OIL EXPLORATION IN THE TROPICS
Guidelines for Environmental Protection

IUCN – The World Conservation Union

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PREFACE

IUCN has produced these guidelines for the use of government agencies and other interested parties within tropical countries for which oil exploration is proposed. Readers having responsibilities in this subject may also wish to consult the 'Oil Industry Operating Guidelines for Tropical Rainforests' issued simultaneously by the Oil Industry International Exploration and Production Forum (E & P Forum), 25/28 Old Burlington Street, London, W1X 1LB, UK.

Chapter 1: INTRODUCTION

The oil industry has made a considerable impact upon the environment since its earliest days: tanker wrecks and blow-outs being the most notorious incidents. However, oil exploration itself can have effects on the environment which, while less spectacular, may be more widespread and longer-lasting.

Exploration for hydrocarbons is moving to ever more remote parts of the world. These include ecosystems which are both fragile and of great importance for wildlife conservation, such as, savannas, woodlands and tropical forests.

However, the chance of finding oil or gas may give the countries concerned their only opportunity to break out of the poverty trap that stifles human development. The environmental challenge, therefore, is to develop safeguards that will enable exploration (and subsequent production) to be undertaken without significant damage to the natural environment, and consequent effects on the people and wildlife that it supports. It is hoped that the guidelines which follow will help to meet that challenge.

The guidelines are arranged in three sections which describe:

- The oil exploration process.
- The potential adverse environmental effects of this process.
- The means of environmental protection to avoid or minimise these effects.

The latter section contains a series of specific environmental protection measures which form the bulk of these guidelines. Notes are also provided on the matters of environmental management, formalisation of protection measures and their monitoring and enforcement.

The guidelines refer only to oil **exploration** and to exploration **on land**. Additional safeguards are needed for the development and production of hydrocarbons and for oil exploration in marine or lacustrine environments.

The guidelines cannot be a substitute for comprehensive environmental assessment prior to campaigns of exploration and for rigorous environmental management during exploration activity.

Figure 1: SUMMARY OF THE EXPLORATION PROCESS

Activity	Requirement on ground
Desk Study Identifies area with favourable geological conditions.	
Aerial Photographic Survey If favourable landscape features are revealed, then	— Low flying aircraft over study area.
Seismic Survey Provides detailed information on geology which if favourable leads to	— Access for survey team and equipment by road or helicopter. — Base camp facilities.
Exploratory Drilling If oil or other hydrocarbon deposits found, the next stage is	— Access for heavier equipment. — Erection of drilling derrick. — Base camp facilities. — Waste disposal facilities.
Appraisal If reserves prove viable, then	— Drilling of additional wells. — Oil storage facilities. — Gas flaring. — Larger base camp. — Waste disposal.
Development and Production Primary recovery methods first, followed by secondary and perhaps tertiary methods. Once all economic reserves recovered, then	— Gathering station, pipelines, increased oil storage, facilities for export of product. — Improved access. — Gas production plant.
De-commissioning and Site Restoration	— Plugging of wells, removal of buildings and production installations. — Regrading of site, restoration of topsoil, restoration of vegetation.

Chapter 2: THE OIL EXPLORATION DEVELOPMENT AND PRODUCTION PROCESS

In order to appreciate the potential impact of oil exploration upon the environment, one must understand the activities involved. The area identified for exploration is known as a 'prospect', the exploration of which moves through a sequence of clearly defined stages, as each confirms (or rejects) the evidence of the previous stage. These exploration steps are summarised at Figure 1 and outlined below.

2.1 Identifying a Potential Hydrocarbon Reserve

In the first stage of the search for hydrocarbon-rich rock formations, geological maps are reviewed to identify major sedimentary basins. Aerial photography may then be used to identify promising landscape formations such as faults and anticlines. These are folds in geological strata which form domes or arches, sometimes trapping hydrocarbons. However, more detailed information is needed about the nature of the underlying rocks. This information is assembled using three main survey methods: magnetic, gravimetric and seismic. Of these, seismic survey is the most common and it is often the first field activity that an oil company will undertake. There are two types of seismic survey: vibroseis and shot hole.

2.1.1 Vibroseis

The vibroseis technique involves the use of a team of heavy vehicles linked together by power and communication cables. There are usually three to five large vibrator units which vibrate the ground subsonically, while a number of support vehicles record the returning shock waves for analysis. The vibrators operate for 20-30 seconds at a time and the unit is then moved on a few metres to the next vibration point. In a typical day, such a team may cover about five kilometres. Vibroseis work is generally confined to roads or other hard surfaces such as grassland areas. In wooded or bushed terrain a trace would have to be cut to provide access for the heavy vehicles.

2.1.2. Shot Hole

The shot hole method involves the detonation of small explosive charges which are placed in boreholes. The boreholes, drilled to a depth of 30 cm, are usually placed 35 m apart in straight survey lines along a specific compass bearing. Detonation produces seismic waves which are reflected to different degrees by the underlying rock strata. The returning shockwaves are recorded by very sensitive microphones, called 'geophones'. The information gathered in this way can then be used to map the underlying strata, while computer modelling can help to calculate the size and shape of any structure worthy of further investigation. The shot hole method can be conducted without the need to cut a trace: if necessary access can be provided by helicopter.

2.2 Exploratory Drilling

Once a promising geological structure has been identified, the only way to confirm the presence of hydrocarbons, and the thickness and internal pressure of any reservoir, is to drill an exploratory borehole.

In current oil industry practice, topsoil and subsoil are removed and banked separately around the edges of the site, ready for replacement once drilling is completed. The site is then levelled or terraced as appropriate to form a base for the drilling rig. If rigs are to be delivered by helicopter (helirigs) then an additional area must be cleared for a flyway. Drilling rigs transported by lorry will require 25-60 lorry loads (depending on size of both rig and lorry) to move the rig on to the site.

Where drilling sites are remote from existing roads and services, the construction of access routes and the provision of water, communications and power, may introduce ancillary activities beyond the boundaries of the site.

Drilling is typically carried out with a rotary drilling rig. The standard rotary rig is about 40 metres high and uses a 'drill string' made up of 12 metre lengths of steel pipe. The drill string is tipped with a drill bit, which grinds through the rock as the drill string is rotated. The rig drill string is supported by a steel framework tower, called a derrick, which sits on a drilling floor. The derrick houses the winching equipment needed to lower and raise the drill string, the rotating table used to turn the drill string, and the power unit. As the borehole gets deeper, drilling has to stop periodically to allow new lengths of pipe to be added to the string and to replace the drill bit. Steel casing is run into completed sections of a borehole and cemented into place. This casing provides structural support to maintain the integrity of the borehole, and protects underground water resources from contamination by oil or drilling fluids.

To cool the drilling bit and flush out rock fragments, water-based drilling mud is continuously circulated down the drill pipe and back up the borehole. A typical borehole 1,500 metres in depth uses between 200,000 and 500,000 litres of drilling mud.

The weight of mud in the borehole also helps to prevent blowouts by providing a counter balance to any underground pressure encountered when the bit enters gas, oil or water bearing rocks. The risk of blowouts is further reduced by the standard use of 'blowout preventers', steel rams which can close around the drill string in a matter of seconds to seal off the well. Drilling sites are also designed to contain accidental spillages, using lined drainage ditches and sumps.

In addition to the drilling rig itself, a typical site will also contain power generator sets; drilling mud tanks and mixing pumps; a shale shaker used to separate rock chippings from drilling mud; tanks for fuel, water and extracted oil; site offices and security arrangements. The whole drilling site may extend to approximately one hectare.

A base camp will also need to be established to service a group of exploratory drilling sites. This will occupy about 1000 m^2 and will be located close to access and delivery routes. The site will usually be surrounded by security fencing. The base camp should be self-contained and provide workforce accommodation, canteen facilities, radio room, water wells, vehicle maintenance and parking area, helipad, bunded areas for the storage and handling of fuels, provision for the collection, treatment and disposal of sewage effluent and for the collection and incineration of refuse.

Drilling operations are a round-the-clock activity. The time taken to drill a borehole depends on the depth of the oil-bearing formation and the geological conditions encountered, but it is commonly in the order of one to two months. Where oil is found, initial tests are carried out to establish flow rates. Any gas produced as a result is vented to the atmosphere or flared (burned off), while any oil is stored in tanks and subsequently may be burnt on site in burn pits.

After one to three months of drilling and initial testing, the rig is dismantled and moved to the next site. If the exploratory drilling has been successful, a small, 1.2 metre well-head valve known as a 'christmas tree' is installed. If the well proves dry, the well is plugged with cement, all site equipment is removed, and the site is reinstated (see 2.5 below).

2.3 Appraisal

The appraisal stage aims to evaluate the size and nature of the reservoir, to determine the number of wells required to extract the hydrocarbons and to establish the probable production profile over the expected life of the field.

The consistency of oil varies considerably, from heavy viscous fluid to light, free-flowing liquid. The nature of the oil and the geological structure within which it is found, determine the number of wells needed to drain the reservoir. Further seismic work and the drilling of additional wells may be needed to establish the size of the reservoir. The operator may opt for 'deviated drilling', which involves drilling at an angle from a site adjacent to the original discovery borehole. If it is thought to be a more significant find, a 'step-out' option will often be pursued, with several new boreholes being drilled at a distance from the original borehole.

During appraisal, the reservoir is tested to see whether the oil will flow under the natural pressure within the reservoir or whether pumping will be needed to bring it to the surface. If pumping is required, a simple pumping mechanism popularly known as a 'nodding donkey', standing four to six metres in height, will be installed to determine the likely flow rate and other characteristics of the reservoir. The oil is stored on site and then removed by road tanker, involving perhaps one or two trips a day.

Associated gas produced during appraisal may be burned off where it is present in small quantities.

2.4 Development and Production

If the field is viable, the reservoir may be small enough to be tapped using one or more of the existing exploratory or appraisal wells. If so, the production stage will result in little extra drilling activity. On the other hand, the reservoir may need to be tapped by additional production wells. The use of deviated drilling can allow more than one production well on a given site. Where two or more well sites tap a reservoir, a gathering station may be needed to provide a central facility for preparing the hydrocarbons and wastes for export from the area. The size of the installations needed for separating oil, water and other wastes depends on the nature of the reservoir and the export option selected.

Any significant quantities of gas produced are treated to produce commercial gas or pumped back into the reservoir to maintain its internal pressure. Smaller quantities of gas are vented or flared. Any water extracted with the oil or gas is treated for disposal or reinjected into the reservoir. Reinjection wells are often bored specifically for this purpose. Where reservoir pressures are particularly low, additional quantities of water may need to be imported to the site requiring pumping stations and water pipelines.

Many oilfields involve a simple production system of nodding donkeys to pump the oil to the surface; facilities to separate oil, gas and water; and road tankers to transport the products off site. Whereas the electrically driven nodding donkeys tend to be relatively inconspicuous and quiet in operation, a gathering station and any associated storage and export terminals needed for larger oilfields can be more noticeable. They will also take up more land. A gathering station which processes the oil from several wells may take up to four hectares. A rail depot or shoreside terminal, to which the oil would be brought by road or pipeline, might need a larger area of perhaps seven hectares.

In small oil fields, road networks are generally sufficient for the tanker transport of oil and gas to the refinery. For fields producing large quantities of oil and gas, a network of underground pipelines may be the most efficient option.

Routine operations at a well-managed production site generally cause little disturbance during production. Periodically, a smaller 'workover' rig may be used to conduct down-hole servicing to maintain production from a borehole . However, much of the other activity is invisible, in that it involves operation of the extensive pipework linking the wells to the processing, storage and distribution installations.

Using natural pressure within the reservoir alone, the operator will only be able to extract a proportion of the oil present. This is called primary recovery. A range of secondary recovery methods are used to increase the efficiency of oil production. For example, water or gas may be pumped into the reservoir to maintain the pressure, and, as previously mentioned, 'injection wells' may need to be drilled for this purpose. Ultimately, tertiary recovery methods using chemicals, carbon dioxide, nitrogen or heat may be considered.

2.5 Site Restoration and Aftercare

Oil and gas installations are decommissioned at the end of their working life. This involves the removal of all the buildings, plant and equipment. The petroleum industry is usually required to restore decommissioned sites to an agreed after-use. For an agricultural after-use, restoration will primarily involve the replacement of the soils, followed by aftercare of the land to encourage the redevelopment of soil structure and fertility. The reinstatement or creation of semi-natural habitats or forestry areas requires different restoration and after care programmes (see 4.2.3 'Well Site Abandonment and Restoration' below).

Chapter 3: POTENTIAL ENVIRONMENTAL IMPACTS OF OIL EXPLORATION ON LAND

The environmental implications of oil exploration may be far-reaching. The main issues of concern in relation to exploration in fragile tropical habitats are summarised below and in Figure 2. These provide the context for the environmental protection guidelines which follow.

3.1 Soil Erosion

Soils may have a high erosion potential due to soil structure, slope or rainfall. Left undisturbed and vegetated, such soils can maintain their integrity. However, poor design and construction standards for oil exploration roads, base camps, well sites, etc, can lead to substantial soil erosion.

3.2 Soil Contamination

Spillage or leakage of chemicals or oil may lead to soil contamination which will prevent revegetation or future arable farming on the site.

3.3 Removal of Vegetation

The removal of trees and vegetative cover is also conducive to soil erosion. This impact could be substantial unless there are strict limits to the amount of vegetation that can be cleared and unless there is revegetation of particularly exposed areas.

Even the removal of dead wood may indirectly accelerate soil erosion. For example, the removal of dead firewood by contractors may lead to the increased felling of living trees by the local population.

Removal of vegetation will also cause a visual scar on the landscape which may persist for a considerable time after exploration operations have ceased, especially if site restoration work is not implemented as part of the site abandonment programme.

Finally, of course, the loss of vegetation itself may be serious, particularly in situations where either a high proportion of the nutrients in an area are held in the vegetation (e.g. tropical rain forest), or where the few trees present are vital for wildlife browsing (e.g. tree savannah).

3.4 Pollution of Water

Both ground water and surface water can become polluted during drilling activities. Water contamination is particularly important where the water is used for household purposes by the local population, where it will affect the local fishing industry or in ecologically important areas. Apart from the obvious risk of a blow-out or major spill, the main risks are:

- Contamination of ground water from drilling fluids and oil during the drilling of wells.
- Leakage from unbunded liquid storage vessels.
- Contaminated site drainage.
- Liquid waste discharges associated with exploration operations.

Figure 2: SUMMARY OF POTENTIAL ADVERSE IMPACTS OF OIL EXPLORATION	
Soil	Erosion due to construction activities, contamination with oil, drilling mud and effluents.
Vegetation	Loss of vegetation due to construction of access tracks and drill sites. Extensive vegetation loss due to fire. Facilitation of encroachment in forests.
Water	Contamination of surface water with oil, drilling mud and effluents. Contamination of ground water with oil and drilling mud. Disruption of water courses or drainage.
Landscape	Visual intrusion of drilling rigs. Night lighting. Flaring of gas.
Air	Smoke from gas flare. Odour.
Noise	Noise from helicopter access and plant delivery. Noise from track access and plant delivery. Drilling noise, especially at night.
Wildlife	Increased poacher access. Disturbance of wildlife. Pollution of water sources.
Communities	Disturbance of previously remote communities. Pollution or loss of vital natural resources. Introduction of diseases.
Culture	Damage to sites of archaeological, historical or cultural importance.
Infrastructure	Truck damage to dirt road and watercourse crossing points.
Secondary Impacts	Settlement, logging or mining induced by new access.

The construction of facilities could also cause disruption to local water courses and may affect water supplies if these factors are not considered at the design stage.

3.5 Visual Intrusion

The natural beauty and solitude of wildlands and their attractiveness to tourists can be greatly diminished by poor design and positioning of exploration operations, including roads and tracks, as well as major installations such as well sites and base camps. Night floodlighting can also be visually intrusive, as can the gas flare.

3.6 Air Pollution

A certain amount of flaring of associated gases is normal during well testing in exploratory drilling and appraisal operations. Poor design can lead to black smoky flares. Strict limits are usually placed upon the quality and frequency of flaring. Flaring can also lead to odour, especially if the well contains 'sour' gas or 'sour' crude. Where this is likely, special consideration should be given to the siting of wells and the treatment of waste gases. Flares can also be an important source of noise (see below).

3.7 Noise Pollution

Noise from low-flying aircraft during the aerial surveys will be transient and therefore generally acceptable. However, helicopters are likely to cause more alarm to wildlife and people than are light aircraft.

Noise during exploration and appraisal drilling operations can be substantial and may thus cause considerable nuisance if close to noise sensitive locations such as villages and safari camps, particularly if operating at night.

3.8 Bush Fire

There is always a fire hazard associated with drilling and production operations. An outbreak of fire during the dry season could cause major environmental damage if left unchecked or uncontrolled.

3.9 Road and Crossing Point Damage

Many of the existing roads and watercourse crossing points in an exploration area may be unsuitable for use during the rainy season. Previous experience has shown that, where industrial operators have used these roads during the wet season, crossing points have been destroyed, roads have been severely damaged and soil erosion problems have occurred along the roads. Often the cost of road repairs and establishing a second crossing point has not been borne by the offending road user.

3.10 Damage to Fossil, Archaeological and Cultural Sites

In remote areas, sites of archaeological, historical, religious or cultural importance may not be immediately obvious. Similarly, fossil-rich and other geologically interesting sites may be easily overlooked in the haste of exploration. Local advice on such sites must therefore be taken before moving into an area if irreversible damage is to be avoided.

3.11 Poaching

The development of easier access routes into previously remote areas and the introduction of local and foreign workforces into rich wildlife areas may lead to increased poaching, which may become a permanent burden on the wildlife resource.

3.12 Social Impacts

Increased access may similarly result in the disturbance of remote communities or the natural resouces upon which they depend, and may introduce them to diseases against which they have no resistance.

3.13 Secondary Impacts

Improved access may result in subsequent secondary impacts comprising those outlined in 3.11 and 3.12 above, along with unplanned settlement and exploitation of natural resources, e.g. logging or mining.

3.14 Planning Conflicts

The prospect of oil industry development may conflict directly with existing plans for the protection or development of an area, or may inflate land prices with similar effect. With care, it may be possible to build oil exploration into existing regional or national development plans. There may also be opportunities to rationalise facilities such as road networks to minimise the ultimate number of roads in protected areas or to bring forward planned infrastructure development.

Chapter 4: ENVIRONMENTAL PROTECTION

Oil exploration within fragile habitats requires a comprehensive approach to environmental protection, encompassing:

- **Management methods** which integrate environmental and operational requirements throughout the exploration process.
- **Specific environmental protection** measures which provide practical guidance on the avoidance of adverse environmental impacts.
- **Formalisation of environmental management procedures** and environmental protection standards/measures by written contract.
- **Monitoring and enforcement** of any agreements, codes of practice, emission/effluent standards and environmental quality objectives that have been applied to specific campaigns of exploration.

These aspects are individually addressed in more detail below.

4.1 Environmental Management

Environmental protection measures to prevent or minimise the environmental risks outlined in Section 3 can only be successfully implemented if they are set within a strong environmental management framework. Key factors in the establishment of this framework are:

- Consultation/liaison.
- Identification of sensitive locations.
- Environmental assessment.
- Management of operations.
- Restoration and aftercare.

There should be a strong commitment to consultation between oil company and government departments at all levels and the local community, at all stages of operations. Establishing common ground between the various interests through consultation can ensure that development proceeds in an acceptable way. The identification of especially sensitive locations enables avoidance strategies to be formulated and implemented in the planning stages.

The first step in the consultation process is for the oil company to communicate with appropriate government authorities responsible for agriculture, environment, forests, water, natural resources, wildlife, tourism and planning. Initially, information will be required on the following:

- **Location and status of protected areas** including World Heritage Sites, national parks, game reserves, forest reserves and tribal/communal areas within or adjacent to the exploration area.

- **Existing planning policies and development plans** for the area, e.g. National Conservation Strategies, Regional Masterplans, National Park Management Plans, Communal Area Development Plans, Forestry Policies and Water Resource Development Plans.

- **Land tenure information,** e.g. land ownership, rights of access, communal land, seasonal grazing/cultivation practices and existing concessions granted in the area, e.g. for mining, logging or water abstraction.

- All federal, state and local **legislation relating to the environment.** (Summaries of existing legislation are available from the IUCN Environmental Law Centre in Bonn – see inside back cover.)

Local liaison is also critical. Each survey team should have a local liaison officer conversant in the local language. He will explain the exploration process to local communities before it begins, obtaining information on their land rights, cultural sites, seasonal activities and personal concerns. This liaison with local communities should be maintained throughout the period of exploration.

It should be the responsibility of the oil company to conduct an environmental impact assessment prior to each campaign of oil exploration. Environmental assessment should ensure that proposed exploration operations are set within their national and local context. It should provide the information needed to determine whether a project is environmentally acceptable, where it should be sited, how it should be designed and operated and what should be done with the site on decommissioning to restore or enhance its quality.

A commitment to sound management of exploration operations is an important factor determining the environmental acceptability of those operations. Once a decision on the location of operations has been made, the risk of environmental damage can be reduced through careful site selection and layout. Equally, the type of drilling and production equipment selected can have a significant influence on the acceptability of a given site.

Management plans should include local liaison and monitoring activities, training and contingency planning and provision for responsible supervision of all operations. Each operational site should have written safety management and environmental protection procedures and a written accident management plan with which all site workers are familiar.

Site restoration and aftercare is an essential part of the environmental management framework for exploration operations. This final stage should ensure that restoration is integrated with any future developments in an area (see 4.2.3 'Well Site Abandonment and Restoration' below).

4.2 Environmental Protection Measures

The measures described below represent current good practice within the oil industry and should not be viewed as an unreasonable burden upon exploration contractors. These environmental protection measures are summarised in Figure 3.

4.2.1 Remote Sensing

Aerial photography and aerial geomagnetic survey techniques are not likely to be of environmental significance. Any disturbance due to low level flying will be transitory and therefore unlikely to merit restriction, other than a ban on early morning/late evening flying.

4.2.2 Seismic Survey

This phase of exploration has the potential for the most severe environmental impacts in remote and fragile habitats, particularly in wildlife conservation areas and forests.

Access to the survey area itself may result in the most important impacts arising from the clearance of vehicle tracks and establishment of small base camps (see 3 above).

The direct effects of gaining access to the survey areas should be reduced by:

- Using the existing road network.
- Using boats to access areas adjacent to major rivers, lakes or coasts.
- Using helicopters or light aircraft to access particularly remote areas (but note noise disadvantage of helicopter use).
- Restricting the size of any camps to the absolute minimum.

The use of all terrain vehicles such as trials motorcycles for access to more distant points is often the most convenient method of minimising the scale of track/road construction.

If roads must be established, then they should be constructed with due regard for their potential environmental effects. Recommendations to minimise the impact of roads are given under para 4.2.3. 'Access'.

Shot hole seismic survey techniques should be used instead of vibroseis wherever practicable as this will avoid the extensive vegetation clearance and grading along trace lies required by vibroseis teams.

During shot hole seismic surveys in remote areas, access for seismic teams is usually on foot and hand carried equipment is used. The survey lines need to be cleared of obstructing vegetation to provide a footpath 0.5-1 m wide, but detours should be made around large trees which may be of high conservation or timber value and should not be felled. In settlement areas, the disturbance or loss of agricultural crops may be unavoidable, but compensation should be paid.

The explosions are safe but may cause noise disturbance in inhabited areas. The oil company would therefore be expected to give prior warning when operating in inhabited areas.

The oil company representative must take full responsibility for the actions of all survey personnel including subcontractors who must be provided with specific instructions forbidding hunting or building fires.

4.2.3 Exploratory Drilling

As with seismic surveying, the oil company should discuss its plans for exploratory drilling with national and local authorities prior to any construction works for road or well facilities. This will provide an opportunity to resolve any land use conflicts and modify the initial proposals if necessary.

Contractors would be required to comply with all existing environmental protection legislation. However, they should also take into consideration the potential environmental impacts referred to in Section 3 and plan for their avoidance or minimisation.

They must also plan for the **prevention** of the following potential impacts:

- bush fire;
- pollution of ground water;
- pollution of surface water;
- land contamination.

The following recommendations relate to the actions needed for individual elements of the exploratory drilling process:

Access

Exploratory drilling will often require the establishment of a more permanent access road unless, due to remoteness or the sensitivity of the area, a helirig is to be used.

Roads should be carefully planned to avoid steep slopes and water courses. In undulating topography, cut and fill operations should be minimised. Slope engineering should incorporate preferential drainage courses or culverts, lined where necessary to prevent erosion. The extent of vegetation clearance should be kept to a minimum and exposed soil should be revegetated.

Once built, roads are rarely removed and will remain as a means of access for many years. It is therefore important that the route should be planned to minimise access to resources which are protected, e.g. certain peoples, forests, minerals, wildlife, etc. Encroachment is an insidious process which will occur unless actively designed against and controlled. It is also important that the siting and building of any new roads is integrated with any future development plans.

If new roads are likely to assist poaching or encroachment, then physical road blocks or removal of bridges may be necessary after exploration. New tracks may be stopped short of junctions with existing roads in order to camouflage their presence. In wildlife or forest conservation areas further support to staff may be necessary e.g. for the establishment of new ranger posts on new access points into a conservation area.

Where access roads take cultivated land, compensation must be paid.

Whilst helicopter noise is not welcomed in conservation areas, helicopter access to exploration drilling sites should be considered, to avoid the need for new roads. However, the use of helirig equipment will often require the clearance of an additional area at well sites to provide a helicopter flyway (usually 150 m x 50 m on either side of the well site). This may lead to restrictions on well site location. In forest areas, the additional clearance of a flyway will almost always be preferable to the cutting of a new road.

Base Camp

Base camps usually require about 1000 m^2 of land, but the area should always be minimised. The base camp site should be selected to minimise impact on wildlife, local communities, cultivated areas and tourism interests. As the site will only be used for a few months it should be selected with abandonment and after-use in mind. In this respect, the provision of a cleared area with hard-standing may be welcomed by the local people in an inhabited area. Alternatively, in a previously undisturbed area, the site should have potential for recolonisation by scrub and trees (see section on restoration below).

Waste disposal is a common problem for base camps in remote areas or where effluent treatment and waste disposal facilities do not exist or are poorly managed. Where solid and liquid waste treatment facilities are available, base camp wastes should be transported to these for treatment and disposal. In the absence of such facilities, a major concern must always be the control of pests, disease and contamination from wastes. Food wastes, packaging and other organic material should therefore be collected regularly and incinerated, and the residue buried in such a way that it cannot subsequently be exposed by livestock or wildlife.

Sewage can be treated in mobile facilities and finally disposed of through a soakaway system, but only if there are no sources of groundwater used as a drinking water supply in the vicinity. Packaged biological treatment plants, e.g. those incorporating RBCs (rotating biological contactors), or fibreglass septic tanks are to be preferred to any chemical treatment systems. Slow disposal of final effluents is preferable to sudden, large volume releases. Liquid wastes should never be disposed of directly into a watercourse (lake or river), nor should soak-away systems be established where they will rapidly drain into a watercourse without a reasonable residence time for attenuation.

Effluent water quality standards should be imposed and effluents monitored periodically to ensure compliance. (Actual standard selected will depend upon situation.) The oil company should routinely carry out this monitoring, but it is also important that spot checks are carried out by government staff. These standards are particularly important in inhabited areas where drinking water supplies may ultimately be affected, or where nutrient inputs could have an unwelcome effect on wetland/lake ecosystems.

Well Site Selection

The well site should be selected with existing land use, drainage and subsequent restoration in mind. The most important physical constraints will be slope and proximity to water courses, both of which have implications for drainage and associated erosion. Where possible a minimum separation of 250 m should be observed between the well site and any watercourses or drainage routes.

There is usually sufficient flexibility in well site location to allow the selection of a sensible site. The well site should be located to minimise impact on landscape, conservation interests and land uses, such as wildlife foci, settlements, cultivated areas and tourist interests. The well site and timing of operations can often be selected to accommodate existing land uses, for example by allowing the local people to harvest crops or extract valuable timber from the well site prior to the commencement of site works.

As exploration well sites may only be occupied for a short duration, the immediate impacts of drilling operations are often less significant than potential long-term impacts. In this respect the well site should be selected primarily with ease and speed of restoration in mind. Restoration should be compatible with an agreed after use. It should be recognised that the most appropriate exploration well site need not necessarily dictate the location of the subsequent production well site should a discovery be made. A minimum impact location for a short-term exploration well site may not be appropriate for long-term production.

When operating in a wooded or forested area it may be possible to locate the well site in a previously cleared area or natural clearing. If an area has been previously disturbed, then existing roads and clearings should be exploited rather than undisturbed areas where environmental impacts would be very much greater. Otherwise a site of least ecological value or low diversity should be sought.

If operating in a previously undisturbed area, then it is unlikely that a low-diversity or minimum impact well site could be readily identified without the use of ecological expertise.

Well Site Preparation

The preparation of a well site will often determine the success of its environmental management and subsequent restoration. Well sites are usually constructed on a square approximately 100 m x 100 m. The land is cleared of vegetation and the site graded to provide a level working surface of compacted soil materials or gravel.

However, these traditional procedures need to be re-examined to assess their suitability for environmentally sensitive locations, as follows:

- Well sites should be reduced in size wherever possible to minimise physical disturbance and reduce the area to be restored. The well site does not need to be square; there are considerable advantages in the site having an irregular outline with areas of undisturbed vegetation retained within the site where possible.

- The well site may not need to be completely levelled. On sloping ground consideration should be given to split-level or partially levelled sites to provide a more stable land form which is less susceptible to erosion.

- Prior to any levelling activities, the grasses and herbs on the site should be clipped and the seed heads retained for re-vegetation after the removal of drilling equipment.

- When vegetation is cleared this should not be automatically burnt or sold. The cleared wood may provide valuable material for the protection and stabilisation of earth slopes and banks from erosion, and it can be used to form barriers to prevent off-road vehicle access to undisturbed areas. Furthermore, brush wood can provide a valuable source of plant seed and mulch for the replacement of vegetation on the site. It should therefore be stored for site restoration.

- The depth of the organic top soil layer should be determined prior to grading and levelling of the site. The topsoil layer should be separated from the underlying sub-soil during site levelling and grading. Mixing of the topsoil with sub-soils should be avoided as a priority. The topsoil should be stored in a loose pile on the edge of the site with the brush wood, and protected from compaction by vehicles. Topsoil protection could be achieved using strategically placed log barriers derived from site clearance if available.

- Slope engineering should incorporate preferential drainage channels which may require lining (e.g. with concrete) to prevent erosion. Channel discharge points may similarly require engineering to dissipate water discharge velocity and reduce erosion potential. All exposed slopes should be revegetated as a priority; stabilisation using geotextiles may also be necessary in certain circumstances. Interceptor channels for water drainage should be directed away from working areas and areas of chemical or fuel storage.

- The shape and grading of the working area itself should be designed to follow the local pattern of drainage, bearing in mind the intensity of rainfall, and the potential for surface flooding and run-off. Siting of the well, together with off-site bunds and drainage channels, should prevent water flow across the site. It may be necessary to intercept drainage and direct this away from the site. Water should not be allowed to flow into or through mud pits.

- In areas of standing water or a high water-table, an alternative approach to site preparation may be required. In these areas the well site and drill platform can be established on a wooden corduroy base. No site levelling is required because of the flat terrain, and the soil profile will remain intact and undisturbed beneath the corduroy. In these circumstances additional safeguards are required to prevent contamination by chemicals, fuel oil and produced crude oil.

- Water movement off-site should be controlled by an interceptor ditch. The interceptor will collect well site run-off water for inspection prior to discharge. In higher rainfall areas a holding tank may also be required to retain any contaminated run-off for treatment or collection.

- All fuel, oil and chemical storage areas should be bunded and sealed to contain any spillages and facilitate clean-up. Good housekeeping is also essential in storage, handling and use of fuel and chemicals.

- Crude oil from well testing should be stored in temporary tanks. All pipework and manifolds should be oil tight. Under no circumstances should oil be spilled or discharged on-site, or dumped in the mud pits.

- A store of equipment for oil spill clean-up should be maintained on-site. Any oiled soils and materials should be excavated and taken away for disposal or incinerated alongside solid wastes in areas lacking waste disposal facilities. Care is required in the siting and control of incineration so that it does not result in bush fire.

- To avoid contamination of groundwater or water courses, especially where they are exploited for potable water nearby, the mud pits will need to be lined and a sealed well cellar used.

Waste Handling

The control, treatment and disposal of domestic solid and liquid wastes has been referred to under the Base Camp details. In summary, waste management should be by removal to an authorised waste treatment or disposal site wherever these are available.

The principal industrial waste arising from drilling operations will be 'spent' drilling-mud. Where local waste disposal facilities are available, the mud can be dewatered, the water tankered to a water treatment plant, and the spent mud and cuttings disposed of to an authorised landfill site. However, waste disposal facilities are often not available and drilling-mud disposal must be managed on-site.

The environmental significance of drilling muds is determined by their formulation. All muds employed in land exploration are normally fresh-water formulations. The majority of freshwater polymer, starch-based and bentonite muds are of relatively low toxicity. However, it should be noted that a number of chemical additives contain compounds which can be toxic in the short or long-term. Barite (90% $BaSO_4$) can contain lead impurities and chrome-lignosulphonates can introduce heavy metal contamination. The toxicity of chrome-lignosulphonates is such that they should not be used in remote/rural tropical situations where they cannot be properly disposed of.

For the majority of freshwater polymer, starch-based and bentonite muds the main environmental concern arises from water soluble contaminants; high concentrations of sodium, potassium and chlorides can be present in the mud fluid. At the concentrations normally found in undiluted mudfluids, these chemicals are toxic to vegetation and aquatic life. Under no circumstances should drilling mud fluid be discharged directly into a water course (lake or river) or pumped over the ground surface. Drilling mud fluids are best disposed of through a slow 'dilute and disperse' process. However, this should not be undertaken if groundwater is used or is likely to be used by wildlife or as a potable water supply nearby. If fluids are to be conducted to a distant disposal site they should be contained within discharge pipelines or road tankers to prevent spillage.

Mud pits should be constructed with sufficient capacity to contain all waste mud cuttings plus a contingency for rain water. The mud pit should be surrounded by a raised bund which prevents ingress of run-off water from the well site and adjacent areas. Mud pits should be constructed from impermeable soil materials. Construction should be assessed on a site by site basis to determine whether an additional liner is necessary to prevent seepage of fluids. Seepage of drilling mud fluids must not be allowed in areas of high groundwater table or where watercourses are close by. Under no circumstances should the mud pit be allowed to overflow. The mud pit should never be used for disposal of oily wastes or sewage effluents.

Well Site Abandonment and Restoration

In many remote tropical locations the oil industry has had a very poor standard of well site abandonment and restoration. Well sites have often been abandoned with no attempt at restoration in an unsightly and unsafe condition which is not acceptable.

The site should be abandoned in a safe condition. For a dry hole, this means sealing the well to the ground surface. The concrete well cellar should be broken up and removed to at least 1m below the ground surface and the cellar cavity infilled with subsoil removed during site levelling.

If necessary the site surface should be broken up to produce run-off and drainage characteristics compatible with surrounding land. For a sloping site, consideration should be given to restoration of the original contours. As a minimum, the site should be left with contours which will not erode or act as a focus for instability.

Following the establishment of compatible contours and drainage, all equipment and debris should be removed. At this stage the topsoil stripped from the site should be spread evenly over the surface. Seeding and revegetation should be conducted as appropriate, possibly protected by a cover of brush wood saved from the original vegetation. It may be necessary to retain some large logs in slopes and banks to aid stability and reduce erosion. Depending on the sensitivity of the site, a moderate fertiliser application may be considered as an aid to plant establishment. Alternatively, the seed mix should contain leguminous species to initiate nitrogen fixation (along with seeds retained at the time of site preparation).

Mud pits should be infilled and restored. Where possible the waste mud and cuttings should be excavated and disposed of to an approved disposal site. Where disposal facilities are not available, the mud pit should be infilled to form a stable surface without displacing or spilling the waste mud. The finished surface of the mud pit should be contoured and restored in line with the rest of the well site using stripped top soil, seed and brush wood as appropriate.

Any new or improved access roads should be treated as described above under the heading 'Access'.

4.2.4 Appraisal Phase

If a significant oil discovery is made then further appraisal wells may be needed. At this stage the location of the discovery well site should be reviewed to determine whether or not it will be a suitable appraisal and production site. The location and construction method for each appraisal well site should be carefully examined as it is more likely that they will be in long-term use. Any additional road access should be planned and constructed to the highest standards.

Generally, exploration boreholes need to be drilled from a site immediately above the point where a suspected oil reservoir is likely to be closest to the surface. Once a reservoir has been identified, however, further appraisal and production boreholes can be drilled from sites away from sensitive areas or clustered around acceptable sites by employing deviated drilling techniques. (The cost of drilling a deviated hole can be 50% higher than drilling a vertical hole to the same depth).

4.2.5 Development and Production Phases

Following appraisal drilling, oil field development planning will commence. A detailed Environmental Impact Assessment should be conducted prior to the development of the discovery. (This is outside the scope of the present guidelines.)

4.2.6 Opportunities for Improvement

Oil exploration may provide opportunities for improvements incidental to its main purpose and it is worth giving thought to this at the planning stage. The likely areas of improvements are as follows:

- Upgrading of existing roads to all-weather quality, the construction of new all-weather roads and the provision of planned roads earlier than scheduled where these coincide with exploration access requirements (in liaison with transport authorities).
- Provision of bridges at river crossing points associated with upgrading to all-weather conditions (see also section 4.2.3 'Access' concerning the removal of bridges or avoidance of bridge-building to prevent secondary impacts of access).
- Provision of additional boreholes where water supplies are required to supply base camps and drilling sites, etc (in liaison with the water resource development authorities).
- Provision of dual use buildings, which, after occupation can be left to provide accommodation for schools, clinics, stores etc.

These improvements would be at little additional cost to the oil company. The possibility of these and other types of improvements should not be overlooked during the consultation and planning stages, as any actions which benefit the locality or the local people will help to compensate for any disruption and inconvenience caused by exploration activities.

However, in sensitive areas such as forests, any such improvement initiatives should be considered within the context of their ability to stimulate encroachment and other unwelcome secondary impacts, as referred to in section 3.13 above. (Such potential impacts should be carefully considered by the oil company before agreeing to road construction as a *quid pro quo* for permission to undertake exploration.)

4.3 Formalisation of Environmental Management

It is necessary for oil exploration companies to be committed to their environmental management and protection procedures by formal agreement with the relevant government authorities. The agreement should include:

- An agreement to full consultation between the company and all interested parties, both at government and community level.
- A requirement to perform an environmental impact assessment prior to each campaign of seismic survey, prior to test drilling and prior to development and production activities. The environmental impact assessments will need to be carried out in stages as work progresses.
- Agreement to issue appropriate environmental regulations and guidelines to, and otherwise train their employees and subcontractors so that they are aware of the environmental consequences of their actions. Compliance with such environmental guidelines must be made a condition of contract for all sub-contractors.
- Agreement to designate an environmental focal point person for the duration of exploration. This person would have overall responsibility for environmental management and act as liaison officer with government authorities. The environmental responsibilities of key exploration personnel should be clearly defined.

- Written oil spill and fire contingency plans must be drawn up and agreed with the government. Special consideration should be given to the type and use of any detergents and dispersants in clearing up oil spills, according to the habitat concerned.
- Special provisions should be made for activities which may occur near rivers, lakes and coasts. Special consideration must be given to the disposal of cuttings in sensitive locations.
- The responsibility for any necessary site restoration or remedial work should be clearly established in the concession agreement.
- Standards for emissions to air, liquid effluents and noise are to be set by the government and included in the agreement.
- An in-house monitoring programme must be specified for air quality, water quality and noise.
- The government, or an appointed independent body, should be specifically permitted to take spot samples or measurements to ensure that agreed standards are being met.
- The agreement should make provisions, general and specific, for the protection of archaeological, paleontological, historical, religious or cultural sites.

4.4 Monitoring and Enforcement

Any agreement established between an oil company and a government should be enforceable at law. Where possible, it should therefore have authority under the statutes and regulations of existing laws relating to mines and minerals, national parks and wildlife, local government and lands, industry, labour, public health and housing.

At the operational level, the primary responsibility for monitoring compliance with the agreement must lie with the oil company representative and through him, the environmental specialist appointed under him. Environmental training, clear definition of the environmental responsibilities of all key personnel and a manual summarising the environmental regulations and guidelines will all help to ensure compliance without resorting to enforcement.

Day to day monitoring of the contractor's activities will be carried out by the appropriate local or national authorities appointed by the government or the authorities responsible at law for such environmental protection.

The government or an appointed independent body should conduct periodic environmental audits which will determine whether the terms of the agreement are being met. In the event of unacceptable environmental damage or hazard, the appropriate action can then be taken, including halting exploration.

Figure 3: SUMMARY OF ENVIRONMENTAL PROTECTION MEASURES	
IDENTIFYING RESERVES	– Shot hole method usually preferable to vibroseis in most situations. – Access to survey sites by methods of minimum disturbance and minimum construction of new infrastructure. – Minimisation of base camp size/facilities.
EXPLORATORY DRILLING	**Access** – 'Helirigs' preferable in sensitive areas. – New access routes to be planned to minimise subsequent national park/forest encroachment and exploitation/ disturbance of natural resources and people. – New tracks/roads to be planned and constructed to minimise erosion potential and vegetation loss. – New access routes to remain unconnected to main feeder roads. – New access routes to be physically blocked after use, where appropriate. – Support for park/forest ranger services where appropriate. – Compensation for loss of agricultural land. **Base Camp** – Planning for after-use at site selection stage. – Minimisation of land take. – Export of solid and liquid wastes to treatment facilities. – Alternatively, treatment of liquid effluents and incineration of solid wastes on site. – Final effluent of controlled quality and disposed via 'soakaway', avoiding potable water sources.
WELL SITE SELECTION	– Siting to minimise impacts on water resources, conservation interests, settlements, agriculture and landscape. – Consideration of subsequent restoration within site-selection. – Selection of site that is previously cleared/disturbed or of low ecological value. – Application of ecological expertise in site selection.

Figure 3: SUMMARY OF ENVIRONMENTAL PROTECTION MEASURES

WELL SITE PREPARATION	– Minimise cleared area. – Collection of seeds from site prior to clearance. – Storage of bushwood for erosion control, etc. – Minimise levelling activities. – Separation and storage of topsoil for subsequent restoration. – Engineering of slopes and drainage channels to avoid erosion. – Bunding and drainage design to avoid contamination of surface water. – Use of wooden corduroy drill platform in wet areas. – Interceptor ditches for site run-off. – Bunding and sealing of all fuel, oil and chemical storage areas. – Produced oil stored in sealed tanks/pipes. – Provision of oil spill clean-up equipment. – Mud pits to be lined and to have contingency capacity.
INDUSTRIAL WASTE HANDLING	– Separation and export of drilling mud solids and liquids for proper disposal when possible. – Toxic chrome-lignosulphonates not to be used in areas without disposal facilities. – Drilling mud fluids to be disposed of by soakaway only if water courses or aquifers are not at risk.
WELL SITE ABANDONMENT AND RESTORATION	– Sealing of well and removal of all structures. – Site surface contouring, restoration of natural drainage characteristics and replacement of top soil. – Stabilisation and re-vegetation. – Extraction and proper disposal of drilling muds and infilling of mud pits. – Severance or obstruction of access road, if appropriate.
APPRAISAL	– Detailed planning of location and construction method and after-use of each appraisal site.
IMPROVEMENT	– Where appropriate, design and construction of roads, bridges, water-supplies and building for subsequent use by local communities.

GLOSSARY OF OIL INDUSTRY TERMS

abandon (a well) To cease work on a well and seal it off with cement plugs.

aftercare programme A management programme which follows the decommissioning and restoration of a site to ensure that full restoration to a predetermined after-use is achieved.

appraisal well Well drilled after a hydrocarbon discovery to delineate the extent of a reservoir, and to test its productivity and properties.

barrel Unit of measurement equal to 35 imperial gallons or 42 US standard gallons (159 litres).

bentonite A naturally occurring clay, which is often a major constituent of drilling muds.

blow-out Occurs when gas, oil or salt water escapes in an uncontrolled manner from a well.

blow-out preventer (BOP) A hydraulically operated device fitted to the top of wells to seal off the well should a blow-out situation develop.

cap rock Impervious layer of rock overlying reservoir rock which prevents leakage of the oil or gas to the earth's surface.

casing Steel tube which is cemented into an oil well to prevent the collapse of the well and possible contamination of the groundwater.

christmas tree An array of pipes and valves fitted to a production wellhead to control the flow of oil and gas and to prevent blow-outs.

contingency planning Procedures developed by an operator which provide a strategy for dealing with unplanned events, for example oil spillages or blow-outs.

crown block A fixed system of pulleys fitted at the top of a derrick for use in raising and lowering the drill string, casing etc.

crude oil Oil produced from a reservoir after any associated gas has been removed, often simply referred to as 'crude'.

derrick The elongated pyramid of latticed steel mounted over a borehole for drilling and well servicing purposes.

development well Well drilled in a formation for the purpose of producing oil and gas. (Also called a production well).

deviated or directional drilling Controlled progressive deviation of a well away from the vertical in order to reach different parts of a reservoir from a single drilling site.

drill bit The part of the drilling tool which actually cuts through the rock in the drilling of a borehole or well.

drill stem test — A test during which the nature and quantity of the formation fluids in a possible oil- or gas-bearing stratum are determined by allowing them to flow to the surface through the drill string under controlled conditions.

drill string — Lengths of steel tubing roughly 10m long screwed together to form a pipe connecting the drill bit to the drilling rig. The string is rotated to drill the hole and also serves as a conduit for drilling mud. (Also called drill pipe).

drilling mud — Specialised fluid made up of a mixture of clays, water (and sometimes oil), and chemicals which is pumped down a well during drilling operations to lubricate the system, remove cuttings, and control pressure.

drilling rig — The complete machinery and structures needed for drilling a well (the most visible component being the derrick).

drilling table — The table on the derrick floor with which the drill string is rotated. (Also called the rotary table).

dry hole — A well drilled without finding gas or oil in commercial quantities.

enhanced oil recovery — A process whereby oil is recovered other than by the natural pressure in a reservoir, using secondary or tertiary recovery methods.

exploration drilling — Drilling carried out to determine whether hydrocarbons are present in a particular area or geological structure.

exploration phase — The phase of operations in which an operator searches for oil and gas by carrying out detailed geological and geophysical surveys followed up, where appropriate, by exploratory drilling in the most promising places.

flaring — Burning of gas extracted from an oil and gas reservoir which is not worth commercial production.

gas field — A hydrocarbon reservoir containing natural gas but no oil.

gathering station — A facility at which oil or gas from a number of wells in a producing field is collected, and where the oil, gas and water are separated, and products prepared for export from the area.

geophones — The detectors used in seismic surveys to pick up sound waves reflected from sub-surface strata.

injection well — A well used to inject gas or water into an oil/gas reservoir rock in order to maintain reservoir pressure during the secondary recovery process.

marginal oil field — A field that may or may not produce enough net income to make it worth developing at a given time; should technical or economic conditions change, such a field may subsequently become commercial.

nodding donkey — Pumping unit, used to extract crude oil from a reservoir which has insufficient internal pressure to force the oil to the surface.

obligatory wells	Exploration wells that an operator undertakes to drill in a given area as a condition for being allocated an exploration licence.
oilfield	A productive oil or gas formation comprising one or more reservoirs, usually related to the same geological features.
primary recovery	Recovery of oil or gas from a reservoir by using only the natural pressure in the reservoir to force oil or gas out.
prospect	A geological feature which has the potential of containing oil and gas that merits further exploration work.
recoverable reserves	That proportion of the oil/gas in a reservoir that can be removed using currently available techniques.
reservoir	A stratum in which oil/gas is present.
reservoir rock	Porous and permeable rock, such as sandstone, limestone, or dolomite, containing petroleum within the small spaces in the rock.
restoration	The activities undertaken immediately after a site is decommissioned to restore it to a predetermined land-use.
rotary drilling	Drilling in which the entire drill string and bit are rotated, as opposed to turbine drilling where just the drill bit is rotated by a down-hole turbine.
secondary recovery	Recovery of oil or gas from a reservoir by artificially maintaining or enhancing the reservoir pressure by injecting gas, water or other substances into the reservoir rock.
seismic survey	A technique for determining the detailed structure of the rocks underlying a particular area by passing acoustic shock waves into the strata and measuring the reflected signals.
shale shaker	A vibrating or rotating screen which removes the coarse drill cuttings from the drilling mud prior to recirculation.
shot hole seismic method	Seismic survey which uses a small explosion down a shallow borehole to produce shock waves.
sour crude or gas	Oil or gas which has a high sulphur content.
spudding-in	The process of starting to drill a well by making a hole in the surface with a large diameter drill bit.
tertiary recovery	Recovery of oil or gas from a reservoir over and above that which can be obtained by primary and secondary recovery – generally involves sophisticated techniques such as heating the reservoir to reduce the viscosity of the oil.
vibroseis	A seismic survey technique which uses a large vehicle fitted with vibrating plates to produce the shock waves.
water injection	A process whereby treated water is pumped into the reservoir rock in order to maintain the reservoir pressure.

wildcat well A well drilled to find oil and gas in an unproven area on the basis of incomplete geological information.

workover A process by which a completed production well is subsequently re-entered and any necessary cleaning, repair and maintenance work done.

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