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Title of Report: Petroleum Operations Notice N°10 – Use and discharge of non-aqueous drilling fluids and associated cuttings

Paper No: 253/13

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Report of: Director of Mineral Resources

1.0 Purpose

1.1 To approve and bring into force a Petroleum Operations Notice outlining the process and regulations for the approval of oil-based drilling fluids, disposal of associated cuttings; and relevant reporting requirements.

2.0 Recommendations

2.1 Honourable Members are recommended to approve the attached draft Petroleum Operations Notice so that it may be implemented and enforced by the Department of Mineral Resources.

3.0 Additional Budgetary Implications

3.1 None.

4.0 Background

4.1 Drilling muds are an essential component of drilling operations and fulfil a number of roles, most notably transporting drill cuttings out of the wellbore and providing stability. Drilling operations in the Falklands have historically been carried out with water-based muds (WBMs); indeed, under the terms of their production licences, operators are obliged to use WBMs "wherever technically possible"[1].

4.2 Oil-Based Muds (OBM, also known as Non-Aqueous Drilling Fluids) have been increasingly used internationally in deeper and/or highly-deviated wells due to their increased lubricity and well-bore stability performance. OBMs reduce drilling time, instances of stuck pipe and fluid loss to the formation, making highly-technical wells quicker, safer, and in cases, altogether possible.

[1] Additional conditions to licences as laid out in schedule 6 of 1995 Competitive Round Licences and schedule 7 of 2000 Open-Door Licences.

The environmental impact of such fluids, however, has been the subject of widespread scrutiny. While wholesale discharge of fluids is rare, the discharge of tainted cuttings from well sections drilled with OBMs can lead to an accumulation of that fluid on the sea-bed. For example, initial OBMs used in the North Sea in the 70s and 80s were diesel-oil based, and the disposal of untreated cuttings led to the creation of persistent cuttings piles on the sea bed and long-term environmental damage. Technological advances in both fluid design and treatment technology have eliminated such drastic impacts, but the subtler, longer-term impacts are still the focus of much study.

4.3 Sea Lion development drilling is certain to involve a number of horizontal extended-reach wells, and Premier Oil have approached the Department to request guidance on OBM use. Similarly, stability issues encountered in one of the wells drilled in the South Falklands Basin (which resulted in a failure to reach all geological targets), have led Southern-area operators to investigate the possibility of employing OBMs.

4.4 Consequently, the Department carried out a review of existing technology, applicable regulations worldwide, and research into possible environmental impacts. The full document is attached, but its findings are summarised below:

4.4.1 **There are three categories of oil based-muds, Group I, II, and Group III,** differentiated primarily by their polycyclic aromatic hydrocarbon[2] (PAH) content, which in turn determines their level of environmental impact. Group I Oil Based Muds (PAH content of 0.35% or more) have been widely discontinued internationally, while Group II and III are used with varying degree of regulation.

4.4.2 **Best available cutting-treatment technology allows cuttings to be cleaned to 1% or less oil-on-cutting (OOC) content,** with actual levels regularly reaching 0.1% or less. Such technology is proven and widely used, particularly in the North Sea, and has a cost of around $20,000 to $25,000 per day depending on redundancy equipment mobilised.

4.4.3 **Strictest international regulations call for OBM-tainted cuttings to be cleaned to 1% OOC or less prior to offshore discharge.** This is the case in OSPAR[3] countries, which include the UK and Norway, though it is recognised that on some parts of the Norwegian continental shelf, offshore discharge is completely prohibited. Other levels of OOC requirements range between 6% and 10%, such as in the US, Canada, or Australia.

4.4.4 **The alternative to offshore discharge, and the only way to categorically eliminate the risk to the marine environment, is through onshore disposal or cutting re-use/recycling.** Onshore disposal requires careful planning to

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[2] Polycyclic aromatic hydrocarbons are organic compounds with two or more benzene rings in their molecular structure. They are known to have a wide range of impacts on the environment and human health at high concentrations.

[3] Oslo Paris Convention for the protection of the marine environment of the North East Atlantic

ensure that the onshore environmental impact (e.g. through pollutant leaching) is no more significant than it would be for offshore discharge. Established specialist contractors with dedicated facilities are employed for this purpose in areas such as the North Sea. The re-use of cuttings is at best at an experimental stage, and ultimately depends on the type of rock being drilled, which is liable to vary. Discussions with both cutting treatment contractors and the Director of Public Works would suggest that, as a general rule, the more that cuttings have been treated to remove oil content (a process usually involving heat), the less useful they will become for other purposes due to their increased water absorption.

4.4.5 **The environmental impact of any given fluid and its associated cuttings is, in general terms, a factor of its PAH content.** Fluids with a lower PAH content have faster biodegradation rates and are less likely to bio-accumulate or prove directly toxic to marine organisms. Similarly, lower PAH contents have been proven to improve cutting dispersal, thereby reducing the possible "smothering" impacts of OBM-associated cuttings. Numerous studies have demonstrated that fish are capable of breaking down PAH compounds, thereby further reducing bioaccumulation potential.

4.5 The review made a number of recommendations and was circulated to the Offshore Hydrocarbons Environmental Forum (OHEF), which incorporates all current operators, environmental groups, and other potentially-affected parties, such as the fishing industry. Comments were received on both the contents and recommendations of the review. A synopsis of those comments and the Department's response is attached with this paper. The major concerns received are as follows:

4.5.1 Concern was expressed by the fishing industry regarding the possible impact on fishing stocks of increased PAH discharge, and it was highlighted that fish exported to the European Union are routinely analysed for PAH content. Although the low/ negligible PAH content of fluids and the efficiency of modern treatment would mean that the amount actual PAH discharge would be minimal, advice was sought from the UK Department of Energy and Climate Change (DECC), who confirmed that regular testing has shown that North Sea fish stocks have not been affected by PAH discharge. Additionally, research from other fisheries has reliably demonstrated that finfish are able to metabolize PAH compounds, thereby eliminating the risk to human health through bioaccumulation.

As part of the proposed PON, PAH content of proposed fluids will be required to be reported and the risk to the environment accordingly addressed. In their application, operators will also be required to place particular emphasis on the possible impact to fishing stocks.

4.5.2 Operators expressed concern at the inclusion of "skip & ship" and onshore disposal as a possible discharge option. The process of shipping all cuttings to shore for discharge would, they argued, considerably increase crane lifting activities, shipping, and onshore transport, which would consequently increase health & safety risks and lead to potential bottlenecks at sensitive points in the

logistics chain (e.g. vessel berthing space). Additionally, to ensure that the disposal of cuttings has no onshore environmental impact, a fully-engineered facility would almost certainly be required. This would not only prove costly for the operator, but it could have a large onshore footprint and therefore may be far from ideal in terms of town planning (particularly as the amount of cuttings, and therefore space required, is only likely to grow in the long term).

Other forum members rightly argued that cost to the operator should not be a deciding factor in determining measures to mitigate or eliminate environmental impact. The Department fundamentally agrees with this, but nonetheless remains wary of implementing measures which incur high costs with minimal or negligible overall environmental benefit. Indeed, such measures could undermine operator acceptance of any future costly measures that have real and obvious environmental benefits.

However, given the early stages of the industry in the Islands, it would be inappropriate to rule out any option, particularly as inter-operator co-operation could lead to more effective solutions in the medium to long-term. Operators will therefore be requested to accompany their discharge application with an in-depth analysis of why other discharge options have been ruled out.

4.5.3 Two operators requested that the level of cutting treatment be raised to 5-6.9% OOC, thereby making it achievable with conventional cutting treatment technology and eliminating the need for costly add-ons and redundancy. One operator felt particularly hard-done-by, as they could be the first to use such a system and would arguably be facing much of the onshore redundancy costs alone. While this was recognised by the department, the reality of the upcoming drilling campaign is that a single rig will be shared by several operators drilling successive mini-campaigns, opening up the opportunity for companies to share such costs also.

Ultimately, the technology required for the level of treatment being proposed is proven and widely used worldwide (including by Falklands operators elsewhere in the world), and although lead-times are likely to require an increased measure of planning by operators, the use of this technology is not deemed unreasonable or overly onerous. The level of cutting treatment required for offshore discharge was therefore left unchanged at 1% OOC.

4.6 Following the receipt of comments, the following final recommendations were made:

4.6.1 **That approval for use and discharge of NADF be given on a well-by-well basis, with operators making a technical argument for their use in each well section. Campaign-wide approvals may be considered for wells of similar designs and falling within the same EIA.**

4.6.2 **That the release to the sea of whole NADF in any stage of the drilling process or the use of NADF in any open part of a well (where the mud and cuttings are not returned to the drilling unit) be prohibited.**

4.6.3 **If the use of NADF is approved, that operators make an application to discharge cuttings associated with NADF. In said application, operators should demonstrate, through a baseline survey and environmental impact assessment that the maximum area that is likely to be affected does not contain sensitive and/or rare species, or eco-systems that are not widely represented throughout the Falkland Islands designated area; and that the environmental impact to that area is acceptable. Discharge applications should also be accompanied by an in-depth argument of why other discharge options have been discounted.**

4.6.4 **That all offshore discharge of NADF-associated cuttings be restricted to a 1% or less dry weight OOC. The technology required for this is widely available, used and proven to achieve that very threshold and therefore not considered to be beyond the expectations of best industry practice. Operators should also be required to make redundancy plans for alternative processing or storage of cuttings if offshore equipment becomes unserviceable.**

4.6.5 **That only Low Toxicity Oil Based Muds or Synthetic Based Muds with low or negligible poly aromatic content be permitted. Such fluids are widely used and available, and therefore the threshold is not considered to be beyond the expectations of international best practice.**

4.6.6 **That FIG reserve the right to amend these regulations based on changes of best international practice, available services in the Falkland Islands, and environmental findings or advances in relevant technology upon consultation with licence interest holders and environmental stakeholders.**

4.7 A final paper was distributed to the Environmental Forum along with a draft Petroleum Operations Notice form. The form itself includes guidance on the approval process, what information is expected from operators as per the above recommendations. It borrows heavily from the UK PON 15, which outlines a system for assessing the risk to the environment and incorporates the CEFAS/ ONCS chemical certification system. This system essentially ranks chemicals according to their environmental hazard potential as determined by a number of standardised tests (biodegradation, bioaccumulation, and eco-toxicity), thereby allowing operators and the Department to gauge the actual risk to the environment at any given drilling location.

4.8 Following the presentation of the draft PON at the Environmental Forum in September, members were informed that a paper for its approval would be submitted to Mineral Resources Committee and Executive Council in November – December. No further comments have since been received from operators or stakeholders.

This paper, the draft PON, and the supporting documents were presented to the Mineral Resources Committee on 14th November 2013, where it was consequently agreed to submit the PON to Executive Council for final approval.

5.0 Financial Implications

None

6.0 Legal Implications

6.1 Although operators are bound by the terms of their licence to comply with Petroleum Operations Notices, the legal aspects of introducing new Petroleum Operating Notices were previously discussed with the Attorney General's Chambers in March 2012 prior to the introduction of PON 9. The then Senior Crown Counsel believed that new PONs would indeed come under licence obligations but concluded that:

"Licensees would have a good argument for saying that it is inequitable to consider them bound by any onerous PONs of which they did not have prior notice when they took up their licence. The question is one of degree. […] If [the Department] wanted to introduce any further PONs of a more onerous nature (requiring operators to do something they do not do at present, or cease an existing practice, or spend money) then [the Department] would be well advised to take further advice at that stage and to only introduce the PON after a lengthy period of advance consultation and notification to the industry."

The proposed regulations only introduce a financial burden on operators insofar as the use of oil-based muds is concerned. The Department will continue to consider water-based muds as the preferred option and will require a sound technical argument before the use of OBM is authorised. Therefore, these regulations will not incur any onerous extra cost to the majority of exploratory drilling operations.

Nevertheless, operators were given two months to comment on the original report, and a further month to comment on the Department's response to comments. A presentation was given on the proposed PON at the Offshore Hydrocarbons Environmental Forum (OHEF), and operators invited to discuss the matter with the department following that presentation. Additionally, environmental stakeholders and the fishing industry have been fully involved in the consultation process through their OHEF membership.

The Department therefore believes that the level of consultation carried out (and consequent broad agreement) represents a fair and transparent process as per the above advice, and recommend that the attached Petroleum Operations Notice is approved and brought into force.

7.0 Human Resources Implications

None.

Falkland Islands Government

Department Of Mineral Resources

Proposal for regulations on discharge of non-aqueous drilling fluids and associated cuttings.

List of Abbreviations

CHARM – Chemical Hazard And Risk Management (system)

CEFAS – Centre for Environment, Fisheries and Aquaculture Science

DECC – Department of Energy and Climate Change

FIG – Falkland Islands Government

FIOHEF – Falkland Islands Offshore Hydrocarbons Environmental Forum

IO – Internal Olefins

LAO – Linear Alpha Olefins

LTOBM – Low Toxicity Oil Based Mud

NADF – Non Aqueous Drilling Fluid

NWQ – Non-water quality (impact)

OBM – Oil Based Mud

OCNS – Offshore Chemical Notification System

OOC – Oil On Cuttings

OPF – Organic Phase Fluid

OSPAR – Oslo Paris Convention

PAH – Polycyclic Aromatic Hydrocarbons

PAO – Poly-Alpha Olefins

PEC/PNEC – Predicted Environmental Concentration / Predicted No-Effect Concentration

PON – Petroleum Operations notice

UKCS – United Kingdom Continental Shelf

WBM – Water Based Mud

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Executive Summary

The discharge of drill cuttings and associated fluids arguably represents one of the main impacts of day-to-day offshore drilling activities and is therefore subject to regulations dictating their use in most, if not all, oil exploration regimes.

As technology has developed and exploration moved further afield over the last 30 years, there has been an increase in directional, deviated, and/or ultra-deep water drilling. Consequently, drilling muds made up of an oil base fluid (also known as non-aqueous drilling fluids, NADFs) as opposed to the traditional water-based fluids were introduced to overcome safety and technical challenges generated by the increasingly technical wells. Increased exploration in deeper waters and production drilling will require the use of such drilling muds within the Falkland Islands Designated Area.

Early Oil-Based Muds (OBM) were composed of diesel-oil or conventional mineral oils with relatively high Poly-Cyclic Aromatic Hydrocarbons (PAH) content, low bio-degradability, and relatively high toxicity. Discharge of cuttings associated with such fluids has in certain areas led to the creation of persistent “cutting piles” causing lasting damage to the sea bed and surrounding environment. Their use has now been widely prohibited or discontinued.

Low-toxicity Oil Based Muds (LTOBM) and Synthetic oil Based Muds (SBM) have since been developed with lower PAH contents and generally more acceptable levels of bio-degradability and toxicity, as demonstrated by a number of both industry-led and independent studies.

Regulations regarding the level of “cleaning” that LTOBM/SBM-associated cuttings must undergo before they are discharged are also internationally widespread. As a result, technology has evolved to allow operators to conform to increasingly stricter regulations. At present, technology that allows cuttings to be consistently cleaned to less than 1% oil content (dry weight) is widely available and used.

Certain areas have seen operators “skip and ship” cuttings to shore for processing and/or disposal. Such solutions obviously eliminate offshore environmental impacts, but can be technically and logistically complicated as well as costly. Furthermore, onshore disposal is not necessarily without its own environmental impacts and as such, must be weighed up against the environmental risk of offshore discharge for any given situation.

Recommendations are made in this document for proposed permitted fluids and minimum cutting cleaning levels. Additionally, this paper recommends a process whereby operators are encouraged to explore all possible means of cutting disposal and processing and demonstrate the environmental risk associated with the chosen method. Recommendations are also made requiring operators to carry out baseline surveys and ongoing monitoring operations in order to quantify the level of longer-term impact, if any, of NADF use and discharge.

1.0 Introduction

The use of Non-Aqueous Drilling Fluids (NADFs) and discharge of associated drill cuttings is at present largely unaddressed by existing legislation and regulations in the Falkland Islands. This document aims to give an overview of issues surrounding NADFs, relevant technology, possible environmental impacts, and relevant regulations in other oil provinces. As such, it is not a definitive binding document or an extensive environmental or biological risk assessment.

The document also incorporates the above into recommendations for regulations to be implemented in the Falkland Islands. These recommendations will be subject to a consultation period with members of the Falkland Islands Offshore Environmental Forum (which groups licensees and environmental stakeholders), and following consideration of respective representations, will be submitted to the Mineral Resources Committee, and Executive Council for approval as a Petroleum Operations Notice (PON).

1.1 Legal Framework

As mentioned previously, the use and discharge of NADFs and their associated cuttings is not specifically addressed in existing legislation, but is broadly incorporated in additional conditions to licences, which make up Schedule 6 or 7 of licences issued under the Offshore Petroleum (Licensing) Regulations 1995 and Offshore Petroleum (Licensing) Regulations 2000 respectively.

Paragraph B2 of that schedule reads:

B2. *"The Licensees shall use water based muds for drilling wherever technically possible. Prior to commencing any drilling operations the Licensees shall notify the Director of Oil and British Geological Survey of the drilling mud and any chemicals the Licensees intends to use (including chemical additives the Licensees intends to use in emergencies) and the methods the Licensees intends to use to dispose of drilling cuttings and spent mud and the Director of Oil may on consideration of that information by notice in writing to the Licensees require the Licensees to dispose of drill cuttings and spent mud in accordance with such conditions as may be specified in the notice and the Licensee shall comply with those conditions."*

The regulations recommended by this paper aim to provide a baseline of NADF approval and associated cutting discharge limits, but do not constitute a definitive judgement on approval requirements or an area-wide environmental risk assessment. **Ultimately, by virtue of the above licence condition FIG shall reserve the right to approve or refuse the use and/or discharge of NADFs and cuttings depending on the environmental and technical merits of each specific case and expert advice received by FIG.**

The introduction of Petroleum Operations Notices (PONs) is also provided for in paragraph A5 of the above-mentioned additional conditions:

A5. *"The Licensees shall comply with Petroleum Operations Notices issued from time to time by or on behalf of the Director of Oil in so far as they are relevant to the operations of the Licensees under the Licence. […]*

It is not considered necessary to incorporate regulations arising from this document into legislation at this stage, although this does not rule out their incorporation in a wider system of overall environmental compliance and associated legislation in the medium to long term.

2.0 Background

2.1 Drilling Muds/Fluids

A drilling mud is a chemical suspension with a carefully formulated density pumped from a drilling rig, through the drill bit into the well before returning to the rig or being discharged to the sea bed, depending on the well section. The drilling mud fulfils a number of roles, including:

- A coolant and lubricant for the drill-bit
- A transport system out of the well for drill cuttings to avoid clogging
- Hydrostatic pressure to avoid wells collapsing in on themselves
- Hydrostatic pressure to avoid pressurised hydrocarbons from entering the well

Once the mud cycle is completed and the mud has been returned to the rig, it is separated from suspended cuttings before being re-used. Cuttings may be discharged to the sea or "skipped and shipped" for disposal elsewhere.

Drilling muds can be separated into two basic types: non-aqueous drilling fluids (NADFs[1]) and water based muds (WBMs).

WBMs are muds in which the base fluid is fresh or salt water. Added to this are weighting agents (barite), clay or organic polymers and various other additives, each of which modify the physical properties and density of the mud as required. WBMs are used in most offshore drilling operations, particularly for the initial "open" sections of a well, where cuttings and spent mud cannot be returned to the rig.

WBMs can nonetheless be troublesome in areas where there are potentially hydratable shale formations[2] to be perforated or in ultra-deep water, extended reach, or deviated wells.

Shale formations are known to absorb the water content of WBM and expand as they do so, consequently compromising the structural integrity of the borehole and leading to a higher incidence of sloughing[3] and stuck drill pipe. This not only results in costly downtime, but can also become a safety issue. Extended-reach wells can encounter high temperatures and pressures; an environment in which WBMs can become unstable. This may lead to solid gas hydrate formation, which can in turn plug choke lines as well as the annular spaces, and may cause interruption of the drilling operation and lead to serious safety issues.

[1] The term NADF is interchangeable with OPF, or organic-phase fluid, but different to OBM, or oil-based mud, which for the purposes of this document is used to refer to Group I NADFs only as discussed below.

[2] Subsurface shales that have been dehydrated by the pressure of the overlying sediments. Drilling a well relieves the lateral pressure and the formation imbibes water from the drilling fluid. This change can result in very high swelling pressures which destabilize the borehole. (Talabani *et al* :1993)

[3] The partial or complete collapse of the walls of a borehole.

Where such factors are considered a possibility, operators look to use non-aqueous base drilling muds on account of their chemical and physical properties, which are engineered to counter these very issues. It is common practice to use WBMs for one section of a well and then switch to another for a more complicated section if and when required.

In NADFs, the base fluid is a liquid hydrocarbon mixture or other insoluble organic chemical. Much like WBMs, they also contain additives such as barite, clay, emulsifiers, water, calcium chloride, lignite and lime in order to adjust their density and physical properties as required. Despite being more expensive than WBMs, NADFs are technically preferable in a number of situations, namely:

- drilling through hydratable shales;
- drilling deep, hot wells where WBMs might be unstable
- drilling through formations such as those containing hydrogen sulphide and carbon dioxide;
- serving as a workover fluid where water might damage the formation.

As such, NADFs considerably reduce well drilling time by increasing lubricity, which in turn decreases torque and drag and minimises the likelihood of differential sticking of the drillpipe in the hole. The reduced drilling time and downtime therefore offsets the higher costs of using NADFs.

There are three types of NADFs:

i) Group I - Oil Based Muds (OBMs) – contain diesel fuel or conventional mineral oil as the base fluid and are the least expensive NADFs. They are characterised by a high amount (>0.35%) of polycyclic aromatic hydrocarbons (PAHs) and heavy metals, both of which can be toxic and thus have long term, severe impacts on the environment (Jacque Whitford Stantec Ltd: 2009)

ii) Group II -Enhanced Mineral Oil Based Fluids (EMOBFs), also known as Low-Toxicity Oil Based Muds (LTOBM) – contain enhanced mineral oil as the base fluid. These are normally conventional paraffinic oils that have been hydrotreated and purified to reduce polycyclic aromatic hydrocarbon content. Generally they contain between 0.35 and 0.001% total PAHs (Melton *et al :* 2000); and

iii) Group III - Synthetic Based Muds (SBMs) – with a water-insoluble synthetic organic material as the base fluid, SBMs are produced from a reaction of a specific purified chemical feedstock (as opposed to being derived from crude oil through a physical separation process). Being synthesised from purified compounds, synthetic materials suitable for use in drilling fluids are considered PAH free (actual PAH is less than 0.001%), and therefore less toxic and more biodegradable than OBMs but with similar drilling properties.

   There are a number of types of SBMs, The SBM base fluid (or synthetic) may be a hydrocarbon, ether, ester, or acetal. Synthetic hydrocarbons include normal (linear) paraffins (LPs), linear-α-olefins (LAOs), poly-α-olefins (PAOs), and internal olefins (IOs).

Group I NADF/OBMs are generally cheaper than other NADFs. However, cleaning OBM cuttings to a 1% dry weight oil on cutting (OOC) requirement (current highest requirement of cutting cleaning) has been historically difficult to achieve. Furthermore, the environmental effects of discharging untreated cuttings associated with OBM into the marine environment can have severe and long-term detrimental effects on the benthos. OBM cuttings can therefore only be responsibly disposed of through onshore processing, although that can lead to non-water quality (NWQ) environmental concerns arising from their transport and/or final disposal. Ocean discharge of OBM cuttings is prohibited in most offshore oil regions around the world.

It is generally acknowledged that Group II muds are environmentally preferable to OBMs principally due to their reduced PAH content. Practice elsewhere however would indicate that the preference is for the use of PAH free muds as opposed to these intermediate types. One of the reasons that operators may prefer SBMs over OBMs, is to reduce the environmental implications of any release that occurs when having to carry out riser disconnect procedures. This is however not the case in North Sea countries, where the use of SBM has been phased out due to concerns over biodegradability, but Group II fluids are still widely used and discharged if treated appropriately.

Group III NADFs/ SBMs are the most expensive muds and, if ocean discharge of cuttings is prohibited, the added cost of ship to shore for land based disposal can make the use of SBMs cost prohibitive in certain drilling scenarios. Under oil regimes such as those of Australia, Brazil and Norway, an application must be made for ocean discharge of SBM cuttings and as part of this, there must be a justification for this and a supporting environmental impact assessment which is then assessed by the regulating authority. SBMs are extensively used worldwide under various regulations.

The selection of an appropriate drilling mud, for the operator, is not only down to economic and environmental factors. Also considered are factors such as:

- Formation pressure;
- Hydrate prevention;
- Ability to reach well objective(s);
- Production quality;
- Logging quality;
- Likelihood of drilling problems e.g. stuck drill bit;
- Temperature stability

Nonetheless, and depending on the relevant regulations of each country, a deciding factor in choosing a drilling mud is the possible means of treatment and discharge of contaminated cuttings. Cuttings are generally more difficult to remove from WBMs than SBMs because of the tendency for solids to disperse in the water phase of the WBMs, and as such markedly different solid control systems are required.

2.2 Treatment of cuttings

Treatment of cuttings is the process by which the drilling fluid and the drill cuttings are separated whilst retaining the rheology[4] of the drilling fluid in order to re-use it. The standard method is through the use of a solids control system on the rig, the most basic design of which includes a sequence of shale shakers (vibrating screens of decreasing mesh size) and/or centrifuges.

Shale shakers usually occupy the primary and secondary positions in what's known as the solids control equipment train. The primary shale shaker receives the cuttings and drilling fluid returned from the well and separates them into coarse cuttings waste stream and a drilling fluid stream. The secondary shaker receives the aforementioned drilling fluid stream and removes smaller cuttings and fine particles. A third (drying) shaker may be used to treat the drill cuttings from the primary shaker by removing additional drilling fluid from the waste cuttings before they are discharged, injected or transported off site. Using this standard equipment, cuttings can be treated to OOC content of between 9.32-13.8% (USEPA: 2000). The use of equipment such as a High-g shaker (applies a higher g-force than the standard shakers and can be used as well, resulting in OOC of 9.4% for cuttings (USEPA: 2000).

Centrifuges are used in solids control systems in place of, or in addition to, shale shakers. They can increase the solids removal efficiency of a standard solids control system by 30-40% (Walters: 1991). Combined with a sequence of shale shakers and high-g shakers, a centrifuge system can result in an OOC of 3.72 - 3.85% on cuttings.

Other pieces of equipment such as squeeze presses can also be added to the solids control train but these only bring the OOC down to 6.71%.

One method of treatment being increasingly used is heat treatment technology, which includes incineration and thermal desorption - the use of high temperatures to reclaim or destroy hydrocarbon contaminated material. (DWIMS: 2012b).

Thermal desorption involves heat being directly or indirectly applied to wastes to vaporise volatile and semi-volatile components without incinerating the solid (DWIMS: 2012a). Those vapours (water and oil) are returned to their liquid state in separate condensers. Thermal desorption technology can clean cuttings to OOC level of less than 1%. Manufacturers of one particular system claim that their machinery achieves a typical OOC of 0.01%. (TWMA: 2012b). This level of OOC is considered to be environmentally acceptable by OSPAR countries, and as such the discharge of Low Toxicity Oil Based Muds following thermal desorption treatment is commonplace in the UK Continental Shelf (UKCS).

Pilot studies are currently underway looking into the microwave cleaning of cuttings. Indications are that achievable OOC would be around 0.1% or less, though this method has yet to be extensively tested in the field (Robinson *et al* :2009).

[4] The rheological properties of a mud are used to design and evaluate the hydraulics and to assess the functionality of the mud system. Rheology is an extremely important property of drilling muds and is measured on a continual basis while drilling and adjusted with additives or dilution to meet the needs of the operation.

2.3 Discharge of Cuttings

Cuttings associated with WBMs can generally be discharged into the ocean at the rig site, but discharge difficulties and environmental concerns arise in cases where OBMs and SBMs are used. There are a number of alternative practices to offshore discharge currently undertaken by the oil industry, though most require the cuttings to be shipped to shore.

Cuttings re-injection (CRI) is a viable and proven offshore discharge method is some oil regions. Cuttings are ground up into a slurry and re-injected (either through an old well hole or one specifically drilled for this purpose) into a suitable rock formation where it can be effectively contained. However, this technique requires extensive information about the rock formations and their precise locations, and can require the drilling of more wells as there is no technology available to inject cuttings slurry into sub sea well heads (El Haggar : 2007).

Other discharge techniques include stabilisation and solidification. The former is a technique that reduces the hazard potential of a waste by converting the contaminants into their least soluble, mobile or toxic form whereas the latter encapsulates the waste in solid blocks, where the contaminant migration is restricted by decreasing the surface area exposed to leaching and/or by isolating wastes within an impervious capsule. The results of both these methods can then be shipped-to-shore for use in building materials or as road capping materials.

An important limiting factor in the offshore treatment and discharge method adopted is the availability of space on the rig. The standard solids control system of shale shakers and/or centrifuges is found on most rigs, but the resultant OOC from this treatment does not tend to meet the requirements of the industry regulators worldwide. Operators and rig owners have in the past argued that the inclusion of further equipment to the solids control system is impossible due to space limitations but cutting processing systems can increasingly be configured to fit into the available deck space. (Offshore: 2012)

Alternative options include offloading and transport of untreated cuttings for onshore disposal. However, increased handling increases the environmental and health and safety risks for that operation; untreated cuttings could be spilt into the ocean resulting in a significant environmental incident requiring costly clean-up operations.

Space for the storage of the cleaned product is also an issue, making over-the-side discharge and CRI are the preferred options (where possible). Alternatively, the cleaned cuttings have to be shipped to shore (in their original form or solidified/stabilised) for discharge on land. In their original, cleaned form cuttings can be used in land farming (repeated applications of treated cuttings to the soil, where the natural occurring microbial population metabolise, transform and assimilate the waste constituents), land spreading (same as land farming except there is only one application) and composting. There is little evidence, however, that this use is of any particular benefit (or detriment) to the soil though studies are ongoing (Ball *et al, :* 2011; TRC : 2011; and Zimmerman & Robert : 1991).

In order for ship-to-shore and onshore discharge to be feasible, suitable facilities must also be available, including appropriate shipping and port services facilities, heavy lifting equipment and suitable onshore transport in addition to the specialist equipment for treatment and suitable discharge areas

2.4 Waste Management Hierarchy

Regulators worldwide, and OSPAR member states in particular, are increasingly encouraging operators to adopt a holistic approach to waste management rather than the ‘end-of-pipe’ approach, which solely looks at the most effective methods of treatment and disposal. As environmental awareness and the cost of treatment and disposal have increased, so has the incentive to improve oil field processes and practices in order to reduce or eliminate wastes.

Indeed, an ethos widely adopted by industry is that of the ‘Waste Management Hierarchy’, a process of waste management advocating the elimination, reduction in volume and/or toxicity, or the recycling of generated wastes wherever possible.

The first tier of the hierarchy encourages developers/operators to reduce the amount of waste produced at source. At the pre-planning stage, a discussion of the anticipated waste generation and its management should be an integral part of the process. This provides the developer/operator with an opportunity to design a drilling fluid with waste minimisation in mind i.e by using substitute low toxic additives (where possible) instead of the traditional highly toxic forms. Through using less toxic additives it reduces the impact of any accidental release, ultimately reducing costs.

In this particular instance, NADFs can contribute to a reduction in cuttings produced by reducing incidence of sloughing. The use of SBM and OBMs also reduces waste as recovered muds of these types can be re-used/recycled through the fluid system. (Onwukwe & Nwakaudu: 2012)

The waste management hierarchy also endorses addressing treatment and discharge as part of the management plan, where source reduction in itself is insufficient. It advocates the use of those treatments and forms of disposal discussed previously herein. A key factor to bear in mind is that, whilst the elements of this management approach always remain the same (source minimisation, treatment & discharge), it is a dynamic model that recognises that each drilling operation is different. As such, the onus is on the operators to approach each operation with this model in mind and to develop a mud, a substitute additive list, drilling plan and solids control system that compliments that specific operation whilst ensuring waste is kept to a minimum and the natural environment is safeguarded.

There are potential benefits for the operator too, as a waste management plan can reduce costs, increase revenue, improve operating efficiency, reduce regulatory compliance concerns and the potential for both civil and criminal liability and can enhance public perception of the company and the industry as a whole (Railroad Commission of Texas: 2001).

3.0 Environmental Impact

The discharge of cuttings and associated drilling fluids arguably constitutes the principal environmental impact of normal offshore drilling operations. The severity of the impact is a factor of the physical impact of the cuttings themselves as well as the possible biological and chemical impacts of the drilling fluids with which they will have been associated. This section discusses the possible environmental impacts of cuttings from well formations drilled with Non-aqueous drilling fluid (NADF) drilling muds. The below is a synopsis of a number of regulator and industry reports and scientific papers.

3.1 Dispersion and Deposition

Much of the environmental impact of drill cuttings and associated drilling fluids is dependent on their dispersion and sea-bed deposition pattern upon release, which in turn is dependent of several factors, most importantly:

- Currents
- Concentration of drilling fluid (when using NADFs)
- Fall velocity
- Water depth

It is recognised that, due to their hydrophobic nature, NADF cuttings will clump together in small masses when discharged into the ocean to a greater extent than WBF cuttings; thereby settling rapidly to the sea bed (Neff *et al*: 2000).

Within different NADFs themselves, there are different levels of dispersibility, and studies have shown that Group III NADFs such as Esters, IOs and LAOs disperse in water more readily than Group II Low Toxicity Mineral Oils or Group I OBFs (Neff *et al*: 2000). Furthermore, a lower concentration of oil on cuttings can further aid dispersion in the water column. Studies suggest that a 5% or less OOC concentration of Group III NADFs can result in dispersion levels comparable to those of WBMs; thereby reducing the risk of oleaginous cutting piles forming on the sea bed, which in turn would reduce the impact (physical and chemical) on the benthos. (Neff *et al*: 2000, USEPA: 2000). This view is mirrored by OSPAR, and the UK Department of Climate Change in particular, who believe that the potential for the creation of cuttings piles is considerably reduced following treatment to 1% OOC with existing technology, both due to the oil content on the cuttings and the size of the post-treatment cuttings, which resembles a fine dust.

Conversely, Group I NADF cuttings have proven to be slow to disperse and biodegrade, and their discharges in the North Sea, for instance, have led to large, persistent cutting piles causing lasting environmental damage to the immediate and surrounding area (OGP: 2003 reference). Moreover, and despite the creation of large piles near drill sites, field studies have further shown that Group I NADFs persist in relatively high concentrations in large areas surrounding drill and cutting discharge sites sites.

Comparable studies have found that elevated concentrations of Group II NADF are generally restricted to smaller areas surrounding discharge sites; while elevated concentrations of Group III NADFs are limited to smaller areas still. There is therefore a clear indication that NADFs with lower PAH content are less likely to persist in high concentrations in large areas of the ocean floor.

This is in all likelihood a factor of each group's relative biodegradability as much as dispersion patterns. However, deposition thickness plays an important role in the breakdown of NADFs adhered to cuttings; a thicker deposition will reduce the surface area of the pile that is in contact with sea water, thereby reducing the available oxygen within the pile itself and slowing the aerobic biodegradation process. Biodegradation is discussed to a greater extent below.

In addition to biodegradation, drill cutting piles depend on the natural energy of the environment in question for re-suspension and transport for ultimate dispersal, as well as on the biodegradability of the drilling fluid. As such, benthic environments with high-energy tidal and/or storm activity (typically shallower water environments) are likely to see quicker dispersion of cuttings piles. (OGP: 2003, Neff *et al*: 2000). However, there is also evidence that Group III NADF cuttings are unlikely to aggregate in piles when deposited in deep-water drill sites (Neff *et al*: 2000) due to increased dispersibility and depth in which to disperse.

3.2 Biodegradation

Biodegradation is the gradual breakdown of organic compounds by naturally occurring micro-organisms into harmless by-products. All NADFs have organic fluids as their base fluid and most are therefore prone to biodegradation, albeit at different rates dictated by their own chemical and molecular make-up, and sea bed conditions, namely: oxygen availability, water temperature, and sediment particle size.

As NADF-cuttings are deposited on a sediment, the increased organic content and ensuing biodegradation leads to increased oxygen demand by the organisms carrying out the biodegradation. When this demand outstrips the oxygen available through diffusion from sea water, a depletion in oxygen concentrations (anoxia) occurs in the benthos, slowing biodegradation rates and, ultimately, leading to increased mortality among benthic species with low tolerance for anoxic conditions. As such, sites of NADF cutting deposition often show a marked decrease in overall benthic taxa, but an increase in the number individuals of organisms with increased tolerance to low oxygen conditions, thereby resulting in a minimal reduction in the overall organic production of the affected area (Neff *et al*: 2000).

Under these conditions, biodegradation is almost entirely anaerobic and therefore slower. Many regulators require proposed drilling fluids to be tested for their anaerobic (oxygen-poor) biodegradation properties as well as aerobic (oxygen-rich) biodegradation before they are approved.

Higher water temperatures have been proven to lead to faster biodegradation, as have sediments composed of small clay/ silt particles. Similarly, high-energy benthic environments are more likely to re-suspend and transport cuttings, increasing the surface area that is exposed to sea water and, in turn, oxygen availability. Specific site conditions are therefore also key in determining the ultimate recovery of any NADF drill site.

Group I NADFs have been extensively proven to have very low biodegradation potential, resulting in long term persistence on the sea bed. Consequently, their use and discharge has been largely discontinued internationally. The biodegradability of group II NADFs has been shown to be higher than that of Group I, with studies showing that persistence of NADF surrounding drill sites is limited to smaller areas and a drop of NADF concentration over time. (Neff *et al*: 2000)

Considerable research has been carried out into the biodegradation properties of Group III NADFs, which in general are quicker to biodegrade than Group I and Group II NADFs. Group III NADFs themselves, have been found to follow a proven hierarchy of biodegradability (USEPA: 2000).

Esters > Linear Alpha Olefins/ Internal Olefins > Poly-Alpha Olefins > acetal > Ether

In particular, Esters, LAOs and IOs have been found to biodegrade at significantly faster rates than oil based fluids. Their increased biodegradability, coupled with their higher dispersibility, mean that Group III fluids are less likely to accumulate to toxic concentrations in large areas and those areas affected are more likely to recover over time. Recovery ultimately depends on the rate of recruitment and re-colonisation by the benthic fauna of that area, and therefore recovery could be slower in deeper-water areas where benthic communities reproduce slowly. There is nonetheless evidence that recovery of areas affected by Group III discharges begins soon, if not immediately, after cessation of discharges. (Neff *et al*: 2000)

Biodegradation is widely used as one of several parameters measured by regulators to assess the environmental suitability of any given fluid, and there are a number of internationally-recognised tests designed to determine biodegradation. There is however some divergence internationally as to what the optimal biodegradation rate is in order to minimise the overall environmental impact through organic enrichment and anoxia

The US Environmental Protection Agency (USEPA: 2000) believes that "faster biodegradation [of drilling fluids] (especially anaerobic) is environmentally preferable to slower biodegradation despite the increased risk of short term anoxia that accompanies faster biodegradation"(USEPA: 2000), further arguing that benthic recovery is more dependant on the disappearance of the drilling fluids than on reduced anoxic conditions. Furthermore, fluids with lower biodegradation rates may have higher PAH content or bioaccumulation potential and could therefore prove chronically toxic.

The Western Australian Government, however, remains wary of looking at biodegradation as a sole parameter to judge the suitability of any drilling fluid, arguing that the damaging effect of organic enrichment and fast biodegradation in specific environments must be considered. (Cobby & Craddock: 1999 , Queensland Government: 2012)

The anaerobic biodegradation of Group III NADFs is also a concern in the North Sea and North East Atlantic, where the use and discharge of NADFs is ruled by the OSPAR[5] convention . In particular, decision 2000/3, notes "that recently developed synthetic drilling fluids [ie Group III NADFs] are likely to persist when discharged into the marine environment at high concentration on drill cuttings where anaerobic conditions develop;" (OSPAR: 2000/3) and establishes that their discharge shall only be allowed in exceptional circumstances.

This decision is seemingly at odds with a large amount of research, (both industry and regulator-led), that suggests that biodegradation of most SBM/ Group III NADFs is quicker than Groups I and II. It is further at odds with its own policy of allowing discharge of Group II NADF cuttings at 1% dry weight OOC.

[5] OSPAR, or Oslo-Paris Convention, is "the current legal instrument guiding international cooperation on the protection of the marine environment of the North-East Atlantic" www.ospar.org

This divergence, however, may well be down to the available cutting cleaning technology at the time, which was widely believed to be unable to reach a 1% OOC content (OGP: 2003,). It's also possible that the decision was designed to effectively stop discharge of all NADF cuttings and/ or promote research and development of new technologies to achieve 1% OOC (which has since been achieved). There have also been arguments made by industry suggesting that the OSPAR decision was based on a flawed laboratory test (Friedheim & Candler: 2008).

Nevertheless, reports of the present level of permits of Group III discharge in the North Sea suggests that they are currently used and discharged (Cobby & Craddock 1999) to a greater extent than the OSPAR decision 2000/3 would suggest, particularly Ester-based fluids, and, although still relatively rare, this suggests reduced concern over fast biodegradation rates. Although the discharge of SBM cuttings at 1% OOC hasn't been studied in great depth, it would seem logical, given the patterns identified by studies into the environmental impact of SBM in other concentrations, that SBM are equally safe as LTOBM when discharged at 1% OOC or less.

3.3 Bioaccumulation

Bioaccumulation is the absorption and retention of hydrocarbons into the biomass of exposed organisms, thereby leading to possible toxicity to the organism itself and any consequent food chain.

PAH compounds in Group I and II NADFs are likely to bio-accumulate in benthic invertebrates and demersal (bottom-dwelling) fish (Neff *et al*: 2000). There are suggestions too, however, that these compounds are unlikely to bio-accumulate in fish or mammals further down the food chain due to those organisms' ability to metabolize such chemicals (OGP: 2003).

In particular, there is a wealth of research into the ability of fish to metabolise and consequently excrete PAH compounds. Lee et al. 1972 concluded that the while there is a fast uptake of PAH by fish, "detoxification mechanisms exist which allow efficient removal of [PAH] compounds from the body tissues". Similar conclusions have been drawn by fisheries regulating bodies such as NOAA's Northwest Fisheries Science Center, who argue that "teleost (backboned) fish of commercial and recreational importance have a well-developed capacity to bio-transform PAHs to compounds that can be readily eliminated" (NOAA: 2013)

Oil spills across the world have allowed for a wide range of seafood PAH content testing, most recently in the Gulf of Mexico following the Macondo blowout and subsequent oil spill. A Human Health working paper by the Deepwater Horizon Study Group[6] recently found that sampled fish, crab, shrimp and oysters from parts of the Louisiana coast affected by the Macondo spill did not contain PAH levels above the FDA level of concern and in the majority of samples, there was no PAH content at all (White: 2011). It is important to note that PAH exposure through oil spills is much higher than through NADF-tainted cuttings due to the typically higher PAH content of crude oil.

[6] The Deepwater Horizon Study Group is a spin-off from the University of Berkeley's Center for Catastrophic Risk Management (CCRM), a "group of academic researchers and practitioners from diverse disciplines who attempt to share their knowledge of safety, organizational reliability and the mitigation of adverse human and natural events."

NOAA documents (NOAA: 2002) suggest that the rate of PAH uptake and metabolisation is dependant on the molecular weight and structure of PAH, where those with a higher molecular weight (higher number of benzene rings) are more persistent.

A compound's propensity to bio-accumulate is usually measured in one of two ways, the first of which is the octanol : water partition coefficient, normally expressed as log P_{OW} or log K_{OW} . Because non-polar organic chemicals, such as the base fluids in NADFs, have low water solubility and high lipid solubility, the relative affinity of the chemical to a (ambient) water phase and a (tissue) lipid phase can be used to gauge that chemical's bio-accumulation potential. Log P_{OW} tests use octanol as a substitute for tissue lipid because solubility of non-polar organic compounds in octanol and tissue lipids is similar and there are published Log P_{OW} values for a large number of non-polar organic chemicals. (Neff *et al*: 2000).

The second is the bio-concentration factor, expressed as BCF or Log BCF. BCF is determined by exposing an organism to a constant concentration of a test substance in water until equilibrium is reached between the concentration in the water and the concentration in the tissues of the organism. (OGP: 2003) BCF is the tissue concentration divided by the water concentration at equilibrium, therefore the higher the BCF figure, the more likely it is to bio-accumulate.

As with biodegradation, there are a number of internationally recognised standardised tests to determine both Log P_{OW} and BCF.

Research suggests that hydrophobic chemicals with a Log P_{OW} of 3 or less have a potential to bio-accumulate, but not to high concentrations due to their high water solubility (Neff *et al*: 2000, USEPA: 2000, OGP: 2003). As such, a Log P_{OW} of ≤3 is widely considered to be the threshold at which bio-accumulation risk is negligible. Hydrophobic chemicals with Log P_{OW} greater than 6.5/7 are also thought not to bio-accumulate effectively from water due to the extremely low solubility in both water and lipids (Neff *et al*: 2000). Similarly, bioaccumulation may be lower in large hydrophobic molecules with a molecular weight of over 600 daltons due to a physical inability to permeate organism membranes. (CHARM: 2005)

Log P_{OW} values are available for a number of Group III NADF, as can be seen in the below table from (Neff *et al*: 2000). Where a range is shown, the values represent the minimum and maximum results of Log P_{OW} studies carried out into a number of base fluids with that structure

Group III NABF	**LOG P_{OW}**
Ester	1.69
Acetal	11.8
Linear α Olefin	>6.43
Internal Olefins	8.5 - <9
Poly α Olefins	10-15.7

Ester based NADFs therefore carry the lowest bioaccumulation risk, while all other Group III NADFs (with the exception of Linear α Olefins) have Log P_{OW} values of over 7, thereby making them unlikely to bio-accumulate due to their large molecular size and/or low solubility in a lipid phase.

The US Environmental Protection Agency endorses the view that a safe Log P_{OW} value is one which is equal or less than 3 **OR** one which is higher than 6.5/7 (USEPA: 2000). However, bioaccumulation potential is not one of its criteria for determining the suitability of Group III NADFs, arguing that Group III NADFs with acceptable biodegradation and ecotoxicity levels will have acceptable bioaccumulation levels by virtue of their chemical and molecular composition.

Under its Harmonised Offshore Chemical Notification Format (HOCNF) regulations, OSPAR only recognises the lower limit of Log $P_{OW} \leq 3$ as an indication of acceptable bioaccumulation risk. OSPAR does nonetheless recognise that fluids with molecular weights of over 700 Daltons or with proven BCF factors of less than 100 are less likely to bio-accumulate. (OSPAR 2008/5) OSPAR considers bioaccumulation in conjunction with biodegradation levels and eco-toxicity, so the components of any given organic fluid must have produced satisfactory test results in any two of those three criteria before they can be ranked and risk-assessed through the CHARM model, which is described in more depth below. (OSPAR 2010/4).

3.4 Eco-toxicity

Eco-toxicity is a measure of a given chemical's direct harmful effects on organisms in the water column or in the benthos. Widespread research has shown that Group I NADFs are significantly toxic, particularly those with a high PAH or diesel content (USEPA: 2000). Again, there is a proven hierarchy of toxicity of NADFs:

Ester < IO < LAO < Paraffin < Mineral Oil < Diesel

Toxicity of NADFs is generally thought to be higher in the benthos than in the water column due to NADFs low water solubility and lower dispersal, which results in faster sinking rates of cuttings associated with those fluids (Neff *et al*: 2000).

Toxicity testing is an integral aspect of drilling fluid permits across the world, and can be of the whole drilling fluid or mud, its base fluid, or every one of its components. Such tests are generally carried on water column species, benthic species and filter-feeders. OSPAR regulations, for example, call for toxicity tests to be carried out on Microscopic Algae, Copepods, Bivalve Molluscs, and Amphipods. The choice of species is key, as they must be representative of the habitat on which the impact is being assessed; indeed, the Western Australian government calls for internationally standardised tests to be used with local species in order to determine the most likely impact in each respective area (Cobby & Craddock: 1999).

Toxicity is measured in LC_{50} and EC_{50}; where LC_{50} is the lethal concentration for 50% of a group of test organisms to die over a specific period of time; and EC_{50} is the concentration required to cause 50% growth inhibition compared to a test sample over a specific period of time.

The below scale used by the Government of Western Australia provides a point of reference in terms of how water column toxicity is gauged (Cobby & Craddock: 1999).

LC_{50}	Relative Toxicity
>100,000 mg/l	Non – Toxic
10,000 – 100,000 mg/l	Almost Toxic
1,000 – 10,000 mg/l	Slightly Toxic
100 – 1,000 mg/l	Moderately Toxic
1 – 100 mg/l	Toxic
<1 mg/l	Very Toxic

Similarly North Sea countries have the below toxicity limits for water column and solid-phase species tests (Neff *et al*: 2000):

Taxon	Species	Lowest Acceptable EC50 / LC50
Microscopic Alga	*Skelotonema costatum*	EC50 > 1000mg/L
Copepod	*Acartia tonsa*	LC50 >2000 mg/L
Bivalve Mollusc	*Abra alba*	EC50 > 20 mg/kg*
Amphipod	*Corophium volutator*	LC50> 1000 mg/kg*

*dry sediment weight

The table below, showing the results of US standard 10-day toxicity tests carried out on two different species of amphipods, demonstrates the relative toxicity through different NADF groups, broadly confirming the hierarchy suggested above (Neff *et al*: 2000)

Drilling Mud base chemical	Mean LC50 (95% Confidence Interval) mg/kg	
	Ampelisca abdida	*Corophium volutator*
Enhanced Mineral Oil (Gp II)	557 (493 – 630)	7,146 (5708 – 8,945)
Diesel Fuel (Gp I)	879 (695 – 1,112)	840 (690 – 1,008)
Internal Olefin (Gp III)	3,121 (2,503 – 3,893)	> 30,000 (ND)
Poly-α-olefin	10,680 (7,665 – 18,599)	> 30,000 (ND)

ND – Not Determined

Similarly, the below table groups a number of comparable studies (involving North Sea standard toxicity tests) to demonstrate the relative toxicity of a range of Group III base fluids and whole muds on an amphipod and a bivalve mollusc (Neff *et al*: 2000)

SBF	*Corophium volutator* LC50	*Abra alba* LC50
Ester base chemical	NA	>100,000
Acetal Mud	NA	~1500
Acetal base chemical	NA	549
PAO Mud	>10,000	7,000
PAO Mud Study II	> 10,000	572
PAO Base chemical	NA	7,900
IO Mud	7,131	303
IO Base Chemical	7,100	300
LAO Mud	1,021	NA
LAO Mud Study II	1,268	277

These results demonstrate that, in general, the Group III NADF toxicity levels on benthic species are within the limits required by OSPAR.

Relative toxicity is given particular importance by the US Environmental Protection Agency, which, much like with bio-degradation levels, requires the eco-toxicity levels of any proposed Group III NADF to be equal or less than those of an Internal Olefin (USEPA: 2000).

3.5 OSPAR: Pre-screening, CHARM, and OCNS

OSPAR decision 2000/2 set out a Harmonised Mandatory System Control System for Offshore Substances under which signatory countries are obliged to adopt a common system of offshore chemical screening and registration. The decision was consequently incorporate into UK legislation under the Offshore Chemicals Regulations 2002 (as amended in 2011).

In order to obtain permits for the use and discharge of chemicals (including drilling fluids and associated cuttings), operators in the UKCS must arrange for all chemicals to be pre-screened and ranked under the Chemical Hazard and Risk Management (CHARM) system and Offshore Chemical Notification Scheme (OCNS). The schemes, a requirement under the OSPAR agreement, provide a system whereby chemicals are ranked according to their environmental impact as measured by biodegradability, eco-toxicity, and bioaccumulation potential. That ranking is in turn used to gauge the associated risk in discharging any given chemical, and a permit granted or refused as appropriate.

The CHARM model (which is used to rank all chemicals except inorganic substances, hydraulic fluids and chemicals used only in pipelines), effectively calculates the ratio of the Predicted Environmental Concentration, PEC (the expected concentration of a chemical to which the environment will be exposed during and after the discharge of that chemical) to the Predicted No Effect Concentration, PNEC (an estimate of the highest concentration of a chemical in a particular environmental compartment at which no adverse effects are expected) (CHARM : 2005). The PEC : PNEC ratio then becomes a Hazard or Risk Quotient (HQ or RQ) used to rank the chemical as below:

Minimum HQ	Maximum HQ	Colour Banding	Lowest Hazard
>0	<1	Gold	
≥1	<30	Silver	
≥30	<100	White	
≥100	<300	Blue	
≥300	<1000	Orange	
≥1000		Purple	Highest Hazard

Before a chemical is eligible to undergo CHARM evaluation, it is subject to a pre-screening process as shown in Annex 1. This pre-screening process ensures that chemicals meet any two of three bio-degradation, bio-accumulation, and eco-toxicity criteria. Failure to do so results in operators having to seek a suitable alternative or apply for a temporary permit if there is no alternative available and the chemical in question is vital for normal operations.

Chemicals that cannot be assessed under the CHARM model (inorganic substances, hydraulic fluids or chemicals only used in pipelines) are assessed and ranked using the Offshore Chemical Notification Scheme (OCNS) grouping system; a system that tests a given chemical's eco-toxicity, bio-degradation, and bio-accumulation potential and assigns it to a OCNS Grouping from A – E, where E is the safest or has most acceptable environmental impact. (CEFAS 2011)

Although whole NADFs are not normally assessed using the CHARM or OCNS system as whole fluids, their constituent substances are, thereby assessing the environmental impact of every one of its components.

In the UK the screening and ranking of chemicals is carried out by the Centre for Environment, Fisheries, and Aquaculture Sciences (CEFAS), an executive agency of Defra. Parallel to this, CEFAS provides advice to the Department of Energy and Climate Change (DECC) on specific environmental issues arising from the possible discharge of a given chemical at a given site.

Conclusion

Deep-water exploration and production drilling in the Falklands' designated area is set to increase considerably the short to medium term. As such, the use of non-aqueous drilling fluids, which are proven to reduce drilling time in certain problematic conditions, could prove crucial in order to carry out safe and efficient drilling operations.

The environmental effects of NADFs have been the subject of both controversy and extensive research, and in areas such as the North Sea the long-term effects of certain fluids have only been determined through long-term, tangible damage. The development of highly-engineered SBMs, and LTBOMs, has reduced NADF environmental impact through eco-toxicity and consequent bio-accumulation. LTOBMs and SBMs have, as a result, become widely used and in oil provinces they are the only drilling fluids permitted for discharge on cuttings. While those liquids' increased biodegradability reduces environmental impact in the long term, the immediate effects of organic enrichment on the local benthic environment is severe, albeit not permanent, and therefore sensitive species or eco-systems remain at risk.

Recent developments in cutting treatment technology have meant that a ≤1% level of oil on cuttings (a level considered safe in a number of oil regimes, most importantly the North Sea) is achievable through widely available technology. The adoption of holistic approaches to waste management, where reduction is a key aspect of project design at an early stage, has further led to more efficient and therefore environmentally acceptable re-use of drilling muds and discharge of cuttings.

A "Falklands Factor" must nonetheless be applied to any regulations affecting cutting discharge, and there are arguably two key issues arising from the Falklands' unique logistical and environmental situation: The first is the lack of onshore cutting treatment and disposal facilities present in the Falklands, which in the short term could make onshore disposal both unfeasible and environmentally unacceptable (E.g. groundwater contamination). Nonetheless, the long-term natural progression of the industry should move towards a zero-discharge regime, and as exploration and auxiliary services increase so should the feasibility of zero-discharge.

The second factor is the Islands' diverse ecosystems and environmental responsibility, both of which are assets to the Islands' economy and international reputation. The importance of safeguarding the Islands' unique environment has been continuously recognised by operators and licence interest holders through membership of the Hydrocarbons Forum and considerable financial investment in environmental impact assessment, surveys, and mitigation.

As a new entrant to oil regulation, the Falkland Islands Government has the benefit of other regimes' experience and mistakes, and there can be little argument to implement but the highest international practice while retaining enough flexibility to account for the Islands' unique logistical challenges. Indeed, the importance of maintaining a superior level of environmental stewardship becomes all the more crucial in light of the international political and media focus that the Falklands and global oil industry are increasingly subjected to.

Recommendations

1. That approval for use and discharge of NADF be given on a well-by-well basis, with operators making a technical argument for their use in each well section.

"Campaign" approval for wells may be considered if the wells meet both of the following conditions:

- The wells have a similar technical requirement for the use of NADF, such as:

- They are all penetrating the same reservoir and the same overlying geological structures posing the same potential geological drilling challenges;

- They are all highly deviated/ directional production wells;

- They are all being drilled in ultra-deep water AND are likely to pose drilling challenges that require NADF.

AND

- They fall within the same EIA and addendum and are geographically close enough so that the baseline environment for each well faces the same level of risk from NADF discharge. (Except for onshore disposal options)

2. That the release to the sea of whole NADF in any stage of the drilling process or the use of NADF in any open part of a well (where the mud and cuttings are not returned to the drilling unit) be prohibited.

3. If the use of NADF is approved, that operators make an application to discharge cuttings associated with NADF. In said application, operators should demonstrate, through a baseline survey and environmental impact assessment that the maximum area that is likely to be affected does not contain sensitive and/or rare species, or eco-systems that are not widely represented throughout the Falkland Islands designated area; and that the environmental impact to that area is acceptable. As stipulated in recommendation 5, applications for the use and of NADF should include CEFAS chemical ranking and hazard data in order to present a specific risk assessment for the discharge of that chemical.

Similarly, operators should make use of available survey vessels and resources in the Islands in order to carry out regular monitoring of the impact on and recovery of the area of discharge following completion of drilling operations. Five-year revisions to Environmental Impact Assessments should accordingly include monitoring data in order for the risk/impact assessment to be current as possible.

When applying for approval to discharge NADF cuttings, operators should also be required to demonstrate that options other than offshore discharge, such as onshore treatment and/or re-use, have been considered and ruled out on the basis of being logistically impracticable or for having an unacceptable environmental impact elsewhere.

While the facilities for environmentally acceptable onshore disposal of cuttings do not exist at present in the Falkland Islands, it is not considered appropriate to make a blanket assumption as to its future feasibility given the likely increase in onshore oil industry auxiliary services in the medium to long term. Licensees should therefore be encouraged to explore alternatives on an ongoing basis in order that increasingly economic and environmentally-friendly, long-view solutions be found through innovation and co-operation between companies.

4. **That all offshore discharge of NADF-associated cuttings be restricted to a 1% or less dry weight OOC. The technology required for this is widely available, used and proven to achieve that very threshold and therefore not considered to be beyond the expectations of best industry practice. Operators should also be required to make redundancy plans for alternative processing or storage of cuttings if offshore equipment becomes unserviceable.**

5. **That only Low Toxicity Oil Based Muds or Synthetic Based Muds with low or negligible poly aromatic content be permitted. Such fluids are widely used and available, and therefore the threshold is not considered to be beyond the expectations of international best practice.**

   Additionally, all components of proposed NADF are to be pre-screened and ranked under CEFAS' CHARM/OCNS certification system and their discharge risk-assessed in relation to the specific environment into which they will be discharged as per North Sea/ OSPAR requirements.

6. **That FIG reserve the right to amend these regulations based on changes of best international practice, available services in the Falkland Islands, and environmental findings or advances in relevant technology upon consultation with licence interest holders and environmental stakeholders.**

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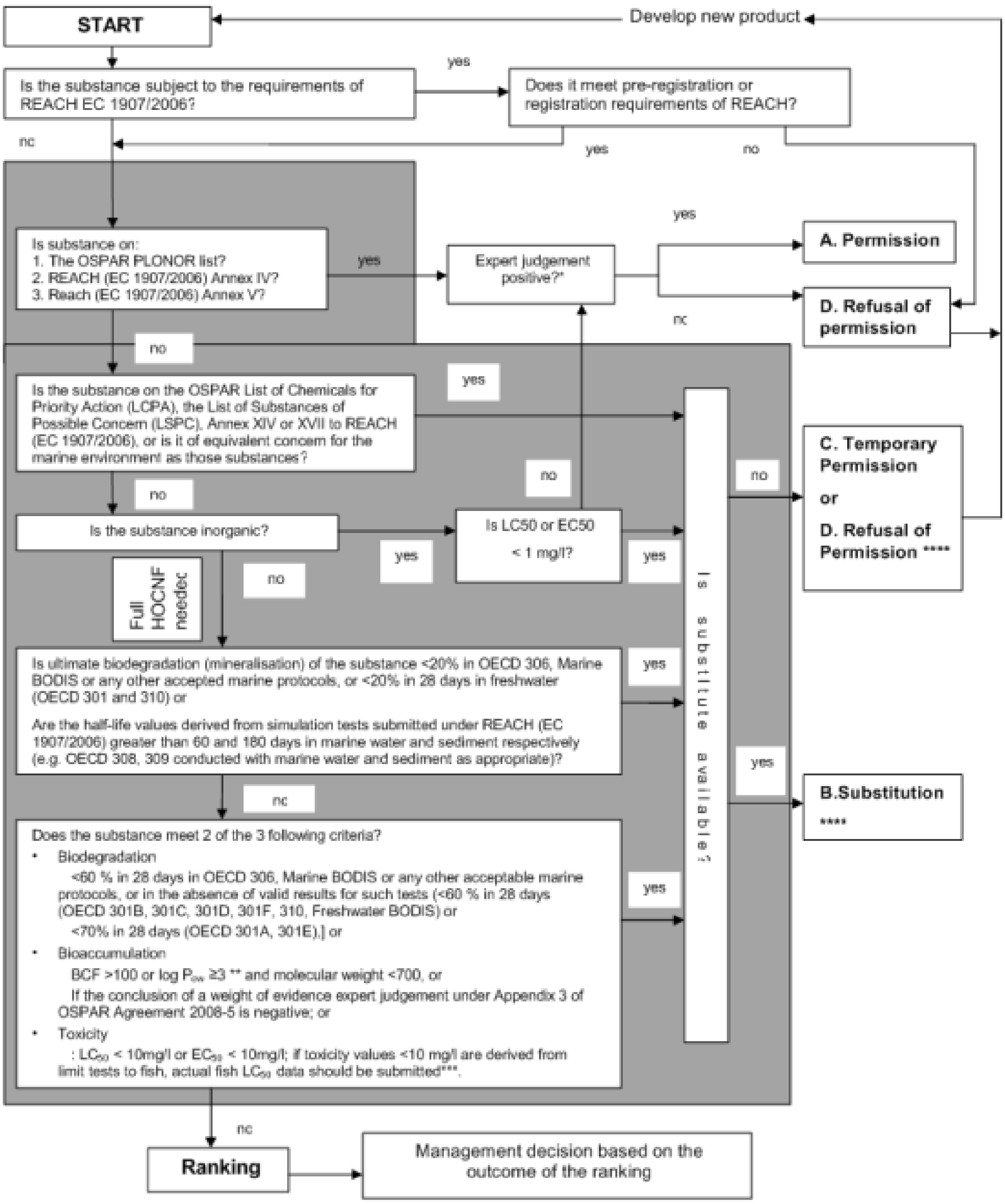
Appendix 1

The Harmonised Pre-Screening Scheme (shaded) as Part of the Whole Harmonised Mandatory Control System for Offshore Substances set out in the applicable OSPAR Decision



(OSPAR: 2010/4)

Proposal for regulations on discharge of non-aqueous drilling fluids and associated cuttings.

Synopsis of comments received and responses

- It was noted that the polycyclic aromatic hydrocarbon (PAH) content in fish imported to the European Union is tested for as a potential harmful substance and, as such, the use of drilling fluids with PAH content should be avoided wherever feasible to avoid serious environmental (and, in turn, economic) impacts to fish stocks in the Falklands designated area.

The paper effectively outlaws the use of group 1 drilling fluids, which typically have a PAH content of over 0.35% and which have been found to be the most persistent and toxic when discharged. The level of cutting cleaning being proposed requires technology which has been proven to consistently clean cuttings to less than 1% oil on cutting (OOC) dry weight, and have even been known to achieve OOC levels as low as 0.01%. As such, were a Group II fluid with 0.35% PAH content used, PAH discharge would only represent 0.0035% of all cuttings discharge. Obviously the significance of this figure (which is essentially the worse-case scenario under the regulations being proposed) is a factor of the amount of drill cuttings discharged, which in itself will depend on well-design and will therefore have to be dealt with in specific EIA documents and NADF discharge applications.

As proposed in the document, it will be the responsibility of the operator to demonstrate that the chosen fluid, coupled with the level of discharge, will not have a significant nor irreversible impact on the environment. Given the fishing industry's concerns here, we would expect there to be consensus with industry stakeholders and regulatory authorities that the environmental impact assessment is comprehensive and takes into account risks to fish stocks and/or their market value.

There are obviously parallels with the North Sea fishery here, and advice was sought from the Department of Energy & Climate Change (DECC) Environmental Team on possible fish PAH contamination due to drilling operations: "*Regular fish taint sampling is undertaken by Marine Scotland and there is no evidence of higher PAH content in fish from background levels in the North Sea from drilling or production operations (discharges associated with drilling operations in the UK are limited to WBM cuttings and treated OBM cuttings to < 1% oil in cuttings). Further, sampling results from fish samples taken during the Elgin blowout incident and subsequent well kill operations last year did not show any evidence of increase in PAH levels either".*

- It was noted that the study quoting fish ability to metabolise PAH compounds was from an industry-led study, where an academic paper would be more appropriate.

There is a wealth of research into the ability of fish to metabolise and consequently excrete PAH compounds, but one of the most established is Lee et al. 1972[1], which concluded that the while there is a fast uptake of PAH by fish, "detoxification mechanisms exist which allow efficient removal of [PAH] compounds from the body tissues". Similar conclusions have been drawn by fisheries regulating bodies such as NOAA's Northwest Fisheries Science Center, who argue that "teleost (backboned) fish of commercial and recreational importance have a well-developed capacity to bio-transform PAHs to compounds that can be readily eliminated".[2]

Oil spills across the world have allowed for a wide range of seafood PAH content testing, most recently in the Gulf of Mexico following the Macondo blowout and subsequent oil spill. A Human Health working paper by the Deepwater Horizon Study Group[3] recently found that sampled fish, crab, shrimp and oysters from parts of the Louisiana coast affected by the Macondo spill did not contain PAH levels above the FDA level of concern and in the majority of samples, there was no PAH content at all (White, 2011[4]). It is important to note that PAH exposure through oil spills is much higher than through NADF-tainted cuttings due to the typically higher PAH content of crude oil.

NOAA documents[5] suggest that the rate of PAH uptake and metabolisation is dependant on the molecular weight and structure of PAH, where those with a higher molecular weight (higher number of benzene rings) are more persistent. It would therefore be useful to for the exact PAH content in any given drilling fluid to be known in order to determine the possible risk.

A recurring theme in the comments was a concern that choice of drilling fluids and waste management options should not be guided by their cost to operators alone. Conversely, it was commented by operators that environmental risks should be viewed within a holistic "Best Practical Environmental Option" approach that takes into account other issues such as emissions, Health and Safety risks as well as cost.

Clearly the value of mitigating environmental impacts cannot be viewed as relative to its cost, particularly when the possible consequences are serious, far-reaching and/or permanent. As was pointed out in the document, oil companies have widely recognised this

[1] Lee, R.F., Sauerheber, R., and Dobbs, G.H.. (1972). Uptake, Metabolism and Discharge of Polycyclic Aromatic Hydrocarbons by Marine Fish. *Marine Biology*. 17, p201-208.
[2] NOAA. 2013. *Metabolism of PAHs by teleost fish - Scientific Findings*. [ONLINE] Available at: http://docs.lib.noaa.gov/noaa_documents/DWH_IR/reports/Attachment_5.pdf. [Accessed 04 July 13].
[3] The Deepwater Horizon Study Group is a spin-off from the University of Berkeley's Center for Catastrophic Risk Management (CCRM), a "group of academic researchers and practitioners from diverse disciplines who attempt to share their knowledge of safety, organizational reliability and the mitigation of adverse human and natural events."
[4] LuAnn White. (2011). *Deepwater Horizon Study Group - Human Health Working Paper.* Available: http://ccrm.berkeley.edu/pdfs_papers/DHSGWorkingPapersFeb16-2011/HumanHealth-LAW_DHSG-Jan2011.pdf. Last accessed 3rd Jul 2013.
[5] NOAA. 2002. *Managing Seafood Safety after an Oil Spill*. [ONLINE] Available at: http://docs.lib.noaa.gov/noaa_documents/NOS/ORR/963_seafood2.pdf. [Accessed 04 July 13].

fact through investment in EIAs, baseline surveys, and mitigation planning. The oil industry (or any other private sector group for that matter) would nonetheless question onerous costs for questionable or minimal environmental benefits. Ultimately different situations will call for different levels of compromise.

The economic benefits of NADF use are worth re-highlighting, particularly in terms of saved drilling time: the US Environmental Protection Agency, quoting industry-supplied data, suggests that the rate of penetration (ROP) is up to 50% higher with NADF than with WBM, and their use results in a reduced number of incidents of stuck-pipe, lost circulation and bore-hole integrity[6].

While the notion of Best Practical Environmental Option would seem the best approach (the open meaning of "practical" notwithstanding), it does raise questions about how environmental impacts should be weighted in any given situation; increased greenhouse gas emissions being a case in point.

Increased emissions were one of several deciding factors in the US Environment Protection Agency's logic in establishing NADF discharge regulations for the Gulf of Mexico. Onerous discharge regulations, the organisation argued, would encourage more shipping of cuttings to shore, and the consequent increase in vessel traffic would result in increased exhaust emissions, thereby reducing the net environmental benefit of the regulations (or, a cynic would point out, shifting the impact to a more scrutinised and publicised environmental topic, turning it politically uncomfortable).

It is doubtful, however, that the argument can be applied in the Falklands: the number of drilling units currently (July 2013) operating in the Gulf of Mexico is 76[7]; given that the number of rigs simultaneously operating in the Falklands' designated area within the next 5 years is likely to be 3-4 at most, it is difficult to see how the increase of emissions would be meaningful both on a global scale and in terms of the Islands' existing emissions from shipping, aviation, land transport, and power/heat generation.

The increased Health and Safety risk was raised as a factor to be borne in mind in a ship-to-shore scenario, particularly in rough weather. It was roughly estimated that cuttings could generate as many as 3000-4000 additional crane lifts per well. The operational risks and consequent downtime of not being able to transfer skips to a rig in bad weather was also pointed out, as was the increased berthing space.

The increased Health & Safety risk is recognised. However, given that ship-to-shore is common in the Central North Sea, which has comparable weather and sea conditions to the North Falklands Basin[8] , that risk is clearly manageable to regulatory standards acceptable in the Falklands.

Increased berthing space could potentially lead to congestion, delays and friction with other port users if berthing options remained unchanged from the last drilling campaign. Current operator and government plans however would suggest that there will be improved

[6] EPA Development Document for Final Effluent Limitation Guidelines for Synthetic-Based Fluids in the Oil & Gas Extraction Point Category. [pdf] Available at: http://water.epa.gov/scitech/wastetech/guide/oilandgas/upload/OG_SBF_DD_Final_2000.pdf

[7] IHS. (2013). *IHS Petrodata Weekly Rig Count.* Available: http://www.ihs.com/products/oil-gas-information/drilling-data/weekly-rig-count.aspx. Last accessed 3rd July 2013.

[8] Rockhopper Exploration, Corporate Update January 2013, p17

berthing facilities available to some if not all operators within the next 2-3 years, relieving the stress on existing facilities and providing more options.

Other potential issues arising from onshore disposal that were identified included:

- **Greater level of recycling of drilling fluids, leading to reduced amount of drilling fluid being shipped to the rig from shore** (thereby possibly reducing emissions and handling/ HSE risk)

- **Processing of contaminated cuttings and associated oil contaminated water onshore**

- **Disposal and land take of cuttings**

- **Permitting**

- **Monitoring of disposal process**

While the above are valid concerns given the lack of facilities in the Falklands, we believe it is important for operators to demonstrate that alternatives to offshore disposal have been thoroughly considered. Indeed, there may be situations where the environmental circumstances make onshore treatment and disposal the only viable option. The nature of new oil provinces is such that operators may be required to take a pro-active approach in establishing auxiliary services; the use of a directly-appointed helicopter contractor for SAR cover being a good example of this.

It was suggested that operators be asked to investigate the possibility of exporting cuttings for disposal in other countries. Similarly, solutions involving the recycling of cuttings into building materials were also encouraged.

This is something that operators may well want to consider, although at first glance the geography and geo-political issues in the Falklands mean that the process would not be a straightforward one; much less so once cost and logistics of shipping, treatment, and permitting elsewhere are factored in.

Such a solution would also arguably be of questionable socio-economic value; assuming that the distances involved alone would make the process an expensive one, that investment would be of much better value to the Falklands if it was directed towards a longer-term onshore disposal facility.

Informal discussions with the Director of Public Works suggest that the use of cuttings as building materials depends on the type of rock and size of the cuttings, and therefore not automatically suitable (particularly given that cuttings processed by the proposed methods resemble a fine dust or powder). Nonetheless, this could presumably be determined with relative ease by operators through discussions with DPW or local building companies, who are likely to have a fairly instant idea of their suitability.

Onshore disposal of cuttings would in any case be subject to other concerns (avoiding groundwater contamination, for instance), and not necessarily environmentally straightforward.

Reservations with the 1% OOC limit were expressed, arguing that required redundancy plans would require onshore disposal facilities that are not likely to be available in the short term. It was suggested by some operators that the limit be raised to 6.9% OOC (in line with US and Canada) or that a 2-3 year interim 5% OOC limit be introduced to allow the required onshore redundancy to be phased in.

Discussions with Thermal Desorption equipment manufacturers suggest that redundancy plans are designed as part of the overall cutting treatment package, including an additional unit being mobilised and kept at the onshore base (Stanley, in this case) during drilling operations for relatively little more than the base day-rate. If manufacturer stats are to be believed, thermal desorption equipment can have uptime rates of 98%.

The concept of a 2-3 year phase-in period is a valid one in principle, but the reality is that a large part of planned production drilling in the North Falkland Basin will fall within that time window. Allowing such a campaign (which is likely to involve a high number of wells requiring NADF) to discharge cuttings at a higher OOC limit would put the environment at undue risk.

Ultimately, the fact that operators with relatively firm drilling plans and timelines did not object the 1% level suggests that any issues that may arise out of redundancy requirements are not insurmountable. This may seem particularly harsh on companies carrying out short exploration campaigns, but we believe that parallel or concurrent campaigns in the pipeline for the coming 3-5 years (be they exploration or production) present numerous synergy opportunities for operators (not least in terms of onshore cutting redundancy). Indeed, one of the implicit drivers behind the proposed limit was that operators explore those synergies and jointly develop the required auxiliary services. Setting a higher OOC limit, albeit temporarily, would effectively remove that incentive.

It was pointed out that a monitoring programme as suggested by recommendation #3 was vague and too open-ended in terms of requirements and time-period.

The monitoring proposed would be to measure any possible impact of NADF on the environment as compared to the baseline surveys carried out for exploration or production EIAs; therefore the impact on benthic flora and fauna, background hydrocarbon content etc. The cost of mobilising vessels for this sole purpose is recognised but we believe there is scope, as above, to make use of survey resources deployed for baseline surveys in other licence areas and/or by other operators as well as exploration/production support vessels and ROV equipment. NADF-related monitoring will be expected in 5-year reviews to EIA documents if appropriate.

It was noted that "slowing of biodegradation" under anoxic conditions is slightly inaccurate, as the process does not necessarily slow, but is rather shifted towards organisms that thrive in such conditions. There is however a risk to benthic communities from physical smothering and/or burial by cutting deposition.

The comment is noted. Paradoxically perhaps, there is less risk of negative effects through burial or smothering from cuttings processed through thermal desorption than conventionally processed WBM-associated cuttings, as the thermal desorption process renders cuttings into a fine dust or powder that is highly dispersible.

It was suggested that the proposal reflect MARPOL regulations on the discharge of waste material from support vessels travelling from and to any offshore installation.

While a relevant point, it is difficult to see how MARPOL requirements fit within the document, which is solely designed to cover the discharge of NADF and associated cuttings. As pointed out in the comments, offshore drilling units and the discharge of cuttings are issues not covered by MARPOL. In any case, it is a more than safe assumption to make that Masters of support vessels will be fully aware of their obligations under MARPOL.

It was suggested that onshore cuttings disposal options be incorporated into the ongoing FIG Oil Readiness Review.

While the increase in waste caused by oil exploration and its support industry (and the limitations of current disposal options) has been recognised by FIG, the onshore disposal of cuttings is, we believe, not a public health issue and therefore facilities for such disposal do not fall under the Government's remit (other than ensuring that any facility designed for that purpose complies with planning regulations and environmental requirements). We believe that that environmentally acceptable treatment and disposal of cuttings falls under operators' environmental responsibility and obligations under the Offshore Minerals Ordinance and consequent amendments.

It was suggested that permission for the use and discharge of cuttings be given on a campaign basis rather than well-by-well basis, as the geology and consequent well design/ mud choice for a given suite of wells within the same licence area is likely to be similar.

The meaning of campaign is key here. A campaign could be defined as a series of consequent wells drilled by the same operator using the same rig, and as such could feasibly comprise production and exploration/appraisal wells. A blanket NADF-use approval for such a "campaign" would not be appropriate, as the exploration aspect may not require the use of NADF where production wells would.

The comment, however, is valid, and it would be beneficial to offer blanket "campaign" approval if the wells covered within that approval meet both of the following criteria

- That they are penetrating the same reservoir or perceived reservoir and the same overlying geological structures; have the same purpose (production or exploration/appraisal); or are all being drilled in ultra-deep water and as such have similar well design and mud-use requirements.

- That they fall within the same EIA document and addendum, and have baseline environments that are perceived to be similar enough so as to be at the same risk from NADF discharge.

There are two distinct elements of approval here one being the use of NADF, and the other the discharge of associated cuttings. It is envisioned that the use of NADF would be proposed within Basis of Design/Geological Evaluation Plan documents (PON 4), although in reality it's likely to be pre-approved in advance through discussions with the Department of Mineral Resources and its technical and geological advisors as the "campaign" requires it.

The discharge of NADF cuttings, meanwhile, will be approved through normal environmental approval channels (see below comment and answer for more details).

Clarity was sought regarding a possible repetition of efforts regarding wider baseline studies, EIA approval and approvals for use and discharge of mud and mud-tainted cuttings.

A separate baseline or EIA study to cover risks posed by NADF cutting discharge is not expected as long the valid EIA (and contributing baseline studies) covers the at-risk area in sufficient depth so as to comprehensively gauge possible impacts.

The proposed system of separate approvals is one similar to the UK PON 15 system, where a separate application (PON 15b) is made for the discharge of chemicals giving specific details of well dimensions, mud volumes, CHARM rankings, metocean data etc. It is hoped that a wider chemical discharge permitting system in the Falklands will evolve out of this and therefore it is considered appropriate that operators become accustomed to submitting such separate information in addition to EIA commitments.

Nonetheless, this is matter of process rather than limits and regulations, and therefore easier to vary as experience requires it, so we are happy to work together with operators in order to find a solution that is as streamlined as possible and yet does not result in corners being cut.

Falkland Islands Government
Department of Mineral Resources

Petroleum Operations Notice 10
Application to Use and Discharge Non-Aqueous Drilling Fluids and Associated Cuttings

Draft v1.1 – September 2013

Background and approval process

This Petroleum Operations Notice (PON) establishes conditions for the use of non-aqueous drilling fluids (NADF) in drilling operations and acts as an application form for the discharge of NADF and their associated cuttings.

While the use of NADF will be sanctioned as part of the PON 4 Basis-of-Well-Design application, operators will be required to engage with the Department of Mineral Resources as soon as they have identified possible drill targets in order to present their case for the use of NADF.

NADF use will only be permitted in complex production wells or exploration wells whose surrounding geology, water depth, or design is likely to incur severe delays or safety issues if drilled with Water-Based Muds (WBM). Situations where NADF use could be permitted include (but are not limited to): hydratable shales; extended reach or deep, hot wells where water-based muds may become unstable; ultra deep water wells; or wells penetrating formations with high carbon dioxide and hydrogen sulphide content. Permission for NADF use will not be given solely on drilling time advantages except for very extraordinary circumstances (e.g. relief wells).

Operators will be required to present evidence from known WBM issues in offset wells if available, or, if not available, a solid argument demonstrating that not using NADF would compromise the safety of the well and/or the ability to reach the planned well target; and how that conclusion has been reached in the absence of offset data or homologous wells. Initial options on how to treat and discharge NADF and associated cuttings should also be presented at this stage. Treatment and discharge options should include redundancy plans as discharge of untreated NADF cuttings will not be permitted except for exceptional cases that would otherwise pose safety risks.

In deciding whether to allow the use of NADF the Department will seek advice from consultants on safety, geological, and technical matters relating to the application. Each request to use NADF will be judged on the specific well's merits and while it is the aim to the Department to make the system as flexible as possible, NADF use should be considered as exceptional and permission for any well should not be pre-empted. Approaching the Department at the earliest possible opportunity would therefore avoid a final decision impacting negatively upon campaign planning.

It is also advised that the relevant members of the Offshore Hydrocarbons Environmental Forum (or Environmental Planning Department if onshore discharge is being planned) are engaged as early as possible to ensure that the discharge risk assessment is as well-informed and comprehensive as possible.

This PON may be submitted as a stand-alone document or as an Annex to an EIA addendum. If a statutory EIA contains enough information on the specifics of an operation (drilling unit, timings, etc.) so as to not require an addendum, then it may be submitted as an Annex to that EIA. The timings for approval will be similar to those of an EIA addendum and therefore this PON should be submitted no later than any EIA addendum.

Approval for use of NADF

Permission to use NADF will only normally be given on a well by well basis. “Campaign” approval may be considered if the wells meet both of the following conditions:

1. The wells have a similar technical requirement for the use of NADF, such as:

  - They are all penetrating the same reservoir and the same overlying geological structures posing the same potential geological drilling challenges;

  - They are all highly deviated/ directional production wells;

  - They are all being drilled in ultra-deep water AND are likely to pose drilling challenges that require NADF

AND

2. They fall within the same EIA and addendum and are geographically close enough so that the baseline environment for each well faces the same level of risk from NADF discharge. (Not applicable to onshore discharge options)

NADF use will not be permitted during the open part of a well where cuttings are discharged straight to the sea bed.

Permitted fluids

Only group II and III NADFs with a low or negligible poly-cyclic aromatic hydrocarbon (PAH) content will be permitted. Operators will be required to demonstrate that their choice of fluid will not have an unacceptable impact on the local environment, with particular emphasis on the direct or indirect risk (if any) to fishing stocks.

Discharge

The offshore discharge of whole NADF fluids will not be permitted at any stage of the well.

Offshore discharge of NADF-associated cuttings will only be permitted if the cuttings have been treated to 1% or less Oil On Cuttings (OOC) content (dry weight) and if the risk or impact to the environment is deemed acceptable. If permission for offshore discharge is granted, operators will be required to submit section-by-section reports of treatment performance and levels of NADF, PAH, and cuttings discharged to the Department of Mineral Resources. Regular monitoring of at-risk elements of the environment will also be expected and should form an integral part of statutory 5-year EIA revisions.

Onshore discharge or re-use of cuttings will only be permitted if the cuttings do not pose an unacceptable environmental or public health risk. If cuttings are to be processed, handled, and/or accepted by third-party contractors onshore, operators should demonstrate a clear chain of liability agreed upon by all parties.

Discharge Application Form

A. WELL INFORMATION

Well Number

Type of well Exploration/ Appraisal/ Development/ Injection / Other (specify)

If an injection well, what type? Water/ Cuttings/ Produced Water

Estimated Spud date	
Estimated time to reach target reservoir	Days
Estimated total drilling period	Days
Anticipated vertical depth of well	Metres
Anticipated total length of well	Metres
Estimated total weight of cuttings	Tonnes

Complete only for production wells

Name of prospect or development		
Is the well to be drilled from an existing facility		Yes/No
If yes, how many wells have been drilled from this facility?		
Please state rig type and and name		
Is it a platform or satellite well?		Platform/ Satellite
Are hydrocarbons expected?		Yes/No
If yes, what is the estimated flow rate?	Oil	Tonnes/day
	Condensate	Tonnes/day
	Gas	m^3/day
If a workover of well-test may occur, What quantities of materials will be flared?	Oil/Condensate	Tonnes/day
	Gas	m^3/day
Is an extended well test planned?		Yes/No
If so, what disposal route will be used for the hydrocarbons?		

B. ENVIRONMENTAL INFORMATION

Is the proposed well in a fish or cephalopod spawning area? Yes/No

If yes, what species and at what time of year?

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

S: Spawning, N: Nursery, J: Juveniles, NS: No documented sensitivity, Blank: No data
(more than one code can be entered)

Are there times of the year when seabirds in the vicinity of the well location are more vulnerable than other times of the year? Yes/No

Please detail seabird vulnerability at the well location and adjacent blocks

Quad/ Block	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

1: Very High, 2: High, 3: Moderate, 4: Low, Blank: No data

Are there times of the year when sea mammals in the vicinity of the well location are more vulnerable than other times of the year? Yes/No

If yes, what species and at what time of year?

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

1: High density, 2: Moderate Density, 3: Low Density, Blank= No data

Sources of information

Fish/cephalopods	Seabirds	Mammals

Please provide details of any other outstanding or unusual environmental features in the vicinity of the well location (e.g. seasonal algal blooms, sessile benthic species or geological or archaeological features) in an attachment to this application.

C. METOCEAN DATA

Residual current

Please provide residual current data for the development location (if relevant data is not available please insert "Not Measured")

Surface Speed	metres/second	Direction
Seabed speed	metres/second	Direction

Source of data

Measurement location

Wind Rose

Please provide wind roses for the area in an attachment to this application

Source of data

Measurement location

D. DRILLING FLUID USAGE

Sections E1 and E2 are required for every well covered by the application, section E3 is required for every well section of each well.

Guidance in relation to the completion of sections E1, E2, and E3 is detailed below

Water depth: The water depth should be confirmed. This can be obtained from surveys, or from Admiralty Charts.

Mean residual current: The mean residual current (u) is required to calculate the refreshment rate. Residual current data can be obtained from surveys. Where data are available for the entire water column, the average surface and seabed value should be entered. Where data are only available for the sea surface, this value should be entered. If data are not available, CHARM uses a default value of 0.24 for the refreshment rate.

Platform density: The number of discharging installations within a 10 km^2 area centred at the drilling location should be confirmed, and used to calculate the platform density per km^2. If data is not available, the CHARM default value of 0.1 (one discharging installation within the 10 km^2 area) should be entered.

Organic fraction in sediment: The percentage organic carbon in the surface seabed sediments can be obtained from surveys. If the organic carbon level is 2.6%, the decimal value would be 0.026. If data is not available, the CHARM default value of 0.04 (organic carbon level of 4%) should be entered.

Well section diameter: All well sections should be detailed, including proposed and contingency sidetracks. Separate copies of section E3 should be completed for each well section identified.

Estimated weight of cuttings: The weight of cuttings should be calculated by multiplying the volume of the well section by the estimated density of the formation sediment. Standard density values can be used for typical sediments. Corrections for predicted washout should also be included.

Batch dilution factor: The dilution factor for batch discharges can be determined using the tables provided in the CHARM manual. Two tables are provided, one for drilling fluids and one for cementing, completion, work-over etc chemicals. Using the appropriate table, you should select the nearest example density (in the case of cementing, completion, work-over etc chemicals, it is appropriate to select the nearest example to the estimated density of the carrier fluid or, if known, the discharge stream); the nearest example discharge rate; and the nearest example discharge volume. You can then derive the dilution factor. The batch dilution factor entered on the form should be the reciprocal of the figure derived from the table. If density, discharge rate and discharge volume estimates do not fit the table, dilution factors can be interpolated using a calculator that is available on the EOSCA website, at www.eosca.com.

Chemical and formulation names: Chemical and formulation names are detailed in the ranked lists of approved chemicals on the CEFAS website at www.cefas.co.uk. All chemicals and formulations must be on these lists. For NADF it will only be necessary to enter details for the complete formulation, and will be unnecessary to enter details for the components of that formulation. However, it will be necessary to enter full details of all chemicals that are not part of the approved NADF formulation.

Chemical function group: The chemical function groups are detailed in the ranked lists of approved chemicals on the CEFAS website at www.cefas.co.uk. You must enter the group name detailed in the lists, and should not enter a numeric function code. If you are uncertain about the correct function group, please contact CEFAS for clarification.

Chemical label codes: The chemical label codes include whether a substance is on the OSPAR PLONOR list; whether it is a candidate for substitution; and detail any relevant product warnings The following chemical label codes should be used to summarise relevant properties (more than one code may be necessary).

PLO	PLONOR (Automatic OCNS Group E)
SUB	Candidate for substitution
As	Arsenic warning
Cd	Cadmium warning
Cr	Chromium warning
Cu	Copper warning
Pb	Lead warning
Hg	Mercury warning
Ni	Nickel warning
O-VII	Organo-halogen warning
O-P	Organo-phosphorous warning
O-Sn	Organo-tin warning
P	Phosphorus warning
Zn	Zinc warning
ED	Endocrine disrupter warning
Taint	Taint warning

Estimated use and discharge: Estimated total use and discharge should be confirmed.

Dosage: For chemicals added to the drilling fluids, the application dosage rate should be stated as lb/bbl drilling fluid. For chemicals used during cementing, completion, work-over etc operations, the dosage should be as stated as mg/l carrier fluid. Where chemicals are diluted by a waste stream prior to discharge (e.g. added to the produced water waste stream), the dosage can be re-calculated and stated as mg/l discharge stream, to generate a more realistic Risk Quotient (RQ).

HQ values: Hazard Quotient (HQ) values are generated using the latest version of CHARM, and can be obtained from the chemical supplier. Although the HQ values are not required to complete the application forms, they provide a useful indication of the potential hazard. Drilling chemicals will usually be ascribed three HQ values, for different sections of the well. The lowest value will usually relate to the 17.5" section, as CHARM assumes that drilling this section will not involve a batch discharge. Chemicals are ranked according to their worst-case HQ, and the ranking group (as below) should be entered in the tables. CHARM algorithms cannot be used for all chemicals. Where HQ values cannot be generated using CHARM, chemicals continue to be ranked according to their revised OCNS group, and this ranking group (as below which also includes temporary and provisional categories, etc) should be entered in the tables.

HQ Colour Band
Gold
Silver
White
Blue
Orange
Purple

OCNS Category
A
B
C
D
E
Provisional A-E
Temporary A-E

If you are uncertain about the HQ or OCNS ranking group, please contact CEFAS for clarification.

RQ values: CHARM uses different algorithms for each use and discharge process, and Risk Quotient (RQ) values must be generated using the appropriate CHARM algorithms. Where RQ values are

generated using the latest version of CHARM (available from the OGP website at www.ogp.org.uk), it is acceptable to use the CHARM default values or installation-specific data. If installation-specific data are used for any parameters that are not included in the tables, the data must be detailed in Section C. Similarly, if data not included in the product templates provided by the chemical suppliers are used to generate the RQ values, e.g. NOEC data held by the suppliers, the data must be detailed in Section C. Where RQ values have not been generated using the latest version of CHARM, any additional parameters required to run the modelling software that are not included in the tables, e.g. product density, discharge stream density, product concentration in discharge, discharge rate etc, must be detailed in Section C., together with supporting information justifying use of the selected modelling software. Where chemicals are still assigned to a revised OCNS group (because the CHARM algorithms are not applicable), it will not be possible to generate RQ values, and the risk assessment should be based on the physical, chemical and toxicological properties of the chemical, and the proposed method of use and/or discharge.

CHARM algorithm code: The following codes should be used to confirm which CHARM algorithms were employed when completing the tables.

DR	value based on drilling algorithms
CWS	value based on completion/workover algorithms, usage as a surface / rig wash
CWO	value based on completion/workover algorithms, usage as a standard completion / workover product
CS	value based on cementing algorithms, dosage as spacer
CM	value based on cementing algorithms, dosage into the mixwater
CNA	CHARM algorithms not applicable
OTH	Other

Discharge code: The following codes should be used to confirm the method of disposal:

CTN	Continuous discharge into the sea
BAT	Batch discharge into the sea
CT/BT	Continuous and batch discharges into the sea
ZDH	Zero discharge, retained downhole
ZSS	Zero discharge, skip and ship
ZCR	Zero discharge, cuttings re-injection
OOC	≤ 1% oil in cuttings discharge into the sea
PRO	Discharged through production facilities
OTH	Other discharge method (details must be provided in Section C)

Using the combined continuous and batch discharge code will simplify completion of the tables. However, some combined continuous and batch discharge RQs may be significantly greater than 1. If combined assessment generates an acceptable RQ, this will usually be sufficient to support the risk assessment. If combined assessment generates an unacceptable RQ, it may be useful to differentiate between the continuous and batch components, and to generate separate RQs to support the risk assessment. For example, it may be easier to justify chemical use if it can be demonstrated that continuous discharge of the vast majority of the chemical has a low RQ.

E. DRILLING FLUID AND CUTTING INFORMATION

1. Well site information

Water depth (metres)	
Mean residual current (Metres per second)	
Platform Density (platforms per km^2)	
Organic fraction in sediment (0 – 1)	

2. Well section, General information

Please complete for all well sections, including proposed or contingency sidetracks. The tables in section E3 must be completed for each well section identified.

Well section diameter (inches)	WBF Use	WBF Discharge	NADF Use	NADF Discharge	Length of section (m)	Volume of Section (m^3)	Estimated weight of cuttings (Tonnes)
	Yes/No	Yes/No	Yes/No	Yes/No			
	Yes/No	Yes/No	Yes/No	Yes/No			
	Yes/No	Yes/No	Yes/No	Yes/No			
	Yes/No	Yes/No	Yes/No	Yes/No			
	Yes/No	Yes/No	Yes/No	Yes/No			
	Yes/No	Yes/No	Yes/No	Yes/No			
	Yes/No	Yes/No	Yes/No	Yes/No			

3. Well section, specific information (copy and fill out page for each well section)

Mud/ Fluid data

Mud/fluid name	
Mud/fluid supplier	
Mud/ fluid density (g/cm^3)	
Drilling time (days)	
Volume of mud/fluid discharged on a continuous basis (m^3)	
Continuous discharge rate (m^3/hr)	
Volume of mud/fluid discharged on a batch basis (m3)	
Batch discharge rate (m^3/hr)	
Dilution factor for batch discharge	

Mud/fluid formulation and chemical data

Chemical & formulation names	Chemical function group	Chemical label code	Estimated use (tonnes)	Estimated discharge (tonnes)	Dosage (lb/bbl)	HQ*	RQ	CHARM algorithm	Discharge code

Enter the HQ ranking (Gold, silver, white, etc) or, if not appropriate, the revised OCNS group

F. RISK ASSESSMENT

Attach a risk assessment for the discharge of the chosen mud/fluid. This should take into account information gathered through baseline surveys; the risk quotient/ OCNS category of the chemical; PEC:PNEC[1] ratios; bioaccumulation, eco-toxicity, and biodegradation data; and predicted dispersion and dilution rates in order to present an argument for the discharge of the fluid and associated cuttings weighed up against the possible impacts on the local environment. Future or ongoing monitoring plans of the at-risk environment should be included in this section. CEFAS templates for chemicals or formulations can be annexed here also.

G. DISCHARGE AND TREATMENT

Attach a document outlining the chosen discharge and treatment options, including redundancy plans should treatment plant become unserviceable. Details and plans for measuring treatment performance and quality assurance systems should also be included in this section.

This should also include a thoroughly researched discussion and balanced argument of why other discharge options have been sidelined. Onshore disposal options/ re-use should include a risk-assessment of the onshore impact and must have been sanctioned by FIG's Environmental Planning Department.

H. CONTACT DETAILS AND FURTHER INFORMATION

Completed application forms, reports, or requests for information related to this PON should be submitted to:

Department of Mineral Resources
Ross Road
Stanley

Tel: +(500) 27322
Fax: +(500) 27321

Reporting@mineralresources.gov.fk

[1] Predicted Environmental concentration : Predicted No Effect Concentration