Todd Energy Limited
Mangahewa-A Hydraulic Fracturing Monitoring Programme Report 2013-2015

Technical Report 2015-02

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Executive summary

Todd Energy Limited (Todd) operates the Mangahewa-A wellsite, located at Otaraoa Road, Tikorangi. The wellsite lies within the Waitara catchment and contains a hydrocarbon producing well and associated infrastructure.

Todd holds resource consent 9238-2, authorising the discharge of contaminants associated with hydraulic fracturing activities into land at depths greater than 3,200 m TVD beneath the Mangahewa-A wellsite. The consent was issued by Taranaki Regional Council (the Council) on 30 June 2014 and contains a total of 17 special conditions which set out the requirements that Todd must satisfy. This is a renewal of consent 9238-1, under which the hydraulic fracturing of the Mangahewa-05 well occurred.

The following report for the period July 2013 to August 2014 outlines and discusses the results of the monitoring programme implemented by the Council in relation to the programme of hydraulic fracturing undertaken by Todd, within their Mangahewa-A wellsite. The report also assesses Todd's level of environmental performance and compliance with the resource consent held in relation to the activity.

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

The programme of hydraulic fracturing was undertaken on the Mangahewa-05 well and took place on 18 July and 4 August 2012.

The programme of monitoring implemented by the Council in relation to fracturing activities commenced in the 2011-2012 monitoring year. The results of monitoring undertaken between April 2012 and October 2012 were presented in the 2012-2013 annual report (Taranaki Regional Council, 2013). The results of monitoring undertaken between August 2013 and August 2014 are presented in this report. Monitoring included groundwater sampling at four sites and the analysis of samples for a range of chemicals.

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

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

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

This report includes recommendations for the 2015-2016 year.

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1. Introduction

1.1 Compliance monitoring programme reports and the Resource Management Act 1991

1.1.1 Introduction

The following report outlines and discusses the results of the monitoring programme implemented by the Taranaki Regional Council (the Council) in relation to the programme of hydraulic fracturing undertaken by Todd Energy Limited (Todd) at their Mangahewa-A wellsite, Otaraoa Road, Tikorangi over the period August 2013 – August 2014. The wellsite is located in the Waitara catchment. The report also assesses Todd's level of environmental performance and compliance with the resource consents held in relation to the activity.

The programme of hydraulic fracturing undertaken by Todd at the Mangahewa-A wellsite included the fracturing of one well, Mangahewa-05. The monitoring programme implemented by the Council commenced during the 2011-2012 period. The programme has consisted of groundwater monitoring components. Surface water monitoring in relation to hydraulic fracturing events was not in practice by the Council when this well was fractured.

A report was completed in September 2013 which outlined and discussed the results of the monitoring carried out during the 2011-2012 and 2012-2013 monitoring periods. The following report provides an update on the results of further monitoring carried out since the initial report was issued and includes monitoring undertaken in the 2013-2014 and 2014-2015 monitoring period.

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 though annual programmes, the resource consent 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 interpretations, and their significance for the environment.

Section 4 presents recommendations to be implemented in the 2015-2016 monitoring year.

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

1.1.3 The Resource Management Act 1991 and monitoring

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

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

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

1.1.4 Evaluation of environmental and consent performance

Besides discussing the various details of the performance and extent of compliance by the consent holder/s 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 issues 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 are 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, formation fluids and hydrocarbons are drawn to the surface.

1.2.2 Mangahewa-A wellsite history

Surrounding land uses are predominantly agricultural and the area consists of predominantly low density housing due to its rural location. The wellsite lies in an active petrochemical exploration and production area, which includes the McKee oil field and the Kowhai and Turangi gas fields. The topography of the site is flat countryside. The Waitara River is located approximately 1.1 km southwest of the wellsite.

The Mangahewa-05 well was drilled between 18 April and 6 May 2012 and hydraulic fracturing occurred on 18 July and 4 August 2012 (Table 1). The location of the wellsite is illustrated in Figure 1.

Table 1 Summary of hydraulic fracturing activity at the Mangahewa-A wellsite.

Well	Wellsite	Consent	Date		Injection zone (m TVDss)	Formations
			First event	Second event		
Mangahewa-05	Mangahewa-A	9238-1	18/07/12	04/08/12	3,437 to 4,093	Turi & Otaraoa

A report was completed in September 2013 (Taranaki Regional Council), which outlined and discussed the results of the monitoring carried out during the 2011-2012 and 2012-2013 monitoring periods. The report presented herein provides an update on the results of further monitoring carried out since the 2013 report was written.

1.3 Resource consent

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 holds resource consent **9238-2**, authorising the discharge of water based hydraulic fracturing fluids into land at the Mangahewa-A wellsite. Consent 9238-1 was granted to Todd Taranaki Limited on 16 April 2012. It is under this consent that Mangahewa-05 was hydraulically fractured. The consent was transferred to Todd Energy Limited on 16 December 2013. On 30 June 2014, consent 9238-1 was reviewed, and four additional special conditions were added. This new consent is 9238-2. Consent 9238-2 contains a total of 17 special conditions which set out the requirements that Todd must satisfy. The conditions are summarised below.

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

Condition 2 stipulates the date after which no hydraulic fracturing fluids may be discharged.

Condition 3 requires the consent holder to ensure that the exercising of the consent does not result in any contaminants reaching any useable freshwater aquifers.

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 and the well 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 within 90 days after the commencement date.

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.

A copy of this consent is attached in Appendix I.

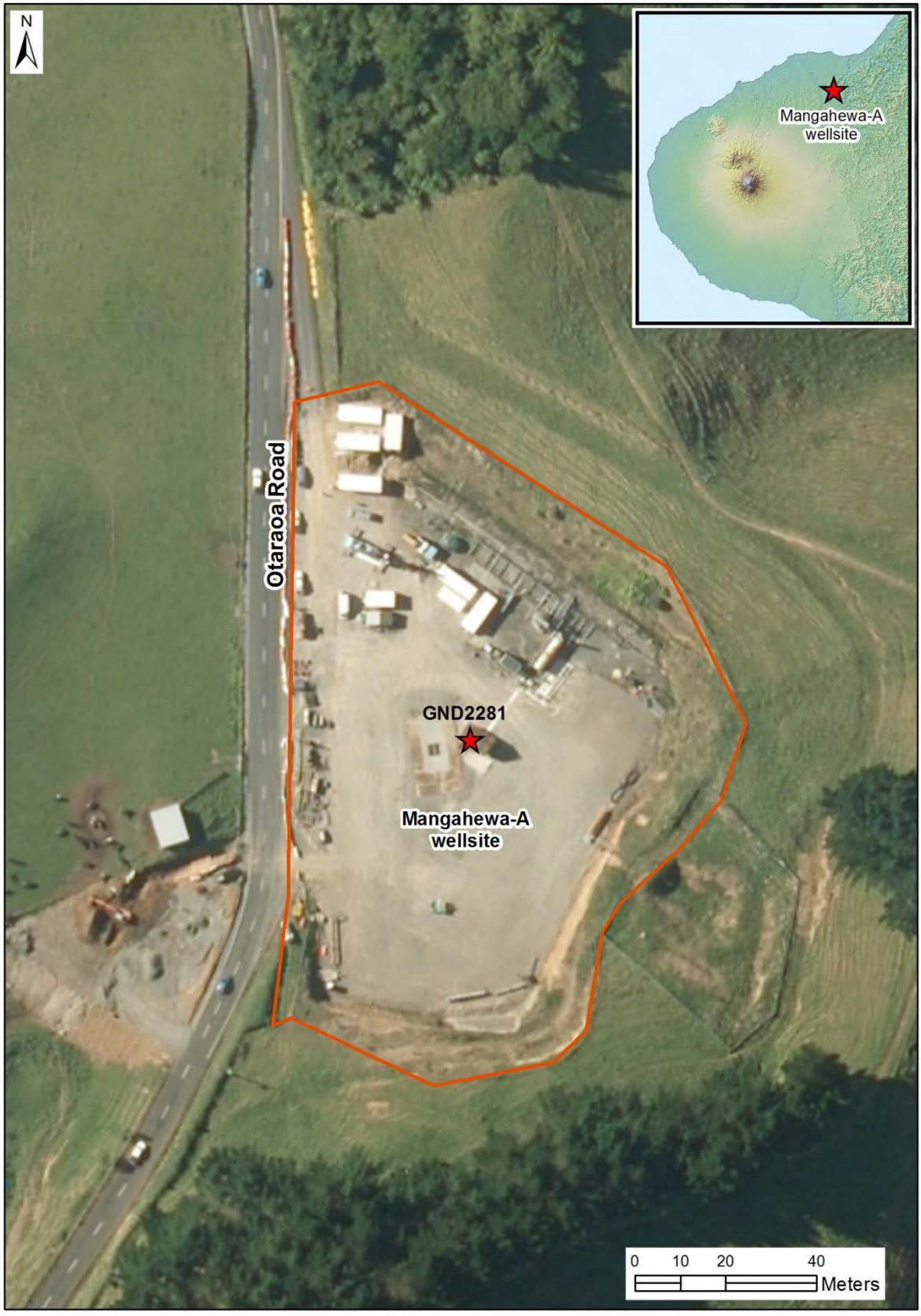

Figure 1 Location of Mangahewa-A wellsite

1.4 Monitoring programme

1.4.1 Introduction

Section 35 of the RMA sets obligations upon the Council to gather information, monitor, and conduct research on the exercise of resource consents, and the effects arising, within the Taranaki region and report upon these.

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

The monitoring programme implemented in relation to the hydraulic fracturing of the Mangahewa-05 well consisted of three primary components.

1.4.2 Programme liaison and management

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

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

1.4.3 Review of consent holder submitted data

As required by the conditions of consent 9238-1, Todd submitted a post-fracturing discharge report to the Council following the completion of the Mangahewa-05 fracturing programme. Post-fracturing reports confirm details of the fracturing activities that occurred. The specific range of information required in the report is stipulated in the conditions of the resource consent. The post-fracturing discharge report is discussed in detail in the 2011-2013 annual report (Taranaki Regional Council, 2013).

1.4.4 Chemical sampling

The groundwater monitoring programme over the period in question included the sampling of four existing groundwater supply wells located in the vicinity of the wellsite at which hydraulic fracturing took place, and the analysis of the results.

The details of each site are included in Table 2 and their proximity to the Mangahewa-A wellsite is illustrated in Figure 2.

Table 2 Details of groundwater sites included in the monitoring programme

Hydraulically fractured well	Monitoring site	Distance from wellsite (m)	Total depth (m)	Aquifer
Mangahewa-05 (GND2281)	GND1081	485	5	Taranaki Volcanics
	GND2258	1,041	5	Taranaki Volcanics
	GND2263	534	5	Taranaki Volcanics
	GND2279	575	5	Taranaki Volcanics

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

Three rounds of groundwater sampling occurred between April 2012 and October 2012. The results of these sampling rounds are outlined in the 2012-2013 annual report (Taranaki Regional Council, 2013).

Sampling was undertaken between August 2013 and August 2014 to monitor potential residual effects of the hydraulic fracturing of the Mangahewa-05 well on local groundwater resources. Where access to the bore was available, samples were obtained using a pneumatic bladder or peristaltic pump, using a low-flow sampling methodology. Where access to the bore was not available, samples were obtained at a point in the water distribution network as close to the wellhead as practicable. Samples taken from wide diameter wells were taken directly from the well. All samples were transported to Hill Laboratories Limited for analysis following standard chain of custody procedures.

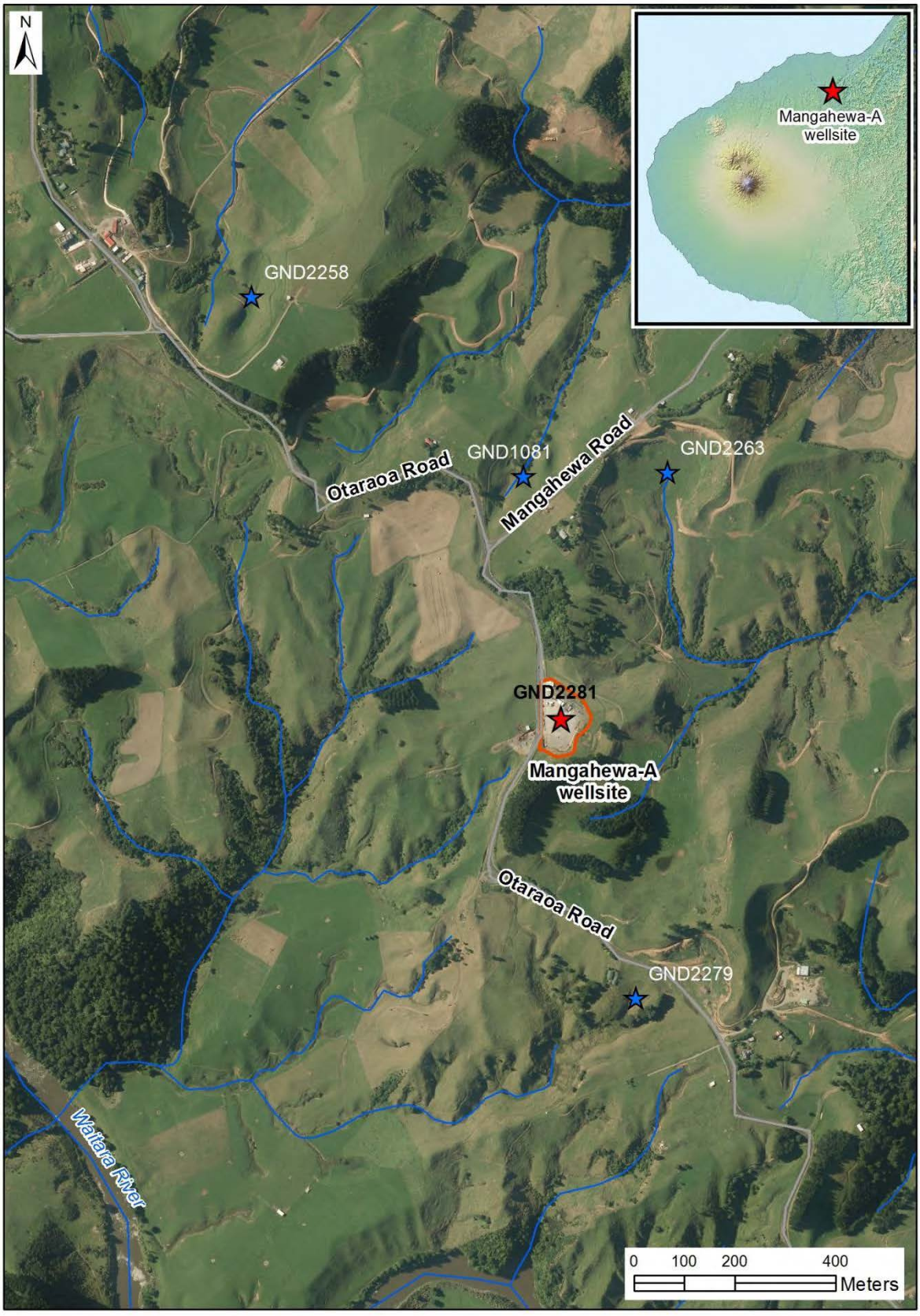

Figure 2 Location of groundwater sampling sites in relation to the Mangahewa-A wellsite

2. Results

2.1 Groundwater sampling

Between August 2013 and August 2014, groundwater samples were collected from four sites. As a continuation of the 2012–2013 annual report, key indicator parameters pH, electrical conductivity, chloride and total dissolved solids are plotted against time (Figures 3, 4, 5 and 6). If the concentration of these parameters changed it could indicate the migration of deep formation water, which is highly saline in composition, via fractures or conduits created by the hydraulic fracturing process, leakage from the wellbore due to integrity issues, or the mishandling of fluids at the surface.

The results of the monitoring carried out indicate that the pH concentrations in GND2258 and GND2263 remained consistent across the sampling period, whereas a slight increase was observed in GND1081 and GND2279. The increase in conductivity was not within a significant range. In all wells, values are still close to the pre-fracturing values. Electrical conductivity values were consistent across GND1081 and GND2258, but increased at GND2263 and GND2279. There were some minor increases in chloride concentrations in GND2263 and GND 2279 between the October 2012 and August 2013 sampling events, but these concentrations decreased between the August 2013 and August 2014 sampling events. Total dissolved solids concentrations varied slightly throughout the monitoring period. The changes in the concentrations of these four analytes are a result of natural variations in water composition and are unrelated to fracturing activities.

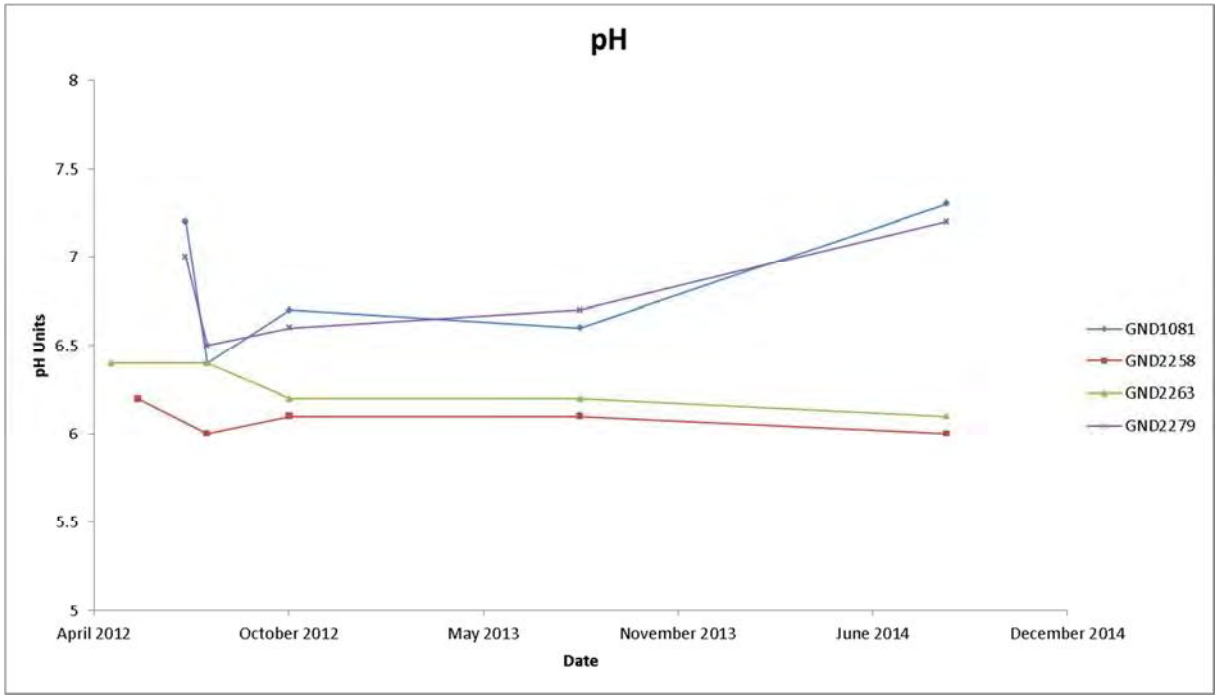

Figure 3 Results of pH analysis at private water supplies

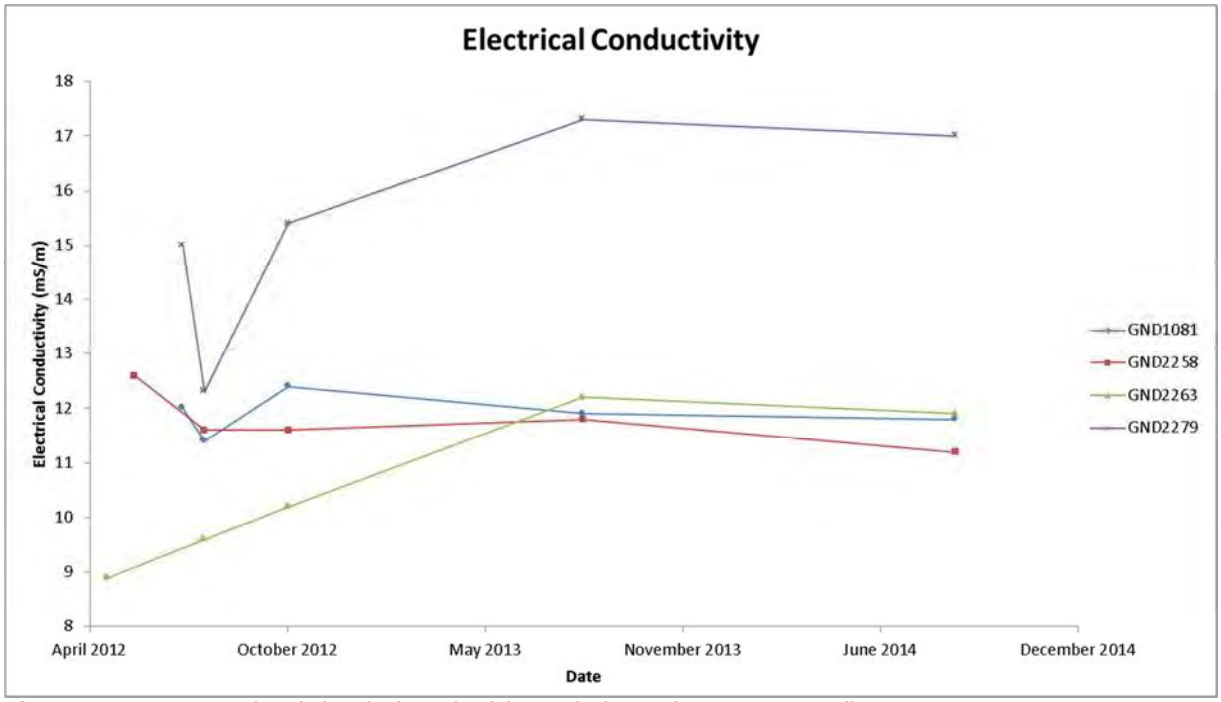

Figure 4 Results of electrical conductivity analysis at private water supplies

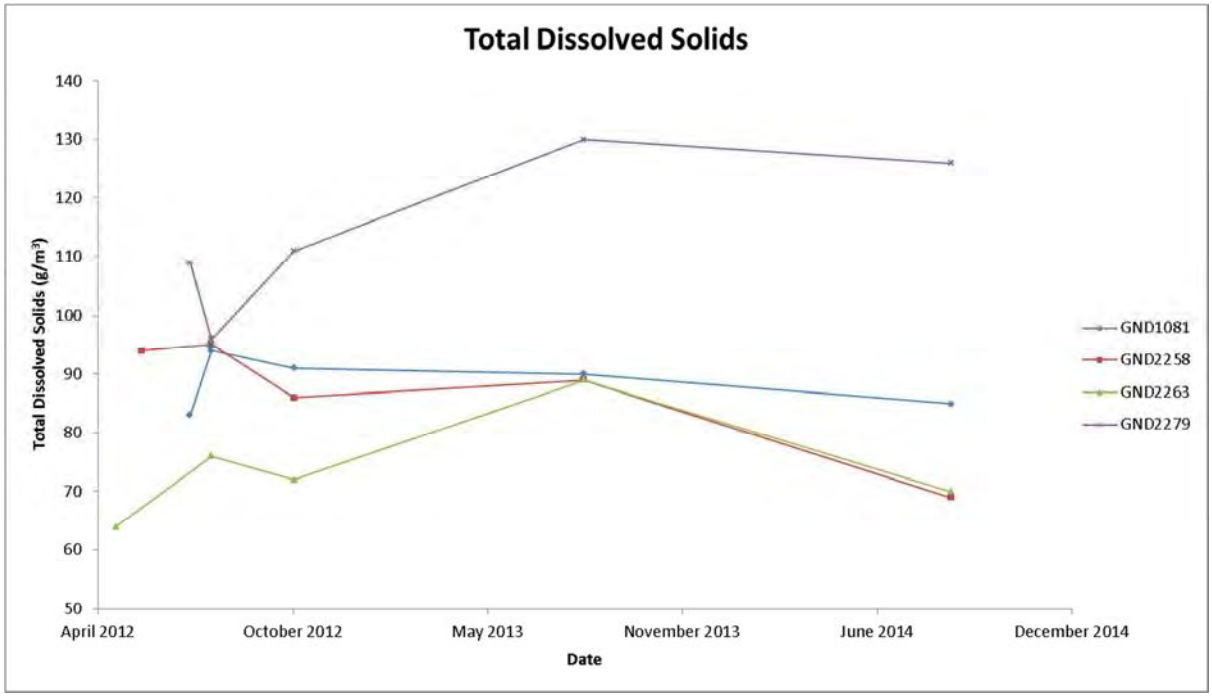

Figure 5 Results of total dissolved solids analysis at private water supplies

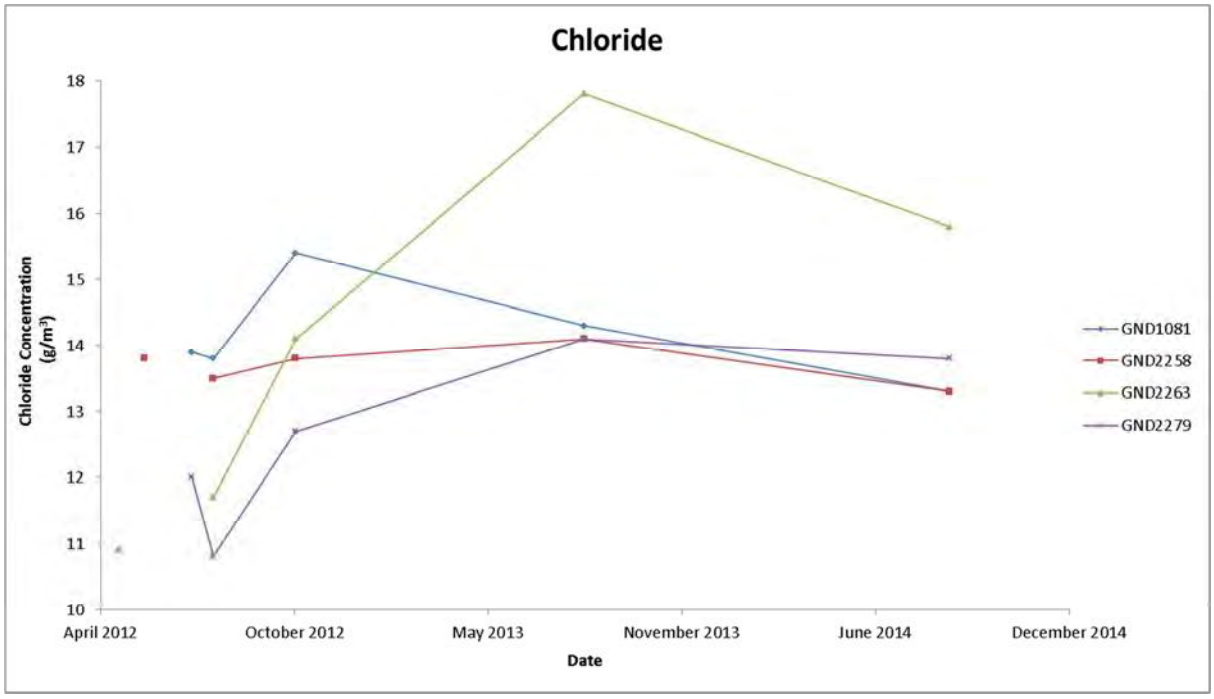

Figure 6 Results of chloride analysis at private water supplies

There were no traces of any substance associated with hydraulic fracturing fluids, or hydrocarbons relating to fracturing activities, in any of the post-fracturing samples obtained from the private water supply wells during the monitoring period. No methane was detected at any sites sampled.

The certificates of analysis are included in Appendix II. The full results of the groundwater monitoring carried out during the period under review are included in Appendix III.

2.2 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, there was no requirement for the Council to undertake any significant additional investigations and/or interventions, or record incidents, in association with the conditions in Todd's resource consent for hydraulic fracturing at the Mangahewa-A wellsite or provisions in Regional Plans.

3. Discussion

3.1 Environmental effects of hydraulic fracturing on useable freshwater resources

This is a report regarding monitoring for residual environmental effects post hydraulic fracturing that occurred in the 2011-2012 period.

To assess the level of environmental performance and compliance by Todd during the period being reported, the monitoring programme implemented by the Council consisted primarily of a groundwater monitoring component. The groundwater monitoring component of the programme included the sampling of groundwater at selected sites in the vicinity of the hydraulically fractured well. The groundwater system was surveyed prior to any hydraulic fracturing occurring to determine baseline conditions, allowing comparisons to be made with post-fracturing results.

The results of post-fracturing groundwater sampling carried out in the vicinity of the Mangahewa-05 well showed only very minor variations in water composition in comparison to baseline results. The minor variations in some analytes are a result of natural variations in water composition and unrelated to fracturing activities.

No traces of substances associated with hydraulic fracturing fluids, or hydrocarbons relating to fracturing activities were present in the groundwater. No methane was present in any of the groundwater samples taken.

In summary, the monitoring carried out by the Council indicates that the hydraulic fracturing activities undertaken by Todd prior to the monitoring period being reported, had no subsequential adverse effects on local groundwater 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 3.

Table 3 Summary of performance for Consent 9238-2:
To discharge contaminants in association with hydraulic fracturing activities into land at depths greater than 3,410 mTVD beneath the Mangahewa-A wellsite.

Condition requirement	Means of monitoring during period under review	Compliance achieved?
1. Any discharge shall occur below 3,410 mTVD	Assessment of consent holder submitted data	Yes
2. No discharge shall occur after 1 June 2019	Assessment of consent holder submitted data	N/A
3. Exercise of consent shall not result in any contaminants reaching any useable freshwater aquifers	Results of groundwater monitoring	Yes
4. Consent holder shall undertake sampling programme	Development and certification of a monitoring programme	Yes

5. It may be necessary to install at least one monitoring bore if no suitable existing bores are present	Assessment of consent holder submitted data	N/A
6. All water samples taken to be analysed for a certain set of parameters.	Assessment of consent holder submitted data	Yes
7. All sampling to be carried out in accordance with a certified sampling and analysis plans	Development and certification of a sampling and analysis plan	Yes
8. Well and equipment pressure testing to be carried out prior to any hydraulic fracturing programme commencing	Assessment of consent holder submitted data	Yes
9. A pre-fracturing discharge report is to be provided to the council 14 days prior to discharge	Pre-fracturing discharge report received	Yes
10. Consent holder shall notify the Council of hydraulic fracturing discharge	Notification received	Yes
11. A post-fracturing discharge report is to be provided to the Council within 90 days of any commencement date	Post-fracturing discharge report received	Yes
12. The reports outlined in conditions 9 and 11 must be emailed to consents@trc.govt.nz	Reports received via email	Yes
13. The consent holder shall provide access to a location where samples of hydraulic fracturing fluids and return fluids can be obtained by the Council officers	Access provided	Yes
14. Consent holder to adopt best practicable option at all times	Site inspections, sampling and assessment of consent holder submitted data	Yes
15. No hydrocarbon based hydraulic fracturing fluid shall be discharged	Assessment of consent holder submitted data and sampling of fracturing fluid	Yes
16. Lapse clause	Receive notifice of exercise of consent	Yes
17. Notice of Council to review consent	No provision for review during period	N/A
Overall assessment of environmental performance and compliance in respect of this consent		High
Overall assessment of administrative performance and compliance in respect of this consent		High

During the 2013-2015 monitoring period, Todd demonstrated a high level of environmental and administrative performance and compliance with its resource consents as defined in Section 1.1.4.

3.3 Alterations to monitoring programmes for 2015-2016

In designing and implementing the monitoring programmes for air/water discharges in the region, the Council has taken into account the extent of information made available by previous authorities, its relevance under the RMA the obligations of the RMA in terms of monitoring 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 discharging to the environment.

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

3.4 Exercise of optional review of consent

Resource consent 9238-2 provides for an optional review of the consent on 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 that 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.

4. Recommendations

1. THAT no further monitoring be carried out in relation to previously undertaken hydraulic fracturing events at the Mangahewa-A wellsite. Monitoring should recommence however if any further fracturing is undertaken at the site.

2. THAT the option for a review of the resource consent in June 2015, as set out in condition 17 of consent 9238-2, is not exercised, on the grounds that the current conditions of the consents are adequate to ensure that any significant adverse effects on the environment are avoided.

Glossary of common terms and abbreviations

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

g/m^3	Grams per cubic metre, and equivalent to milligrams per litre (mg/L). In water, this is also equivalent to parts per million (ppm), but the same does not apply to gaseous mixtures.
Incident	An event that is alleged or is found to have occurred that may have actual or potential environmental consequences or may involve non-compliance with a consent or rule in a regional plan. Registration of an incident by the Council does not automatically mean such an outcome had actually occurred.
Intervention	Action/s taken by Council to instruct or direct actions be taken to avoid or reduce the likelihood of an incident occurring.
Investigation	Action taken by Council to establish the circumstances/events surrounding an incident including any allegations of an incident.
mS/m	Millisiemens per metre.
m^3	Cubic metre (1,000 litres).
pH	A numerical system for measuring acidity in solutions, with 7 as neutral. Numbers lower than 7 are increasingly acidic and higher than 7 are increasingly alkaline. The scale is logarithmic i.e. a change of 1 represents a ten-fold change in strength. For example, a pH of 4 is ten times more acidic than a pH of 5.
Resource consent	Refer Section 87 of the RMA. Resource consents include land use consents (refer Sections 9 and 13 of the RMA), coastal permits (Sections 12, 14 and 15), water permits (Section 14) and discharge permits (Section 15).
RMA	*Resource Management Act* 1991 and including all subsequent amendments.

Bibliography and references

Taranaki Regional Council (2012) Mangahewa-A Groundwater Monitoring Programme 2012-2013 Sampling and Analysis Plan.

Taranaki Regional Council (2013) Mangahewa-A Hydraulic Fracturing Groundwater Monitoring Programme Report 2012-2013. Technical Report 2013-19.

TODD Energy Limited (2012) Mangahewa-05 Post Fracturing Discharge Report.

Appendix I

Resource consent 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 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 3200 mTVDss beneath the Mangahewa-A wellsite
Expiry Date:	01 June 2024
Review Date(s):	June annually
Site Location:	Mangahewa-A wellsite, Otaraoa Road, Tikorangi (Property owner: F & K Wyatt & K & M Downs)
Legal Description:	Lot 2 DP 384951 (Discharge source & site)
Grid Reference (NZTM)	1714115E-5674291N
Catchment:	Waitara

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 3200 mTVDss.

   Note: mTVDss = metres true vertical depth subsea, i.e., the true vertical depth in metres below mean sea level.

2. There shall be no discharge of hydraulic fracturing fluids after 1 June 2019.

3. The consent holder shall ensure that the exercise of this consent does not result in contaminants reaching any useable fresh water (groundwater or surface water). Usable fresh groundwater is defined as any groundwater having a Total Dissolved Solids concentration of less than 1000 mg/l.

4. The consent holder shall undertake a programme of sampling and testing that monitors the effects of the exercise of this consent on fresh water resources to assess compliance with condition 3 (the 'Monitoring Programme'). The Monitoring Programme shall be certified by the Chief Executive, Taranaki Regional Council ('the Chief Executive'), before this consent is exercised, and shall include:

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

5. Depending on the suitability of existing bores within 500 metres of the wellsite for obtaining a representative groundwater sample, it may be necessary for the Monitoring Programme to include installation of, and sampling from, at least one monitoring bore. The bore(s) would be of a depth, location and design determined after consultation with the Chief Executive, Taranaki Regional Council and installed in accordance with NZS 4411:2001.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Signed at Stratford on 30 June 2014

For and on behalf of
Taranaki Regional Council

_____

A D McLay
Director - Resource Management

Appendix II

Certifcates of analysis

Hill Laboratories
BETTER TESTING BETTER RESULTS

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

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

ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1316016 SPv1
Contact:	Regan Phipps	**Date Registered:**	26-Aug-2014
	C/- Taranaki Regional Council	**Date Reported:**	08-Sep-2014
	Private Bag 713	**Quote No:**	47915
	STRATFORD 4352	**Order No:**	
		Client Reference:	Mangatewa A - Post HF GW
		Submitted By:	Regan Phipps

Sample Type: Aqueous

Sample Name:		GND2258 25-Aug-2014 9:18 am	GND2263 25-Aug-2014 10:38 am	GND1081 25-Aug-2014 11:20 am	GND2279 25-Aug-2014 12:02 pm	
Lab Number:		1316016.1	1316016.2	1316016.3	1316016.4	
Individual Tests						
Sum of Anions	meq/L	0.99	1.06	1.09	1.65	-
Sum of Cations	meq/L	1.00	1.06	1.08	1.62	-
pH	pH Units	6.0	6.1	7.3	7.2	-
Total Alkalinity	g/m³ as $CaCO_3$	17.4	17.7	21	53	-
Bicarbonate	g/m³ at 25°C	21	22	26	65	-
Total Hardness	g/m³ as $CaCO_3$	28	32	30	56	-
Electrical Conductivity (EC)	mS/m	11.2	11.9	11.8	17.0	-
Total Dissolved Solids (TDS)	g/m³	69	70	85	126	-
Dissolved Barium	g/m³	0.068	0.0120	0.0157	0.0107	-
Dissolved Bromine*	g/m³	0.063	0.056	0.063	0.071	-
Dissolved Calcium	g/m³	6.0	6.7	6.4	13.6	-
Dissolved Copper	g/m³	0.0033	< 0.0005	< 0.0005	< 0.0005	-
Dissolved Iron	g/m³	< 0.02	0.36	< 0.02	< 0.02	-
Dissolved Magnesium	g/m³	3.2	3.7	3.3	5.3	-
Dissolved Manganese	g/m³	0.0046	0.0063	< 0.0005	< 0.0005	-
Dissolved Mercury	g/m³	< 0.00008	< 0.00008	< 0.00008	< 0.00008	-
Dissolved Nickel	g/m³	0.0005	< 0.0005	< 0.0005	< 0.0005	-
Dissolved Potassium	g/m³	3.3	1.66	1.51	1.54	-
Dissolved Sodium	g/m³	8.0	8.3	10.3	10.6	-
Dissolved Zinc	g/m³	0.034	0.0012	0.0016	0.0017	-
Chloride	g/m³	13.3	15.8	13.3	13.5	-
Nitrite-N	g/m³	< 0.002	< 0.002	< 0.002	< 0.002	-
Nitrate-N	g/m³	2.5	2.2	2.9	1.20	-
Nitrate-N + Nitrite-N	g/m³	2.5	2.2	2.9	1.20	-
Sulphate	g/m³	4.2	5.2	3.9	6.1	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	< 4	< 4	< 4	< 4	-
Propylene Glycol in Water						
Propylene glycol*	g/m³	< 4	< 4	< 4	< 4	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m³	< 2	< 2	< 2	< 2	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	-
Toluene	g/m³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	-
Ethylbenzene	g/m³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	-
m&p-Xylene	g/m³	< 0.002	< 0.002	< 0.002	< 0.002	-

Sample Type: Aqueous						
Sample Name:		GND2258 25-Aug-2014 9:18 am	GND2263 25-Aug-2014 10:38 am	GND1081 25-Aug-2014 11:20 am	GND2279 25-Aug-2014 12:02 pm	
Lab Number:		1316016.1	1316016.2	1316016.3	1316016.4	
BTEX in Water by Headspace GC-MS						
o-Xylene	g/m³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m³	< 0.02	< 0.02	< 0.02	< 0.02	-
Gases in groundwater						
Ethane	g/m³	< 0.003	< 0.003	< 0.003	< 0.003	-
Ethylene	g/m³	< 0.003	< 0.003	< 0.003	< 0.003	-
Methane	g/m³	< 0.002	< 0.002	< 0.002	< 0.002	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m³	< 0.10	< 0.10	< 0.10	< 0.10	-
C10 - C14	g/m³	< 0.2	< 0.2	< 0.2	< 0.2	-
C15 - C36	g/m³	< 0.4	< 0.4	< 0.4	< 0.4	-
Total hydrocarbons (C7 - C36)	g/m³	< 0.7	< 0.7	< 0.7	< 0.7	-

SUMMARY OF METHODS

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

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

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1-4
Dissolved Mercury	0.45µm filtration, bromine oxidation followed by atomic fluorescence. US EPA Method 245.7, Feb 2005.	0.00008 g/m³	1-4
Dissolved Nickel	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1-4
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m³	1-4
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m³	1-4
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0010 g/m³	1-4
Chloride	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl^- E (modified from continuous flow analysis) 22nd ed. 2012.	0.5 g/m³	1-4
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012.	0.002 g/m³	1-4
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m³	1-4
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012.	0.002 g/m³	1-4
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B 22nd ed. 2012.	0.5 g/m³	1-4

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

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

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

Hill Laboratories
BETTER TESTING BETTER RESULTS

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

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

ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1166991 SPv1
Contact:	Regan Phipps	**Date Registered:**	14-Aug-2013
	C/- Taranaki Regional Council	**Date Reported:**	22-Aug-2013
	Private Bag 713	**Quote No:**	47915
	STRATFORD 4352	**Order No:**	
		Client Reference:	Mangahewa A - GW Monitori
		Submitted By:	R McDonnell

Sample Type: Aqueous

Sample Name:		GND 2263 13-Aug-2013 11:50 am	GND 1081 13-Aug-2013 12:30 pm	GND 2279 13-Aug-2013 11:10 am	GND 2258 13-Aug-2013 1:10 pm	
Lab Number:		1166991.1	1166991.2	1166991.3	1166991.4	
Individual Tests						
Sum of Anions	meq/L	1.09	1.09	1.69	1.04	-
Sum of Cations	meq/L	1.03	1.06	1.67	1.05	-
pH	pH Units	6.2	6.6	6.7	6.1	-
Total Alkalinity	g/m³ as $CaCO_3$	17.4	22	54	18.9	-
Bicarbonate	g/m³ at 25°C	21	26	66	23	-
Total Hardness	g/m³ as $CaCO_3$	31	29	57	30	-
Electrical Conductivity (EC)	mS/m	12.2	11.9	17.3	11.8	-
Total Dissolved Solids (TDS)	g/m³	89	90	130	89	-
Dissolved Barium	g/m³	0.0119	0.0151	0.0095	0.082	-
Dissolved Bromine*	g/m³	0.047	0.051	0.058	0.058	-
Dissolved Calcium	g/m³	6.5	6.4	13.6	6.7	-
Dissolved Copper	g/m³	< 0.0005	0.0008	< 0.0005	0.0010	-
Dissolved Iron	g/m³	< 0.02	< 0.02	< 0.02	< 0.02	-
Dissolved Magnesium	g/m³	3.7	3.2	5.5	3.2	-
Dissolved Manganese	g/m³	0.0014	0.0035	< 0.0005	0.0032	-
Dissolved Mercury	g/m³	< 0.00008	< 0.00008	< 0.00008	< 0.00008	-
Dissolved Nickel	g/m³	< 0.0005	< 0.0005	< 0.0005	< 0.0005	-
Dissolved Potassium	g/m³	1.58	1.31	1.51	3.9	-
Dissolved Sodium	g/m³	8.3	10.3	11.6	8.1	-
Dissolved Zinc	g/m³	0.0049	0.0030	0.0017	0.0127	-
Chloride	g/m³	17.8	14.3	14.1	14.1	-
Nitrite-N	g/m³	< 0.002	0.003	< 0.002	< 0.002	-
Nitrate-N	g/m³	1.96	2.5	1.33	2.5	-
Nitrate-N + Nitrite-N	g/m³	1.96	2.5	1.33	2.5	-
Sulphate	g/m³	4.9	4.0	5.6	4.4	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	< 4	< 4	< 4	< 4	-
Propylene Glycol in Water						
Propylene glycol*	g/m³	< 4	< 4	< 4	< 4	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m³	< 2	< 2	< 2	< 2	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	-
Toluene	g/m³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	-
Ethylbenzene	g/m³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	-
m&p-Xylene	g/m³	< 0.002	< 0.002	< 0.002	< 0.002	-

Sample Type: Aqueous						
Sample Name:		GND 2263 13-Aug-2013 11:50 am	GND 1081 13-Aug-2013 12:30 pm	GND 2279 13-Aug-2013 11:10 am	GND 2258 13-Aug-2013 1:10 pm	
Lab Number:		1166991.1	1166991.2	1166991.3	1166991.4	
BTEX in Water by Headspace GC-MS						
o-Xylene	g/m³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m³	< 0.02	< 0.02	< 0.02	< 0.02	-
Gases in groundwater						
Ethane	g/m³	< 0.003	< 0.003	< 0.003	< 0.003	-
Ethylene	g/m³	< 0.004	< 0.004	< 0.004	< 0.004	-
Methane	g/m³	< 0.002	< 0.002	< 0.002	< 0.002	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m³	< 0.10	< 0.10	< 0.10	< 0.10	-
C10 - C14	g/m³	< 0.2	< 0.2	< 0.2	< 0.2	-
C15 - C36	g/m³	< 0.4	< 0.4	< 0.4	< 0.4	-
Total hydrocarbons (C7 - C36)	g/m³	< 0.7	< 0.7	< 0.7	< 0.7	-

SUMMARY OF METHODS

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

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Samples**
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	-	1-4
Propylene Glycol in Water*	Direct injection, dual column GC-FID	-	1-4
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	-	1-4
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	-	1-4
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS	-	1-4
Gases in groundwater	Manual headspace creation and sub-sampling, GC-FID analysis.	-	1-4
Total Petroleum Hydrocarbons in Water	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734]	-	1-4
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1-4
Total anions for anion/cation balance check	Calculation: sum of anions as mEquiv/L.	0.07 meq/L	1-4
Total cations for anion/cation balance check	Calculation: sum of cations as mEquiv/L.	0.05 meq/L	1-4
pH	pH meter. APHA 4500-H^+ B 21st ed. 2005.	0.1 pH Units	1-4
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (Modified for alk <20) 21st ed. 2005.	1.0 g/m³ as $CaCO_3$	1-4
Bicarbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO_2 D 21st ed. 2005.	1.0 g/m³ at 25°C	1-4
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 21st ed. 2005.	1.0 g/m³ as $CaCO_3$	1-4
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 21st ed. 2005.	0.1 mS/m	1-4
Total Dissolved Solids (TDS)	Filtration through GF/C (1.2 µm), gravimetric. APHA 2540 C (modified; drying temperature of 103 - 105°C used rather than 180 ± 2°C) 21st ed. 2005.	10 g/m³	1-4
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.00010 g/m³	1-4
Dissolved Bromine*	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.005 g/m³	1-4
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.05 g/m³	1-4
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.0005 g/m³	1-4
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.02 g/m³	1-4
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.02 g/m³	1-4

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Samples**
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.0005 g/m³	1-4
Dissolved Mercury	0.45µm filtration, bromine oxidation followed by atomic fluorescence. US EPA Method 245.7, Feb 2005.	0.00008 g/m³	1-4
Dissolved Nickel	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.0005 g/m³	1-4
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.05 g/m³	1-4
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.02 g/m³	1-4
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.0010 g/m³	1-4
Chloride	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl^- E (modified from continuous flow analysis) 21st ed. 2005.	0.5 g/m³	1-4
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3- I 21st ed. 2005.	0.002 g/m³	1-4
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N.	0.002 g/m³	1-4
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I 21st ed. 2005.	0.002 g/m³	1-4
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B 21st ed. 2005.	0.5 g/m³	1-4

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

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

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

Appendix III

Results of physico-chemical analysis

Parameter	Unit	GND1081					GND2258					GND2263					GND2279				
		Pre-frac		Post-frac			Pre-frac		Post-frac			Pre-frac		Post-frac			Pre-frac		Post-frac		
Sample date		04 Jul 2012	26 Jul 2012	19 Oct 2012	13 Aug 2013	25 Aug 2014	16 May 2012	26 Jul 2012	19 Oct 2012	13 Aug 2013	25 Aug 2014	19 Apr 2012	26 Jul 2012	19 Oct 2012	13 Aug 2013	25 Aug 2014	04 Jul 2012	26 Jul 2012	19 Oct 2012	13 Aug 2013	25 Aug 2014
Alkalinity	g/m^3 as $CaCO_3$	22	22	21	22	21	25	18	18.5	18.9	17.4	18	17.5	17	17.4	17.7	47	37	48	54	53
Barium	g/m^3	0.0165	0.0153	0.016	0.0151	0.0157	0.076	0.091	0.08	0.082	0.068	0.0082	0.0097	0.0102	0.0119	0.0120	0.0108	0.0101	0.0095	0.0095	0.0107
Benzene	g/m^3	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.001	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Bromine	g/m^3	<0.05	0.07	0.1	0.051	0.063	0.06	0.07	0.07	0.058	0.063	<0.05	<0.05	<0.05	0.047	0.056	0.06	<0.05	0.07	0.058	0.071
Calcium	g/m^3	6.6	6	6.6	6.4	6.4	7.5	6.9	6.7	6.7	6.0	4.9	5.3	5.9	6.5	6.7	11.8	9.6	12.2	13.6	13.6
Chloride	g/m^3	13.9	13.8	15.4	14.3	13.3	13.8	13.5	13.8	14.1	13.3	10.9	11.7	14.1	17.8	15.8	12	10.8	12.7	14.1	13.5
ElectricalConductivity	mS/m	12	11.4	12.4	11.9	11.8	12.6	11.6	11.6	11.8	11.2	8.9	9.6	10.2	12.2	11.9	15	12.3	15.4	17.3	17.0
Dissolved Copper	g/m^3	<0.0005	0.0009	0.0007	0.0008	<0.0005	0.0042	0.0007	<0.0005	0.0010	0.0033	<0.0005	0.0076	<0.0005	<0.0005	<0.0005	0.0007	<0.0005	<0.0005	<0.0005	<0.0005
Ethylbenzene	g/m^3	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Ethane	g/m^3	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Ethylene	g/m^3	<0.004	<0.004	<0.004	<0.004	<0.003	<0.004	<0.004	<0.004	<0.004	<0.003	<0.004	<0.004	<0.004	<0.004	<0.003	<0.004	<0.004	<0.004	<0.004	<0.003
Dissolved Iron	g/m^3	<0.02	<0.02	<0.02	<0.02	<0.02	0.1	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.36	<0.02	<0.02	<0.02	<0.02	<0.02
Formaldehyde	g/m^3	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Ethylene Glycol	g/m^3	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4
Total Petroleum Hydrocarbons	g/m^3	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7
Bicarbonate	g/m^3 $CACO_3$	27	27	25	26	25.6	30.5	22	23	23	21.2	22	21	21	21	21.6	58	45	58	66	64.7
Total Hardness	g/m^3	30	28	30	29	30	34	30	30	30	28	24	25	29	31	32	49	39	52	57	56
Potassium	g/m^3	1.45	1.46	2.5	1.31	1.51	3.8	3.7	3.6	3.9	3.3	1.42	1.61	1.42	1.58	1.66	1.54	1.3	1.38	1.51	1.54
Methanol	g/m^3	<2	<2	<2	<2	<2	<2	<2	<4	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Methane	g/m^3	<0.002	<0.002	<0.002	<0.002	<0.002	0.003	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Magnesium	g/m^3	3.3	3.1	3.3	3.2	3.3	3.7	3.1	3.2	3.2	3.2	2.9	3	3.4	3.7	3.7	4.8	3.7	5.1	5.5	5.3
Dissolved manganese	g/m^3	<0.0005	0.0009	0.0044	0.0035	<0.0005	0.053	0.0011	0.0019	0.0032	0.0046	0.0013	0.0023	0.0009	0.0014	0.0063	0.0006	<0.0005	<0.0005	<0.0005	<0.0005
Sodium	g/m^3	10.3	9.7	10.5	10.3	10.3	7.7	7.5	7.8	8.1	8.0	7	7.1	7.5	8.3	8.3	10.1	8.6	10.2	11.6	10.6
Nickel	g/m^3	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.0006	<0.0005	<0.0005	<0.0005	0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Nitrate + Nitrite	g/m^3	2.8	2.4	2.7	2.5	2.9	2.4	3.1	2.8	2.5	2.5	1.03	1.33	1.51	1.96	2.2	0.9	0.65	1.13	1.33	1.20
Nitrite	g/m^3	<0.002	<0.002	0.007	0.003	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Nitrate	g/m^3	2.7	2.4	2.7	2.5	2.9	2.4	3.1	2.8	2.5	2.5	1.03	1.33	1.51	1.96	2.2	0.9	0.65	1.13	1.33	1.20
pH	pH units	7.2	6.4	6.7	6.6	7.3	6.2	6	6.1	6.1	6.0	6.4	6.4	6.2	6.2	6.1	7	6.5	6.6	6.7	7.2
Sulphate	g/m^3	4.2	4.1	4.3	4.0	3.9	3.9	4.2	4.5	4.4	4.2	6.3	5.6	5.6	4.9	5.2	6.2	5.4	5.7	5.6	6.1
Total Dissolved Solids	g/m^3	83	94	91	90	85	94	95	86	89	69	64	76	72	89	70	109	96	111	130	126
Temperature	deg C	14.5	14.7		13.6	13.9	14	14.3	14.9	14.8	14.6		13.3	12.7	13.8	13.3	14.3	13.5	14.5	14.1	13.7
Toluene	g/m^3	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
m-Xylene	g/m^3	<0.002	<0.002	<0.002	<0.0010	<0.0010	<0.002	<0.002	<0.002	<0.0010	<0.0010	<0.002	<0.002	<0.002	<0.0010	<0.0010	<0.002	<0.002	<0.002	<0.0010	<0.0010
o-Xylene	g/m^3	<0.0010	<0.0010	<0.0010	<0.002	<0.002	<0.001	<0.0010	<0.0010	<0.002	<0.002	<0.0010	<0.0010	<0.0010	<0.002	<0.002	<0.0010	<0.0010	<0.0010	<0.002	<0.002
Dissolved Zinc	g/m^3	0.0021	0.0061	0.0036	0.0030	0.0016	0.028	0.0182	0.0108	0.0127	0.034	0.0012	0.0136	0.0022	0.0049	0.0012	0.0072	0.0031	<0.0010	0.0017	0.0017