MODELING THE BIOLOGICAL IMPACT OF AN OIL SPILL; BIOS MODEL

by

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INTRODUCTION

The BIOS (Biological Impact of an Oil Spill) ecosystem simulation model has been documented in several recent publications (Swan 1984, Gallagher 1984, Gallagher and Pola 1984, Pola et al. 1985). The model was developed at the request of the Outer Continental Shelf Environment Assessment Program (OCSEAP) as part of their eastern Bering Sea environmental impact study. Two hypothetical oil spill scenarios (well blowout and tanker diesel spill) were simulated at each of three locations in the eastern Bering Sea: Offshore of Port Moller, Port Heiden and Cape Newenham.

During the course of the study, the BIOS model was modified to address particular questions. For example, species-specific uptake and deputation rates and their relative sensitivities were determined using a version of the model with no spatial resolution (Gallagher and Pola 1984), while the spatial and temporal extents of "tainting" of fish were examined using a gridded version of the model with fewer species, but including fish migrations (Pola et al. 1985).

This document describes the BIOS model concept and presents three versions of the model developed for particular applications. It is intended to be used by the prospective modeller as a general guide for application of a B]OS-type model to any location. In addition, it serves a library maintenance function by presenting the present physical locations (tape, disk, etc.) and file names of model computer source code, input data and output programs.

BIOS MODEL

Conceptualization

Effective computer simulation of the impact of an oil spill on an ecosystem is dependent upon the accuracy of field and empirical data. Ecosystem interactions are complex and poorly understood; the added stress imposed on the ecosystem by

an oil spill further complicates the situation. The eastern Bering Sea ecosystem has been effectively simulated by such models as PROBUB (Prognostic Bulk Biomass Model) and DYNUMES (Dynamical Numerics"1 Marine Ecosystem Simulation], both developed by Dr. Taivo Laevastu of the Northwest and Alaska Fisheries Center (NWAFC; Laevastu et al. 1982, Laevastu and Larkins 1981). General ecosystem simulation concepts used in these models were adapted to the BIOS model. Available information on oil toxicity and the effects of pollution on fish were then incorporated into the BIOS model.

Many of the processes included in DYNUMES and PROBUB were not applicable to the simulation of the oil-spill scenarios. For example, the simulation of growth was unnecessary, due to the short time step (daily) and duration of the BIOS model run ($\leq$50 days). The DYNUMES species composition was adjusted to include only those species known to occupy the Bristol Bay region in summer. However, several species groups were divided into juvenile and adult stages, to allow for differences in susceptibility to oil toxins. The effect of oil on the biota was modeled as a single-compartment uptake-depuration process. No attempt was made to partition the effect of oil among various compartments (gut, liver, etc.) due to insufficient quantitative data on oil uptake processes. As a general rule, the BIOS model was kept as simple and generic as possible, to avoid unnecessary assumptions.

Simulation

Gridded daily subsurface oil concentrations for each scenario and location were provided by Rand Corporation. Sedimentation of the oil was simulated with a model developed by Laevastu and Fukuhara (198s). The subsurface oil concentrations (oil dissolved or in suspension in the water column, referred to as WSF) and the sedimented oil concentrations (oil in or uPon the sediments,

migration velocity components, and G_x and G_y are contamination gradients:

$$G_x = [C(t)_{n,m+j} - c(t)_{n,m}] \tag{7}$$

$$G_y = [C(t)_{n+i,m} - C(t)_{n,m}] \tag{8}$$

The subscripts i and j are defi''ned as:

$$i = \begin{cases} 1, & V < 0 \\ 0, & V=0 \\ -1, & V > 0 \end{cases}$$

$$j = \begin{cases} -1, & U < 0 \\ 0, & U = 0 \\ 1, & U > 0 \end{cases}$$

such that the gradients G_x and G_y are taken in the "upstream" direction. The contamination is then redistributed over the grid:

$$C(t+1)_{n,m} = C(t)_{n,m} - R_{x,n,m} - R_{y,n,m} \tag{9}$$

$$C(t+1)_{n,m+j} = C(t)_{n,m+j} + R_{x,n,m} \tag{10}$$

$$C(t+1)_{n+i,m} = C(t)_{n+i,m} + R_{y,n,m} \tag{11}$$

The migration time step, t, is restricted by the stability criterion:

$$t\,|U^*| < L \tag{12}$$

where U^* is the maximum migration speed in km/day. That is, for a migration speed of 15 km/day and grid spacing of 2 km, t < .13 days.

COMPUTER PROGRAMS AND DATA FILES

File Names and Locations

Computer FORTRAN source codes for all three model versions resideon disk and tape files on the Northwest and Alaska Fisheries Center (NWAFC) Burroughs B7800

compute r. All BIOS files are stored under user code REFM0250. Disk files are located on the TYVO pack and tape files are located on tape number 4857. The following are the program and data file names:

Program Files

PROG/BIOS/NOGRID	:Nongridded version of the BIOS model used to estimate model parameters.
PROG/BIOS/GRID	:Gridded version of the model; uses subsurface oil concentrations (WSF) as input.
PROG/BIOS/MIGR	:Gridded version of the model with fish migrations and only two fish species.
SUBROUTINE/PLOTR	:Generalized subroutine to draw line plots of up to four variables.

Input Data Files

OCSEAP/OILCON/LOC1	:Gridded WSF for accident scenario, Port Moller.
OCSEAP/OILCON/LOC2	:Gridded WSF for accident scenario, Port Heiden.
OCSEAP/OILCON/LOC3	:Gridded WSF for accident scenario, Cape Newenham.
OCSEAP/OILCON/BLOW/LOC1	:Gridded WSF for blowout scenario, Port Moller.
OCSEAP/OILCON/BLOW/LOC2	:Gridded WSF for blowout scenario, Port Heiden.
OCSEAP/OILCON/BLOW/LOC3	:Gridded WSF for blowout scenario, Cape Newenham.

Program Listings

Annotated FORTRAN source codes for the three BIOS model versions and for the plotting subroutine are listed in the following pages. An example of a plot generated by the plotting subroutine is given in Figure 1.

referred to as TARS) were used as input to the BIOS model. Model calculations were performed with a dai y time step at each grid point. A 32 x 34 grid was used at each location for the accident scenario and a 50 x 50 grid was used for the blowout scenario; in each case, 2 km grid spacings were used.

Wind and water temperatures used by Rand Corp. in the calculations of the oil trajectories were chosen so as to maximize the oil concentrations in the water. The selected conditions corresponded to those typical of August. The fish species which would be expected in August at each location were then determined (Fukuhara (1985), and fish biomasses over each grid were estimated (Gallagher and Pola 1984). Biomass was assumed to be equally distributed over all grid points, due to insufficient spatial resolution of the data (Pola et al. 1985), and was kept constant over the short duration (≤50 days) of the simulations .

Fish contamination was simulated by a single-compartment uptake-depuration model (Wilson 1975). The species-specific uptake and deputation rates were determined from field and empirical studies (Gallagher and Pola 1984) and were kept constant for each species group throughout each simulation. Contamination was computed in parts per million (ppm; mg hydrocarbons per kg biomass). Contamination of 5 ppm was taken as the threshold level for "tainting" (detectable aroma or taste of petroleum] of fish, based on available empirical data (Pola et al. 1985). In a recent study, Teal (1977) found that uptake of contaminants from the water column (through respiration or swallowing) was approximately equal to uptake of contaminants from feeding. In the absence of studies to the contrary, this result was incorporated into BIOS; that is, uptake through feeding was computed and the resulting contamination was multiplied by two. It was assumed that adequate food was available for all model led fish species, therefore starvation was not included in BIOS. The

fraction of pelagic or demersal food in each species' diet was estimated; contamination of the food was assumed to be directly proportional to the concentration of the napthalene fraction of the WSF (for pelagic food) or the TARS (for demersal food).

Three versions of the BIOS model were eventually developed. The first, BIOS/NOGRID, was used to determine species-specific uptake and deputation rates and their sensitivities. It contains no spatial resolution and the external oil concentration is preset as a constant, or as a linear or exponential function of time. Sixteen species groups (Table1) were used in BIOS/NOGRID, as well as in the second version of the model, BIOS/GRID. This second version includes spatial resolution and uses the gridded WSF values provided by Rand Corp. and TARS concentrations computed by the Laevastu and Fukuhara (]985) model. The final model version, BIOS/MIGR, includes fish migrations. A larger computational grid (e.g., 64 x 68 for the accident scenario) is used in this version; however, only two fish species groups are included. Migration speeds and directions are input to BIOS/MIGR.

Computation

The amount of contamination in a fish species (C_f) at any time step (td) is computed in all versions of BIOS as:

$$C_f(t_d) = \frac{k_1 C_o(t_d)}{k_2} (1-\exp(-k_2)) + C_f(t_d-1)\exp(-k_2) \qquad (1)$$

where C_0 is the external oil concentration, k_1 is the uptake rate, and k_2 is the deputation rate. Equation 1 is a finite-difference approximation to the single compartment model discussed by Wilson (1975) and Moriarty (1975).

Equation 1 can be rewritten as:

$$C_f(t_d) = C'' + CD \quad (2)$$

where C_U is the amount of contamination taken up by a fish species at simulation time step t_d and CD is the amount accumulated over previous time steps, after deputation. The uptake of contamination is computed in the model as:

$$C_U = (F_p B_p C_{WSF} + F_d B_d C_{TARS})\ (1-\exp(-k_2)) \quad (3)$$

where F_p and F_d are the fractions of pelagic and demersal food, respectively, in a species' diet, B_p and B_d are the pelagic and demersal bioconcentration factors, and C_{WSF} and C_{TARS} are the napthalene fractions of the oil concentrations in the water column and in the sediments, respectively.

All versions of the model were run for up to 50 days. The oil concentrations provided by Rand Corporation were computed for 10 days in the accident scenario and for 15 days in the blowout scenario. At time steps greater than those limits, the oil concentrations in the water column for the gridded model versions (BIOS/GRID and BIOS/MIGR) were decayed at a constant rate:

$$WSF(t_d)_{n,m} = WSF(t_d-1)_{n,m} e^{-k} \quad (4)$$

where a decay rate (k) of 0.3 was estimated from the Rand data.

Migrations are simulated in BIOS/MIGR by the advection of contamination through the enlarged grid, keeping biomass constant. The amount of contamination leaving gridpoint (n,m) in the x-direction is:

$$R_{x,n,m} = (G_x t|U|)/L \quad (5)$$

and in the y-direction is:

$$R_{y,n,m} = (G_y t|V|)/L \quad (6)$$

where t is the migration time step, L is the grid spacing, U and V are the

Table 1.--Species groups in the BIOS model.

No.	Species
1	Herring juveniles
2	Herring adul ts
3	Pol lock juveniles
4	Pol lock adults
5	Pacific cod juveniles
6	Halibut juveniles
7	Yellowfin sole juveniles
8	Other flatfish juveniles
9	Yel lowfin sole adults
Jo	Other flatfish adults
11	Pacific cod adults
12	King and Bairdi crab juveniles
13	King and Bairdi crab adults
14	Mobile epifauna
15	Sessile epifauna
16	I nfauna

```
$RESET FREE
$SET LIST LINEINFO STACK
FILE  6(KIND=PRINTER)
FILE  7(KIND=DISK,NEWFILE=.TBLE.)
      DIMENSION TABLE(16),TABLE1(30,12),TJ(16),TCH(16),CONVAL(4),
     &KOMAX(4),FODCMP(16),KK2(16),SAVDEC(50,16),PWSF(50),
     &PTARS(50),SFDCMP(16)
      REAL KK2,K2,KOMAX,NEWOIL
      DATA CONVAL/.005,.10,1.0,10.0/
      DATA J1,J2,J3,IFPLOT/1,6,16,0/
      DATA TJ/.016,.010,.012,.007,.015,.012,.012,.012,.006,.006,
     *.007,.012,.006,.019,.006,.006/
      DATA FODCMP/1.00,.95,.95,.72,.81,.43,.20,.20,.15,.25,.30,
     *.30,.10,0.0,0.0,0.0/
      DATA KK2/.198040,.132027,.198040,.132027,.198040,.1664,.1664,.1664
     &,.1109,.1109,.132027,.334234,.222823,.198042,.03460,.06930/
C
C*****************************************************************
C
C       THIS VERSION IS USED FOR SENSITIVITY ANALYSIS
C
C       THIS PROGRAM USES THE OIL UPTAKE AND DEPURATION EQUATION FROM
C       FEDOIL. THE CONC IS DECREASED AFTER DAY 1 BY: CONC=CONC*EXP(-0.3)
C       THIS PROGRAM FOLLOWS THE DURATION OF THE CONTAMINATION; I.E.
C       FOR 24, 48, OR 96 HOURS.
C
C-----------------------------------------------------------------
C
C       KK2(J) IS THE DEPURATION RATE CONSTANT FOR SPECIES J
C
C       K2 IS THE KK2 VALUE AFTER ADJUSTING FOR + OR - SOME X PERCENT FOR
C       SENSITIVITY ANALYSIS.
C
C       BCFPEL IS THE BIOCONCENTRATION FACTOR OF EACH PELAGIC SPECIES J
C
C       SBCFP  IS THE BCFPEL VALUE AFTER ADJUSTING FOR + OR - SOME X
C       PERCENT FOR SENSITIVITY ANALYSIS.
C
C       BCFDEM IS THE BIOCONCENTRATION FACTOR OF EACH DEMERSAL SPECIES J
C
C       SBCFD  IS THE BCFDEM VALUE AFTER ADJUSTING FOR + OR - SOME X
C       PERCENT FOR SENSITIVITY ANALYSIS.
C
C       FRCNAF IS THE FRACTION OF WSF THAT IS NAPHTHALENES.
C
C       FRCNAC IS THE FRACTION OF TARS THAT IS NAPHTHALENES.
C
C       FODCMP IS THE FOOD COMPOSITION AS FRACTION OF PELAGIC FOOD IN
C       A PREDATORS DIET.
C
C       SFDCMP IS THE FOOD COMPOSITION VALUE, FODCMP, AFTER ADJUSTING FOR
C       + OR - SOME X PERCENT FOR SENSITIVITY ANALYSIS.
C
C-----------------------------------------------------------------
C
C       IPRINT=1 MEANS CONC=CONC*RATEX2 FOR LL GT 1; IPRINT=0 MEANS CONC
C       IS CONSTANT UP TO LL EQ LLVAL AND THEN EQ 0 THEREAFTER; IPRINT=2
```

```
C       MEANS CONC IS CONSTANT UP TO LL EQ LLVAL AND THEN C THEREAFTER,
C       BUT THE EQUATION USED IS NOT "THE FEDCOIL EQUATION" BUT THE BASIC
C       EQUATION FROM THE LITERATURE. IPRINT=3 MEANS CONC=CONC*RATEX2 FOR
C       LL GT 13 THE EQUATION USED IS NOT THE "FEDCOIL EQUATION" BUT
C       THE EQUATION FROM THE LITERATURE. (IF THE EQUATION FROM THE
C       LITERATURE IS USED, SIMPLE DEPURATION STARTS AT LL GT LLVAL.)
C
C       IBCF=1 MEANS THE SENSITIVITY ANALYSIS IS DONE ON BCFFEL AND/OR
C       BCFDEM. IPEL=1 MEANS SENSITIVITY ANALYSIS ON BCFPEL AND IDEM=1
C       MEANS SENSITIVITY ANALYSIS ON BCFDEM.
C
C       ISEN=0 MEANS -X% AND ISEN=1 MEANS +X%.
C       SENANL IS THE % CHANGE FOR THE SENSITIVITY ANALYSIS.
C
C       IFDCMP=1 MEANS THE SENSITIVITY ANALYSIS IS DONE ON THE FOOD
C       COMPOSITION TABLE, FOODCMP.
C
C*****************************************************************
C       SET CONSTANTS
C
      K=8
      LLVAL=10
      LLMAX=30
      RAD=0.0174532 9
      ALP=30.*RAD
      GKAP=175.*RAD
      VALCA=COS(ALP*K-GKAP)
      R2=0.6
      RATEX2=EXP(-R2)
      FRCNAP=.50
      FRCNAD=.10
      BCFPEL=170.
      BCFDEM=170.
      IPRINT=1
      SENPRT=.10
      ISEN=1
      IFDCMP=1
      IPEL=0
      IDEM=0
      IBCF=0
C-----------------------------------------------------------------
C
C
      DO 999 IISEN=1,10
      SENANL=SENANL+.10
      SEN=SENANL*100.
C
C
      IF(IFPLOT.NE.1)GO TO 7777
      WRITE(7,609)
      WRITE(7,/)J1,J2,J3
  609 FORMAT(" CONTAMINATION IN SPECIES FROM ART/FEDCOIL3"
     &", TEST RUN #6")
C
C
 7777 DO 99 J=1,16
      K2=KK2(J)
      RATEXP=EXP(-K2)
      SBCFP=BCFPEL
      SBCFD=BCFDEM
```

```
      SFDCMP(J)=FCDCMF(J)
      IF(IFDCMP.EQ.1) GO TO 760
      IF(IBCF.EQ.1) GO TO 720
      GO TO 860
  720 IF(ISEN.EQ.0) GO TO 740
      IF(IPEL.EQ.0) GO TO 730
      SBCFP=BCFPEL+(BCFPEL*SENANL)
  730 IF(IDEM.EQ.0) GO TO 860
      SBCFD=BCFDEM+(BCFDEM*SENANL)
      GO TO 860
  740 IF(IPEL.EQ.0) GO TO 750
      SBCFP=BCFPEL-(BCFPEL*SENANL)
  750 IF(IDEM.EQ.0) GO TO 860
      SBCFD=BCFDEM-(BCFDEM*SENANL)
      GO TO 860
C
  760 IF(ISEN.EQ.0) GO TO 830
      SFDCMP(J)=FCDCMF(J)+(FCDCMF(J)*SENANL)
      IF(SFDCMF(J).GT.1.0) SFDCMF(J)=1.0
      GO TO 860
  830 SFDCMP(J)=FCDCMF(J)-(FCDCMF(J)*SENANL)
      IF(SFDCMF(J).LT.0.) SFDCMP(J)=0.0
C
  860 IF(IPRINT.EQ.1) GO TO 97
      PRINT 71,J,IPRINT,K2
   71 FORMAT(1H1,"TABLE OF CONTAMINATION FOR DIFFERENT LEVELS OF CONSTAN
     &T EXTERNAL CONCENTRATIONS FOR SPECIES ",I3/,1X,"AFTER DAY 15, CONV
     &AL=0.0, NEWOIL IS ALWAYS SET TO OILCON"/,1X,"THE *FEDOIL EQUATION"
     & IS USED IN THIS RUN. IPRINT =",I3,", K2 = ",F7.6)
      PRINT 69,SBCFP,SBCFD,FRCNAP,FRCNAD
   69 FORMAT(1X,"BCFPEL = ",F8.3,", BCFDEM = ",F8.3,", FRCNAP = ",F5.3,"
     &, FRCNAD = ",F5.3)
      IF(IFDCMP.EQ.1) GO TO 1200
      IF(IBCF.EQ.0) GO TO 98
      IF(ISEN.EQ.0) GO TO 610
      IF(IPEL.EQ.0) GO TO 607
      PRINT 605,SEN
  605 FORMAT(1X,"SENSITIVITY ANALYSIS: BCFPEL = BCFPEL + ",F6.2,"% FOR A
     &LL SPECIES")
  607 IF(IDEM.EQ.0) GO TO 98
      PRINT 615,SEN
  615 FORMAT(1X,"SENSITIVITY ANALYSIS: BCFDEM = BCFDEM + ",F6.2,"% FOR A
     &LL SPECIES")
      GO TO 98
  610 IF(IPEL.EQ.0) GO TO 617
      PRINT 620,SEN
  620 FORMAT(1X,"SENSITIVITY ANALYSIS: BCFPEL = BCFPEL - ",F6.2,"% FOR A
     &LL SPECIES")
  617 IF(IDEM.EQ.0) GO TO 98
      PRINT 625,SEN
  625 FORMAT(1X,"SENSITIVITY ANALYSIS: BCFDEM = BCFDEM - ",F6.2,"% FOR A
     &LL SPECIES")
      GO TO 98
C
 1200 IF(ISEN.EQ.0) GO TO 1210
      PRINT 1205,SEN
 1205 FORMAT(1X,"SENSITIVITY ANALYSIS: FODCMP =FODCMP + ",F6.2,"% FOR A
     &LL SPECIES")
      GO TO 98
 1210 PRINT 1215,SEN
```

```
 1215 FORMAT(1X,"SENSITIVITY ANALYSIS: FOCCMP =FOCCMP - ",F6.2,"% FOR A
     &LL SPECIES")
      GO TO 98
C
   97 CONTINUE
      PRINT 70,J,R2,IPRINT,K2
   70 FORMAT(1H1,"TABLE OF CONTAMINATION FOR DIFFERENT LEVELS OF CONSTAN
     &T EXTERNAL CONCENTRATIONS FOR SPECIES ",I3/,1X,"AFTER DAY  1, CONV
     &AL=CONVAL*EXP(-",F3.1,")) THE "FEDOIL EQUATION" IS USED IN THIS RU
     &N. IPRINT =",I3,", K2 = ",F7.6)
      PRINT 69,SBCFP,SECFD,FRCNAP,FRCNAD
      IF(IFDCMP.EQ.1) GO TO 1400
      IF(IBCF.EQ.0) GO TO 99
      IF(ISEN.EQ.0) GO TO 640
      IF(IPEL.EQ.0) GO TO 647
      PRINT 605,SEN
  647 IF(ICEM.EQ.0) GO TO 98
      PRINT 615,SEN
      GO TO 98
  640 IF(IPEL.EQ.0) GO TO 667
      PRINT 620,SEN
  667 IF(ICEM.EQ.0) GO TO 98
      PRINT 625,SEN
      GO TO 98
C
 1400 IF(ISEN.EQ.0) GO TO 1410
      PRINT 1205,SEN
      GO TO 98
 1410 PRINT 1215,SEN
C
C
   98 CONTINUE
C     TOH(J)=TJ(J)+(0.35*TJ(J)*VALCA)
C
      NEWOIL=0.0
      OILVAL=0.0
      DO 80 ICON=1,4
      CONC=CONVAL(ICON)
C
C
      ICON1=ICON+2*(ICON-1)
      ICON2=ICON1+1
      ICON3=ICON2+1
C
      DO 50 LL=1,LLMAX
      OILCON=0.0
      VALUE=0.0
      IF(LL.GT.30) GO TO 52
      TABLE1(LL,ICON1)=0.0
      TABLE1(LL,ICON2)=0.0
      TABLE1(LL,ICON3)=0.0
   52 CONTINUE
      IF(IPRINT.NE.1.AND.IPRINT.NE.3) GO TO 55
      IF(LL.GT.1) CONC=CONC*RATE)2
C     IF(LL.EQ.10.OR.LL.EQ.20) CONC=CONVAL(ICON)/2.0
      GO TO 56
   55 IF(LL.LE.LLVAL) GO TO 56
      CONC=0.0
   56 WSF=CONC
      TARS=CONC
```

```
      IF(ICON.NE.3) GO TO 15
      PWSF(LL)=WSF
      PTARS(LL)=TARS
   15 IF(LL.GT.30) GO TO 57
      TABLE1(LL,ICON1)=WSF
      TABLE1(LL,ICON2)=TARS
   57 CONTINUE
C
      IF(SFDCMP(J).GT.0..AND.SFDCMP(J).LT.1.0) GO TO 20
      IF(SFDCMP(J).EQ.1.0) GO TO 30
      CO=TARS*FRCNAD
      VALUE=CO*SBCFD*2.0
      IF(J.EQ.16) VALUE=CO*SECFD
      IF(LL.EQ.1) KCMAX(ICON)=VALUE
      GO TO 130
   20 PEL=SFDCMP(J)
      DEM=1.0-PEL
      CO1=WSF*FRCNAP
      CO2=TARS*FRCNAD
      VALUE1=(CO1*SECFP)
      VALUE2=(CO2*SECFD)
      VALUE=(PEL*VALUE1+DEM*VALUE2)
      IF(LL.EQ.1) KCMAX(ICON)=VALUE
      GO TO 130
   30 CO=WSF*FRCNAP
      VALUE=(CO*SECFP)
      IF(LL.EQ.1) KCMAX(ICON)=VALUE
  130 CONTINUE
      IF(IPRINT.EQ.2.OR.IPRINT.EQ.3) GO TO 1130
      OILCON=VALUE*(1.0-RATEXP)+NEWOIL*(RATEXP)
      NEWOIL=OILCON
      GO TO 1140
 1130 IF(LL.GT.LLVAL) GO TO 1135
      RATEX3=EXP(-K2*LL)
      OILCON=VALUE*(1.0-RATEX3)
      IF(LL.EQ.LLVAL) OILVAL=OILCON
      GO TO 1140
 1135 RATEX3=EXP(-K2*(LL-LLVAL))
      OILCON=OILVAL*RATEX3
 1140 CONTINUE
      IF(LL.GT.30) GO TO 54
      TABLE1(LL,ICON3)=OILCON
   54 CONTINUE
      IF(ICON.NE.3) GO TO 50
      SAVDEC(LL,J)=OILCON
C
   50 CONTINUE
C
      NEWOIL=0.0
      OILVAL=0.0
C
      PRINT 60,CONVAL(ICON),WSF,TARS
   60 FORMAT(1),"FOR CONVAL = ",F9.3," THE FINAL WSF CONC = ",F9.3," AND
     & THE FINAL TARS CONC = ",F9.3)
      PRINT 65,CONVAL(ICON),KCMAX(ICON)
   65 FORMAT(1),"FOR CONVAL = ",F9.3," THE MAX CONC = ",F9.3)
C
   80 CONTINUE
C
C
```

```
      PRINT 73
   73 FORMAT(//4X,"TIME",50X,"CONSTANT"/,4X,"STEP",47),"CONCENTRATIONS"/
     &)
      PRINT 74,(CONVAL(M),M=1,4)
   74 FORMAT(19X,4(F8.4,19X)/)
      PRINT 174
  174 FORMAT(15X,4("WSF",5X,"TARS",6X,"INT",6X)/)
C
C
      DO 888 N=1,30
      PRINT 75,(N,(TABLE1(N,M),M=1,12))
   75 FORMAT(4),I3,2X,12F9.3)
  888 CONTINUE
C
      PRINT 775,(N,N=1,16)
  775 FORMAT(//5X,"FOOD COMPOSITION TABLE (FRACTION PELAGIC) FOR SPECIES
     &:",/1X,16(1X,I3,1X))
      PRINT 777,(SFDCMP(N),N=1,16)
  777 FORMAT(1),16F5.2)
C
C
   99 CONTINUE
C
C
      IF(IFPLOT.NE.1)GO TO 999
      IF(SENAPL.NE.SENPRT) GO TO 999
      DO 600 LL=1,LLMAX
      WRITE(7,608)PWSF(LL),PTARS(LL),SAVDEC(LL,J1),SAVDEC(LL,J2),
     &SAVDEC(LL,J3)
  608 FORMAT(5F10.3)
  600 CONTINUE
C
  999 CONTINUE
C
C
 9998 IF(IFPLOT.NE.1) GO TO 9999
      CLOSE(7,DISP=KEEP)
C
C
 9999 STOP
      END
```

```
$RESET FREE
$SET OWN OWNARRAYS
FILE  1(KIND=DISK,TITLE="OCSEAF/OILCON/LOC1",FILETYPE=7)
FILE  2(KIND=DISK,TITLE="OCSEAF/OILCON/LOC2",FILETYPE=7)
FILE  3(KIND=DISK,TITLE="OCSEAF/OILCON/LOC3",FILETYPE=7)
FILE  6(KIND=PRINTER)
FILE  7(KIND=DISK,FILETYPE=7)
FILE  9(KIND=DISK,NEWFILE=.TRUE.)
      COMMON/ELK1/NE,ME,K,LL,ISL
      COMMON/ELKBIO/LOC,ACTBIO(16)
      COMMON/TAPBIO/BIOLC(3,16)
      COMMON/ELKOIL/OILCON(16,32,34)
      COMMON/ELKNEW/NEWOIL(16,32,34)
      COMMON/OIL/WSF(32,34),TARS(32,34)
      DIMENSION ITAB1(10,4),ITAB2(5,4),TI1(5,2),TI2(5,2),IT(5)
      DIMENSION ISL(32,34),D(32,34),TB(4),S7(32,34),S8(32,34),
     &IS(32,34)
C
C
C    DATA STATEMENT FOR SUBROUTINE FECOIL. IFEDOL=0 FOR NO PRINTING OF
C    OUTPUT; IFEDOL=1 FOR PRINTING OF SUMMARY TABLE ONLY; IFEDOL=2 FOR
C    PRINTING OF CONCENTRATIONS AT EACH GRID POINT ONLY; IFEDOL=3 FOR
C    PRINTING OF BOTH.
C
      DATA IFEDOL/0/
C
      REAL NEWOIL
      NE=32;ME=34;K=8;LL=1;LLMAX=50;LOC=2
C
      DO 25 J=1,16
      ACTBIO(J)=BIOLC(LOC,J)
   25 CONTINUE
C
   30 IF(LL.GT.10) GO TO 35
      READ(LOC,/)NHRS
      READ(LOC,/)((WSF(N,M),M=1,ME),N=1,NE)
      GO TO 40
C
   35 DO 38 N=1,NE
      DO 38 M=1,ME
      WSF(N,M)=WSF(N,M)*EXP(-0.3)
      S7(N,M)=WSF(N,M)
   38 CONTINUE
      GO TO 42
C
C
C    CHANGE OIL CONCENTRATIONS FROM PPB TO   PPM
C
C
   40 CONTINUE
      DO 32 N=1,NE
      DO 32 M=1,ME
      WSF(N,M)=WSF(N,M)/1000.
   32 S7(N,M)=WSF(N,M)
C
C    COMPUTE OIL ON THE BOTTOM
```

```
   42 CONTINUE
      BLC=1.
C     BLC=2 CONTINUOUS SOURCE, BLC=1 INSTANTANEOUS SOURCE.
      DL=2000.
C     TAT TIME STEP IN HOURS
      TAT=24.
      TD=20.
      T=LL*1440.
      KAL=0
C     KAL=0 - NO OIL MOVEMENT ON THE BOTTOM, 1 OIL ADVECTED ON BOTTOM
C     KU - CURRENT INDEX, SEE CURCIL; KA - TURBULENCE INDEX(NOT USED);
C     LU - PRINT SCALING INDEX
      KU=3
      KA=1
      LU=0
      LI=0.
      VI=0.
      CALL OILBOT(S7,LL,TD,DL,D,S8,TB,BLO,UI,VI,KU,KAL,T,KA,TAT)
      IF(LL.GT.1) GO TO 55
C
      DO 54 N=1,NE
      DO 54 M=1,ME
      ISL(N,M)=0
      IF(D(N,M).GT.0) ISL(N,M)=1
   54 CONTINUE
C
   55 UI=60.
      VI=8.
      IF(KAL.NE.1)GO TO 31
      CALL CURCIL(S8,KL,UI,VI,DL,LL,BLO,T,KAL)
   31 DO 33 N=1,NE
      DO 33 M=1,ME
   33 TARS(N,M)=S8(N,M)
      CALL FECOIL(IFECOL)
      J=1
 1200 DO 1000 I=1,4
      IT(I)=0
 1000 CONTINUE
      DO 1201 N=1,NE
      DO 1201 M=1,ME
      IF(OILC(N,J,N,M).LT.5.0)GO TO 1201
      IF(OILC(N,J,N,M).GE.5.0)IT(1)=IT(1)+4
      IF(OILC(N,J,N,M).GE.10.)IT(2)=IT(2)+4
      IF(OILC(N,J,N,M).GE.50.)IT(3)=IT(3)+4
      IF(OILC(N,J,N,M).GT.100.)IT(4)=IT(4)+4
 1201 CONTINUE
      WRITE(9,/)LL,J
      WRITE(9,/)(IT(I),I=1,4)
      IF(J.EQ.13)GO TO 778
      J=13
      GO TO 1200
 1303 FORMAT(15X,2A6,1X,5I8)
 1307 FORMAT(15X,2A6,1X,5I8//)
  778 LL=LL+1
      IF(LL.LE.LLMAX)GO TO 30
      CLOSE(9,DISP=KEEP)
C
 9999 STOP
      END
      BLOCK DATA
```

```
      COMMON/INPBIO/BIOLC(3,16)
      COMMON/VALUES/FCDCMP(16),TJ(16),K2(16)
      REAL K2
      DATA BIOLC/1409.,521.,1551., 1121.,414.,1234.,
     &3708.,2322.,3261., 11007.,6893.,9679., 424.,279.,307.,
     &730.,330.,240., 831.,555.,819., 2004.,1472.,1650.,
     &922.,615.,908., 2004.,1472.,1650., 861.,461.,681.,
     &664.,222.,432., 1656.,553.,1078., 5970.,4995.,6075.,
     &13930.,11655.,14175., 19150.,13750.,19250./
      DATA FCDCMP/1.00,.95,.95,.72,.81,.43,.20,.20,.15,.25,.30,
     *.30,.10,0.0,0.0,0.0/
      DATA TJ/.016,.010,.012,.007,.015,.012,.012,.012,.006,.006,
     *.007,.012,.006,.019,.006,.006/
      DATA K2/.198040,.132027,.198040,.132027,.198040,.1664,.1664,.1664,
     &.1109,.1109,.132027,.334234,.222823,.198042,.03460,.06930/
      END
      SUBROUTINE FEDOIL(IFEDOL)
      COMMON/OIL/WSF(32,34),TARS(32,34)
      COMMON/ELKBIO/LOC,ACTBIO(16)
      COMMON/ELKOIL/OILCON(16,32,34)
      COMMON/ELKNEW/NEWOIL(16,32,34)
      COMMON/ELK1/NE,ME,K,LL,ISL(32,34)
      COMMON/VALUES/FCDCMP(16),TJ(16),K2(16)
      COMMON/ELKTAB/MS(16,9),AREA(16,9),FRCCON(16,9,2)
      DIMENSION CR(14),CCR(14),TOH(16),S1(32,34)
      REAL MS,K2,NEWOIL
c     DATA CR/10.,7.51,7.5,5.01,5.0,2.51,2.5,1.01,1.,0.11,0.1,0.011,0.01
C    &,.001/
C     DATA CCR/10.,7.51,7.5,5.01,5.0,2.51,2.5,1.01,1.,0.11,0.1,0.011,0.0
c    &1,.001/
      DATA CR/100.,50.01,50.,10.01,10.,5.01,5.,1.01,1.,0.11,0.1,0.011,0.
     &01,0.001/
      DATA CCR/100.,50.01,50.,10.01,10.,5.01,5.,1.01,1.,0.11,0.1,0.011,0
     &.01,0.001/
C
c      ART/FEDOL13 - THIS IS THE 'BCF VERSION' OF FEDOIL IN WHICH ONLY
C      K2, AND BCF ARE USED IN COMPUTING UPTAKE AND DEPURATION.
C
c      K2(J) IS THE DEPURATION RATE CONSTANT FOR SPECIES J
C
C      BCFPEL IS THE BIOCONCENTRATION FACTOR OF EACH PELAGIC SPECIES J
C
c      BCFDEM IS THE BIOCONCENTRATION FACTOR OF EACH DEMERSAL SPECIES J
c
C      FRCNAP IS THE FRACTION OF WSF THAT IS NAPHTHALENES.
r
C      FRCNAD IS THE FRACTION OF TARS THAT IS NAPHTHALENES.
C
C.........................................................................
C
c     SET CONSTANTS
c
      RAD=0.01745329
      ALP=30.*RAD
      GKAP=175.*RAD
      VALCA=COS(ALP*K-GKAP)
      FRCNAP=.50
      FRCNAD=.10
      BCFPEL=170.
      BCFDEM=170.
```

```
C
C-----------------------------------------------------------------------
C
C     COMPUTE UPTAKE AND DEPURATION OF OIL CONTAMINANTS. FOR OUTPUT,
C     ALL CONCENTRATIONS ARE IN PPM AND ACTBIO IS IN KG
C-----------------------------------------------------------------------
C
      DO 99 J=1,16
C
      DO 100 I=1,9
      MS(J,I)=0.
      AREA(J,I)=0.
      FRCCON(J,I,1)=0.
      FRCCON(J,I,2)=0.
  100 CONTINUE
C
      RATEXP=EXP(-K2(J))
      TOH(J)=TJ(J)+(0.35*TJ(J)*VALCA)
      TONS=(ACTBIO(J)*4.0)/1000.
C
      TAREA=0.
      TTONS=0.
      TCOUNT=0.
      DO 10 N=1,NE
      DO 10 M=1,ME
      IF(ISL(N,M).EQ.0) GO TO 10
      VALUE=0.0
      S1(N,M)=0.0
      TAREA=TAREA+4.0
      TTONS=TTONS+TONS
      TCOUNT=TCOUNT+1.0
      IF(FODCMP(J).GT.0..AND.FODCMP(J).LT.1.0) GO TO 20
      IF(FODCMP(J).EQ.1.0) GO TO 30
      CO=TARS(N,M)*FRONAC
      VALUE=CO*BCFDEM*2.0
      IF(J.EQ.16) VALUE=CO*BCFDEM
      GO TO 130
   20 PEL=FODCMP(J)
      DEM=1.0-PEL
      CO1=WSF(N,M)*FRONAP
      CO2=TARS(N,M)*FRONAC
      VALUE1=(CO1*BCFPEL)
      VALUE2=(CO2*BCFDEM)
      VALUE=(PEL*VALUE1+DEM*VALUE2)
      GO TO 130
   30 CO=WSF(N,M)*FRONAP
      VALUE=(CO*BCFPEL)
  130 CONTINUE
      OILCON(J,N,M)=VALUE*(1.0-RATEXP)+NEWOIL(J,N,M)*(RATEXP)
      NEWOIL(J,N,M)=OILCON(J,N,M)
      S1(N,M)=OILCON(J,N,M)
      IF(IFEDCL.NE.1.AND.IFEDCL.NE.3) GO TO 10
      IF(S1(N,M).LT.CCR(14)) MS(J,9)=MS(J,9)+TONS
      IF(S1(N,M).LT.CCR(14)) AREA(J,9)=AREA(J,9)+4.0
      IF(S1(N,M).LE.CCR(13).AND.S1(N,M).GE.CCR(14))
     &MS(J,8)=MS(J,8)+TONS
      IF(S1(N,M).LE.CCR(13).AND.S1(N,M).GE.CCR(14))
     &AREA(J,8)=AREA(J,8)+4.0
      IF(S1(N,M).LE.CCR(11).AND.S1(N,M).GE.CCR(12))
     &MS(J,7)=MS(J,7)+TONS
```

```
      IF(S1(N,M).LE.CCR(11).AND.S1(N,M).GE.CCR(12))
     &AREA(J,7)=AREA(J,7)+4.0
      IF(S1(N,M).LE.CCR(9).AND.S1(N,M).GE.CCR(10))
     &MS(J,6)=MS(J,6)+TONS
      IF(S1(N,M).LE.CCR(9).AND.S1(N,M).GE.CCR(10))
     &AREA(J,6)=AREA(J,6)+4.0
      IF(S1(N,M).LE.CCR(7).AND.S1(N,M).GE.CCR(8))
     &MS(J,5)=MS(J,5)+TONS
      IF(S1(N,M).LE.CCR(7).AND.S1(N,M).GE.CCR(8))
     &AREA(J,5)=AREA(J,5)+4.0
      IF(S1(N,M).LE.CCR(5).AND.S1(N,M).GE.CCR(6))
     &MS(J,4)=MS(J,4)+TONS
      IF(S1(N,M).LE.CCR(5).AND.S1(N,M).GE.CCR(6))
     &AREA(J,4)=AREA(J,4)+4.0
      IF(S1(N,M).LE.CCR(3).AND.S1(N,M).GE.CCR(4))
     &MS(J,3)=MS(J,3)+TONS
      IF(S1(N,M).LE.CCR(3).AND.S1(N,M).GE.CCR(4))
     &AREA(J,3)=AREA(J,3)+4.0
      IF(S1(N,M).LE.CCR(1).AND.S1(N,M).GE.CCR(2))
     &MS(J,2)=MS(J,2)+TONS
      IF(S1(N,M).LE.CCR(1).AND.S1(N,M).GE.CCR(2))
     &AREA(J,2)=AREA(J,2)+4.0
      IF(S1(N,M).GT.CCR(1)) MS(J,1)=MS(J,1)+TONS
      IF(S1(N,M).GT.CCR(1)) AREA(J,1)=AREA(J,1)+4.0
   10 CONTINUE
C
      IF(IFEDCL.NE.1.AND.IFEDCL.NE.3) GO TO 250
      DO 200 I=1,9
      FRCCON(J,I,1)=MS(J,I)/TTONS
      FRCCON(J,I,2)=AREA(J,I)/TAREA
  200 CONTINUE
C
C-----------------------------------------------------------------
C     PRINT OIL CONCENTRATION FIELDS
C-----------------------------------------------------------------
C
  250 IF(IFEDCL.NE.2.AND.IFEDCL.NE.3) GO TO 99
      PRINT 1005,J,LL
 1005 FORMAT("1CONTAMINATION INDEX (PPM) IN FEDOIL FOR SPECIES #"I2,2X,"
     &TIME STEP #"I2)
      PRINT 1006,((S1(N,M),M=1,14),N=1,NE)
 1006 FORMAT(2X,14F9.5)
      PRINT 1008,((S1(N,M),M=15,ME),N=1,NE)
 1008 FORMAT(13F9.5)
C
   99 CONTINUE
C
C-----------------------------------------------------------------
C-----------------------------------------------------------------
C
C
      IF(IFEDCL.NE.1.AND.IFEDCL.NE.3) GO TO 999
      ICOUNT=1
      DO 300 J=1,16
      ITAB=LL
      IF(ICOUNT.GT.1) GO TO 1320
      PRINT 1121,ITAB,ICOUNT
 1121 FORMAT(1H1,//6X,"TABLE",I3,".--- AREA COVERED BY   INTERNAL   CONC
     &ENTRATIONS FOR SELECTED LEVELS OF CONTAMINATION"/,19X,"ACCIDENT SC
     &ENARIO; EACH GRID POINT IS 2 KM BY 2 KM; GRID COUNT = ",F6.0)
```

```
      GO TO 116
 1320 PRINT 1119,ITAB,ICOUNT
 1119 FORMAT(///6X,"TABLE",I3,"---- AREA COVERED BY   INTERNAL   CONCENT
     &RATIONS FOR SELECTED LEVELS OF CONTAMINATION"/,19X,"ACCIDENT SCENA
     &RIO; EACH GRID POINT IS 2 KM BY 2 KM; GRID COUNT = ",F6.0)
  116 IF(LOC.NE.1) GO TO 324
      PRINT 118,LL
  118 FORMAT(19X,"LOCATION: FORT MOLLER, TIME STEP: DAY",I3)
      GO TO 328
  324 IF(LOC.NE.2) GO TO 326
      PRINT 220,LL
  220 FORMAT(19X,"LOCATION: FORT HEIDEN, TIME STEP: DAY",I3)
      GO TO 328
  326 PRINT 222,LL
  222 FORMAT(19X,"LOCATION: CAPE NEWENHAM, TIME STEP: DAY",I3)
  328 PRINT 223
  223 FORMAT(19X,"(CONTAMINATED BIOMASS IS SUMMED OVER THE GRID AND GIVE
     &N IN TONS)")
      GO TO (224,224,224,224,225,225,225,224,224,224,225,225,224,225,225
     &,225)J
  224 PRINT 124,J,ACTEIO(J)
  124 FORMAT(///6X,"SPECIES NO.",I3," - A MIGRATING SPECIES (BIOMASS",F9
     &.2," KG/KM2)")
      GO TO 226
  225 PRINT 221,J,ACTEIO(J)
  221 FORMAT(///6X,"SPECIES NO.",I3," - A NON-MIGRATING SPECIES (BIOMASS
     &",F9.2," KG/KM2)")
  226 PRINT 123
  123 FORMAT(/8X,"CONCENTRATIONS IN PPM (MG/KG)",28X,"TOTAL CONTAMINATED
     & BIOMASS")
      PRINT 2225
 2225 FORMAT(58X,"BIOMASS(TONS)",18X,"AREA(KM2)")
      PRINT 323
  323 FORMAT(55X," BIOMASS ",5X,"FRACTION",5X,"  AREA   ",6X,"FRACTION")
      PRINT 122,CR(1),MS(J,1),FRCCON(J,1,1),AREA(J,1),
     &FRCCON(J,1,2)
  122 FORMAT(/6X,24HCONT.INDEX GREATER THAN ,F9.3,8X,F16.2,6X,F8.3,6X,F8
     &.2,6X,F8.3)
      PRINT 125,CR(2),CR(1),MS(J,2),FRCCON(J,2,1),AREA(J,2),
     &FRCCON(J,2,2)
  125 FORMAT(6X,1HCONT.INDEX,F9.3,2X,3HTO ,F9.3,8X,F16.2,6X,F8.3,6X,F8.
     &2,6X,F8.3)
      PRINT 125,CR(4),CR(3),MS(J,3),FRCCON(J,3,1),AREA(J,3),
     &FRCCON(J,3,2)
      PRINT 125,CR(6),CR(5),MS(J,4),FRCCON(J,4,1),AREA(J,4),
     &FRCCON(J,4,2)
      PRINT 125,CR(8),CR(7),MS(J,5),FRCCON(J,5,1),AREA(J,5),
     &FRCCON(J,5,2)
      PRINT 125,CR(10),CR(9),MS(J,6),FRCCON(J,6,1),AREA(J,6),
     &FRCCON(J,6,2)
      PRINT 125,CR(12),CR(11),MS(J,7),FRCCON(J,7,1),AREA(J,7),
     &FRCCON(J,7,2)
      PRINT 125,CR(14),CR(13),MS(J,8),FRCCON(J,8,1),AREA(J,8),
     &FRCCON(J,8,2)
      PRINT 126,CR(14),MS(J,9),FRCCON(J,9,1),AREA(J,9),
     &FRCCON(J,9,2)
  126 FORMAT(6X,"CONT.INDEX LESS THAN    ",F9.3,8X,F16.2,6X,F8.3,6X,F8.2
     &,6X,F9.3)
C
      ICOUNT=ICOUNT+1
```

```
      IF(ICOUNT.EQ.3) ICOUNT=1
  300 CONTINUE
C
C
C-----------------------------------------------------------------------
C                              END SUBROUTINE
C-----------------------------------------------------------------------
C
C
  999 RETURN
      END
      SUBROUTINE CILBCT(S,K,TC,DL,D,AC,TB,BLO,UI,VI,KU,KAL,T,KA,TAT)
      COMMON/ELKBIC/LCC,ACIBIC(16)
      DIMENSION S(32,34),D(32,34),AC(32,34),TB(4),PLC(2),W(3)
C     D-DEPTH
C     AO-OIL ON THE BOTTOM
C     TB-BOTTOM TEMPERATURE, FOUR VALUES GIVEN
C     PLC-THERMOCLINE DEPTH, TWO VALUES
C     W-WIND SPEED, THREE VALUES
C     KT-INDEX OF TB VALUE CHOSEN FOR THE RUN
C     KP-INDEX OF PLD VALUE
C     KW-INDEX OF WIND VALUE
C     BLO=1 INSTANTANEOUS SOURCE, =2 CONTINUOUS SOURCE
C     UI-SURFACE CURRENT SPEED
C     KAL=1 COMPUTATION OF OIL MOVEMENT ON BOTTOM
C     LU=1 DEPTH DATA
C     LU=2 DECAY OF OIL ON THE BOTTOM
C     LU=3 OIL ON THE BOTTOM BEFORE ADVECTION
C     LU=4 OIL ON THE BOTTOM,LAYER THICKNESS DECREASING, ADVECTED
C     LU=5 ADVECTED OIL ON THE BOTTOM
C     LU=6 CONTAMINATION INDEX, PELAGIC FOOD
C     LU=7 CONTAMINATION INDEX, DEMERSAL FOOD
      NE=32
      ME=34
      MO=10
C     MO IS THE M LOCATION OF BLOWOUT
C     SIMULATION OF DEPTH,
C     KB-AREA NUMBER FOR TANKER ACCIDENT, 4 TO 6
   16 KB=LOC+3
      IF(KB-5)305,330,360
  305 DO 319 N=1,NE
      DO 319 M=1,ME
      SDS=M
      IF(N-17)306,306,307
  306 D(N,M)=70.-0.35*SDS
      GO TO 319
  307 IF(N-26)308,308,311
  308 IF(M-20)309,309,310
  309 D(N,M)=62.-1.0*SDS
      GO TO 319
  310 D(N,M)=62.-1.5*SDS
      GO TO 319
  311 IF(M-20)312,312,313
  312 D(N,M)=54.-1.2*SDS
      GO TO 319
  313 D(N,M)=54.-1.4*SDS
  319 CONTINUE
      ALPHA=0.9
      CALL SILITA(D,ALPHA,NE,ME,S,1)
      GO TO 10
```

```
CXXXXXXXXXXXXXXXX
  330 DO 359 N=1,NE
      DO 359 M=1,ME
      SDS=M
      IF(N-22)331,331,332
  331 D(N,M)=50.-1.0*SDS
      GO TO 359
  332 IF(M-25)333,333,334
  333 D(N,M)=45.-1.6*SDS
      GO TO 359
  334 D(N,M)=0.
  359 CONTINUE
      ALPHA=0.9
      CALL SILITA(D,ALPHA,NE,ME,S,1)
      GO TO 10
CXXXXXXXXXXXXXXXX
  360 DO 379 N=1,NE
      DO 379 M=1,ME
      SDS=M
      IF(N-12)361,361,362
  361 D(N,M)=38.
      GO TO 379
  362 D(N,M)=45.
  379 CONTINUE
      ALPHA=0.9
      CALL SILITA(D,ALPHA,NE,ME,S,1)
CXXXXXXXXXXXXXXXXXXXXXX
   10 LU=1
      IF(K-1)17,17,20
      IF(K-1)9,9,20
    9 CALL PRIMFS(D,T,UI,VI,DL,K,KA,KAL,BLO,LU,NE,ME)
CXXXXXXXXXXXXXXXXXXXXX
   17 DO 18 N=1,NE
      DO 18 M=1,ME
      AC(N,M)=0.
   18 CONTINUE
C     INPUT PARAMETERS
   20 TB(1)=1.
      TB(2)=4.
      TB(3)=8.
      TB(4)=12.
      PLO(1)=20.
      PLO(2)=40.
      W(1)=5.
      W(2)=10.
      W(3)=15.
C     PP - RELATIVE CONC. OF PLANKTON
C     R - INDEX OF SUSPENDED MATTER
C     BB - BOTTOM TYPE INDEX
      PP=1.5
      R=40.
      BB=0.8
C     SETTING OF INDICES FOR INPUT PARAMETERS
      KT=3
      KP=1
      KW=2
CXXXXXXXXXXXXXXXXXXXXX
C     DECAY OF OIL ON THE BOTTOM
      IF(K-2)30,25,25
   25 DO 29 N=1,NE
```

```
      DO 29 M=1,ME
      IF(D(N,M))29,29,290
  290 IF(AO(N,M))29,29,26
   26 TFA=(TB(NT)**2.7)*0.0001
      DFA=0.15/SQRT(D(N,M))
      EFA=-(TFA+DFA)
      AO(N,M)=AO(N,M)*EXP(EFA)
      IF(TAT-12.)29,29,27
   27 AO(N,M)=AO(N,M)*EXP(EFA)
   29 CONTINUE
C XXXXXXXXXXXXXXXXXXXXXXXX
      LU=2
C     CALL PRINFS(AO,T,UI,VI,DL,K,KA,KAL,ELO,LU,NE,ME)
C XXXXXXXXXXXXXXXXXXXXXXXX
   30 IF(BLO-1)31,31,51
C     INSTANTANEOUS SOURCE (TANKER ACCIDENT)
   31 DO 45 N=1,NE
      DO 45 M=1,ME
      IF(D(N,M))45,45,291
  291 IF(PLD(MF)-D(N,M))40,33,33
C      NO PYCNOCLINE
   33 SK=K
   35 STK=SK/(3.+0.2*SK)
   36 BCF=0.0015
      CCF=0.15
      RR=(R+0.2*D(N,M))/SQRT(D(N,M))
      FS=(BCF*W(KW)+CCF/(D(N,M)**0.7))*STK
      AO(N,M)=AO(N,M)+S(N,M)*FS*PP*RR*BB
      IF(K-1)45,45,131
  131 IF(TAT-12.)45,45,37
   37 AO(N,M)=AO(N,M)+S(N,M)*FS*PP*RR*BB
      GO TO 45
C     THERMOCLINE PRESENT
   40 IF(K-1)45,45,38
   38 SK=K
      TDK=SK/(3.+0.5*SK)
      BCF=0.001
      CCF=0.20
      RR=(R+0.2*D(N,M))/SQRT(D(N,M))
      FDD=(BCF*W(KW)+CCF/(D(N,M)**0.7))*TDK
      AO(N,M)=AO(N,M)+S(N,M)*FDD*PP*RR*BB
      IF(K-1)45,45,132
 132  IF(TAT-12.)45,45,44
   44 AO(N,M)=AO(N,M)+S(N,M)*FDD*PP*RR*BB
   45 CONTINUE
      GO TO 70
C     CONTINUOUS SOURCE (BLOWOUT)
   51 DO 65 N=1,NE
      DO 65 M=1,ME
      IF(D(N,M))65,65,292
  292 DIS=((M-MO)*0.001*DL)
      IF(DIS)53,53,54
   53 DIS=0.001
   54 APD=2.5
C     NO COMPUTATION IN IMMEDIATE AREA OF BLOWOUT
C     I.E. 2.5KM FROM THE SOURCE
      IF(DIS-APD)65,59,59
   59 IF(PLD(MF)-D(N,M))60,55,55
C     NO PYCNOCLINE
```

```
   57 STK=SK/(3.+0.2*SK)
   58 BWF=0.0016
      CDF=0.15
      RR=(R+0.2*D(N,M))/SQRT(D(N,M))
      DIFAC=(DIS+4.)/(20.+0.1*DIS)
      FS=(BWF*W(KW)+CDF/(D(N,M)**0.7))*STK*(DIFAC)
      AO(N,M)=AO(N,M)+S(N,M)*FS*PP*RR*BB
      IF(K-1)65,65,69
   69 IF(TAT-12.)65,65,71
   71 AO(N,M)=AO(N,M)+S(N,M)*FS*PP*RR*BB
      GO TO 65
C     COMPUTATION WITH THERMOCLINE PRESENT
   60 APD=2.5
      IF(DIS-APD)65,61,61
   61 SK=K
   62 STK=SK/(3.+0.5*SK)
   64 BWF=0.001
      CDF=0.20
      DDP=D(N,M)**0.74
      RR=(R+0.2*D(N,M))/SQRT(D(N,M))
      DIFAC=(DIS+4.)/(20.+0.1*DIS)
      FS=(BWF*W(KW)+CDF/DDP)*STK*(DIFAC)
      AO(N,M)=AO(N,M)+S(N,M)*FS*PP*RR*BB
      IF(K-1)65,65,66
   66 IF(TAT-12.)65,65,67
   67 AO(N,M)=AO(N,M)+S(N,M)*FS*PP*RR*BB
   65 CONTINUE
CXXXXXXXXXXXXXXXXXXX
   70 ALPHA=0.78
      CALL SILITA(AO,ALPHA,NE,ME,D,C)
CXXXXXXXXXXXXXXXXXXXXXXXXX
      LU=3
C     CALL PRIMFS(AO,T,UI,VI,DL,K,KA,KAL,BLO,LU,NE,ME)
CXXXXXXXXXXXXXXXXXXXXXXXX
  100 RETURN
      END
      SUBROUTINE CURDIL(S,KU,UI,VI,DL,K,BLO,T,KAL)
      DIMENSION S(32,34),PF(32,34),D(32,34)
CXXXXXXXXXXXXXXXXXXX
C     INDICES
C     KG-GRID SIZE 1-2KM;2-4KM
C     KT-TIME STEP 1-20MIN, 2-40MIN.
C     KF-FLUCTUATION PARAMETER (FAF);PERIOD 15 MIN,KF=1,FAF=0.4
C        30 MIA,KF=2,FA=0.2
C     KA-LAMINAR FLOW OR INCREASING LAYER  1-LAMINAR; 2-INCREASING LAYER
C     KU-UNIDIRECTIONAL                CURRENT 1-UNIDIRECTIONAL,U-DIRECTION
C        2-UNIDIRECTIONAL V-DIRECTION, 3-UNIDIRECTIONAL AT 45 DEG. ANGEL
C     KR-UNIDIRECTIONAL OR ROTATING, 1-UNIDIRECTIONAL, 2-ROTATING
C     KS-SPEED COUNTER FOR 4 DIFERENT SPEEDS
C     CURRENT SPEED IN, M/SEC
CXXXXXXXXXXXXXXXXXX
C     THIS SUBROUTINE HAS BEEN USED FOR COMPUTATION OF
C     DISTRIBUTION OF SMELL FROM BAITS
C     XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
      KG=1
      KT=1
      KF=1
      KA=1
      KR=1
CXXXXXXXXXXXXXXXXXX
```

```
      NE=32
      NEH=NE-1
      ME=34
      MEH=ME-1
      IF(KG-1)1,1,2
    1 DL=2000.
      GO TO 3
    2 DL=4000.
    3 IF(KT-1)4,4,5
    4 TD=20.
C     IAC=3
C     IPR=36
      IAC=9
      IPR=3*24
      GO TO 6
    5 TD=40.
      IAC=2
      IPR=18
    6 IF(KF-1)7,7,8
    7 FAF=0.4
      GO TO 9
    8 FAF=0.2
    9 CON=0.0174533
      ALPHA=0.82
      ALP=FAF*CON
      TCAP=45.*CON
      SO=100.
CXXXXXXXXXXXXXXXX
C     ADVECTION COMPUTED FOR 24 HOURS
      TSTO=24.*60.
      TI=0.
C     TF=10080.+TD
CXXXXXXXXXXXXXXXX
      KS=1
      KKK=0
      TURC=0.02
C     XXXXXX
C     CURRENT SPEED INPUT
      IF(KR-1)12,12,16
   12 IF(KL-2)13,14,15
   13 UA=0.1*UI
      VA=0.1*VI
      GO TO 18
   14 UA=0.15*UI
      VA=0.15*VI
      GO TO 18
   15 UA=0.15*UI
      VA=0.15*VI
      GO TO 18
   16 UA=0.15*UI
      VA=0.15*VI
      ADO=0.006
      AROT=ADO*CON
      AKADI=90.*CON
      APARP=180.*CON
      DL=4000.
      TF=14400.
CXXXXXXXXXXXXXXXX
C     KAL=1, OIL MOVEMENT ON THE BOTTOM
      IF(KAL)18,18,519
```

```
CXXXXXXXXXXXXXXXXX
   18 T=T+TD
      TI=T
  515 ITC=0
      ITCP=0
      TI=TI+TD
   10 ITC=ITC+1.
      ITCP=ITCP+1
   20 IF(KR-1)41,41,47
   41 IF(KU-2)42,43,44
   42 U=UI+UA*COS(ALP*TI)
      V=VI*COS(ALP*TI+TCAP)
      GO TO 49
   43 V=VI+VA*COS(ALP*TI)
      U=UI*COS(ALP*TI+TCAP)
      GO TO 49
   44 U=UI+UA*COS(ALP*TI)
      V=VI+VA*COS(ALP*TI+TCAP)
      GO TO 49
   47 U=UI*COS(ARCT*TI+AKADI)
      V=VI*COS(ARCT*TI+APARP)
   49 CONTINUE
      IF(KAL-1)253,27,27
  253 IF(BLO-1)250,250,252
C     100 UNITS OF OIL ADDED EACH TIME STEP (SO=100.)
  252 S(12,10)=S(12,10)+SO
      GO TO 27
CXXXXXXXXXXXXXXXXXXX
  250 IF(K-1)251,251,27
  251 S(12,10)=600.

CXXXXXXXXXXXXXXXXXXX
   27 SUS=0.
      SUA=0.
   30 DO 50 N=2,NEH
      DO 50 M=2,MEH
      SUA=SUA+S(N,M)
      IF(U)32,31,31
   31 SH=(S(N,M)-S(N,M-1))/DL
      GO TO 33
   32 SH=(S(N,M)-S(N,M+1))/DL
   33 IF(V)34,36,36
   34 SV=(S(N,M)-S(N-1,M))/DL
      GO TO 35
   36 SV=(S(N,M)-S(N+1,M))/DL
   35 S(N,M)=S(N,M)-(TD*ABS(U)*SH)-(TD*ABS(V)*SV)
      SUS=SUS+S(N,M)
   50 CONTINUE
      IF(SUS)80,80,95
   95 IF(ITC-IAC)80,55,80
CXXXXXXXXXXXXXXXXXX
   55 IF(KAL-1)550,551,551
  551 ALPHA=0.78
CXXXXXXXXXXXXXXXXXX
  550 CALL SILITA(S,ALPHA,NE,ME,D,1)
      ITC=0
      U1=SUA/SUS
      DO 60 N=1,NE
      DO 60 M=1,ME
      S(N,M)=S(N,M)*U1
```

```
   60 CONTINUE
C     EFFECTS OF INCREASING LAYER THICKNESS,APPROXIMATE
C     FACTOR -CTR REFERRES TO MILLIMETERS FROM SOURCE
C     OBS. N AND M ARE LOCATION OF SOURCE
CXXXXXXXXXXXXXX
C     THE FOLLOWING SECTION >CT USED IN OIL PROBLEMS
CXXXXXXXXXXXXXX
      CTR=0.015
      IF(KA-1)81,81,61
   61 DO 131 N=1,NE
      DO 131 M=1,ME
      PF(N,M)=S(N,M)
  131 CONTINUE
      IF(KR-1)62,62,69
   62 IF(KU-2)63,65,67
   63 DO 64 N=1,NE
      DO 64 M=1,ME
      DIS=(M-10)*0.01*DL
      IF(DIS)51,51,52
   51 RRC=1.
      GO TO 53
   52 RRC=(1.-(CTR*DIS))
   53 PF(N,M)=FF(N,M)*RRC
   64 CONTINUE
      GO TO 81
   65 DO 66 N=1,NE
      DO 66 M=1,ME
      DIS=(N-20)*0.01*DL
      IF(DIS)54,54,56
   54 RRC=1.
      GO TO 57
   56 RRC=(1.-(CTR*DIS))
   57 PF(N,M)=FF(N,M)*RRC
   66 CONTINUE
      GO TO 81
   67 DO 68 N=1,NE
      DO 68 M=1,ME
      IF(M-10)58,58,59
   58 RRC=1.
      GO TO 82
   59 IF(N-10)58,58,83
   83 DIS=SQRT((M-10)**2.+(N-10)**2.)*0.01*DL
      RRC=(1.-(CTR*DIS))
   82 PF(N,M)=FF(N,M)*RRC
   68 CONTINUE
      GO TO 81
   69 DO 84 N=1,NE
      DO 84 M=1,ME
      IF(M-10)86,86,87
   86 RRC=1.
      GO TO 88
   87 DIS=(M-10)*0.01*DL
      RRC=(1.-(0.5*CTR*DIS))
   88 PF(N,M)=FF(N,M)*RRC
      IF(N-20)89,89,91
   89 RRC=1.
      GO TO 94
   91 DIS=(N-20)*0.01*DL
      RRC=(1.-(0.5*CTR*DIS))
   94 PF(N,M)=FF(N,M)*RRC
```

```
   84 CONTINUE
   81 ITC=0.
   8C IF(ITOP-IPR)590,85,590
C     XXXXXXXXXXXXXXX
  59C TI=TI+TC
      IF(TSTC-TI)1CC,1C,1C
C 59C T=T+TD
C     IF(TF-T)100,10,10
C      XXXXXXXXXXXXXXX
   85 IF(KA-1)122,122,121
  121 LU=4
C     CALL PRIMFS(PF,T,UI,VI,CL,K,KA,KAL,ELC,LU,NE,ME)
      DO 132 N=1,NE
      DO 132 M=1,ME
      S(N,M)=FF(N,M)
  132 CONTINUE
      GO TC 123
  122 LU=5
C     CALL PRIMFS(S,T,UI,VI,CL,K,KA,KAL,BLC,LU,NE,ME)
  123 ITOP=0
  1CC RETURN
      END
      SUBROUTINE SILITA (S,ALPHA,NE,ME,D,I)
      DIMENSICN S(32,34),D(32,34)
      NEH=NE-1
      MEH=ME-1
      BET=(1.-ALPHA)/4.
      DO 123 N=2,NEH
      DO 123 M=2,MEH
      IF(I-1)1C1,1C2,1C2
  101 IF(D(N,M))124,124,103
  102 IF(S(N,M))124,124,103
  103 IF(1-N)1C5,1C7,105
  105 VALP=S(N-1,M)
      GC TC 1C8
  107 VAUP=S(N,M)
  108 IF(NE-N)110,112,110
  11C VALC=S(N+1,M)
      GO TC 113
  112 VALC=S(N,M)
  113 IF(1-M)115,116,115
  115 VALE=S(N,M-1)
      GO TC 117
  116 VALE=S(N,M)
  117 IF(ME-M)119,121,119
  119 VARI=S(N,M+1)
      GO TC 122
  121 VARI=S(N,M)
  122 S(N,M)=ALPHA*S(N,M)+BET*(VALP+VALC+VALE+VARI)
      GO TC 123
  124 S(N,M)=C.
  123 CONTINUE
      RETURN
      END
      SUBROUTINE PRIMFS(S,T,LI,VI,CL,K,KA,KAL,BLC,LU,NE,ME)
      DIMENSICN S(32,34),IS(32,34)
C     IF(LU-1)202,4C1,420
      IF(LU-1)270,4C1,420
  202 PRINT 2C1,K,T,UI,VI,DL,KA,KAL
  201 FORMAT(1H1,5X,18HOIL CCNCENTRATIONS,2X,2HK=,I5,3X,2HT=,F6.C,3),3HU
```

```
     2I=,F6.4,3X,3HVI=,F6.4,3X,3HDL=,F6.0,3X,3HKA=,I3,3X,4HKAL=,I3)
  270 PRINT 271,K,DL
  271 FORMAT(1H1,5X,18HOIL CONCENTRATIONS,2X,2HK=,I5,3X,3HDL=,F6.0)
C     PRINT 203
      PRINT 504
  203 FORMAT(,5X,12HCONC. IN PPB/)
  504 FORMAT(5X,19HPRINT FACTOR = 0.1,4X,7HPPB/10./)
CXXXXXXXXXXXXXXXXXXXXXXX
      GO TO 212
  401 PRINT 402
  402 FORMAT(1H1,5X,16HDEPTHS IN METERS,)
      GO TO 320
  420 IF(LU-3)421,425,430
  421 PRINT 422,K
  422 FORMAT(1H1,5X,34HDECAY OF OIL ON THE BOTTOM, PERIOD,I5)
      GO TO 212
  425 PRINT 426,K
  426 FORMAT(1H1,5X,41HNEW OIL ON BOTTOM BEFORE ADVECTION,PERIOD,I5)
      GO TO 212
  430 IF(KAL-1)2022,431,431
  431 PRINT 432,K
  432 FORMAT(1H1,5X,34HADVECTED OIL ON THE BOTTOM, PERIOD,I5)
      PRINT 272,UI,VI
  272 FORMAT(5X,3HUI=,F5.2,3X,3HVI=,F5.2)
      GO TO 212
CXXXXXXXXXXXXXXXXXXXXXXX
      IF(KA-1)210,210,215
  210 PRINT 211
  211 FORMAT(5X,12HLAMINAR,FLOW/)
      GO TO 212
  215 PRINT 216
  216 FORMAT(5X,26HLAYER THICKNESS INCREASING/)
CXXXXXXXXXXXXXXXXXXXXXXX
C 212 IF(KAL-1)230,220,220
  212 IF(KAL-1)530,220,220
  220 IF(BLO-1)250,250,252
  250 DO 225 N=1,NE
      DO 225 M=1,ME
      IS(N,M)=S(N,M)*1000.
  225 CONTINUE
      PRINT 260
  260 FORMAT(5X,16HPRINT FACTOR = 1/)
      GO TO 240
  252 DO 253 N=1,NE
      DO 253 M=1,ME
      IS(N,M)=S(N,M)*100.
  253 CONTINUE
      PRINT 261
  261 FORMAT(5X,18HPRINT FACTOR = 0.1,4X,7HPPB/10./)
      GO TO 240
  320 DO 321 N=1,NE
      DO 321 M=1,ME
      IS(N,M)=S(N,M)
  321 CONTINUE
      GO TO 240
  230 DO 205 N=1,NE
      DO 205 M=1,ME
      IS(N,M)=S(N,M)*1000.
  205 CONTINUE
  530 DO 531 N=1,NE
```

```
      DO 531 M=1,ME
      IS(N,M)=S(N,M)*100.
  531 CONTINUE
  240 IF(ME-40)610,640,640
  640 PRINT 206,(N,N=1,40)
  206 FORMAT(/4X,40I3)
      PRINT 207,(N,(IS(N,M),M=1,40),N=1,50)
  207 FORMAT(/1X,I2,1X,40I3)
C     XXXXXXXXXXXXXXXXXXXX
      GO TO 300
C     XXXXXXXXXXXXXXXXXXXX
      PRINT 208,(N,N=41,50)
  208 FORMAT(1h1,//4X,10I3)
      PRINT 209,(N,(IS(N,M),M=41,50),N=1,50)
  209 FORMAT(/1X,I2,1X,10I3)
C     XXXXXX
      GO TO 300
  610 PRINT 611,(N,N=1,34)
  611 FORMAT(/4X,34I3)
      PRINT 612,(N,(IS(N,M),M=1,34),N=1,32)
  612 FORMAT(/1X,I2,1X,34I3)
  300 RETURN
      END
```

```
$RESET FREE
$SET OWN OWNARRAYS
FILE  1(KIND=DISK,TITLE="CCSEAP/OILCON/LOC1",FILETYPE=7)
FILE  2(KIND=DISK,TITLE="CCSEAP/OILCON/LOC2",FILETYPE=7)
FILE  3(KIND=DISK,TITLE="OCSEAP/OILCON/LOC3",FILETYPE=7)
FILE  6(KIND=PRINTER)
FILE  8(KIND=DISK,NEWFILE=.TRUE.)
FILE  9(KIND=DISK,NEWFILE=.TRUE.)
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C     THIS VERSION HAS MIGRATIONS (OVER A 64X68 GRID)
C       BUT ONLY TWO SPECIES:
C         SPECIES 1 (JUVENILE HERRING) AND
C         SPECIES 13 (ADULT CRABS)
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      COMMON/ELK1/NE,ME,K,LL
      COMMON/ELKBIO/LOC,ACTBIO(2)
      COMMON/INPBIO/BIOLC(2)
      COMMON/ELKOIL/OILCON(2,32,34)
      COMMON/ELKNEW/NEWOIL(2,32,34)
      COMMON/OIL/WSF(32,34),TARS(32,34)
      DIMENSION ISL(32,34),D(32,34),TE(4),S7(32,34),S8(32,34),
     &IS(32,34)
C
C    SET MIGRATION PARAMETERS
C
      RP=.95; NE=2; ANG=45; VEL=10.
C
C    DATA STATEMENT FOR SUBROUTINE FEDOIL. IFEDOL=0 FOR NO PRINTING OF
C    OUTPUT; IFEDOL=1 FOR PRINTING OF SUMMARY TABLE ONLY; IFEDOL=2 FOR
C    PRINTING OF CONCENTRATIONS AT EACH GRID POINT ONLY; IFEDOL=3 FOR
C    PRINTING OF BOTH.
C
      DATA IFEDOL/0/
C
      REAL NEWOIL
      NE=32;ME=34;K=8;LL=1;LLMAX=50;LOC=2
C
      DO 25 J=1,2
      ACTBIO(J)=BIOLC(J)
   25 CONTINUE
C
   30 IF(LL.GT.10) GO TO 35
      READ(LOC,/)NHRS
      READ(LOC,/)((WSF(N,M),M=1,ME),N=1,NE)
      GO TO 40
C
   35 DO 38 N=1,NE
      DO 38 M=1,ME
      WSF(N,M)=WSF(N,M)*EXP(-0.3)
      S7(N,M)=WSF(N,M)
   38 CONTINUE
      GO TO 42
C
C
```

```
C   CHANGE OIL CONCENTRATIONS FROM PPB TO PPM
C
C
   40 CONTINUE
      DO 32 N=1,NE
      DO 32 M=1,ME
      WSF(N,M)=WSF(N,M)/1000.
   32 S7(N,M)=WSF(N,M)
C
C   COMPUTE OIL ON THE BOTTOM
C
   42 CONTINUE
      BLO=1.
C     BLO=2 CONTINUOUS SOURCE, BLO=1 INSTANTANEOUS SOURCE.
      DL=2000.
C     TAT TIME STEP IN HOURS
      TAT=24.
      TD=20.
      T=LL*1440.
      KAL=0
C     KAL=0 - NO OIL MOVEMENT ON THE BOTTOM, 1 OIL ADVECTED ON BOTTOM
C     KU - CURRENT INDEX, SEE CURCIL; KA - TURBULENCE INDEX(NOT USED);
C     LU - PRINT SCALING INDEX
      KU=3
      KA=1
      LU=0
      UI=0.
      VI=0.
      CALL OILECT(S7,LL,TD,DL,D,S8,T8,BLO,UI,VI,KU,KAL,T,KA,TAT)
      IF(LL.GT.1) GO TO 55
C
      DO 54 N=1,NE
      DO 54 M=1,ME
      ISL(N,M)=0
      IF(D(N,M).GT.0) ISL(N,M)=1
   54 CONTINUE
C
   55 UI=60.
      VI=8.
      IF(KAL.NE.1)GO TO 31
      CALL CURCIL(S8,KU,UI,VI,DL,LL,BLO,T,KAL)
   31 DO 33 N=1,NE
      DO 33 M=1,ME
   33 TARS(N,M)=S8(N,M)
      CALL FEICIL(IFECOL)
      CALL MIGR(RF,KE,ANG,VEL)
  778 LL=LL+1
      IF(LL.LE.LLMAX)GO TO 30
      CLOSE(8,DISP=KEEP)
      CLOSE(9,DISP=KEEP)
C
 5999 STOP
      END
      BLOCK DATA
      COMMON/INPBIO/BICLC(2)
      COMMON/VALUES/FCOCMP(2),TJ(2),K2(2)
      REAL K2
      DATA BICLC/330.,1472./
      DATA FCICMP/1.00,.10/
      DATA TJ/.016,.006/
```

```
      DATA K2/.198040,.222823/
      END
      SUBROUTINE MIGR(RP,KE,ANG,VEL)
C
CXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
C
C                    MIGRATION SUBROUTINE
C
C   SET UP FOR MIGRATIONS OF 45,135,225, OF 315 DEGREES
C             (0=TOWARDS EAST;  90=TOWARDS NORTH)
C
C         USES TWICE NORMAL GRID SIZE   RP=MIGRATION FRACTION
C
CXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
      DIMENSION ISPC(2),S1(64,68),S2(64,68),S3(64,68),DAT(2,64,68),IT(4)
      COMMON/OIL/WSF(32,34),TARS(32,34)
      COMMON/ELKOIL/OILCON(2,32,34)
      COMMON/ELKNEW/NEWOIL(2,32,34)
      COMMON/ELK1/NE,ME,K,LL
      COMMON/VALUES/FCOCMP(2),TJ(2),K2(2)
      DATA ISPC/1,13/
      REAL NEWOIL
      RAD=0.017453 3
      A=ANG
      IF(KE.EQ.1)A=ANG+180.
      NNE=64;MME=68
      IF(A.EQ.45)GO TO 1
      IF(A.EQ.135)GO TO 2
      IF(A.EQ.225)GO TO 3
      M1=1
      N1=1
      GO TO 4
    1 M1=1
      N1=33
      GO TO 4
    2 M1=35
      N1=33
      GO TO 4
    3 M1=35
      N1=1
    4 MM=(M1-1)+34
      NN=(N1-1)+32
      MO=0;NO=0
      IF(M1.GT.1)MO=34
      IF(N1.GT.1)NO=32
      A=A*RAD
      U=COS(A)*VEL
      V=SIN(A)*VEL
C
C
      DO 999 J=1,2
      RATEXP=EXP(-K2(J))
      DO 801 N=N1,NN
      NX=N-NO
      DO 801 M=M1,MM
      MX=M-MO
  801 DAT(J,N,M)=NEWOIL(J,NX,MX)
      DO 5 N=1,NNE
      DO 5 M=1,MME
    5 S1(N,M)=DAT(J,N,M)
```

```
      DO 65 N=1,NNE
      DO 65 M=1,MME
      IF(S1(N,M).GT.0.)GO TO 64
      S1(N,M)=0.
      S2(N,M)=0.
      S3(N,M)=0.
      GO TO 65
   64 S2(N,M)=S1(N,M)*RP
      S3(N,M)=S1(N,M)-S2(N,M)
   65 CONTINUE
      CALL RANNAK (J,L,V,S2)
C     S2 - SPECIES (PORTION WHICH MIGRATED)
C     ISL-SEA-LAND TABLE
C
C     ADDING NONMIGRATING PORTION
      SUMNEW=0.
      DO 63 N=1,NNE
      DO 63 M=1,MME
      S1(N,M)=S3(N,M)+S2(N,M)
   63 CONTINUE
 1200 DO 1000 I=1,4
      IT(I)=0
 1000 CONTINUE
      DO 1201 N=1,NNE
      DO 1201 M=1,MME
      IF(S1(N,M).LT.5.0)GO TO 1201
      IF(S1(N,M).GE.5.0)IT(1)=IT(1)+4
      IF(S1(N,M).GE.10.)IT(2)=IT(2)+4
      IF(S1(N,M).GE.50.)IT(3)=IT(3)+4
      IF(S1(N,M).GT.100.)IT(4)=IT(4)+4
 1201 CONTINUE
      WRITE(9,/)LL,ISPC(J)
      WRITE(9,/)(IT(I),I=1,4)
      IF(LL.NE.5.AND.LL.NE.10.AND.LL.NE.20.AND.LL.NE.30)GO TO 70
      WRITE(8,/)LL,ISPC(J)
      WRITE(8,/)((S1(N,M),M=1,MME),N=1,NNE)
   70 DO 778 N=1,NE
      NX=N+NO
      DO 778 M=1,ME
      MX=M+MO
      NEWOIL(J,N,M)=S1(NX,MX)
  778 S1(NX,M)=0.
      DO 779 N=1,NNE
      DO 779 M=1,MME
  779 DAT(J,N,M)=S1(N,M)*RATEXP
C
  999 CONTINUE
 8888 RETURN
      END
      SUBROUTINE RANNAK(J,L,V,S8)
      DIMENSION S8(64,68),ANEW(64,68),OLD(64,68)
      COMMON/OIL/WSF(32,34),TARS(32,34)
      COMMON/ELK1/NE,ME,K,LL
C     ISL- SEA-LAND TABLE
C     S8 - (SPECIES)
C     KRO - NUMBER OF MIGRATIONS PER DAY
      AL=2.0
      NNE=64;MME=68
C
C
```

```
C   U,V VELOCITY COMPONENTS
C
C   KE IS INDICATOR OF SEASON
C   KE=1 IF MIGRATION IS TO SHALLOWER WATER; KE=2 FOR MIGRATION TO DEEP
C
   20 TD=.125
      NEH=NNE-1
      MEH=MME-1
C
C   MIGRATE 8 TIMES PER DAY (TD=.125 DAYS)
C
C   SE IS MIGRATING CONTAMINATION
C
      DO 254 NRC=1,8
C
C   CALCULATE MIGRATION AT EACH GRID POINT
C
      DO 133 N=1,NNE
      DO 133 M=1,MME
      OLD(N,M)=SE(N,M)
C
C   DETERMINE GRID POINT TO GO TO
C
      IF(U)230,231,232
  230 IM=-1
      GO TO 233
  231 IM=0
      GO TO 233
  232 IM=1
  233 IF(V)234,235,236
  234 IN=1
      GO TO 237
  235 IN=0
      IF(IM.EQ.0)GO TO 133
      GO TO 237
  236 IN=-1
C
C   GX,GY ARE PTS LEAVING IN X,Y DIRECTION
C   OLD IS ORIGINAL CONTAMINATION LEFT AT GRIDPOINT N,M
C   ANEW IS FIELD OF MIGRATED CONTAMINATION
C
  237 IF(M.EQ.1 .AND. IM.GT.0)GO TO 2000
      IF(M.EQ.MME .AND. IM.LT.0)GO TO 2000
      GONX=(SE(N,M)-SE(N,M-IM))
      GO TO 2001
 2000 GONX=(SE(N,M+IM)-SE(N,M))
 2001 IF(N.EQ.NNE .AND. IN.LT.0)GO TO 2002
      IF(N.EQ.1 .AND. IN.GT.0)GO TO 2002
      GONY=(SE(N,M)-SE(N-IN,M))
      GO TO 2003
 2002 GONY=(SE(N+IN,M)-SE(N,M))
 2003 GX=GONX*ABS(U)*TD/AL
      IF(GX.LT.0.)GX=0.
      GY=GONY*ABS(V)*TD/AL
      IF(GY.LT.0.)GY=0.
      IF(OLD(N,M).LT.1.)GO TO 991
      IF(M.EQ.MME .AND. IM.GT.0)GO TO 991
      IF(M.EQ.1 .AND. IM.LT.0)GO TO 991
      ANEW(N,M+IM)=ANEW(N,M+IM)+GX
  991 IF(OLD(N,M).LT.1.)GO TO 133
```

```
      IF(N.EQ.1 .AND. IN.LT.0)GO TO 992
      IF(N.EQ.NNE .AND. IN.GT.0)GO TO 992
      ANEW(N+IN,M)=ANEW(N+IN,M)+GY
  992 OLD(N,M)=OLD(N,M)-GX-GY
      IF(OLD(N,M).LT.0.)OLD(N,M)=0.
  133 CONTINUE
  591 DO 751 M=1,MME
      DO 751 M=1,MME
      SS(N,M)=OLD(N,M)+ANEW(N,M)
      OLD(N,M)=0.
      ANEW(N,M)=0.
  751 CONTINUE
  254 CONTINUE
      RETURN
      END
      SUBROUTINE FEDOIL(IFEDOIL)
      COMMON/OIL/WSF(32,34),TARS(32,34)
      COMMON/ELKBIO/LOC,ACTBIO(2)
      COMMON/ELKOIL/OILCON(2,32,34)
      COMMON/ELKNEW/NEWOIL(2,32,34)
      COMMON/ELK1/NE,ME,K,LL
      COMMON/VALUES/FOOCMP(2),TJ(2),K2(2)
      DIMENSION TCH(2),S1(32,34)
      REAL MS,K2,NEWOIL
C
C      ART/FEDOIL13 - THIS IS THE "BCF VERSION" OF FEDOIL IN WHICH ONLY
C      K2, AND BCF ARE USED IN COMPUTING UPTAKE AND DEPURATION.
C
C      K2(J) IS THE DEPURATION RATE CONSTANT FOR SPECIES J
C
C      BCFPEL IS THE BIOCONCENTRATION FACTOR OF EACH PELAGIC SPECIES J
C
C      BCFDEM IS THE BIOCONCENTRATION FACTOR OF EACH DEMERSAL SPECIES J
C
C      FRCNAP IS THE FRACTION OF WSF THAT IS NAPHTHALENES.
C
C      FRCNAD IS THE FRACTION OF TARS THAT IS NAPHTHALENES.
C
C-----------------------------------------------------------------------
C
C     SET CONSTANTS
C
      RAD=0.01745329
      ALP=30.*RAD
      GKAP=175.*RAD
      VALCA=COS(ALP*K-GKAP)
      FRCNAP=.50
      FRCNAD=.10
      BCFPEL=170.
      BCFDEM=170.
C
C-----------------------------------------------------------------------
C
C     COMPUTE UPTAKE AND DEPURATION OF OIL CONTAMINANTS. FOR OUTPUT,
C     ALL CONCENTRATIONS ARE IN PPM AND ACTBIO IS IN MG
C-----------------------------------------------------------------------
C
      DO 99 J=1,2
C
      DO 100 I=1,9
```

```
  100 CONTINUE
C
      RATEXP=EXP(-K2(J))
      TOH(J)=TJ(J)+(0.35*TJ(J)*VALCA)
      TONS=(ACTBIC(J)*4.0)/1000.
C
      TAREA=0.
      TTONS=0.
      TCOUNT=0.
      DO 10 N=1,NE
      DO 10 M=1,ME
      VALUE=0.0
      S1(N,M)=0.0
      TAREA=TAREA+4.0
      TTONS=TTONS+TONS
      TCOUNT=TCOUNT+1.0
      IF(FODCMP(J).GT.0..AND.FODCMP(J).LT.1.0) GO TO 20
      IF(FODCMP(J).EQ.1.0) GO TO 30
      CO=TARS(N,M)*FRCNAD
      VALUE=CO*BCFDEM*2.0
      GO TO 130
   20 PEL=FODCMP(J)
      DEM=1.0-PEL
      CO1=WSF(N,M)*FRCNAP
      CO2=TARS(N,M)*FRCNAD
      VALUE1=(CO1*BCFPEL)
      VALUE2=(CO2*BCFDEM)
      VALUE=(PEL*VALUE1+DEM*VALUE2)
      GO TO 130
   30 CO=WSF(N,M)*FRCNAP
      VALUE=(CO*BCFPEL)
  130 CONTINUE
      OILCON(J,N,M)=VALUE*(1.0-RATEXP)+NEWOIL(J,N,M)*(RATEXP)
      NEWOIL(J,N,M)=OILCON(J,N,M)
      S1(N,M)=OILCON(J,N,M)
C-------------------------------------a------------------------------
C                              END SUBROUTINE
C-------------------------------------9------------------------------
C
   10 CONTINUE
   99 CONTINUE
  999 RETURN
      END
      SUBROUTINE OILBOT(S,K,TD,DL,D,AO,TB,BLO,UI,VI,KU,KAL,T,KA,TAT)
      COMMON/ELKBIO/LOC,ACTBIC(2)
      DIMENSION S(32,34),D(32,34),AO(32,34),TB(4),PLO(2),W(3)
C     D-DEPTH
c     AO-OIL ON THE BOTTOM
C     TB-BOTTOM TEMPERATURE, FOUR VALUES GIVEN
C     PLO-THERMOCLINE DEPTH, TWO VALUES
c     W-WIND SPEED, THREE VALUES
c     KT-INDEX OF TB VALUE CHOSEN FOR THE RUN
c     KP-INDEX OF PLO VALUE
C     KW-INDEX OF WIND VALUE
C     BLO=1 INSTANTANEOUS SOURCE, =2 CONTINUOUS SOURCE
c     UI-SURFACE CURRENT SPEED
C     KAL=1 COMPUTATION OF OIL MOVEMENT ON BOTTOM
C     LU=1 DEPTH DATA
c     LU=2 DECAY OF OIL ON THE BOTTOM
C     LU=3 OIL ON THE BOTTOM BEFORE ADVECTION
```

```
C       LU=4 OIL ON THE BOTTOM,LAYER THICKNESS DECREASING, ADVECTED
C       LU=5 ADVECTED OIL ON THE BOTTOM
C       LU=6 CONTAMINATION INDEX, PELAGIC FOOD
C       LU=7 CONTAMINATION INDEX, DEMERSAL FOOD
        NE=32
        ME=34
        MO=10
C       MO IS THE M LOCATION OF BLOWOUT
C       SIMULATION OF DEPTH,
C       KB-AREA NUMBER FOR TANKER ACCIDENT, 4 TO 6
   16   KB=LOC+2
        IF(KB-5)305,330,360
  305   DO 319 N=1,NE
        DO 319 M=1,ME
        SDS=M
        IF(N-17)306,306,307
  306   D(N,M)=70.-0.35*SDS
        GO TO 319
  307   IF(N-26)308,308,311
  308   IF(M-20)309,309,310
  309   D(N,M)=62.-1.0*SDS
        GO TO 319
  310   D(N,M)=62.-1.5*SDS
        GO TO 319
  311   IF(M-20)312,312,313
  312   D(N,M)=54.-1.2*SDS
        GO TO 319
  313   D(N,M)=54.-1.4*SDS
  319   CONTINUE
        ALPHA=0.9
        CALL SILITA(D,ALPHA,NE,ME,S,1)
        GO TO 10
CXXXXXXXXXXXXXXXX
  330   DO 359 N=1,NE
        DO 359 M=1,ME
        SDS=M
        IF(N-22)331,331,332
  331   D(N,M)=50.-1.0*SDS
        GO TO 359
  332   IF(M-25)333,333,334
  333   D(N,M)=45.-1.6*SDS
        GO TO 359
  334   D(N,M)=0.
  359   CONTINUE
        ALPHA=0.9
        CALL SILITA(D,ALPHA,NE,ME,S,1)
        GO TO 10
CXXXXXXXXXXXXXXXX
  360   DO 379 N=1,NE
        DO 379 M=1,ME
        SDS=M
        IF(N-12)361,361,362
  361   D(N,M)=38.
        GO TO 379
  362   D(N,M)=45.
  379   CONTINUE
        ALPHA=0.9
        CALL SILITA(D,ALPHA,NE,ME,S,1)
CXXXXXXXXXXXXXXXXXXXX
   10   LU=1
```

```
      IF(K-1)17,17,20
      IF(K-1)5,9,20
    9 CALL PRIMFS(D,T,UI,VI,CL,K,KA,KAL,BLO,LU,NE,ME)
CXXXXXXXXXXXXXXXXXXXXX
   17 DO 18 N=1,NE
      DO 18 M=1,ME
      AO(N,M)=0.
   18 CONTINUE
C     INPUT PARAMETERS
   20 TB(1)=1.
      TB(2)=4.
      TB(3)=8.
      TB(4)=12.
      PLD(1)=20.
      PLD(2)=40.
      W(1)=5.
      W(2)=10.
      W(3)=15.
C     PP - RELATIVE CONC. OF PLANKTON
C     R - INDEX OF SUSPENDED MATTER
C     BB - BOTTOM TYPE INDEX
      PP=1.5
      R=40.
      BB=0.8
C     SETTING OF INDICES FOR INPUT PARAMETERS
      KT=3
      KP=1
      KW=2
CXXXXXXXXXXXXXXXXXXXXX
C     DECAY OF OIL ON THE BOTTOM
      IF(K-2)30,25,25
   25 DO 29 N=1,NE
      DO 29 M=1,ME
      IF(D(N,M))29,29,290
  290 IF(AO(N,M))29,29,26
   26 TFA=(TB(KT)**2.7)*0.0001
      DFA=0.15/SQRT(D(N,M))
      EFA=-(TFA+DFA)
      AO(N,M)=AO(N,M)*EXP(EFA)
      IF(TAT-12.)29,29,27
   27 AO(N,M)=AO(N,M)*EXP(EFA)
   29 CONTINUE
CXXXXXXXXXXXXXXXXXXXXXX
      LU=2
C     CALL PRIMFS(AO,T,UI,VI,CL,K,KA,KAL,BLO,LU,NE,ME)
CXXXXXXXXXXXXXXXXXXXXXXX
   30 IF(BLO-1)31,31,51
C     INSTANTANEOUS SOURCE (TANKER ACCIDENT)
   31 DO 45 N=1,NE
      DO 45 M=1,ME
      IF(D(N,M))45,45,291
  291 IF(PLD(KP)-D(N,M))40,33,33
C      NO PYCNOCLINE
   33 SK=K
   35 STK=SK/(3.+0.2*SK)
   56 BCF=0.0015
      CCF=0.15
      RR=(R+0.2*D(N,M))/SQRT(D(N,M))
      FS=(BCF*W(KW)+CCF/(D(N,M)**0.7))*STK
      AO(N,M)=AO(N,M)+S(N,M)*FS*PP*RR*BB
```

```
      IF(K-1)45,45,131
  131 IF(TAT-12.)45,45,37
   37 AO(N,M)=AO(N,M)+S(N,M)*FS*PP*RR*BB
      GO TO 45
C     THERMOCLINE PRESENT
   40 IF(K-1)45,45,38
   38 SK=K
      TDK=SK/(3.+0.5*SK)
      BCF=0.001
      CCF=0.20
      RR=(R+0.2*D(N,M))/SQRT(C(N,M))
      FDD=(BCF*W(KW)+CCF/(D(N,M)**0.7))*TDK
      AO(N,M)=AO(N,M)+S(N,M)*FDD*PP*RR*BB
      IF(K-1)45,45,132
  132 IF(TAT-12.)45,45,44
   44 AO(N,M)=AO(N,M)+S(N,M)*FDD*PP*RR*BB
   45 CONTINUE
      GO TO 70
C     CONTINUOUS SOURCE (BLOWOUT)
   51 DO 65 N=1,NE
      DO 65 M=1,ME
      IF(D(N,M))65,65,292
  292 DIS=((M-MO)*0.001*DL)
      IF(DIS)53,53,54
   53 DIS=0.001
   54 APD=2.5
C     NO COMPUTATION IN IMMEDIATE AREA OF BLOWOUT
C     I.E. 2.5MM FROM THE SOURCE
      IF(DIS-APD)65,59,59
   59 IF(PLD(MF)-D(N,M))60,55,55
C     NO PYCNOCLINE
   55 SK=K
   57 STK=SK/(3.+0.2*SK)
   58 BWF=0.0016
      CDF=0.15
      RR=(R+0.2*D(N,M))/SQRT(C(N,M))
      DIFAC=(DIS+4.)/(20.+0.1*DIS)
      FS=(BWF*W(KW)+CDF/(D(N,M)**0.7))*STK*(DIFAC)
      AO(N,M)=AO(N,M)+S(N,M)*FS*PP*RR*BB
      IF(K-1)65,65,69
   69 IF(TAT-12.)65,65,71
   71 AO(N,M)=AO(N,M)+S(N,M)*FS*PP*RR*BB
      GO TO 65
C     COMPUTATION WITH THERMOCLINE PRESENT
   60 APD=2.5
      IF(DIS-APD)65,61,61
   61 SK=K
   62 STK=SK/(3.+0.5*SK)
   64 BWF=0.001
      CDF=0.20
      DDP=C(N,M)**0.74
      RR=(R+0.2*D(N,M))/SQRT(C(N,M))
      DIFAC=(DIS+4.)/(20.+0.1*DIS)
      FS=(BWF*W(KW)+CDF/DDP)*STK*(DIFAC)
      AO(N,M)=AO(N,M)+S(N,M)*FS*PP*RR*BB
      IF(K-1)65,65,66
   66 IF(TAT-12.)65,65,67
   67 AO(N,M)=AO(N,M)+S(N,M)*FS*PP*RR*BB
   65 CONTINUE
C XXXXXXXXXXXXXXXXXXXX
```

```
   7C ALPHA=0.78
      CALL SILITA(AC,ALPHA,NE,ME,C,C)
CXXXXXXXXXXXXXXXXXXXXXXXXXX
      LU=3
C     CALL PRIMFS(AC,T,UI,VI,CL,K,KA,KAL,ELO,LU,NE,ME)
CXXXXXXXXXXXXXXXXXXXXXXXXXX
  100 RETURN
      END
      SUBROUTINE CURDIL(S,KU,UI,VI,CL,K,BLO,T,KAL)
      DIMENSION S(32,34),PF(32,34),D(32,34)
CXXXXXXXXXXXXXXXXXXXX
C     INDICES
C     KG-GRID SIZE 1-2KM;2-4KM
C     KT-TIME STEP 1-20MIN, 2-40MIN.
C     KF-FLUCTUATION PARAMETER (FAF);PERIOD 15 MIN,KF=1,FAF=0.4
C        30 MIN,KF=2,FA=0.2
C     KA-LAMINAR FLOW OR INCREASING LAYER  1-LAMINAR; 2-INCREASING LAYER
C     KU-UNIDIRECTIONAL                 CURRENT 1-UNIDIRECTIONAL,U-DIRECTION
C        2-UNIDIRECTIONAL V-DIRECTION, 3-UNIDIRECTIONAL AT 45 DEG. ANGEL
C     KR-UNIDIRECTIONAL OR ROTATING, 1-UNIDIRECTIONAL, 2-ROTATING
C     KS-SPEED COUNTER FOR 4 DIFERENT SPEEDS
C     CURRENT SPEED IN, M/SEC
CXXXXXXXXXXXXXXXXXXX
C     THIS SUBROUTINE HAS BEEN USED FOR COMPUTATION OF
C     DISTRIBUTION OF SMELL FROM BAITS
C     XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
      KG=1
      KT=1
      KF=1
      KA=1
      KR=1
CXXXXXXXXXXXXXXXXXX
      NE=32
      NEH=NE-1
      ME=34
      MEH=ME-1
      IF(KG-1)1,1,2
    1 DL=2000.
      GO TO 3
    2 DL=4000.
    3 IF(KT-1)4,4,5
    4 TD=20.
C     IAC=3
C     IPR=36
      IAC=9
      IPR=3*24
      GO TO 6
    5 TD=40.
      IAC=2
      IPR=18
    6 IF(KF-1)7,7,8
    7 FAF=0.4
      GO TO 9
    8 FAF=0.2
    9 CON=0.0174533
      ALPHA=0.82
      ALP=FAF*CON
      TCAP=45.*CON
      SO=100.
CXXXXXXXXXXXXXXXXX
```

```
C       ADVECTION COMPUTED FOR 24 HOURS
        TSTC=24.*60.
        TI=0.
C       TF=10080.+TC
CXXXXXXXXXXXXXXXXXX
        KS=1
        KKK=0
        TURC=0.02
C       XXXXXX
C       CURRENT SPEED INPUT
        IF(KR-1)12,12,16
   12   IF(KU-2)13,14,15
   13   UA=0.1*UI
        VA=0.1*VI
        GO TO 18
   14   UA=0.15*UI
        VA=0.15*VI
        GO TO 18
   15   UA=0.15*UI
        VA=0.15*VI
        GO TO 18
   16   UA=0.15*UI
        VA=0.15*VI
        ADD=0.008
        ARCT=ADD*CON
        AKADI=90.*CON
        APARP=180.*CON
        DL=4000.
        TF=14400.
CXXXXXXXXXXXXXXXXXX
C       KAL=1, OIL MOVEMENT ON THE BOTTOM
        IF(KAL)18,18,519
CXXXXXXXXXXXXXXXXXX
   18   T=T+TD
        TI=T
  519   ITC=0
        ITCP=0
        TI=TI+TC
   10   ITC=ITC+1.
        ITCP=ITCP+1
   20   IF(KR-1)41,41,47
   41   IF(KU-2)42,43,44
   42   U=UI+UA*COS(ALP*TI)
        V=VI*COS(ALP*TI+TCAP)
        GO TO 49
   43   V=VI+VA*COS(ALP*TI)
        U=UI*COS(ALP*TI+TCAP)
        GO TO 49
   44   U=UI+UA*COS(ALP*TI)
        V=VI+VA*COS(ALP*TI+TCAP)
        GO TO 49
   47   U=UI*COS(ARCT*TI+AKADI)
        V=VI*COS(ARCT*TI+APARP)
   49   CONTINUE
        IF(KAL-1)253,27,27
  253   IF(BLO-1)250,250,252
C       100 UNITS OF OIL ADDED EACH TIME STEP (SO=100.)
  252   S(12,10)=S(12,10)+SO
        GO TO 27
CXXXXXXXXXXXXXXXXXXXXX
```

```
  250 IF(K-1)251,251,27
  251 S(12,10)=600.

CXXXXXXXXXXXXXXXXXXXX
   27 SUS=0.
      SUA=0.
   30 DO 50 N=2,NEH
      DO 50 M=2,MEH
      SUA=SUA+S(N,M)
      IF(U)32,31,31
   31 SH=(S(N,M)-S(N,M-1))/DL
      GO TO 33
   32 SH=(S(N,M)-S(N,M+1))/DL
   33 IF(V)34,36,36
   34 SV=(S(N,M)-S(N-1,M))/DL
      GO TO 35
   36 SV=(S(N,M)-S(N+1,M))/DL
   35 S(N,M)=S(N,M)-(TD*ABS(U)*SH)-(TD*ABS(V)*SV)
      SUS=SUS+S(N,M)
   50 CONTINUE
      IF(SUS)80,80,95
   95 IF(ITC-IAC)80,55,80
CXXXXXXXXXXXXXXXXXXXX
   55 IF(KAL-1)550,551,551
  551 ALPHA=0.78
CXXXXXXXXXXXXXXXXXXXX
  550 CALL SILITA(S,ALPHA,NE,ME,C,1)
      ITC=0
      U1=SUA/SUS
      DO 60 N=1,NE
      DO 60 M=1,ME
      S(N,M)=S(N,M)*U1
   60 CONTINUE
C     EFFECTS OF INCREASING LAYER THICKNESS,APPROXIMATE
C     FACTOR -CTR REFERRES TO KILOMETERS FROM SOURCE
C     OBS. N AND M ARE LOCATION OF SOURCE
CXXXXXXXXXXXXXXXX
C     THE FOLLOWING SECTION NOT USED IN OIL PROBLEMS
CXXXXXXXXXXXXXXXX
      CTR=0.015
      IF(KA-1)81,81,61
   61 DO 131 N=1,NE
      DO 131 M=1,ME
      PF(N,M)=S(N,M)
  131 CONTINUE
      IF(KR-1)62,62,69
   62 IF(KU-2)63,65,67
   63 DO 64 N=1,NE
      DO 64 M=1,ME
      DIS=(M-10)*0.01*DL
      IF(DIS)51,51,52
   51 RRC=1.
      GO TO 53
   52 RRC=(1.-(CTR*DIS))
   53 PF(N,M)=PF(N,M)*RRC
   64 CONTINUE
      GO TO 81
   65 DO 66 N=1,NE
      DO 66 M=1,ME
      DIS=(N-20)*0.01*DL
```

```
      IF(DIS)54,54,56
   54 RRC=1.
      GO TO 57
   56 RRC=(1.-(CTR*DIS))
   57 PF(N,M)=FF(N,M)*RRC
   66 CONTINUE
      GO TO 81
   67 DO 68 N=1,NE
      DO 68 M=1,ME
      IF(M-10)58,58,59
   58 RRC=1.
      GO TO 82
   59 IF(N-10)58,58,83
   83 DIS=SQRT((M-10)**2.+(N-10)**2.)*0.01*DL
      RRC=(1.-(CTR*DIS))
   82 PF(N,M)=FF(N,M)*RRC
   68 CONTINUE
      GO TO 81
   69 DO 84 N=1,NE
      DO 84 M=1,ME
      IF(M-10)86,86,87
   86 RRC=1.
      GO TO 88
   87 DIS=(M-10)*0.01*DL
      RRC=(1.-(0.5*CTR*DIS))
   88 PF(N,M)=FF(N,M)*RRC
      IF(N-20)89,89,91
   89 RRC=1.
      GO TO 94
   91 DIS=(N-20)*0.01*DL
      RRC=(1.-(0.5*CTR*DIS))
   94 PF(N,M)=FF(N,M)*RRC
   84 CONTINUE
   81 ITC=0.
   80 IF(ITOP-IPR)590,85,590
C     XXXXXXX))XXXXXX
  590 TI=TI+TD
      IF(TSTC-TI)100,10,10
C 590 T=T+TD
C     IF(TF-T)100,10,10
C      XXXXXXX))XXXXXX
   85 IF(KA-1)122,122,121
  121 LU=4
C     CALL PRINFS(PF,T,UI,VI,DL,K,KA,KAL,BLO,LU,NE,ME)
      DO 132 N=1,NE
      DO 132 M=1,ME
      S(N,M)=FF(N,M)
  132 CONTINUE
      GO TO 123
  122 LU=5
C     CALL PRINFS(S,T,UI,VI,DL,K,KA,KAL,BLO,LU,NE,ME)
  123 ITOP=0
  100 RETURN
      END
      SUBROUTINE SILITA (S,ALPHA,NE,ME,D,I)
      DIMENSION S(32,34),D(32,34)
      NEH=NE-1
      MEH=ME-1
      BET=(1.-ALPHA)/4.
      DO 123 N=2,NEH
```

```
      DO 123 M=2,MEM
      IF(I-1)101,102,102
  101 IF(D(N,M))124,124,103
  102 IF(S(N,M))124,124,103
  103 IF(1-N)105,107,105
  105 VAUP=S(N-1,M)
      GO TO 108
  107 VAUP=S(N,M)
  108 IF(NE-N)110,112,110
  110 VALO=S(N+1,M)
      GO TO 113
  112 VALO=S(N,M)
  113 IF(1-M)115,116,115
  115 VALE=S(N,M-1)
      GO TO 117
  116 VALE=S(N,M)
  117 IF(ME-M)119,121,119
  119 VARI=S(N,M+1)
      GO TO 122
  121 VARI=S(N,M)
  122 S(N,M)=ALPHA*S(N,M)+BET*(VAUP+VALO+VALE+VARI)
      GO TO 123
  124 S(N,M)=0.
  123 CONTINUE
      RETURN
      END
      SUBROUTINE PRIMFS(S,T,UI,VI,DL,K,KA,KAL,BLO,LU,NE,ME)
      DIMENSION S(32,34),IS(32,34)
C     IF(LU-1)202,401,420
      IF(LU-1)270,401,420
  202 PRINT 201,K,T,UI,VI,DL,KA,KAL
  201 FORMAT(1H1,5X,18HOIL CONCENTRATIONS,2X,2HK=,I5,3X,2HT=,F6.0,3X,3HU
     2I=,F6.4,3X,3HVI=,F6.4,3X,3HDL=,F6.0,3X,3HKA=,I3,3X,4HKAL=,I3)
  270 PRINT 271,K,DL
  271 FORMAT(1H1,5X,18HOIL CONCENTRATIONS,2X,2HK=,I5,3X,3HDL=,F6.0)
C     PRINT 203
      PRINT 504
  203 FORMAT(/5X,12HCONC. IN PPB/)
  504 FORMAT(5X,19HPRINT FACTOR = 0.1,4X,7HPPB/10./)
CXXXXXXXXXXXXXXXXXXXXXXXX
      GO TO 212
  401 PRINT 402
  402 FORMAT(1H1,5X,16HDEPTHS IN METERS,)
      GO TO 320
  420 IF(LU-3)421,425,430
  421 PRINT 422,K
  422 FORMAT(1H1,5X,34HDECAY OF OIL ON THE BOTTOM, PERIOD,I5)
      GO TO 212
  425 PRINT 426,K
  426 FORMAT(1H1,5X,41HNEW OIL ON BOTTOM BEFORE ADVECTION,PERIOD,I5)
      GO TO 212
  430 IF(KAL-1)202,431,431
  431 PRINT 432,K
  432 FORMAT(1H1,5X,34HADVECTED OIL ON THE BOTTOM, PERIOD,I5)
      PRINT 272,UI,VI
  272 FORMAT(5X,3HUI=,F5.2,3X,3HVI=,F5.2)
      GO TO 212
CXXXXXXXXXXXXXXXXXXXXXXXX
      IF(KA-1)210,210,215
  210 PRINT 211
```

```
  211 FORMAT(5),12HLAMINAR,FLOW/)
      GO TO 212
  215 PRINT 216
  216 FORMAT(5),26HLAYER THICKNESS INCREASING/)
C)XXX)XXXXXXXX)XXX XXXX)XXX
C 212 IF(KAL-1)230,220,220
  212 IF(KAL-1)530,220,220
  220 IF(BLO-1)250,250,252
  250 DO 225 N=1,NE
      DO 225 M=1,ME
      IS(N,M)=S(N,M)*1000.
  225 CONTINUE
      PRINT 260
  260 FORMAT(5),16HPRINT FACTOR = 1/)
      GO TO 240
  252 DO 253 N=1,NE
      DO 253 M=1,ME
      IS(N,M)=S(N,M)*100.
  253 CONTINUE
      PRINT 261
  261 FORMAT(5),18HPRINT FACTOR = 0.1,4X,7HPPB/10./)
      GO TO 240
  320 DO 321 N=1,NE
      DO 321 M=1,ME
      IS(N,M)=S(N,M)
  321 CONTINUE
      GO TO 240
  230 DO 205 N=1,NE
      DO 205 M=1,ME
      IS(N,M)=S(N,M)*1000.
  205 CONTINUE
  530 DO 531 N=1,NE
      DO 531 M=1,ME
      IS(N,M)=S(N,M)*100.
  531 CONTINUE
  240 IF(ME-40)610,640,640
  640 PRINT 206,(N,N=1,40)
  206 FORMAT(/4X,40I3)
      PRINT 207,(N,(IS(N,M),M=1,40),N=1,50)
  207 FORMAT(/1X,I2,1X,40I3)
C    XXXXXXXX)XXX XXXX)XX
      GO TO 300
C    XXXXXXXX)XXX XXXX)XXX
      PRINT 208,(N,N=41,50)
  208 FORMAT(1H1,//4X,10I3)
      PRINT 209,(N,(IS(N,M),M=41,50),N=1,50)
  209 FORMAT(/1X,I2,1X,10I3)
C     XXXXXX
      GO TO 300
  610 PRINT 611,(N,N=1,34)
  611 FORMAT(/4X,34I3)
      PRINT 612,(N,(IS(N,M),M=1,34),N=1,32)
  612 FORMAT(/1X,I2,1X,34I3)
  300 RETURN
      END
```

```
$RESET FREE
      SUBROUTINE PLOTR(DX,DY,X,Y,S1)
      DIMENSION S1(4,50),X(50),Y(14), S2(50)
      DATA SIZW,SIZH/.12,.185/
C
Cxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
c
C  SUBROUTINE  TODRAW LINE PLOTS
C
C DY IS UNITS PER X INCREMENT
C  DY IS UNITS PER Y INCREMENT
C  Y IS ARRAY OF VALUES FOR Y INCREMENTS
c  X IS ARRAY OF VALUES OF X INCREMENTS
C S2 IS ARRAY OF DATA TO BE PLOTTED
C SIZW,SIZH ARE SIZES (IN INCHES) OF CHARACTER WIDTH OR HEIGHT
c
cxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
C
C   THIS PLOT USES PLOTCOMP PLOTTING PACKAGE ROUTINES
c          CAN BE ADAPTED TO CALCOMP
c            ALL UNITS ARE INCHES
C
Cxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
      CALL PLOT(6.,0.,2)
      CALL PLOT(0.,0.,3)
      CALL PLOT(C).,4.,2)
      CALL PLOT(Q. ,0. ,3)
      DO 10 I=1,50
      CALL PLOT(X(I),.1,3)
      CALL PLOT(X(I),-.1,2)
      IF(MOD(I,10).NE.0)GO TO 10
      FI=I
      XX=X(I)-SIZH
      CALL NUMBER(XX,-.25,SIZH,FI,0. ,-1)
   10 CONTINUE
      DO 20 I=1, 14
      CALL PLOT(-.1,Y(I),3)
      CALL PLOT(.1,Y(I),2)
      IF(MOD(I,5).NE.0)GO TO 20
      FI=I*100.
      FACT=3.
      IF(FI.GE.1000.)FACT=4.
      xx=.2+(FACT*SIZW)
      YY=Y(I)-.06
      CALL NUMBER(-XX,YY,SIZH,FI,0. ,-1)
   20 CONTINUE
      DO 30 I=1,50
   30 S2(I)=(S1(1,I)/100.)*DY
      CALL NEWPEN(2)
      CALL PLOT(0. ,0. ,3}
      DO 40 I=1,50
   40 CALL PLOT(X(I),S2(I),2)
      DO 50 I=1,50
   50 S2(I)=(S1(2,I)/100.)*DY
      CALL NEWPEN(1)
      CALL PLOT(0. ,0. ,3)
      DO 60 I=1,50
      CALL PLOT(X(I),S2(I),2)
```

```
      CALL SPCSYM(X(I),S2(I),SIZH,88,0.,-1)
      CALL PLOT(X(I),S2(I),3)
60    CONTINUE
      DO 70 KNT=1,2
      KK=KNT+2
      DO 71 I=1,50
71    S2(I)=(S1(KK,I)/100.)*DY
      IDSH=KNT+1
      CALL DASHPT(0.,0.,-1)
      DO 72 I=1,50
72    CALL DASHPT(X(I),S2(I),IDSH)
70    CONTINUE
      RETURN
      END
```

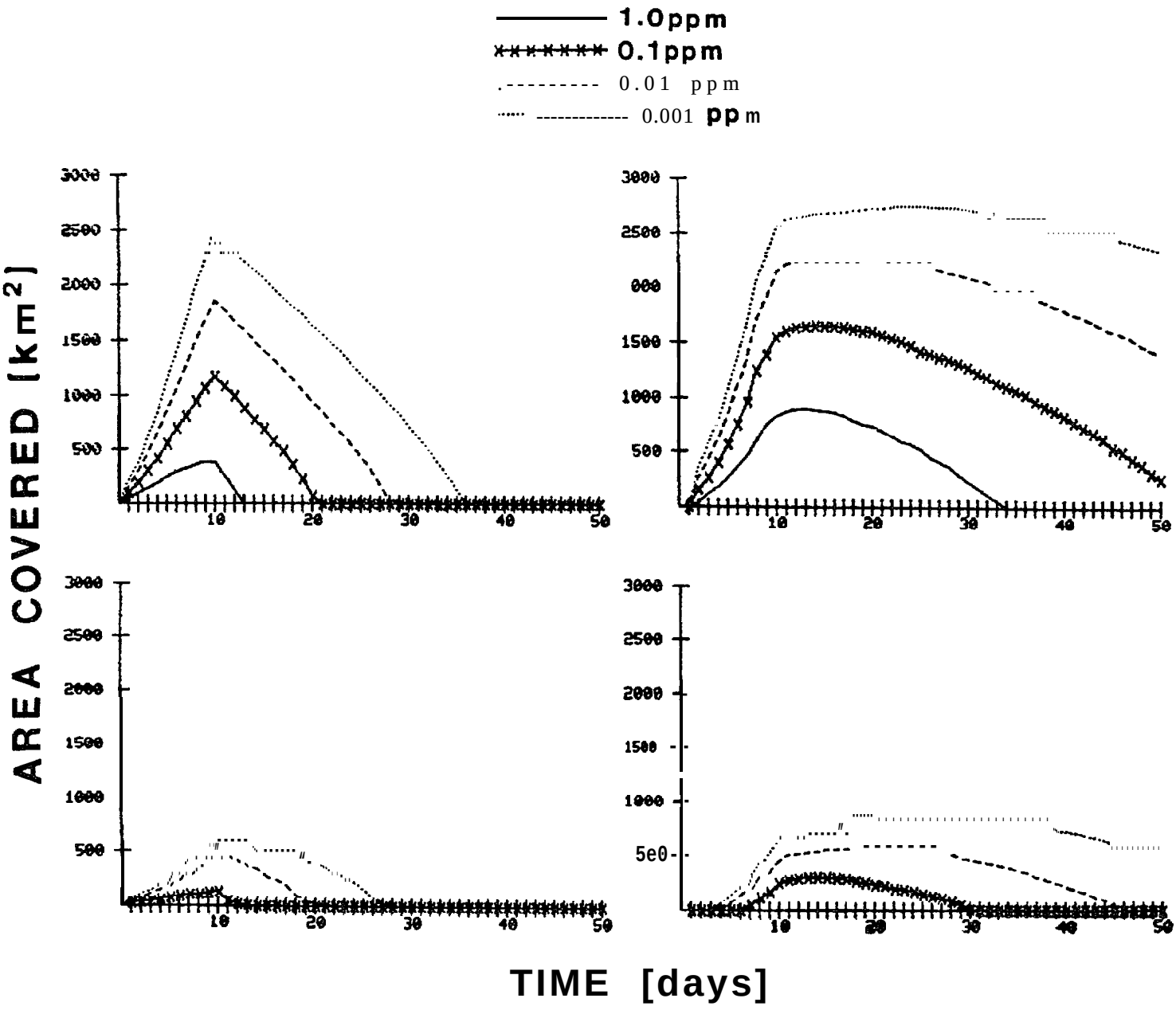

Figure 1.--Example of plot drawn using SUB ROUT INE/PLOTR. In this example, DX = (length of x-axis)/50 and DY = (length of y-axis)/30.

Laevastu, T. and H.A. Larkins.

1981. Marine Fisheries Ecosystem, Its Quantitative Evaluation and Management. Fishing News Books Ltd., Farnham, Surrey, U.K., 162 pp.

Moriarity, F.

1975. Organochlorine Insecticales: Persistent Organic Pollutants. Academ c Press, Londoı , 302 pp.

Pola, N.B., R.K. M yahara, and A.F. Gallagher, Jr.

1985. Spatial and temporal extent of hydrocarbon contamination in marine species of Bristol Bay. Natl. Mar. Fish. Serv., Northwest and Alaska Fisheries Center, Seattle, WA, Processed Rep. 85-08, 40 pp.

Swan, Nancy Pola.

1984. Biological Impact of an Oil Spill (BIOS) model documentation. Part 1: Fish migrations and exposure to contamination. Nat. Mar. Fish. Serv. , Northwest and Alaska Fisheries Center, Seattle, WA., Program Documentation No. 21, 17 pp.

Teal, John M.

1977. Food chain transfer Of hydrocarbons. In: Fate and Effects of Petroleum Hydrocarbons in Marine Ecosystem and Organisms (D.A. Wolfe, Ed.), pp 71-77.

Wilson, K.W.

1975. The laboratory estimation of the biological effects of organic pollutants. Proc. R. Sot. Lend. B., 189:459-477.