MODEL AND ASSESSMENT OF THE CONTRIBUTION OF DREDGED MATERIAL DISPOSAL TO SEA-SURFACE CONTAMINATION IN PUGET SOUND

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MODEL AND ASSESSMENT OF THE CONTRIBUTION
OF DREDGED MATERIAL DISPOSAL TO SEA-SURFACE
CONTAMINATION IN PUGET SOUND

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SUMMARY

Hydrophobic or floatable materials released to the water column during dredge disposal operations may accumulate in high concentrations on the water surface. If such surface accumulations occur, they could impact the reproduction of fish and shellfish with neustonic (floating) eggs or larvae. Also, floatable surface contaminants could deposit on nearby beaches. In order to examine the potential impacts of such processes, an interactive computer (IBM PC) model was developed. The FORTRAN model, allows input of contaminant concentrations on the dredge material, the surface area of the disposal site, the floatable fraction of the contaminated material, and the baseline concentrations of contaminants present in the sea-surface microlayer. The model then computes the resultant concentrations of each contaminant in the microlayer and the potential impact on floating fish eggs. The utility of the model would be greatly improved by empirical data, not yet available, on the vertical upward and lateral movement of contaminants during dredge material disposal.
INTRODUCTION

The sea-surface microlayer (SSM) is a vital biological habitat (Hardy 1982). Many fish and shellfish, including cod, sole, flounder, hake, anchovy, crab, and lobster have egg or larval stages that develop in this upper layer. Contaminants from atmospheric deposition, urban runoff, wastewater outfalls, industrial point sources, and ocean dumping enter coastal waters and partition. A large portion of these contaminants associate with suspended particles and deposit in the bottom sediments. However, contaminants that have low water solubility or that associate with floatable particles concentrate at the air-water interface. Consequently, high concentrations of toxic PAHs, PCBs, and metals have been found in the surface microlayer at some sites in Puget Sound (Hardy et al. 1986). At present, the spatial distribution of this SSM contamination remains unknown. Also, the relative contribution that dredged material disposal may make to SSM contamination remains to be assessed. As part of the Puget Sound Dredged Disposal Analysis program of the Seattle District Corps of Engineers, this project was undertaken to examine the potential of dredged material contaminants to accumulate in harmful concentrations at the sea surface. This study was performed to 1) develop a model that will allow estimation of the increase in, and the resulting concentration of, a series of pollutants in the SSM caused by dredging activities and 2) to estimate the resulting impact of SSM contamination in terms of its toxicity to fish eggs that float on the water surface during the spawning season.
CONCLUSIONS AND RECOMMENDATIONS

Significant SSM contamination and toxicity already exists in Elliott Bay. Dredge disposal could only significantly add to this contamination and toxicity within the disposal area if the floatable fraction exceeds $1 \times 10^{-10}$ to $10^{-9}$ and most of the surface contamination remains in the microlayer for some time. Also, additional contamination from floatables could, through horizontal transport, add to the load of contamination deposited on nearby beaches. However, several gaps in information seriously impair the usefulness of this model. These include lack of information on the floatable and bioavailable fraction of the dredged material and the "footprint" or area of the water surface likely to be impacted from the disposal.

We recommend that laboratory and field experiments be conducted to

- Determine the floatable fraction of dredged material under a variety of different mixing and disposal regimes.
- Collect and chemically analyze sea-surface microlayer contaminant concentrations during a typical dredge disposal operation.
- Evaluate the toxicity of the floatable fraction of dredged material to neustonic (floating) eggs and larvae.
MODEL

The model we have developed is written in FORTRAN to run on an IBM PC. The model is interactive and requests all the necessary input data from the user. Results are displayed and can be printed on hard copy. The data from a given simulation can be stored, if desired, on a file specified by the user. The user has the option of changing one or more of the parameters for the simulation including the mass of material dumped, the floatability fraction, the concentration of contaminants in the dredged material and that initially in the microlayer. The program then computes the final concentrations of contaminants in the SSM and the resulting expected fish egg mortality.

The structure for the model is presented in a series of flow charts (see Appendix A), and the program is listed in Appendix B. Basically, the model uses data on the characteristics of the dredged material to determine how much of the contaminated material accumulates in the SSM. Input variables are concentrations of up to 10 contaminants in the sediment, total mass of dredged material to be dumped at the site, area of the disposal site, and a measure of the fraction of the material that is floatable. Floatability is, of course, a function of the particle size and density, and is affected by the presence of organic coatings. This is probably the largest unknown input variable at present. From these parameters the total mass of each contaminant added to the microlayer is computed. Other input variables are the initial (baseline) concentration of each contaminant in the microlayer and the water surface area of the disposal site that is estimated to be affected. When the initial (baseline) concentrations of contaminants are entered as 0, the computed final concentrations and toxicity represent those resulting solely from the dredge material. The thickness of the SSM is 50 μm, a depth that other studies have shown contains the bulk of all surface contaminant enrichments. From the size of the area and the thickness of the microlayer, the volume of water affected by the dredged material is computed and the final resulting concentrations of contaminants in the SSM estimated. Based on a relationship between total organic and metal contaminant concentrations in the SSM and toxicity (Hardy et al. 1985, Table 1; Hardy et al. 1986, Tables 7 and 8 and p. 3), the resultant percent mortality to fish (sole) eggs is calculated.
ASSUMPTIONS AND LIMITATIONS

The model, in its present form, has several limitations that could be improved through future acquisition of field and laboratory data:

- The model does not include the horizontal transport of SSM contaminants (e.g., movement to the beach).
- The model does not take into account currents or the depth at the disposal site that may affect the area of the resulting "footprint" reaching the surface.
- The model calculates the initial partitioning of dredged material into the SSM, but does not follow the temporal changes in the concentrations of contaminants in the SSM. The model is conservative, because processes that affect the temporal concentration, such as losses due to evaporation, dissolution into the subsurface waters, biological and chemical degradation, and increases caused by gas generation from the sediment, are not included.
- Biological effects on the concentrations in the SSM are not considered. This includes adsorption and settling out on fecal pellets, bicturbation and feeding by organisms in the SSM. The computed toxic effects on fish larval hatch assume that the embryos are exposed to the microlayer contamination throughout their 6- to 7-day period of embryonic development. This may very well represent a realistic situation, because once trapped in an organic surface film, the embryos are likely to remain in association with the film. Also, toxicity is computed using only PAH and metal concentrations; other contaminants are not included in the model that is used to predict fish larval hatching success.
SAMPLE SCENARIOS

Four sample scenarios have been computed (see Appendix C). All use inputs of 1500 yd$^3$ of dredged material with a specific gravity of 1.350 g/mL and a radius for the disposal area of 900 ft. Typical contaminant concentrations on dredged material and baseline concentrations in the microlayer of Elliott Bay (Hardy et al. 1985, 1986) are used. The floatable fraction was varied between $1 \times 10^{-11}$ and $1 \times 10^{-6}$. The results of tests 1 to 4 suggest that significant toxicity to fish eggs from the addition of dredged material would not occur if the floatable fraction is less than $1 \times 10^{-10}$ (tests 1 and 2). Assuming no existing contamination, larval hatch is about 84%. When the mean microlayer contaminant concentrations already present in Elliott Bay are used as input variables, predicted live larval hatch is reduced to 54% and in some areas would be even lower. However, if the floatable fraction is as great as $1 \times 10^{-8}$, dredge disposal would decrease larval hatch in the disposal area to 3 to 22% (test 3). At $1 \times 10^{-6}$ floatable fraction, no larvae would survive in the disposal area (test 4).

In addition to single dredge disposal events, the model can be used to compute average enrichments over longer periods of time or over large areas (e.g., the annual 6-day average disposal contribution to an area the size of Elliott Bay).
How do the predicted microlayer concentrations resulting from dredge material disposal compare to water quality criteria? The quality criteria for metals generally range from 2 to 58 pg/L and for PCBs is 0.001 pg/L (see Table 1). U.S. Environmental Protection Agency (EPA) water quality criteria are not available for most organic compounds. Criteria for aquatic effects have not been established for PAHs, but the EPA suggests that the level where adverse effects may be expected is above 300 µg/L of total PAH. Available information suggests that exposure of eggs and larvae of fish and shellfish to concentrations of petroleum hydrocarbons greater than 100 µg/L will result in harmful effects (Table 1). When herring eggs are exposed to crude oil, droplets adhere to the surface of the eggs and, at exposure concentrations of 4 to 761 µg/L, hatched larvae showed an increased incidence of abnormalities (Pearson et al. 1985). Reduced or abnormal larval hatch of fish eggs can result from exposure to concentrations of an individual PAH compound, benzo(a)pyrene, as low as 0.1 to 0.2 µg/L (Table 1).

The sole egg bioassay, on which our model of microlayer effects is based, provides a very sensitive measure of effects. If sole eggs were exposed for 6 days to a mixture containing all the metals at their EPA water quality criteria concentrations shown in Table 1, the model would predict about a 40% decrease in live larval hatch from these metals alone. The sample dredge disposal scenarios (Appendix C), suggest that scenarios (tests) 1 and 2 would have no effect in increasing microlayer contaminant concentrations. In tests 2 and 3, microlayer concentrations of both metals, PAHs and PCBs reach concentrations that are both expected to be harmful from past studies (see Table 1) and that are also predicted to reduce live larval hatch by our own model.
TABLE 1. Effects of Contaminants on Marine Organisms

<table>
<thead>
<tr>
<th>Organism</th>
<th>Effects</th>
<th>Contaminant</th>
<th>Concentration µg/liter</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Quality criteria</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variety of marine</td>
<td>24 to 96 h</td>
<td>Pb</td>
<td>8.6</td>
</tr>
<tr>
<td>organisms</td>
<td>LC-50</td>
<td>Cu</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ag</td>
<td>2.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Zn</td>
<td>58</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cd</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PCB</td>
<td>.001</td>
</tr>
<tr>
<td><strong>Acute lethality</strong></td>
<td>24 to 48 h</td>
<td>Soluble H-carbons</td>
<td>100 to 1,000</td>
</tr>
<tr>
<td>Variety of eggs and</td>
<td>LC-50</td>
<td>#2 Fuel oil</td>
<td>100 to 4,000</td>
</tr>
<tr>
<td>larvae</td>
<td></td>
<td>or kerosene</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fresh crude</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>oil</td>
<td>100 to 100,000</td>
</tr>
<tr>
<td><strong>Sublethal effects</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turbot eggs</td>
<td>Delayed hatch &amp;</td>
<td>Petroleum</td>
<td>0 to 10,000</td>
</tr>
<tr>
<td></td>
<td>abnormal larvae</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plaice larvae</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sea urchin larvae</td>
<td>Egg fertilization</td>
<td>Extracts of</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bunker C</td>
<td></td>
</tr>
<tr>
<td>Crab larvae</td>
<td>Increase</td>
<td>011</td>
<td>10,000 to 100,000</td>
</tr>
<tr>
<td></td>
<td>respiration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trout2 eggs</td>
<td>Increased</td>
<td>Benzo(a)pyrene</td>
<td>.21</td>
</tr>
<tr>
<td></td>
<td>abnormal larvae</td>
<td></td>
<td></td>
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<tr>
<td>Sole3 eggs</td>
<td>Reduced</td>
<td>Benzo(a)pyrene</td>
<td>.1</td>
</tr>
<tr>
<td></td>
<td>larval hatch</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Herring4 larvae</td>
<td>Increased</td>
<td>Crude oil</td>
<td>4 to 761</td>
</tr>
<tr>
<td></td>
<td>incidence</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>abnormal</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

REFERENCES


APPENDIX A

FLOW CHART OF MODEL
Flow Chart: Main Program DREDGE

1. Introductory Screen
   - Print Input Data and Simulation Results
     - Yes → Set Flag for Printing
     - No → Input Data in a File
       - Yes → Call DATAREAD
         - Call DATAWRITE
       - No → Check to See if File Exists
         - Yes → Call DATAREAD
           - Call DATAWRITE
         - No → Get New Data File
           - Run Simulation
             - Modify Data or Get New Data File
               - Call SIMUL
                 - Run Another Simulation
                   - Yes → Stop
                   - No → No
Flow Chart: Subroutine DATAENTER

1. Ask for and Read Concentration of
   in Dredged Material
2. Specify Units of
   Concentration: 1. ppm  2. ppb
   - Yes: Check to be Sure That
   - No: Unit Number is 1 or 2
3. Ask for and Read Volume of
   Dredged Material (Cubic Yards)
   - Yes: Ask for and Read
   - No: Check to be Sure That
   Unit Number is 1 or 2
4. Ask for and Read Specific Gravity
   gm/ml
5. Ask for and Read Number of Contaminants
   - Yes: Begin Loop for
   - No: Return
6. Ask for and Read the Name of the Contaminant
7. Ask for and Read the Category of the
   Contaminant: 1. PAH  2. Cl, Pb, Zn, Ag or Hg  3. Other
    - Yes: Check that Category
    - No: Return
8. Ask for and Read Category
   Number is in Range 1-3
9. Ask for and Read the Category of the
   Contaminant: 1. PAH  2. Cl, Pb, Zn, Ag or Hg  3. Other
10. Ask for and Read Floatable Fraction
    - Yes: Copy into Data File for
    - No: Floatable Fraction to be
      Used for all Contaminant
11. Ask for and Read Mean, Minimum and
    Maximum Microlayer
    Concentration of Contaminant (µg/L)
12. End Loop
13. Ask for and Read Radius of Disposal
    Area (ft)
14. Return
Flow Chart: Subroutine DATAFILE

Entry

Do You Want to Store Data in a File

Yes

Request and Read File Name

Check to See if File Exists

No

Open File

Write Title
Volume, Specific Gravity of Dredged Material
Radius of Disposal Area
Number of Contaminants

For Each Contaminant:
Name, Concentration, Units, Floatable Fraction Microlayer Concentrations,
Contaminant Category

Close File

Return

Do You Want to Write Over the File?
Flow Chart: Subroutine DATAREAD

1. Entry
2. Open File
3. Read Title
4. Read Volume and Specific Gravity of Dredged Material and Radius of Disposal Area
5. Read Number of Contaminants
6. Begin Loop for # of Contaminant
   a. Read Name, Concentration, Units, Floatable Fraction, Microlayer, Concentrations and Contaminant Categories
   b. End Loop
7. Close File
8. Return
Flow Chart: Subroutine DATAWRITE

Entry

Write Title

Write Volume and Specific Gravity of Dredged Material and Radius of Disposal Area

For Each Contaminant

Write Name, Contaminant Category, Concentration and Floatable Fraction

For Each Contaminant

Write Name, Microlayer Concentrations

Check to See if Printer Flag is Set

No

Yes

Write Same as Screen Display to Printer

Return
Flow Chart: Subroutine MODDATA

Entry

Choose Section of Data to Modify
1. Title
2. Volume, Specific Gravity of Dredged Material and Radius of Disposal Area
3. Concentration Category, Floatable Fraction of Contaminant
4. Concentrations in Microlayer
5. Add New Contaminants
6. No More Changes

If Option is 6

If Option is 1

If Option is 2

If Option is 3

If Option is 4

If Option is 5

Ask for and Read Title

Return

A.6
Option is 2

A

Choose Data to be Modified
1. Volume
2. Specific Gravity
3. Radius of Disposal Area
4. No More Changes

If Option is 4

If Option is 1

If Option is 2

If Option is 3

Ask for and Read Volume

Ask for and Read Specific Gravity

Ask for and Read Radius of Disposal Area
Option is 3

Specify Number of Contaminant

Choose Section of Data to be Modified
1. Concentration
2. Units of Concentration
3. Floatable Fraction
4. Contaminant Category
5. New Contaminant Number
6. No More Changes

If Option is 6

If Option is 5

If Option is 1

Ask for and Read Concentration

If Option is 2

Ask for and Read Units of Concentration

If Option is 3

Ask for and Read Floatable Fraction

If Option is 4

Ask for and Read Contaminant Category
Option is 4

C

Specify Number of Contaminant

Specify the Microlayer Concentration to be Modified
1. Mean
2. Minimum
3. Maximum
4. New Contaminant
5. No More Changes

If Option is 5

If Option is 4

If Option is 1

Ask for and Read Mean Concentration

If Option is 2

Ask for and Read Minimum Concentration

If Option is 3

Ask for and Read Maximum Concentration

A.9
Flow Chart: Subroutine SIMUL

1. **Entry**
2. Compute Volume of Water Affected From Radius and Thickness of Microlayer (50 μm)
3. Loop for Each Contaminant
4. Compute Incremental Increase in Contaminant Concentration
5. Add Increase to Microlayer Concentrations
6. Sum Metal and PAH Concentrations in Microlayer
7. End Loop
8. Compute Percent Live Larvae
9. Print to Screen Final Microlayer Concentrations and Percent Live Larvae
10. **Check to see if Printer Flag is Set**
11. **Print Microlayer Concentrations and Percent Live Larvae**
12. **Yes**
13. **No**
14. **Return**
Ask for and Read Number of Contaminants

Begin Loop for # of Contaminants Added

Ask for and Read the Name of the Contaminant

Ask for and Read the Category of the Contaminant
1. PAH
2. Cu, Pb, Zn, Ag or Hg
3. Other

Check that Category Number is in Range 1-3

Yes

Ask for and Read Concentration of in Dredged Material

Specify Units of Concentration
1. ppm
2. ppb

No

Check to be Sure That Unit Number is 1 or 2

Yes

Ask for and Read Floatable Fraction

Copy into Data File for All Contaminants

No

Ask for and Read Mean, Minimum and Maximum Microlayer Concentration of Contaminant (µg/L)

End Loop
APPENDIX B

DREDGE PROGRAM
C PROGRAM DREDGE
C PROGRAM FOR PREDICTING THE ENRICHMENT OF CONTAMINANTS IN THE SEA-SURFACE MICROLAYER DUE TO DREDGING OR DISPOSAL OF DREDGED MATERIAL.
C CALCULATIONS BASED ON SIMPLE PARTITIONING THEORY
C PROGRAMMED BY CHRISTINA E. COWAN
C JANUARY 1986
C DIMENSIONING
$INCLUDE 'COMMON.DAT'
LOGICAL*2 TEST
TEST*=.FALSE.
C INTRODUCTORY SCREEN
WRITE(*,10)
10 FORMAT('IMPACT OF DREDGING AND DREDGED MATERIAL',//
     'DISPOSAL ON THE SEA-SURFACE MICROLAYER',//,
     'THIS PROGRAM CALCULATES THE ENRICHMENT IN THE SEA-SURFACE',
     'MICROLAYER',//, 'CONCENTRATION OF CONTAMINANTS',//,
     'THE INCREASE IN THE EXISTING MICROLAYER',//,
     'CONCENTRATION IS CALCULATED FROM THE',
     'PROPERTIES OF THE DREDGED MATERIAL',//,
     'THE ESTIMATES MADE',
     'ARE CONSERVATIVE AND REPRESENT A SINGLE POINT ESTIMATE',//,
     'OF THE CONCENTRATIONS',//).
WRITE(*,24)
WRITE(*,23)
23 FORMAT('THE EQUATION USED TO CALCULATE THE INCREASE IN',
     'THE MICROLAYER',//, 'CONCENTRATION FOR EACH CONTAMINANT IS',//,
     'I = VOLD*CON*FLOAT/VOLW',//,'WHERE I IS THE',
     'INCREASE IN THE MICROLAYER CONCENTRATION',//,
     'VOLD IS THE',
     'VOLUME OF DREDGED MATERIAL; CON IS THE CONCENTRATION',//,
     'OF CONTAMINANT IN THE DREDGED MATERIAL; FLOAT IS THE',
     'FLOATABLE',//, 'FRACTION AND VOLW IS THE VOLUME OF WATER THAT',
     'IS IMPACTED',//,'VOLW IS COMPUTED FROM THE RADIUS OF THE',
     'DISPOSAL AREA AND THE MICROLAYER',//, 'DEPTH-50UM',//)
WRITE(*,92)
READ(*,92)
WRITE(*,24)
24 FORMAT('THE PERCENT OF LIVE SAND SOLE LARVAE THAT CAN BE',
     'EXPECTED TO HATCH',//,'FROM EGGS THAT ARE EXPOSED TO THE',
     'CALCULATED MICROLAYER CONCENTRATIONS',//,'IS ESTIMATED USING',
     'THE EQUATION DEVELOPED BY HARDY ET AL. (1986)',//,
     'THIS PERCENT',
     'LIVE LARVAE IS CALCULATED FROM POLYAROMATIC HYDROCARBONS',//,
     'AND METAL CONCENTRATIONS IN THE MICROLAYER ONLY. THE',
     'EQUATION IS',//,'% LIVE = EXP(4.43 - 7.0E-6*PAH - ',
     '6.0E-3*MET)',//,'WHERE PAH IS THE TOTAL CONCENTRATION OF PAH',
     'IN UG/L AND MET IS THE TOTAL',//,
     'METAL CONCENTRATION IN MG/L',//)
C C CHOOSE TO PRINT THE INPUT DATA AND RESULTS OUT ON PRINTER
B.1
WRITE(*,92)
READ(*,*)
WRITE(*,93)
21 FORMAT(': DO YOU WANT A PRINTER LISTING OF THE INPUT DATA AND',
1 ' THE SIMULATION RESULTS? ', /, ' ANS: Y OR N (DEFAULT = Y)')
READ(*,21) ANS
IF (ANS.EQ.'Y' OR ANS.EQ.'y') GOTO 90
OPEN(5,FILE='LPT1',STATUS='NEW')
TEST4=.TRUE.
WRITE(*,11)
11 FORMAT('YOU HAVE THE OPTION OF ENTERING THE INPUT DATA ',
1 'FOR THE MODEL FOR EACH', /, ' SIMULATION AND SAVING THE DATA',
2 ' IN A ',
3 'FILE OR YOU MAY RETRIEVE A ', /, 'FILE OF INPUT DATA FOR USE IN ',
4 ' THIS SIMULATION', /)
100 WRITE(*,12)
12 FORMAT('DO YOU HAVE AN EXISTING FILE OF DATA THAT YOU ',
1 'WANT TO USE?', /, ' ANS: Y OR N (DEFAULT = Y)')
READ(*,21) ANS
21 FORMAT(A12)
IF (ANS.EQ.'N' OR ANS.EQ.'n') THEN
CALL DATAENTER
CALL DATAWRITE
CALL DATAFILE
GOTO 110
ENDIF
WRITE(*,13)
13 FORMAT('TYPE IN NAME OF FILE: ')
READ(*,14) FILEIN
14 FORMAT(A12)
INQUIRE(FILE=FILEIN,EXIST=TEST)
IF (TEST) THEN
CALL DATAREAD
CALL DATAWRITE
ELSE
WRITE(*,15)
15 FORMAT('FILE NOT FOUND: TRY AGAIN')
GOTO 100
ENDIF
110 CONTINUE
120 WRITE(*,15)
16 FORMAT('DO YOU WISH TO RUN SIMULATION WITH THIS DATA OR',
1 ' MODIFY THIS DATA BEFORE RUNNING THE SIMULATION OR', /
2 ' GET A NEW DATA FILE', /, 
3 ' 1) RUN SIMULATION ', /, ' 2) MODIFY DATA', /
4 ' 3) GET NEW DATA FILE OR START OVER', /, 
5 ' GIVE NUMBER OF OPTION ')
READ(*,17) IANS
17 FORMAT(I1)
IF(IANS.GT.3 OR IANS.LT.1) THEN
WRITE(*,18)
18 FORMAT('OPTION NUMBER NOT CORRECT TRY AGAIN')
GOTO 120
ENDIF
IF (IANS EQ 3) GOTO 70
IF (IANS EQ 2) THEN
    CALL MODDATA
    WRITE(*(,92))

92  FORMAT ('CONTINUE?')
    READ(*,*)
    ENDIF
    CALL SIMUL
    WRITE(*(,9))

19  FORMAT('DO YOU WANT TO RUN ANOTHER SIMULATION? Y OR N (DEFAULT = N)')
    READ(*,*) ANSI
    IF (ANSI EQ 'Y') THEN
        GOTO 120
    ENDIF
    IF (TEST4) THEN
        CLOSE(5)
    ENDIF
    STOP
    END

SUBROUTINE DATAENTER
C
C DATA ENTRY ROUTINE FOR THE PROGRAM
C
*INCLUDE 'COMMON DAT'
LOGICAL*2 TEST2
TEST2= TRUE
C ENTER TITLE OF THE SIMULATION
WRITE(*,99)
99  FORMAT('GIVE TITLE OF THE SIMULATION')
    READ(*,*) TITLE

25  FORMAT('ENTER MASS OF DREDGED MATERIAL')
    WRITE(*,10)
10   FORMAT('ENTER VOLUME OF DREDGED MATERIAL (CUBIC YARDS)')
    READ(*,11) Dmass

31  FORMAT('ENTER SPECIFIC GRAVITY OF THE DREDGED MATERIAL')
    WRITE(*,32)
32   FORMAT('ENTER SPECIFIC GRAVITY OF THE DREDGED MATERIAL')
1    (G/M/ML)
    READ(*,31) SPCRAV

C ENTER INFORMATION ON THE CONTAMINANTS IN THE DREDGED MATERIAL
WRITE(*,13)
13   FORMAT('SPECIFY NUMBER OF CONTAMINANTS FOR WHICH ...'
1    'MICROLEYER ENRICHMENT IS TO BE CALCULATED NUMBER IS ...')
    READ(*,14) NUMC

14   FORMAT('DO 130 NUMC=1,NUMC')
    WRITE(*,15)
15   FORMAT('ENTER THE NAME OF CONTAMINANT (MAXIMUM 10 CHARACTERS LONG)')
    READ(*,16) CNAM

16   FORMAT('ENTER THE NAME OF CONTAMINANT')
    WRITE(*,17)
17   FORMAT('ENTER THE NAME OF CONTAMINANT')

FORMAT(' INDICATE CATEGORY TO WHICH CONTAMINANT BELONGS:

1) PAH, 2) CU, PB, ZN, AG, OR HG, 3) OTHER.

GIVE NUMBER OF THE CATEGORY')
READ(*,30) CCAT(I)
IF(CCAT(I) LT 1 OR CCAT(I) GT 3) THEN
WRITE(*,51)
FORMAT(' ERROR IN CATEGORY SPECIFIED: TRY AGAIN')
GOTO 52
ENDIF
WRITE (*,39) CNAM(I)
39 FORMAT(' ENTER CONCENTRATION OF 'AS' IN DREDGED MATERIAL')
READ(*,30) CMAS8(I)
WRITE(*,40) CNAM(I)
40 FORMAT(' SPECIFY UNITS OF 'AS' CONCENTRATION: '/,
1 'SE, '1 FPM 2. 'PPM', '9 GIVE NUMBER:')
READ(*,30) UNITC(I)
33 FORMAT(I)
IF (UNITC(I) GT 2 OR UNITC(I) LT 0) THEN
WRITE(*,41)
41 FORMAT(' ERROR IN UNITS SPECIFIED: TRY AGAIN')
GOTO 211
ENDIF
IF (TEST1) THEN
WRITE(*,42) CNAM(I)
42 FORMAT(' SPECIFY FLOATABLE FRACTION OF 'AS': ')
READ(*,43) CFRAC(I)
43 FORMAT(' ENTER FLOATABLE FRACTION')
WRITE(*,44)
44 FORMAT(' IS THIS FLOATABLE FRACTION TO BE USED FOR ALL 'AS',
1 'CONTAMINANTS? ANS: Y OR N (DEFAULT N'):)
READ(*,45) ANS
45 FORMAT(A2)
IF (ANS.EQ.'Y' OR ANS.EQ.'Y') THEN
DO 214 J=1, NUCM
CFRAC(J)=CFRAC(I)
214 CONTINUE
ENDIF
WRITE(*,46) CNAM(I)
46 FORMAT(' SPECIFY BASELINE CONCENTRATION OF 'AS' IN :
1 'MICROLAYER', 'MEAN (UG/L)' )
READ(*,47) CMICRO(I)
47 FORMAT(' ENTER MEAN (UG/L)')
WRITE(*,48)
48 FORMAT(' MINIMUM (UG/L)')
READ(*,49) CLMICRO(I)
49 FORMAT(' ENTER MINIMUM (UG/L)')
WRITE(*,50)
50 FORMAT(' MAXIMUM (UG/L)')
READ(*,51) CUMICRO(I)
51 FORMAT(' ENTER MAXIMUM (UG/L)')
CONTINUE
C RADIUS OF DISPOSAL AREA
WRITE(*,52)
52 FORMAT(' SPECIFY THE RADIUS OF DISPOSAL AREA POTENTIALLY EFFECTED BY DREDGING OR DREDGED MATERIAL DISPOSAL ( Feet)')
READ (*,31) RAD
RETURN
END

*******************************************************************************
SUBROUTINE DATAREAD
C
C READS THE DATA FROM THE SPECIFIED INPUT DATA FILE
C
INCLUDE: 'COMNC.J.DAT'
OPEN (7, FILE='FILEIN')
READ (7,10) TITLE
READ (7,11) DMASS, SFGRAV, RAD
READ (7,12) NUMC
DO 400 I=1, NUMC
READ(7,13) CNAM(I), CMASS(I), UNITC(I), CFRC(I), CMICRO(I)
1 , CLMICRO(I), CUMICRO(I), CCAT(I)
400 CONTINUE
CLOSE (7)
RETURN

TO
FORMAT(Alf)
FORMAT(3(FY3))
FORMAT(12)
FORMAT(5(FY3),12)
FORMAT('DO YOU WANT TO STORE THE DATA IN A FILE SO THAT IT MAY BE USED IN FUTURE SIMULATIONS? ANS: Y OR N')
2 ' (DEFAULT: Y)'
READ (*,20) ANS
FORMAT(A2)
IF (ANS EQ 'Y' OR ANS EQ 'y') GOTO 390
READ (*,14) FILEOUT
FORMAT(A20)
INQUIRE (FILE=FILEOUT, EXIST=TEST3)
IF (TEST3) THEN
WRITE(*,61)
FORMAT: 'FILE ALREADY EXISTS \.
1 ' DO YOU WANT TO OVERWRITE THE FILES? ANS Y OR N '
2 ' (DEFAULT = N) '
READ (*,20) ANS
IF (ANS EQ 'N' OR ANS EQ 'n') GOTO 310
ENDIF
OPEN (4, FILE=FILEOUT, STATUS='NEW')

85
WRITE (6,10) TITLE
WRITE (6,11) DMASG, SFGRAV, RAD
WRITE (6,12) NUMC
DO 320 I=1, NUMC
WRITE (4,13) CNAM(I), CMASS(I), UNITC(I), CFrac(I), CMICRO(I),
1 CMICRO(I), CMICRO(I), CCAT(I)
320 CONTINUE
CLOSE(6)
RETURN
FORMAT(A80)
11 FORMAT(3(F9.3))
12 FORMAT(12)
13 FORMAT(A5,F9.3,12,E9.3,3(F9.3),12)
END

SUBROUTINE WRITE
C
C WRITE SUMMARY OF INPUT DATA TO THE SCREEN
C
9INCLUDE 'COMMON DAT'
C
CHARACTER*3 UNITP
CHARACTER*5 CCATP
WRITE(*,78) TITLE
78 FORMAT(/, 'TITLE OF THE SIMULATION IS: ', A80, //)
WRITE (*,71) DMASG, SFGRAV, RAD
71 FORMAT(' VOLUME OF DREDGED MATERIAL IS ')
1 ' F P 3,' CUBIC YARDS'
2 '/', ' SPECIFIC GRAVITY OF THE DREDGED MATERIAL IS ', F9.3,
3 ' CM/ML '/,' RADIUS OF THE DISPOSAL AREA IS ', F9.3, ' FEET',//
WRITE (*,72)
72 FORMAT(I, ' CONTAMINANT INFORMATION',//)
1 ' NAME CATEGORY CONCENTRATION FLOATABLE '
2 ' NAME CATEGORY CONCENTRATION FLOATABLE '
DO 74 I=1, NUMC
74 IF(UNITC(I).EQ.1) THEN
' UNITP = ' PPM'
ELSE
' UNITP = ' PPS'
ENDIF
IF(CCAT(I).EQ.1) THEN
' CCATP = ' FAM'
ELSEIF(CCAT(I).EQ.2) THEN
' CCATP = ' METAL'
ELSE
' CCATP = '
ENDIF
WRITE (*,73) CNAM(I), CCATP, CMASS(I), UNITP, CFrac(I)
73 FORMAT(18,A5,5X, A5,5X, F9.3,18,A5,6X,1F,F9.3)
74 CONTINUE
WRITE (*,75)
75 FORMAT(/, ' INITIAL MICROLAYER CONCENTRATIONS',//)
1 ' NAME CONCENTRATION (UG/L)',//
2 ' NAME CONCENTRATION (UG/L)',//
DO 77 I=1, NUMC
77 WRITE(*,76) CNAM(I), CMICRO(I), CMICRO(I)
76 FORMAT(/, ' INIT MICROLAYER CONCENTRATIONS',//)
1 ' NAME CONCENTRATION (UG/L)',//
2 ' NAME CONCENTRATION (UG/L)',//
C WRITE TO PRINTER
IF (TEST4) THEN
C CONTINUE
C CONTINUE
C WRITE (5, 70)
C WRITE (5, 71) DNAMA, SPGRAV, NAD
C WRITE (5, 72)
C DO 79 I = 1, NUMC
C IF (UNITC(I) .EQ. 1) THEN
C UNITP = 'FPM'
C ELSE
C UNITP = 'PPS'
C ENDIF
C IF (CCAT(I) .EQ. 1) THEN
C CCATP = 'PAH'
C ELSEIF (CCAT(I) .EQ. 2) THEN
C CCATP = 'METAL'
C ELSE
C CCATP = '
C ENDIF
C WRITE (5, 73) CNAM(I), CCATP, CMASA(I), UNITP, CFRAC(I)
C CONTINUE
C WRITE (5, 75)
C DO 85 I = 1, NUMC
C WRITE (5, 76) CNAM(I), CMNICRO(I), CLMICRO(I), CUMICRO(I)
C CONTINUE
C RETURN
C END
C******************************************************************************************
C SUBROUTINE MODDATA
C C THIS SUBROUTINE ALLOWS AN EXISTING DATA SET TO BE MODIFIED
C BEFORE CONDUCTING THE SIMULATION
C C INCLUDE 'COMMON DAT'
C LOGICAL TEST2
C TEST2 = TRUE
C 300 WRITE (*, 50)
C 50 FORMAT (' INDICATE WHICH SECTION OF DATA YOU WISH TO MODIFY ',
C 1 /, ' 1) TITLE OF THE SIMULATION' , ' 2) VOLUME AND SPECIFIC' ,
C 2 /, ' 3) GRAVITY OF DREDGED MATERIAL, RADIUS OF DISPOSAL AREA' , ' ,
C 3 /, ' 4) CONCENTRATION, CATEGORY, FLOATABLE FRACTION OF CONTAMINANTS' , ' ,
C 4 /, ' 5) ADD NEW CONTAMINANTS' , ' ,
C 5 /, ' 6) NO MORE CHANGES' , ' , GIVE NUMBER OF OPTION:' )
C READ (*, *) OPT.ON
C IF (OPTION LT 1 OR OPTION GT 6) THEN
C WRITE (*, 51)
C 51 FORMAT (' ERROR IN OPTION SPECIFIED: TRY AGAIN' )
C GOTO 300
C ENDIF
C EXIT
IF (OPTION.EQ.6) GOTO 900
C
C change the title
C
IF (OPTION.EQ.1) THEN
WRITE (*,29)
29 FORMAT (' GIVE TITLE OF THE SIMULATION')
READ (*,28) TITLE
28 FORMAT (A80)
GOTO 300
ENDIF
C
C changes in volume, specific gravity of dredged material
C or in radius of disposal area
C
IF (OPTION.EQ.2) THEN
WRITE (*,52)
52 FORMAT (' INDICATE WHICH DATA YOU WISH TO MODIFY: ',/,
1 ' 1) VOLUME OF DREDGED MATERIAL',/ ' 2) SPECIFIC GRAVITY',
2 ' OF DREDGED MATERIAL',/ ' 3) RADIUS OF DISPOSAL AREA',/,
3 ' 4) NO MORE CHANGES',/ ' GIVE NUMBER OF OPTION: ')
READ (*,99) OPTION2
IF (OPTION2.LT.1.OPTION2.GT.4) THEN
WRITE (*,51)
51 FORMAT (' ENTER VOLUME OF DREDGED MATERIAL (CUBIC YARDS): ')
READ (*,31) DMASS
GOTO 301
ENDIF
IF (OPTION2.EQ.4) GOTO 300
IF (OPTION2.EQ.1) THEN
WRITE (*,30)
30 FORMAT (' ENTER VOLUME OF DREDGED MATERIAL (CUBIC YARDS): ')
READ (*,31) DMASS
GOTO 301
ENDIF
IF (OPTION2.EQ.2) THEN
WRITE(*,32)
32 FORMAT (' ENTER SPECIFIC GRAVITY OF THE DREDGED MATERIAL',
1 '(GM/ML): ')
READ (*,31) SPGRAV
GOTO 301
ENDIF
IF (OPTION2.EQ.3) THEN
WRITE(*,49)
49 FORMAT (' SPECIFY THE RADIUS OF DISPOSAL AREA POTENTIALLY ',
1 'EFFECTED BY DREDGING OR DREDGED MATERIAL DISPOSAL (FEET): ')
READ (*,31) RAD
GOTO 301
ENDIF
ENDIF
C
C changes in concentration, category and floatable fraction of contaminants
C
IF (OPTION.EQ.3) THEN
303 WRITE (*,54)
54 FORMAT (' SPECIFY NUMBER OF THE CONTAMINANT: ')
DO 56 I=1,NUMC
WRITE(*,55) I, CNAM(I)
55 FORMAT(12,3X,AS)
56 CONTINUE
WRITE(*,57)
57 FORMAT(' GIVE CONTAMINANT NUMBER: ')
READ(*,*) ICONT
WRITE(*,53)
53 FORMAT(' INDICATE WHICH DATA YOU WANT TO MODIFY: ',/,
1 ' 1) CONCENTRATION IN DREDGED MATERIAL',/,
2 ' 2) UNITS OF CONCENTRATION',/,
3 ' 3) FLOATABLE FRACTION',/,
4 ' 4) CONTAMINANT CATEGORY',/,
4 ' 5) NEW CONTAMINANT NUMBER',/,
4 ' 6) NO MORE CHANGES',/,' GIVE NUMBER OF OPTION:
')
READ(*,*) OPTION3
IF (OPTION3.LT.1.OR.OPTION3.GT.6) THEN
WRITE(*,51)
GOTO 302
ENDIF
IF (OPTION3.EQ.1) THEN
WRITE(*,53) CNAM(ICONT)
WRITE(0,54) CNAM(ICONT)
ENDIF
IF (OPTION3.EQ.2) THEN
WRITE(*,55) CNAM(ICONT)
ENDIF
IF (OPTION3.EQ.3) THEN
WRITE(*,56) CNAM(ICONT)
ENDIF
WRITE(*,57) CNAM(ICONT)
READ(*,*) CMASS0(ICONT)
GOTO 302
ENDIF
IF (OPTION3.EQ.4) THEN
WRITE(*,58) CNAM(ICONT)
READ(*,59) CMAS0(ICONT)
ENDIF
IF (OPTION3.EQ.5) THEN
WRITE(*,59) CNAM(ICONT)
ENDIF
IF (OPTION3.EQ.6) THEN
WRITE(*,60) CNAM(ICONT)
ENDIF
READ(*,*) CMASS0(ICONT)
GOTO 302
ENDIF
GO TO 302
ENDIF

IF (OPTION.EQ.4) THEN
WRITE(*,80) CNAM(I,CONT)
FORMAT(' INDICATE CATEGORY TO WHICH CONTAMINANT BELONGS:
1 / , 1) PAH, / , 2) Cu, Pb, Zn, Ag, Hg, / , 3) OTHER ,/
2 / GIVE NUMBER OF THE CATEGORY:-')
READ(*,33) CCAT(CONT)
IF(CCAT(I).LT.1 OR CCAT(I).GT.3) THEN
WRITE(*,86)
FORMAT(' ERROR IN CATEGORY SPECIFIED: TRY AGAIN')
GO TO 302
ENDIF
GOTO 302
ENDIF

CHANGE CONCENTRATIONS IN MICROLAYER

IF (OPTION.EQ.4) THEN
WRITE(*,374)
DO 60 I=1,NUMC
WRITE(*,55) I, CNAM(I)
60 CONTINUE
WRITE(*,375)
READ(*,*) ICONT
WRITE(*,384)
FORMAT(' SPECIFY THE BASELINE MICROLAYER :
1 ' CONCENTRATION YOU WANT',
2 ' TO MODIFY:/ , 1) MEAN',/ , 2) MINIMUM',/ , 3) MAXIMUM',/
3 ' 4) NEW CONTAMINANT',/ , 5) NO MORE CHANGES',/
4 ' GIVE NUMBER OF OPTION :')
READ(*,*) OPTION4
IF (OPTION4.LT.0 OR OPTION4.GT.5) THEN
WRITE(*,31)
GOTO 306
ENDIF
IF (OPTION4.EQ.5) GOTO 300
IF (OPTION4.EQ.4) GOTO 305
IF (OPTION4.EQ.1) THEN
WRITE(*,46) CNAM(I,CONT)
40 FORMAT(' SPECIFY MEAN CONCENTRATION OF ',AS,' IN MICROLAYER')
READ(*,31) CMICRO(I,CONT)
GOTO 306
ENDIF
IF (OPTION4.EQ.2) THEN
WRITE(*,47)
FORMAT(' SPECIFY MINIMUM CONCENTRATION OF ',AS,' IN MICROLAYER')
READ(*,31) CMICRO(I,CONT)
GOTO 306
ENDIF
IF (OPTION4.EQ.3) THEN
WRITE(*,48)
FORMAT(' SPECIFY MAXIMUM CONCENTRATION OF ',AS,' IN MICROLAYER')
READ(*,31) CMICRO(I,CONT)
GOTO 306
B.10
C ADD ADDITIONAL CONTAMINANTS

C IF(OPTION.EQ.3) THEN
  NUM=NUMC
  WRITE(*,70)
  FORMAT(' SPECIFY THE NUMBER OF ADDITIONAL CONTAMINANTS ',
  1 ' TO BE ENTERED:')
  READ(*,36) NUMA
  FORMAT(12)
  DO 210 I=1,NUMA
       NUMC=NUMC+1
      WRITE(*,37) NUMC
  ENDIF
  FORMAT (' ENTER THE NAME OF CONTAMINANT ' ,12,' (MAXIMUM',
  1 , '5 CHARACTERS LONG) ')
  READ(*,38) CNAM(NUMC)
  WRITE(*,80)
  READ(*,33) CCAT(NUMC)
  IF (CCAT(NUMC).LT.1.OR.CCAT(NUMC).GT.3) THEN
    WRITE(*,86) ENDIF
    GOTO 92
  ENDIF
  WRITE(*,39) CNAM(NUMC)
  READ(*,31) CMASSE(NUMC)
  WRITE(*,40) CNAM(NUMC)
  READ(*,33) UNITC(NUMC)
  IF (UNITC(I).GT.2.OR.UNITC(I).LT.0) THEN
    WRITE(*,41) ENDIF
    GOTO 93
  ENDIF
  IF (TEST2) THEN
    WRITE(*,42) CNAM(NUMC)
    READ(*,43) CFRAC(NUMC)
    WRITE(*,44)
    READ(*,45) ANS
    IF (ANS.EQ.'Y'.OR.ANS.EQ.'y') THEN
      NUMT=NUM+NUMA
      DO 94 J=1,NUMT
           CFRAC(J)=CFRAC(I)
         CONTINUE
      TEST2=.FALSE.
    ENDIF
  ENDIF
  WRITE(*,95) CNAM(NUMC)
  FORMAT (' SPECIFY BASELINE CONCENTRATION OF ' ,A5,' IN ',
  1 'MICROLAYER',/,' MEAN (UG/L) : ')
  READ(*,31) CMICRO(NUMC)
  WRITE(*,96)
  FORMAT (' MINIMUM (UG/L) : ')
  READ(*,31) CLMICRO(NUMC)
  WRITE(*,97)
  FORMAT (' MAXIMUM (UG/L) : ')

B.11
READ (*,31) CUMICRO(NMIC)
CONTINUE
ENDIF
CALL DATAFILE
CALL DATAWRITE
RETURN
END

SUBROUTINE SIMUL

C
C THIS SUBROUTINE CALCULATES THE INCREMENTAL INCREASES IN THE
C CONCENTRATION OF THE CHEMICALS IN THE MICROLAYER AND COMPUTES
C THE MORTALITY TO FISH LARVA
C
INCLUDE 'COMMON.DAT'
DIMENSION CINC(10), CMFINAL(10), CLFINAL(10), CUFINAL(10)
C
C SPECIFY CONSTANTS FOR CALCULATIONS
C
CON1 = 6.744E-6
CON2 = 50.8E-6
CON3 = 3.141E3
CON4 = 9.799E-2
CON5 = 1.0E+3
CON6 = 1.6E+3
CMFAH=0.0
CLFAH=0.0
CUPAH=0.0
CMMET=0.0
CLMET=0.0
CUMET=0.0
C
C CALCULATE THE INCREASE IN THE MICROLAYER CONCENTRATION
C FINAL CONCENTRATION IN UC/L
C
AREA = (RAD**2) * CON3 * CON4
VOL = CON3 * AREA * CON6
DO 90 I=1,NMIC
IF(UNITC(I).EQ.1) THEN
CON5=1.0E+3
ELSE
CON5=1.0
ENDIF
CINC(I) = CMASS3(I) * SPGRAV * CFRAC(I) * DMASS * CON1 * CON5
CMFINAL(I) = CMICRO(I) + CINC(I) / VOL
CLFINAL(I) = CLMICRO(I) + CINC(I) / VOL
CUFINAL(I) = CUMICRO(I) + CINC(I) / VOL
IF(CCAT(I) EQ 1) THEN
CMFAH=CMFAH+CFINAL(I) * CON6
CLFAH=CLFAH+CLFINAL(I) * CON6
CUPH=CUFAH+CUFINAL(I) * CON6
ENDIF
IF(CCAT(I) EQ 2) THEN
CMMET=CMMET+CMFINAL(I) * CON6
CLMET=CLMET+CLFINAL(I) * CON6
CUMET=CUMET+CUFINAL(I) * CON6
ENDIF

B.12
CONTINUE
AMLARVA = EXP(4.43-0.00007*CMFAH-0.006*CMET)
ALLARVA = EXP(4.43-0.00007*CLFAH-0.006*CLMET)
AULARVA = EXP(4.43-0.00007*CFUFAH-0.006*CFUMET)
IF(AMLARVA < 0.0) AMLARVA = 0.0
IF(AMLARVA > 100.0) AMLARVA = 100.0
IF(ALLARVA < 0.0) ALLARVA = 0.0
IF(ALLARVA > 100.0) ALLARVA = 100.0
IF(AULARVA < 0.0) AULARVA = 0.0
IF(AULARVA > 100.0) AULARVA = 100.0
DAMLARVA = ABS(AMLARVA)
DALLARVA = ABS(ALLARVA)
DAULARVA = ABS(AULARVA)
WRITE(*,88) AREA
FORMAT('/,' 'AREA OF WATER IMPACTED BY THE DISPOSAL OF DREDGED
1 ' MATERIAL',/, ' IS ',1P,E9.3, ' SQUARE METERS',/)WRITE(*,91)
FORMAT('/,' 'FINAL CONTAMINANT CONCENTRATIONS IN THE
1 ' MICROLAYER'
2 '/',10X,'CONCENTRATION (UG/L)',/, ' NAME MEAN
3 ' MINIMUM MAXIMUM')
DO 95 I=1,NUMC
WRITE(*,76) CNAM(I), CMF&NAL(I), CLFINAL(I), CVFINAL(I)
96 CONTINUE
WRITE(*,93) DAMLARVA,DALLARVA,DAULARVA
FORMAT('/,'5X,'REDUCTION IN THE PERCENT OF LIVE SOLE LARVAE'
1 ' FROM A BACKGROUND',/, ' PERCENT OF 83.93% IS',
2 F9.3, ' WHEN CALCULATED FROM ',/, ' MEAN MICROLAYER ',
3 'CONCENTRATIONS', ',F9.3, ' WHEN CALCULATED FROM MINIMUM',
4 ' MICROLAYER CONCENTRATIONS; AND ',F9.3, ' WHEN ',
5 'CALCULATED FROM MAXIMUM',/,,
6 'MICROLAYER CONCENTRATIONS OF POLYAROMATIC
7 ' HYDROCARBON AND METALS',/)IF(TEST4) THEN
WRITE(*,88) AREA
WRITE(5,91)
DO 96 I=1,NUMC
WRITE(5,76) CNAM(I), CMF&NAL(I), CLFINAL(I), CVFINAL(I)
96 CONTINUE
WRITE(5,93) DAMLARVA,DALLARVA,DAULARVA
ENDIF
RETURN
END
APPENDIX C

SAMPLE DREDGE DISPOSAL SCENARIOS
TITLE OF THE SIMULATION IS: TEST

VOLUME OF DREDGED MATERIAL IS 1500.000 CUBIC YARDS
SPECIFIC GRAVITY OF THE DREDGED MATERIAL IS 1.333 GM/ML
RADIUS OF THE DISPOSAL AREA IS 90.000 FEET

CONTAMINANT INFORMATION

<table>
<thead>
<tr>
<th>NAME</th>
<th>CATEGORY</th>
<th>CONCENTRATION</th>
<th>FLOATABLE IN MATERIAL</th>
<th>FRACTION</th>
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<tr>
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<td>Metal</td>
<td>90.000 PPM</td>
<td>1.000E-11</td>
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<td>Cu</td>
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<td>PAH</td>
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</tr>
<tr>
<td>PCB</td>
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<td>500 000 PPM</td>
<td>1.000E-11</td>
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INITIAL MICROLAYER CONCENTRATIONS

<table>
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<tr>
<th>NAME</th>
<th>MEAN</th>
<th>MINIMUM</th>
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<tr>
<td>Pb</td>
<td>30.000</td>
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<tr>
<td>Cu</td>
<td>28.000</td>
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<tr>
<td>PAH</td>
<td>13.000</td>
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<td>166.000</td>
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<td>0.000</td>
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AREA OF WATER IMPACTED BY THE DISPOSAL OF DREDGED MATERIAL IS 2.364E+05 SQUARE METERS

FINAL CONTAMINANT CONCENTRATIONS IN THE MICROLAYER CONCENTRATION (UG/L)

<table>
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<th>NAME</th>
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<td>6.544E-04</td>
<td>1.500E+03</td>
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REDUCTION IN THE PERCENT OF LIVE SOLE LARVAE FROM A BACKGROUND PERCENT OF 83.93% IS 29.893 WHEN CALCULATED FROM MEAN MICROLAYER CONCENTRATIONS; .111 WHEN CALCULATED FROM MINIMUM MICROLAYER CONCENTRATIONS; AND 70.777 WHEN CALCULATED FROM MAXIMUM MICROLAYER CONCENTRATIONS OF POLYAROMATIC HYDROCARBON AND METALS
TITLE OF THE SIMULATION IS:
TEST 1

VOLUME OF DREDGED MATERIAL IS 1500.000 CUBIC YARDS
SPECIFIC GRAVITY OF THE DREDGED MATERIAL IS 1.350 GM/ML
RADIUS OF THE DISPOSAL AREA IS 900.000 FEET

CONTAMINANT INFORMATION

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<td>METAL</td>
<td>80.000 PPM</td>
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INITIAL MICROLAYER CONCENTRATIONS

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<tr>
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<td>.000</td>
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<td>.000</td>
<td>1500.000</td>
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AREA OF WATER IMPACTED BY THE DISPOSAL OF DREDGED MATERIAL IS 2.364E+05 SQUARE METERS

FINAL CONTAMINANT CONCENTRATIONS IN THE MICROLAYER

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REDUCTION : IN THE PERCENT OF LIVE SOLE LARVAE FROM A BACKGROUND PERCENT OF 83.93% IS 30.541 WHEN CALCULATED FROM MEAN MICROLAYER CONCENTRATIONS; 1.115 WHEN CALCULATED FROM MINIMUM MICROLAYER CONCENTRATIONS, AND 70.934 WHEN CALCULATED FROM MAXIMUM MICROLAYER CONCENTRATIONS OF POLYAROMATIC HYDROCARBON AND METALS.
**TITLE OF THE SIMULATION IS**
**TEST 1**

**VOLUME OF DREDGED MATERIAL IS 1500.000 CUBIC YARDS**
**SPECIFIC GRAVITY OF THE DREDGED MATERIAL IS** 1.350 GM/ML
**RADIUS OF THE DISPOSAL AREA IS 900 000 FEET**

**CONTAMINANT INFORMATION**

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<th>CONCENTRATION IN MATERIAL</th>
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**INITIAL MICROLAYER CONCENTRATIONS**

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**AREA OF WATER IMPACTED BY THE DISPOSAL OF DREDGED MATERIAL IS 2 364E-05 SQUARE METERS**

**FINAL CONTAMINANT CONCENTRATIONS IN THE MICROLAYER**

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**REDUCTION IN THE PERCENT OF LICE SOLE LARVAE FROM A BACKGROUND PERCENT OF 83 93% IS 89 75% WHEN CALCULATED FROM MEAN MICROLAYER CONCENTRATIONS, 81 74% WHEN CALCULATED FROM MINIMUM MICROLAYER CONCENTRATIONS, AND 90 48% WHEN CALCULATED FROM MAXIMUM MICROLAYER CONCENTRATIONS OF POLYAROMATIC HYDROCARBON AND METALS**
TITLE OF THE SIMULATION IS
TEST 4

VOLUME OF DREDGED MATERIAL IS 1500,000 CUBIC YARDS
SPECIFIC GRAVITY OF THE DREDGED MATERIAL IS 1.350 GM/ML
RADIUS OF THE DISPOSAL AREA IS 700,000 FEET

CONTAMINANT INFORMATION

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INITIAL MICROLAYER CONCENTRATIONS

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AREA OF WATER IMPACTED BY THE DISPOSAL OF DREDGED MATERIAL IS 2 364E+05 SQUARE METERS

FINAL CONTAMINANT CONCENTRATIONS IN THE MICROLAYER CONCENTRATION (UG/L)

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REDUCTION IN THE PERCENT OF LIVE SOLE LARVAE FROM A BACKGROUND PERCENT OF 83.9% IS 83.930 WHEN CALCULATED FROM MEAN MICROLAYER CONCENTRATIONS, 83.930 WHEN CALCULATED FROM MINIMUM MICROLAYER CONCENTRATIONS, AND 83.930 WHEN CALCULATED FROM MAXIMUM MICROLAYER CONCENTRATIONS OF POLYAROMATIC HYDROCARBON AND METALS
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