SECTION III
PREVENTION AND CONTROL OF
OIL SPILLS ON PUGET SOUND

This segment of the report is divided into three parts - identification of oil spill sources, containment and cleanup of these spills, and prevention of such oil spills. Section III-A categorizes potential sources of spills, quantities involved, and associated probabilities. Section III-B analyzes current state-of-the-art oil spill response capabilities, culminating in a recommended inter-agency proposal. The section also delineates orders of priority in resource conservation, proposed containment and cleanup techniques for specific locales, and the required organizational cooperation.

Section III-C delves into the topic of oil spill prevention. Areas covered include tankers design and operation, traffic control, oil detectors and oil handling facilities. Again, state-of-the-art techniques and equipment, and evaluation and their applicability to Puget Sound are discussed.
III-A. IDENTIFICATION OF SOURCES OF OIL SPILLS

1. INTRODUCTION

The purpose of this section of the study is:

1. to identify the sources of potential oil discharge into Puget Sound, and
2. to establish a ranking of sources to indicate which of these require the greatest priority for preventive attention.

Before a listing of all sources can be analyzed and ranked, an objective scheme of criteria must be chosen to evaluate the impact of the various types of spills.

Ideally, a strictly quantitative analysis would employ the following relationship to establish priorities:

\[ \text{Ranking} = \text{Probable Frequency of Spill} \times \text{Probable Quantity of Spill} \times \text{Weighting Factor} \]

where

Weighting Factor is a function of (1) oil type spilled and (2) the maximum concentrations that result (time dependent effects). (For example, the weighting factor would allow for possible damage variation between the case where a specific quantity of a certain oil type is spilled instantaneously and the case where the same quantity is spilled over a longer period of time.)

At the present time, data is insufficient to allow an accurate estimate of statistically probable spill frequencies and quantities. While some extensive data is available for the statistical analysis of the probability of waterborne traffic collision or grounding, this data does not directly relate to oil spill frequency or quantity in a particular body of water, or part thereof. An analysis of probable waterborne accidents involving commercial vessels is described in Part 5 of Section II-B and Appendix 13 of this report. The data for shipping is probably more complete than for any of the other potential sources of oil discharge, but it needs further refinement for a strictly objective quantitative analysis. In addition, a useful estimate of the weighting factor is dependent upon research actively in progress by various elements of industry, government, and private institutions. Also, the data assessing oil spill effects is not yet conclusive.
Even though a strictly quantitative statistical analysis of probable spill frequency and quantity is not possible at this time, a complete listing of sources ranked in a subjective manner can be useful for the direction of immediate preventive and control measures analysis. It must be stressed that the resultant ranking of sources is preliminary, and based upon incomplete data. Its purpose and intent is not to suggest that it has been proved that any source assigned a high priority has been or will damage Puget Sound resources, but that each is a threat to these resources. It is hoped that the discussion of the requirements for a strictly objective quantitative analysis will indicate the type of data that should be obtained for more refined statistical studies in the future.

The following categories of oil discharge have been identified on Puget Sound, and each category will be examined in the following sections to obtain a ranking for preventive priority.

a. Waterborne traffic (large vessels).
b. Waterborne traffic (intermediate size vessels).
c. Waterborne traffic (small vessels).
d. Vessel/shore transfer facilities.
e. Vessel/vessel transfer operations.
f. Shore storage and transportation facilities.
g. Municipal, industrial, private waste disposal.
h. Submarine oil drilling.

Within each category, the parameters examined include source of spill, quantity of oil spilled, and the probable frequency of occurrence.

2. SOURCES OF OIL SPILLS

Category (a): Waterborne Traffic (Large Vessels)

1. Sources:
   a. Bulk oil carriers (including tankers, barges, oilers).
      i. Structural failure of tank spaces due to grounding, collision, explosion and fire, foundering.
      ii. Intentional pumping of tank compartments or bilge spaces in case of emergency.
b. Non-petroleum cargo vessels.
   i. Structural failure due to collision, grounding, fire and explosion, foundering.
   ii. Pumping bilge spaces.

2. Quantities:
   Considerable quantities of various types of petroleum are transported over the waters of Puget Sound. Table III-Al summarizes the annual volume of each major type of product from 1965-1970. The sum total of refined products represents approximately 42% of the total amount transported by all modes, while the total for crude oil represents about 7% for all modes.2 The bulk of the crude oil coming into the Sound travels by the Trans-Canada pipeline. Most of the crude oil that is shipped by water is exported from Puget Sound.

   Gasoline represents the largest portion of the petroleum products shipped in the Sound, averaging 4.6 million short tons over the six years analyzed. Most of the gasoline is shipped within the Sound from refineries to population centers. The majority of gasoline is moved by small vessels or barges.

   Distillate oil is also shipped in large quantities, as noted in the table. Although a sizable portion of the distillate fuel transported to Puget Sound markets, significant amounts are also shipped outside to other states and countries. Residual fuel oil, kerosene and jet fuel are transported primarily to Puget Sound markets.

3. Probable Frequency:
   When dealing with large vessels (tankers, barges, and freighters), an estimate should be made of their potential for an oil spill of a given size. A quantitative analysis of the loss of a certain amount of oil over a given time based on probabilities is useful in answering the problem of the relative size of different sources of oil pollution.

   To encompass the many assumptions and uncertainties inherent in a statistical prediction of this nature, and to form a basis for further discussion of potential oil spill situations, the following procedure is outlined to arrive at an order-of-magnitude estimate for oil potentially spilled by a collision involving a large vessel:
TABLE III-A1: ANNUAL PUGET SOUND OIL TRANSPORT VOLUME

(in 1000 short tons)

<table>
<thead>
<tr>
<th>Year</th>
<th>Total</th>
<th>Crude</th>
<th>Gasoline</th>
<th>Distillate</th>
<th>Residual</th>
<th>Lube Oil</th>
<th>Jet</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>1965</td>
<td>15,783</td>
<td>1,163</td>
<td>6,646</td>
<td>5,014</td>
<td>1,442</td>
<td>101</td>
<td>186</td>
<td>1,231</td>
</tr>
<tr>
<td>1966</td>
<td>12,348</td>
<td>671</td>
<td>4,638</td>
<td>3,655</td>
<td>1,837</td>
<td>73</td>
<td>189</td>
<td>1,285</td>
</tr>
<tr>
<td>1967</td>
<td>12,528</td>
<td>1,481</td>
<td>3,905</td>
<td>4,195</td>
<td>1,365</td>
<td>70</td>
<td>299</td>
<td>1,212</td>
</tr>
<tr>
<td>1968</td>
<td>14,750</td>
<td>2,496</td>
<td>4,271</td>
<td>4,207</td>
<td>2,106</td>
<td>119</td>
<td>773</td>
<td>778</td>
</tr>
<tr>
<td>1969</td>
<td>12,580</td>
<td>1,619</td>
<td>3,635</td>
<td>3,932</td>
<td>2,009</td>
<td>264</td>
<td>1,054</td>
<td>517</td>
</tr>
<tr>
<td>1970</td>
<td>12,891</td>
<td>1,899</td>
<td>3,871</td>
<td>3,930</td>
<td>1,701</td>
<td>226</td>
<td>899</td>
<td>365</td>
</tr>
</tbody>
</table>
1. Determine the probability of ship collisions in Puget Sound—this has been done for various areas of the Sound using traffic and historical collision data.

2. Compute probabilities as applied to commercial vessels only—given the probabilities in step 1. Proportion these according to the population ratio of commercial to total ship traffic.

3. Distribute this commercial probability among ship type using frequency of port call data.4

4. Compute an average size for each ship type according to number of barrels of oil carried— for freighters and barges compute an average size from Waterborne Commerce Data—for tankers use size estimates by port of call as reported in Puget Sound Task Force Report.5

5. Estimate an average extent of damage by vessel type for each collision by using IMCO casualty card file6 for tankers and by making further assumptions for barges and freighters. Since partial damage to a ship can cause a major oil spill, these data must not be overlooked. The damage card data from IMCO can therefore give an estimate of the type and heavy damage included in the partial loss column. (If the ratio of partial to total loss is considered for the entire fleet due to stranding and contact damage to be about 50 to 1, and the ratio reported in the IMCO data cards to be about 10 to 1, then these cards must reflect heavier than average partial loss incidents.)

6. Combining all of the above data properly, an estimated potential spill size due to the chance of a collision on Puget Sound may be determined.

7. Check this number with one based on world fleet casualty statistics prorated to tonnage of oil spilled on the Sound.7

Following this elaborate procedure, an order-of-magnitude estimate of the potential amount of oil that would be spilled on the Sound from ship collision can be estimated. This estimate may be unwarranted if the oil spill hazard from other situations is neglected. The tendency is to consider ship collisions as the most probable source of ship damage leading to an oil spill. However, the recent oil spill data suggests that collision is not the only significant source of waterborne oil spills.8

Information from Lloyd's Registry shows that, up to 1966, the total damage to oil tankers could be credited to four main causes of relatively
equal magnitude — wrecked, foundered, burned, and lost by collision.

Further information from the Liverpool Underwriter's Assn. indicates that partial damage to ships in the world fleet can be equally attributed to weather damage, collisions, and "other" causes. The concept of a traffic advisory system is directed toward only part of these potential hazards. Land based radar and bridge-to-bridge communication among all vessels in the Sound could minimize the possibility of collisions, and groundings. But, older and less seaworthy ships are subject to foundering. Also, tankers are subject to fire and explosion damage. The latter two potential hazards could not be minimized by a traffic advisory system. Therefore, collision predictions are not the only factor to be considered with waterborne traffic oil spills.

As mentioned earlier this data is based upon the total number of ships in commission and is not truly accurate. The partial loss data compiled by Liverpool Underwriters is valuable in that it does include all ship damage. This basis could possibly be adjusted with IMCO damage card data to give a reasonable picture of heavy damage which could lead to oil spills. The question naturally arises in this context as to whether a fire or explosion causing partial damage to the ship would lead to as large an oil spill as a partially ripped bottom. Even if these details could be decided on some arbitrary scale, the Liverpool data is not presented so as to discriminate vessel size. The original files would have to be consulted for monthly accident reports for further analysis.

The total loss data analyzed by Beers present some interesting trends. Among his conclusions are:

1. Small ships historically have a high casualty rate as part of a pattern dictated by coastal trade; its trend has not worsened.

2. Collisions show increased losses for oil tankers which are largely due to fire consequent upon collision.

3. "Burnt" losses have increased for dry cargo ships, but mostly in port; the worst trend of all is for oil tankers burned in port.

These conclusions are interesting but not at all inclusive. Total losses average around 0.5% (by number) of the world fleet per year, whereas partial
losses are about 35% (by number) per year. Added to this is the fact that fires and explosions tend to weigh heavier in the total loss column. These combined facts indicate that great caution must be employed when extrapolation of damage data to potential for oil spills is attempted.

The main result drawn from this discussion is that the threat of oil spills can be equally distributed among weather damage, collisions, fires and explosions, contact damage, and "other" casualties. With this in mind, any estimate of oil lost from ship collision must be amplified by an arbitrary factor of at least two. Considering that the above data is for world shipping trends, with only limited input of Puget Sound data, an estimate of oil spill potential is very preliminary, at best.

Category (b): Waterborne Traffic (Intermediate Size Vessels)

Category (b) also includes tugs, fishing vessels, larger recreational "inboard" boats.

1. Sources:
   a. Bilge pumping.
   b. Engine operation: vessels that allow machinery exhaust to discharge through cooling water effluent have potential to release oily water depending upon condition of machinery.

2. Quantities:
   Difficult to determine. Probably less than 1 gallon per boat per month. However, there were approximately 200 tug boats, 1500 fishing vessels, and over 20,000 inboard pleasure craft on Puget Sound in 1965.  
   The following data is available on quantities:
   Registered inboard boats - 18,200
   Mean annual fuel consumption, inboard boats - 536.9 gal/boat
   which includes diesel and gasoline (approximately 95% of inboards use gasoline, 5% use diesel).

3. Probable Frequency:
   a. Intermittent for bilge pumping.
   b. Continuous for all boats in operation with motors operating.
Category (c): Waterborne Traffic (Small Vessels)

Category (c) also includes outboard boats with two cycle engines.

1. Sources:
   a. Leakage and spillage from portable tanks.
   b. Inherent inefficiency of two cycle engines passes oil with cooling water and exhaust.

2. Quantities:
   Depending upon condition of motor, up to 1/2 pint of lubricating oil per 1 gallon of fuel might be lost during operation.

   In 1965, there were 94,400 outboard boats on Puget Sound of which the vast majority were two cycle. Mean annual fuel consumption 189.5 gallons of fuel per boat.

3. Probable Frequency:
   Continuous with motor operation.

   However, boating is seasonal.

   Boating Activity - % Total Boats per Month:

<table>
<thead>
<tr>
<th>Month</th>
<th>% Total Boats</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>37%</td>
</tr>
<tr>
<td>February</td>
<td>38</td>
</tr>
<tr>
<td>March</td>
<td>41</td>
</tr>
<tr>
<td>April</td>
<td>57</td>
</tr>
<tr>
<td>May</td>
<td>83</td>
</tr>
<tr>
<td>June</td>
<td>97</td>
</tr>
<tr>
<td>July</td>
<td>100</td>
</tr>
<tr>
<td>August</td>
<td>99</td>
</tr>
<tr>
<td>September</td>
<td>97</td>
</tr>
<tr>
<td>October</td>
<td>69</td>
</tr>
<tr>
<td>November</td>
<td>41</td>
</tr>
<tr>
<td>December</td>
<td>33</td>
</tr>
</tbody>
</table>
Category (d): Vessel/Shore Transfer Facilities

1. Sources:
   a. Bulk Transfer.
      i. Leaking transfer equipment (i.e. hoses, Chiksans) during operation.
      ii. Leakage during removal and handling of transfer equipment.
      iii. Improper filling procedure.
   b. Unit Fueling Facilities.
      i. Leaking hoses in operation.
      ii. Removal and handling of transfer equipment.
      iii. Overfilling of tanks.

2. Quantities:
   a. Bulk Transfer.
      Large diameter hoses and large flow rates; quantity depends upon nature of conduit failure and procedure before and after transfer.
      There are 77 piers on Puget Sound for the receipt of oil, and 13 for shipment.
   b. Unit Fueling Facilities.
      There are 30 fueling piers on Puget Sound for large vessels with large flow rate transfer systems.
      There are over 100 marine service stations on Puget Sound for smaller vessels. Quantity depends upon nature of conduit failure. Up to several gallons of refined oil may be spilled per fueling event due to technique of "topping off" tanks by filling until fuel pours out air vents.

3. Probable Frequency:
   a. Bulk Transfer.
      Some dripping may occur during hose or conduit handling, but quantitative data unavailable.
   b. Unit Fueling.
      Dripping before and after each fueling possible, but no quantitative data present.
      "Topping off" overfilling spillage may occur each fueling event.
Category (e): Vessel/Vessel Transfer Operations

1. Sources:
   Fueling or bunkering larger vessels by barges, oilers, or lighters create the same problems as vessel/shore transfer operations.

2. Quantities:
   There are ten facilities in the Seattle area and three in Tacoma that fuel vessels from barges. Total capacity for these barges is 104,050 barrels.

3. Probable Frequency:
   Details on frequencies not available at publication time.

Category (f): Shore Storage and Transfer of Oil and Products

1. Sources:
   a. Tank farms ( refineries, storage).
      i. Structural failures.
   b. Tank trucks.
      i. Structural failure due to wreckage near shoreline or near sewer intake.
      ii. Overfilling, emptying procedures.
   c. Railroad Tank Cars.
      i. Structural failure due to accident or derailment near shoreline or sewer system.
      ii. Overfilling, emptying procedures.
   d. Pipelines.
      i. Structural failure due to excessive pressure or geologic event (i.e. earthquake, foundation or slope failure).

2. Quantities:
   a. Tank farms.
      Dependent upon nature of failure and safety cofferdam effectiveness.
   b. Tank Trucks.
      Up to 10,000 gallons/truck if entire cargo lost.
   c. Up to 10,000 gallons/car if total load discharged.
   d. Pipeline.
      Large volume pipeline (Olympic or Trans-Canada) may be considerable depending upon nature of failure.
Smaller Tributary Lines.
Dependent upon flow rates and types of failures.

3. Probable Frequency:
Details of analysis were not available at publication time.

Category (g): Municipal, Industrial, Private Waste Disposal

1. Sources:
   a. Industrial.
      i. Refineries - "Oily water" effluence, ballast transfer from tankers, barges.
      ii. Shipyards - accidental spillage during repair and maintenance of vessels.
   b. Municipal.
      Addition of waste oil to sewer system.
   c. Private.
      Illegal disposal of waste oil in fill areas or water.

2. Quantities:
   a. Industrial.
      Industrial firms are regulated to approximately 100 parts per million oil discharge into the sewer system or waterways so that effluence is limited to several barrels per day, at most. This effluence includes lubricating and quenching oils, plus oil-water emulsions. A 1969 Seattle area study indicated that of the estimated 1.3 million gallons of industrial waste oil, approximately one million gallons were reclaimed. The remaining 300,000 gallons were unaccounted.

Data on ship and tank cleanings reveals between 2-2.6 million gallons of oily wastes are accumulated annually, of which approximately 60% is oil.

No data was available on quantities of oil handled or discharged from shipyards, but their effluence has been handled by tank or ship cleaning firms.
b. Municipal.

The quantities of oil wastes added into sewer systems is uncertain, but as much as two million gallons per year are discharged in King and Snohomish counties alone. The percent of oil in this waste is unknown. Also unknown is the amount of this oil that reaches Puget Sound. Though no written standard exists a maximum allowable discharge 10 ppm into Puget Sound has been used by the State Department of Ecology in relation to the Seattle Metro system. 22

c. Private.

The quantities of waste oil discharged from private sources are primarily through boating and automotive uses. The former has been covered in Category (c). Seven independent studies have been conducted on estimating the amount of oil waste in King, Snohomish, and Pierce counties. Since these encompass the bulk of the populous in the Puget Sound region, the numbers are indicative of the magnitude of the oil waste situation. The quantities estimated range from one million to 6.6 million gallons of waste motor oil annually, with a mean of 4.9 million gallons. 23 Of this amount, approximately 2.5 million gallons are collected and re-refined. The remainder is unaccounted for. 24

3. Probable Frequency:
   a. Industrial.
      i. Refineries - Effluence continuously.
      ii. Shipyard data unavailable.
   b. Municipal.
      Uncertain, probably daily.
   c. Private.
      Uncertain, probably daily.
Category (b): Submarine Drilling Operations

1. Sources:
   a. Exploration Drilling.
      i. Oily drilling mud leakage.
      ii. Leakage through equipment failure.
      iii. Leakage through faults in strata.
      iv. Structural failure due to collision because of navigational hazard.
   b. Production Drilling and Operations.
      i. Conduit leakage.
      ii. Handling after production.
      iii. Leakage through geological failures (faults).
      iv. Structural failure due to collision because of interference with navigation.

2. Quantities:
   Pollution due to escaping drilling mud difficult to evaluate—probably slight.
   For equipment failure due to collision, operational defect, or geological failure, quantity of crude oil could be essentially unlimited. (Eighty percent of submarine lands in Central Puget Sound that might be available for drilling in the future is in water deeper than 60 feet. The technological problems in repairing well heads in depths up to 600 feet are considerable. Therefore, any accident on a drilling platform would be difficult to control.)

3. Probable Frequency:
   a. For drilling mud, continuous during drilling operation.
   b. From operational failure, insufficient data; from collision due to interference to navigation, insufficient data.

   From geological failure, preliminary evidence indicates that recently active fault zones are present under Puget Sound and that these faults might be a problem to submarine drilling.
3. SUMMARY

In 1970, there were 242 oil spills reported in the State of Washington. The usual method of detection was visual, and most spills were reported by other than the responsible party. Thus, it was difficult to assess the amount of oil spilled or the cause. Table III-A2 lists these spills by source and size. In 42 percent of the spills, the source was unknown, and for about 90 percent of the spills, the quantity spilled was not known. In order to improve statistical analysis of oil spill probabilities, more sophisticated detection and reporting techniques are necessary.

Table III-A3 shows the geographical distribution of the 1970 reported oil spills. The subzones have been described in Section II-A. Almost 80% of the reported spills occurred in subzones 4 and 5, encompassing the Seattle, Tacoma, and Olympia metropolis, and Bremerton. As shown in Section II-B and II-C, these are also the areas of heavily concentrated waterborne commerce and oil transfer facilities.

While no compilations are available on quantities of oil spilled either in the State or nation, a study was made on estimated oil discharged into the world's waters in 1969. Table II-A4 summarizes this study. The applicability of this data to Puget Sound is questionable for several reasons. First, the worldwide data is for all areas, coastal and inland. Second, the method of analysis is not known.

Data is available on the quantity of oil spill for a given port, Milford Haven, S.W. Wales, Great Britain, which is an arm enclosing 70 miles of coastline. It is primarily an oil port, with three refineries and one tank farm. Surveillance consists of continuous patrolling through day and night, with 20-30 inspections daily. The oil spill data has been accumulated since 1963. Table III-A5 presents a summary of the oil spilled in quantity and percent of total transference in that port. Table III-A6 lists the sources and sizes of the oil spills.

The number of incidents per year has increased some, though the percentage of tankers involved in oil spills has slightly decreased. It is interesting to note that, even with such detailed information, respected scientists and
<table>
<thead>
<tr>
<th>Source</th>
<th>Number of Spills Reported</th>
<th>Quantity of Spill Known Unknown</th>
<th>Known Quantity (Gal)</th>
<th>Unknown Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Waterborne Traffic Large Vessels</td>
<td>21</td>
<td>1</td>
<td>20</td>
<td>1 0 0</td>
</tr>
<tr>
<td>b. Waterborne Traffic Intermediate Size Vessels</td>
<td>3 0 3</td>
<td>0</td>
<td>0 0 0</td>
<td>3 0 0</td>
</tr>
<tr>
<td>c. Waterborne Traffic Small Vessel</td>
<td>4 1 3</td>
<td>0</td>
<td>0 1 0</td>
<td>2 1 0</td>
</tr>
<tr>
<td>d. Vessel/Shore Transfers</td>
<td>11 9 2</td>
<td>5</td>
<td>1 3 0</td>
<td>0 2 0</td>
</tr>
<tr>
<td>e. Vessel/Vessel Transfers</td>
<td>0 0 0</td>
<td>0</td>
<td>0 0 0</td>
<td>0 0 0</td>
</tr>
<tr>
<td>f. Shore Storage</td>
<td>18 5 13</td>
<td>2</td>
<td>0 3 0</td>
<td>8 5 0</td>
</tr>
<tr>
<td>g. Municipal</td>
<td>8 0 8</td>
<td>0</td>
<td>0 0 0</td>
<td>8 0 0</td>
</tr>
<tr>
<td>h. Industrial</td>
<td>61 5 56</td>
<td>2</td>
<td>2 1 0</td>
<td>37 15 4</td>
</tr>
<tr>
<td>i. Private</td>
<td>15 1 14</td>
<td>1</td>
<td>0 0 0</td>
<td>11 3 0</td>
</tr>
<tr>
<td>j. Unknown</td>
<td>101 4 97</td>
<td>2</td>
<td>2 0 0</td>
<td>74 15 8</td>
</tr>
<tr>
<td>TOTAL</td>
<td>242 26 216</td>
<td>13</td>
<td>6 7</td>
<td>155 47 14</td>
</tr>
</tbody>
</table>
TABLE III-A3: GEOGRAPHIC DISTRIBUTION OF 1970 REPORTED OIL SPILLS IN WASHINGTON STATE.27

<table>
<thead>
<tr>
<th>Subzone</th>
<th>Total</th>
<th>Known (Gallons)</th>
<th>Unknown</th>
<th>Min</th>
<th>Mod</th>
<th>Ext</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>&lt;100 100-1000 &gt;1000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>5</td>
<td>0 0 0</td>
<td>2 2 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>1 2 0</td>
<td>4 1 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>7</td>
<td>0 0 2</td>
<td>3 2 0</td>
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<td></td>
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<tr>
<td>4</td>
<td>154</td>
<td>9 5 1</td>
<td>102 32 5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>42</td>
<td>1 0 1</td>
<td>33 5 2</td>
<td></td>
<td></td>
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<td>6</td>
<td>5</td>
<td>1 0 0</td>
<td>2 1 1</td>
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<td></td>
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<tr>
<td>Other</td>
<td>19</td>
<td>1 1 1</td>
<td>11 3 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>242</td>
<td>13 8 5</td>
<td>157 46 13</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
TABLE III-A4: ESTIMATE FOR QUANTITIES OF OIL DISCHARGED INTO WORLD WATERS, 1969

(gallons per year)

<table>
<thead>
<tr>
<th>Source</th>
<th>Quantities</th>
<th>Percent of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Tankers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Normal operation using</td>
<td></td>
<td></td>
</tr>
<tr>
<td>control measures</td>
<td>9,040,000</td>
<td></td>
</tr>
<tr>
<td>b. Normal operation not</td>
<td>150,000,000</td>
<td>159,040,000</td>
</tr>
<tr>
<td>using control measures</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Other Ships</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Bilges, etc.)</td>
<td>150,000,000</td>
<td>10.1</td>
</tr>
<tr>
<td>3. Offshore Production</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Normal operations)</td>
<td>30,000,000</td>
<td>2.0</td>
</tr>
<tr>
<td>4. Accidental Spills</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Ships</td>
<td>30,000,000</td>
<td></td>
</tr>
<tr>
<td>b. Non-ships</td>
<td>30,000,000</td>
<td>60,000,000</td>
</tr>
<tr>
<td>5. Refineries and Petrochemicals</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>90,400,000</td>
<td>6.0</td>
</tr>
<tr>
<td>5. Industrial and Automotive</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Highway vehicle</td>
<td></td>
<td></td>
</tr>
<tr>
<td>spentoils</td>
<td>542,000,000</td>
<td></td>
</tr>
<tr>
<td>b. Industrial plus other</td>
<td>452,000,000</td>
<td>994,000,000</td>
</tr>
<tr>
<td>vehicles</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GRAND TOTAL</td>
<td>1,483,440,000</td>
<td>100.0</td>
</tr>
</tbody>
</table>

---
### Table III-A5: Quantities of Oil Spilled at Milford Haven

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Quality Handled $\times 10^6$ Tons</th>
<th>Quality Spilled-Tons</th>
<th>% of Total Spilled</th>
</tr>
</thead>
<tbody>
<tr>
<td>1963</td>
<td>13.0</td>
<td>9.8</td>
<td>0.00008</td>
</tr>
<tr>
<td>1964</td>
<td>17.7</td>
<td>8.8</td>
<td>0.00005</td>
</tr>
<tr>
<td>1965</td>
<td>24.9</td>
<td>35.8</td>
<td>0.00014</td>
</tr>
<tr>
<td>1966</td>
<td>28.9</td>
<td>30.5</td>
<td>0.00011</td>
</tr>
<tr>
<td>1967</td>
<td>28.2</td>
<td>267.4</td>
<td>0.00095</td>
</tr>
<tr>
<td>1968</td>
<td>30.0</td>
<td>13.6</td>
<td>0.00006</td>
</tr>
<tr>
<td>1969</td>
<td>39.9</td>
<td>16.5</td>
<td>0.00005</td>
</tr>
<tr>
<td>1970</td>
<td>41.3</td>
<td>14.9</td>
<td>0.00004</td>
</tr>
<tr>
<td>Yearly Average</td>
<td>28.0</td>
<td>49.7</td>
<td>0.00018</td>
</tr>
</tbody>
</table>

1 short ton = 273 gallons
<table>
<thead>
<tr>
<th>Year</th>
<th>Number of Tankers</th>
<th>Number of Spill Incidents</th>
<th>Probability of Spill %</th>
<th>Source or Incident</th>
<th>Size of Incident</th>
</tr>
</thead>
<tbody>
<tr>
<td>1963</td>
<td>1,236</td>
<td>28</td>
<td>2.3%</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>1964</td>
<td>1,392</td>
<td>34</td>
<td>2.4%</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>1965</td>
<td>1,985</td>
<td>83</td>
<td>4.2%</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td>1966</td>
<td>2,378</td>
<td>72</td>
<td>3.0%</td>
<td>2</td>
<td>17</td>
</tr>
<tr>
<td>1967</td>
<td>2,680</td>
<td>50</td>
<td>1.9%</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>1968</td>
<td>2,669</td>
<td>52</td>
<td>1.9%</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>1969</td>
<td>3,226</td>
<td>58</td>
<td>1.8%</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>1970</td>
<td>3,440</td>
<td>55</td>
<td>1.6%</td>
<td>3</td>
<td>15</td>
</tr>
</tbody>
</table>
engineers often misquote the data in their publications. Therefore, improvement in accumulating data on oil spills in Puget Sound should be well documented and made available to interested parties in such a manner as to eliminate ambiguity.

4. CONCLUSIONS

As indicated in the introduction, quantitative data are insufficient to allow a strictly objective ranking of oil discharge sources on Puget Sound. However, several sources appear to be worthy of close attention because of their very large handling volumes or their very large potential frequency of spillage. Several classes of sources will be relegated to a lesser priority because existing data is not yet conclusive. Therefore, the following listing of priority is suggested as a guide for interim analyses of preventive methods and as an indication for areas of further study where data is inadequate.

First Priority:
(a) Waterborne Traffic (Large Vessels).
(d) Vessel/Shore Transfer Facilities.
(g) Municipal, Industrial, Private Waste Disposal.

Second Priority:
(c) Waterborne Traffic (Small Vessels).
(e) Vessel/Vessel Transfer Operations.
(h) Submarine Oil Drilling (if undertaken).

Third Priority:
(f) Shore Storage and Transportation Facilities.
(b) Waterborne Traffic (Intermediate Size Vessels).

The above priority ranking suggests a method of allocating the scarce resources of manpower and technology to cope with oil spills. Because of time constraints, the study team had to realistically narrow its field of investigation. This report concentrates on waterborne traffic and vessel/shore transfer facilities, though parts of the conclusions and recommendation apply equally well to large and small vessels, and vessel/vessel transfer operation categories.
Municipal, industrial, and private waste disposals are recognized as a high priority item, and much has been documented on methods to alleviate this situation. An oil disposal facility has been proposed for the Seattle area. 34 This facility would handle private, municipal, ship cleaning, and industrial oil wastes. As of this writing, no further progress has been made on the project.

Processing plants for handling private oil wastes are presently in operation in various locations around Puget Sound. 35 A plan to collect and recycle crankcase oil directly from private auto owners was initiated by Superior Refineries, in April, 1971. 36 Evidence has shown that response to this program is negligible. 37

Recycling of marine waste oil is performed by Chemical Processors at their Pier 91 Seattle plant. This outfit processed about 300,000 gallons of marine oil in the first month of operation. The firm has formulated plans, through a third party, to handle the waste oil from the prospective tankers from Alaska. 38

Submarine oil drilling has been relegated to second priority only because there currently is no major oil drilling operation on Puget Sound. The American Petroleum Institute chaired a 1970 conference relating to oil drilling and has published a document with numerous articles on preventive techniques in this field. 39 In addition, other publications have documented technological advances on the same topic. 40 This report does not attempt to criticize the published information; neither does it delve into the analysis of drilling operations.

Shore storage and transfer of oil products are covered indirectly in this report. The recommendations for vessel/shore transfer facilities are applicable in most cases. One area in need of further investigation is the probable frequency of shoreside spills. There is presently no mandatory reporting procedure of shoreside spills. In fact, there are no known statistics on the number of shoreside oil transfer operations in the Puget Sound area.

Improvements in data collection techniques will enhance the quantitative definitions of sources, probability and amounts of oil spills. It is projected that these new informations will reinforce this priority rankings assigned by the study team.
1 Included are Shell Oil Company, the National Marine Fisheries Service, and
the American Petroleum Institute.

2 Dolan, Savage, Clark, Environmental Statement on the Proposed Leasing
of Puget Sound Shorelands and Beds of Navigable Waters for Oil and Gas Exploration,
1970, p. 3.

3 Data for 1965-1969 provided by annual reports, Waterborne Commerce, Part 4,
by U.S. Army Corps of Engineers. 1970 data supplied by a galley proof of that
year's report.

4 Ibid.

5 Puget Sound Task Force, Puget Sound and Adjacent Waters, Appendix VIII,

6 IMCO sub-committee on Ship Design and Equipment, 5th Session, Grounding

7 IMCO sub-committee on Ship Design & Equipment, Statistic on Grounding and
Stranding Damage, May 7, 1970. Lloyd's Registry keeps detailed information
on total losses from collision, whereas Liverpool Underwriters Association
keeps data on partial losses that could cause total oil spills. Local
tonnage data for Puget Sound can be extracted from either the Corps of Engineers
reports or the Puget Sound Task Force Report.

8 System Study of Oil Spill Cleanup Procedures, Volume 1; Analysis of
Oil Spill and Control Materials, Dillingham Corporation, p. 10.

9 Beers, W. J., "Analysis of World Merchant Ship Losses", a paper presented

10 The tug population was obtained from estimates by Foss Launch and Tug,
and Puget Sound Tug and Barge Companies. The fishing fleet and pleasure
boats population are found in the Puget Sound Task Force Report, Appendices
XI and VIII, respectively.

11 Puget Sound Task Force, Pleasure Boat Study, Puget Sound and Adjacent

12 Ibid. p. 4.

13 Ibid. p. 18.

14 See section II-C; III-C, part 4; and Appendix I of this report for
detailed analysis.

15 Data supplied in Corps of Engineers Port Series reports, also presented
in Tables II-C1 thru II-C6 of this report.

16 See Tables II-C1 thru II-C6 and Figures II-C1 thru II-C6.

17 See Tables II-C4 and II-C5.
Standard used by State Department of Ecology and City of Seattle with respect to hexane solubles.


Ibid, p. 11.

Ibid., p. 11.

Conversation with Mr. A. Poole, engineer for Metro, August 16, 1971.


Ibid. p. 8.


Monthly reports of reported oil spills for 1970, provided by Water Pollution Control Commission. A minimum reported spill occurs when the investigator sees no oil at the site, or where light oil is. A moderate spill is one which requires some cleanup, usually involving a heavier oil. An extensive spill is one where the investigator cannot estimate the area affected by ground surveillance.

Rollis M. Dole, Assistant Secretary of Interior, stated on p. 38 of the April 27, 1970 issue of Oil and Gas Journal, that in 1968, 714 oil spills occurred in U.S. waters, of which 2 came from oil wells, 347 from docked vessels, and 300 from shore facilities.

A letter dated July 22, 1971, from Mr. George Moeins, of the Division of Oil and Hazardous Materials, Environmental Protection Agency, to the editor of this report indicated that records of oil spills are stored on computers for the agency's internal use.

The source of this data is the December 1970 issue of Oil and Hazardous Materials Research Newsletter, Volume 3, Federal Water Quality Administration. The original table was in metric tons. To obtain gallons, the conversion formula, 1 metric tone = 301 gallons, was used.


Written Submission by L. R. Breybon for Alaska Pipeline Service Company Report on Oil Spill Statistics at Milford Haven. Mr. Breybon is head of Environmental Studies in the Technical Development Division of British Petroleum.
D.R. Arthur, "The Biological Problem of Littoral Pollution by Oil and Emulsiforms -- A Summing Up" in Carthy and Arthur. He states that in 1966, 29,000 million kilograms of oil were handled at Milford Haven, with 29,000 kilograms spilled, (1 kg = .905 short tons = 1 metric ton). He also presents a relative figure of 0.01% for spillage amount. The two quantities quoted correspond closely to the Breynon table. But, many an eminent scientist and engineer has used the misquoted percentage figure. Until now, it is a common household word to many oil spill analyses.

Cornell, et al.

Among these are Superior Refineries in Woodinville, and National Oil Refining in Tacoma.

Article in April 25, 1971 issue of Seattle Times.

Conversation with personnel of Superior Refineries in August 13, 1971.

Conversation with Mr. Kent Clark, vice president of Chemical Processors.


In a conversation on November 12, 1971 with Mr. John C. Doolittle of the Washington State Oil Spill Cooperative, the following information was obtained:

"In the last quarter of 1971 the Washington State Oil Spill Cooperative (WSOSC) has progressed toward their intended goal. They have committed $100,000 toward the purchase of 1000 feet of off-shore Bennett boom and a 40-foot long Huskey SBG floating skimmer. This equipment is to be stored in the Port of Bellingham with the skimmer arriving in early November and the boom in late December. The Coop has also retained for three months a technical and managerial advisor/coordinator to provide the WSOSC membership with a three year illustrative budget and to draft an oil spill response plan. The contingency plan draft will be completed by late December. The Coop is currently considering hiring a full time manager to formalize the organizational plans currently being developed and to coordinate the activities in the oil spill response plan."