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The Oil Spill Incidence and Simulation Model: Description and User's Manual

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**MIT Sea Grant
College Program**

**Massachusetts
Institute of Technology
Cambridge,
Massachusetts 02139**

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THE OIL SPILL INCIDENCE SIMULATION MODEL:
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by

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RELATED REPORTS

Fazal, Riyaz A. and Jerome H. Milgram. THE EFFECTS OF SURFACE PHENOMENA ON THE SPREADING OF OIL ON WATER. MITSG 79-31. Cambridge: Massachusetts Institute of Technology, 1979. 170 pp. \$4.00.

Devanney, John W., III, S. Protopapa and R. Klock. TANKER SPILLS, COLLISIONS AND GROUNDINGS. MITSG 79-14. NTIS: PB299204/AS. Cambridge: Massachusetts Institute of Technology, 1979. 105 pp. \$6.00.

Pollack, Andrew M. and Keith D. Stolzenbach. CRISIS SCIENCE: INVESTIGATIONS IN RESPONSE TO THE ARGO MERCHANT OIL SPILL. MITSG 78-8. NTIS: PB285646/AS. Cambridge: Massachusetts Institute of Technology, 1978. 328 pp. \$10.00.

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0. INTRODUCTION AND GENERAL BACKGROUND

The purpose of this report is to describe work conducted to date on a component of the overall modeling structure of the research project "Oil Spill Clean-Up Economic and Regulatory Models." This component is the so-called Oil Spill Incidence Simulation Model (or, more simply, the simulation model). It is intended to simulate random spill incidents of different types of oil, occurring at various locations from different sources, during a period of specified duration.

The reader is referred to references such as [1, 2, 3 and 4] for more information on the overall modeling effort and on progress associated with the above project.

In its current state, the simulation model represents a working, flexible and versatile structure that can be used as a tool in the overall oil spill model. It is by no means a complete and comprehensive package that can simulate all aspects of oil spill incidence. For instance, while the model can generate random spills according to a rather wide variety of probabilistic assumptions about their occurrence, a minimal attempt has been made so far to determine specifically which probability distributions are applicable to each specific case, or how these distributions can be linked to region-specific oil spill incidence data. References [5, 6 and 7] provide analyses on how and when the latter can be done. The simulation model is flexible enough so that considerations on specific regional probabilistic data can be incorporated into it in the future.

At this state of model development, the time scale of simulated spillage events has been decided to be of the order of months or years, instead of hours and days. This has the important implication that the model can be used to examine hypothetical spill scenarios on a life-cycle basis (e.g. what spills are likely to happen in a general geographical region in, say, 20 years) rather than on a real-time basis (e.g. what is likely to happen in a specific location from a single spill in, say, 5 days). In that respect, the simulation model is currently associated more with the strategic, rather than the tactical and operational elements of the overall model structure. It can be used to evaluate what can happen on a long term rather than on a short term basis. It should be noted however that the structure of the simulation model is such, that it can be made to operate on a real-time basis as well, by proper adjustment of the time scale. In that respect, the simulation of oil spill events on a long-term basis is currently the first implemented feature of a model which is structured so as to be able to include simulation of related processes, not necessarily of the same time scale, such as clean-up operations, transportation and storage of recovered oil and various environmental processes.

The simulation model is modular in structure, with adequate provisions for input/output interfaces with other components of the overall oil spill model. A complete description of this structure is presented in subsequent sections of this report. One of the uses of the simulation model can be to link the tactical

model with the strategic one and thus evaluate alternative long-term spill scenarios. This can be done according to the following generic sequence of steps:

- Step 1: Decide on a particular strategic clean-up system configuration: locations, types and quantities of clean-up equipment to be stockpiled along the coast.
- Step 2: Using appropriate forms of probability distributions for oil spill frequency and volume, run the simulation model for a period of specified duration, to "generate" spills of various types, occurring in the geographical area of interest.
- Step 3: For each of the random spills generated in Step 2, run the tactical model for oil spill response, so as to determine an appropriate response tactic to that spill. Tabulate clean-up and damage costs for that spill.
- Step 4: Evaluate the net present value of the total costs incurred by the sequence of spills generated over the specified period. Include capital costs of clean-up equipment acquisition as well as maintenance and operating costs.
- Step 5: Without changing the system described in Step 1, repeat Steps 2 to 4 as many times as necessary to draw statistically significant conclusions.
- Step 6: (Optional) Change the configuration of the system of Step 1 and repeat Steps 2 to 5 in order to decide upon an "optimal", or "good" strategic system. Measure the

expected value of the damages averted due to that system versus a "baseline" system.

Several remarks should be made to clarify the above algorithm: First, the logic by which strategic decisions in Steps 1, 6 and tactical decisions in Step 3 are going to be made is the object of separate and extensive studies, and is by no means trivial; it is outside the scope of this report. The reader is referenced to [1, 4] and forthcoming technical reports for further details on optimal oil spill decision making.

Second, the number of times necessary to repeat Steps 2 to 4, as specified in Step 5 may be large, particularly if one wishes to draw statistically significant conclusions about very large, very rare spills. If we combine this fact with the fact that the computational effort associated with Step 3 (running the tactical model) may also be significant, we conclude that testing the capability of a single, specified strategic oil spill clean-up system (Steps 1 to 5) is likely to require a significant amount of computing time. A fortiori, optimizing by this manner such a system (Step 6) will require even more computational effort. It is the purpose of the research effort in the strategic model to determine ways to overcome this problem.

It can thus be seen that the value of the simulation model does not lie so much in the desirability of it being used explicitly as a subroutine in the strategic optimization algorithm, but in its capability to generate random spills over a period of spe-

cified duration and hence help analyze the various impacts of those spills.

It should be also pointed out that various means to reduce the computational effort of Step 3 will be sought. For instance, experience from various runs of the tactical model might enable one to draw conclusions on what are the parameters (e.g. spill volume , distance from the coast, toxicity, etc.) upon which the clean-up and the damage costs of a single spill mostly depend. Such conclusions might alleviate or even eliminate the need to run the tactical model repeatedly, once for each spill generated by the simulation model. It should be noted that, as of the time of the writing of this report, such conclusions have not been drawn, since they demand extensive sensitivity analyses on the tactical model, analyses scheduled for the immediate future.

Nevertheless, this cannot preclude somebody to investigate several simplifying hypotheses in lieu of running the tactical model many times. A hypothetical example is the following: "What will be the impacts from oil spills generated during 20 years, if we assume that the damage cost of each spill is proportional to its volume and inversely proportional to its distance from the coast and that the cost of clean-up is proportional to the volume of oil recovered? What is the impact of different constants of proportionality?" The simulation model is able to assess "what if" questions of that nature, and is, in that respect, a flexible tool for analysis of alternative spill scenarios.

The report is organized as follows: Section 1 presents the

model's inputs, outputs and user options. Section 2 presents a sample simulation run. Section 3 describes the computer program associated with the model. Section 4 discusses possible program extensions and Section 5 outlays plans for further work. Two appendices are included: Appendix A is a listing of the computer program developed and Appendix B a sample of program error messages.

1. INPUTS, OUTPUTS AND USER OPTIONS

The concept used to describe oil spills in the simulation model is the concept of spill class. A spill class C is a combination of type of spilled oil T, geographical area of spill occurrence A and spill source S.

Careful processing of historical files (such as the Pollution Incidence Reporting System (PIRS) database of the USCG and others), can produce two types of probability distributions: The first one describing the periods of time between consecutive spill events belonging to a specified class C and the second one displaying the distribution of the volumes of oil spilled in spills of that class. An underlying assumption here is that occurrence of future spills is governed by the same random processes that produced spills in the past, as those were recorded in the data files. Any evidence supporting the argument that these underlying processes will be different in the future (e.g. due to a drastic change in the pattern of transportation or production of oil in a region) should be adequately reflected in changes in the probability distributions that will be used to generate these future spills.

Input data to the simulation model is entered by the user in an interactive way: The computer program prompts the user step by step to enter specific types of information, as it will also be seen in Section 2.

The first group of input data consists of a set of parameters concerning the simulation process as a whole. These param-

ters define the length of the simulation process and its structure as follows:

1. Lengths of simulated periods in any time units. At least one period is necessary, and the maximum is four. Distinction into periods is useful if one wishes to examine different seasons in a year (e.g. spring/summer vs. fall/winter).
2. Number of replications within each period. Each simulation period is to be repeated a sufficient number of times in order to satisfy statistical considerations of sufficient sample size according to the Monte Carlo method.
3. Random number generator seed.

The second group of input data describes the spill classes to be simulated in a given run. Spill classes are described as follows:

1. Number and name of class. The class number is for internal computer manipulations. The class name is a label that displays whatever information is necessary to identify the class to the user (Type of oil, area and source).
2. Attributes for spill frequency. These are a set of parameters defining the probabilistic nature of the time interval between successive spills belonging to the class in question.
3. Attributes for spill volume.
4. (Optional) Attributes for spill discharge rate. Information on discharge rate is not necessary if the simulation program is to run in the strategic setting, as it stands to date. This

information becomes necessary for possible future runs in the tactical setting.

Specifically, information relating to each of the attributes has the following structure, and is required from the user:

1. Attribute type: In that respect we have SPILLFRQ for frequency, SPILLVOL for volume and FLOWRATE for discharge rate.
2. Identification of pertinent simulation period(s) (e.g. 1,2,3 or 4)
3. Probabilistic method which is to be used to sample values for the random variable in question during the simulation process.

The following options are available:

- * Option FIXED, in which the variable in question is deterministic (e.g. a spill occurs exactly every month; or, the spill volume is 5,000 gallons).
- * Option GAMMA, in which the variable in question has a Gamma distribution of parameters to be specified by the user.
- * Option NEGEXPON, in which the variable follows a negative exponential distribution (actually, this is a special case of GAMMA).
- * Option POISSON, in which the variable follows a (discrete) Poisson distribution.
- * Option NORMAL, in which the variable follows a Gaussian distribution.
- * Option UNIFORM, in which the variable is uniformly

distributed inside some interval.

- * Option TABLE, in which the variable is drawn from a discrete distribution, specified by the user.

4. One or more values which constitute the parameters of the probabilistic method to be used. The program prompts the user to enter these parameters. Depending on what probabilistic method is chosen, the required parameters are:

- * The deterministic value (for FIXED).
- * The mean value and standard deviation (for GAMMA and NORMAL).
- * The mean value (for NEGEXPON and POISSON).
- * The upper and lower limits (for UNIFORM).
- * A list of pairs (values and frequencies) for TABLE.

The third (and last) type of input data are output specifications. There are several ways outputs can be presented.

1. In the form of a time series (Option TSER). In that form, the model outputs a list of values of the random variables of interest, as these evolve in time.
2. In the form of histograms (Option HIST). In that form, the model outputs histograms of the values of the random variables of interest.

The above two basic forms of presentation of simulation results can be displayed in a number of different ways:

1. Individually for every specific class and attribute (code name: CLASSES)
2. Combined, for a given group of classes and specified attri-

bute (code name: SUMMARY)

3. Individually for all listed classes, followed by combined (code name: CLASSUM).

A set of statistical indicators is calculated and printed out following each histogram:

- total number of observations (size of population);
- arithmetic mean;
- variance;
- standard deviation;
- measure of stochastic convergence;
- maximum observed value;
- minimum observed value;
- number of values above mean;
- number of values below mean.

The various user options can be best illustrated in the sample simulation run of Section 2.

2. EXAMPLE SIMULATION RUN

The test run was performed for three classes of spill incidents in one period of 365 days repeated 50 times for the sake of better precision of results.

Computer program enquiries (except for error messages) are printed in lower case letters and user's inputs in capital letters. The explanation of the notes that appear numbered alongside the run is after the listing of the run.

* RUN SIMSPIL

Enter run title: SIMULATION OF OIL SPILL INCIDENTS --- A TEST RUN ①

GENERAL PARAMETERS OF THE SIMULATION PROCESS

Length of simulation period(s): 365 ②
No. of replications of each period: 50 ③
Random numbers generator seed is: 1357 ④

DESCRIPTION OF CLASSES

Enter spill class number and its full name: 1, LIGHT CRUDE FROM TANKERS - NEW ENGLAND ⑥
Name class attribute (SPILLFRQ, FLOWRATE, SPILLVOL) & for which period(s): SPILLFRQ 1 ⑦
Enter name of calculation method: NEGEXPON ⑧
Give mean value: 60 ⑨

Name class attribute (SPILLFRQ, FLOWRATE, SPILLVOL) & for which period(s): SPILLVOL 1 ⑩
Enter name of calculation method: FIXED ⑪
The deterministic value is: 12000 ⑫
EA ⑬

Enter spill class number and its full name: 2, DIESEL OIL FROM BARGES - NEW ENGLAND
Name class attribute (SPILLFRQ, FLOWRATE, SPILLVOL) & for which period(s): SPILLFRQ 1
Enter name of calculation method: NORMAL ⑭
Give mean value and standard deviation: 30.5 ⑮

Name class attribute (SPILLFRQ, FLOWRATE, SPILLVOL) & for which period(s): SPILLVOL 1
Enter name of calculation method: UNIFORM ⑯
Give range of values: 2000, 7000 ⑰
EA ⑱

Enter spill class number and its full name: 3, HEAVY CRUDE FROM OFFSHORE PRODUCTION - NEW ENGLAND
Name class attribute (SPILLFRQ, FLOWRATE, SPILLVOL) & for which period(s): SPILLFRQ 1
Enter name of calculation method: GAMMA ⑲
Give mean value and standard deviation: 90.10 ⑳

Name class attribute (SPILLFRQ, FLOWRATE, SPILLVOL) & for which period(s): SPILLVOL 1
Enter name of calculation method: TABLE
Indicate table length and pairs of values (frequency, value):
10 15 5000 20 5500 50 6000 100 6500 5 4500 ⑳

----- OUTPUT SPECIFICATIONS -----

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- Define output selection criteria (name attribute and spill class(es)): SPILLVOL 2 19
- Indicate required form of output (TSER or HIST) and parameters: TSER 40 20
- Choose report version (type: CLASSES, CLASSUM or SUMMARY): CLASSES 21
- 22
- Define output selection criteria (name attribute and spill class(es)): SPILLFRG 1
- Indicate required form of output (TSER or HIST) and parameters: HIST 1,10,40 26
- Choose report version (type: CLASSES, CLASSUM or SUMMARY): CLASSES 21
- 23
- Define output selection criteria (name attribute and spill class(es)): SPILLFRG 1,2,3
- Indicate required form of output (TSER or HIST) and parameters: HIST 24
- Choose report version (type: CLASSES, CLASSUM or SUMMARY): CLASSUM 25
- 22
- Define output selection criteria (name attribute and spill class(es)): SPILLVOL 3
- Indicate required form of output (TSER or HIST) and parameters: HIST 1501,500,20
- Choose report version (type: CLASSES, CLASSUM or SUMMARY): CLASSES 21
- 27
- Define output selection criteria (name attribute and spill class(es)): SPILLVOL 1,2,3
- Indicate required form of output (TSER or HIST) and parameters: HIST
- Choose report version (type: CLASSES, CLASSUM or SUMMARY): SUMMARY 28
- ES

Do you want to modify input data or start simulation (type: MODIFY or SIMULATE) ---- SIMULATE

SIMULATION OF OIL SPILL INCIDENTS --- A TEST RUN

SPILL SIZE FOR CLASS: 2 DIESEL OIL FROM BARGES - NEW ENGLAND

OUTPUT NO. 1 FOR PERIOD 1 - TIME SERIES

DATE VALUE

26	3750
82	4445
98	4314
130	2884
180	2840
193	2328
222	3283
247	2650
275	5534
303	5862
338	5386
368	6979
387	2754
413	5830
442	5327
472	2821
500	4445
528	3176
567	3964
603	6868
631	5890
653	5835
683	5339
707	3494
738	5381
762	3824
791	3792
822	4968
855	2241
884	2928
913	2765
939	3791
987	4250
995	2800
1021	6683
1057	4181
1084	6765
1118	4185
1145	6204
1183	5386

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SIMULATION OF OIL SPILL INCIDENTS --- A TEST RUN

INTERVALS BETWEEN SPILLS FOR CLASS: 1 LIGHT CRUDE FROM TANKERS

OUTPUT NO. 2 FOR PERIOD 1 - HISTOGRAM

RANGE OF VALUES			FREQUENCY	%	
1	-	10	39	12.91	.XXXXXXXXXXXXXXXX
11	-	20	40	13.25	.XXXXXXXXXXXXXXXX
21	-	30	32	10.60	.XXXXXXXXXXXXXX
31	-	40	38	12.58	.XXXXXXXXXXXXXXXX
41	-	50	22	7.28	.XXXXXXX
51	-	60	19	6.29	.XXXXXX
61	-	70	23	7.62	.XXXXXXXXXX
71	-	80	17	5.63	.XXXXXX
81	-	90	14	4.64	.XXXXX
91	-	100	6	1.99	.XX
101	-	110	7	2.32	.XX
111	-	120	5	1.66	.XX
121	-	130	4	1.32	.X
131	-	140	6	1.99	.XX
141	-	150	3	0.99	.X
151	-	160	6	1.99	.XX
161	-	170	3	0.99	.X
171	-	180	1	0.33	.
181	-	190	2	0.66	.X
191	-	200	3	0.99	.X
201	-	210	1	0.33	.
211	-	220	1	0.33	.
221	-	230	3	0.99	.X
231	-	240	0	0.00	.
241	-	250	0	0.00	.
251	-	260	1	0.33	.
261	-	270	2	0.66	.X
271	-	280	0	0.00	.
281	-	290	2	0.66	.X
291	-	300	0	0.00	.
301	-	310	1	0.33	.
311	-	320	0	0.00	.
321	-	330	0	0.00	.
331	-	340	0	0.00	.
341	-	350	1	0.33	.

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STATISTICAL ESTIMATES

NUMBER OF OBSERVATIONS = 302
 SUM OF OBSERVED VALUES = 18249.0
 MEAN = 60.4272
 VARIANCE = 3529.20
 STANDARD DEVIATION = 59.4070
 MAXIMUM OBSERVED VALUE = 341.000
 MINIMUM OBSERVED VALUE = 1.00000
 NO. OF VAL. BELOW MEAN = 190
 NO. OF VAL. ABOVE MEAN = 112
 STOCHASTIC CONVERGENCE = 3.41849

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SIMULATION OF OIL SPILL INCIDENTS --- A TEST RUN

INTERVALS BETWEEN SPILLS FOR CLASS: 1 LIGHT CRUDE FROM TANKERS
 OUTPUT NO. 3 FOR PERIOD 1 - HISTOGRAM

RANGE OF VALUES		FREQUENCY	%	
1	-	7	31	10.26 .XXXXXXXXXX
8	-	14	24	7.95 .XXXXXXXXXX
15	-	21	29	9.60 .XXXXXXXXXX
22	-	28	24	7.95 .XXXXXXXXXX
29	-	35	28	9.27 .XXXXXXXXXX
36	-	42	18	5.96 .XXXXXX
43	-	49	16	5.30 .XXXXXX
50	-	56	11	3.64 .XXXX
57	-	63	17	5.63 .XXXXXX
64	-	70	15	4.97 .XXXXXX
71	-	77	9	2.98 .XXX
78	-	84	12	3.97 .XXXX
85	-	91	10	3.31 .XXX
92	-	98	4	1.32 .X
99	-	105	3	1.00 .XX
106	-	112	4	1.32 .X
113	-	119	5	1.66 .XX
120	-	126	3	0.99 .X
127	-	133	2	0.66 .X
134	-	140	5	1.66 .XX
141	-	147	3	0.99 .X
148	-	154	3	0.99 .X
155	-	161	3	0.99 .X
162	-	168	3	0.99 .X
169	-	175	1	0.33 .
176	-	182	0	0.00 .
183	-	189	2	0.66 .X
190	-	196	3	0.99 .X
197	-	203	0	0.00 .
204	-	210	1	0.33 .
211	-	217	1	0.33 .
218	-	224	3	0.99 .X
225	-	231	0	0.00 .
232	-	238	0	0.00 .
239	-	245	0	0.00 .
246	-	252	0	0.00 .
253	-	259	1	0.33 .
260	-	266	1	0.33 .
267	-	273	1	0.33 .
274	-	280	0	0.00 .
281	-	287	1	0.33 .
288	-	294	1	0.33 .
295	-	301	0	0.00 .
302	-	308	1	0.33 .
309	-	315	0	0.00 .
316	-	322	0	0.00 .
323	-	329	0	0.00 .
330	-	336	0	0.00 .
337	-	343	1	0.33 .

STATISTICAL ESTIMATES

 NUMBER OF OBSERVATIONS = 302
 SUM OF OBSERVED VALUES = 18249.0
 MEAN = 60.4272
 VARIANCE = 3529.20
 STANDARD DEVIATION = 59.4070
 MAXIMUM OBSERVED VALUE = 341.000
 MINIMUM OBSERVED VALUE = 1.00000
 NO. OF VAL. BELOW MEAN = 190
 NO. OF VAL. ABOVE MEAN = 112
 STOCHASTIC CONVERGENCE = 3.41849

SIMULATION OF OIL SPILL INCIDENTS --- A TEST RUN

INTERVALS BETWEEN SPILLS FOR CLASS: 2 DIESEL OIL FROM BARGES - NEW ENGLAND

OUTPUT NO. 3 FOR PERIOD 1 - HISTOGRAM

RANGE OF VALUES	FREQUENCY	%
14	1	0.16
15	0	0.00
16	0	0.00
17	2	0.32
18	2	0.32
19	3	0.48
20	3	1.29
21	8	1.13
22	7	1.75
23	17	2.36
24	27	3.72
25	40	5.46
26	41	5.62
27	47	6.55
28	54	7.72
29	46	7.43
30	53	7.56
31	47	7.59
32	42	6.49
33	34	5.49
34	26	4.20
35	27	4.36
36	19	3.07
37	14	2.26
38	16	2.58
39	8	1.29
40	8	1.29
41	2	0.32
42	4	0.65
43	1	0.16

STATISTICAL ESTIMATES

NUMBER OF OBSERVATIONS	=	619
SUM OF OBSERVED VALUES	=	18253.0
MEAN	=	29.4879
VARIANCE	=	23.4153
STANDARD DEVIATION	=	4.83883
MAXIMUM OBSERVED VALUE	=	43.0000
MINIMUM OBSERVED VALUE	=	14.0000
NO. OF VAL. BELOW MEAN	=	318
NO. OF VAL. ABOVE MEAN	=	301
STOCHASTIC CONVERGENCE	=	0.194493

SIMULATION OF OIL SPILL INCIDENTS --- A TEST RUN

INTERVALS BETWEEN SPILLS FOR CLASS: 3 HEAVY CRUDE FROM OFFSHORE
 OUTPUT NO. 3 FOR PERIOD 1 - HISTOGRAM

RANGE OF VALUES			FREQUENCY	%
26	-	28	1	0.49 .
29	-	31	1	0.49 .
32	-	34	1	0.49 .
35	-	37	0	0.00 .
38	-	40	1	0.49 .
41	-	43	4	1.96 .XX
44	-	46	0	0.00 .
47	-	49	5	2.45 .XX
50	-	52	5	2.45 .XX
53	-	55	5	2.45 .XX
56	-	58	4	1.96 .XX
59	-	61	6	2.94 .XXX
62	-	64	10	4.90 .XXXXX
65	-	67	9	4.41 .XXXX
68	-	70	10	4.90 .XXXXX
71	-	73	10	4.90 .XXXXX
74	-	76	8	3.92 .XXXX
77	-	79	11	5.39 .XXXXX
80	-	82	5	2.45 .XX
83	-	85	8	3.92 .XXXX
86	-	88	7	3.43 .XXX
89	-	91	7	3.43 .XXX
92	-	94	2	0.98 .X
95	-	97	15	7.35 .XXXXXXXX
98	-	100	8	3.92 .XXXX
101	-	103	6	2.94 .XXX
104	-	106	4	1.96 .XX
107	-	109	6	2.94 .XXX
110	-	112	2	0.98 .X
113	-	115	2	0.98 .X
116	-	118	3	1.47 .X
119	-	121	2	0.98 .X
122	-	124	0	0.00 .
125	-	127	7	3.43 .XXX
128	-	130	6	2.94 .XXX
131	-	133	5	2.45 .XX
134	-	136	0	0.00 .
137	-	139	3	1.47 .X
140	-	142	2	0.98 .X
143	-	145	1	0.49 .
146	-	148	3	1.47 .X
149	-	151	1	0.49 .
152	-	154	1	0.49 .
155	-	157	2	0.98 .X
158	-	160	2	0.98 .X
161	-	163	0	0.00 .
164	-	166	0	0.00 .
167	-	169	0	0.00 .
170	-	172	2	0.98 .X

STATISTICAL ESTIMATES

 NUMBER OF OBSERVATIONS = 204
 SUM OF OBSERVED VALUES = 18251.0
 MEAN = 89.4657
 VARIANCE = 940.733
 STANDARD DEVIATION = 30.8714
 MAXIMUM OBSERVED VALUE = 191.000
 MINIMUM OBSERVED VALUE = 26.0000
 NO. OF VAL. BELOW MEAN = 112
 NO. OF VAL. ABOVE MEAN = 92
 STOCHASTIC CONVERGENCE = 2.14743

INTERVALS BETWEEN SPILLS FOR CLASSES:

- (1) LIGHT CRUDE FROM TANKERS - NEW ENGLAND
 (2) DIESEL OIL FROM BARGES - NEW ENGLAND
 (3) HEAVY CRUDE FROM OFFSHORE PRODUCTION - NEW ENGLAND
 OUTPUT NO. 3 FOR PERIOD 1 - HISTOGRAM

RANGE OF VALUES		FREQUENCY	%
1 -	7	31	2.76 .XXX
8 -	14	25	2.22 .XX
15 -	21	51	4.53 .XXXXX
22 -	28	274	24.36 .XXXXXXXXXXXXXXXXXXXXXXXXXXXX
29 -	35	305	27.11 .XXXXXXXXXXXXXXXXXXXXXXXXXXXX
36 -	42	93	8.27 .XXXXXXX
43 -	49	23	2.04 .XX
50 -	56	23	2.04 .XX
57 -	63	32	2.84 .XXX
64 -	70	37	3.29 .XXX
71 -	77	30	2.67 .XXX
78 -	84	32	2.84 .XXX
85 -	91	25	2.22 .XX
92 -	98	24	2.13 .XX
99 -	105	19	1.69 .XX
106 -	112	13	1.16 .X
113 -	119	11	0.98 .X
120 -	126	10	0.89 .X
127 -	133	14	1.24 .X
134 -	140	9	0.80 .X
141 -	147	8	0.71 .X
148 -	154	5	0.44 .
155 -	161	7	0.62 .X
162 -	168	3	0.27 .
169 -	175	3	0.27 .
176 -	182	0	0.00 .
183 -	189	2	0.18 .
190 -	196	4	0.36 .
197 -	203	0	0.00 .
204 -	210	1	0.09 .
211 -	217	1	0.09 .
218 -	224	3	0.27 .
225 -	231	0	0.00 .
232 -	238	0	0.00 .
239 -	245	0	0.00 .
246 -	252	0	0.00 .
253 -	259	1	0.09 .
260 -	266	1	0.09 .
267 -	273	1	0.09 .
274 -	280	0	0.00 .
281 -	287	1	0.09 .
288 -	294	1	0.09 .
295 -	301	0	0.00 .
302 -	308	1	0.09 .
309 -	315	0	0.00 .
316 -	322	0	0.00 .
323 -	329	0	0.00 .
330 -	336	0	0.00 .
337 -	343	1	0.09 .

STATISTICAL ESTIMATES

NUMBER OF OBSERVATIONS	=	1125
SUM OF OBSERVED VALUES	=	54753.0
MEAN	=	48.6693
VARIANCE	=	1668.71
STANDARD DEVIATION	=	40.8621
MAXIMUM OBSERVED VALUE	=	341.000
MINIMUM OBSERVED VALUE	=	1.00000
NO. OF VAL. BELOW MEAN	=	797
NO. OF VAL. ABOVE MEAN	=	328
STOCHASTIC CONVERGENCE	=	1.21827

SIMULATION OF OIL SPILL INCIDENTS --- A TEST RUN

SPILL SIZE FOR CLASS: 3 HEAVY CRUDE FROM OFFSHORE PRODUCTION - NEW ENGLAND

OUTPUT NO. 4 FOR PERIOD 1 - HISTOGRAM

RANGE OF VALUES	FREQUENCY	%
4001 - 4500	5	2.45 .XX
4501 - 5000	28	13.73 .XXXXXXXXXXXXXXXXXX
5001 - 5500	46	22.55 .XXXXXXXXXXXXXXXXXX
5501 - 6000	106	51.96 .XXXXXXXXXXXXXXXXXX
6001 - 6500	19	9.31 .XXXXXXXXXX

STATISTICAL ESTIMATES

NUMBER OF OBSERVATIONS	=	204
SUM OF OBSERVED VALUES	=	0.117500E+07
MEAN	=	5759.80
VARIANCE	=	215421.
STANDARD DEVIATION	=	464.134
MAXIMUM OBSERVED VALUE	=	6500.00
MINIMUM OBSERVED VALUE	=	4500.00
NO. OF VAL. BELOW MEAN	=	79
NO. OF VAL. ABOVE MEAN	=	125
STOCHASTIC CONVERGENCE	=	32.4959

SIMULATION OF OIL SPILL INCIDENTS --- A TEST RUN

SPILL SIZES FOR CLASSES:

- (1) LIGHT CRUDE FROM TANKERS - NEW ENGLAND
- (2) DIESEL OIL FROM BARGES - NEW ENGLAND
- (3) HEAVY CRUDE FROM OFFSHORE PRODUCTION - NEW ENGLAND

OUTPUT NO. 5 FOR PERIOD 1 - HISTOGRAM

RANGE OF VALUES		FREQUENCY	%	
2041 -	2247	35	3.11	.XXX
2248 -	2454	28	2.49	.XX
2455 -	2661	20	1.78	.XX
2662 -	2868	26	2.31	.XX
2869 -	3075	25	2.22	.XX
3076 -	3282	27	2.40	.XX
3283 -	3489	21	1.87	.XX
3490 -	3696	30	2.67	.XXX
3697 -	3903	21	1.87	.XX
3904 -	4110	22	1.96	.XX
4111 -	4317	30	2.67	.XXX
4318 -	4524	28	2.49	.XX
4525 -	4731	26	2.31	.XX
4732 -	4938	25	2.22	.XX
4939 -	5145	58	5.16	.XXXXXX
5146 -	5352	21	1.87	.XX
5353 -	5559	72	6.40	.XXXXXX
5560 -	5766	28	2.49	.XX
5767 -	5973	33	2.93	.XXX
5974 -	6180	132	11.73	.XXXXXXXXXXXXXX
6181 -	6387	19	1.69	.XX
6388 -	6594	46	4.09	.XXXX
6595 -	6801	22	1.96	.XX
6802 -	7008	28	2.49	.XX
7009 -	7215	0	0.00	.
7216 -	7422	0	0.00	.
7423 -	7629	0	0.00	.
7630 -	7836	0	0.00	.
7837 -	8043	0	0.00	.
8044 -	8250	0	0.00	.
8251 -	8457	0	0.00	.
8458 -	8664	0	0.00	.
8665 -	8871	0	0.00	.
8872 -	9078	0	0.00	.
9079 -	9285	0	0.00	.
9286 -	9492	0	0.00	.
9493 -	9699	0	0.00	.
9700 -	9906	0	0.00	.
9907 -	10113	0	0.00	.
10114 -	10320	0	0.00	.
10321 -	10527	0	0.00	.
10528 -	10734	0	0.00	.
10735 -	10941	0	0.00	.
10942 -	11148	0	0.00	.
11149 -	11355	0	0.00	.
11356 -	11562	0	0.00	.
11563 -	11769	0	0.00	.
11770 -	11976	0	0.00	.
11977 -	12183	302	26.84	.XXXXXXXXXXXXXXXXXXXXXXXXXXXX

STATISTICAL ESTIMATES

NUMBER OF OBSERVATIONS = 1125
 SUM OF OBSERVED VALUES = 0.758873E+07
 MEAN = 6745.54
 VARIANCE = 0.115600E+08
 STANDARD DEVIATION = 3400.00
 MAXIMUM OBSERVED VALUE = 12000.0
 MINIMUM OBSERVED VALUE = 2041.00
 NO. OF VAL. BELOW MEAN = 788
 NO. OF VAL. ABOVE MEAN = 337
 STOCHASTIC CONVERGENCE = 101.368

EXPLANATION OF NOTES

1. The run title (up to 80 alphanumeric characters) is printed as a heading before every output.
2. 365 days of spill incidence scenario are assumed.
3. 50 replications of the one-year simulation period are required.
4. If the seed for the random number generator is not a user input then the program supplies a default value of 17.
5. Classes should be entered in numerical order starting with class number 1; this should be separated from spill class name by a comma.
6. The spill class name can be up to 80 characters long. This name is printed later on output headings.
7. Spill frequency of occurrence (reserved symbol).
8. Period number; in this case only one. If, for instance, this spill frequency information relates to period 1, 3 and 4 then it should be entered as: SPILLVOL 1,3,4.
9. Time interval between successive spills has an average of 60 days, and is to be sampled from a negative exponential probability density function.
10. Next attribute input is involed by pressing "return" key.
11. Spill volume (reserved symbol).
12. Fixed volume of 12,000 gallons is assumed each time a spill event of class 1 occures.
13. "EA" is an abbreviation for "end of attributes". This should be typed in order to signal the end of description of a

spill class which, however, is not the last in sequence. In the latter case the letters "EC" should be input which mean "end of classes" (see note 18).

14. Time interval between successive spills is to be sampled from a normal probability function with mean value of 30 days and standard deviation of 5. The two parameters should be separated by comma.

15. Spill volume is to be determined by means of a uniform distribution (rectangular) with a lower bound of 2,000 gallons and an upper bound of 7,000 gallons.

16. Class 3 spill frequency is to be sampled from a Gamma theoretical distribution with a mean value of 90 days and standard deviation of 10.

17. Spill volume for class 3 is to be sampled from a discrete empirical distribution (or table). The first number (10) indicates the table length (i.e. total number of values). The pairs of values have the following meaning:

15%	5,000 gallons
20%	5,500 gallons
50%	6,000 gallons
10%	6,500 gallons
5%	4,500 gallons

These numbers can be interpreted either as probabilities (0.15, 0.2, 0.5, 0.1, 0.05), or as numbers of empirical observations (15 observations, 20 observations, 50 observations etc.) relating to corresponding spill volumes.

18. The letters EC signal to the program that this is the end of the description of classes. After entering EC, the program switches to the output specifications mode.

19. This means that we require information concerning spill volume for class number 2.

20. Simulated amounts of spills are to be printed out in the form of time series with up to 40 consecutive print lines.

21. Output for each individual class, as listed.

22. Next output specification is invoked by pressing "return" key.

23. Simulated intervals between consecutive spill events are outputs in the form of an automatically scaled histogram.

24. Output for specified classes individually and combined.

25. Spill volume output in the form of a histogram with parameters as follows:

- from value 1501 (including)
- increment 500
- up to 20 bins.

The three parameters should be separated by commas.

26. Intervals between simulated spill occurrence are to be output in histogram form with the following parameters:

- lowest value to be registered in histogram = 1
- increment (bin size) = 10
- maximum of 40 bins to be printed out.

27. Spill volumes for all three classes combined in an automatically scaled histogram.

28. Letters ES are entered to indicate the end of output specifications.

29. The dates are relative to the start of simulation at time = 0. Thus, the first pair of numbers 26 and 3750 means that the first spill event occurred at the 26th day and that the amount of released oil was 3750 gallons. The second spill event occurred at the 62nd day with 4445 gallons etc. Intervals between spills are sampled from a normal probability function and corresponding volumes from a uniform probability function.

30. In graphical form, percentages are rounded up to the nearest integer. Every character "X" represents 1%.

31. 40 print positions were specified in the output specifications (see note 26), but the length of the histogram was shortened to 35 lines because there were no simulated time intervals between class 1 spills longer than 341 days.

32. Number of observations included in the histogram.

3. DESCRIPTION OF COMPUTER PROGRAMS

The simulation program consists of three main subroutines. INTLZ, SPNCL and RESPONSE which are called from the control program named SIMSPILL.

The basic functions of these subroutines are as follows:

(1) Subroutine INTLZ:

- accepting model parameters in interactive way;
- control of input data;
- setting up initial state of the model.

Subroutine INTLZ calls other subroutines which perform house-keeping functions:

- Subroutine ICO is used to identify 8 character reserved words which are entered to describe the spill classes and output requirements.
- Subroutine CO is used to identify 4 character reserved words which are used to define forms of required outputs.
- Block Data segment BVOC serves as a vocabulary of all the reserved words which are identified by means of subroutines ICO and CO.
- Subroutine DETVAL is called by INTLZ to determine the dates of the first spill events before the simulation process is started. This subroutine is called frequently by the main simulation algorithm (more details on DETVAL functions are given in the description of subroutine SPNCL).

Subroutine INTLZ sets up the basic data structure of the model represented by arrays JP, FP, PA, D, SP and E which are

placed in an unlabelled COMMON block.

Integer array IP

This 50-element array is used to store the general simulation process parameters, various counters and other values which are utilized, checked and updated throughout the run.

The meaning of the array elements is as follows:

1. Length of simulation period 1.
2. Length of simulation period 2.
3. Length of simulation period 3.
4. Length of simulation period 4.
5. Required number of replications for each period.
6. Random number generator seed value; if not specified on input, it is set to a default value = 17.
- 7-9. Spare elements.
10. Number of output specifications.
11. Number of spill classes.
12. Input data error counter.
13. Current number of time-cells. Every element $E(n,3)$ is called a time-cell used to control occurrences of events.
14. Total number of simulated periods.
15. Number of simulation output logical records stored on disc file; one record is 2000 words long
16. Run repetition indicator:
 - 1 - for the first run
 - 2 - for a repetition with some modification in the original input data.

17-50.Spare elements.

Real Array FP

This 50-element array is presently used as follows:

1-20. Simulation run title

21. Length of simulation period 1

22. Length of simulation period 2

23. Length of simulation period 3

24. Length of simulation period 4

25-50.Spare elements

Integer Array PA(CLASS, REF, PER, V)

DIMENSION (100, 16, 4, 4)

This array contains description of spill data.

CLASS: A class of oil (in case of oil spills)

REF: Class Attribute.

1 - spill frequency (SPILLFRQ)

2 - flow rate (FLOWRATE)

3 - spill volume (SPILLVOL)

4,...16 - Spare for future model extension.

PER: Period number

V: parameters -

V = 1, PA(CLASS, REF, PER, 1) : the type of calculation
procedure.

1 Deterministic

2 Sampling from tables (theoretical or empirical)

3 Poisson

4 Normal

- 5 Gamma
- 6 Negative Exponential
- 7 Uniform
- 8,...,10 Spare

V = 2, PA(CLASS, REF, PER, 2):

- fixed value in case of deterministic option;
- mean value in case of sampling from theoretical functions: Poisson, Normal, Gamma, Negative Exponential;
- Upper bound value in case of uniform distribution;
- Unique table number assigned by program in case of sampling from empirical type distribution.

V = 3, PA(CLASS, REF, PER, 3):

- Standard deviation in case of sampling from theoretical functions: Normal, or Gamma.
- lower bound value in case of uniform distribution.

V = 4, PA(CLASS, REF, PER, 4)

- Length of time between successive releases of oil

Integer Array D

This 3000 element array contains empirical or theoretical tables which are used for sampling discrete values during the simulation process. Tables are entered in the form of pairs of numbers: frequency - observed value. The frequencies are then converted to percentages in subroutine INTLZ so as to enable sampling. Every table occupies 100 elements of array D, and every observed value is repeated in n elements, where n is frequency expressed as a

percentage of the total number of observations.

Integer Array SP(N,V)

- N - Output specification number (up to 20 outputs)
V - Parameter relating to the output No. N (max. value 26)

Meaning of parameters for a given output N:

SP(N,1) - Class attribute:

- 1 Spill frequency (SPILLFRQ)
- 2 Flow rate (FLOWRATE)
- 3 Spill volume (SPILLVOL)

SP(N,2) - Output type:

- 1 Time series (TSER)
- 2 Histogram with statistical data (HIST)
- 3 Plotting (PLOT)

SP(N,3) - SP(N, 4) - spare

SP(N,5) - Histogram parameter: starting value

SP(N,6) - Histogram parameter: incremental value

SP(N,7) - Histogram parameter: number of print lines.

SP(N,8) - Report type:

- 1 for each class separately (CLASSES)
- 2 for each class separately and summary (CLASSSUM)
- 3 summary report for all listed classes (SUMMARY)

SP(N,9),...,SP(N,26) Numbers of classes to be included in the output N.

Integer Array E

DIMENSION E(1000,5)

Array E contains the simulated system state which is under the

control of the main simulation algorithm. The notation is $E(U,P)$ where U is a model element (or entity) which represents a feature, such as spill frequency, spill volume, released rate or others, and P is an index representing some parameters.

The meaning of parameters is as follows:

$E(U,1)$ - Oil spill class number (1-100)

$E(U,2)$ - Class attribute (1-16)

$E(U,3)$ - Time cell; its meaning depends upon the value of $E(U,2)$
i.e. what class attribute it represents.

if $E(U,2) = 1$: entity U represents control of spill events for the
class $E(U,1)$

$E(U,3)$ - time cell whose current value gives amount of time
before nearest spill event; if the value of $E(U,3) =$
0 it signals the occurrence of spill event for the
class given by $E(U,1)$

$E(U,4)$ - spare

$E(U,5)$ - spare

if $E(U,2) = 2$: entity U represents control of cyclic releases of
oil from a spillage source;

$E(U,3)$ - time cell whose current value represents amount of
time before next release of oil; if the value of
 $E(U,3) = 0$ then it signals time now for a release
event;

$E(U,4)$ - size of one release

$E(U,5)$ - spare

If $E(U,2) = 3$: entity U represents the total amount of spilled

oil in a given event.

- E(U,3) - time cell which measures time of stay of a given spill in system.
- E(U,4) - total spill volume determined at spill event then decreased cyclically until it reaches zero.
- E(U,5) - current amount of released oil from a given spill event; at the time of spill event it is equal to zero, then it is cyclically incremented by flow rate value.

(2) Subroutine SPNCL

This subroutine constitutes the algorithm which controls the simulation of oil spill events and the flow of oil from the spillage source (see fig. 3.1. - 3.4.). The framework of the subroutine is constructed so as to allow future expansion which would include simulation of cleanup operations, behavior of oil at sea, transportation and storage of recovered oil and other related processes. SPNCL activities are supported by the following subroutines:

- Subroutine MOVE contains the general purpose time flow mechanism which simulates the discrete passage of time from event to event (see Fig. 3.4.)
- Subroutine STATE is called at each time there is a need to record a set of data connected with the spill event as indicated by the output specifications. Observations generated during the simulation process are either stored by this subroutine into the main memory, or, alternatively, sent to a disc file, depending upon the amount of data. Subroutine STATE

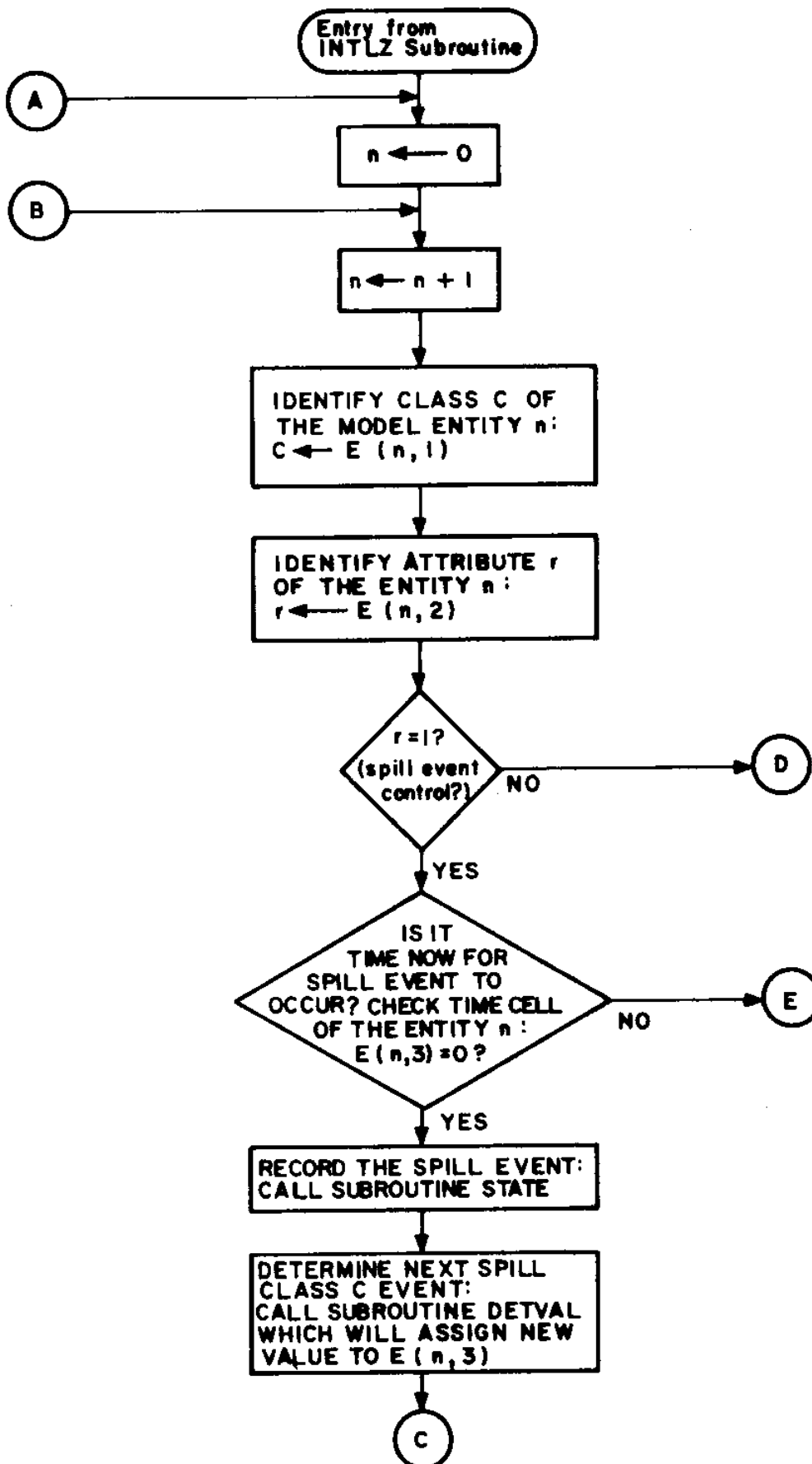


Fig. 3.1 Simulation algorithm — part A

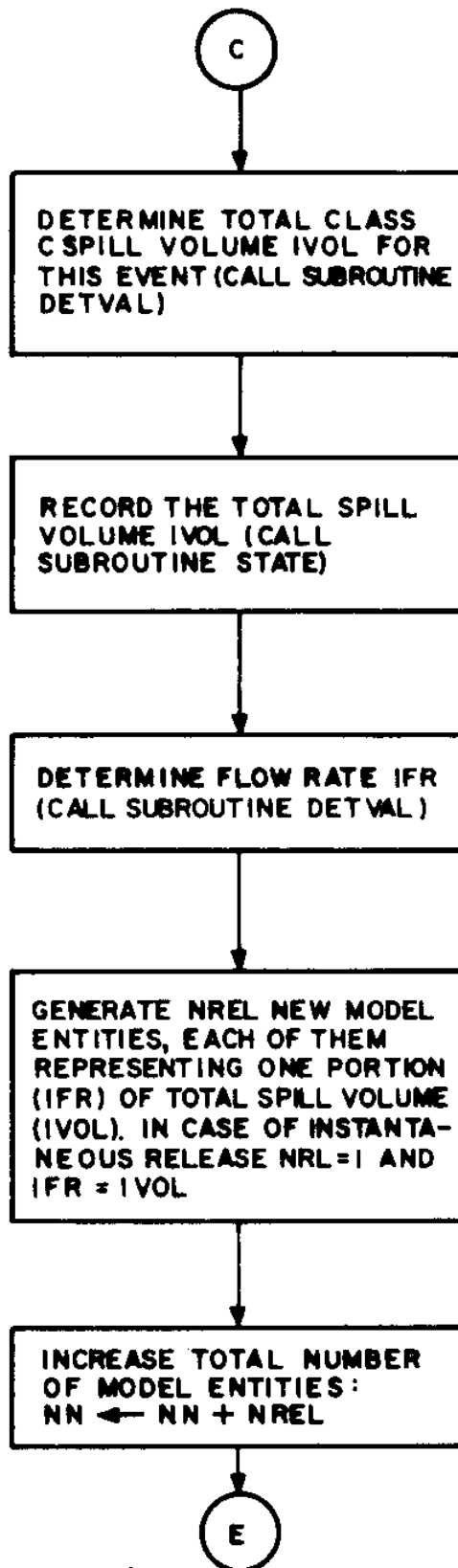


Fig. 3.2 Simulation algorithm — part B

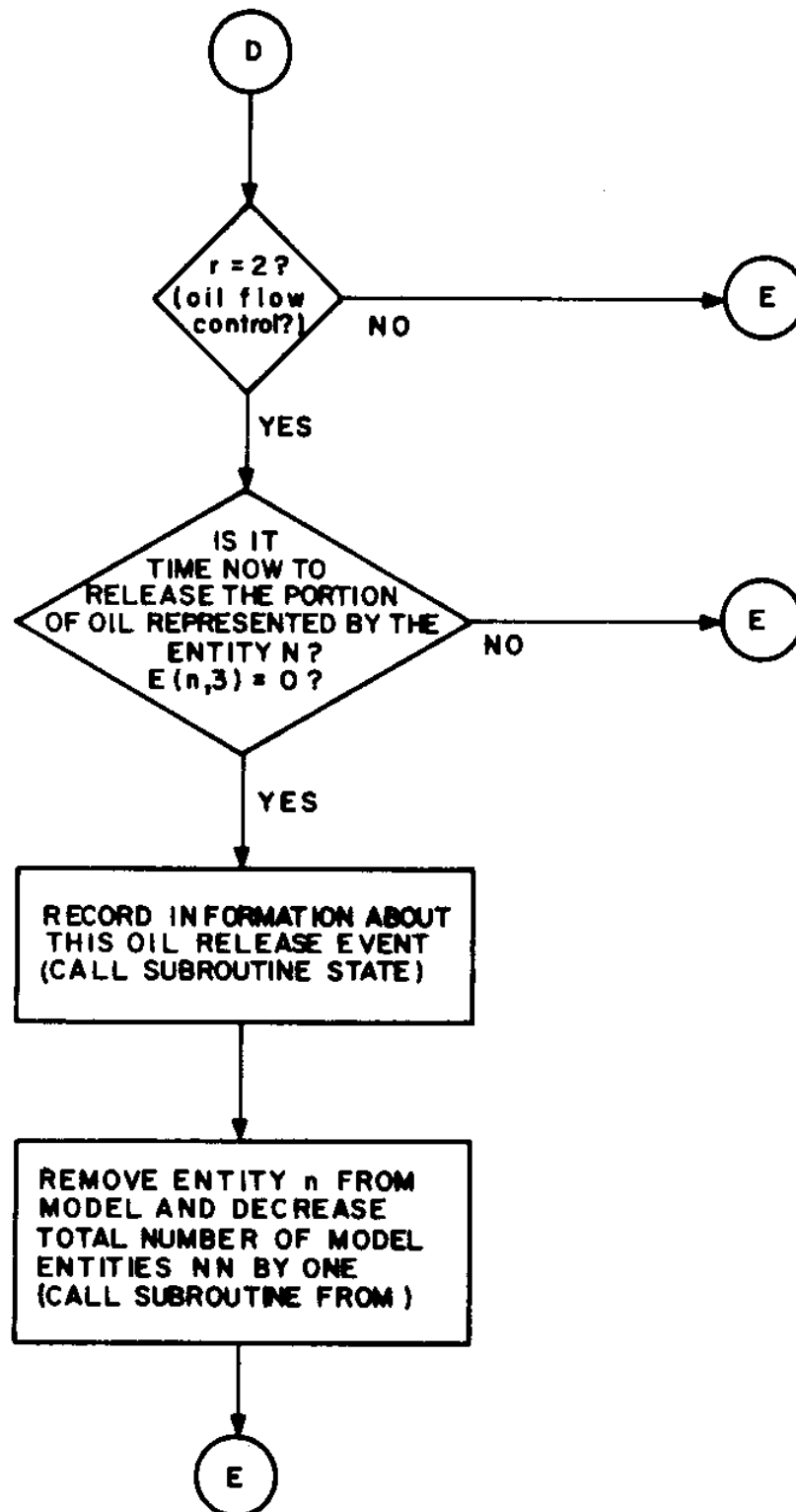


Fig. 3.3 Simulation algorithm — part C

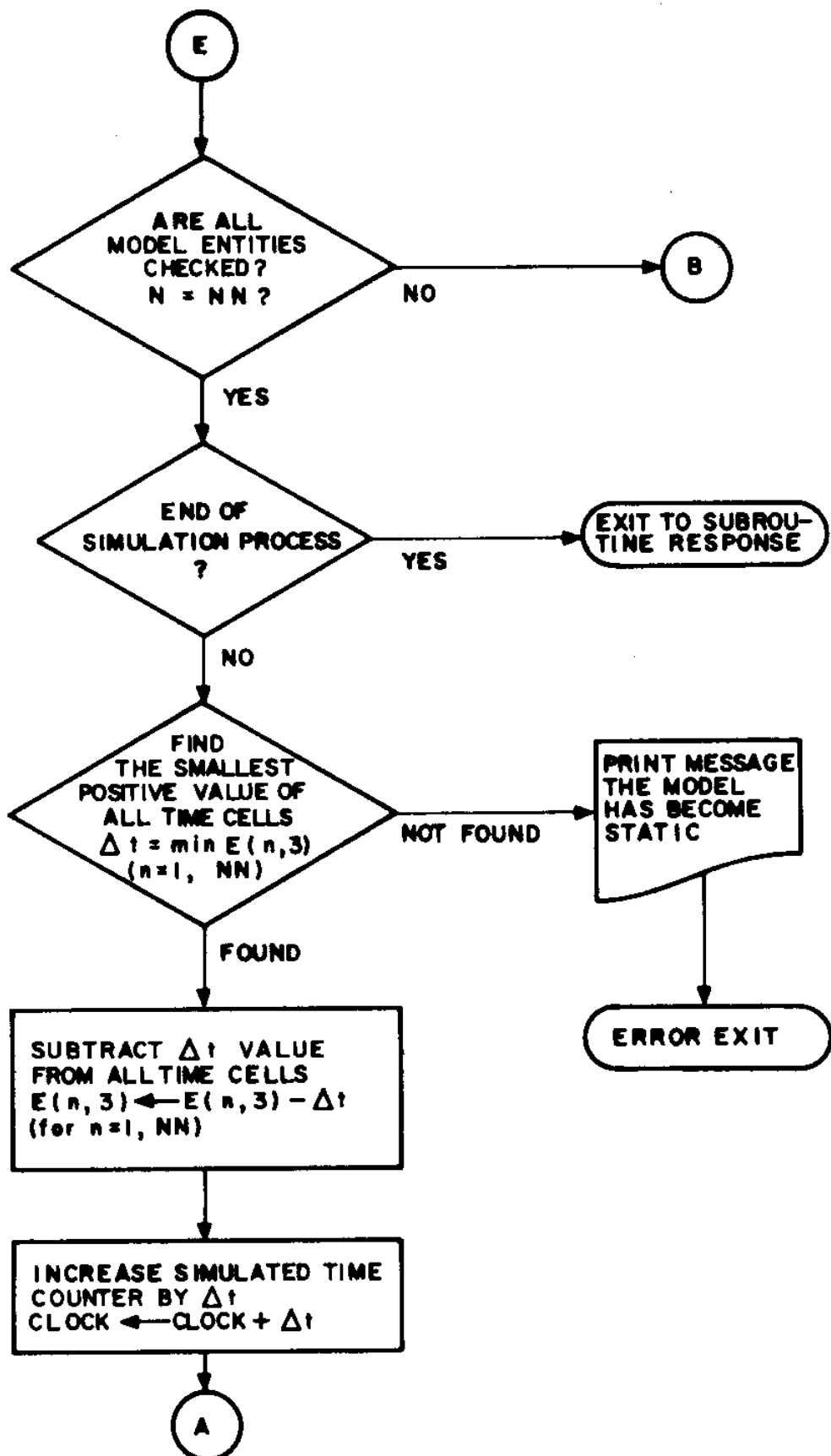


Fig. 3.4 Simulation algorithm — part D

is also prepared to accept time series relating to cleanup operations and other aspects of the oil spill scenario.

Integer Array OB

Array OB is used by subroutine STATE to store information on simulated spill events, volumes and flow rates in the form of 5 element sets as follows:

OB(NOBS-4) - Simulation clock value ("current date")
OB(NOBS-3) - Spill class
OB(NOBS-2) - Class attribute
OB(NOBS-1) - Period number
OB(OBS) - Observed value relating to the subject defined by
OB(OBS-2)

with $5 \leq \text{OBS} \leq 2000$

If total number of observations reaches 2000 items, matrix OB is sent to disc and number of records on disc file (IP(15)) is updated. One or more blocks of 2000 elements each, form a time series which is processed by subroutine RESPONSE after simulation process is completed.

- subroutine FROM is a housekeeping procedure used to remove the spilled oil from the simulated scene in order to avoid model overflow. The simulation algorithm structure was constructed so as to include cleanup operations, behavior of oil at sea, recovered oil transportation and storage etc. As these functions have not yet been included in the model, subroutine FROM is a temporary mechanism which removes from the model information about a spilled amount as soon as it is recorded by the STATE

subroutine.

- subroutine DETVAL is called each time there is a need to calculate:

- (a) time period before next spill event.
- (b) volume of spilled oil.
- (c) amount of every release, in case of continuous flow. Several computation methods are available in the subroutine. Apart from deterministic option, it is possible to sample random variates using the following probability density functions:

- (a) Negative exponential
- (b) Gamma
- (c) Rectangular (or Uniform)
- (d) Normal

There is also a procedure of sampling from theoretical or empirical or theoretical discrete tables (or histograms) which are stored in array D set up by a number of entries are available to insert other specific functions.

(3) Subroutine RESPONSE

This is the program segment which performs the following output functions:

- retrieval of time series generated during simulation process;
- processing simulation model response so as to obtain required estimates;
- printout of simulation results in forms defined in output specifications and stored in array SP.

After the printout control is turned over to the SIMSPIL program

in order to enquire: to end the run or to repeat it with some modifications in input parameters.

Real array ST is used by subroutine RESPONSE to store statistical indicators calculated from simulated time series.

ST(C,P,V) with DIMENSION (11,5,10)

where C is class number

P is period number

V is vector of statistical indicators for class C and period

P as follows:

ST(C,P,1) - Total number of observations

ST(C,P,2) - Sum of observed values

ST(C,P,3) - Arithmetic mean

ST(C,P,4) - Sum of squares of differences:

ST(C,P,5) - Variance

ST(C,P,6) - Standard deviation

ST(C,P,7) - Maximum observed value

ST(C,P,8) - Minimum observed value.

ST(C,P,9) - Number of values below mean.

ST(C,P,10) - Number of values above mean.

ST(C,5,V) - Contains statistical data calculated for all simulated periods combined.

ST(11,P,V) Contains statistical data calculated for all classes combined.

4. POSSIBLE PROGRAM EXTENSIONS

All the input and output routines as well as the simulation algorithm are organized at a high level of generality so as to enable the simulation of cleanup operations, transportation and storage of recovered oil, breakdown of equipment, behavior of oil at sea, weather changes and many other phenomena.

In order to make use of the versatility of the program, it is necessary to take into consideration the following basic features:

1. The classes and attributes can be related not only to oil spills but to any simulated physical or abstract objects, or to any simulated processes (or phenomena). For instance, a set of cleanup equipment type T can be interpreted as a class which is characterized by a number of attributes describing e.g. its efficiency under different weather conditions, unit costs, deployment time etc. In order to increase the input capacity it is necessary to expand the program vocabulary by defining new symbolic names of class attributes in the Block Data segment (BVOC). These names can then be used as inputs to identify various properties of cleanup equipment, weather, sea state, storage facilities etc.
2. The simulated objects (physical or abstract) are represented in the program data structure by the array E. Every element $n - E(n,i)$ - corresponds to some portion of the original entity. This reference is indicated by $E(n,1)$, which gives the class number, and by $E(n,2)$ which defines the attribute number. Action of the

appropriate simulation subprogram is initiated according to the attribute number.

3. The third dimension of vector $i - E(n,3)$ - is a time cell which is under control of the general time flow mechanism (subroutine MOVE). This is independent of the type of simulated system.

4. The determination of any space and time values concerning spills, cleanup, weather etc. during the simulation process is executed by the general purpose routine (DETVAL) which is independent of the type of the simulated process. However, it is possible to insert additional functions for specific calculations.

5. Observations on the changing states of the simulated system are being collected and recorded in the form of time series by subroutine STATE. The structure of the time series is uniform and independent of the meaning of its elements. Thus the subroutine STATE can handle all data related not only to oil spills but also to other processes.

6. Subroutine RESPONSE whose main function is to process the time series generated during the simulation has a sufficiently abstract structure so as to perform calculations for any reference (i.e. attribute/class combination). Subroutine STATE records observations only on the attributes of those classes which have been specified as inputs. Consequently, subroutine RESPONSE also processes the time series which are related to the indicated references.

5. REFERENCES

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7. Belantoni, J. et al. "Deployment Requirements for U.S. Coast Guard Pollution Response Equipment", Report to U.S. Department of Transportation, Transportation Systems Center, February 1979.

APPENDIX A

SIMPIL SOURCE PROGRAM LISTING

PROGRAM SIMSPILL

```

C      DIMENSION IP(50),FP(50)
      DATA Y/'YES '/
C
      COMMON IP,FP
      DO 20 I=1,50
        IP(I)=0
20      FP(I)=0.0
        IP(16)=1
1      CALL INTLZ
2      CALL SPNCL
3      CALL RESPONSE
      PRINT 50
50      FORMAT(///5X,'Do you want to modify input ',
1'data and repeat simulation (type YES or NO)? ',*)
      READ 60, RPLY
60      FORMAT(A4)
      IF(RPLY-Y) 98,65,98
65      IP(16)=2
      GO TO 1
C
98      PRINT 100
100     format(////)
      STOP 'End of simulation run'
      end

```

subroutine intlz

```

C      INTEGER V,PA,CLASS,D,PER,P,E,DISNO,SP
C
      DATA XX/'MODI'/
      DATA Y/'YES '/
      DIMENSION CLNAM(100,20), REF(2), V(3), TP(2)
      DIMENSION PA(100,16,4,4), D(3000), PER(4)
      DIMENSION IP(50),FP(50),ITB(100),E(1000,5)
      DIMENSION SP(20,26), ICS(11)
C
      COMMON IP,FP,CLNAM,SP,PA,E,D
C
      N=IP(10)
      ISW=IP(16)
      GO TO(25,130),ISW
25      CONTINUE
C
      OPEN(UNIT=4,TYPE='SCRATCH',ACCESS='DIRECT',
1RECORDTYPE='FIXED',RECORDSIZE=8004,INITIALSIZE=50)
C

```

```

      DO 30 I=1,100
      DO 30 J=1,20
30     CLNAM(I,J)=0.0
      DO 40 I=1,100
      DO 40 J=1,16
      DO 40 NFM=1,4
      DO 40 NTL=1,4
40     PA(I,J,NFM,NTL)=0
      DO 50 I=1,1000
      DO 50 J=1,5
50     E(I,J)=0
      DISNO=-100
      CLASS=0
      DO 55 I=1,20
      DO 55 J=1,26
55     SP(I,J)=0
C
C
C     READ RUN TITLE AND GENERAL PARAMETERS OF THE SIMULATION
C
      PRINT 1110
130     GO TO(145,135),ISW
135     PRINT 1135
      READ 1510,RPLY
      IF(RPLY-Y) 910,145,910
145     PRINT 1111
150     READ 1150, (FP(I),I=1,20)
910     GO TO(920,915),ISW
915     PRINT 1915
      READ 1510, RPLY
      IF(RPLY-Y) 178,920,178
920     PRINT 1120
      PRINT 1151
152     READ 1152, (IP(I),I=1,4)
      IF(IP(1)) 155,155,157
155     PRINT 9155
      GO TO 152
157     PRINT 1157
      READ 1158, IP(5)
160     IF(IP(5)) 165,165,170
165     PRINT 9165
      GO TO 152
170     PRINT 1170
      READ 1158, IP(6)
      IF(IP(6))175,175,178
175     IP(6)=17
178     GO TO(179,940),ISW
940     PRINT 1940
      READ 1510,RPLY
      IF(RPLY-Y)798,179,798
```

```
179 PRINT 1178
180 PRINT 1182
C
C READ DESCRIPTIONS OF MODEL CLASSES AND ATTRIBUTES
C
READ 1180,CLASS,(CLNAM(CLASS,I),I=1,20)
IP(11)=IP(11)+1
190 PRINT 1183
READ 1180,REF,PER
CALL ICO(2,40,2,REF,IRF)
IF(IRF) 192,192,195
192 PRINT 9192, REF
GO TO 190
195 IF(IRF-17) 193,180,300
193 P=0
DO 90 I=1,4
IF(PER(I)) 90,90,89
89 P=P+1
90 CONTINUE
IF(P) 212,212,194
212 PRINT 9212
GO TO 190
194 PRINT 1194
READ 1195,TP
CALL ICO(42,60,2,TP,ITP)
IF(ITP) 196,196,200
196 PRINT 9196, TP
GO TO 194
C
200 GO TO(1,2,3,4,5,6,7,8,8,8),ITP
1 PRINT 1001
GO TO 15
2 PRINT 1002
READ *, NRG, (ITB(I),I=1,NRG)
GO TO 17
3 PRINT 1003
GO TO 15
4 PRINT 1004
GO TO 15
5 PRINT 1004
GO TO 15
6 PRINT 1006
GO TO 15
7 PRINT 1007
GO TO 15
8 CONTINUE
15 READ 1015, V
IF(ITP-5) 17,95,17
95 XK=FLOAT(V(1))/FLOAT(V(2))
AL=(XK/FLOAT(V(1)))*1000.0
```

```
      V(1)=NINT(AL)
      V(2)=NINT(XK)
C
17      DO 210 I=1,4
      IF(PER(I)) 210,210,202
202      P=PER(I)
      PA(CLASS,IRF,P,1)=ITP
      DO 205 J=2,4
205      PA(CLASS,IRF,P,J)=V(J-1)
210      CONTINUE
      IF(ITP-2) 280,215,280
C
C      PREPARE FREQUENCY TABLE FOR SAMPLING
C
215      DISNO=DISNO+1
      NTL=DISNO
      SM=0.0
      DO 220 I=2,NRG,2
220      SM=SM+FLOAT(ITB(I-1))
      DO 240 I=2,NRG,2
      PCN=(FLOAT(ITB(I-1))/SM)*100.0
      ITB(I-1)=NINT(PCN)
      IF(ITB(I-1)) 225,225,230
225      ITB(I-1)=1
230      NFM=NTL+1
      NTL=NFM+ITB(I-1)-1
      DO 235 J=NFM,NTL
235      D(J)=ITB(I)
240      CONTINUE
      DO 243 I=1,4
      IF(PER(I)) 243,243,242
242      P=PER(I)
      PA(CLASS,IRF,P,2)=DISNO
243      CONTINUE
      GO TO 280
C
280      IF(IRF-2) 280,281,280
281      PRINT 1281
      READ 1158, PA(CLASS,IRF,P,4)
290      READ 1510, RPLY
      CALL CO(65,71,RPLY,IJ)
      IF(IJ) 282,282,285
282      PRINT 9282, RPLY
      GO TO 280
285      GO TO(190,190,190,190,180,300,400),IJ
C
C      READ OUTPUT SPECIFICATIONS
C
300      CONTINUE
798      GO TO(799,960),ISW
```

```

960  PRINT 1960
      READ 1510,RPLY
      IF(RPLY-Y) 400,799,400
799  PRINT 1700
800  PRINT 1801
      READ 1800, REF, ICS
      IF(ICS(1)) 805,805,810
805  PRINT 9805
      GO TO 800
810  CALL ICD(2,40,2,REF,IRF)
      IF(IRF) 815,815,818
815  PRINT 8192, REF
      GO TO 800
818  IF(IRF-18) 819,400,400
819  IP(10)=IP(10)+1
      N=N+1
      SP(N,1)=IRF
820  PRINT 1820
821  READ 1821, OTP, (ITB(I),I=1,4)
      CALL CD(65,69,OTP,IJ)
      IF(IJ) 825,825,828
825  PRINT 9825, OTP
      GO TO 820
828  GO TO(827,827,827,840,840),IJ
827  DO 828 I=1,4
828  SP(N,I+4)=ITB(I)
      SP(N,2)=IJ
840  DO 850 I=1,11
850  SP(N,I+8)=ICS(I)
860  PRINT 1860
      READ 9402, TP
      CALL ICD(73,77,2,TP,SP(N,8))
      IF(SP(N,8)) 865,865,870
865  PRINT 9865, TP
      GO TO 860
870  READ 1510, RPLY
      CALL CD(65,71,RPLY,IJ)
      GO TO(800,800,800,800,800,800,400),IJ

C
400  DO 405 I=1,4
405  FP(I+20)=FLOAT(IP(I))
      NTL=IP(11)

C
C  SET UP INITIAL STATE OF THE MODEL
C
      J=0
      DO 450 CLASS=1,NTL
      IDT=0
      DO 448 NP=1,4
      IF(PA(CLASS,1,NP,1)) 448,448,410

```

```

410      J=J+1
        E(J,1)=CLASS
        E(J,2)=1
        CALL DETVAL(CLASS,1,NP,E(J,3),IP(S),PA,D)
        E(J,3)=E(J,3)+IDT
448      IDT=IDT+IP(NP)*IP(5)
450      CONTINUE
        IP(13)=J
C
      DO 500 I=1,4
        IF(IP(I))500,500,490
        IP(14)=IP(14)+1
490      CONTINUE
500      PRINT 1500
        READ 1510,RPLY
        IF(RPLY-XX)9999,550,9998
550      ISW=2
        GO TO 130
C
9999      ISW=1
        RETURN
C
9885      FORMAT(40X,'*** INPUT ERROR - INCORRECT NAME OF ',
1'REPORT VERSION: ',2A4)
9805      FORMAT(40X,'*** INPUT ERROR - INCORRECT LIST OF CLASSES')
9155      FORMAT(40X,'*** INPUT ERROR - INDICATE LENGTH OF PERIOD 1')
9165      FORMAT(40X,'*** INPUT ERROR - INDICATE NUMBER OF REPLICATIONS')
9212      FORMAT(40X,'*** INPUT ERROR - NO REFERENCE TO PERIOD')
9216      FORMAT(40X,'*** INPUT ERROR - INDICATE NUMBER OF RANGES')
9192      FORMAT(40X,'*** INPUT ERROR - UNRECOGNIZED ATTRIBUTE NAME: ',2A4)
9198      FORMAT(40X,'*** INPUT ERROR - UNRECOGNIZED TYPE OF ALGORITHM:',
12A4)
9825      FORMAT(40X,'*** INPUT ERROR - UNRECOGNIZED TYPE OF REQUIRED OUTPUT:
1',A4)
9282      FORMAT(40X,'*** Input error - I do not understand ',
1'this word: ',A4)

```

```

1150 FORMAT(20A4)
1152 FORMAT(4I7)
1180 FORMAT(I3,I9A4,A1)
1190 FORMAT(2A4,4I3)
1800 FORMAT(2A4,11I4)
1120 FORMAT(///,' GENERAL PARAMETERS OF THE SIMULATION PROCESS'
1/,1x,4('-'//))
1110 FORMAT(1H1)
1111 FORMAT(' Enter run title: ', $)
1151 FORMAT(' Length of simulation period(s): ',5x,$)
1157 FORMAT(' No. of replications of each period: ', $)
1158 FORMAT(I7)
1170 FORMAT(' Random numbers generator seed is: ',3X,$)
1182 FORMAT(//,' Enter spill class number and its full name: ', $)
1700 FORMAT(//,' OUTPUT SPECIFICATIONS',/,1X,21('-'//))
1178 FORMAT(//,' DESCRIPTION OF CLASSES',/,1X,22('-'//))
9402 FORMAT(2A4)
1183 FORMAT(' Name class attribute (SPILLFRG, ',
1'FLOWRATE, SPILLVOL) & for which period(s): ', $)
1185 FORMAT(5X,$)
1194 FORMAT(' Enter name of calculation method: ', $)
1195 FORMAT(2A4)
1001 FORMAT(' The deterministic value is: ', $)
1002 FORMAT(' Indicate table length and pairs of values ',
1,'(frequency, value):')
1003 FORMAT(' Parameter Lambda is: ', $)
1004 FORMAT(' Give mean value and standard deviation: ', $)
1006 FORMAT(' Give mean value: ', $)
1007 FORMAT(' Give range of values: ', $)
1801 FORMAT(//,' Define output selection criteria (name ',
1'attribute and spill class(es): ', $)

```



```

1820 FORMAT(' Indicate required form of output (TSER or HIST) '
1      1,'and parameters: ', $)
1821 FORMAT(A4,I7)
1015 FORMAT(3I7)
1843 FORMAT(2I3)
1500 FORMAT('//5X,'Do you want to modify input data or ',
1      1,'start simulation (type: MODIFY or SIMULATE) --- ', $)
1510 FORMAT(A4)
1135 FORMAT(5X,'Do you want to change run title (type: YES or '
1      1,'NO) --- ', $)
1915 FORMAT(5X,'Do you want to modify general simulation process '
1      1,'parameters (type: YES or NO) --- ', $)
1940 FORMAT(5X,'Do you want to modify descriptions of classes ',
1      1,'(type YES or NO) --- ', $)
1960 FORMAT(5X,'Any changes in output specifications ',
1      1,'(type YES or NO) --- ', $)
1281 FORMAT(' Time between consecutive releases of oil is: ', $)
1860 FORMAT(' Choose report version ',
1      1,'(type: CLASSES, CLASSUM or SUMMARY): ', $)
C
END

      block data buoc
C
      DIMENSION CH(77)
      COMMON /A/CH
      DATA CH/'SPIL','LFRQ','FLOW','RATE','SPIL','LVOL','4141','4242',
1'5151','5252','8161','6262','7171','7272','8181','8282',
2'9191','9292','1011','1021','1111','1121','1211','1221',
3'1311','1321','1411','1421','1511','1521','1611','1612',
3' ',' ','END',' ','SIMU','LATE','2311','2312',
4'FIXE','D','TABL','E','POIS','SON','NORM','AL',
5'GAMM','A','NEGE','XPON','UNIF','ORM','FUNC','T1',
6'FUNC','T2','FUNC','T3','2712','2722','2812','2822',
7'TSER','HIST','PLOT',' ','EA','EC','ES','CLAS',
8'SES','CLAS','SUM','SUMM','ARY'//

```

```

C      SUBROUTINE CO(IFM,ITL,XNM,IVA)
C
C      DIMENSION CH(77)
C
C      COMMON /A/CH
C
C      IVA=0
C      DO 100 I=IFM,ITL
C      IF(CH(I)-XNM) 100,50,100
50      IVA=I-IFM+1
C      RETURN
100     CONTINUE
C      RETURN
C      END

C      subroutine ico(fm,tl,nn,xnm,iva)
C
C      integer fm,tl
C      DIMENSION CH(77), XNM(2)
C      COMMON /A/ CH
C      iva=0
C      do 100 i=fm,tl,nn
30      if(ch(i-1)-xnm(1)) 100,40,100
40      if(ch(i)-xnm(2)) 100,50,100
50      iva=(i/nn)-(fm/nn)+1
C      return
100     continue
C      return
C      end

C      subroutine detval(class,ref,p,v,seed,pa,d)
C
C      integer d,ref,type,v,seed,class,p,pa
C      dimension d(3000), pa(100,16,4,4)
C      DIMENSION IP(50), FP(50)
C
C      COMMON IP,FP
C
C      IZR=0
C      NGU=0
C      type=pa(class,ref,p,1)
999     GO TO(1,2,3,4,5,6,7,8,9,10),TYPE
C
C      C
C      DETERMINISTIC OPTION
C
C      1      v=pa(class,ref,p,2)
C      return
C
C

```

C SAMPLING FROM TABLES (THEORETICAL OR EMPIRICAL)

C

2

x=ran(seed)*100.0

if(x-100.0) 200,2,2

200 n=ifix(x) + pa(class, ref, p, 2) +1

v=d(n)

return

c

C

C

GENERATION OF POISSON VARIATES

C

3

XLAMBDA=FLOAT(PA(CLASS,REF,P,2))

XV=0.0

B=EXP(-XLAMBDA)

TR=1.0

30

R=RAN(SEED)

TR=TR*R

IF(TR-B) 99,35,35

35

XV=XV+1.0

GO TO 30

C

C

GENERATION OF NORMAL VARIATES

C

4

EX=FLOAT(PA(CLASS,REF,P,2))

STDV=FLOAT(PA(CLASS,REF,P,3))

SUM=0.0

DO 40 I=1,12

R=RAN(SEED)

40

SUM=SUM+R

XV=STDV*(SUM-6.0)+EX

GO TO 99

C

C

GENERATION OF GAMMA VARIATES

C

5

A=FLOAT(PA(CLASS,REF,P,2))/1000.0

K=PA(CLASS,REF,P,3)

TR=1.0

DO 50 I=1,K

R=RAN(SEED)

50

TR=TR*R

XV=-LOG(TR)/A

GO TO 99

C

C

GENERATION OF EXPONENTIAL VARIATES

C

C

6

R=RAN(SEED)

XV=FLOAT(PA(CLASS,REF,P,2))

XV=-XV*LOG(R)

GO TO 99

```
C
C      GENERATION OF UNIFORM VARIATES
C
7      R=RAN(SEED)
      FM=FLOAT(PA(CLASS,REF,P,2))
      TL=FLOAT(PA(CLASS,REF,P,3))
      XV=FM+(TL-FM)*R
      GO TO 99

C
C
C      ROOM FOR EXTERNAL FUNCTION: FUNCT1
C
8      CONTINUE

C
C      ROOM FOR EXTERNAL FUNCTION: FUNCT2
C
9      CONTINUE

C
C      ROOM FOR EXTERNAL FUNCTION: FUNCT3
C
10     CONTINUE
C
99     V=NINT(XV)
      IF(V) 500,800,1000
500    NGV=NGV+1
      IF(NGV-10) 999,511,511
511    PRINT 1511
1511   FORMAT(///40X,' *** Negative values - run interrupted')
      GO TO 900
600    IZR=IZR+1
      IF(IZR-10) 999,611,611
611    PRINT 1611
1611   FORMAT(///40X,' *** Zero values - run interrupted')
900    STOP
1000   RETURN
      END
```

```
      subroutine sfncl
C
C      main simulation algorithm
C
      integer c,r,e,s,clock,pa,d,sp,ob,p
C
      DIMENSION IP(50), FP(50), E(1000,5), SP(20,26)
      dimension ob(2000), cnam(100,20), pa(100,16,4,4)
      dimension d(3000)
C
      common ip,fp,cnam,sp,pa,e,d,ob
C
C
```

```
s=ip(6)
p=1
nn=ip(13)
clock=0
nob=0
nrec=0
ns=ip(10)
NSIM=IP(1)*IP(5)

c
c
400  n=0
500  n=n+1
      c=e(n,1)
      r=e(n,2)
      go to(1,2,3,4,5,6,7,8,9,900),r

c
c  control of spillage events
c
1    if(e(n,3)) 900,620,900
620  call detval(c,r,p,e(n,3),s,pa,d)
      call state(clock,c,r,p,e(n,3),nob,nrec,ob,sp,ns)

c
      CALL DETVAL(C,2,P,IFR,S,PA,D)
      CALL DETVAL(C,3,P,IVOL,S,PA,D)
      CALL STATE(CLOCK,C,3,P,IVOL,NOB,NREC,OB,SP,NS)
      IF(IFR) 625,625,628
625  IFR=IVOL
      NREL=1
      IRDAT=0
      GO TO 635
628  NREL=IVOL/IFR
      JVOL=IFR*NREL
      IF(IVOL-JVOL) 630,630,629
629  IFR=IFR+((IVOL-JVOL)/NREL)
630  IRDAT=-PA(C,2,P,4)
635  DO 645 I=1,NREL
      NN=NN+1
      E(NN,1)=C
      E(NN,2)=2
      IRDAT=IRDAT+PA(C,2,P,4)
      E(NN,3)=IRDAT+PA(C,2,P,4)
645  E(NN,4)=IFR
      GO TO 900

c
c  CONTROL OF OIL FLOW FROM SPILLAGE SOURCES
c
c
2    IF(E(N,3)) 900,650,900
650  CALL STATE(CLOCK,C,R,P,E(N,4),NOB,NREC,OB,SP,NS)
      CALL FROM(N,NN,E)
```

```

      GO TO 900
C
3      CONTINUE
      so to 900
4      continue
c
c
c
5      continue
c
c
c
6      continue
c
c
c
7      continue
c
c
c
8      continue
c
c
c
9      continue
c
c
c
900    if(n-nn) 500,1000,1000
1000   IF(CLOCK-NSIM) 1500,1100,1100
1100   IF(P-4)1150,2000,2000
1150   P=P+1
      if(ip(P)) 2000,2000,1200
1200   NSIM=NSIM+IP(P)*IP(5)
1500   call move(clock,nn,e)
      so to 400
c
c
2000   if(nrec) 2007,2005,2007
2005   ip(17)=nob
      GO TO 9999
2007   IF(NOB)9999,9999,2010
2010   nrec=nrec+1
      write(4'nrec)  nob,ob
c
c
9999   continue
      ip(15)=nrec
      return
c
      end
c
```

```
      subroutine move(clc, nn, e)
c
      integer clc, e, dt
      DIMENSION E(1000,5)
c
c
      dt=9999999
      do 30 i = 1, nn
      if(e(i,3)) 30,30,10
10    if(e(i,3)-dt) 20,30,30
20    dt=e(i,3)
30    continue
      if(dt-9999999) 40,60,60
40    do 50 i=1,nn
50    e(i,3)=e(i,3)-dt
      clc=clc+dt
      return
60    PRINT 1060, CLC
1060  FORMAT(/ /40X, '*** ERROR: MODEL BECAME STATIC AT
      SIMULATION TIME',
117)
      STOP 'CHECK TIME DEPENDENT VARIABLES'
      end

      SUBROUTINE STATE(CLC,C,R,P,V,NOB,NREC,OB,SP,NS)
c
      INTEGER CLC,C,R,P,V,OB,SP
      DIMENSION OB(2000),SP(20,26)
c
      do 3 i=1,ns
      do 1 j=9,18
      IF(C-SP(I,J)) 1,2,1
1    continue
      so to 3
2    IF(R-SP(I,1)) 3,4,3
3    continue
      return
c
4    NOB=NOB+5
c
      OB(NOB-4)=CLC
      OB(NOB-3)=C
      OB(NOB-2)=R
      OB(NOB-1)=P
      OB(NOB)=V
      if(nob-2000) 20,10,10
10    nrec=nrec+1
      write(4'nrec) nob, ob
      nob=0
20    return
      end
c
```

```

      subroutine From(n, nn, e)
c
      integer e
      DIMENSION E(1000,5)
c
      m=nn-1
      if(n-nn) 20,100,100
20    do 50 i=n,m
      k=i+1
      do 50 j=1,5
50    e(i,j)=e(k,j)
100   n=n-1
      nn=m
      return
      end

      subroutine response
c
      integer sp,hs,rhs,ol,ts,edate
      INTEGER OB
      INTEGER E,D
c
      DIMENSION NL(11,2)
      DIMENSION PA(100,16,4,4), E(1000,5), D(3000)
      DIMENSION STARS(100)
      DIMENSION SP(20,26), HS(11,100,3), RHS(11)
      DIMENSION TS(300,20), IP(50), FP(50), OB(2000)
      DIMENSION CLNAM(100,20), ST(11,5,10)
      DATA STARS/100*'XXXX'/
c
      COMMON IP,FP,CLNAM,SP,PA,E,D,OB,ST,HS,RHS,TS
c
c
      nrec=ip(15)
      np=ip(14)
      ns=ip(10)
      IOPT=1
      NOB=IP(17)
      IF(NREC) 9,8,9
8     IOPT=2
c
c
c
9     DO 1000 N=1,NS
      KRT=SP(N,8)
c
      DO 14 I=1,11
      DO 14 J=1,2
14    NL(I,J)=0

```



```

DO 20 I=1,11
DO 15 J=1,5
DO 10 K=1,10
10 ST(I,J,K)=0.0
ST(I,J,7)=-999999999.0
ST(I,J,8)=999999999.0
15 CONTINUE
20 CONTINUE
C
ncl=0
c
IF(SP(N,5)) 22,22,23
22 MXL=300
GO TO 25
23 MXL=SP(N,5)
c
25 DO 50 I=9,26
if(sp(n,i)) 50,50,40
40 ncl=ncl+1
rhs(ncl)=sp(n,i)
50 continue
c
NCS=NCL+1
c
c set up histograms
c
IF(SP(N,7)) 190,190,120
120 nrm=sp(n,7)
nfm=sp(n,5)
140 do 180 i=1,nrm
ntl=nfm+sp(n,8)-1
DO 170 J=1,11
hs(J,i,1)=nfm
170 HS(J,I,2)=NTL
180 nfm=ntl+1
DO 181 I=1,11
181 NL(I,1)=NRG
C
MXPR=0
C
190 DO 800 IPN=1,NP
MXPR=MXPR+IP(IPN)*IP(5)
c
C SET UP TIME SERIES ARRAY
DO 185 I=1,300
DO 185 J=1,20
185 TS(I,J)=1919191
c

```

```
      DO 200 I=1,100
      DO 200 J=1,11
200    HS(J,I,3)=0
      C
      DO 705 LPASS=1,2
      GO TO(206,202),LPASS
202    DO 204 NH=1,NCS
      IF(ST(NH,IPN,1)) 204,204,203
203    ST(NH,IPN,3)=ST(NH,IPN,2)/ST(NH,IPN,1)
204    CONTINUE
      DO 201 I=1,11
201    NL(I,2)=0
      C
      C      AUTOMATIC SCALING OF HISTOGRAMS
      C
400    IF(SP(N,7)) 405,405,206
405    DO 460 NH=1,NCS
      NRG=50
      IF(ST(NH,IPN,1)) 460,460,408
408    NFM=NINT(ST(NH,IPN,8))
      MXV=NINT(ST(NH,IPN,7))
      IF(MXV-NFM) 409,409,410
409    NRG=1
      GO TO 417
410    INC=(MXV-NFM)/48
      IF(INC) 417,417,420
417    INC=1
420    NL(NH,1)=NRG
      DO 450 I=1,NRG
      NTL=NFM+INC-1
      HS(NH,I,1)=NFM
      HS(NH,I,3)=0
      HS(NH,I,2)=NTL
450    NFM=NTL+1
460    CONTINUE
      C
206    DO 700 II=1,NREC
      GO TO(208,208),IOPT
208    FIND(4'II)
      read(4'ii) nob, ob
      C
209    DO 560 KK=1,2
      C
      DO 550 I=5,N0B,5
      IF(OB(I)) 550,550,207
207    IF(OB(I-1)-IPN) 550,210,550
210    IF(OB(I-4)-MXPR) 215,215,560
      C
215    IF(OB(I-2)-SP(N,1)) 550,220,550
220    do 240 J=9,18
```

```

                if(sp(n,j)-ob(i-3)) 240,250,240
240      continue
          so to 550
250      GO TO(255,252),KK
252      NH=NCS
          GO TO 262
c
255      DO 260 NH=1,NCL
          IF(OB(I-3)-RHS(NH)) 260,262,260
260      continue
          GO TO 550
c
262      X=FLOAT(OB(I))
          GO TO(263,270),LPASS
263      ST(NH,IPN,1)=ST(NH,IPN,1)+1.0
          ST(NH,IPN,2)=ST(NH,IPN,2)+X
          IF(X-ST(NH,IPN,7)) 265,265,264
264      ST(NH,IPN,7)=X
265      IF(X-ST(NH,IPN,8)) 268,550,550
268      ST(NH,IPN,8)=X
          GO TO 550
c
270      NRG=NL(NH,1)
          DO 290 JJ=1,NRG
                if(ob(i)-hs(nh,jj,1)) 280,280,275
275      if(ob(i)-hs(nh,jj,2)) 280,280,290
280      hs(nh,jj,3)=hs(nh,jj,3)+1
          GO TO 291
290      continue
c
291      ST(NH,IPN,4)=ST(NH,IPN,4)+(X-ST(NH,IPN,3))**2
          IF(X-ST(NH,IPN,3)) 292,292,293
292      ST(NH,IPN,9)=ST(NH,IPN,9)+1.0
          GO TO 298
293      ST(NH,IPN,10)=ST(NH,IPN,10)+1.0
c
c      select time series
c
298      IF(NL(NH,2)-MXL) 300,550,550
300      NL(NH,2)=NL(NH,2)+1
          L=NL(NH,2)
310      ITS=NH*2
          JTS=ITS-1
          TS(L,JTS)=OB(I-4)
          TS(L,ITS)=OB(I)
550      continue
560      CONTINUE
700      continue
705      CONTINUE

```

```

c
c      Print output for period ipn
c
710    NFM=1
      NTL=NCL
      GO TO(703,704,702),KRT
702    NFM=NCS
704    NTL=NCS
703    DO 790 NH=NFM,NTL
      IF(ST(NH,IPN,1)) 790,790,711
711    IF(ST(NH,IPN,2))790,790,718
718    CL=RHS(NH)
c
      DO 770 JJ=2,4
      IF(SP(N,JJ)) 770,770,712
712    IF(SP(N,JJ)-4) 714,770,770
714    ITP=SP(N,JJ)
      IR=SP(N,1)
      PRINT 5712, (FP(I),I=1,20)
      IF(NH-NCS) 655,610,655
610    GO TO(611,612,613), IR
611    PRINT 6611
      GO TO 620
612    PRINT 6612
      GO TO 620
613    PRINT 6613
      GO TO 620
620    DO 625 I=9,19
      IF(SP(N,I))625,625,622
622    CL=SP(N,I)
      PRINT 6622, SP(N,I), (CLNAM(CL,J),J=1,20)
625    CONTINUE
      GO TO 713
655    GO TO(1,2,3), IR
1      PRINT 6001, CL, (CLNAM(CL,I),I=1,20)
      GO TO 713
2      PRINT 6002, CL,(CLNAM(CL,I),I=1,20)
      GO TO 713
3      PRINT 6003, CL,(CLNAM(CL,I),I=1,20)
      GO TO 713
c
713    GO TO(715,730,750,770),ITP
c
c      PRINT TIME SERIES
c
715    PRINT 5715, N, IPN
      NT=NH*2
      ITS=NT-1
      L=NL(NH,2)

```

```
      DO 720 J=1,L
      IF(TS(J,NT)-1919191) 718,720,718
718  PRINT 5718, TS(J,ITS), TS(J,NT)
720  CONTINUE
      PRINT 5720
      GO TO 770

C
C      PRINT HISTOGRAM
C
730  PRINT 5730, N, IPN
      PRINT 5731
      NRG=NL(NH,1)
      K=NRG+1
      DO 735 I=1,NRG
      K=K-1
      IF(HS(NH,K,3)) 734,734,736
734  NRG=NRG-1
735  CONTINUE
736  MFR=1
      DO 743 I=1,NRG
      IF(HS(NH,I,3)) 742,742,744
742  MFR=MFR+1
743  CONTINUE
744  DO 745 K=MFR,NRG
      IK=1
      PCT=0.0
      IF(HS(NH,K,3)) 738,740,738
738  W=FLOAT(HS(NH,K,3)) * 100.0
      PCT=W/ST(NH,IPN,1)
      IPCT=NINT(PCT)
      IF(IPCT) 740,740,732
732  IF(IPCT-76) 739,739,733
733  IPCT=76
      IK=2
739  PRINT 5739, (HS(NH,K,I),I=1,3),PCT,(STARS(J),J=1,IPCT)
      GO TO(745,746),IK
746  PRINT 5746
      GO TO 745
740  PRINT 5740, (HS(NH,K,I), I=1,3), PCT
745  CONTINUE
C
C      PRINT SET OF STATISTICAL ESTIMATES
C
      ST(NH,IPN,5)=ST(NH,IPN,4)/(ST(NH,IPN,1)-1.0)
      ST(NH,IPN,6)=SQRT(ST(NH,IPN,5))
      W=ST(NH,IPN,6)/SQRT(ST(NH,IPN,1))
      PRINT 5752
      I=NINT(ST(NH,IPN,1))
      PRINT 5754, I
```

```

PRINT 5756, ST(NH,IPN,2), ST(NH,IPN,3)
PRINT 5758, ST(NH,IPN,5)
PRINT 5760, ST(NH,IPN,6)
PRINT 5762, ST(NH,IPN,7)
PRINT 5764, ST(NH,IPN,8)
I=NINT(ST(NH,IPN,9))
PRINT 5766, I
I=NINT(ST(NH,IPN,10))
PRINT 5768, I
PRINT 5769, W

C
750  CONTINUE
c
770  CONTINUE
c
780  CONTINUE
800  continue
1000 continue
      return
c
5712 FORMAT(1H1,5X,20A4,/)
6001  FORMAT(5X,'INTERVALS BETWEEN SPILLS FOR CLASS: ',
1I2,2X,19A4,A1,/)
8002  FORMAT(5X,'FLOW RATES FOR CLASS ',I2,2X,19A4,A1,/)
6003  FORMAT(5X,'SPILL SIZE FOR CLASS: ',I2,2X,19A4,A1,/)
5715  FORMAT(5X,'OUTPUT NO.',I2,' FOR PERIOD',I2,2X,
1'- TIME SERIES',/,7X,'DATE',2X,'VALUE',/)
5718  FORMAT(5X,2I7)
5730  FORMAT(5X,'OUTPUT NO.',I2,' FOR PERIOD',I2,2X,
1'- HISTOGRAM',/)
5731  FORMAT(5X,'RANGE OF VALUES          FREQUENCY    %',/)
5739  FORMAT(5X,I7,2X,'-',I7,4X,I6,3X,F6.2,' .',100A1)
5740  FORMAT(5X,I7,2X,'-',I7,4X,I6,3X,F6.2,' .')
5752  FORMAT(/5X,'STATISTICAL ESTIMATES'/5X,21('-'))
5754  FORMAT(9X,'NUMBER OF OBSERVATIONS =',I7)
5756  FORMAT(9X,'SUM OF OBSERVED VALUES =',G13.6/
19X,'MEAN',19X,'=',G13.6)
5758  FORMAT(9X,'VARIANCE',15X,'=',G13.6)
5760  FORMAT(9X,'STANDARD DEVIATION      =',G13.6)
5762  FORMAT(9X,'MAXIMUM OBSERVED VALUE =',G13.6)
5764  FORMAT(9X,'MINIMUM OBSERVED VALUE =',G13.6)
5766  FORMAT(9X,'NO. OF VAL. BELOW MEAN =',I7)
5768  FORMAT(9X,'NO. OF VAL. ABOVE MEAN =',I7)
5769  FORMAT(9X,'STOCHASTIC CONVERGENCE =',G13.6)
5746  FORMAT(1H+,118X,'+')
5720  FORMAT(' ')
6611  FORMAT(5X,'INTERVALS BETWEEN SPILLS FOR CLASSES:')
6612  FORMAT(5X,'FLOW RATES FOR CLASSES:')
6613  FORMAT(5X,'SPILL SIZES FOR CLASSES:')
6622  FORMAT(15X,'(',I2,') ',19A4,A1)
END

```

APPENDIX B

SAMPLE OF PROGRAM ERROR MESSAGES

RUN SIMSPIL

Enter run title: ----- PROGRAM ERROR MESSAGES -----

GENERAL PARAMETERS OF THE SIMULATION PROCESS

Length of simulation period(s): *** INPUT ERROR - INDICATE LENGTH OF PERIOD 1
1000
No. of replications of each period: *** INPUT ERROR - INDICATE NUMBER OF REPLICATIONS

No. of replications of each period: 10
Random numbers generator seed is:

DESCRIPTION OF CLASSES

Enter spill class number and its full name: 1, DIESEL OIL FROM BARGES
Name class attribute (SPILLFRQ, FLOWRATE, SPILLVOL) & for which period(s): SPEEDVOL 1
Name class attribute (SPILLFRQ, FLOWRATE, SPILLVOL) & for which period(s): SPEEDVOL
Name class attribute (SPILLFRQ, FLOWRATE, SPILLVOL) & for which period(s): SPILLVOL
Name class attribute (SPILLFRQ, FLOWRATE, SPILLVOL) & for which period(s): SPILLVOL
Enter name of calculation method: GAME
Enter name of calculation method: GAME
Give mean value and standard deviation: 12345,123
EC

OUTPUT SPECIFICATIONS

Define output selection criteria (name attribute and spill class(es)): SPILLANT 3, 67
*** INPUT ERROR - UNRECOGNIZED ATTRIBUTE NAME: SPILLANT
Define output selection criteria (name attribute and spill class(es)): SPILLVOL
*** INPUT ERROR - INCORRECT LIST OF CLASSES
Define output selection criteria (name attribute and spill class(es)): SPILLVOL 3, 67
Indicate required form of output (TUSER or HIST) and parameters: SERS
*** INPUT ERROR - UNRECOGNIZED TYPE OF REQUIRED OUTPUT SERS
Indicate required form of output (TUSER or HIST) and parameters: TUSER
Choose report version (type: CLASSES, CLASSUM or SUMMARY): CLASSES
Choose report version (type: CLASSES, CLASSUM or SUMMARY): CLASSES
ES

Do you want to modify input data or start simulation (type: MODIFY or SIMULATE) --- SIMULATE

CHECK TIME DEPENDENT VARIABLES
*** ERROR: MODEL BECAME STATIC AT SIMULATION TIME 0

