Australian Government
Australian Maritime Safety Authority

Management and disposal of oil spill debris

The National Plan for Maritime Environmental Emergencies.

Introduction

Environmentally and technologically sound disposal of oil spill debris is essential for minimising the environmental damage from an oil spill.

The very nature of an oil spill emergency clean-up has the potential to contribute to the implementation of less-than-adequate disposal practices. In an emergency situation, sufficient time or resources may not be available to evaluate the suitability of alternative disposal options in the area and to choose the one that offers the best conditions for environmental protection, in addition to securing the appropriate approvals to dispose of the waste.

It is therefore crucial for strategic planning purposes, that relevant authorities consider appropriate disposal methods and suitable sites for temporary storage and disposal within varying jurisdictions, taking into account the possible range of sizes and types of oil spills likely to occur, and the industries likely to be involved.

Given the volumes of oil that are transported worldwide on a daily basis, a realistic oil spill response strategy must recognise that a major spillage could occur at any time or place in our estuarine or coastal waters.

If recovery of the oil or dispersion at sea are not or appropriate feasible options, and the oil subsequently reaches the shore, it is usually emulsified and contaminated with a variety of solids which complicate handling and disposal.

This document is designed as an operational aid for Commonwealth, State and local authorities and, oil spill clean-up personnel concerned with the problems of marine oil pollution especially those involved in post spill waste management.

Use of this document can assist in two basic areas:

Developing a contingency plan for oil spill debris disposal, including selection of a site (or alternative sites) before the need arises, and

Providing guidance to individuals responsible for disposing of oil spill debris after a spill has occurred.

During oil spill response operations oil is often recovered at sea, before it strands on shorelines. An inevitable consequence of vessel-based operations is the collection of large amounts of sea water, along with the oil. This oily water needs to be managed to optimise oil recovery, and one option is to discharge the water back into the sea. This may be done in special circumstances, which are described at Maritime discharges of oil and oily water during emergency and response situations.

The Nature of Collected Oil and Oily Wastes

In the event of an oil spill at sea, the amount of oil beached, the time it takes to reach the shore, and the length of coastline affected, will depend on a number of inter-related factors. These include the volume and nature of the oil spilled, the distance of the spill from the shore, sea and tidal conditions, prevailing wind direction and strength and the efforts made to contain or disperse the oil at sea.

Similarly, several factors will affect the amount of oil that will ultimately be beached as a result of a spill. This includes the rate of evaporation (50% of most crude oils will evaporate within the first 24 hours and refined products may evaporate completely), spreading (oils can spread to a thickness of 3mm within one hour), dispersion, solution, emulsification, biodegradation and photo-oxidation. The significance of beached oil is also strongly dependent on the nature (i.e. sensitivity, amenity value, vulnerability etc) of the affected coastline.

Recovered Oil

Regardless of oil type and quantity, a significant degree of emulsification can occur within 24 hours of an oil spill as a result of wave action and wind agitation. With certain types of crude oil, highly stable water-in-oil emulsions are formed typically containing 50-80% sea water. These emulsions may exhibit viscosities ranging from 3000 to several hundred thousand centipoises at ambient temperature, making them difficult to handle or pump. The high water content often renders them unsuitable for combustion. An additional problem is encountered when the pour point of the oil is higher then the ambient temperature as it is with some heavy crudes, waxy oil and fuel oils. Heavy residues are invariably encountered after a fire.

Evaporation is another natural process which alters the composition of spilt oils even in the case of crude oils. The evaporative rate is determined mainly by the volatility of the crude oil or product, surface water temperature and wind velocity.

Oil Spill Debris

Oil collected from the surface of the sea can contain debris such as seaweed, wood, plastic materials of various types, dead birds and animals. Collection and disposal are greatly complicated by the variation in waste composition and appropriate disposal techniques have to be selected for the particular circumstances.

Other waste which may require disposal include oily sand and gravel, pebbles, rocks, seaweed and beach debris, sorbent material (such as straw, plastic foam or porous beads) and in practice, often a combination of these. When removing sand or structural material from a beach it should be remembered that a minimum volume should be taken to preserve the integrity of the beach and to minimise the volume of waste requiring disposal.

Disposable overalls and gloves oiled in the cleanup effort should be wiped at the end of each day with rags dipped in kerosene and reused. The rags and the items themselves may be disposed of to landfill as solid oily waste.

The type and volume of waste will depend upon the size and location of the spill and the clean-up methods employed. Generally, irrespective of whether it is a water or land based oil spill, significant volumes of solid debris will be generated and collected as a result of efforts to clean-up the waterbody or land area affected by the spill. It has been estimated that for an oil spill at sea the volume of waste requiring disposal will the collected oil multiplied by a factor of five to take into account the entrained water content. For shore based cleanup, the volume of collected oil should be multiplied by a factor of ten.

The collected mass of oil spill debris must be properly stored, transported and disposed of to minimise the potential for further adverse environmental impacts. The subsequent clean-up and disposal efforts must be remedial, not sources of additional, more long term environmental problems.

Storage of Collected Oil and Oily Debris

Plans for the storage of collected material may sometimes be neglected in oil spill contingency planning. To avoid or mitigate problems of storage in the event of an oil spill, pre-designated emergency and longer term intermediate areas should be identified.

Contingency plans should designate routes to and from the storage sites and should ensure suitable access in relation to the location of potential spills. As with the interim storage of any hazardous waste, care must be taken to avoid secondary pollution problems as a result of respillage, odours, creation of fire hazards, general nuisance etc. Suitable emergency storage can allow time to undertake disposal in a systematic manner.

Emergency Storage

Because spills can occur at isolated and inaccessible parts of the coast, it may be difficult and expensive to collect and transport material to ongoing storage sites. Emergency storage of liquids and solid waste is an issue that needs to be addressed as the need arises depending upon the site, and nature of the spill.

It is therefore difficult to establish pre-designated areas, other than a recognition that any site chosen for emergency storage should conform to the following criteria:

The area is close to the hub of response operations, but sufficiently away to avoid confusion between the primary cleanup and the operations relating to the management of the emergency stockpile itself;

The site provides for easy access, preferably with a one way traffic flow to (e.g. to allow receipt of equipment need for pit/shed construction) and from the area (e.g. for transport vehicles carting segregated wastes to more appropriate longer term or final disposal sites);

Sufficient flat-pan area to allow for the efficient segregation of lightly and heavily contaminated items of various natures.

Emergency storage should be in such a position that easy access is provided. The distance from the spill area should be as short as possible and unpaved areas or light duty roads subjected to heavy traffic flow should be reinforced wherever possible to reduce deterioration of the surface. Precautions should be taken to avoid oil spills on the road, and suitable absorbent material should be on-hand to mitigate environmental harm should this occur.

Liquids

Relatively cheap and simple short-term emergency storage can be readily provided by digging pits in the ground and lining the base and walls with heavy gauge oil-impermeable material such as PVC, polyethylene or oil resistant rubber sheeting to prevent groundwater and soil contamination. Prelining the pit with sand prevents the plastic sheet being punctured by sharp stones etc. Long narrow pits are the most practical shape since they are easier to dig, fill, and empty.

Where the land adjacent to the spill site is not suitable for pits to be dug in the ground for temporary storage, consideration should be given to constructing bund walls using suitable quality soil brought into the area. Usually where the height of the wall will exceed 1 metre, engineering advice should be sought on selecting appropriate soil, and the method of compacting. The volume of liquid placed within the pit should be limited to avoid the risk of wall breakage by hydrostatic pressure. It should also be remembered that rain water will accumulate in the storage area especially in high rainfall areas, add to the hydrostatic pressure on the bund wall, and perhaps cause the oily liquid to overflow. For this reason, any pits used for the temporary storage of liquid waste must not be filled to capacity or a makeshift roofing system erected to prevent the ingress of rainwater. Provision for pumping water from the bottom of the pit can alleviate this problem. Particular care must be taken to ensure that the walls are not damaged in any way by vehicles delivering the oily material.

During the recovery operation of oil by vacuum trucks large quantities of free water can be collected with the oil unless the oil layers are very thick. Before removing this material from pits to permanent disposal sites, it is essential to collect only the oil, leaving behind (as much as possible) the free water. This may be achieved by skimming the surface of a pit using a skimmer and transferring the collected oil into a second pit.

Oil collected by vacuum trucks may contain large quantities of seaweeds and other solids that are mixed in with the floating oil. As the subsequent oil transfer operations may involve a pumping operation it is essential to filter out the solids. This may be achieved by placing an expanded metal sheet or series of sheets (large apertures) at one end of the pit with the vehicles discharging the oil behind the filter(s) to remove solid debris.

Liquids may also be contained within flexible open top and pillow tanks such as Fastanks, Porta tanks or Trans-Pac Containers.

Semi-Solids/Solids

Semi-solids and solid waste can be stored in lined areas surrounded with temporary bunded walls to prevent leakage. The walls should be sufficiently substantial not to be washed away. In an emergency, discarded booms can be used as bund walls and the plastic lining extended from the base over the booms.

Sealed or covered skip bins are useful for small quantities of solid waste. With larger quantities, large heavy duty plastic sheets may be used for lining excavated pits to receive oil. The sheets allow for a pit size of about 15.2 x 3 x 1.82 metres deep giving a capacity of about 82 m3. These pits may be sited at any convenient area where the sand or earth is reasonable firm. Care should be taken to ensure that there are no sharp protrusions in the pit walls or base which may puncture the plastic liner. A layer of sand may help in this regard. In the case of unstable ground, wooden boarding may be used to shore up the sides of a pit prior to fitting a plastic liner. Good vehicular access and firm ground adjacent to the pits for heavy vehicles is essential.

Inflatable barges (such as Lancer Barges) can also be used for emergency and intermediate storage.

Intermediate Storage

Depending on the size and location of the spill, the method and location of final disposal sites and the storage capacity of emergency storage measures implemented at the site of the spill, longer term interim storage is likely to be necessary at existing waste management company depots and landfills.

The waste likely to be received at these locations is waste that has been transported from the primary emergency containment onsite at the spill site following segregation and consolidation. The interim storage facility may or may not be the final disposal destination, however in the case of interim storage at a landfill, the site should be one that can accommodate the waste into the site for final disposal in accordance with pre-determined arrangements and site operating permit conditions. In this case, 'interim storage' is unlikely to take the form of more than a matter of days to prepare the area within the landfill (e.g. dig trenches, or prepare for acceptance into the domestic refuse area for co-disposal) that has been previously earmarked for disposal in preparation for an oil spill incident

Waste Segregation

Wastes collected from the scene of an oil spill should be segregated into distinct waste streams to avoid cross contamination of hazardous and essentially non-hazardous materials which may have vastly different handling requirements.

Transport

Transport will be required for three main duties:

At sea

small tankers, barges or towed flexible containers for moving collected oil from the skimming vessels to the shore station. Barges will be particularly useful on inland waters.

Onshore transport for liquids (eg oils and low viscosity emulsions)

closed or covered tanks, tankers vehicles, vacuum trucks

Onshore transport for semi-solids and solids (eg high viscosity emulsions, oily sand, pebbles, stones and general debris)

open topped tanks with covers, non drip containers, tipper trucks.

Land Transport of Liquids

Any conventional road vehicle approved to convey liquid waste hydrocarbons can be used for the transport of oil to the storage/treatment/disposal site.

In an emergency, improvisation will probably be required and vehicles such as vacuum trucks, farm tank vehicles, flat tray trucks carrying open tanks (with precautions against spillage by slopping) or drums with temporary covers may be used. Tipper trucks and lightweight vehicles fitted with broad tyres are useful for beach work. The use of heavy vehicles on beaches should be avoided or minimised to prevent damage to the beaches and their approaches. Attention to safety factors and codes of safe practice must always be a prime consideration. When transporting low flash point materials, only suitably equipped vehicles should be used.

Land Transport of High Viscosity Liquids, Emulsions, Oily Solids and Debris

Conventional vehicles for moving solids are generally suitable. However, attention should be given to the prevention of spillage or seepage from the vehicle (perhaps due to reduced viscosity from exposure to sunlight) by the use of plastic sheeting.

Heavy duty plastic bags (capacity 25kg or larger if half filled) may be used to collect oily pebbles, sand and debris. While this is a convenient method of collection, problems are encountered at the disposal site, with time-consuming and labour-intensive handling needed, and the bags themselves posing an additional disposal problem (generally requiring incineration). Open topped 200 litre oil drums can be quite effective for transferring oily material to the transport vehicle. Ordinary metal or plastic garbage bins or other liquid-tight garbage containers can also be useful. Such drums or containers should only be half to two-thirds full to allow easier handling.

Approvals from appropriate Government agencies must generally be obtained to transport hazardous waste for fee or reward.

Oil Recovery Techniques

Natural Recovery

In certain circumstances, material contaminated with up to 5% of oil can be left to degrade naturally. If the spill is at a remote or isolated location, a site with no amenity value, or has occurred during the winter season in temperate climate areas, it is worth considering the possibility of allowing natural processes to proceed, and then to reassess the situation as conditions allow.

Oil/Water Separation

Gravity Separation

Most of the oil present in oil/water mixtures can be skimmed off, provided that it is not emulsified. To avoid the formation of such finely dispersed droplets, it is important to avoid or minimise the pumping of mixtures of oil and water before gravity separation can be effected. Collected oil/water mixtures should be allowed to separate into layers in the collecting device, which may be a vacuum truck, wagon or static tank. The lower aqueous (water) layer can be run or pumped out.

Oil/Water Separation in Remote Locations

At remote sites, improvisation may be necessary to achieve maximum oil recovery and minimise the volume of oily waste to be transported to intermediate storage. If the terrain permits, damming can be carried out to contain oil, which can then be picked up by vacuum trucks. Small floating skimmers are available commercially and can be used in conjunction with a vacuum truck, thus increasing the efficiency of oil collection. Alternatively, a baffle in conjunction with a weir arrangement could provide a make-shift separator. In locations where a serious water pollution hazard exists and no fixed installation is viable, the use of compact skid-mounted units should be considered.

Emulsion Breaking

Most crude and fuel oils spilt at sea normally spread rapidly. In the process of spreading, the low molecular weight hydrocarbons immediately begin to evaporate into the air or dissolve in the seawater, while the heavier petroleum hydrocarbons begin to absorb seawater. The wind and wave action cause the formation of water-in-oil emulsions within hours in some cases. These emulsions can be very viscous and can contain as much as 50-80% seawater.

Emulsions can cause serious operating problems and reduction of the water content to 2% may be necessary to allow subsequent reprocessing by lowering the viscosity. However, during oil spill disposal, even a small reduction in water content will decrease transport and storage requirements by reducing the overall volume to be managed and will ease handling by improving pumpability.

Unstable Emulsions

Unstable emulsions may be dealt with on a large scale by simple gravity separation or by heat treatment followed by gravity separation. The effect of heat on the oil/water mixture reduces the viscosity promoting faster and more efficient separation. Because of the high viscosity of the emulsions, natural circulation cannot be relied upon to transmit heat throughout the storage tank and as a result it is possible that pockets of water vapour can build up and eventually cause rupture of the tank if steam coils or live steam injection into the tanks are used. Therefore the oil/water mixture should preferably be heated by circulation through an external heat-exchanger. In this way, temperatures can easily be controlled within safe working limits (ie flash point of oil, less 8(C) and no incidents should result. Generally, a working temperature of 60-66(C) is used with a maximum temperature of 80(C) to maintain operational safety.

However, it may not be feasible to bring heating equipment to an oil spill site in which case the emulsions may need to be transported to a suitable facility.

Stable Emulsions

Stable crude oil emulsion ('chocolate mousse') are formed when a mechanically strong film composed of naturally occurring oil components surrounds each water droplet. This film must be destroyed before the emulsion will separate into oil and water. Stable emulsions produced in refineries when pumping oil/water mixtures have been successfully broken by the use of demulsifying chemicals. A demulsifier is a chemical compound which when added at a relatively low concentration, reduces the stability of an emulsion so that the viscosity is decreased and/or separation between the oil and water phases is achieved. Concentrations required will depend on the kind of oil and its state. Screening to select the most suitable demulsifier for each application must be performed in the absence of a 'universal' demulsifier.

Weathering of a thin layer of emulsion increases its viscosity and its stability, and therefore the addition of a demulsifier to a chocolate mousse emulsion should be carried out at the earliest opportunity. The treatment should be effected during transfer into a tank or truck during transfer of the emulsion under vacuum. Devices have been designed that allow this addition in the proper ratio, with homogenous mixing of the demulsifier and the emulsion. The recommended dose rate varies with the type of oil and the age of the emulsion. It can range from 250-5000 parts per million (ppm).

Separation into an upper oil layer and lower water layer normally takes 10-20 minutes but this period may increase as a result of:

- imperfect mixing of the demulsifier
- high viscosity of the oil constituent in the emulsion
- aging and aerial oxidation of the emulsion before treatment

After separation into two layers, the water phase (generally containing less than 1000ppm of oil) may be disposed of on-site since the residual oil content is unlikely to increase damage to any species in an area affected by a significant oil spill. Preferably however, this oily water should undergo further treatment via a separator unit to further reduce oil content.

Solid Washing Techniques

Cold Water Flushing

The simple technique of cold water washing large quantities of oil debris with a high pressure hose to loosen and float away oil may be moderately successful. The resulting oil/water mixture can then be treated via a separator (eg a ballast water separator) since the throughput can be controlled to low levels by appropriate selection of pumping rate, or by the use of a gravity feed system to the separator.

Warm/Hot Water Flushing

A method for cleaning pebbles, gravel and sand contaminated with oil or emulsion may be used based on standard mineral processing equipment coupled to a conventional oil/water separator.

A similar process strips oil by storing the oil containing contaminated sand in heated water, with subsequent oil separation by air flotation or centrifuging. The process utilises liquid fluidisation to effect oil/sand separation and is reportedly capable of cleaning about 1 tonne of oil contaminated sand per hour. When operating with sand containing up to 2% oil approximately 95% of the oil may be removed. The presence of various types of debris can lead to reduced efficiency due to plugging of the equipment, therefore bulky items should be removed prior to processing.

Steam

High velocity steam jets directed onto an inclined, vibrating, perforated tray placed above a collector to trap oil and condensate, may be used to clean oil-contaminated sand.

The polluted sand is mixed with a demulsifier on heated plates and oil is recovered by condensation while solids are skimmed and recovered by collection. The collected solids are subsequently burnt to provide plant heating if the oil content is sufficiently high. Large pieces of debris cannot be handled so the process may be somewhat limited.

Solvent Extraction

The established chemical engineering principle of solvent extraction has been considered as a possible means of removing and recovering oil from collected sand, pebbles and debris. Limited research has been carried out in relation to the use of this technique.

Reception and Processing at Established Facilities

Following an oil spill, refineries and other specialised facilities may be approached to receive and process collected material ranging from clean oil (with or without water) to sand or debris containing a small percentage of oil. Oil refineries are well suited to handling liquids however solids handling does not normally come within their scope. Local authorities deploying transport and equipment for handling solids may the best agents to deal with such material. It is essential that individual local authorities and the oil industry establish clear mutual understanding about allocation of costs and the capacity of individual units of the processing industry to deal with collected oil.

Clean Oil or Oil/Water Mixtures

Non-emulsified, pumpable mixtures of oil and water containing either recovered crude or products could subject to quality compatibility and the availability of tank mixing facilities, be routed to reception tanks at a refinery, for subsequent normal processing. A possible route for recovered oil/water mixtures is through a de-ballasting system provided the design is appropriate. Where a direct line exists to the refineries slop system, this route may be preferable to normal crude product reception facilities, the choice of route being at the discretion of local management. A high chloride content may cause corrosion problems with equipment and care should be taken to prevent this from occurring.

Weathered Crude Oil

Provided the material is pumpable, the disposal routes described above may be appropriate, subject to the refinerys capacity to produce oil blends which can be processed satisfactorily.

Oil Containing Dispersants

It is possible for collected oil to contain dispersant, and the processing of such material may cause some emulsification of crude oil or offset to some extent the action of de-salter demulsifiers. Such cases must therefore be considered individually. Some refiners have reported processing oil containing dispersants without encountering significant problems, but others have experienced difficulties. The possibility of re-routing such oil directly to the refinery fuel system should also be considered.

Stabilisation of Oily Wastes

The aim of this treatment is to render the waste physically and chemically suitable for use as a filling material, as raw material in civil works, or to be left insitu in a stabilised condition.

Large Quantities of Oily Sand

Where road building equipment can gain access to sandy beaches, the collection and disposal of oil can be carried out at the spill site. With the help of roadmaking milling machines, binding agents may be mixed with the oily sand and such mixtures subsequently used for road beds or can go into contractors storage for use in civil engineering works or for land reclamation. The mixture of binding agents and oily sand is a clean, easily handled material which can be readily transported and stored.

Treatment with Quicklime

Treatment may be carried out near the shore or in a treatment station.

Treatment near the Shore

The waste is spread out into a bed of 0.2-0.3m depth and mixed using a pulverising mixer or front end loader/back hoe which incorporates the lime. The quantity of lime must be determined by insitu tests (from 5-20% according to the percentage of oil in the waste). The lime used is either ordinary quicklime (with or without additives such as aluminium sulphate or phosphogypsum) or 'hydrophobic lime' (98% lime and 2% oleic acid) which is claimed to retard desorption of the oil.

Suitable protective eye equipment and clothing must be worn while spreading the lime as dust generation may be an additional problem. After mixing, the material is compacted, using conventional construction equipment. Costs incurred depends on the level of contamination of the waste, transport costs and disposal requirements.

Treatment with other Hydraulic Binding Materials

Similar reactions to the hydration phenomena with lime occur with a variety of proprietary hydraulic binding materials (eg CHEMFIX, PETRIFIX). The methods essentially involve mixing oily waste with inorganic reagents (specifically selected after testing) in a fixed or mobile unit. The mixed and reacted material is in the form of pseudo-mineral powder or solid blocks which are stable and practically insoluble. The waste to be treated must be relatively homogenous. Costs depend on contamination and tonnage, transport and disposal requirments.

Gelling Agents

The technique of converting liquid oil into a jelly like substance has been considered for a number of situations:

- minimising or preventing the loss of oil from a distressed tanker
- containment of an oil slick by converting the edges of a slick to a floating semi-rigid collar
- gelling oil slicks to render them less polluting upon reaching the shore
- cleaning rocks and sea walls by gelling the oil which is then easily removed and transported.

The first three applications have been extremely limited in scope because the use of gelling agents presents a number of practical and economic problems. Future large scale usage seems unlikely unless new agents are developed. However, gelling agents may be encountered in small quantities for cleaning sea walls or rocks. Gels currently available can be reliquefied by heating to about 60(C) and because of their aqueous solubility, the presence of water will prevent regelling during cooling. Any new gelling agent developed should be capable of easy reliquification and the gels themselves should not give rise to disposal or environmental problems.

Only those products endorsed by AMSA through the National Plan for Maritime Environmental Emergencies (NatPlan) should be used.

Final Disposal

All the possible disposal methods should be considered including direct recovery of product, processing of oils to saleable products, use as fuel, incineration (preferably with energy recovery), biological degradation, immobilisation etc. Adoption of a single technique should be avoided, since the best results are often obtained by using several methods in parallel or in series. The prime aim should be to recover oil for re-use, with destructive methods such as incineration being used only as a last resort.

Various methods of oil spill debris disposal have been practiced:

- Land farming - oily wastes are spread on and mixed with soils to promote aerobic microbial degradation
- Landfilling with refuse - oil spill debris is incorporated into an active landfill along with municipal refuse or industrial wastes.
- Burial - oil spill debris is deposited into pits, trenches or other depressions prepared for debris disposal onsite. The excavated soil is used as intermediate and final cover of the debris.
- Bioremediation
- Insitu burning
- Incineration

Each disposal method is best suited for certain circumstances, depending on debris characteristics, climate and disposal site features. Primary considerations include land availability, accessibility of existing suitable landfills, degree of regulatory control over waste disposal practices, and prevailing weather conditions.

The characteristics of oil spill debris can vary significantly depending on the spill location, clean-up method, oil type and other factors. Basic debris parameters important in selecting a compatible disposal method include:

- Size distribution of the solid matter collected during spill clean-up
- Biodegradability of the debris constituents
- Oil content in the debris

Selection of a Land Disposal Site

Ultimately, the majority of oil spill debris will require land disposal, therefore proper site selection is fundamental to an effective oil spill response plan. Proper site selection can be assured only if it occurs through a rational planning process before a spill.

Problems which can arise if oil spill debris is disposed of at an improperly situated site are:

- Environmental pollution
  - oil migration through the soil
  - groundwater contamination
  - surface water runoff of oily material
  - washout of disposal area due to floods
  - long term effects of vegetation

- Operational problems (availability of all-weather access roads, and ease of construction)
- Social, Institutional and legal problems (approvals, adverse public reactions, lack of resources, time to secure suitable sites)

To avoid these problems it is highly desirable for local agencies to predetermine a list of alternative sites that may be used for disposal of oil spill debris in all oil spill clean-up contingency plans.

Minimum information about oil spill debris disposal sites for inclusion in an oil spill clean-up plan is as follows:

- Vicinity map showing all possible disposal sites and major access roads from areas of possible oil spills;
- List of local authorities (and contact numbers) with jurisdiction over solid and liquid waste disposal and water quality protection;
- List of site owners (and contact numbers) and those owners of land over which site access may be required;
- List of hazardous waste transport businesses operating in the area;
- List of heavy equipment rental companies or local government agencies with heavy equipment that may be useful for debris disposal.

Whether the site is selected in advance of its actual need, or during the rush of an emergency effort to find a disposal location, the same basic site location procedures should be followed:

- Identify existing waste disposal sites:
    - Identify vacant land;
    - Use maps, aerial or ground reconnaissance;
    - Confer with large landowners/brokers.

- Determine ownership:
    - For assessment of difficulties to secure;
    - For personal contract negotiations;
    - To determine whether public lands are preferred.

- Gather background information
- Apply environmental criteria
- Evaluate suitability of each prospective site.
- Select one or two sites for contingency use for debris disposal.

Location of Prospective Sites

An initial survey of potential debris disposal sites in the State should be the first step in locating a site or sites. The use of large scale maps showing major roads, schools, residential neighborhoods, water bodies and catchment areas, topography and other significant land uses is essential.

The use of existing municipal and hazardous waste disposal sites should be considered first. Approval to use this land for waste disposal is already secured and the land already dedicated to waste disposal uses.

However, use of an existing site may not be practical for various reasons including:

- The site(s) is (are) too far from the scene of spill cleanup;
- The site(s) may be unacceptable due to poor access roads;
- The site(s) is (are) not approved for receipt of oily waste such as spill debris.

Thus it is usually necessary to include for further evaluation at least two sites that are not presently used for waste disposal.

Major land holders or managers should be contacted to determine where suitable sites might be located. Consultation with local planning officials can aid in the location of prospective sites. Any vacant plot of land near the expected source of oil spills should be considered. When canvassing the landowners, it should be emphasized that this is a preliminary survey to locate several alternative sites from which to select two best suited ones. Depending on the size of the region and the number of individual areas where oil spill debris collection is expected, anywhere from three to six or more prospective sites should be located.

Land Potentially Suitable for an Emergency Oil Spill Debris Disposal Site

- Federal Land
- Crown Land
- National Park land
- Military Owned Land
- State Land/Corporation Land
- Highway projects
- State Reserves
- Waste Disposal Sites (active/inactive)
- DPIF owned agricultural land
- Port Authority owned land
- Coastal Reserves
- Forestry Land

Private Property:

- Oil Company property or leases
- Agricultural land
- Mining Company property
- Industrial waste disposal sites
- Utility Company Property

Site Selection Criteria

The following four criteria should be considered for site selection. Major problems with any one site in regard to these criteria should be reason for its dismissal.

(a) Land Use Compatibility
Any site considered for waste deposition must be compatible with surrounding land uses. Sites in recreational, residential or certain industrial areas may not be suitable due to dust,

odour, and noise generated by a land disposal operation. Burial of waste may alter landforms which may be unacceptable in a park or recreational area with conservation or heritage values. These issues should be weighed against the need to relocate waste quickly after a spill, especially if emergency storage capacity is insufficient. In this case if the site offers good conditions for land application or burial, the noise, odour and/or dust problems may be tolerable in a built up area for the short time frame likely to be involved. Even disposal sites located on prime land should not be discounted as long as environmental and public health standards can be met and proper monitoring procedures can be implemented.

(b) Water Quality
Oil is a potential pollutant. However, measures can be implemented to prevent water pollution occurring through assessing the various physical conditions of a site to determine its potential vulnerability to pollution;

- Soil characteristics
- Subsurface hydrology
- Geologic conditions
- Surface features, such as topography, surface water occurrence and vegetation.

Of course, climatic factors such as precipitation, evaporation, humidity, and wind also influence the suitability of a site for receipt of oil spill debris. Examination of these factors should provide for the rapid elimination of many poorly suited sites from being considered for debris disposal.

(c) Site Location in Relation to Oil Spill Areas
A major criterion is the site location with respect to areas where oil spill debris is expected to be generated and/or stockpiled. Transport of debris from the emergency storage or stockpiling area to the disposal site may represent a significant portion of the overall cleanup costs, possibly more than the debris disposal operations. Disposal sites should therefore be as close to the areas of expected debris generation to minimise costs and amount of oil potentially spilled in transit. Sites likely to be involved in an oil spill should be clearly marked on a map and potential disposal sites identified in relation to the following sites:

- Oil storage areas (e.g. tank farms, lagoons if any)
- Oil transportation facilities or transfer depots (e.g. pipelines, docks, railroad yards, major highways)
- Major oil consumers (docking facilities, electrical generating utilities, major industries)
- Sensitive areas such as beaches, river or lake banks, wetlands, aquaculture areas etc)

(d) Site Access
Existing roads into the site should be of all weather construction. If none exist, access roads should be easily constructed in an emergency situation (e.g. placement of a gravel road or military lending mats).

Access roads serving existing landfill are usually adequate to handle all types of debris transport vehicles expected. Many other potential disposal sites are vacant lands not presently served by improved or even dirt access roads from main roads. A suitable access road into a debris disposal site should meet the following basic conditions:

- Width; approximately 3-6m depending on the volume of spill debris requiring disposal.
- Grade: less than 7%, especially if the debris delivery truck will be going upgrade while loaded;
- Bearing Capacity: sufficient to carry a gross vehicle weight of about
- 32 000kg.

It is usually unnecessary to construct a new road into the site or improve existing ones prior to an oil spill emergency. However, prior access road preparation may be required if extensive work is necessary.

(e) Arrangements with Site Owners
Once an environmentally acceptable site has been selected, it is necessary to negotiate an agreement for its use with the site owner or manager. Several factors should be included in the site use agreement and resolved during negotiations:

- Procedures for site access during emergencies;
- Notification of intention to use site for waste disposal purposes;
- Responsibilities for waste disposal permit fees, etc.
- Responsibilities for site operation, cleanup and maintenance; and
- Responsibilities for post-disposal monitoring.

The use of a site not presently used for waste disposal may also require the development of an operational contingency plan in cooperation with the site owner. This plan should include timeframes for waste disposal, environmental measures to be implemented to prevent environmental harm from occurring and to comply with all environmental legislative requirements, and rehabilitation plans. Site purchase is generally not necessary; instead lease arrangements should be negotiated between the relevant parties.

The use of an existing landfill for oil spill debris disposal should present no problems, especially if the site is approved for receipt of oily materials. It may be necessary to alter permit condition to allow disposal to particular sites to occur. Disposal fees for debris delivered to a landfill during an emergency should also be discussed with site operators and all relevant information included on a Register.

The Chemistry of Oily Wastes: Physical and Chemical Interactions of Oil and Soil

Significant removal of certain oily components can be achieved through volatilisation and long term oil migration. Loss by volatilisation and subsequent movement through the soil matrix is related to the vapour pressures of the oil and soil substances and the partial pressure of oxygen in the soil environment.

Four basis debris characteristics of oil spill debris influence the potential for immediate and long term oil migration from the debris mass:

- Oil content
- Water content
- Chemical content
- Biodegradability of solid debris and/or sorbents

Generally, the higher the oil content in collected debris, the greater the likelihood that oil could escape from the mass at the disposal site at the time of or soon after deposition. Debris containing a relatively low percentage of oil would tend to retain oil on surfaces of vegetation, soil, rock and other debris constituents. High vapour pressure hydrocarbons such as propane will volatilise before any significant degree of outward migration or biological oxidation can occur in soils. However, low vapour pressure hydrocarbons such as heavy fuel oil, residual fuel oils, grease, solid paraffins and high molecular weight asphaltenes may migrate or be biologically oxidised before they are evaporated.

Once the hydrocarbon vapour from a debris disposal site enters the atmosphere as a result of evaporation due to handling, mixing and discing, its exact fate and its rate of reaction depends on its particular characteristics. Ultimately, all evaporated oil in the atmosphere is oxidised. The saturated, straight chain hydrocarbons are relatively unreactive in photochemical reactions and so remain in the air for long periods. Many of the aromatics are very reactive in photochemical reactions involving ozone, NOx gases and ultraviolet light. Reaction products are typical of normal photochemical smog forming reactions.

Biodegradation
Biodegradation is the metabolic utilisation of organic compounds by microorganisms which require oxygen, nutrients, water and specified physicochemcial conditions such as moderate temperature and pH. Microbial populations increase rapidly in the soil or water after an oil spill. Oil spilt on the ground can rapidly disappear completely under optimal conditions often within a year or two as a result of microbial oxidation of the hydrocarbons. Consequently it may be useful to employ the natural soil microflora in the clean-up of oil spills. Several hundred species of yeasts, moulds, bacteria and actinomycetes are now known to possess the capacity to oxidise hydrocarbons.

Since biodegradation is a natural process it has many advantages with few ecological side effects:

- it is relatively inexpensive with low energy requirements
- it can be carried out without elaborate equipment
- it is applicable to oily debris, sand, animal and plant remains etc.

Disadvantages include:

- the rate of oxidation is temperature-dependent
- the presence of toxic compounds, exhaustion of dissolved oxygen or lack of nutrients can inhibit microbial action which requires mild conditions
- large land areas are necessary (unless space for prolonged storage is available)
- no energy is recovered from the oil (except for a small increase in the soil humus content).

The British Marine Pollution Control Unit (MPCU) produced guidelines in 1995 on the use of stimulating bioremediation through the addition of additives in response to an oil spill (MPCU 1995). The decision to use bioremediation should be based upon the following considerations:

The residence time of the oil in the absence of further treatment. Shorelines subject to significant wave and tidal energy are in appropriate (Little et al., 1993)

The biodegradability of the oil. Oils with a high asphaltene and resin content degrade slowly due to molecular recalcitrance of the hydrocarbons (ie the process is not generally nutrient-limited) while oils with a high aliphatic and aromatic content is a much more nutrient-dependent process.

The natural nutrient content of the shoreline. To achieve maximum biodegradation, sediment pore water should exhibit concentrations of 1.5 mg nitrate/litre (Venosa et al., 1995), Phosphorous concentrations of approximately one-tenth of the nitrate levels (Swannell et al., 1996), with oxygen levels above 2 mg/litre.

The shoreline type (ie bioremediation has been shown to be effective on sands and cobble shorelines with evidence of enhanced oil degradation being noted on shale/fine gravel shorelines (Swannell et al., 1994).

The degree of oil penetration. Oil lying on the surface of the beach is unlikely to be successfully treated through bioremediation (Lunel et al., 1995).

Liquid Phase Biodegradation

The rate of oxidation of oil by microorganisms is dependent on the availability of oxygen and nutrients (especially nitrogen, potassium and phosphate), temperature, pH value and the degree of dispersal of oil in the water phase. Microorganisms live in the aqueous phase and attack the surface of the oil, so that the larger the surface area, the more rapidly the oil will be decomposed. As microbial species are selective in their attack on hydrocarbons, the complete oxidation of the complex mixture in petroleum would undoubtedly require mixed cultures. Inoculation of oil/water mixtures by mixed enrichment cultures have been proposed in literature. Such cultures may be sprayed onto the surface of contained slicks to which ammonium sulphate has been added as a mineral supplement (Kator 1971). Most microbial studies have been carried out at temperatures between 10 and 30(C) using mesophilic organisms however, significant oxidation by psychrophilic organisms may occur under cold conditions (-1 and 5(C)) (Robertson et al 1973, Zobell 1973, Atlas 1974)

Since biodegradation at sea is rate-limited by the paucity of nutrients and water soluble sources of N, K and P would be ineffective in the ocean, oleophilic fertilisers may be used to stimulate biodegradation of spilt oil in purpose built shallow ponds dug in the vicinity of the spill. Oily waste may be tipped into the ponds and sufficient water added to fluidise the mass. Aeration by mobile compressors should supply sufficient oxygen to the bacteria and will achieve adequate mixing.

Land Farming of Oil and Oily Debris

Contaminated sands and soils may be spread directly onto suitably designated land. The aerobic nature of landfarming techniques have been shown to be more efficient in degrading oils than the anaerobic conditions encountered within a landfill.

Degradation of oil by land farming is best suited to warm climates with moderate precipitation and evaporation. The degradation process may stop when temperatures fall below freezing. Sufficient moisture is required in the oil/soil mixture to support microbial activity at a land farming site. Except in very dry areas, adequate moisture is usually naturally available.

Site Selection

Oil-farming requires adequate inexpensive land within reasonable transport distance to be economically feasible. The most severe difficulty encountered in disposal problems is often the acquisition of an acceptable site, hence preplanning is essential. In selecting a site for oil-spill debris disposal, the area should be located where waterbodies and other supplies of potable water are not at risk from the possible release of contaminants. Soil permeability should be low to avoid percolation of leachates into the ground water.

Land farming should be restricted to land where the slope does not exceed 6%. Wherever a land farming site is situated on slopes of greater than 4%, a runoff catch channel or basin should be installed downstream especially in an area where heavy rainfall and high soil erosion potential are likely. Valleys and gullies may not be acceptable.

Oily material is a definite threat to water quality, however effective land farming degrades oil into carbon dioxide gas, water and cell matter within several years or less.

Land Area Required

Area requirement for land farming of oil spill debris depends on many factors, including:

- Depth of spreading
- Local climate
- Concentration of oil in the debris
- Type of debris
- Oil characteristics
- Volume of oil
- Equipment used

An estimate of the land needed for debris disposal by this method can be calculated by allowing 0.43-0.70 m2 (average 0.565m2) per litre of oil spilt, where mixing depth is 10 cm and a moderate climate prevails. Land area requirements will increase with increasing oil concentrations and volumes, and will decrease with greater mixing depths and a warmer, more humid climate.

Site Preparation

A site to be used for land cultivation requires some preparation prior to receipt of the first load of debris.

(i) Access Road Construction
An access road from the main road servicing the area should be constructed to one end of the landfarm area. Land farming equipment and debris transport vehicles will use this road so it should be of a suitable width, grade and surface (eg gravel may be needed in wet weather). The site may be divided into sections by roads, to provide access for heavy trucks. Access into muddy areas may be temporarily facilitated by placement of a gravel road or military landing mats. Heavily trafficked areas may require surface reinforcement.

(ii) Grading and Removal of Rocks and Vegetation
Land farming is best suited for debris comprised of small particles such as oiled soils, and should not be attempted for waste comprised of particles larger then 15cm to avoid handling difficulties and problematic mixing of the waste. Therefore, all boulders, logs, rocks, and other hard materials larger than approximately 15 cm in diameter and any dense brush should be removed from the intended land farming area. Vegetation such as seaweed, brush, or leaves that can be readily broken up and mixed with the soil can also be included in debris intended for land farming. Debris with some large, bulky items can be land farmed if the bulky items are pre-segregated and either cleaned or disposed of to an approved landfill or burial site. Grasses and low shrubs need not be removed unless so prolific as to inhibit access.

The site should be graded to a uniform 1-2% slope.

(iii) Scarifying the Soil
The surface soil should be scarified using conventional farm implements such as tillers, harrows, disc or ploughs. Depth of scarification depends on local climate conditions. For normal climates, a shallow depth of 5-10cm is preferred while for warmer climates a depth of 20-35cm is recommended.

(iv) Surface Drainage Diversion
Runoff diversion channels should be dug during site preparation. Depending on site conditions and the volume of runoff expected, half round corrugated metal pipe may be preferable to unlined earthen channels. Diversion drains should lead to a collection basin to contain any liquid runoff and siltation.

Bunds should also be constructed as an additional measure to prevent water or oil flowing from the disposal areas.

(v) Additives
Most agricultural soils contain sufficient amounts of nutrients and moisture to support the growth of hydrocarbon-consuming microorganisms naturally present in the soil. However the nutrient status is generally poorer in the soil at a routinely or heavily used oily waste disposal site compared to agricultural soil due to continued additions of oily wastes into the soil. These wastes and hence the soils have high carbon:nitrogen (C:N) ratios due to a very low nitrogen content. Furthermore, most soils are low in available phosphorous. Additions of nitrogen (as ammonium nitrate) and soluble phosphorous (eg superphosphate) are necessary for the degradation of oily wastes at optimum rates. Since the optimum pH for the activity of a large number of soil microorganisms, including hydrocarbon-consuming bacteria, is approximately 6.8 to 7.2, maintaining the pH in this range is advisable. Bacterial seeding organisms are commerically available to accelerate oil degradation.

To determine the levels of available nitrogen, phosphorous and other pertinent parameters in soil, representative surface samples (0-30 cm deep) should be taken from the disposal sites. Soil pH, nitrate-nitrogen or ammonium-nitrogen, total nitrogen, total organic carbon, and soluble phosphorous are determined by standard soil analytical methods. The nutrient status of the soil is then evaluated to construct a proper fertilisation program. Generally, application of 56-90 kg/ha/yr each of nitrogen and phosphorus should be sufficient to maintain favourable soil conditions for biodegradation of hydrocarbons.

If the soil is strongly acidic, the first step is to apply lime to neutralise pH. Nitrogen and phosphorous fertilisers should be applied when the soil is relatively dry so they can be evenly incorporated into the soil, The disposal area should be kept aerobic by constant discing to increase microbial activity and to avoid denitrification and increased mobilisation of some heavy metals (eg manganese and iron).

(vi) When to Prepare the Site
Site preparation can usually be performed once it has been decided to land farm the waste. However if road access or other aspects of site preparation are expected to require more than one day, the contingency site should be readied prior to its actual need.

Implementing land farming of oil spill debris

There are five basic steps in implementing land farming of oil spill debris:

- Receipt of debris
- Spreading and mixing with soil
- Clean-up of Site
- Periodic recultivation
- Return of land to original use.

Receipt of Debris and Stockpiling

Debris delivered to the land farming site may be either deposited directly on the area or stockpiled nearby for later spreading. Direct deposit is preferable to eliminate double handling, but onsite stockpiling may be required if available equipment cannot properly farm all the debris as it is received, or if insufficient land area is available to enable spreading all debris in one batch.

The debris stockpile should be located near the spreading area, readily accessible to the landspreading equipment. If the amount of debris is small, it may be left in covered skip bins, garbage cans, 200 litre drums or bags. If the amount is large, it should be placed on an impermeable liner, surrounded by an earthen bund and covered (to minimise runoff from rain). If the debris is very wet and the site soil is porous, it may be advisable to line the stockpile area with clay or other fine grained soils or membrane liner to contain or minimise the potential for leachate generation. Liners may not be well suited for a stockpile area that is intended to be reused. Equipment operating in the stockpile area may inadvertently remove or puncture the liner with the debris.

Polymeric membrane liners appear to have the greatest potential for containing oily wastes, yet even these materials do not have extensive useful lives in the presence of hydrocarbons. Polychloroprene (neoprene) liners appear to offer the longest life (in excess of 1 year) while chlorosulfonated and polyethylene are useful for a maximum of approximately one month, after which they begin to lose integrity and leak. Most liners degrade by swelling or hardening or will dissolve in the presence of many types of hydrocarbons. Asphalts, butyl rubbers and ethylene propylene rubber are particularly subject to degradation and should not be considered for use at oil spill debris stockpiling areas.

Use of membrane liners generally requires subgrading and removal of angular objects that might puncture the liner material. If the debris itself contains sharp objects such as branches, a soil cover over the liner is required. Methods of installing the various liner materials differ depending on the type of liner and local conditions. Liners are generally shipped in large rolls and are placed into position in the field. Joints can be sealed by suitable adhesives or in some cases by heat treatment at the site. Manufacturers' specifications usually require certain liner sections overlapping, installation temperature and other procedures are to be observed.

Application

The oily debris should be evenly spread over the scarified land surface in a layer 2-10cm thick. If the debris contains materials up to about 15cm, the spreading will be uneven but subsequent mixing should help disperse the oil.

Large oily lumps and all bulky items greater than 15cm in size must be removed to ensure proper spreading and mixing. Disposal by land farming is impractical if bulky items cannot be readily removed from the debris.

Where possible, the layer should be allowed to weather (several days to several weeks) until it no longer appears wet and sticky. This may take several weeks in warm weather and much longer in cold weather. In addition, mixing the debris into the soil should not begin immediately after a rain, since equipment may become bogged down. It is preferable to wait until the soil has become reasonably dry. Immediate ploughing is recommended in areas frequented by birds in order to prevent them becoming contaminated with oil.

While the debris is weathering, an inspection should be made of all bunds around the site to ensure that they properly contain any surface runoff from the site and to divert off site runoff.

Spreading and Mixing with Soil

The debris should then be thoroughly mixed into the soil with a harrow, plough or rototiller or other locally available equipment. Thorough mixing of oil spill debris with the site soils is necessary to expose all oil to microbial action and available oxygen. There is no one correct procedure to spread and mix oily waste to promote degradation; procedures will depend on local soil, debris and weather conditions, and equipment capabilities.

Mixing should be repeated at increasing intervals (monthly at first, to seasonally after two years) to increase aeration and therefore the rate of decomposition. The depth of mixing will depend on local conditions. Depths of 5-10cm in colder climates and 20-35cm in warmer climates should be adequate. Debris may be mixed to deeper depths in granular soils, shallower depths in silty or clay-based soils.

Equipment used for pulling mixing devices can be track or wheel dozers or loaders, farm tractors, or any other type or suitable heavy equipment.

Tilling the soil and debris mixing should proceed systematically based on practices used in normal agricultural soil preparation.

Sufficient mixing is achieved when the oil is dispersed in the soil so it is not longer visually recognisable as oil. No ponded liquid (water or oil) should be apparent. The number of repetitive passes required to achieve this condition depends on the debris and soil characteristics. Usually at least two passes will be necessary. Sometimes more than five passes will required. If necessary, the soil pH should be adjusted to a value higher than 6.5 with lime to provide a suitable environment for microbial growth. Fertilisers such as urea, ammonium phosphate etc may be added to enhance oil degradation rates (as a rule, 10 parts of Nitrogen and 1 part Phosphorous should be added per 100 parts of oil). The practical limits to oil addition generally occur when the amount added results in the soil becoming so soft that heavy equipment cannot be used. In the case of debris with a low oil content, frequent application and cultivation can increase the amount that may be disposed of on a given site, allowing the ground to dry as much as possible between successive applications.

Site Clean-up

After land farming all oil spill debris, all evidence of activities should be removed, including bulky debris and cleared brush. Access roads should be left in place to enable subsequent mixing if necessary.

Subsequent Mixing Needs

It will be necessary to periodically remix the soil and debris to aerate the material and expose more oil to microbial action. In general, when the surface of the land farming site appears grey, the material should be mixed again.

Remixing can be performed at varying intervals. Weekly tilling can be beneficial in the first month after initial land cultivation where once each six months may be adequate in the second year. In some cases, oil refinery waste land cultivation sites are ploughed only once every two to four months year round until all oil is degraded.

Remixing is usually conducted for a period of six months to several years. The period depends on the degree of degradation and varies significantly with climate, season, oil type and soil characteristic. The degree of oil degradation can be estimated by visual inspection. If no oil is visible after remixing, the process need not be continued.

Equipment and Personnel

Requirements for equipment units and personnel depends on the volume of debris to be disposed of, the area and location of the site, and the need for other duties such as traffic control and unloading direction.

Liquid wastes may be applied from vacuum trucks. Heavy solids should be collected in tipper trucks which distribute the wastes directly over the site bulldozers used to spread them to a uniform thickness. Various kinds of light and heavy equipment are also needed for the periodic cultivation of the soil; these may be small rototillers or large tractor drawn equipment, depending primarily on the scale of the operation and the condition of the plot. To minimise total costs, locally available equipment should be utilised where possible.

At least one equipment operator is necessary for each piece of heavy equipment used. Other personnel may be useful to spot debris delivery trucks and to direct traffic. At least two personnel should be present at all times at the site. The site should also be provided with potable water supplies and sanitation units. Fencing may need to be and appropriate signage displayed to secure the site.

Revegetation and Future Amenity of the Site

A plot for oil spill debris land farming can be kept available for contingency disposal use in the future, or it can be returned to the owner for other uses. In either case, grasses should be established to minimise erosion and improve site aesthetics. Salt tolerant species may need to be chosen depending on the effect of salt in the waste on re-vegetation options.

Native grasses or other vegetation may naturally re-establish if nutrients have been applied to the area to promote biodegradation. Introduced vegetation such as crested wheat and rye grass have been successfully grown from seed on cultivated sites. However, sown grass may not germinate during the first growing season.

While agricultural crops will grow on a cultivated site, the health effects of human or animal consumption of such products are not well defined. The effects will depend on many factors including crop type and oil characteristics. It is safest not to plant the area with crops intended for human or animal consumption, especially if the oil spill debris contained any heavy metals.

A land farming site is generally suitable as a foundation for building construction. However, if significant quantities of vegetative or organic matter other than oil was spread with the debris, more time is usually necessary for degradation of all organic debris components.

Environmental Aspects

In the case of farming collected oil after an oil spill, which is likely to be a once off event, certain environmental aspects may be reviewed. Heavy metal accumulation will not occur nor ground water pollution in a well managed site, and land may therefore be returned to its normal use after biodegradation is complete. As a precautionary approach, subsequent use of the land should be for non-food plants only (timber reserves, fibre crops, recreational grassland etc). Periodic soil sampling may be performed for TPH, nutrients (N,K,P) and pH. Nutrient content should be maintained if the maximum degradation rate is desired and soil pH should not be allowed to drop below 6.5. (CONCAWE Sludge Farming Report no. 3/80).

The basic intent of land farming is to promote microbial degradation of the carbonaceous matter. Thus landfarming should not be practiced if noticeable amounts of inorganic (heavy metals) or nondegradable items such as plastics are present in the debris, unless the land farming is to be conducted at an existing landfill or the items are easily segregated from the mass.

Composting

Composting is the biological conversion of organic waste solids into stable, humic materials which contribute to the soil structure as well as its nutritional status, and hence enhances its suitability for the cultivation of useful plants. Such an operation may also be amenable to producing saleable materials, depending on the success of the composting operation and the identification of end markets.

Natural Sorbents

Natural sorbent (straw, peat, wood shavings etc) are often used to mop up small quantities of oil on or near the shore. Although these materials may have lower oil-absorbing capacities than some of the synthetic sorbents, it has been claimed that they offer a compensating advantage. This is the rapid breakdown of the sorbent and absorbed oil to dry, fine, compost like material within months. Used sorbent are therefore useful as co-disposal agent in compost heaps and in municipal tips.

Landfilling

Landfilling remains the most common method of disposing of solid marine oily waste. If an existing landfill is used, few special arrangements need be made for disposal if the site has been properly prepared and operated. Oil spill debris should be mixed with the ordinary refuse which can act as an absorptive agent. The combined debris is then compacted at the site usually without special preparation of the subsoil or significant interruption of normal daily operations

To respond quickly to a spill, it is essential to have an up-to-date schedule of available sites and an in-principle agreement with the site operator as previously discussed. Finding sites to accept oily wastes in the quantities likely to arise from a beach clean-up may be difficult as the site permit or licence specifies what wastes may be deposited there and in what quantities.

Having identified a site that is acceptably close to the spill area, it is then important to ascertain whether the operator would be prepared to accept waste at short notice, what the likely costs would be, whether any restrictions exist on daily quantities at the site and the anticipated remaining life of the site. Disposal costs for large quantities of waste are likely to be considerable.

The provision of a fully-engineered containment site, dedicated to the monodisposal of oily waste, ready for almost immediate use is not considered to be a viable option. Such sites need to be lined with synthetic membranes that are protected from excessive exposure to sunlight and mechanical damage caused by vermin, birds and humans. The high capital costs and long term management problems associated with such a site would be excessive and would be subject to the restrictions associated with site selection procedures and approvals process.

If oily material is incorporated into a domestic waste tip (at up to 1-2% of total landfill tonnage received) it will degrade fairly rapidly. The bacterial activity in the tip is exothermic and it must be remembered that as the temperature of the tip rises, so the viscosity of the oil will fall and percolation rates increase. Domestic refuse tips therefore have a limited capacity to decompose oils. Overloading the tips will cause undecomposed oil to appear in the leachate or groundwater. This may be mitigated by mixing the recovered oil with uncrushed or compressed municipal waste garbage in a shallow pit sealed by a clay layer and covered with soil. After some months the mixture is transformed into an inert cake-like residue. Biological degradation is usually slow in cool weather but more rapid in warm weather. The addition of organic material or waste will usually cause the oily waste to degrade at a faster rate. The capacity of local authorities to deal with recovered oil will be largely limited by the standard of the landfills. In most cases the quantities generated during a spill will necessitate intermediate storage rather than immediate disposal.

Land Area Requirements

Most major landfills generally have sufficient area and volume capacity to accept the volume of oil spill debris generated from even a large spill. A landfill's size could be considered adequate if it has capacity for the debris and at least 5 more years of wastes normally received. A problem might arise if the landfill site preselected as the debris disposal contingency area is nearing completion, and may not have sufficient cover soil or remaining capacity to accept the debris. Landfill sites with adequate remaining life should therefore be selected to avoid this problem. In the case of large oil spills, several landfills may be needed to accommodate the debris.

Site Preparation

(i) Subsoil Preparation
No subsoil preparation is usually required for this form of disposal, unless normal landfill practices at the site involve special precautions. It may be desirable to line the section of the landfill intended for debris disposal with clay based material if the natural soils are relatively permeable. Any landfill disposal requires prior Council approval.

(ii) Traffic Control and Debris Unloading
The projected increase of vehicular traffic at the landfill may require some adjustments in personnel allocations and vehicle routing. A systematic plan for unloading of oil spill debris should be formulated in advance in order to eliminate confusion.

It may be desirable to unload very wet oil spill debris at different sections of the site to ensure that any single area does not become oversaturated with water or oil.

Arrival of the debris at the landfill will likely coincide with the arrival of regular refuse disposal vehicles. Thus mixing of the refuse and debris can be conveniently accomplished and a minimum of mechanical mixing will be required.

(iii) When to Prepare the Site
Burial with refuse at an existing active disposal site does not generally require special land preparation prior to the actual receipt of the oil spill debris. All arrangements with the landfill authorities should be planned at the time of site selection. It is, of course, desirable that a specific landfill be selected before the need for oil spill debris disposal arises. Therefore, operators of the contingency landfill should be notified as soon after an oil spill as possible and advised of the expected quantity of debris and of the anticipated time of debris delivery. This early warning should enable the operator to adjust his daily operations and to arrange for any additional personnel that may be required.

Disposal Procedures

Disposal of oil spill debris at an existing landfill will require few special adjustments. The operator should follow the regulatory authority's approved or other accepted guidelines for landfill disposal operations. Oily wastes should be mixed with other refuse.

As with standard landfill practices, the oily debris/refuse mass will require proper covering at the end of each day. Ideally, the soil cover should have a high clay content to provide a relatively impermeable cap above the oily debris/refuse mixture. However, most available soil is sufficient as long as covered surfaces are graded to enhance runoff, minimise erosion and prevent ponding. Cover thickness should be at least 15cm. The amount of cover soil used should constitute roughly 20% of the total volume or refuse within the fill.

By landfilling, the debris is sequestered under cover, greatly reducing or eliminating the possibility for aerobic microbial decomposition of oil. For this reason, landfilling necessitates longer term monitoring, but less site preparation (and none of the subsequent mixing) as compared to the land farming disposal method.

Equipment Needs

Equipment normally employed at the landfill should also be sufficient for disposal of the oil spill debris. For large spills, arrangements should be made with landfill operators in advance to obtain additional equipment and personnel needed for any increase in volume associated with a large spill.

Track dozers, wheel dozers, compacters and other equipment normally used at a landfill will be adequate for mixing the refuse and spill debris.

Site Clean-up

Normal management procedures for the landfill should be followed. The refuse and oil spill debris should be covered, and all evidence of oily waste disposal activity should be removed. The landfill will most likely continue to receive refuse, therefore no special site clean-up activities should be required. However, equipment used for mixing and spreading the oil spill debris may require steam or manual cleaning to remove any build up of oil or debris.

When all, or sections of the landfill are decommissioned, care should be taken to ensure that the surface is properly graded and that planting to prevent cover soil erosion is completed promptly. As with land farming, no vegetation intended for human consumption should be planted. Rehabilitation of the site should be in accordance with the Site Rehabilitation Plan or requirements of the State authorities.

Environmental Aspects

The choice of landfill site must be agreed with the regulatory authorities. The landfilling of wastes treated with binding agents, or untreated solids with less than approximately 3% oil, must be carried out in a suitable manner. Test bores around the site should be analysed at intervals to establish whether hydrocarbon desorption is occurring.

Potential Problems

(i) Ignition of Oily Debris/Refuse
Although the probability of refuse/oil ignition is low, the potential does exist. If the oily debris has been stockpiled or stored for any length of time, dispersion of the volatile constituents will lessen the chance of ignition. Precaution should be taken against operating any equipment without proper spark arresters or exhaust systems in the oily debris/refuse disposal area.

Spontaneous combustion of buried oily waste has not been reported. Landfills are usually anaerobic and thus would not present enough oxygen to support combustion.

Use as Fuel

Fuel quality specifications are generally stringent and may be restricted by:

- safety (light hydrocarbons may be present)
- corrosion (high chloride content)
- undesirable suspended solids present

The high water content greatly reduces the calorific value to a point where combustion cannot be supported without auxiliary fuel (often in significant amounts). Similarly, pasty or solid wastes with comparable calorific values will have similar requirements and disposal costs. The use of demulsifiers may obviate the need for auxiliary fuel to burn mousse, reducing the treatment cost to a very low level.

High temperature incineration followed by gas scrubbing can be used to convert oily sludges into inert solid residues and environmentally acceptable gases. Several types of incinerators are commercially available including:

- fluidised bed
- rotary kiln with after burners
- vortex
- multiple hearth

The choice of incinerator type depends on the material to be processed (fluidised bed type is suitable for 50% hydrocarbon + 40% H2O + 10% solids, while a rotary kiln would deal with low oil content material with 70-80% solids).

Mobile incinerators and special purpose built units may be built near storage areas. Treatment costs may be high but transport costs are much reduced.

Generally, costly pre-treatment is required including dewatering, removal of debris and suspended solids.

Burial

Burial of oil spill debris without refuse usually requires excavation or utilisation of an existing pit or trench for disposal. In some cases, however, the oil spill debris can be contained within a bund mounded above ground and covered with soil, with little or no excavation involved. Burial above ground may be preferable since any lateral leakage can be readily observed without subsurface exploration. Alternate layering of oil spill debris and soil is usually employed in any burial disposal operation. Generally this option should only be considered where the waste is well aerated and only lightly contaminated, the costs of transport and deposition are cost prohibitive, a suitable landfill cannot be found, and the proposed location of onsite burial is considered appropriate (i.e. not subject to public access or amenity, or with recognised conservation or heritage values).

The possibility of disposal of oily beach material close to the site of origin (generally in sandy dune areas beyond the tidal influence in low amenity areas) has many advantages in time, cost and convenience (Daniels et al., 1995). The main problems with this approach have long been considered to be associated with the possible toxicity of oils, long-term presence of oil, leaching to groundwater and disruption to existing plant and animal communities. Research has shown that microbial decomposition of hydrocarbons in oily beach material begins very quickly after deposition in dune systems and that it leads to almost the complete breakdown of at least crude oil. Problems associated with establishing deposits and development of appropriate plant and animal communities on them may be more pressing than any risks associated with actual or perceived toxic effects of the oil residues. Sand dunes are susceptible to erosion if the binding cover of vegetation is removed. Natural recolonisation of vegetation does occur, however, minimal disturbance to vegetation during the deposition of the oily material and to vegetation development following completion of operations are important in order to maintain or promote stability in sand dune areas.

Burial may involve more site preparation and longer term monitoring but eliminates the subsequent mixing required of the land farming disposal method. The risk of groundwater contamination must be avoided by the use of impermeable layers or minimised by the use of binding agents. Costs of burial, transportation and construction of access roads as necessary must be considered.

Land Requirements

Land requirements for landfilling without refuse will depend upon:

- The volume of debris generated by the oil spill;
- The depth and lateral extent to which the site can be excavated; and
- The particular burial method selected.

Land characteristics at some sites allow excavation equal to the volume of oil spill debris. At other sites, debris may be deposited level with the existing relief and covered. In such cases, land requirements will be determined not only by available land area, but by the height to which the debris can be mounded above grade. For example, local planning agency requirements may limit final grades at the site to a certain elevation to conform with adjacent land uses.

Preparation of Site for Burial

(i) Access Road and Drainage Control
Expected truck types, traffic volumes, and routing of on-site vehicles should be considered in the design of access roads. Ramps and/or soil and oil spill debris stockpiling areas should be located near the disposal area to avoid the need for extensive road development.

Drainage control should be a major feature of site preparation planning. Drainage patterns at the site and adjacent areas should be assessed to minimise the surface runoff into the fill area. Natural drainage channels emptying onto the planned disposal area should be diverted so that the potential for runoff to infiltrate the fill is minimised. Drainage channels can be earth ditches, if low flows are expected. Lining with asphalt may be necessary to handle higher flows. Half round corrugated metal pipe may also be used for drainage channels.

(ii) Trench Excavation
Burial of oil spill debris may require the use of excavated trenches. The trenches should not intersect groundwater or a permeable subsoil. Any runoff from off site should be readily controllable. The disposal area should be easily accessible by vehicles delivering debris. Designing the trenches in this manner will contribute to the ease of disposal and guarantee minimal environmental hazards.

(iii) Subsoil Preparation
Burial of oil spill debris at suitable sites will generally not require special subsoil preparation. However, it may be desirable to prepare the subsoil at a site where soils would not otherwise be acceptable for debris disposal. Preparation of an above-grade burial site might include lining the bottom and sides with a fine grained soil imported from off site. This material would act to retard or eliminate outward migration of oil from the debris.

The need for a liner at a burial site, if any, will be determined not only by the nature of the spill debris, but also by geohydrological conditions at the disposal site. When evaluating suitable liner materials, the selective placement of indigenous and nearby fine grained soils should be considered before synthetic membrane materials.

Receipt of Debris from Delivery Vehicles

Transfer of oil spill debris from delivery vehicles to the disposal area may require special handling. Ideally, the vehicles will deposit the material directly into the trenches or bunded area. Prevailing site characteristics, however, may require that the debris be mechanically removed from the vehicles and carried to the desired disposal location. The volume and arrival rate of delivery vehicles may require systematic traffic control so that stockpiled debris is stored near the actual disposal area. This way, subsequent movement, if any, will be minimal.

Spreading and Layering Debris

It is usually best to spread and then layer the debris into the disposal trench or area. The total depth to which debris is spread will depend on the method of burial and on local topographic limitations. Each debris layer should be compacted then covered with an intermediate layer of soil. This process improves the overall compaction and prevents equipment from becoming bogged down in the debris.

The depth of each intermediate soil layer depends on the size of debris constituents. For beach sand and seaweed, without bulky items, one to two feet of debris should be adequate. Debris containing bulky brush or flotsam may necessitate use of deeper intermediate layers. An intermediate layer of soil may not be necessary if the equipment can operate satisfactorily on the uncovered debris. Procedures should plan for wet weather in advance.

Equipment Needs

Heavy equipment will be required to prepare the burial disposal site and to receive, deposit, and cover the delivered debris. The types of equipment needed will depend upon the extent of excavation necessary and the distinctive geological and topographic features of the disposal site. If extensive excavation is necessary, equipment that can be handle the types of soil or rock at the site will be needed. Useful equipment may include track dozers (equipped with one or two toothed rippers), backhoes, self propelled scrapers or bucket cranes. Track or wheel dozers or loaders would usually be adequate for placing the debris in the disposal trench or area. The same equipment can be used to apply intermediate and final cover and to grade the filled site surface.

Disposal operations involving above-grade mounding may require different equipment. Track dozers equipped with a bucket or grader would be appropriate for constructing any containment bunds that may required.

Personnel

The number and tasks of personnel will vary according to the quantity of spill debris, its rate of delivery to the site and the disposal burial method chosen. In general, certain duties will need to be performed either by an individual or by a team assigned to a specific task. Necessary personnel categories and their tasks include:

Site Coordinator to oversee all on-site activities including metering of debris, implementing proper disposal techniques and coordinating traffic.

Unloading personnel to assist in unloading debris from delivery trucks either manually or using equipment.

Heavy equipment operator to move debris from the unloading area, place it in the disposal area, cover it with soil and grade the site surface after site completion.

Site Clean-up

Clean-up procedures for oil spill debris burial sites are similar to those used for land farming activities. All signs of disposal activities should be removed from the surface and surrounding areas. Any areas used for stockpiling should also be returned to their pre-disposal appearances.

Final Cover Soil and Revegetation of the Site

The final cover over the completed burial area may consist of soil excavated from the trenches, other onsite soils, or materials imported from off site. Low permeability soils are necessary to impede infiltration of precipitation. The cover soil should be compacted and graded to a 3-4% slope to further ensure minimum infiltration. Slopes greater than about 4% may tend to erode. A final cover depth of 2-4ft is recommended.

Grasses should be planted over the burial site surface to inhibit erosion and improve site aesthetics. Grasses selected for cover plantation should:

- germinate rapidly
- constitute a perennial strain; and
- provide thick growth.

All vegetation should be protected until fully grown. Edible crops should not be planted.

Burial of oil spill debris without refuse has the potential for problems such as ground and surface water contamination, slumping of fill or failure of cover grasses to germinate. This may be addressed by measures as shown in Table 11.

Environmental Monitoring

Potential Environmental Problems

An oil spill debris disposal site may present ongoing environmental problems. Degradation may require hundreds of years or more for sites where oil is buried, or only several years at aerobic land farming sites. Migration of oil spill debris constituents can occur after the completion of disposal activities due to natural causes or man-induced alterations to the disposal site and its environs.

Both short- and long-term pollution problems must be defined in order that a comprehensive monitoring program maybe formulated. Early recognition of potential problems and possible solutions will increase the effectiveness of a monitoring program.

Possible environmental problems may include:

- surface runoff of oily materials
- surface settlement and ponding of surface water
- contamination of groundwater with constituents of the debris via:\
  - infiltration of groundwater into the debris
  - leaching of debris constituents form the debris to groundwater
- retarded oil degradation (at land farming sites)

Surface Runoff of Oily Materials

Surface runoff may occur at land farming sites where debris is near to or exposed to the surface of the soil to enhance aeration. Runoff may enter a debris burial or landfill area and exit as a surface leachate downgrade subsequently contaminating surface waters.

Surface Settlement and Ponding of Surface Waters

Differential settlement of buried wastes at a landfill or burial site may adversely alter surface drainage patterns or result in rupture of the cover soil. Operation of heavy equipment or other activities on the surface could create local depressions at any type or debris disposal site, thus impeding the runoff of surface waters.

Contamination of Groundwater

Leaching of water containing oil and/or contaminants into ground waters is a potential problem at most disposal sites. Surface waters can infiltrate the debris mass and leach out the soluble constituents. Further migration of leachate through subsoils will remove some but not all contaminants. Any remaining materials will be added to whatever groundwater basin the leachate ultimately intersects.

A less probable potential hazard exists if subsurface waters infiltrate into sanitary landfill and buried debris. Fluctuations in groundwater levels causing leaching of the debris may occur due to natural or man-caused events during the 100 year plus oil degradation period estimated for burial and landfill disposal techniques. Groundwater basin characteristics could also change during this period, resulting in horizontal leaching of groundwater into the oil spill debris.

Retarded Oil Degradation (at Land Farming Sites)

Observation of the oil and soil mixture at a land farming site may indicate that degradation is preceding at a rate slower than originally anticipated. This delay may in turn affect scheduled reclamation plans for the site.

Contaminated Vegetation

Vegetation growing at a disposal site where oily debris is not yet fully degraded could be inadvertently or purposely consumed by animals or humans. Because available information on the safety of such vegetation is not widely available, the safest course is to recommend that no animal or human food crops should be grown on waste disposal sites. If this recommendation is followed, monitoring of this vegetation is unnecessary.

Depending on the particular arrangements developed during negotiations for the use of a disposal site, it may be the responsibility of the agency coordinating oil spill clean-up operations, the landowner, another agency, or a combination of these to monitoring for ongoing environmental effects.

Development of a Monitoring Program

The form and extent of the environmental monitoring to be implemented at a particular oil spill debris disposal site depends on the type of disposal operation and site geohydrological conditions. Requirements of local regulatory agencies with jurisdictions covering water quality, environmental protection, and solid waste management should be met. Routine monitoring of the groundwater and surface waters, and oil/soil mixture (for land farming sites) should occur. Depths and numbers of each type of sample to be taken will be site specific depending on local regulatory requirements and geohydrological conditions. Frequency of sampling also depends on local conditions. It is usually advisable to sample a new disposal site several times each year during the first two or three years after completion of disposal activities, since any liner leakage or oil migration would not be immediately detectable. A land farming operation will require a short monitoring program on the order of several years due to the relatively rapid degradation of hydrocarbons. Much longer time periods may be necessary to monitor landfill and burial sites where oil degradation will occur at far slower rates.

Laboratory Analyses to be Performed

The main purpose of a monitoring program is to examine to what extent contaminants are leaving the site. Water and soil samples should therefore be analysed for the contaminants known to be present in the original spill debris. The concentration of any known intermediate decomposition by-product should also be determined.

Recommended parameters for water and soil samples include:

- pH
- Organic Acids
- Oil content
- Organic nitrogen
- Phosphate
- Lead
- Iron

- Chlorides
- Biological activity (plate Count)
- Total extractable hydrocarbons
- Oil fractions, % by weight paraffins, aromatics and polar hydrocarbons.
- Benzene, Toluene, Xylene, Ethyl Benzene (BTEX)

Soil samples should also have:

- Moisture content
- Permeability
- Grain size distribution

It is recommended that pH, oil content, and organic acids should be analysed as part of a routine monitoring program. The solubilities of most elements, particularly trace metals, are known to be greatly influenced by pH. Low pH (strongly acidic conditions) increase the solubility and availability of toxic heavy metals (eg Cd, Cr, Ni, Zn) thereby facilitating their movement in the soil and aquatic environments. Hydrocarbon consuming bacteria, on the other hand, are favoured by a neutral pH.

Data on oil content indicates the biodegradation rate of the material. Accumulations of organic acids suggests incomplete decomposition of the hydrocarbons and an anaerobic environment. When present in high concentrations, organic acids are harmful to plants and fish.

Correcting Environmental Problems

Monitoring programs are designed for early detection of any off-site contamination as a result of debris management failure. Corrective actions should have two goals:

- to remedy any environmental harm that has already occurred; and
- to prevent further environmental harm

Groundwater Contamination

Detection of groundwater contamination require further characterisation of pollutant source and extent of affected area in order to assess short and long term impacts.

Groundwater pollution from an oil spill debris disposal site can result from several events acting together or separately:

- Leaching of oil and other contaminants by infiltration of surface water through the debris; and/or
- Drainage of the liquids contained in the debris itself; and/or
- Flushing of the debris materials by groundwater rising into the debris mass.

Vertical Infiltration

As discussed, vertical infiltration of waters from the surface into the debris may leach the deposited oil spill debris, transporting contaminants to the groundwater. Construction of diversion drains to minimise the volume of water draining into the fill should prevent this problem and should be included as part of effective site design. Proper site revegetation to minimise water accumulation and penetration will also reduce the possibility of vertical infiltration.

Infiltration can be caused by ponding of precipitation due to differential settling of the debris fill. Ponding can be prevented by regrading the surface to a 3-4% slope. Additional soil cover may be necessary when regrading. Plants with high transpiration rates can be planted at the site to reduce the amount of water available for infiltration. A cracked or eroded portion of the cover soil may also allow precipitation to infiltrate directly into the fill. More soil cover may need to be added in this case, however the failure may be due to the type of soil used. In this case an alternative should be chosen to reduce the likelihood of future cracking and erosion.

Leaching of Oily Matter from Debris Mass

Groundwater contamination may also be caused by leachate generated by the moisture present in the debris mass. A trench can be constructed to intercept leachate before it penetrates the aquifer, or excess moisture may be pumped out of the debris mass to reduce the volume of leachate available for groundwater infiltration.

Whenever groundwater contamination occurs, remedial solutions must necessarily be site specific. As a last resort, groundwater may be pumped out from the water table and treated. This procedure requires detailed knowledge of the boundary and degree of contamination for effective well placement. Where a shallow aquifer exists, an interceptor trench may provide an adequate solution. Proper disposal site selection could preclude groundwater contamination problems that require costly pumping solutions.

Infiltration of Groundwater into Debris Mass

Contamination can result from the infiltration of groundwater into the fill caused by local mounding or areal changes in the groundwater level. Pumping a short distance up gradient may lower the groundwater to a level no longer in contact with the filled material. Diversion channels may also provide a solution. Such channels lined with corrugated pipe, gravels or screened PVC pipe, would transport water away from the fill thereby preventing contamination. Peripheral subsurface drains to intercept the groundwater flow offer a third alternative. These techniques are all intended to divert groundwater from the fill.

As a last resort, the oil spill debris may need to be fully excavated from the site. This would only be in the most extreme instances of groundwater contamination. The waste could be relocated or temporarily stockpiled until a low permeability soil could be installed in the disposal area.

Water Contamination

Surface runoff of oily materials from a disposal site presents another potential environmental hazard. Runoff can be impeded by the construction of bunds to contain oily water within the site boundaries. Runoff can be recycled through the debris matter if the groundwater is protected and if the annual net evapotranspiration rate exceeds precipitation.

If contact between surface waters and oil spill debris is the source of contamination, replacement of cover soil at the points of contact is the most direct corrective measure. If erosion has caused the problem, a more thorough analysis and possible variation of soil type should be undertaken.

Onsite surface waters are particularly undesirable in land farming operations since cover soil is not utilised. Maintenance of upstream diversion trenches will reduce the flow of water into the area. Also contour ploughing will inhibit runoff from the land farming site. Collection of contaminated waters down gradient of the site offers a far less desirable alternative. Again, correct site selection should prevent surface water pollution from occurring.

Impeded Oil Degradation at Land Farming Sites

Impeded oil degradation can present environmental problems such as readily available oil for surface runoff. More frequent tilling and discing together with nutrient supplements can accelerate the degradation rate of oil and thereby reduce the total time that the site poses an environmental hazard. Consideration should also be given to seeding the land cultivation surface with commercially available oil degrading bacterial strains.

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