Natural Recovery

Objective:	No attempt to remove any stranded oil either to minimize impacts to the environment or because there is no effective method for cleanup. Oil is left in place to degrade naturally.
Description:	No action is taken, although monitoring of contaminated areas may be required.
Applicable Habitat Types:	All habitat types.
When to Use:	When natural removal rates are fast (e.g., gasoline evaporation, high-energy coastlines), when the degree of oiling is light, or when cleanup actions will do more harm than natural removal.
Biological Constraints:	This method may be inappropriate for areas used by high numbers of mobile animals (birds, marine mammals) or endangered species.
Environmental Effects:	Same as from the oil alone.
Waste Generation:	None.

Booming

Objective:	To prevent oil from contacting resources at risk, and to facilitate oil removal.
Description:	A boom specially designed for pollution response is a floating, physical barrier, placed on the water to contain, divert, deflect, or exclude oil. Containment is deploying a boom to contain and concentrate the oil until it can be removed. Deflection is moving oil away from sensitive areas. Diversion is moving oil toward recovery sites that have slower flow, better access, etc. Exclusion is placing boom to prevent oil from reaching sensitive areas. Booms must be properly deployed and maintained, including removing accumulated debris.
Applicable Habitat Types:	Can be used on all water environments (weather permitting). Booms begin to fail by entrainment when the effective current or towing speed exceeds 0.7 knots perpendicular to the boom. Waves, wind, debris, and ice contribute to boom failure.
When to Use:	When preventing oil from contacting sensitive resources is important. Most responses to spills on water involve deploying boom to help remove floating oil. Containment booming of gasoline spills is usually not attempted, because of fire, explosion, and inhalation hazards. However, when public health is at risk, gasoline can be boomed if foam is applied and extreme safety procedures are used.

Booming (cont.)

Biological Constraints:	Placing and maintaining boom and anchoring points should not cause excessive physical disruption to the environment, and both must be maintained so they do not fail nor tangle and cause more damage. Vehicle and foot traffic to and from boom sites should not disturb wildlife unreasonably, and booms in very shallow water should be monitored so they do not trap wildlife (such as migrating turtles returning to sea or fish coming in at high tide).
Environmental Effects:	Minimal, if disturbance during deployment and maintenance is controlled.
Waste Generation:	Cleaning booms will generate contaminated wastewater that must be collected, treated, and disposed of appropriately. Discarded booms will need to be disposed of according to appropriate waste disposal regulations.

Skimming

Objective:	To recover floating oil from the water surface using mechanized equipment. This includes specifically designed pollution equipment called skimmers, and other mechanical equipment such as draglines and dredges.
Description:	There are numerous types of skimming devices, described in the annually published World Catalog of Oil Spill Response Products (Schulze 1998): weir, centrifugal, submersion plane, and oleophilic. They are placed at the oil/water interface to recover, or skim, oil from the water's surface and may be operated independently from shore, be mounted on vessels, or be completely self-propelled. Because large amounts of water are often simultaneously collected (incidental to skimmer operation) and treated, efficient operations require that floating oil be concentrated at the skimmer head, usually using booms. Adequate storage of recovered oil/water mixtures must be available, as must suitable transfer capability. Skimmers are often placed where oil naturally accumulates in pockets, pools, or eddies.
Applicable Habitat Types:	Can be used on all water environments (weather and visibility permitting). Waves, currents, debris, seaweed, kelp, ice, and viscous oils will reduce skimmer efficiency.
When to Use:	When sufficient amounts of floating oil can be accessed. Skimming spilled gasoline is usually not feasible because of fire, explosion, and inhalation hazards to responders. However, when public health is at risk, gasoline can be skimmed if foam is applied and extreme safety procedures used.

Skimming (cont.)

Biological Constraints:	Vehicle and foot traffic to and from skimming sites should not disturb wildlife unreasonably.
Environmental Effects:	Minimal if surface disturbance by cleanup work force traffic is controlled.
Waste Generation:	Free-floating oil can be recycled. Emulsions formed during the process must be treated (broken) before recycling. Oil-contaminated waste from the treatment phase should be treated as wastewater.

Barriers/Berms

Objective:	To prevent entry of oil into a sensitive area or to divert oil to a collection area.
Description:	A physical barrier (other than a boom) is placed across an area to prevent oil from passing. Barriers can consist of earthen berms, trenching, or filter fences. When it is necessary for water to pass because of water volume, underflow or overflow dams are used.
Applicable Habitat Types:	At the mouths of creeks or streams to prevent oil from entering, or to prevent oil in the creek from being released into offshore waters. Also, on beaches where a berm can be built above the high-tide line to prevent oil from overwashing the beach and entering a sensitive back-beach habitat (e.g., lagoon).
When to Use:	When the oil threatens sensitive habitats and other barrier options are not feasible.
Biological Constraints:	Responders must minimize disturbance to bird nesting areas, beaver dams, or other sensitive areas. Placement of dams and filter fences could cause excessive physical disruptions, particularly in wetlands.
Environmental Effects:	May disrupt or contaminate sediments and adjacent vegetation. The natural beach (or shore) profile should be restored (may take weeks to months on gravel beaches). Trenching may enhance oil penetration and quantity of contaminated sediments.
Waste Generation:	Sediment barriers will become contaminated on the oil side and filter fence materials will have to be disposed of as oily wastes.

Physical Herding

Objective:	To free any oil trapped in debris or vegetation on water; to direct floating oil towards containment and recovery devices; or to divert oil from sensitive areas.
Description:	Plunging water jets, water or air hoses, and propeller wash can be used to dislodge trapped oil and divert or herd it to containment and recovery areas. May emulsify the oil. Mostly conducted from small boats.
Applicable Habitat Types:	In nearshore areas where there are little or no currents, and in and around man-made structures such as wharves and piers.
When to Use:	In low-current or stagnant water bodies, to herd oil toward recovery devices. In high-current situations to divert floating oil away from sensitive areas.
Biological Constraints:	When used nearshore and in shallow water, must be careful not to disrupt bottom sediments or submerged aquatic vegetation.
Environmental Effects:	May generate high levels of suspended sediments and mix them with the oil to deposit contaminated sediments in benthic habitats.
Waste Generation:	None.

Manual Oil Removal/Cleaning

Objective:	To remove oil with hand tools and manual labor.
Description:	Removal of surface oil using hands, rakes, shovels, buckets, scrapers, sorbents, pitchforks, etc., and placing in containers. No mechanized equipment is used except for transport of collected oil and debris. Includes underwater recovery of submerged oil by divers, for example, with hand tools.
Applicable Habitat Types:	Can be used on all habitat types.
When to Use:	Light to moderate oiling conditions for stranded oil, or heavy oils on water or submerged on the bottom that have formed semi-solid or solid masses and that can be picked up manually.
Biological Constraints:	Foot traffic over sensitive areas (wetlands, tidal pools, etc.) should be restricted or prevented. There may be periods when shoreline access should be avoided, such as during bird nesting.
Environmental Effects:	Minimal, if surface disturbance by responders and waste generation is controlled.
Waste Generation:	May generate significant quantities of oil mixed with sediment and debris that must be properly disposed of or treated. Decontamination of hand tools may produce oily wastewater that must be treated properly. Worker personal protective gear is usually disposed of daily or decontaminated and the resulting oily wastewater treated properly.

Mechanical Oil Removal

Objective:	To remove oil from shorelines, and bottom sediments using mechanical equipment.
Description:	Oil and oiled sediments are collected and removed using mechanical equipment not specifically designed for pollution response, such as backhoes, graders, bulldozers, dredges, draglines, etc. Requires systems for temporary storage, transportation, and final treatment and disposal.
Applicable Habitat Types:	On land, possible wherever surface sediments are both amenable to, and accessible by, heavy equipment. For submerged oil, used in sheltered areas where oil accumulates. On water, used on viscous or solid contained oil.
When to Use:	When large amounts of oiled materials must be removed. Care should be taken to remove sediments only to the depth of oil penetration, which can be difficult with heavy equipment. Should be used carefully where excessive sediment removal may erode the beach or shore. Buried oil lift-off consists of removing clean overburden and oiled sediments, and replacing them with clean overburden. Care is also needed to minimize further oil penetration from uncontrolled vehicle traffic.
Biological Constraints:	Heavy equipment use may be restricted in sensitive habitats (e.g., wetlands, soft substrates) or areas containing endangered species. Will need special permission to use in areas with known cultural resources. Dredging in seagrass beds or coral reef habitats may be prohibited. The noise generated by the mechanical equipment may present a constraint as well.

Mechanical Oil Removal (cont.)

Environmental Effects:	The equipment is heavy, with many support personnel required. May be detrimental if excessive sediments are removed without replacement. All organisms in the sediments will be affected, although the need to remove the oil may make this response method the best overall alternative. Resuspension of exposed oil and fine-grained, oily sediments can affect adjacent bodies of water.
Waste Generation:	Can generate significant quantities of contaminated sediment and debris that must be cleaned or landfilled. The amount of waste generated by this cleanup option should be given careful consideration by response planners when reviewing potential environmental impacts of the oily wastes, debris, and residues.

Sorbents

Objective:	To remove surface oil by using oleophilic (oil-attracting) material placed in water or at the waterline.
Description:	Sorbent material is placed on the floating oil or water surface, allowing it to sorb oil, or is used to wipe or dab stranded oil. Forms include sausage boom, pads, rolls, sweeps, snares, and loose granules or particles. These products can be synthetically produced or be natural substances. Efficacy depends on the capacity of the particular sorbent, wave or tidal energy available for lifting the oil off the substrate, and oil type and stickiness. All sorbent material must be recovered. Loose particulate sorbents must be contained in a mesh or other material.
Applicable Habitat Types:	Can be used on any habitat or environment type.
When to Use:	When oil is free-floating close to shore or stranded on shore. The oil must be able to be released from the substrate and sorbed by the sorbent. As a secondary treatment method after gross oil removal, and in sensitive areas where access is restricted. Selection of sorbent varies by oil type: heavy oils only coat surfaces, requiring use of sorbents with high surface areas to be effective (adsorbents); lighter oils can penetrate sorbent material (absorbents).
Biological Constraints:	Access for deploying and retrieving sorbents should not adversely affect wildlife or be through soft or sensitive habitats. Sorbents should not be used in a fashion that would endanger or trap wildlife. Sorbents left in place too long can break apart and present an ingestion hazard to wildlife.

Sorbents (cont.)

Environmental Effects:	Physical disturbance of habitat during deployment and retrieval. Improperly deployed or tended sorbent material can crush or smother sensitive organisms.
Waste Generation:	Sorbents must eventually be collected for proper disposal so care should be taken to select and use sorbents properly, and prevent overuse and generation of large amounts of lightly oiled sorbents. Because large amounts of waste may be generated, recycling should be emphasized rather than disposal.

Vacuum

Objective:	To remove oil pooled on a shoreline substrate or subtidal sediments.
Description:	A vacuum unit is attached via a flexible hose to a suction head that recovers free oil. The equipment can range from small, portable units that fill individual 55-gallon drums to large supersuckers that are truck- or vessel-mounted and can generate enough suction to lift large rocks. Removal rates from substrates can be extremely slow.
Applicable Habitat Types:	Any accessible habitat type. May be mounted on vessels for water-based operations, on trucks driven to the recovery area, or hand-carried to remote sites.
When to Use:	When oil is stranded on the substrate, pooled against a shoreline, concentrated in trenches, or trapped in vegetation. Usually requires shoreline access points.
Biological Constraints:	Special restrictions should be established for areas where foot traffic and equipment operation may be damaging, such as soft substrates. Operations in wetlands must be very closely monitored, and a site-specific list of procedures and restrictions developed to prevent damage to vegetation.
Environmental Effects:	Minimal, if foot and vehicular traffic are controlled and minimal substrate is damaged or removed.
Waste Generation:	Collected oil and or oil/water mix will need to be stored temporarily before recycling or disposal. Oil may be recyclable; if not, it will require disposal in accordance with local regulations. Large amounts of water are often recovered, requiring separation and treatment.

Debris Removal

Objective:	To remove debris in path of spill before oiling and to remove contaminated debris from the shoreline and water surface.
Description:	Manual or mechanical removal of debris (driftwood, seaweed, trash, wreckage) from the shore or water surface. Can include cutting and removal of oiled logs.
Applicable Habitat Types:	Can be used on any habitat or environment type where access is safe.
When to Use:	When debris is heavily contaminated and provides a potential source of secondary oil release; an aesthetic problem; a source of contamination for other resources in the area is likely to clog skimmers; or likely to cause safety problems for responders. Used in areas of debris accumulation on beaches before oiling to minimize the amount of oiled debris to be handled.
Biological Constraints:	Foot traffic over sensitive areas (wetlands, spawning grounds) must be restricted. May be periods when entry should be denied (spawning periods, influx of large numbers of migratory waterbirds). Debris may also be a habitat.
Environmental Effects:	Physical disruption of substrate, especially when mechanized equipment must be deployed to recover a large quantity of debris.

Debris Removal (cont.)

Waste Generation: Will generate contaminated debris (volume depends on what, and how much, is collected, e.g., logs, brush). Unless there is an approved hazardous waste incinerator that will take oily debris, burning will seldom be allowed, especially on-site burning. However, this option should still be explored, especially for remote locations, with the appropriate state or Federal agencies that must give approvals for burning.

The advantage of pre-spill debris collections is that waste disposal requirements will likely be less restrictive than if the debris is oiled. Once oiled, the debris is likely to be handled as a hazardous waste.

Sediment Reworking/Tilling

Objective:	To break up oily sediments and surface oil deposits, increasing their surface area, and mixing deeper subsurface oil layers, thus enhancing the rate of degradation through aeration.
Description:	The oiled sediments are roto-tilled, disked, or otherwise mixed using mechanical equipment or manual tools. Along beaches, oiled sediments may also be pushed to the water's edge to enhance natural cleanup by wave activity (surf washing). The process may be aided with high-volume flushing of gravel.
Applicable Habitat Types:	On any sedimentary substrate that can support mechanical equipment or foot traffic and hand tilling.
When to Use:	On sand to gravel beaches with subsurface oil, where sediment removal is not feasible (due to erosion or disposal problems). On sand beaches where the sediment is stained or lightly oiled. Appropriate for sites where the oil is stranded above the normal high waterline.
Biological Constraints:	Avoid use on shores near sensitive wildlife habitats, such as fish-spawning areas or bird-nesting or concentration areas because of the potential for release of oil and oiled sediments into adjacent bodies of water. Should not be used in clam beds.
Environmental Effects:	Due to the mixing of oil into sediments, this method could further expose organisms that live below the original layer of oil. Repeated reworking could delay re-establishing of these organisms. Refloated oil from treated sites could contaminate adjacent areas.
Waste Generation:	None.

Vegetation Cutting/Removal

Objective:	To remove portions of oiled vegetation or oil trapped in vegetation to prevent oiling of wildlife or secondary oil releases.
Description:	Oiled vegetation is cut with weed trimmers, blades, etc., and picked or raked up and bagged for disposal.
Applicable Habitat Types:	Habitats composed of vegetation, such as wetlands, sea grass beds, kelp beds, which contain emergent, herbaceous vegetation or floating, aquatic vegetation.
When to Use:	When the risk of oiled vegetation contaminating wildlife is greater than the value of the vegetation that is to be cut, and there is no less-destructive method that removes or reduces the risk to acceptable levels.
Biological Constraints:	Operations must be strictly monitored to minimize the degree of root destruction and mixing of oil deeper into the sediments. Access in bird-nesting areas should be restricted during nesting seasons. Cutting only the oiled portions of the plants and leaving roots and as much of the stem as possible minimizes impacts to plants.
Environmental Effects:	Vegetation removal will destroy habitat for many animals. Cut areas will have reduced plant growth and, in some instances, plants may be killed. Cutting at the base of the plant stem may allow oil to penetrate the substrate, causing sub-surface contamination. Along exposed sections of shoreline, the vegetation may not recover, resulting in erosion and habitat loss. Trampled areas will recover much more slowly.
Waste Generation:	Cut portions of oiled plants must be collected and disposed.

Flooding

Objective:	To wash oil stranded on land to the water's edge for collection.
Description:	A perforated header pipe or hose is placed above the oiled shore or bank. Ambient-temperature water is pumped through the header pipe at low pressure and flows downslope to the water where any oil released is trapped by booms and recovered by skimmers or other suitable equipment. On porous sediments, water flows through the substrate, pushing loose oil ahead of it. On saturated, fine-grained sediments, the technique becomes more of a surface flushing.
Applicable Habitat Types:	All shoreline types where the equipment can be effectively deployed. Not effective in steep intertidal areas.
When to Use:	In heavily oiled areas when the oil is still fluid and adheres loosely to the substrate, and where oil has penetrated into gravel sediments. This method is frequently used with other washing techniques (low- or high-pressure, cold- to hot-water flushing).
Biological Constraints:	Special care should be taken to recover oil where nearshore habitats contain rich biological communities. Not appropriate for muddy substrates.
Environmental Effects:	Habitat may be physically disturbed by foot traffic during operations and smothered by sediments washed down the slope. If containment methods are not sufficient, oil and oiled sediments may be flushed into adjacent areas. Flooding may cause sediment loss and erosion of the shoreline and shallow rooted vegetation. Oiled sediment may be transported to nearshore areas, contaminating them and burying benthic organisms.
Waste Generation:	Depends on the effectiveness of the collection method.

Low-pressure, Ambient-Water Flushing

Objective:	To remove fluid oil that has adhered to the substrate or man-made structures, pooled on the surface, or become trapped in vegetation.
Description:	Ambient-temperature water is sprayed at low pressures (<10 psi), usually from hand-held hoses, to lift oil from the substrate and float it to the water's edge for recovery by skimmers, vacuum, or sorbents. Usually used with a flooding system to prevent released oil from re-adhering to the substrate downstream of the treatment area.
Applicable Habitat Types:	On substrates, riprap, and solid, man-made structures, where the oil is still fluid. In wetlands and along vegetated banks where oil is trapped in vegetation.
When to Use:	Where fluid oil is stranded onshore or floating in shallow intertidal areas.
Biological Constraints:	May need to restrict use so that the oil/water effluent does not drain across sensitive intertidal habitats, and so that mobilized sediments do not affect rich subtidal communities. Use from boats will reduce the need for foot traffic in soft substrates and vegetation. Flushed oil must be recovered to prevent further oiling of adjacent areas.
Environmental Effects:	If containment methods are not sufficient, oil and oiled sediments may be flushed into adjacent areas. Flooding may cause sediment loss and erosion of the shoreline and shallow rooted vegetation. Some trampling of substrate and attached biota will occur.
Waste Generation:	Depends on the effectiveness of the collection method.

High-pressure, Ambient-Water Flushing

Objective:	To remove oil that has adhered to hard substrates or man-made structures.
Description:	Similar to low-pressure flushing, except that water pressure is 100-1,000 psi (720-7,200 kpa). High-pressure spray will more effectively remove sticky or viscous oils. If low water volumes are used, sorbents are placed directly below the treatment area to recover oil.
Applicable Habitat Types:	On bedrock, man-made structures, and gravel substrates.
When to Use:	When low-pressure flushing is not effective at removing adhered oil, which must be removed to prevent continued oil release or for aesthetic reasons. When a directed water jet can remove oil from hard-to-reach sites.
Biological Constraints:	May need to restrict flushing so that the oil does not drain across sensitive habitats. Flushed oil must be recovered to prevent further oiling of adjacent areas. Should not be used directly on attached algae nor rich, intertidal areas.
Environmental Effects:	All attached animals and plants in the direct spray zone will be removed, even when used properly. May drive oil deeper into the substrate or erode fine sediments from shorelines if water jet is improperly applied. If containment methods are not sufficient, oil and oiled sediments may be flushed into adjacent areas. Some trampling of substrate and attached biota will occur.
Waste Generation:	Depends on the effectiveness of the collection method.

Low-pressure, Hot-Water Flushing

Objective:	To remove non-liquid/non-fluid oil that has adhered to the substrate or man-made structures, or pooled on the surface.
Description:	Hot water (90°F [32°C] up to 171°F [77°C]) is sprayed with hoses at low pressures (<10 psi [<72 kpa]) to liquefy and lift oil from the substrate and float it to the water's edge for recovery by skimmers, vacuums, or sorbents. Used with flooding to prevent released oil from re-adhering to the substrate.
Applicable Habitat Types:	On bedrock, sand to gravel substrates, and man-made structures.
When to Use:	Where heavy, but relatively fresh, oil is stranded onshore. The oil must be heated above its pour point so it will flow. Less effective on sticky oils.
Biological Constraints:	Avoid wetlands or rich intertidal communities so that the hot oil/water effluent does not contact sensitive habitats. Operations from boats will help reduce foot traffic in soft substrates and vegetation. Flushed oil must be recovered to prevent further oiling of adjacent areas. Should not be used directly on attached algae or in rich, intertidal areas.
Environmental Effects:	Hot water contact can kill attached animals and plants. If containment methods are not sufficient, oil may be flushed into adjacent areas. Flooding may cause sediment loss and erosion of the shoreline and shallow rooted vegetation. Some trampling of substrate and biota will occur.
Waste Generation:	Depends on the effectiveness of the collection method.

High-pressure, Hot Water Flushing

Objective:	To mobilize weathered and viscous oil strongly adhered to surfaces.
Description:	Hot water (90°F [32°C] up to 171°F [77°C]) is sprayed with hand-held wands at pressures greater than 100 psi (720 kpa). If used without water flooding, this procedure requires immediate use of vacuum or sorbents to recover the oil/water runoff. When used with a flooding system, the oil is flushed to the water surface for collection by skimmers, vacuum, or sorbents.
Applicable Habitat Types:	Gravel substrates, bedrock, and man-made structures.
When to Use:	When oil has weathered to the point that warm water at low pressure no longer effectively removes oil. To remove viscous oil from man-made structures for aesthetic reasons.
Biological Constraints:	Use should be restricted so that the oil/water effluent does not drain across sensitive habitats (damage can result from exposure to oil, oiled sediments, and hot water). Should not be used directly on attached algae nor rich, intertidal areas. Released oil must be recovered to prevent further oiling of adjacent areas.
Environmental Effects:	All attached animals and plants in the direct spray zone will be removed or killed, even when used properly. Oiled sediment may be transported to shallow nearshore areas, contaminating them and burying benthic organisms.
Waste Generation:	Depends on the effectiveness of the collection method.

Steam Cleaning

Objective:	To remove heavy residual oil from solid substrates or man-made structures.
Description:	Steam or very hot water (171°F [77°C] to 212°F [100°C]) is sprayed with hand-held wands at high pressure (2,000+ psi [14,400 kpa]). Water volumes are very low compared to flushing methods.
Applicable Habitat Types:	Man-made structures such as seawalls and riprap.
When to Use:	When heavy oil residue must be removed for aesthetic reasons, when hot water flushing is not effective, and no living resources are present.
Biological Constraints:	Not to be used in areas of soft substrates, vegetation, nor high biological abundance directly on, nor below, the structure.
Environmental Effects:	Complete destruction of all organisms in the spray zone. Difficult to recover all released oil. If containment methods are not sufficient, oil may be flushed into nearshore areas.
Waste Generation:	Depends on the effectiveness of the collection method. Usually sorbents are used, generating significant waste volumes.

Sand Blasting

Objective:	To remove heavy residual oil from solid substrates or man-made structures.
Description:	Use of sandblasting equipment to remove oil from the substrate. May include recovery of used (oiled) sand.
Applicable Habitat Types:	On heavily oiled bedrock, artificial structures such as seawalls and riprap.
When to Use:	When heavy oil residue must be cleaned for aesthetic reasons, and even steam-cleaning is not effective.
Biological Constraints:	Not to be used in areas of soft substrates, vegetation, nor high biological abundance directly below, nor adjacent to, the structures.
Environmental Effects:	Complete destruction of all organisms in the blast zone. Possible smothering of organisms in adjacent areas. Unrecovered, used sand will introduce oiled sediments into the adjacent habitat. Oiled sediment may be transported to shallow nearshore areas, contaminating them and burying benthic organisms.
Waste Generation:	Will need to recover and dispose of oiled sand used in blasting.

Dispersants

Objective:	To reduce impact to sensitive shoreline habitats and animals that use the water surface by chemically dispersing oil into the water column.
Description:	Dispersants reduce the oil/water interfacial tension, thereby decreasing the energy needed for the slick to break into small particles and mix into the water column. Specially formulated products containing surface-active agents are sprayed (at concentrations of 1-5 percent by volume of the oil) from aircraft or boats onto the slicks. Some agitation is needed to achieve dispersion.
Applicable Habitat Types:	Water bodies with sufficient depth and volume for mixing and dilution.
When to Use:	When the impact of the floating oil has been determined to be greater than the impact of dispersed oil on the water-column community.
Biological Constraints:	Use in shallow water could affect benthic resources. Consideration should be made to avoid directly spraying any wildlife, especially birds or fur-bearing marine mammals.
Environmental Effects:	Until sufficiently diluted, the dispersed oil can adversely impact organisms in the upper 30 feet (10 meters) of the water column. Because dispersion may be only partially effective, some water-surface and shoreline impacts could occur.
Waste Generation:	None.

Emulsion-treating Agents

Objective:	To break or destabilize emulsified oil into separate oil and water phases. Can be used to prevent emulsion formation, increasing oil recovery rates, extending the window for dispersant application, or making burning possible.
Description:	Emulsion-treating agents are surfactants that are applied to emulsified oil at low concentrations (0.1-2 percent). They can be injected into skimmer reservoirs to break the emulsion as it is skimmed from the water. They can be sprayed (similar to dispersants) directly onto slicks to break or prevent emulsions, although this type of application has not been successfully used in the field.
Applicable Habitat Types:	On all water environments where emulsified oil is present.
When to Use:	Where storage capacities are very limited, to separate the recovered, emulsified oil and water so that the water can be treated and discharged. On floating slicks, where emulsified oil can reduce skimmer efficiency and dispersant effectiveness.
Biological Constraints:	There is insufficient information to fully evaluate biological constraints. Use in shallow water could affect benthic resources. Responders should avoid directly spraying any wildlife, especially birds or fur-bearing marine mammals.

Emulsion-treating Agents (cont.)

Environmental Effects:	Because this is a new method, there are few data available to evaluate environmental effects. Effective dosages are one to two orders of magnitude lower than dispersants. Environmental concerns include the potential for increased oil content of separated water; whether the oil will be more readily dispersed; and how the treated oil will behave upon contact with skimming equipment, birds, mammals, and shorelines.
Waste Generation:	May enable recycling of oil/water mixtures by breaking down emulsions.

Elasticity Modifiers

Objective:	To impart visco-elastic properties to floating oil, thereby increasing skimming rates.
Description:	The product is applied as a liquid, slurry, or solid onto the oil. Some mixing is required and is usually provided by the water spray during application. Treated oil is gelatinous, or semi-solid, but still fluid; there is no chemical change in the oil. The primary purpose is to increase skimmer efficiency removal rates while minimizing water recovery amounts. Increases the efficiency of some skimmers, but may clog other skimmers and pumps.
Applicable Habitat Types:	On all water environments where oil can be contained for skimming. Not for use near wetlands nor debris because of increased adhesive properties of the treated oil.
When to Use:	When skimmer efficiency is low. Must be used with booming or other physical containment. Not for use on heavy oils, which are already highly viscous.
Biological Constraints:	Not suitable for vegetated shores nor where extensive debris is mixed in the oil. Should be avoided when birds or other wildlife cannot be kept away from the treated oil.
Environmental Effects:	May increase the smothering effect of oil on organisms; therefore, the treatment should be considered only where recovery of the treated oil is likely.
Waste Generation:	If skimming efficiency is increased, will reduce the volume of water in oil/water collections. Effects on recycling of oil treated with elasticity modifiers is unknown.

Herding Agents

Objective:	To collect or herd oil into a smaller area and thicker slick in order to increase recovery. Can be used to herd oil away from sensitive areas or to help contain oil when it is necessary to move a boom.
Description:	These agents, which are insoluble surfactants and have a high spreading pressure, are applied in small quantities (1-2 gallons per lineal mile) to the clean water surrounding the edge of a fresh oil slick. They contain the oil, prevent spreading, but do not hold the spill in place. Hand-held or vessel-mounted systems can be used. Must be applied early in spill, when oil is still fluid.
Applicable Habitat Types:	On all still-water environments.
When to Use:	Potential use for collection and protection. For collection, used to push slicks out from under docks and piers where it has become trapped, or in harbors where the equipment is readily accessible for use early in the spill. For protection in low-current areas, used to push slicks away from sensitive resources such as wetlands. Not effective in fast currents, rough seas, nor rainfall.
Biological Constraints:	Not suitable for use in very shallow water nor fish-spawning areas.
Environmental Effects:	Direct acute toxicity to surface-layer organisms possible, though available products vary greatly in their aquatic toxicity.
Waste Generation:	Same as for manual oil recovery.

Solidifiers

Objective:	To change the physical state of spilled oil from a liquid to a solid.
Description:	Chemical agents (polymers) are applied to oil at rates of 10-45 percent or more, solidifying the oil in minutes to hours. Various broadcast systems, such as leaf blowers, water cannons, or fire suppression systems, can be modified to apply the product over large areas. Can be applied to both floating and stranded oil. Can be placed in sorbent booms and used like sorbents.
Applicable Habitat Types:	All water environments, bedrock, sediments, and artificial structures.
When to Use:	To immobilize the oil or prevent refloating from a shoreline, penetration into the substrate, or further spreading. However, the oil may not fully solidify unless the product is well mixed with the oil, and may result in a mix of solid and untreated oil. Generally not used on heavy oil spills that are already viscous.
Biological Constraints:	Must be able to recover all treated material.
Environmental Effects:	Products are insoluble and have very low aquatic toxicity. Unrecovered solidified oil may have longer impact because of slow weathering rates. Physical disturbance of habitat is likely during application and recovery.
Waste Generation:	If skimming efficiency is increased, solidifiers may reduce the volume of water collected during oil recovery. Oil treated with solidifiers is typically disposed of in landfills.

Shoreline Cleaning Agents (Surface Washing Agents)

Objective:	To increase the efficiency of oil removal from contaminated substrates.
Description:	Special formulations are applied to the substrate, as a presoak and/or flushing solution, to soften or lift weathered or heavy oils from the substrate to enhance flushing methods. The intent is to lower the water temperature and pressure required to mobilize the oil from the substrate during flushing. Some agents will disperse the oil as it is washed off the beach, others will not.
Applicable Habitat Types:	On any habitat where water flooding and flushing procedures are applicable.
When to Use:	When the oil has weathered to the point where it cannot be removed using ambient water temperatures and low pressures. This approach may be most applicable where flushing effectiveness decreases as the oil weathers.
Biological Constraints:	When the product does not disperse the oil into the water column, the released oil must be recovered from the water surface. Use may be restricted where suspended sediment concentrations are high, near wetlands, and near sensitive nearshore resources.
Environmental Effects:	The toxicity and effects on dispersability of treated oil vary widely among products. Selection of a product should consider its toxicity.
Waste Generation:	Because treated oil must be recovered, waste generation is a function of recovery method, which often includes sorbents.

Nutrient Enrichment (Biostimulation)

Objective:	To accelerate the rate of oil hydrocarbon degradation due to natural microbial processes by adding nutrients (generally nitrogen and phosphorus) that stimulate microbial growth.
Description:	If nutrients are a limiting factor (as measured using the interstitial pore water) in an area where shoreline oiling has occurred, water-soluble nutrients can be applied by a spray irrigation system. Nutrients should be applied daily if the impacted area gets completely submerged by tides and waves and if maximum biostimulation is desired. If the impacted area gets submerged only during spring tides, the frequency of nutrient addition will be determined by the intertidal zone water coverage. Slow-release granular or encapsulated nutrients or oleophilic fertilizer (which adheres to the oil residue on the surface) should require less frequent addition, but time-series monitoring of interstitial pore water nutrient levels is needed to ensure target levels are being maintained, especially throughout the depth of the impacted intertidal zone.
Applicable Habitat Types:	Could be used on any shoreline habitat type where access is allowed and nutrients are deficient.
When to Use:	On moderate- to heavily-oiled substrates, after other techniques have been used to remove free product; on lightly-oiled shorelines, where other techniques are destructive or ineffective; and where nutrients limit natural attenuation. Most effective on light to medium crude oils and fuel oils (asphaltenes tend to inhibit rapid biodegradation). Less effective where oil residues are thick. Not considered for gasoline spills, which evaporate rapidly.

Nutrient Enrichment (Biostimulation) (cont.)

Biological Constraints:	Avoid using ammonia-based fertilizers at highly elevated concentrations because un-ionized ammonia is toxic to aquatic life. Nitrate is an equally good nitrogen source, minus the toxicity. Sodium tripolyphosphate is a better phosphorus source than orthophosphates because it is more soluble in seawater. If nutrients are applied properly with adequate monitoring, eutrophication should not be a problem. Only nutrient additives proven to be nontoxic and effective in either the laboratory or the field should be used in the environment. Contact toxicity of oleophilic nutrients may restrict their use, as other chemicals in the product could be more toxic to aquatic organisms in the presence of oil.
Environmental Effects:	Detrimental effects to shoreline from foot or vehicle traffic caused by workers applying nutrients (unless nutrients are sprayed from a vessel or aircraft).
Waste Generation:	None.

Natural Microbe Seeding (Bioaugmentation)

Objective: A form of bioremediation used to accelerate natural microbial degradation of oil by adding high numbers of oil-degrading microorganisms.

Description: Formulations containing specific hydrocarbon-degrading microbes are added to the oiled area because there are few indigenous hydrocarbon degraders, or those that are present cannot degrade the oil effectively. Since microbes require nitrogen and phosphorus to convert hydrocarbons to biomass, formulations containing these oil degraders must also contain adequate nutrients. Research studies conducted with bioengineered organisms or organisms enriched from different environments, grown in the laboratory to high numbers, and applied to an oiled beach to stimulate rapid biodegradation, have failed to prove conclusively that seeding is effective.

Bioaugmentation appears less effective than biostimulation because: 1) hydrocarbon degraders are ubiquitous in nature and, when an oil spill occurs, the influx of oil will cause an immediate increased response in the hydrocarbon-degrading populations; but, 2) if nutrients are in limited supply, the rate of oil biodegradation will be less than optimal; thus, 3) supplying nutrients will enhance the process initiated by the spill, but adding microorganisms will not, because they still lack the necessary nitrogen and phosphorus to support growth.

The maximum number of microbial organisms achievable will determine the maximum biodegradation rate. If nutrient supplementation is sufficient to maximize that rate, bioaugmentation will not further increase the biodegradation rate.

Natural Microbe Seeding (Bioaugmentation) (cont.)

Applicable Habitat Types:	There is insufficient information on impacts or effectiveness of this method to make a judgment on applicable habitat.
When to Use:	There is insufficient information on impacts or effectiveness of this method to make a judgment on when to use it.
Biological Constraints:	Avoid using products containing ammonia-based fertilizers at elevated concentrations because un-ionized ammonia is toxic to aquatic life. Nitrate is an equally good nitrogen source, minus the toxicity. If the product containing nutrients is applied properly with adequate monitoring, eutrophication should not be a problem, but toxicity tests should be evaluated carefully, as other chemicals in the product could be toxic to aquatic organisms.
Environmental Effects:	Detrimental physical effects to shoreline from foot or vehicle traffic caused by workers applying bioaugmentation products (unless nutrients are sprayed from a vessel or aircraft).
Waste Generation:	None.

In-situ Burning

Objective:	To remove oil from the water surface or habitat by burning it in place.
Description:	Oil floating on the water surface is collected into slicks at least 2-3 mm thick and ignited. The oil can be contained in fire-resistant booms, or by natural barriers such as ice or the shore. On land, oil can be burned when it is on a combustible substrate such as vegetation, logs, and other debris. Oil can be burned from non-flammable substrates using a burn promoter. On sedimentary substrates, it may be necessary to dig trenches for oil to accumulate in pools to a thickness that will sustain burning. Heavy oils are hard to ignite but can sustain a burn. Emulsified oils may not ignite nor sustain a burn when the water content is greater than 30 to 50 percent.
Applicable Habitat Types:	On most habitats, except dry, muddy substrates where heat may impact the biological productivity of the habitat. May increase oil penetration in permeable substrates. Not suitable for woody vegetation such as mangroves.
When to Use:	On floating slicks, early in the spill event when the oil can be kept thick enough (2-3 mm). On land, where there is heavy oil in sites neither amenable nor accessible to physical removal and the oil must be removed quickly. In wetlands and mud habitats, a water layer will minimize impacts to sediments and roots. Many potential applications for spills in ice. There are many operational and public health limitations.
Biological Constraints:	The possible effects of large volumes of smoke on nesting birds and populated areas should be evaluated.

In-situ Burning (cont.)

Environmental Effects:	Temperature and air quality effects are likely to be localized and short-lived. Toxicological impacts from burn residues have not been evaluated. On water, burn residues may sink. On land, removal of burn residues is often necessary for crude and heavy oils. Residue removal can physically disrupt sensitive habitats such as wetlands. There are few studies on the relative effects of burning oiled wetlands compared to other techniques or natural recovery. Limited data indicate recovery of wetland vegetation will depend on season of burn, type of vegetation, and water level in the marsh at time of burn.
Waste Generation:	Any residues remaining after burning will need to be collected and landfilled but, with an efficient burn, will be a small fraction of the original oil volume.