# ANALYSIS OF OIL SPILL STATISTICS

by

J.W. Devanney III

R.J. Stewart

Massachusetts Institute of Technology

Assisted by

Virgil Keith

Joseph Porricelli

ECO Inc.

Report to

Council on Environmental Quality

April 1974

ANALYSIS OF OIL SPILL STATISTICS

TABLE OF CONTENTS

## 1. Introduction

The purpose of the analysis described in this report is to utilize past spill experience to generate estimates of the likelihood of spillage by number and size of individual spill for a range of hypothetical offshore petroleum developments on the Atlantic and Gulf of Alaska continental shelf.

The data bases with which we have to work are:

a. The Coast Guard Pollution Incident Reporting Systems reports for the calendar years 1971 and 1972 [1] as amemded by the Coast Guard, October, 1973.* This data purports to cover all spills which reached United States navigable waters. It contains some 15,600 oil spills.

b. A record of 2,999 tanker casualties worldwide over the period 1969 to 1972 inclusive, containing reports on some 612 spills compiled by ECO Inc. [2]. We are reasonably confident that this data covers almost all the large tanker spills for this four-year period.

c. A data base generated for the Environmental Protection Agency by Computer Sciences Corporation and upgraded by ECO Inc. [3]. This tape combines records of the Office of Pipeline Safety and the Environmental Protection Agency, portions of U.S. Geological Survey records, and files of a number of state and

*This tape also contains the Coast Guard reports for 1970. However, the reporting system was not in full operation in that year.

Canadian provincial agencies, including the Texas Railroad Commission, the Louisiana Fish and Wild Life Commission and a number of California agencies. This data contains about 8,500 spills.

d. A data base compiled by MIT during the Georges Bank report based on a USGS survey of large spills and a survey of tanker casualties compiled by Westinform Ltd. [4].

e. A sample of some 300 spills at single buoy moorings worldwide gleaned from a number of sources, principally the Shell Oil submittal to the U.K. House of Lords during the hearings on the Anglesey Terminal made available to us through the Anglesey Defence Action Group. [5].

Obviously, in using this data to generate estimates of the probabilities of future spills we are implicitly assuming that future developments will employ present technology operated to recent-past standards. In this sense, these estimates will serve as a baseline from which any improvements will have to start.

1.1 Oil spill statistics in general

Anything more than a cursory glance at oil spill statistics reveals three striking features of this data which together pose an unusually difficult problem for statistical analysis:

a. The size range of an individual spill is extremely large. Magnitudes of spills range from a few gallons to tens of millions of gallons. The "Torrey Canyon" spill was approximately thirty million gallons and, with present tanker sizes, spills three and four times this size are conceivable. With respect to spill size, we are dealing with a variable which can range over eight orders of magnitude.

b. The great majority of all spills are at the lower end of this range. 96% of all the petroleum industry-related spills reported by the Coast Guard in 1972 were less than 1000 gallons and 85% of these spills were reported as less than 100 gallons. 85% of all the offshore platform spills reported by the Coast Guard in 1971 were less than 100 gallons and 98.6% of all these spills were less than 1000 gallons. Relatively speaking, most oil spills are small.

c. Most of the oil spilled is spilled in a few very large spills. The "Torrey Canyon" spilled twice as much oil as all the oil which was reported spilled in the United States in 1970, and two-thirds of the oil which was spilled in the United States in 1970 was spilled in three spills. 17 spills accounted for 70% of all the oil reported spilled in the United States in 1971, and 18 spills accounted for 85% of all the oil which was reported spilled in the U.S. in 1972.

These characteristics of oil spills imply that, with respect to prediction, a single-number estimate of the amount of oil which will be spilled in association with a particular development is almost meaningless. At very best, this estimate will be the average of the amount that will be spilled. However, in situations where the amount spilled can vary by a factor of a million, an average is of little use, for it is unlikely that the actual amount spilled will be anywhere near that average. For example, the average spill size of all offshore production spills in the United States in 1972 was reported by the Coast Guard to be 103 gallons. However, 55% of all these spills were at least ten times smaller than this average, while most of the oil was spilled in spills which ranged up to 1000 times this average, and we have observed offshore production spills which were over 10,000 times the size of this average. In short, even if we could estimate the average amount of oil which will be spilled in the future for some development, we would have learned very little, for few of the actual spills will be anywhere close to this average. Most will be much smaller. A few will be very much larger. It would be like characterizing a class made up entirely of Einsteins and idiots by their average I.Q. Further, the biological impact of any given amount of spillage will depend on the frequency and size of the spills making up that volume. Both the biological impact and the esthetic impact of ten average-sized spills will be quite different from the impact of a single spill which is ten times the average volume.

To make matters still worse, the fact that most of the oil spilled is spilled in the very large, very rare spills implies that even if we wanted to estimate the average of the amount which will be spilled from a particular development from the available spill data, our estimate of this average is unlikely to be very accurate. This problem can be demonstrated from the offshore production category. If in 1972 we had observed one Santa Barbara-sized spill, then the average of the amount spilled in that year from offshore production facilities would have been increased by more than a factor of ten. To put it another way, if we had used the data for offshore spills in 1970 rather than 1972 for our estimate of the average of offshore production facilities, our estimate would have been increased by more than a factor of ten. Obviously, an estimate which can be affected by a factor of ten by a single, not completely unlikely, occurrence cannot be regarded to be extremely accurate.

The usual approach to this problem is to use the average observed as an estimate of the average which will be spilled and then use classical statistical analysis which employs the sample size together with the variability observed in the sample to make such statements as "with 90% confidence the actual average is within y of the estimated average." Unfortunately, when one applies this reasoning to such spill categories as offshore pipelines where we have observed many small spills together with two extremely large spills, one finds that in order to be 90% confident, y is many times the estimated average. The statement that with 90% confidence the average of future large offshore pipeline spills is between 1,007,000 and 3,159,000 gallons, while perhaps true, affords us little insight into offshore pipeline spillage.* Therefore, it behooves us to find a better way.

In so doing, it is of interest to compare the Coast Guard spill reports for 1971 and 1972. Table 1.1 gives an overall summary of the results. The first category is for all oil spills, the second category involves only those coastal and offshore spills emanating from oil industry-related activities. Inland spills are not included in this category, nor are oil spills which occur after the oil is in the hands of the final users, e.g. spills from a utility's fuel tank. The final three categories break the non-inland, oil industry spills down by offshore tanker, terminal, offshore production facilities (platforms and pipelines), and onshore pipelines. The offshore tanker spills include only those tanker spills which did not occur in harbors or near terminals. Since the Coast Guard's reporting authority extends only out to the three-mile limit with respect to vessels, this category may not be indicative.

For now, the important thing to notice about this table is that while total oil production and consumption in the United States in 1972 was not that different from that in 1971, the volumes spilled, both total and in most of the categories, are quite different. This is because these totals

*Based on assuming that all known offshore pipeline spills over 1000 barrels are samples of a Normal process.

| | | 1971 | 1972 |
|---|---|---|---|
| All Spills | Number | 7,461 | 8,287 |
| | Volume (gal) | 8,611,173 | 21,742,320 |
| Non-inland, Petroleum Industry Spills | Number | 4,023 | 4,078 |
| | Volume | 6,322,459 | 5,934,478 |
| Terminal | Number | 1,475 | 1,632 |
| | Volume | 5,283,915 | 2,296,828 |
| Ships-offshore | Number | 22 | 32 |
| | Volume | 16,315 | 2,168,811 |
| Offshore production facilities | Number | 2,452 | 2,252 |
| | Volume | 655,117 | 239,515 |
| Onshore pipeline | Number | 74 | 162 |
| | Volume | 367,112 | 1,229,324 |

Table 1.1

Comparison of 1971 and 1972 USCG Data

are completely dominated by a few very large spills. In 1971, there was only one spill over 1 million gallons (2,000,000 gal.) reported; in 1972, there were three such spills totaling 15,000,000 gallons. Given the dependence of the total amount spilled on a very few, very large spills, there is little reason to expect the volumes to agree. Our sample of very large spills is simply too small to expect any statistical regularity with respect to these particular spills.

On the other hand, the number of spills, both total and by major category, exhibits a definite pattern. With respect to incidence as opposed to amount, each individual spill counts equally and the sample of all spills is large enough so that if the processes generating spillage in 1971 and 1972 were similar, one would be quite surprised if the number of spills did not exhibit statistical regularity.

Table 1.2 breaks the 1971 and 1972 non-inland, oil industry-related spills down by region. Once again, there is much better agreement with respect to number of spills than there is to spill volume.

Table 1.3 shows a more detailed breakdown of the non-inland oil industry-related Coast Guard data by spill category. The terminal spills follow the same basic pattern - definite correspondence between number, little correspondence in total volumes. However, the offshore facilities spills when broken down into pipeline and production platform offer a glaring exception. This anomaly was presented to the relevent Coast Guard personnel, who commented that it was often a

| | 1971 | 1972 |
|---|---|---|
| New England | | |
| Number | 311 | 365 |
| Volume | 852,763 | 397,731 |
| Mid Atlantic | | |
| Number | 894 | 1034 |
| Volume | 465,087 | 9,431,839 |
| Gulf | | |
| Number | 3927 | 3632 |
| Volume | 1,426,186 | 6,444,977 |
| So. California | | |
| Number | 552 | 507 |
| Volume | 301,362 | 43,141 |

TABLE 1.2

COMPARISON OF REGIONAL STATISTICS

| | | 1971 | 1972 |
|---|---|---|---|
| BREAKDOWN OF TERMINAL SPILLS | | | |
| Tanker & barge | Number | 917 | 912 |
| | Volume (gal) | 2,586,993 | 817,396 |
| Refinery | Number | 167 | 172 |
| | Volume | 2,197,417 | 34,624 |
| Bulk storage & transfer | Number | 391 | 548 |
| | Volume | 499,506 | 1,494,808 |
| BREAKDOWN OF OFFSHORE PRODUCTION SPILLS | | | |
| Offshore tower | Number | 1,087 | 2,211 |
| | Volume | 117,661 | 231,738 |
| Offshore pipelines within 3 mi limit | Number | 1,204 | 36 |
| | Volume | 515,913 | 7,326 |
| Offshore pipelines outside 3 mi limit | Number | 156 | 5 |
| | Volume | 14,540 | 451 |

Table 1.3

purely judgemental decision upon the part of the data coder whether to place a spill in the offshore production category or the offshore pipeline category and that due to personnel changes, it was quite possible that coding habits had changed. In view of the other data presented and in view of the agreement between the sum of the offshore pipeline and offshore production spills, we believe it is reasonable to assume that this was the case.

Table 1.4 compares the size distribution of non-inland, oil industry-related spill volumes for 1971 and 1972. Once again a definite pattern is demonstrated. It appears quite reasonable to assume that the same basic process is generating spill sizes in 1971 as in 1972. Note, however, that because there are so few spills in the very large categories, it is not particularly surprising that, for example, there were three spills over 1 million gallons in 1972 as opposed to one in 1971. Table 1.5 shows the volume distributions by category. Once again, with the aforementioned exception of offshore pipeline and towers, a definite pattern is observed.

In summary, the characteristics of oil spillage are such that dealing with total volume spilled directly leads to very little insight. Using classical techniques, confidence intervals are sometimes orders of magnitude larger than the estimator and only very weak statements can be made. However, both the number of spills and the spill size distributions exhibit definite regularity given the sample sizes available. These findings, together with the fact that, from the point

| Gallons | 1971 | 1972 |
|---|---|---|
| 0-1 | 2497 | 2387 |
| 1-10 | 1526 | 2020 |
| 10-100 | 2146 | 2509 |
| 100-1000 | 1000 | 1068 |
| 1K-10K | 222 | 232 |
| 10K-100K | 53 | 54 |
| 100K-1M | 16 | 14 |
| 1M-10M | 1 | 3 |
| > 10 M | 0 | 0 |
| | 7461 | 8287 |

TABLE 1.4

VOLUME DISTRIBUTION COMPARISON

ALL SPILLS

| | | 0-1 | 1-10 | 10-100 | 100-1000 | 1K-10K | 10K-100K | 100K-1M | 1M-10M |
|---|---|---|---|---|---|---|---|---|---|
| Terminal | | | | | | | | | |
| | 1971 | 384 | 247 | 458 | 282 | 77 | 19 | 7 | 1 |
| | 1972 | 351 | 347 | 544 | 298 | 71 | 16 | 5 | 0 |
| Ship-Offshore | | | | | | | | | |
| | 1971 | 4 | 6 | 8 | 0 | 4 | 0 | 0 | 0 |
| | 1972 | 15 | 2 | 10 | 3 | 0 | 0 | 1 | 1 |
| Pipeline | | | | | | | | | |
| | 1971 | 222 | 403 | 496 | 257 | 42 | 13 | 2 | 0 |
| | 1972 | 15 | 24 | 61 | 61 | 32 | 7 | 3 | 0 |
| Towers | | | | | | | | | |
| | 1971 | 230 | 305 | 395 | 146 | 13 | 2 | 0 | 0 |
| | 1972 | 431 | 784 | 728 | 244 | 20 | 4 | 0 | 0 |

TABLE 1.5
VOLUME DISTRIBUTION BY CATEGORY
(Offshore and Coastal Petroleum Industry Data only)

of view of environmental impact, estimates of the numbers and sizes of individual spills are at least as important as estimates of the total volume spilled, strongly suggest that the way to attack oil spill statistics is through a two-step process:

1. First, one should attempt to say what one can about how many spills will occur.

2. Secondly, one should attempt to say what one can about how much oil will be spilled in an individual spill.

Once one has completed these two sets of analyses, they can be combined, if desired, to yield statements about the total amount of oil which will be spilled.

This is the basic approach that will be undertaken. In so doing, we will divide spillage into five categories:

1. tankers and barges
2. onshore terminals
3. single buoy moorings (SBM's)
4. offshore production
5. offshore pipelines

This division by category, while somewhat arbitrary, will allow us to compare tanker versus pipeline transportation alternatives and is also suggested by the form of the available data.

In our analyses, we will make one further subdivision which is forced on us, in part, by the available data and, in part, by the fact that the processes generating large spills exhibit qualitative differences from the processes generating small spills.

All the available data bases we have on oil spillage falls into one of two categories:

A. Data which purports to be a complete record of <u>all</u> spills in a certain period emanating from a specific activity. These data bases typically contain a very large number of spills most of them quite small. They cover a relatively short period and a restricted geographic area (single county, single state) and contain none or very few large spills. The Coast Guard data is an example as is the Texas Railroad Commission report on the EPA tape.

B. Data which is a selective sample, either by design or by necessity, of only large spills. These data sets contain a relatively small number of spills, all or almost all by them quite large, but they usually cover longer periods of time than the (A) type data. The U.S. Ecological Survey of large offshore spills from 1964 on, is an example, as for all practical purposes is the ECO data on worldwide tanker spills.

In the face of this dichotomy, one is forced to analyze large spills separately from small spills lest one throw away the valuable information on the rare, very large spills contained in the selective compendia type B, but not in the type A. The dividing line between "large" and "small" spills is, of course, arbitrary but a convenient choice is 42,000 gallons (1000 barrels or 150 tons). Henceforth then, "large" is a shorthand way of saying "over 42,000 gallons" and "small" is a shorthand way of saying under 42,000 gallons. No value judgments about the biological implications are implied by these terms.