Guidelines for the control of disposal of drilling wastes onto and into land

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Executive summary

The Taranaki Regional Council has previously prepared guidelines to the environmentally sound disposal of drilling wastes (cuttings and muds) to land, with the assistance of expert consultants and consultation with interested parties (both within the exploration and disposal industry, and with environmental groups and submitters to the Regional Freshwater Plan). The document was entitled 'Guidelines on the disposal of drilling wastes onto and into land' (July 2003). This document has since been the basis for advice to applicants and the public. It included standardised conditions for the Council to apply to proposals for the land farming or burial of drilling wastes.

The guidelines were based on disposal of water-based (WBM) and synthetic-based (SBM) mud systems.

More recently, some companies have re-introduced oil-based mud operations (OBM). The base material for these is usually either diesel or crude oil/condensate, together with the various proprietary additives necessary for the particular drilling conditions. Generally OBM systems are considered less desirable environmentally than WBM or SBM, because they take longer to degrade and are more toxic. In particular they may contain aromatics at various concentrations, which are toxic and some of which are carcinogenic. The USEPA is more restrictive of OBM disposal than of WBM or SBM. The re-introduction of this practice has led the Council to expand its original guidelines to incorporate OBM. The opportunity has also been taken to include comment upon deep well re-injection, a practice used particularly for the disposal of produced water (typically high salinity with traces of hydrocarbons).

The guidelines set out in this document represent generic guidance for potential operators, Council staff, and the regional community as to what the Council expects from consent applicant and field operators. The guidance also serves as a source of information and explanation behind the Council's approach. It is not a rulebook rigidly applied. Applicants are encouraged to contact the Council to discuss their particular operations including the applicability of the conditions set out here. They present a general framework within which specific applications will be considered, and provide certainty as to outcome for applications that fall within agreed boundaries, while retaining flexibility and structure for the consideration of applications that may not conform to the conventional exploration practices.

The intention is that the management of applications should be more efficient in process and offer more reassurance in outcome, both for applicants and for the interested regional community, than would otherwise be the case.

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Guidelines on the disposal of drilling wastes onto and into land

Introduction

1. A resource consent is needed to discharge drilling fluids, cuttings or wastes onto or into land in the Taranaki region in accordance with the Regional Fresh Water Plan for Taranaki [RFWP]. This includes any discharge arising during interim storage prior to disposal as well as discharge for disposal purposes.

2. In the absence of any New Zealand guidelines for the disposal of drilling wastes the Taranaki Regional Council [the Council] initially used the G-50 Guideline for Drilling Waste Management produced by the Alberta Energy and Utilities Board, Canada [G-50 Guidelines] as a reference document when preparing such consents. However it was noted that there are significant climatological and geological differences between Alberta and Taranaki and therefore the Council undertook a review of the applicability of the G-50 Guidelines for use in Taranaki [Turner 2002 (Appendix 1), Taranaki Regional Council 2002 (Appendix 2) and 2001].

3. The review incorporated local research into environmental effects associated with disposal of drilling wastes, and biodegradation and attenuation conditions in Taranaki. Likely environmental effects and loading rates were assessed against national guidelines and criteria for soil and water quality.

4. Based on the findings of this review, a tiered approach to the disposal of drilling wastes [i.e. water based drilling muds and cuttings, and synthetic based drilling muds and cuttings] to land was prepared and set out in a memorandum describing the Council's approach to the disposal of drilling wastes onto and into land, as a guideline for applicants and the regional community. This memorandum, dated 27 May 2003, was circulated amongst interested parties and became the basis of the Council's assessment of consent applications.

5. It was noted that the guidelines represented the best current knowledge and practices being undertaken in Taranaki and nationally at the time, and that they would be subject to review and modification as greater knowledge and experience was obtained. The Council sought to also encourage and pursue continued investigation into improved, and additional, techniques for disposal of waste drilling material, e.g. enhanced bioremediation.

6. At the time, the industry was using water-based (WBM) and synthetic-based (SBM) mud systems, and the guidelines were geared towards these mixtures. However, in 2004 the Council had to deal with two applications for the disposal of oil-based muds (OBM). OBM systems are considered as less environmentally friendly than WBM and SBM systems. The applications were granted, on more stringent conditions than applied to disposal of WBM or SBM, including conditions making it plain that these approvals were essentially for trial activities that were to be tightly controlled and monitored, and that the results would be carefully assessed before the Council moved to any stance of more generally approving such applications.

7. The Council has also had to deal with a situation that involving the un-consented disposal of OBM in the region.

8. While the particular management of OBM disposal to date has not been entirely satisfactory, nevertheless monitoring data gathered to date assists in confirming appropriate conditions for operation and environmental performance.

9. Therefore this memorandum updates the 2003 guidelines, to also incorporate guidance to potential applicants as to how the Council will deal with OBM disposal to land.

10. Disposal of some particular types of drilling and production wastes via deep well re-injection also occurs in the region. Because of the present use of this technique, and the potential that it will become more widespread, the opportunity is taken to set out in this updated guideline, the Council's expectations in regard to deep well re-injection, together with background information.

Consent requirements

Land farming and mix-bury-cover

11. The following sets out criteria that applicants must meet, and accompanying information requirements, when applying for discharge consents to dispose of drilling wastes onto and into land. If the criteria as outlined below are met then the Council will generally consider an application on a non-notified basis. If the criteria can not be met then the Council will still consider processing an application on a non-notified basis however additional supporting information may be required. In all cases, except where the standards of controlled Rule 42 of the RFWP can be met, the Council retains the right to grant or decline the application.

12. These updated guidelines represent the best current knowledge and practices being undertaken in Taranaki and nationally. They will be subject to review and modification as greater knowledge and experience is obtained. While these guidelines are considered to represent and incorporate current best practice as generally utilised, the Council will also encourage and pursue continued investigation into improved, and additional, techniques for disposal of waste drilling material, e.g. enhanced bioremediation.

13. A resource consent is required to discharge waste material from drilling onto or into land during interim storage and disposal of material. Waste materials from drilling can include drill cuttings [mainly solids], drilling fluids [mud or slurry] and drilling wastes [liquid], including water produced from the well. There are several classes of drilling fluids: water-based, oil-based [diesel oil or crude mineral oil], enhanced mineral oil-based [i.e. mineral oils treated to reduce PAH level] or synthetic-based [polymerised olefins, synthesized vegetable esters, and / or other synthesized materials]. Waste materials from drilling are produced from treatment, workover, and completion activities.

14. There are two conventional methods for disposal of such wastes onto land, namely land spreading and mix-bury-cover [MBC]. Land spreading involves spreading the drilling solids on the land surface and mixing them into the surface soil. MBC involves mixing the drilling solids with clean soil and burying the mixed material in an unlined pit.

15. A third disposal method involves disposal of waste material onto an impervious pad for composting. In such circumstances no discharge to land occurs, however if there is potential for run off to land to occur [i.e. leaching] a discharge permit is required with respect to the disposal of the leachate material. Because no discharge permit is required for placement of the waste drilling material on the impervious pad, this method of management is not considered further in these guidelines.

16. The Council will assess any proposal for the disposal of waste drilling material by land spreading or MBC on a case-by-case basis based on the extent of compliance with the guidelines produced in Canada [the G-50 Guidelines] and modified to Taranaki conditions [Turner 2002, Taranaki Regional Council 2001, 2002, 2003, and these guidelines].

17. For any land disposal activity, the Council would implement a compliance monitoring programme at a level that reflects the nature of the activity, and modified to reflect the performance record of the consent holder.

Land spreading and incorporation

18. It is considered that the land spreading disposal method described in the G-50 Guidelines is more suitable to the Taranaki situation than MBC and the Council would therefore encourage land spreading disposal of drilling wastes as the preferred method of disposal. The requisite land spreading area is based on a calculated loading rate, which in turn is based on loading criteria outlined in Table 1 below.

19. Table 1 below, and Table 2 following, outline the loading limits that must be met at two stages following a disposal operation. ‘Maximum application’ rates must not be exceeded immediately following disposal [being predominantly metals that do not break down], while ‘post application conditions’ must be satisfied prior to the relinquishing of the discharge permit.

20. Experience has shown that the limits in Table 1 cannot be met by land spreading of OBM without additional measures. This is particularly true of the hydrocarbon limits. Experience to date in Taranaki is that the concentrations of polyaromatic and monoaromatic (‘BTEX’) compounds may also have to be restricted. The Council’s approach is to look at allowing a higher initial concentration along with a longer consent duration and a requirement that such limits are satisfied before the consent is relinquished. In some circumstances a bond could be considered as security for site reinstatement to acceptable limits.

21. Sites to be used for land farming should ideally be located on relatively flat sandy country prone to wind erosion. The greatest environmental benefit and lowest potential for adverse effects are associated with such land.

22. Sites where there are hard iron or clay pans close to the surface are less suitable

23. Sites should have adequate buffer distances from streams or water bodies. There should be little likelihood of utilisation of water resources (surface water or groundwater).

24. Sites should be isolated from dwellings to avoid potential problems with dust and odour.

Table 1 Loading criteria for disposal of waste drilling material (non OBM) via land spreading

Maximum application	Post application conditions
Maximum concentrations of **heavy metals** in surface soils, [mg/kg] [Department of Health (1992)] Arsenic 10 Cadmium 3 Chromium 600 Copper 140 Lead 300 Mercury 1 Nickel 35 Zinc 300 **Hydrocarbon Content:** <0.1% on a dry weight basis in the soil waste mix [or the discharge shall not exceed 0.0015% (15 mg/kg) on a dry weight basis if applying under Rule 42 – controlled activity - of the Regional Fresh Water Plan for Taranaki]. Level of hydrocarbons in the soil shall comply with the guideline values for appropriate soil in the surface layer [less than 1 metre depth] set out in Tables 4.12 and 4.15 of the Guidelines for Assessing and Managing Petroleum Hydrocarbon Contaminated Sites in New Zealand [Ministry for the Environment, 1999].	**Electroconductivity:** 290 mS m^{-1} [waste-soil mixed layer] - the Council may consider an electro-conductivity of 400 mS m^{-1} in the interim - if background electroconductivity already exceeds 400 mS m^{-1} the soil electroconductivity should not be increased by more than 100 mS m^{-1}. **Sodium:** 460 gm^{-3} **Chloride:** 700 gm^{-3} **Sodium absorption ratio** [SAR] of the soil after application shall be less than 18.0, or alternatively if the background soil SAR exceeds 18.0, the application of waste shall not increase the SAR by more than 1.0. Discharge shall not take place within 25 metres of **surface water courses** [including streams and/or drains] or property boundaries.

25. The key information that must accompany land spreading applications is:
- Description of proposal / activity
- Adoption of best practicable option and measures outlined
- Source and volume of material, maximum daily application rate, area and boundaries of land to be used for spreading
- Nature of the wastes to be spread, including Material Safety Data Sheets [MSDS] for additives
- Description of soil and sub-surface geology
- Aerial photo and / or 1:50,000 [or less] topographic map showing proposed land spreading area[s] in relation to surface water, property boundaries, waahi tapu, land contours, ground water contours and any other features of interest with respect to land spreading
- Assessment of environmental effects summary including environmental pathways, receptors and sensitivity of receptors
- Any actual or potential use of water resources in the vicinity
- Site and operation management plan, including but not limited to any stockpiling, means of spreading, means of soil incorporation and tilling to a preferred target depth of 250 mm, post-spreading management and site reinstatement and monitoring for up to five years, control of site access, procedures for notification to Council of disposal activities, and sampling regime
- Contingency plans e.g. for interruption of access to site, weather-related restrictions, spillages or overland flows
- Outline of consultation with interested and affected parties, including tangata whenua.

26. If the criteria in Table 1 above are satisfied, the above information supplied and land owner[s] consent obtained, then the Council is likely to process the consent on a non-notified basis. Conditions would be attached similar to those set out in Appendix 3.

27. Where an applicant cannot meet criteria outlined in Table 1 above, the activity may still be granted a resource consent but the Council will pay particular attention to the potential effects on soil, ground water and surface water, and parties likely to be affected by the activity. The Council may impose additional conditions, for example relating to management and rehabilitation of the site and supply of information to the Council during the life of the consent.

Mix-bury-cover

28. If there are particular reasons why MBC should be preferred to the land spreading disposal method [for example the sensitivity of the receiving environment or financial implications] then the criteria outlined in Table 2 below should be satisfied. Provided applicants can obtain written approval from the landowner, Council is likely to process the application on a non-notified basis and grant the consent with conditions based on the criteria in Table 2. Conditions will also include buffer distances from all water bodies and property boundaries.

29. Data that should accompany MBC disposal site applications is as follows:
    - Description of proposal/activity
    - Adoption of best practicable option and measures outlined
    - Volume of material
    - Nature of the wastes to be spread, including Material Safety Data Sheets [MSDS] for additives
    - Number of distinct MBC areas proposed
    - Description of sub-surface geology and hydrogeology, including porosity and hydraulic conductivity, ground water levels and direction, and speed of ground water flows
    - Aerial photo and/or 1:50,000 [or less] topographic map showing proposed MBC areas in relation to surface water, land contours, ground water contours and any other features of interest with respect to MBC
    - A summary of an assessment of environmental effects, in particular relating to potential ground water contamination and water use impacts, and including environmental pathways, receptors and sensitivity of receptors.
    - Site and operation management plan
    - Outline of consultation with interested and affected parties, including tangata whenua.

Table 2 Loading criteria for disposal of waste drilling material via mix-bury-cover

Pre-application conditions	Maximum application	Post application conditions
Site: Water table and permeable material must be at least 1m below subsoil and waste mixture.	**Chloride:** <2000mg/kg in the subsoil after blending with the waste mix. **Hydrocarbon Content**: <0.1% on a dry weight basis in the subsoil and waste blended mix [or the discharge shall not exceed 0.0015% (15 mg/kg) on a dry weight basis if applying under Rule 42 – controlled activity - of the Regional Fresh Water Plan for Taranaki]. **Subsoil and waste mix** must be at least 3 parts clean subsoil to 1 part waste. A minimum 1m of **clean topsoil or subsoil** must cover subsoil and waste blended mix.	**Chloride:** Lifetime loading limit of 1600 kg per disposal site **Nitrogen:** Lifetime loading limit of 400kg per disposal site Maximum concentrations of **heavy metals** in surface soil, [mg/kg] [Department of Health (1992)] Arsenic 10 Cadmium 3 Chromium 600 Copper 140 Lead 300 Mercury 1 Nickel 35 Zinc 300

30. In addition, analysis of the waste should be carried out at all sites. Analyses should include pH, Cl, N, Na, Ca, Mg, SO_4 and Ba, as well as for any other contaminant that may be of relevance because of the type of drilling additives programme employed at the particular site.

Mix-bury-cover – non-compliance with loading criteria

31. Where an applicant cannot achieve the criteria outlined in Table 2 above the Council may still grant a discharge consent if additional information is supplied in support of the application. For example if the applicant proposes a greater total site loading or a higher maximum application rate [e.g. hydrocarbons greater than 5%], or proposes other specific disposal requirements such as a higher mix ratio or lower burial depth, then the Council will look carefully at what is proposed and how potential adverse effects on the environment are to be avoided. Based on the likely environmental effects of the discharge, and receipt of written approval from potentially affected parties, the Council will consider whether to grant or decline the discharge consent.

32. In addition to the base application information requirement [outlined in Section 2.1 above], the applicant will also be required to provide the following information:
    - a detailed description of the sub-surface geology
    - measurement of hydraulic conductivity, relevant ground water hydrology and connection with any surface water body
    - Contingency plan – detailing what measures will be taken should monitoring indicate that the effect on the environment is adverse.

33. The Council will also undertake a more detailed monitoring programme at each site to enable the effects of the discharge to be fully assessed. The monitoring may include the installation of monitoring bores to enable sampling of ground water upflow and downflow of the site. Sampling of the bores would be likely to occur four-monthly for two years or until the downstream water quality reaches acceptable levels.

Deep well re-injection

Substances currently disposed of in Taranaki via deep well injection:

34. Existing consents currently limit the substances authorised for disposal via deep well injection to a narrow range of contaminants. These are:
    - Saline produced water [typically containing hydrocarbon residues];
    - Specified system additives [biocides, anti-scaling, anti-corrosion agents, etc];
    - Hydrocarbon wellsite contaminated stormwater;
    - Waste water-based drilling mud.

35. For these waste types, deep well re-injection is generally considered to be an environmentally acceptable practice, and one that in some circumstances may be preferable overall to other options (e.g. disposal to surface water course).

36. Any proposal to expand the scope of current or new discharge consents to include the disposal of waste types other than those currently would require a significant increase in the type of information supplied in support of an application, and monitoring subsequently undertaken.

37. Any applications to dispose of contaminants other than those currently authorised would be considered on a case by case basis, and information additional to that specified below would be required. Applicants are invited to consult the Council early in the development of any proposal.

Information requirements for applicants seeking to discharge produced water, system additives, wellsite stormwater, and waste water-based drilling mud by deep well re-injection

38. The level of monitoring, and therefore the cost to the consent holder, largely depends on the level of confidence that the Council has that the activity will not contaminate any fresh water aquifer, now or in the future.

39. The level of monitoring may be reduced if a consent holder demonstrates that the risk of leakage of contaminants is negligible. This applies to both the disposal well and the disposal interval/s.

40. The Council requires specific information to be provided by the consent holder prior to exercising a consent. High quality information and current good practice will include:

    - A well engineering completion summary report, including pressure test results; (Note that the results of periodic pressure testing to show the disposal well is secure may be a monitoring requirement).

    - The use of acid resistant cement plugs in the well to isolate zones;

    - A summary section [cartoon] showing geological formations and identifying the impermeable and laterally persistent units [confining layer/s], any major faults or shear zones, disposal well path and perforated intervals, and the FW-SW interface in the well;

- Geophysical log and interpretation to support geological data and depth to FW-SW interface;
- A full and complete list of all contaminants to be disposed of [eg. system additives, etc] in addition to saline produced water containing hydrocarbon residues. System additives may be described with MSDS or Chemwatch data sheets;
- Results to show that the water chemistry in the disposal zone is compatible with that of the fluids to be disposed of [*adverse reactions can and do occur as a result of incompatible fluid chemistries eg. BaSO4 scaling*];
- 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;
- All depths to be given as true vertical depth below a specified datum.

41. If the above information is provided and reasonably shows that the risk of contaminants escaping via the well annulus and/or the injection zone is negligible, then the level of requisite monitoring could be adjusted appropriately (taking into account also early monitoring results).

Factors that may limit the applicability and effectiveness of deep well injection processes, and which should be addressed in an application

42. This section refers to all injected substances. The extent to which any or all of the following points need to be considered will be assessed on a case by case basis, and according to the nature of the waste material.

- Injection of wastes must not occur in any areas where there are known active faults or shear zones.
- Injected wastes must be compatible with the mechanical components of the injection well system and the natural formation water.
- For certain types of hazardous waste, a consent holder may be required to perform physical, chemical, biological, or thermal treatment for removal of various contaminants or constituents from the waste to modify the physical and chemical character of the waste to assure compatibility.
- Suspended solids (typically >2 ppm) can lead to plugging of the injection interval. Note that suspended solids are difficult to measure representatively in waste fluids containing more than a trace of oil.
- Corrosive media may react with the injection well components, with injection zone formation, or with confining strata with very undesirable results. Wastes should be pH neutralized.

- High iron concentrations in the waste may result in fouling when conditions alter the valence state and convert soluble to insoluble species.
- Insoluble carbonate [$FeCO_3$, $CaCO_3$, $SrCO_3$] or sulphate scaling [$BaSO_4$, $SrSO_4$] can occur in pipe work and around casing perforations in wells when incompatible fluid chemistries are in contact.
- Organic carbon may serve as an energy source for indigenous or injected bacteria resulting in rapid population growth and subsequent fouling.
- Waste streams containing organic contaminants above their solubility limits may require pre-treatment before injection into a well.
- Site assessment and aquifer characterization are required to determine suitability of site for wastewater injection.

43. Extensive assessments should be completed prior to seeking approval from Taranaki Regional Council, or there may be delays as additional information is provided.

Conclusion

44. Resource consents are required for the disposal of drilling wastes onto or into land. As is the Council's usual practice, monitoring of the discharge would be undertaken. Of the two primary methods of disposal the Taranaki Regional Council prefers land spreading to MBC methods. The Council prefers the use of WBM or SBM over OBM. Where the use of OBM or disposal by MBC methods are proposed the Council will look carefully at the activity before deciding whether to grant or decline consents. More detailed monitoring and contingency planning may also be required if undertaking the disposal of OBM, or the use of MBC as a disposal technique.

References

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Appendix 1 – Sodium, chloride, and salinity

Salinity is the presence of soluble salts in or on soils, or in waters. High salinity levels in soils may result in reduced plant productivity or in extreme cases, the elimination of crops and native vegetation.

Sodicity is the presence of a high proportion of sodium (Na^{+}) ions relative to other cations [predominantly calcium (Ca^{2+}) and magnesium (Mg^{2+})] in soil (in exchangeable and / or soluble form) or water. Sodicity degrades soil properties by making the soil more dispersible and erodible, restricting water entry and reducing hydraulic conductivity (the ability of the soil to conduct water). (from Australian Water Quality Guidelines for Fresh and Marine Waters, Australia and New Zealand Environment and Conservation Council, 1998) (ANZEEC)

Low salinity water can be used on most crops on most soils. This assumes a normal amount of permeability. Medium salinity water can be used if a moderate amount of leaching is expected to occur. Sprinkler irrigation may cause leaf scorch on salt-sensitive crops, especially with low water application rates. Water of higher salinity can be used where factors such as permeable soils, adequate drainage, reasonable rainfall, salt-tolerant species, or limited applications can be taken into account.

The figures given in the ANZEEC guidelines are set out below.

Acceptable salinity and conductivity

EC of Irrigation Water (mSm^{-1})	Water Salinity Rating	Plant Suitability
<65	very low	sensitive crops
65–130	low	moderately sensitive crops
130–290	medium	moderately tolerant crops
290–520	high	tolerant crops
520–810	very high	very tolerant crops
>810	extreme	generally too saline

(from Table 5.1, ANZEEC 1998)

Acceptable chloride concentrations g m^{-3}

Sensitive <175	Moderately sensitive 175–350	Moderately tolerant 350–700	Tolerant >700
Almond	Pepper	Barley	Cauliflower
Apricot	Potato	Maize	Cotton
Citrus	Tomato	Cucumber	Sugar beet
Plum		Lucerne	Sunflower
Grape		Safflower	
		Sesame	
		Sorghum	

(From Table 5.2, ANZEEC)

Acceptable sodium concentrations g m^{-3}

Sensitive <115	Moderately sensitive 115–230	Moderately tolerant 230–460	Tolerant >460
Almond	Pepper	Barley	Cauliflower
Apricot	Potato	Maize	Cotton
Citrus	Tomato	Cucumber	Sugar beet
Plum		Lucerne	Sunflower
Grape		Safflower	
		Sesame	
		Sorghum	

(From Table 5.4 ANZEEC)

Effect of sodium (expressed as sodium adsorption ratio [SAR]) on crop yield and quality under non-saline conditions

Tolerance to SAR and range at which affected	Crop	Growth response under field conditions
Extremely sensitive SAR = 2–8	Avocado Deciduous Fruits Nuts Citrus	Leaf tip burn, leaf scorch
Sensitive SAR = 8–18	Beans	Stunted growth
Medium SAR = 18–46	Clover Oats Tall fescue Rice Dallis grass	Stunted growth, possible sodium toxicity, possible calcium or magnesium deficiency
High SAR = 46–102	Wheat Cotton Lucerne Barley Beets Rhodes grass	Stunted growth, soil structural problems

(From Table 5.5 ANZEEC)

Guide G-50, 'Drilling Waste management', prepared by the Alberta Energy and Utilities Board (October 1996), set limits for land application of drilling wastes to soil at conductivity 400 mSm^{-1} and a SAR (see below) of 8. If either of these were to be exceeded, then the maximum increase over background levels could be only 100 mSm^{-1} or an additional SAR of 1, with no discharge at all if the receiving soil SAR already exceeds 16.

It is considered that in setting limits for Taranaki, greater weight should be given to the ANZEEC guidelines than to the Alberta guidelines. Notwithstanding this, it is considered that in the short term, it may be acceptable in some circumstances to exceed ANZEEC guidelines (where the G-50 guidelines are higher) as long as in the longer term these guidelines are satisfied.

Given Taranaki's rainfall, permeability of soils, and proximity to the coast, it is considered that in the absence of special considerations such as frequently repeated applications of saline wastewaters, an appropriate level of protection of soils used for pasture growth purposes is the setting of soil limits prior to relinquishing or surrendering a consent at **conductivity 290 mSm^{-1}, sodium at 460 g m^{-3}, and chloride at 700 g m^{-3}.** On an interim basis (e.g. after any disposal activity), the electroconductivity of the waste-soil mixed layer should not exceed 400 mS m^{-1}, or alternatively if the background electroconductivity already exceeds 400 mS m^{-1}, the background soil electroconductivity should not be increased by more than 100 mS m^{-1} .

On clay soils, medium sodium water may pose a problem unless gypsum is added. This problem is unlikely on sandy or organic soils. Pasture species such as clover and fescue are considered moderately tolerant to sodium, with other grasses being even more tolerant; some market crops are more sensitive. From ANZEEC, pastures are generally considered able to withstand a sodium adsorption ratio (SAR) of between 18 and 46, where

$$SAR = \frac{Na+}{\left\{\frac{(Ca^{2+} + Mg^{2+})}{2}\right\}^{0.5}}$$

An **SAR limit for soil of less than 18** is therefore considered appropriate in most circumstances, with up to 46 being acceptable depending on the particular situation.

In terms of livestock watering USEPA (1972) consider water of total dissolved salts less than 1000 g m^{-3} to be excellent, and up to 2000 g m^{-3} to be very satisfactory for all classes of livestock and poultry (some possible temporary mild diarrhoea in livestock not accustomed to the higher levels). ANZEEC consider there to be no effects upon cattle or sheep at 2500 g m^{-3} , and with reluctance to drink or some scouring, but no loss of production, 4000 g m^{-3} . ANZEEC suggest 2000 g m^{-3} as the no effect limit for poultry.

Barium

USEPA (1972) have no restriction upon barium for livestock watering or for irrigation. ANZEEC (1998) have no restriction upon barium for livestock watering or for irrigation, nor for any requirement for protection of water ecosystems.

Two criteria for barium have been found during a search of the literature. An interim Canadian soil quality guideline is tagged that there is insufficient data to develop criteria for the protection of human health or the environment. The guideline given is 750 g m^{-3}. The USEPA Region 9 uses a value of 1600 g m^{-3} in soil to protect groundwater as a drinking water source for humans, and 5300 g m^{-3} for residential soil.

References:
Water Quality Criteria, USEPA, 1972
Canadian Soil Quality Guidelines for the protection of environmental and human health, Canadian Council of Ministers of the Environment 1999
Region 9 Preliminary Remediation Goals, EPA Region 9, 1996

Appendix 2 – Report on the Disposal of Drilling Wastes by Mix-Bury-Cover

Introduction

The Taranaki Regional Council (TRC) wishes to adopt a guideline for the disposal of drilling wastes within the greater Taranaki area. Whilst it is generally agreed that the drilling muds currently used in New Zealand do not give rise to heavy metal contamination, the drilling wastes can have high concentrations of chloride, nitrogen and barium.

In the absence of any New Zealand guidelines for the disposal of this material, reference has been made to the G-50 Guideline for Drilling Waste Management produced by the Alberta Energy and Utilities Board. The G-50 Guideline imposes maximum concentrations for key contaminants, as well as total site loadings. It requires that waste be mixed with clean soil at a 3:1 ratio, and that this soil/waste mix be buried at a depth of one metre. Fletcher Challenge Energy (now Shell) have questioned the applicability of this Guideline to conditions in Taranaki, and accordingly, the TRC has requested a review of the available data, with a view to adopting a guideline specific to the Taranaki situation.

Applicability of G-50

The G-50 document has been produced for the conditions which appertain to Alberta, Canada. There are significant climatological and geological differences between Alberta and Taranaki, most notably:

- In Alberta the ground is often frozen for long periods, whereas in Taranaki soils remain relatively warm year round.
- The permeability of soils in Alberta is lower than those in Taranaki. Soil density and permeability are significant in the G-50 Guidelines, where it is assumed that any M-B-C disposal will be over impermeable subsoil, and the soil density is assumed to be $1700kg/m^3$.
- Permeable soils and a high rainfall in Taranaki result in a shallow water table, whereas the G-50 guidelines require that any permeable stratum, or the water table, be at least a metre below the disposed waste.

The G-50 Guideline describes the M-B-C disposal method as waste stabilisation by mixing with subsoil. It states: "*The goal of Mix-Bury-Cover is to incorporate waste into the subsoil below the major rooting zone and above the water table in a manner that preserves the soil chemical properties and protects groundwater quality. Mix-Bury-Cover is not intended for wastes resulting from the use of hydrocarbon based mud systems.*"

The G-50 Guideline loading criteria for mix-bury-cover disposal are summarised in the following table.

Pre-Application Conditions	Maximum Application Rate	Post Application Conditions
Receiving Soil: • Impermeable subsoil Site: • Water table or permeable material must be at least 1m below soil and waste mixture. Waste: • Must pass toxicity assessment if mud additives require testing, or if hydrocarbon was added to the mud system	Chloride: <2000mg/kg in the subsoil and waste mix. Hydrocarbon Content: <0.1% on a dry weight basis in the subsoil and waste mix. Subsoil and waste mix must be at least 3 parts subsoil to 1 part waste. A minimum 1m of clean subsoil must cover subsoil and waste mix.	Chloride: • Lifetime loading limit of 1600kg per disposal site. Nitrogen: • Lifetime loading limit of 400kg per disposal site. Trace Elements – total lifetime loading limits: Boron 10kg Cadmium 3kg Chromium 200kg Copper 400kg Lead 200kg Nickel 50kg Vanadium 200kg Zinc 600kg

It is not clear from the document how the application rates given above were derived, however it appears that the intention of the G-50 M-B-C method is to dilute (stabilise) and isolate the waste. Such isolation will be difficult to achieve in Taranaki, given the high rainfall, permeable soils and high water table.

It is noted that the Land-spreading Disposal Method detailed in the G-50 Guideline is more appropriate to the Taranaki situation, and indeed is successfully used particularly in sandy coastal areas. This method is where drilling waste is spread on the ground and incorporated into the subsoil. The requisite land-spreading area is based on a calculated loading rate. This method does not require impermeable material to be present below the disposed waste, or a cover layer to be applied. Lifetime loading limits are the same as for M-B-C, however loading rates are lower and the receiving soil must have an electrical conductivity (EC) of less than or equal to 4dS/m, and a sodium absorption ration (SAR) of less than or equal to 8.

The main argument apparently advanced by industry against the G-50 M-B-C method is that the chloride levels are higher in drilling muds used in New Zealand, and therefore the lifetime loading rate cannot be achieved, and that the volumes of mud are higher, making a 3:1 soil/waste mix ratio costly to achieve.

Monitoring data

In order to assess the impact of the mix-bury-cover disposal method, some studies have been carried out, principally by Fletcher Challenge Energy. These include the installation of six bores at the Ohanga-A site together with regular monitoring and growing trials, the installation of a monitoring bore at the Toe Toe-A site, and a review of existing data from earlier disposal operations.

Ohanga-A

The study carried out by Fletcher Challenge Energy at Ohanga-A provides the most detailed information currently available (note that the burial conditions are not those specified in G-50, being at a lower mix ratio and with less depth of cover).

Location: North Taranaki, Onaero catchment
Soil type: Clay and ash to 5m over swampy peat.
Volume of disposal: 750m^3 MBC 1:1 drilling waste and soil, 0.5m cover.
Date of burial: Oct 1999
Date of sampling: Oct 1999 – June 2000
Depth to groundwater: 1.2m - 2.5m
Monitoring: Analysis of soil/drilling waste
Analysis of groundwater in six bores

Growing trials – grass and radishes in waste, waste/soil mix and a control.

Results

Soil/waste mix

pH	Ca	Mg	Na	Cl	Ba	TPH
11.6	31000	5720	1520	4440	398	<50

All results except pH in mg/kg dry weight

Groundwater

Range of chloride concentrations over initial 9 month monitoring period, and TRC sampling in March 2002

Bore	Location	pH	Chloride concentration on selected dates							
			12.11.99	*25.11.99*	*10.12.99*	*23.12.99*	*27.01.00*	*10.3.00*	*16.6.00*	*25.3.02*
MW1	Upstream	5.8-6	40	22.3		33				13.9
MW2	Inside MBC	6.8-7	2475	2590	2155	2134	1810	2153	1914	2630
MW3	Downstm edge of MBC	6.6- 5.8	1060	1150	1258	1194	585	899	639	750
MW4	In MBC – old Ohanga-1 sump area	6.8- 6.7	795	1240	1386	1415	1406	928		1130
MW5	Downstm edge of MBC	7.2- 6.8	579	693	909	909	681		542	547
MW6	23m d/s	5.6	40	268	333	316	389	401	359	272

All results except pH in mg/L
Full results are available in the Montgomery Watson report. Data for 25 March 2002 provided by the TRC.

Growing trials

Grass grew well. Radishes all germinated in the growing troughs but failed to flourish in the control and soil/waste mix, and died in the drill cuttings. (ref pp13-14 MWH report).

Comments

There are six bores on this site. MW1 is the control upgradient of the disposal area. MW2 is within the M-B-C area, and MW6 is located at the downstream boundary of the lease site some 23m from the M-B-C area, and 40m from MW2. The monitoring showed that groundwater flow rate is 17m/month (compared with 12m/year as estimated in the AEE prepared for Ohanga-A). It is apparent that there is an impact on receiving groundwater in MW6, which has had a chloride concentration of 300 – 400 mg/L for most of the monitoring period. The latest monitoring round in March 2002, over two years since disposal took place, indicates little overall change in chloride levels in any of the bores.

Toe Toe-A

Note that on this site also the burial conditions are not those specified in G-50, being at a lower mix ratio. The depth of cover is not known.

Location: Bristol Rd south of the Waitara River, on a hill overlooking the Mangaone Stm.
Soil type: Volcanic ash and clay
Volume of disposal: 100m^3 MBC, 2:1 mix which incorporates previously buried Toetoe-6 & 7 solids.
Date of burial: Dec 1999
Date of sampling: Feb 2000
Depth to groundwater: ?
Monitoring: Soil / drilling waste
Groundwater bore 15m d / s

Results

Soil/cuttings

pH	Ca	K	Mg	Total N	Cl	Ba	TPH
11.2	35800	18000		400	16700	522	1000

All results except pH in mg / kg dry weight

Groundwater

Date	pH	Ca	K	Mg	N	Cl	Ba
11.2.2000	6.7		116			416	0.199
24.4.2000						426	

All results except pH in mg / L

Comments

The report on Ohanga-A by Montgomery Watson suggests that the leachate from Toe Toe-A has "*reached steady state*". No evidence is presented in support of this claim, and only two monitoring results (Feb and April 2000) have been made available. Although the waste volume at Toe Toe is relatively small, the concentration of chloride in the waste is much higher that that at Ohanga-A, or any other site for which data is available.

Other monitoring

A study by Woodward Clyde in 1998 looked at monitoring data from four sites (Toko-1, Tuhua-A, Kaimiro-G and Mangahewa-B) where disposal has been carried out in the past. This data appears to show that the long-term effects of disposal are minimal, however too little is known about these disposals to make them of significant use in the current study. For example, there is no data to indicate the volumes of waste disposed, or the concentrations of contaminants in the waste. Moreover, it would appear that on these sites the waste was deposited into cells lined with impermeable membrane.

With respect to the approach taken by other companies, for example Swift Energy and Discovery Geo, there has merely been monitoring of the waste after mixing and disposal to ensure that the loading criteria specified in the consent were met. There is no information on the initial, unmixed, waste concentration, or any follow-up monitoring. However, it is noted that the concentrations of chloride in waste from the Swift Energy site (Rimu-A), and the Discovery Geo site (Warea-A) are considerably lower than those recorded on the FCE sites discussed above. At Warea-A the chloride concentration after 1:1 soil/waste mixing was a maximum of 525mg/kg, and at Rimu-A were a maximum of 728mg/kg after 3:1 soil/waste mixing (this last value giving a potential chloride in unmixed waste of approximately 2900mg/kg).

Conclusions

It is generally accepted that the types of drilling muds used in Taranaki do not give rise to significant concentrations of heavy metal contaminants, with the possible exception of barium. There does, however, appear to be considerable differences in the concentrations of salts in the muds.

The most detailed monitoring data available, from Ohanga-A, indicates that there is elevated chloride at the site boundary. Over the two year monitoring period levels of chloride in the down-gradient bore have remained at 250 – 400 mg/L, with no evidence to suggest that there has been any significant reduction during that time. At Toe Toe-A there were considerably higher concentrations of chloride in the initial waste, although the volume of waste is far smaller. Chloride was also measured in the monitoring bore although there is not sufficient information to assess the impact or any trends. Data provided from sites drilled by Swift Energy and Discovery Geo indicate that the concentration of chloride in the waste is not more than 2900mg/kg (compared with 4400mg/kg at Ohanga-A and 16700mg/kg at Toe Toe-A).

The maximum recommended chloride level in human drinking water is given as 250mg/L in the NZ Drinking Water Standards, and 400mg/L in the ANZECC Water Quality Guidelines for Fresh and Marine Waters. It is understood that shallow groundwater in Taranaki is not used as a human drinking water source, however it should be noted that chloride is also of concern in irrigation water (both for uptake and spray damage). With respect to stock watering (particularly dairy cattle) levels of calcium should not exceed 1000mg/l and total dissolved solids should not exceed 4000mg/l. Levels of nitrate/nitrite and sulphate are also of concern in stock watering.

Climatic and geological conditions in Taranaki make the achievement of G-50 M-B-C specifications difficult (ie isolation and containment of the waste). However, despite the work carried out at Ohanga-A, there is not yet sufficient information available to enable guidelines specific to the Taranaki situation to be derived.

Recommendations

It is recommended that, should the TRC wish to continue to approve the use of M-B-C as a disposal option, the G-50 Guidelines continue to be used as a baseline, or fallback position. Where a company wishes to use less onerous conditions, there should be a detailed monitoring programme instituted at each site to enable the effects to be fully assessed. There should also be a contingency plan submitted with the proposed relaxed conditions, detailing what measures will be taken should monitoring indicate that the effect on the environment is adverse.

Data collected from these sites will enable the full impact of mixed-bury-cover on the environment to be assessed in a variety of geological, groundwater and waste type scenarios. If appropriate, amended guidelines can then be drawn up.

Information provision

Basic data should be required at all disposal sites to enable base information to be compiled. As detailed in the TRC "draft 2001 Guide" this should include:

- Description of proposal / activity;
- Adoption of best practicable option and measures outlined;
- Volume of material;
- Number of distinct MBC areas proposed;
- Description of sub-surface geology including porosity and hydraulic conductivity;
- Aerial photo and / or 1:50,000 [or less] topographic map showing proposed MBC areas in relation to surface water, land contours, groundwater contours and any other features of interest with respect to MBC;
- A summary of an assessment of environmental effects, in particular relating to potential groundwater contamination and water use impacts;

In addition, analysis of the waste should be carried out at all sites. Analyses should include pH, Cl, N, Na, Ca, Mg, SO_4 and Ba, as well as for any other contaminant which may be of relevance because of the type of drilling additives programme employed at the particular site.

Environmental monitoring

Where G-50 conditions cannot be achieved, either in terms of total site loading or calculated maximum application rate, or specific disposal requirements such as mix ratio or burial depth, then environmental monitoring should be required to be carried out.

Monitoring should comprise the following:

- Installation of monitoring bores to enable sampling of the groundwater. Bores should be located at the downgradient edge of the disposal site, and at a suitable distance downgradient to enable the offsite impact of the waste to be assessed. There should be a minimum of three bores, and more where the groundwater flow direction is not well documented. If there is any question about the background water quality it would also be necessary to install a bore upgradient of the disposal site.
- Bores should be sampled four-monthly for two years or until the downstream water quality reaches acceptable levels. Analysis should be carried out for pH, Cl, TDS or EC, SO_4, N and any other parameter which had been identified within the waste as a potential environmental concern.
- A detailed description of the sub-surface geology.
- Measurement of hydraulic conductivity, relevant groundwater hydrology and connection with any surface water bodies.

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Environmental Engineer

3 June 2002

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Discovery Geo Corporation Ltd Warea-A Mix-Bury-Cover: Report on Soil Monitoring, January 2002. BTW Surveyors Ltd

Appendix 3 – Summary of Landcare findings and recommendations arising from trial disposal of OBM

Findings

A report on the Schrider Land Treatment Site was received by the Council in April 2005. The report was prepared by Landcare Research.

The Landcare study focused on the environmental effects of disposal of OBM (including both diesel-based and oil-based mixtures) onto land. Data provided by both the Council and the Company were reviewed, and compared with the resource consent and a range of guidelines for water quality, hydrocarbons in soil, and the disposal of various wastes to land.

The effects of wind blow-out on bare areas in the general locality were noted, with the comment that a good vegetation cover is the best control against wind erosion.

The consultant noted that the application of muds and oils across the various sites was patchy, but this had not affected pasture growth or stock health in the view of the consultant.

The consultant found that oats and ryegrass were generally well-established over the sites. There were patchy areas of poor growth, but these did not appear associated with higher levels of contaminants- indeed the reverse applied, with lower levels of contaminants in the areas of poorer growth when compared with adjacent areas. Disease, pests, or waterlogging were considered more likely.

Initial strikes seemed to take slightly longer in areas where WBM had been applied compared with OBM, due possibly to the deeper applications in WBM disposal areas. In the longer term, WBM disposal areas seemed to produce thicker and more consistent growth The consultant considered that in the long term the distinction would disappear (as OBM denatured).

Ongoing maintenance (e.g. stocking rates, weed control, fertilisation, irrigation) was seen as important if the good initial seed strike and growth was to be sustained.

It was considered that neither the residual hydrocarbons nor the elevated barium levels were having an adverse effect upon livestock. However, it was considered that as a precautionary measure it might be appropriate to withhold stock for a year after pasture was first established.

The productivity and sustainability of the disposal areas as pasture was considered to have been significantly improved by the disposal activities as a whole- the levelling during site preparation, re-sowing, fertiliser application, and soil conditioning effects of the muds, sawdust, and residual hydrocarbons. The initial benefits of this should continue as organic matter builds up from better pasture growth.

Results of analyses before and after application noted that original soil quality was poor, typical of sand dunes with low organic content. Following mud application, soil pH was mainly in the optimum range for pasture growth. The main contaminants were confirmed as hydrocarbons and barium. Other heavy metals were well below soil limiting levels. However, it was suggested that should repeated applications be made to the same site, then monitoring from accumulation would be necessary. The consultant confirmed the appropriateness of conditions controlling soil levels of heavy metals.

The consultant confirmed the decomposition of hydrocarbons, recommending the application of nitrogenous fertiliser to enhance this process (especially with the use of sawdust to regulate liquidity). Given natural levels of microbes able to degrade hydrocarbons, no supplementary inoculation of soils was considered necessary.

It was noted that barium concentrations were higher than desirable, and were reducing (although the reason for the reduction was unclear). However, it was also noted that barium in drilling muds is in an insoluble form (barium sulphate), and that uptake and bioaccumulation by plants is negligible. Ingestion of barium by grazing livestock was not considered to be a significant risk, although hard grazing of pasture, especially when wet, was a practice to be encouraged to reduce ingestion.

The Landcare report included a summary of conclusions, findings and recommendations. These are discussed in the next section.

Conclusions and recommendations:

The conclusions of the Landcare report are that:

a) Land farming of drilling wastes (including OBM) is appropriate, practical, and advantageous, and potentially improves coastal sandy country ;
b) Precautionary management for the first year after application is appropriate;
c) Landfarming should be carried out in accordance with the conditions imposed by the Council; these conditions are in accord with most of the overseas literature on bioremediation of drilling wastes;
d) Differences between OBM and WBM sites in pasture establishment apparent to date do not appear significant and are expected to disappear;
e) The use of sawdust to dilute and enhance the spreading of wastes is useful, and will promote microbial activity; nitrogenous fertiliser, or the use of mature compost as an alternative, to prevent nitrogen deficiency as the sawdust decomposes is probably a necessity;
f) Incorporation to a depth of 250 mm is recommended;
g) Good pasture husbandry practices should be incorporated into on-going site management;
h) The current consent condition preventing repeat applications to a single site is supported, to avoid potential accumulation of heavy metals;
i) Spreading of wastes should aim for as even a spread as practicable;
j) Consent conditions appear to take a precautionary approach that is supported;
k) Avoidance of stock access to pasture for one year would be a recommended precautionary measure;
l) Nitrogen loading rate limits may need to be varied to allow nitrogen applications to match the high organic carbon loadings (sawdust); single application rate limits might be applied in future resource consents;
m) The prohibition on stockpiling OBM prior to spreading is unduly restrictive, and could be varied to allow storage in an impermeable pond;
n) While the responsibility for site management could fall back to the land owner one year after re-instatement, site monitoring at one year and two years after reinstatement should be required, and a requirement to report to the Council on the general state of the land after five years is appropriate.

Appendix 4 – Typical consent conditions – Land spreading and incorporation

Advice notes

i) *'discharge' means spreading, tilling or layering, but excludes stockpiling*
ii) *'stockpiling' means the discharge from vehicles, tanks, or other containers onto land, but without subsequently spreading, tilling, or otherwise blending into soil within 12 hours of such discharge [storing wastes in a holding system with impermeable base and walls is not considered to be either stockpiling or discharge].*
iii) *'Water based mud' means a drilling fluid in which water is the main liquid component*
iv) *'Synthetic based mud' means a drilling fluid is which the main liquid component is mainly a synthetic [man made] fluid rather than oil or water. Synthetic based muds do not contain poly-aromatic hydrocarbons. [Examples of synthetic based muds include: esters; linear parrafins; poly-alpha olefins; linear alkyl benzene; acetal; linear alpha olefins]*
v) *'Oil based mud' means a drilling fluid in which the liquid component is mainly an oil such as diesel, mineral oil, kerosene or crude oil.*

Special conditions

Scenarios:
i) *All conditions 1 to 35 apply to the discharge to WBM, SBM cuttings, OBM cuttings, and oily wastes covered by a single consent;*
ii) *Conditions and sub-conditions marked with ☆ apply to consent for discharge of WBM and SBM cuttings including materials with hydrocarbon content greater than 5%;*
iii) *Conditions and sub-conditions marked with ★ apply to consent for discharge of WBM and SBM cuttings with hydrocarbon content less than 5%.*

★ ☆ 1. The exercise of this consent shall be undertaken generally in accordance with the documentation submitted in support of application <xxxx>. In the case of any contradiction between the documentation submitted in support of application <xxxx> and the conditions of this consent, the conditions of this consent shall prevail.

★ ☆ 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 adverse effects on the environment from the exercise of this consent.

Management plan

★ ☆ 3. Prior to the exercise of this consent, the consent holder shall provide, to the written satisfaction of the Chief Executive, Taranaki Regional Council, a landspreading and incorporation management plan to confirm that the activity will be conducted to comply with all of the conditions of this consent. The management plan shall be reviewed annually and shall include as a minimum:

a) land spreading and incorporation procedures [any stockpiling, means of spreading, means of soil incorporation and tilling to the preferred target depth of 250 mm];
b) procedures for notification to Council of disposal activities;
c) sampling regime;
d) contingency procedures;

e) post-spreading management and site reinstatement and monitoring for up to five years; and
f) control of site access.

Notification and sampling requirements prior to discharge

4. The consent holder shall notify the Chief Executive, Taranaki Regional Council, in writing at least 48 hours, but not more than 10 days, prior to commencement of each operation involving transfer of wastes from a drilling waste holding receptacle, to the discharge site for discharge onto or into land via stockpiling, spreading, tilling and/or layering from each well drilled.

5. The consent holder shall notify the Chief Executive, Taranaki Regional Council, in writing at least 12 hours prior to discharging stockpiled material onto or into land.

6. Prior to discharge of wastes with hydrocarbon content equal to or greater than 5%, from wells drilled with water based muds or synthetic based muds, the consent holder shall provide the Chief Executive, Taranaki Regional Council, with a representative chemical analysis of the wastes, including the results of leachate testing. This condition does not apply to the stockpiling of wastes.

   Alternative condition to put in discharge limits section: “The hydrocarbon content in the waste prior to discharge shall be less than 5%.”

7. Prior to discharge of drilling cuttings and/or oily wastes from any well drilled with oil based muds, the consent holder shall provide to the Chief Executive, Taranaki Regional Council:

   a) information on location of discharge area;
   b) records of all additives used during the drilling process;
   c) a representative chemical analysis of the material to be discharged from each well [from a composite sample, including: concentrations of nitrogen, chloride, pH, K, Ca, Mg, Na, total petroleum hydrocarbon [TPH] composition in the ranges C_6-C_9, C_{10}-C_{14} and C_{15}-C_{36}, polynuclear aromatic hydrocarbon [PAH] composition, density, and BTEX]; and
   d) results of leachate testing.

Discharge limits

8. The rate of discharge shall be limited to:

   a) an application depth of 150 mm for water based drilling wastes and drilling cuttings from wells drilled with synthetic based muds with hydrocarbon content less than 5%;
   b) an application depth of 50 mm for water based drilling wastes and drilling cuttings from wells drilled with synthetic based muds with hydrocarbon content equal to or greater than 5%;
   c) an application depth of 20 mm for drilling cuttings from wells drilled with oil based muds [once mixed 1:1 with an absorbent material such as sawdust] regardless of the hydrocarbon content; and

d) a rate and manner of discharge such that no ponded liquids remain after one hour for oily wastes from wells drilled with oil based muds.

9. As soon as practicable following discharge, the consent holder shall incorporate the material into the soil to a depth of at least 250 mm so that:

a) The hydrocarbon content in the soil / waste mix is less than 5% anywhere in the 250 mm layer below the topsoil layer for water based drilling wastes and drilling cuttings from wells drilled with synthetic based muds; or

b) The hydrocarbon content in the soil / waste mix is less than 1.5% anywhere in the 250 mm layer below the topsoil layer for drilling cuttings and / or oily wastes from wells drilled with oil based muds.

10. As soon as practicable following discharge and incorporation, the discharge area shall be covered with topsoil, and resown into pasture [or into crop]. If revegetation cannot be established within two months of the discharge, the consent holder shall undertake appropriate land stabilisation measures to minimise wind and / or stormwater erosion.

11. The area used for discharge of drilling cuttings and oily wastes from wells drilled with oil based muds is limited to <*nnnn*> square metres per well.

12. No discharge shall take place within 25 metres of a water body [as defined in section 2 of the Resource Management Act 1991], or property boundaries *<or other key facilities or elements of the landscape>*.

13. The exercise of this consent is limited to wastes generated within the Taranaki region.

14. The discharge of drilling cuttings and oily wastes from wells drilled with oil based muds, is limited, in the first instance, to wastes generated at the <*named*> wellsite(s). The discharge of wastes from other wells drilled with oil based muds shall not be allowed until such time that the Chief Executive, Taranaki Regional Council, has received all reports required under special conditions 7 and 32, and considered the need for a review under special condition 34.

15. The stockpiling of material authorised by this consent shall be limited to a maximum volume of <*nnnn*> cubic metres at any one time on the property. In any case all stockpiled material must be discharged onto and into land within two months of being brought onto the site.

16. There shall be no stockpiling of drilling cuttings from wells drilled with oil based muds. *[note: storing drilling cuttings from wells drilled with oil based muds in an "impermeable holding system" is not considered a discharge, and therefore this consent does not apply]*

17. The consent holder shall ensure that areas used for the stockpiling and discharge of water based drilling wastes are kept separate and distinct from areas utilised for the stockpiling and discharge of cuttings from wells drilled with synthetic based muds. Further, stockpile and discharge areas for individual wells shall be kept separate and distinct.

18. The consent holder shall ensure that areas for the discharge of oily wastes and drilling cuttings from wells drilled with oil based muds are kept separate and distinct, with either a buffer or bunding, from areas utilised for the stockpiling and discharge of wastes from wells drilled with water based mud and / or cuttings from wells drilled with synthetic based muds. Further, discharge areas for individual wells shall be kept separate and distinct.

19. The maximum rate of chloride application shall not exceed 800 kg Cl / ha / year.

20. The maximum rate of nitrogen application shall not exceed 50 kg N / ha / application up to a limit of 200 kg N / ha / year. *[Note: an alternative kg/ha/year limit may be appropriate to take into account the need for additional N fertiliser to compensate for the use of sawdust/other organic matter added to OBM cuttings]*

Receiving environment limits

21. At any time the levels of metals in the soil shall comply with the guidelines for heavy metals in soil set out in Table C, Section 9 of the Department of Health's Guidelines for the Disposal of Sewage Sludge to Land [1992].

22. The conductivity of the soil layer containing the discharge shall be less than 400 mSm^{-1}, or alternatively, if the background soil conductivity exceeds 400 mSm^{-1}, the application of waste shall not increase the soil conductivity by more than 100 mSm^{-1}.

23. The sodium absorption ratio [SAR] of the soil layer containing the discharge shall be less than 18.0, or alternatively if the background soil SAR exceeds 18.0, the application of waste shall not increase the SAR by more than 1.0.

24. The exercise of this consent shall not result in a level of total dissolved salts within any surface water or groundwater of more than 2500 gm^{-3}.

25. The exercise of this consent, including the design, management and implementation of the discharge [including but not limited to stockpiling on land and / or discharge onto and into land], shall not lead or be liable to lead to contaminants entering a surface water body.

26. The exercise of this consent shall not result in any adverse impacts on groundwater as a result of leaching, or on surface water including aquatic ecosystems, and / or result in a change to the suitability of use of the receiving water as determined by the Chief Executive, Taranaki Regional Council.

27. The exercise of this consent shall not result in any of the following effects on surface water:

    a) the production of any conspicuous oil or grease films, scums or foams, or floatable or suspended material;
    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.

28. Prior to the expiry, cancellation, or surrender of this consent the levels of hydrocarbons in the soil shall comply with the guideline values for sandy <*or alternative as appropriate*> soil in the surface layer [less than 1 metre depth] set out in Tables 4.12 and 4.15 of the Guidelines for Assessing and Managing Petroleum Hydrocarbon Contaminated Sites in New Zealand [Ministry for the Environment, 1999].

29. Prior to the expiry, cancellation, or surrender of this consent soil parameters shall not exceed the following limits: conductivity, 290 mSm^{-1}; total dissolved salts, 2500 gm^{-3}; sodium, 460 gm^{-3}; and chloride, 700 gm^{-3}.

Monitoring and reporting

30. The consent holder shall keep records of the following:

a) wastes from each individual well [including records of all additives used at the wellsite during the drilling process]
b) stockpiling area[s]
c) discharge area[s] including a map and GPS co-ordinates
d) composition of material [including concentrations of nitrogen, chloride, total hydrocarbons, and C_6-C_9, C_{10}-C_{14}, and C_{15}-C_{36} fractions]
e) polynuclear aromatic hydrocarbon [PAH] composition of oily wastes, and drilling cuttings from each well drilled with oil based muds
f) volumes of material stockpiled
g) volumes of material discharged
h) dates and times of commencement and completion of discharge and stockpiling events
i) treatments applied
j) sampling, analysis and results of monitoring

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

31. The consent holder shall provide to the Chief Executive, Taranaki Regional Council, by 31 July of each year, a report on all records required to be kept in condition 30, and on compliance with conditions of the consent.

32. The consent holder shall collect and analyse a composite representative sample of the soil layer containing the discharge on three occasions after the discharge of oily wastes or drilling cuttings from wells drilled with oil based muds to land. The analysis shall include the analyses listed in condition 34. The three occasions shall be:

a) within one month of the discharge;
b) after three months, but before four months of the discharge; and
c) after nine months but before fifteen months of the discharge.

The results of these analyses shall be provided to the Council within two months of the collection of samples in respect of the discharge of oil based muds, cuttings and wastes from any one well.

Lapse and review

33. This consent shall lapse on the expiry of five years after the date of issue of this consent, 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.

34. 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 consent, including the exclusion of drilling cuttings from wells drilled with oil based muds and/or oily wastes, by giving notice of review within three months of the receipt of any report required under condition 32.

35. 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 20xx, and/or June 20xx, and/or June 20xx and/or June 20xx, 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, or to take into account any Act of Parliament, regulations, national policy statement, and national environmental standard which is relevant to this consent.

Appendix 5 – Typical consent conditions – Mix-Bury-Cover

Special conditions

1. The consent holder shall ensure that the discharge licensed by this consent takes place in general accordance with the information submitted in support of application <*xxxx*>. In particular but without limitation, any amendment to the location of the mix-bury-cover site, pre-treatment of solids, changes to fluids/additives, method of mix-bury-cover, or post burial site management, shall be advised to the Chief Executive, Taranaki Regional Council, prior to any discharge to the mix-bury-cover site, and shall not provide or result in any less environmental protection than that set out or provided for in the information submitted in support of application <*xxxx*>.

2. 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 adverse effects on the environment arising from the discharge, including but not limited to any water body or soil.

Notification and reporting requirements prior to discharge

3. Prior to the exercise of this consent for each separate mix-bury-cover discharge the consent holder shall provide to the written satisfaction of the Chief Executive, Taranaki Regional Council, a report describing proposed mix-bury-cover, including area, location, nature of material, means of compliance with conditions, and the results of any relevant monitoring of existing mix-bury-cover discharge sites under this consent.

4. The consent holder shall notify the Taranaki Regional Council at least 48 hours prior to commencement, and upon completion of the discharge to the mix-bury-cover site[s].

5. The consent holder shall keep records of the composition and volumes of the material to be discharged, including records of quantities and types of drilling fluids and additives used [materials and their composition], and shall forward the records to the Taranaki Regional Council prior to the discharge.

Discharge methods and limits

6. This consent allows for the discharge of up to <*xx*> m^3 per well of solid drilling wastes [including drill cuttings and residual fluids] by way of mix-bury-cover into land on the <*nnnnn*> wellsite and surrounding land.

7. Mix-bury-cover discharge areas for wastes from individual wells shall be kept separate and distinct. Additional mix-bury-cover discharges shall not take place under this consent within 12 months of any previous mix-bury-cover discharge, unless this requirement is waived in writing by the Chief Executive, Taranaki Regional Council.

8. All ponded water shall be removed from the drilling waste holding receptacle prior to the recovery/mixing operation.

9. If sumps are used as drilling waste holding receptacles on the site, and the sump is to be used for a disposal area, the impermeable liner shall be perforated, and where possible removed, so that it no longer encloses the solid drilling wastes.

10. The solid drilling wastes [drill cuttings and residual fluids] shall be incorporated with uncontaminated soils with a mixing ratio of 1 part solid drilling wastes [drill cuttings, additives and residual fluids] to a minimum of 3 parts uncontaminated soil.

11. The solid drilling wastes [drill cuttings and residual fluids] shall be covered by at least 0.5 m of uncontaminated soil, and shall be revegetated and thereafter maintained with pasture cover within 6 months of the completion of any mix-bury-cover operation.

12. The consent holder shall compact and contour the cover material such that all surface stormwater is directed away from the mix-bury-cover site and shall maintain the cover layer of soil so as to ensure its integrity at all times to the satisfaction of the Chief Executive, Taranaki Regional Council.

13. The placement of the solid drilling wastes [drill cuttings and residual fluids] shall as far as practicable be above the watertable.

14. The edge of the mix-bury-cover zone shall be at least 30 metres from any surface water body, spring, or any pre-existing groundwater supply bore.

15. The total loading of trace elements in the solid drilling wastes to be disposed of in the mix-bury-cover operation shall not exceed those listed in Table 3-1 of the Alberta Energy and Utilities Board, 1996, G-50 guidelines.

16. The loading of chloride must not exceed 1,600 kg for each distinct mix-bury-cover disposal area for wastes from an individual well.

17. The loading of nitrogen must not exceed 400 kg for each distinct mix-bury-cover disposal area for wastes from an individual well.

18. The hydrocarbon content of the soil waste mix shall not exceed 0.0015% [15 mg/kg] on a dry weight basis.

Note: other conditions sometimes used…

The exercise of this consent shall be limited to water based drilling solids only and under no circumstances shall synthetic drilling fluids and associated muds and cuttings be discharged under this consent.

The exercise of this consent shall not result in the penetration of the iron pan during the excavation process.

Receiving environment limits

19. At any time, parameters in the soil [less than 0.5 metre depth] shall not exceed the following limits: conductivity 290 mSm^{-1}; total dissolved salts 2500 gm^{-3}; sodium 460 gm^{-3}; and chloride 700 gm^{-3}.

20. At any time the levels of metals in the soil shall comply with the guidelines for heavy metals in soil set out in Table C, Section 9 of the Department of Health's Guidelines for the Disposal of Sewage Sludge to Land [1992].

21. At any time the levels of hydrocarbons in the soil shall comply with the guideline values for the designated soil type in the surface layer [less than 0.5 metre depth] set out in Tables 4.12 and 4.15 of the Guidelines for Assessing and Managing Petroleum Hydrocarbon Contaminated Sites in New Zealand [Ministry for the Environment, 1999].

22. The exercise of this consent shall not result in a level of total dissolved salts within any surface water or ground water of more than 2500 gm^{-3}.

23. The exercise of this consent shall not lead, or be liable to lead, to a direct discharge of contaminants to a surface water body.

24. The exercise of this consent shall not result in any adverse impacts on groundwater as a result of leaching, or on surface water including aquatic ecosystems, and/or result in a change to the suitability of use of the receiving water as determined by the Chief Executive, Taranaki Regional Council.

Lapse and review

25. This consent shall lapse on the expiry of five years after the date of issue of this consent, 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.

26. In accordance with section 128 and 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 consent, by giving notice within three months of receiving data on the volume and composition of the material under condition 5 for the purpose of assessing the adequacy of monitoring and mitigation measures.

27. In accordance with section 128 and 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 20XX and/or June 20XX, 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, or to take into account any Act of Parliament, regulations, national policy statement, and national environmental standard which is relevant to this consent.

Appendix 6 – Background discussion of deep well re-injection application and requirements

USEPA information, description of deep well injection processes, & requirements

Class I wells are designated as hazardous or non-hazardous, depending on the characteristics of the wastewaters injected.

Wastewaters are considered to be hazardous wastes if they demonstrate a hazardous characteristic of ignitability, corrosivity, reactivity, or toxicity, or are a listed waste as determined by EPA.

This designation affects the stringency of the requirements imposed on operators of Class I wells. The wastewater injected into Class I wells typically is associated with the chemical products, petroleum refining, and metal products industries.

Disposal well technology

The geological formation into which the wastewaters are injected, known as the injection zone, 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, known as the confining zone, which will hold injected fluids in place and restrict them from moving vertically toward a freshwater aquifer.

EPA requires that Class I wells be located in geologically stable areas that are free of transmissive fractures or faults through which injected fluids could travel to drinking water sources.

Well operators must also show that there are no wells or other artificial pathways between the injection zone and freshwater aquifers through which fluids can travel. The site-specific geologic properties of the subsurface around the well offer another safeguard against the movement of injected wastewaters to a freshwater aquifer.

All Class I wells must be designed and constructed to prevent the movement of injected waste waters into freshwater aquifers.

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.

A constant pressure is maintained in the annular space and is continuously monitored to verify the well's mechanical integrity and proper operational conditions.

Trained operators are responsible for day-to-day injection well operation, maintenance, monitoring, and testing.

USEPA requirements to minimize risk

There are two potential pathways through which injected fluids can migrate to freshwater aquifers.

First, wells could have a loss of waste confinement; second, improperly plugged or completed wells or other pathways near the well can allow fluids to migrate to freshwater aquifers.

Extensive technical requirements for Class I wells are designed to prevent contamination of freshwater aquifers via these pathways.

Requirements for hazardous wells are more stringent than those for non-hazardous wells.

Operators must demonstrate via geologic and hydrogeological studies that their proposed injection will not endanger freshwater aquifers.

Operators must identify all wells in the vicinity that penetrate the injection or confining zone, determine whether they could serve as pathways for migration of wastewaters, and take any corrective action necessary.

Operators seeking to inject hazardous wastewaters must demonstrate via a no-migration petition that the hazardous constituents of their wastewaters will not migrate from the disposal site for as long as they remain hazardous.

Disposal wells must be operated so that injection pressures will not initiate new fractures or propagate existing fractures in the injection or confining zones.

Class I hazardous wells must be equipped with continuous monitoring and recording devices that automatically sound alarms and shut down the well whenever operating parameters exceed permitted ranges.

Operators must continuously monitor the characteristics of the injected wastewater, annular pressure, and containment of wastewater within the injection zone. Operators also must periodically test the well’s mechanical integrity.

Upon closing their wells, operators must flush the well with a non-reactive fluid, and tag and test each cement plug for seal and stability before the closure is completed. Operators must submit a plugging and abandonment report when closure is complete.

Technology summary

Injection engineering technology, regional and local geologic characterization, and site specific mathematical modelling are combined to ensure that injected fluids from disposal wells travel to their intended location safely away from freshwater aquifers, and remain there for as long as they pose a risk to human health or the environment.

Well failure

Contamination due to well failure is caused by leaks in the well tubing and casing or when injected fluid is forced upward between the well's outer casing and the well bore should the well lose mechanical integrity (MI).

Pathways for fluid movement in the Area of Review

The Area of Review (AoR) is the zone of endangering influence around the well, or the radius at which pressure due to injection may cause the migration of the injectate and / or formation fluid into a freshwater aquifer.

Improperly plugged or completed wells that penetrate the confining zone near the injection well can provide a pathway for fluids to travel from the injection zone to freshwater aquifers.

These potential pathways are most common in areas of oil and gas exploration. Because the geologic requirements for Class I hazardous injection activities are similar to those for oil and gas exploration, these activities often take place in the same areas.

To protect against migration through this pathway, wells that penetrate the zone affected by injection pressure must be properly constructed or plugged. Before injecting, operators must identify all wells within the AoR that penetrate the injection or confining zone, and repair all wells that are improperly completed or plugged before a permit is issued.

Fluids could potentially be forced upward from the injection zone through transmissive faults or fractures in the confining beds which, like abandoned wells, can act as pathways for waste migration to freshwater aquifers.

Faults or fractures may have formed naturally prior to injection or may be created by the waste dissolving the rocks of the confining zone. Artificial fractures may also be created by injecting wastewater at excessive pressures.

To reduce this risk, injection wells are sited such that they inject below a confining bed that is free of known transmissive faults or fractures. In addition, during well operation, operators must monitor injection pressures to ensure that fractures are not propagated in the injection zone or initiated in the confining zone.

Options for de-characterized wastewaters

Under a proposed amendment to HSNO (Hazardous Substances and New Organisms(Approvals and Enforcement) Bill, June 2005), wastewaters that demonstrate the characteristic of ignitability, corrosivity, reactivity, human toxicity or ecotoxicity greater than minimum criteria will be considered to be hazardous wastes. In USA the RCRA statute applies similar provisions.

- **Ignitable wastes** are capable of causing fire through friction at standard temperature or pressure. Ignitable wastes are produced by the organic chemical production, laboratories and hospitals, paint manufacturing, cosmetics and fragrances, pulp and paper, and construction industries.

- **Corrosive wastes** are extremely acidic or alkaline (i.e., have a pH of 2 or below, or 12.5 or above). The organic chemical production, laboratories and hospitals, paint manufacturing, cosmetics and fragrances, equipment cleaning, soaps and detergents, electronics manufacturing, iron and steel, and pulp and paper industries produce corrosive wastes.

- **Reactive wastes** are normally unstable wastes that react violently or from potentially explosive mixtures with water. Examples of industries that produce reactive wastes include organic chemical production and petroleum refining.

- **Toxic organic wastes** contain toxic constituents in excess of a regulatory level. They are produced by organic chemical production, petroleum refining, and waste management and refuse systems.

Prior to disposal in a Class I non-hazardous well (USA), hazardous wastewaters must be de-characterized (i.e., the hazardous characteristic must be removed) by any means including treatment, dilution, or other deactivation through aggregation of different wastewaters, including co-mingling with non-hazardous or exempt wastewaters.

USEPA disposal well siting requirements

Class I wells must be sited so that wastewaters are injected into a formation that is below the lowermost formation containing, within one-quarter mile of the well, a freshwater aquifer.

In siting Class I wells, operators must use geologic and hydrogeological studies and studies of artificial penetrations of the injection and confining zones to demonstrate that their proposed injection will not endanger freshwater aquifers.

In addition, Class I operators seeking to inject hazardous wastewaters must demonstrate via a no-migration petition that the hazardous constituents of wastewaters will not migrate from the disposal site for as long as the wastewaters remain hazardous.

Additional siting requirements are imposed on Class I hazardous wells to ensure that they are located in geologically stable (e.g., low risk of earthquakes) formations that are free of natural or artificial pathways for fluid movement between the injection zone and freshwater aquifers.

USEPA well construction requirements

During the permit application process, the permitting authority reviews and approves:

- engineering schematics;
- subsurface construction details, incl. design of casing, tubing, and packer;
- chemical and physical characteristics of the injected fluids;
- injection and annular pressure;
- rate, temperature, and volume of injected fluid;
- size of the well casing;
- cementing requirements.

Operating requirements

EPA operating requirements for Class I wells provide multiple safeguards to ensure that injected wastewater is fully confined within the injection zone and the integrity of the confining zone is never compromised.

At a minimum, all Class I wells must be operated so that injection pressures will not initiate new fractures or propagate existing fractures after initial stimulation of the injection zone during well construction.

The annular space between the tubing and the long string casing must contain approved fluids only and permitted pressures must be maintained.

Class I hazardous wells must be equipped with continuous monitoring and recording devices that automatically sound alarms and shut-in the well whenever:

- injection pressure, flow rate, volume, temperature of the injected fluid, or annular pressure exceed operating parameters or are outside permitted ranges [40 CFR 146.67 (f), (g), and (j)].

When this occurs, the owner or operator must cease injection; notify the Director within 24 hours; and identify, analyze, and correct the problem.

USEPA monitoring and testing requirements

Operators of Class I wells must monitor and test for:

- mechanical integrity;
- containment within the injection zone;
- characteristics of the injected wastewater.

Operators must also monitor freshwater aquifers within the AoR for indications of fluid migration and pressure changes indicating a potential for contamination.

Class I well operators must continuously monitor injection pressure, flow rates and volumes, and annular pressure.

Monitoring requirements for Class I hazardous wells have explicit procedures for reporting and correcting problems related to a lack of mechanical integrity or evidence of wastewater injection into unauthorized zones.

In addition to monitoring the well operation, operators of hazardous wells are required to develop and follow a waste analysis plan for monitoring the physical and chemical properties of the injected wastewater.

The frequency of these analyses depends on the parameters being monitored. Complete analysis of the injected wastewaters must be conducted at frequencies specified by the plan or when process or operating changes affect the characteristics of the wastewater.

Operators of Class I hazardous wells must perform tests to demonstrate that wastewater characteristics remain consistent and compatible with well materials with the receiving water.

Periodic testing of all Class I wells also is required. The operator must develop a monitoring program that includes, at minimum, an annual pressure fall-off test in addition to an internal MIT every year and an external MIT every 5 years. (Texas and Michigan require external MITs every year.)

Operators of Class I non-hazardous wells must demonstrate internal MI every 5 years. Every 5 years, all Class I well operators must demonstrate external MI using noise, temperature, or other approved logs to test for fluid movement along the borehole.

Casing inspection logs or sonic, temperature, or other approved logs are also required when a well work over is conducted, or if the Director believes that the long string casing lacks integrity.

The location, target formation, and the types of monitoring wells should be based on potential pathways of contaminant migration.

Monitoring within the freshwater aquifer's can provide geologic data or evidence of contamination [Warner, D. L. "Monitoring of Class I Injection Wells." In: *Deep Injection Disposal of Hazardous and Industrial Waste: Scientific and Engineering Aspects*. John A. Apps and Chin-Fu Tsang, eds. San Diego, California: Academic Press. 1996].

USEPA reporting and record keeping requirements

All operators must report the results of required monitoring and testing to the state or EPA UIC Director. The Taranaki Regional Council would consider similar reporting requirements.

Class I hazardous well operators must report quarterly on monitoring results and annually on the results of radioactive tracer surveys, casing pressure tests, ambient monitoring, and pressure fall-off tests.

They must also report any changes to closure plans, including updates to plugging and abandonment cost estimates.
All operators must report on the physical, chemical, and other relevant characteristics of injected fluids; monthly average, maximum, and minimum values for injection pressure, flow rate, volume, and annular pressure; and monitoring results of freshwater aquifer's in the AoR.

USEPA well closure requirements

On closing a well, an operator must submit a plugging and abandonment report indicating that the well was plugged in accordance with the plugging and abandonment plan (submitted when the well was permitted).

Class I hazardous well operators must also conduct pressure fall-off and mechanical integrity tests, and report on the results in their closure reports.

In addition, Class I hazardous well operators are required to continue and complete outstanding clean-up actions, and continue groundwater monitoring until pressure in the injection zone decays to the point where no potential for influencing the freshwater aquifers exists.

They must also notify and provide appropriate information to local and state authorities regarding the well, its location, and its zone of influence at closure.

How EPA administers the Class I UIC program

Class I wells are subject to a ban on the land disposal of certain wastes, unless owners/operators of these wells demonstrate that the wastewaters will not migrate from the injection zone for 10,000 years, or as long as they remain hazardous.

Several technical staff may review a single petition and may take a year or more to determine whether it should be approved. Each part of a petition is reviewed by a specialist. For example:

- an engineer or geologist reviews information about the construction, operation, maintenance, and compliance history of the well; local and regional geology and seismology; and the compatibility of the wastewater with the well materials and the injection and confining zone rock and fluids;

- a modelling expert evaluates the accuracy of the model's predictions compared to actual conditions at the site, and verifies that the model takes into account all significant processes that affect waste mobility and transformation, is sensitive to subsurface processes, and has been properly validated and calibrated.

Risk associated with Class I wells

Early failures associated with Class I injection in USA illustrated the potential threats of wastewater injection and the need for and importance of the UIC regulations.

The 1980 UIC regulations address many of these risks. Since passage of the regulations, EPA and other organizations have conducted numerous studies of hazardous and non-hazardous Class I wells which demonstrate that such failures are unlikely to occur.

The UIPC study identified malfunctions at 26 facilities, involving 43 wells, suggesting an overall well malfunction rate of approximately 9 percent of the 500 Class I wells reported to exist at the time.

Most of the malfunctions reported in the UIPC study were related to design, construction, or operating practices that are no longer allowed under UIC regulations as follows:

Excessive injection pressure or hydraulic surge causing a blowout at the wellhead or surface piping, leading to contamination at the surface.

The presence of improperly abandoned wells was cited as a factor in contamination at the surface in the UIPC study.

Leaking packer assemblies were the most likely cause of leakage into an un-permitted non-drinking water zone.

Corrosion of the casing or tubing was suspected as the cause of leakage of injected fluids. In one case, corrosion caused the tubing to separate, resulting in a blowout and waste spillage at the surface.

Injection directly through the casing, without packer and tubing, was the primary cause of two cases of drinking water contamination from Class I wells.

EPA studied more than 500 Class I non-hazardous and hazardous wells in 14 states and identified the following:

- From 1988 to 1991, 130 cases of internal MI failures (leakage in the injection tubing that can result from corrosion or mechanical failure of the tubular materials) were reported. All of these internal MI failures were detected during well operation by the continuous annulus monitoring systems or by MITs.

  The wells were shut-in until they were repaired. Of these MI failures, 42 percent occurred in the tubing and 23 percent involved the long string casing.

- One external MI failure (flow along the outside of the casing) occurred. It was detected by a routine external MIT and did not involve wastewater migration.

- Only four cases of significant non-hazardous wastewater migration were detected.

Based on a review of the draft report against its records, TNRCC cites a **37-percent failure rate for Class I wells in Texas from 1993 to 1998**.

Qualitative studies of Class I Wells

Two studies were performed in anticipation of the 1988 updates to the UIC regulations to assess the risks associated with disposal of hazardous wastewater via Class I wells.

The conclusions of the study include:

- Waste confinement increases in scenarios where abandoned unplugged boreholes are farthest from the injection zone;

- Under certain conditions, containment failure can result in migration of waste from the injection zone.

When contamination of overlying strata did occur, waste migration appeared to be localized to within a few hundred to a thousand feet from where the failure occurred;

- The mode of failure (e.g., grout seal failure, presence of an abandoned borehole, or fractured confining zone), was less significant than the degree of failure, the injection fluid characteristics, and the location of the failure pathway relative to the injection well;

- Pumpage in an overlying aquifer with failure pathways increases the amount of waste escaping from the injection zone. (Note: if a freshwater aquifer for public supply is directly over a proposed injection zone, Class I regulations would not allow the well to be constructed; this makes the addition of the pumping scenario to the model overly conservative.)

- To ensure waste confinement, the confining zone should be much less permeable than the injection zone (by one-thousand fold). Where there is less contrast in permeability, significant amounts of wastewater may migrate into the overlying zone.

- Models should provide sufficient hydrogeological detail to account for rock layers between the injection zone and the freshwater aquifer that could attenuate some of the wastewater that migrates upward through a failure pathway. Using simplified zones for injection, confinement, and freshwater aquifer in models may cause overestimation of the potential extent of contamination in freshwater aquifer's.

- The additional stress on the systems related to pumpage in the freshwater aquifer significantly reduced waste containment in all settings.

The underground injection of hazardous waste is particularly low risk compared to other waste management practices and the risks of handling, transporting, and treating segregated Phase III wastes might actually be greater than the risks of injecting the waste.

Appendix 7 – Typical resource consent conditions for deep well re-injection

1. The exercise of this consent shall be carried out in general accordance with the information submitted in support of application <xxxx>. In the case of any contradiction between the documentation submitted in support of application <xxxx> and the conditions of this consent, the conditions of this consent shall prevail.

2. 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 likely adverse effects on the environment from the exercise of this consent.

3. Prior to the exercise of this consent for each individual well to be used for deepwell injection, the consent holder shall submit, to the written satisfaction of the Chief Executive, a log of the injection well, and an injection well operation management plan, to demonstrate that special condition 2 of this consent can be met. The report shall:

   a) identify the injection zone, including a validated bore log and geophysical log;
   b) detail the results of fluid sampled from the injection zone, and the proposed wastes to be injected for maximum and mean concentrations for pH, suspended solids, total dissolved solids, salinity, chlorides, and total hydrocarbons;
   c) demonstrate the integrity of well casing; and
   d) outline design and operational procedure to isolate the zone.

4. The resource consent holder shall ensure that injection will not contaminate or endanger any actual or potential useable freshwater aquifer.

5. The consent holder shall keep weekly records of the nature and amounts of all material injected, including injection pressure and rate, and shall make the records available to the Taranaki Regional Council on an annual basis, and when there has been a significant pressure change event.

6. The consent holder shall monitor the injected wastes weekly for maximum and mean concentrations for pH, suspended solids, total dissolved solids, salinity, chlorides, and total hydrocarbons and shall make the records available to the Taranaki Regional Council on an annual basis.

7. The consent holder shall inject fluids at pressures below the pressure that would be required to fracture the stratigraphic seals of the injection formation.

8. The consent holder shall provide to the Taranaki Regional Council during the month of May of each year, for the duration of the consent, a written report on all matters required under special conditions 3, 4, 5, 6 and 7 above.

9. This consent shall lapse on the expiry of five years after the date of commencement of this consent, 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(b) of the Resource Management Act 1991.

10. 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 20nn and / or June 20nn, 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.