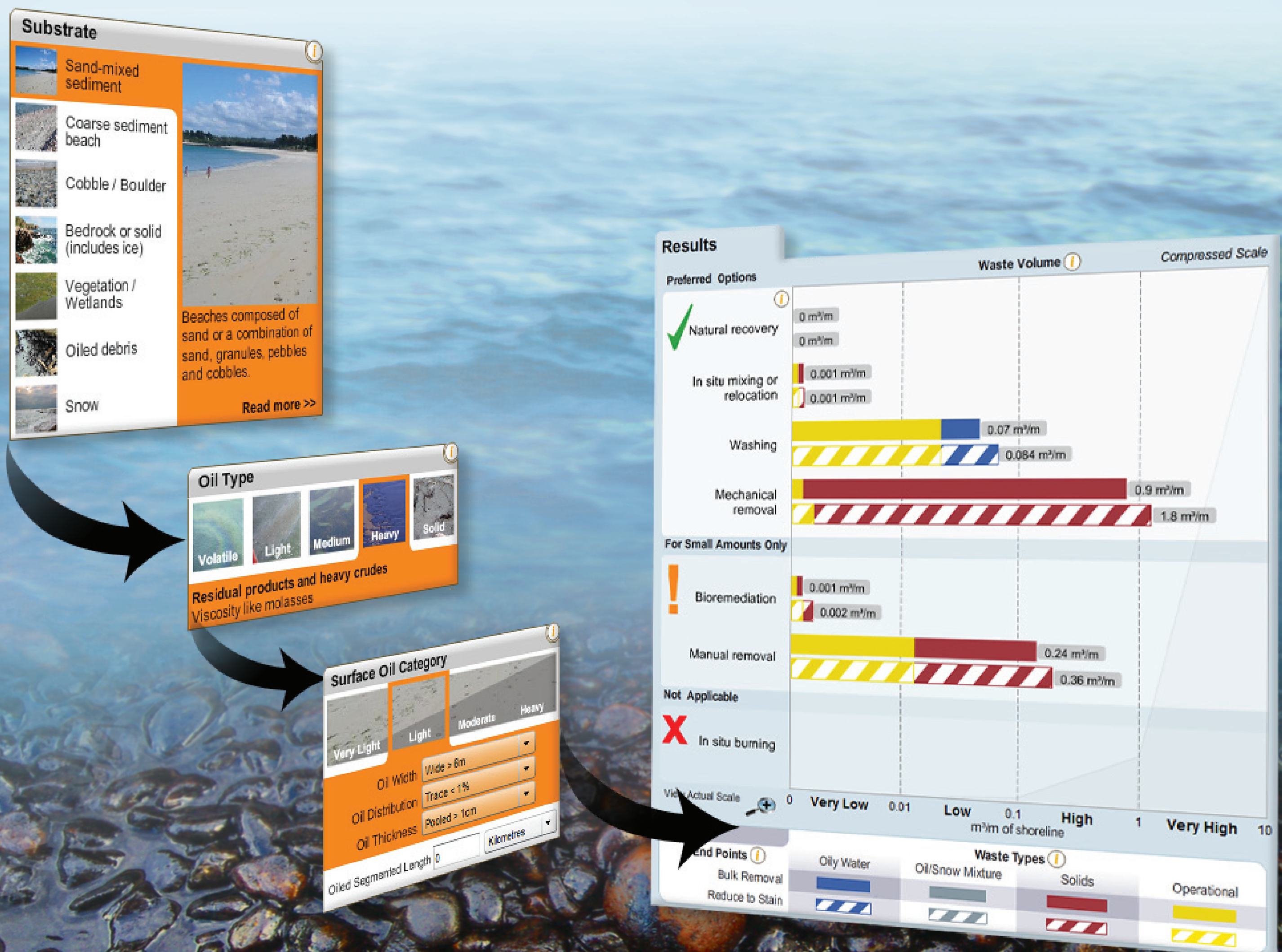
Waste Management Calculator



User's Guide

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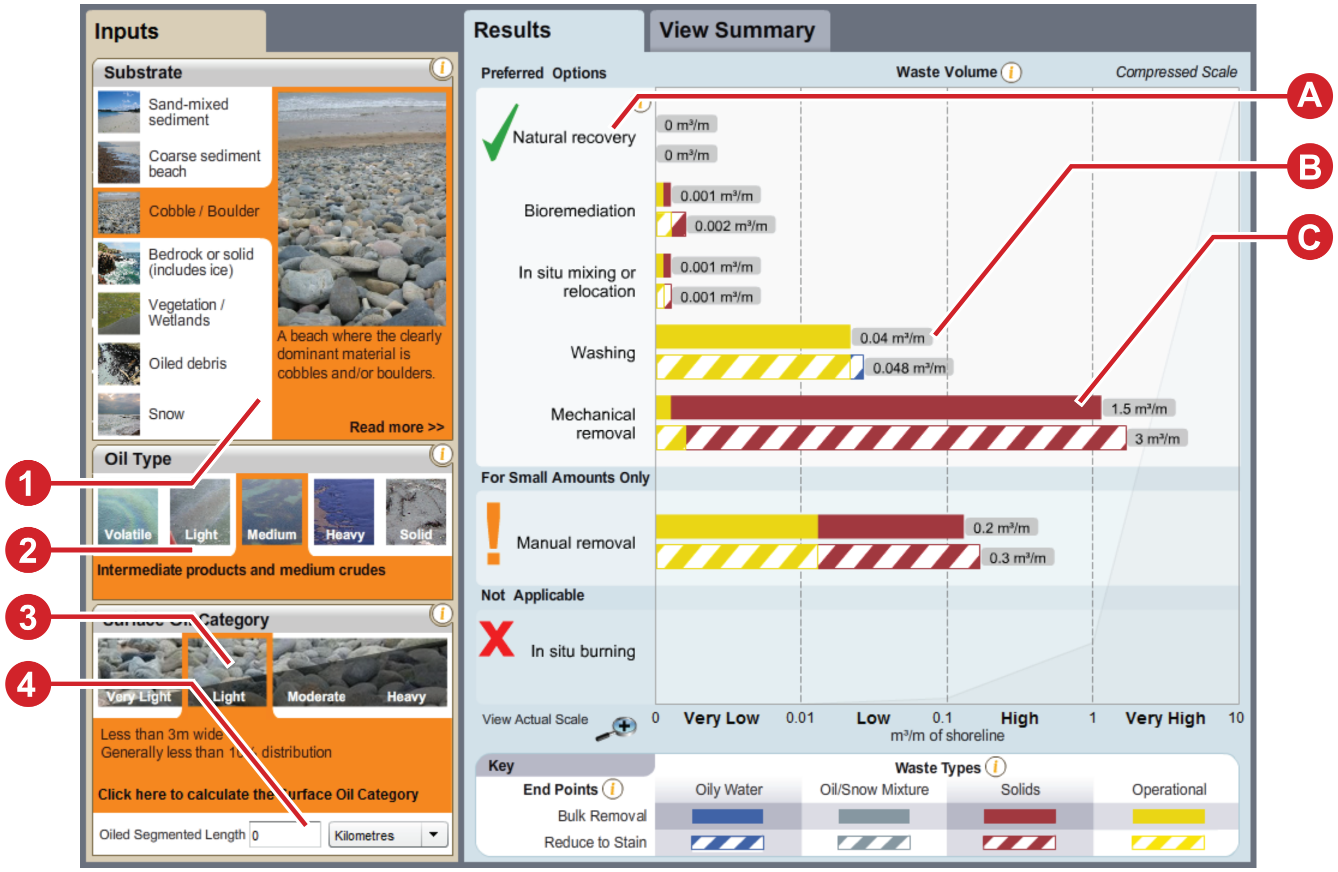
PAS/TOSTC, Waste Management Calculator – User's Guide. 2009. Polaris Applied Sciences Inc., Bainbridge Island, WA USA, and The Oil Spill Training Company Ltd., Inverness UK, 67 pp.

Contents

Chapter 1

Introduction

The Waste Management Calculator is an interactive, graphic-oriented computer tool for use by non-technical (or technical) managers, decision makers, and planners. This tool can be used to evaluate response options with regards to the types and approximate volumes of wastes that potentially would be generated by different response techniques and different treatment endpoint standards. The tool was developed jointly by Polaris Applied Sciences, Inc. and The Oil Spill Training Company Ltd, for the Emergency Prevention, Preparedness and Response (EPPR) Working Group of the Arctic Council under the direction of the Joint Secretariat (Inuvialuit Settlement Region), with support from the Governments of Canada, Norway and the United States.



Input

1. Substrate (shoreline) type
2. Oil type
3. Degree of oiling (surface oiling category)
4. Shoreline length (optional)

Output

A. Preferred treatment options

B. Oily waste volume
   - shoreline treatment endpoint

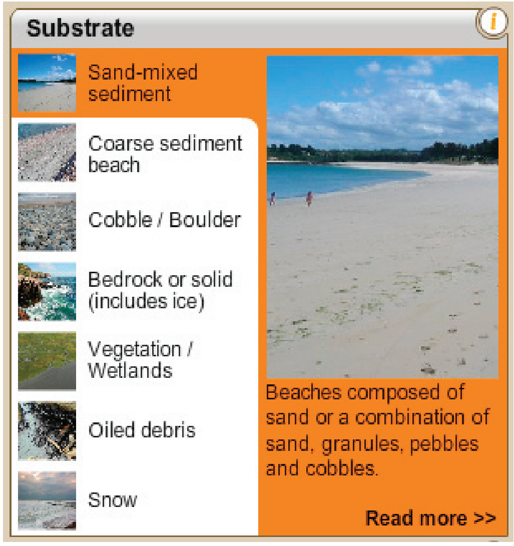
C. Waste types

Chapter 2

Operation of the Waste Management Calculator

Input

1

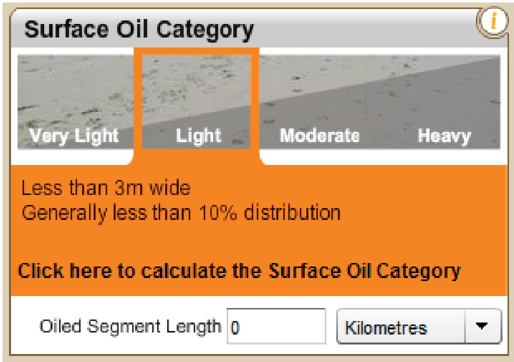


Select a **Substrate**
There is a choice of 7

2

Select an **Oil Type**
There is a choice of 5

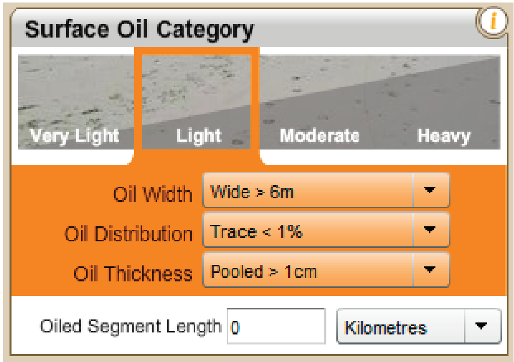
3a



Select a **Surface Oil Category**
There is a choice of 4

OR

3b
Optional



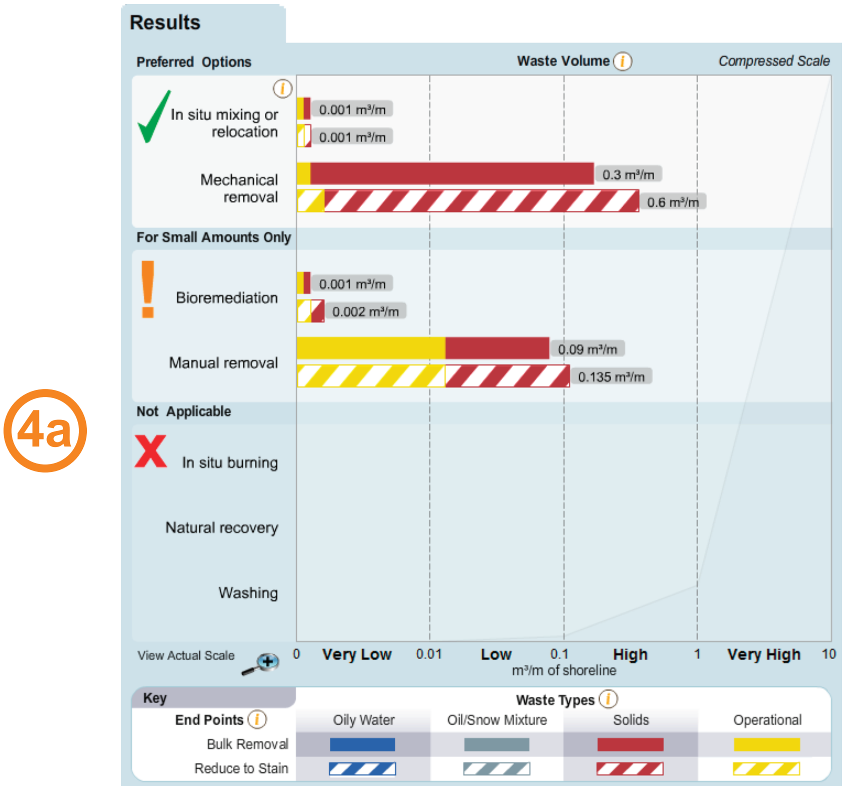
Calculate the **Surface Oil Category**

- Oil width (m)
- Oil distribution (%)
- Oil thickness (cm)

There is a further option to enter the Oiled Segment Length (various units)

Note:
Step 3a generates a default standard unit volume (m^3/m). Step 3b generates waste volume estimates for specific shoreline oiling conditions and lengths of oiled shoreline segments

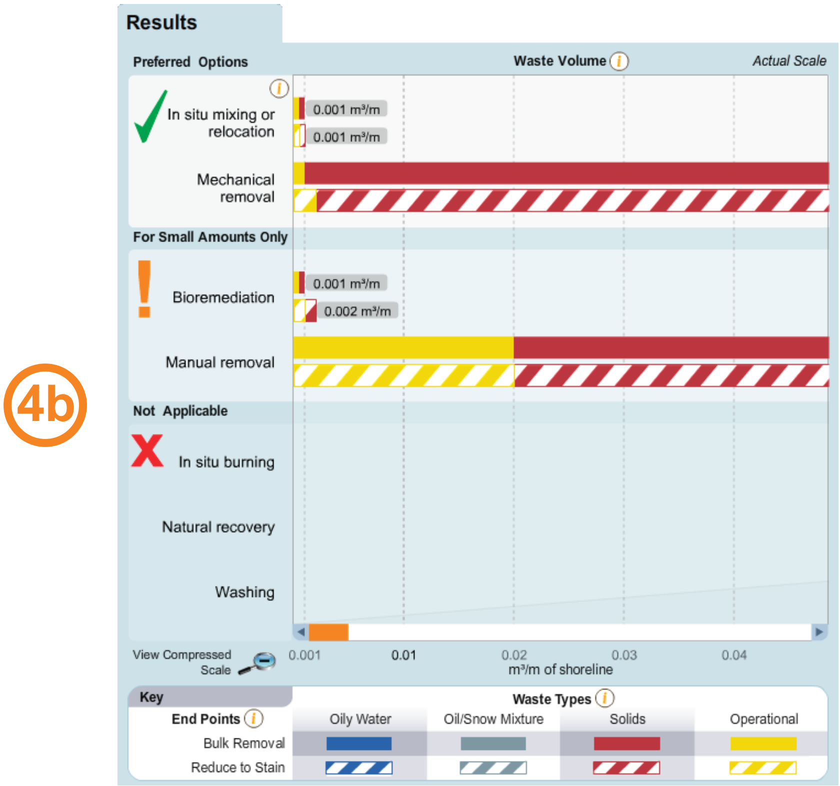
Output



A bar graph that presents the consequences of the selected input parameters is displayed automatically in **Results**

The **Treatment Tactic Options** are listed. The waste volumes for both treatment **endpoints** are displayed

Two Scales are available. In **Compressed Scale** the sub-sections are not in proportion and are not to scale; the full chart can be seen

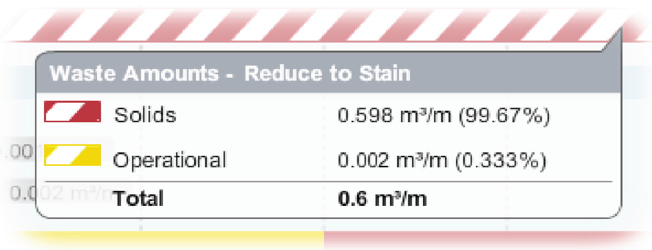


In **Actual Scale** each sub-section on the X-axis is of equal size and the output is shown in proportion

Scrolling is required to view the full chart

Output (cont.)

5

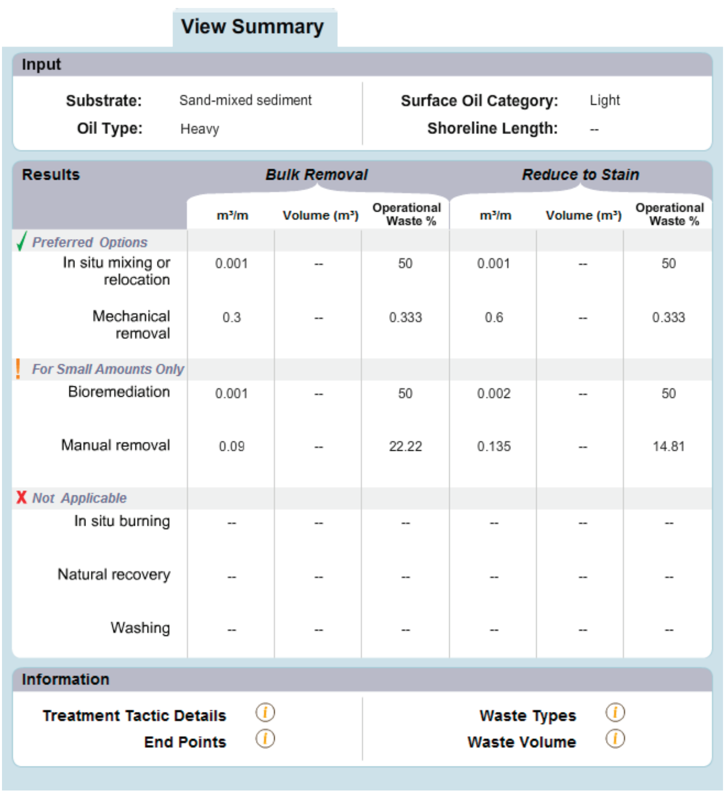


Place the cursor on any one of the horizontal bars:

- unit volume of each waste type (m^3/m)
- percent (%) of the total waste represented by that waste type
- total combined waste volume (m^3/m)

Note:
If the Oiled Segment Length is entered (step 3b) a second table will display the actual Waste Volumes (m^3)

6



View Summary

Input

Substrate:	Sand-mixed sediment	Surface Oil Category:	Light
Oil Type:	Heavy	Shoreline Length:	--

Results	Bulk Removal			Reduce to Stain		
	m³/m	Volume (m³)	Operational Waste %	m³/m	Volume (m³)	Operational Waste %
Preferred Options						
In situ mixing or relocation	0.001	--	50	0.001	--	50
Mechanical removal	0.3	--	0.333	0.6	--	0.333
For Small Amounts Only						
Bioremediation	0.001	--	50	0.002	--	50
Manual removal	0.09	--	22.22	0.135	--	14.81
Not Applicable						
In situ burning	--	--	--	--	--	--
Natural recovery	--	--	--	--	--	--
Washing	--	--	--	--	--	--

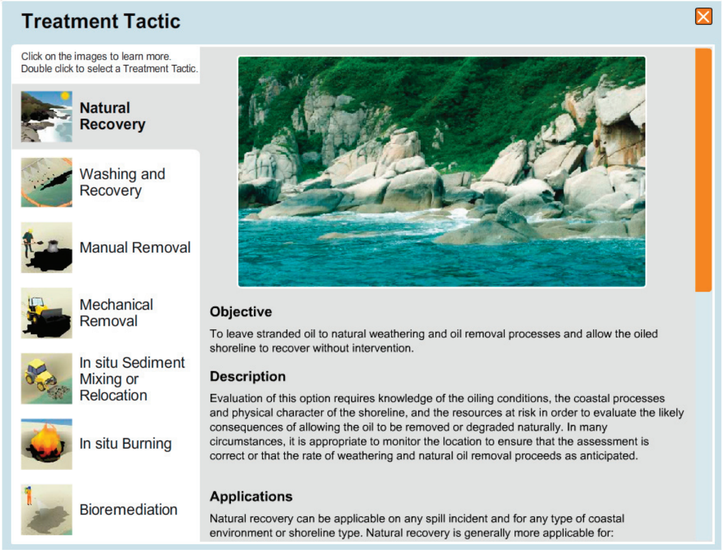
Information

Treatment Tactic Details
End Points
Waste Types
Waste Volume

Click on **View Summary** for a table containing:

- list of the input parameters
- the following for each treatment option and for each of the two treatment endpoints provides:
  - > unit volume of each waste type (m^3/m)
  - > percent (%) of the total waste represented by that waste type
  - > total combined waste volume (m^3/m)
  - > actual waste volume (m^3) if Oiled Segment Length is entered

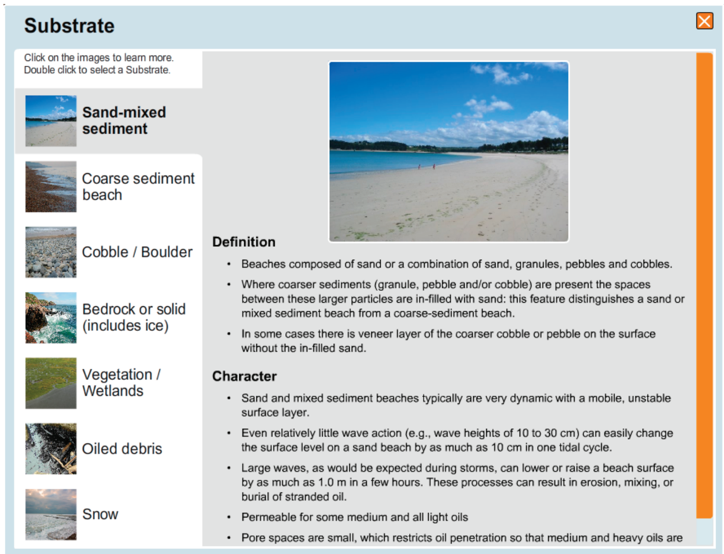
Output (cont.)



Click on any one of the icon boxes for information on that parameter or a definition of the term(s)

For example, first click on the icon box at the top of the **Preferred Options** and then on the thumbnail to view text for each of the seven **Treatment Tactics,** with pages on:

- Objective
- Description
- Applications
- Summary



Similarly, for **Substrate Type,** pages will be displayed on the **Definition** and **Character** for each of the seven types of substrate

Chapter 3

Parameters

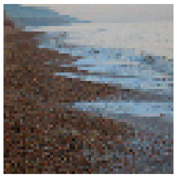
Input Parameters

Substrate (shoreline) Type

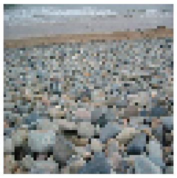
Shoreline treatment and cleanup manuals describe the physical character of the shore zone in different ways, but typically most are based on the primary character of the substrate type, as this parameter controls both the behavior of the oil and the selection of treatment tactics.

‘Oiled debris’ and ‘Snow’ have also been included as both of these materials may exist in conjunction with any of the five other substrates and, where present, constitute an important element of the response and waste management decision process.

Sand and mixed sediment beach



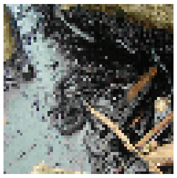
Coarse sediment beach



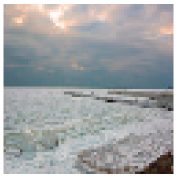
Cobble / Boulder sediment (includes most breakwaters)

Bedrock or solid (includes ice)

Wetland - vegetation



Oiled debris

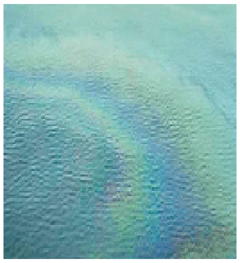


Snow

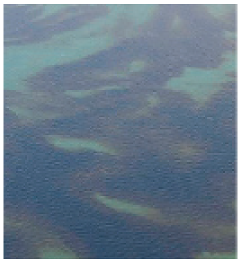
The substrate types are described in Appendix 1.

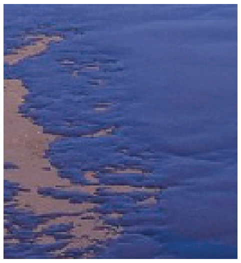
Oil Type

The five oil types used in the Waste Management Calculator are defined in Appendix 2.


Volatile


Light


Medium


Heavy


Solid

Surface Oil Category

All planning decisions are based on an estimate of the amount of oil that is involved. For oil stranded on shorelines the standard procedure follows the Shoreline Clean Assessment Technique (SCAT) process (Owens and Sergy 2000 and 2004: MCA 2007: NOAA 2007). The width of the oiled zone and distribution of oil, expressed as the percentage of the substrate surface that is covered by oil, are combined to provide four categories that define the degree of oiling. The definitions of these categories are provided in Appendix 3.

One option (Step 3a) is to take the standard SCAT 'Degree of Oiling' which is based on a combination of the surface distribution (%) and the width of the oiled area: Heavy (H), Moderate (M), Light (L), and Very Light (VL).

The alternative option (Step 3b) is to enter specific information on the width of the oiled band, surface oil distribution (%), oil thickness, and the length of the oiled shoreline. This option can be used as a planning tool to calculate estimated oily waste generation using real or simulated shoreline oiling data.

Treatment Endpoint

The selection of the shoreline treatment endpoint or endpoints is an essential and critical element of the decision and planning process as this controls the level of effort that is required to meet the treatment objective and, in turn, the volume of waste that is generated by the treatment activities (Sergy and Owens 2007 and 2008). Two commonly used endpoint standards were used for The Waste Management Calculator (Appendix 4):

Removal of Bulk Oil

Reduction to a Stain

'Bulk Oil' refers to stranded oil that could easily be remobilized by tide or wave action. Removal of this oil is typically the first stage of a response operation and, in remote areas, may be sufficient to meet the response objectives. A more thorough treatment could involve the reduction of the stranded oil so that only a Stain (oil thickness ≤ 0.01 cm) remains. The level of effort and the amount of waste that is generated increases as the endpoints become more stringent.

Treatment Tactic

Shoreline treatment or cleanup manuals describe the treatment options in different ways. For example, the Environment Canada Shoreline Treatment Manuals describe a total of twenty individual shoreline response tactics. These tactics can be grouped on the basis of the primary treatment strategy.

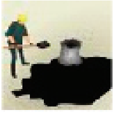
Two tactics not included, dispersants and shoreline cleaners, are appropriate options in certain circumstances and their application typically requires government approval. **Dispersants** are an In-situ treatment tactic and the waste estimates would be in the same range as those for Bioremediation. **Shoreline cleaners** involve collection of the oil and waste volumes would be similar to those for Washing and Recovery.

Natural recovery

In-situ sediment mixing and/or relocation

Washing and recovery

In-situ burning



Manual removal

Bioremediation

Mechanical removal

Each of the seven tactics are described in Appendix 5. For each tactic, an assessment is provided to summarize the key efficiency factors that would be considered in the decision process; these have been consolidated in Table 3.1.

Shoreline Length (optional)

The waste volumes can be calculated either as:

- a standard unit volume (cubic meters per length of oiled substrate - m^3/m) based on the selected degree of oiling (surface oil category) that best represents the character of the stranded oil, or
- a calculated volume (m^3) for a specific length of oiled shoreline

To perform the latter calculation, the operator places the cursor on "**Click here….**" in the Surface Oil Category box in lower left of the screen and selects:

- Oil width (m)
- Oil distribution (%)
- Oil thickness (cm)
- Shoreline length (various units from which to choose)

The drop down options follow standard SCAT terminology and so the results of field surveys can be used to calculate Waste Volumes for specific oiling conditions during a spill operation or for a drill scenario.

Technique	Labour Requirements	Treatment Rate^	Single- or Multiple-Step	Waste Generation
Natural Recovery				
Natural Recovery	only monitoring	not applicable	not applicable	none
Washing and Recovery Techniques				
Flooding	labour intensive	slow	multiple	can be high if collection is done with sorbents
Washing				
Spot Washing				low-moderate
Manual Removal Techniques				
Shovels, rakes	labour intensive	slow	multiple	low-moderate
Vacuums				moderate
Vegetation Cutting				can be high
Sorbents	labour intensive if used extensively with large amounts of oil			can be high if frequent change-outs required
Mechanical Removal Techniques				
Grader	minimal labour support	very rapid	multiple	moderate
Bulldozer		rapid		very high
Scraper		very rapid	single	moderate
Front-end Loader		rapid		high
Backhoe / Excavator		medium		
Dragline/ Clamshell				
In-Situ Sediment - Mixing Treatment				
Dry Mixing	minimal labour support	very rapid	single	minimal
Wet Mixing				
Sediment Relocation				
In-Situ Burning				
In Situ Burning	minimal labour support	very rapid	single	minimal
Bioremediation				
Bioremediation	minimal labour support	very rapid	Single to multiple	minimal

Table 3.1 *Summary of Efficiency Factors for Shoreline Treatment Tactics*
^ Treatment rate refers to the time required to undertake the operational aspect of the treatment.

Output

For the selected input parameters, The Waste Management Calculator:

1. Identifies the preferred shoreline treatment options
2. Calculates the estimated amount of waste that typically would be generated
3. Identifies the amount and percent of the type(s) of waste that are associated with each treatment option

These numerical values represent a reasonable estimate of the amount and type of waste as compared to actual data obtained from response operations.

The results of the calculations, or consequences, for the selected input parameters are presented as bar graphs and in tabular form. In both cases, the treatment options are grouped into:

✓ **Preferred Options**

! **For Small Amounts Only**

X **Not Applicable**

The bars associated with each treatment option represent the two Treatment Endpoints, with the upper bar representing the values associated with Bulk Oil Removal and the lower bar the treatment reduction to a Stain (see example on Page 8). The Waste Volume value is shown at the end of each bar. These values are either cubic meters per length of oiled shoreline (m^3/m) if only the surface oil category is selected or are cubic meters (m^3) if the shoreline length, width, distribution and thickness values are used for the calculation.

The bars can be viewed either as a Compressed Scale presentation or as the Actual Scale.

In the Compressed Scale format (Step 4a on Page 8) the subsections on the X-axis are not in proportion and are not to scale, however, the full chart can be seen. The X-axis subsections are based on the following four categories of Waste Volumes:

Very High	≥ 1.0 m^3/m
High	0.1 to 0.99
Low	0.01 to 0.099
Very Low	< 0.01

In the Actual Scale format (Step 4b on Page 8) each subsection on the X-axis is of equal size and the output is shown in proportion. The full chart can be viewed by scrolling.

The example provided on Page 8 represents the waste volume results for:

- Sand-mixed Sediments
- Medium Oil Type
- Heavy Surface Oil Category

and follow Step 3a on Page 7, rather than the calculated Surface Oil Category, so that the output is expressed in m^3/m.

Chapter 4

Assumptions

The graphical output is based on approximately 2000 separate volume calculations that are the results of combining:

- seven (7) shoreline types
- five (5) oil types
- four (4) oil volumes
- seven (7) treatment tactics
- two (2) endpoint criteria

This section of the User's Guide describes the key assumptions used in the calculations.

Shoreline Type and Treatment Tactic

The first step in the process defines whether each of the 7 treatment tactics is appropriate for the 7 substrate types and the 5 oil types. The results of this review are provided in Table 4.1. 'YS' indicates that the tactic applies but typically for only small amounts of oil (i.e. localized amounts rather than Very Light or Light oil categories).

	Treatment Tactic - Volatile Oil						
Substrate Type	Natural Recovery	Washing Recovery	Manual Removal	Mechanical Removal	In-situ Mixing Relocation	In-situ Burning	Bio-remediation
sand-mixed	Y	Y	N	N	N	N	N
coarse sediment	Y	YS	N	N	N	N	N
cobble / boulder	Y	Y	N	N	N	N	N
bedrock - solid	Y	Y	YS	N	N	N	N
vegetation	Y	Y	N	N	N	Y	N
oiled debris	Y	N	Y	Y	N	Y	N
snow	Y	Y	YS	Y	Y	Y	N

	Treatment Tactic - Light Oil						
Substrate Type	Natural Recovery	Washing Recovery	Manual Removal	Mechanical Removal	In-situ Mixing Relocation	In-situ Burning	Bio-remediation
sand-mixed	Y	Y	YS	Y	Y	N	YS
coarse sediment	Y	Y	YS	Y	Y	N	YS
cobble / boulder	Y	Y	YS	Y	Y	N	YS
bedrock - solid	Y	Y	YS	N	N	N	YS
vegetation	Y	Y	N	N	N	Y	N
oiled debris	Y	N	YS	Y	N	Y	N
snow	Y	Y	YS	Y	Y	Y	N

Tables 4.1

Substrate Type	Treatment Tactic - Medium Oil						
	Natural Recovery	Washing Recovery	Manual Removal	Mechanical Removal	In-situ Mixing Relocation	In-situ Burning	Bio-remediation
sand-mixed	Y	Y	YS	Y	Y	N	YS
coarse sediment	Y	Y	YS	Y	Y	N	YS
cobble / boulder	Y	Y	YS	Y	Y	N	YS
bedrock - solid	Y	Y	YS	N	N	N	YS
vegetation	Y	Y	YS	N	N	Y	N
oiled debris	Y	N	YS	Y	N	Y	N
snow	YS	Y	YS	Y	Y	Y	N

Substrate Type	Treatment Tactic - Heavy Oil						
	Natural Recovery	Washing Recovery	Manual Removal	Mechanical Removal	In-situ Mixing Relocation	In-situ Burning	Bio-remediation
sand-mixed	N	N	YS	Y	Y	N	YS
coarse sediment	N	N	YS	Y	Y	N	YS
cobble / boulder	N	N	YS	Y	N	N	YS
bedrock - solid	YS	Y	YS	N	N	N	YS
vegetation	YS	N	YS	N	N	Y	N
oiled debris	Y	N	YS	Y	N	Y	N
snow	N	N	YS	Y	N	N	N

Substrate Type	Treatment Tactic - Solid Oil						
	Natural Recovery	Washing Recovery	Manual Removal	Mechanical Removal	In-situ Mixing Relocation	In-situ Burning	Bio-remediation
sand-mixed	N	N	YS	Y	N	N	N
coarse sediment	N	N	YS	Y	N	N	N
cobble / boulder	N	N	YS	N	N	N	N
bedrock - solid	YS	Y	YS	N	N	N	N
vegetation	N	N	YS	N	N	N	N
oiled debris	Y	N	YS	Y	N	N	N
snow	N	N	YS	Y	N	N	N

Tables 4.1 *(continued)*

Volume of Stranded Oil

The volume of oil (liters) per unit area (m^2) is calculated from Table 4.2.

Category	Distribution (%)	Oil Width (m)	Thickness (m)	Volume (l)
Heavy	100	4.5	0.001	45
Moderate	50	2.5	0.001	12.5
Light	10	1.5	0.001	1.5
Very Light	5	1	0.001	0.5

Table 4.2 *Oil Volume Calculation*

Penetration and Volume of Oiled Sediment

The volume of oiled material on sedimentary substrates takes into account estimates of penetration. The depths of cut for manual and mechanical removal are assumed to be the same as the depths of penetration (Table 4.3).

A. Manual Removal

	Volatile and Light Oils (cm)	Medium, Heavy and Solid Oils (cm)
Sand-mixed	50	10
Coarse sediment	20	20
Cobble / boulder	25	25

B. Mechanical Removal

	Volatile and Light Oils (cm)	Medium, Heavy and Solid Oils (cm)
Sand-mixed	50	20
Coarse sediment	50	50
Cobble / boulder	100	100

Tables 4.3 *Depth of Oil Penetration into Sediments*

Estimated Liquid Recovery Rates from Washing

The assumption is made that oil and water are separated during the recovery process. The amounts of oily liquids recovered depends to a large degree on the amount of stranded oil (see Table 4.2 above) and the oil type (Table 4.4).

Amount of Oil	Volatile and Light Oils (%)	Medium, Heavy and Solid Oils (%)
Heavy	40	60
Moderate	40	60
Light	20	40
Very Light	20	20

Table 4.4 *Recovery Rates from Washing Oiled Substrates*

Operational Waste

The recent (2007-2008) "M/V Cosco Busan" response involved predominantly manual cleaning and washing. During this response 4,200 m^3 oily waste was generated from the treatment of 100.9 km of oiled shoreline, 65 km of which was VL. This is equal to an average of $1 m^3$ of waste generated for every 24 m of oiled shoreline – all oiling categories combined. Based on this data, the following assumptions are made for oily waste (Personal Protective Equipment (PPE,) sorbents, oil and sediments) generated by Manual Treatment and Washing/Recovery.

Manual Treatment = 0.02 m^3 per meter length of oiled shoreline
Washing/Recovery = 0.04 m^3 per meter length of oiled shoreline

The generation of non-oily solid waste (food, paper, cardboard, plastics, metal and glass) in remote areas by the response teams was evaluated, based on:

1. One support person for each responder (Carpenter et al. 1991)
2. A US Navy value for shipboard solid waste generation of 0.012 m^3/person/day (Kelly et al. 1997)
3. Manual treatment rates of 1000m^2 /day with crew sizes varying from 20 responders for Very Light oiling to 100 responders for Heavy oiling to achieve this rate
4. Washing rates of 50m^2 / hour (400 m^2/day) with crew sizes vary from 20 responders for Very Light oiling of Volatile and Light Oils to 200 responders for Heavy oiling of Medium, Heavy and Solid Oils to achieve this rate

This value was not included in the final volume estimates as the highest waste volume values generated by these calculations are at least one order of magnitude below any of the calculated oil waste volumes for Manual Treatment and Washing / Recovery.

Chapter 5

Calculations

The assumptions described in Chapter 4 provide the basis for the series of calculations that were used to generate the estimated waste volumes.

Washing and Recovery

This calculation is based on the assumptions of the volume of oil stranded on the shoreline (Table 4.2) and the estimate of the amounts of oil (%) that would be recovered following washing, assuming skimming and oil-water separation (Table 4.4). Waste generated by PPE and sorbents is added based on the values given in Chapter 4.

Manual Removal

The calculated value is based on:

- Depth of cut (Table 4.3)
- Width of oiled band (Table 4.2)
- PPE (Chapter 4)

Manual removal on Bedrock and of Oiled Debris = 75% of the Sand-mixed value.

Mechanical Removal

The calculated value is based on:

- Depth of cut (Table 4.3)
- Width of oiled band (Table 4.2)
- PPE (Chapter 4)

Mechanical removal of Oiled Debris = 75% of the Sand-mixed value.

Vegetation – Manual Cutting

Unpublished data from the Rio Desaguadero spill response indicates that manual vegetation cutting generated in the order of 0.07 to 0.23 m^3/m^2.

The waste generated during the Selandang Ayu response from manual cutting of Light-Moderate oiled vegetation in SKN-14 was 420.9 m^3 for an area of 57,000 m^2, or 0.007 m^3/m^2.

Waste is calculated on the basis of 0.1 m^3/m oiled shoreline length x the oil band width (Table 4.2). PPE is added as per Chapter 4.

In-situ Sediment Mixing and/or Relocation

The tactic is intended to involve only mechanical actions and not any follow on manual pick up. Waste constants of 0.001 and 0.002 m^3/m are applied for the two treatment levels. If a second phase of treatment is required to meet the treatment endpoint then the waste generation values for manual removal would have to be added.

In-situ Burning

The tactic would be used to burn oiled vegetation, oiled debris or pooled oils. The assumption is that these would be burned completely.

A small amount of waste would be generated from used PPE and packaging (Chapter 4).

Bioremediation

The waste generated is only that associated with PPE and packaging (Chapter 4).

Snow

Snow depth is highly variable and for this exercise a universal 1 m depth has been adopted. A cubic meter of snow can sorb up to 200 liters of light oil and potentially as much as 400 liters of medium oil.

- It is assumed that manual removal can separate oil from snow to some degree but that mechanical tactics remove the entire 1 m depth
- Waste volume is based on a 1 m depth and the width of oiled band parameter (Table 4.2) per meter length
- The volume generated by the Manual Removal tactic is assumed to be half that of the Mechanical Removal tactic

The value is the amount of the snow-oil mixture that would be generated prior to any second-phase treatment. PPE waste constants (Chapter 4) are applied to Manual Removal (0.001 and 0.002 m^3/m) for the two treatment levels.

Treatment Endpoints

All calculations are generated for 'Bulk Oil removal' treatment endpoint operation. The multipliers listed in Table 5.1 are applied when the treatment endpoints change from 'Bulk Oil Removal' to 'Removal to Stain'.

Treatment Tactic	Weighting Factor
Washing	1.2
Manual removal	1.5
Mechanical removal	2.0
In-situ mixing / relocation	1.0
In-situ burning	2.0
Bioremediation	2.0
Vegetation cutting	4.0

Tables 5.1 *Weighting Factors for Increased Treatment Endpoints*

Chapter 6

References

References

Carpenter, A.D., R.G. Dragnich and M.T. Smith 1991. Marine Operations and Logistics during the “Exxon Valdez Spill” Cleanup. Procedings International Oil Spill Conference, American Petroleum Institute, Washington, DC, Publication No. 4529, 205-211

ExxonMobil 2005. Oil Spill Response Field Manual. ExxonMobil Research and Engineering Co., Fairfax, VA, 300 pp.

IPIECA 2004. Guidelines for Oil Spill Waste Minimization and Management. International Petroleum Industry Environmental Conservation Association, London, Report Series Vol. 12, 19 pp.

Kelly, C.M., W.K. Upton III, and A. Budzichowski 1997. Shipboard Solid Waste Management Equipment Guide. U.S. Navy, Survivability, Structures and Materials Directorate, Naval Surface Warfare Center, Report NSWCCD-TR-63-97/25, West Bethesda MD, 97 pp [1] .

MCA 2007. The UK SCAT Manual: A Field Guide to the Documentation of Oiled Shorelines in the UK. Maritime & Coastguard Agency, Southampton, UK, 47 pages + vi.

NOAA 2007. Shoreline Assessment Job Aid. National Oceanographic and Atmospheric Administration, Office or Response and Restoration, Seattle, WA, 35 pp[2].

PAS, 2009. Guidelines and Strategies for Oil Spill Waste Management in Arctic Regions. Unpublished report by Polaris Applied Sciences, Inc., Bainbridge Island, WA USA, for Joint Secretariat, Inuvialuit Renewable Resources, Inuvik, NT Canada, 46 pp. + appendices.

Owens, E.H. and G.A. Sergy 2000. The SCAT Manual - A Field Guide to the Documentation and Description of Oiled Shorelines (Second Edition). Environment Canada, Edmonton AB, 108 pp.

Owens, E.H. and G.A. Sergy 2004. The Arctic SCAT Manual – A Field Guide to the Documentation of Oiled Shorelines in Arctic Regions. Environment Canada, Edmonton AB, 172 pages.

Owens, E.H., E. Taylor, K. O’Connell and C. Smith. 2009. Waste Management Guidelines for Remote (Arctic) Regions. Proceedings 32nd Arctic Marine Oilspill Program (AMOP) Technical Seminar, Environment Canada, Ottawa ON.

Sergy, G.A. and E.H. Owens 2007. Guidelines for Selecting Shoreline Treatment Endpoints for Oil Spill Response. Emergencies Science and Technology Division, Environment Canada, Ottawa, ON, 30 pp.

Sergy, G.A. and E.H. Owens 2008. Selection and Use of Shoreline Treatment Endpoints for Oil Spill Response. Proceedings International Oil Spill Conference, American Petroleum Institute, Washington DC, 435-441.

1 http://www.p2pays.org/ref/21/20771.pdf
2 http://response.restoration.noaa.gov/book_shelf/71_jobaid_shore_assess.pdf

Appendix 1

Substrate Types

Sand and Mixed Sediment Beach

Definition

A beach composed of sand or a combination of sand, granules, pebbles and cobbles.

Where coarser sediments (granules, pebbles and/or cobbles) are present, the spaces between these larger particles are in-filled with sand: this feature distinguishes a sand or mixed sediment beach from a coarse sediment beach.

In some cases, there is veneer layer of the coarser cobble or pebble on the surface without the in-fill sand.

Character

Sand and mixed sediment beaches are typically very dynamic with a mobile, unstable surface layer.

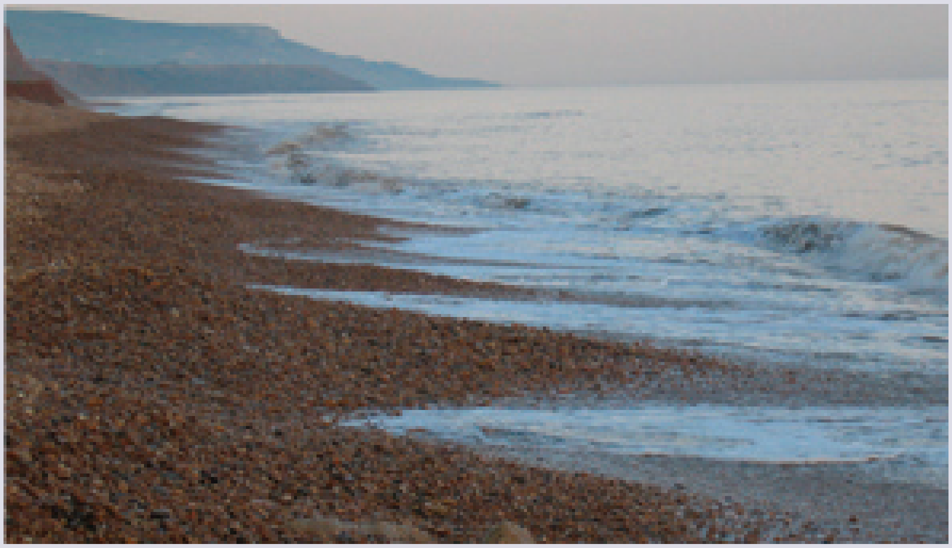
Even relatively little wave action (e.g. wave heights of 10 - 30 cm) can easily change the surface level on a sandy beach by as much as 10 cm in one tidal cycle.

Large waves, as would be expected during storms, can lower or raise a beach surface by as much as 1.0 m in a few hours. These processes can result in erosion, mixing or burial of stranded oil.

Permeable for some medium and all light oils.

Pore spaces are small, which restricts oil penetration so that medium and heavy oils are unlikely to penetrate more than 25 cm.

Coarse Sediment Beach



Definition

A beach where the clearly dominant material is pebbles and/or cobbles. Pebbles have a grain-size diameter of 4 - 64 mm; cobbles are in the 64 - 256 mm range.

The interstitial spaces are relatively open and not in-filled with finer material. Some sand may be present e.g. ≤10%. Granules (diameter 2 - 4 mm) are usually included in the pebble category.

For comparison, 4 mm is about the width of a pencil, 64 mm is approximately the size of a tennis ball, and 256 mm is a little larger than a soccer ball (225 mm) or a basketball (240 mm).

Character

Pebble-cobble beaches are very permeable and have a dynamic, mobile, unstable surface layer.

The interstitial or pore spaces between the individual pebbles or cobbles are open.

The supply of coarse sediment usually is very low. Sediment that is removed may be replaced only at a very slow rate (decades) or not at all.

Coarse sediment beaches are permeable to all but semi-solid oils so that subsurface oiling would be expected.

Depth of oil penetration is a function of the oil type (viscosity) and the sediment size. The larger the particle size the easier it is for oil to penetrate. However, retention is also relatively low so that the oil can be flushed naturally from these coarse sediments.

Oil-in-sediment amounts (by weight or by volume) are usually very low, often less than 1% unless the oil is pooled or very thick.

Light or non-sticky oils may be easily flushed out of the surface or subsurface sediments by tidal pumping.

Usually, only the surface layer of sediments is reworked by normal wave action. Oil that penetrates below the surface may not be physically reworked except during infrequent, high-energy storms or run-off events.

Cobble / Boulder

Definition

A beach where the clearly dominant material is cobbles and/or boulders. Cobbles are in the 64 - 256 mm range and boulders are greater than 256 mm.

The interstitial spaces are relatively open and not in-filled with finer material. Some sand may be present e.g. ≤10%. Granules (diameter 2 - 4 mm) usually are included in the pebble category.

For comparison, 4 mm is about the width of a pencil, 64 mm is approximately the size of a tennis ball, and 256 mm is a little larger than a soccer ball (225 mm) or a basketball (240 mm).

Character

Cobble / boulder beaches are very permeable and the interstitial or pore spaces between the individual cobbles or boulders are open.

Sediment supply to this type of beach is usually very slow. Sediment that is removed may be replaced only at a very slow rate (decades) or not at all.

Cobble / boulder beaches are permeable to all but the semi-solid oils so subsurface oiling is expected.

Depth of oil penetration is a function of the oil type (viscosity) and the sediment size. The larger the particle size, the easier it is for oil to penetrate. However, retention is also relatively low so that the oil can be flushed naturally from these coarse sediments.

Oil-in-sediment amounts (by weight or by volume) are usually very low, often less than 1% unless the oil is pooled or very thick.

Oil residence time or persistence is primarily a function of the oil type, depth of penetration, retention factors and wave-energy levels on the beach.

Light or non-sticky oils may be easily flushed out of the surface or subsurface sediments by tidal pumping.

Usually, only the surface layer of sediment is reworked by normal wave action. Oil that penetrates below the surface may not be physically reworked except during infrequent, high-energy storms or run-off events.

Bedrock or Solid (includes ice)

Definition

Bedrock shorelines are impermeable outcrops of consolidated native rock.

Ice shorelines occur where glaciers or ice shelves reach the coast, where permafrost is exposed or where solid seasonal ice forms on the shore.

Character

Resistant bedrock outcrops, such as granites, are stable whereas non-resistant bedrock types, such as sandstone or chalk are easily abraded by wave and ice action; the surface may erode at the rates in the order of several cm/year.

A stable surface on which a zonation of plants and animals in the intertidal zone is common. Biological communities usually are more prolific in the subtidal or lower intertidal zones. On coasts where ice is common, there are few attached intertidal organisms or plants due to the reduced growing season and ice abrasion. This is particularly true on exposed bedrock shorelines with steep slopes. The biological community usually is scraped off the bedrock each year so that plants and animals only survive in cracks and crevices where they are protected from scouring.

Bedrock is impermeable so that stranded oil remains on the surface of the outcrop.

The presence of an ice foot or a frozen ice layer prevents oil from making contact with the shoreline substrate.

Wetland - Vegetation

Definition

A coastal zone that is covered at least once a month by salt or brackish water at high tide and which supports significant (>15% cover) non-vascular salt-tolerant plants (e.g. grasses, rushes, reeds, sedges).

The primary type of marine wetland is a salt marsh and the following material focuses on this variation. Other marine wetlands include mangroves (found in tropical locations) and supratidal meadows.

Character

Saltwater marshes are common in sheltered wave-energy environments, such as estuaries, lagoons, deltas, or behind barrier beaches. Marshes usually:

- develop above the high-tide level and are only flooded during spring high-tides or wind-driven surges
- support a stable surface-vegetation cover and root system, the leafy portion of which dies-back during winter months
- are characterized by a surface accumulation of organic matter deposited in water, although inorganic sediments dominate the substratum

Oil can impact the fringe of a wetland during neap high-tides or normal water levels, or can be deposited on higher interior meadow areas during periods of spring tides or higher water levels. Fringe oiling may be washed by subsequent tides and weathered more rapidly, depending on energy levels. Oil on the meadow area, which experiences little or no current and wave action, would weather slowly.

Most oil types readily adhere to, and are retained on the stems and leaves of vegetation; the width (i.e. height) of an oiling coating band would vary depending on the tidal stages. Oil may or may not adhere to the sediments.

Light oils can penetrate into marsh sediments or fill animal burrows and cracks.

Medium to heavy oils tend to pool on the sediments, frequently creating a tenacious tarry surface cover as they weather. Due to the low wave energy level, the oil may persist for very long periods. The fine mud substrate prevents penetration.

Natural recovery rates vary depending on the oil type, total area affected, oil thickness, plant type, growth rates and season during which the oil occured. Recovery may take as little as a few years following light oiling but can take decades in extreme circumstances (extensive, thick deposits of viscous oil).

Oiled Debris

Definition

Scattered organic or inorganic materials that have washed up onto the shore. These materials are not part of the normal shore zone substrate such as: sediments, attached animals (e.g. mussels or barnacles), live sea grasses or marsh plants.

Character

Organic debris can range in size and character from small twigs or leaf material to shells, seaweed mats, branches, and logs.

Debris can include inorganic or synthetic materials, such as plastic bottles, cans, metal, rubber, styrofoam, or trash.

Debris is typically deposited in the same zone (upper intertidal) where floating oil strands on shorelines so that mixing of oil and debris is likely.

Large accumulations of shells or logs can dominate the shore zone character and in effect become the substrate type. In these cases the behaviour of stranded oil is similar to the size range of the naturally occurring equivalent material.

Snow

Definition

A shoreline composed of seasonal snow that covers the underlying substrate.

Character

The character of the snow surface can be highly variable, ranging from:

- Fresh powder with a soft surface or drifting snow
- A loose granular surface that results after powder or packed powder thaws, then refreezes and recrystalizes, or from an accumulation of sleet
- A hard dry crusty surface
- Wet slush

Snow can accumulate with a simple vertical variation in density and porosity. Typically, this steady accumulation is interrupted by the effects of freeze-thaw cycles and wind. As air temperatures oscillate around the freezing point, ice layers are generated as snow melts during daylight warm-temperatures and freezes at night when temperatures drop below zero. If this freeze-thaw cycle is accompanied by precipitation, a range of features can form that may include alternate layers of snow and ice.

Snow accumulates on another substrate so that, in practice, response planning considers both the snow layer and the underlying substrate of the shoreline.

The behaviour of oil on a snow-covered shore depends on:

- the type of snow (fresh, compacted, or contains ice layers)
- the air temperatures
- the surface character of the shore (flat or sloping)

Snow falling onto oil tends to accumulate on the oil surface.

Snow is a good, natural oil sorbent. The oil content may be very low (< 1%) in the case of light oils or if the oil has spread over a wide area.

Oil-snow proportions depend on the oil type and the snow character; the oil content being highest for medium oil rather than for light products.

Oil content is lowest on firm compacted snow surfaces in below-freezing temperatures and highest for fresh snow conditions.

Appendix 2

Oil Types

There are 5 types of oil selectable in the Waste Management Calculator:

Volatile Oils	gasoline products – viscosity like water
Light Oils	diesel and light crudes – viscosity like water
Medium Oils	intermediate products and medium crudes
Heavy Oils	residual products and heavy crudes – viscosity like molasses
Solid Oils	bitumen, tar, asphalt – does not pour

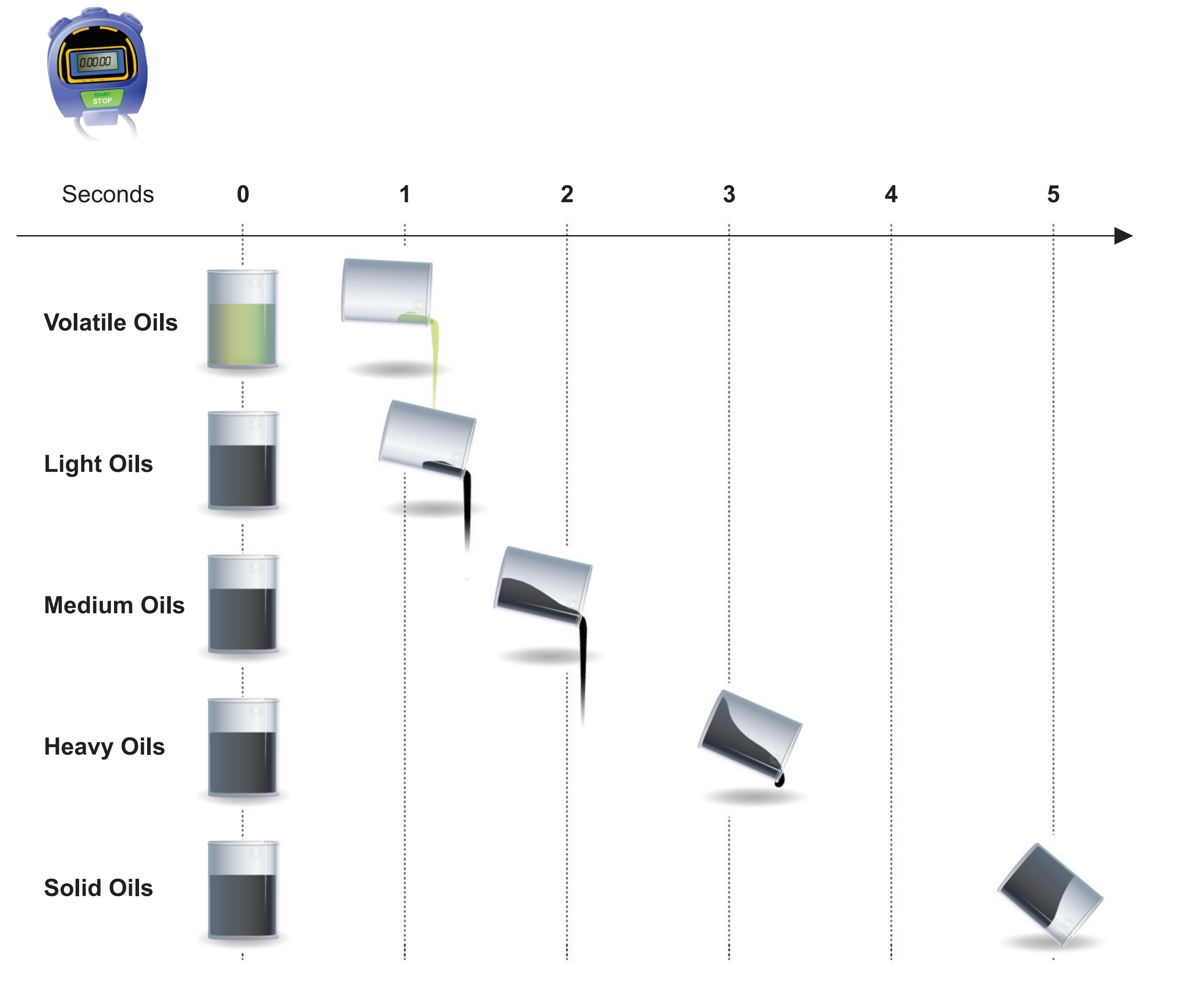


Fig A.2.1 *Oil Types*

Appendix 3

Degree of Oiling

		Width of Oiled Area			
		Wide >6m	Medium 3-6m	Narrow 0.5 – 3m	Very Narrow <0.5m
Oil Distribution	Continuous 91-100%	Heavy	Heavy	Moderate	Light
	Broken 51-90%	Heavy	Heavy	Moderate	Light
	Patchy 11-50%	Moderate	Moderate	Light	Very Light
	Sporadic 1-10%	Light	Light	Very Light	Very Light
	Trace <1%	Very Light	Very Light	Very Light	Very Light

Heavy	>3m wide and >50% Distribution
Moderate	0.5m to 3m wide and generally 10 to 50% Distribution
Light	<3m wide and generally <10% Distribution
Very Light	<0.5m wide and generally <10% Distribution

Terminology based on Owens and Sergy 2000 and MCA 2007[3]

3 Owens, E.H. and Sergy, G.A., 2000. The SCAT Manual - A Field Guide to the Documentation and Description of Oiled Shorelines (Second Edition). Environment Canada, Edmonton AB, 108 pp.

MCA 2007. The UK SCAT Manual: A Field Guide to the Documentation of Oiled Shorelines in the UK. Maritime & Coastguard Agency, Southampton, UK, 47 pages + vi.

Appendix 4

Treatment Endpoints

Bulk Oil Removal

Involves the safe removal of the heavy oil concentrations that could be remobilized to oil previously unaffected or cleaned shorelines.

Removal to Stain

Involves removal of thick oil or oil cover and allowing the oil coat or stain residue to weather naturally.

Category	Definition
Pooled or Thick Oil	Generally consists of fresh oil or mousse accumulations > 1.0cm thick
Cover	≤ 1.0cm and > 0.1cm thick
Coat	≤ 0.1cm and > 0.01cm thick coating, can be scratched off with a fingernail on coarse sediments/bedrock
Stain	≤ 0.01cm; cannot be scratched off easily on coarse sediments/bedrock
Film	Transparent or translucent film or sheen

Table A.4.1 *Standard Oil Thickness Categories for Stranded Oil (Owens and Sergy, 2000)*

Appendix 5

Treatment Tactics

Natural Recovery

Objective

Leave stranded oil to natural weathering and oil removal processes and allow the oiled shoreline to recover without intervention.

Description

Evaluation of this option requires: knowledge of the oiling conditions; the coastal processes and physical character of the shoreline, and; the resources at risk, in order to evaluate the likely consequences of allowing the oil to be removed or degraded naturally. In many circumstances, it is appropriate to monitor the location to ensure that the assessment is correct or that the rate of weathering and natural oil removal proceeds as anticipated.

Applications

Natural recovery can be applicable on any spill incident and for any type of coastal environment or shoreline type. Natural recovery is generally more applicable for:

- small rather than large amounts of oil
- non-persistent rather than persistent oil
- exposed shorelines rather than sheltered, low energy environments
- remote or inaccessible areas

Selection of the natural recovery strategy may result from an evaluation which concludes that:

- to treat or clean stranded oil may cause more damage than leaving the environment to recovery naturally or
- response techniques cannot accelerate natural recovery or
- safety considerations could place response personnel in danger either from the oil (itself) or from environmental conditions (weather, access, hazards, etc.)

Natural recovery should always be considered as the preferred option; particularly for small amounts of oil. The trade-off or net environmental benefit for each segment typically considers:

- the predicted fate and persistence of the residual oil
- the estimated rate of natural recovery
- the possible benefits of a response to accelerate recovery
- the risks associated with the presence of the oil as it weathers
- the possible delays to recovery that may be caused by response activities

Technique	Labour Requirements	Relative Cleanup Rate	Single or Multiple Step	Waste Generation
Natural Recovery	only monitoring	not applicable	not applicable	none

Table A.5.1 *Summary of Efficiency Factors for Natural Recovery*

Washing and Recovery

Objective

These methods involve a variety of techniques to wash or flush and recover the oil from the shoreline substrate.

Description

Typically, the oil is moved by the water stream from hand-operated or remote-controlled hoses to a down slope location for containment, recovery and collection for disposal. The oil is washed either:

1. onto the adjacent water where it can be contained by booms and collected by skimmers or recovered with sorbent materials
   or
2. towards a collection area, such as a lined sump or trench, where it can be removed by a vacuum system or skimmer

Oil is washed by a variety of methods that can include:

- flooding
- low-pressure or high pressure cold (ambient) or warm temperature washing
- steam cleaning
- sand blasting

Tactic	Pressure Range		Temperature Range (°C)
	psi	bars	
flooding (“deluge”)	< 20	< 1.5	ambient water
low-pressure, ambient wash	< 50	< 3	ambient water
low-pressure, warm/hot wash	< 50	< 3	30 - 100
high-pressure, ambient wash	50-1000	4 - 70	ambient water
“pressure washing”	> 1000	> 70	ambient water
high-pressure, warm/hot wash	50-1000	4 - 70	30 - 100
steam cleaning	50-1000	4 - 70	200
sandblasting	~ 50	~ 4	n/a

Table A.5.2 *Summary of Washing Temperature and Pressure Ranges*

The variables that distinguish one particular washing tactic or technique from another are pressure and temperature. The higher water pressures and temperatures provide more physical force necessary to dislodge and flush oil that cannot be removed using lower pressure and/or ambient temperature water. The washing or steam cleaning techniques are sometimes referred to as ‘spot washing’ when applied to small sections of shoreline.

<table>
<tr><th>Technique</th><th>Labour Requirements</th><th>Relative Cleanup Rate</th><th>Single or Multiple Step</th><th>Waste Generation</th></tr>
<tr><td>Flooding</td><td rowspan="3">labour intensive</td><td rowspan="3">slow</td><td rowspan="3">multiple</td><td rowspan="2">high</td></tr>
<tr><td>Washing</td></tr>
<tr><td>Spot Washing</td><td>moderate</td></tr>
</table>

Table A.5.3 *Summary of Efficiency Factors for Washing and Recovery*

Applications

Washing techniques can be practical and effective on most shoreline types. Low-pressure, ambient water washing can be practical and effective on most impermeable shoreline types and on some permeable shores (beaches) or marshes. Effectiveness decreases as the oil viscosity increases and as depth of oil penetration increases on cobble or boulder beaches.

Manual Removal

Objective

To remove oil or oiled materials (including oiled sediments) with manual labour and hand tools.

Description

This technique involves cleanup teams to pick up oil, oiled sediments or oily debris with gloved hands, rakes, forks, trowels, shovels, sorbent materials or buckets. It may include scraping or wiping with sorbent materials or sieving, if the oil has come ashore as tar balls. Collected material is placed directly in plastic bags, drums or other containers for transfer.

Applications

This technique can be used practically and effectively in any location or on any shoreline type or oil type. Manual removal is most applicable for:

- small amounts of viscous oil (e.g. asphalt pavement)
- surface or near-surface oil
- areas inaccessible to vehicles or where vehicles cannot operate

This technique is labour intensive and slow for large oiled areas. This is a significantly slower method than mechanical removal but generates less waste and the waste materials (tar balls, oiled sediment, oiled debris, etc.) can be segregated easily during cleanup.

<table>
<tr><th>Technique</th><th>Labour Requirements</th><th>Relative Cleanup Rate</th><th>Single or Multiple Step</th><th>Waste Generation</th></tr>
<tr><td>Shovels, rakes</td><td rowspan="3">labour intensive</td><td rowspan="4">slow</td><td rowspan="4">multiple</td><td>low-moderate</td></tr>
<tr><td>Vacuums</td><td>moderate</td></tr>
<tr><td>Vegetation Cutting</td><td>can be high</td></tr>
<tr><td>Sorbents</td><td>labour intensive if used extensively with large amounts of oil</td><td>can be high if frequent change-outs required</td></tr>
</table>

Table A.5.4 *Summary of Efficiency Factors for Manual Removal Techniques*

Manual removal typically requires vehicle or vessel support to transfer collected materials to temporary storage or permanent disposal sites.

Temporary waste storage

Mechanical Removal

Objective

To remove oil and oiled materials using mechanical equipment.

Description

Oil or oiled materials are removed from the shore zone for disposal by earth moving equipment such as graders or bulldozers that move material for removal by other machines and by scrapers, excavators, loaders, or back hoes that lift or remove material directly, for offsite transfer.

Efficiency and cost may be evaluated in terms of the resource requirements, cleanup rates, the number of times the material is handled and the volume of waste that is generated. Mechanical removal is more rapid than manual removal but generates larger quantities of waste.

Off-site beach cleaning machines that treat or wash oiled materials are included with this technique. These involve a waste management program of transfer, temporary storage, and treatment, even if sediments are replaced on the shore. These off-site cleaners involve a multi-step process as oiled material is removed from a beach and subsequently replaced by one or more types of earth-moving equipment.

Technique	Labour Requirements	Relative Cleanup Rate	Single or Multiple Step	Waste Generation
Grader	minimal labour support	very rapid	multiple	moderate
Bulldozer		rapid		very high
Scraper		very rapid	single	moderate
Front-end Loader		rapid		high
Backhoe / Excavator		medium		
Dragline/ Clamshell				

Table A.5.5 *Summary of Efficiency Factors for Mechanical Removal Techniques*

Applications

Mechanical removal can be used on all but bedrock or solid man-made shoreline types. The various types of commercially available earth-moving equipment have different operational requirements and different applications. The most important variable is the bearing capacity, which controls the ability of a piece of equipment to travel on a shore type without becoming immobilized. Traction for wheeled equipment on soft sediments (low bearing capacity) can be improved by reducing tire pressures. Tracked equipment may be able to operate where wheeled vehicles cannot, but is not a preferred option as tracks disturb sediments to a much greater degree than tires.

Each type of equipment has a particular application:

- **Scrapers** and **graders** can only operate on hard and relatively flat surfaces and are capable of moving only a thin cut (~10 cm) of surface material
- **Loaders**, **bulldozers**, and **backhoes** can operate in a wider range of conditions and are designed to dig and move large volumes of material
- **Backhoes**, **draglines**, and **clamshells**, with an extending arm or crane so that they may be operated from a barge or from a backshore area, are designed to reachout to pick up material
- **Beach cleaning machines** operate in a number of different ways. Mobile equipment operates on a beach, whereas other equipment operates off-site (adjacent) to treat oiled sediment so that cleaned material may be replaced on the beach
- **Vacuum trucks** remove pooled oil or oil collected in lined sumps

In-situ Sediment Mixing and/or Relocation

Objective

To break up or increase the exposure of the surface and/or sub-surface oil to both air and water action in order to accelerate natural weathering and the removal processes. Mechanical mixing of oiled sediments can involve agitation either in the absence of water ('dry' mixing) above the water line or underwater ('wet' mixing). In both cases, the intent is to mix or turn-over the sediment in-situ. This differentiates mixing from sediment relocation where sediments are purposely moved from one location to another that has higher levels of physical (wave) energy in order to accelerate natural oil removal processes.

Description

In-situ sediment treatment can include dry or wet mixing and sediment relocation and for which there is no removal (transfer and disposal) of oiled sediments. These tactics either physically expose oiled sediments and/or change the location of the oiled sediments with respect to wave exposure in order to promote or increase natural weathering and natural water-born removal process. Oil that is released during a rising tide can be contained and recovered, for example with sorbent materials. In some cases, oil released in the water and which resurfaces can be recovered by sorbents or from within a boomed containment area. Some oil is introduced into fine particle suspension in the water column and is left to natural dispersion and biodegradation processes.

Dry mixing can involve tilling or raking, that agitates oiled surface sediments, and digging or ploughing actions that physically turn over or displace surface and subsurface sediments. Manual mixing involves rotary garden tillers or rakes. Heavier machinery includes agricultural equipment, such as disc systems, harrows, ploughs, rakes or tines; or earth-moving equipment, such as rippers (tines), front-end loaders, backhoes, graders, or bulldozers. Agricultural 'rippers' or 'scarifiers' typically can mix sediments up to a depth of 50cm whereas backhoes could work to significantly greater depths; on the order of a meter or more.

Wet mixing is used in shallow water (typically <1m) either in the intertidal zone during rising or falling tides or at the water line during the tidal low-water slack. The sediments are agitated in-situ to release the oil by physical abrasion. Agricultural equipment, such as: disc systems, harrows, ploughs, rakes or tines or earth-moving equipment, such as rippers (tines), front-end loaders, or backhoes; or high-volume, low-pressure or low-volume high-pressure water jets agitate the underwater sediments within a boomed containment area. Custom-designed machines which combine mechanical mixing with water jets have proved to be very effective.

Sediment relocation differs from mixing as oiled sediments are physically moved from one location to another. The physical movement of oiled sediments causes mixing of those sediments, however the intent is to move the material to areas with higher physical energy levels, for example, from a location above the normal high water level to the upper intertidal zone where sediments can be reworked during each high tide period.

Technique	Labour Requirements	Relative Cleanup Rate	Single or Multiple Step	Waste Generation
Dry Mixing	minimal labour support	very rapid	single	minimal
Wet Mixing				
Sediment Relocation				

Table A.5.6 *Summary of Efficiency Factors for In Situ Sediment Treatment*

Applications

Dry mixing increases the exposure of surface and subsurface oiled sediments to air and water, and/or breaks up a surface oil layer to prevent the formation of an asphalt pavement. This technique can be used on sand, mixed sediment, coarse sediment beaches or sand tidal flats and is particularly useful in promoting the evaporation of light oils or product.

Wet mixing can be used on sand, mixed-sediment, coarse-sediment beaches or tidal flats for light and medium oils that will float to the water surface when agitated.

Sediment relocation has been proven effective on sand, mixed-sediment and coarse-sediment beaches and is particularly useful:

- where oiled sediments are located above the limit of normal wave action (i.e. if a beach was oiled during a storm surge or a period of higher tide levels)
- for ‘polishing’ of sand or fine mixed sediments where other cleanup or treatment activities have removed most of the bulk oil or oiled sediment and only light oiling (i.e. stains) remain

All three in-situ sediment treatment techniques are effective in promoting evaporation and physical abrasion:

- where sediment removal is undesirable due to
    - a lack of natural sediment replenishment
    - waste transfer and/or disposal issues
    - logistical constraints in remote areas
    - inaccessibility to a segment location
- immediately prior to expected storm events or periods of high wave-energy levels
- where a rapid/immediate removal of stranded oil is warranted or required

Dry mixing and sediment relocation may be used in conjunction with manual removal (to pick up patches of oil that are exposed) or bioremediation. This technique may be appropriate after initial removal of bulk oil by mechanical removal methods.

In-situ Burning

Objective

To remove or reduce the amount of oil or oily material from the shoreline by burning in place.

Description

Oil on a shore will not sustain combustion by itself unless it is pooled or has been concentrated in sumps, trenches, or other types of containers. This technique is used primarily where combustible materials, such as logs or debris have been oiled and can be collected and burned. It can also be used where vegetation, such as that found in a wetland, has been heavily oiled.

Burning efficiency can be improved by using fans to provide wind on burn piles. Torches can burn oil from hard substrates but this is a labour intensive method that uses large amounts of energy to remove small amounts of oil. In most cases, burned oil residues remain and recovery of these heavy or solid oil residues would involve manual removal.

As a general guideline, mixtures of oil and snow that contain up to 70% snow can be burned. Snow with less than 30% oil would likely require a promoter, such as diesel.

Portable incinerators based on a number of different technologies can be used to burn oiled sediments or debris.

Technique	Labour Requirements	Relative Cleanup Rate	Single or Multiple Step	Waste Generation
In-situ Burning	minimal labour support	very rapid	single	minimal

Table A.5.7 *Summary of Efficiency Factors for In Situ Burning*

Applications

This technique is applicable primarily for oiled logs and debris or where oil has been collected in sumps or drums and can be ignited with sustained combustion.

Burning has been used effectively for oil spills in salt marshes and on ice or in ice leads.

Oil burning on ice

Bioremediation

Objective

To enhance or increase the rate of biodegradation of oil in the intertidal zone by the addition of oil spill bioremediation agents.

Three classes of oil spill bioremediation tactics have been recognized: Bioenhancement agents contain only non-living materials such as nutrients (fertilizers containing nitrogen and phosphorus) intended to enhance the natural oil-degrading activity of the indigenous microbial population at a spill site; Bioaugmentation agents contain living microbes (and possibly also chemical agents to enhance oil biodegradation) intended to increase or supplement the natural rate of hydrocarbon biodegradation at a spill site. Phytoremediation, which involves the use of plants to accelerate oil degradation, may have a role in ex-situ treatments.

Historically, bioaugmentation and phytoremediation techniques have had limited use and application to the remediation of oil on shorelines, so this description focuses on bioenhancement – the in-situ addition of nutrients to oiled substrates.

Description

Naturally occurring micro-organisms (bacteria) use oxygen to convert hydrocarbons into water and carbon dioxide. This process usually occurs at the oil/water interface and is often limited by oxygen and nutrient availability and by the exposed surface area of the oil. If these three factors can be increased then the rate of biodegradation can be accelerated.

If nutrient levels are low, fertilizers can be applied in solid or liquid form and typically are applied in-situ. Slow-release fertilizers, such as pellets, can be broadcast on an oiled substrate using seed spreaders that are commonly used on lawns; on contact with water, the fertilizer slowly dissolves and releases water-soluble nutrients over time. Liquid oleophilic fertilizers can be sprayed onto a shoreline using a number of commercially available types of equipment, such as paint sprayers or back packs.

Technique	Labour Requirements	Relative Cleanup Rate	Single or Multiple Step	Waste Generation
Bioremediation	minimal labour support	very rapid	single	minimal

Table A.5.8 *Summary of Efficiency Factors for Bioremediation*

There is no removal of oiled sediments and the only waste generated is from packing material and PPE.

Off-site treatment of oiled sediments is similar to land farming technology and could involve bioaugmentation and/or phytoremediation as well as nutrient addition.

Applications

Bioremediation is an in-situ treatment technique that is applicable where there is light oiling or on residual oil ('polishing') after other techniques have been used to remove mobile or bulk oil from the shoreline. Bioremediation is not a short-term solution (days to weeks) and is not a suitable where short term oil removal is required. Applications may be repeated periodically (weeks or months as appropriate) to continue the supply of nutrients.

Fertilizers may be used alone on a shore to degrade residual surface and/or subsurface oil, however the process is more effective if combined with mixing or other methods of breaking up the oil into smaller particles. This significantly increases the surface area available to the micro-organisms.

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