II. FATE AND EFFECT OF OIL AND ROUTES OF EXPOSURE TO COMMERCIAL FISHERIES

The fate and effect of spilled oil refers to the impacts of physical and chemical processes on the oil behavior once it is spilled to water. For the purpose of this manual, fate and effect are discussed in general terms in order to facilitate an understanding of how oil properties and behavior may impact fishery organisms, commercial fishing vessels and gear, and/or processing operations. Before developing a commercial fisheries water quality sampling program, it is important to have a basic understanding of how the spilled oil may behave on water, where the oil may be traveling, and how fishery organisms may be exposed to the oil.

Specific information about the fate and effect of spilled oil is often available at the incident through scientific support personnel. Fisheries water quality sampling programs should factor in all available information about oil fate and behavior.

BEHAVIOR OF OIL SPILLED TO WATER

Oil types and properties may influence whether fishery resources are exposed and/or contaminated, based on the way various types of oils behave in water. Oil changes rapidly once it is spilled into water. These changes are enhanced by the processes of evaporation, dilution and emulsification (when water incorporates into the oil, forming a stable mixture). Some changes help dissipate spilled oil, but others can make it linger in the water, on the bottom, or on the shore. Evaporation tends to remove the more toxic components and reduces the toxicity of spilled oil. Emulsification can slow degradation of spilled oil. Ultimately, the more toxic elements of oil products spilled in the marine, estuarine, or freshwater environment are broken down. Exposure to air, sunlight, wave and tidal action, and certain microscopic organisms degrades and/or disperses oil. The rate of degradation and dispersion depends on many factors like the type of oil, weather, temperature, and the type of shoreline and bottom.

Crude oils and the refined products derived from them are complex and variable mixtures of hydrocarbons of different molecular weights and structures. They can contain hundreds of different compounds. Oils have been grouped into types with similar properties to help predict their behavior when spilled. This same approach can be used to characterize the relative risk of contamination of seafood by oil type, as shown in Table II-1. (Yender et al., 2004).

- ***Group I*** oils are very light and highly volatile, which means they evaporate quickly, usually completely within one to two days after a spill. These oils are also flammable and contain high concentrations of soluble toxic compounds. Very light oils can mix with water and kill aquatic life that lives in the upper

layers. Cleanup is usually not necessary, or possible, with spills of Group I oil. Group I oils are rarely transported in Alaska.

- ***Group II*** oils are light and moderately volatile, but can leave a residue of up to one-third of the amount spilled after a few days. These oils contain moderate concentrations of soluble toxic compounds. Group II oils leave a film or layer on intertidal resources with the potential of long term contamination. Cleanup can be very effective on spills of light oil.
- ***Group III*** oils are medium and less volatile than lighter oils, leaving a residue of about two-thirds of the amount spilled after 24 hours. These oils are less likely to mix with water, and oil contamination of intertidal areas can be severe and long-term. Cleanup is most effective with spills of medium oil if conducted quickly.
- ***Group IV*** oils are heavy and have far less evaporation or dilution potential, and they weather more slowly than light or medium oils. These oils do not readily mix with water. Spills of heavy oils can cause severe contamination of intertidal areas and possible long-term contamination of sediments. Shoreline cleanup in spills of this type is difficult and long term under most conditions.
- ***Group V*** oils, mostly very heavy oils, can float, sink, or hang in the water. These oils can become oil drops and mix in the water, or accumulate on the bottom, or mix with sand and then sink. As a rule, these oils are less toxic than lighter oils, however they pose significant problems to responders because they are extremely difficult to track or predict. They may impact many commercially important groundfish and crab species.

The National Oceanic and Atmospheric Administration (NOAA) has developed the ADIOS2 (Automated Data Inquiry for Oil Spills) modeling tool to predict the characteristics and behavior of certain oil types when spilled to water. Data from ADIOS or other modeling programs may help to predict the fate and effects of the spilled oil and thus shape the water quality sampling program design.

Relationship between oil characteristics and fisheries water quality sampling

For the purpose of this manual, oil is described as existing in one of two "phases": dissolved phase oil or whole oil. The impact of various weathering processes, combined with the chemical composition of the oil itself, will determine whether oil is expected to be dissolved into the water column or in whole oil form, as tar balls, tar patties, emulsified mousses, or other whole forms. It is important to remember that oil weathering is a dynamic process, and the phase or characteristics of the oil may change over the course of the sampling program.

Table II-1 describes the typical behavior of various types of oil when they are spilled to water. In general, heavier oils are more likely to be encountered as whole oil, while lighter oils may dissolve more readily into the water column, or evaporate into the atmosphere.

Table II-1. Relationship between oil characteristics and potential for seafood contamination (modified from Yender et al., 2004).

	Group I Oils (non-persistent)	Group II Oils (persistent)	Group III Oils (persistent)	Group IV Oils (persistent)	Group V Oils (persistent)
Examples	Gasoline products and non-persistent oils	No. 2 fuel oil, jet fuels, kerosene, Alberta crude, marine diesel oil	North Slope crude, IFO 180, lube oils	Venezuelan crude, No. 6 fuel oil, IFO 380	Very heavy No. 6 fuel oil, residual oils, vacuum bottoms, heavy slurry oils
Characteristics	Specific gravity <0.80	Specific gravity of <0.85; API gravity of 35-45	Specific gravity of 0.85-0.95; API gravity of 17.5-35	Specific gravity of 0.95-1.00; API gravity of 10-17.5	Specific gravity >1.00; API gravity <10
Floating behavior	Floats on surface	Usually floats on surface, can contaminate suspended sediments that are then deposited on the bottom.	Usually floats on surface, although can mix with sand by stranding on beaches or in the surf zone and be deposited in nearshore.	Usually floats on surface but can sink in fresh water or in seawater if emulsified or mixed with sand (in surf zone or after stranding on beaches) and deposited in nearshore.	Will sink in fresh water; may sink in seawater if emulsified or mixed with sand (in surf zone or after stranding on beaches) and deposited in nearshore.
Evaporation	High evaporation rates; narrow cut fraction with no residues	Refined products can evaporate to no residue; crude oils do leave residues.	Up to 1/3 will evaporate in the first 24 hours; will form persistent residues.	Very little product loss by evaporation; will form persistent residues.	Very little evaporation when submerged; also very slow weathering when submerged.
Viscosity	Low viscosity; spread rapidly to a thin sheen; rapidly dispersed; will not emulsify	Low to moderate viscosity; spread rapidly into thin slicks; readily dispersed by natural processes, may form unstable emulsions.	Moderate to high viscosity; dispersed by natural processes only very early in the spill; readily emulsifies.	Very viscous to semi-solid; will not readily disperse or mix into the water column; can form stable emulsions.	Very viscous to semi-solid; will not readily disperse or mix into the water column; can form stable emulsions.
Risk of Seafood Contamination	Low risk of seafood contamination because of rapid and complete loss via evaporation; potential contamination for spills in confined areas with high mixing, such as small rivers; no reported cases of tainting for marine spills	Moderate to high risk of seafood contamination because relatively high content of low molecular weight, water-soluble aromatic hydrocarbons, which are semi-volatile and evaporate slowly; dispersed droplets are also bio-available.	Moderate to high risk of seafood contamination because of high percentage of low-molecular weight aromatic hydrocarbons; coating of gear and intertidal species can be significant.	Low risk of finfish contamination because of low water-soluble fraction and little natural mixing in the water; moderate to high risk of shellfish contamination where shoreline oiling is heavy; can coat gear and intertidal species.	Low risk of finfish contamination because of high viscosity; where thick oil accumulates on the bottom, could become a chronic source; moderate to high risk of contamination of benthic species because of coating and persistence of submerged oil.
Potential Exposure Pathways	Dissolved oil fraction via water column or surface	Dissolved and whole oil fractions via the water column and water surface; sediment or shoreline contamination less likely; ingestion of contaminated food possible.	Dissolved and whole oil via water column and water surface; sediment and shoreline contamination possible; ingestion of contaminated food possible.	Dissolved (less likely) and whole oil via water column and water surface; sediment and shoreline contamination more likely; ingestion of contaminated food possible.	Dissolved (very unlikely) and whole oil via water column and water surface; sediment and shoreline contamination more likely; ingestion of contaminated food possible.
Relative Toxicity	High	High	Moderate	Low	Low

OIL TYPE, POTENTIAL FISHERY IMPACTS, AND SAMPLING CONSIDERATIONS

The fate and behavior of spilled oil will determine the risk to fisheries organisms, gear, and processing operations. This, in turn, will determine the types of water quality sampling techniques used. For each sampling method, an icon is used to indicate whether the method is intended to detect whole or dissolved phase oil.

Whole oil may be present in the form of tar balls, mousse, tar patties, contaminated sediments, or other particulate oil fractions. In general, medium to heavy oils are more likely to be encountered as whole oil.

Dissolved phase oil occurs when the soluble components of the oil dissolve into the water column. This occurs most readily with light to medium oils.

Potential Routes of Exposure to Fisheries Organisms and Seafood

Once the probable behavior and trajectory of spilled oil is understood, this information may then be used to determine potential exposure pathways for fishery organisms. The process through which environmental contaminants are accumulated in an organism is referred to as uptake. Target fish species may uptake oil through any of the following mechanisms:

- Adsorption or adhesion of oil on the skin or to the lipid surfaces in the gills
- Absorption of dissolved components from the water through the skin or through the gills
- Ingestion of whole oil droplets directly or on food contaminated with oil. Many factors influence oil uptake, such as the concentration and duration of exposure, and the feeding and metabolic rates of the organism. A detailed discussion of the relationship between habitat and ecological factors and contamination of seafood by oil spills is contained in the NOAA publication entitled, "Managing Seafood Safety After an Oil Spill" (Yender et al., 2004).

Potential Routes of Exposure to Vessels, Gear, and Processing Operations

Because of the manner in which Alaska's "zero tolerance" regulations are written and applied, the issue of oil spill impacts to commercial fisheries requires an assessment not only of the direct impact to the target species, but also to the potential contamination of vessels, gear, and seafood processing facilities.

The potential exposure pathways for commercial fishing vessels, gear, and processing operations depend largely upon the characteristics of the oil.

- Dissolved phase oil poses a risk to operations where seawater is extracted from a potentially contaminated source and used to store or process fish.
- Whole oil may directly contaminate fishing vessels or gear used to catch or process fish. Whole oil may also contaminate fish storage or processing by entering seawater intakes.

Selection of Sampling Methods

This manual organizes water quality sampling methods into four main categories:

- **Water column** sampling methods detect whole or dissolved phase oil in the water column;
- **Benthic** sampling methods detect whole oil in the bottom sediments;
- **Water intake** sampling methods detect whole or dissolved phase oil within the seawater circulation systems of vessels or seafood processors.
- **Fish gear and vessels** sampling methods detect whole oil on fishing vessels or gear.

Selection of one or more sampling methods will involve a consideration of the oil type, the anticipated behavior of the oil in water, and the potential implications to fishery organisms, fishing vessels and gear, and seafood processing operations. Figure II-1 provides a flow chart to assist in selecting a sampling method based on the oil type, fate and effect, and potential impacts.
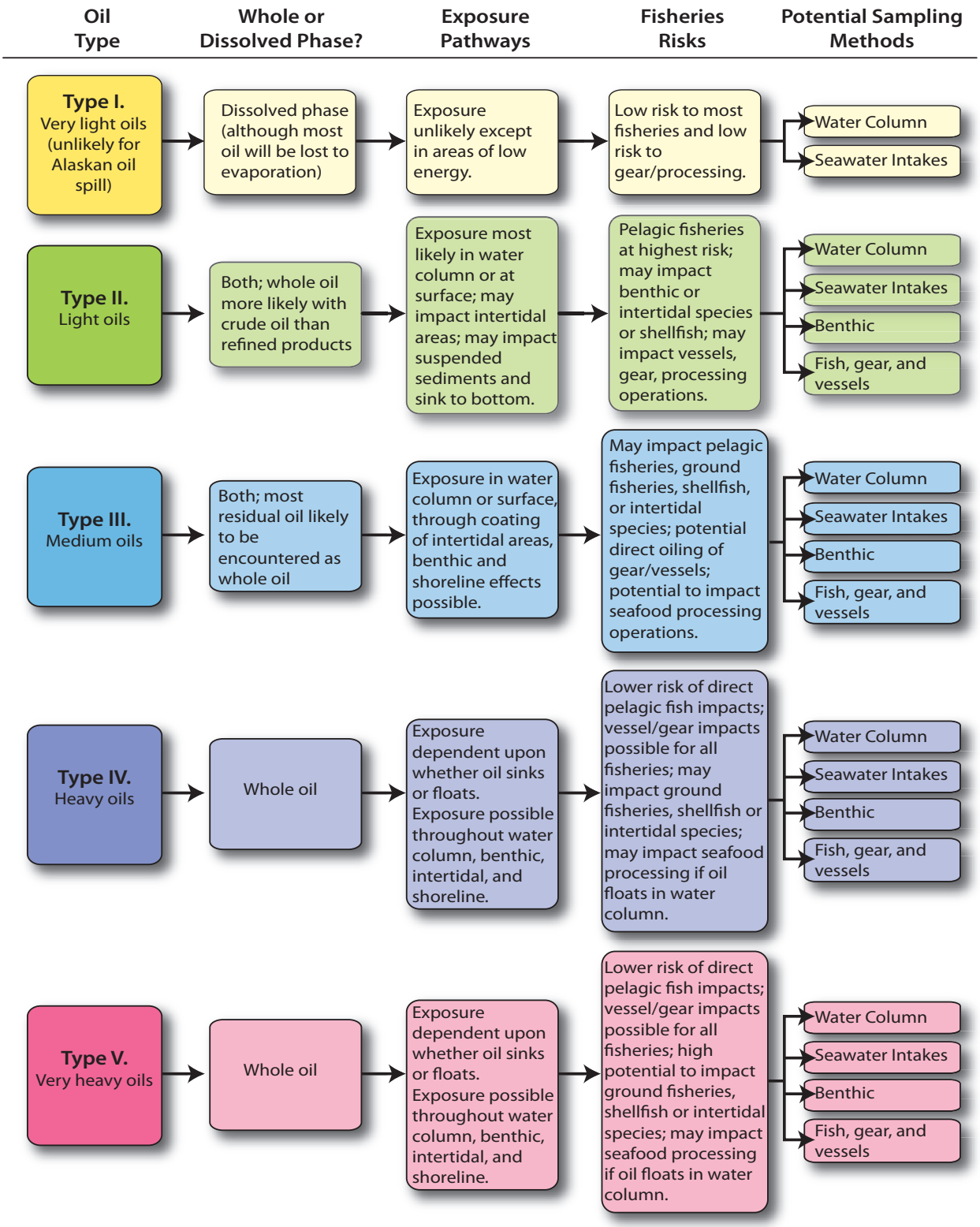
Figure II-1. Flow chart to assist in selecting sampling methods.