Guide to

regulating oil and gas exploration and development activities under the Resource Management Act

Taranaki
Regional Council

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1. Introduction

This section outlines the purpose, scope and structure of the guide. It also contains a brief description on how to use the guide.

1.1 Purpose of document

The purpose of this document is to provide a guide to regulating petroleum exploration activities under the Resource Management Act 1991.

The guide is primarily intended for the information of consenting, monitoring and enforcement staff in regional councils, district councils and other regulators to promote good practice in this area, built up over more than 30 years of regulation, and a consistent and integrated approach to regulating petroleum exploration in New Zealand among the various agencies involved.

In fulfilling this purpose, the document has other uses. In particular, it provides access to a wide range of information on the different operations and processes involved in petroleum exploration which will assist in improving the understanding of petroleum exploration activities and in particular, hydraulic fracturing operations. This will be useful to regions and communities outside of Taranaki where oil and gas exploration is not yet undertaken or well established, but could become so in future.

In presenting comprehensive and up to date information on petroleum exploration, and effective and efficient approaches and methods for managing its environmental effects, the guide assists in providing assurances to local communities that petroleum exploration activities are and can be managed appropriately consistent with international best practice applied with regard to local circumstances.

1.2 Scope

The focus of the guide is on the regulation of petroleum exploration activities under the Resource Management Act 1991 (RMA). It is worth noting that the purpose of the RMA is to promote the sustainable management of natural and physical resources. Under the RMA 'sustainable management' means:

> *'…managing the use, development and protection of natural and physical resources in a way, or at a rate, which enable people and communities to provide for their social, economic, and cultural well being and for their health and safety while –*
>
> *a) Sustaining the potential of natural and physical resources (excluding minerals) to meet the reasonably foreseeable needs of future generations; and*
> *b) Safeguarding the life-supporting capacity of air, water, soil, and ecosystems; and*
> *c) Avoiding, remedying, or mitigating any adverse effects of activities on the environment.'*

The guide therefore provides information and guidance on how these requirements can be weighed up and balanced in decision-making processes and subsequently monitored and enforced to ensure compliance with the outcomes sought.

The guide also includes information and discussion on other statutes and regulations that apply to petroleum exploration and which are administered by other agencies. This is to provide context for the regulatory activities of regional councils and territorial authorities under the RMA and to promote integrated management.

The guide presents information on all aspects of wellsite operations including exploration drilling, well construction and subsurface assessment. It contains an in-depth discussion of hydraulic fracturing operations in a separate chapter in recognition of the public interest in this aspect of petroleum exploration and the lack to date of accurate, relevant and succinct information to inform public and regulator understanding. Hydraulic fracturing can be used in the production phase as well as the exploration phase.

The guide deals with regulating oil and gas industry exploration, appraisal and development activities. It does not deal with the oil and gas production or subsequent use in manufacturing or industry, although the Council also has long experience in these areas.

Given the primary purpose of the document, a significant part of the guide deals with resource consent considerations in regulating petroleum exploration activities under the RMA. There are also important matters allied with resource consenting processes – cost recovery, public reporting and benchmarking – that are also dealt with in the guide.

Finally in relation to scope, the guide draws heavily on the experience of the Taranaki Regional Council as Taranaki is currently the only oil and gas producing region in the country. The guide sets out current practices which have evolved over many years and are reflected in resource consent conditions and monitoring approaches. While the guide draws on the Taranaki experience, this is considered highly relevant and useful for other councils and regulators to consider in other parts of New Zealand because of the very long experience Taranaki has in oil and gas exploration and the degree to which its approaches have been successfully applied and refined over many years. Of course, the details of environmental effects assessments, consent requirements, etc., will need to be tailored specifically to the particular circumstances of each region.

1.3 Structure

The structure of the report is as follows:

Section 1 **Introduction** sets out the purpose of the document, its scope and structure and how to use the document.

Section 2 **Background** provides background to the oil and gas industry in New Zealand, the environmental effects and their regulation based on the Taranaki experience under the RMA and regional council collaboration on regulation of the industry.

Section 3 **Subsurface assessment, well construction and exploration drilling** describes the well development and well drilling process and discusses the importance of well construction and well integrity to normal well operations including hydraulic fracturing. This section includes an introduction to the exploration process, pre-drilling seismic assessment and well logging and the importance of this data for subsurface assessments for hydraulic fracturing and deep well injection of waste disposal activities.

Section 4 **Hydraulic fracturing** provides a description of hydraulic fracturing, how it is used for well stimulation and enhanced recovery of hydrocarbons from reservoirs and hydraulic fluids management and composition. The frequency of hydraulic fracturing in Taranaki and elsewhere is discussed. Also addressed in this section are the environmental effects to be managed and relevant investigations and studies that have been undertaken in Taranaki. This section concludes with a discussion of the technical expertise required for regulators of hydraulic fracturing and where this can be sourced.

Section 5 **Regulatory requirements** outlines the regulatory regimes that apply to petroleum exploration activities and the various agencies and their general responsibilities. This provides important context for regulators under the RMA to understand the roles of other agencies to assist in coordinated and integrated management.

Section 6 **Resource consent considerations** contains the major part of the document. It provides a description of resource consent considerations for various aspects of petroleum exploration from both a regional council and district (or city) council perspective.

Section 7 **Cost recovery** addresses cost recovery provisions for the regulatory process.

Section 8 **Public reporting** addresses public reporting of consent processing, consent compliance monitoring, and enforcement activities.

Section 9 **Benchmarking** benchmarks the approaches outlined in the guide against good practice guidelines in relation to hydraulic fracturing, including the recommendations of the UK Royal Society and the Royal Academy of Engineering, on hydraulic fracturing.

Section 10 **Review, research needs and challenges** addresses future investigations and research requirements related to scientific and regulatory issues particularly in respect of hydraulic fracturing, but it also touches on issues of wider relevance to the sector. It identifies possible factors that may influence future regulation of the sector and cause the current approach to be reviewed. This chapter also identifies some of the challenges for regulating oil and gas exploration activities given the multiple agencies that are involved. It also comments on options to address the potentially limited experience and capacity in territorial authorities to regulate the industry beyond Taranaki.

Section 11 **Conclusions** provides a summary and conclusions.

A **Glossary** provides explanations or definitions of technical terms used in the oil and gas industry.

The **References** section contains a list of articles, papers, reports and other documents or sources referenced in the guide. It provides a useful resource for regulatory staff who may wish to follow up on particular aspects of interest.

Appendices to the guide provide copies of some useful technical papers on oil and gas exploration and hydraulic fracturing, copies of the Taranaki Regional Council investigation reports into the environmental effects and regulation of hydraulic fracturing, and consent conditions for petroleum exploration and hydraulic fracturing activities.

1.4 How to use this document

The document is designed to be a guide to the regulation of oil and gas exploration activities under the RMA. Its focus is therefore on activities and effects and consequent good practice approaches relevant to the RMA.

The guide has been structured to provide users with a broad understanding and appreciation of the oil and gas industry in New Zealand, the exploration process, and regulatory requirements, in the early sections of the document, particularly sections 2 to 5.

The major content of the guide sits in section 6 which details the resource consent considerations for various aspects of petroleum exploration. This allows users to identify which activity is of interest to them and to go directly to that section. Users are encouraged to make use of the References and Appendices, which provide a good source of supporting information on many aspects of petroleum exploration and hydraulic fracturing.

Users are also encouraged to consider the supporting sections which follow section 6, (i.e., sections 7 to 10), as the matters raised in these sections, (e.g., cost recovery and reporting), are important elements of a comprehensive and transparent regulatory regime for any one or more of the petroleum exploration activities addressed in this guide.

2. Background

This section of the guide provides background information on the oil and gas industry in New Zealand, (including its contribution to the New Zealand economy), the environmental effects of the industry and their regulation based on the Taranaki experience under the RMA, and regional council collaboration on regulation of the industry. This section provides context for later sections of the guide.

2.1 The oil and gas industry in New Zealand

The Taranaki Basin, covering an area of about 330,000 km^2 is currently the only producing oil and gas basin in New Zealand. The location of the major oil and gas fields in Taranaki, both onshore and offshore, are shown in Figure 1.

Figure 1 Location of oil and gas fields and production facilities in Taranaki

The first oil well was drilled at Moturoa on the Taranaki foreshore in 1865. Since then over 1,000 petroleum wells have been drilled in New Zealand. Over 600 onshore and offshore exploration and production wells have been drilled in Taranaki to date. The Taranaki Basin remains underexplored compared to many comparable basins of its size elsewhere in the world and there is considerable potential for further discoveries.

According to New Zealand Petroleum and Minerals, the rest of New Zealand is 'severely' underexplored (New Zealand Petroleum and Minerals 2012). However, New Zealand Petroleum and Minerals has further noted that frontier basins drilled to date have all yielded discoveries confirming viable petroleum systems. Given that many untested structures mapped to date are larger than the Maui field (New Zealand's largest), there is considerable potential for further commercial hydrocarbon discoveries (New Zealand Petroleum and Minerals, 2012).

The oil and gas industry makes a significant contribution to the New Zealand economy and society generally. Oil is New Zealand's fourth largest export (after dairy, meat and wood) with a value of around $2.2 billion. Gas is an important contributor to domestic industries and electricity generation, generating 18% of New Zealand's electricity supply in 2011 (Petroleum Exploration and Production Association of New Zealand, 2012).

Other key facts in relation to the oil and gas industry in New Zealand are:

- The oil and gas industry contributes close to $3 billion to national GDP, most of which is captured in Taranaki
- The Government collects about $300 million in company tax per annum
- The Government collects more than $400 million in royalties per annum
- The industry provides close to 4,000 direct, well-paid jobs (most of which are in Taranaki) and supports a further 4,000 downstream jobs in other parts of the economy (almost 8,000 jobs nationwide)
- New Zealand companies capture between 30% and 80% of the construction of major oil and gas projects in New Zealand and there is potential to capture more
- The government will receive around 42% of the profit of new oil and gas developments
- Future royalty income from known oil and gas reserves is estimated at $3.2 billion net present value. Royalty income could rise to $12.7 billion with a 50% increase in exploration (see Venture Taranaki, 2010, and Petroleum Exploration and Production Association of New Zealand, 2012).

The industry has contributed to buoyant economic conditions in Taranaki over a number of years and has helped cushion against economic downturns. Taranaki frequently tracks above national trends in economic activity and employment as reflected in the regular National Bank Regional Economic surveys and this can in part be attributed to the strength of the oil and gas sector in the region (Chamberlain, 2012).

Apart from the income and employment benefits to individuals, communities and regions, the income generated for central government is used directly in the provision of government services such as health, education, and welfare.

The Ministry of Business, Innovation and Employment (MoBIE) has assessed the benefits of New Zealand's petroleum potential. The Ministry's report concludes that based on plausible oil and gas discovery and development scenarios, exports in the sector could grow by $1.5 billion per annum, royalty payments could increase by $320 million per annum, and a further 5,500 jobs could be created. Counting both direct and indirect effects, the Ministry estimates that national GDP could be increased on average by $2.1 billion for each year of a 30 year development of a new basin (Ministry of Business, Innovation and Employment, 2012).

The Ministry also estimates that a single field could generate between $557 million and $3.2 billion in regional GDP over the life of the development.

While the scenarios are hypothetical, the Ministry's report concludes that the potential for growth of the oil and gas sector is real and that 'there is reason to be confident that ongoing exploration investment will lead to new field discoveries and that local economies can benefit from such developments' (Ministry of Business, Innovation and Employment, 2012).

2.2 Environmental effects and regulation– the Taranaki experience

The Taranaki Regional Council makes a major on-going investment in state of the environment monitoring, aimed at providing reliable continuous trend information to inform policy decisions and interventions. The Council distinguishes this type of overview and long term monitoring, from the more consent and activity-specific compliance monitoring which is discussed later.

Freshwater quality is one of the key areas of focus. In 2011, the Auditor-General, with assistance from NIWA, undertook a very detailed investigation of the Taranaki Regional Council's management of freshwater (Office of the Auditor General, 2011, 2011a). The Council's capability, systems, processes and results on the ground were very favourably commended with minimal qualification. They also agreed with the Council's analysis that overall, Taranaki's water quality is being maintained and in some places enhanced. Very recent results, published in August- October 2012, fully confirm that positive situation (Chamberlain, 2012).

Great improvements have been made in the management of point-source wastewaters from towns, industries and farms in recent decades, and there have noticeable improvements in water quality in our rivers and coastal waters. These improvements have involved major commitments and investments by industry, individuals and communities. Total spending on the environment by the Taranaki community has been conservatively estimated at around $85 million a year (Business and Economic Research Ltd, 2008). Many oil and gas, petrochemical and energy companies have been leaders in investing to ensure that Taranaki's environment is as good as any developed part of the world. Efforts are now being squarely directed at non-point sourced contamination from pasture runoff. Addressing this issue is the key aim of the very large and successful Taranaki Riparian Management Programme that is transforming the Taranaki landscape (Chamberlain, 2012).

The adverse impacts of the oil and gas industry at the regional state of environment level of monitoring, putting greenhouse gas emissions aside, across land, freshwater, air or coastal resources, are negligible. This is not surprising, but nonetheless a remarkable result, consistent over many years of state of environment monitoring in Taranaki (Chamberlain, 2012).

The Taranaki Regional Council has been regulating the oil and gas industry for over 30 years. Resource consent, compliance monitoring and enforcement data from the last 10 years is set out below to illustrate the level of regulation.

Over this period the Council has assessed and issued a total of 950 resource consents for hydrocarbon exploration and production activities. These involve all types of consents across the full range of hydrocarbon exploration and production activities from well-site water takes, to waste treatment and disposal, to land-farming and deep-well injection, to production station operations and more recently, hydraulic fracturing. The total number of current resource consents held for hydrocarbon exploration and production activities in the region is 852.

Fundamental to the Council's approach is a rigorous monitoring, inspection and enforcement regime (Chamberlain, 2012). This includes regular site inspections for consent compliance monitoring purposes, consent investigations, incident investigations, and advice and information to the industry. In the last 30 years there have been over 4,500 site visits and more than 13,000 compliance monitoring inspections of specifically consented oil and gas activities.

Inspections are complemented by appropriate water, soil and air, physicochemical and biological sampling surveys, which are conducted by trained professionals, using accredited laboratories. In the last 10 years, the Council estimates sampling has involved over 700 freshwater bio-monitoring surveys, and over 4,600 water or soil samples, with around 30,000 parameter analyses. Freshwater biological surveys around new exploration sites were severely scaled back a few years ago, because of the lack of any effects being found.

Photo 1 Wellsite flare (background) and skimmer pit (foreground), and discharge sampling

Overall, in the last 10 years, there have been over 20,000 recorded interactions with the oil and gas industry as part of the Council's regulation of the industry.

The TRC takes action where it finds cases of non-compliance. And as with any resource use sector, there are non compliance incidents, most of which are minor in nature. The most significant incident occurred at the McKee 13 wellsite in 1995, where there was well integrity failure during drilling. This was a moderate event, where stream recovery occurred within 18 months after contamination, but for which Petrocorp Ltd was prosecuted with a record fine for the time (Chamberlain, 2012).

There are 96 well-sites currently in existence and 10 operational production stations in the region. This compares for example, with over 1,800 farm dairy effluent discharge systems in the region.

In terms of non-compliance within the oil and gas sector in the last 10 years the Council has issued 13 abatement notices and 9 infringement notices (instant fines). There have also been 2 prosecutions by the Council against oil and gas companies for more serious breaches of the RMA in the last decade.

It is worth noting that across all resource uses over the same time period, the Council issued well in excess of 1,000 abatement notices and about 400 infringement notices and completed 35 prosecutions (Chamberlain, 2012).

The Council scrutinises the sector very carefully and closely, but enforcement interventions are significantly less common than for other sectors. This is no accident. It reflects and requires dedicated industry focus on environmental compliance and significant investment by the sector (Chamberlain, 2012).

2.3 Regional council collaboration

During 2011 there was increasing public interest in and concern over the potential effects of hydraulic fracturing activities in the oil and gas industry. At an August 2011 meeting, the Regional Council Chief Executives group decided that a paper on hydraulic fracturing should be prepared to guide councils when considering the regulation of this activity under the RMA.

Given experience with researching and regulating the oil and gas industry's activities in Taranaki, including hydraulic fracturing, the Taranaki Regional Council was requested to prepare a draft sector paper for consideration by other councils. A draft position paper was subsequently prepared and a sector position agreed for the regulation of hydraulic fracturing activities.

In order to give the community confidence that the actual and potential effects of hydraulic fracturing are being managed appropriately, it was agreed that each regional council would have an operative regional plan with policies and rules covering activities such as taking water, discharging contaminants to air, water, and land, and if necessary, land use rules for well/bore authorisations.

Policies and rules would be developed to address the particular circumstances and conditions unique to each region and this would determine precisely how each council would evaluate a resource consent application. However, it is likely that most regional plans would treat at least some of the activities associated with hydraulic fracturing as discretionary. The only new considerations for most councils under the RMA in relation to the consents process for hydraulic fracturing, is likely to be the design and installation of wells and the high pressure subsurface discharge of fracture fluids.

In addition, during 2011, regional councils collaborated to develop a standard regional council approach to resource consent processing for hydraulic fracturing activities. The Resource Managers Group' (RMG) instructed the Consents Managers (CMG) Special Interest Group to develop a standard regional council approach to consent processing, including suitable guidance for consent applicants and processing officers, minimum requirements for Assessment of Environmental Effects reports and template resource consent conditions for the consideration and assessment of resource consent applications, particularly for the well design and subsurface discharge components[1].

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[1] The RMG also instructed the Policy Managers Special Interest Group to look at drafting a regional plan rule or rules to specifically deal with the activity, particularly for the well design and subsurface discharge components, in the event that existing rules are not suitable. This work will naturally follow that of the CMG and ongoing experience with regulating hydraulic fracturing operations.

It was noted at the time that developing a standard approach could include the employment of appropriate expertise and assessment of overseas regulatory regimes, to build on the expertise that already exists. A review of overseas literature on the actual environmental effects of hydraulic fracturing could also be undertaken and made available to councils to assess whether these effects were relevant under New Zealand conditions.

This guide fulfils the requirement on the RMG in relation to hydraulic fracturing activities and the resource consents process. However, as noted in section 1.2, the scope of this guide extends beyond hydraulic fracturing to include other aspects of oil and gas exploration. In this way the guide is intended to assist councils in the management of oil and gas exploration activities under the RMA, in the likelihood that interest in oil and gas exploration in other regions of New Zealand is likely to increase in future.

3. Subsurface assessment, well construction and exploration and development drilling

The subsurface assessment, well construction and drilling components of the oil and gas exploration process, including the process of hydraulic fracturing, are interrelated and are introduced in this section of the guide. It describes the processes of exploration that might lead to the decision to undertake various forms of surveying, drilling, well testing or stimulation (e.g., hydraulic fracturing (HF)) before a commitment is made to install production facilities. A description of the exploration process also provides information for the necessary Resource Management Act applications. These processes will apply regardless of whether the explorer is investigating conventional, tight gas or unconventional reservoir types.

3.1 Exploration process

The typical process of exploration involves the following steps:

- Gathering all existing information for a review of a basin, a fairway or a play (a play is defined as combination of source, migration route, trap, seal and reservoir rock, which might contain hydrocarbons; a fairway is a mapped area in which the conditions for a particular play may occur);
- Structural mapping (based upon maps, mapping and any pre-existing seismic data);
- 'Shooting' 2D seismic surveys (generally used in exploration situations, where reconnaissance information over a wide area is required);
- Drilling an exploratory well (selection of the site for a well is based upon as much pre-existing information as possible. Exploration wells are drilled to test hydrocarbon prospects but become valuable data points in their own right);
- Continued drilling and/or 3D seismic (if the exploration well finds hydrocarbons, the explorer may elect to drill further appraisal wells and/or to shoot a 3D seismic survey, which usually covers a much smaller area than a 2D seismic survey);
- Appraisal drilling and HF (in the first instance, HF is most likely to be undertaken in an appraisal well which has not flowed hydrocarbons at a commercial rate, to confirm whether HF stimulation can increase flows to commercial levels);
- Reservoir modelling (as the explorer accrues more information, this will be built into a model of the reservoir in the prospect);
- Application for mining permit (with sufficient encouragement of the size and proposed production profile of a proposed field, a mining permit application may be submitted);
- Continued appraisal drilling and production wells (continued drilling and testing may happen, before the mining permit is granted); and
- Installation of pipelines and production facilities (once the mining permit has been granted, the explorer will commit to installing production facilities).

3.2 Pre-existing geologic and geophysical data evaluation

The first phase of any exploration programme is the gathering and evaluation of as much pre-existing geologic and geophysical data as is available for the basin, fairway or play. This can be a lengthy process but it is always cheaper than seismic data acquisition or exploratory well drilling. Wildcatting, in the sense of drilling to find oil without any prior geologic evaluation, was possible in early US shallow oil drilling but is unheard of nowadays (Huckerby J, 2012 pers com).

The usual outcomes of this desktop exercise are either to acquire further information (seismic or well drilling) at the explorer's cost or to abandon the particular area as not prospective. Explorers aim to make basin, fairway or play maps, which help to define areas for 2D seismic surveying or even exploratory well drilling.

3.3 Seismic survey assessment

Seismic surveying is the primary subsurface investigative tool used within the exploration industry. Exploration companies use seismic surveys to map the structure of subsurface formations in order to infer the existence of possible petroleum traps. In addition, seismic investigations are used to identify lithology (rock type), fluid content (oil, gas, or water) and find structures (fractures) within formations - all indicators of the potential presence and volume of oil and/or gas reserves in an area of interest. Data obtained by seismic surveying is typically correlated with other forms of petrophysical and geophysical logs from boreholes in the locality of the survey area or existing information on the stratigraphy of the area.

Seismic surveys can also provide some useful subsurface information for locating wells, designing hydraulic fracturing, deep well injection of waste and other subsurface activities with the mapping of geologic structure including faults (major), fractures and folds. In some instances, the rock type, thickness, dip and structural character of underlying strata can also be identified.

3.3.1 Seismic survey techniques

The surveying of underground formations using seismic methods is based on the principles of seismic reflection and refraction. Seismic methods utilise seismic waves to determine the properties of underlying formations. Seismic waves are generated by artificial methods, typically by small explosive charges lowered into shallow bores known as shot holes. When detonated, the energy released by the charge is transmitted through the geologic strata to the surface. Three types of waves can be created: compressional, shear and surface waves. The arrival of a seismic wave at the surface is detected by geophones spaced across the survey area (Figure 2).

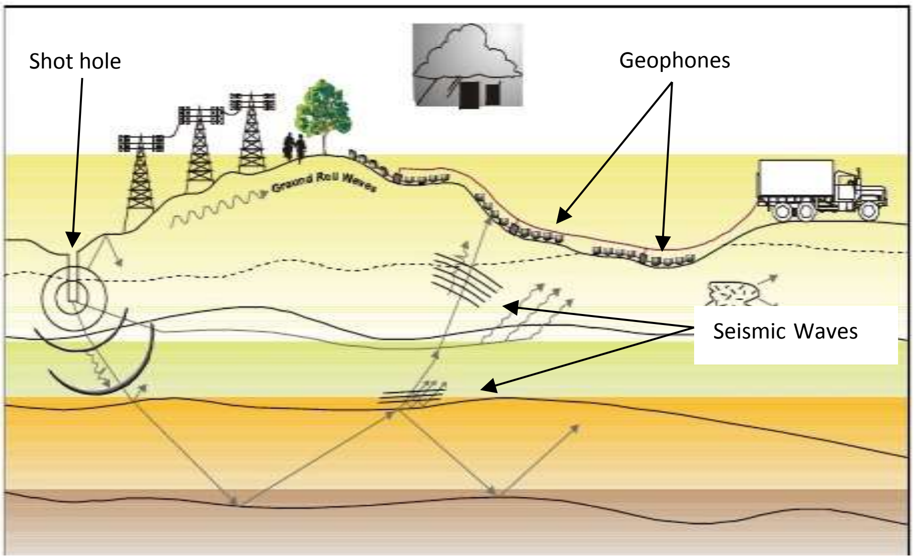

Figure 2 Schematic of seismic survey process

Compressional waves are the first to arrive at the geophones following the detonation of the explosive charge and therefore are the most useful in seismic surveys. In general, the higher the elasticity and density (and the lower the porosity) of the rock unit, the faster the compressional wave will be transmitted. Velocity is reduced and energy dissipated more rapidly, if the rock material is porous, poorly consolidated or unconsolidated. Coals have rapid velocities, followed by shales and then sandstones.

During a survey, the time it takes for the seismic wave to reach one or more of the geophones, placed at known distances from the shot hole, is recorded. By plotting the distance-time relationship, the properties of geologic units can be assessed. Each geologic formation has a characteristic seismic velocity that dictates the speed that a seismic wave reaches the geophones. Representative seismic velocities have been approximated for various rock types. Characteristic seismic velocities can also be estimated for formations within a specific exploration area, for which depths have been previously ascertained from drilling logs.

There are two main forms of seismic survey used in the exploration industry, 2D and 3D surveys (Figure 3). A 2D seismic survey is recorded using straight lines of geophones and shot holes crossing the surface of the earth. They produce only vertical sections along the line of the geophone receivers. A 3D seismic survey requires a much greater density of survey points for both shot holes and geophones, so the cost of 3D is much greater than 2D surveying. In the 3D seismic method, many lines of geophones and multiple shot holes are laid across the survey area. The geophone array and associated shot holes is referred to as a “patch”. By setting multiple patches within an area of investigation, it is possible to accumulate overlapping subsurface coverage and build a much more detailed model of underlying geology. The main difference between the two methods is the enhanced detail and clarity of 3D subsurface models produced, when compared with 2D vertical sections.

2D Seismic Array **3D Seismic Array**

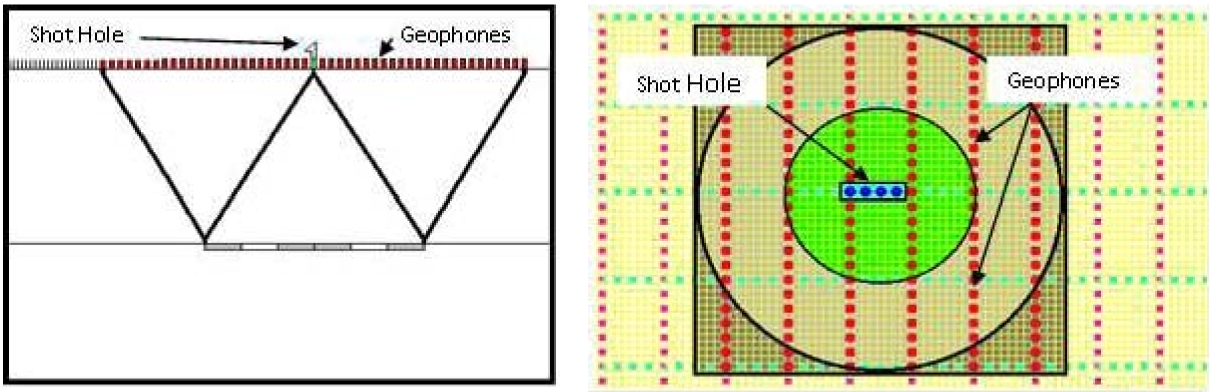

Figure 3 2D versus 3D seismic arrays

Survey Patch

3.3.2 Survey results and interpretation

Data obtained during a seismic survey is used to compile a model of the underlying geologic structure, including the depth and extent of various formations and the potential presence of structures, which may trap oil and gas. The output from the survey will vary depending on whether 2D or 3D survey methods were used. An example of a typical model produced using each respective survey method is included below in Figure 4.

2D Model **3D Model**

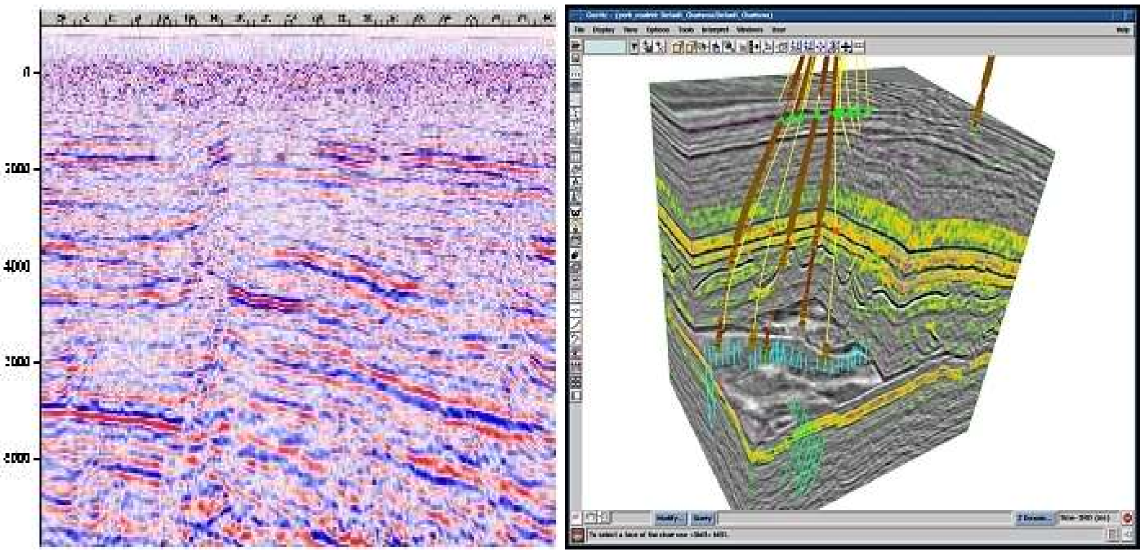

Figure 4 2D versus 3D seismic survey output model

3.3.3 Summary

The data obtained using seismic investigation techniques and the subsequent modelling of this data allows exploration companies and regulators to characterise geologic formations and their stratigraphy within the survey area. The results of the survey can indicate the presence of potential oil- and gas-bearing structures. Almost all of petroleum exploration is carried out using seismic investigation methods. Compared to other investigative methods, seismic gives by far the best subsurface structural and lithological image.

3.4 Drilling and casing a well

Drilling starts after a potential hydrocarbon accumulation has been located through geologic studies, seismic interpretation and petrophysical assessment; followed by land access agreement and resource consenting. The output from this work is the best scientific proposal on where to drill (and where not to drill). Before identification of a drilling location, geologic studies range from regional geologic mapping and investigation to petrophysical evaluation of rocks and cores from earlier drilled wells.

3.4.1 Exploratory and development drilling

Photo 2 Drilling rig (background) and production facilities (foreground) at the Cheal A wellsite/production station, Taranaki

Exploratory drilling, which can take from a few weeks to a few months, is undertaken to collect information about the reservoir rock, composition of fluids in the rock and the productive capacity of the formation. The productive zones and development areas are also remapped with information gathered in this step, causing many development areas to be shifted to the best areas to develop and away from areas with poor reserves, shallow hazards or other problems.

Photo 3 Cheal B drilling rig November 2012

Various muds can be used in the drilling of a well. Water based muds are generally used for the upper section of the well that passes through freshwater aquifer systems. Synthetic based muds are used in the remainder of the hole. The latter generally provide better stability for the wellbore avoiding clay swelling and well collapse issues before casing is installed in the well.

A well is drilled in sections, after which steel casing of decreasing sizes is placed to seal off the formation and then is cemented in place. Each casing and cementing operation forms an individual but interconnected system of pressure barriers, designed to keep fluids, including hydrocarbons inside the casing, separate from fresh or salt water sources outside the casing (API, 2009). Most exploratory wells are drilled as straight and vertical wells, since they are relatively cheap. (Vertical wells can be up to 30 degrees from true vertical). However, more sophisticated 'deviated' drilling may be justified in unconventional and even tight gas reservoirs, with a horizontal end-section penetrating hydrocarbon reservoirs, such that the wellbore exposes more of the target reservoir interval (Figure 5). Horizontal wells improve production performance for certain types of formations (API, 2009).

Drilling an exploratory or an appraisal well, after a discovery has been made in the first exploratory well, is a necessary requirement to demonstrate that hydrocarbons have accumulated in a mapped structure. There is no substitute for this confirmation – all other methods of remote sensing cannot confirm the presence of hydrocarbons. The results of exploratory or appraisal well will determine whether and how the exploration programme will continue.

Once a field is proven for development and a mining licence issued development drilling is undertaken following a similar drilling process.

The drilling rig is the most visible part of the operation but it is the subsurface operation that is the critical element. Drilling a well, from the surface to the TD (total depth) of the well, usually below the target productive zone, may take several weeks and utilises many pieces of equipment, specialised techniques and additives, such as drilling muds.

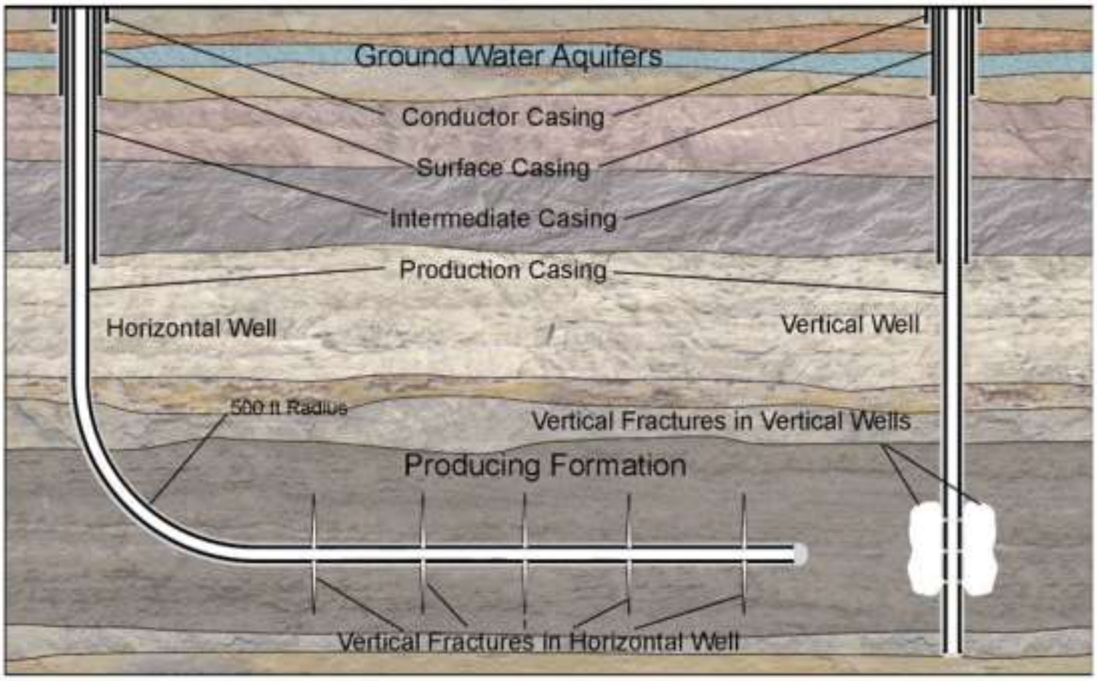

Figure 5 Examples of horizontal and vertical wells (Source: API, 2009)

3.4.2 Drilling muds

Drilling muds serve multiple purposes in mud-rotary drilling. They provide hydrostatic pressure to keep formation fluids out of the borehole and control formation pressure, provide cooling to the drill bit, and carry cuttings away from the drill bit and up the borehole. There are three commonly used types of muds in the petroleum hydrocarbon industry: water-based mud (WBM); oil-based mud (OBM); and synthetic oil-based mud (SBM).

WBMs may range in formulation from freshwater to water with viscosifiers, weighting agents and various additives to control formation properties such as swelling clays. Barite ($BaSO_4$) is a commonly used weighting agent. Good oilfield practice requires the use of freshwater as a base drilling fluid at shallower depths to minimise problems with the very small amount of fluid leakoff in shallow, highly permeable formations that may occur prior to the freshly drilled hole being cased.

OBMs and SBMs have been formulated and used in Taranaki to control 'swelling clays' and to improve drilling performance in deeper sections. Swelling clays are particular types of naturally-occurring clay minerals, which swell in the presence of water. OBM and SBM can be used to control these swelling clays. SBMs are increasingly favoured as they may have lower environmental impacts.

However, water-based mud is universally used for near-surface drilling (say to 500m depth) and, if necessary, the mud system is then changed to an OBM or SBM system, once the surface casing string has been set across shallow aquifers.

Some additives to the mud are designed to increase its density (e.g. barite to weigh the mud) to control formation pressures. Well pressures are kept in check so long as the mud weight is sufficient to balance reservoir pressure. Mud tank levels are also monitored and regular "flow checks" are performed to make sure the mud weight is sufficient to prevent flows from the formations being drilled.

At the surface, the blow our preventer (BOP) is a specialised piece of equipment, through which the mud is flowed into and out of the wellbore. The BOPs are essentially a series of emergency valves, which can be used to shut in or control well pressures in the event of unexpected pressure changes, such as a 'gas kick', caused by pockets of over-pressured gas. BOPs allow the closing of the well and are regularly pressure tested and function tested as part of company safety procedures based on good oilfield practice and standards, such as the American Petroleum Institute. As higher pressures are encountered in deeper formations, mud density is increased during drilling by the addition of barite to offset the pressure and additives may be necessary to prevent clay swelling.

On a drilling rig, mud is pumped from a mud storage tank, down the drill string to the bit where it exits through nozzles, cleaning and cooling the bit before lifting the cuttings to the surface. Lifting the cuttings up in the space between the outside of the drill string and the drilled hole requires both sufficient flow velocity and a viscous mud. The returning mud may contain natural gases liberated by the bit that are separated from the mud and are either vented or flared during drilling. Rock cuttings are separated or filtered out of the mud and the mud returns to the mud pit. The cuttings provide the primary evidence of the lithologies being penetrated and of potential fluids, so regular and frequent samples are taken for immediate and later analysis and archiving. Eventually, excess rock cuttings will be disposed under a resource consent. (While inert, the cuttings may have adhering mud additives, and trace levels of hydrocarbons, and NORMS (section 4.8.5)).

3.4.3 Well casing

Poor well construction, which could lead to barrier failure, is a potential pathway for contamination of groundwater. Barrier failure can be eliminated by proper engineering for the well design and proper construction. Pressure testing of each casing string may be required. In addition the integrity of the cementation may also be required to be established by cement bond logs or other in-depth investigation, to meet good oilfield practice or regulations. The use of pressure testing and cement bond logs on each casing string can vary between operators. In the extremely rare occasion where a well failure does occur, damage to the inner casing pipe of a multiple barrier well will by design not affect the overall well integrity. There is sufficient redundancy built into the well design. This may create a need for a work-over to repair the flow path of hydrocarbons but leaves the outer protective barriers intact, preventing environmental contamination.

3.4.4 Well completion

In the event of intersection of a potentially attractive accumulation of hydrocarbons, the final stage of well drilling is running a well completion (tubing and packers) and provision of pipelines and processing facilities. When the final casing strings of the well are set and cemented and the completion run, the BOP is replaced with a wellhead complete with valves and connections to the production facilities (sometimes called a “Christmas Tree”).

Surface facilities include specially designed surface vessels that aid in separation of gas, oil and water phases with no loss of any fluid, including gas. Methane may be flared from the first few wells in an area to determine well production rates.

Access to subsurface zones for hydraulic fracturing is via the wellbore. Production tubing is located inside the innermost casing. A well schematic is shown in Figure 6.

Before the hydraulic fracturing process can proceed the well casing must be perforated across the target formation (i.e., within the reservoir at depth).

3.4.5 Shallow gas hazards

Care needs to be taken to manage the effects of shallow gas when drilling a well. To encounter shallow gas and not have sufficient mud weight in the well could result in a loss of well control incident and muds flowing to the surface. Seismic assessment may show the presence of shallow gas. Shallow gas is likely to be gas derived from the breakdown of biogenic material just below the surface (e.g., swamps). It may also be thermogenic methane from deep hydrocarbon reservoirs that has migrated to the surface over a long period of time. Compositionally, shallow biogenic gas is easily recognisable from thermogenic gas, as the former is nearly 100% methane while thermogenic methane usually occurs in the company of the related gases, ethane, propane, butane and pentane, derived from thermal decomposition (King, 2012). They can also be discriminated on the basis of their common stable (non-radioactive) carbon isotopes, ^{12}Carbon (^{12}C has 6 neutrons) and ^{13}Carbon (^{13}C has 7 neutrons). Biogenic methane contains more ^{12}Carbon while thermogenic methane contains more of the ^{13}C carbon isotope. Recently generated methane is biogenic. Surface gas seeps of both biogenic and thermogenic methane occur naturally in New Zealand. Biogenic methane may be naturally generated in shallow subsurface aquifers. The occurrence of thermogenic methane in surface gas seepage would indicate leakage from an underlying petroleum reservoir. Specialist laboratories have the capability to differentiate between biogenic and thermogenic methane.

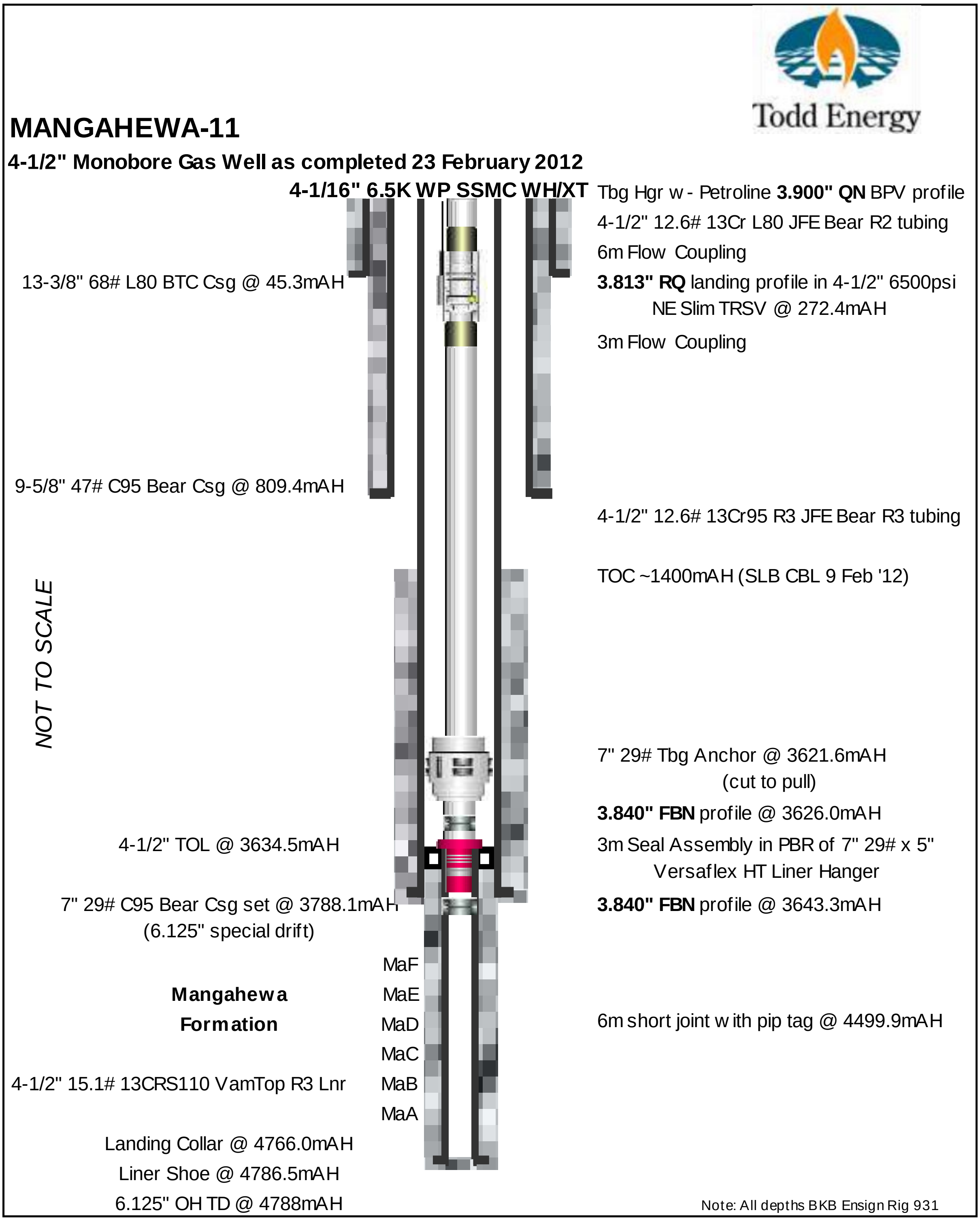

Figure 6 Todd Energy Mangahewa 11 well schematic showing casing strings, production tubing, and cement (shaded)

3.5 Well logging techniques

Well logging is a critical tool for hydrocarbon explorers and regulators, which includes the analysis of immediately recovered cuttings and fluids but also recording of wireline logs. Wireline and/or drill pipe logging of a section of open hole will allow exploration companies to assess the potential for hydrocarbon recovery, identify target zones and well construction requirements. Logging data can also provide information on the extent of freshwater aquifers and the depths at which formation waters become increasingly saline. Wireline logs can also provide information on the integrity of the well (i.e., the physical integrity of the casing and the bond between the casing and cement and the bond between the cement and the formation). For example, if the cement bond is found to be defective, a second cement 'squeeze job' can be performed to improve the cement bond quality. However, 'the importance of getting a good primary cement job … cannot be overstated. Remedial cementing options do not provide high success rates for zonal isolation' (Hetrick, 2011). Taken together this data can be used to determine (i.e., identify and characterise) intervals for hydraulic fracturing. An instructive but brief video on well logging can be found at the following URL:

http://www.youtube.com/watch?v=8fRZC1ZA_pc&feature=relmfu

Well logging is the process of measuring and recording the physical, chemical and structural properties of geologic formations penetrated by a well. The log may be based on visual inspections of samples brought to the surface during drilling (mud log and geologic log) or on physical measurements made by instruments lowered on a wireline or drill pipe into the hole during or after drilling (wireline logs). Well logging can be used to assess the properties of both the rock and fluids within underlying geologic formations and the depth and extent of potentially hydrocarbon bearing zones. Typically a combination of geologic and geophysical logging techniques will be used to assess various parameters of interest with the data used to build a conceptual model of the penetrated formations. The data is also used to finalise the well completion details, including the depth of surface casing, cementing and perforation zones for production.

Well logging can be carried out at any stage of a well's lifecycle including during drilling, completion, production and before abandonment. The logging methods available and the range of data obtainable will, however, vary based on the operational phase and condition of the well and particularly whether the wellbore is an open hole, or cased with steel casing, secured to the formation with cement. Common practice would be to run open-hole logs while drilling, or as each well section is completed before casing is run. Cased-hole sonic logs may be run to confirm the cement bond or during work-over procedures in cased and cemented production wells.

Logging can be time-consuming and expensive, so companies may only wish to assess the zones of interest for hydrocarbon discovery. A regulator may require data over a greater interval and this requirement should be established early on.

Measurement whilst drilling and logging while drilling techniques are presented in Section 3.7.6.

3.5.1 Depth measurements

Drillers use different measures for depth in a well, based upon 3 parameters:

The units, i.e., feet or metres.

The measurement path, i.e., along the hole or from a specific depth, like sea level.

The datum, i.e., the reference from which the depth is recorded, e.g., subsea (i.e., sea level), RT, i.e., the rotary table or drill floor (DF).

Two common measures:

- Driller's depth can be compared with logger's depth, the depth determined from wireline logging. In general logger's depth is considered more accurate, as it is measured using a single cable, while driller's depth involves accumulating the length of each piece of drill string.
- In deviated or horizontal wells, such as shale gas wells, it is usual to quote both MDBRT (Measured Depth Below Rotary Table) and TVDSS (True Vertical Depth Subsea) depths down hole.

Also different companies can have different conventions on what datum to use for down hole measurement so care is needed.

3.5.2 Mud and geologic logging

Mud logs have become the industry standard for oil and gas exploration. Drilling mud is circulated down the drill pipe, out through ports in the drill bit, which then flushes and clears the rock cuttings created by the bit, as well as cooling and lubricating it. The cuttings then travel up the annulus of the wellbore, i.e., between the drill pipe and the drilling formation, suspended in the drilling mud and return to the surface. The cuttings are then separated from the drilling mud, across a series of 'shakers'. Sample of cuttings are obtained at regular depth intervals and are analysed and described by a mudlogger or a wellsite geologist. The assessment of cuttings will generally include an analysis of cutting size, shape, colour, texture and hydrocarbon content. The mudlogger will produce the mudlog, which is a combination of drilling, mud and lithological information.

Meanwhile, the wellsite geologist will be producing a geologic log, called a well log, which utilises mudlogging information but focusses on the geologic formations that have been penetrated, compared with those anticipated before drilling in the drilling plan.

Gas returning to the surface with the mud is also measured and analysed, with the results plotted in the mud log.

3.6 Wireline logs

Wireline and drill pipe logging is used to obtain continuous downhole data relating to the petrophysical and geophysical properties of subsurface rock formations and associated fluids. Parameters of particular interest may include rock porosity, permeability and formation fluid composition.

Wireline logging is a specialist activity usually conducted in open-hole after the completion of each drilled well section before casing is set. A series of logging tools sometimes over 20 m long will be lowered to the current total depth of the well on the end of a wireline, which measures depth and transmits information from the logging tools back to the surface. A wide range of logging tools and methods are available, the most widely used include electrical, radioactivity (gamma), electromagnetic, and acoustic logging. Wireline logs are usually run in suites. In the shallower part of a well, wireline logging may be minimal, while a full suite of logs may be run across zones of particular interest. The logging method selected for use will depend on the objective of the logging work, the type and range of data required and the physical characteristics of the well bore.

Some of the tools have sensors, which must be in contact with the formation, while others are proximity tools. Most wireline logs are run in open holes prior to casing the well. Logging is achieved by running a wireline, which bears the weight of the tool string but also connects the tools electronically with the surface, so logging can be undertaken in real time. The tool string is usually run to the bottom of the hole and logging occurs as the tool is being pulled up-hole. Upward logging reduces the chances of the tool 'hanging up' on borehole irregularities. As the toolstring traverses the wellbore, the individual tools gather information about the surrounding formations. A typical open hole log will have information about the density, porosity, permeability, lithology, rock strength, water and hydrocarbon saturations and water salinity.

Cased hole logging operations can be used to gather data once a well has been cased. The logging of cased wells can provide data on formation properties but also casing integrity and the cement bond/seal quality and production rates for individual intervals.

An outline of commonly used wireline logging methods and their respective uses are detailed below.

3.6.1 Electric logs

In electrical well logging, two electrical properties are measured in the borehole; electrical potential and resistivity. Potential and resistivity data are recorded simultaneously. Electrical logging is an open hole logging method typically used during the drilling and/or construction phase of a well. Electrical logging requires the section of the wellbore being logged to be filled with formation or drilling fluids and cannot be carried out once the wellbore has been cased.

3.6.2 Potential fields

It has been observed that in a borehole, the electrical potential varies according to the nature of the geologic structure traversed. For example, salt water sands and brackish waters are less resistive than shale or clay. Borehole potentials are caused by electrochemical reactions taking place between the formations and the mud column. Potential measurements are made by recording the potential changes between an electrode in the hole and another electrode at the surface, usually in the mud pit. From a potential curve it is possible to pick up the boundaries of geologic formations and to obtain information on the nature of these formations including porosity, permeability and water salinity.

3.6.3 Resistivity logs

The electrical conductivity of a formation is controlled by the nature, quantity and distribution of the fluid contained within it. Because these factors vary appreciably from one formation to another, conductivity measurements made within the wellbore can be used to detect formation changes and to obtain information on the physical properties of the formations traversed.

In practice it is not the conductivity but its reciprocal, the resistivity, which is measured. The resistivity curve is obtained by recording either the resistance changes of a single electrode placed in the hole, or the apparent resistivity given by a multiple-electrode arrangement. Alternating current of low frequency is used for this measurement. As the logging electrode travels up the hole, changes in formation resistivity cause changes in the electrode resistance, which in turn cause voltage changes in the logging circuit. Data is recorded and plotted to create a resistivity log, which graphically illustrates the changes in formation resistance along the length of the logged sections.

Resistivity is usually measured at three different depths within the formation and the differences between these three measurements can provide useful information about the characteristics of the fluids at these three different depths. One of the consequences of the use of drilling mud is that the mud can penetrate into the near-wellbore area, displacing formation fluids. The extent to which this happens can be a measure of the permeability of the rock and the 'moveability' of the formation fluid in the rock.

The resistivity log is fundamental in formation evaluation as hydrocarbons do not conduct electricity while saline formation waters do. Therefore a large difference exists between the resistivity of rocks filled with hydrocarbons and those filled with saline formation water. Similarly a large difference exists between the resistivity values of freshwater and saline water and thus the resistivity data can be used to identify the depth to which freshwater aquifers extend below surface and the depth of the freshwater/saline water interface zone. In providing these data, resistivity logs also illustrate the depth of permeable zones within a formation.

3.6.4 Interpretation of electric logs

The combination of a potential curve and of one or several resistivity curves placed side by side constitutes an electric log. As outlined above, such logs are extremely valuable for geologic studies (formation properties, subsurface mapping, correlation between wells and surface geophysics) and for determining the extent of fresh water aquifers and the freshwater/saline water interface zone. An example of a standard electrical log is presented below in Figure 7.

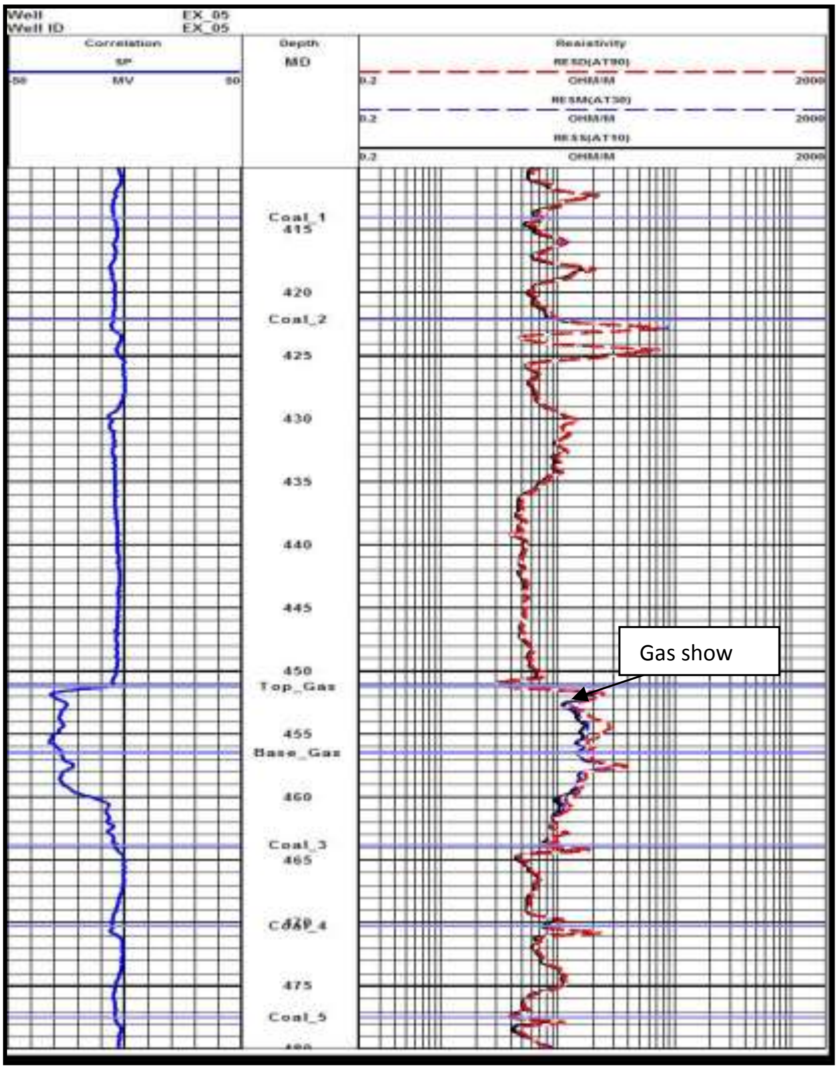

Figure 7 Electrical log example (Source: http://spec2000.net/07-eslog.htm)

3.7 Other types of logs

3.7.1 Gamma ray logs

In gamma logging, measurements are made of naturally occurring radiation being emitted by the formations encountered along the length of the wellbore. The gamma rays detected during logging originate from material within a short distance outside the borehole - 90 percent of the gamma rays detected during logging originate within 150 mm – 300 mm of the well bore wall. Gamma radiation is used to distinguish lithologies and properties of geologic formations, including porosity. The fundamental advantage of gamma ray logging over electrical logging techniques is that it can be carried out in cased and cemented holes or holes which contain no fluids. For that reason almost all logging runs include a gamma ray log, which allows depth correlation of all logging data.

All natural rocks contain some radioactive material (see section 4.8.5). However, compared to that of uranium or radium ore, even of low grade, the radioactivity of most rocks is very low. The radioactivity of a rock is usually expressed in terms of equivalent amount of radium per gram of rock required to produce the same gamma ray intensity. Although there is no fixed rule regarding the amount of radioactivity a given rock may contain, shales, clays and marls are generally several times more radioactive than clean sands, sandstones, limestones and dolomites. As the radiological properties of various rock types are known, the data obtained from a gamma-ray survey can be used to classify the rock types and properties of formations penetrated in a well to create a stratigraphic record of these formations.

3.7.2 Density logs

Gamma-gamma logging is usually referred to as the 'density log' because this is the fundamental characteristic inferred from the log. Gamma–gamma logging is carried out by lowering an active source of low-level radiation into the wellbore along with a detector, which counts only the back-scattered gamma rays. The source and detector are set against the wellbore wall and the gamma rays directed out into the surrounding formations. The amount of gamma rays returned to the detector above the gamma source is directly proportional to the bulk density of the formation. In general, the higher the density, the lower the rock porosity will be. Porosity is a fundamental consideration when assessing a formation's ability to store fluids, whether they are water or hydrocarbons. Hence porosity data is critical when considering the production potential of a formation.

3.7.3 Neutron logs

Neutron logs are also used to assess the porosity of geologic formations. Similarly to gamma-gamming logging, neutron logging utilises a radiation source and a detector unit spaced apart from the source point. The neutron log is obtained by recording the volume of neutrons emitted from the source that are captured by the detector. Before reaching the detector, many of the neutrons emitted from the source collide with various particles, lose energy and are eventually captured. Most of the energy is lost in collisions with hydrogen ions and since hydrogen is found mainly in the pore fluids, the neutron porosity log responds principally to porosity.

Neutron logs can be can be used in cased and un-cased wells either filled with fluid or dry. The depth of neutron penetration in the formation depends on porosity, hole diameter and spacing between the source and the detector. For high porosity material, the depth of penetration may be 150 mm or less, whereas for low porosity materials it may be up to 600 mm.

3.7.4 Electromagnetic logs

Electromagnetic logging is an open hole logging method that can be used in both dry wells and those containing formation or drilling fluids. The most common form of electromagnetic logging is the induction tool. An induction tool generates an alternating magnetic field around the wellbore, which in turn induces electrical eddy currents that are proportional to the electrical conductivity of the formation. The investigation depth of the induction tool is typically 0.6 – 3.5 m. Conductivity measurements can be used to classify lithologies and fluid composition. This data can be especially useful when analysing the extent of freshwater aquifers and the depth of the freshwater/saltwater interface zone, below which formation fluids become increasingly saline.

3.7.5 Acoustic (sonic) logs

Acoustic logs have multiple potential uses and are commonly used to assess the porosity of a formation in an open hole. Acoustic logging can only be carried out within a well, or sections of a well, filled with formation fluid or drilling mud. They can also be used to test the cement bond after a well has been cased. The cement bond log (CBL) measures the integrity and quality of the cement bond between the casing and the formation.

Acoustic logging measures the interval travel time and attenuation of an acoustic signal created by an electromechanical source in the wellbore. The sonic velocity of formations control the interval travel time. Soft, porous formations tend to have slow travel times, whilst hard, non-porous formations tend to have faster travel times. Rock and/or grain material conducts the acoustic wave more rapidly than fluid in pore spaces. The rate of signal transmission can be related to the amount of fluid stored within the formation and therefore its porosity.

Sonic log data also provides information on the formation strength.

The analysis of acoustics is also important in verifying how well a section of casing has been cemented into the formation. In a well cemented bore, most of the sound energy is carried by the cement and the nearby formation materials which results in a reduced amplitude and a delayed travel time of acoustic signal to the receiver. Conversely, in a poorly cased well, the acoustic signals will be returned to the receiver with higher energy and at a much faster rate. The data obtained is critical in assessing the integrity of the wellbore and its isolation from surrounding geologic structures.

3.7.6 Measurement while drilling and Logging while drilling

Especially in deviated and horizontal wells, it is usual to undertake Measurement while drilling (MWD) to assist controlling the depth and direction of the drill bit in the deviated hole section. MWD became essential in horizontal wells, since the pull of gravity of a wireline tool is absent in the horizontal section of a well.

MWD measurements include directional information and basic information about the formation being drilled. MWD tools are usually run immediately behind the drill bit, so MWD measurements can provide valuable information about the character and fluid content of potential reservoirs, shortly after they are drilled (and thus before they are infiltrated by drilling mud.

MWD tools may measure gamma ray response, azimuth, borehole temperature, resistivity, and pressure and other mechanical properties. The MWD tools also allow communication with rotary steering tools, which can alter and control the azimuth and direction of drilling. MWD results can be stored in the tool or transmitted to the surface using mud pulser telemetry (i.e., acoustic signals transmitted through drilling mud).

MWD thus enables directional drilling for deviated and horizontal well sections. It can also provide early-stage information on the rocks being penetrated before their native fluids are fully replaced with mud filtrate. Comparison of MWD data results with subsequent wireline logging data can provide useful ‘time-lapse’ data, showing changes over relatively short periods of time between drilling and logging.

Logging while drilling (LWD) is a later development of MWD, capturing 'real time' data to replace or complement post-drilling wireline logging. As the suite of LWD tools has grown, LWD is increasingly used for geo-steering (trying to locate a horizontal well section within a specific horizon) and formation evaluation. LWD is commonly used in Taranaki and is a cost effective compared to wireline logging (W Boeren, pers com, 2012).

3.8 Formation evaluation

The logging of boreholes using geologic and geophysical techniques provides critical data that can be used to assess the properties of underlying geologic strata including the rock types, vertical extent of formations, porosity, permeability and the composition of formation fluids. This integrative process is usually called "Formation Evaluation". These determinations of reservoir and fluid properties allow exploration companies to assess the potential of a well for further investigation and identify zones of interest. They also allow assessment of the geologic integrity of zones above hydraulic fracturing discharge zones by the regulator.

The different types of wireline logs that can be run downhole provide a variety of information on the lithology, density, porosity and fluid content in the wellbore. Some of this information is different and some similar. While individual logs can provide useful information on the character of the rocks, their fluid contents and saturations, a suite of logs can be integrated to provide a more complete interpretation (Table 1). No single log in isolation can provide full information on a formation. As a simple example, coals and limestones generally have very fast transit times indicated by the sonic log but limestones generally have very low gamma ray log responses, whilst coals have high gamma ray log responses. Consequently use of two of the most common logs – gamma ray and sonic – will provide an easy analysis of these rocks.

Logging data can also provide information on the vertical extent of freshwater aquifers and the depths at which formation waters become increasingly saline. Following well completion, geophysical logging methods also allow operators to confirm that construction of a well meets specification with regard to its structural integrity and isolation from surrounding formations.

Table 1 Summary of wireline logging tools

Log Type	Specific Log	Borehole Conditions	Information
Electrical	Potential Resistivity Focused resistivity	Open or screened holes with fluid	Lithology, formation water composition analysis (salinity), calibration of surface geophysics
Radioactivity	Gamma-ray Gamma-gamma (density) Neutron (porosity) Spectral gamma-ray	Open or cased holes with or without fluid	Lithology, density, porosity, calibration of surface geophysics
Electromagnetic	Induction Susceptibility	Open and PVC-cased holes with or without fluid	Lithology, porosity, salinity.
Acoustic	Sonic	Open holes with fluids	Lithology, porosity, cement bond, rock strength
Physical	Caliper	Open or cased holes with or without fluids	Borehole diameter
Fluid	Water quality	Open or cased holes with fluids	Conductivity, temperature, pH

3.9 Well development

As noted above, drilling starts after a potential hydrocarbon resource has been located through geologic studies, seismic interpretation and petrophysical assessment; followed by land access and resource consenting. The output from this work is the best scientific proposal on where to drill (and where not to drill). Before identification of a drilling location, geologic studies range from regional geologic mapping and investigation to petrophysical evaluation of rocks and cores from earlier drilled wells.

Details of the drilling process have been provided earlier. Exploratory drilling, which can take from a few weeks to a few months, is undertaken to collect information about the reservoir rock, composition of fluids in the rock and the productive capacity of the formation. The productive zones and development areas are also remapped with information gathered in this step, causing many development areas to be shifted to the best areas to develop and away from areas with poor reserves, shallow hazards or other problems.

Well integrity is a critical component of a successful well development operation. The objective is to keep different zones isolated from each other. Poor well construction, which could lead to barrier failure, compromises zonal isolation and sets up a potential pathway for contamination of groundwater. Barrier failure can be eliminated by proven design and proper application. Pressure testing of every cemented casing string is required and for the majority of well barriers (steel casing pipe plus cement), a cement bond log or other in-depth investigation will be required to confirm seal quality and to meet good oilfield practice or regulations.

For a new field wildcat well where subsurface conditions are not known pressure testing and cement bond logs are likely on each section of the well. Where subsurface conditions have been established through a number of wells the running of cement bond logs on all upper well cemented casing may not be required (W Boeren, pers com, 2012).

3.10 Well perforation

Perforation of casing is achieved by running a perforating gun, either on a wireline or on tubing to the location of the reservoir zone of interest. Once at the target depth a series of small shaped charges are used to blast small holes though the casing and cement into the formation to allow hydrocarbons to potentially flow (Figure 8).

Perforating is the only operation connected with hydraulic fracturing in which explosives are used. The purpose of perforating is simply to provide a controlled accessway to the reservoir formation for the input and recovery of fluids. Any fractures subsequently created in the formation are created solely by water pressure (applied at greater than formation breakdown strength) and not by explosives.

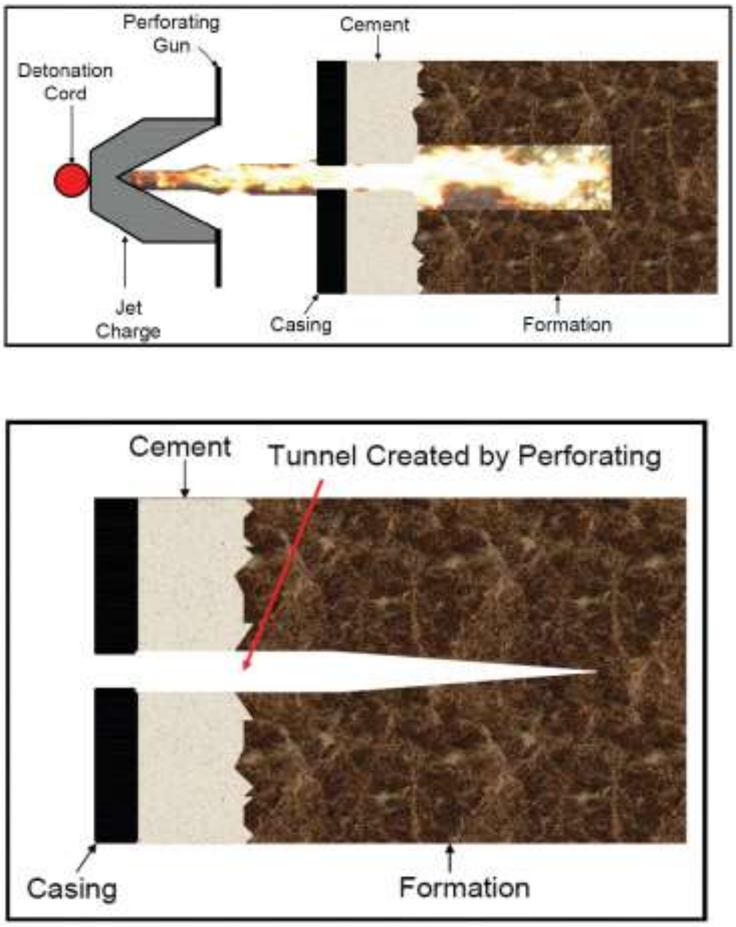

Figure 8 Well Perforation Process (Source: API, 2009)

4. Hydraulic fracturing

This section of the guide describes the process of hydraulic fracturing, the equipment used and the management and composition of hydraulic fracture fluids. It outlines the use of hydraulic fracturing in Taranaki and elsewhere and the environmental effects to be managed. It notes the regulatory technical expertise required to manage hydraulic fracturing operations.

The findings of relevant investigations and studies carried out by the Taranaki Regional Council are outlined. These provide useful context as to whether environmental issues raised in overseas literature and by the public are relevant for Taranaki and New Zealand.

4.1 What is hydraulic fracturing

Hydraulic fracturing (HF) is a well stimulation technique used to increase the flow of hydrocarbons to the surface, which would not otherwise flow or flow at commercially attractive rates. There are other well stimulation techniques, such as acidizing, but HF is usually undertaken in what are described as 'tight gas', coal seam or shale reservoirs to produce oil and gas. HF is a separate activity from drilling and whilst drilling is a requirement to access a reservoir, the decision to undertake a HF operation is usually taken subsequent to, and based upon, the results of drilling. Since they are separate activities, operators may not seek consents for drilling and HF at the same time, even if they recognize the potential need to undertake HF before drilling commences.

Put simply HF is the controlled creation and enlargement of an artificial fracture in a 'tight' reservoir by pumping fluids from the surface at pressures sufficient to inject into and thus fracture the reservoir rock, propping open that fracture by emplacement of permeable material (called "proppant") and then flowing back to the surface the produced fluids. These fluids are likely to be dominated by the fracturing fluids in the first instance but should subsequently (typically a few hours to a few days) be replaced by formation fluids (water and hydrocarbons). The objective is to create a permanent and permeable pathway from the reservoir to the wellbore, so that hydrocarbon fluids will flow to the surface at commercially attractive rates.

The primary purpose of HF is to increase the area of the target reservoir that is exposed to the wellbore and which, therefore, may contribute to fluid flow, once the HF operation has been completed. The HF fracture provides this increase by creating a broad permeable zone, connected to the perforated intervals in the wellbore.

HF is an expensive operation with equipment and expert personnel frequently brought in from overseas, so operators do not undertake HF lightly. Considerable preparation and analysis is required before a resource consent application for an HF operation will be made.

4.2 Target reservoirs

HF is only used in rocks with low to extremely low permeabilities (i.e., 'tight gas' and 'unconventional' types of oil and gas reservoirs (Figure 9)). Natural fluid flow is much easier in conventional reservoirs with higher permeabilities but HF is required for tight gas and unconventional reservoirs to assist fluid flows.

To date in Taranaki HF has been applied to tight gas sandstone reservoirs, though some operators are considering HF operations on unconventional shale reservoirs elsewhere in New Zealand. The principles of HF are the same for tight gas reservoirs and unconventional reservoirs. Hence the approach used to regulate HF in Taranaki can be applied to similar tight sandstone or shale formations elsewhere in New Zealand. However, local hydrogeologic, subsurface and other environmental factors need to be carefully considered.

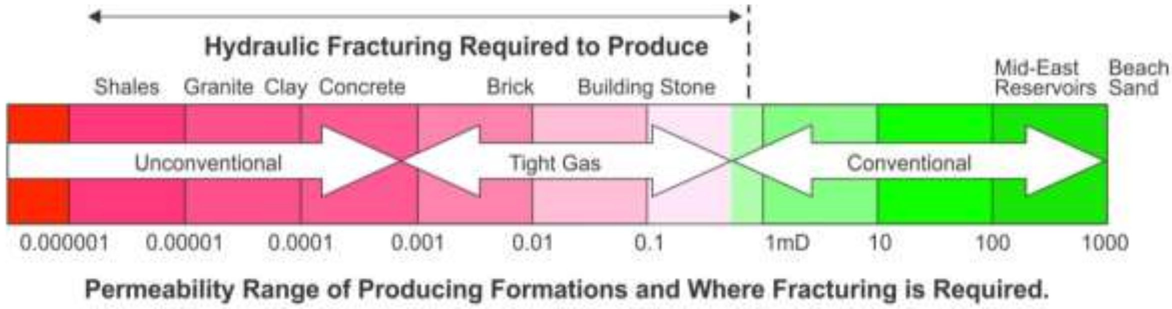

Figure 9 Permeability range of conventional, tight gas and unconventional reservoirs (Source: King, 2012)

There are three principal types of target reservoirs that may be subjected to hydraulic fracturing:

- Tight gas and oil sandstones;
- Coal seams; and
- Shale gas and oil reservoirs.

4.2.1 Tight gas and oil sandstones

HF operations in New Zealand have been undertaken to access tight oil and gas resources. Swift Energy used HF on south Taranaki oil reservoirs between 2000-2006 (Figure 15) (TRC, 2012b). All of the recent HF operations in Taranaki have been undertaken to stimulate 'tight gas' sandstone reservoirs. These are reservoirs usually at depths in excess of 3 km below surface, in which the permeability, (i.e., the ability of the reservoir rock to allow fluid flow, is extremely low).

4.2.2 Coal seams

Coal seams are unconventional reservoirs for gas, sometimes also referred to as 'coalbed methane'. It is not unusual to undertake degassing of coal seams in coal mines before commencing mining. Since coals are one of the principal sources of natural gas, they usually contain significant volumes of gas in situ. Although coal itself has extremely low porosity, (i.e., the volume of pores in the rock), and low permeability, coal has cleats (i.e., closely-spaced natural fractures), which can contain significant volumes of gas (and water).

Hydraulic fracturing of coal seams differs from hydraulic fracturing of 'tight gas sandstones', because the coal seams are usually shallower (less than 1,000 m below surface) and because greater volumes of fluids may be pumped during fracturing operations. Further, the process of flowing gas from the coal seam after the HF operation involves dewatering the seams. Water within the coal will flow preferentially to the gas, which is more tightly bound in the coal, so dewatering the seams can take some time before the gas will flow and disposal of produced water (usually brackish in character) can be expected to involve larger volumes of water than for a conventional 'tight gas sandstone' reservoir.

4.2.3 Shale oil and gas reservoirs

Over the last 10 years and particularly in the United States, the potential for extracting oil and gas from shales, as opposed to sandstone reservoirs, has been recognised and put into practice. Shales have extremely low porosity and permeability (Figure 9) but occur in very large volumes. Hydraulic fracturing of shale intervals can successfully stimulate oil or gas flow to the surface. The practice of shale gas fracturing has grown rapidly in the continental United States, where the use of this technology has restored the US to self-sufficiency in gas production.

4.3 Hydraulic fracturing operations

4.3.1 Types of hydraulic fracturing operations

The type of reservoir to be fractured generally defines the scale of the HF operation that will take place. A US shale gas fracturing operation will typically be substantially larger than a tight gas sandstone reservoir fracturing operation in Taranaki (Table 2).

Table 2 Comparison of typical fracturing operations in NZ and USA

	New Zealand	United States
Well Type	Vertical/Deviated	Horizontal
Reservoir Type	Tight gas sandstones	Coal seams and shales
Typical Depth	> 3,000 m	> 800 m
Pumping Units	4 - 5	20+
Water Use	<230 cubic metres / fracture operation	>>1,500 cubic metres / fracture operation
Pumping Rates	30 bbl/min	150 bbl/min

Source: Boeren(2011) and Boeren pers com (2012)

While the information contained in Table 2 is typical of hydraulic fracturing operations in New Zealand and in the US, there are a range of depths and water use etc. involved. One estimate for example, is that approximately 19,000 m3 of water use per well is typical in the US for the Marcellus Shale (Zemansky, 2012, pers com).

4.3.2 Use of hydraulic fracturing in Taranaki and elsewhere

The world's first successful oil well was drilled in the US in 1859. The practice of hydraulic fracturing also originated in the US in the late 1940s. It has become increasingly used in the US for unconventional (e.g., tight formations) oil and gas reservoirs over the last 20 years. It is estimated that more than one million wells in the US and two million wells worldwide have undergone hydraulic fracturing treatment and that 95% of oil and gas wells drilled today are hydraulically fractured (Conoco Phillips, 2012). The level of such activity in the US is three to four orders of magnitude greater on an annual basis than in New Zealand. For example, in the Barnett Shale alone in northern Texas, 9,400 wells were drilled over a six year period to depths in the 2 – 5 km range. Most of these were horizontal wells which were hydraulically fractured (Zemansky, 2012a).

In comparison, by the end of June 2012 1,051 wells had been drilled in New Zealand for hydrocarbon exploration and production purposes. Six hundred of these were drilled in the Taranaki region, including the coastal marine area out to the 12 nautical mile boundary. However, most wells are on land. There are a further 120 wells drilled off the Taranaki coast beyond the 12 nautical mile limit. No offshore wells have been subject to hydraulic fracturing operations. Those wells subject to hydraulic fracturing comprise less than 5 % of the total.

As of September 2013 in Taranaki there had been only 60 wells (39 historical and 21 consented) drilled which had undergone hydraulic fracturing treatment (for a total of 93 HF operations).

It is common practice in Taranaki (and elsewhere) to carry out HF in a number of intervals in one wellbore, where the target reservoir horizon may be made up of a number of stacked intervals, as is the case in the Mangahewa Formation. So the number of hydraulically fractured intervals is greater than the number of wells. To date there have been a minimum of 81 tight gas/ oil sandstone HF operations in Taranaki.

A small number of shallow coalseam gas fracturing jobs were undertaken by Solid Energy in the Waikato in the last five years and two coalseam gas fracturing jobs were undertaken near Ohai, Southland in 2003. Fracturing is not used in geothermal reservoirs in the Waikato region (M Broklesby, pers com, 2012).

To date no shale gas reservoir fracturing operations have been undertaken in New Zealand but a TAG venture has indicated that it is considering future well drilling and fracturing operations to test and stimulate shale gas and shale oil reservoirs on the East Coast.

It is very likely that the vast majority of future consent applications for HF operations in Taranaki will be for tight gas sandstone targets. Despite operational similarities, tight gas sandstone fracturing jobs are different from equivalent jobs for coalseam gas and shale gas reservoirs, because of differences in depth, the nature of the well (i.e. horizontal or deviated wells), and volumes of produced water. So the next section focusses on tight gas sandstone operations.

The scale of operations and differences in the regulatory framework between NZ and the US should be considered, when evaluating the US experience with regard to potential environmental concerns from hydraulic fracture operations in New Zealand (Zemansky, 2012a). The majority of HF jobs in the US are for shale gas or coalbed methane targets, which require significantly more energy (i.e., pumping equipment) and water than tight gas reservoir target HF jobs. For example, the volumes of fluids and chemical additives used in US shale gas reservoirs exceed the typical tight sandstone HF jobs in NZ by orders of magnitude (Zemansky, 2012a).

The following photographs illustrate the typical difference in scale for wellsite operations in a US shale gas verses a New Zealand tight sandstone hydraulic fracturing operation. Refer Figure 13 for identification of the equipment involved.

Photo 4 USA wellsite showing typical shale hydraulic fracture wellsite layout around the wellhead (Source: Boeren, 2011)

Photo 5 New Zealand wellsite - Mangahewa wellsite photographic mosiac showing from left to right coil tubing, storage tanks and pump trucks around the wellhead, gas processing equipment, and flare pit (Source: Boeren, 2011)

In Taranaki, hydraulic fracturing has been mainly undertaken in tight gas sand reservoirs, although some oil reservoirs have been subject to the activity (e.g., Cheal, Manutahi, Kauri, and Rimu wells). It has also been used in the Waikato by Solid Energy in coal seam gas recovery and there is interest in possibly using the same practice on coal resources in Southland.

Figure 10 shows the hydraulic fracturing undertaken in Taranaki (historical and consented) up to 31 July 2012. In the early 2000s HF of oil reservoirs in south Taranaki dominated, while from mid-2000 onward tight gas reservoirs dominated.

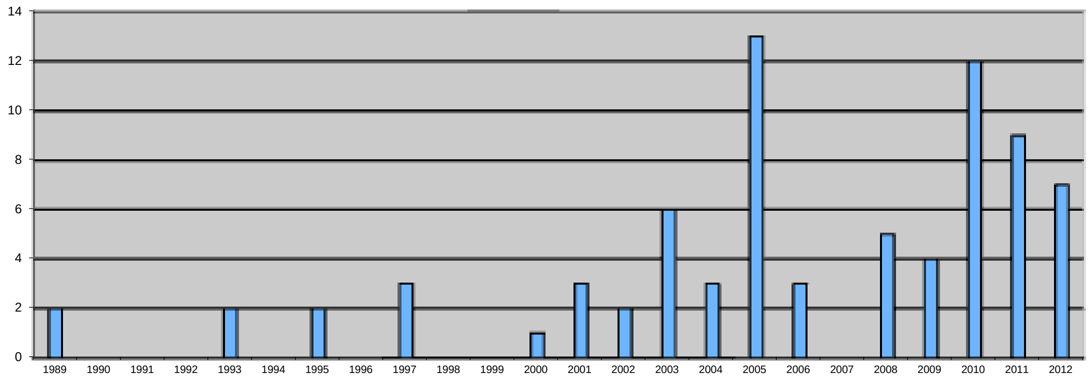

Figure 10 Hydraulic fracturing events in Taranaki up to 31 July 2012

Twenty one consents have been issued since August 2012 when a consent for the discharge began to be required, under the RMA, by the Taranaki Regional Council. Hydraulic fracturing activity increased since 2001 when the oil and gas prices increased and made the activity economic.

4.4 The hydraulic fracturing process

4.4.1 Hydraulic fracturing - a specialist process

Hydraulic fracturing is undertaken as a specialist exercise with equipment that is not present on the wellsite for a conventionally drilled and completed well. The fracturing operation is very sophisticated – there are multiple stages of a single pumping job and the formulation of the fracturing fluids during the phases of the job. Real-time control of the job is provided by surface and downhole monitoring of flowing and static pressures, as well as careful measurement of materials used and calculations/modelling of fracturing activity parameters.

Hydraulic fracturing involves pumping fracturing fluids, under extremely high pressure (2,000 – 10,000 psi at the surface), down the wellbore, through the perforations and into subsurface geological formations at pressures that will exceed the tensile strength of the target reservoir rocks but is less than the burst pressure of the well casing. At depths of 3,000 m or more the least principal stress direction is usually vertical, as the overburden pressure is so high. So hydraulic fractures are usually vertical, shaped like an aircraft wing, up to 100 m long by 20 m high but very narrow (2-7 mm, equivalent to the diameter of a drinking straw). Alternatively the fracture may open micro-fissures, micro-fractures and weak zones within the rock creating a high-permeability pathway within the rock matrix. This type of complex fracture may look something like a fractured windshield.

The size and extent of fractures created is a function of the target reservoir characteristics and the planned fracturing operation.

The purpose of the hydraulic fracturing job is thus to create a large increase of the surface area of the target formation, which can contribute to flow into the wellbore, compared with a natural completion, in which the wellbore circumference is actually a relatively small area (Figure 11).

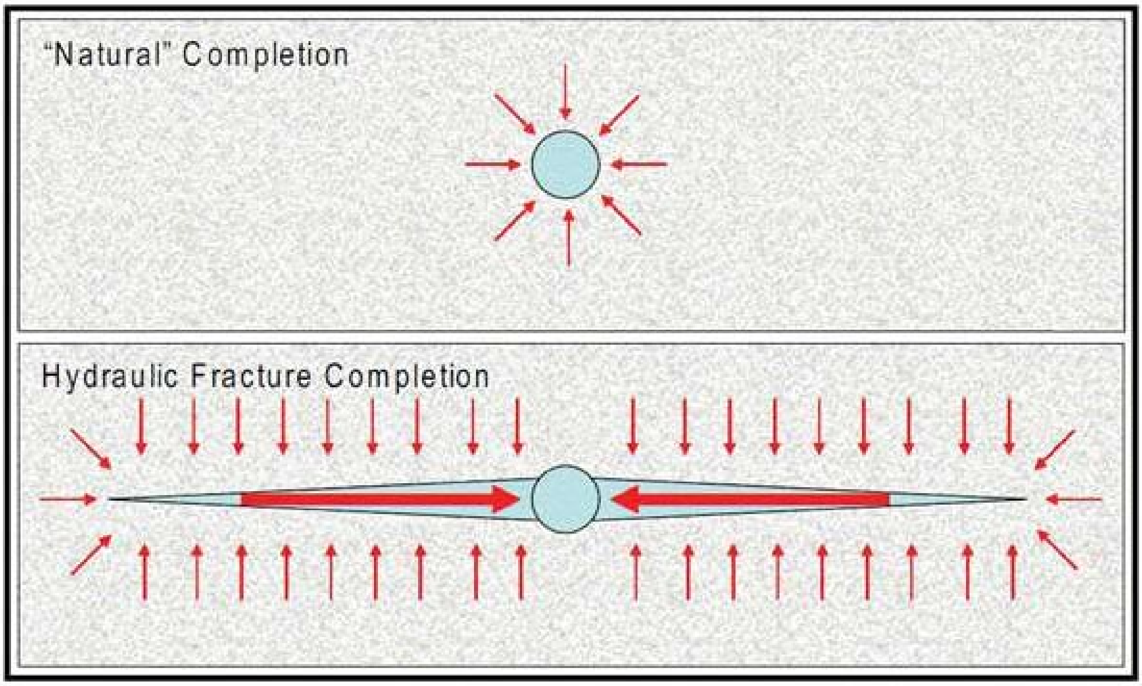

Figure 11 Fractured and non-fractured well completions (Source: API, 2009).

4.4.2 Hydraulic fracturing phases

A hydraulic fracturing operation consists of the following phases (Figure 12):

a) Mini-frac- a short pumping job to assess the reservoir tensile strength and fluid leakoff. This job may be done one or two days before the main job, so is not shown in Figure 12 below. The main pumping job phases are set out below.
b) Pre-pad volume- injection of water to initiate the fracture;
c) Pad volume- injection of water, viscosifier and friction reducer to grow the fracture; an emulsion (or gel) breaker is added towards the end of the pad;
d) Slurry- injection of the pad fluid plus proppant to fill the fracture and prop it open;
e) Displacement or flush- injection of water to force the remaining slurry from the wellbore into the fracture; and
f) Flow-back (or return fluids)- reduction of pressure at the surface to encourage spent fracturing fluids and formation fluids to flow into the fracture and, via the perforations, up the wellbore to the surface for collection and licenced disposal.

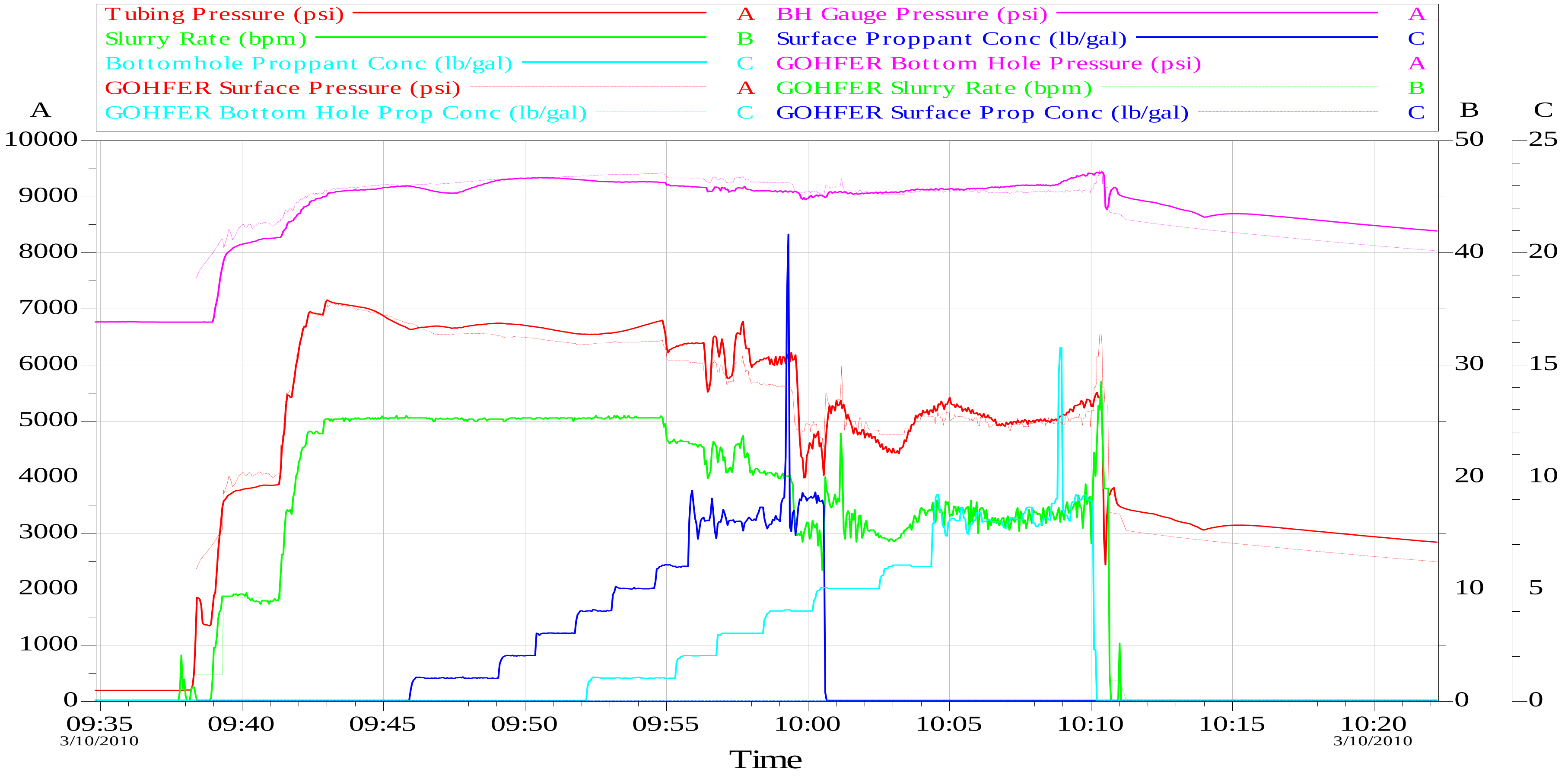

Figure 12 An example of a fracture at the Mangahewa 6 well (10/3/2012) undertaken by Todd Energy

An example of a fracture operation undertaken in Taranaki in a tight gas sandstone reservoir is shown in Figure 12. The chart shows the progress of a single hydraulic fracturing job in the Mangahewa-6 well at the Mangahewa C wellsite. The chart records both actual (thick lines) and modelled (thin lines) parameters for surface pressures in psi, bottom-hole (BH) pressures (just below the perforations) in psi, proppant concentrations in lb/gallon and slurry pumping rates in barrels per minutes (bpm). The colour coding is noted below.

Red: surface (tubing) pressures (0 – 10,000 psi)

Magenta: bottom-hole pressures (0 – 10,000 psi)

Blue: surface proppant concentrations (0 to 25 lb/gal)

Turquoise: bottom-hole proppant concentrations (0 to 25 lb/gal), and

Green: slurry rates (0 – 50 bpm).

A typical pumping job in the region may last for approximately 30 to 60 minutes with about 700 barrels of fracture fluids. Subsurface pressures will be sufficient to allow the fracture to propagate into the hydrocarbon reservoir. In the Mangahewa-6 case, the whole recording of the job lasts only 45 minutes with pumping starting at 09:38 and ending at 10:11. The phases of the fracturing job shown in the chart are as follows:

09:39 – 09:43 : Pumping the pre-pad volume, which contains a mixture of low-to-mid strength acid and water to initiate the fracture.

09:43 : Fracture occurs.

09:43 – 09:46 : The pad, including gels and friction reducters is injection to grow the fracture.

09:46 – 10:09 : Slurry pumping, which is injection of the pad fluid plus proppant to fill the fracture and prop it open. Note that the proppant concentration is increased in 1 lb/gal increments from 0 to 9 lb/gal and that it takes approximately 6 – 9 minutes for the slurry increments to reach the reservoir. Pumping rates go down as the slurry enters the formation.

10:00 – 10:01: Proppant concentrations are maximum at 9 lb/gal at the surface.

10:10 – 10:11: Displacement - the concentrated slurry arrives in the reservoir, causing an increase in both slurry rate and bottom-hole pressure. The fracture is effectively packed with proppant.

10:11: The spikes in pressure, slurry rate and proppant concentration indicate a screen-out, so pumping is stopped and the well is shut-in.

The plot (Figure 12) shows the comparison of a real-time modelling prediction tool (GOHFER – grid-oriented hydraulic fracture extension replicator). These are shown in the thin lines on the chart, whilst the actual real-time measured results are shown in the bolder lines. The model has been developed from input data from prior hydraulic fracturing jobs. There are a number of models available for HF. In the case of Mangahewa-6, a number of earlier Mangahewa wells have been hydraulically fractured and the well operator has a good understanding of the target reservoir and its response to fracturing.

The HF operator will have used information from all previous fracturing jobs and may have been able to incorporate information from the present target reservoir, if a mini-frac had been conducted. A mini-frac is usually undertaken a day or more before the actual fracturing job(s) so that the data gathered can be incorporated into any late design changes to the main frac job. A mini-frac will have provided more accurate parameter information to the HF operator to refine the modelling results from surrounding wells.

In the fracturing job illustrated in Figure 12 , there is good data comparison between the modelled and actual results. The modelled and actual slurry rates are so close that the two (green) lines overlie each other except for a couple of minutes early in the job. The modelled and actual surface and bottom-hole pressures (red and magenta lines, respectively) are very close, though there are small variations as the job progresses. These variations are negligible and indicate that the model forecast of the pressure trends was accurate and reliable.

Continued pumping requires steady tubing pressures and slurry rates, though the pressures drop as the proppant begins to feed into the fracture (around 09:59 in Figure 12). At this time the pumped fluids are predominantly KCl-dosed freshwater (from municipal supplies, combined with KCl to prevent clay expansion), combined with a changing and sophisticated mixture of chemicals to reduce friction and prevent scale and biological growths.

Once the fracture has been initiated around 09:43, pumping continues but the composition of the fracturing fluid changes. A key element is the inclusion of material, such as sand or artificial sand, called proppant. The proppant will be placed in the fracture to prevent the natural tendency for the fractures to close, once pumping stops and hydraulic pressures are reduced. Proppant begins to be added at surface at 09:46 and increased in 1 lb/gal increments until 09:56. The first proppant arrives at the perforations at about 09:52 and downhole gauges record the same incremental increases in proppant concentration. There is always a lag between pumping/proppant operations at the surface and when their effects are felt at the perforations deep in the well. Real-time data from the GOHFER model and downhole pressure gauges provide instant information about subsurface conditions downhole, so the GOHFER model also addresses the time lag during pumping.

To facilitate the correct placement of the proppant the fracturing fluids contain what are called “cross-linked gels” (usually derived from natural starches). These are solutions, which are liquid at the surface but, when mixed, form long-chain polymer bonds and thus become like gels, which can transport the proppant into the formation. The cross-linked gels thus assist in carrying the proppant into the fracture, so that it does not accumulate in the wellbore (causing a failure called a ‘screen-out’). Once the proppant and cross-linked gels have been pumped into the fracture, the reservoir temperature and other chemicals called ‘breakers’ cause the gel links to ‘break’ and the gel return to a water-like composition. The fracturing fluid is maintained under pressure for a short period of time determined by the fracturing design engineer (10:10 – 10:22).

Pumping the main frac job in Mangahewa-6 was relatively brief (38 minutes), but depends upon the design and intent of the fracture operation. This period of high-pressure operation is probably the only time most wells will experience pressures above a level that will force reverse fluid flow (i.e., into the formation).

Fracture vertical growth may extend a few metres or more above the pay zone in a few cases, where there are no natural upper rock fracture barriers immediately over the zone of interest, but more likely, the fracture will be quickly limited by one of dozens of rock barriers above and below the zone of interest and the natural overburden pressure. Fracture growth will be self-limiting because of increasing loss of fracture fluid into the formation as the fracture grows, exposing more target reservoir to the flow (called 'leak-off').

Driving a fracture upwards through several thousands of metres of rock or up major faults is exceedingly unlikely because:

- Mechanical limitations of the equipment in use
- The energy available to inject fluids
- Natural fracture barriers
- Increasing leak-off as the fracture grows
- Natural stresses of the formation above the zone of interest
- Operators do not fracture near major faults (with long fault traces)
- Where faults have been intersected by fracturing (e.g., Preese Hall, Lancashire), the faults were too small to register on seismic data
- Most reservoirs are naturally sealed by 'cap rocks', which are usually shales. These cap rocks are more plastic than the reservoir rocks, and faults (on any scale) do not readily propagate through them. Faults through such cap rocks do not easily transmit fluids, as the cap rocks tend to reseal naturally.
- The fact that the Mangahewa Formation reservoirs are over-pressured by over 1,000 psi confirms that the overlying seal rocks are very competent and have not leaked in recent geological time.

Similarly driving fracture fluid up the outside of casing for any significant distance is most unlikely, because the cement is 'squeezed' into place at pressures greater than the natural reservoir pressure and, in deeper casing intervals, the cement bond will have been confirmed by wireline logging.

4.4.3 Multiple fracturing jobs in a single wellbore

The fracturing process may be repeated a number of times in a single wellbore, depending upon the number of target reservoirs. In most cases the lowest interval is fractured first, flowed briefly to clean up the perforations, and then spacer sand (usually beach sand) is placed to isolate this interval, using a 'coiled tubing unit'(Photo 5), to protect the fractured interval, whilst higher intervals are treated. A plug in the well may be used for the same purpose. The spacer sand or plug effectively seals off an existing fracture so that a higher interval may be fractured, without affecting the existing fracture. This process is repeated up the wellbore until each of the target reservoirs has been fractured. Then, depending on the flow rates achieved after each fracturing job, the operator may decide to co-mingle the flows from each interval by removing the spacer sand across each interval, using a coiled tubing unit, including a pump.

Once pumping stops and pressure is reduced at the surface, the high target formation pressures will cause the spent fracturing fluids (now like water) to flow from the formation back into and along the fracture (without dislodging the proppant), through the perforations and up the wellbore to the surface. The proppant will continue to keep the fracture open as a permeable conduit between the tight formation and the wellbore.

The initial return fluids are likely to be predominantly spent fracturing fluids but, with continued flow, these fluids should be gradually replaced by formation fluids, including as hoped hydrocarbons, within a few hours (Todd Taranaki, 2011). Overseas literature notes the percentage of fracture fluids that are immediately discharged in the return flow can vary between about 20% and 80% of the fracture fluids but this is dependent on the geology, fracture formation properties and the fracturing operation (King, 2012). The remaining fracturing fluids initially stay in the reservoir, being gradually "leached" out with the hydrocarbon flow and are brought to the surface with continued hydrocarbon production. Such saline produced water is separated from the hydrocarbons at surface treatment facilities and disposed of at licensed facilities.

If the well is in development stage, a pipeline will already have been connected and methane emissions during post-fracture well preparation or flow back can be minimised with saleable gas recovered.

4.4.4 Importance of well design and construction

The actual act of fracturing in a properly designed and constructed wellbore, is the lowest risk action involved in the well development process, especially in wells more than about 2,000 metres deep. If well construction is not properly done, then communication may be possible through the wellbore annulus (the area between the cement and rock wall), which could become a groundwater contamination risk. The closer the fracture operation is to freshwater, the greater the risk and need for very careful evaluation.

A good well design is intended to protect the non-oil or gas zones, including freshwater aquifers, from

Photo 6 Equipment used in fracture operations at a Taranaki wellsite – pumping equipment, liquid storage, and separator vessel and overflow trough

produced hydrocarbons, protect the well from formation problems external to the well such as corrosive gas or salt water, and protect against movements, such as earthquakes.

The elements of good well design and casing are set out in section 3.4.

4.4.5 Fracturing fluid composition and selection

Water- and oil-based fracture techniques are available, with the former the most common in Taranaki (Taranaki Regional Council, 2012b). Oil-based fracturing fluids are developed from petroleum-based products, such as diesel or condensate. Diesel was used by Swift Energy at the Rimu and Manutahi fields in South Taranaki, as a way of dealing with water-sensitive swelling clays in the reservoir formations. Diesel contains a mixture of volatile organic compounds (VOCs), including benzene, ethylbenzene, toluene, and xylene (BTEX). They are usable within New Zealand's regulatory framework. However, oil-based fracturing fluids pose a potentially greater environmental hazard than water-based fluids, if not managed correctly. Benzene, for example, is considered carcinogenic even though it is found in household products such as adhesives, asphalts, lighters and gasoline. Oil-based fracturing fluids which can only be used in reservoirs with low to medium temperatures have not been used elsewhere in New Zealand and are unlikely to be used because of their composition and potential environmental effects.

Further detail on the composition of hydraulic fracturing fluids and their management is provided in section 4.6.

4.4.6 Summary of hydraulic fracturing operations

Hydraulic fracturing jobs are designed by experts utilising local experience and computer models to specify the fracture volume, rate and other factors required to achieve goals of fracture height, fracture width and fracture length or fracture complexity. Real-time monitoring of pumping operations, using fluid tracers, micro-seismic analysis or tilt meters is useful to check the first few fractures in an area and to enable tuning of the results of the fracture models (refer section 4.5). The goal is to design a fracture operation that will be confined to the zone of interest, develop the maximum producing formation contact and achieve maximum flow of hydrocarbons and minimum flow of produced water, whilst protecting the overlying structure and hence the economic value of the formation.

The potential that fracturing fluids might not to be contained within the target reservoirs and migrate upward to freshwater aquifers has been identified as a potential source of contamination (Taranaki Regional Council, 2012b). However, overburden stress in deep reservoirs prevents fractures from propagating vertically for long distances, particularly in more 'plastic' rocks, such as shales and mudstones. Fracture containment should however be verified by computer simulation calibrated with actual rock strength data from formation cores. Shales can only be successfully fractured it there are no brittle formations (like sandstones) in the vicinity (W Boeren 2012, pers com). Seismic impacts have been identified as a potential adverse effect of hydraulic fracturing activities. The issues of potential groundwater contamination and induced harmful seismicity from hydraulic fracturing operations are addressed in sections 4.8.1 and 4.8.2, respectively.

4.4.7 Hydraulic fracturing equipment

Hydraulic fracturing operations require the use of large amounts of specialist equipment, which is not usually present on a well drilling project. The specialist equipment is collectively called a 'frac spread' and comprises the principal pieces of equipment shown in Figure 13 and described below.

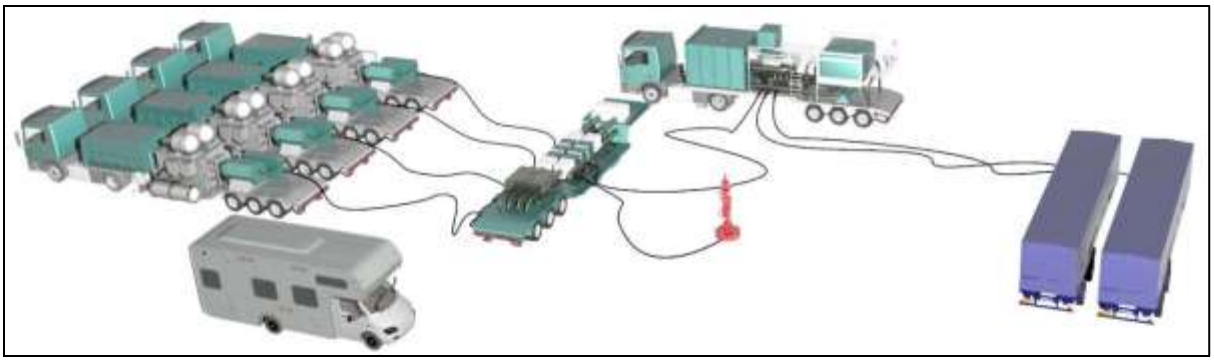

Figure 13 Typical Taranaki hydraulic fracturing equipment schematic (Source: Todd, 2012)

Clustered around the wellhead are the following pieces of equipment:

1. Data monitoring van ('frac van') or container on site from which the operation is controlled;
2. Sand storage units, which contain the proppant (and spacer sand);
3. Water and chemical storage tanks or containers ;
4. Truck-mounted pumping units ;
5. Blender (a unit which mixes the water, chemicals, proppant and sand); and
6. Manifold (combines a series of high-pressure pipes, which connect the equipment to the wellhead).

In addition there are two other pieces of equipment:

1. A wireline unit, which conveys pressure monitoring equipment downhole to the reservoir interval for real-time reservoir pressure measurements may be used; and
2. A coiled tubing unit, which is used to emplace and remove sand, used to block off zones of interest after they have been fractured, so higher zones can be treated.

Note that the frac fluid is usually mixed on demand', i.e., as it is pumped from the respective storage units to the wellhead.

4.5 Hydraulic fracture monitoring

Four very useful papers on hydraulic fracturing have been produced by the Society of Petroleum Engineers, relating to: (1) the basic practice of hydraulic fracturing (King, 2012); (2) seismic-induced hydraulic fracturing (Cipolla and Wright, 2000);(3) the measurement of hydraulic fracture induced seismicity in gas shales (Warpinski et al, 2012); and (4) a practical guide to hydraulic fracture diagnostic technologies (Barree et al, 2002). They are available on the Council's website. This section of the guide draws on some of these papers to provide a description of fracture monitoring and introduces the diagnostic techniques that are available and used in Taranaki to determine the destination and fate of the introduced proppant and fracturing fluids.

Hydraulic fracturing produces a fracture or narrow fracture zone in the reservoir rock as a response to relief of the hydraulic pressure applied to the interval. The crack that develops is narrow, usually 2 to 3 mm in width and grows outward, upward and downward. The crack will widen slightly until a barrier is encountered or there is sufficient leak-off into the formation to stop the fracture from growing. Even at an injection rate of 150 barrels (bbls) per minute (New Zealand rates are more likely to be around 30 bbls per minute), secondary fractures and permeable streaks absorb enough liquid from the main fracture to limit outward and upward fracture growth. Fracture growth is thus self-limiting: as the fracture grows under constant surface pumping pressures, downhole pressures will be increasingly relieved as more and more of the fracture is opened. Eventually, the fracture will stop growing.

It is not possible to see the fractures created directly, although some research wells have been drilled and fractured, with downhole cameras used to view in situ fractures. However, such wells require special equipment and a change to the conventional mud system and this is not usually done. Instead a number of remote diagnostic techniques have been developed to determine fracture dimensions and characteristics (King, 2012).

Real-time monitoring of pumping pressures, pumping rates and materials usage are used to control a hydraulic fracturing job. Since the pumped fracturing fluids are not usually mixed until immediately before pumping down the wellbore, it is possible to closely monitor all materials usage. Real-time monitoring can give useful information, such as the timing of the initiation of a fracture, fracture growth and its cessation. It cannot, however, provide a full diagnosis of the outcome and success of an HF job. Consequently a suite of pre-, syn- and post-fracturing tools is used to assess these characteristics.

Diagnostic tools for hydraulic fracturing will be used to evaluate the performance and outcome of a HF operation. These include the fracture height, length and containment and the location of any HF fluids and proppant. The diagnostic tools fall into three categories:

1. Indirect measurements or analyses derived from modelling of the HF operation either before or after pumping;
2. Direct near-field measurements, that is, downhole measurements after the HF job has been pumped. These include pressure monitoring, production and temperature logging and downhole video cameras; or
3. Direct far-field measurements, that is near-surface or downhole measurements made in adjacent wells to determine changing conditions during pumping.

Some diagnostic tools are run in every HF operation, whilst others may be used for specific purposes or in specific situations, where conditions allow, such as the presence of adjacent observation well bores.

4.5.1 Common diagnostic tools

A number of diagnostic tools are used in all HF operations in New Zealand. These tools provide some forecast of the requirements for the operation, modify proposed operational specifications based upon preliminary results and provide real-time pressure monitoring of downhole conditions during the HF operation. These are as follows:

Modelling
HF modelling is used to design the operation before pumping begins. An HF model is based upon assumptions, calibrated with available field data, such as borehole conditions, rock characteristics and reservoir data. The model can be reviewed after pumping to provide a better assessment of the outcome of the HF operation.

'Mini-fracs' or 'Diagnostic Fluid Injection Testing'
A 'mini-frac' or 'diagnostic fluid injection testing' is a small HF treatment performed before the main HF operation to acquire critical HF design and execution data. Final HF procedures and parameters are refined according to the mini-frac treatment results.

Pressure Monitoring
Pressure monitoring is undertaken before, during and after the HF operation. Pressure data assist in calibrating the HF model and also identify pressure communication, in which HF fluid and proppant are being lost due to poor cement jobs or well casing integrity issues. An HF operation should be discontinued immediately, if unexpected pressure losses are detected.

Low-level Radioactive Tracers
Low-level radioactive tracers will identify the location of the proppant after the HF treatment has been pumped. Low-level radioactive ceramic beads are added to the proppant during pumping. A gamma ray log run after the pumping will identify the location of proppant but only in a narrow radius around the wellbore (<0.5 m). The log can thus provide an estimate of fracture height and any losses of HF fluid and proppant outside the casing, due to poor quality cementing.

Temperature Logs
Temperature logging will assess the location of the perforations and the HF fluid (and entrained proppant), as well as provide a rough assessment of the fracture height. Tools include wireline logs and downhole fibre-optic cables, which detect temperature changes caused by the cooler HF fluid. Repeated logging after the HF operation can give an indication of where flow-back of the HF fluid is coming from, that is, the effective part of the fracture.

Production Analysis
Hydrocarbon production analysis is a key tool in generally determining whether the HF has been successful. Significantly increased production from a fractured interval or a number of intervals in a zone indicates that fractures have been successfully placed and filled with proppant. The integrity of the reservoir has also been maintained and likely the fractures have been confined to the target reservoir.

Screen-outs
Screen-outs occur when it is no longer possible to propagate proppant into the formation and can have complex causes. This usually occurs when the proppant-laden fluids reach the tip of the fracture (a 'tip screen-out'). A screen-out may also occur if and when there is a blockage in the perforations, which prevents the

proppant being transmitted into the fracture, leading to unwanted accumulation of proppant in the wellbore.

4.5.2 Selection of diagnostic tools

HF modelling is the central diagnostic tool that is assisted by the other above tools. The tools are summarised in Table 3 and not all the tools are technically feasible in all situations. A combination of tools is required to answer a range of questions, such as fracture height, width and containment and the contribution to production flows from the HF zone. The model provides an estimate of fracture height, width and containment and the resultant fracture performance.

During the HF operation diagnostic tools are used to control fracture growth and to prevent and detect unexpected and unwanted events, such as proppant and fluid loss up the outside of casing or via an unknown fault that can cause a 'screen-out'. The selection of tools is also influenced by local conditions, for example, the depth of the interval to be fractured, the presence of nearby observation wells for some technologies and the level of detailed information desired by the operator or the regulator from the HF job.

The supply of information from diagnostic tools is a requirement of recommended consent conditions to assess the fracture height, length and containment and the location of any HF fluids and proppant to determine any effects on groundwater.

The attached technical papers from (Appendix I) set out further details on the various diagnostic techniques that are available and their strengths and weaknesses. Case studies are included to show how several fracture diagnostic tools can be used in concert to provide reliable estimates of fracture dimensions. The papers specifically focus on HF placement/diagnostics with an effort to improve design and placement execution of the HF programme. They are not specifically focused on whether thousands of metres of formation layers provide containment, but provide a good overview of the various technologies available.

Table 3 Available diagnostic techniques to evaluate hydraulic fracture length, height and containment

		Hydraulic Fracture					Perforations	Proppant	
Grouping	**Diagnostic Technology**	**Length**	**Height**	**Width**	**Orientation**	**Volume**	**Location**	**Location**	**Comments**
Indirect Measurements (dependent on modelling)	Frac modelling								A frac model is based upon assumptions, calibrated with field data and other diagnostic techniques. Once the model is calibrated, treating pressures and reservoir data can provide reasonable indications of fracture height and length
	Mini-frac								A mini-frac (sometimes called a 'data-frac') is a small fracturing treatment performed before the main hydraulic fracturing treatment to acquire critical job design and execution data and confirm the predicted response of the treatment interval. It provides key design data from the parameters associated with the injection of fluids and the subsequent pressure decline. The final job procedures and treatment parameters are refined according to the results of the minifrac treatment. Pumping pressures will be set below the burst pressure of the casing
	Annulus Pressure Monitoring								The annulus pressure is monitored prior to the frac job for indications of pressure communication (pressure losses behind casing due to a poor cement job). The frac job will not commence, if pressure communication is detected
	Production Analysis								Post-frac production analysis can give an estimate of the effective fracture length - the part contributing to flow (usually less than the actual fracture length). The difference between the pre- and post-frac flows is a measure of the effectiveness of the frac job
	Well Testing								Well testing involves flowing the well after fracturing and then shutting it in. Stopping the flow causes a pressure transient in the fluid reservoir, which can be used to determine fracture length and permeability.
Direct - Near Field (down-hole measurements after frac treatment)	Low-level Radioactive Tracers								Low-level radioactive ceramic beads provide an indication of the location of proppant after the frac job but only in range out to 0.5 m radius from the wellbore. They can provide an estimate of the range of fracture height and any losses of frac fluid and proppant outside the casing
	Production Logging								Noise logs can identify which perforations fluids are flowing through. Wireline tools called spinners have multiple sensors, which can measure flow, temperature, pressure and fluid density. Such surveys can give evidence of where frac fluid has travelled into the formation
	Temperature Logging								Temperature logs are produced by wireline tools drawn past the perforations. Hydraulic fracture fluids cool the formation and so the invaded formation can be detected and fracture height can be determined; losses outside the casing can be detected. Repeated logging after the frac job can give an indication of the flow-back of the frac fluid
	Distributed Temperature Sensing (DTS)								DTS uses a fibre-optic cable to determine a temperature profile down the well. Hydraulic fracture fluids cool the formation where placed, so fracture height can be determined
	Downhole Video								A downhole video can be run in open hole to give visual evidence of fracture height and orientation. In a cased hole the video will only give evidence of the location of perforations
	Screen-outs								Screen-outs occur when the fracture stops growing during the pumping operation, resulting in proppant being dropped from the frac fluid, usually in the wellbore or across the perforations. Some screen-outs may be deliberately designed to sacrifice fracture growth, in favour of increasing fracture width (and thus permeability).
	Annulus Pressure Monitoring								During the frac pumping operation, surface and downhole pressures, pumped volumes and material quantities will be measured. These real-time measurements allow the frac crew to monitor downhole conditions as the frac job proceeds. As an example, the annulus pressure is monitored during the frac job for indications of pressure communication (pressure losses behind casing due to a poor cement job). The frac job will be terminated, if pressure communication is detected
Direct - Far Field (surface or down-hole)	Surface Tilt Mapping								A hydraulic fracture causes deformation in surrounding rocks. Very accurate 'carpenter's levels' placed in shallow observation boreholes near the well being fractured produce a deformation map that can be used to measure fracture orientation and possibly volume. The technique becomes increasingly inaccurate with depth. Because of the distance from the fracture to the surface, surface tiltmeters cannot resolve fracture length or height
	Downhole Tilt Mapping								Tiltmeters are placed downhole in adjacent deep observation wells (if available) at the depth of the planned hydraulic fracture. The tiltmeters are much closer to the fracture so they can provide information on fracture height, length and width
	Microseismic Mapping								Downhole geophones are placed in nearby observations wells (within 250 - 400 m of the fractured well to achieve adequate signal-to-noise ratio). Microseismic events caused by movement along natural or induced fractures are picked up by the geophones. The microseismic data can be processed to determine fracture growth and geometry. Some formations may not generate microseisms.

Will Determine	
May Determine	
Cannot Determine	

Notes

All tests are designed to improve economic and environmental performance

There is no single diagnostic test and an array of diagnostic tests allow you to determine the evaluate fracture length, height and containment

Once the frac job has been designed, pressures are monitored during pumping to ensure that there is no unexpected pressure losses

4.6 Hydraulic fracture fluids management and composition

4.6.1 Containment, storage, transport

The transport and storage of fracture fluids, chemicals and equipment have been identified as potential sources of contamination. However, the risk of this contamination can be substantially reduced or mitigated by the following methods:

1. Storing chemicals in double-wall containers or with bunding;
2. Surface storage vessel leaks and spills can range from less than a few litres during connections in fracture fluid lines to the very rare leak of greater volumes if both container and secondary containment fail. Leak impact can be reduced by container mats underneath pipe connections, portable tank containment berms and tank monitoring to immediately spot leaks;
3. The impact of fracturing fluid leaks is usually minor, since the base fluid is fresh water and most chemical additives are mixed into the base fluids, as the fracture fluid is being pumped into the well; and
4. Safe transport, storage and handling of chemical concentrates are major concerns. These risks are sharply reduced when non-toxic or even food-grade additives replace traditional chemicals.

Mixing and pumping of the fracture fluid increases the risk of leaks and spills as the fracture fluid is pumped from storage, first to the chemical addition trailer and then the blender where sand is added, before going to the manifold and down the well (Figure 13).

The provisions of HASNO apply to the transportation, use and storage of hazardous substances (see section 5.3).

4.6.2 Composition of fracturing fluids

Water and sand (proppant) make up 98% to 99.5% of the fluid used in hydraulic fracturing. In addition, chemical additives are used. The exact formulation varies depending on the well. Chemicals serve many functions in hydraulic fracturing. From limiting the growth of bacteria to preventing corrosion of the well casing, chemicals are needed to ensure that the fracturing job is effective and efficient.

The number of chemical additives used in a typical fracture treatment depends on the conditions of the specific well being fractured. A typical fracture treatment will use very low concentrations of between 3 and 12 additive chemicals, depending on the characteristics of the water and the tight sand/shale formations being fractured. Each component serves a specific, engineered purpose. For example, the predominant fluids currently being used for fracture treatments in the gas shale plays overseas are water-based fracturing fluids mixed with friction-reducing additives (called slickwater). The addition of friction reducers allows fracturing fluids and sand, or other solid materials called proppants, to be pumped to the target zone at a higher rate and reduced pressure than if water alone were used. In addition to friction reducers, other additives include: biocides to prevent microorganism growth which can interfere with the gel management system, and to reduce biofouling of the fractures and the production of sour gas; oxygen scavengers and other stabilisers to prevent corrosion of metal pipes; and sometimes used acids that are used to remove drilling mud damage within the near-wellbore area. These fluids are used to create the fractures in the formation and to carry a propping agent (typically silica sand), which is deposited in the induced fractures to keep them from closing up.

The make-up of fracturing fluid varies from one geologic basin or formation to another. Evaluating the relative volumes of the components of a fracturing fluid reveals the relatively small volume of additives that are present.

Figure 14 shows the volumetric percentages of additives that were used for a nine-stage shale gas hydraulic fracturing treatment of a US Fayetteville Shale horizontal well.

The additives depicted on the right side of the pie chart represent less than 0.5% of the total fluid volume. Overall the concentration of additives in most slickwater fracturing fluids is a relatively consistent 0.5% to 2% with water making up 98% to 99.5%. Because the make-up of each fracturing fluid varies to meet the specific needs of each area, there is no one-size-fits-all formula for the volumes for each additive. In classifying fracturing fluids and their additives, it is important to realise that service companies that provide these additives have developed a number of compounds with similar functional properties to be used for the same purpose in different well environments. The difference between additive formulations may be as small as a change in concentration of a specific compound. Although the hydraulic fracturing industry may have a number of compounds that can be used in a hydraulic fracturing fluid, any single fracturing job would only use a few of the available additives. For example, the chart shown below (Figure 14), represents 12 additives used, covering the range of possible functions that could be built into a fracturing fluid.

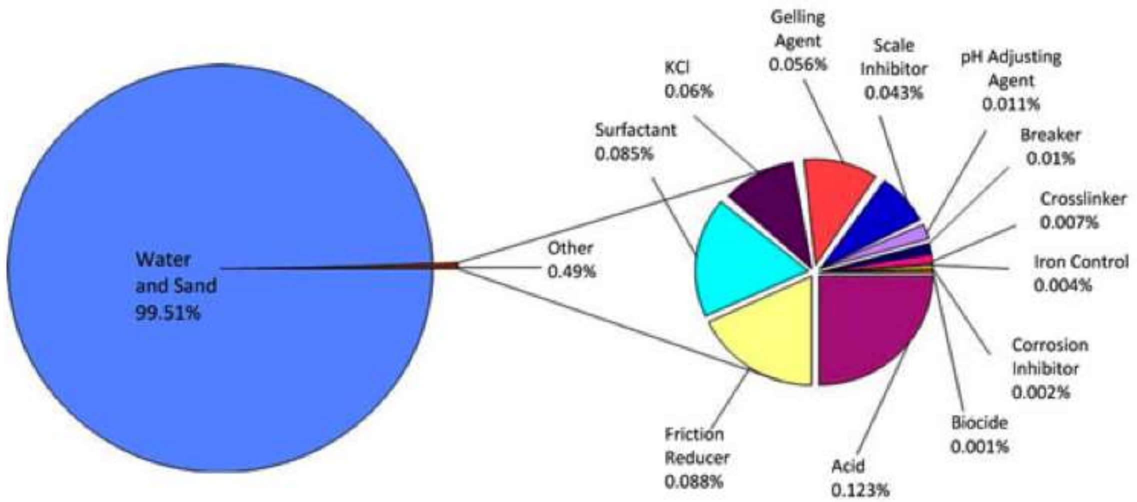

Figure 14 Composition of hydraulic fracturing fluids (Source: Ground Water Protection Council, 2009)

4.6.3 Chemicals used

As previously noted, chemicals perform many functions in a hydraulic fracturing job. Although there are dozens to hundreds of chemicals which could be used as additives, there are a limited number which are routinely used in hydraulic fracturing. Table 4 is a list of the chemicals used most often, sorted alphabetically by the Product Function to make it easier to compare to the fracturing records.

Table 4 Chemicals used in hydraulic fracturing, by product function

Chemical name	CAS	Chemical purpose	Product function
Hydrochloric Acid	007647-01-0	Helps dissolve minerals and initiate cracks in the rock	Acid
Glutaraldehyde	000111-30-8	Eliminates bacteria in the water that produces corrosive by-products	Biocide
Quaternary Ammonium Chloride	012125-02-9	Eliminates bacteria in the water that produces corrosive by-products	Biocide
Quaternary Ammonium Chloride	061789-71-1	Eliminates bacteria in the water that produces corrosive by-products	Biocide
Tetrakis Hydroxymethyl-Phosphonium Sulfate	055566-30-8	Eliminates bacteria in the water that produces corrosive by-products	Biocide
Ammonium Persulfate	007727-54-0	Allows a delayed break down of the gel	Breaker
Sodium Chloride	007647-14-5	Product Stabiliser	Breaker
Magnesium Peroxide	014452-57-4	Allows a delayed break down the gel	Breaker
Magnesium Oxide	001309-48-4	Allows a delayed break down the gel	Breaker
Calcium Chloride	010043-52-4	Product Stabiliser	Breaker
Choline Chloride	000067-48-1	Prevents clays from swelling or shifting	Clay Stabiliser
Tetramethyl ammonium chloride	000075-57-0	Prevents clays from swelling or shifting	Clay Stabiliser
Sodium Chloride	007647-14-5	Prevents clays from swelling or shifting	Clay Stabiliser
Isopropanol	000067-63-0	Product stabiliser and / or winterising agent	Corrosion Inhibitor
Methanol	000067-56-1	Product stabiliser and / or winterising agent	Corrosion Inhibitor
Formic Acid	000064-18-6	Prevents the corrosion of the pipe	Corrosion Inhibitor
Acetaldehyde	000075-07-0	Prevents the corrosion of the pipe	Corrosion Inhibitor
Petroleum Distillate	064741-85-1	Carrier fluid for borate or zirconate crosslinker	Crosslinker
Hydrotreated Light Petroleum Distillate	064742-47-8	Carrier fluid for borate or zirconate crosslinker	Crosslinker
Potassium Metaborate	013709-94-9	Maintains fluid viscosity as temperature increases	Crosslinker
Triethanolamine Zirconate	101033-44-7	Maintains fluid viscosity as temperature increases	Crosslinker
Sodium Tetraborate	001303-96-4	Maintains fluid viscosity as temperature increases	Crosslinker
Boric Acid	001333-73-9	Maintains fluid viscosity as temperature	Crosslinker

Chemical name	CAS	Chemical purpose	Product function
		increases	
Zirconium Complex	113184-20-6	Maintains fluid viscosity as temperature increases	Crosslinker
Borate Salts	N/A	Maintains fluid viscosity as temperature increases	Crosslinker
Ethylene Glycol	000107-21-1	Product stabiliser and / or winterising agent.	Crosslinker
Methanol	000067-56-1	Product stabiliser and / or winterising agent.	Crosslinker
Polyacrylamide	009003-05-8	"Slicks" the water to minimise friction	Friction Reducer
Petroleum Distillate	064741-85-1	Carrier fluid for polyacrylamide friction reducer	Friction Reducer
Hydrotreated Light Petroleum Distillate	064742-47-8	Carrier fluid for polyacrylamide friction reducer	Friction Reducer
Methanol	000067-56-1	Product stabiliser and / or winterising agent.	Friction Reducer
Ethylene Glycol	000107-21-1	Product stabiliser and / or winterising agent.	Friction Reducer
Guar Gum	009000-30-0	Thickens the water in order to suspend the sand	Gelling Agent
Petroleum Distillate	064741-85-1	Carrier fluid for guar gum in liquid gels	Gelling Agent
Hydrotreated Light Petroleum Distillate	064742-47-8	Carrier fluid for guar gum in liquid gels	Gelling Agent
Methanol	000067-56-1	Product stabiliser and / or winterising agent.	Gelling Agent
Polysaccharide Blend	068130-15-4	Thickens the water in order to suspend the sand	Gelling Agent
Ethylene Glycol	000107-21-1	Product stabiliser and / or winterising agent.	Gelling Agent
Citric Acid	000077-92-9	Prevents precipitation of metal oxides	Iron Control
Acetic Acid	000064-19-7	Prevents precipitation of metal oxides	Iron Control
Thioglycolic Acid	000068-11-1	Prevents precipitation of metal oxides	Iron Control
Sodium Erythorbate	006381-77-7	Prevents precipitation of metal oxides	Iron Control
Lauryl Sulfate	000151-21-3	Used to prevent the formation of emulsions in the fracture fluid	Non-Emulsifier
Isopropanol	000067-63-0	Product stabiliser and / or winterising agent.	Non-Emulsifier
Ethylene Glycol	000107-21-1	Product stabiliser and / or winterising agent.	Non-Emulsifier
Sodium Hydroxide	001310-73-2	Adjusts the pH of fluid to maintains the effectiveness of other components, such as crosslinkers	pH Adjusting Agent

Chemical name	CAS	Chemical purpose	Product function
Potassium Hydroxide	001310-58-3	Adjusts the pH of fluid to maintains the effectiveness of other components, such as crosslinkers	pH Adjusting Agent
Acetic Acid	000064-19-7	Adjusts the pH of fluid to maintains the effectiveness of other components, such as crosslinkers	pH Adjusting Agent
Sodium Carbonate	000497-19-8	Adjusts the pH of fluid to maintains the effectiveness of other components, such as crosslinkers	pH Adjusting Agent
Potassium Carbonate	000584-08-7	Adjusts the pH of fluid to maintains the effectiveness of other components, such as crosslinkers	pH Adjusting Agent
Copolymer of Acrylamide and Sodium Acrylate	025987-30-8	Prevents scale deposits in the pipe	Scale Inhibitor
Sodium Polycarboxylate	N/A	Prevents scale deposits in the pipe	Scale Inhibitor
Phosphonic Acid Salt	N/A	Prevents scale deposits in the pipe	Scale Inhibitor
Lauryl Sulfate	000151-21-3	Used to increase the viscosity of the fracture fluid	Surfactant
Ethanol	000064-17-5	Product stabiliser and / or winterising agent.	Surfactant
Naphthalene	000091-20-3	Carrier fluid for the active surfactant ingredients	Surfactant
Methanol	000067-56-1	Product stabiliser and / or winterising agent.	Surfactant
Isopropyl Alcohol	000067-63-0	Product stabiliser and / or winterising agent.	Surfactant
2-Butoxyethanol	000111-76-2	Product stabiliser	Surfactant

One of the problems associated with identifying chemicals is that some chemicals have multiple names. For example Ethylene Glycol (commonly know as anti-freeze) is also known by the names Ethylene alcohol; Glycol; Glycol alcohol; Lutrol 9; Macrogol 400 BPC; Monoethylene glycol; Ramp; Tescol; 1,2-Dihydroxyethane; 2-Hydroxyethanol; HOCH2CH2OH; Dihydroxyethane; Ethanediol; Ethylene gycol; Glygen; Athylenglykol; Ethane-1,2-diol; Fridex; M.E.G.; 1,2-Ethandiol; Ucar 17; Dowtherm SR 1; Norkool; Zerex; Aliphatic diol; Ilexan E; Ethane-1,2-diol 1,2-Ethanedio.

This multiplicity of names can make a search for chemicals somewhat difficult and frustrating. However, if searches for a chemical are undertaken by the CAS number it will return the correct chemical, even if the name on the fracturing record does not match. For example, if the fracturing record listed the chemical hydrogen chloride and this chemical is searched for by name using a chemical search site, there may not be a result. But if a search is carried out for CAS # 007647-01-0 it might return hydrochloric acid, which is another name hydrogen chloride. Therefore, by using the CAS number the issue of multiple names for the same chemical can be avoided.

Multiple names for the same chemical can also leave the impression that there are more chemicals than actually exist. The National Institute of Standards and Technology (NIST) ‡ website lists the alternate names of chemicals. This may help identify the precise chemical being looked for. The NIST site also contains the CAS numbers for chemicals. NIST is only one of many websites that can be used to locate additional information about chemicals. The following websites can also be searched using the chemical name or CAS number:

Occupational Safety and Health Administration (USA) chemical database: http://www.osha.gov/chemicaldata/

The Chemical Database (Dept of Chemistry, University of Akron: http://ull.chemistry.uakron.edu/erd/)

US EPA Chemical Fact Sheets (http://www.epa.gov/chemfact/).

4.6.4 Toxicity of chemicals as used

Most of the additives used in fracturing in their concentrated (pure) product form are extremely toxic, as indicated by the Material Safety Data Sheets (MSDS) required by legislation. However, they are heavily diluted by the water carrier and, therefore, are present in relatively low concentrations. These concentrations decline in the produced water coming back to the surface after the HF operation has been completed. Nonetheless, even in low concentrations, care is needed in the use of some products to avoid any potential impacts on human health or the environment. When used properly in hydraulic fracturing operations and not introduced into overlying groundwater or other sensitive environments, there is no pathway for these additives to be harmful.

The additives that are needed for the fracturing process to work are required to be named and explained to, and approved for use by the Environmental Protection Agency (EPA; see section 5.3).

It is important to understand that the vast majority of the additives used in hydraulic fracturing operations are substances that are also present in a wide range of everyday household products. However, because of their toxicity, any use of these substances, whether in industrial or domestic household situations, must always be undertaken with appropriate precautions. When used properly in hydraulic fracturing operation these chemicals do not introduce a significantly new or 'alien' risk into environmental management.

Information on the additives used by Origin Energy in coal seam gas extraction in Australia is available on the PEPANZ website (www.pepanz.org) as examples of the type of products used in hydraulic fracturing in New Zealand. The link , http://vimeo.com/47064328 , goes to a video produced by Queensland Gas Company in Australia for coal bed methane extraction. It gives a basic idea on how fracturing fluids are made up and why certain additives are used. A copy is available on their website (www.qgc.com.au).

4.6.5 What happens to the chemicals used

During the process of fracturing, some of the chemicals are absorbed by the geologic media (e.g., clay stabilisers). Process design provides for some chemical degradation due to pressure, temperature and physical-chemical reactions (e.g., biocide and gel breakers).

A proportion of the fracturing fluid remains behind in the formation after the initial clean-up period due to gas breakthrough (i.e., enough fracture fluid has been produced that gas production commences). Additional fracturing fluid can be entrained over time as part of the mixed well stream. The chemical composition of the produced fluid slowly changes from being predominantly fracturing fluid to primarily in situ formation fluid (e.g., hydrocarbons and some salty water). How long it takes to essentially recover the fracture fluids depends on several factors, primarily the overall production flow rate (higher is better), the producing gas/fluid ratio, and nature of the target reservoir rock.

The volume of fracture fluid that is recovered in initial return flow, and then subsequently over time in the well bore flow, depends on the fracture operation itself and the properties of the formation being fractured. For example, in the Mangahewa-6 well hydraulic fracturing job an estimated 40% of fracturing fluids were recovered initially in the return flow. Most of the remainder of the fracturing fluid will be recovered, so that only a relatively minor fraction will be unrecoverable, principally that which is retained on the proppant due to capillary action. Fracturing fluids that are returned to the surface in return flow may contain naturally occurring hydrocarbons (including BTEX). These contaminants are usually present in low concentrations (measurements showed less than 8 ppm for Waitui-1 well return fluids) but still require careful management to avoid potential adverse environmental effects (Taranaki Regional Council, 2012b).

Hence there is a subsurface discharge of contaminants (energy, chemicals, water and sand/small ceramic pellets) to land at considerable depth which produces relatively minor and short-term changes to the physical and chemical condition of the land (i.e., the reservoir) in a way that does not affect other foreseeable users of the land resource.

The fluids returned to the surface also need to be properly managed and regulated to avoid potential for adverse environmental effects. Hydraulic fracturing return fluids should be stockpiled in lined pits or tanks to prevent escape to the environment. The return fluids should be stored separate from other wastes and labelled to indicate the individual well or source. Fluids are usually injected into authorised deep disposal wells (well below existing freshwater aquifers) with some land farmed with appropriate environmental standards in place (see sections 6.1.2, 6.1.3, and 4.8.1).

4.6.6 Example: Mangahewa well Taranaki

As an example of a typical Taranaki fracturing job, details of a hydraulic fracturing operation by Todd Energy in 2010, using a water-based fracturing fluid and selected chemicals/additives, are presented below. The location of the Mangahewa Field is shown in Figure 1. Todd Energy supplied the following data on a volume-weighted average basis for the four formation zones fractured. There were minor variations between the four fracture treatments:

Mangahewa-6 well in North Taranaki at the Mangahewa-C well site:

- Four reservoir zones
- Injection interval: 3887- 4190 m total vertical depth
- Maximum surface pressure used: 10,400 psi
- Total water used: 1500 cubic metres with three fracs using on average 224 cubic metres, all water sourced from a municipal supply
- Proppant: Ceramic proppant - 117 tonnes
- Return fluid volume: 600 cubic metres (estimated)
- Chemical additives: 35 cubic metres, including the following (2.5 % of total by volume) :
    - Xcide 102 – this is a biocide to prevent certain kinds of bacterial action underground interfering with the gel management system, or, which may, in unusual cases, create a sour gas generation (H_2S or hydrogen sulfide) problem in the reservoir (0.1 %)
    - Claytrol – this is a clay stabiliser to prevent any clay minerals in the reservoir rock expanding on contact with water and plugging the reservoir (0.16 %)
    - GS-1 – sodium thiosulfate, which is a gel stabiliser (0.02 %)
    - GLFC-1b – this is a gelling agent to hold the sand in suspension, natural guar gum (0.86 %)
    - Inflo-150 – contains ethylene glycol (antifreeze), methanol and other compounds, which serve as a friction reducer to ease pumping and evacuation of fluid, thereby reducing required pump horsepower output and air emissions from the pumps (0.14 %)
    - BF-7LD – this is a buffer fluid (potassium carbonate) (0.53 %)
    - XLW-56 – this is a crosslinking agent (0.43 %)
    - GBW-41L – this is a gel breaker (hydrogen peroxide) (0.16 %)
    - GBW-12cd – this is an enzyme (hemicellulase enzyme) (0.11 %)
    - GBW-5 – this is a gel breaker (ammonium persulphate) (0.001 %).

4.7 Environmental effects to be managed

The actual or potential environmental effects of high pressure hydraulic fracturing discharges depend on the nature of the subsurface discharge and local environment. Relevant factors may include:

a) Well location and depth;
b) The integrity of the well delivery system, and the management of potential for leakage through the casing or up the outside of the casing at the base of the well, causing contamination of potable aquifers;
c) Then integrity of the receiving formation surrounding the subsurface discharge, particularly the geologic seal that confines the formation itself, geologic seals above that, and management of the potential for a breach of these seals, causing contamination of potable aquifers above;
d) Potential for increased seismic vibrations/earthquakes locally during the fracturing process;
e) Management of the types of contaminants used in the fracture fluids including site management measures to avoid or contain contaminant spills; and

f) Discharge of return fluids, including the spent fracturing fluid and formation fluids.

4.8 Relevant investigations and studies

The following is a summary of the various investigations and studies the Taranaki Regional Council has commissioned or undertaken to provide some context, as to whether environmental issues raised in overseas literature and by some members of the public are relevant for Taranaki and New Zealand conditions. The Council undertakes regular reviews of its management approaches and updates its guidelines, policies, and consent conditions as best practice evolves.

4.8.1 Hydrogeologic risk assessment

The Council has undertaken an assessment of the hydrogeologic risks associated with the practice of hydraulic fracturing of hydrocarbon reservoirs in Taranaki up to mid-2011. The report was originally released in November 2011, with data from the period 2000 to mid-2011 but updated in February and May 2012 (see Taranaki Regional Council (2012b) Table 5 footnote) to include an assessment of all hydraulic fracturing data. The assessment has been peer-reviewed by Dr G.M. Zemansky, Senior Hydrogeologist with the Institute of Geologic and Nuclear Sciences Ltd (GNS Science). This GNS Science peer review supports the assessment and conclusions of the Council.

The key findings of the Council's assessment were as follows:

- Oil and gas companies operating in the Taranaki Region that have undertaken hydraulic fracturing operations up to mid-2011 (or their successors) provided data for this investigation and assessment. The Ministry of Economic Development also provided data. The first hydraulic fracturing operation was in 1989.
- The data provided shows that during the period 1989 to mid-2011 a total of 65 hydraulic fracturing jobs were undertaken in 39 wells accessing oil and gas reservoirs that are up to 4 km underground, with the majority deeper than 2.4 km. The shallowest fracturing treatment occurred at 1.15 km at the Manutahi well sites, at 1.36 km at the Kaimiro well sites, at 1.56 km at the Ngatoro well sites, and at 1.75 km at the Cheal well sites. These relatively shallow activities were assessed in more detail in this report.
- Most of the ingredients used in fracturing fluids are found within products that are widely used in society, including in products used in the home. While most of the additives used in fracturing are toxic in their concentrated (pure) product form, as shown by MSDS sheets, they are severely diluted (97.5% municipal water, 2.5% chemicals) by the water carrier and, therefore, are present when injected into the target reservoir at relatively low concentrations. Indeed, most of the chemicals/additives are only mixed with the water-based fluid, as the fluid is being pumped downhole. However, even in these low concentrations care is needed with some of these products to avoid any potential impacts on human health. Therefore, regulation of their use and disposal is appropriate.
- If hydraulic fracturing operations are carried out properly, it is unlikely that contaminants will reach overlying freshwater aquifers in the Taranaki region. Although unlikely, it is not impossible. There are four potential routes for that to occur:

1. leakage through well casing or annular space due to defective installation or cementing;
2. leakage through the natural geology overlying the hydrocarbon reservoir;
3. leakage from improper handling of chemicals used and/or from hydraulic fracturing wastewaters (i.e., flow back or produced water from the formation) brought back to the surface at the well site; or
4. a well blowout resulting in underground leakage into aquifers or surface recharge via spillage. The probability of a well blowout is extremely small, but cannot be completely discounted and has occurred during hydraulic fracturing operations in other countries.

- This review of the hydraulic fracturing operations which have been conducted in the Taranaki Region from 1989 to mid-2011 has not found any evidence of related environmental problems. Figure 15 summarises the likely reasons for this by showing that generally substantial thicknesses of low permeability geologic seals separate freshwater aquifers from the petroleum hydrocarbon reservoirs being hydraulically fractured.

The report concludes that there is little risk to freshwater aquifers from properly conducted hydraulic fracturing operations in the Taranaki Region. This assumes a combination of natural geologic factors, the use of good practices by industry and regulation by the Council as follows:

1. Satisfactory methods for well design, installation and operation are used by the petroleum industry, as well as quality control checks to ensure well installation integrity;
2. Hydraulic fracturing occurs in deep reservoirs well separated from shallow freshwater aquifers (i.e., about 3,500 metres below ground level, in comparison to freshwater aquifers less than 1,000 metres below ground);
3. The presence of thick intervals (1,000s of metres) of shales and mudstones, which act as seals to trap the hydrocarbons in place; and
4. Operational management and monitoring by the petroleum hydrocarbon industry and regulation and monitoring (including sampling and auditing operational data) by the Council.

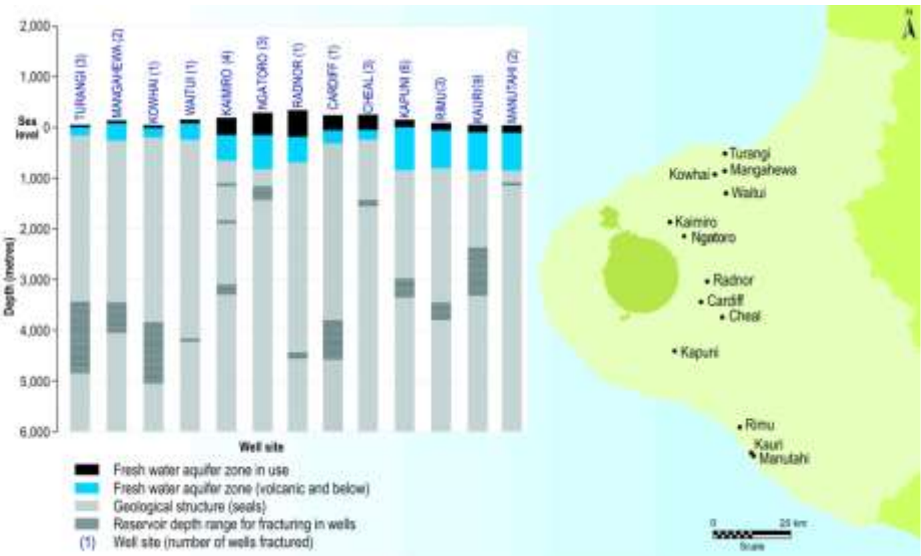

Figure 15 Location of freshwater aquifer zones and fractured reservoir zones in selected Taranaki wells

5. Although the risk that properly conducted hydraulic fracturing operations could adversely affect freshwater aquifers is very low, the Council recognises that the level of risk is greater when hydraulic fracturing is carried out at relatively shallow depths below freshwater aquifers, due to the proximity of the target reservoirs and the overlying aquifers. In such case, a more stringent regulatory oversight is called for.
6. The Council decided to require resource consents for all subsurface fracturing discharges to land beneath the region after July 2011 and has processed these in accordance with the requirements of the Resource Management Act 1991. Compliance monitoring of the discharges has been undertaken and will be reported to the community.
7. An assessment of groundwater resources closeby the relatively shallow HF undertaken at the Kaimiro, Ngatoro, Cheal, Waitui, and Manutahi wellsites has been undertaken using existing bores/wells. No impacts on groundwater quality from HF were found.

A copy of the *Hydrogeologic Risk Assessment of Hydraulic Fracturing for Gas Recovery in the Taranaki Region (2012)* report is available on the Council's website.

4.8.2 Seismic impact and risk assessment

GNS Science undertook a seismic impact and risk assessment for the Council using data from the GeoNet network. Most of the information below is drawn from the GNS Science report (Sherburn, 2012). The report examines seismic data for any evidence of seismic activity associated with hydraulic fracturing or deep well re-injection operations in Taranaki, over the period 2001-2011.

Seismic monitoring

Seismic monitoring in Taranaki is carried out by GNS Science through the GeoNet project. Felt events are posted on the GeoNet web page. Non-felt earthquakes are also located and archived in a publicly available National Earthquake Information Database. GeoNet operates seismic monitoring sites (seismographs) throughout New Zealand at an average spacing of about 100 km. There are additional seismographs at a closer spacing in Taranaki. The Taranaki network was originally designed to provide specific monitoring for volcanic activity at Mt. Taranaki, but has been extended and upgraded more recently to provide data on seismic activity throughout the region, as well as to increase its sensitivity. This network has been used to monitor seismic activity since 1994. Data are reported annually to the Taranaki CDEM Group and this report is available to the public on the Taranaki Regional Council's website.

There have been a few cases, all overseas, where hydraulic fracturing or deep well re-injection of petroleum waste fluids have been found to be associated with seismic events ('induced seismicity'). Taranaki Regional Council asked GNS Science to query the Taranaki earthquake database to determine if there is any evidence of induced seismicity related to hydraulic fracturing, how that can be assessed, and what the effects on people and structures could be if hydraulic fracturing were to trigger earthquakes in Taranaki.

Taranaki is an area of considerable seismic activity, although not as much as some other parts of New Zealand. The region typically accounts for 1-2% (or about 300 annually) of all located earthquakes nation-wide. The surface effects of an earthquake depend upon the strength of the earthquake, the depth and location of the epicentre of the earthquake movement, and the surface geology.

Measurement of Earthquake Strength

The strength of earthquakes is measured in two ways. There is the magnitude (M) of the earthquake itself. This is a measure of the energy released at the point of origin. The magnitude scale is logarithmic, that is, each change of one unit in magnitude represents approximately a 10-fold increase in seismic shaking and a 30-fold increase in total energy release. An earthquake of M3 is approximately 30 times as energetic as one of M2; M4 is approximately 30 times as energetic as one of M3 and approximately 900 times as energetic as one of M2. There are also the felt effects. These are measured by the Modified Mercalli Intensity scale (MM; Table 5).

Table 5 Modified Mercalli Intensity Scale

Modified Mercalli Intensity scale (MM).	
MM1	Imperceptible. Barely sensed only by a very few people.
MM2	Scarcely felt. Felt only by a few people at rest in houses or on upper floors.
MM3	Weak. Felt indoors as a light vibration. Hanging objects may swing slightly.
MM4	Largely observed. Generally noticed indoors, but not outside, as a moderate vibration or jolt. Light sleepers may be awakened. Walls may creak, and glassware crockery, doors or windows rattle.
MM5	Strong. Generally felt outside and by almost everyone indoors. Most sleepers are awakened and a few people alarmed. Small objects are shifted or overturned, and pictures knock against the wall. Some glassware and crockery may break, and loosely secured doors may swing open and shut.

A very shallow earthquake (5 km deep or less) of magnitude M2 might produce a maximum intensity for the closest people of up to MM4. This would be equivalent in its effect to that of someone sitting in a house when a large truck drove past on a road outside. There would be an intensity of MM3 within the adjacent area. The minimum magnitude for an earthquake to possibly be damaging is M4-5, which is 1,000 to 30,000 times more energetic than one of M2.

The effectiveness of the GeoNet system at detecting and then determining a point of origin for any seismic event is affected by how small the event is, how far the event is, from any detector, how shallow the event is, and the extent of interfering 'noise' at the time. For example, the system's sensitivity is such that heavy surf conditions on Taranaki's beaches interfere with its low-frequency sensitivity. In relation to hydrocarbon exploration and development, the siting of the GeoNet seismographs is well suited to the McKee and Kaimiro fields around and north-east of Inglewood, but less so for fields around Stratford (Cheal, Waihapa, Kapuni) and south to Hawera-Manutahi (Rimu, Kauri/Manutahi). In the onshore area of oil and gas exploration in Taranaki (east of Mt Taranaki), the GeoNet system in Taranaki can detect some earthquakes of magnitude down to about M1.5, but cannot pinpoint (depth and horizontal location) all events of this magnitude. The GeoNet system is considered to be able to detect and locate all earthquakes in Taranaki above about M2.0 or a little higher.

Tensile Fracturing

As noted in earlier sections of this guide, hydraulic fracturing is a process where fluids are pumped into a target reservoir via a wellbore at pressures sufficient to exceed the tensile strength of the reservoir rock. The high pressure fluid creates the fracture and holds it open but, as the fracture grows, the pressure begins to drop, so fracture growth will eventually stop. Tensile failure produces relatively high-frequency signals, as the seismic source is small at the crack tip only, which can usually only be detected by specialised downhole instruments and unlikely ever to be felt on the surface. The magnitude for these seismic signals is typically about M<0. It is thus almost impossible for tensile failure fracturing to be felt at the surface, as the intensities are thousands of time too small to cause effects detectable by humans - even when fracturing in shallow reservoirs.

Shear Failures

Shear failure can also occur as a result of hydraulic fracturing, though it is a secondary effect which does not physically open fractures. It can, however, improve permeability. Shear failure occurs when elevated pressure spreads through the reservoir rocks, and to the extent that pre-existing favourably oriented cracks and fractures under existing high shear stress and already close to failure (release) exist, then slip (and produce an earthquake). The size of any seismic event triggered in this way depends entirely on the area of the fracture that slips and on how much it slips. The possibility of an event being induced artificially (e.g., through fracturing) depends on the existing shear stress within any formation and the need for high injection pressures. These in turn depend on the geology and depth of the rock. Shear failure will generate earthquakes larger than those generated by tensile failure. In some cases these induced earthquakes have been large enough to be felt nearby. Recent cases, in which earthquakes were attributed to hydraulic fracturing (i.e., in Lancashire, UK and Oklahoma, USA), produced earthquakes with magnitudes of M2.3 and M2.8, respectively, which were triggered by shear failure, rather than tensile failure.

Almost all damaging earthquakes start at least 5 – 10 km underground and require a fault to slip over a length of several kilometres as a minimum, with lateral formation movement of tens of centimetres or more, resulting in a magnitude of at least M4-5 (i.e., at least 1,000 to 30,000 times more energetic than occurs with hydraulic fracturing). Hydraulic fracturing typically involves tensile fracturing of a few metres to perhaps one hundred metres in length, with actual lateral movement of a few millimetres (i.e., opening of the fracture). The pore pressure effects generated by hydraulic fracturing will dissipate as the pressure front spreads, and before they can reach the depth that is generally understood to be necessary to trigger damaging earthquakes. Based on overseas examples, the maximum seismic event that could be credibly envisaged in Taranaki due to hydraulic fracturing is an event of about M2 (Table 5). Such an event would be very shallow and non-damaging, though it might be felt nearby at the surface.

Deep Well Injection

Deep well re-injection is the process of injecting wastes (typically produced water, which is highly saline with traces of hydrocarbons) back into subsurface saline formations far below the fresh water-saline water interface. Injection pressures have to be high enough to overcome the natural hydrostatic pressures within the formation but they are still significantly lower than the pressures needed to cause fracturing of the reservoir rock. Because deep well injection is a continuing process over the long term, if it triggered detectable earthquakes we might expect to see a long-term cluster of earthquakes close to (say within 10 km) any re-injection well at which earthquakes were triggered. This has not been seen in Taranaki.

Findings on Induced Seismicity

Within the limitations of the GeoNet seismic monitoring system to detect and locate seismic activity, there is no evidence that hydraulic fracturing activities in Taranaki between 2000 and mid-2011 have triggered, or have had any observable effect on, natural earthquake activity.

There is no evidence that long-term deep injection activities, typically associated with waste water disposal at oil and gas operations in Taranaki, have had any observable effect on natural earthquake activity.

Given the location of hydraulic fracturing and deep injection operations there is no evidence of any effect on volcanic activity at Mt Taranaki. It is unlikely that any earthquakes that may be induced by hydraulic fracturing operations in the Taranaki Region would have a significant effect. Observations do not support any suggestion that hydraulic fracturing or deep well re-injection activities could trigger a large earthquake, a sequence of moderate-sized earthquakes or a widespread zone of earthquakes in Taranaki.

A copy of the GNS seismic assessment report *An Assessment of the Effects of Hydraulic Fracturing on Seismicity in the Taranaki Region (2012)* is available on the Council's website. The full citation for this reference is listed at the end of this guide under Sherburn, 2012.

4.8.3 Assessment of flare emissions

The Taranaki Regional Council has previously investigated the nature of air emissions and downwind effects arising from the flaring of hydrocarbons (both natural gas and condensate) at exploration sites (TRC, 1998,1998a). This information has proven valuable in the development of robust and defensible technical requirements for incorporation into the Council's regional air quality plans, and for assessing applications for discharges to air from flaring at exploration and production sites. The combustible flows to flare pits giving rise to flaring activities will initially include entrained materials used in drilling activities, such as drilling mud residues.

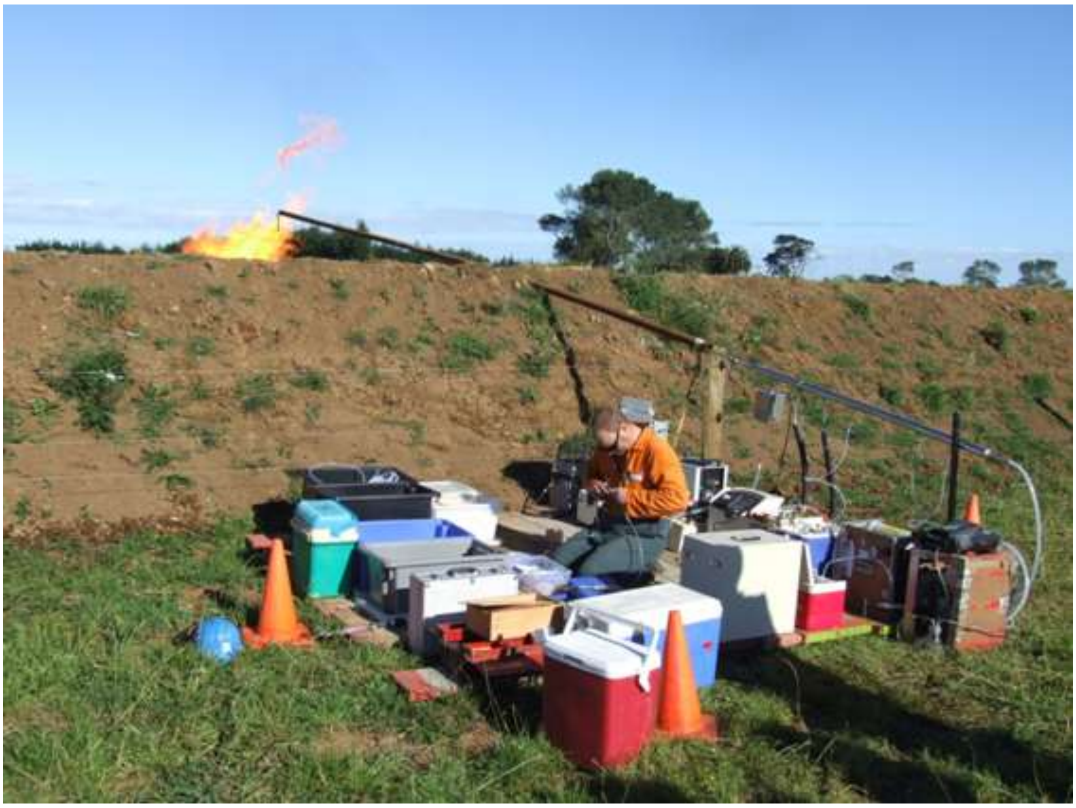

Photo 7 Air quality sampling of fracture fluids flaring at a well site reported in this report (section 4.8.3)

Photo 8 Lined flare pit with fracture fluids being flared and air quality sampling occurring as reported in this report (section 4.8.3)

More recently, speculation has focussed on the potential effects arising from emissions from returned HF fluids within production enhancement activities, as these fluids include compounds additional to those used in drilling. These compounds will include biocides, gelling and gel-breaking agents, inert proppants, such as sand or microscopic ceramic beads, and 'slicking' agents (refer Sections 4.1 & 4.6.2).

Normal exploration practice is to separate the return fluids from the entrained hydrocarbon gases. However, under emergency circumstances, safety and equipment protection requirements may necessitate the discharge of fluids to a flare pit without separation so that the entrained hydrocarbon gases can be combusted. In this situation, some of the fluids will be combusted/evaporated with the gases, with the majority of the fluids remaining within the pit for recovery at some point after the emergency event is under control. While used at extremely low concentrations within the hydraulic fluids, the presence of hydraulic fracture compounds within the mixture entering a flare raises the possibility of additional environmental effects other than those previously quantified.

The Council therefore undertook a study of the nature of flare characteristics and downwind consequences at a wellsite in North Taranaki in February 2012. While the region's exploration and production companies endorsed the project, it should be noted that its design and implementation were completely independent of any influence or direction from the companies. The design was subject to peer review. It reflected and developed the original flaring investigations conducted by the Council in 1998.

The HF fluids used within this study had additives at a somewhat higher concentration than is typical.

The results of the Council's investigation are presented in Taranaki Regional Council (2012a).

Investigations

The investigation covered combustion zone emissions of particulate matter (PM), dioxins and furans (PCDD/PCDF), polyaromatic hydrocarbons (PAHs), aldehydes (formaldehyde, acetaldehyde and propionaldehyde), volatile organic compounds (VOCs), methanol, and the more conventional products of combustion (oxygen, carbon dioxide, carbon monoxide, nitrogen oxides, and sulphur dioxide).

Emissions from the fluid surface were collected to determine emissions by evaporation of PAHs, aldehydes, VOCs and methanol. Ambient (downwind) measurements covered particulates (of particle sizes PM1.0, 2.5, and 10), carbon monoxide and dioxide, formaldehyde and VOCs.

Estimates were made of ambient concentrations of dioxins, PAHs and methanol, using emission and receiving environment data for other parameters. Because of differences in timing around sample collection for various parameters, these estimates should be treated with caution and regarded as approximations only. Nevertheless they serve a useful purpose, if regarded as indicative rather than absolute.

It should be noted that all results relate to a field study carried out under specific source, topographic and meteorological conditions. Therefore they cannot and must not be applied universally without discernment. To gain greater value and more regional application from this study, modelling of dispersion under varying meteorological conditions is being undertaken, utilising the emission data generated herein. Provisionally, the results of this study are consistent with and uphold those of the studies (field monitoring and modelling studies) conducted in 1998, which established that a separation distance of 300 metres between a flare and residential properties gave a substantial health and safety buffer for the protection of local populations.

Particulate matter (PM2.5, PM10 i.e., particle sizes less than 2.5 or 10 microns in diameter, respectively): the PM2.5 data showed no correlation of distance downwind of the flare with concentration (the closest sampling point was about 120 metres downwind), indicating that, at the most, 120 metres from the site and the flare, there was no effect upon ambient PM2.5. The two sites closest to the flare and wellsite had the lowest PM2.5 results.

The PM2.5 concentrations in the vicinity of the flare were similar to or slightly below those found elsewhere in the region as background (ambient) concentrations, and are far below international guidelines.

The PM10 data showed no correlation of distance downwind of the flare with concentration (the closest sampling point was about 120 metres downwind), indicating that at the most by 120 metres from the flare and wellsite there was no effect upon ambient PM10. The two sites closest to the flare and wellsite had the lowest PM10 results, while the second highest result was recorded at the site that was furthest away.

The PM10 concentrations in the vicinity of a flare are somewhat below those found elsewhere in the region, and are far below (less than 10% of) the national environmental standards for air quality (Air Quality National Environmental Standard AQNES) (50 $\mu g/m^3$). The air downwind of the flare would be rated, according to MfE criteria, as 'excellent' in respect of the PM10 concentration.

Dioxins/furans: emissions of dioxins and furans expressed as toxic equivalents could not be distinguished from zero (i.e., there was no meaningful difference between the combustion zone result and the laboratory blank result, at the limits of detection of mass quantities used within the study). This is consistent with the very low levels of particulate matter emitted from the combustion zone.

Polyaromatic hydrocarbons (including BaP): PAHs were detected within the combustion zone and at much lower concentrations within the evaporation zone. The two samples had quite different compositions. BaP, the PAH of most significance, comprised 63% of the USEPA BaP toxicity-equivalent concentration in the PAHs found in the combustion zone sample, but was not detected in the evaporation zone sample.

The estimation of downwind (ambient) PAH concentration suggested an elevation in downwind concentration of all PAHs at a distance of 70 metres, of between 12 and 38 ng/m^3 (total BaP equivalent), and in actual BaP of between 7.5 and 24 ng/m^3. As noted above, these figures should be regarded as estimates only; and further, that they are specific to this particular study.

Even within the evaporation zone, levels of BaP equivalents were lower than is found in ambient air within central city locations in New Zealand, and only minimal further dilution (dispersion) would be required to reduce PAH/BaP concentrations to levels similar to or lower than is typically encountered in urban areas.

Aldehydes (including formaldehyde): the formaldehyde concentrations in the vicinity of the flare, including those sites closest to the flare, are similar to those found elsewhere in the region, and are well below (less than 20% of) the MfE air quality guideline.

The air downwind of the flare beyond the closest ambient monitoring location would be rated as 'excellent', according to MfE criteria, in respect of the formaldehyde concentrations, and even at the site 70 metres downwind would be rated as 'good'.

Volatile organic compounds (including BTEX): benzene results show that within a distance of 300 metres from the flare, benzene levels had reduced to a steady (background) level. All results, including those closest to the flare, were below the MfE guideline criterion, and at 140 metres downwind were half or less of the MfE guideline value.

Air beyond 140 metres downwind of the flare would be rated as 'good' according to MfE criteria in respect of the benzene concentrations, and further away (beyond 300 metres) would be rated as 'excellent' in respect of benzene concentrations.

Toluene and xylene were found 70 metres downwind of the flare, at 10% and 3% respectively, of the MfE ambient guidelines. The air at all points sampled downwind of the flare would be rated as 'excellent', according to MfE criteria, in respect of the toluene and xylene concentrations. The study has identified that benzene is the parameter of most interest in terms of most closely approaching guideline values; whereas toluene is the compound of highest concentration of any of the BTEX compounds.

Methanol: even within the combustion zone and the evaporation zone as sampled, the levels of methanol were far below limits that might be derived for population health protection.

Carbon monoxide and carbon dioxide: no carbon monoxide was detected downwind at the limit of detection of the meter used. This means that the air at all points sampled downwind of the flare would be rated as 'good' or better according to MfE criteria in respect of the carbon monoxide concentration.

Section 5 of the report:

1. Noted that there were minimal effects upon ambient air quality in the vicinity of a flare at which the incidental combustion of hydraulic fracturing fluids was undertaken, in the context of prevailing air quality within the region and nationwide;
2. Results relate to a field study carried out under specific source, topographic and meteorological conditions, but as a provisional finding, it can be noted that the results of this study are consistent with and uphold those of the air quality studies of flaring (field monitoring and modelling studies) conducted in 1998;
3. The report may be referenced by Taranaki Regional Council in the assessment of any applications for air discharge permits for contingency flaring, and in any review of the Regional Air Quality Plan for Taranaki (2011);

4. The report should be distributed to hydrocarbon exploration companies and their consultants, for reference in the preparation of Assessments of Environmental Effects in support of applications for air discharge permits, and to other interested parties upon request; and
5. Emissions data contained herein be incorporated into modelling of dispersion from flares in which hydraulic fracturing fluids are combusted, to apply the findings and results of this study more widely across the variety of meteorology and landscapes that could be encountered within Taranaki.

A copy of the Council's *Investigation of air quality arising from flaring of fracturing fluids- emissions and ambient air quality (2012)* report is available on the Council's website.

4.8.4 Review of overseas environment concerns and regulatory approaches

The Taranaki Regional Council commissioned GNS Science to undertake a review of environmental concerns and regulatory approaches for HF. The objective of the Zemansky (2012a) report was to present background information on environmental concerns associated with the practice of HF and regulatory mechanisms that have been developed to address these concerns in other jurisdictions (primarily North America). Well stimulation technology dates back to the 1860s, but the first use of fluids under pressure for HF took place in Kansas in 1947. HF allows for the development of unconventional oil and gas in low permeability formations and has been widely used in the United States (US) and Canada for the development of shale gas. HF has also been used in the Taranaki Region of New Zealand over the last 20 years, albeit at a much smaller scale. Whereas there may be over 10,000 HF operations a year performed in the US, there have only been an average of 3 per year in Taranaki.

More recently the application of HF treatments in shale gas wells has become controversial. This appears to be mainly because of a combination of the use of poor procedures, sometimes by improperly trained personnel, in conjunction with inadequate government regulation. Government regulatory programmes in the US were unprepared to address the number and scale of expansion of shale gas developments over the last five years. There have been incidents of contamination of water supply wells and streams, well blowouts, residential house explosions and mortality of livestock. There has been considerable litigation with private water well owners suing the energy corporations involved for damages. Examples of such incidents are presented in the GNS Science report. These incidents have generated political pressure to upgrade laws and regulations, to increase penalties for non-compliance, to increase regulatory agency staff and to conduct relevant research. They have also resulted in the banning of HF operations in some jurisdictions. There is a lack of information indicating the rate of contamination incidents compared to the total number of operations, but with the possible exception of methane gas emissions, it is likely relatively low.

There is a complex patchwork of laws and regulations relevant to the oil and gas industry and protection of the environment in both the US and Canada. There are industry-specific agencies, boards, commissions and environmental agencies at both the state and federal level in the US and the provincial and national level in Canada. In general, regulatory programs have not kept pace with industry operations and are now having to run to catch up, rather than being on top of things. For example, the U.S. Environmental Protection Agency (US EPA) only recently (in 2011) began a detailed study of the environmental impacts of HF operations, which is not scheduled for completion until 2014. Similarly, new federal regulations that have been proposed to apply to the disposal of wastewater and to air emissions from HF operations are not expected to be finalised until 2014.

The differences in numbers, types of reservoirs and scale of hydraulic fracturing operations in New Zealand and the United States, as well as differences in the regulatory frameworks, should be taken into account when comparing environmental effects and experiences arising from HF operations in both countries.

An important and largely controllable aspect of environmental protection with regard to HF operations is the design, installation and operation of petroleum hydrocarbon wells. Zonal isolation between target reservoirs through properly designed and performed cementing operations is a critical factor. However, even if a satisfactory cementing of the annular space of the well is achieved, it can be damaged by subsequent well pressure testing and HF treatment operations if conducted at excessive pressures. Furthermore, the risk of cement failure and leakage increases with well age.

Prevention of groundwater contamination from the impacts of HF operations is a multifaceted approach. It requires a good faith effort by industry to know and follow best available technical practice in their field and regulatory oversight by government to ensure that industry does so. When this occurs, the risk of substantial short-term problems will probably be small, but not zero. The risk of longer-term problems is primarily a question of the long-term reliability of zonal isolation in wells (i.e., how good the design, construction, and cementing of the well is and the longevity of the isolation achieved). Regulatory programs should be geared to ensure that zonal isolation is achieved and documented when the well is constructed and is maintained through the well's active life and ultimate abandonment.

GNS Science concluded that to effectively regulate HF operations, government must develop regulations that will adequately protect groundwater and the environment in general from the consequences of wellbore failure. Such regulations must be technically detailed and up to date when developed. It is also important to subsequently review regulations and ensure they are updated to keep pace with technological advances. Regulations should specify protective methods for drilling, casing, and cementing wells. In addition, government should enforce regulations requiring that industry submit complete information on intended operations. Of particular importance in this regard are detailed site-specific plans showing baseline conditions and how the industry will address all facets of environmental protection including preventing impact to groundwater from deficiencies or failings in HF operations. Baseline water quality sampling in advance of both drilling and HF operations is an important part of monitoring to demonstrate good performance. This also includes identification of the chemical additives to be used in HF fluids. Government must also have staff resources with appropriate expertise and the ability to review industry plans and properly inspect industry operations for compliance.

A copy of the GNS Science report *Hydraulic Fracturing for Oil and Gas Development: Environmental Concerns and Regulation (2011)* report is available on the Council's website.

4.8.5 Radioactivity in hydrocarbon exploration

The Taranaki Regional Council has undertaken surveys and commissioned national authorities to present information relating to the questions around radioactivity that have arisen in association with hydrocarbon exploration in Taranaki. The information below is mostly drawn from the Councils February 2013 report (Taranaki Regional Council, 2013).

Previously overseas, and more recently within New Zealand, questions have been raised around whether radioactivity is associated with hydrocarbon exploration and production. There are two central issues: does the recovery of natural gas and condensate bring with it the potential for release of naturally occurring radioactive materials (NORMs), and secondly, is there a health risk associated with the use or disposal of radioactive isotope tracers that may be used during activities associated with drilling or fracturing?

By way of context NORMs are found almost everywhere. It is found in the air and soil, and even radioactive potassium in our own bodies. It is found in more concentrated forms in foods such as brazil nuts and peanut butter (King, 2012).

It has also been recorded in Taranaki beach iron sands. NORMs above normal background levels are an issue in some US petroleum hydrocarbon reservoirs but are not known to be in Taranaki. It should be understood that if NORMS are present within a natural gas reservoir, they will become a potential issue regardless of whether hydraulic fracking is used to enhance gas extraction from the source reservoir.

It should be noted first of all that the use of radioactive materials is a matter under the jurisdiction of the Ministry of Health, and all enquiries or concerns should be directed to that agency in the first instance. The Council has sought or welcomed information provided on radioactivity related to hydrocarbon exploration and production, for the sake of reassurance and public confidence. To the extent that radioactivity might be present in a discharge for which the Council has regulatory control under the Resource Management Act, the Council would also have a degree of statutory function in this regard (but notwithstanding the explicit role of the Ministry of Health).

The Council has been addressing the issue for close to twenty years, for its own information and to respond to public enquiries made from time to time. More particularly, there has been recently something of a concerted focus on radioactivity through the media, which might be seen as one aspect of a wider conversation on the pros and cons of the introduction of fracturing as a means of enhancing hydrocarbon production.

This report sets out a short summary of the Council's work and findings in this area. It addresses the use of radioactive tracers, the use of radioactive materials within well logging activities, disposal of drilling wastes potentially containing radioactive materials, and the question of naturally occurring radioactive materials (NORMs) that might be released during exploration or production.

A draft of this report has been reviewed by ESR. All ESR comments and proposed recommendations have been incorporated in the final version. The Taranaki Regional Council remains responsible for the content of this report.

It should be understood that not all field operators in Taranaki use radioactive tracers, and not all uses of radioactive tracers relate to fracturing. Both chemical and radioactive tracers can be an integral part of a conventional well drilling operation, with a range of applications that encompass, for example, demonstration of well integrity, the accurate placement of down-well equipment, tracking drilling muds during drilling operations, and flow testing.

The Council has been seeking and receiving advice and information from the appropriate specialist and regulatory agencies since 1995 on matters relating to radioactivity and hydrocarbon exploration and production in the Taranaki Region. More recently it has undertaken a range of sampling and analytical investigations of its own accord.

A consistent theme runs through all information the Council has accessed. In summary:-

- The Council has sought and received assurances at all points, from the competent statutory authorities and experts, that the use and management of radioactive materials within the hydrocarbon exploration and production sector as established in Taranaki is lawful, and is not harmful to human health;
- The Council has sought and received assurances at all points, from the competent statutory authority and expert body, that the release of any NORMs during hydrocarbon exploration and production as established in Taranaki is not harmful to human health;
- The Council has undertaken its own surveys of produced fluids and soil levels at land farming receiving industry wastes, to ensure from its own direct measurement that the release of radioactive materials from these sources is not harmful to human health. Measurements have confirmed that this is indeed the case; and indeed neither radioactive tracers as used in hydraulic fracturing nor NORMs that are present in Taranaki fields are 'radioactive' in terms of statutory definitions[2], and indeed they contain levels of radioactivity that are orders of magnitude below those at which controls are required;
- The Council has been repeatedly advised by the appropriate competent authorities and has repeatedly found on its own account, that the levels of radioactivity associated with these activities are comparable to normal, everyday exposure for an average person;
- The determinations made by Geological Nuclear Sciences and the National Radiation Laboratory in 1995 are worth re-iterating:
  '*I find it very difficult to conceive of a credible concern for the health of the general public in the vicinity of a natural gas field*'… '*radon levels in New Zealand do not constitute a health risk. The level is lower than the world average and we have no areas of elevated radon concentrations*'; and
- In summary, the Council finds no evidence of a health or environmental issue arising from the use of radioactive tracers, the use of radioactive materials

[2] Radioactive tracers before dilution (i.e. before field use) are regulated quantities of radioactive material

within well logging activities, disposal of drilling wastes potentially containing radioactive materials, or the release of naturally occurring radioactive materials (NORMs) during exploration or production.

A copy of the Council's *Radioactivity in hydrocarbon exploration (including fracturing activities) (2013)* report is available on the Council's website.

4.8.6 Land farming

The Taranaki Regional Council commissioned Dr D Edmeades, of agKnowledge Ltd, in 2013 to assess whether land used for land farming activities being returned afterwards back to pastoral farming in a state that was 'fit for purpose'. The study noted waste products (drilling muds and rock cuttings) from the oil exploration industry were being incorporated into re-contoured formed sand dunes and re-sown back into pasture in a process known as land farming. The drilling muds contain potential contaminants: petrochemical residues, barium, heavy metals and salts. The question arises: are these reformed soils 'fit-for-purpose', in this case pastoral farming and especially dairy farming. As required by the consents regular soil samples were collected and analysed during the disposal process. These results were summarised and examined relative to various national and overseas criteria for the various potential contaminants. The three completed sites were visited and the pasture and soils inspected. Soil and pasture samples were collected and analysed for all potential contaminants. These results were compared to the properties of normal New Zealand pastorals soils.

The study concluded that these modified soils were 'fit –for-purpose'. The concentrations of: nutrients (macro and micro), heavy metals and soluble salts in these soils and pasture are similar to normal New Zealand soils. The form of barium present is as environmentally benign barite, and there is no evidence of accumulation of petrochemical residues. The process of land farming these otherwise very poor soils, together with appropriate management (irrigation, fertiliser and improved pastures) has increased the agronomic value of the land from about $3-5000/ha to $30-40,000/ha (Edmeades, 2013). That is about to a 10-fold increase in land value following its use as a land farm.

The Council also commissioned in 2013 Paddle Delamore Partners Ltd to undertake a review of the conditions imposed through consents on land farming and compliance monitoring results for several land farms being used to bioremediate hydrocarbon-containing wastes from the oil exploration and production industry. The broad intent of the review was to determine whether land farming was an environmentally viable activity and, if so, whether the process was being managed appropriately by the Council. In summary the review noted land farming is a valid and environmentally acceptable means of waste treatment with appropriate controls. Wastes are incorporated into soil allowing natural bioremediation and various soil processes to biodegrade, transform and assimilate wastes**.** In general, the intent and nature of the controls imposed by the Council were appropriate. These controls, based on international best practice, have evolved as experience has been gained with Taranaki conditions (G Proffit, 2013). Recommendations for amendments to incorporate best international practice have been implemented.

A copy of the agKnowledge Ltd *The Taranaki Landfarms are they "Fit for Purpose"* (2013) report is available on the Council's website.

4.8.7 Conclusions

The above investigations were undertaken to provide some context, as to whether environmental issues raised in overseas literature and by the public are relevant for Taranaki and New Zealand conditions. The investigations also address some of the misconceptions and errors that have been publicised in the public debate about hydraulic fracturing. These investigations provide information for the regulation of hydraulic fracturing and other activities, will help inform all concerned, will provide useful information in the review of Council policies and plans, and assist applicants for resource consent prepare their assessment of environmental effects reports.

4.9 Required regulatory technical expertise

The Taranaki Regional Council has appropriately qualified staff with oilfield experience, including knowledge of and experience in managing the activities that are the subject of this report and has access to additional expertise, if required (e.g., Dr J Huckerby (consultant) and Dr G Zemansky (GNS Science) who both have international experience). Deepwell injection of petroleum industry wastes (mainly produced water) has been a long established practice that has been regulated in the Taranaki region under the RMA. The environmental effects that require management for such activities are very similar to those associated with hydraulic fracturing, so expertise has existed at the Council for some time.

The Council continues to invest in up-skilling staff in oil and gas field practices to enable it to carry out full and proper assessments and make appropriate decisions under the RMA in relation to hydraulic fracturing and other activities.

To successfully undertake regulation of the upstream oil and gas sector the following expertise is required:

- Hydrogeologic skills for the hydraulic fracture discharge, deep well injection, and land farming activities
- Hydrocarbon waste treatment and management skills for the stormwater, deep-well injection, and land farming activities
- Well drilling and integrity understanding for the hydraulic fracture discharge and deepwell injection activities
- Sediment control and management for wellsite establishment and land farming activities
- Air quality and chemistry skills for the wellsite emissions, particularly the flare
- Resource consenting skills to adopt/ adapt this Council's approach to local conditions
- Compliance monitoring of freshwater, soil, and air resources skills for all activities
- Enforcement skills for all activities.

Many of the above skills already exist within councils as part of their normal current operations and will assist councils in the regulation of the oil and gas sector. Independent expert assistance is available in New Zealand to assist councils and the Taranaki Regional Council is also able to provide assistance. The key environmental issue to manage is well integrity as oil and gas wells operate at higher pressure than water wells and if there are problems there is the potential for significant adverse environmental effects. Councils are entitled to rely on MoBIE's regulating well integrity matters under the petroleum regulations (see section 5.4), rather than duplicating this highly technical work themselves.

5. Regulatory requirements

There are a number of agencies involved in regulating the oil and gas exploration industry under different statutes. This section of the guide outlines, in broad terms, the main statutes and their requirements. Specific details of regulatory requirements in respect of health and safety in relation to the casing of wells and well abandonment are given. References to further sources of information are provided.

5.1 Resource Management Act

The stated purpose of the Resource Management Act (RMA), as contained in Section 5 of that Act, is to promote the sustainable management of natural and physical resources. Included within this purpose is the need to avoid, remedy or mitigate any adverse effects of activities on the environment.

The diversity of activities associated with oil and gas operations require a broad consideration of RMA provisions. Part 3 of the RMA (sections 9 – 16) outlines the duties and restrictions in relation to the use of natural and physical resources that govern the way in which regional and district councils manage their respective regulatory responsibilities under the Act. Included in Part 3 of the RMA are duties and restrictions that relate to:

- the use of land;
- the use of the coastal marine area;
- the use of river and lake beds;
- the taking, use, damming and diversion of water;
- the discharge of contaminants to land, air or water; and
- noise.

For many of these uses, the nature of the restrictions in the RMA means that resource consents will be required (particularly in relation to regional council functions) unless the use is authorised under the RMA itself or a regional plan permits the activity. In the case of territorial authorities (district and city councils), resource consents may or will also be required for oil and gas exploration activities.

Under section 30 of the RMA (functions of regional councils), regional councils are responsible for controlling discharges of contaminants to the environment, the use of water, uses of river and lake beds, activities in the coastal marine area and control of the use of land for certain purpose such as soil conservation and water quality.

Under section 31 of the RMA territorial authorities control the effects of the use of land (for example noise, light and traffic effects etc).

Resource consents for petroleum exploration activities will therefore be required under the RMA for activities ranging from wellsite construction earthworks and stormwater discharges and air emissions, to disposal of drilling wastes and return fluids, water abstraction, discharges of hydraulic fracturing fluids, as well as land use consents for wellsite establishment and land farming waste disposal.

Under the RMA, the construction and drilling of a well is addressed under section 9 (restrictions on use of land). Under this section, a resource consent is only required if the activity contravenes a regional rule, for example, if it does not comply with the standards, terms or conditions of a permitted activity rule.

Ensuring well integrity is critical to ensuring that adverse environmental effects are avoided, remedied or mitigated, both from normal well operations and where well pressures are increased with hydraulic fracturing and deep well injection of wastes.

Regulation of the well integrity component of oil and gas exploration and development (such as ensuring there is adequate casing and cementing of the wellbore), is the responsibility of the High Hazard Unit currently within the Ministry of Business, Innovation and Employment under the Health and Safety in Employment (Petroleum Exploration and Extraction) Regulations 2013 (see section 5.4 for details of these regulatory requirements). Local authorities are entitled to rely on this agency to administer the Regulations to ensure well integrity, without all affected local authorities across New Zealand having to duplicate or replicate specific specialist expertise in this area. The reality is the requirements associated with environmental protection that relate to well integrity are precisely those that relate to health and safety.

Currently under the Taranaki Regional Council's Fresh Water Plan, the drilling and construction of a bore (as a land use activity) is a permitted activity subject to compliance with the standards, terms and conditions listed in the rule. One of the conditions of the rule is that all bores must be cased and sealed to prevent the potential for cross-aquifer contamination or leakage form the surface. The Council has taken a risk-based approach to this issue and has relied on (and is entitled to rely on) the legal responsibilities of central government agencies to ensure that issues relating to well integrity (i.e., the construction, casing and sealing of wells) are adequately addressed under the Petroleum Exploration and Extraction Regulations 2013, as noted above.

Whether or not a consent should be required for the discharge of hydraulic fracturing fluids to deep petroleum hydrocarbon reservoirs in the Taranaki region is a matter of varied opinion. The Taranaki Regional Council obtained a legal opinion specifically on this matter which concluded that while the situation is complex, the Council could require a resource consent for the activity of hydraulic fracturing on the grounds that it is a discharge of contaminants (energy, chemicals, water and proppant) to land, (albeit at depth), from an industrial or trade premise, therefore coming within section 15 1 (d) of the RMA. While the Council's Regional Fresh Water Plan (2001) does not specifically address the activity, a catch-all rule (Rule 44) allows the Council to process hydraulic fracturing discharge applications as a discretionary activity under the RMA, if deemed necessary.

To avoid any doubt, the Council has adopted a conservative approach and informed the industry in late July 2011 that a resource consent would henceforth be required for hydraulic fracturing (i.e., the discharge of fracturing fluids to land).

Resource consents can therefore be required for hydraulic fracturing activities at a wellsite under the RMA. Given the nature of the activity, (and depending on the specific plan provisions in different regions), resource consent applications for the following activities will be required as follows:

a) the well delivery system under section 9 RMA;
b) the taking and use of water for the hydraulic fracturing activities under section 14 RMA;
c) the subsurface discharge under section 15, particularly section 15 (1) (d) RMA;

d) the discharge of return fluids under section 15 RMA.

For unitary councils, there will also be further land use considerations for the well site under section 9 of the RMA, including traffic movements, light, noise and hazardous substance management.

The Taranaki Regional Council's legal advice noted that the RMA is the appropriate legislation under which regional councils could consider the environmental effects of hydraulic fracturing discharges. The discharge of fracturing fluid into land would fall for consideration under section 15 of the Act and each case needs to be assessed in the particular circumstances to determine which subsection applies. If the ground level operation or the source of the fracturing fluid (or both) qualify as an industrial or trade premise, it follows that section 15 (1) (d) of the RMA could be used to require a resource consent for the discharge. If there was potential for the fracturing fluid to enter water, section 15(1)(b) would be relevant.

The RMA can address activities many kilometres beneath the land surface. The moratoria put in place banning hydraulic fracturing in some parts of the world arise partly because of a lack of a suitable existing environmental regulatory framework to assess and manage the environmental effects of the activity (Zemansky, 2012a).

Section 2.2 of this guide summarised the extensive nature of the Taranaki Regional Council's regulation of the oil and gas exploration industry in Taranaki under the RMA. This, coupled with the regulatory framework outlined above means that there is a strong regulatory approach in place at the regional level and not a reliance on industry self regulation or on 'passive' regulation.

The Council has strong local presence on the ground and is actively managing the industry through regular and ongoing consenting, monitoring and enforcement.

The following parts of this section show that there are clearly areas of overlapping interest in regulating environmental effects, with other aspects of oil and gas operations such as health and safety in the workplace.

It is important, (and one of the challenges for New Zealand's regulation of the oil and gas sector), that all agencies with various regulatory responsibilities work together in a coordinated and integrated way. This issue is discussed further in section 10 (Review, research needs and challenges).

5.2 Crown Minerals Act

Under the Crown Minerals Act, the Minister of Energy gives approval for hydrocarbon exploration and production work programmes. Such approval can be withheld if it is considered contrary to recognised good exploration or mining practice. 'Good practice' is not defined in the Act but Ministry of Economic Development (MED, now the Ministry of Business Innovation and Employment or MoBIE), documents indicate that it relates to efficient use of the mineral resource to avoid wastage or contamination of the mineral resource, rather than relating to environmental considerations. MoBIE leaves consideration of environmental matters to local authorities under the RMA, although some MoBIE requirements do have flow-on environmental impacts in practice. The proposed Crown Minerals Act and the associated regulations and work programme, does require the Minister to consider the health, safety and environmental capacity of the applicant.

5.3 Hazardous Substances and New Organisms Act

The Environment Protection Agency (EPA) has approved use of the fracturing fluid chemicals under the Hazardous Substances and New Organisms Act 1996 (HSNO). HSNO approval and Material Safety Data Sheets are available for the chemicals/ additives used in hydraulic fracturing in New Zealand.

5.3.1 Substance approvals and disclosure

The importation, manufacture, use, storage and disposal of hazardous substances are covered by the Hazardous Substances and New Organisms Act 1996 (HSNO). The licensing of such substances is carried out by the EPA. Therefore in the first instance, proof of authorisation for use in New Zealand and disclosure of the composition of the various trademarked compounds can be sought either from EPA, or directly from the user by requesting proof of their HSNO approval and the consequent documentation as stipulated by the EPA.

It should be noted that there are also several disclosure websites now publicly accessible, whereby companies will provide information either on their own account (per industry best practice) or via a regulator's website. Attached to this section is one of the best (comprehensive) lists found by the Taranaki Regional Council.

MSDS (Materials Safety Data Sheets) for each compound or chemical will in most cases provide relatively complete information on composition (ingredients and proportions). In some cases, the MSDS may make reference to proprietary information that is not readily available via the MSDS. In such cases, it is suggested that reference is made in the first instance to EPA or to the supplying company. Confidentiality agreements may be necessary under section 42 of the RMA (see section 8.5.2).

The Council routinely requires disclosure of all fracturing compounds intended for use, as part of the consent application; it also requires confirmation following fracturing, of volumes and compounds actually used, and it also routinely collects return fracturing fluids for independent analysis. There are several authoritative or regulatory checklists as to matters for consideration and key parameters for analysis.[3]

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[3] e.g., New Brunswick Natural Gas Group Responsible environmental management of oil and gas activities in New Brunswick pp35-36;
Ohio Dept of Natural Resources Senate Bill 315 Sec 1509.2 - 1509.23
Ohio Dept of Natural Resources April 28 2005 Best management practices for pre-drilling water sampling
Ohio EPA June 2011 Recommendations for water well sampling before oil and gas drilling
Colorado Oil and Gas Conservation Commission Docket No 1112-RM-04
United States House of Representatives April 2011 *Chemicals used in hydraulic fracturing*
API Guidance document HF2 First edition June 2010 Water management associated with hydraulic fracturing
API Guidance document HF3 First edition January 2011 Practices for mitigating surface impacts associated with hydraulic fracturing

5.3.2 Substance approvals and the setting of environmental and human health protection exposure limits

Currently the EPA does not generally set Environmental Exposure Limits (EELs) on substances, including for any substances that might be used during fracturing.

Previously (*i.e.*, pre 2003) the EPA (as ERMA) did set a few EELs using the provisions in Part 3 of the Hazardous Substances (Classes 6, 8, and 9 Controls) Regulations – but only for some pesticides and antifouling paints. The EPA has flagged that at this time they will not be extending EELs to fracturing substances. Thus, a regional council can set whatever environmental limits it considers appropriate, without having to take into account section 142 of HSNO (see section 5.3.3). Similarly, regional councils will not be able to take guidance from any EPA EELs already in existence, but must find appropriate criteria elsewhere (*e.g.*, existing MfE guidance on environmental limits pertaining to contaminated land, or ANZECC guidelines for water quality).[4]

EPA regularly sets Workplace Exposure Standards (WES) values on substances and/ or components of a substance. EPA does this by adopting values from the Department of Labour. (See http://www.osh.govt.nz/publications/booklets/wes-jul-2011/wes-jul-2011.pdf - Workplace Exposure Standards and Biological Exposure Indices document). These relate to air quality as the means of exposure. WESs may be considered in setting consent conditions.

5.3.3 Monitoring and enforcement of HSNO in respect of hazardous substances

Section 142 of the HSNO Act states that: 'Every person exercising a power or function under the Resource Management Act 1991 relating to the storage, use, disposal, or transportation of any hazardous substance shall comply with the provisions of this Act and with regulations and notices of transfer made under this Act'. This compliance is to be enforced by the Ministry of Business, Innovation and Employment (formerly the Department of Labour (DoL)). Thus as a general position, the on-site management of substances approved under HSNO will fall in the first instance to MoBIE inspectors. (For some years the Taranaki Regional Council delivered this function under contract to the Department of Labour).

Sections 97 (1) (h) (ii) and 97 (2) (a), respectively, of the HSNO Act allow but do not oblige officers of territorial authorities or regional councils who are on a site for RMA purposes, to also conduct HSNO functions. This would require that they are appropriately warranted (under sections 98 and 100 of HSNO Act) for the purpose.

It should be noted that the discharge as fracturing wastes of a mixture of compounds that may include some hazardous substances may not fall within the scope of previously granted HSNO approvals or be covered by HSNO at all, as effectively a new mixture has been created and the degree of hazard has almost certainly changed. In some instances the point of discharge may itself not be within a 'workplace' (eg if any discharge were to be allowed to a stream. Best practice is

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[4] http://www.mfe.govt.nz/issues/hazardous/contaminated/#tools and *Australian and New Zealand guidelines for fresh and marine water quality 2000* Australian and New Zealand Environment and Conservation Council, http://www.mfe.govt.nz/publications/water/anzecc-water-quality-guide-02/index.html

that this should not be allowed. Disposal is to land for bioremediation, or by deep well reinjection).

Councils should be aware that the proportion of any particular hazardous substance in a fracturing fluid mixture will be greatly diluted - typically well below 1% of product concentrations upon injection and even less upon return to surface. When diluted to this extent, some hazardous substances may no longer pose an environmental hazard.

5.4 Health, Safety and Employment Act and Petroleum Exploration and Extraction Regulations

The design, construction, operation, maintenance, suspension and abandonment of all petroleum operations and related well drilling operations, whether they involve fracturing or other techniques, are subject to the provisions of the Health and Safety in Employment (Petroleum Exploration and Extraction) Regulations 2013 administered by the High Hazard Unit , currently part of the Ministry of Business, Innovation and Employment (MoBIE)).

The object of the Health and Safety in Employment Act 1992 (the 'Act') is to promote the prevention of harm to all persons at work and other persons in, or in the vicinity of, a place of work through a number of methods. These include promoting excellence in health and safety management; defining hazards and harm in a comprehensive way so that all hazards and harm are covered; imposing various duties on persons who are responsible for work and those who do the work; and setting requirements that relate to taking all practicable steps to ensure health and safety and are flexible to cover different circumstances.

Regulations can be made under section 21 of the Act that impose duties on employees or other people on all or any of the following:

(a) imposing duties relating to the health or safety of employees or other people on all or any of the following:
  (i) employers, and other persons who or that control places of work:
  (ii) employees:
  (iii) designers, manufacturers, sellers, and suppliers, of plant, substances, protective clothing, or protective equipment:
  (iv) principals, or self-employed persons:

(b) providing for any other matters contemplated by, or necessary for giving full effect to, the Act.

The Health and Safety in Employment (Petroleum Exploration and Extraction) Regulations 2013 (the Regulations) address health and safety management in petroleum extraction and production activities. The new regulations came into force on 30 June 2013.

The Regulations were first developed in 1996 and have moved from being prescriptive to goal based, underpinned by guidelines. This approach was adopted to keep pace with advances by the sector in terms of new technologies and techniques (DOL, 2012).

Some details from the Regulations are provided below to show the scope of the Regulations and how these are important for the critical aspect of well integrity for hydraulic fracturing and importantly for environmental regulation.

Well integrity is a critical operational component from a health/safety and environmental perspective. There are significant overlaps between regulatory regimes that seek to address both these important areas.

To avoid adverse environmental effects from normal well operations, and where well pressures are increased with activities such as hydraulic fracturing and deep well injection of waste, well integrity is extremely important.

Well integrity ensures the containment and prevention of the escape of fluids (i.e. liquids or gases) to subterranean formations or surface. It can be defined as the structural soundness and strength of a borehole drilled for the purpose of exploring for, appraising, or extracting petroleum. It also includes any well for injection or reinjection purposes, down-hole pressure containing equipment, and any pressure containing equipment on top of the well. This latter definition is drawn from the Regulations by combining the definition of 'integrity' and 'well'.

The Montara wellhead platform uncontrolled release of hydrocarbons (or blow out) which occurred in August 2009, during drilling operations 254 km north-west of the Western Australian coast , shows what can happen when well integrity issues arise. The total cost of the oil spill, fire, and clean-up is expected to reach A$177 million. The Deepwater Horizon semi-submersible drilling ship incident in the Gulf of Mexico, in April 2010, was much larger. Eleven lives were lost and five million barrels of oil were discharged to the environment from the Macondo well blow out. The costs from the incident are not fully counted, but it is already clear that impacts on the region's natural systems and people were enormous, and the economic losses total tens of billions of US dollars (Department of Labour, 2012).

The McKee 13 well blow out in Taranaki in 1995 shows New Zealand is not immune from well integrity issues. Gas, oil and drilling mud erupted around the base of the rig and spouted up to 30 metres into the air. There was a partial collapse of the surface area. It took some 35 hours to bring the blowout under control. Fortunately, no injuries were suffered by persons in the workplace in this instance and environmental monitoring showed the local stream recovered in 18 months. In due course, Petrocorp Ltd was charged in relation to breaches under sections 15 (duties of employers to people who are not employees) and 16 (duties of persons who control places of work) of the Health and Safety in Employment Act 1992. The operator was fined $20,000 plus costs on these charges. The Taranaki Regional Council led the enforcement action and was also successful in an action for breaches under the Resource Management Act 1991 and Petrocorp Ltd was fined $50,000 plus costs (Department of Labour, 2012).

The Petroleum Regulations were promulgated in 2013 shortly after the McKee 13 incident and there have been no recorded well integrity incidents since the date.

5.4.1 Petroleum regulations

The Regulations address well integrity through general duties (s10), the safety case regime (ss21-43), and well operations (ss63-67), including the well examination scheme (ss71-72). Each of these is addressed below and their role in environmental management assessed.

General duties

The duty holder must take all practicable steps to ensure that an installation, and activities on it, is safe for any person on or near it. The installation must at all times possess such integrity as is reasonably practicable. Integrity in relation to an installation, and wells connected to it, is defined as structural soundness and strength, and stability.

Hence well integrity should stop any unplanned escape of fluids from the well or from strata to which the well is connected. This matter is considered in more detail in the well control measures section below.

Safety case

The safety case applies to an installation and includes the wells by which petroleum is extracted. It includes a detailed safety management system that provides for all activities that will, or are likely to, take place on, or in connection with, the installation. Performance monitoring of the system includes an overview of the arrangements in place for independent and competent persons to verify that safety-critical elements remain effective (Schedule 1, (m) (iv)) and arrangements are in place for the periodic assessment of the installation's (which includes wells) integrity (Schedule 1 (m) (v)).

Particulars of all New Zealand and international standards that have been applied or will be applied must be set out (Schedule 4, s6).

The installation cannot be operated without an accepted safety case (s25).

The case must meet certain requirements (s26).

Consultation with petroleum workers, who may be affected by a safety incident, must be undertaken (s27).

Further information requests may be made (s29).

Criteria for acceptance of a case have been established (s31)

There is an ability to impose limits or conditions on the case (s32). The case may be rejected (s33).

The Secretary has an important role in approving the safety case and this is the only approval role in the Regulations.

The case must be revised in certain situations (s34). The Secretary may request a revised case (s35).

The case must be reviewed within 5 years (s36). The case may be withdrawn under certain circumstances (s38).

Records of the safety case must be retained (s41).

The provision of a safety case means well integrity risks have been identified, monitored, and managed so that there should not be any unplanned escape of fluids from the well. An 'as far as reasonably practicable' test is applied to this requirement. Refer to the well control section for more detail.

Interestingly the safety case process has many elements of a resource consent process under the Resource Management Act (RMA), except there is no public input process. The regulator has an active role in processing the safety case application and an on-going role through investigating any safety incidents or other matters that could affect the safety case and safety of the installation. The ultimate power is to be able to withdraw the safety case approval whereby the installation could not operate.

Well operations

The well operator's primary duty is to ensure that the well is designed, constructed, commissioned, equipped, operated, maintained, modified, suspended, and abandoned so that: so far as reasonably practicable, there can be no unplanned escape of fluids from the well; and risks to the health and safety of persons from the well or anything in it, or from strata to which the well is connected, are as low as is reasonably practicable (s64).

A well operator must assess conditions below ground before a well is designed (s66) in order to comply with the primary duty set out above. Well operations are required to continue to assess conditions below ground during well operations (s67). Well operations mean drilling, completion, suspension, or abandonment of a well (s3).

A well operator must take all reasonable steps to ensure that every part of a well is composed of suitable material (s69) in order to comply with the primary duty set out above.

A well operator is required to prepare and implement a well examination scheme before the design of a well is commenced or adopted (s71). The scheme means arrangements for examinations of wells that are recorded in writing and suitable for ensuring (together with the assistance of any other measures the well operator may take) that the well is designed, constructed, operated, maintained, modified, suspended, and abandoned so that – so far as reasonably practicable, there can be no unplanned escape of fluids from the well; risks to health and safety of persons from the well or anything in it, or from strata to which the well is connected, are as low as reasonably practicable; and conducted by an independent and competent person. 'Independent' and 'competent' are defined in section 3 of the regulations. Transition provisions apply in sections 71(5)–(6).

A well operator must retain records of the well examination scheme including revision of the scheme, examination and testing carried out, the findings of any examination and testing carried out, and remedial action recommended and performed (s72).

A well operator must give notice of well operations (s73), 21 days before commencement, and schedule 7 of the Regulations sets out the comprehensive information that is required to be provided, which includes well integrity information.

A well operator must make and retain daily well operation reports and store these at an address notified by the Secretary and must make them available to an inspector on request (s76). The well operations addressed include drilling, completion, workover, suspension or abandonment, and any other operation involving substantial risk of unplanned escape of fluids from the well.

A well operator must notify any dangerous occurrence as soon as practicable. A dangerous occurrence is defined in the Regulations and includes: an event that did not cause, but might reasonably have caused, a major accident; the failure of any part of a well whose failure would cause or contribute to, or whose purpose is to prevent or limit the effect of, the unintentional release of fluids from a well or a reservoir being drawn on by a well; damage to, or failure of, a safety critical element that required intervention to ensure it will operate as designed; an unintended collapse of an installation or part of an installation (noting a well is included in the definition of an installation); and damage to an installation caused by earthquakes or other natural events that had the potential to cause death or serious harm of any person.

A notice of a dangerous occurrence must include details as set out in Schedule 8 and includes fluid escape from a well. It requires details of the estimated quantity and composition of fluids that escaped (including known toxicity), the duration of escape, and immediate action taken or intended to be taken to prevent recurrence of the incident, and an immediate cause analysis.

A duty holder must prepare an emergency response plan for the installation (s79) which must take into account the operating and environmental conditions at the intended location of the installation (includes wells). A copy of the plan shall be given to the Secretary as soon as practicable after the plan is developed, and at least 30 days before commencing operations. The duty holder is required to regularly review and test the plan (s80). The plan is for responding to emergencies that occur while petroleum workers are working on an installation (noting a well is included in the definition of an installation).

Regulatory overlap

Drilling a borehole and installing casing are two intertwined activities. A section of hole is drilled and then casing set and cemented. The process is then repeated with smaller diameter casing.

From an RMA perspective, the drilling of a borehole into land and associated construction and commissioning of the well (steel casing and cement), are essentially section 9 land use matters, and are more than adequately addressed in the Regulations. A well operator's primary duty under clause 64 of the Regulations covers all aspects of well operations from design and construction (including drilling) through to commissioning, operation, maintenance and abandonment.

Any planned discharge from the well, such as deep well injection, hydraulic fracturing, or water flooding operations, and associated discharge to land at depth is addressed under section 15 RMA. Any minor losses of drilling fluid prior to casing being installed should also be addressed under this section. From an environmental risk perspective, the type of drilling muds used is important. If water based muds are used through the freshwater zone then there is minimal risk. Synthetic based muds can be used below this in saline zones.

Any unplanned casing leakage would also be subject to the enforcement provisions of the RMA, for example, abatement notice through to prosecution or the requirement for resource consent under section 15. However, any enforcement option, including requiring a resource consent, will be dependent upon the level of environmental effect. Where there is insignificant environmental effect the de miminus principle may apply.

There are however, some other legal issues to consider. The well operator's duty under clause 64 of the Regulations is to ensure that a well is designed, constructed, operated etc. so that 'as far as is reasonably practicable, there can be no unplanned escape of fluids from the well.' This is in contrast to the RMA duty that 'no person may discharge any contaminant… unless the discharge is expressly allowed by a national environmental standard or other regulations, a rule in a regional plan as well as a rule in a proposed regional plan …., or a resource consent.' These matters are being addressed with a view to develop solutions and make the provisions of the Regulations and RMA work more closely together to reduce duplication and cost.

6. Resource consent considerations

This section of the guide outlines resource consent considerations for the main activities associated with petroleum exploration. It deals with both regional council and district council consents under the RMA. Guidance is provided on the assessment of environmental effects, notification, consent conditions and compliance monitoring for regional councils. Some examples of consent conditions applied in Taranaki are provided.

6.1 Regional councils

6.1.1 Hydraulic fracturing fluid subsurface discharge

This section of the guide provides resource consent considerations for the hydraulic fracturing fluid subsurface discharge, includes consent conditions, based on a search of overseas literature and the results of studies outlined in Section 4.8 of this report. It includes an assessment of environmental effects requirements, RMA notification provisions, consent conditions, compliance monitoring, and consent surrender considerations.

Assessment of Environmental Effects Requirements
An application to discharge hydraulic fracture fluids to land at depth under the Resource Management Act 1991 (RMA) must be accompanied by an Assessment of Environmental Effects (AEE) report. Section 5.1 of the report sets out the RMA requirements for a discharge in more detail. The purpose of the AEE is to determine the likely adverse effects that the activity will have on the environment and how these effects can be avoided, remedied or mitigated. The AEE should present such detail as corresponds with the scale and significance of the effects the activity may have on the environment (RMA section 88 (2)). Section 88 and the Fourth Schedule of the RMA sets out what should be included in an AEE.

The following is a possible outline of a very comprehensive AEE in the Taranaki region recognising under section 88 (2) the AEE could be less comprehensive and may not need to contain all the information outlined below:

1. Introduction

   1.1 Background

   - Brief description of drilling history of site and any abandoned wells
   - Brief description of previous and current consents applied for by applicant.

   1.2 Site Location Information

   - Well site location address, map reference and grid reference
   - Catchment area.

2. Resource Consents Sought

   - Description of proposed activity(s)

- Which rules in the Regional Freshwater Plan apply to the activity.

3. Related Consents

   - More detailed description of related resource consents sought which are relevant to the proposed programme (e.g., air discharge, stormwater, etc.).

4. Existing Environment

   4.1 General Location and Topography

   - Map showing location of well site(s)
   - Description of the topography of the land.

   4.2 Land Use

   - Brief description of surrounding land use activities.

   4.3 Vegetation and Wildlife

   - Description of any significant native vegetation in the immediate area
   - Details of any scenic or recreation reserves, Regional or National parks in the immediate vicinity of the site.

   4.4 Adjacent Water Ways

   - Location of adjacent waterways in relation to the well site (shown on a map).

   4.5 Geohydrology and Ground Water Resources

   - Description and location of aquifers/water abstractions within the area of interest
   - Details of the freshwater/saltwater interface (FW/SW I)
   - Resistivity logs, if available, and other data that support the depth determination for the SW/FW I.
   - Petrophysical (wire line data) evaluation
   - Geology, lithology and overpressure contaminant (provide a schematic showing geologic formations identifying impermeable and laterally persistent units, any faults or shear zones, and the FW/SW interphase)
   - Description of the geologic formations and dominant lithology within the area
   - Description of formation properties including permeability and pressures
   - Geologic logs (including Spontaneous Potential , resistivity, sonic)
   - Gamma ray logs.

   4.6 Faulting

   - Analysis of known faults within the area.

5. Description of Proposed Activity

- As required by section 1(a) of Schedule 4 of the RMA.

5.1 Overview of proposed HF stimulation programme

- Description of the HF process
- Indicative HF stimulation programme – details to include planned execution timeframe, number of HF treatments/well , target interval depth range (including the location of casing perforations in 3 dimensions in terms of NZMG co-ordinates and true vertical depth in metres below ground)
- Modelling and use of 'mini-frac' results to calibrate the model, conceptual design (e.g., fracture pressure)
- Fracturing fluid fate modelling techniques used (e.g., proppant concentration diagrams and interpretation of models and diagnostics)
- Assessment of modelling or tracer techniques used or reasons for not using tracers
- Well integrity pressure testing (when it happened, what the results were)
- Operational procedures
- Results of previous of HF operations in similar formations and representative data in graphical form of: tubing pressure (psi), slurry rate(bpm), bottom hole proppant concentration (bpm), grid oriented hydraulic fracture extension replicator(or similar model) surface predicted pressure(psi), grid oriented hydraulic fracture extension replicator (or similar model) predicted bottom hole proppant concentration (lb/gal), borehole gauge pressure (psi), surface proppant concentration (lb/gal), grid oriented hydraulic fracture extension replicator (or similar model) predicted bottom hole pressure(psi), grid oriented hydraulic fracture extension replicator (or similar model) predicted slurry rate (bpm), grid oriented hydraulic fracture extension replicator (or similar model) predicted surface proppant concentration (lb/gal); prior to, during and after each hydraulic fracture treatment (see Figure 12 for an example of this data) shown during an HF operation).
- Detail the procedures to be carried out during the HF stimulation programme and the sequence of operations.

5.2 Well Construction and Design (well integrity)- noting many of these details are the responsibility of MoBIE under the Petroleum Regulations and would only be included for interest and completeness reasons

- Provide details of well construction, materials used and relevant standards
- Details of cementing practices, including cement bond logs and

interpretation

- Outline of pressure test results and interpretation
- Well construction diagram
- Details of ongoing life cycle well monitoring
- Well maintenance programmes and procedures
- For old wells that are subject to HF treatments the assessment needs to focus on the condition of the well casing and cement as this can slowly deteriorate over time
- Consideration of any abandoned wells in the vicinity and their condition.

5.3 Details of HF Stimulation Fluids

- Provide details of the composition of the fluids to be used in the stimulation
- Briefly describe the function of each fluid component
- Provide MSDS sheets for all products/chemicals used
- Provide an estimate of fluid volumes to be used, expected return flow volumes and period.

5.4 Subsurface Monitoring

- Provide details on the proposed diagnostic tools to be used
- Monitoring and modelling of fracture extent (half-length)
- Monitoring and modelling of fracture extent
- Assessment of modelling and tracer techniques used or reasons for not using specific techniques (refer Table 3)
- Any other analytical tools or process monitoring data that will demonstrate the fate of injected fluids, proppant and the fracture growth (e.g., well annulus pressure).

5.5 Waste Management

- Detail how return fluids will be managed on-site. Include details on the storage, transport and disposal of waste fluids. Relevant construction standards for storage vessels and testing carried out should be included. Noting these matters are the responsibility of other regulatory agencies and could be included for interest and completeness reasons.

6. Assessment of Environmental Effects and Mitigation Measures

- As required by Sections 1 of Schedule 4 of the RMA. To assess the actual or potential effect on the environment and to outline mitigation measures, which will help prevent or reduce the actual or potential effects on the environment.

6.1 Potential Adverse Environmental Effects

- Detail the potential environmental effects relating to the proposed activity. To include, but not be limited to, the issues identified in 6.2 below.

6.2 Potential Contamination of Freshwater Aquifers

- Leakage due to defective well installation/operation
- Leakage through geologic media
- Leakage or improper handling of chemical or wastewater
- Risk of well blowouts
- Detail both the physical and process/procedural mitigation measures that will be implemented for each of the above to ensure actual or potential contamination will be avoided. May include details of the integrity of overlying geologic seals, results of testing undertaken on formations and the wellbore, standard operating procedures, planning and design, construction standards, quality control and assurance, on going process monitoring, alarms and response procedures. This may also include an assessment of the condition of nearby abandoned wells as a possible pathway for HF fluids and gas leakage to the surface.

6.3 Chemical Handling and Waste Management

- Detail procedures for chemical handling, including the delivery, transport and storage of chemicals. Include standard operating procedures, construction details and relevant standards for storage vessels, bunding, and approved handler certification. Recognising these matters are the responsibility of other regulatory agencies and could be included for interest and completeness reasons.
- Provide details of plans and procedures to be carried out in the event of a spill
- Provide details of any attempts made to minimise the volume and toxicity of chemicals being used in stimulation fluids
- Outline the wastes to be produced on-site and expected volumes
- Detail procedures for the handling, storage, transport and disposal of waste materials.

6.4 Use of Water

- Provide an estimate of potential water use volume
- Provide details of where water will be sourced
- Detail any measures implemented to reduce water usage on-site.

6.5 Potential Seismic Effects

- Assess the risk of the proposed activity inducing seismic activity
- Detail any seismic or vibration monitoring to be carried out.

6.6 Positive Environmental Effects

- Detail the positive impacts of the proposed HF stimulation activities.

6.7 Assessment of Alternatives

- Provide a brief assessment of any potential alternative location for the activity or HF stimulation methods.

6.8 Consultation and Affected Parties

- Provide details of any parties deemed to be affected by the proposed activities and any consultation undertaken.

7. Regulatory Context

7.1 Regulatory Background

- Brief description of section 104 of the RMA and description of additional documents which must be considered in assessing the application (Part II of the RMA, NPS, RPS etc).

7.2 Part II of the Resource Management Act

- Assessment of how the proposed activities are in accordance with Part II (Sections 5, 6, 7 and 8) of the RMA.

7.3 National Policy Statement - Freshwater Management

- Assessment of how the proposed activities are in compliance with the relevant objectives outlined in the NPS for Freshwater Management. In particular objectives A1 and A2.

7.4 Regional Policy Statement for Taranaki

- Assessment of how the proposed activities are in compliance with the relevant policies outlined in the RPS for Taranaki .

7.5 Regional Freshwater Plan for Taranaki

- Assessment of the activities against the relevant polices and rules in the Regional Freshwater Plan and justification as to why the activities comply with the policies
- In particular the following policies should be looked at: 4.1.1 to 4.1.6, 5.1.1, 5A.1.1, 5A.2.1, 6.2.1 to 6.2.7, and 6.5.1 to 6.5.5.

8. Conclusion

An AEE in support of hydraulic fracturing discharge applications for four well sites in the Kapuni Field, prepared by Shell Todd Oil Services Ltd, is provided on the Council's website as an example of a very comprehensive AEE.

The MSDS sheets will show the HSNO approval status for the products to used. Under HSNO a chemical may have had an EEL assigned to it (see section 5.3.2), although the EPA advises this is unlikely. If an EEL has been assigned, then a resource consent cannot set a limit that is more generous than that established in the EEL. Section 5.4 of this report has further details on the role of the EPA/MoBIE in regulating HF activities.

While seismic impacts of HF discharges in Taranaki are not considered significant, by the GNS assessment, a Society of Petroleum Engineers paper on the measurement of HF induced seismicity in shale formations is provided in Appendix I.

The above matters for consideration in an AEE include an assessment of the condition of nearby abandoned wells as a possible pathway for HF fluids and gas leakage to the surface. In the US this has been an issue in a limited number of cases (Zemansky, 2012a). However, there are well integrity and abandonment regulation differences between the two jurisdictions and this is not considered to be an issue for NZ, with the exception of the very first few wells drilled into the Moturoa Field in what is now New Plymouth. Well abandonment in these wells, which were up to 1,200 m deep and drilled from the 1860s onwards, was crude and resulted in natural well leakage and property damage in 2001 and an investigation into the location and condition of the other wells in the area by the Taranaki Regional Council (Taranaki Regional Council, 2003).

Notification

Section 95 of the RMA sets out the notification/non-notification provisions for resource consent applications. It should be noted that amendments to the RMA in 2009 removed the presumption that consent applications would be notified. The Council follows clearly established procedures in making decisions on notification or non-notification of resource consent applications and these procedures are fully consistent with the RMA. Each consent application must be assessed on its merits. Given that an application for hydraulic fracturing at considerable depth using good oil field practices would likely meet the 'no more than minor adverse environmental effects' and the 'no affected party' tests in the RMA, the application can, and properly should, be non-notified. While there are some groups, which have declared themselves as interested parties, this does not mean that these interest groups are affected parties to a resource consent application as recognised under the RMA.

Under section 95A(4) a consent authority may publicly notify an application, if it decides that special circumstances exist in relation to the application. There is some case law available on what constitutes 'special circumstances' and this concludes that public interest is not sufficient to justify notification, if the other tests in the RMA are met.

Consent conditions

Consent conditions have been developed for HF discharge consents based on an assessment of overseas literature, knowledge of the activity and the hydrogeologic risks that HF poses.

The four risks were identified in the Council's hydrogeologic risk assessment report (Taranaki Regional Council, 2012b):

a) leakage due to defective well installation/ operation;
b) leakage through geologic media;
c) leakage or improper handling of chemicals and wastewaters; and
d) well blow outs;

and are addressed by way of consent conditions.

The risk of induced seismicity is not assessed because of work undertaken by GNS concluded that HF operations do not pose a credible risk in the region (refer Section 4.8.2 of this report).

The conditions from a recently processed HF application (by Todd Taranaki Ltd are presented below (in italics) with a commentary, which sets out the rationale for each condition. The same consent is also included in Appendix I with a Conditions Analysis Table, which notes the reason for the condition, how compliance will be determined and the reason for any limits set.

To discharge contaminants associated with hydraulic fracturing activities into land at depths greater than 3200 mTVDss beneath the Mangahewa-E wellsite.

The above purpose of the consent allows the discharge of hydraulic fracturing contaminants to land below a certain depth at a defined well site subject to conditions. While the contaminants are not specified in the consent purpose, they are set out in the application and include: energy, hydraulic fracture fluids (municipal water), proppant, chemicals and possibly tracers.

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.

The above general condition is applied to all consents to pay to the Council all the administration, monitoring and supervision costs of this consent, fixed in accordance with section 36 of the RMA.

1) *The discharge point shall be deeper than 3,200 mTVDss.*

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

   The above requirement is to discharge below a specific depth beneath the well site or beneath sea level, so appropriate elevation data according to a specified datum is required (*e.g.*, mTVDss (metres true vertical depth subsea, i.e., the true vertical depth in metres below mean sea level. Other units can be specified *e.g.*, MDBRT, measured depth below the rotary table. Section 3.5.1 of this report provided further information on depth measurement in the industry.

2) *There shall be no discharge of hydraulic fracturing fluids into the reservoir after 1 June 2015.*

   The above requirement ensures the HF programme will be completed by the stated date, monitoring may be needed beyond this date.

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

   The above requirement is to ensure that the exercise of this consent does not result in contaminants reaching any usable fresh water (groundwater or surface water), where usable fresh water is defined according to ANZEEC Guidelines and can include salty water. This addresses where the salt water/freshwater interface is in terms of potential water use. The other conditions of this consent are expected to protect fresh water. However, the inclusion of this condition is reasonably needed to provide sufficient assurance that adverse effects on usable water resources are and are to be avoided.

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) *The Monitoring Programme shall include sampling of groundwater from a bore between 20 m and 50 m deep, installed in accordance with NZS 4411:2001 and drilled at a location established after consultation the Chief Executive, Taranaki Regional Council.*

   Depending on the suitability of existing bores within 500 m of the wellsite for obtaining a representative groundwater sample, it may be necessary for the Monitoring Programme to include installation of, and sampling from, a monitoring bore and condition 5 will be required. The bore would be of a suitable depth, location and design and installed in accordance with NZS 4411:2001.

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

   a) *pH;*
   b) *conductivity;*
   c) *total dissolved solids;*
   d) *major ions (Ca, Mg, K, Na, total alkalinity, bromide, chloride, nitrate-nitrogen, and sulphate);*
   e) *trace metals (barium, copper, iron, manganese, nickel, and zinc);*
   f) *total petroleum hydrocarbons;*
   g) *formaldehyde;*
   h) *dissolved methane and ethane gas;*
   i) *methanol;*
   j) *glycols;*
   k) *benzene, toluene, ethylbenzene, and xylenes (BTEX); and*
   l) *carbon13 composition of any dissolved methane gas discovered (13C-CH4).*

   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. This plan shall specify the use of standard protocols recognised to constitute good professional practice, including quality control and assurance. An International Accreditation New Zealand (IANZ) accredited laboratory shall be used for all sample analysis. Results shall be provided to the Chief Executive within 30 days of sampling and shall include supporting quality control and assurance information. These results will be used to assess compliance with condition 3.*

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

The above four conditions require a water quality monitoring programme and reporting to establish baseline and post fracturing water quality data to confirm that adverse environmental effects on water are avoided. It is very unlikely that any escape of chemicals or adverse environmental effects will occur as a result of HF discharges through the wellbore or via the fracture zone. However, a comprehensive monitoring programme (including drilling of a monitoring bore if no suitable one exists or using those within 500 m of the wellsite, whereby a different consent condition would be used (see base of CAT table in Appendix II) is necessary to provide the public with a reasonable level of assurance that any such occurrence would be detected and its effects evaluated. Testing for source of methane (i.e., biogenic or thermogenic) (refer Section 3.4 of this guide) is included in the parameters to be tested if methane is detected during initial sampling. Sampling is conducted according to recognised field procedures and analysis by a suitably qualified laboratory is required. The Council certifies the monitoring programme. The monitoring described is consistent with best practice guidance for monitoring developed in overseas regulatory regimes.

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.*

The above is a requirement to undertake well and equipment pressure testing to confirm the integrity of the well and equipment so that any adverse environmental effects associated with the HF material escaping from the well or equipment are avoided. Also supports MoBIE 2013 Petroleum Regulations requirements.

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 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 14;
e) results of modelling showing an assessment of the likely extent and dimensions of the fractures that will be generated by the discharge;
f) the preventative and mitigation measures to be in place to ensure the discharge does not cause adverse environmental effects and complies with condition 3;
g) the extent and permeability characteristics of the geology above the discharge point to the surface;
h) any identified faults within the modelled 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.*

The above is a requirement to provide a comprehensive pre-fracturing discharge report to enable checking of compliance with conditions, and consistency with details provided, and assessed, in the application and AEE. The note clarifies that 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.

10) *The consent holder shall notify the Taranaki Regional Council of each discharge by emailing worknotification@trc.govt.nz. Notification shall include the date that the discharge is to occur and identify the 'Pre-fracturing Discharge Report', required by condition 9, which details the discharge. Where practicable and reasonable notice shall be given between 3 days and 14 days before the discharge occurs, but in any event, 24 hours notice shall be given.*

The above is a requirement to provide notice to the Council so there is an opportunity to monitor the operation for compliance with any consent conditions. It should be noted by compliance agencies that because of the speed at which wellsite activities progress, resourcing of monitoring capacity must provide for ready availability.

11) *At the conclusion of a hydraulic fracturing programme on a given well, the consent holder shall submit a comprehensive 'Post-fracturing Discharge Report' to the Chief Executive. The report shall be provided within 60 days after the programme is completed and, as a minimum, shall contain:*

a) *confirmation of the interval(s) where fracturing occurred for that programme, and the geographical position (i.e,. depth and lateral position) of the discharge point for each fracture interval;*
b) *the contaminant volumes and compositions discharged into each fracture interval;*
c) *the volume of return fluids from each fracture interval;*
d) *an analysis for the constituents set out in conditions 6(a) to 6(k), in a return fluid sample taken within the first two hours of flow-back, for each fracture interval if flowed back individually, or for the well if flowed back with all intervals comingled;*
e) *an estimate of the volume of fluids (and proppant) remaining underground;*
f) *the volume of water produced with the hydrocarbons (produced water) over the period beginning at the start of the hydraulic fracturing programme and ending 50 days after the programme is completed;*
g) *an assessment of the extent and dimensions of the fractures that were generated by the discharge, based on modelling undertaken after the discharge has occurred and other diagnostic techniques, including production analysis, available to determine fracture length, height and containment;*

h) *the results of pressure testing required by condition 8, and the top hole pressure (psi), slurry rate(bpm), surface proppant concentration (lb/gal), bottom hole proppant concentration (lb/gal), and calculated bottomhole pressure(psi), as well as predicted values for each of these parameters ; prior to, during and after each hydraulic fracture treatment;*
i) *details of the disposal of any returned fluids, including any consents that are relied on to authorise the disposal;*
j) *details of any incidents where hydraulic fracture fluid is unable to pass through the well perforations (screen outs) that occurred, their likely cause and implications for compliance with conditions 1 and 3; and*
k) *an assessment of the effectiveness of the mitigation measures in place with specific reference to those described in the application for this consent.*

12) *The reports described in conditions 7 and 9 shall be emailed to consents@trc.govt.nz with a reference to the number of this consent.*

The above is a requirement to supply a post-fracturing discharge report to confirm that details of the activity are consistent with the application and that the discharge complies with the conditions of the consent. In particular it provides information essential to giving confidence that discharged material remains within the fracture interval or is otherwise accounted for and did not and will not reach fresh water. It includes the results of modelling predictions, preventative and mitigation measures in place, the extent and permeability characteristics of the geology above the discharge point to the surface, the burst pressure of the casing, the anticipated maximum well and discharge pressures and the duration of the pressures.

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.*

The above is a requirement to provide access for sampling to allow appropriate compliance monitoring to occur.

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 minimise 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.*

The above is a requirement to adopt the Best Practicable Option (BPO) to prevent or minimise any actual or likely adverse effect of the activity on the environment. The condition requires that the operator strives for a higher standard than that required by the conditions, if that higher standard can reasonably be achieved, recognising the definition of BPO in the RMA. It also requires the consent holder to continually review methods and practices and make reasonable improvements, even though the conditions are being met. The condition is reasonably necessary to avoid adverse environmental effects and includes a provision for regular reviews of the chemicals used 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.*

The above is a requirement on the composition of HF fluids being water based. This ensures the discharge is consistent with that applied for and assessed, and ensures that the adverse environmental effects associated with hydrocarbon based HF fluids are avoided.

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

a) ensuring that the conditions are adequate to deal with any significant adverse effects on the environment arising from the exercise of this consent, which were either not foreseen at the time the application was considered or which it was not appropriate to deal with at the time; and/or
b) further specifying the best practicable option as required by condition 14; and/or
c) ensuring that hydraulic fracturing operations appropriately take into account any best practice guidance published by a recognised industry association or environmental regulator.

The above is an option to review the conditions of consent under specified conditions that include dealing with significant adverse effects on the environment; further specifying the best practicable option; and/or ensuring hydraulic fracturing operations appropriately take into account any best practice guidance published by a recognised industry association or environmental regulator.

Compliance Monitoring

Section 35 of the Resource Management Act 1991 sets obligations upon the Council to gather information, monitor, and conduct research on the effects arising from consented activities within the Taranaki region and report upon these. To perform its statutory obligations, the Council may be required to take 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 Council adopts a risk-based approach to monitoring. The greater the risk, the more monitoring that is required. Given the substantial depth of the HF regulated in the region since August 2011 there has been no requirement to install monitoring bores. If HF was being considered closer to the freshwater/saltwater interface then monitoring bores would be considered on a case by case basis. Where there is existing shallow aquifer utilisation in the general proximity of an HF operation, the Council has sought to utilise existing bores for monitoring purposes.

The activity involves work occurring over a HF programme, which could be a period of a few weeks with, however, a potential for environmental effects to occur over a longer term. Therefore, required monitoring primarily involving sampling of groundwater, will have to take baseline information of groundwater quality and the long-term variables into account. Consent conditions require the consent holder to develop a sampling programme and have it certified by the Council's Chief Executive.

A full compliance monitoring programme will be established by the Council and in addition to groundwater sampling and return fluid sampling will include site inspections, assessment of the mitigation measures, data assessment and reporting. The compliance monitoring programme may be included in the programme for the other resource consents for the well site. The results of the monitoring programme will be presented in a monitoring report that is presented to the Council and the community. Reasonable costs associated with the monitoring will be charged to the consent holder.

While the environmental risks of the HF discharge are considered extremely low, overseas literature notes that it is important to have pre-fracturing monitoring data from nearby groundwater wells. This not only provides baseline monitoring data to determine compliance with recommended condition 3, but also provides an opportunity for public assurance. For these reasons relevant consent groundwater monitoring conditions are recommended.

The monitoring specified in recommended conditions includes standard water testing for pH, conductivity and suspended solids as a way to characterise the baseline groundwater quality. All these determinants could increase, if groundwater was to be affected by HF chemicals, so testing for them provides a general 'indicator' of the presence of HF fluids.

The other determinants are more specific contaminants associated with HF operations, for example KCL is used to stop clays swelling and the carbon-13 composition of dissolved methane gas ($^{13}C\text{-}CH_4$) would help differentiate between biogenic and thermogenic methane associated with the migration of gases from deep reservoirs resultant from HF processes.

The monitoring programme must also focus on the information required in the post fracture report to determine the fate of HF fluids and the risks to contaminating fresh water aquifers (i.e., leakage due to defective well installation/operation; leakage through geologic media; leakage or improper handling of chemical or wastewater; and risk of well blowout). An assessment of the diagnostic data and information will also be required and appropriate expertise is required for this and may involve the use of consultants.

Consent Surrender Considerations

Section 138 of the RMA sets out the considerations that apply to the surrender of an HF discharge consent. The section is set out below for ease of reference:

1. The holder of a resource consent may surrender the consent, either in whole or part, by giving written notice to the consent authority.
2. A consent authority may refuse to accept the surrender of part of a resource consent where it considers that surrender of that part would—
    a. affect the integrity of the consent; or
    b. affect the ability of the consent holder to meet other conditions of the consent; or
    c. lead to an adverse effect on the environment.
3. A person who surrenders a resource consent remains liable under this Act—
    a. for any breach of conditions of the consent which occurred before the surrender of the consent; and
    b. to complete any work to give effect to the consent unless the consent authority directs otherwise in its notice of acceptance of the surrender under subsection (4).

4. A surrender of a resource consent takes effect on receipt by the holder of a notice of acceptance of the surrender from the consent authority.

Section 138(2) presents a number of tests for the Council before a resource consent can be surrendered Two key tests are whether the surrender will affect the ability of the consent holder to meet other conditions of the consent or lead to an adverse effect on the environment.

The compliance monitoring of the consent should show whether compliance has been achieved. The assessment of the total volume of HF fluids discharged, the volume of flow back (return flow), and the volume of produced water over time will provide data on the volume of HF fluids still in the land (reservoir). The use of other diagnostic information, such as screen-outs and radioactive tracers, will show the fate of the HF fluids and proppant. Together with this information sampling of local water resources will show whether there has been a change from baseline conditions.

The significance of the above considerations is a function of the degree of risk to freshwater. Discharges at considerable depths (3+ km) pose minimal risk, as there is virtually no way for HF fluids to reach fresh water from any activity at this depth, unless there is a significant well integrity issue. For applications to discharge closer to freshwater there would be reliance on actual groundwater monitoring as opposed to diagnostic information.

The well abandonment provisions of the Health Safety and Employment-Petroleum Exploration and Extraction Regulations (refer Section 5.4) also apply to the HF well if it is not to be used for production or other purposes.

The term of the consent should take the above into consideration and ensure an assessment can be made at an appropriate time to determine the fate of any HF fluids remaining in the reservoir.

Conclusions

HF operations that are properly planned, executed, and regulated can be undertaken without adverse environmental effects. The resource consent process, including the preparation of a comprehensive AEE and a thorough assessment by the Council can determine the potential for the proposed activity to have any adverse environmental effects and to address these through appropriate consent conditions, including a requirement for on-going monitoring of the activity to ensure the environmental impact of HF operations will be less than minor.

6.1.2 Flow back or return fluid discharge by deep well injection

This section of the guide provides a description of the Deep Well Injection (DWI) process and outlines resource consent considerations for the disposal of waste fluids by DWI, including assessment of environmental effects (AEE) requirements, RMA notification provisions, consent conditions, compliance monitoring, and consent surrender considerations.

In 2012 the Council employed the Institute of Geological and Nuclear Sciences (GNS Science) to review the regulation of DWI, of fluids produced in association with oil and gas exploration and production, to ensure the Councils regulatory programme is consistent with international best practice. GNS Science found the Council's consent conditions cover many of the most important provisions found in the USEPA and Canadian regulatory programmes (Zemanski, 2013). GNS noted a number of improvements to MoBIE's regulations that address well integrity, monitoring and management.

Description of activity
DWI is a liquid waste disposal technology. The DWI process utilises specially designed injection wells to pump liquid waste into geologic formations or confined saline aquifers. The receiving formations generally contain water that is too saline to have any alternative use and are unsuitable for use as hydrocarbon producing reservoirs. Overlying geologic seals confine the material to the receiving formation and prevent the vertical migration of injected wastes into shallow freshwater aquifers. DWI provides an alternative to the surface disposal of liquid waste streams generated by exploration and production activities.

A typical injection well consists of several strings of steel casing, which are cemented in place, isolating the contents of the wellbore from surrounding geologic formations above and below the intended injection zone. Surface pumps generate pressure which drives the waste fluid into the receiving formation pressure via an internal injection string. Higher density fluids may not need pumping in order to flow into the formation. The depth of injection wells can range from many hundred to several thousands of metres depending on site-specific geologic characteristics and the depth of suitably permeable and confined zones that can be utilised for injection.

International standards (US EPA standard generally adopted in the Taranaki region) for the construction of disposal wells emphasise the importance of surface casing extending below the base of the freshwater zones and for the casing to be cemented back to surface. The standards also highlight the requirement for internal casing strings to be cemented back up the hole to seal off and isolate the disposal interval from the overlying fresh water zones. As part of the resource consent application process for DWI activities, applicants are required to submit information that details both the design and construction specifications of the injection well(s) and demonstrates well integrity and the isolation of the well bore from surrounding geologic formations. This information is also important in demonstrating compliance with the Petroleum Regulations administered by MoBIE (High Hazard Unit) under the Petroleum Regulations.

In Taranaki, contaminants disposed of by DWI are generally limited to saline produced water, waste drilling fluids, contaminated stormwater, HF and well work-over return fluids and production sludges. The Council has approved, on specific occasions, the discharge of small volumes of other specified contaminants by DWI. Any application to discharge waste material not specifically licenced by an existing resource consent is assessed by the Council on a case-by-case basis.

Produced saline water makes up the greatest volume of waste fluids generated by oil and gas exploration activities. Proportionately higher quantities of water are produced from a hydrocarbon field, that is subject to water drive, as more oil or gas is extracted and the productive life of the field declines. Produced waters have been disposed of by DWI in Taranaki since the development of the Kapuni Field in 1970. Waste fluids generated by HF activities, including HF and return fluids make up a small percentage of the total volume of waste fluids disposed of by DWI across the region. Other waste streams such as drilling waste fluids, production sludges and contaminated stormwater are disposed of on short-term or intermittent bases.

Waste fluids generated by exploration activities are typically highly saline and contain hydrocarbon residues and chemical additives. Under appropriate geologic and operational conditions, the disposal of liquid wastes by DWI is currently the most cost-effective and environmentally sound disposal option and should result in no more than minor environmental effects. The control of DWI activities through the resource consent process is considered an appropriate regulatory regime. The practice is summarised in Figure 16 below.

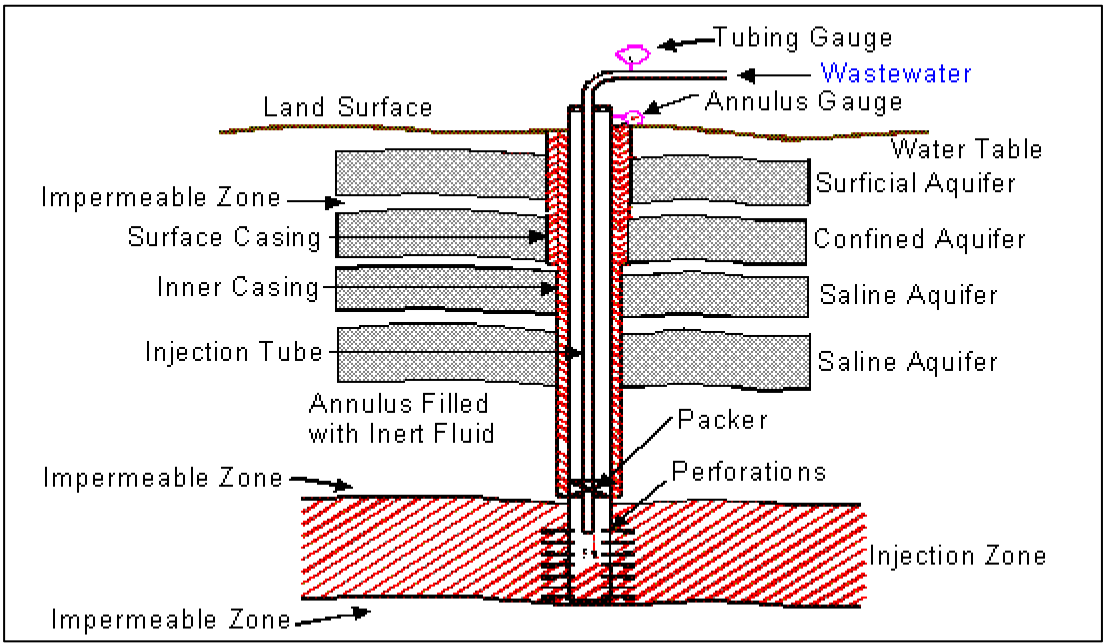

Figure 16 DWI schematic showing the well (casing and cement) and associated equipment and injection interval (source http://web.deu.edu.tr/atiksu/ana58/deepwell.html)

The Taranaki Regional Council is responsible for regulating the environmental effects from hydrocarbon exploration and development activities under the Resource Management Act 1991 (RMA). Sections 15 and 30 of the RMA give the Council the responsibility for regulating the discharge of contaminants into the environment. The discharge of contaminants onto or into land that may result in water contamination may not take place, unless expressly allowed by a rule in a regional plan, resource consent or other relevant regulations.

In the Taranaki region, the discharge of contaminants by DWI requires resource consent from the Council. The activity falls under Rule 51 of the Regional Fresh Water Plan for Taranaki (2001) and is classified as a discretionary activity. The application may be non-notified, if no parties are deemed to be adversely affected by the proposed activity.

In September 2013 there were a total of 21 current resource consents for DWI in Taranaki. However, several resource consents have been issued for relatively short-term activities during exploration phase drilling, and several may never be exercised and will be lapsed. Five consents currently allow the DWI of HF return fluids.

AEE requirements
A detailed AEE is required for any application for consent to discharge waste fluids by DWI. The information presented in the AEE must demonstrate that the proposed activity will not result in any adverse environmental effect that is deemed

to be more than minor. Specific examples of the range of information and data that could be required to make this assessment are as follows:

- Specific details of the proposed injection site including well site and well reference names, address, the legal description of property, ownership details, geographical co-ordinates of site and injection well and the location of any nearby water abstraction points;
- A summary section [schematic] showing geologic formations and identifying the impermeable and laterally persistent units [confining layer(s)], any major faults or shear zones, the disposal well path and well perforation intervals;
- The depth to which freshwater extends below the site and the location of the freshwater/saline water interface zone;
- Geophysical logs and interpretation to support geologic data and depth to freshwater/saline water interface zone;
- Details of the proposed injection well including a well engineering completion summary report, including the initial and proposed pressure test programme to show the disposal well will remain secure;
- Consideration of any abandoned wells in the vicinity and their condition;
- The location of the injection zone and associated casing perforations;
- A full and complete list of all contaminants to be disposed of [eg. contaminated storm water, HF fluids and operational products used] in addition to saline produced water containing hydrocarbon residues;
- The maximum expected volumes of materials to be disposed of over the life of the activity, and the modelled radius of influence of the contaminant plume;
- A description of equipment installed on the disposal well used to monitor injection pressure and annular pressure;
- A written procedure that identifies the conditions which would trigger concerns about the integrity of the disposal well or injection zone, and the action to be taken by the consent holder when triggered; and
- Results to show that the water chemistry in the disposal zone is compatible with that of the fluids to be disposed of and any possible adverse geochemistry effects that may arise.

The AEE must as a minimum adequately demonstrate that:

- The geologic formation into which the wastewaters are injected is sufficiently porous and permeable so that the wastewater can enter the rock formation without an excessive build up of pressure;
- The injection zone is overlain by a relatively non-permeable layer of rock which will confine the injected fluids within the intended disposal interval and prevent them from moving vertically toward a freshwater aquifer;
- The site-specific geologic properties of the subsurface around the well offer another safeguard against the movement of injected wastewaters to a freshwater aquifer;
- There are no wells or other artificial pathways between the injection zone and freshwater aquifers through which fluids can travel;

- That the injection well is designed and constructed to prevent the movement of injected waste waters into freshwater aquifers;
- A constant pressure will be maintained in the annular space and will be continuously monitored to verify the injection well's mechanical integrity and proposed operational conditions; and
- All of the materials of which injection wells are made are corrosion-resistant and compatible with the wastewater and the formation rocks and fluids into which they come in contact.

The provisions of section 88(2) of the RMA apply to any application made. After reviewing the information submitted with the consent application, the Council can request additional information from applicant which is deemed necessary to adequately assess the application. The Council can also set consent conditions that require additional information to be submitted prior to or while the consent is being exercised.

Notification
Section 95 of the RMA sets out the notification/non-notification provisions for resource consent applications. It should be noted that amendments to the RMA in 2009 removed the presumption that consent applications would be notified. The Council follows clearly established procedures in making decisions on notification or non-notification of resource consent applications and these procedures are fully consistent with the RMA. Each consent application must be assessed on its merits. Given that an application for DWI at considerable depth using good oil field practices would likely meet the 'no more than minor adverse environmental effects' and the 'no affected party' tests in the RMA, the application can, and properly should, be non-notified.

The Council follows clearly established procedures in making decisions on notification or non-notification of resource consent applications and these procedures are fully consistent with the RMA.

Providing applicants have prepared a thorough AEE which allows the Council to establish the adverse effects of the proposed activity are likely to be no more than minor the application is non-notified.

Consent conditions
When granting resource consents for the disposal of wastes by DWI, the Council imposes a number of special conditions which are deemed reasonably necessary to avoid, remedy or mitigate any potential adverse environmental effects and to ensure that the nature and scale of the activity is consistent with the application and the assessment of environmental effects presented.

As with HF consent processing, specific consent conditions have been developed for the disposal of liquid wastes by DWI. DWI and HF are similar activities in that both involve the injection of fluids into underground formations, although discharges by DWI are injected at significantly lower pressure and remain underground while a high proportion of HF fluids are returned to the surface in flow back or return fluids.

As for HF well integrity is a responsibility of MoBIE under the Petroleum Regulations.

Most of the major risks associated with HF operations, as identified in the Council's hydrogeologic risk assessment report (Taranaki Regional Council, 2012b), are also applicable to DWI activities. The major risks:

a) leakage due to defective well installation/ operation;
b) leakage through geologic media; and
c) leakage or improper handling of chemicals and wastewaters;

are addressed by way of consent conditions.

The risk of induced seismicity is not assessed because of work undertaken by GNS concluded that HF and DWI operations do not pose a credible seismic risk in the region (refer Section 4.8.2 of this report).

The conditions from a recently processed DWI application (by Greymouth Petroleum) are presented below (in italics) with a commentary, which sets out the rationale for each condition. The same consent is also included in Appendix II with a Conditions Analysis Table, which notes the reason for the condition, how compliance will be determined and the reason for any limits set.

To discharge produced water, well drilling fluids, well workover fluids into the Mount Messenger Formation by deepwell injection via the Kaimiro-G wellsite.

The purpose of the consent limits the range of fluids that can be discharged, the formation in which they can be injected and the well by which disposal can be carried out.

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.

The above general condition is applied to all consents to pay to the Council all the administration, monitoring and supervision costs of this consent, fixed in accordance with section 36 of the RMA.

1. *Before this consent is exercised, the consent holder shall submit an "Injection Operation Management Plan" which shall include the operational details of the injection activities and identify the conditions that would trigger concerns about the integrity of the injection well, injection zone or overlying geologic formations. The plan will also detail the action(s) to be taken by the consent holder if trigger conditions are reached.*

   Prior to exercising the consent, the consent holder must submit to the Council, a document which fully details the planned operational process surrounding the consented DWI activities. The plan also needs to stipulate the on-going process monitoring procedures to be implemented, including the parameters to be monitored and expected operational ranges. Also required is detail of the actions to be taken if process monitoring indicates any operational issues with the injection well or geologic integrity issues.

2. *Before this consent is exercised the consent holder shall provide to the Chief Executive of the Taranaki Regional Council:*

   (a) *A final well completion log for the injection well including subsurface construction details, design of the exterior surface casing, the intermediate protective casing, and the innermost casing, tubing, and/or packer(s);*

(b) *Well cementing details, cement bond log and results of annular pressure testing which demonstrates well integrity;*

(c) *Details of on-going well integrity monitoring, well maintenance procedures and safe operating limits for the well;*

(d) *A detailed geologic log of the well;*

(e) *Details and results of the Formation Integrity Testing carried out on the receiving formation and confining layers and an assessment of the results against the estimated modelled values submitted in the consent application;*

(f) *Results of an electrical resistivity survey, clearly showing the confirmed depth of freshwater as defined in condition 12; and*

(g) *A full chemical analysis of the receiving formation water.*

Note: These details can be included within the "Injection Operation Management Plan."

Prior to exercising the consent the consent holder is required to submit data relating to the injection well construction, testing, monitoring, and maintenance. Also required are full details of the geologic properties of the receiving and confining formations. This information is fundamental in ensuring the proposed injection activities will have minimal environmental impact.

3. *The injection pressure at the wellhead shall not exceed 1,077 psi (73 bars). If exceeded, the injection operation shall be ceased immediately and the Chief Executive of the Taranaki Regional Council informed immediately.*

4. *The rate of injection shall not exceed 8.6 cubic metres per hour (0.9 bpm).*

Conditions 3 and 4 require the consent holder to maintain injection pressures and flow rates below specified levels. The maximum limits set are designed to ensure that the injection of wastes does not result in any hydraulic fracturing of the receiving formation or confining geologic seals.

5. *The volume of fluid injected shall not exceed 206 cubic metres per day (1,296 bpd).*

Condition 5 limits the total volume of waste that can be injected into the receiving formation. The maximum permitted injection volume is set below the calculated hydraulic capacity of the injection zone. This limiting of injection volumes is required to ensure that the receiving formation has the ability to assimilate the waste fluids being injected.

6. *The injection of fluids shall be confined to the Mt. Messenger Formation, deeper than 995 metres True Vertical Depth Sub-sea.*

Condition 6 requires that injected wastes be confined to a specific geologic unit below a specific depth. The condition is necessary to ensure the discharge remains in the intended receiving formation and that separation between the receiving formation and overlying freshwater zones is maintained.

7. *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 minimise any actual or likely adverse effect on the environment; in particular, ensuring that the injection material is contained within the injection zone.*

A requirement to adopt the BPO to prevent or minimise any actual or likely adverse effect of the activity on the environment. The condition requires that a higher standard than that required by the conditions be met if it can reasonably be achieved, recognising the definition of BPO in the RMA. It also requires the consent holder to continually review methods and practices and make reasonable improvements even though the conditions are being met.

8. *Only the fluids listed below and originating from the consent holder's operations may be discharged:*

   (a) *produced water;*

   (b) *well drilling fluids;*

   (c) *well workover fluids, including hydraulic fracturing return fluids; and*

   (d) *contaminated stormwater.*

   Condition 8 limits both the range and origin of waste fluids that can be discharged under the operation of the consent. This condition is necessary to limit the potential effects to those assessed in the consent application.

9. *Once the consent is exercised, the consent holder shall keep daily records of the:*

   (a) *total injection hours;*
   (b) *volume of fluid injected;*
   (c) *maximum and average rate of injection; and*
   (d) *maximum and average injection pressure.*

   This condition is necessary to allow the Council to assess compliance with the relevant consent conditions, specifically those conditions related to the limiting of injection pressure, rates and volumes.

10. *For each waste stream arriving on site for discharge, the consent holder shall record the following information:*

    (a) *Type of fluid;*

    (b) *Source of fluid (site name and location);*

    (c) *An analysis of the fluid for:*

      (i) *pH;*

      (ii) *suspended solids concentration;*

      (iii) *temperature;*

      (iv) *salinity;*

      (v) *chloride concentration; and*

      (vi) *total hydrocarbon concentration.*

    The analysis required by condition 10(c) above is not necessary if a sample of the same type of fluid, from the same source, has been taken and analysed within the previous 6 months.

    This condition is necessary to allow the Council to assess compliance with the relevant consent conditions, specifically conditions relating to the type, source and chemical composition of injected fluids.

11. *The information required by conditions 9 and 10 above, for each calendar month, shall be provided to the Chief Executive, Taranaki Regional Council before the 15th day of the following month.*

This condition is necessary to ensure the relevant consent conditions are being complied with.

12. *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.*

Condition 12 is required to ensure useable freshwater resources are not contaminated by the waste discharge. The other conditions of this consent are expected to protect freshwater resources, however the inclusion of the condition is reasonably needed to ensure adverse effects are to be avoided.

13. *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 12 (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 sampling sites;

(b) well/bore construction details; and

(c) sampling frequency.

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

(a) pH;

(b) conductivity;

(c) chloride; and

(d) total petroleum hydrocarbons.

Note: The samples required, under conditions 13 and 14, could be taken and analysed by the Council or other contracted party on behalf of the consent holder.

15. *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 12.*

Note: The Sampling and Analysis Plan may be combined with the Monitoring Programme required by condition 13.

Conditions 13, 14 and 15 require the establishment of a water quality monitoring programme in the vicinity of the proposed DWI site or area of review. Water quality monitoring is necessary to establish baseline water quality levels and ensure the exercising of the DWI consent does not impact on local ground or surface water quality. Sampling is according to recognised field procedures and analysis by a suitably qualified laboratory. The monitoring programme is certified by the Council.

Depending on the suitability of existing bores within an area of review encompassing a radius of 500 m from the wellsite for obtaining a representative groundwater sample, it may be necessary for the Monitoring Programme to include installation of, and sampling from, a dedicated monitoring bore.

16. *The consent holder shall provide to Taranaki Regional Council, during the month of July of every year, a summary of all data collected and a report detailing compliance with consent conditions over the previous 1 July to 30 June period. The report shall also provide and assess data which illustrates the on-going integrity and isolation of the wellbore, well performance and condition. The consent holder shall also provide an updated injection modelling report, illustrating the ability of the receiving formation to continue to accept additional waste fluids and estimating its remaining storage capacity.*

    This condition requires the consent holder to submit an annual report to the Council. The report and the data within it is requires to assess compliance with consent conditions, monitor environmental effects and assess environmental risk.

17. *The consent holder shall notify the Chief Executive, Taranaki Regional Council, in writing at least 5 days prior to the first exercise of this consent. Notification shall include the consent number and a brief description of the activity consented and be emailed to worknotification@trc.govt.nz.*

    Condition 17 requires the consent holder to provide notice to the Council of intention to commence with the exercising of the consent. This condition allows the Council to implement monitoring procedures as required and ensure that all consent conditions are being complied with.

18. *There shall be no fluids discharged under this consent after 1 June 2027.*

    This condition allows for the monitoring to be continued after discharge has ceased and potential effects associated with the activity have diminished to an acceptable level.

19. *In accordance with section 128 and section 129 of the Resource Management Act 1991, the Taranaki Regional Council may serve notice of its intention to review, amend, delete or add to the conditions of this resource consent by giving notice of review during the month of June each year, for the purpose of ensuring that the conditions are adequate to deal with any adverse effects on the environment arising from the exercise of this resource consent, which were either not foreseen at the time the application was considered or which it was not appropriate to deal with at the time.*

    This condition provides the Council an option to review the conditions of the consent on an annual basis and to amend as required.

Compliance monitoring

Section 35 of the Resource Management Act 1991 sets obligations upon the Council to gather information, monitor, and conduct research on the effects arising from consented activities within the Taranaki region and report upon these. To perform its statutory obligations, the Council may be required to take 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 Council adopts a risk based approach to monitoring. The greater the risk the more monitoring that is required.

A full compliance monitoring programme will be established by the Council. Reasonable costs associated with the monitoring will be charged to the consent holder.

The monitoring of active DWI consents comprises of a series of inspections, environmental sampling and data assessment. There is generally a significant investment of time and resources by the Council in on-going liaison with resource consent holders over consent conditions and their interpretation and application.

Inspections at active disposal sites allow the Council to assess the infrastructure around the DWI activities and the general condition of the site. Inspections tasks include liaising with on-site staff, identifying and viewing the injection well, monitoring equipment and injection logs.

DWI consents can also require the consent holder to provide the Council with analytical results of its own injectate sampling programmes. Generally, this will include details of the type and source of fluid being injected the results of laboratory analysis of various parameters including temperature, pH, salinity, suspended solids and total hydrocarbons, carried out at the frequency specified in the consent. Additional injectate samples are also collected by the Council, typically at 6 monthly intervals. The samples are analysed at the TRC laboratory for same parameters outlined above. The sampling aims to characterise the general chemical nature of the discharge and its variation across the monitoring period.

For each well used for deep well injection, the consent holder is required to provide dates and times that the injection of waste is carried out, the injection pressure, maximum and average rate of injection and total volume of fluid injected. All data received is reviewed and analysed by the Council.

Historically, resource consents issued for DWI activities have included a groundwater monitoring provision that could be requested by the Council if any potential contamination was suspected. The condition provided for the sampling of up to 3 water supplies in the vicinity of any active disposal wells(s), or the installation of a monitoring well specifically for this purpose. However, any new consents being issued for DWI activities now include a mandatory groundwater monitoring component as detailed in consent conditions 12, 13 and 14.

The Council prepares biennial DWI monitoring reports for each company operating in the Taranaki region. The reports present the data collected by the Council and also that submitted by the consent holder over the period under review. The reports provide an assessment of all data, overall environmental performance and resource consent compliance. The monitoring report is presented to the Council and the community.

Consent surrender considerations

Section 138 of the RMA sets out the considerations that apply to the surrender of a DWI discharge consent. The section is set out below for ease of reference:

1) The holder of a resource consent may surrender the consent, either in whole or part, by giving written notice to the consent authority.

2) A consent authority may refuse to accept the surrender of part of a resource consent where it considers that surrender of that part would—
   a) affect the integrity of the consent; or
   b) affect the ability of the consent holder to meet other conditions of the consent; or
   c) lead to an adverse effect on the environment.
3) A person who surrenders a resource consent remains liable under this Act—
   a) for any breach of conditions of the consent which occurred before the surrender of the consent; and
   b) to complete any work to give effect to the consent unless the consent authority directs otherwise in its notice of acceptance of the surrender under subsection (4).
4) A surrender of a resource consent takes effect on receipt by the holder of a notice of acceptance of the surrender from the consent authority.

Section 138(2) presents a number of tests for the Council before a resource consent can be surrender. Two key tests are whether the surrender will affect the ability of the consent holder to meet other conditions of the consent or lead to an adverse effect on the environment. Monitoring information should be used as part of these assessments, particularly that showing the integrity of the injection well and injection zone.

The term of the consent should take the above into consideration and ensure an assessment can be made at an appropriate time to confirm the location of injected fluids and any actual or potential adverse environmental effects.

The well integrity and abandonment provisions of the Health Safety and Employment- Petroleum Exploration and Extraction Regulations (refer Section 5.4), also apply to the well.

Conclusions

DWI is an environmentally sound disposal option for waste fluids produced by exploration and production activities in the Taranaki region, including HF and well workover fluids. The resource consent process, including the preparation of a comprehensive AEE and a thorough assessment by the consent authority can determine the potential for the proposed activity to have any adverse environmental effects and to address these through appropriate consent conditions, including a requirement for on-going monitoring of the activity, by both the consent holders and the Council, to ensure the environmental impact of DWI operations will be less than minor.

6.1.3 Drilling waste and return fluid discharge via land farming

This section of the guide provides resource consent considerations for the discharge of return fluids and other drilling wastes by land farming and includes assessment of environmental effects requirements, RMA notification provisions, consent conditions, compliance monitoring, and consent surrender considerations. Mainly drilling cuttings and muds are land farmed in Taranaki with return fluids deep well injected.

The process of drilling and casing a well and the cuttings that are produced and drilling muds that are used were discussed in section 3 of this guide. The origin of flow back or return fluids from an HF subsurface discharge was presented in section 4. The composition of typical HF flow back fluids was presented in Appendix III of the hydrogeologic risk report (Taranaki Regional Council, 2012b).

Land farming is the process whereby drilling wastes (typically rock cuttings with residual muds and some hydrocarbons and water based and synthetic based muds) are disposed of via application to land. The practice is a valid and environmentally acceptable means of waste treatment with appropriate controls. Waste are incorporated into soil allowing natural bioremediation and various soil processes to biodegrade, transform and assimilate wastes (refer section 4.8.6 for further information on land farming in the region).

Photo 9 Oeo land farm – lined waste storage pits and groundwater sampling

In Taranaki to date, land farming has consisted of single applications of drilling wastes to designated treatment areas. In more recent times it has been used as a method of disposing well work-over fluids and return fluids from hydraulic fracturing. At present there is one site which is consented to dispose of return fluids in the region and it is about to be completed and closed.

Photo 10 Oeo land farm – lined waste storage pits and soil sampling

Description of activity

Optimal land farming techniques balance additions of waste against a soil's capacity to assimilate waste constituents. This is important to avoid detrimental effects on soil quality and integrity, subsurface soil contamination problems, or other adverse environmental impacts. Studies conducted in Canada and the USA in Alberta, Saskatchewan, Oklahoma, Colorado and also in Belgium and Croatia (Bates 1988; Genouw et al. 1994; Kisic et al. 2009; Hubalek et al 2007; Vail, 2002) have indicated that if wastes are applied correctly, land farming does not adversely affect soils. Furthermore, some studies as well as anecdotal evidence have indicated that land farming may even benefit certain sandy soils by increasing their water-retaining capacity and reducing fertiliser losses (Biederbeck, 1991).

The results of a review of land farming regulation and an assessment of whether land used for land farming activities being returned afterwards to pastoral farming in a state that is 'fit for purpose' are presented in section 4.8.6.

Basic steps in the land farming process include the following:

1. Drilling waste is transported from well sites by truck (cuttings) or tanker (liquids), and may be discharged directly to land or placed in a dedicated storage pit. In the case of fracturing return fluids, this waste is stored in a lined pit, separate from other wastes and labelled to indicate individual well/source.
2. Required area is prepared by removing any existing pasture/topsoil and levelling out uneven ground.

3. Waste may be blended with additional materials such as sawdust, to reduce free liquids, reduce concentrations of hydrocarbons, and provide organic content.
4. Waste is transferred to prepared area by excavator and truck and spread out with a bulldozer. Liquids may be discharged by tanker or spray system.
5. Waste is allowed to dry sufficiently before being tilled into the soil to the required depth with a tractor and discs.
6. Area is levelled with chains or harrows.
7. Removed topsoil/clay is applied to aid stability and assist in grass establishment.
8. Fertiliser may be applied and the area is sown in crop or pasture at a suitable time of year.

Photo 11 Oeo land farm area

Land farming consenting and monitoring in Taranaki has been mostly developed on the basis of Canadian (Alberta) practices, outlined in the Energy Resources Conservation Board Directive 50 for drilling waste management (Energy Resources Conservation Board, 2012) but adapted to the Taranaki environment, with modifications in place to account for the influences of coastal processes and a more moderate maritime climatic setting.

Soil chemistry and biochemistry analysis of the spreading areas of land farming sites in Taranaki show that hydrocarbons are quickly and effectively biodegraded to within surrender criteria limits. Land farming of HF return fluids remains in the early stages, however, laboratory analyses of return fluids from Taranaki wells indicate that the chemical concentrations and composition of HF return fluids are similar to those of other drilling wastes that have been used in land farming thus far. Furthermore, initial receiving environment soil sample results for areas where return fluids have been spread show that constituent levels are consistent with areas spread with other types of drilling waste.

Photo 12 Oeo drilling waste land farm – lined mud storage pit

AEE requirements
Assessment of environmental effects (AEE) reports must be supplied with any application to discharge drilling waste and/or HF return fluids to land via land farming. It may be desirable for individual regulatory authorities to develop their own application guidelines to give applicants a clear understanding of what information is required in an AEE to dispose of drilling wastes to land, as well as complying with the requirements of the RMA. AEE considerations for land farming must include an assessment of the following:

Effects on water quality
Disposal of drilling waste may affect water quality in one of two ways, either through surface water or groundwater contamination. AEEs provided to the TRC must address the location of nearby waterways, with thorough investigations into possible pathways for contaminants to enter water resources. AEEs must also outline measures to be taken to eliminate or minimise these potential effects. Consideration must also be given to any other (and particularly down-gradient) users of these water resources.

Effects on surface water
Appropriateness of site selection is crucial to removing the risk of contaminants entering surface water. Generally in Taranaki, sites without any overland watercourses are preferred for such activities. In the event of a site being in proximity to one or more streams/lakes/farm drains, buffer zones are established to prevent overland flow from activity site boundaries into any waterways. AEEs should propose adequate buffer distances from surface water bodies to reduce risk of overland/through flow from spreading areas into surface water. Storage areas

should not be in close proximity to surface water resources. To establish baseline water quality, testing prior to any disposal activities (including stockpiling) should be conducted by the applicant and reviewed by the regulatory authority.

Groundwater
AEEs must contain relevant hydrogeologic information about proposed sites. This should contain a depth to water table analysis. Groundwater monitoring bores should ideally be installed prior to the activity commencing at the sites to confirm groundwater flow paths and background water quality to provide a comparative baseline. A groundwater scientist can best assess the location, design, depth and number of groundwater bores needed at a site. This can be done as part of the application but needs to be approved by the regulatory authority to ensure it is done to the required standard.

Permeability of storage pits should also be assessed, as waste can be stored in these pits for months in a concentrated form, posing a greater risk to groundwater resources than the wastes in their diluted form post-application to land via farming. With water based muds (WBM) and synthetic based muds (SBM) wastes, common constituents barite and bentonite have a natural sealing effect and assist in reducing permeability of pit floors, minimising the risk for groundwater contamination from fluid percolation through the soil profile and into the water table. These pits are being lined as a precaution/requirement.

For fracking well workover fluids, due to the high liquid component, pits should be lined and shown to be, for all intents purposes, impermeable. Best practice is to use a combination of high grade HDPE synthetic liner in conjunction with compacted clay. AEEs should contain information on pit design and lining plans. Preferably engineer assessments of pit integrity would be provided to the regulatory authority after construction, but prior to operations commencing on site. Groundwater monitoring can be used to assist in the assessment of pit integrity over time whether they are lined or not. Monitoring of groundwater has occurred at sites even though there is no requirement in the consent to do so.

Effects on soil quality
Taranaki Regional Council Guidelines relating to land farming in Taranaki suggest that land farming operations should ideally be located on relatively flat sandy country prone to wind erosion as this is where the greatest environmental benefits are likely to be obtained.

AEEs should address background soil characteristics. These soils will generally but not necessarily be sandy in nature. Basic soil profiling will assist in the AEE assessment of possible affects and allow consenting authorities to make informed decisions regarding site suitability. The potential effects on soil quality that should be addressed are the effects of excess salts and chlorides on the health of soil biota and potentially pasture establishment. Coastal sites obviously will generally have high background chloride levels; increasing these levels further may affect the ability of soil biota to degrade hydrocarbons and other biodegradable contaminants. AEEs and site plans must consider these effects and how to manage waste application to stay within consent limits for chloride.

In Taranaki, these effects have been shown to be relatively short-term, as excess chlorides are leached from the soil within a few months of application of wastes.

Also in coastal areas chloride levels can be naturally high due to the effects of storm events and prevailing wind directions.

Effects on air quality

Monitoring of air quality effects at disposal sites in Taranaki has shown that any odour effects are generally localised, with detection unlikely beyond property boundaries. These odours are generally hydrocarbon based and are more likely to be sourced from SBM, rather than return fluids, which generally have lower hydrocarbon content. Dust emissions can arise from unsealed access tracks and around storage areas but there are generally no affected parties. AEEs should consider the location of storage pits in relation to odour effects, as pit areas are likely the main source of any odours. Proximity of storage areas to property boundaries, prevailing wind directions and neighbouring land uses should all be addressed in AEEs and/or site management plans.

The Council has also undertaken monitoring at a land farming site for ambient levels of BTEX and of formaldehyde, the chemicals present within return fracturing fluids that are generally of most interest because of their potential toxic nature and high volatility. The survey showed clearly that such emissions are negligible, and indeed can barely be distinguished from background (baseline) concentrations on a regional basis.

In respect of formaldehyde, the highest boundary concentration detected downwind of the land farm was less than 15% of the national air quality guideline, which in turn is about half of what indoor air can typically contain. Other results were within background ranges.

In respect of benzene, none could be detected, at a detection level that was 5% of the national guideline and much less than 10% of what is typically found in urban areas around New Zealand. Toluene and xylene were detected (ethyl benzene was not), with the highest downwind concentration of either only 5% of national guidelines at the boundary.

Notification and the RMA

Section 95 of the RMA sets out the notification/non-notification provisions for resource consent applications. It should be noted that amendments to the RMA in 2009 removed the presumption that consent applications would be notified. The Council follows clearly established procedures in making decisions on notification or non-notification of resource consent applications and these procedures are fully consistent with the RMA. Each consent application must be assessed on its merits. In considering whether to publicly notify, consenting authorities must consider the extent of potential environmental impacts from the activity. The consenting authority must thoroughly assess the provided AEE, ideally visit the proposed site, and have on-going communication with the applicant. If managed correctly using best practice, land farming of drilling wastes creates effects that are no more than minor, and are generally confined to the consented property.

If a resource consent is to be processed on a non-notified basis, under sections 95E and 95F, the consenting authority must determine whether there are any affected persons in relation to the activity. This will generally be the landowner and neighbouring landowners, local Iwi representatives and other affected parties depending on site characteristics.

Providing applicants have written landholder approval, have consulted with local Iwi and other affected parties and have prepared a thorough AEE, consents have been processed on a non-notified basis.

Consent conditions

Careful consideration is required in the setting of consent conditions for discharge consents for drilling waste. The following section provides recommended special conditions for a consent issued to dispose different types of waste from well site operations (SBM and WBM drilling wastes, oily wastes and HF return fluid wastes), and an explanation of the rationale behind each condition.

The conditions below are from a recently processed land farming application (by Remediation NZ Ltd). The conditions are presented in italics with a commentary that gives the rationale for each condition. This consent is also included in Appendix III with a Conditions Analysis Table, which also provides detail of how compliance is determined and gives the rationale behind any contaminant limits set.

a. *The consent holder shall pay to the Taranaki Regional Council (the Council) all the administration, monitoring and supervision costs of this consent, fixed in accordance to section 36 of the Resource Management Act*

The above condition is a general consent condition that requires the consent holder to pay to the Council all costs involved with the administration, monitoring and supervision of the consent in question, in accordance with section 36 of the RMA.

1. *For the purposes of this consent the following definitions shall apply:*

   (a) *stockpiling means a discharge of drilling wastes from vehicles, tanks, or other containers onto land for the purpose of interim storage prior to land farming, but without subsequently spreading onto, or incorporating the discharged material into the soil within 48 hours; and*

   (b) *land farming means the discharge of drilling wastes onto land, subsequent spreading and incorporation into the soil, for the purpose of attenuation of hydrocarbon and/or other contaminants, and includes any stripping and relaying of topsoil.*

   The above condition provides definitions of the activities covered under the consent for the purposes of clarification.

2. *The consent holder shall adopt the best practicable option [as defined section 2 of the Resource Management Act 1991] to prevent or minimise any actual or potential effects on the environment arising from the discharge.*

   This condition requires the consent holder to adopt the Best practicable Option (BPO) to prevent or minimise any actual or likely adverse effect of the activity on the environment. The condition requires that a higher standard than that required by the conditions be met if it can reasonably be achieved, recognising the definition of BPO in the RMA. It also requires the consent holder to continually review methods and practices and make reasonable improvements even though the conditions are being met.

3. *Prior to the exercise of this consent, the consent holder shall provide a stockpiling and land farming management plan that, to the reasonable satisfaction of the Chief Executive, Taranaki Regional Council, demonstrates the activity can and will be conducted to comply with all of the conditions of this consent. The management plan*

shall be reviewed annually (on or about the anniversary of the date of issue of this consent) and shall include as a minimum:

(a) procedures for notification to Council of disposal activities;

(b) procedures for the receipt and stockpiling of drilling wastes onto the site;

(c) methods used for the mixing and testing of different waste types;

(d) procedures for site preparation;

(e) procedures for land farming drilling wastes (including means of transfer from stockpiling area, means of spreading, and incorporation into the soil);

(f) procedures for sowing land farmed areas, post-land farming management, monitoring and site reinstatement;

(g) contingency procedures;

(h) sampling regime and methodology;

(i) control of site access; and

(j) documentation for all the procedures and methods listed above.

4. *Prior to the exercise of this consent, the consent holder shall after consultation with the Chief Executive, Taranaki Regional Council, install a minimum of three groundwater monitoring bores. The bores shall be at locations and to depths, that enable monitoring to determine any change in groundwater quality resulting from the exercise of this consent. The bores shall be installed in accordance with NZS 4411:2001 and all associated costs shall be met by the consent holder.*

   Conditions 3 and 4 allow groundwater monitoring to occur to access effects from the activity, confirm that adverse effects are being adequately avoided, remedied or mitigated and compliance with consent conditions is being achieved.

5. *The consent holder shall notify the Chief Executive, Taranaki Regional Council, [by emailing worknotification@trc.govt.nz.] at least 48 hours prior to permitting drilling wastes onto the site for stockpiling, from each well drilled. Notification shall include the following information:*

   (a) the consent number;

   (b) the name of the well[s] from which the waste was generated;

   (c) the type of waste to be stockpiled; and

   (d) the volume of waste to be stockpiled.

   This condition requires the consent holder to notify the Council prior to accepting drilling waste onsite to be stockpiled. This condition outlines the information that must be included in the notification for waste tracking purposes.

6. *The consent holder shall notify the Chief Executive, Taranaki Regional Council, [by emailing worknotification@trc.govt.nz.] at least 48 hours prior to land farming stockpiled material, or material brought onto the site for land farming within 48 hours. Notification shall include the following information:*

   (a) the consent number;

   (b) the name of the well[s] from which the waste was generated;

(c) *the type of waste to be land farmed;*

(d) *the volume and weight [or density] of the waste to be land farmed;*

(e) *the concentration of chlorides, nitrogen and hydrocarbons in the waste; and*

(f) *the specific location and area over which the waste will be land farmed.*

Condition 6 is a notification condition that requires the consent holder to notify the Council prior to the disposal of material through spreading. The information included in the notification allows the Council to track the movement of waste from stockpiling areas to disposal areas, which in turn allows the Council to monitor the receiving environment for adverse environmental effects relating to disposal.

7. *The consent holder shall take a representative sample of each type of waste, from each individual source, and have it analysed for the following:*

(a) *total petroleum hydrocarbons [C6-C9, C10-C14, C15-C36];*

(b) *benzene, toluene, ethylbenzene, and xylenes;*

(c) *polycyclic aromatic hydrocarbons screening; and*

(d) *chloride, nitrogen, pH, potassium, and sodium.*

This condition requires the consent holder to sample wastes prior to disposal for potential contaminants which have been identified as posing risk to soil and/or water quality. The testing of representative samples of all wastes allows identification of the source of any contamination post application. The results of the sample also allow the consent holder to calculate spreading areas and application depths to ensure loading limits are met upon spreading.

8. *The consent holder shall keep records of the following:*

(a) *wastes from each individual well;*

(b) *composition of wastes [in accordance with condition 7];*

(c) *stockpiling area[s];*

(d) *volumes of material stockpiled;*

(e) *land farming area[s], including a map showing individual disposal areas with GPS co-ordinates;*

(f) *volumes and weights of wastes land farmed;*

(g) *dates of commencement and completion of stockpiling and land farming events;*

(h) *dates of sowing land farmed areas;*

(i) *treatments applied; and*

(j) *details of monitoring, including sampling locations, sampling methods and the results of analysis;*

and shall make the records available to the Chief Executive, Taranaki Regional Council.

Condition 8 outlines the information the Council requires from a land farming consent holder to determine compliance with consent conditions.

9. *The consent holder shall provide to the Chief Executive, Taranaki Regional Council, by 31 August of each year, a report on all records required to be kept in accordance with condition 8, for the period of the previous 12 months, 1 July to 30 June.*

Condition 9 is a requirement for the consent holder to submit an annual report to the Council of all activities conducted at the site during a July to June monitoring year for the Council to review. This ensures the Council have all necessary information to assess whether consent compliance has been achieved.

10. *The discharge shall only occur on the disposal sites shown in the Drawing entitled 'Remediation NZ Ltd Proposed Disposal Site' submitted with the application and attached to this consent.*

The drawing sets out the areas where disposal will occur.

11. *There shall be no discharge within buffer zone, being:*

- *25 metres of the Manawapou River;*
- *25 metres of the unnamed tributary;*
- *10 metres from any property boundary; and*
- *50 metres from the QE II covenant Key Native Ecosystem areas.*

This condition is necessary to adequately avoid adverse effects from wastes or contaminated stormwater flowing into surface water courses or onto neighbouring properties.

12. *For the purposes of land farming, drilling wastes shall be applied to land in a layer not exceeding:*

(a) 100 mm thick for wastes with a hydrocarbon concentration less than 50,000 mg/kg dry weight; or

(b) 50 mm thick for wastes with a hydrocarbon concentration equal to or greater than 50,000 mg/kg dry weight; and

(c) in a rate and manner such that no ponded liquids remain after one hour, for all wastes;

prior to incorporation into the soil.

Condition 12 is necessary to ensure that waste is applied in a appropriate waste to soil ratio to allow a maximum thickness for biodegradation of the hydrocarbons in the waste over a period of time that appropriately mitigates adverse effects. Application thickness limits also account for the loading of other constituents such as chloride.

13. *As soon as practicable following the application of solid drilling wastes to land, the consent holder shall incorporate the wastes into the soil to a depth of at least 250 mm.*

This condition requires the consent holder to ensure the waste is adequately mixed with fresh soil in the zone of optimal microbial activity so that microbes naturally occurring in the soil come into contact with, and break-down, the hydrocarbon content in the waste.

14. *The hydrocarbon concentration in the soil over the land farming area shall not exceed 50,000 mg/kg dry weight at any point where:*

(a) liquid waste has been discharged; or

(b) *solid waste has been discharged and incorporated into the soil.*

Condition 14 is a post application measure to ensure that the receiving environment soil is not overloaded with hydrocarbons. This condition must be met to allow the effective biodegradation of hydrocarbons through microbial processes.

15. *An area of land used for the land farming of drilling wastes in accordance with conditions 12 and 13 of this consent, shall not be used for any subsequent discharges of drilling waste.*

This condition is necessary to avoid the accumulation of contaminants which do not biodegrade or leach from the soil. Multiple applications also increase risks to groundwater.

16. *All material must be land farmed as soon as practicable, but no later than twelve months after being brought onto the site.*

This condition is reasonably necessary to prevent adverse environmental effects to groundwater and or soil from the continued stockpiling of material.

17. *As soon as practicable following land farming, areas shall be sown into pasture [or into crop]. The consent holder shall monitor revegetation and if adequate establishment is not achieved within two months of sowing, shall undertake appropriate land stabilisation measures to minimise wind and stormwater erosion.*

Condition 17 requires the consent holder to ensure pasture establishment is achieved in a reasonable timeframe following spreading of waste. Pasture/crop establishment prevents erosion and encourages microbial activity, thereby avoiding significant adverse effects.

18. *The exercise of this consent shall not result in the concentration of total dissolved salts in any fresh water body exceeding 2500 g/m^3.*

Condition 18 exists to ensure that the salinity of any fresh water in the vicinity of the consented site is not increased to a level where it becomes an unsuitable habitat/resource for fresh water aquatic plants or animals.

19. *Other than as provided for in condition 18, the exercise of this consent shall not result in any contaminant concentration, within surface water or groundwater, which after reasonable mixing, exceeds the background concentration for that particular contaminant.*

Condition 19 is designed to mitigate against any contamination of surface water or groundwater from the consented activity to ensure there are no adverse effects on water quality relating to the activity.

20. *The conductivity of the soil/waste layer after land farming shall be less than 400 mS/m, or alternatively, if the background soil conductivity exceeds 400 mS/m, the land farming of waste shall not increase the soil conductivity by more than 100 mS/m.*

21. *The sodium absorption ratio [SAR] of the soil/waste layer after land farming shall be less than 18.0, or alternatively if the background soil SAR exceeds 18.0, the land farming of waste shall not increase the SAR by more than 1.0.*

Conditions 20 and 21 are reasonably necessary to avoid significant adverse effects by ensuring soil quality is maintained so that the bioremediation of wastes occurs and the land is properly reinstated.

22. *The concentration of heavy metals in the soil shall at all times comply with the Ministry for the Environment and New Zealand Water & Wastes Association's Guidelines for the safe application of biosolids to land in New Zealand [2003], as shown in the following table:*

Constituent	Standard [mg/kg dry weight]
Arsenic	20
Cadmium	1
Chromium	600
Copper	100
Lead	300
Mercury	1
Nickel	60
Zinc	300

Condition 22 gives the concentration limits for metals in the receiving environment soil. These limits are taken from the MfE Guidelines for the safe application of biosolids to land in New Zealand (2003), which are deemed to be appropriate for the consented activity. These limits are in place to ensure that land is fit for the most sensitive future land use, upon completion of the process.

23. *From 1 March 2028 [three months prior to the consent expiry date], constituents in the soil shall not exceed the standards shown in the following table:*

Constituent	Standard
conductivity	290 mS/m
chloride	700 mg/kg
sodium	460 mg/kg
total soluble salts	2500 mg/kg
MAHs PAHs TPH	Guidelines for Assessing and Managing Petroleum Hydrocarbon Contaminated Sites in New Zealand [Ministry for the Environment, 1999]. Tables 4.12 and 4.15, for soil type sand.

MAHs - benzene, toluene, ethylbenzene, xylenes

PAHs - napthalene, non-carc. [pyrene], benzo(a)pyrene eq.

TPH - total petroleum hydrocarbons [C_7-C_9, C_{10}-C_{14}, C_{15}-C_{36}]

The requirement to meet these standards shall not apply if, before 1 March 2028, the consent holder applies for a new consent to replace this consent when it expires, and that application is not subsequently withdrawn.

Condition 23 outlines the surrender environmental criteria for the waste constituents associated with the land farming process and requires the consent holder to apply for a consent renewal if the constituents are outside of these limits at the time of consent expiry. (Thus ensuring the consent holder cannot simply abandon a "contaminated site").

24. *This consent may not be surrendered at any time until the standards in condition 23 have been met.*

    Condition 24 is necessary to ensure effects are adequately mitigated before the consent holder relinquishes responsibility for the consent.

25. *In the event that any archaeological remains are discovered as a result of works authorised by this consent, the works shall cease immediately at the affected site and tangata whenua and the Chief Executive, Taranaki Regional Council, shall be notified within one working day. Works may recommence at the affected area when advised to do so by the Chief Executive, Taranaki Regional Council. Such advice shall be given after the Chief Executive has considered: tangata whenua interest and values, the consent holder's interests, the interests of the public generally, and any archaeological or scientific evidence. The New Zealand Police, Coroner, and Historic Places Trust shall also be contacted as appropriate, and the work shall not recommence in the affected area until any necessary statutory authorisations or consents have been obtained.*

    Discovery of archaeological remains is considered unlikely but this condition is necessary to ensure that, if they are discovered, appropriate action to avoid or mitigate effects is taken.

26. *This consent shall lapse on 3 June 2017, 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.*

    If this condition was not imposed the consent would lapse under the provisions of the RMA after 5 years, provided the consent was not given effect to within this timeframe. This condition is simply to advise the consent holder of that provision.

27. *In accordance with section 128 and section 129 of the Resource Management Act 1991, the Taranaki Regional Council may serve notice of its intention to review, amend, delete or add to the conditions of this resource consent by giving notice of review during the month of June 2016 and/or June 2022, for the purpose of ensuring that the conditions are adequate to deal with any adverse effects on the environment arising from the exercise of this resource consent, which were either not foreseen at the time the application was considered or which it was not appropriate to deal with at the time.*

    In general, conditions of consent can only be reviewed if provision to do so is included in the consent. The Council's preference is to make provision to review the conditions of all consents, for specified reasons, to ensure that the conditions are effective, as an alternative to granting consents for a shorter duration.

All the above conditions have been reviewed by an independent expert (Proffit, 2013) and the average and maximum hydrocarbon loading rates and hydrocarbon surrender conditions will be reduced in future land farming consents (refer section 4.8.6).

The following conditions address waste storage facilities and will be imposed on any future land farming consents for certainty reasons. Existing facilities have lined storage facilities (e.g. photographs 10 & 12).

1. All stockpiled material that is stored on-site prior to being discharged, shall be stored in a tank or silo, or in a pit with a high-grade impermeable

synthetic liner that prevents infiltration of fluids through the pit walls or base into land. Before storage of any waste the consent holder shall demonstrate to the Chief Executive, Taranaki Regional Council that any storage facility is fit for purpose and meets the requirements of this condition.

2. The consent holder shall monitor pit liner integrity through visual inspections and groundwater monitoring (where applicable) for the life of the storage pit.

3. Before exercising this consent, the consent holder shall after consultation with the Chief Executive, Taranaki Regional Council, install a minimum of three groundwater monitoring bores. The bores shall be at locations and to depths that enable monitoring to determine any change in groundwater quality resulting from the exercise of this consent. The bores shall be installed in accordance with NZS 4411:2001 and all associated costs shall be met by the consent holder.

Compliance monitoring
The Council is required to monitor the effects of consented activities under Section 35 of the Resource Management Act 1991. In conjunction with the granting of land farming consents, the Council prepares compliance monitoring programmes to ensure consent holders are adhering to the consent conditions. Monitoring programmes designed and implemented by the Council include conducting site inspections, reviewing consent holder supplied data, liaising with consent holders and physicochemical monitoring consisting of the following.

Soil sampling
Composite soil sampling of disposal areas is used at Taranaki sites to ensure that contaminant levels are below limits specified in consents, to track biodegradation, and more broadly, to ensure that soil quality is not significantly adversely affected by land farming of drilling wastes. The process implemented in Taranaki has typically been as follows: waste is sampled by the consent holder prior to application, samples are sent to external IANZ certified laboratories, and the results are reviewed by the monitoring programme job manager. Following application, samples are taken from the area used for disposal by the consent holder periodically until samples are within surrender criteria. Additionally, receiving environmental samples are taken by the Council and analysed at the Council's IANZ accredited laboratory.

Surface water monitoring
As noted above, some sites will have streams, farm drains and other bodies of surface water. In Taranaki, surface water samples taken from land farm sites are analysed by the Council for common fresh water parameters (e.g., pH, conductivity, chloride and suspended solids or total dissolved solids).The Council also test for the presence of hydrocarbons and barium. Consent holders test for pH, conductivity, total dissolved solids, specific gravity, total potassium, total sodium, chloride, nitrogen, arsenic, cadmium, chromium, copper, lead, nickel and zinc, BTEX and total petroleum hydrocarbons and make this data available to the Council.

Groundwater sampling
Best practice is to install groundwater monitoring bores in close proximity to the pit area, with one control bore located up-gradient as a control bore, and minimum two down-gradient bores to monitor for any effects from the stockpiling of wastes. Ideally, if storage pits are well lined, there should be no waste leaching to groundwater at these sites. Groundwater sampling in Taranaki has typically tested for similar parameters to surface water.

Additional monitoring programmes and research projects
In Taranaki further research is being conducted on the effects of drilling waste in general, and HF return fluid waste specifically, on soil biota at various disposal sites in the region. Additional monitoring has been undertaken to assess whether any effects are detectable in the coastal environment immediately down-gradient of disposal areas at one land farm site which has taken drilling and HF wastes.

The soil biota study was undertaken as part of a three year research project into the effects of land farming on nematode populations. The first two years of the project have been completed. Overall, there were very few statistical differences in the parameters investigated for assessing the health of soil biota communities and soil chemical composition among control and treatment areas. However, this may be due to the relatively small samples' sizes and replicate numbers, and differences in site management after drilling waste application. Initial results suggested changes to nutrient levels, and microbial biomass and respiration, after the application of drilling wastes to some treatment areas, with these differences becoming more apparent in areas where synthetic-based muds had been applied (water-based muds have less impact). Nematode abundances and pasture yield were largely unaffected by drilling waste application (Taranaki Regional Council, 2011). The third year of this study has been replaced with a laboratory-based programme.

This laboratory-based project builds upon and complements previous field-based soil monitoring studies undertaken by the Council, which investigated the effects of earthworm, nematode and microbe populations *in situ* where land farming was being carried out. This project is still in the planning phase, but is designed to eliminate the variability in the field-based results caused by the physical processes of land farming and environmental biases will allow for a more specific understanding of the possible effects of land farming on soil biota and ecosystems. Results from the lab-based studies will be combined with results from the Council's field-based programmes to date, which will provide a comprehensive report on the various elements of land farming and their effects on soils in Taranaki. Thus, this study will aim to assess the possible toxic effects of fluid disposal on earthworm and microbial community structure and activity in a controlled laboratory environment. This survey is particularly motivated by a need to examine the potential implications of recent changes to consent conditions relating to the disposal of HF return fluids at land farms.

Consent surrender considerations
Timeframes for activity at a land farm site can be variable in length depending on drilling operations and disposal options taken by client companies. Consents in Taranaki to date have been for single applications of waste per disposal area. This means if there are high activity levels, land capacity can be reached well before consent expiry, and alternatively, if activity slows an operator may no longer require use of the disposal sites. Both of these situations may lead to the consent

holder wishing to surrender the consent, and the Council is then responsible for assessing whether the consent surrender criteria have been met. Consents granted state the contaminant levels acceptable in soil samples at the time of consent surrender. The consent holder will sample all areas spread and supply test results to the Council. Monitoring officers will also collect samples to independently ensure the results are also within surrender criteria. Pit areas will generally be re-instated, following which they should also be tested. Once all areas are compliant with consent surrender criteria, the consent may be surrendered. In the granting of consents it may also be beneficial to require full reinstatement of areas to pasture prior to surrender to ensure that the entire process is completed with the desired effects.

Conclusions

Disposing of drilling waste and return fluids to land through land farming, if managed effectively, is recognised internationally as presenting a relatively low cost disposal option with low environmental impacts. The use of natural microbial respiration processes to degrade waste presents an environmentally sound and environmentally beneficial disposal option for waste fluids produced by exploration and production activities in the Taranaki region, including hydraulic fracturing and well workover fluids. The resource consent process, including the preparation of a comprehensive AEE and a thorough assessment by the applicant can determine the potential for the proposed activity to have any adverse environmental effects and to address these through appropriate consent conditions, including a requirement for on-going monitoring of the activity, by both the consent holder and the Council.

6.1.4 Wellsite emissions

This section of the guide provides resource consent considerations for wellsite emissions, including where hydraulic fracturing is undertaken, and includes assessment of environmental effects requirements, RMA notification provisions, consent conditions and compliance monitoring considerations. The main emission source is flaring but there are other minor wellsite emissions that are considered.

Photo 13 Cheal B wellsite thermal oxidiser (flare box)

Description of the activity

A well site has a number of emissions to air from drilling activities and site equipment. The major emission is from any flaring that is undertaken which can be in a flare pit and/or a flare box (Photos 8 and 13) or thermal oxidiser. However, there are a number of other miscellaneous emissions. Table 6 provides an inventory of the main well site emissions during various well site activities (drilling, testing (including HF), and production).

The drilling and well completion processes have been described in section 3.4 of this report. Upon well completion, the testing phase of a conventional well begins with 'cleaning up' the well (removal of drill cuttings and debris and/or drilling fluids from the well), and then perforating the casing in the deepest potentially productive zone and allowing it to flow. A properly designed separator and clean burning flare system are utilised to eliminate the return of solids and liquids to the flare system, thus avoiding the potential for black smoke from the flare because of incomplete combustion of heavier hydrocarbons, during clean up and/or testing operations.

After separation of liquid hydrocarbons, gas, and water has been achieved, initial zone testing will normally continue over a period of up to 15 days but usually for a shorter period. Liquid hydrocarbons produced during initial testing are usually directed to storage tanks prior to removal from the wellsite by road tanker or, once sufficient pressure is established, can be directed to a production pipeline where one exists.

In cases where the flow of hydrocarbons is low following initial flow testing, hydraulic fracturing may be undertaken to create fractures within the hydrocarbon bearing formation to enhance reservoir flow. This process has been described in section 4.4 of this guide.

Initial recovery will be entirely fracture fluid and some solids (proppant) which can be sent directly to tanks for recycling or disposal offsite. As well cleanup continues hydrocarbon gas entrained in the fluid will start to flow back. The flowback stream, still mainly water, will be directed to the separator / flare system. The liquids will be separated out, to the greatest extent practicable, and again sent to tanks. The hydrocarbon gas will be sent to the flare system. This process continues until the well is essentially cleaned up of return fluids and is flowing primarily gas. The well is now ready to be production tested as described above.

Certain contingency scenarios exist in which solids may begin to plug up the surface equipment, risking overpressure, and the well would need to be directed to a lined flare pit without passing through the separator. In the event of such an emergency potentially dangerous levels of hydrocarbons could build up in the pit, and so the gas would be proactively ignited to prevent a potentially dangerous explosive atmosphere forming. After the emergency situation has been addressed the well will no longer be flowed to the pit, the flare will extinguish, and the fluid in the pit should be sucked out and disposed of appropriately.

The intention of lighting the gas in the emergency flare pit is to burn off hydrocarbon gas to prevent explosive risk. The intention is not to burn off the liquids, although some will evaporate in the process. The emergency system can be configured in a number of ways, some of which include burner heads on the end of the pipe entering the pit, and potential injection of pilot gas to ensure the flare stays lit.

Therefore there can at times be an operational requirement to discharge the return flow to a flare pit, without complete recovery and containment within tanks.

Operators therefore seek consent to allow the material entrained in the well stream, namely the gas and other fluids (fracture fluid, sand, and potentially reservoir fluid), to be ignited in the flare pit if needs be. The environmental effects of the emissions from the flare pit are described in section 4.8.3.

Below is a summary of the other, miscellaneous emissions implicit in consents which may be included on a wellsite. Each wellsite is different, however the miscellaneous emissions could include (but not necessarily be limited to) the following, during the three main wellsite phases.

Table 6 Well site drilling emissions inventory

Potential Source	Nature of emissions	Notes/comment
Diesel generator(s) - Rig	Products of combustion of diesel	Large diesel generators onsite to power the rig
Diesel generator(s) - Camp	Products of combustion of diesel via exhaust	Smaller generator to power the rig camp
Diesel storage tanks	Tank vapour Vapour displacement & fugitive emissions during re-filling	
Produced hydrocarbons tanks	Tank vapour venting	
Produced water tanks	Odour/tank venting	
Mud pumps & mixing units - engines	Products of combustion of diesel via exhaust	
Water pumps (small for water takes & site water reticulation)	Products of combustion (petrol or diesel) via exhaust and vapour from re-fuelling.	
Camp kitchen extraction units	Odour Smoke/oil and grease	Small quantities.
Septic tanks/wastewater storage tanks	Odour emissions via tank vent	Small quantities
Gravel pad and exposed soil, access track	Dust	Wet suppression a common option for suppression, or tracks are sealed.
Dry chemical handling	Dust Odour	Handling restrictions. Very localised onsite
Mud tanks	Odour	
Welder	Process emissions	Very localised onsite
Compressor Engines	Products of combustion	
Mud - degassing	Depends on reservoir	Minor quantities due to changes in pressure when muds return to surface in the well.
Chemical stores	Odour	Localised and minor
Vehicles – tanker loading	Vapour displacement during filling	

Table 6a Well site reservoir testing, including hydraulic fracturing emissions inventory

Potential Source	Nature of emissions	Notes/comment
Diesel generators - plant	Products of combustion of diesel	Large diesel generators onsite to power rig.
Diesel generators - Camp	Products of combustion of diesel via exhaust	Smaller generator to power the camp.
Diesel tanks	Tank vapour Vapour displacement & fugitive emissions during re-filling	
Produced hydrocarbons tanks	Tank vapour venting	

Potential Source	Nature of emissions	Notes/comment
Fluid Pump Engines	Products of combustion of diesel	
Produced water tanks	Odour/tank venting	
Water pumps	Products of combustion (petrol or diesel) via exhaust and vapour from re-fuelling.	
Camp kitchen extraction units	Odour Smoke/oil and grease	Small quantities. Smaller camp than drilling (or may not be a camp)
Septic tanks/wastewater storage tanks	Odour emissions via tank vent	Small quantities
Gravel pad and exposed soil, access track	Dust	Wet suppression a common option for suppression, or tracks are sealed.
Dry chemical handling	Dust Odour	Handling restrictions. Very localised onsite
Chemical stores	Odour	Localised and minor
Vehicles – tanker loading	Vapour displacement during filling	

Table 6b Well site production emissions inventory

Potential Source	Nature of emissions	Notes/comment
Produced hydrocarbons tanks	Tank vapour venting	May not be onsite if wellsite is connected to network via pipeline
Produced water tanks	Odour/tank venting	
Gravel pad and exposed soil, access track	Dust	Wet suppression a common option for suppression, or tracks are sealed
Compressor engines	Products of combustion (usually gas, either sourced from well or stored onsite as LPG)	
Heaters	Products of combustion (usually gas, either sourced from well or stored onsite as LPG)	
Pipework & vessels	Venting of gas – e.g., during pigging	
Vehicles – tanker loading	Vapour displacement during filling	Only if tankering liquid hydrocarbons

Where a wellsite has wells which enter into production there are potential minor air emission sources as detailed above. For a major oil and gas production station servicing a number of wells there will be much larger processing equipment and a separate air discharge consent.

AEE requirements
An application to discharge contaminants to air from hydrocarbon exploration well sites is required under the Council's Regional Air Quality Plan (Taranaki regional Council, 2011a) which was reviewed in 2011. Under Rule 9 of the Plan the discharge of contaminants to air from hydrocarbon exploration well sites, including combustion involving flaring or incineration of petroleum recovered from natural deposits, in association with well development or redevelopment and testing or enhancement of well head production flows, is a controlled activity.

The AEE should, according to section 88(2) of the RMA, present such detail as corresponds with the scale and significance of the effects the activity may have on the environment. Section 88 and the Fourth Schedule of the RMA sets out what should be included in an AEE and for controlled activities as a minimum need only address the matters over which the Council has reserved control/discretion.

The required standards to be a controlled activity under Rule 9 are as follows:

a) flare or incinerator point is at least 300 m from any dwelling house
b) the discharge to air from the flare must not last longer than 15 days cumulatively, inclusive of testing, clean-up, and completion stages of well development or work-over, per zone to be appraised
c) no material to be flared or incinerated, other than those derived from or entrained in the well stream.

The matters over which the Council has reserved control/discretion over are as follows:

a) Duration of consent
b) Duration of flaring or other emissions
c) The material to be flared
d) Imposition of limits on or relating to discharge or ambient concentrations of contaminants, or on or relating to mass discharge rates
e) Best practicable option to prevent or minimise any adverse effects on the environment
f) Location of any facilities or equipment for hydrocarbon flaring in relation to surrounding land uses
g) Separation of natural gas from liquid hydrocarbons and water
h) Notification of flaring to neighbours, affected parties, and the Council
i) Recording of flare usages and smoke emissions
j) Oil recovery requirements
k) Visual effects, loss of amenity value of air, chronic or acute human health effects, soiling or damage to property, odour, annoyance and offensiveness, effects on ecosystems, plants and animals and effects on areas identified in Policy 2.3
l) Monitoring and information
m) Contingency measures and investigations, remediation and response procedures for non-routine discharge events and complaints
n) Review of the conditions of consent and the timing and purpose of the review
o) Payment of administrative charges
p) Payment of financial contribution.

There are other rules in the Air Quality Plan that apply to exploration and production activities at well sites or production stations (Taranaki Regional Council, 2011a).

Notification

Section 95 of the RMA sets out the notification/non-notification provisions for resource consent applications. It should be noted that amendments to the RMA in 2009 removed the presumption that consent applications would be notified. The Council follows clearly established procedures in making decisions on notification or non-notification of resource consent applications and these procedures are fully consistent with the RMA. Each consent application must be assessed on its merits.

Given that air quality studies undertaken by the Council over the years and referenced in this report there are effects on air quality within 200 m of a flare. Hence written approval for non-notification of an application needs to be obtained from affected parties within the 200 m zone of effect.

Consent conditions

The conditions below are from a recently processed air discharge application (by Tag Oil (NZ) Ltd to discharge contaminants to air from hydrocarbon exploration at a wellsite, including combustion involving flaring or incineration of petroleum recovered from natural deposits, in association with well development or redevelopment and testing or enhancement of well production flows. The conditions are presented in italics with a commentary, which sets out the rationale for each condition. The same consent is also included in Appendix IV with a Conditions Analysis Table, which notes the reason for the condition, how compliance will be determined and the reason for any limits set.

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.*

The above general condition is applied to all consents to pay to the Council all the administration, monitoring and supervision costs of this consent, fixed in accordance with section 36 of the RMA.

1. *For the purposes of this consent:*
   (a) *'flaring' means the uncontrolled or partially controlled open air burning of hydrocarbons derived from or entrained in the well stream. 'Flare', as a verb, has the corresponding meaning and, as noun, means the flame produced by flaring.*
   (b) *'incineration' means the controlled, enclosed burning of formation hydrocarbons within a device designed for the purpose. 'Incinerate' has the corresponding meaning.*
   (c) *'Combustion' means burning generally and includes both flaring and incineration as well as other burning such as fuel in machinery.*

   The definitions are necessary for clarity of conditions.

2. *Incineration shall only occur in a device with a minimum chimney height determined by the method detailed in Appendix VIII of the Regional Air Quality Plan for Taranaki.*

   Specified height reasonably needed to avoid/mitigate adverse environmental effects.

3. *Flaring shall only occur over a pit, or similar containment area, consisting of impermeable material that prevents any liquid from leaking through its base or sidewalls and discharging to land.*

4. *Flaring and incineration shall only occur within 20 metres of the location defined by NZTM 1694593-5640370.*
   The above conditions address discharge location and flare pit specifications and ensure the environmental effects are as assessed in the application, i.e. they relate only to a discharge air at the location specified.

5. *Discharges to air from flaring or incineration shall not last longer than 15 days, cumulatively, inclusive of testing, clean-up, and completion stages of well development or work-over, per zone to be appraised, with a maximum of 4 zones per well and 12 wells.*

The above requirement sets out flaring restrictions as specified and assessed in the application. The 15 day limit is the controlled activity standard under the RAQP.

6. *The consent holder shall notify the Chief Executive, Taranaki Regional Council, at least 24 hours before the flaring or incineration from each zone commences. Notification shall include the consent number and a brief description of the activity consented and be emailed to worknotification@trc.govt.nz.*

   Notice to Council so that the Council has the opportunity to monitor the work for compliance with consent conditions.

7. *At least 24 hours before any flaring or incineration, other than in emergencies, the consent holder shall provide notification to the occupants of all dwellings within 300 metres of the wellsite and all landowners within 200 metres, of the commencement of flaring or incineration. The consent holder shall include in the notification a 24-hour contact telephone number for a representative of the consent holder, and shall keep and make available to the Chief Executive, Taranaki Regional Council, a record of all queries and complaints received in respect of any combustion activity.*

   Notification to neighbours reasonably necessary to avoid adverse effects on neighbours.

8. *No material shall be flared or incinerated, other than those derived from or entrained in the well stream.*

   Flaring/incineration of only substances originating from the well stream which is a standards of a controlled/restricted discretionary activity.

9. *To the greatest extent possible, all gas that is flared or incinerated must first be treated by effective liquid and solid separation and recovery.*

10. *Only gaseous hydrocarbons originating from the well stream shall be flared or incinerated, except that if, for reasons beyond the control of the consent holder, effective separation can not be achieved and combustion of liquid hydrocarbon is unavoidable, the consent holder shall reinstate effective separation as soon as possible and if separation can not be achieved within 3 hours combustion must cease.*

    The above conditions ensures separation as far as possible which is reasonably necessary to avoid adverse effects associated with burning liquid hydrocarbons, but recognises that sometimes in spite of best endeavours burning of liquid hydrocarbon for a short duration is unavoidable.

11. *If liquid hydrocarbon is combusted in accordance with the exception provided for in condition 10, the consent holder shall prepare a report that details:*

    (a) the reasons that separation could not be achieved;
    (b) the date and time that separation was lost and reinstated;
    (c) what was done to attempt to reinstate separation and, if it the attempt was unsuccessful the reasons why.

    The report shall be provided to the Chief Executive, Taranaki Regional Council within 5 working days from the date of combustion of liquid hydrocarbon.

    Reporting on loss of separation to check compliance with condition 10.

12. *The consent holder shall adopt the best practicable option, as defined in section 2 of the Resource Management Act 1991, to prevent or minimise any actual or potential effect on the environment arising from any emission to air, including, but not limited to having regard to the prevailing and predicted wind speed and direction at the time of initiation, and throughout, any episode of combustion so as to minimise offsite effects (other than for the maintenance of a pilot flame).*

This condition requires that a higher standard than that required by the conditions be met if it can reasonably be achieved. It also requires the consent holder to continually review methods and practices and make reasonable improvements even though the conditions are being met. The condition is reasonably necessary to avoid adverse environmental effects.

13. *The discharge shall not cause any objectionable or offensive odour or any objectionable or offensive smoke at or beyond the boundary of the property where the wellsite is located.*

Objectionable and offensive odour or smoke are significant adverse effects that must be avoided.

14. *The consent holder shall control all emissions of carbon monoxide, nitrogen dioxide, fine particles (PM_{10}) and sulphur dioxide to the atmosphere from the site, in order that the maximum ground level concentration of any of these contaminants arising from the exercise of this consent measured under ambient conditions does not exceed the relevant ambient air quality standard as set out in the Resource Management (National Environmental Standards for Air Quality Regulations, 2004) at or beyond the boundary of the property on which the wellsite is located.*

Limits on contaminants are set and while it is unlikely that the standards will be exceeded in the discharge, the limits are established by regulations and are reasonably necessary to avoid adverse effects on the health of humans, flora and fauna.

15. *The consent holder shall control all emissions of contaminants to the atmosphere from the site, other than those expressly provided for under special condition 14, in order that they do not individually or in combination with other contaminants cause a hazardous, noxious, dangerous, offensive or objectionable effect at a distance greater than 100 metres from the emission source.*

Control of other contaminants (not provided for under condition 14) which are unlikely to be exceeded in the discharge, the limits are reasonably necessary to avoid adverse effects on the health of humans, flora and fauna.

16. *The consent holder shall make available to the Chief Executive, Taranaki Regional Council, upon request, an analysis of a typical gas and condensate stream from the field, covering sulphur compound content and the content of carbon compounds of structure C_6 or higher number of compounds.*

Providing an analysis of a typical gas and condensate stream with details of sulphur and carbon content in the gas/condensate stream will aid in determining compliance with conditions 14 & 15.

17. *All permanent tanks used as hydrocarbon storage vessels, shall be fitted with vapour recovery systems.*

This condition is reasonably necessary to avoid adverse effects associated with release of vapours from the tanks.

18. *The consent holder shall record and make available to the Chief Executive, Taranaki Regional Council, a 'combustion log' that includes:*
   (a) the date, time and duration of all flaring or incineration episodes;
   (b) the zone from which flaring or incineration occurred;
   (c) the volume of substances flared or incinerated;
   (d) whether there was smoke at any time during the combustion episode and if there was, the time, duration and cause of each 'smoke event'.

   The combustion log is to enable Council Officers to determine compliance with consent conditions.

19. *This consent shall lapse on 30 September 2018, 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.*

   If this condition was not imposed the consent would lapse under the provisions of the RMA after 5 years in any case. This condition is simply to advise the consent holder of that provision. The lapse period provides enough time to give effect to the activity without 'locking up' the resource for an unduly long period.

20. *In accordance with section 128 and section 129 of the Resource Management Act 1991, the Taranaki Regional Council may serve notice of its intention to review, amend, delete or add to the conditions of this resource consent by giving notice of review:*

   (a) during the month of June 2017 and/or June 2023; and/or
   (b) within 1 month of receiving a report provided in accordance with condition 11;

   for any of the following purposes:

   (i) dealing with any significant adverse effect on the environment arising from the exercise of the consent which was not foreseen at the time the application was considered or which it was not appropriate to deal with at the time; and/or
   (ii) requiring the consent holder to adopt specific practices in order to achieve the best practicable option to remove or reduce any adverse effect on the environment caused by the discharge; and/or
   (iii) to alter, add or delete limits on mass discharge quantities or ambient concentrations of any contaminant;
   (iv) reducing emissions or environmental effects that may arise from any loss of separation.

   In general, conditions of consent can only be reviewed if provision to do so is included in the consent. The Council's preference is to make provision to review the conditions of all consents to ensure that the conditions are effective, as an alternative to granting consents for a shorter duration. The frequency and timing of the reviews is appropriate having considered the duration of the consent, its likely environmental effects, and the adequacy of the knowledge of those effects.

Compliance monitoring

Section 35 of the Resource Management Act 1991 sets obligations upon the Council to gather information, monitor, and conduct research on the effects arising from consented activities within the Taranaki region and report upon these. To perform its statutory obligations, the Council may be required to take 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.

A full compliance monitoring programme will be established by the Council. Reasonable costs associated with the monitoring will be charged to the consent holder.

The monitoring of wellsite emissions comprises of a series of inspections, environmental sampling and data assessment. There is generally a significant investment of time and resources by the Council in on-going liaison with resource consent holders over consent conditions and their interpretation and application.

The monitoring of wellsite emissions comprises of a series of inspections, environmental sampling and data assessment. There is generally a significant investment of time and resources by the Council in on-going liaison with resource consent holders over consent conditions and their interpretation and application. Inspections of wellsites in regard to potential air emissions are based on best current international regulatory practice (Manual 001: Facility and wellsite Inspections, September 2010, http://ercb.ca/manuals/Manual001.pdf, and Directive 60: Upstream Petroleum Industry Flaring, Incinerating, and Venting, updated November 2011 http://ercb.ca/directives/Directive060.pdf , from the Energy Resources and Conservation Board, Alberta).

The following matters related to emissions are routinely inspected or checked:

- Site layout, especially the flare location, is as submitted for consenting, especially showing regard to prevailing wind direction, topography, surrounding land uses, and distances to offsite sensitive receptors.
- Design and construction of flare pit and flare head and associated pipework-lined pit, high bunds, liquids separator
- Hydrocarbons storage tanks and vapour recovery systems, and glycol regeneration units if in use
- Storage and handling of any odorous chemicals
- Other miscellaneous potential discharges to air
- Flaring log records
- Smoke incident records
- Complaints register
- Notification register
- Boundary survey for odours travelling offsite
- Visual check on flare for burning and for any smoke
- Stormwater collection systems and separators for stagnant or high-hydrocarbon wastewaters
- Site facilities such as sewage plants
- Dust potential and available dust control measures, including both the wellsite platform and any access tracks, and any other associated earthworks
- On an occasional basis, Council officers will also undertake suspended particulate monitoring using a portable meter with instant read-out (either for total suspended solids, as a measure of dust nuisance, or for PM10 as a measure of products of combustion), and will deploy passive absorption gas detectors for screening measurements of BTEX. The Council also has a portable multi-gas meter for measuring ambient methane or carbon monoxide.

The Council has conducted comprehensive and intensive surveys of air quality effects arising from flare emissions. It does not as a matter of practice repeat such programmes at every site, as unless there is a very significant change in site activities from the norm at a particular site, the results should be broadly representative of all flaring activities (adjusting for local meteorology and topography).

In addition the Council responds to any complaints re odour, dust, smoke, or excessive (prolonged) flaring.

The Council prepares annual monitoring reports for each company operating in the Taranaki region. The reports present the data collected by the Council and also that submitted by the consent holder over the period under review. The reports provide an assessment of all data, overall environmental performance and resource consent compliance. The results of the monitoring programme will be presented in a monitoring report that is presented to the Council and the community.

The environmental effects of the air discharge are such that there are generally no issues with the consent surrender process.

Conclusions
Wellsite activities that result in air emissions that are properly planned, executed, and regulated can be undertaken without adverse environmental effects. The resource consent process, including the preparation of a comprehensive AEE and a thorough assessment by the Council can determine the potential for the proposed activity to have any adverse environmental effects and to address these through appropriate consent conditions, including a requirement for on-going monitoring of the activity to ensure the environmental impact of the emissions will be less than minor.

6.1.5 Water abstraction

This section of the guide provides a brief discussion on water requirements and water sources for hydraulic fracturing activities.

The volume of water required for a hydraulic fracture operation is a function of the well characteristics (i.e., diameter and depth) and the properties of the proposed fracture zone.

Case examples reported by the Taranaki Regional Council (2012b) indicate that volumes of water used in an HF operation in vertically drilled wells varied between 77 cubic metres (Cheal A7 well) to 1,500 cubic metres (Mangahewa 6 well). The well depths were 1750 m and 4190 m, respectively. There were four fracture operations at the Mangahewa 6 well with three averaging 224 cubic metres water use.

This compares with the total daily allocation of 143,432 cubic metres per day for water treatment and supply and 49,500 cubic metres per day for dairy processing and manufacture (Taranaki Regional Council, 2009).

The HF water used is sourced from municipal supplies and trucked to the well site. Resource consents for municipal abstractions and use should allow for both domestic and industrial supplies so with appropriate approval from the municipal supply operator HF draw off should be authorised.

Given the high water quality requirements, to avoid introducing unwanted bacteria into the reservoir and creating problematic sour gas, treated rather than untreated supplies are favoured. However, the water is also treated with a biocide (e.g., glutaraldehyde) before use to further address the bacterial risk.

The resource consents held by the district councils for municipal supply allow water to be extracted for industrial use, such as HF, and no compliance issues have arisen from the supply of water for this purpose in the region.

The water take is not continuous as HF activities are intermittent. Under the current and any likely future level of HF in the region the water requirements are not considered to exert any pressure on water resources.

This may be compared to volumes of HF fluids in the range of 7,570 to 18,900 cubic metres used in one horizontally drilled well in a US shale formation (Zemanski, 2012a). In such locations water can also be in short supply because of the arid environment, and abstraction can cause environmental concerns that are not relevant for this region.

Where there are water supply and return fluid disposal environmental issues the reuse of produced water is being considered overseas (King, 2012).

6.1.6 Well site construction earthworks and stormwater discharges

This section of the guide provides a brief overview of resource consent considerations for well site stormwater discharges including discharges from earthworks during site establishment and the ongoing operational stormwater discharge. It includes a description of how the wellsite is established, a summary of the applicable regional rules, a description of the assessment of environmental effects requirements, RMA notification provisions, consent conditions, compliance monitoring, and consent surrender considerations.

Photo 13 Cheal B wellsite – sampling wellsite drainage

Wellsite establishment

Establishment of a wellsite typically involves:

- Construction of access – roads and culverts;
- Removal of topsoil and levelling of the site. A wellsite is typically 1.0-1.5 ha;
- A layer of plastic material is laid over the site, and a geotextile cloth laid over that;
- A layer of approximately 250 mm of compacted aggregate/pit metal is laid over the geotextile to provide foundations for the drilling rig and other site equipment, and a relatively impermeable surface; and
- Ring drains and skimmer pits are established.

Regional rules

The stormwater discharge from earthworks is usually a controlled activity under the Council's RFWP.

Consents for the operational stormwater discharge from wellsites usually allow for the inclusion of some saline produced water.

Assessment of environmental effects requirements

As with any application for a resource consent under the Resource Management Act 1991 (RMA), an application to discharge stormwater must be accompanied by an Assessment of Environmental Effects (AEE) report. The purpose of the AEE is to determine the likely adverse effects that the activity will have on the environment and how these effects can be avoided, remedied or mitigated. The AEE should present such detail as corresponds with the scale and significance of the effects the activity may have on the environment. Section 88 and the Fourth Schedule of the RMA set out what should be included in an AEE.

The Council has requirements for avoiding adverse environmental effects of well site stormwater discharges that are well understood and accepted by the industry. AEE's that accompany applications therefore generally include these requirements. An AEE would therefore include:

- Details about the stormwater catchment area;
- Some information about expected stormwater quality;
- For operational stormwater discharges, details of how adverse effects are avoided including by establishing perimeter drains around the site and ensuring that all site drainage goes to sealed skimmer pits;

Photo 14 Wellsite skimmer pit with site stormwater entering the lined pit and a "goose neck" pipe exiting the pit

- For operational stormwater discharges, a Contingency Plan that is followed in an emergency or unforeseen event which results in a significant discharge at the well site to ensure that adverse environmental effects associated with that event are avoided, remedied or mitigated; and
- For earthworks stormwater a sediment control plan is typically provided to comply with the controlled activity rule.

Notification

Section 95 of the RMA sets out the notification/non-notification provisions for resource consent applications. It should be noted that amendments to the RMA in 2009 removed the presumption that consent applications would be notified. The Council follows clearly established procedures in making decisions on notification or non-notification of resource consent applications and these procedures are fully consistent with the RMA. Each consent application must be assessed on its merits. Given that discharges of wellsite stormwater during operations invariably involves comprehensive controls such as impermeable perimeter drains and skimmer pits they would likely meet the 'no more than minor adverse environmental effects' and the 'no affected party' tests in the RMA, applications can, and properly should, be non-notified.

The controlled activity rule for discharge of stormwater from earthworks specifies that the application may be non-notified without written approval of affected parties.

The Council follows clearly established procedures in making decisions on notification or non-notification of resource consent applications and these procedures are fully consistent with the RMA.

Consent conditions

The conditions from two recently processed applications to discharge stormwater are presented below. These discharge applications relate to stormwater from earthworks during wellsite development and ongoing operational stormwater discharges. The conditions (in italics) have some commentary, which sets out the rationale for each condition. The same consents are also included in Appendix V with a Condition Analysis Table, which notes the reason for the condition, how compliance will be determined and the reason for any limits set.

Earthworks stormwater discharge

1. *This consent authorises the discharge of stormwater from no more than 4000 m^2 of land where earthworks is being undertaken for the purpose of creating a working area for the re-establishment of the Kahili wellsite, as shown in the details of the application for this consent.*

   This condition limits the scale of the activity to that which was applied for and assessed in the application. While discharge permits are usually limited by a discharge rate it is not practicable to do so for stormwater discharges so a catchment area is used instead.

2. *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 minimise any actual or likely adverse effect on the environment associated with the discharge of contaminants from the site.*

The above is a requirement to adopt the Best Practicable Option (BPO) to prevent or minimise any actual or likely adverse effect of the activity on the environment. The condition requires that the operator strives for a higher standard than that required by the conditions, if that higher standard can reasonably be achieved, recognising the definition of BPO in the RMA. It also requires the consent holder to continually review methods and practices and make reasonable improvements, even though the conditions are being met. The condition is reasonably necessary to avoid adverse environmental effects.

3. *At least 7 working days before the commencement of earthworks for the purpose of wellsite construction and establishment, the consent holder shall notify the Taranaki Regional Council of the proposed start date for the earthworks. Notification shall include the consent number and a brief description of the activity consented and shall be emailed to worknotification@trc.govt.nz.*

   This condition helps ensure that the Council has the opportunity to monitor compliance with consent conditions.

4. *At least 7 working days before the commencement of earthworks for the purpose of wellsite construction and establishment, the consent holder shall notify the Taranaki Regional Council of the proposed start date for the earthworks. Notification shall include the consent number and a brief description of the activity consented and shall be emailed to worknotification@trc.govt.nz.*

   This condition helps ensure that the Council has the opportunity to monitor compliance with consent conditions and that all necessary stormwater controls are in place before drilling commences.

5. *All run off from any area of exposed soil shall pass through settlement ponds or sediment traps with a minimum total capacity of:*

   a) 100 cubic metres for every hectare of exposed soil between 1 November to 30 April; and

   b) 200 cubic metres for every hectare of exposed soil between 1 May to 31 October;

   unless other sediment control measures that achieve an equivalent standard are agreed to by the Chief Executive of the Taranaki Regional Council.

6. *The sediment control measures necessary to comply with condition 5 above shall be constructed before soil is exposed for the construction of the wellsite and shall remain in place, in respect of any particular area, until that area is stabilised.*

   Note: For the purpose of conditions 5 and 6, "stabilised" in relation to any site or area means inherently resistant to erosion or rendered resistant, such as by using rock or by the application of base course, colluvium, grassing, mulch, or another method to the reasonable satisfaction of the Chief Executive, Taranaki Regional Council and as specified in the Taranaki Regional Council's Guidelines for Earthworks in the Taranaki Region, 2006. Where seeding or grassing is used on a surface that is not otherwise resistant to erosion, the surface is considered stabilised once, on reasonable visual inspection by an officer of the Taranaki Regional Council, an 80% vegetative cover has been established.

7. *All earthworked areas shall be stabilised vegetatively or otherwise as soon as is practicable and no longer than 6 months after the completion of soil disturbance activities.*

Note: For the purposes of this condition "stabilised" has the same definition as that set out in condition 6.

Conditions 5, 6 and 7 are reasonably needed to avoid the adverse environmental effects of sediment entering waterways. The volumes of sediment traps specified in condition 5 are those specified on the Council's Earthworks Guidelines.

Operational stormwater discharge

1. *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 minimise any actual or likely adverse effect on the environment associated with the discharge of contaminants from the site.*

The above is a requirement to adopt the Best Practicable Option (BPO) to prevent or minimise any actual or likely adverse effect of the activity on the environment. The condition requires that the operator strives for a higher standard than that required by the conditions, if that higher standard can reasonably be achieved, recognising the definition of BPO in the RMA. It also requires the consent holder to continually review methods and practices and make reasonable improvements, even though the conditions are being met. The condition is reasonably necessary to avoid adverse environmental effects.

2. *Stormwater discharged shall be from a catchment area of no more than 7700 m^2.*

This condition limits the scale of the activity to that which was applied for and assessed in the application. While discharge permits are usually limited by a discharge rate it is not practicable to do so for stormwater discharges so a catchment area is used instead.

3. *At least 5 working days prior, the consent holder shall advise the Chief Executive, Taranaki Regional Council of the date of each of the following events:*
   a) *commencement of any site works (site works includes the introduction of a drilling rig, drilling equipment or any other associated equipment or facilities to the site for any purpose other than for the construction of the site);*
   b) *commencement of any well drilling operation; and*
   c) *recommencement of any site works or drilling operations following a period of inactivity exceeding 30 days.*

If any of these events is rescheduled or delayed, the consent holder shall immediately provide further notice advising of the new date.

Any advice given in accordance with this condition shall include the consent number and the wellsite name and be emailed to worknotification@trc.govt.nz.

This condition helps ensure that the Council has the opportunity to monitor compliance with consent conditions.

4. *All stormwater and produced water (with a maximum chloride concentration of 50 ppm) shall be directed for treatment through the two skimmer pits, for discharge into an open man-made drain adjacent to the site. The skimmer pits shall have a minimum capacity of 180 m^3.*

Specifies the method of discharge and ensures that all the discharged water gets the required treatment before discharge. The skimmer pits are designed so that any hydrocarbons that may be in the water are contained there and not discharged.

5. *All skimmer pits and other stormwater retention areas shall be lined with an impervious material to prevent seepage through the bed and sidewalls.*

   Having impervious skimmer pits and retention areas ensures that the discharge can be controlled. This means that sampling of the discharge can occur and the discharge is directed to the location specified in the consent.

6. *Constituents of the discharge shall meet the standards shown in the following table:*

Constituent	**Standard**
pH	*Within the range 6.0 to 9.0*
suspended solids	*Concentration not greater than 100 gm^{-3}*
total recoverable hydrocarbons	*Concentration not greater than 15 gm^{-3}*
chloride	*Concentration not greater than 50 gm^{-3}*

   This condition shall apply before entry of the treated stormwater into the receiving waters at a designated sampling point approved by the Chief Executive, Taranaki Regional Council.

   This condition establishes reasonable discharge standards to ensure adverse environmental effects are avoided in the receiving environment.

7. *After allowing for a mixing zone of 10 metres, the discharge shall not give rise to an increase in temperature of more than 2 degrees Celsius.*

   This condition establishes a reasonable receiving water standard to ensure adverse environmental effects associated with elevated temperature are avoided.

8. *After allowing for reasonable mixing, within a mixing zone extending 10 metres downstream of the discharge point, the discharge shall not, either by itself or in combination with other discharges, give rise to any or all of the following effects in the receiving water:*

   a) the production of any conspicuous oil or grease films, scums or foams, or floatable or suspended materials;
   b) any conspicuous change in the colour or visual clarity;
   c) any emission of objectionable odour;
   d) the rendering of fresh water unsuitable for consumption by farm animals;
   e) any significant adverse effects on aquatic life.

   Section 107 of the Resource Management Act sets minimum standards for any discharge permit, by specifying that the Council can not grant a consent that would allow any of the effects specified to occur after reasonable mixing in the receiving waters. It is not expected that any of the effects would occur but this condition is included as a precaution and to specify the distance that is deemed to be 'reasonable mixing' in this case.

9. *The consent holder shall maintain a contingency plan that, to the satisfaction of the Chief Executive, Taranaki Regional Council, details measures and procedures to be undertaken to prevent spillage or accidental discharge of contaminants not authorised*

by this consent and measures to avoid, remedy or mitigate the environmental effects of such a spillage or discharge. The contingency plan shall be provided to the Council prior to discharging from the site.

Provision and maintenance of a contingency plan ensures that the consent holder prepares for unforeseen events. In the event of such an event, e.g., an escape of oil, the existence of a contingency plan helps avoid, remedy and mitigate any adverse environmental effects that occur as a result.

10. *Subject the other conditions of this consent the design, management and maintenance of the stormwater system shall be undertaken in accordance with the stormwater management plan submitted in support of the consent application 7170, in particular Appendix C of the assessment of environmental effects.*

    Sometimes a Stormwater Management Plan is submitted with an application and includes important detail about measures proposed to avoid, remedy or mitigate the adverse environmental effects of the discharge. Requiring compliance with the Plan is therefore about ensuring that the activity is undertaken as proposed in the application, and assessed by the Council.

11. *The consent holder shall advise the Chief Executive, Taranaki Regional Council, in writing at least 48 hours prior to the reinstatement of the site and the reinstatement shall be carried out so as to minimise adverse effects on stormwater quality. Notification shall include the consent number and a brief description of the activity consented and emailed to worknotification@trc.govt.nz.*

    When the site is abandoned it is essential that all discharges from it comply with permitted activity rules. This condition ensures that Council staff have the opportunity to confirm that before the consent holder relinquishes responsibility of the site.

12. *This consent shall lapse on 30 September 2017, 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.*

    Unless they specify otherwise all consents lapse after five years from issue if they are not exercised. This condition is therefore in some sense superfluous but is included on all consents to ensure that the consent holder is informed about the consent lapsing.

13. *In accordance with section 128 and section 129 of the Resource Management Act 1991, the Taranaki Regional Council may serve notice of its intention to review, amend, delete or add to the conditions of this resource consent by giving notice of review during the month of June 2015 and/or June 2021, for the purpose of ensuring that the conditions are adequate to deal with any adverse effects on the environment arising from the exercise of this resource consent, which were either not foreseen at the time the application was considered or which it was not appropriate to deal with at the time.*

    This condition provides an opportunity to for the Council to review the conditions of the consent, in accordance with the provisions of the Resource Management Act, if it deems that the current conditions are not adequate to deal with the adverse environmental effects resulting from the stormwater discharge.

Compliance monitoring
A specific monitoring programme is developed for each wellsite discharge consent. The monitoring programme includes regular inspections based on consent conditions and the RMA requirements. Inspections involve, on each visit, checking matters such as bunds, perimeter drains, skimmer/sedimentation pits, site layout, placement of drilling equipment, storage facilities, flarepits, piping, staff amenities, the state of any surface waters in the vicinity, separation distances to offsite surface water and nearby residences, contingency plans, and operational records, and observing any discharges and receiving waters for odour (a marker for any hydrocarbon contamination) and appearance (slicks for hydrocarbons, cloudiness for suspended solids).

For discharges to, or on land near to, water, biological monitoring (MCI) occurs before the discharge commences and again afterwards to determine of there is any change in the macroinvertebrate communities that could indicate adverse effects of the discharge. Sampling of the discharge itself also occurs and may extend to receiving waters.

Consent surrender considerations
Section 138 of the RMA sets out the considerations that apply to the surrender of a discharge consent. The section is set out below for ease of reference:

1) The holder of a resource consent may surrender the consent, either in whole or part, by giving written notice to the consent authority.
2) A consent authority may refuse to accept the surrender of part of a resource consent where it considers that surrender of that part would—
    a) affect the integrity of the consent; or
    b) affect the ability of the consent holder to meet other conditions of the consent; or
    c) lead to an adverse effect on the environment.
3) A person who surrenders a resource consent remains liable under this Act—
    a) for any breach of conditions of the consent which occurred before the surrender of the consent; and
    b) to complete any work to give effect to the consent unless the consent authority directs otherwise in its notice of acceptance of the surrender under subsection (4).
4) A surrender of a resource consent takes effect on receipt by the holder of a notice of acceptance of the surrender from the consent authority.

Section 138(2) presents a number of tests for the Council before a resource consent can be surrendered. Two key tests are whether the surrender will affect the ability of the consent holder to meet other conditions of the consent or lead to an adverse effect on the environment.

The compliance monitoring of the consent would show whether compliance has been achieved.

Conclusions
Discharges of stormwater from earthworks during site establishment are managed by ensuring that sediment controls are established and maintained to ensure that

adverse effects on waterways are avoided. The basis of these controls is *Guidelines for Earthworks in the Taranaki Region* (Taranaki Regional Council, 2006).

The discharge of stormwater (often including produced water) during operations at a wellsite is managed by ensuring that any discharge is collected in impermeable perimeter drains and skimmer pits. This ensures that any hydrocarbon that may reach the stormwater system is prevented from being discharged, and generally the discharge is controlled.

These stormwater controls ensure that adverse environmental effects are generally avoided, and the Council undertakes monitoring of discharges and any nearby streams to confirm compliance with consent conditions.

6.2 District councils

This section of the guide provides a brief overview of land use resource consent considerations for well sites and land farming waste disposal areas by district councils. The well site drilling and testing landuse consent considerations generally include the hydraulic fracturing activity and a separate consent is not required. Environmental considerations include cultural, noise, light, vehicle movements, hazardous substance management and flaring matters.

Assessment of environmental effects or monitoring requirements is not addressed in this section. However, the types of effects addressed in consent conditions shows the key environmental concerns and likely information that is required with an application. Compliance monitoring activities will be based on consent conditions.

A survey of the three district council in the region's well site and waste disposal consents was undertaken to provide the scope of environmental effects addressed in consent conditions. As an example the New Plymouth District Council well site consent is attached as Appendix VI. The South Taranaki District Council and Stratford District Council can provide an example of their resource consents upon request.

There is less detail in this section than in others. The Ministry for the Environment is preparing a draft guide for regulating petroleum development activities (including hydraulic fracturing), based on this document, and provides greater detail on district council responsibilities (Ministry for the Environment 2013).

6.2.1 Well sites

The survey identified the following environmental effects that are addressed in consent conditions across the three district councils. Not surprisingly there were many similarities between the types of environmental effects considered by the three district councils. The list below includes reference to all the consent conditions and advice note considerations based on the individual Council's district plan provisions and other site by site considerations under the Resource Management Act. It should be noted not every consent has all the considerations shown below.

Activity specification/limitation
Consent conditions describe the use and development proposed, site layout, including the number of wells to be drilled and whether hydraulic fracturing is to be undertaken.

Consent conditions set limitations on the type of drilling to be undertaken (e.g. horizontal drilling not permitted).

Commencement/ notification
Consent conditions require a provision to notify the date of well establishment and drilling commencement.

Cost recovery
A consent condition notes the type of charges payable by the consent holder to the Council under the RMA.

Hazardous substance management
A consent condition requires a hazardous substance emergency plan to be prepared prior to drilling commencing.

A consent condition requires hazardous materials and dangerous goods stored and used on site to be in accordance with legislative requirements (HSNO).

A consent condition requires hazardous materials disposal locations to be notified.

A consent condition requires secondary spill containment (bunding) for hazardous substances.

A consent condition requires signage to be in place.

Spill or emergency management
A consent condition requires any spills or other hazardous substance emergencies to be notified to the Council.

A consent condition requires a Emergency Management Plan and Spill Response Plan involving hazardous substances to be prepared.

Also refer to section 6.1.6 above on contingency planning under the regional council stormwater consent.

Waste management
A consent condition requires identification of the waste management operator able to accept both process wastes and any contaminated material.

Noise management
A consent condition requires provision of a noise monitoring programme for construction, exploration, testing and production.

A consent condition requires establishing permitted noise levels and measurement locations.

A consent condition requires prior notification of commencement of drilling to households within a defined radius of the well site.

Vibration management
A consent condition establishes vibration levels at nearby residential dwellings, according to a New South Wales standard, with the exclusion of construction noise.

Lighting
A consent condition requires light to be directed away from dwellings and to avoid light spill to adjoining properties.

Dust
A consent condition requires dust nuisance to be minimised and to adopt dust suppressing measures.

Cultural/Archaeological
A consent condition requires provision for artefact, taonga, koiwi, or other archaeological or cultural evidence unearthed or otherwise discovered, to be managed, including iwi notification and consultation.

Landscape planting
A consent condition requires the consent holder to submit and comply with a landscape planting plan.

Traffic movements
A consent condition limiting the timing of heavy traffic movements.

A consent condition requiring a local newspaper alert for rig mobilisation to and from the well site.

Flaring
Consent conditions limiting flaring duration and purpose, and limiting flaring to a number of target geologic zones (reservoirs) per well.

Decommissioning and site restoration
A consent condition requiring a well site decommissioning programme.

A consent condition that establishes standards for well site restoration.

Review
A consent condition providing the opportunity to review the consent conditions at specified times.

Advice notes on the consents may also address the following:

Required to satisfy the HAZNO (1996) requirements

Provision of sanitary services

Right of objection provisions under the RMA

Lapse provisions under the RMA

Routine site inspections being undertaken

Hazardous Facilities Management Plan prepared according to specified guidelines

Adherence to health, safety and environmental systems.

6.2.2 Waste disposal sites

The following is a summary of the environmental effects considered by District Councils in land use consents for oil and gas industry land farming waste disposal sites including for hydraulic fracturing return fluids.

Activity specification/limitation
A consent condition describing the use and development proposed, including the identification of the disposal sites and types of waste able to be disposed.

Commencement/ notification
A consent condition requiring the date of delivery of drilling waste to the site and the completion of land farming to be notified to the Council.

Land Management
A consent condition limiting the period when drilling waste is incorporated into the land.

A consent condition limiting the period for the revegetation of each disposal stage.

A consent condition requiring appropriate land stabilisation measures to minimise erosion to be adopted.

A consent condition requiring a site access vehicle crossing to be to an all weather standard.

Dust
A consent condition requiring the control of site dust to avoid a nuisance.

Archaeological
A consent condition requiring an archaeological authority prior to the commencement of the activity.

A consent condition requiring provision for archaeological and cultural remains management including iwi notification and consultation.

Cost recovery
A consent condition notes the type of charges payable by the consent holder to the Council under the RMA.

6.2.3 Discussion and conclusions

District councils noted that the consideration of hydraulic fracturing operations at a well site represented very limited further consideration of environmental effects than for normal drilling operations. For example the noise from pumps used in the operation is generally greater than that from the rig and mud pumps during drilling operations, but is limited to day time hours. Also, the management of hazardous substances on the site for drilling operations is similar to that for any chemicals used in hydraulic fracturing.

The actual or potential environmental effects of a high pressure hydraulic fracture discharge include and relate to the management of the type of chemicals used in the fracture fluids including site management measures to avoid or contain chemical spills (refer sections 4.6 and 6.1.6 of this report). District council consents address hazardous substance used in the fracture fluids and their management, including storage, bunding, and spill response. The consents also require notification of how any wastes (e.g., return fluids), will be discharged to the environment.

The type of hydraulic fracturing environmental concerns addressed in land use resource consents by district councils generally falls within the environmental effect envelop established for normal drilling and testing operations at well sites. Considerations are also similar for waste disposal consents.

7. Cost recovery

This section of the guide addresses cost recovery provisions, under section 36 of the Resource Management Act 1991, for all resource consent applicants and holders, and the Taranaki Regional Council's approach. The Council has a charging policy under the Act and the information below is drawn from this policy and practice with specific reference to oil and gas activities, including hydraulic fracturing activities. The policy is currently under review but no major changes in approach are envisaged.

7.1 Taranaki Regional Council context

All of the consent processing and compliance monitoring costs are recovered as direct charges from the applicant/holder under the Council's funding policy. The Council's direct charges are cost recovery charges under the Resource Management Act 1991. The proportion of user charges is high compared to other councils and reflects a long-standing Council position to recover consent and monitoring costs from resource users, rather than from the general population through rates.

7.2 General principles

The Taranaki Regional Council has a number of over-riding principles which apply to its charging policy. The following four principles are derived from section 36 of the Act. The first principle is that of being lawful and the following three principles are derived from the tests contained in section 36(4) of the Act.

7.2.1 Charges must be lawful

The Council can only fix charges as allowed by and in accordance with the requirements of the Resource Management Act 1991 and the Local Government Act 2002.

7.2.2 Charges must be reasonable

The sole purpose of a charge is to recover the reasonable costs incurred by the Council in respect of the activity to which the charge relates (pursuant to section 36(4)(a) of the Act) .

7.2.3 Charges must be equitable

The Council must consider the benefits to the community and to the consent holders when setting a charge. It would be inequitable to charge consent holders for resource management work undertaken for the interests of the regional community, and vice versa (pursuant to section 36(4)(b)(i) of the Act).

7.2.4 Charges must be justified

Charges must relate to costs incurred as a result of the consent holder's activities and/or must reflect the benefits obtained by the person as distinct from the regional community. The Council can only charge consent holders to the extent that their actions have contributed to the need for the Council's action and/or to the extent that they derive benefits from the Council's actions (pursuant to section 36(4)(b)(i) and (iii) of the Act).

7.3 Other principles

The following are general principles adhered to by the Council in fixing charges.

Charges must be Uniformly Applied.

Irrespective of the location of an activity within the region, the Council should provide the same service, for the same price. Charges should be applied uniformly and consistently to users whose activities require them to hold a consent, and where the Council incurs ongoing costs.

7.3.1 Charges must be simple to understand

Charges should be clear and easy to understand. The administration and collection of charges should be simple and cost effective.

7.3.2 Charges must be transparent

Charges should be calculated in a way that is clear, logical and justifiable. The work of the Council for which costs are to be recovered should be identifiable.

7.3.3 Charges must be predictable and certain

Consent applicants and resource users are entitled to certainty about the cost in their dealings with the Council. The manner in which charges are set should enable customers to evaluate the extent of their liability.

7.4 Charges for resource consent applications

Section 36(1) (b) of the Act allows the Council to fix, via the Annual Plan process, charges payable by applicants for resource consents (including certificates of compliance) or for charges to, or reviews of, resource consents. These charges cover all aspects of receiving, processing, reviewing and granting consents including hearings and engaging lawyers and consultants costs.

These cost recovery charges include a scale of fixed charges for staff time, based on charge out rates for support, technical, professional, managers and senior management calculated as per the IPENZ method.

The actual charge recovers on an actual and reasonable basis the time taken to process the consent application and any additional costs.

Pre-application consultation with consent applicants is good practice for major and complex applications, including those associated with the oil and gas sector. Agreement can be reached prior to such applications being made on the scope and detail needed for the application and draft applications and assessment of environmental effects considered before lodgement. Agreement can also be reached on the payment for Council input to the pre-lodgement phase outside the provisions of the Act. This practice has become more important given the imposition of the discount provisions of the Act for applicants, whose application is not processed in accordance with the timelines set out in the Act.

7.4.1 Charges for consent compliance monitoring

Section 36(1)(c) of the Act allows the Council to fix , via the Annual Plan process, charges payable by holders of resource consents for the carrying out of its functions in relation to:

- the administration, monitoring, and supervision of resource consents (including certificates of compliance); and
- resource management functions under section 35 of the Act.

The Council has historically fixed charges and recovered costs for compliance monitoring of most resource consents, particularly significant consents. With respect to the Council's resource management functions under section 35 of the Act, the Council has determined not to fix charges to recover cost. In particular this includes those resource management functions associated with state of the environment monitoring, the monitoring of the suitability and effectiveness of its policy statement or plans, and the exercise of any delegated or transferred functions, powers or duties.

The Council's compliance monitoring is based on a structured three-tier regime which is as follows:

- tailored compliance monitoring programmes;
- annual inspection programmes; and
- once only compliance inspections.

Currently there are over 220 tailored compliance monitoring programmes which includes all oil and gas production activities, waste disposal activities (land farming or deepwell injection), and the downstream industries (e.g., power generation, fertiliser manufacture). They are discussed and confirmed with consent holders prior to confirmation by the Council and subsequent implementation. Drilling and hydraulic fracturing are also subject to a tailored compliance monitoring programme for the well site. These are compiled as the activities arise, using the charges set out in the Annual Plan, as opposed to being set out on an annual basis like the 220 tailored programmes. The annual compliance programmes are fully detailed down to (for example) sampling sites, number of samples, the full range of analyses, number of inspections, hours to be spent, and matters to be checked, on the basis of a 'business-as-usual' monitoring programme. That is, all additional investigations and any follow-up to any matters arising during the year incur additional monitoring charges.

A typical well site drilling compliance monitoring programme includes the following components:

- programme supervision/management by the job manager including programme design, and liaison /correspondence with the consent holder
- site inspections (at least weekly) with particular reference to consent conditions, including operation of the well site, stormwater system and receiving environment effects; checking measures to control and minimise effects of emissions, including the log of flaring and smoke events, and monitoring for toxic or noxious emissions and odours at or beyond the boundary; and site house keeping, including handling and storage of any environmentally hazardous substance storage

- physicochemical monitoring of the stormwater discharge and receiving environment
- biomonitoring of nearby surface waters if applicable (wellsites may be well isolated from surface waters)
- air monitoring for the site and flare
- review of the oil spill contingency plan for the site
- data review of data and annual reports supplied by the consent holder
- preparation of a comprehensive monitoring report to the Council (and community) on the results of monitoring and making recommendations about future monitoring.

  The typical cost of such a programme is about $5,000 (plus GST) for a single well. Should non-compliance issues arise, additional monitoring may be required and a charge to cover the actual and reasonable costs of this can be made.

  A typical well site hydraulic fracturing compliance monitoring programme involves the following components:

- programme supervision/management by the job manager including programme design, and liaison with the consent holder
- physicochemical sampling at designated wells (or springs) for parameters set out in consent conditions: prior to the hydraulic fracture operation (baseline); one week after the operation; one month after the operation; three months after the operation; one year after the operation
- site inspections during hydraulic fracturing with particular reference to consent conditions, including equipment pressure testing
- physico-chemical sampling of return fluids according to consent conditions
- assessment of whether the best practicable option has been followed by the consent holder
- assessment of the pre and post fracture report required by consent conditions, including input from an appropriate consultant
- assessment of fracture fluids according to the consent condition
- consideration of consent review based on the matters set out in the consent condition
- preparation of a monitoring report to the Council (and community) on the results of monitoring and making recommendations about future monitoring

The typical cost of such a programme is about $50,000 (plus GST), with a large proportion of the costs being for the local baseline and ongoing groundwater monitoring. Should non-compliance arise additional monitoring may be required and a charge to cover the actual and reasonable costs of this can be made.

Deepwell injection and land farming monitoring programmes are based on exactly the same approach and assess compliance with consent conditions for the activities and include an annual monitoring report.

7.5 Specific investigations

Over the years the Council, in conjunction with various consent holders and industry sector representative groups, has undertaken investigations into the environmental effects of the oil and gas sector. These have included the assessment of flare emissions from oil and gas wells flare pits in the 1990s to inform the policy development and consent processes. Such investigations and their peer review can be agreed between parties and Council costs recovered by agreement. The investigations provide information for resource consent applications.

8. Public reporting

This section of the guide briefly addresses public reporting of consent processing, consent monitoring, and enforcement activities. Delegations are an important part of consent processing, monitoring and enforcement. Most of the activities described in this section involve reporting to the Council and the Taranaki community on the exercise of delegations to provide transparency and accountability. There are however, limitations on the release of commercially sensitive information and this matter is also addressed in this section. Most of the information noted below is reported on the Council's website http://www.trc.govt.nz. The only exception is that information related to prosecutions, which must stay confidential for legal reasons, until the matter is heard and determined by the Court.

8.1 Taranaki Regional Council context

The Taranaki Regional Council has a Delegations Manual in place that sets out the Council's policies, procedures and delegations relating to decision making when giving effect to its statutory duties, responsibilities and powers. For the purposes of administrative efficiency and expediency when conducting its day-to-day business, the Council delegates certain statutory duties, responsibilities and powers to its standing committees, subcommittees, members or staff. Likewise the Chief Executive delegates certain duties and responsibilities to a subordinate level. These delegations are a necessary operational requirement to promote effective and expeditious decision-making. Delegations avoid administrative delays and inefficiencies that might otherwise occur if all matters have to be referred to Council or Chief Executive every time a decision needs to be made.

The Council has also prepared guides for consent processing, compliance monitoring, and enforcement activities that guide staff in these important activities and manage associated risks and further information can be found in these reports (Taranaki Regional Council, 2009a, 2009b, 2009c).

8.2 Consents

The Council's Consents and Regulatory Committee meets every six weeks and receives a report on the exercise of delegations for consent processing. The non-notified or limited notified consents granted by senior Council officers are presented. The applications subject to time extensions, further information requests, and awaiting affected party approvals are presented. Details on those applications under renewal, declined, surrendered, cancelled, lapsed and under appeal are also presented.

Annually the Council processes about 400 applications and about 98 % of these are non-notified, which is in line with national trends (Ministry for the Environment, 2012). Oil and gas sector applications comprise about 20 % of the applications processed each year and of the total number of current consents.

8.3 Monitoring

Compliance monitoring reports from annual tailored and one off monitoring programmes are presented to the Council's Consents and Regulatory Committee meeting every six weeks for consideration.

The reports include an environmental performance ranking ('high', 'good', 'poor', 'improvement desired' ratings) and commentary about what enforcement action was taken for non-compliance. Recommendations about next year's monitoring programme are also provided. Each report is submitted to the consent holder for comment prior to publication.

8.4 Enforcement

The Council receives and responds to pollution events, public complaints and non-compliances with rules in the Council's regional plans, resource consents and the Resource Management Act 1991 throughout the year, with most complaints responded to within four hours. Compliance monitoring undertaken can also identify non-compliance. Non-compliance responses may include issuing an inspection, abatement or infringement notice, or initiating a prosecution. This information is recorded in the Incident Register (previously termed the Unauthorised Incidents Register), together with the results of investigations and any enforcement actions. A summary of incidents for the period is provided. Incidents are publicly reported to the Council through the Consents and Regulatory Committee every six weeks for consideration.

Following the recommendation of the Auditor General to the local government sector, the Council ceased making decisions on prosecutions on 3 April 2012. These are now made by the Chief Executive of the Council under delegation and reported, in the publicly excluded part of the Consents and Regulatory meeting, to the Councillors for their information.

Monitoring and enforcement data for the oil and gas industry for the last 10 years is presented in Section 2.2 of this guide.

8.5 Management of commercially sensitive information

Some of the information that is required for the regulation of the oil and gas industry, including hydraulic fracturing, is considered commercially sensitive by applicants. This information is associated with subsurface geology, particularly reservoir and geotechnical details, and what can be inferred in terms of hydrocarbon reserves. Adjacent permit operators may be very interested in what a neighbour is doing to assist their own operation and development of a reservoir. The sector may also be interested in reserves information for marketing gas purposes so as to maximise the return.

The Local Government Official Information and Meetings Act 1987 (LGOIMA) and the Resource Management Act 1991 apply to Council operations. The provisions of the Crown Minerals Act 1991 and its amendments and related regulations are also relevant and considered below.

8.5.1 Local Government Official Information and Meetings Act

LGOIMA applies to all information held by a local authority (excluding material in a library or museum for public reference purposes or held as an agent). Any information lodged by consent applicants and submitters (whether informally or otherwise) will be official information for the purposes of LGOIMA.

As soon as a consent applicant commences pre-lodgement discussions or lodges its consent application with the Council, the information given to the Council through that process will qualify as official information for the purpose of LGOIMA. LGOIMA will continue to apply throughout the consent application process and afterwards (for example in relation to monitoring and compliance information about the consented activity). Section 5 of LGOIMA sets out the principle that official information "shall be made available unless there is good reason for withholding it". This principle guides all decisions about whether official information can be withheld.

Even though section 7(b), which addresses disclosure of trade secrets or prejudice to a commercial position, of the LGOIMA may apply to the information put forward by consent applicants, it does not provide absolute protection of that information, and the Council's decision to refuse an official information request may still be investigated and reviewed by the Ombudsman.

The first step when considering the release or withholding of commercial information is to identify precisely what prejudice is likely to be caused by the disclosure of the information. As noted above in general terms, the prejudice would be caused by commercially sensitive information being made available to competitors that could have a significant prejudicial effect on the applicant's commercial position. The Council is likely to require that the exact nature, and likely impact, of the prejudice be identified explicitly, to enable the Council to undertake an assessment. This should be undertaken on a case-by-case basis.

There are guidelines from the Ombudsmen on the implementation of the provisions of LGOIMA.

There is no difficulty with applicants and submitters specifying what aspects of the information they are providing to the Council are commercially sensitive by inclusion of a rider such as "the following information is commercially sensitive". An applicant providing information that they consider triggers one of the protections under LGOIMA should refer to the specific LGOIMA provision they consider is triggered, and use the words from that section in their rider (for example, "commercially sensitive – we consider that making this information available to the public would unreasonably prejudice our commercial position in terms of section 7(2)(b)(ii) of the Local Government Official Information and Meetings Act 1987', or 'commercially sensitive in terms of section 7(2)(b)(ii) of the Local Government Official Information and Meetings Act 1987'). However, such statements will not override or determine the legislative tests in the RMA or LGOIMA, and it is up to the Council to apply those tests objectively and in good faith.

An important factor in this assessment is the stage of development and level of knowledge that may have been published about a reservoir. For example Shell Todd Oil Services Ltd provided detailed discharge depth information for its hydraulic fracture application whereas Greymouth Petroleum Ltd supplied discharge depth data that was rounded to the nearest 100 m. Given the 3,000+ m depth of the hydraulic fracture operations the depth the discharge could still be adequately assessed with the rounded data.

8.5.2 Resource Management Act

Under section 42 of the RMA a local authority can make an order to prevent the disclosure of certain information. Section 42(1) of the RMA relevantly provides:

1) A local authority may, on its own motion or on the application of any party to **any proceedings or class of proceedings**, make an order described in subsection (2) **where it is satisfied that the order is necessary—**

   a) *To avoid serious offence to tikanga Maori or to avoid the disclosure of the location of waahi tapu; or*

   b) ***To avoid** the disclosure of a trade secret or **unreasonable prejudice to the commercial position** of the person who supplied, or is the subject of, the information, –*

   ***and**, in the circumstances of the particular case, the importance of avoiding such offence, disclosure, or prejudice **outweighs the public interest** in making that information available.*

   (emphasis added).

Under section 42(2), the local authority can make orders, either on its own motion or on the application of a party to the proceedings, to:

1) exclude the public from the whole or part of the hearing; and
2) prohibit or restrict the publication or communication of any information supplied or obtained in the course of the proceedings.

These powers are in addition to the LGOIMA requirements. LGOIMA continues to apply throughout the processing of a resource consent application, but during 'proceedings' relating to a resource consent application, the Council also has the powers under section 42.

Section 42 of the RMA sets out three factors that must be considered before the Council makes an order in the course of proceedings, namely the order must be necessary to avoid unreasonable prejudice that outweighs the public interest in making that information available. These factors must be considered on a case by case basis. In general, the principles that apply to these factors will be similar to those under LGOIMA as discussed above.

There is case law available to determine 'public interest' in the context of the RMA and section 42.

8.5.3 Crown Minerals Act 1991, the Crown Minerals (Petroleum) Regulations 2007 and the Minerals Programme for Petroleum (2013)

The prospecting, exploration and mining of petroleum in onshore and offshore New Zealand basins is managed and regulated by New Zealand Petroleum and Minerals (NZPAM), part of the Ministry of Business, Innovation and Employment (MoBIE). These activities are legislated under the Crown Minerals Act 1991 and regulated under the Crown Minerals (Petroleum) Regulations 2007.

The Government's expectations with regard to petroleum prospecting, exploration and mining are set out in the Minerals Programme for Petroleum (2013).

In order to acquire a prospecting permit, an exploration permit or a mining permit, an Operator (i.e., the permit holder, which may acquire the permit on behalf of itself and other joint venture partners) must submit a review of the geologic and geophysical information available to the Operator that causes his interest in the proposed permit.

Prospecting permit

A prospecting permit can be awarded for regional and areal evaluations of geologic and geophysical data. An Operator may apply for a prospecting permit at any time. The permit can only be over an area of open acreage, though the size of the proposed permit is negotiable. A prospecting permit is non-exclusive and only valid for one year.

Exploration permit

An exploration permit can be awarded to identify petroleum accumulations and evaluate any discoveries made by drilling. A proposed work programme for an exploration permit is likely to include geologic and geophysical surveying (including reworking existing data and new data acquisition), to be followed by exploratory drilling and appraisal drilling, if a discovery is made. Since the beginning of 2012, exploration permits will only be awarded through a competitive 'Permit Blocks Offer' made by NZPAM, usually on an annual basis, on the basis of competitive work programme offers. NZPAM determines the location and size of the permits on offer. Exploration permits offer exclusive rights to the Operator to explore and a further right to submit a mining permit application, if a discovery is made and appraised to have economic potential. Exploration permits have an initial five-year term but may be extended for five more years, with a 50% relinquishment of the acreage. A further four years may be granted to allow the appraisal of any discovery.

The application must also propose a work programme of geologic and geophysical data acquisition, processing and analysis, which will help to determine whether he wishes to acquire an exploration permit or drill an exploratory well. Most proposed work programmes are staged, so that the Operator can undertake an annual work programme, review the results with NZPAM and, if agreed, either commit to the next year's work programme or drop the permit. NZPAM expects that a proposed work programme would include a plan to drill an exploratory well, though the 'drill or drop' provisions enable Operators to undertake the necessary exploratory research, until such as they are in a position to commit to the cost of drilling a well or not.

Mining permit

A mining permit can be awarded for the development of a petroleum accumulation to allow the extraction and production of the petroleum. A mining permit application must give details of the Operator's plans to extract, separate, treat and process the petroleum. A mining permit will only be awarded once a full exploration and appraisal programme has been fulfilled. The mining permit is exclusive and can last for up to 40 years, depending upon the size of the discovery and the proposed rate of production. There is no size limit but a mining permit area will typically be smaller than an exploration permit. The information requirements for a mining permit application are much more demanding than for the other types of permits. A mining permit application must satisfy NZPAM's rigorous evaluation process, which includes:

1) Sufficient information to confirm to identify and delineate the petroleum accumulation;

2) An acceptable work programme to produce the petroleum in accordance with good exploration and oilfield practice, so that the field can be soundly managed and wastage can be avoided;

3) The proposed mining permit area and term are appropriate to the delineated accumulation; and

4) That the Operator has the technical and financial capabilities to deliver the proposed work programme.

Failure to meet all of these conditions to NZPAM's satisfaction would lead to the refusal of a mining permit.

NZPAM publishes and regularly updates maps of all existing permits and permit applications.

Regulation of information

The Crown Minerals (Petroleum) Regulations 2007 set out how the NZ Government expects Operators to supply information regarding their proposed permit applications, prospecting and exploration activities and reporting during the life of the permit and after a permit's expiry or relinquishment.

The Regulations set out how and when Operators must supply information to NZPAM and deal with requests for extensions and exemptions to information provision. Notices relating to applications for awards, ownership transfers and amendments of permits, together with applications to vent petroleum are prescribed in the Regulations as are the provisions for notices relating to surrender of permits, access arrangements and intentions to carry out surface and subsurface surveying and drilling.

The Regulations also prescribe the requirements for information gathering and submission to NZPAM for mining operations, including well drilling, avoidance of wastage of petroleum and the preparation and submission of daily and biennial activity reports.

Lastly the Regulations deal with the preparation of royalty statements and payment of royalties from petroleum production to the Crown.

Commercial confidentiality

The oil and gas industry internationally and in New Zealand operates under commercial confidentiality. The high costs of prospecting, exploration and oilfield operations mean that Operators and any joint venture partners hold information closely confidential. The Petroleum Regulations are in place in part to ensure that Operators do submit and lodge information with NZPAM to required standards of content and format, so that NZPAM can make informed decisions about an Operator's performance in delivering its agreed work programme.

Operators do not usually expect to share their plans or reports with third parties, except in exceptional circumstances (for instance, when an Operator is seeking additional investors in a permit or work programme). Consequently NZPAM respects the confidentiality of an Operator's activities and reports during the life of a permit.

NZPAM holds all information confidential for a period, which is defined the shorter of:

1) five years after the data was acquired by the permit holder; and
2) when the permit has been surrendered.

By and large, whilst a permit is operational, any information submitted to NZPAM is held in 'closed file' – i.e., it is not publicly accessible.

When an Operator surrenders a permit, it is required to lodge information on the permit work programme that has been undertaken. This may include geologic and geophysical survey results, together with analysis of this information and drilling, testing and production information. Operators are not required to provide commercially sensitive information, such as their own economic evaluations and commercial decisions.

Once a permit terminates or is relinquished by the Operator, information lodged with NZPAM becomes publicly available in the 'open-file' part of NZPAM's electronic and paper databases. This is done to try to avoid duplication of efforts by successive parties. Importantly it also provides regulators with an opportunity to view the data some of which may be useful for resource management purposes. However, expertise would be required to make use of the information.

8.6 Annual activity report

An annual activity report on Council's performance and achievement on its consent processing and administration, compliance monitoring and pollution incidents response functions is prepared and presented to the Consents and Regulatory Committee. The report also fulfils the Council's statutory obligation under Section 35 of the Resource Management Act 1991 to report to the regional community on its performance in monitoring the exercise of resource consented activities in the Taranaki region.

Photo 15 Consent processing, compliance monitoring and incidents response annual report to the Council and community

The level of performance throughout the financial year is assessed and where available benchmarked against other available data. The monitoring of the level of compliance with the conditions of resource consents issued is a primary focus of the Council.

The Council also has responsibilities for marine oil spill response under the Maritime Transport Act 1994. The Council directs an effective oil spill response through implementation of the Taranaki Regional Council Marine Oil Spill Contingency Plan and takes action to mitigate or remedy the adverse effects of any marine oil spills within the Taranaki region. An overview of the Council’s Marine Oil Spill Response work undertaken during the year is provided.

The report presents and comments on trends in activities and sets out the work undertaken by the Council to monitor compliance, and outlines the Councils level of success in carrying out its functions under the Resource Management Act 1991. The report also summarises incidents (an activity that does not comply with the conditions of a consent or the rules in the Council's regional plans) investigated by Council during the year. The report for 2011/12 showed the Council’s consent processing functions continued to achieve high standards and consent compliance rates were also high (Taranaki Regional Council, 2012).

9. Benchmarking

This section of the guide benchmarks the Taranaki Regional Council's approach to HF against the recommendations of the UK Royal Society and the Royal Academy of Engineering for shale gas HF and the findings of a report prepared by Todd Energy in relation to their HF operations in Taranaki.

9.1 UK Royal Society and Royal Academy of Engineering report

In June 2012 the UK Royal Society and the Royal Academy of Engineering (RS and RAE) produced a report entitled *Shale gas extraction in the UK: a review of hydraulic fracturing (*Royal Society and Royal Academy of Engineering, 2012). The report should be acknowledged and welcomed as an authoritative, robust, and objective assessment of this controversial technology.

The UK's chief scientific advisor asked the Royal Society and the Royal Academy of Engineering to review the scientific and engineering evidence related to risks associated with the practice of hydraulic fracturing. The study presented recommendations in 10 major themes for the UK.

The Council has reviewed its approach to regulating HF against the recommendations contained in the UK report (Table 7). The Council also sought comment from the Ministry of Business, Innovation and Economics (MoBIE), which incorporates the former Department of Labour, in preparing the review.

The Royal Society and the Royal Academy of Engineering report finds

> '*the health, safety and environmental risks associated with hydraulic fracturing (often termed 'fracking') as a means to extract shale gas can be managed effectively in the UK as long as operational best practices are implemented and enforced through regulation.*'

This is a very significant and authoritative statement on the subject, which should be allowed to fully inform the current national discussion.

In considering the UK Royal Society recommendations, context is important. The extraction of shale gas (the subject of the UK study) generally occurs at much shallower depths, in formations of different structure and composition and with discharge of much greater volumes of produced water, than the practice of hydrocarbon gas and condensate recovery in Taranaki. There is thus a different risk profile. Accordingly, a management and operational regime that is suitable for shale gas extraction would, all other things being equal, afford an even more secure regime for hydraulic fracturing in Taranaki.

It is also important to note that shales have a very low permeability range for a producing formation as opposed to the tight gas sandstone reservoirs that are subject to hydraulic fracturing in Taranaki (Figure 9). This means greater use of energy and fluids in the HF operation.

9.2 Benchmarking

The details of the UK recommendations and their corresponding status in New Zealand, are benchmarked and set out in Table 7.

The Health and Safety in Employment (Petroleum Exploration and Extraction) Regulations 2013 (the Regulations), administered by the High Hazard Unit in MoBIE, have been recently reviewed and moved from a prescriptive to a goal based regime.

Table 7 Review of the Council's approach to regulating hydraulic fracturing against the ten recommendations for hydraulic fracturing from the UK Royal Society and the Royal Academy of Engineering report

GOOD PRACTICE	RESPONSE
1. Detection of Groundwater Contamination	
(a) Baseline surveys of methane and other contaminants	TRC supports as good practice. Addressed in consent conditions with the requirement for a baseline and on going groundwater monitoring programme. TRC generally undertakes the monitoring for the consent holder. Note technology allows distinction of biogenic (gas from shallow organic formations) and thermogenic (gas from decomposition of buried organic matter at depth, i.e., fossil fuels) methane.
(b) Site specific monitoring of methane and other contaminants before and after operations	TRC supports as good practice. Methane is found naturally in shallow groundwater in Taranaki, as consequence of swamp decomposition (biogenic) and natural hydrocarbon 'seeps' (thermogenic). Addressed in consent conditions with the requirement for a baseline and on-going groundwater monitoring programme. TRC generally undertakes the monitoring for the consent holder. Note technology allows distinction of biogenic (gas from shallow organic formations) and thermogenic (gas from decomposition of buried organic matter at depth, i.e., fossil fuels) methane.
(c) Develop method for monitoring abandoned wells	Monitoring of an abandoned well is not something that the High Hazard Unit (in MoBIE) intend to address going forward as it makes no material difference to the safety of workers if it is no longer a place of work, i.e., the drilling unit or production installation is no longer in the vicinity. Council has undertaken some monitoring of very old wells in New Plymouth. A matter that will be addressed as part of the Council's regional plan review process and others consideration.
(d) Data collected by operators submitted to regulator	Addressed in consent conditions with a requirement for HF operational and well condition data to be submitted in a post HF report.
2. To Ensure Well Integrity	
(a) Ensure independence of the well examiner from the operator	Under the Regulations there are well operations requirements over the lifecycle of the well. This includes a well examination scheme and well examiner that address well integrity. The well examiner is required under the Regulations to be independent and competent. 'Independent' is defined in the Regulations. Similar requirements are placed on operators of offshore installations in the UK.
(b) Well designs should be reviewed by well examiner from H & S and environmental views	Primarily reviewed from H & S view point, but significant overlap in the Regulations between H & S and environmental considerations in terms of well integrity. .
(c) Well examiner should carry out onsite inspections	Likely well examiner does carry out site inspections.
(d) Operators should ensure that well integrity tests are carried out	TRC supports as good practice. With respect to potential discharge into the environment, addressed in consent condition with a requirement for well and equipment pressure testing prior to HF operation
(e) Results of well tests should be submitted to NZ equivalent of DECC (MfE?)	TRC supports as good practice. Addressed in consent condition with a requirement to supply this data to the Council

GOOD PRACTICE	RESPONSE
3. To mitigate Induced Seismicity	
(a) Operators should carry out site specific surveys	TRC supports as good practice. GNS seismic study commissioned by the Council showed this was not an issue in the region. It should be noted that induced seismicity is so low, that only largest conceivable events could register on regional seismic monitoring networks (and would still be orders of magnitude below human awareness or perception). However, there is generally some consideration of this matter by consent applicants in any case.
(b) Monitoring of seismicity before, during and after operations	TRC supports as good practice. See above. There is a regional volcano-seismic monitoring network in place in the Taranaki region that would show any impacts of HF operations that were more than negligible (and still orders of magnitude below human perception). NZ has the GeoNet and GNS monitoring and assessment capabilities to call on in the assessment and measurement of seismic impacts.
(c) Traffic light monitoring system	See above.
(d) Consideration of how induced seismicity is to be regulated	RMA allows seismic effects of an HF operation to be considered by councils. TRC has commissioned independent authoritative work on the issue, as noted above, and this matter should be assessed in resource consent applications if HF operations spread to other regions. Do not think a national assessment would add much value as need more of a region-specific assessment of risk and monitoring requirements.
4. To Detect Potential Leakages of Gas	
(a) Operators to monitor potential leakages before, during and after operations	TRC supports as good practice. Has the baseline and on going groundwater survey of methane, and pressure testing of the well and equipment prior to an HF operation, as requirement in the consent.
(b) Data to be submitted to regulator to inform wider assessments	TRC supports as good practice. Monitoring data is submitted to the Council and publically reported annually in compliance monitoring reports (and any non-compliance is reported publicly every 6 weeks).
5. Water Managed in an Integrated Way	
(a) Minimise water use avoid abstracting water from under stress supplies	Water is taken from municipal supplies in Taranaki so no water use issues. This would be a standard matter for consideration by a consenting authority anywhere in NZ and the impact of the abstraction would be a function of the allocation pressure on the resource.
(b) Wastewater recycled and reused where possible	Not an issue as no water supply issues and produced wastewater (return fluids) are not recycled.
(c) Options for treating and disposing of wastes should be planned from the outset	TRC supports as good practice. Proposed disposal method for produced wastes (return fluids) should be covered in the HF consent application and activity monitored by the Council.
6. Manage Environmental Risks	
(a) Environmental Risk Assessment should be mandatory for all operations	TRC supports as good practice. In NZ, RMA provides the framework for consideration of environmental effects/risks. The definition of environmental effect in the RMA is broad. Adverse effects are identified and measures to avoid, remedy or mitigate these effects are presented by applicants for resource consent. There is no comprehensive risk assessment per se. The Regulations require that a safety case be prepared. The case applies to an installation and includes the wells by which petroleum is extracted. It includes a detailed safety management system. The regime should prevent and/or reduce harm to the environment l (although this is not the primary purpose of the safety case).
(b) The ERA should assess risks across the entire lifecycle of operation	See above.
7. Best Practice for Risk Management	

GOOD PRACTICE		RESPONSE
(a)	**Operators carry out goal-based risk assessments according to the principle of reducing risks to As Low As Reasonably Practicable (ALARP)**	The Regulations incorporate the ALARP principle and require safety case to be prepared and approved. (This is the only requirement subject to an approval process under the Regulations). With regard to environmental risk, the TRC routinely adopts a 'best practicable option' approach (as defined in the RMA), capturing similar concepts as ALARP.
(b)	**Operators ensure that mechanisms are put in place to audit the processes**	As part of their safety case employers are required to provide a description of their safety management system, how it will be implemented, and the audit procedures that will be adopted.
(c)	**Assessments should be submitted to regulators**	As mentioned previously, employers are required to submit their safety case to the Secretary of Labour prior to the commencement of operations.
(d)	**Mechanisms should be put in place for reporting well failures and other incidents**	The Regulations have a 'dangerous occurrence' reporting regime. Environmental reporting: TRC implements comprehensive and frequent monitoring, as well as maintaining a 24-hour public response service for complaints; and industry practices a high degree of self-reporting already.
8.	**UK regulators determine requirements to regulate a shale gas industry. Skill gaps and training should be identified**	The Regulation require the duty holder to ensure that every person who is , or is to be, engaged in any capacity in a well operation has the necessary knowledge , skills, experience, and ability to perform their job safely and effectively. The safety case regime requires duty holders to demonstrate (in their safety case) that each member of the workforce at the installation has, or will have, the necessary skills, training, and ability to meet their responsibilities and perform their job safely and effectively. Environmental /RMA: Councils exchanging information on good practice in regulation and monitoring, with expert advice obtained already (e.g., in seismicity, geohydrology, and regulation practice)
9.	**Co-ordination of numerous bodies with regulatory responsibilities. Single body should take lead**	NZ has set up an HS&E Steering Team (involving MoBIE, Transport, regional councils, EPA, MfE, Doc, MNZ) specifically to address coordination and best practice. Note : High Hazard Unit (MoBIE) (workplace health and safety), EPA (management hazardous substances), district and regional councils (environmental effects; e.g., emissions to air, discharges to land, water takes, noise, light, traffic movements) are involved in regulating HF. There is no single supervising body as may exist overseas. But reasonable networks are in place to share information
•	**Clarify roles and responsibilities**	TRC has a working relationship with the High Hazard Unit officers in New Plymouth regarding their HSE (and HSNO) responsibilities. Have a working relationship with district councils in terms of their responsibilities. Have regular work shops with 3 district councils to discuss any regulatory issues for the oil and gas industry.
•	**Develop mechanisms to support integrated ways of working**	An integrated approach to monitoring RMA and HSNO at well sites and production stations was in place until 2011, under a contract between the Council and former DoL (now MoBIE). Opportunity for an integrated approach lost when the (then) DoL cancelled the contract. See above for national co-ordination.
•	**Formal mechanisms to share information**	No (but note above). Extensive informal networks of key agencies and players.
•	**Joined-up engagement of local communities**	No joint regulatory authority community engagement given the different regulatory regimes in place, some of which allow for public input and others do not. Consent holders generally have good relationships with well site neighbours and keep them informed about well site activities, including HF, and answer any questions. RMA encourages consultation on site by site basis. TRC provides high level of reporting back to local communities. RMA provides for extensive public consultation at time of preparing regional policy statements and regional plans that set the 'rules' for HF.
•	**Mechanisms to learn from**	Council makes regular assessment of overseas literature, reports, studies, regulation and legislation, news announcements etc via the web and

GOOD PRACTICE	RESPONSE
operational and regulatory best practise internationally	notification services. Senior Council officers have also been overseas to gain knowledge. The Council commissioned GNS to review HF regulatory practices overseas.
10. Research sector should consider including shale gas extraction in their research programmes. Priorities should include into the public acceptability of the extraction and use of shale gas.	TRC has already commissioned analytical review of original data (e.g., seismic records). Applications for HF research, that will inform the NZ situation, are being made.

Having a contingency plan in place for well site incidents is a matter of best practice identified by other overseas commentators for HF operations. Contingency planning for well site spills is a requirement of the stormwater consent, issued by the regional council, and also applies to HF operations on well sites. The contingency plan for the McKee 13 wellsite blowout in 1995 worked well and minimised adverse environmental effects. The scope of the incidents to be addressed in any plan is an important issue that requires further consideration by the various statutory agencies involved.

Section 6.1.6 of this report provides further information on the stormwater consent issued by the Taranaki Regional Council, and contingency planning.

As part of its submissions to the Parliamentary Commissioner for the Environment's inquiry into Hydraulic Fracturing, Todd Energy prepared a report on hydraulic fracturing which looked at the hydraulic fracturing process and science, the potential environmental effects and mitigation here and overseas as well as its own hydraulic fracturing operations in Taranaki (Todd Energy, 2012).

The report notes that Todd Energy's hydraulic fracturing operations are in line with international best practice and are safe and have minimal impact on the environment. The report also notes that Todd Energy fully complies with the New Zealand regulatory regime, which it regards as sound and fit for purpose. A number of Taranaki Regional Council reports and studies are cited in the report in support of its conclusions.

The report was reviewed by a number of independent experts in Australia, Canada, the UK as well as New Zealand.

The Ministry for the Environment has prepared a guide for regulating hydraulic fracturing, which is due to be published later this year. The guide draws heavily on what is in this document. The Ministry commissioned a peer review, by international experts, of their document that confirmed the approach being adopted was competent and represented best practice.

9.3 Conclusion

A comparison of current Taranaki Regional Council practice and practice in New Zealand against the Royal Society's recommendations concerning good HF practice indicates that the Council and New Zealand are well-positioned to demonstrate good practice, risk minimisation and management for HF operations.

10. Review, research needs and challenges

This section of the guide identifies possible factors that may influence future regulation of hydraulic fracturing and cause the Taranaki Regional Council's current approach to be reviewed. It also importantly identifies future research and investigation needs to address scientific and regulatory issues that have been identified to date for HF discharges and the disposal of wastes produced. Finally, the section identifies some of the challenges for regulating oil and gas exploration activities, including HF, given the multiple agencies that are involved, and comments on the potentially limited experience and capacity in territorial authorities to regulate the sector beyond Taranaki. Some options to address this are provided.

10.1 Review

The following events could influence the future regulation of HF in the region and nationally:

- The results of the second part of the Parliamentary Commissioner for the Environment's investigation, due for release in late 2013;
- The results of the review of the Petroleum Extraction and Production Regulations being undertaken by MoBIE, particularly concerning safety cases, well integrity and abandonment;
- The review of the Council's Regional Fresh Water Plan over the next two years;
- The detailed USEPA study of the environmental impacts of hydraulic fracturing due in 2014 and any relevant Australian studies;
- Changes to HF practices by industry within Taranaki/ New Zealand; and
- Future regulatory practices in other jurisdictions (whether at a state, federal, or national level), particularly those which have implemented temporary moratoria on hydraulic fracturing.

There will also be a need to capture HF related technological developments, innovations, and efficiencies that emerge over time that lower environmental risks.

10.2 Research needs

The following HF research needs have been identified into:

- Reducing the toxicity of chemicals used in HF activities;
- Recycling/reuse of hydraulic fracturing return fluids;
- Improved diagnostic and monitoring techniques to more accurately identify the fate of subsurface HF discharges, including pre-fracture formation characterisation and modelling, and post-fracture 'proof of intended performance';
- The need and utility of broad emergency response plans for well sites;
- Long-term well integrity issues and their regulation;
- Authoritative and comprehensive review of adverse environmental incidents associated with HF activities, for cause of failure identification;

- Investigation of adverse heath effects claims, nationally and overseas, causal pathways, contaminants, critical concentrations, directly associated potential health outcomes; and
- Responsibility for wells that have not been abandoned according to good oilfield practice (e.g., Moturoa Field in New Plymouth (Refer Taranaki Regional Council , 2003).

10.3 Challenges

The following challenges have been identified for regulating oil and gas exploration activities, including HF given the multiple agencies that are involved. These challenges include and relate to:

- Clarifying roles and responsibilities of regulatory agencies to ensure integration and comprehensive coverage of all aspects of oil and gas exploration including wellsite and well abandonment, without duplication of effort and overlap of responsibilities;
- Ensuring that a coordinated approach is adopted by regulatory agencies and that there are formal mechanisms to share information between agencies and to inform the public (including addressing any non-disclosure issues);
- Ensuring there are mechanisms to learn from and share international operational and regulatory best practice; and
- Developing mechanisms to support integrated ways of working with the various regulatory agencies, particularly concerning joint or contracted compliance monitoring.

Taranaki territorial authorities have experience and capacity to successfully regulate the oil and gas exploration and production sector, including HF. Those territorial authorities outside the region may not have the necessary experience and capacity. While this report will assist these authorities there may still be the need to seek guidance and assistance. One possibility is to contract the capacity that exists in Taranaki to establish suitable regulatory regimes until experience levels increase. The reasonable cost of this could be cost recovered from users.

A challenge for regions where there has been limited oil and gas exploration will be the availability of subsurface information given the limited number of wells drilled. Seismic assessments provide some subsurface data but this needs to be complemented by actual drilling and logging activities to indicate subsurface geology.

A challenge for regulatory agencies is developing effective mechanisms for coordinating and integrating the regulation of well drilling and well construction activities. This guide has highlighted the critical importance of well integrity in ensuring good environmental and health and safety outcomes.

Well integrity is regulated by central government agencies under separate health and safety in employment legislation and associated regulations as noted in section 5.4. This has important implications for regulators under the RMA, as does regulation of oil and gas operations by central government agencies under the Crown Minerals Act. Coordination and integration of these various functions is important as noted above. In carrying out its environmental regulatory responsibilities under the RMA to ensure there are no adverse environmental effects from well failure, the Taranaki Regional Council has relied on, and is entitled to rely on, the responsible central government agencies to ensure that well integrity issues are properly addressed under the legislation specifically dealing with this aspect of oil and gas operations.

Councils need to be aware of well drilling activities and that the practices being applied avoid, remedy or mitigate any actual or potential adverse effects on the environment to acceptable levels as this has implications for their management responses under the RMA. Improved coordination and integration of the various regulatory processes would assist with this.

At the other end of the industry life-cycle, there is a need to clarify responsibilities and develop effective mechanisms to deal effectively with well abandonment. As previously noted, the MoBIE is primarily responsible for ensuring well integrity and proper standards of well abandonment as part of the requirements of the Health and Safety in Employment (Petroleum Exploration and Extraction) Regulations 2013 (section 5.4). Issues of responsibility and liability can arise if abandoned wells begin to cause environmental or other problems through degradation over time or failure, and the site is no longer a workplace.

Furthermore, previous employers associated with abandoned wells may no longer be in existence, meaning liability must be carried by others.

In the absence of a party responsible for an abandoned well, the enforcement tools under the RMA could be used to require the owner or occupier of the land on which the problem exists, to undertake remedial action. However, there are reasonable arguments against taking this course of action. Land owners and occupiers are likely to have taken ownership and/or residence on the property without any knowledge of past petroleum operations. The cost of addressing well abandonment problems and the likely limited financial resources of property owners or occupiers means that effectively dealing with well abandonment issues may represent an insurmountable cost.

Currently there is no clear legislative framework through which to resolve these potential 'legacy' issues. However, the Crown is the regulator responsible for ensuring well integrity and that proper well abandonment standards are in place in the first instance. The Crown also owns and controls petroleum resources and derives benefits from their extraction through royalties etc. There are therefore strong arguments that the Crown should assume responsibility for any legacy issues associated with well abandonment.

11. Conclusions

The Taranaki Regional Council has had more than thirty years experience in regulating the environmental effects of the oil and gas sector, including exploration and production activities on and off shore (out to the 12 nautical mile boundary). This has involved developing with the community suitable policy, delivering this through plan provisions (e.g., permitted activities, resource consents, and prohibited activities), comprehensive compliance monitoring regimes and, where necessary, the full use of the enforcement provisions of the RMA. The approach also involves mechanisms to identify and learn from operational and regulatory best practice internationally. As a result the organisation has considerable capacity to offer other interested parties. This includes regulating hydraulic fracturing activities and associated waste disposal practices.

This document was prepared to guide other councils and give communities confidence that the actual and potential effects of oil and gas exploration, including hydraulic fracturing, are recognised and are being managed appropriately according to international good practice. The guide also aims to address some of the misconceptions and errors that have been publicised in the public debate about hydraulic fracturing and other industry activities.

While the guide is based on the experience of the Taranaki Regional Council in regulating oil and gas exploration activities, and specific investigations under Taranaki environmental conditions, the approach adopted is considered very useful for other councils and regulators to consider should the oil and gas industry apply for resource consents beyond the Taranaki region. The environmental effects assessment for such applications needs to be specific to the environmental conditions in each region. The level of subsurface information and confidence will also be a function of the extent of seismic assessment and the number of wells drilled.

Investigations have been undertaken into the hydrogeologic risk, seismic impact, impact of flare emissions, and a review of overseas environmental concerns and regulatory approaches for hydraulic fracturing. Land farming of drilling and other industry waste has also been reviewed. These investigations have been peer reviewed or undertaken by independent parties. They confirm the environmental effects are minor and the approach being adopted by the Council is appropriate in the circumstances.

Resource consent considerations for the hydraulic fracture subsurface discharge, return fluid discharge by deepwell injection and land farming, wellsite emissions, water abstraction, and landuse consent considerations for district councils are provided in some detail for consideration by other regulators.

Information on the Council's approach to cost recovery and public reporting of consent, compliance monitoring and enforcement activities are also provided.

Well integrity is the critical operational component to get right to avoid adverse environmental effects from normal well operations and where well pressures are increased with hydraulic fracturing and deep well injection of wastes activities. Regulation of this operational component is extremely important. Well integrity is currently regulated by the High Hazard Unit, within the Ministry of Business, Innovation and Employment, under the Health and Safety in Employment (Petroleum Exploration and Extraction) Regulations 2013. The Regulations are goal based to provide flexibility to keep pace with international best practice. Guidelines are currently being prepared by the Ministry of Business, Innovation and Employment to underpin the Regulations. Recent high profile offshore overseas experience has shown what can happen when well integrity fails and hydrocarbons are released to the environment. There is also a much smaller scale terrestrial example in New Zealand with the failure of the McKee 13 well in Taranaki in 1995. However, there have been no reported well integrity failures since the McKee 13 incident and the development of regulations that were put in place in 1999.

The possible factors that may influence future regulation of hydraulic fracturing and cause the Council's current approach to be reviewed are outlined as are future research and investigation needs to address any scientific and regulatory issues that have been identified. The report also identified some of the challenges for regulating oil and gas exploration activities including HF, given the multiple agencies that are involved, and comments on the available capacity to regulate the sector beyond Taranaki.

The guide outlines the regulations that apply to hydraulic fracturing activities, specifically the Resource Management Act 1981, the Crown Minerals Act 1991, and the Hazardous Substances and New Organisms Act 1996 (refer section 5). Clarity of roles and responsibilities, mechanisms to support integrated approaches and formal mechanisms to share information are considered important to achieve integrated management.

The UK Royal Society and the Royal Academy of Engineering, (2012) report finds

'the health, safety and environmental risks associated with hydraulic fracturing as a means to extract shale gas can be managed effectively in the UK as long as operational best practices are implemented and enforced through regulation.'

This is a very significant and authoritative statement on the subject, which should be allowed to fully inform the current national discussion. A comparison of current Council practice in New Zealand against the Royal Society's recommendations concerning good hydraulic fracturing practice indicates that the Council and New Zealand are well-positioned to demonstrate good practice, risk minimisation and management for future hydraulic fracturing operations.

The interim findings of the Parliamentary Commissioner for the Environment in evaluating the environmental impacts of fracking in New Zealand concluded the environmental risks associated with fracking can be managed provided operational best practices are implemented and enforced through regulation (Parliamentary Commissioner for the Environment, 2012).

Finally, the guide identifies and discusses some of the research needs and challenges for the future. These include the critical importance of ensuring well integrity as noted above and clarifying responsibilities and developing better mechanisms for dealing with well abandonment. There is a need for coordination and integration of regulatory activities across the various agencies and to better understand what others are doing, particularly if there are 'passive' as well as active regulatory regimes operating.

Glossary

This Glossary contains some of definitions of terms commonly used in the oil and gas industry.

An excellent online search-based glossary is the Schlumberger Oilfield Glossary which provides comprehensive definitions of major oilfield activities and which contains illustrations and photographs, and citations of significant technical papers for further reading. The Schlumberger Oilfield Glossary can be found at www.glossary.oilfield.slb.com/

Abandon
To cease work on a well which is non-productive, to plug off the well with cement plugs and salvage all recoverable equipment. Also used in the context of field abandonment.

Anticline
A fold in layered rocks originating below the surface in form of an elongated dome.

Associated gas
Natural gas produced with crude oil from the same reservoir.

Appraisal Well
A well drilled as part of an appraisal drilling programme which is carried out to determine the physical extent, reserves and likely production rate of a field.

Associated Gas
Natural gas associated with oil accumulations, which may be dissolved in the oil at reservoir conditions or may form a cap of free gas above the oil.

Barrel (bbl)
A unit of volume measurement used for petroleum and its products (7.3 barrels = 1 ton: 6.29 barrels = 1 cubic metre). 1 barrel = 35 Imperial gallons (approx.), or 159 litres (approx.).

bcf
Billion cubic feet; 1 bcf = 0.83 million tonnes of oil equivalent.

bcm
Billion cubic metres (1 cubic metre = 35.31 cubic feet).

Blow-out preventers
(BOPs) are high pressure wellhead valves, designed to shut off the uncontrolled flow of hydrocarbons.

Blow-out
When well pressure exceeds the ability of the wellhead valves to control it.

Bottom-hole assembly
Components, together as a group, that make up the lower end of the drill-string (drill bit, drill collars, drill pipe and ancillary equipment.)

Borehole
The hole as drilled by the drill bit.

Bridge plug
A downhole tool that is located and set to isolate the lower part of the wellbore. Bridge plugs may be permanent or retrievable, enabling the lower wellbore to be permanently sealed from production or temporarily isolated from a treatment conducted on an upper zone.

Cap Rock
Impervious layer which overlies a reservoir rock preventing hydrocarbons escaping.

Casing
Metal pipe inserted into a wellbore and cemented in place to protect both subsurface formations (such as groundwater) and the wellbore. A surface casing is set first to protect groundwater. The production casing is the last one set. The production tubing (through which hydrocarbons flow to the surface) will be suspended inside the production casing.

Casing string
The steel tubing that lines a well after it has been drilled. It is formed from sections of steel tube screwed together.

Choke
Device to restrict rate of flow during testing of an exploration discovery.

Christmas tree
The assembly of fittings and valves on the top of the casing which control the production rate of gas and oil.

Completion
The installation of permanent wellhead equipment for the production of oil and gas.

Condensate
Hydrocarbons which are in the gaseous state under reservoir conditions and which become liquid when temperature or pressure is reduced. A mixture of pentanes and higher hydrocarbons.

Coring
Taking rock samples from a well by means of a special tool -- a "core barrel".

Cuttings
Rock chippings cut from the formation by the drill bit, and brought to the surface with the mud. Used by geologists to obtain formation data.

Derrick
The tower-like structure that houses most of the drilling controls.

Development well
A well drilled within the proved area of an oil or gas reservoir to the depth of a stratigraphic horizon known to be productive; a well drilled in a proven field for the purpose of completing the desired spacing pattern of production.

Directional Drilling
Controlled drilling at a specified angle from the vertical.

Downhole
A term used to describe tools, equipment, and instruments used in the wellbore, or conditions or techniques applying to the wellbore.

Downstream
When referring to the oil and gas industry, this term indicates the refining and marketing sectors of the industry. More generically, the term can be used to refer to any step further along in the process.

Drill bit
Located at end of drill-string cutting head is generally designed with three cone-shaped wheels tipped with hardened teeth. Drill bits used for extra-hard rock are studded with thousands of tiny industrial diamonds.

Drill pipe
A steel pipe, in approximately 30-foot (9 metre) lengths, screwed together to form a continuous pipe extending from the drilling rig to the drilling bit at the bottom of the hole. Rotation of the drill pipe and bit causes the bit to bore through the rock.

Drill Stem Test (DSM)
A conventional method of testing a formation to determine its potential productivity before installing production casing in a well. A testing tool is attached to the bottom of the drill pipe and placed opposite the formation to be tested which has been isolated by placing packers above and below the formation. Fluids in the formation are allowed to flow up through the drill pipe by establishing an open connection between the formation and the surface.

Drilling fluids
While a mixture of clay and water is the most common drilling fluid, wells can also be drilled with air or water as the drilling fluid. See also Mud.

Drilling rig
A drilling unit that is not permanently fixed to the land, e.g. a drillship, a semi-submersible or a jack-up unit. Also means the derrick and its associated machinery.

Dry gas
Natural gas composed mainly of methane with only minor amounts of ethane, propane and butane and little or no heavier hydrocarbons in the gasoline range.

Dry hole
Any exploratory or development well that does not find commercial quantities of hydrocarbons.

E&A
Abbreviation for exploration and appraisal.

E&P
Abbreviation for exploration and production. The ‘upstream’ sector of the oil and gas industry.

Exploration well
Drilling carried out to determine whether hydrocarbons are present in a particular area or structure. Also known as a ‘wildcat well’.

Fairway

A mapped area in which the conditions for a particular play may occur.

Farm in
When a company acquires an interest in a block by taking over all or part of the financial commitment for drilling an exploration well.

Field
A geographical area under which an oil or gas reservoir lies.

Fishing
Retrieving objects from the borehole, such as a broken drillstring, or tools.

Formation
Sedimentary bed or deposit composed substantially of the same minerals throughout, and distinctive enough to be a unit.

Formation damage
The reduction in permeability in reservoir rock due to the infiltration of drilling or treating fluids into the area adjacent to the wellbore.

Formation pressure
The pressure at the bottom of a well when it is shut in at the wellhead.

Formation water
Salt water underlying gas and oil in the formation.

Fracturing
A method of breaking down a formation by pumping fluid at very high pressure. The objective is to increase production rates from a reservoir.

Gas field
A field containing natural gas but no oil.

Geology
Field of science concerned with the origin of planet earth, its history, its shape, materials forming it and processes that are acting or have acted on it.

Geologist
Scientist whose duties consist of obtaining and interpreting data dealing with the Earths history and its life, especially as recorded in rocks.

Horizontal Drilling
Technique for cutting a bore holes in geological strata in a horizontal, rather than normal vertical, direction.

Hydrocarbon
A compound containing only the elements hydrogen and carbon. May exist as a solid, a liquid or a gas. The term is mainly used in a catch-all sense for oil, gas and condensate.

Impermeable
When fluids cannot flow through rocks (clays, cemented sandstone or salt) where cracks and pore spaces are very small or are blocked by mineral growth

Injection well
A well used for pumping water or gas into the reservoir

Kick
Back pressure in a well from invading oil/gas/water.

Liner
Small diameter casing extending into producing layer from just inside bottom of final string of casing cemented in a well.

mmboe
Million Barrels Oil Equivalent.

Metric tonne
Equivalent to 1000 kilos, 2204.61 lbs; 7.5 barrels.

Migration
Natural movement of oil or gas within or out of a formation.

mmcfd
Millions of cubic feet per day (of gas).

Mud
A mixture of base substance and additives used to lubricate the drill bit and to counteract the natural pressure of the formation.

Usually colloidal suspensions of clays in water with chemical additives that are circulated through the wellbore during rotary drilling and workover operations. Water based muds (WBM) use water as the main medium, synthetic based muds (SBM) use lighter oils (eg sowing machine oil) as the medium, and oil based muds (OBM) use oil as the medium.

Midstream
A term sometimes used to refer to those industry activities that fall between exploration and production (upstream) and refining and marketing (downstream). The term is most often applied to pipeline transportation of crude oil and natural gas.

Natural Gas
Gas, occurring naturally, and often found in association with crude petroleum.

Oil
A mixture of liquid hydrocarbons of different molecular weights.

Oil field
A geographic area under which an oil reservoir lies.

Oil in place
An estimated measure of the total amount of oil contained in a reservoir, and, as such, a higher figure than the estimated recoverable reserves of oil.

Operator
The company that has legal authority to drill wells and undertake production of hydrocarbons. The operator is often part of a consortium and acts on behalf of this consortium.

Payzone
Rock in which oil and gas are found in exploitable quantities.

Perforate
To pierce holes through well casing within and oil or gas-bearing formation by means of a perforating gun lowered down the hole and fired electrically from the surface. The perforations permit production from a formation which has been cased off.

Permeability
The property of a formation which quantifies the flow of a fluid through the pore spaces and into the wellbore.

Petroleum
A generic name for hydrocarbons, including crude oil, natural gas liquids, natural gas and their products.

Play
A group of fields with similar trap structures/ reservoir rock.

P&A (plugged and abandoned)
A depleted well or dry hole that has been (typically) filled with cement and marked, with all surface equipment removed.

Porosity
A ratio between the volume of the pore space in reservoir rock and the total bulk volume of the rock. The pore space determines the amount of space available for storage of fluids.

Possible reserves
Those reserves which at present cannot be regarded as 'probable' but are estimated to have a significant but less than 50% chance of being technically and economically producible.

Primary recovery
Recovery of oil or gas from a reservoir purely by using the natural pressure in the reservoir to force the oil or gas out.

Probable reserves
Those reserves which are not yet proven but which are estimated to have a better than 50% chance of being technically and economically producible.

Produced water
The water extracted from the subsurface with oil and gas. It may include water from the reservoir, water that has been injected into the formation, and any chemicals added during the production/treatment process. Produced water is also called 'brine' (and may contain high mineral or salt content) or 'formation water'. Some produced water is quite fresh and may be used for livestock watering or irrigation (where allowed by law).

Production packer
A downhole device used in almost every completion to isolate the annulus from the production conduit, enabling controlled production, injection or treatment. A typical packer assembly incorporates a means of securing the packer against the casing or liner wall, such as a slip arrangement, and a means of creating a reliable hydraulic seal to isolate the annulus, typically by means of an expandable elastomeric element. Packers are classified by application, setting method and possible retrievability.

Proven field
An oil and/or gas field whose physical extent and estimated reserves have been determined.

Proven reserves
Those reserves which on the available evidence are virtually certain to be technically and economically producible (i.e. having a better than 90% chance of being produced).

Recoverable reserves
That proportion of the oil and/gas in a reservoir that can be removed using currently available techniques.

Recovery factor
The ratio of recoverable oil and/or gas reserves to the estimated oil and/or gas in place in the reservoir.

Reservoir
The underground formation where oil and gas has accumulated. It consists of a porous rock to hold the oil or gas, and a cap rock that prevents its escape.

Rotary Table/Drilling Table
Turning device on derrick floor in which drill-string is held and rotated.

Roughneck
Drill crew members who work on the derrick floor, screwing together the sections of drillpipe when running or pulling a drillstring.

Roustabout
Drill crew members who handle the loading and unloading of equipment and assist in general operations around the rig.

Royalty
A percentage interest in the value of production from a lease that is retained and paid to the Crown.

Secondary recovery
Recovery of oil or gas from a reservoir by artificially maintaining or enhancing the reservoir pressure by injecting gas, water or other substances into the reservoir rock.

Seismic Surveys
Measurements of seismic-wave travel. Seismic exploration is divided into refraction and reflection surveys, depending on whether the predominant portion of the seismic waves' travel is horizontal or vertical. Refraction seismic surveys are used in exploration. Seismic reflection surveys detect boundaries between different kinds of rocks; this detection assists in mapping of geologic structures.

Separation
The process of separating liquid and gas hydrocarbons and water. This is typically accomplished in a pressure vessel at the surface, but newer technologies allow separation to occur in the wellbore under certain conditions.

Shale shaker
Drilling mud passed over to sieve out cuttings.

Sidetracking
Drilling past an obstruction in the hole, usually done using a special tool known as a whipstock.

Spud-in
The operation of drilling the first part of a new well.

Stratigraphic trap
Formed by Earth movements that fold rocks into suitable shapes or juxtapose reservoir and sealing rocks along faults.

Structure
Subsurface geological feature capable of acting as a reservoir for oil and/or gas.

Stuck Pipe
Drill pipe, casing, or tubing that cannot be worked in or out of the hole as desired.

Suspended well
A well that has been capped off temporarily.

Syncline
Trough-shaped subsurfaces structure of folded stratified rock. Opposite of anticline.

tcf
Trillion Cubic Feet (of gas).

Tubing
Pipe in the annulus suspended from hangers for various purposes, including production. Packers hold the tubing in place in the annulus.

Tubing hanger
A device attached to the topmost tubing joint the wellhead to support the tubing string. The tubing hanger typically is located in the tubing head, with both components incorporating a sealing system to ensure that the tubing conduit and annulus hydraulically isolated.

Toolpusher
Second-in-command of a drilling crew under the drilling superintendent. Responsible for the day-to-day running of the rig and for ensuring that all the necessary equipment is available.

Top Drive
Powerful electric motor that rotates whole drill-string from top down.

Total Depth
Maximum depth reached in a well.

Tripping
Re-insertion of drill-string/ withdrawing drill-string.

Upstream
The exploration and production portions of the oil and gas industry.

Wellhead
The equipment at the surface of a well used to control the pressure; the point at which the hydrocarbons and water exit the ground

Well log
A record of geological formation penetrated during drilling, including technical details of the operation.

Wet gas
Natural gas containing significant amounts of liquifiable hydrocarbons.

Wildcat well
A well drilled in an area where no current oil or gas production exists.

Workover
Operations on a producing well to restore or increase production. A workover may be performed to stimulate the well, remove sand or wax from the wellbore, to mechanically repair the well, or for other reasons.

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Appendix I

Example of consent conditions and a conditions analysis table for a subsurface hydraulic fracture discharge

Consent 9457-1

That application 7283, to discharge contaminants associated with hydraulic fracturing activities into land at depths greater than 3200 mTVDss beneath the Mangahewa-E wellsite, be approved for a period to 1 June 2020, subject to the following conditions:

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 into the reservoir after 1 June 2015.

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). Useable 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. The Monitoring Programme shall include sampling of groundwater from a bore installed in accordance with NZS 4411:2001. The bore shall be of a depth, location and design determined after consultation with the Chief Executive, Taranaki Regional Council.

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

   (a) pH;
   (b) conductivity;
   (c) total dissolved solids;
   (d) major ions (Ca, Mg, K, Na, total alkalinity, bromide, chloride, nitrate-nitrogen, and sulphate);
   (e) trace metals (barium, copper, iron, manganese, nickel, and zinc);
   (f) total petroleum hydrocarbons;

(g) formaldehyde;
(h) dissolved methane and ethane gas;
(i) methanol;
(j) glycols;
(k) benzene, toluene, ethylbenzene, and xylenes (BTEX); and
(l) carbon-13 composition of any dissolved methane gas discovered ($^{13}C-CH_4$).

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. This plan shall specify the use of standard protocols recognised to constitute good professional practice including quality control and assurance. An International Accreditation New Zealand (IANZ) accredited laboratory shall be used for all sample analysis. Results shall be provided to the Chief Executive within 30 days of sampling and shall include supporting quality control and assurance information. These results will be used to assess compliance with condition 3.

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

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

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

(a) the specific well in which each discharge is to occur, the intended fracture interval(s) ('fracture interval' is the discrete subsurface zone to receive a hydraulic fracture treatment), and the duration of the hydraulic fracturing programme;
(b) the number of discharges proposed and the geographical position (i.e. depth and lateral position) of each intended discharge point;
(c) the total volume of fracture fluid planned to be pumped down the well, including mini- fracture treatments, and their intended composition, including a list of all contaminants and Material Safety Data Sheets for all the chemicals to be used;
(d) the results of the reviews required by condition 14;
(e) results of modelling showing an assessment of the likely extent and dimensions of the fractures that will be generated by the discharge;
(f) the preventative and mitigation measures to be in place to ensure the discharge does not cause adverse environmental effects and complies with condition 3;
(g) the extent and permeability characteristics of the geology above the discharge point to the surface;

(h) any identified faults within the modeled fracture length plus a margin of 50%, and the potential for adverse environmental effects due to the presence of the identified faults;
(i) the burst pressure of the well and the anticipated maximum well and discharge pressures and the duration of the pressures; and
(j) details of the disposal of any returned fluids, including any consents that are relied on to authorise the disposal.

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

10. The consent holder shall notify the Taranaki Regional Council of each discharge by emailing worknotification@trc.govt.nz. Notification shall include the date that the discharge is to occur and identify the 'Pre-fracturing discharge report', required by condition 9, which details the discharge. Where practicable and reasonable notice shall be given between 3 days and 14 days before the discharge occurs, but in any event 24 hours notice shall be given.

11. At the conclusion of a hydraulic fracturing programme on a given well, the consent holder shall submit a comprehensive 'Post-fracturing discharge report' to the Chief Executive. The report shall be provided within 60 days after the programme is completed and, as a minimum, shall contain:

(a) confirmation of the interval(s) where fracturing occurred for that programme, and the geographical position (i.e. depth and lateral position) of the discharge point for each fracture interval;
(b) the contaminant volumes and compositions discharged into each fracture interval;
(c) the volume of return fluids from each fracture interval;
(d) an analysis for the constituents set out in conditions 6(a)to 6(k), in a return fluid sample taken within the first two hours of flow back, for each fracture interval if flowed back individually, or for the well if flowed back with all intervals comingled;
(e) an estimate of the volume of fluids (and proppant) remaining underground;
(f) the volume of water produced with the hydrocarbons (produced water) over the period beginning at the start of the hydraulic fracturing programme and ending 50 days after the programme is completed or after that period of production;
(g) an assessment of the extent and dimensions of the fractures that were generated by the discharge, based on modelling undertaken after the discharge has occurred and other diagnostic techniques, including production analysis, available to determine fracture length, height and containment;
(h) the results of pressure testing required by condition 8, and the top hole pressure (psi), slurry rate (bpm), surface proppant concentration (lb/gal), bottom hole proppant concentration (lb/gal), and calculated bottomhole

pressure (psi), as well as predicted values for each of these parameters; prior to, during and after each hydraulic fracture treatment;

(i) details of the disposal of any returned fluids, including any consents that are relied on to authorise the disposal;

(j) details of any incidents where hydraulic fracture fluid is unable to pass through the well perforations (screen outs) that occurred, their likely cause and implications for compliance with conditions 1 and 3; and

(k) an assessment of the effectiveness of the mitigation measures in place with specific reference to those described in the application for this consent.

12. The reports described in conditions 9 and 11 shall be emailed to consents@trc.govt.nz 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 are undertaken of the preventative and mitigation measures adopted to ensure the discharge does not cause adverse environmental effects; and

(c) regular reviews of the chemicals used are undertaken with a view to reducing the toxicity of the chemicals used.

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

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

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

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

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

Condition Analysis Table Consent 9457-1

No.	Description	Reason for condition	Determination of compliance	Reason for limits
1	Minimum discharge depth	As applied for and necessary to avoid adverse effects on fresh water resources above.	Information provided in Post fracturing report provided in accordance with condition 11.	As requested in the application.
2	Last HF discharge date	The consent relates to a HF programme which will be completed by that date, though monitoring may be needed beyond that date.		N/A
3	No contaminants reaching fresh water	The other conditions of this consent are expected to protect fresh water. However, the inclusion of the condition is reasonably needed to provide sufficient assurance that adverse effects on usable water resources are avoided.	Monitoring undertaken in accordance with condition 3	TDS is used as an indicator of salinity and a level of 1000 mg/l is noted in the ANZEEC Guidelines as the maximum for potable water.
4 5 6 & 7	Water quality monitoring	To establish baseline and post HF water quality data to confirm that adverse environmental effects on water are avoided. It is very unlikely that any escape of chemicals or adverse environmental effects will occur as a result of HF discharges. However, a comprehensive monitoring programme (including drilling of a monitoring bore if no suitable one exists) is necessary to provide the public with a reasonable level of assurance that any such occurrence would be detected and its effects evaluated. Depending on the suitability of existing bores within 500 m of the wellsite for obtaining a representative groundwater sample, it may be necessary for the Monitoring Programme to include installation of, and sampling from, a monitoring bore and condition 5 will be required. The bore would be of a suitable depth, location and design and installed in accordance with NZS 4411:2001.	Reports, analyses and other information provided as required by the conditions.	See discussion in report.
8	Pressure testing for well and equipment integrity	To help confirm that the integrity of the well and equipment so that any adverse environmental effects associated with the HF material escaping from the well or equipment are avoided.	Testing undertaken and information supplied to the Council including the burst pressure and other information required by conditions 9(i) and 11(h).	N/A

No.	Description	Reason for condition	Determination of compliance	Reason for limits
9	Pre-fracturing discharge report	Details of the discharge are reasonably needed to enable checking of compliance with conditions, and consistency with details provided, and assessed, in the application and AEE.	Required information supplied within time.	Provision of the report 14 days beforehand is reasonable for the Council to plan for any monitoring work required and assess the information provided. The distance specified in condition 9(h) is reasonable in the circumstances.
10	Notice to Council	So that the Council has the opportunity to monitor the discharge for compliance with any conditions.	Notice received.	Timing specified is reasonable.
11	Post-fracturing discharge report	To confirm that details of the activity are consistent with the application and that the discharge complies with the conditions of the consent. In particular it provides information essential to providing confidence that discharged material remains within the fracture interval or is otherwise accounted for and does not reach fresh water.	Information provided within time.	60 days is a reasonable period for the information to be collected and provided. 50 days is a reasonable period to monitor produced water to account for HF fluids that are included in it.
12	Notification method	Reasonably needed to ensure RMA processes occur efficiently.	Notice received as required.	N/A
13	Allow access for sampling	Sampling reasonably needed to ensure appropriate compliance monitoring can occur.	Access provided.	N/A
14	Adoption of best practicable option (BPO)	This condition requires that a higher standard than that required by the conditions be met if it can reasonably be achieved, recognising the definition of BPO in the RMA. It also requires the consent holder to continually review methods and practices and make reasonable improvements even though the conditions are being met. The condition is reasonably necessary to avoid adverse environmental effects.	General observation, checking of records and information provided, in particular information about reviews required by condition 9(d).	N/A
15	Composition of HF fluid	Ensures the discharge is consistent with that applied for and assessed, and ensures that the adverse environmental effects associated with hydrocarbon based HF fluids are avoided.	Information provided in the pre and post fracturing reports, in particular the information required by conditions 9(c) and 11(b). Analysis of HF discharge fluid as required.	Percentage specified is consistent with that specified in the application.
16	Review	In general conditions of consent can only be reviewed if provision to do so is included in the consent. The Council's preference is to make provision to review the conditions of all consents to ensure that the conditions continue to be appropriate and effective. This is as an alternative to granting consents for a shorter duration.	N/A	The frequency and timing of the reviews is appropriate having considered the duration of the consent, its likely environmental effects, the adequacy of the knowledge of those effects, and the monitoring conditions.

Appendix II

Example of consent conditions and a conditions analysis table for a subsurface deepwell injection discharge

Consent 9470-1

That application 7302, to discharge produced water, well drilling fluids, well workover fluids into the Mount Messenger Formation by deepwell injection via the Kaimiro-G wellsite, be approved for a period to 1 June 2032, subject to the following conditions:

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. Before this consent is exercised, the consent holder shall submit an "Injection Operation Management Plan" which shall include the operational details of the injection activities and identify the conditions that would trigger concerns about the integrity of the injection well, injection zone or overlying geological formations. The plan will also detail the action(s) to be taken by the consent holder if trigger conditions are reached.

2. Before this consent is exercised the consent holder shall provide to the Chief Executive of the Taranaki Regional Council:

   (a) a final well completion log for the injection well including subsurface construction details, design of the exterior surface casing, the intermediate protective casing, and the innermost casing, tubing, and/or packer(s);
   (b) well cementing details, cement bond log and results of annular pressure testing which demonstrates well integrity;
   (c) details of on-going well integrity monitoring, well maintenance procedures and safe operating limits for the well;
   (d) a detailed geological log of the well;
   (e) details and results of the Formation Integrity Testing carried out on the receiving formation and confining layers and an assessment of the results against the estimated modelled values submitted in the consent application 7302;
   (f) results of an electrical resistivity survey, clearly showing the confirmed depth of freshwater as defined in condition 11; and
   (g) a full chemical analysis of the receiving formation-water.

   (Note: These details can be included within the "Injection Operation Management Plan.")

3. The injection pressure at the wellhead shall not exceed 1,077 psi (73 bars). If exceeded, the injection operation shall be ceased immediately and the Chief Executive of the Taranaki Regional Council informed immediately.

4. The rate of injection shall not exceed 8.6 cubic metres per hour (0.9 bpm)

5. The volume of fluid injected shall not exceed 206 cubic metres per day (1,296 bpd).

6. The injection of fluids shall be confined to the Mt. Messenger Formation, deeper than -995 metres True Vertical Depth Sub-sea.

7. 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 minimise any actual or likely adverse effect on the environment; in particular, ensuring that the injection material is contained within the injection zone.

8. Only the fluids listed below and originating from the consent holder's operations may be discharged:

   (a) produced water;
   (b) well drilling fluids;
   (c) well workover fluids, including hydraulic fracturing return fluids; and
   (d) contaminated stormwater.

9. Once the consent is exercised, the consent holder shall keep daily records of the:

   (a) total injection hours;
   (b) volume of fluid injected;
   (c) maximum and average rate of injection; and
   (d) maximum and average injection pressure.

10. For each waste stream arriving on site for discharge, the consent holder shall record the following information:

   (a) type of fluid;
   (b) source of fluid (site name and location);
   (c) an analysis of the fluid for:
      (i) pH;
      (ii) suspended solids concentration;
      (iii) temperature;
      (iv) salinity;
      (v) chloride concentration; and
      (vi) total hydrocarbon concentration.

   The analysis required by condition 10(c) above is not necessary if a sample of the same type of fluid, from the same source, has been taken, analysed and provided to the Chief Executive, Taranaki Regional Council within the previous 6 months.

11. The information required by conditions 9 and 10 above, for each calendar month, shall be provided to the Chief Executive, Taranaki Regional Council before the 15th day of the following month.

12. 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.

13. 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 12 (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 sampling sites;
(b) well/bore construction details; and
(c) sampling frequency.

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

(a) pH;
(b) conductivity;
(c) chloride; and
(d) total petroleum hydrocarbons.

<u>Note</u>: *The samples required, under conditions 13 and 14, could be taken and analysed by the Council or other contracted party on behalf of the consent holder.*

15. 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 12.

<u>Note</u>: *The Sampling and Analysis Plan may be combined with the Monitoring Programme required by condition 13.*

16. The consent holder shall provide to Taranaki Regional Council, during the month of July of every year, a summary of all data collected and a report detailing compliance with consent conditions over the previous 1 July to 30 June period. The report shall also provide and assess data which illustrates the on-going integrity and isolation of the wellbore, well performance and condition. The consent holder shall also provide an updated injection modeling report, illustrating the ability of the receiving formation to continue to accept additional waste fluids and estimating its remaining storage capacity.

17. The consent holder shall notify the Chief Executive, Taranaki Regional Council, in writing at least 5 days prior to the first exercise of this consent. Notification shall include the consent number and a brief description of the activity consented and be emailed to worknotification@trc.govt.nz.

18. There shall be no fluids discharged under this consent after 1 June 2027.

19. In accordance with section 128 and section 129 of the Resource Management Act 1991, the Taranaki Regional Council may serve notice of its intention to review, amend, delete or add to the conditions of this resource consent by giving notice of review during the month of June each year, for the purpose of ensuring that the conditions are adequate to deal with any adverse effects on the environment arising from the exercise of this resource consent, which were either not foreseen at the time the application was considered or which it was not appropriate to deal with at the time.

Condition Analysis Table Consent 9470-1

No.	Description	Reasons for condition	Determination of compliance	Reason for limit
1	Submit and operate in accordance with approved Injection Management Plan.	Avoiding adverse effects on groundwater by ensuring integrity of injection well and the receiving and confining geological formations.	Assessment by Council Officers.	N/A
2	Supply of specific data relating to injection well construction, testing, monitoring, maintenance and detail the properties of receiving and confining geological formations.	Details required to ensure the injection well is fit for purpose and will be maintained in such condition. Details of the geological properties of the receiving and confining formations are fundamental in ensuring the proposed operation and management of injection activities will ensure protection of local groundwater resources.	Assessment of data supplied by the applicant by Council Officers.	N/A
3 & 4	Limit the maximum fluid injection pressure and flow rate to the receiving formation.	To reasonably protect the receiving formation from pressures and flows capable of causing fracturing, thereby avoiding adverse environmental effects associated with fracturing of the formation.	Information provided under condition 9.	As requested in the application.
5	Maximum injection volume.	Limits the effects of the discharge to that applied for and assessed.	Information provided under condition 9.	Calculated based on maximum injection rate requested in the application.
6	Restricting the depth of discharge to the proposed receiving formation.	Necessary to limit the effects to that assessed in the application.	Injection of fluids to occur into the specified formation, at a depth of at or below -1,000 m TVDSS. Well completion and geological logs indicate injection as proposed	Proposed injection interval and formation as specified in the application
7	Adoption of best practicable option.	This condition requires that a higher standard than that required by the conditions be met if it can reasonably be achieved. It also requires the consent holder to continually review methods and practices and make reasonable improvements even though the conditions are being met. The condition is reasonably necessary to avoid adverse environmental effects.	General observation and checking of records.	N/A
8	Limit the type and origin of fluids that can be discharged via the injection well.	Necessary to limit the effects to that assessed in the application	Information provided by condition 10	As requested in the application.
9 & 10	Maintain records of injection activities and composition of injected fluid.	Check compliance with consent conditions.	Information received within specified timeframes and assessment by Council.	N/A

No.	Description	Reasons for condition	Determination of compliance	Reason for limit
11	Provision of information	Check compliance with consent conditions.	Information provided as required	Records at least necessary for timely monitoring of compliance.
12	Ensure useable freshwater resources are not contaminated by the discharge	The other conditions of this consent are expected to protect freshwater resources. However the inclusion of the condition is reasonably needed to ensure adverse effects are avoided. Reasonably needed to avoid adverse effects on groundwater resources	Monitoring undertaken as specified in conditions 13, 14 & 15.	N/A
13, 14 & 15	Water quality monitoring	To establish baseline and post discharge water quality data to confirm that adverse environmental effects on water are avoided.	Reports, analyses and other information provided as required by the conditions.	Relevant water quality standards/guidelines.
16	Submission of annual report.	Reasonably needed to check compliance with consent conditions, monitor environmental effects and assess environmental risk.	Annual report submitted to council, during the month of May each year.	Annual reporting is reasonable.
17	Notification of discharge occurring.	Provides Council with an opportunity to monitor the activity.	Notice received	5 days is sufficient for the Council to organise monitoring.
18	Last DWI discharge date	Allows for the monitoring to be continued after discharge has ceased and potential effects associated with the activity have diminished to an acceptable level.	N/A	N/A
19	Review	In general, conditions of consent can only be reviewed if provision to do so is included in the consent. The Council's preference is to make provision to review the conditions of all consents to ensure that the conditions are effective, as an alternative to granting consents for a shorter duration.	N/A	The frequency and timing of the reviews is appropriate having considered the duration of the consent, its likely environmental effects, and the adequacy of the knowledge of those effects.

Appendix III

Example of consent conditions and a conditions analysis table for a land farming discharge

Consent 7795-1

That application 6705, to discharge drilling wastes (consisting of drilling cuttings and drilling fluids from water based muds and synthetic based muds), from hydrocarbon exploration and production activities, onto and into land via landfarming, be approved to 1 June 2028, subject to the following conditions:

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. For the purposes of this consent the following definitions shall apply:
   a) stockpiling means a discharge of drilling wastes from vehicles, tanks, or other containers onto land for the purpose of interim storage prior to landfarming, but without subsequently spreading onto, or incorporating the discharged material into the soil within 48 hours; and
   b) landfarming means the discharge of drilling wastes onto land, subsequent spreading and incorporation into the soil, for the purpose of attenuation of hydrocarbon and/or other contaminants, and includes any stripping and relaying of topsoil.

2. The consent holder shall adopt the best practicable option (as defined section 2 of the Resource Management Act 1991) to prevent or minimise any actual or potential effects on the environment arising from the discharge.

Requirements prior to exercise of consent

3. Prior to the exercise of this consent, the consent holder shall provide a stockpiling and landfarming management plan that, to the reasonable satisfaction of the Chief Executive, Taranaki Regional Council, demonstrates the activity can and will be conducted to comply with all of the conditions of this consent. The management plan shall be reviewed annually (on or about the anniversary of the date of issue of this consent) and shall include as a minimum:
   a) procedures for notification to Council of disposal activities;
   b) procedures for the receipt and stockpiling of drilling wastes onto the site;
   c) methods used for the mixing and testing of different waste types;
   d) procedures for site preparation;
   e) procedures for landfarming drilling wastes (including means of transfer from stockpiling area, means of spreading, and incorporation into the soil);
   f) procedures for sowing landfarmed areas, post-landfarming management, monitoring and site reinstatement;
   g) contingency procedures;
   h) sampling regime and methodology;
   i) control of site access; and
   j) documentation for all the procedures and methods listed above.

4. Prior to the exercise of this consent, the consent holder shall after consultation with the Chief Executive, Taranaki Regional Council, install a minimum of three groundwater monitoring bores. The bores shall be at locations and to depths, that enable monitoring to determine any change in groundwater quality resulting from the exercise of this consent. The bores shall be installed in accordance with NZS 4411:2001 and all associated costs shall be met by the consent holder.

Notifications, monitoring and reporting

5. The consent holder shall notify the Chief Executive, Taranaki Regional Council, (by emailing worknotification@trc.govt.nz) at least 48 hours prior to permitting drilling wastes onto the site for stockpiling, from each well drilled. Notification shall include the following information:

   a) the consent number;
   b) the name of the well(s) from which the waste was generated;
   c) the type of waste to be stockpiled; and
   d) the volume of waste to be stockpiled.

6. The consent holder shall notify the Chief Executive, Taranaki Regional Council, (by emailing worknotification@trc.govt.nz.) at least 48 hours prior to landfarming stockpiled material, or material brought onto the site for landfarming within 48 hours. Notification shall include the following information:

   a) the consent number;
   b) the name of the well(s) from which the waste was generated;
   c) the type of waste to be landfarmed;
   d) the volume and weight (or density) of the waste to be landfarmed;
   e) the concentration of chlorides, nitrogen and hydrocarbons in the waste; and
   f) the specific location and area over which the waste will be landfarmed.

7. The consent holder shall take a representative sample of each type of waste, from each individual source, and have it analysed for the following:

   a) total petroleum hydrocarbons (C6-C9, C10-C14, C15-C36);
   b) benzene, toluene, ethylbenzene, and xylenes;
   c) polycyclic aromatic hydrocarbons screening; and
   d) chloride, nitrogen, pH, potassium, and sodium.

8. The consent holder shall keep records of the following:

   a) wastes from each individual well;
   b) composition of wastes (in accordance with condition 5);
   c) stockpiling area(s);
   d) volumes of material stockpiled;
   e) landfarming area(s), including a map showing individual disposal areas with GPS co-ordinates;
   f) volumes and weights of wastes landfarmed;
   g) dates of commencement and completion of stockpiling and landfarming events;
   h) dates of sowing landfarmed areas;
   i) treatments applied; and

j) details of monitoring, including sampling locations, sampling methods and the results of analysis;

and shall make the records available to the Chief Executive, Taranaki Regional Council.

9. The consent holder shall provide to the Chief Executive, Taranaki Regional Council, by 31 August of each year, a report on all records required to be kept in accordance with condition 6, for the period of the previous 12 months, 1 July to 30 June.

Discharge limits

10. The discharge shall only occur on the disposal sites shown in the Drawing entitled 'Remediation NZ Ltd Proposed Disposal Site' submitted with the application and attached to this consent.

11. There shall be no discharge within buffer zone, being:

- 25 metres of the Manawapou River;
- 25 metres of the unnamed tributary;
- 10 metres from any property boundary; and
- 50 metres from the QE II covenant Key Native Ecosystem areas.

12. For the purposes of landfarming, drilling wastes shall be applied to land in a layer not exceeding:

a) 100 mm thick for wastes with a hydrocarbon concentration less than 50,000 mg/kg dry weight;
b) 50 mm thick for wastes with a hydrocarbon concentration equal to or greater than 50,000 mg/kg dry weight; and
c) in a rate and manner such that no ponded liquids remain after one hour, for all wastes;

prior to incorporation into the soil.

13. As soon as practicable following the application of solid drilling wastes to land, the consent holder shall incorporate the wastes into the soil to a depth of at least 250 mm.

14. The hydrocarbon concentration in the soil over the landfarming area shall not exceed 50,000 mg/kg dry weight at any point where:

a) liquid waste has been discharged; or
b) solid waste has been discharged and incorporated into the soil.

15. An area of land used for the landfarming of drilling wastes in accordance with conditions 10 and 11 of this consent, shall not be used for any subsequent discharges of drilling waste.

Operational requirements

16. All material must be landfarmed as soon as practicable, but no later than twelve months after being brought onto the site.

17. As soon as practicable following landfarming, areas shall be sown into pasture (or into crop). The consent holder shall monitor revegetation and if adequate establishment is not achieved within two months of sowing, shall undertake appropriate land stabilisation measures to minimise wind and stormwater erosion.

Receiving environment limits - water

18. The exercise of this consent shall not result in the concentration of total dissolved salts in any fresh water body exceeding 2500 g/m3.

19. Other than as provided for in condition 18, the exercise of this consent shall not result in any contaminant concentration, within surface water or groundwater, which after reasonable mixing, exceeds the background concentration for that particular contaminant.

Receiving environment limits - soil

20. The conductivity of the soil/waste layer after landfarming shall be less than 400 mS/m, or alternatively, if the background soil conductivity exceeds 400 S/m, the landfarming of waste shall not increase the soil conductivity by more than 100 mS/m.

21. The sodium adsorption ratio (SAR) of the soil/waste layer after landfarming shall be less than 18.0, or alternatively if the background soil SAR exceeds 18.0, the landfarming of waste shall not increase the SAR by more than 1.0.

22. The concentration of heavy metals in the soil over the disposal area shall at all times comply with the Ministry for the Environment and New Zealand Water & Wastes Association's Guidelines for the safe application of biosolids to land in New Zealand (2003), as shown in the following table:

Constituent	Standard (mg/kg dry weight)
Arsenic	20
Cadmium	1
Chromium	600
Copper	100
Lead	300
Mercury	1
Nickel	60
Zinc	300

23. From 1 March 2028 (three months prior to the consent expiry date), constituents in the soil shall not exceed the standards shown in the following table:

Constituent	Standard
conductivity	290 mS/m
chloride	700 mg/kg
sodium	460 mg/kg
total soluble salts	2500 mg/kg
MAHs PAHs TPH	Guidelines for Assessing and Managing Petroleum Hydrocarbon Contaminated Sites in New Zealand (Ministry for the Environment, 1999). Tables 4.12 and 4.15, for soil type sand.

MAHs - benzene, toluene, ethylbenzene, xylenes
PAHs - napthalene, non-carc. (pyrene), benzo(a)pyrene eq.
TPH - total petroleum hydrocarbons (C7-C9, C10-C14, C15-C36)

The requirement to meet these standards shall not apply if, before 1 March 2028, the consent holder applies for a new consent to replace this consent when it expires, and that application is not subsequently withdrawn.

24. This consent may not be surrendered at any time until the standards in condition 23 have been met.

Archaeological remains

25. In the event that any archaeological remains are discovered as a result of works authorised by this consent, the works shall cease immediately at the affected site and tangata whenua and the Chief Executive, Taranaki Regional Council, shall be notified within one working day. Works may recommence at the affected area when advised to do so by the Chief Executive, Taranaki Regional Council. Such advice shall be given after the Chief Executive has considered: tangata whenua interest and values, the consent holder's interests, the interests of the public generally, and any archaeological or scientific evidence. The New Zealand Police, Coroner, and Historic Places Trust shall also be contacted as appropriate, and the work shall not recommence in the affected area until any necessary statutory authorisations or consents have been obtained.

Lapse and review

26. This consent shall lapse on 30 June 2017, 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.

27. In accordance with section 128 and section 129 of the Resource Management Act 1991, the Taranaki Regional Council may serve notice of its intention to review, amend, delete or add to the conditions of this resource consent by giving notice of review during the month of June 2016 and/or June 2022, for the purpose of ensuring that the conditions are adequate to deal with any adverse effects on the environment arising from the exercise of this resource consent, which were either not foreseen at the time the application was considered or which it was not appropriate to deal with at the time.

Condition Analysis Table Consent 7795-1

No.	Description	Reasons for condition	Determination of compliance	Reason for limit
1.	Definitions	To clarify the terminology used in consent conditions.	N/A	N/A
2.	Best practicable option	This condition requires that a higher standard than that required by the conditions be met if it can reasonably be achieved. It also requires the consent holder to continually review methods and practices and make reasonable improvements even though the conditions are being met. The condition is reasonably necessary to avoid adverse environmental effects.	General observation and checking of records	N/A
3.	Maintenance of and adherence to a management plan	Ensures the discharge is within the scope of the application and the authorised activity. The condition ensures that the consent holder continues to review (in a pro-active manner) the way in which operations at the site are undertaken to ensure compliance with the consent. It also ensures that procedures in place for staff to follow to ensure consent compliance remain relevant. For the consent holder, it is also a means of documenting how special condition 2 (adoption of the best practicable option) has been determined, and put into practice at the site. Answers the question "During this operation a spill could happen. What controls could prevent it, and therefore avoid a breach of consent conditions.	Review of plan submitted to Council and assessment of implementation at inspection by a Council officer	N/A
4.	Monitoring bores installation	To allow groundwater monitoring to assess effects from the activity and to confirm that adverse effects are being adequately avoided, remedied or mitigated.	Liaison prior to installation to determine suitable locations. Checking of the wells by a Council officer once installed.	N/A
5.	Notice to Council (stockpiling)	So that the Council has the opportunity to monitor the activity for compliance with consent conditions.	Notice received	48 hours prior is sufficient for the Council to organise an inspection.
6.	Notice to Council (landfarming)	So that the Council has the opportunity to monitor the activity for compliance with consent conditions.	Notice received	48 hours prior is sufficient for the Council to organise an inspection.
7.	Analysis of wastes	Necessary to assess the nature of the wastes being discharged.	Review of consent holders records.	N/A
8.	Records to be kept	Reasonably needed to determine compliance with consent conditions.	Liaison with consent holder and provision of records in the annual report.	N/A
9.	Annual report	So that the Council has all of the information required to assess compliance with the consent conditions.	Report received and sufficiently detailed.	Two months after the end of the monitoring year should be sufficient for the consent holder to prepare the report. Required annually for the Council to complete an annual monitoring report.
10.	Discharge area	As specified by the applicant	Inspection by a Council officer and review of consent holders records.	N/A
11.	Buffer distance	Necessary to adequately avoid adverse effects from wastes or contaminated stormwater flowing into surface water courses or onto neighbouring properties.	Inspection by a Council officer	Buffer distances will be adequate to prevent the overland or through flow of contaminants and are

No.	Description	Reasons for condition	Determination of compliance	Reason for limit
				consistent with buffer distances specified in the RFWP, with additional distance required for the QE II sites.
12.	Waste application thickness	At the maximum thickness biodegradation of the hydrocarbon content in the waste occurs in a period of time that appropriately mitigates adverse effects.	Inspection by a Council officer and review of consent holders records.	The specified limits will result in a ratio of waste to soil that includes a sufficient population of soil microbes to break- down hydrocarbons in the waste.
13.	Incorporation of waste into soil	The waste needs to be mixed with soil so that microbes naturally occurring in the soil come into contact with, and break-down, the hydrocarbon content in the waste.	Inspection by a Council officer.	The specified limit is that which can be reasonably achieved with modern agricultural equipment.
14.	Soil/waste hydrocarbon limit	To ensure that the soil is not overloaded with hydrocarbons and that biodegradation occurs in a reasonable period of time.	Results of soil sampling by a Council officer and/or review of soil sampling results provided to Council by the consent holder.	The specified limits ensure that the soil is not overloaded with hydrocarbons and that biodegradation occurs in a reasonable period of time.
15.	Single application of waste to a single area of land only	Reasonable necessary to avoid the accumulation of contaminants which do not biodegrade or leach from the soil. Multiple applications also increase risks to groundwater.	Inspection by a Council officer and review of consent holders records.	N/A
16.	Limit on stockpiling period	To avoid significant adverse effects wastes need to be landfarmed in a reasonable period of time so that they are bioremediated and risks to the environment from stockpiling are minimised.	Inspection by a Council officer and review of consent holders records.	Twelve months is sufficient for operators to plan around wellsite activities and unfavourable weather.
17.	Resowing	Pasture/crop establishment prevents erosion and encourages microbial activity, thereby avoiding significant adverse effects.	Inspection by a Council officer and review of consent holders records.	Two months is sufficient time to establish pasture/crop cover if sowing is undertaken at a suitable time of year.
18.	Limit on total dissolved salts in fresh water bodies	To protect fresh water for potential use by animals.	Results of water sampling by a Council officer and/or review of water sampling results provided to Council by the consent holder.	The limit is that referred to in the TRC Guidelines and is considered appropriate.
19.	Contaminant concentrations in surface water and groundwater shall not exceed background	Reasonably needed to prevent adverse effects on water immediately down-gradient or downstream as a result of the activity.	Results of water sampling by a Council officer and/or review of water sampling results provided to Council by the consent holder.	No increase after reasonable mixing is achievable and reasonably necessary in meeting Part 2 of the RMA.
20.	Limit on soil/waste conductivity	Reasonably necessary to avoid significant adverse effects by ensuring soil quality is maintained so that the bioremediation of wastes occurs and the land is properly reinstated.	Results of soil sampling by a Council officer and/or review of soil sampling results provided to Council by the consent holder.	The limit is that referred to in the TRC Guidelines and is considered appropriate.
21.	Limit on SAR	Reasonably necessary to avoid significant adverse effects by ensuring soil quality is maintained so that the bioremediation of wastes occurs and the land is properly reinstated.	Review of soil sampling results provided to Council by the consent holder.	The limit is that referred to in the TRC Guidelines and is considered appropriate.
22.	Limit on metal concentrations in the soil	To ensure that land is fit for the most sensitive future land use, upon completion of the process.	Review of soil sampling results provided to Council by the consent holder.	The guidelines are considered the most appropriate to ensure that land is fit for the most

No.	Description	Reasons for condition	Determination of compliance	Reason for limit
				sensitive future land use, upon completion of the process.
23.	Limits for certain parameters in the soil at the time of expiry, or surrender of the consent	To ensure effects are adequately mitigated before the consent holder relinquishes responsibility for it.	Results of soil sampling by a Council officer and/or review of soil sampling results provided to Council by the consent holder.	Limits are taken from the TRC and MfE Guidelines which are considered the most appropriate.
24.	Condition 22 must be met prior to surrender	As above	As above	As above
25.	Discovery of archaeological remains	Recognising and providing for the values of Tangata Whenua is necessary to meet the requirements of Part 2 of the RMA, the RPS and Regional Plans. Avoiding, where possible, but otherwise appropriately mitigating adverse effects on waahi tapu is essential to meeting these requirements. Discovery of archaeological remains is considered unlikely but this condition is necessary to ensure that, if they are discovered appropriate action to avoid or mitigate effects is taken.	Checking of the site by the consent holder or the person/s undertaking the works on behalf of the consent holder. Council Officer will also be informed of any discovery and will attend the site.	N/A
26.	Lapse	If this condition was not imposed the consent would lapse under the provisions of the RMA after 5 years in any case. This condition is simply to advise the consent holder of that provision.	N/A. The consent will simply lapse if it is not given effect to within the period stated	The lapse period provides enough time to give effect to the activity without 'locking up' the resource for an unduly long period. See discussion in officer report
27.	Review	In general, conditions of consent can only be reviewed if provision to do so is included in the consent. The Council's preference is to make provision to review the conditions of all consents to ensure that the conditions are effective, as an alternative to granting consents for a shorter duration.	N/A	The frequency and timing of the reviews is appropriate having considered the duration of the consent, its likely environmental effects, and the adequacy of the knowledge of those effects

Appendix IV

Example of consent conditions and a conditions analysis table for the discharge of well site emissions to air

Consent 9660-1

That application 7561, to discharge contaminants to air from hydrocarbon exploration at the Heat Seeker wellsite, including combustion involving flaring or incineration of petroleum recovered from natural deposits, in association with well development or redevelopment and testing or enhancement of well production flows, be approved for a period to 1 June 2029, subject to the following conditions:

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. For the purposes of this consent:

   (a) 'flaring' means the uncontrolled or partially controlled open air burning of hydrocarbons derived from or entrained in the well stream. 'Flare', as a verb, has the corresponding meaning and, as noun, means the flame produced by flaring.

   (b) 'incineration' means the controlled, enclosed burning of formation hydrocarbons within a device designed for the purpose. 'Incinerate' has the corresponding meaning.

   (c) 'Combustion' means burning generally and includes both flaring and incineration as well as other burning such as fuel in machinery.

2. Incineration shall only occur in a device with a minimum chimney height determined by the method detailed in Appendix VIII of the *Regional Air Quality Plan for Taranaki.*

3. Flaring shall only occur over a pit, or similar containment area, consisting of impermeable material that prevents any liquid from leaking through its base or sidewalls and discharging to land.

4. Flaring and incineration shall only occur within 20 metres of the location defined by NZTM 1694593-5640370.

5. Discharges to air from flaring or incineration shall not last longer than 15 days, cumulatively, inclusive of testing, clean-up, and completion stages of well development or work-over, per zone to be appraised, with a maximum of 4 zones per well and 12 wells.

6. The consent holder shall notify the Chief Executive, Taranaki Regional Council, at least 24 hours before the flaring or incineration from each zone commences. Notification shall include the consent number and a brief description of the activity consented and be emailed to worknotification@trc.govt.nz.

7. At least 24 hours before any flaring or incineration, other than in emergencies, the consent holder shall provide notification to the occupants of all dwellings within 300 metres of the wellsite and all landowners within 200 metres, of the commencement of flaring or incineration. The consent holder shall include in the notification a 24-hour contact telephone number for a representative of the consent holder, and shall keep and make available to the Chief Executive, Taranaki Regional Council, a record of all queries and complaints received in respect of any combustion activity.

8. No material shall be flared or incinerated, other than those derived from or entrained in the well stream.

9. To the greatest extent possible, all gas that is flared or incinerated must first be treated by effective liquid and solid separation and recovery.

10. Only gaseous hydrocarbons originating from the well stream shall be flared or incinerated, except that if, for reasons beyond the control of the consent holder, effective separation can not be achieved and combustion of liquid hydrocarbon is unavoidable, the consent holder shall reinstate effective separation as soon as possible and if separation can not be achieved within 3 hours combustion must cease.

11. If liquid hydrocarbon is combusted in accordance with the exception provided for in condition10 the consent holder shall prepare a report that details:

    (a) the reasons that separation could not be achieved;

    (b) the date and time that separation was lost and reinstated;

    (c) what was done to attempt to reinstate separation and, if it the attempt was unsuccessful the reasons why.

    The report shall be provided to the Chief Executive, Taranaki Regional Council within 5 working days from the date of combustion of liquid hydrocarbon.

12. The consent holder shall adopt the best practicable option, as defined in section 2 of the Resource Management Act 1991, to prevent or minimise any actual or potential effect on the environment arising from any emission to air, including, but not limited to having regard to the prevailing and predicted wind speed and direction at the time of initiation, and throughout, any episode of combustion so as to minimise offsite effects (other than for the maintenance of a pilot flame).

13. The discharge shall not cause any objectionable or offensive odour or any objectionable or offensive smoke at or beyond the boundary of the property where the wellsite is located.

14. The consent holder shall control all emissions of carbon monoxide, nitrogen dioxide, fine particles (PM_{10}) and sulphur dioxide to the atmosphere from the site, in order that the maximum ground level concentration of any of these contaminants arising from the exercise of this consent measured under ambient conditions does not exceed the relevant ambient air quality standard as set out in

the Resource Management (National Environmental Standards for Air Quality Regulations, 2004) at or beyond the boundary of the property on which the wellsite is located.

15. The consent holder shall control all emissions of contaminants to the atmosphere from the site, other than those expressly provided for under special condition 14, in order that they do not individually or in combination with other contaminants cause a hazardous, noxious, dangerous, offensive or objectionable effect at a distance greater than 100 metres from the emission source.

16. The consent holder shall make available to the Chief Executive, Taranaki Regional Council, upon request, an analysis of a typical gas and condensate stream from the field, covering sulphur compound content and the content of carbon compounds of structure C_6 or higher number of compounds.

17. All permanent tanks used as hydrocarbon storage vessels, shall be fitted with vapour recovery systems.

18. The consent holder shall record and make available to the Chief Executive, Taranaki Regional Council, a 'combustion log' that includes:

    (a) the date, time and duration of all flaring or incineration episodes;

    (b) the zone from which flaring or incineration occurred;

    (c) the volume of substances flared or incinerated;

    (d) whether there was smoke at any time during the combustion episode and if there was, the time, duration and cause of each 'smoke event'.

19. This consent shall lapse on 30 September 2018, unless the consent is given effect to before the end of that period or the Taranaki Regional Council fixes a longer period pursuant to section 125(1)(b) of the Resource Management Act 1991.

20. In accordance with section 128 and section 129 of the Resource Management Act 1991, the Taranaki Regional Council may serve notice of its intention to review, amend, delete or add to the conditions of this resource consent by giving notice of review:

    (a) during the month of June 2017 and/or June 2023; and/or
    (b) within 1 month of receiving a report provided in accordance with condition 11;

    for any of the following purposes:

    (i) dealing with any significant adverse effect on the environment arising from the exercise of the consent which was not foreseen at the time the application was considered or which it was not appropriate to deal with at the time; and/or

(ii) requiring the consent holder to adopt specific practices in order to achieve the best practicable option to remove or reduce any adverse effect on the environment caused by the discharge; and/or
(iii) to alter, add or delete limits on mass discharge quantities or ambient concentrations of any contaminant;
(iv) reducing emissions or environmental effects that may arise from any loss of separation.

Condition Analysis Table - Consent 9660-1

No.	Description	Reasons for condition	Determination of compliance	Reason for limit
1	Definitions	Necessary for clarity of conditions	N/A	N/A
2	Incinerator chimney height	Reasonably needed to avoid/mitigate adverse environmental effects	Inspection and measurement of chimney	Consistency with RAQP
3 & 4	Discharge location and flare pit specifications	Ensures the environmental effects are as assessed in the application, i.e. they relate only to a discharge air at the location specified.	Monitoring of activity by Council Officers	N/A
5	Flaring limits	As specified and assessed in the application. 15 day limit is controlled activity standard.	Log provided to Council in accordance with condition 18	As specified in the application
6	Notice to Council	So that the Council has the opportunity to monitor the work for compliance with consent conditions	Notice received	24 hours is sufficient for the Council to organise an inspection
7	Notification to neighbours	Reasonably necessary to avoid adverse effects on neighbours	Notice received	300 m from dwellings is the controlled activity standard Council research indicates that effects on bare land would not go beyond 200m
8	Flaring/incineration only substances originating from the well stream	Standards of a controlled/restricted discretionary activity	Monitoring of activity by Council Officers	N/A
9 & 10	Separation as far as possible	Reasonably necessary to avoid adverse effects associated with burning liquid hydrocarbons, but recognises that sometimes in spite of best endeavours burning of liquid hydrocarbon for a short duration is unavoidable	Report in accordance with condition 11	3 hours is a reasonable time to reinstate separation, recognising likely environmental effects and practicalities of reinstatement
11	Reporting on loss of separation	To check compliance with condition 10	Report received	5 days is a reasonable timeframe to provide the report
12	Adoption of best practicable option (BPO)	This condition requires that a higher standard than that required by the conditions be met if it can reasonably be achieved. It also requires the consent holder to continually review methods and practices and make reasonable improvements even though the conditions are being met. The condition is reasonably necessary to avoid adverse environmental effects	General observation and checking of records	N/A

No.	Description	Reasons for condition	Determination of compliance	Reason for limit
13	No objectionable or offensive odour or smoke beyond the boundary	Objectionable and offensive odour or smoke are significant adverse effects that must be avoided	Monitoring of activity as necessary by Council Officers	N/A
14	Limits on CO, NO_2, SO_2 and PM_{10}	While it is unlikely that the standards will be exceeded in the discharge, the limits are established by regulations and are reasonably necessary to avoid adverse effects on the health of humans, flora and fauna.	Monitoring of activity by Council officers	Limits as set out in the NES ambient air quality standards.
15	Control of other contaminants (not provided for under condition 14	While it is unlikely that the standards will be exceeded in the discharge, the limits are reasonably necessary to avoid adverse effects on the health of humans, flora and fauna.	Monitoring of activity by Council Officers and assessment against the relevant guidelines such as Ambient Air Quality Guidelines, Workplace Exposure standards and Biological exposure indices for New Zealand 1992, Department of Labour.	Council research indicates that the required standard can be achieved within 100 m.
16	Providing an analysis of a typical gas and condensate stream	Providing details of sulphur and carbon content in the gas/condensate stream will aid in determining compliance with conditions 14 & 15.	Data provided to Council	N/A
17	Hydrocarbon storage vessels	This condition is reasonably necessary to avoid adverse effects associated with release of vapours from the tanks.	Monitoring of activity as necessary by Council Officers	N/A
18	Combustion log	To enable Council Officers to determine compliance with consent conditions	Log provided to Council	N/A
19	Lapse	If this condition was not imposed the consent would lapse under the provisions of the RMA after 5 years in any case. This condition is simply to advise the consent holder of that provision	The consent will simply lapse if it is not given effect to within the period stated	The lapse period provides enough time to give effect to the activity without 'locking up' the resource for an unduly long period. See discussion in Officer report
20	Review	In general, conditions of consent can only be reviewed if provision to do so is included in the consent. The Council's preference is to make provision to review the conditions of all consents to ensure that the conditions are effective, as an alternative to granting consents for a shorter duration.	N/A	N/A

Appendix V

Example of consent conditions and a conditions analysis table for a well site stormwater discharge

Consent 9356-1

That application 7182, to discharge stormwater and sediment from earthworks during the re-development of the Kahili wellsite onto and into land, be approved for a period to 1 June 2017, subject to the following conditions:

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. This consent authorises the discharge of stormwater from no more than 4000 m^2 of land where earthworks is being undertaken for the purpose of creating a working area for the re-establishment of the Kahili wellsite, as shown in the details of the application for this consent.

2. 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 minimise any actual or likely adverse effect on the environment associated with the discharge of contaminants from the site.

3. At least 7 working days before the commencement of earthworks for the purpose of wellsite construction and establishment, the consent holder shall notify the Taranaki Regional Council of the proposed start date for the earthworks. Notification shall include the consent number and a brief description of the activity consented and shall be emailed to worknotification@trc.govt.nz.

4. The consent holder shall notify the Chief Executive, Taranaki Regional Council, in writing following the completion of the wellsite construction and establishment and before commencement of any drilling operation at the Kahili wellsite Notification shall be given at least 7 working days before the commencement of the Kahili wellsite drilling operation and shall include the consent number and a brief description of the activity consented and be emailed to worknotification@trc.govt.nz.

5. If any area of soil is exposed, all run off from that area shall pass through settlement ponds or sediment traps with a minimum total capacity of:

   a) 100 cubic metres for every hectare of exposed soil between 1 November to 30 April; and

   b) 200 cubic metres for every hectare of exposed soil between 1 May to 31 October;

   unless other sediment control measures that achieve an equivalent standard are agreed to by the Chief Executive of the Taranaki Regional Council.

6. The obligation described in condition 5 above shall cease to apply, and accordingly the erosion and sediment control measures can be removed, in respect of any particular site or area of any site, only when the site is stabilised.

Note: For the purpose of conditions 5 and 6, "stabilised" in relation to any site or area means inherently resistant to erosion or rendered resistant, such as by using rock or by the application of basecourse, colluvium, grassing, mulch, or another method to the reasonable satisfaction of the Chief Executive, Taranaki Regional Council and as specified in the Taranaki Regional Council's Guidelines for Earthworks in the Taranaki Region, 2006. Where seeding or grassing is used on a surface that is not otherwise resistant to erosion, the surface is considered stabilised once, on reasonable visual inspection by an officer of the Taranaki Regional Council, an 80% vegetative cover has been established.

7. All earthworked areas shall be stabilised vegetatively or otherwise as soon as is practicable and no longer than 6 months after the completion of soil disturbance activities.

Note: For the purposes of this condition "stabilised" has the same definition as that set out in condition 6.

Condition Analysis Table – Consent 9356-1

No.	Description	Reasons for condition	Determination of compliance	Reason for limit
1	Earthworks area	Ensure the discharge is as specified and as assessed in the application.	Check of work by council officers.	N/A
2	Adoption of best practicable option (BPO)	This condition requires that a higher standard than that required by the conditions be met if it can reasonably be achieved. It also requires the consent holder to continually review methods and practices and make reasonable improvements even though the conditions are being met. The condition is reasonably necessary to avoid adverse environmental effects	General observation and checking of records	N/A
3	Prior notice of works	So that the Council has the opportunity to monitor the work for compliance with consent conditions	Notice received	7 days is sufficient for the Council to organise an inspection
4	Notice to Council	So that the Council has the opportunity to monitor the work for compliance with consent conditions	Notice received	7 days is sufficient for the Council to organise an inspection
5 & 6	Sediment and erosion control measures	Sediment in waterways is a significant potential adverse effect of earthworks. Avoiding it as much as practicable, through appropriate treatment, is essential to meeting the requirements of Part 2 of the RMA	Check of work by Council Officers	The two minimum total capacities stated in the condition are consistent with the requirements of the '*Guidelines to earthworks in the Taranaki region'* (October 2006)
7	Re-vegetation to stabilise land following earthworks	To minimise the potential for sedimentation from on-going erosion, scouring and slumping of areas which have undergone earthworks and to ensure discharge is only temporary as per the application	Check of work by Council Officers	N/A

Consent 9335-1

That application 7170, to discharge stormwater from skimmer pits at the Mangahewa-D wellsite onto and into land and into an unnamed tributary of the Manganui River, be approved for a period to 1 June 2027, subject to the following conditions:

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 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 minimise any actual or likely adverse effect on the environment associated with the discharge of contaminants from the site.

2. The stormwater discharged shall be from a catchment area of no more than 7700 m^2.

3. At least 7 days working days prior, the consent holder shall advise the Chief Executive, Taranaki Regional Council of the date of each of the following events:

   a) commencement of any site works; and
   b) commencement of any well drilling operation.

   If either of these events is rescheduled or delayed, the consent holder shall immediately provide further notice advising of the new date.

   Any advice given in accordance with this condition shall include the consent number and a brief description of the activity consented and be emailed to worknotification@trc.govt.nz.

4. All stormwater and produced water (with a maximum chloride concentration of 50 ppm) shall be directed for treatment through the two skimmer pits, for discharge into an open man-made drain adjacent to the site. The skimmer pits shall have a minimum capacity of 180 m^3.

5. All skimmer pits and other stormwater retention areas shall be lined with an impervious material to prevent seepage through the bed and sidewalls.

6. There shall be no discharge of produced water with a chloride concentration greater than 50 ppm.

7. Constituents of the discharge shall meet the standards shown in the following table.

Constituent	Standard
pH	Within the range 6.0 to 9.0
suspended solids	Concentration not greater than 100 gm^{-3}
total recoverable hydrocarbons	Concentration not greater than 15 gm^{-3}
chloride	Concentration not greater than 50 gm^{-3}

This condition shall apply before entry of the treated stormwater into the receiving waters at a designated sampling point approved by the Chief Executive, Taranaki Regional Council.

8. After allowing for a mixing zone of 10 metres, the discharge shall not give rise to an increase in temperature of more than 2 degrees Celsius.

9. After allowing for reasonable mixing, within a mixing zone extending 10 metres downstream of the discharge point, the discharge shall not, either by itself or in combination with other discharges, give rise to any or all of the following effects in the receiving water:

   a) the production of any conspicuous oil or grease films, scums or foams, or floatable or suspended materials;
   b) any conspicuous change in the colour or visual clarity;
   c) any emission of objectionable odour;
   d) the rendering of fresh water unsuitable for consumption by farm animals;
   e) any significant adverse effects on aquatic life.

10. The consent holder shall maintain a contingency plan that, to the satisfaction of the Chief Executive, Taranaki Regional Council, details measures and procedures to be undertaken to prevent spillage or accidental discharge of contaminants not authorised by this consent and measures to avoid, remedy or mitigate the environmental effects of such a spillage or discharge. The contingency plan shall be provided to the Council prior to discharging from the site.

11. Subject the other conditions of this consent the design, management and maintenance of the stormwater system shall be undertaken in accordance with the stormwater management plan submitted in support of the consent application 7170, in particular Appendix C of the assessment of environmental effects.

12. The consent holder shall advise the Chief Executive, Taranaki Regional Council, in writing at least 48 hours prior to the reinstatement of the site and the reinstatement shall be carried out so as to minimise adverse effects on stormwater quality. Notification shall include the consent number and a brief description of the activity consented and emailed to worknotification@trc.govt.nz.

13. This consent shall lapse on 30 September 2017, 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.

14. In accordance with section 128 and section 129 of the Resource Management Act 1991, the Taranaki Regional Council may serve notice of its intention to review, amend, delete or add to the conditions of this resource consent by giving notice of review during the month of June 2015 and/or June 2021, for the purpose of ensuring that the conditions are adequate to deal with any adverse effects on the environment arising from the exercise of this resource consent, which were either not foreseen at the time the application was considered or which it was not appropriate to deal with at the time.

Condition Analysis Table Consent 9335-1

No.	Description	Reasons for condition	Determination of compliance	Reason for limit
1	Adoption of best practicable option (BPO)	This condition requires that a higher standard than that required by the conditions be met if it can reasonably be achieved. It also requires the consent holder to continually review methods and practices and make reasonable improvements even though the conditions are being met. The condition is reasonably necessary to avoid adverse environmental effects.	General observation and checking of records	N/A
2	Limit on stormwater catchment area	Limits the scale and effect of activity to that considered in the application. Variability of stormwater discharges means it is not practicable to limit the discharge rate.	Assessment by a Council officer at inspection	As requested in application
3	Notice to Council	So that the Council has the opportunity to monitor the work for compliance with consent conditions	Notice received	7 working days is sufficient for the Council to organise an inspection
4	Stormwater treatment system	To ensure that the system adopted is as assessed in the application	Assessment by a Council officer at inspection	As requested in application
5	Impermeable liner to skimmer pits	Ensures discharge is to the location applied for and assessed in the application by preventing discharge into the ground through the bed of the skimmer pit. It also ensures better control of the discharge, containment of spills and provides for sampling of the discharge.	Assessment by a Council officer at inspection	N/A
6	No discharge of produced water with a chloride concentration greater than 50 ppm	To avoid adverse effects on the receiving environment by ensuring only non-saline water is discharged	Assessment by Council Officers	50 ppm of chloride reasonably defines non-saline water
7	Discharge standards	Although at this site there are many contaminants that may become entrained in the stormwater, the most common contaminants likely to be associated with this activity are controlled by this condition. Ensuring these contaminants are kept to an acceptable level is necessary to avoid or mitigate adverse environmental effects	Sampling and testing of discharge as necessary by Council staff	Limits, other than BOD limits, are based on standards in the RFWP. All limits are reasonably achievable, and considering the dilution available, will adequately mitigate adverse effects.
8 & 9	Effects on surface water	The standards specified in this condition are required by Section 107 of the Resource Management Act. The other conditions of this consent are expected to ensure that these standards are met, but the inclusion of this condition provides more certainty and specifies the mixing zone.	Sampling and testing of receiving water as necessary by Council staff	Standards from S107 RMA. The 10 m mixing zone is reasonable, considering the dilution available in the stream.

No.	Description	Reasons for condition	Determination of compliance	Reason for limit
10	Maintenance of, and adherence to a contingency plan	This requirement ensures that the consent holder continues to review the way in which operations at the site are undertaken, identifying the scenarios that could result in spillage or unauthorised discharge of contaminants, and ensuring that the equipment is available and staff are trained such that a planned (albeit reactive) approach can be taken to avoid unauthorised discharges/effects any from any spill. Answers the question "A spill has happened, how do we manage, and therefore minimise or mitigate adverse environmental effects?"	Review of plan submitted to Council and assessment of implementation at inspection by a Council officer	N/A
11	Maintenance of and adherence to a stormwater management plan	Ensures the discharge is within the scope of the application and the authorised activity. The condition ensures that the consent holder continues to review (in a pro-active manner) the way in which operations at the site are undertaken to ensure compliance with the consent. It also ensures that procedures in place for staff to follow to ensure consent compliance remain relevant. For the consent holder, it is also a means of documenting how special condition 1 (adoption of the best practicable option) has been determined, and put into practice at the site. Answers the question "During this operation a spill could happen. What controls could prevent it, and therefore avoid a breach of consent conditions?"	Review of plan submitted to Council and assessment of implementation at inspection by a Council officer	N/A
12	Reinstatement of the site	So that the Council has the opportunity to check whether the work has been undertaken such that any stormwater discharge from the site meets the required standards.	Notice received	48 hours is sufficient for the Council to organise an inspection
13	Lapse	If this condition was not imposed the consent would lapse under the provisions of the RMA after 5 years in any case. This condition is simply to advise the consent holder of that provision.	N/A. The consent will simply lapse if it is not given effect to within the period stated	N/A
14	Review	In general, conditions of consent can only be reviewed if provision to do so is included in the consent. The Council's preference is to make provision to review the conditions of all consents to ensure that the conditions are effective, as an alternative to granting consents for a shorter duration.	N/A	N/A

Appendix VI

Example of consent conditions template for a well site in New Plymouth District Council area

RESOURCE CONSENT No. (Number)

Granted under Sections 104, 104C and 108 of the Resource Management Act 1991

APPLICANT:	(Name)
LOCATION:	(Physical address)
LEGAL DESCRIPTION:	(Legal description)
STATUS:	The proposal is a **(type of resource consent)** activity under the following rules of the (name) District Plan Operative (date): Rules (identify rules subject to consent),
PROPOSAL:	To construct a wellsite, drill wells from the site, test each well and undertake gas flaring associated with the testing, and produce oil and gas from the wells if they are successful.

DECISION:

The proposal (**Resource Consent No: (number)**) as described above and in the application is granted under Section 104C of the Resource Management Act 1991. The following conditions are imposed under Section 108 of the Resource Management Act 1991 as they are considered necessary to promote the sustainable management of natural and physical resources subject to Part II of the Resource Management Act 1991.

These conditions must be complied with when exercising this Resource Consent:

General Conditions and Scope

1. The proposed activity shall be established and carried out substantially in accordance with the application documentation and technical reports listed below, except as specifically modified by these conditions:
   - *"Application for consent and Assessment of Environmental Effects – (report title)*
   - *"Hazardous Substances Risk Assessment Report" - (report title)*
   - *"Assessment of Noise Effects – (report title)*
   - *"Traffic Management Plan – (report title)*
   - *"Noise Attenuation Measures – (report title)*

- *Land Care report – (report title)*

2. A total of X (number) wells may be drilled on the wellsite pad.

3. Only one well may be drilling at any one time.

4. Consent for exploration drilling and testing shall be limited to a period of X (number) years from the commencement of this consent. For clarification, no term is imposed on any production from the wells.

5. The production shall be piped off site to a remote processing facility. Only minor well head and associated facilities for production shall be located within the consented wellsite pad.

Mitigation Bund and Planting and Boundary Planting

6. *Prior to the commencement of any drilling activities (including drilling and flaring), and for the life of production from the well site, the consent holder shall establish the earth bund in accordance with (report title) and shall include bunding around the lay down area. The earth bund and perimeter of the well pad shall then be grassed and planted substantially in accordance with report Wise Land Care prepared by (report title). The consent holder shall certify that these works have been completed and provide this certification to the Council.*

7. *The bund shall be X (number) metres wide at the base and X (number) metres wide across the top. The bund shall be a height of X (number) metres along the (describe) of the well site. Along the (describe) boundaries of the well site the bund shall taper uniformly from a height of X (number) metres at its northern end to X (number) metres in height at the southern end. The bund shall be permanent and not temporary.*

8. *For the duration of this consent, the consent holder shall maintain the bund structure and planting in a good condition.*

9. *The boundaries of the site, (legal description) shall be planted as follows:*

   a. *The boundaries of the site with (legal description) shall be planted in accordance with Land Care planting plan.*
   b. *The (describe) boundary shall be planted in accordance with Land Care planting plan.*

   This planting shall be completed prior to the establishment of any drilling activity onsite.

10. *The area of the site to be utilised for the consented activity shall be limited to the area defined within the plans lodged as part of this resource consent and technical reports. The remainder of the site shall not be utilised for the consented activity.*

Hazardous Substances Storage Facilities

11. The maximum quantity and type of hazardous substances stored and used on the (name) Wellsite shall not exceed that described in the application and assessed within (report title).

12. Prior to the commencement of any drilling activities, the consent holder shall provide a *Hazardous Substances Environmental Management Plan (HSEMP)* to the Manager Consents or nominee. The consent holder shall comply with the HSEMP at all times and update the HSEMP when circumstances change. The HSEMP may be part of a wider Environmental or Site Management Plan and shall include details of the hazardous substances use and storage as well as matters required under the Hazardous Substances (Emergency Management) Regulations 2001. The HSEMP shall specify a process for its ongoing review and updating.

13. Prior to the commencement of any drilling activities, the consent holder shall provide details of the waste management operator able to accept both process wastes and any contaminated material required to be disposed of off-site in the case of an incident to the Manager Consents or nominee.

14. Except during well testing, pipeline maintenance or in emergency situations in relation to the wells on site, the (name) wellsite or other infrastructure, produced hydrocarbons extracted from wells shall not be stored on site and shall be piped to the (name), or elsewhere.

15. Prior to all drilling activities, the coordinates of each well head shall be provided to the Consents Manager or nominee and confirmation provided that the risk contours remain within the site boundaries (report title).

16. All hazardous materials and dangerous goods shall be stored on site within bunded areas, and used on site in accordance with all relevant legislative requirements (including the Hazardous Substances and New Organisms Act 1996 and associated regulations), the manufacturers' instructions, and best industry practice.

17. In addition to other relevant statutory agencies the Council is to be advised of any spills or other hazardous substance emergencies on the site at the earliest possible opportunity, but no later than 72 hours after the event.

18. Secondary spill containment (bunding) shall be provided for all tanks and storage areas for hazardous substances on the site. The containment shall be sufficient to contain 120% of the capacity of the largest tank, or the total quantity of any material in drums or other smaller containers, whichever is the greater.

19. The secondary spill containment area is to be monitored by the consent holder as required (particularly during rain events). Any accumulation of rain water in the secondary spill containment area is to be emptied when the rain water reaches a maximum of 10% of the bund capacity.

20. Any flaring during exploration may be intermittent but shall not exceed 15 days per zone for a maximum of 4 zones per well.

Transportation

21. The consent holder shall enter into a roading maintenance agreement with the Council prior to the commencement of the drilling activity. This agreement shall require the consent holder to make a contribution towards the strengthening (Area Wide Pavement Treatment) of (name) Road from (name) Road to the vehicle access

point to (name) wellsite. The annual assessment of the condition of the road will be commenced once the roading work has been completed.

22. The programme for each rig mobilisation and demobilisation shall be notified in writing to Council's Manager Consents or nominee and owners and occupiers along (describe) at least 10 working days prior to commencement of each rig mobilisation or demobilisation.

23. Prior to commencement of any activity authorised by this consent (including first rig mobilisation), the consent holder shall under take the following physical works and measures to mitigate the effects of the additional traffic movements on the local roading network:

(Site specific condition examples)

a. The new entrance to the site shall be constructed X *(number)* m to the (describe) of the existing access point. This will allow for better visibility in either direction. The access shall be constructed to Type H tanker crossing standard and shall be set back to a security gatehouse. The distance from the carriageway edge to the gatehouse shall be the length of the largest vehicle to access the site. This will ensure all vehicles are off the road prior to stopping at the gatehouse. The gatehouse will have a security barrier. The radius of the access shall be great enough to accommodate the largest vehicle to use the site.

b. The bank shall be cut back along the site's boundary edge with (name) Road to allow for improved visibility.

c. (name) Road shall be widened to a sealed width of X *(number)* m from (describe) to the entrance of the proposed site.

d. Engineering plans for the road widening shall be provided to the Manager Consents or nominee for approval prior to the road widening construction commencing.

e. As built plans for the road widening shall be provided to the Manager Consents or nominee on completion of the road widening.

f. The entrance to (describe) shall be upgraded to a Type G rural vehicle access.

g. An acceleration lane leaving the site shall be constructed for a length of X (number) metres to the north from the vehicle access point to (name) wellsite.

h. Engineering plans for the acceleration lane shall be provided to the Manager Consents or nominee for approval prior to the acceleration lane construction commencing.

i. As built plans for the acceleration lane shall be provided to the Manager Consents or nominee on completion of the acceleration lane construction.

j. Parking spaces as required for a permitted activity under the District Plan shall be provided and they shall be constructed to an all weather standard.

k. A double solid yellow centre line shall be painted over the crest of the road in front of the site entrance to prevent vehicles overtaking.

24. All vehicular traffic associated with the activities authorised by this consent shall use the route from and to (describe route).

25. All heavy and light vehicle equivalent movements (VEM) (excluding construction traffic) shall be restricted to 50 VEM per day and an average 30VEM per day measured over any 7 day period.

26. All traffic movements will be managed and operated to be in accordance with the (report title), including the designated traffic route and restrictions on hours for heavy truck movements.

27. The consent holder shall install and operate in-vehicle GPS recording equipment for the purpose of monitoring compliance with the conditions of this consent. The consent holder shall submit a Traffic Monitoring Report to the Manager Consents or nominee on the last working day of any month in which well drilling occurs, which shall summarise the traffic monitoring data and specifically confirm full compliance with the conditions of this consent or detail any areas of non-compliance. If non-compliance is identified, then the consent holder shall be required to demonstrate how this non-compliance was rectified for any subsequent activity.

28. In addition to Condition 27 the consent holder shall make the traffic log required under that condition available to the Council's Manager Consents or nominee upon request within three (3) working of any such request.

29. No vehicles transporting hazardous substances shall travel past the (name) School or Playcentre between the open hours of 8.00am and 3.45pm on any school day.

30. No heavy vehicles associated with activities at (name) wellsite shall:

a. Use (name) Road on school days between the hours of 8.00am – 9.00am and 2.30pm –3.30pm.

b. Pass (name) School or Playcentre on school days between the hours of 8.00am – 9.00am and 2.30pm and 3.30pm.

c. Pass (name) School or Playcentre on (days) between the hours of 11:30am and 12.30pm.

Noise

31. All activities on the site shall not exceed the following noise limits at any point at or within the notional boundary of any habitable dwelling within the Rural Environment Area (other than those habitable buildings for which written consent has been provided);

On any day	7am – 10pm	50 dBA L_{10}
	10pm – 7am	45 dBA L_{10}
		70 dBA L_{max}

Noise shall be measured in accordance with NZS6801:1991 *Measurement of* Sound and assessed in accordance with NZS6802:*1991 Assessment of Environmental Sound.*

32. The following mitigation measures shall be utilised to ensure the compliance with the Permitted Activity noise standards and shall be installed prior to the commencement of any drilling activity. The mitigation measures shall include but not be limited to;

(Application specific examples below)

- A X *(number)* m high earth bund;
- Mud motors fitted with new louver silencers;
- Mud motors fitted with new silencers;
- Silencer added to draw works;
- New sound barrier to surround platform;
- New portable sound barriers; and
- Second silencer added to the generator.

As detailed in (report title).

Pre-Installation Noise Emission Report

33. At least 2 weeks prior to each well drilling commencing the consent holder shall provide to the Manager Consents or nominee a Noise Emission Report from a suitably qualified and experienced person that the sound levels from the drilling rig will not exceed those levels set out in Condition 32. The Noise Emission Report shall state but not be limited to:

a. Which drilling rig is to be used;
b. The different drilling activities and other machinery;
c. The noise emissions from the drilling rig and ancillary equipment;
d. How those emissions were determined;
e. The potential noise levels at all Habitable Buildings where the predicted level exceeds 35dBA L_{10};
f. Noise mitigation measures including the location of silencers, muffling, shielding, enclosures and barriers/bunds;
g. The likely effectiveness of the mitigation measures;
h. The predicted noise levels with mitigation;
i. The meteorological conditions during which noise limits may be exceeded;
j. The likelihood of those conditions occurring;
k. Any uncertainty in the predictions and safety factors employed in the calculations.

Noise Monitoring

34. All noise monitoring of drilling activities shall be supervised by a suitably qualified and experienced person.

35. A noise logger and a weather station shall be deployed for the full duration of each drilling and testing operation of each well at or within the notional boundary of the habitable building on (legal description). The weather station shall record wind speed, wind direction, temperature and the presence of rainfall at 15 minute intervals which shall be correlated to the noise logger data.

36. The noise logger (referred to in condition 35) shall be installed prior to each well drilling operation commencing and remain for the entire period of each well drilling and testing operation.

37. The noise logger shall be supported by attended noise monitoring. The attended noise monitoring shall be representative of all drilling and testing activities on site.

38. During any period of drilling and testing, a weekly noise monitoring report and results shall be provided to the Manager Consents (or nominee). The results shall be analysed and provided in a form that allows a ready assessment of the readings so that compliance can be demonstrated. This shall include graphs of noise levels and weather conditions. Where the monitoring demonstrates any period of non-compliance during any periods, details of the rig activity at those times shall be provided along with any other relevant description of circumstances, including a description of attended monitoring undertaken.

39. The weekly noise monitoring report and results shall be provided to the Manager Consents (or nominee) within five working days of the completion of weekly monitoring.

Noise Management Plan

40. The consent holder shall submit a Noise Management Plan prepared by a suitably qualified person to the Manager Consents (or nominee) for approval prior to the commencement of any work at the site. The plan shall include, but not be limited to:
    - The identification of noisier activities and timing of those activities to avoid noise sensitive times (particularly at night);
    - A restriction the use of amplified music between the hours of 8pm and 8am;
    - Education of workers and management in quiet work practices and in maintaining community goodwill;
    - The process of community liaison including any special measures for immediate residents;
    - The need to keep all sound attenuating doors normally closed;
    - The complaints procedure including the person responsible for receiving complaints and actions to be taken regarding reducing noise, recording and feedback;
    - Consultation procedures for special works;

- Any changes to the rig to minimise noise shall require an updated Noise Management Plan.

41. The Council may review Conditions 32 to 40 of this Consent in accordance with Section 128 of the Resource Management Act 1991 at the conclusion of the testing of the first well drilled from this site in order to deal with any adverse acoustic effect that was not foreseen at the time of granting this Consent.

Site Maintenance

42. During any periods where the site is not actively being used for drilling and testing activities, and throughout the operational life of any permanent production facilities on site, the consent holder shall inspect the site at least once a month and remove all visible rubbish, to ensure the site is maintained in neat and tidy condition.

Consultation & Notification

43. At least 48 hours prior to the commencement of any wellsite (drilling, testing and flaring) activity the Manager Consents or nominee, (name) School and Playcentre and all property owners and occupiers within X (number) metres of the (name wellsite) shall be notified in writing as to when the activity will commence and its likely duration.

44. Should all activity at the (name) wellsite (drilling, testing and flaring) be suspended for a period of more than eight weeks with the intention of recommencement, the Manager Consents or nominee, (name) School and (name) Wellsite shall be advised accordingly by the consent holder.

45. The consent holder shall include in the notification a 24-hour contact telephone number for a representative of the consent holder. The consent holder shall keep and maintain and within 48 hours of request make available to the Council a record of any complaints received regarding each drilling and testing activity authorised by this consent.

Decommissioning and Restoration

46. The consent holder shall inform the Council's Manager Consents or nominee when the consented exploration and/or production at the site ceases. Subject to any landowner agreement (should the consent holder not remain the landowner at the time of decommissioning), the consent holder shall restore the site and prepare it for re-vegetation. Prior to commencing restoration works, the consent holder shall provide Council's Manager Consents or nominee with restoration details, including timeframes and plans, by way of notification.

47. Prior to decommissioning and restoration of the site the consent holder shall provide to the Manager Consents or nominee a report from a suitably qualified person that assesses the risk of soil contamination on the land and, if required, a Remediation Action Plan to manage those risks.

Monitoring

48. The consent holder shall pay Council's reasonable costs associated with monitoring the conditions of this consent in accordance with section 36 of the Resource Management Act 1991.

Review

49. The conditions of this consent may be reviewed by the Council in accordance with Section 128 of the Resource Management Act 1991 in order to deal with any adverse effects on the environment which may arise from the exercise of this consent that were not foreseen at the granting of the consent. The first such review (if necessary) shall occur within one month after the drilling of the first well.

NOTES:

This application for Resource Consent has been considered in accordance with Section 104 of the Resource Management Act 1991 and has been approved, as the Council is satisfied that the proposal is consistent with Part II of the Resource Management Act 1991 in that the adverse effects on the environment of the activity will be minor and that no persons will be adversely affected by the granting of the Resource Consent.

This Resource Consent lapses 5 years after the date of its commencement unless the Consent is given effect to before that date; or unless an application is made before the expiry of that date for the Council to grant an extension of time for establishment of the use. An application for an extension of time will be subject to the provisions of Section 125 of the Act.

This Consent is subject to the Right of Objection as set out in Section 357A of the Resource Management Act 1991.

DATED: (date)

(Name of Officer)