the Mangahewa-D wellsite is illustrated in Figure 2.

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

Monitoring site	Distance from wellsite (m)	Total depth (m)	Screened interval (m)	Aquifer
GND2304	781	NA*	NA*	Volcanics
GND2305	804	7	Unlined	Volcanics
GND2306	265	NA*	NA*	Volcanics
GND2459	58	30.5	11.5 – 27.5	Volcanics

\* Spring

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

Where access to the bore was available, samples were obtained using a pneumatic bladder pump, using a low-flow sampling methodology. Samples taken from wide diameter wells were obtained directly from the well, or at a point within the water distribution network as close to the wellhead as practicable. Samples taken from springs were obtained directly from the spring discharge. All samples were transported to Hill Laboratories Limited for analysis following standard chain of custody procedures.

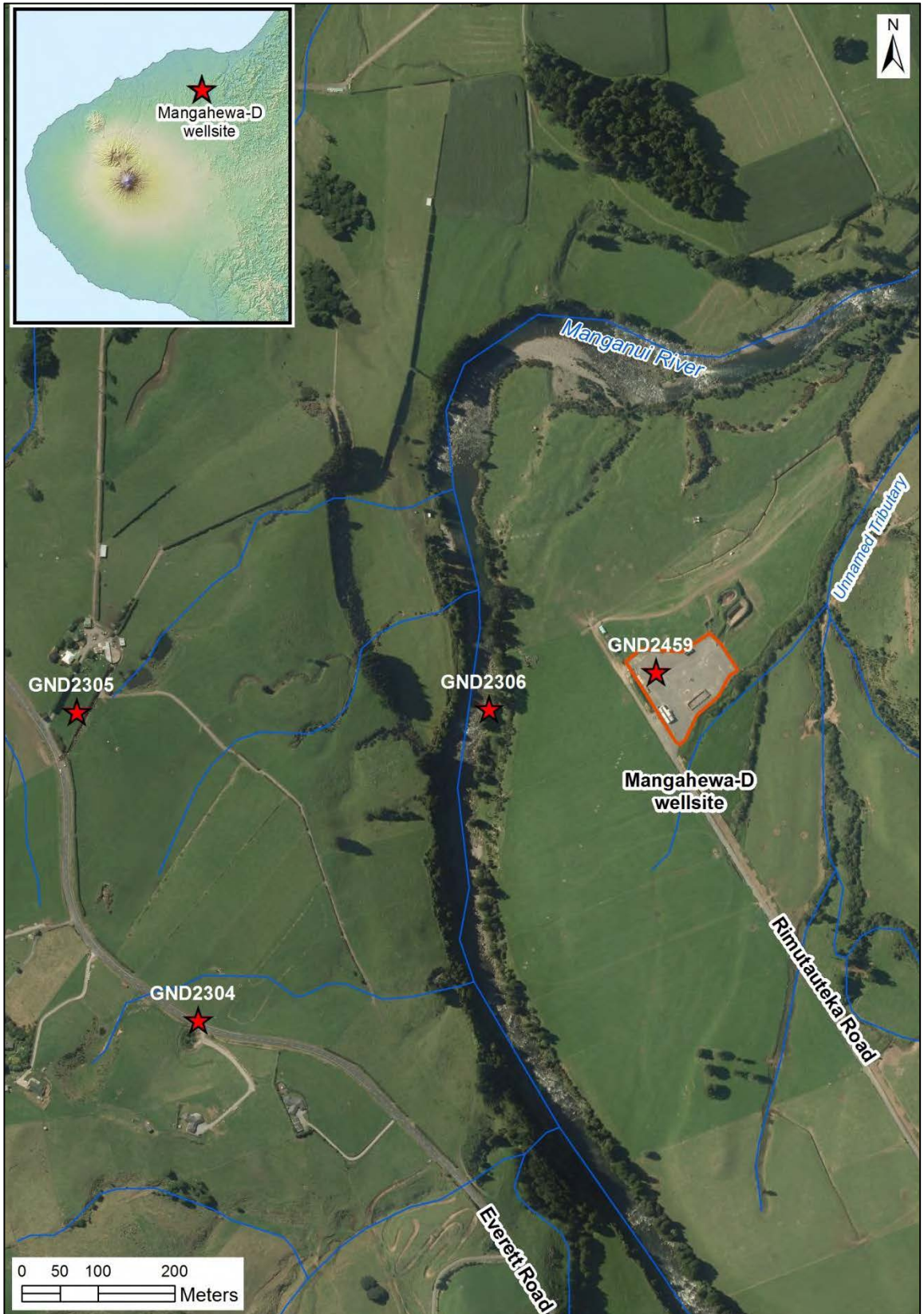
#### 1.4.4.2 Hydraulic fracturing and return fluids

In addition to the sampling of local groundwater, samples of the 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.

Samples of hydraulic fracturing fluid were obtained from storage tanks on-site. Due to the viscosity of the sample of the hydraulic fracturing fluid samples obtained, the range of analyses that were able to be performed on each sample were limited. 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.

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

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



**Figure 2** Location of groundwater sampling sites in relation to the Mangahewa-D wellsite

### 1.4.5 Biomonitoring surveys

Biological surveys were performed in an unnamed tributary of the Mangonui River pre and post-fracturing of the Mangahewa-16 well. The unnamed tributary receives stormwater discharges from the Mangahewa-D wellsite.

Biomonitoring surveys were carried out to assess whether any stormwater discharges from the Mangahewa-D wellsite during the course of the fracturing operations resulted in any detrimental effects upon the biological communities within the receiving water.

Samples of streambed macroinvertebrates were collected from the unnamed tributary of the Mangonui River using the Council's standard 'kick-sampling' and 'vegetation sweep' sampling techniques. Samples were obtained pre and post -fracturing and processed to determine 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 indicate the degree of adverse effects (if any) of the discharges being monitored.

The details of each biomonitoring site included in the surveys are presented in Table 4. Their location and proximity to the Mangahewa-D wellsite is illustrated in Figure 3.

**Table 4** Details of biomonitoring sites included in the monitoring programme

Site code	GPS reference (NZTM)	Location	Sampling method
MGN000489 (Site 1)	E1711359 N5673793	50 m upstream of the stormwater discharge point	Kick sampling/vegetation sweep
MGN000492 (Site 2)	E1711375 N5673893	50 m downstream of the stormwater discharge point	Kick sampling/vegetation sweep
MGN000493 (Site 3)	E1711391 N5673935	50 m downstream of MGN000492	Kick sampling/vegetation sweep





**Figure 3** Location of biomonitors sites in relation to Mangahewa-D wellsite.

## 2. Results

### 2.1 Consent holder submitted data

#### 2.1.1 Mangahewa-04 post-fracturing discharge report

The conclusions from the Mangahewa-04 post-fracturing discharge report are summarised as follows:

- A total of three discrete zones were fractured over the period 17 October to 21 November 2011, at depths between 4,006 to 4,052 m TVDss.
- A total of 3,457 barrels (bbls) (550 m<sup>3</sup>) of liquid was discharged across the three fractured zones. The total proppant weight was 108 tonnes.
- By volume, 1.3% (7 m<sup>3</sup>) of the fluid injected was chemical additives.
- 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.
- The Mangahewa-04 well was opened for flow-back following the completion of fracturing operations. At the completion of the flow-back period, approximately 2,410 bbls (383 m<sup>3</sup>) of fracture fluids and formation fluid were returned to the surface, leaving at least 1,050 bbls (167 m<sup>3</sup>) of the fluids injected remaining in the formation. Additional fluid is likely to be returned back to the surface as the well produces.
- The majority of waste fluid from the Mangahewa-04 well was trucked from the Mangahewa-D wellsite to BTW's Wellington Road disposal site, Brown Road, Waitara, where the fluids were stored in a designated lined pit prior to being landfarmed under consent 7884-1.
- The Christmas tree, isolation tool, tubing and casings and wellhead maintained full integrity throughout the fracture treatment. The surface manifolding had a seal gasket leak which was repaired before continuing with the treatment.
- All fracturing treatments were placed successfully. It is considered that the mitigation measures implemented by Todd were effective in ensuring there were no adverse environmental effects associated with fracturing operations.

#### 2.1.2 Mangahewa-07 post-fracturing discharge report

The conclusions from the Mangahewa-07 post-fracturing discharge report are summarised as follows:

- A total of three discrete zones were fractured over the period 1 November to 12 November 2014, at depths between 3,861 to 4,057 m TVDss.
- A total of 4,809 bbls (764 m<sup>3</sup>) of liquid was discharged across the three fractured zones. The total proppant weight was 115 tonnes.

- By volume, 2.4% (18 m<sup>3</sup>) of the fluid injected was chemical additives.
- 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.
- The Mangahewa-07 well was opened for flow-back following the completion of fracturing operations. At the completion of the flow-back period, approximately 2,584 bbls (411 m<sup>3</sup>) of fracture fluids and return fluids were returned to the surface, leaving at least 2,220 bbls (353 m<sup>3</sup>) of the fluids injected (46%) remaining in the formation. Additional fluid is likely to be returned back to the surface as the well produces.
- 86% of the return fluid and waste from the Mangahewa-07 fracturing operations were disposed of by deep well injection, via the McKee-1 injection well, as authorised by consent 4182-2. The remainder (14%) of the return fluid was trucked from Mangahewa-D site to BTW's Wellington disposal site, Brown Road, where fluids were held in a designated lined prior to being landfarmed under consent 7884-1. In a separate waste management operation, water contaminated with additives used in drilling processes were trucked to BTW's Oeo disposal site, South Road, Manaia, for landfarming under consent 7613-1.
- The Christmas tree, isolation tool, tubing and casings and wellhead maintained full integrity throughout the fracture treatment.
- All fracturing treatments were placed successfully. It is considered that the mitigation measures implemented by Todd were effective in ensuring there were no adverse environmental effects associated with fracturing operations.

### 2.1.3 Mangahewa-16 post-fracturing discharge report

The conclusions from the Mangahewa-16 post-fracturing discharge report are summarised as follows:

- A total of six discrete zones were fractured over the period 11 May to 2 June 2014, at depths between 3,330 to 4,029 m TVDss.
- A total of 14,623 bbls (2,325 m<sup>3</sup>) of liquid was discharged across the six fractured zones. The total proppant weight was 278 tonnes.
- By volume, 95.6% of the fluid injected was water, 3.9% was proppant, with the remaining 0.5% comprised of chemical additives.
- 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.
- The Mangahewa-16 well was opened for flow-back following the completion of fracturing operations. In total, 3,445 bbls (548 m<sup>3</sup>) of fluid was returned from the



well over the flow-back period, leaving approximately 11,178 bbls (1,777 m<sup>3</sup>) of the fluids injected (76%) remaining in the formation. Additional fluid is likely to be returned back to the surface as the well produces.

- All return fluid from the Mangahewa-16 fracturing operations was disposed of by deep well injection, via the McKee-1 injection well, as authorised by consent 4182-2.
- The Christmas tree, tubing string, casing strings and wellhead maintained full integrity throughout the treatment.
- It is considered that the mitigation measures implemented by Todd were effective in ensuring there were no adverse environmental effects associated with fracturing operations.

## **2.2 Physicochemical sampling**

### **2.2.1 Groundwater**

A total of three sites were sampled to monitor for any adverse effects on groundwater quality resulting from the Mangahewa-07 hydraulic fracturing event.

Pre-fracturing samples were collected at sites GND2304, GND2305 and GND2306. Following a review sampling locations following the pre-fracturing sampling event it was decided to take no further samples from site GND2304, as it was deemed to be hydraulically disconnected from shallow groundwater underlying the Mangahewa-D wellsite. A six month post-fracturing sample was obtained from site GND2305, but no sample could be obtained from site GND2306 as the spring was not discharging at the time of sampling. Nine month post-fracturing samples were collected from both GND2305, but again GND2306 was not discharging when visited so no sample could be obtained. GND2306 was revisited in October, when seasonal groundwater levels are generally at the highest across Taranaki, at which time the spring was discharging and a sample collected.

The results of the laboratory analysis of samples from sites GND2305 and GND2306 indicate that there were no significant changes in groundwater composition at either site post-fracturing of the Mangahewa-04 well. There were no traces of any substances associated with the hydraulic fracturing process in any of the samples obtained.

A full summary of results for all groundwater samples taken in relation to hydraulic fracturing of the Mangahewa-07 well is included below in Table 5. The certificates of analysis are included in Appendix III.

**Table 5** Results of groundwater sampling carried out in relation to the Mangahewa-07 fracturing event

Parameter	Unit	GND2304	GND2305			GND2306	
		Pre-frac	Pre-frac	Post-frac		Pre-frac	Post-frac
Sample date		31/10/12	31/10/12	13/05/13	13/08/13	31/10/12	02/10/13
Lab number		TRC123685	TRC123684	TRC136049	TRC136757	TRC123682	TRC137177
Total alkalinity	g/m <sup>3</sup> CaCO <sub>3</sub>	24	21	19.2	18.8	37	34
Barium	mg/kg	0.0081	0.05	0.049	0.053	0.027	0.028
Benzene	g/m <sup>3</sup>	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Dissolved bromine	g/m <sup>3</sup>	0.05	-	-	0.067	-	0.035
Calcium	g/m <sup>3</sup>	4.7	9.7	8.6	9.0	13.2	13.0
Chloride	g/m <sup>3</sup>	10.5	18.5	19.8	20	8.3	8.6
Conductivity	mS/m@20°C	9.1	14.3	14.1	14.8	12.1	12.6
Dissolved copper	g/m <sup>3</sup>	<0.0005	0.0006	0.0013	0.0007	<0.0005	<0.0005
Ethylbenzene	g/m <sup>3</sup>	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ethane	g/m <sup>3</sup>	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Ethylene	g/m <sup>3</sup>	<0.004	<0.004	<0.004	<0.004	<0.004	<0.003
Dissolved iron	g/m <sup>3</sup>	0.09	<0.02	<0.02	<0.02	<0.02	<0.02
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>	29	26	23	23	45	42
Total hardness	g/m <sup>3</sup> CaCO <sub>3</sub>	22	33	29	31	40	39
Dissolved mercury	g/m <sup>3</sup>	-	-	-	<0.00008	-	<0.00008
Potassium	g/m <sup>3</sup>	0.75	18.9	5.2	5.6	2.7	2.4
Methanol	g/m <sup>3</sup>	<2	<2	<2	<2	<2	<2
Methane	g/m <sup>3</sup>	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Magnesium	g/m <sup>3</sup>	2.5	2.1	1.73	2.0	1.60	1.60
Dissolved manganese	g/m <sup>3</sup>	0.0044	0.0013	0.0012	0.0016	<0.0006	0.0008
Sodium	g/m <sup>3</sup>	8.7	11.1	11.9	12.1	7.1	7.5
Nickel	mg/kg	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Nitrate & nitrite nitrogen	g/m <sup>3</sup> N	0.75	2.6	2.4	3.0	0.69	1.47
Nitrite nitrogen	g/m <sup>3</sup> N	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Nitrate nitrogen	g/m <sup>3</sup> N	0.75	2.6	2.4	3.0	<0.69	1.47
pH	pH	6.9	5.9	6.3	6.2	6.8	6.5
Propylene glycol	g/m <sup>3</sup>	-	-	-	<4	-	<4
Sulphate	g/m <sup>3</sup>	2.4	6.1	5.5	5.7	7.2	6.3
Total dissolved solids	g/m <sup>3</sup>	67	82	100	104	110	103
Toluene	g/m <sup>3</sup>	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
o-Xylene	g/m <sup>3</sup>	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
m-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>	<0.001	0.0061	0.0139	0.011	<0.001	<0.001
Bromide	g/m <sup>3</sup>	-	0.07	0.10	-	-	-

As outlined previously in section 1.4.4.1, following the issues experienced during the groundwater sampling campaign associated with the Mangahewa-04 fracturing event, such as intermittent spring flows and impact of local hydrologic divides on sampling site suitability, a request was made to Todd to install a suitable monitoring well in the vicinity of the Mangahewa-D wellsite. The well (GND2459) was installed in April 2014, prior to the fracturing of the Mangahewa-16 well.

GND2459 was the sole site sampled to monitor the effects of the Mangahewa-16 hydraulic fracturing event on local groundwater resources. A pre-fracturing groundwater sample was taken in May 2014, and a three month post-fracturing sample was taken in August 2014. While the post-fracturing groundwater sample was actually collected during the 2014-2015 monitoring period, the results have been included in this report to allow comparison with pre-fracturing data.

The results of the laboratory analysis of samples from sites GND2459 indicate that the concentrations of the majority of analytes remained consistent across the monitoring period. There was however a trace of toluene detected in the post-fracturing sample. It is important to note that the concentration was extremely low, at part per billion levels, well below the guideline value stipulated for toluene in the Drinking-water Standards for New Zealand (2008).

Methane was detected in low concentrations in the pre-fracturing sample and significantly higher concentrations in the post-fracturing sample. This is primarily a result of variations in sampling methodology between the each event. Access to the well itself was not possible during the pre-fracturing sampling visit and the sample was obtained from a wide diameter hose connected to well. The hose would only operate at a high flow rate, causing considerable turbulence in water flow. This is likely to have degassed the sample, lowering its dissolved methane concentration. The follow-up post-fracturing sample was obtained using a bladder pump, enabling a much higher proportion of dissolved gas within underlying groundwater to be retained within the sample. Isotopic analysis of the dissolved methane within the post-fracturing sample indicates the methane gas is neither strongly biogenic, nor strongly thermogenic, but potentially of mixed origin. Isotopic analysis of dissolved methane in the pre-fracturing sample was not possible given the low concentration.

A full summary of results for all groundwater samples taken in relation to hydraulic fracturing of the Mangahewa-16 well is included below in Table 6. The certificates of analysis are included in Appendix III.

**Table 6** Results of groundwater sampling carried out in relation to the Mangahewa-16 fracturing event

Parameter	Unit	GND2459	
		Pre-frac	Post-frac
Sample date	-	01/05/2014	26/08/2014
Lab number	-	TRC149933	TRC1410894
Total alkalinity	g/m <sup>3</sup> CaCO <sub>3</sub>	99	112
Barium	mg/kg	0.024	0.0172
Benzene	g/m <sup>3</sup>	<0.001	<0.001
Dissolved bromine	g/m <sup>3</sup>	0.059	0.050
Calcium	g/m <sup>3</sup>	13.0	10.1
Chloride	g/m <sup>3</sup>	12.8	12.7
Conductivity	mS/m@20°C	23.1	25.2
Dissolved copper	g/m <sup>3</sup>	0.0023	0.0014
Ethylbenzene	g/m <sup>3</sup>	<0.001	<0.001
Ethane	g/m <sup>3</sup>	<0.003	0.005
Ethylene	g/m <sup>3</sup>	<0.003	<0.003
Dissolved iron	g/m <sup>3</sup>	2.5	2.5
Formaldehyde	g/m <sup>3</sup>	<0.02	0.03
Ethylene glycol	g/m <sup>3</sup>	<4	<4
Hydrocarbons	g/m <sup>3</sup>	<0.7	<0.7
Bicarbonate	g/m <sup>3</sup> HCO <sub>3</sub>	121	137
Total hardness	g/m <sup>3</sup> CaCO <sub>3</sub>	54	45
Dissolved mercury	g/m <sup>3</sup>	<0.00008	<0.00008
Potassium	g/m <sup>3</sup>	5.5	5.3
Methanol	g/m <sup>3</sup>	<2	<2
Methane	g/m <sup>3</sup>	0.46	13.7
δ13C value*	‰	-	-53
Magnesium	g/m <sup>3</sup>	5.2	4.7
Dissolved manganese	g/m <sup>3</sup>	0.20	0.24
Sodium	g/m <sup>3</sup>	24	37
Nickel	mg/kg	0.0008	0.0005
Nitrate & nitrite nitrogen	g/m <sup>3</sup> N	0.044	<0.002
Nitrite nitrogen	g/m <sup>3</sup> N	0.041	<0.002
Nitrate nitrogen	g/m <sup>3</sup> N	0.003	<0.002
pH	pH	7.4	7.3
Propylene glycol	g/m <sup>3</sup>	<4	<4
Sulphate	g/m <sup>3</sup>	1.2	<0.5
Total dissolved solids	g/m <sup>3</sup>	145	179
Temperature	Deg.C	12.3	14.6
Toluene	g/m <sup>3</sup>	<0.001	0.007
o-Xylene	g/m <sup>3</sup>	<0.001	<0.001
m-Xylene	g/m <sup>3</sup>	<0.002	<0.002
Dissolved zinc	g/m <sup>3</sup>	0.04	1.98

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

## 2.2.2 Hydraulic fracturing and return fluids

The results of the analyses carried out on samples of the hydraulic fracturing fluid used in the treatment of the each of the Mangahewa-07 and Mangahewa-16 wells are summarised below in Table 7. The certificates of analysis are included in Appendix IV.

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

Parameter	Unit	Mangahewa-07	Mangahewa-16
Sample date	-	10/11/2012	25/05/2014
Lab number	-	TRC123680	TRC1410369
Benzene	g/m <sup>3</sup>	0.0041	0.0016
Ethylbenzene	g/m <sup>3</sup>	0.0033	<0.0010
Ethylene glycol	g/m <sup>3</sup>	280	460
Total hydrocarbons	g/m <sup>3</sup>	430	174
Methane	g/m <sup>3</sup>	9	6
Propylene glycol	g/m <sup>3</sup>	-	43
Toluene	g/m <sup>3</sup>	0.023	0.003
o-Xylene	g/m <sup>3</sup>	0.0080	0.0037
m-Xylene	g/m <sup>3</sup>	0.012	0.005

The results of the analyses carried out on the return fluid samples obtained following the hydraulic fracturing of the each of the Mangahewa-07 and Mangahewa-16 wells are summarised below in Table 8 and certificates of analysis are included in Appendix IV. The relatively high levels of chloride, sodium and hydrocarbons in each sample indicate that the composite samples prepared contained a greater proportion of reservoir fluids than fluids introduced during fracturing activities (comprised predominantly of freshwater). The elevated ethylene glycol concentrations are indicative of some fracturing fluid still in the samples, and hence residual fracturing fluid still being flushed out..

**Table 8** Results of hydraulic fracturing return fluid sampling

Parameter	Unit	Mangahewa-07	Mangahewa-16
Sample date		27 Nov 2012	14 Jun 2014
Lab number		TRC136613	TRC1410618
Total alkalinity	g/m <sup>3</sup> CaCO <sub>3</sub>	1,730	2,300
Barium	g/m <sup>3</sup>	119	29
Benzene	g/m <sup>3</sup>	26	4.5
Bromide	g/m <sup>3</sup>	39	14.2
Calcium	g/m <sup>3</sup>	150	47
Chloride	g/m <sup>3</sup>	9,800	3,700
Conductivity	mS/m@20C	3,110	1,605
Dissolved copper	g/m <sup>3</sup>	<0.005	0.006
Ethylbenzene	g/m <sup>3</sup>	3.2	0.37
Ethane	g/m <sup>3</sup>	0.35	0.29
Ethylene	g/m <sup>3</sup>	<0.003	<0.004

Parameter	Unit	Mangahewa-07	Mangahewa-16
Dissolved iron	g/m <sup>3</sup>	3.8	14.4
Formaldehyde	g/m <sup>3</sup>	1.12	0.7
Ethylene glycol	g/m <sup>3</sup>	65	74
Hydrocarbons	g/m <sup>3</sup>	1,050	220
Bicarbonate	g/m <sup>3</sup> HCO <sub>3</sub>	410	1,995
Total hardness	g/m <sup>3</sup> CaCO <sub>3</sub>	410	155
Dissolved mercury	g/m <sup>3</sup>	-	<0.011
Potassium	g/m <sup>3</sup>	810	530
Methanol	g/m <sup>3</sup>	<2	5
Methane	g/m <sup>3</sup>	0.75	3.0
Magnesium	g/m <sup>3</sup>	10	9
Dissolved manganese	g/m <sup>3</sup>	3.7	3.0
Sodium	g/m <sup>3</sup>	6,900	3,700
Nickel	mg/kg	<0.03	<0.03
Nitrate & nitrite nitrogen	g/m <sup>3</sup> N	<0.2	<0.2
Nitrite nitrogen	g/m <sup>3</sup> N	<0.2	<0.2
Nitrate nitrogen	g/m <sup>3</sup> N	<0.2	<0.2
pH	pH	7.3	6.6
Dissolved sulphur	g/m <sup>3</sup>	-	22
Sulphate	g/m <sup>3</sup>	19	66
Propylene glycol	g/m <sup>3</sup>	-	<4
Toluene	g/m <sup>3</sup>	37	3.7
o-Xylene	g/m <sup>3</sup>	5.7	0.79
m-Xylene	g/m <sup>3</sup>	16.1	1.7
Dissolved zinc	g/m <sup>3</sup>	0.05	0.06

## 2.3 Biomonitoring surveys

A biomonitoring survey was carried out in the unnamed tributary of the Manganui River in April 2014, prior to the hydraulic fracturing of the Mangahewa-16 well. The results of the survey indicated the macroinvertebrate community within the unnamed tributary had moderate biological richness. The MCI score calculated from the survey was similar to that recorded at 'control' sites in similar streams, at comparable altitudes, across Taranaki. The SQMCI<sub>S</sub> score was slightly higher than recorded at control sites.

A follow up survey was carried out in the unnamed tributary in August 2014, following the completion of the Mangahewa-16 hydraulic fracturing programme. A comparison of the pre and post- hydraulic fracturing survey results showed no significant variation in MCI and SQMCI<sub>S</sub> scores between surveys at all three sites surveyed. The slight variations in taxa richness, MCI and SQMCI<sub>S</sub> scores between sites and surveys are considered to be due to habitat variability, rather than a change in water quality. There is no indication of hydraulic fracturing activities at the Mangahewa-D wellsite having any adverse effects on biological communities within the unnamed tributary of the Manganui River.

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 year was based on what was considered to be an appropriate level of monitoring, review of data, and liaison with the consent holder. During the year matters may arise which require additional activity by the Council, for example provision of advice and information, or investigation of potential or actual 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, the Council was required to undertake additional investigations to assess Todd's compliance with consent conditions.

An investigation was carried out in relation to the disposal of fluids dispatched from the Mangahewa-D wellsite over the period that the Mangahewa-07 well was hydraulically fractured. Dispatch records provided by Todd in their Mangahewa-07 post-fracturing discharge report referred to 'return/produced water' being trucked to BTW's Oeo landfarm for disposal. The Oeo landfarm was not authorised to receive such wastes under its discharge consent (7613-1). On further investigation, the Council is satisfied that that no return/produced water was actually taken to the site. The reference was actually to well testing fluids ('DFIT contaminated water') and 'contaminated water'. 'DFIT contaminated water' is water containing a small proportion of additives that are used in the drilling process to prevent clay swelling and to reduce friction and the 'contaminated water' contained residual drilling fluids. Given that the range of contaminants in these fluids was similar to those contained in wastes authorised for disposal by consent 7613-1, no further action was pursued by the Council. There were no wastes disposed of at the Oeo site containing any trace of hydraulic fracturing fluids.

All liquid wastes being generated in relation to hydraulic fracturing activities across Taranaki are now disposed of by deep well injection.

A further investigation was initiated by the Council in relation to the late submission of Todd's Mangahewa-16 post-fracturing discharge report. In response to the late submission, an incident was registered and Todd were issued with a letter requesting an explanation. Todd's explanation was that, due to an administrative error within their office, the report had been completed but not dispatched to the Council. The

Council viewed this as an administrative oversight on Todd's behalf, rather than a deliberate non-compliance or attempt to deceive. In considering Todd's strong track record in achieving compliance with their hydraulic fracturing consents, no further action was deemed necessary, other than to remind them of their compliance responsibilities.



### **3. Discussion**

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

A total of three wells were stimulated by hydraulic fracturing at the Mangahewa-D wellsite between October 2011 and June 2014.

The initial hydraulic fracturing programme carried out at the site was that of the Mangahewa-04 well between October and November 2011. This fracturing programme was authorised by the original version of consent 7912-1. The consent only required Todd to provide details of works undertaken in the form of pre and post-fracturing discharge reports and it did not stipulate any specific environmental monitoring requirements. The fracturing of the Mangahewa-04 well was undertaken by Todd in compliance with the resource consent in place for the activity at the time.

The Mangahewa-07 well was hydraulically fractured during November 2012. Groundwater samples were obtained from three sites prior to and post-fracturing of the well. The results of post-fracturing sampling 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.

The Mangahewa-16 well was hydraulically fractured between May and June 2104. Monitoring carried out by the Council in relation to the fracturing event included both groundwater and surface water monitoring components. Groundwater monitoring incorporated pre and post-fracturing sampling of a monitoring well installed by Todd. The surface water monitoring component of the programme comprised biomonitoring surveys of an unnamed tributary of the Manganui River pre and post-fracturing of the well.

The results of post-fracturing groundwater sampling carried out showed only very minor variations in water composition in comparison to baseline results. The minor variations in most analytes are a result of natural variations in water composition. A trace of toluene was detected in the post-fracturing sample. It is important to note that the concentration was extremely low, at part per billion levels, well below the guideline value stipulated for toluene in the Drinking-water Standards for New Zealand (2008). The source of the toluene is unknown; no spills or uncontrolled discharges were noted during any site inspection visits carried out by the Council, or reported by Todd. No other hydrocarbons were present in the sample obtained, nor were any other substances associated with hydraulic fracturing operations. The toluene concentration in the fluid used during the treatment of the Mangahewa-16 was extremely low. The results of isotopic analysis indicate that dissolved methane gas in shallow groundwater underlying the Mangahewa-D wellsite is neither strongly biogenic nor strongly thermogenic in origin.

The results of the biomonitoring surveys undertaken in relation to the Mangahewa-16 fracturing event indicate that site activities had no adverse effects on local surface water resources.

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

### 3.2 Evaluation of performance

A tabular summary of the consent holder's compliance record for the year under review is set out in Table 9.

**Table 9** Summary of performance for Consent 7912-1: To discharge contaminants associated with hydraulic fracturing activities into land at depths greater than 3,325 mTVDss beneath the Mangahewa-D wellsite.

Condition requirement	Means of monitoring during period under review	Compliance achieved?
1. Any discharge shall occur below 3,325 mTVDss	Assessment of consent holder submitted data	Yes
2. 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
3. Consent holder shall undertake sampling programme	Development and certification of a monitoring programme	Yes
4. 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
5. 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
6. Well and equipment pressure testing to be carried out prior to any hydraulic fracturing programme commencing	Assessment of consent holder submitted data	Yes
7. A pre-fracturing discharge report is to be provided to the Council 14 days prior to discharge	Pre-fracturing discharge report received	Yes
8. Consent holder shall notify the Council of hydraulic fracturing discharge	Notification received	Yes
9. 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	No
10. The reports outlined in conditions 7 and 9 must be emailed to <a href="mailto:consents@trc.govt.nz">consents@trc.govt.nz</a>	Reports received via email	No
11. 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

Condition requirement	Means of monitoring during period under review	Compliance achieved?
12. Consent holder to adopt best practicable option at all times	Site inspections, sampling and assessment of consent holder submitted data	Yes
13. No hydrocarbon based hydraulic fracturing fluid shall be discharged	Assessment of consent holder submitted data and sampling of fracturing fluid	Yes
14. 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		Good

\*The Mangahewa-16 post-fracturing discharge report was not received within the required timeframe (see section 2.4)

During the 2011-2014 monitoring period, Todd demonstrated a high level of environmental and a good level of administrative performance and compliance with its resource consents as defined in Section 1.1.4.

### 3.3 Alterations to monitoring programmes for 2014-2015

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 2014-2015 year, a further round of groundwater sampling be carried out to assess any delayed effects of hydraulic fracturing activities at the Mangahewa-D wellsite on local groundwater resources. The results of this sampling round will dictate whether any further sampling is required. Should Todd plan to undertake any further hydraulic fracturing at the site, additional groundwater and surface water monitoring will be carried out.

### 3.4 Exercise of optional review of consent

Resource consent 7912-2 provides for an optional review of the consent an annual basis, with the next optional review date being June 2015. Condition 17 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 during the 2014-2015 monitoring year, a further round of groundwater sampling be carried out to assess any delayed effects of hydraulic fracturing activities at the Mangahewa-D wellsite on local groundwater resources. The results of this sampling round will dictate whether any further sampling is required.
2. THAT the option for a review of consent 7912-2 in June 2015, as set out in conditions of the consent, is not exercised, on the grounds that the current conditions 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.
Physicochemical	Measurement of both physical properties (e.g. temperature, clarity, density) and chemical determinants (e.g. metals and nutrients) to characterise the state of an environment.
Resource consent	Refer Section 87 of the RMA. Resource consents include land use consents (refer Sections 9 and 13 of the RMA), coastal permits (Sections 12, 14 and 15), water permits (Section 14) and discharge permits (Section 15).
RMA	<i>Resource Management Act 1991</i> and including all subsequent amendments.
Screen Out	A condition that occurs when the solids carried in a treatment fluid, such as proppant in a fracture fluid, create a bridge across the perforations or similar restricted flow area. This creates a sudden and significant restriction to fluid flow that causes a rapid rise in pump pressure.
SQMCI	Semi quantitative macroinvertebrate community index.
TVDss	True vertical depth sub-sea
Workover	The repair or stimulation of an existing production well for the purpose of restoring, prolonging or enhancing the production of hydrocarbons.

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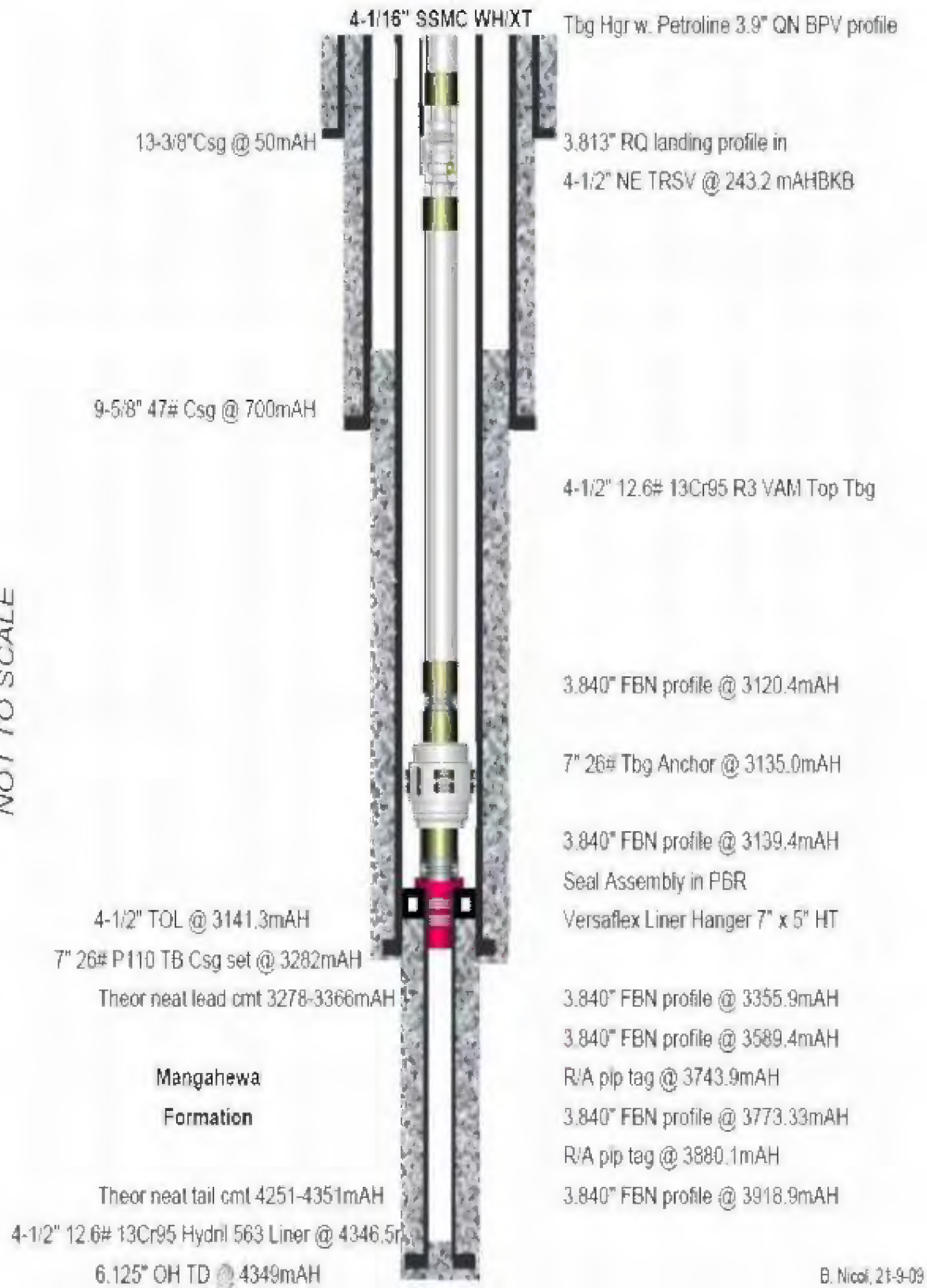
## **Appendix I**

### **Well construction geological stratigraphy schematics**





NOT TO SCALE





MHW07

WELL STATUS RECORD
As Completed

SITHP: 0 bar DATE: 31-Jul-12
HUD: 4,565.2m CT m DATE: 11-Aug-14

Table with columns: Depth (Top/Bottom/Dev), ITEM LENGTH (m), Description, PART #, GRADE, WEIGHT, COUPLING, DRIFT (in), OD (in), ID (in). Rows include various tubing, joints, and hangers with their respective specifications and depths.

Notes: 1. ALL DEPTHS ON THIS RECORD ARE METRES BELOW ROTARY TABLE (10.14m ABOVE TUBING HANGER landing shoulder)
2. 7" Annulus fluid - Sodium Formate brine 10.5ppg. Treated with Corrosion Inhibitor and Oxygen scavenger.
3. Tubing Hanger top thread is 6-3/8", 4 TPI, LH, Stub acme ( for Cameron running/pulling tool)
4. TUBING ANCHOR - cut to pull 2.97m above FBN profile
5. TD updated from 4723.65 to 4720m as confirmed by Ops Geo 26/2/13
6. Hud tagged @4587 30/11/12 previously 30/6/2012 4693mD

Revision history table with columns: Revision, Date, and Name. Includes revisions 1 through 5, detailing updates to the well status record.



MHW16

WELL COMPLETION SCHEMATIC
As Logged - 17/04/14

Table with 4 columns: SITHP, HUD, psi, m, DATE, DATE. Values: 3635, 5129, psi, m, 22-Jun-14, 30-Mar-14

Main completion schematic table with columns: Depth (m BRT), Sleeve mid-point (m BRT), FM, Dev (deg), ITEM, LGTH (m), Description, PART #, GRADE, WEIGHT, COUPLING, DRIFT (in), OD (in), ID (in). Includes a central well diagram and various completion components like tubing, hangers, and frac sleeves.

Notes: 1. ALL DEPTHS ON THIS RECORD ARE METRES BELOW ROTARY TABLE (9.96m ABOVE TUBING HANGER landing shoulder)
2. 9-5/8" x 7" Annulus fluid - Sodium Formate brine 8.6ppg. Treated with Corrosion Inhibitor, Oxygen Scavenger, Biocide and pH Buffer.
3. Tubing Hanger top thread is 6-3/8", 4 TPI, LH, Stub acme (for Cameron running/pulling tool)
4. TUBING ANCHOR - cut to pull 2.16m above FBN profile
5. 4-1/2in Trican i-Can MOC and Peak Iso-Port frac sleeves are shift up to open, shift down to close. Modified B shifting profile
6. Upper Completion tubing length increased by 1.687m compared to tally. This is so component depths match wireline logged depths.

Revision history table with 3 columns: Rev, Description, Author. Rows: Rev 0 (Completion as run 30/9/13), Rev 1 (Completion as logged by GBL on 17/04/14), Rev 2 (Updated with Well Entry Campaign information April - June 2014), Rev 3 (Updated for well history information and removal of bridge plug).

Revision history
Rev 0 Completion as run 30/9/13. Depths are as per liner pipe tally.
Rev 1 Completion as logged by GBL on 17/04/14.
Rev 2 Updated with Well Entry Campaign information April - June 2014
Rev 3 Updated for well history information and removal of bridge plug.



## **Appendix II**

### **Resource consents held by Todd**



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

Name of Consent Holder: Todd Energy Limited  
P O Box 802  
NEW PLYMOUTH 4340

Decision Date (Change): 14 November 2012

Commencement Date (Change): 14 November 2012 (Granted: 9 September 2011)

**Conditions of Consent**

Consent Granted: To discharge contaminants associated with hydraulic fracturing activities into land at depths greater than 3325mTVDSS, beneath the Mangahewa-D wellsite at or about (NZTM) 1711149E-5673522N

Expiry Date: 1 June 2016

Review Date(s): June 2013, June 2014, June 2015

Site Location: Mangahewa-D wellsite, Rimutauteka Road, New Plymouth  
(Property owner: KV & SJ Collins)

Legal Description: Rimutauteka 1A Blk X Waitara SD  
(Discharge source & site)

Catchment: Waitara

Tributary: Manganui

*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. Any discharge shall occur at or below 3325 mTVDSS.  
Note: mTVDSS = metres true vertical depth sub sea, i.e. the true vertical depth in metres below sea level.
2. 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.
3. 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 2 (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.
4. 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 (<sup>13</sup>C-CH<sub>4</sub>).

*Note: The samples required, under conditions 3 and 4 could be taken and analysed by the Council or other contracted party on behalf of the consent holder.*



5. 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 2.

*Note: The Sampling and Analysis Plan may be combined with the Monitoring Programme required by condition 2.*

6. 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.
7. 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 and the intended fracture interval(s) ('fracture interval' is the discrete subsurface zone to receive a hydraulic fracture treatment);
  - (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 and its 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 12;
  - (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 2;
  - (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.*

## Consent 7912-1

8. 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 7, 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.
9. 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 4(a) to 4(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;
  - (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 6, and the well and discharge pressure durations and the maximum pressure reached during the hydraulic fracture discharge;
  - (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 2; 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.
10. The reports described in conditions 7 and 9 shall be emailed to [consents@trc.govt.nz](mailto:consents@trc.govt.nz) with a reference to the number of this consent.
11. 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 7912-1

12. 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.
13. The fracture fluid shall be comprised of no less than 95% water and proppant by volume.
14. 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 12; 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 15 November 2013

For and on behalf of  
Taranaki Regional Council

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**Director-Resource Management**



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

Name of  
Consent Holder: Todd Energy Limited  
PO Box 802  
NEW PLYMOUTH 4340

Decision Date: 30 June 2014

Commencement Date: 30 June 2014

**Conditions of Consent**

Consent Granted: To discharge water based hydraulic fracturing fluids into land at depths greater than 3325 mTVDss beneath the Mangahewa-D wellsite

Expiry Date: 01 June 2024

Review Date(s): June annually

Site Location: Mangahewa-D wellsite, Rimutauteka Road,  
New Plymouth (Property owner: KV & SJ Collins)

Legal Description: Rimutauteka 1A Blk X Waitara SD (Discharge source & site)

Grid Reference (NZTM) 1711149E-5673522N

Catchment: Waitara

Tributary: Manganui

*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 3325 mTVDss.  
Note: mTVDss = metres true vertical depth subsea, i.e., the true vertical depth in metres below mean sea level.
2. There shall be no discharge of hydraulic fracturing fluids after 1 June 2019.
3. The consent holder shall ensure that the exercise of this consent does not result in contaminants reaching any useable fresh water (groundwater or surface water). Usable fresh groundwater is defined as any groundwater having a Total Dissolved Solids concentration of less than 1000 mg/l.
4. The consent holder shall undertake a programme of sampling and testing that monitors the effects of the exercise of this consent on fresh water resources to assess compliance with condition 3 (the 'Monitoring Programme'). The Monitoring Programme shall be certified by the Chief Executive, Taranaki Regional Council ('the Chief Executive'), before this consent is exercised, and shall include:
  - (a) the location of the discharge point(s);
  - (b) the location of sampling sites; and
  - (c) sampling frequency with reference to a hydraulic fracturing programme.
5. Depending on the suitability of existing bores within 500 metres of the wellsite for obtaining a representative groundwater sample, it may be necessary for the Monitoring Programme to include installation of, and sampling from, at least one monitoring bore. The bore(s) would be of a depth, location and design determined after consultation with the Chief Executive, Taranaki Regional Council and installed in accordance with NZS 4411:2001.
6. All water samples taken for monitoring purposes shall be taken in accordance with recognised field procedures and analysed for:
  - (a) pH;
  - (b) conductivity;
  - (c) total dissolved solids;
  - (d) major ions (Ca, Mg, K, Na, total alkalinity, bromide, chloride, nitrate-nitrogen, and sulphate);
  - (e) trace metals (barium, copper, iron, manganese, nickel, and zinc);
  - (f) total petroleum hydrocarbons;
  - (g) formaldehyde;
  - (h) dissolved methane and ethane gas;
  - (i) methanol;
  - (j) glycols;
  - (k) benzene, toluene, ethylbenzene, and xylenes (BTEX);
  - (l) carbon-13 composition of any dissolved methane gas discovered ( $^{13}\text{C-CH}_4$ );

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

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

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

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

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

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

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

## Consent 7912-2.0

10. The consent holder shall notify the Taranaki Regional Council of the date that each discharge is intended to commence by emailing [worknotification@trc.govt.nz](mailto:worknotification@trc.govt.nz). Notification also shall identify the 'Pre-fracturing discharge report', required by condition 9, which details the discharge and be given no less than 3 days before the intended discharge date. If any discharge occurs more than 30 days after the notification date, additional notification as specified in this condition is required.
11. Within 90 days of any commencement date as advised under condition 10, the consent holder shall submit a comprehensive 'Post-fracturing discharge report' to the Chief Executive. The report shall, as a minimum, contain:
  - (a) date and time of discharge;
  - (b) confirmation of the interval(s) where fracturing occurred for that programme, and the geographical position (i.e. depth and lateral position) of the discharge point for each fracture interval;
  - (c) the contaminant volumes and composition of fluid discharged into each fracture interval;
  - (d) the volume of return fluids from each fracture interval;
  - (e) an analysis for the constituents set out in conditions 6(a) to 6(k), in a return fluid sample taken within the first two hours of flow back, for each fracture interval if flowed back individually, or for the well if flowed back with all intervals comingled;
  - (f) an estimate of the volume of fluids (and proppant) remaining underground;
  - (g) the volume of water produced with the hydrocarbons (produced water) over the period beginning at the start of the hydraulic fracturing programme and ending 50 days after the programme is completed or after that period of production;
  - (h) an assessment of the extent and dimensions of the fractures that were generated by the discharge, based on modelling undertaken after the discharge has occurred and other diagnostic techniques, including production analysis, available to determine fracture length, height and containment;
  - (i) the results of pressure testing required by condition 8, and the top hole pressure (psi), slurry rate (bpm), surface proppant concentration (lb/gal), bottom hole proppant concentration (lb/gal), and calculated bottom hole pressure (psi), as well as predicted values for each of these parameters; prior to, during and after each hydraulic fracture treatment;
  - (j) details of the disposal of any returned fluids, including any consents that are relied on to authorise the disposal;
  - (k) details of any incidents where hydraulic fracture fluid is unable to pass through the well perforations (screen outs) that occurred, their likely cause and implications for compliance with conditions 1 and 3; and
  - (l) results of the monitoring referred to in condition 9 (d);
  - (m) an assessment of the effectiveness of the mitigation measures in place with specific reference to those described in the application for this consent.

*Note: For programs including multiple hydraulic fracturing discharges, more than one 'Post-fracturing discharge report' may be required in order to meet the specified 90 day deadline.*
12. The reports described in conditions 9 and 11 shall be emailed to [consents@trc.govt.nz](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 7912-2.0

14. The consent holder shall at all times adopt the best practicable option, as defined in section 2 of the Resource Management Act 1991, to prevent or minimize any actual or likely adverse effect of the activity on the environment by, as a minimum, ensuring that:
  - (a) the discharge is contained within the fracture interval;
  - (b) regular reviews of monitoring techniques used to ensure the discharge does not cause adverse environmental effects are undertaken;
  - (c) regular reviews are undertaken of the preventative and mitigation measures adopted to ensure the discharge does not cause adverse environmental effects; and
  - (d) regular reviews of the chemicals used are undertaken with a view to reducing the toxicity of the chemicals used.
15. The fracture fluid shall be comprised of no less than 95% water and proppant by volume.
16. This consent shall lapse on 30 June 2019, unless the consent is given effect to before the end of that period or the Taranaki Regional Council fixes a longer period pursuant to section 125(1)(b) of the Resource Management Act 1991.
17. The Taranaki Regional Council may review any or all of the conditions of this consent by giving notice of review during the month of June each year, for the purposes of:
  - (a) ensuring that the conditions are adequate to deal with any significant adverse effects on the environment arising from the exercise of this consent, which were either not foreseen at the time the application was considered or which it was not appropriate to deal with at the time; and/or
  - (b) further specifying the best practicable option as required by condition 14; and/or
  - (c) ensuring hydraulic fracturing operations appropriately take into account any best practice guidance published by a recognised industry association or environmental regulator.

Signed at Stratford on 30 June 2014

For and on behalf of  
Taranaki Regional Council

---

A D McLay  
**Director - Resource Management**



## **Appendix III**

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





## ANALYSIS REPORT

<b>Client:</b>	Taranaki Regional Council	<b>Lab No:</b>	1064766	SPV1
<b>Contact:</b>	Regan Phipps C/- Taranaki Regional Council Private Bag 713 STRATFORD 4352	<b>Date Registered:</b>	01-Nov-2012	
		<b>Date Reported:</b>	15-Nov-2012	
		<b>Quote No:</b>	47915	
		<b>Order No:</b>		
		<b>Client Reference:</b>	Groundwater	
		<b>Submitted By:</b>	Regan Phipps	

### Sample Type: Aqueous

Sample Name:	151 Everett Rd 31-Oct-2012 11:50 am	184 Everett Rd 31-Oct-2012 12:15 pm	Spring 31-Oct-2012 2:10 pm		
Lab Number:	1064766.1	1064766.2	1064766.3		

#### Individual Tests

Sum of Anions	meq/L	1.26	0.87	1.17	-	-
Sum of Cations	meq/L	1.62	0.84	1.17	-	-
pH	pH Units	5.9	6.9	6.8	-	-
Total Alkalinity	g/m <sup>3</sup> as CaCO <sub>3</sub>	21	24	37	-	-
Bicarbonate	g/m <sup>3</sup> at 25°C	26	29	45	-	-
Total Hardness	g/m <sup>3</sup> as CaCO <sub>3</sub>	33	22	40	-	-
Electrical Conductivity (EC)	mS/m	14.3	9.1	12.1	-	-
Total Dissolved Solids (TDS)	g/m <sup>3</sup>	82	67	110	-	-
Dissolved Barium	g/m <sup>3</sup>	0.050	0.0081	0.027	-	-
Dissolved Calcium	g/m <sup>3</sup>	9.7	4.7	13.2	-	-
Dissolved Copper	g/m <sup>3</sup>	0.0006	< 0.0005	< 0.0005	-	-
Dissolved Iron	g/m <sup>3</sup>	< 0.02	0.09	< 0.02	-	-
Dissolved Magnesium	g/m <sup>3</sup>	2.1	2.5	1.60	-	-
Dissolved Manganese	g/m <sup>3</sup>	0.0013	0.0044	0.0006	-	-
Dissolved Nickel	g/m <sup>3</sup>	< 0.0005	< 0.0005	< 0.0005	-	-
Dissolved Potassium	g/m <sup>3</sup>	18.9	0.75	2.7	-	-
Dissolved Sodium	g/m <sup>3</sup>	11.1	8.7	7.1	-	-
Dissolved Zinc	g/m <sup>3</sup>	0.0061	< 0.0010	< 0.0010	-	-
Bromide	g/m <sup>3</sup>	0.07	0.05	< 0.05	-	-
Chloride	g/m <sup>3</sup>	18.5	10.5	8.3	-	-
Nitrite-N	g/m <sup>3</sup>	< 0.002	< 0.002	< 0.002	-	-
Nitrate-N	g/m <sup>3</sup>	2.6	0.75	0.69	-	-
Nitrate-N + Nitrite-N	g/m <sup>3</sup>	2.6	0.75	0.69	-	-
Sulphate	g/m <sup>3</sup>	6.1	2.4	7.2	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m <sup>3</sup>	< 4	< 4	< 4	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m <sup>3</sup>	< 4	< 4	< 4	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m <sup>3</sup>	< 2	< 2	< 2	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m <sup>3</sup>	< 0.0010	< 0.0010	< 0.0010	-	-
Toluene	g/m <sup>3</sup>	< 0.0010	< 0.0010	< 0.0010	-	-
Ethylbenzene	g/m <sup>3</sup>	< 0.0010	< 0.0010	< 0.0010	-	-
m&p-Xylene	g/m <sup>3</sup>	< 0.002	< 0.002	< 0.002	-	-
o-Xylene	g/m <sup>3</sup>	< 0.0010	< 0.0010	< 0.0010	-	-



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>	151 Everett Rd 31-Oct-2012 11:50 am	184 Everett Rd 31-Oct-2012 12:15 pm	Spring 31-Oct-2012 2:10 pm			
<b>Lab Number:</b>	1064766.1	1064766.2	1064766.3			
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m <sup>3</sup>	< 0.02	< 0.02	< 0.02	-	-
Gases in groundwater						
Ethane	g/m <sup>3</sup>	< 0.003	< 0.003	< 0.003	-	-
Ethylene	g/m <sup>3</sup>	< 0.004	< 0.004	< 0.004	-	-
Methane	g/m <sup>3</sup>	< 0.002	< 0.002	< 0.002	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m <sup>3</sup>	< 0.10	< 0.10	< 0.10	-	-
C10 - C14	g/m <sup>3</sup>	< 0.2	< 0.2	< 0.2	-	-
C15 - C36	g/m <sup>3</sup>	< 0.4	< 0.4	< 0.4	-	-
Total hydrocarbons (C7 - C36)	g/m <sup>3</sup>	< 0.7	< 0.7	< 0.7	-	-

## SUMMARY OF METHODS

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

Sample Type: Aqueous			
Test	Method Description	Default Detection Limit	Samples
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	-	1-3
Propylene Glycol in Water*	Direct injection, dual column GC-FID	-	1-3
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	-	1-3
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B	-	1-3
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS	-	1-3
Gases in groundwater	Manual headspace creation and sub-sampling, GC-FID analysis.	-	1-3
Total Petroleum Hydrocarbons in Water	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines	-	1-3
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1-3
Total anions for anion/cation balance check	Calculation: sum of anions as mEq/L.	0.07 meq/L	1-3
Total cations for anion/cation balance check	Calculation: sum of cations as mEq/L.	0.05 meq/L	1-3
pH	pH meter. APHA 4500-H <sup>+</sup> B 21 <sup>st</sup> ed. 2005.	0.1 pH Units	1-3
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (Modified for alk <20) 21 <sup>st</sup> ed. 2005.	1.0 g/m <sup>3</sup> as CaCO <sub>3</sub>	1-3
Bicarbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO <sub>2</sub> D 21 <sup>st</sup> ed. 2005.	1.0 g/m <sup>3</sup> at 25°C	1-3
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 21 <sup>st</sup> ed. 2005.	1.0 g/m <sup>3</sup> as CaCO <sub>3</sub>	1-3
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 21 <sup>st</sup> ed. 2005.	0.1 mS/m	1-3
Total Dissolved Solids (TDS)	Filtration through GF/C (1.2 µm), gravimetric. APHA 2540 C (modified; drying temperature of 103 - 105°C used rather than 180 ± 2°C) 21 <sup>st</sup> ed. 2005.	10 g/m <sup>3</sup>	1-3
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 21 <sup>st</sup> ed. 2005.	0.00010 g/m <sup>3</sup>	1-3
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 21 <sup>st</sup> ed. 2005.	0.05 g/m <sup>3</sup>	1-3
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 21 <sup>st</sup> ed. 2005.	0.0005 g/m <sup>3</sup>	1-3
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 21 <sup>st</sup> ed. 2005.	0.02 g/m <sup>3</sup>	1-3
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 21 <sup>st</sup> ed. 2005.	0.02 g/m <sup>3</sup>	1-3
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 21 <sup>st</sup> ed. 2005.	0.0005 g/m <sup>3</sup>	1-3
Dissolved Nickel	Filtered sample, ICP-MS, trace level. APHA 3125 B 21 <sup>st</sup> ed. 2005.	0.0005 g/m <sup>3</sup>	1-3
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 21 <sup>st</sup> ed. 2005.	0.05 g/m <sup>3</sup>	1-3

Sample Type: Aqueous			
Test	Method Description	Default Detection Limit	Samples
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 2 <sup>1st</sup> ed. 2005.	0.02 g/m <sup>3</sup>	1-3
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 2 <sup>1st</sup> ed. 2005.	0.0010 g/m <sup>3</sup>	1-3
Bromide	Filtered sample. Ion Chromatography. APHA 4110 B 2 <sup>1st</sup> ed. 2005.	0.05 g/m <sup>3</sup>	1-3
Chloride	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl E (modified from continuous flow analysis) 2 <sup>1st</sup> ed. 2005.	0.5 g/m <sup>3</sup>	1-3
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO <sub>3</sub> - I (Modified) 2 <sup>1st</sup> ed. 2005.	0.002 g/m <sup>3</sup>	1-3
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO <sub>2</sub> N.	0.002 g/m <sup>3</sup>	1-3
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NQ I (Modified) 2 <sup>1st</sup> ed. 2005.	0.002 g/m <sup>3</sup>	1-3
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B 2 <sup>1st</sup> ed. 2005.	0.5 g/m <sup>3</sup>	1-3

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

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

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





# ANALYSIS REPORT

Page 1 of 3

<b>Client:</b>	Taranaki Regional Council	<b>Lab No:</b>	1166986	SPV1
<b>Contact:</b>	Regan Phipps C/- Taranaki Regional Council Private Bag 713 STRATFORD 4352	<b>Date Registered:</b>	14-Aug-2013	
		<b>Date Reported:</b>	22-Aug-2013	
		<b>Quote No:</b>	47915	
		<b>Order No:</b>		
		<b>Client Reference:</b>	Mangahewa D - GW Monitori	
		<b>Submitted By:</b>	R McDonnell	

## Sample Type: Aqueous

<b>Sample Name:</b>	GND2305 13-Aug-2013 2:10 pm				
<b>Lab Number:</b>	1166986.1				
Individual Tests					
Sum of Anions	meq/L	1.28	-	-	-
Sum of Cations	meq/L	1.29	-	-	-
pH	pH Units	6.2	-	-	-
Total Alkalinity	g/m <sup>3</sup> as CaCO <sub>3</sub>	18.8	-	-	-
Bicarbonate	g/m <sup>3</sup> at 25°C	23	-	-	-
Total Hardness	g/m <sup>3</sup> as CaCO <sub>3</sub>	31	-	-	-
Electrical Conductivity (EC)	mS/m	14.8	-	-	-
Total Dissolved Solids (TDS)	g/m <sup>3</sup>	104	-	-	-
Dissolved Barium	g/m <sup>3</sup>	0.053	-	-	-
Dissolved Bromine*	g/m <sup>3</sup>	0.067	-	-	-
Dissolved Calcium	g/m <sup>3</sup>	9.0	-	-	-
Dissolved Copper	g/m <sup>3</sup>	0.0007	-	-	-
Dissolved Iron	g/m <sup>3</sup>	< 0.02	-	-	-
Dissolved Magnesium	g/m <sup>3</sup>	2.0	-	-	-
Dissolved Manganese	g/m <sup>3</sup>	0.0016	-	-	-
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>	5.6	-	-	-
Dissolved Sodium	g/m <sup>3</sup>	12.1	-	-	-
Dissolved Zinc	g/m <sup>3</sup>	0.0110	-	-	-
Chloride	g/m <sup>3</sup>	20	-	-	-
Nitrite-N	g/m <sup>3</sup>	< 0.002	-	-	-
Nitrate-N	g/m <sup>3</sup>	3.0	-	-	-
Nitrate-N + Nitrite-N	g/m <sup>3</sup>	3.0	-	-	-
Sulphate	g/m <sup>3</sup>	5.7	-	-	-
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>	GND2305 13-Aug-2013 2:10 pm					
<b>Lab Number:</b>	1166986.1					
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>	< 0.004	-	-	-	-
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	Samples
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	-	1
Propylene Glycol in Water*	Direct injection, dual column GC-FID	-	1
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	-	1
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	-	1
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS	-	1
Gases in groundwater	Manual headspace creation and sub-sampling, GC-FID analysis.	-	1
Total Petroleum Hydrocarbons in Water	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734]	-	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 21 <sup>st</sup> ed. 2005.	0.1 pH Units	1
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (Modified for alk <20) 21 <sup>st</sup> ed. 2005.	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 21 <sup>st</sup> ed. 2005.	1.0 g/m <sup>3</sup> at 25°C	1
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 21 <sup>st</sup> ed. 2005.	1.0 g/m <sup>3</sup> as CaCO <sub>3</sub>	1
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 21 <sup>st</sup> ed. 2005.	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) 21 <sup>st</sup> ed. 2005.	10 g/m <sup>3</sup>	1
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 21 <sup>st</sup> ed. 2005.	0.00010 g/m <sup>3</sup>	1
Dissolved Bromine*	Filtered sample, ICP-MS, trace level. APHA 3125 B 21 <sup>st</sup> ed. 2005.	0.005 g/m <sup>3</sup>	1
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 21 <sup>st</sup> ed. 2005.	0.05 g/m <sup>3</sup>	1
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 21 <sup>st</sup> ed. 2005.	0.0005 g/m <sup>3</sup>	1
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 21 <sup>st</sup> ed. 2005.	0.02 g/m <sup>3</sup>	1
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 21 <sup>st</sup> ed. 2005.	0.02 g/m <sup>3</sup>	1

Sample Type: Aqueous			
Test	Method Description	Default Detection Limit	Samples
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 2 <sup>1st</sup> ed. 2005.	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 2 <sup>1st</sup> ed. 2005.	0.0005 g/m <sup>3</sup>	1
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 2 <sup>1st</sup> ed. 2005.	0.05 g/m <sup>3</sup>	1
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 2 <sup>1st</sup> ed. 2005.	0.02 g/m <sup>3</sup>	1
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 2 <sup>1st</sup> ed. 2005.	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) 21 <sup>st</sup> ed. 2005.	0.5 g/m <sup>3</sup>	1
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO <sub>3</sub> - I 21 <sup>st</sup> ed. 2005.	0.002 g/m <sup>3</sup>	1
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO <sub>2</sub> N.	0.002 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 21 <sup>st</sup> ed. 2005.	0.002 g/m <sup>3</sup>	1
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B 2 <sup>1st</sup> ed. 2005.	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>	1134739	SPV2
<b>Contact:</b>	Regan Phipps C/- Taranaki Regional Council Private Bag 713 STRATFORD 4352	<b>Date Registered:</b>	14-May-2013	
		<b>Date Reported:</b>	22-May-2013	
		<b>Quote No:</b>	47915	
		<b>Order No:</b>		
		<b>Client Reference:</b>	Groundwater	
		<b>Submitted By:</b>	Regan Phipps	

## Sample Type: Aqueous

<b>Sample Name:</b>	GND2305 13-May-2013 8:10 am				
<b>Lab Number:</b>	1134739.1				

### Individual Tests

Sum of Anions	meq/L	1.23	-	-	-	-
Sum of Cations	meq/L	1.22	-	-	-	-
pH	pH Units	6.3	-	-	-	-
Total Alkalinity	g/m <sup>3</sup> as CaCO <sub>3</sub>	19.2	-	-	-	-
Bicarbonate	g/m <sup>3</sup> at 25°C	23	-	-	-	-
Total Hardness	g/m <sup>3</sup> as CaCO <sub>3</sub>	29	-	-	-	-
Electrical Conductivity (EC)	mS/m	14.1	-	-	-	-
Total Dissolved Solids (TDS)	g/m <sup>3</sup>	100	-	-	-	-
Dissolved Barium	g/m <sup>3</sup>	0.049	-	-	-	-
Dissolved Calcium	g/m <sup>3</sup>	8.6	-	-	-	-
Dissolved Copper	g/m <sup>3</sup>	0.0013	-	-	-	-
Dissolved Iron	g/m <sup>3</sup>	< 0.02	-	-	-	-
Dissolved Magnesium	g/m <sup>3</sup>	1.73	-	-	-	-
Dissolved Manganese	g/m <sup>3</sup>	0.0012	-	-	-	-
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>	5.2	-	-	-	-
Dissolved Sodium	g/m <sup>3</sup>	11.9	-	-	-	-
Dissolved Zinc	g/m <sup>3</sup>	0.0139	-	-	-	-
Bromide	g/m <sup>3</sup>	0.10	-	-	-	-
Chloride	g/m <sup>3</sup>	19.8	-	-	-	-
Nitrite-N	g/m <sup>3</sup>	< 0.002	-	-	-	-
Nitrate-N	g/m <sup>3</sup>	2.4	-	-	-	-
Nitrate-N + Nitrite-N	g/m <sup>3</sup>	2.4	-	-	-	-
Sulphate	g/m <sup>3</sup>	5.5	-	-	-	-
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	-	-	-	-

Sample Type: Aqueous						
<b>Sample Name:</b>	GND2305 13-May-2013 8:10 am					
<b>Lab Number:</b>	1134739.1					
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>	< 0.004	-	-	-	-
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	-	-	-	-

### Analyst's Comments

Supplement to test report 1134739v1, issued 21/5/13. The sample name has been amended from GND2304 to GND2305 at the request of the client.

## 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	Samples
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	-	1
Propylene Glycol in Water*	Direct injection, dual column GC-FID	-	1
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	-	1
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	-	1
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS	-	1
Gases in groundwater	Manual headspace creation and sub-sampling, GC-FID analysis.	-	1
Total Petroleum Hydrocarbons in Water	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734]	-	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 21 <sup>st</sup> ed. 2005.	0.1 pH Units	1
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (Modified for alk <20) 21 <sup>st</sup> ed. 2005.	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 21 <sup>st</sup> ed. 2005.	1.0 g/m <sup>3</sup> at 25°C	1
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 21 <sup>st</sup> ed. 2005.	1.0 g/m <sup>3</sup> as CaCO <sub>3</sub>	1
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 21 <sup>st</sup> ed. 2005.	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) 21 <sup>st</sup> ed. 2005.	10 g/m <sup>3</sup>	1
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 21 <sup>st</sup> ed. 2005.	0.00010 g/m <sup>3</sup>	1
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 21 <sup>st</sup> ed. 2005.	0.05 g/m <sup>3</sup>	1
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 21 <sup>st</sup> ed. 2005.	0.0005 g/m <sup>3</sup>	1
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 21 <sup>st</sup> ed. 2005.	0.02 g/m <sup>3</sup>	1

Sample Type: Aqueous			
Test	Method Description	Default Detection Limit	Samples
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 2 <sup>1st</sup> ed. 2005.	0.02 g/m <sup>3</sup>	1
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 2 <sup>1st</sup> ed. 2005.	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 2 <sup>1st</sup> ed. 2005.	0.0005 g/m <sup>3</sup>	1
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 2 <sup>1st</sup> ed. 2005.	0.05 g/m <sup>3</sup>	1
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 2 <sup>1st</sup> ed. 2005.	0.02 g/m <sup>3</sup>	1
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 2 <sup>1st</sup> ed. 2005.	0.0010 g/m <sup>3</sup>	1
Bromide	Filtered sample. Ion Chromatography. APHA 4110 B 2 <sup>1st</sup> ed. 2005.	0.05 g/m <sup>3</sup>	1
Chloride	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl E (modified from continuous flow analysis) 21 <sup>st</sup> ed. 2005.	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 (Modified) 21 <sup>st</sup> ed. 2005.	0.002 g/m <sup>3</sup>	1
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO <sub>2</sub> N.	0.002 g/m <sup>3</sup>	1
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO <sub>3</sub> <sup>-</sup> I (Modified) 21 <sup>st</sup> ed. 2005.	0.002 g/m <sup>3</sup>	1
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B 2 <sup>1st</sup> ed. 2005.	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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Graham Corban MSc Tech (Hons)  
Client Services Manager - Environmental Division





# ANALYSIS REPORT

Page 1 of 3

<b>Client:</b>	Taranaki Regional Council	<b>Lab No:</b>	1187311	SPV1
<b>Contact:</b>	Regan Phipps C/- Taranaki Regional Council Private Bag 713 STRATFORD 4352	<b>Date Registered:</b>	03-Oct-2013	
		<b>Date Reported:</b>	10-Oct-2013	
		<b>Quote No:</b>	47915	
		<b>Order No:</b>		
		<b>Client Reference:</b>	Mangakewa D-GW	
		<b>Submitted By:</b>	R McDonnell	

## Sample Type: Aqueous

<b>Sample Name:</b>	GND2306 02-Oct-2013 9:45 am				
<b>Lab Number:</b>	1187311.1				
Individual Tests					
Sum of Anions	meq/L	1.16	-	-	-
Sum of Cations	meq/L	1.17	-	-	-
pH	pH Units	6.5	-	-	-
Total Alkalinity	g/m <sup>3</sup> as CaCO <sub>3</sub>	34	-	-	-
Bicarbonate	g/m <sup>3</sup> at 25°C	42	-	-	-
Total Hardness	g/m <sup>3</sup> as CaCO <sub>3</sub>	39	-	-	-
Electrical Conductivity (EC)	mS/m	12.6	-	-	-
Total Dissolved Solids (TDS)	g/m <sup>3</sup>	103	-	-	-
Dissolved Barium	g/m <sup>3</sup>	0.028	-	-	-
Dissolved Bromine*	g/m <sup>3</sup>	0.035	-	-	-
Dissolved Calcium	g/m <sup>3</sup>	13.0	-	-	-
Dissolved Copper	g/m <sup>3</sup>	< 0.0005	-	-	-
Dissolved Iron	g/m <sup>3</sup>	< 0.02	-	-	-
Dissolved Magnesium	g/m <sup>3</sup>	1.60	-	-	-
Dissolved Manganese	g/m <sup>3</sup>	0.0008	-	-	-
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>	2.4	-	-	-
Dissolved Sodium	g/m <sup>3</sup>	7.5	-	-	-
Dissolved Zinc	g/m <sup>3</sup>	< 0.0010	-	-	-
Chloride	g/m <sup>3</sup>	8.6	-	-	-
Nitrite-N	g/m <sup>3</sup>	< 0.002	-	-	-
Nitrate-N	g/m <sup>3</sup>	1.47	-	-	-
Nitrate-N + Nitrite-N	g/m <sup>3</sup>	1.47	-	-	-
Sulphate	g/m <sup>3</sup>	6.3	-	-	-
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>	GND2306 02-Oct-2013 9:45 am					
<b>Lab Number:</b>	1187311.1					
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	Samples
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	-	1
Propylene Glycol in Water*	Direct injection, dual column GC-FID	-	1
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	-	1
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	-	1
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS	-	1
Gases in groundwater	Manual headspace creation and sub-sampling, GC-FID analysis.	-	1
Total Petroleum Hydrocarbons in Water	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734]	-	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 21 <sup>st</sup> ed. 2005.	0.1 pH Units	1
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (Modified for alk <20) 21 <sup>st</sup> ed. 2005.	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 21 <sup>st</sup> ed. 2005.	1.0 g/m <sup>3</sup> at 25°C	1
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 21 <sup>st</sup> ed. 2005.	1.0 g/m <sup>3</sup> as CaCO <sub>3</sub>	1
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 21 <sup>st</sup> ed. 2005.	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) 21 <sup>st</sup> ed. 2005.	10 g/m <sup>3</sup>	1
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 21 <sup>st</sup> ed. 2005.	0.00010 g/m <sup>3</sup>	1
Dissolved Bromine*	Filtered sample, ICP-MS, trace level. APHA 3125 B 21 <sup>st</sup> ed. 2005.	0.005 g/m <sup>3</sup>	1
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 21 <sup>st</sup> ed. 2005.	0.05 g/m <sup>3</sup>	1
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 21 <sup>st</sup> ed. 2005.	0.0005 g/m <sup>3</sup>	1
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 21 <sup>st</sup> ed. 2005.	0.02 g/m <sup>3</sup>	1
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 21 <sup>st</sup> ed. 2005.	0.02 g/m <sup>3</sup>	1

Sample Type: Aqueous			
Test	Method Description	Default Detection Limit	Samples
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 2 <sup>1st</sup> ed. 2005.	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 2 <sup>1st</sup> ed. 2005.	0.0005 g/m <sup>3</sup>	1
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 2 <sup>1st</sup> ed. 2005.	0.05 g/m <sup>3</sup>	1
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 2 <sup>1st</sup> ed. 2005.	0.02 g/m <sup>3</sup>	1
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 2 <sup>1st</sup> ed. 2005.	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) 21 <sup>st</sup> ed. 2005.	0.5 g/m <sup>3</sup>	1
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO <sub>3</sub> - I 21 <sup>st</sup> ed. 2005.	0.002 g/m <sup>3</sup>	1
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO <sub>2</sub> N.	0.002 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 21 <sup>st</sup> ed. 2005.	0.002 g/m <sup>3</sup>	1
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B 2 <sup>1st</sup> ed. 2005.	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

<b>Client:</b>	Taranaki Regional Council	<b>Lab No:</b>	1316723	SPV1
<b>Contact:</b>	Regan Phipps C/- Taranaki Regional Council Private Bag 713 STRATFORD 4352	<b>Date Registered:</b>	27-Aug-2014	
		<b>Date Reported:</b>	04-Sep-2014	
		<b>Quote No:</b>	47915	
		<b>Order No:</b>		
		<b>Client Reference:</b>	Mangehewa D Post HF GW	
		<b>Submitted By:</b>	Regan Phipps	

### Sample Type: Aqueous

<b>Sample Name:</b>	GND2459 26-Aug-2014 10:04 am				
<b>Lab Number:</b>	1316723.1				

#### Individual Tests

Sum of Anions	meq/L	2.6	-	-	-	-
Sum of Cations	meq/L	2.8	-	-	-	-
pH	pH Units	7.3	-	-	-	-
Total Alkalinity	g/m <sup>3</sup> as CaCO <sub>3</sub>	112	-	-	-	-
Bicarbonate	g/m <sup>3</sup> at 25°C	137	-	-	-	-
Total Hardness	g/m <sup>3</sup> as CaCO <sub>3</sub>	45	-	-	-	-
Electrical Conductivity (EC)	mS/m	25.2	-	-	-	-
Total Dissolved Solids (TDS)	g/m <sup>3</sup>	179	-	-	-	-
Dissolved Barium	g/m <sup>3</sup>	0.0172	-	-	-	-
Dissolved Bromine*	g/m <sup>3</sup>	0.050	-	-	-	-
Dissolved Calcium	g/m <sup>3</sup>	10.1	-	-	-	-
Dissolved Copper	g/m <sup>3</sup>	0.0014	-	-	-	-
Dissolved Iron	g/m <sup>3</sup>	2.5	-	-	-	-
Dissolved Magnesium	g/m <sup>3</sup>	4.7	-	-	-	-
Dissolved Manganese	g/m <sup>3</sup>	0.24	-	-	-	-
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>	5.3	-	-	-	-
Dissolved Sodium	g/m <sup>3</sup>	37	-	-	-	-
Dissolved Zinc	g/m <sup>3</sup>	1.98	-	-	-	-
Chloride	g/m <sup>3</sup>	12.7	-	-	-	-
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>	0.0070	-	-	-	-
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>	GND2459 26-Aug-2014 10:04 am					
<b>Lab Number:</b>	1316723.1					
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>	0.03	-	-	-	-
Gases in groundwater						
Ethane	g/m <sup>3</sup>	0.005	-	-	-	-
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>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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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>	1316723	SPV1
<b>Contact:</b>	Regan Phipps C/- Taranaki Regional Council Private Bag 713 STRATFORD 4352	<b>Date Registered:</b>	27-Aug-2014	
		<b>Date Reported:</b>	04-Sep-2014	
		<b>Quote No:</b>	47915	
		<b>Order No:</b>		
		<b>Client Reference:</b>	Mangehewa D Post HF GW	
		<b>Submitted By:</b>	Regan Phipps	

## Sample Type: Aqueous

<b>Sample Name:</b>	GND2459 26-Aug-2014 10:04 am				
<b>Lab Number:</b>	1316723.1				
Individual Tests					
Sum of Anions	meq/L	2.6	-	-	-
Sum of Cations	meq/L	2.8	-	-	-
pH	pH Units	7.3	-	-	-
Total Alkalinity	g/m <sup>3</sup> as CaCO <sub>3</sub>	112	-	-	-
Bicarbonate	g/m <sup>3</sup> at 25°C	137	-	-	-
Total Hardness	g/m <sup>3</sup> as CaCO <sub>3</sub>	45	-	-	-
Electrical Conductivity (EC)	mS/m	25.2	-	-	-
Total Dissolved Solids (TDS)	g/m <sup>3</sup>	179	-	-	-
Dissolved Barium	g/m <sup>3</sup>	0.0172	-	-	-
Dissolved Bromine*	g/m <sup>3</sup>	0.050	-	-	-
Dissolved Calcium	g/m <sup>3</sup>	10.1	-	-	-
Dissolved Copper	g/m <sup>3</sup>	0.0014	-	-	-
Dissolved Iron	g/m <sup>3</sup>	2.5	-	-	-
Dissolved Magnesium	g/m <sup>3</sup>	4.7	-	-	-
Dissolved Manganese	g/m <sup>3</sup>	0.24	-	-	-
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>	5.3	-	-	-
Dissolved Sodium	g/m <sup>3</sup>	37	-	-	-
Dissolved Zinc	g/m <sup>3</sup>	1.98	-	-	-
Chloride	g/m <sup>3</sup>	12.7	-	-	-
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>	0.0070	-	-	-
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>	GND2459 26-Aug-2014 10:04 am					
<b>Lab Number:</b>	1316723.1					
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>	0.03	-	-	-	-
Gases in groundwater						
Ethane	g/m <sup>3</sup>	0.005	-	-	-	-
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



## **Appendix IV**

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





## ANALYSIS REPORT

<b>Client:</b>	Taranaki Regional Council	<b>Lab No:</b>	1069389	SPV1
<b>Contact:</b>	Regan Phipps C/- Taranaki Regional Council Private Bag 713 STRATFORD 4352	<b>Date Registered:</b>	14-Nov-2012	
		<b>Date Reported:</b>	28-Nov-2012	
		<b>Quote No:</b>	50522	
		<b>Order No:</b>		
		<b>Client Reference:</b>	Hydraulic fracturing fluid testi	
		<b>Submitted By:</b>	Regan Phipps	

### Sample Type: Aqueous

Sample Name:	GND2310 10-Nov-2012 4:30 pm	GND2311 12-Nov-2012 5:40 pm			
Lab Number:	1069389.1	1069389.2			
Ethylene Glycol in Water					
Ethylene glycol*	g/m <sup>3</sup>	280	240	-	-
Propylene Glycol in Water					
Propylene glycol*	g/m <sup>3</sup>	55	57	-	-
Methanol in Water - Aqueous Solvents					
Methanol*	g/m <sup>3</sup>	9	9	-	-
BTEX in Water by Headspace GC-MS					
Benzene	g/m <sup>3</sup>	0.0041	0.0069	-	-
Toluene	g/m <sup>3</sup>	0.023	0.033	-	-
Ethylbenzene	g/m <sup>3</sup>	0.0033	0.0044	-	-
m&p-Xylene	g/m <sup>3</sup>	0.012	0.017	-	-
o-Xylene	g/m <sup>3</sup>	0.0080	0.0107	-	-
Total Petroleum Hydrocarbons in Water					
C7 - C9	g/m <sup>3</sup>	< 0.15	< 0.15	-	-
C10 - C14	g/m <sup>3</sup>	110	152	-	-
C15 - C36	g/m <sup>3</sup>	320	310	-	-
Total hydrocarbons (C7 - C36)	g/m <sup>3</sup>	430	470	-	-

### 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	Samples
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	-	1-2
Propylene Glycol in Water*	Direct injection, dual column GC-FID	-	1-2
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	-	1-2
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B	-	1-2
Total Petroleum Hydrocarbons in Water	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines	-	1-2



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.

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.

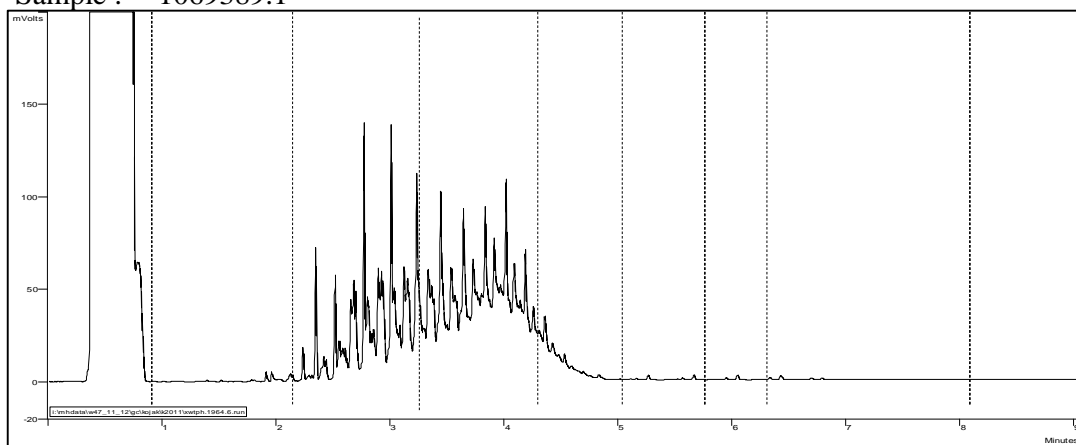
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A handwritten signature in blue ink, consisting of several overlapping, stylized strokes.

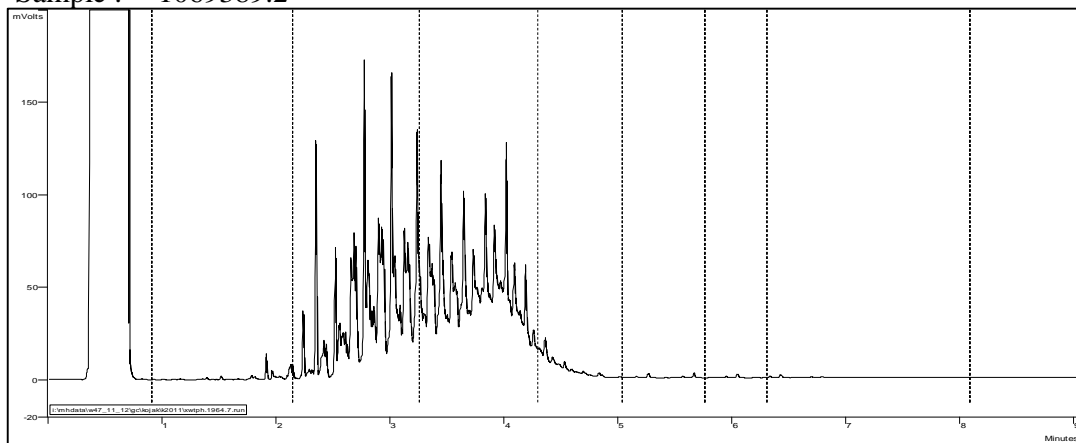
Ara Heron BSc (Tech)  
Client Services Manager - Environmental Division



Sample : 1069389.1



Sample : 1069389.2



C7 C10 C15 C20 C25 C30 C34 C44





## ANALYSIS REPORT

<b>Client:</b>	Taranaki Regional Council	<b>Lab No:</b>	1076008	SPV1
<b>Contact:</b>	Regan Phipps C/- Taranaki Regional Council Private Bag 713 STRATFORD 4352	<b>Date Registered:</b>	01-Dec-2012	
		<b>Date Reported:</b>	17-Dec-2012	
		<b>Quote No:</b>	49265	
		<b>Order No:</b>		
		<b>Client Reference:</b>	Mangahewa D Return Fluids	
		<b>Submitted By:</b>	Regan Phipps	

### Sample Type: Saline

<b>Sample Name:</b>	GN02310 27-Nov-2012 10:30 pm				
<b>Lab Number:</b>	1076008.1				

#### Individual Tests

pH	pH Units	7.3	-	-	-	-
Total Alkalinity	g/m <sup>3</sup> as CaCO <sub>3</sub>	1,730	-	-	-	-
Total Hardness	g/m <sup>3</sup> as CaCO <sub>3</sub>	410	-	-	-	-
Electrical Conductivity (EC)	mS/m	3,110	-	-	-	-
Dissolved Barium	g/m <sup>3</sup>	119	-	-	-	-
Dissolved Calcium	g/m <sup>3</sup>	150	-	-	-	-
Dissolved Copper	g/m <sup>3</sup>	< 0.005	-	-	-	-
Dissolved Iron	g/m <sup>3</sup>	3.8	-	-	-	-
Dissolved Magnesium	g/m <sup>3</sup>	10	-	-	-	-
Dissolved Manganese	g/m <sup>3</sup>	3.7	-	-	-	-
Dissolved Nickel	g/m <sup>3</sup>	< 0.03	-	-	-	-
Dissolved Potassium	g/m <sup>3</sup>	810	-	-	-	-
Dissolved Sodium	g/m <sup>3</sup>	6,900	-	-	-	-
Dissolved Sulphur	g/m <sup>3</sup>	6	-	-	-	-
Dissolved Zinc	g/m <sup>3</sup>	0.05	-	-	-	-
Bromide	g/m <sup>3</sup>	39	-	-	-	-
Chloride	g/m <sup>3</sup>	9,800	-	-	-	-
Nitrite-N	g/m <sup>3</sup>	< 0.2	-	-	-	-
Nitrate-N	g/m <sup>3</sup>	< 0.2	-	-	-	-
Nitrate	g/m <sup>3</sup>	< 0.9	-	-	-	-
Nitrate-N + Nitrite-N	g/m <sup>3</sup>	< 0.2	-	-	-	-
Sulphate	g/m <sup>3</sup>	19	-	-	-	-

#### Ethylene Glycol in Water

Ethylene glycol	g/m <sup>3</sup>	65	-	-	-	-
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#### Propylene Glycol in Water

Propylene glycol	g/m <sup>3</sup>	20	-	-	-	-
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#### Methanol in Water - Aqueous Solvents

Methanol	g/m <sup>3</sup>	< 2	-	-	-	-
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#### BTEX in Water by Headspace GC-MS

Benzene	g/m <sup>3</sup>	26	-	-	-	-
Toluene	g/m <sup>3</sup>	37	-	-	-	-
Ethylbenzene	g/m <sup>3</sup>	3.2	-	-	-	-
m&p-Xylene	g/m <sup>3</sup>	16.1	-	-	-	-
o-Xylene	g/m <sup>3</sup>	5.7	-	-	-	-

#### Formaldehyde in Water by DNPH & LCMSMS

Formaldehyde	g/m <sup>3</sup>	1.12	-	-	-	-
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Sample Type: Saline						
<b>Sample Name:</b>	GN02310					
	27-Nov-2012					
	10:30 pm					
<b>Lab Number:</b>	1076008.1					
Gases in groundwater						
Ethane	g/m <sup>3</sup>	0.35	-	-	-	-
Ethylene	g/m <sup>3</sup>	< 0.003	-	-	-	-
Methane	g/m <sup>3</sup>	0.75	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m <sup>3</sup>	169	-	-	-	-
C10 - C14	g/m <sup>3</sup>	340	-	-	-	-
C15 - C36	g/m <sup>3</sup>	540	-	-	-	-
Total hydrocarbons (C7 - C36)	g/m <sup>3</sup>	1,050	-	-	-	-

**Analyst's Comments**

Severe matrix interferences required that a dilution be performed prior to analysis of sample 1076008/1, 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.

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	Samples
Ethylene Glycol in Water	Direct injection, dual column GC-FID	-	1
Propylene Glycol in Water	Direct injection, dual column GC-FID	-	1
Methanol in Water - Aqueous Solvents	Direct injection, dual column GC-FID	-	1
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B	-	1
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS	-	1
Gases in groundwater	Manual headspace creation and sub-sampling, GC-FID analysis.	-	1
Total Petroleum Hydrocarbons in Water	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines	-	1
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1
pH	Saline water, pH meter. APHA 4500-H <sup>+</sup> B 21 <sup>st</sup> ed. 2005.	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
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 21 <sup>st</sup> ed. 2005.	1.0 g/m <sup>3</sup> as CaCO <sub>3</sub>	1
Electrical Conductivity (EC)	Saline water, Conductivity meter, 25°C. APHA 2510 B 21 <sup>st</sup> ed. 2005.	0.10 mS/m	1
Filtration for dissolved metals analysis	Sample filtration through 0.45µm membrane filter and preservation with nitric acid. APHA 3030 B 21 <sup>st</sup> ed. 2005.	-	1
Dissolved Barium	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 21 <sup>st</sup> ed. 2005.	0.0006 g/m <sup>3</sup>	1
Dissolved Calcium	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 21 <sup>st</sup> ed. 2005.	1.0 g/m <sup>3</sup>	1
Dissolved Copper	Filtered sample, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 21 <sup>st</sup> ed. 2005.	0.0010 g/m <sup>3</sup>	1
Dissolved Iron	Filtered sample, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 21 <sup>st</sup> ed. 2005.	0.004 g/m <sup>3</sup>	1
Dissolved Magnesium	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 21 <sup>st</sup> ed. 2005.	0.4 g/m <sup>3</sup>	1
Dissolved Manganese	Filtered sample, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 21 <sup>st</sup> ed. 2005.	0.0010 g/m <sup>3</sup>	1
Dissolved Nickel	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 21 <sup>st</sup> ed. 2005.	0.006 g/m <sup>3</sup>	1
Dissolved Potassium	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 21 <sup>st</sup> ed. 2005.	1.0 g/m <sup>3</sup>	1
Dissolved Sodium	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 21 <sup>st</sup> ed. 2005.	0.4 g/m <sup>3</sup>	1
Dissolved Sulphur	Filtered sample, ICP-OES.	0.10 g/m <sup>3</sup>	1

Sample Type: Saline			
Test	Method Description	Default Detection Limit	Samples
Dissolved Zinc	Filtered sample, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 21 <sup>st</sup> ed. 2005.	0.004 g/m <sup>3</sup>	1
Bromide	Filtered sample. Ion Chromatography. APHA 4110 B 21 <sup>st</sup> ed. 2005.	0.05 g/m <sup>3</sup>	1
Chloride	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl E (modified from continuous flow analysis) 21 <sup>st</sup> ed. 2005.	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 (Modified) 21 <sup>st</sup> ed. 2005.	0.002 g/m <sup>3</sup>	1
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO <sub>2</sub> N.	0.002 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 (Modified) 21 <sup>st</sup> ed. 2005.	0.002 g/m <sup>3</sup>	1
Soluble Sulphate	Calculation: from dissolved sulphur.	2 g/m <sup>3</sup>	1

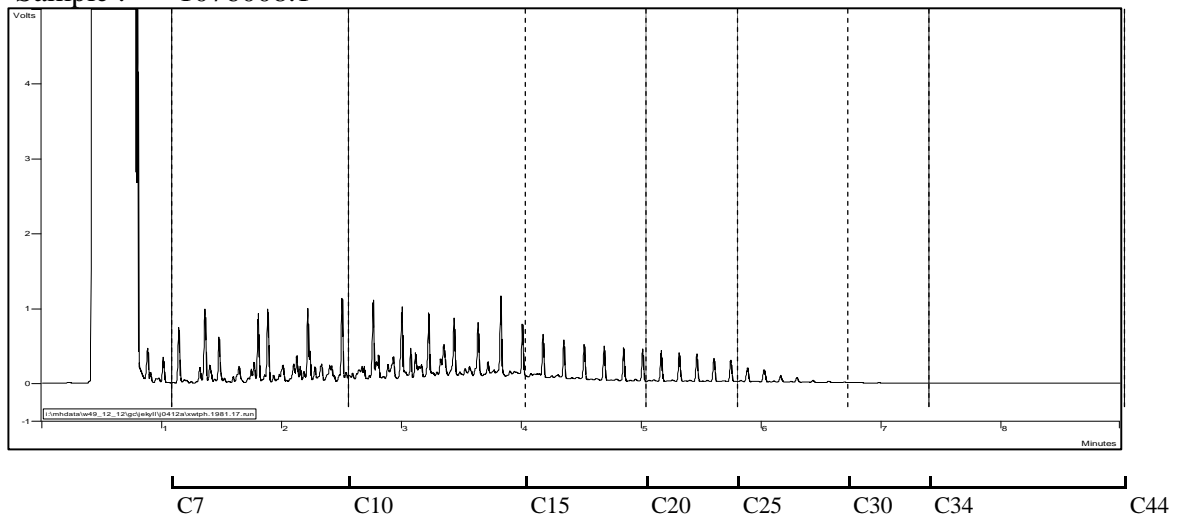
These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

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 (Chem)  
Client Services Manager - Environmental Division

Sample : 1076008.1





## ANALYSIS REPORT

<b>Client:</b>	Taranaki Regional Council	<b>Lab No:</b>	1284400	SPV1
<b>Contact:</b>	Regan Phipps C/- Taranaki Regional Council Private Bag 713 STRATFORD 4352	<b>Date Registered:</b>	06-Jun-2014	
		<b>Date Reported:</b>	18-Jun-2014	
		<b>Quote No:</b>	50522	
		<b>Order No:</b>		
		<b>Client Reference:</b>	Mangahewa D HF Fluid	
		<b>Submitted By:</b>	Regan Phipps	

### Sample Type: Aqueous

<b>Sample Name:</b>	GND2465 25-May-2014 12:00 pm					
<b>Lab Number:</b>	1284400.1					
Ethylene Glycol in Water						
Ethylene glycol*	g/m <sup>3</sup>	460	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m <sup>3</sup>	43	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m <sup>3</sup>	6	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m <sup>3</sup>	0.0016	-	-	-	-
Toluene	g/m <sup>3</sup>	0.0029	-	-	-	-
Ethylbenzene	g/m <sup>3</sup>	< 0.0010	-	-	-	-
m&p-Xylene	g/m <sup>3</sup>	0.005	-	-	-	-
o-Xylene	g/m <sup>3</sup>	0.0037	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m <sup>3</sup>	1.05	-	-	-	-
C10 - C14	g/m <sup>3</sup>	59	-	-	-	-
C15 - C36	g/m <sup>3</sup>	114	-	-	-	-
Total hydrocarbons (C7 - C36)	g/m <sup>3</sup>	174	-	-	-	-

### Analyst's Comments

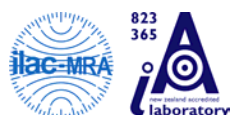
Appendix No.1 - Total Petroleum Hydrocarbon Chromatograms

## 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



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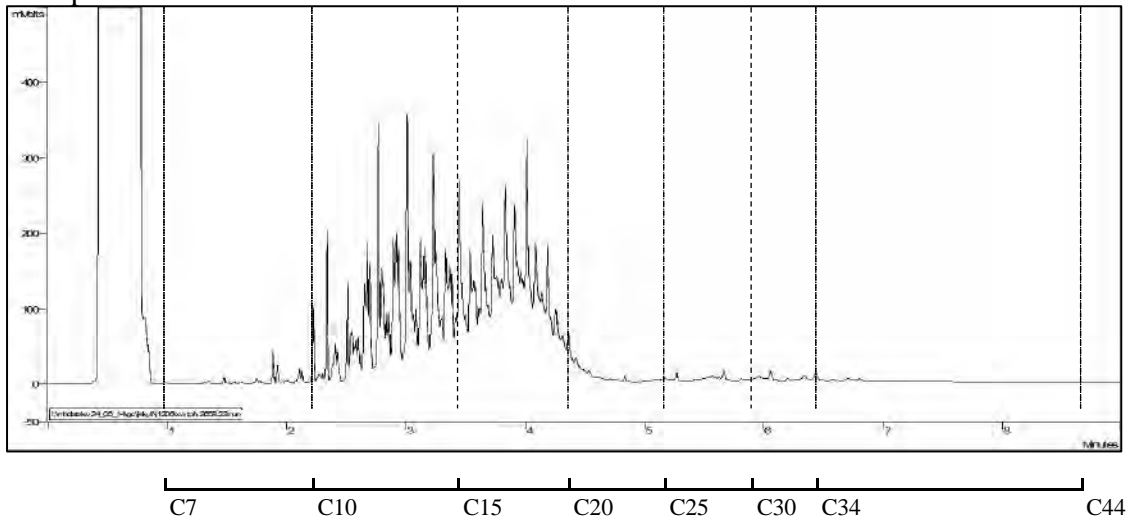
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A handwritten signature in blue ink, consisting of several overlapping, stylized strokes.

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



Sample : 1284400.1







## ANALYSIS REPORT

<b>Client:</b>	Taranaki Regional Council	<b>Lab No:</b>	1284400	SPV1
<b>Contact:</b>	Regan Phipps C/- Taranaki Regional Council Private Bag 713 STRATFORD 4352	<b>Date Registered:</b>	06-Jun-2014	
		<b>Date Reported:</b>	18-Jun-2014	
		<b>Quote No:</b>	50522	
		<b>Order No:</b>		
		<b>Client Reference:</b>	Mangahewa D HF Fluid	
		<b>Submitted By:</b>	Regan Phipps	

### Sample Type: Aqueous

<b>Sample Name:</b>	GND2465 25-May-2014 12:00 pm					
<b>Lab Number:</b>	1284400.1					
Ethylene Glycol in Water						
Ethylene glycol*	g/m <sup>3</sup>	460	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m <sup>3</sup>	43	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m <sup>3</sup>	6	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m <sup>3</sup>	0.0016	-	-	-	-
Toluene	g/m <sup>3</sup>	0.0029	-	-	-	-
Ethylbenzene	g/m <sup>3</sup>	< 0.0010	-	-	-	-
m&p-Xylene	g/m <sup>3</sup>	0.005	-	-	-	-
o-Xylene	g/m <sup>3</sup>	0.0037	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m <sup>3</sup>	1.05	-	-	-	-
C10 - C14	g/m <sup>3</sup>	59	-	-	-	-
C15 - C36	g/m <sup>3</sup>	114	-	-	-	-
Total hydrocarbons (C7 - C36)	g/m <sup>3</sup>	174	-	-	-	-

### Analyst's Comments

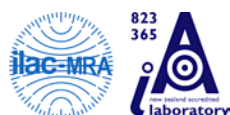
Appendix No.1 - Total Petroleum Hydrocarbon Chromatograms

## 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.

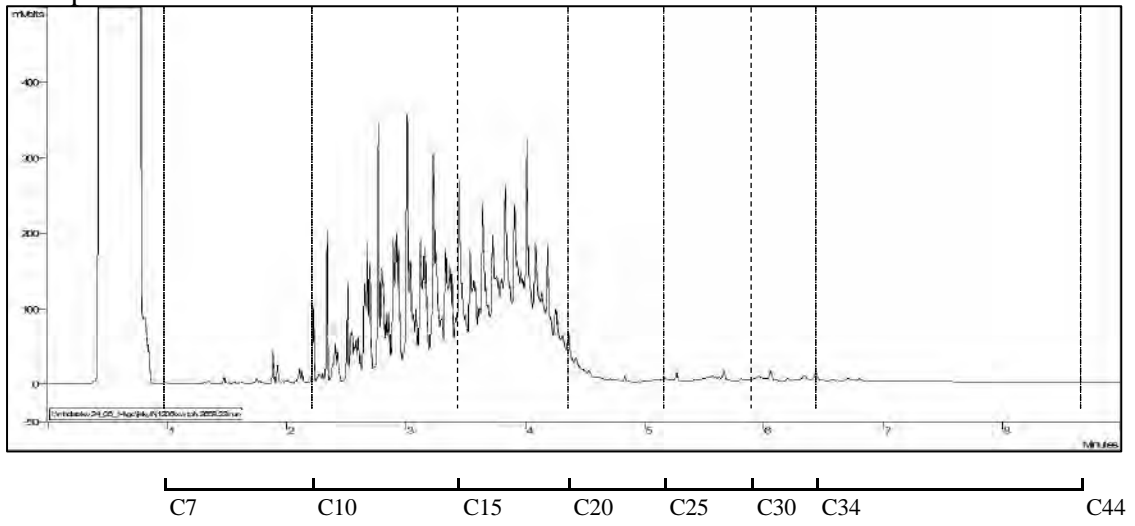
Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

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

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

Sample : 1284400.1





# ANALYSIS REPORT

Page 1 of 3

<b>Client:</b>	Taranaki Regional Council	<b>Lab No:</b>	1296187	SPV1
<b>Contact:</b>	Regan Phipps C/- Taranaki Regional Council Private Bag 713 STRATFORD 4352	<b>Date Registered:</b>	08-Jul-2014	
		<b>Date Reported:</b>	23-Jul-2014	
		<b>Quote No:</b>	49265	
		<b>Order No:</b>		
		<b>Client Reference:</b>	Magahewa D Return Fluid	
		<b>Submitted By:</b>	R McDonnell	

## Sample Type: Saline

<b>Sample Name:</b>	GND2465 14-Jun-2014 7:59 am				
<b>Lab Number:</b>	1296187.1				

### Individual Tests

pH*	pH Units	6.6	-	-	-	-
Total Alkalinity*	g/m <sup>3</sup> as CaCO <sub>3</sub>	2,300	-	-	-	-
Analysis Temperature for Bicarbonate	°C	22	-	-	-	-
Bicarbonate	g/m <sup>3</sup> at Analysis Temperature	1,995	-	-	-	-
Total Hardness*	g/m <sup>3</sup> as CaCO <sub>3</sub>	155	-	-	-	-
Electrical Conductivity (EC)*	mS/m	1,605	-	-	-	-
Total Dissolved Solids (TDS)*	g/m <sup>3</sup>	13,000	-	-	-	-
Dissolved Barium*	g/m <sup>3</sup>	29	-	-	-	-
Dissolved Bromine*	g/m <sup>3</sup>	14.2	-	-	-	-
Dissolved Calcium*	g/m <sup>3</sup>	47	-	-	-	-
Dissolved Copper*	g/m <sup>3</sup>	0.006	-	-	-	-
Dissolved Iron*	g/m <sup>3</sup>	14.4	-	-	-	-
Dissolved Magnesium*	g/m <sup>3</sup>	9	-	-	-	-
Dissolved Manganese*	g/m <sup>3</sup>	3.0	-	-	-	-
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>	530	-	-	-	-
Dissolved Sodium*	g/m <sup>3</sup>	3,700	-	-	-	-
Dissolved Sulphur*	g/m <sup>3</sup>	22	-	-	-	-
Dissolved Zinc*	g/m <sup>3</sup>	0.06	-	-	-	-
Chloride*	g/m <sup>3</sup>	3,700	-	-	-	-
Nitrite-N	g/m <sup>3</sup>	< 0.2 #1	-	-	-	-
Nitrate-N	g/m <sup>3</sup>	< 0.2	-	-	-	-
Nitrate*	g/m <sup>3</sup>	< 0.9	-	-	-	-
Nitrate-N + Nitrite-N	g/m <sup>3</sup>	< 0.2 #1	-	-	-	-
Sulphate*	g/m <sup>3</sup>	66	-	-	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m <sup>3</sup>	74	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m <sup>3</sup>	< 4	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m <sup>3</sup>	5	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene*	g/m <sup>3</sup>	4.5	-	-	-	-
Toluene*	g/m <sup>3</sup>	3.7	-	-	-	-
Ethylbenzene*	g/m <sup>3</sup>	0.37	-	-	-	-

Sample Type: Saline						
<b>Sample Name:</b>	GND2465 14-Jun-2014 7:59 am					
<b>Lab Number:</b>	1296187.1					
BTEX in Water by Headspace GC-MS						
m&p-Xylene*	g/m <sup>3</sup>	1.7	-	-	-	-
o-Xylene*	g/m <sup>3</sup>	0.79	-	-	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde*	g/m <sup>3</sup>	0.7	-	-	-	-
Gases in groundwater						
Ethane*	g/m <sup>3</sup>	0.29	-	-	-	-
Ethylene*	g/m <sup>3</sup>	< 0.004	-	-	-	-
Methane*	g/m <sup>3</sup>	3.0	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9*	g/m <sup>3</sup>	15.7	-	-	-	-
C10 - C14*	g/m <sup>3</sup>	70	-	-	-	-
C15 - C36*	g/m <sup>3</sup>	134	-	-	-	-
Total hydrocarbons (C7 - C36)*	g/m <sup>3</sup>	220	-	-	-	-

### 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.

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*	Saline water, pH meter. APHA 4500-H <sup>+</sup> 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)*	Saline water, Conductivity meter, 25°C. APHA 2510 B 22 <sup>nd</sup> ed. 2012.	0.10 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



Sample Type: Saline			
Test	Method Description	Default Detection Limit	Sample No
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
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 <sup>-</sup> 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

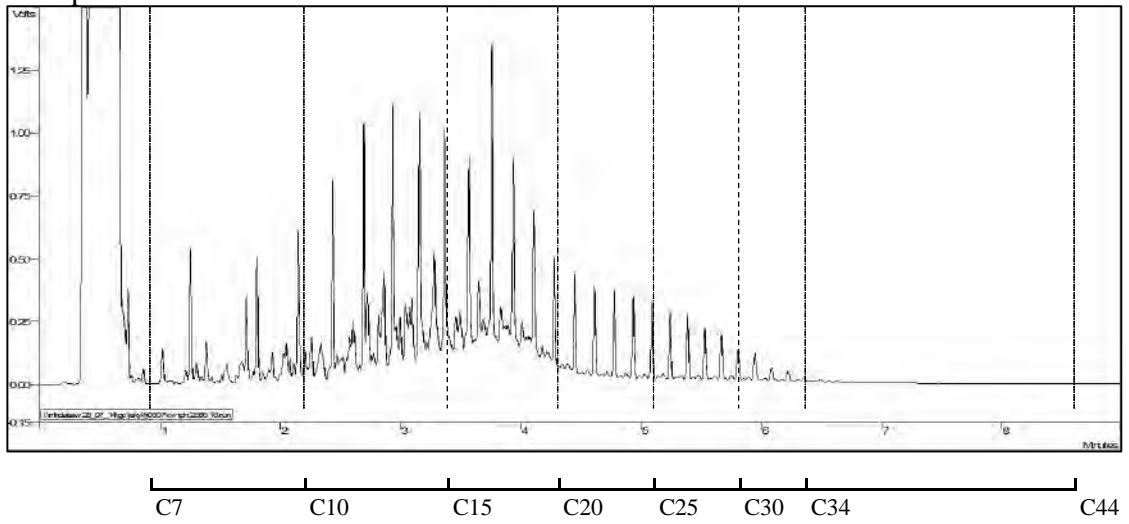
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Ara Heron BSc (Tech)  
Client Services Manager - Environmental Division

Sample : 1296187.1



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



To Job Manager, Callum McKenzie  
From Scientific Officer, Brooke Thomas  
Report No BT037  
Date October 2014

## **Biomonitoring of an unnamed tributary of the Manganui River before and after hydraulic fracturing at Mangahewa D wellsite by Todd Energy Ltd, April 2014 & August 2014.**

### **Introduction**

These biological surveys were performed before and after hydraulic fracturing (HF) at the Mangahewa D wellsite. The intention of these surveys was to determine the health of the macroinvertebrate communities prior to hydraulic fracturing, which then allowed a comparison with the health of the macroinvertebrate communities following hydraulic fracturing. This provided an indication as to whether the hydraulic fracturing activities had an influence on the macroinvertebrate community of the stream.

### **Methods**

A combination of the 'kick-sampling' and 'vegetation sweep' sampling techniques was used at three sites to collect streambed macroinvertebrates upstream and downstream of the stormwater discharge point in the unnamed tributary of the Manganui River, on 15 April 2014 and 28 August 2014 (Table 1). The 'kick-sampling' technique is very similar to C1 (hard-bottomed, semi-quantitative) of the New Zealand Macroinvertebrate Working Group (NZMWG) protocols for macroinvertebrate samples in wadeable streams (Stark *et al*, 2001). The 'vegetation sweep' technique is very similar to Protocol C2 (soft-bottomed, semi-quantitative) of the New Zealand Macroinvertebrate Working Group (NZMWG) protocols for macroinvertebrate samples in wadeable streams (Stark *et al*, 2001).

The Mangahewa D wellsite stormwater was discharged from a skimmer pit onto land near the unnamed tributary of the Manganui River (Figure 1). The three sites monitored in the unnamed tributary of the Manganui River were situated 55m upstream of the drain confluence from the Mangahewa D wellsite (site 1), 60m downstream of the drain confluence (site 2) and 100m downstream of the drain confluence (site 3) ( Table 1).

**Table 1** Biomonitoring sites in the unnamed tributary of the Manganui River related to the Mangahewa D wellsite

Site No.	Site code	GPS Reference (NZTM)	Location
1	MGN000489	E1711359 N5673793	55m upstream of drain confluence
2	MGN000492	E1711376 N5673894	60m downstream of drain confluence
3	MGN000493	E1711392 N5673936	100m downstream of drain confluence



Figure 1 Biomonitoring sites in the unnamed tributary of the Manganui River sampled in relation to the Mangahewa D wellsite

Samples were preserved with Kahle's Fluid for later sorting and identification under a stereomicroscope according to Taranaki Regional Council methodology using Protocol P1 of NZMWG protocols 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> is not multiplied by a scaling factor of 20, so that its corresponding range of values is 20x lower.

## Results and discussion

During the pre-HF survey the water temperature in the unnamed tributary of the Manganui River ranged from 16.6 °C to 17.2°C. During the post-HF survey the water temperature ranged from 9.5°C to 9.8°C. During the pre-HF survey an uncoloured, clear, very low and very slow flow was recorded at site 1. At site 2 an uncoloured, cloudy, low and very slow flow was recorded, whereas at site 3 the flow was clear, low and slow. During the post-HF survey an uncoloured, moderate and steady flow was recorded at site 1 and an uncoloured, cloudy, moderate and slow flow was recorded at sites 2 and 3.

At all three sites the substrate comprised predominantly of silt, sand and fine and coarse gravels, with varying proportions of cobbles, boulders and wood and roots. Greater proportions of woody debris were noted in the post-HF survey at site 2 and 3, and hard clay was present at site 1. No periphyton was recorded at site 2 or site 3 during the pre-HF survey, whereas at site 1 both mats and filaments of periphyton were widespread. During the post-HF survey, patchy mats and filaments were noted at site 1, while only patchy mats were recorded at site 3 and at site 2 only slippery mats were recorded.

During both the pre-HF and post-HF surveys macrophytes were recorded growing at the edges and on the bed of the stream at site 1, and at the edges of the stream at site 2 and site 3. The bed of the stream was not shaded at site 1 during the pre-HF survey, although it was partially shaded during the post-HF survey. Both site 2 and site 3 were partially shaded by steep banks and overhanging vegetation during both the pre-HF and post-HF surveys.

## Macroinvertebrate communities

Table 2 summarises the results of the two macroinvertebrate surveys performed prior to and following hydraulic fracturing at the Mangahewa D wellsite and includes comparative data for sites of similar streams to the unnamed tributary of the Manganui River. Full results for the pre-HF and post-HF surveys are presented Table 3 and 4 respectively.

**Table 2** Number of taxa, MCI and SQMCI<sub>s</sub> values for the unnamed tributary of the Manganui River prior to and following hydraulic fracturing at Mangahewa D wellsite, together with a summary of results from control sites at a similar altitude (60m) in other lowland coastal streams (TRC, 1999, updated October 2013)

Site No.	Site Code	No of taxa		MCI value		SQMCI <sub>s</sub> value	
		15 Apr 2014	28 Aug 2014	15 Apr 2014	28 Aug 2014	15 Apr 2014	28 Aug 2014
1	MGN000489	19	20	66	71	3.3	3.6
2	MGN000492	16	15	69	77	3.3	3.5
3	MGN000493	13	27	78	85	3.7	3.5
Control sites median result		17 (61 samples)		73 (61 samples)		4.0 (33 samples)	

**Table 3** Macroinvertebrate fauna of the unnamed tributary of the Manganui River sampled on 15 April 2014 prior to HF at the Mangahewa D wellsite

Taxa List	Site Number	MCI score	Site 1	Site 2	Site 3
	Site Code		MGN000489	MGN000492	MGN000493
	Sample Number		FWB14199	FWB14200	FWB14201
PLATYHELMINTHES (FLATWORMS)	<i>Cura</i>	3	-	-	R
NEMERTEA	Nemertea	3	-	R	C
NEMATODA	Nematoda	3	-	R	-
ANNELIDA (WORMS)	Oligochaeta	1	C	A	C
HIRUDINEA (LEECHES)	Hirudinea	3	R	R	R
MOLLUSCA	<i>Gyraulus</i>	3	-	R	-
	Lymnaeidae	3	C	-	-
	<i>Physa</i>	3	A	-	-
	<i>Potamopyrgus</i>	4	VA	VA	A
	Sphaeriidae	3	R	R	-
CRUSTACEA	Ostracoda	1	A	A	R
	<i>Paracalliope</i>	5	C	-	R
EPHEMEROPTERA (MAYFLIES)	<i>Zephlebia group</i>	7	-	-	R
ODONATA (DRAGONFLIES)	<i>Ischnura</i>	4	R	-	-
	<i>Xanthocnemis</i>	4	A	R	-
HEMIPTERA (BUGS)	<i>Sigara</i>	3	C	-	-
COLEOPTERA (BEETLES)	Elmidae	6	-	R	-
	Hydrophilidae	5	R	R	-
TRICHOPTERA (CADDISFLIES)	<i>Psilochorema</i>	6	-	-	R
	<i>Oxyethira</i>	2	A	C	-
	<i>Paroxyethira</i>	2	C	-	-
	<i>Triplectides</i>	5	C	C	C
DIPTERA (TRUE FLIES)	Eriopterini	5	-	-	R
	Orthoclaadiinae	2	R	R	-
	Tanypodinae	5	R	C	-
	<i>Austrosimulium</i>	3	R	-	R
ACARINA (MITES)	Acarina	5	R	R	R
No of taxa			19	16	13
MCI			66	69	78
SQMCIs			3.3	3.3	3.7
EPT (taxa)			1	1	3
%EPT (taxa)			5	6	23
'Tolerant' taxa		'Moderately sensitive' taxa		'Highly sensitive' taxa	

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



**Table 4** Macroinvertebrate fauna of the unnamed tributary of the Manganui River sampled on 28 August 2014 following HF at the Mangahewa D wellsite.

Taxa List	Site Number	MCI score	Site 1	Site 2	Site 3
	Site Code		MGN000489	MGN000492	MGN000493
	Sample Number		FWB14234	FWB14235	FWB14236
PLATYHELMINTHES (FLATWORMS)	<i>Cura</i>	3	C	-	-
ANNELIDA (WORMS)	Oligochaeta	1	C	C	VA
	Lumbricidae	5	-	R	-
HIRUDINEA (LEECHES)	Hirudinea	3	R	-	-
MOLLUSCA	Lymnaeidae	3	-	-	R
	<i>Physa</i>	3	C	-	R
	<i>Potamopyrgus</i>	4	XA	VA	XA
	Sphaeriidae	3	R	R	R
CRUSTACEA	Ostracoda	1	R	-	-
	<i>Paracalliope</i>	5	VA	R	A
EPEMEROPTERA (MAYFLIES)	<i>Zephlebia group</i>	7	R	-	R
PLECOPTERA (STONEFLIES)	<i>Acroperla</i>	5	C	C	-
	<i>Zelandobius</i>	5	R	R	C
ODONATA (DRAGONFLIES)	<i>Xanthocnemis</i>	4	C	-	R
	<i>Antipodochlora</i>	5	-	-	R
HEMIPTERA (BUGS)	<i>Microvelia</i>	3	-	-	R
COLEOPTERA (BEETLES)	Elmidae	6	-	-	R
	Hydrophilidae	5	-	-	R
TRICHOPTERA (CADDISFLIES)	Ecnomidae/Psychomyiidae	6	-	-	R
	<i>Hydrobiosis</i>	5	-	R	R
	<i>Psilochorema</i>	6	-	-	R
	<i>Oxyethira</i>	2	A	C	A
	<i>Triplectides</i>	5	C	-	A
DIPTERA (TRUE FLIES)	<i>Aphrophila</i>	5	-	R	C
	Hexatomini	5	-	-	R
	<i>Harrisius</i>	6	-	C	R
	<i>Maoridamesa</i>	3	R	-	R
	Orthoclaadiinae	2	A	C	C
	Tanypodinae	5	R	-	-
	Tanytarsini	3	-	R	-
	Ceratopogonidae	3	R	-	-
	<i>Paradixa</i>	4	R	-	C
	<i>Austrosimulium</i>	3	XA	VA	VA
	Tanyderidae	4	-	R	C
ACARINA (MITES)	Acarina	5	-	-	R
No of taxa			20	15	27
MCI			71	77	85
SQMCIs			3.6	3.5	3.5
EPT (taxa)			4	3	6
%EPT (taxa)			20	20	22
'Tolerant' taxa		'Moderately sensitive' taxa	'Highly sensitive' taxa		

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

## Pre-HF survey

### Site 1

A moderate community richness of 19 taxa was found at site 1 (Table 2 and Table 3), two taxa more than the median richness found at similar sites elsewhere in the region (Table 2). The macroinvertebrate community was comprised of a significant proportion of 'tolerant' taxa (74 %), which was reflected in the MCI score of 66 units. This MCI score was slightly lower (7 units) than the median MCI score for 'control' sites in similar streams at comparative altitudes (Table 2).

The community at this site was characterised by five 'tolerant' taxa [snails (*Physa* and *Potamopyrgus*), ostracod seed shrimp, dragonfly larvae (*Xanthocnemis*) and axe-head caddis (*Oxyethira*)].

The numerical dominance of many 'tolerant' taxa resulted in a SQMCI<sub>s</sub> score of 3.3 units, which was slightly lower (0.7 unit) than the median score for 'control' sites in similar streams at this altitude (Table 2).

### Site 2

A moderate community richness of 16 taxa was found at site 2 (Table 2 and Table 3), three taxa less than what was found at site 1, and one taxon less than the median richness found at similar sites in the region (Table 2). The macroinvertebrate community was comprised of a high proportion of 'tolerant' taxa (69 %) which was reflected in the MCI score of 69 units. This was an insignificant 3 units higher than recorded at site 1 and an insignificant 4 units fewer than the median MCI score for 'control' sites in similar streams at comparative altitudes (Stark, 1998) (Table 2).

The community at this site was characterised by three 'tolerant' taxa [oligochaete worms, snail (*Potamopyrgus*) and ostracod seed shrimp].

The numerical dominance of numerous 'tolerant' taxa resulted in a SQMCI<sub>s</sub> score of 3.3 units, which was an insignificant 0.7 unit less than the median score for 'control' sites in similar streams at this altitude (Table 2), and the same as the upstream control site.

### Site 3

A moderately low community richness of 13 taxa was found at site 3 (Table 2 and Table 3), six taxa less than the upstream control site, and six taxa less than the median richness found at similar sites elsewhere in the region (Table 2). The macroinvertebrate community comprised of similar proportions of 'sensitive' (46 %) and 'tolerant' (54%) taxa, which was reflected in the MCI score of 78 units. This was a significant (Stark, 1998) 12 units higher than that recorded at the upstream 'control' site, nine units higher than that recorded by site 2 and four units higher than the median MCI score for 'control' sites in similar streams at comparative altitudes (Table 2).

The community at this site was characterised by one 'tolerant' taxon [snail (*Potamopyrgus*)]. A numerical dominance of one 'tolerant' taxon resulted in the SQMCI<sub>s</sub> score of 3.7 units which was an insignificant 0.3 unit less than the median score for 'control' sites in similar streams at this altitude elsewhere the region (Stark, 1998) (Table 2), and insignificantly higher (by 0.4 unit) than what was recorded at site 1.

## Post-HF survey

### Site 1

A moderate community richness of 20 taxa was found at site 1 (Table 2 and Table 4), one taxon more than that recorded by the pre-HF survey and three taxa more than the median richness found at similar sites elsewhere in the region (Table 2). The macroinvertebrate community continued to contain a significant proportion of 'tolerant' taxa (70 %), which was reflected in the MCI score of 71 units. This result represented an insignificant (Stark, 1998) increase from that recorded in the pre-HF survey (by 5 MCI units) and was similar to the median MCI score for 'control' sites in similar streams at comparative altitudes (Table 2).

The community at this site was characterised by four 'tolerant' taxa [snail (*Potamopyrgus*), orthoclad midges, axe-head caddis (*Oxyethira*) and black sandfly (*Austrosimulium*)], and one 'sensitive' taxon [amphipod (*Paracalliope*)].

The numerical dominance by 'tolerant' taxa was tempered by one very abundant 'sensitive' taxon, resulting in a SQMCI<sub>s</sub> score of 3.6 units, which was slightly higher (by 0.3 unit) than what was recorded by the pre-HF survey, but lower (0.4 unit) than the median score for 'control' sites in similar streams at this altitude (Table 2).

### Site 2

A moderate community richness of 15 taxa was found at site 2 (Table 2 and Table 4), five taxa fewer than found at site 1, one taxon less than what was recorded by the pre-HF survey and two taxa less than the median richness found at similar sites (Table 2). The macroinvertebrate community contained similar proportions of 'tolerant' (53%) and 'sensitive' (47%) taxa, which was reflected in the MCI score of 77 units; eight units higher than what was recorded during the pre-HF survey and an insignificant six units higher than at the upstream 'control' site. This MCI score was insignificantly Stark, 1998) higher (by 4 units) than the median MCI score for 'control' sites in similar streams at comparative altitudes (Table 2).

This community was characterised by two 'tolerant' taxa [snail (*Potamopyrgus*) and black sandfly larvae (*Austrosimulium*)].

The numerical dominance by two 'tolerant' taxa resulted in the SQMCI<sub>s</sub> score of 3.5 units, which was slightly higher (by 0.2 unit) than recorded by the pre-HF survey, but lower (by 0.5unit) than the median score for 'control' sites in similar streams at this altitude (Table 2). The SQMCI<sub>s</sub> score recorded at sites 1 and 2 were very similar (3.6 and 3.5 units respectively) (Table 4).

### Site 3

A high community richness of 27 taxa was found at site 3 (Table 2 and Table 4), 13 taxa more than that recorded in the pre-HF survey and 10 taxa more than the median richness found at similar sites elsewhere in the region (Table 2). Unlike the pre-HF survey the macroinvertebrate community comprised a greater proportion of 'sensitive' taxa (52 %), which was reflected in the MCI score of 85 units; an insignificant (Stark, 1998) seven units higher than the pre-HF survey. This score was a significant (Stark, 1998) 12 units higher than the median MCI score for 'control' sites in similar streams at comparative altitudes (Table 2).

This community was characterised by four 'tolerant' taxa [oligochaete worms, snail (*Potamopyrgus*), axe-head caddis (*Oxyethira*) and black sandfly larvae (*Austrosimulium*)]; and two 'sensitive' taxa [amphipod (*Paracalliope*) and stick-caddis (*Triplectides*)].

The SQMCI<sub>s</sub> score of 3.5 units recorded at site 3 in this survey represented an insignificant (Stark, 1998) 0.2 unit decrease from the SQMCI<sub>s</sub> score in the pre-HF survey and was 0.5 unit lower than the median score for 'control' sites in similar streams at this altitude elsewhere the region (TRC, 1998 (updated 2013)).

## Summary and Conclusions

A combination of the 'vegetation sweep' and 'kick-sampling' techniques was used at three sites to collect streambed macroinvertebrates from the unnamed tributary of the Manganui River of two sampling occasions. This has provided data to compare with baseline data for the assessment of hydraulic fracturing effects from the Mangahewa D 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.

The April 2014 survey of three sites was undertaken prior to hydraulic fracturing at the Mangahewa D wellsite. Taxa richnesses were moderate and similar to the median taxa richness recorded by similar 'control' sites elsewhere in the region. The macroinvertebrate communities of the stream contained relatively high proportions of 'tolerant' taxa but also moderate proportions of 'moderately sensitive' taxa. A total of 27 taxa was found through the reach of the stream surveyed, with six of these taxa (22%) found at all three sites and nine taxa (33%) found at any two of these sites. Only one 'tolerant' taxon was abundant at all three sites.

There were no significant differences in SQMCI<sub>s</sub> score between sites, however there was a significant (Stark, 1998) increase in MCI score from site 1 to site 3, which can be attributed to slight differences in habitat, in particular to the increased macrophyte and algal cover recorded at site 1. The MCI scores indicated that the stream communities were of poor 'health' (TRC, 2013) and not significantly (Stark, 1998) different to the biological health recorded at 'control' sites in similar streams at a comparative altitude elsewhere in the region.

The August 2014 survey was undertaken following hydraulic fracturing activities at the Mangahewa D wellsite. Taxa richness's at site 1 and site 2 were moderate and similar to the median richness recorded by 'control' sites in similar streams elsewhere in the region. Taxa richness at site three however, was much higher than that recorded by the pre-drill survey and higher than the median richness recorded by 'control' sites in similar streams elsewhere in the region. This can be attributed to seasonal differences and slight changes in habitat from the pre-HF to post-HF surveys. A total of 35 taxa was found through the reach of the stream surveyed, with eight of these taxa (23 %) found at all three sites and 11 taxa (31 %), found at any two of these sites.

The MCI scores recorded at site 1 and site 2 in the pre-HF survey indicated that the stream communities were of poor 'health' (TRC, 2013), but similar to the biological health recorded at 'control' sites in similar streams at a comparative altitude elsewhere in the region. Site 3 recorded an MCI score significantly (Stark, 1998) higher than the median of similar 'control' sites elsewhere in the region and indicated that the stream communities at this site were of 'fair' health.

A comparison of the pre-HF and post-HF survey results showed no significant variation in MCI and SQMCI<sub>s</sub> scores between surveys at all three sites. Slight variations in MCI and SQMCI<sub>s</sub> score and taxa richness between sites and surveys is considered to be due to habitat variability rather than a change in water quality.

There was no indication from the results of the two surveys that the hydraulic fracturing activities at the Mangahewa D wellsite have impacted on the biological communities of the unnamed tributary of the Mangahewa D wellsite.

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