GE
159 Plastics Avenue
Pittsfield, MA 01201
USA

May 14, 2007

Susan Svirsky
U.S. Environmental Protection Agency
c/o Weston Solutions, Inc.
10 Lyman Street
Pittsfield, MA 01201

Re: GE-Pittsfield/Housatonic River Site
Rest of River (GECD850)
Corrective Measures Study Proposal – Model Code

Dear Ms. Svirsky:

As you know, the General Electric Company (GE) submitted its Corrective Measures Study (CMS) Proposal for the Rest of River to the U.S. Environmental Protection Agency (EPA) on February 26, 2007. The CMS Proposal described in general terms certain revisions to EPA's PCB fate and transport model code (EFDC) that GE proposed to make in order to facilitate more efficient use of that model to simulate sediment remedial alternatives during the CMS. Attached is a Technical Memorandum developed by Quantitative Environmental Analysis, LLC (QEA) on behalf of GE that describes those code revisions. The FORTRAN code itself has been sent to you via email, and GE will provide it to other interested parties upon request.

Please let me know if you have any questions about the enclosed Memorandum or the modified code, or if you would like to discuss any issues.

Very truly yours,

Andrew T. Silfer
Andrew T. Silfer, P.E.
GE Project Coordinator

Enclosure

cc: Dean Tagliaferro, EPA
Timothy Conway, EPA
Holly Inglis, EPA
Rose Howell, EPA*
Richard McGrath, Sleeman Hanley & DiNitto
Scott Campbell, Weston Solutions

Joel Lindsay, Weston Solutions
Edward Garland, HydroQual
Michael Palermo, Mike Palermo Consulting
Susan Steenstrup, MDEP (2 copies)
Anna Symington, MDEP*
Jane Rothchild, MDEP*
Dale Young, MA EOEA*
Susan Peterson, CDEP
Michael Carroll, GE*
Roderic McLaren, GE
Kevin Mooney, GE
Stuart Messur, ARCADIS BBL
James Rhea, QEA
Kevin Russell, QEA
James Bieke, Goodwin Procter
Samuel Gutter, Sidley Austin
Public Information Repositories
GE Internal Repository

(* cover letter only)

Quantitative Environmental Analysis, LLC

∂c/∂t

TECHNICAL MEMORANDUM

EFDC Remediation Code

May 14, 2007

Introduction

As discussed in Section 5.2.2.6 of the Corrective Measures Study (CMS) Proposal, Quantitative Environmental Analysis, LLC (QEA) on behalf of General Electric Company (GE) has made a series of additions to the EFDC model code to facilitate simulations of sediment remedial alternatives during the CMS. This memorandum has been developed to document those code changes and transmit the code to EPA for review and approval. Simulation of the various remedial alternatives described in the CMS Proposal required the development of additional "remediation" subroutines and modification of the existing EPA Housatonic River EFDC model code. This memorandum provides: (1) a summary of the approach to simulating the different sediment remedial technologies (e.g., sediment removal, capping) included in the CMS Proposal; (2) a description of the required changes or additions made to existing EFDC inputs and subroutines; and (3) a summary of new subroutines developed to simulate sediment remedial actions. (Note that GE provided additional details on proposed model inputs for evaluating sediment remedial alternatives in the Model Input Addendum, submitted on April 16, 2007.)

During code development, numerous, simplified remedial action test cases were simulated; however, due in part to the model's long run time, the code has not been fully tested for the specific remedial action scenarios described in the CMS proposal. Upon full application of the newly developed remediation subroutines, additional code modification may be necessary to address currently unforeseen problems. QEA will provide updates of the code to the Model Working Group as necessary during the CMS.

Approach to Simulation of Remedial Technologies

The remediation code has been developed to simulate two general types of remediation technologies: (1) sediment removal with subsequent replacement; and (2) capping. Additional options have been included in the code to allow the user to simulate the various sediment and bank soil remedial alternatives specified in the CMS Proposal. These include: (1) bed armoring for use during placement of an engineered cap; and (2) bank soil removal/stabilization. The subsections below describe the general approach used to simulate these remedial technologies and the options available to the user.

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Suite 300
Montvale, NJ 07645
(201) 930-9890
(201) 930-9805 *fax*

290 Elwood Davis Road
Suite 230
Liverpool, NY 13088
(315) 453-9009
(315) 453-9010 *fax*

80 Glen Street
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Glens Falls, NY 12801
(518) 792-3709
(518) 792-3719 *fax*

800 Brazos Street
Suite 308
Austin, TX 78701
(512) 707-0090
(512) 275-0915 *fax*

Removal with Replacement

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- Sediment removal is simulated by setting the sediment PCB concentrations in the bed equal to the specified post-remediation concentration associated with a given remedial technology for the user-specified depth of removal.
- Because the modeled sediment bed is represented as a number of discrete layers of varying thickness, sediment removal is simulated by rounding the specified removal depth to the nearest whole layer (i.e., if more than half of a sediment bed layer is subjected to removal, the entire layer is removed). This discretization will have minimal impact on the simulations because the layer thicknesses in the model are small (i.e., 3 to 6 inches) compared to the anticipated removal depths for the alternatives to be simulated.
- As described in the CMS Proposal, properties of the replacement backfill/cap material (i.e., bed layering, void ratios, grain size distributions, and organic carbon content) are assumed to be the same as the native sediment prior to removal. When the replacement material is an engineered cap, the user may specify the addition of an armor layer (which acts to eliminate erosion of the cap material), as described below.
- Releases of solids and PCBs to the water column during removal are simulated as a flux of solids and PCBs to the water column in a remediated grid cell. The magnitude of that release is determined by the user-specified removal depth, fraction of material released (e.g., 1% for mechanical dredging in the wet as described Section 5.2.2.4 of the CMS Proposal), and production schedule (i.e., time it takes to remediate that grid cell based on its surface area and the assumed areal production rate for the removal technology).

Capping Without Prior Removal

The remediation subroutines were developed to simulate two different types of capping without prior removal of sediment: (1) engineered capping alone; and (2) thin-layer capping. Similar to the removal module described above, both of these capping methods are treated the same in the remediation code; they are only differentiated from one another by the specified thickness of the cap material, the specified post-remediation cap PCB concentration, and the ability to specify an armor layer for engineered cap placement (described in the next section below), all of which are specified by the user as inputs to the model. Below is a summary of the methods/approach to simulating capping in the remediation code:

- Capping is simulated by addition of a new single layer of solids above the topmost native sediment layer in the model bed; the desired thickness of the cap layer is specified by the user in the input files. Adding the cap as a new bed layer (rather than the alternative approach of simulating cap placement as an instantaneous deposition of clean solids) avoids any artificial numerical mixing that may occur between the native sediment and cap material. Hence, the only mechanism to mix the native sediment with the cap material is biological mixing processes, which are already simulated by the model. Following its addition in the model, this single cap layer can then be subject to erosion or deposition processes, and the bed layers are restructured during subsequent time steps.

- As described in the CMS Proposal, the physical properties of the cap material (void ratios, grain size distributions, and organic carbon content) are assumed to be the same as the topmost native sediment layer (with the exception of an armor layer for engineered capping, as described below).
- If the number of bed layers in the model has reached the maximum number of allowed layers at the time of cap placement (i.e., KBT - KB), the bottom two layers are first combined into a single layer and the remaining layer indices are decreased by 1 to allow for additional future deposition.
- Post-remediation cap PCB concentrations can be specified by the user in the inputs as either a fraction of the native surface sediment concentration (to account for potential mixing of cap material with the underlying sediment) or as a constant PCB concentration.
- Placement of a cap assumes there is no release of native bed solids or PCBs to the water column.
- As a result of cap addition, the sediment bed elevation (i.e., sediment/water interface) is increased in the model by the same amount as the user-specified cap thickness. Results of test simulations conducted with the code have not indicated any issues with hydrodynamic model instability associated with this instantaneous change in bed elevation. However, as stated above, the specific set of conditions for the CMS Proposal alternatives has not been simulated with this code. If during such simulations model instabilities are encountered, additional future refinements of the code will be required.

Bed Armoring

Armoring of an engineered cap (when used to replace removed sediment, or when added to the bed without prior removal) is simulated in the model through the use of an additional class of non-cohesive solids (NCx). This additional solids class, the properties of which are specified by the user as inputs (Card C41 in *EFDC.INP*), should contain the same specific volume (SDEN) and specific gravity (SSG) as the other solids classes in the calibrated model; however the particle diameter (SNDDIA) for NCx should be set to a value large enough to prevent erosion of the placed material (e.g., 7 mm). Simulation of the armor layer is achieved in the model code by first aggregating the masses of all cohesive and non-cohesive solids in the topmost sediment layer after cap material placement; this resulting mass is then assigned to the NCx solids class for that same surface layer, while the masses of the other solids classes in that layer are then set to zero. The approach for cap armoring described above allows for deposition and subsequent erosion of new solids on the surface of the armor layer after placement (but no movement of the armor layer itself).

Bank Removal/Stabilization

Simulation of bank erosion in EFDC is specified using two model input files. The first file (*BEMAP.INP*) contains a time series of the total bank solids load for all eroding banks; the second (*BESER.INP*) is a "mapping" file that contains a list of grid cell IDs for all eroding banks (there are actually two grid cell IDs specified at each eroding bank location: one for the channel cell and one for the adjacent floodplain cell). For each pair of grid cells in the mapping file, a fraction is assigned that represents the percentage of the total bank erosion load that is contributed by that particular location.

Bank stabilization at a particular grid cell is simulated in the remediation code by simply removing the appropriate grid cell ID pair from the bank erosion mapping array when that cell is remediated. Following this modification, a revised list of bank erosion cells is output to a model "restart" file (*BEMAP.RESTART*) at the end of the simulation; this file is then used to replace the original mapping file (*BEMAP.INP*) for subsequent "hot starts" of the model.

Remediation Schedule

As described in the CMS Proposal, a realistic schedule of the remedial actions will be developed for the model projections that uses production rate information specific to the particular technology being used (see Table 5-2 in the CMS Proposal for proposed production rates, with additional justification provided in Section 8 of GE's May 11, 2007 CMS Proposal Supplement). The production rates, in conjunction with model grid cell surface areas, will be used to estimate a remediation start and end time (in days) for each model grid cell; these start and end times are specified by the user in the remediation schedule input file (*REMSCHEDULE.INP*). Because the EFDC model is run year-by-year in "hot start" mode, the remediation progress at the end of a given year's simulation (i.e., where the remediation has left off) is recorded in a model restart file (*REM.RESTART*).

Code Additions and Changes

QEA has developed a number of new "remediation" subroutines to facilitate simulation of the remedial technologies described above. Incorporation of these new routines into the existing EFDC model provided by EPA necessitated some changes to existing EFDC subroutines. The sections below briefly summarize: (1) the new routines developed by QEA; (2) the changes made to existing EFDC subroutines; and (3) the new input files required by the additional subroutines. A listing and brief description of key variables used in the Housatonic River sediment remediation code are provided in the Appendix to this Memorandum.

New Remediation Subroutines

- **rembedctrl.for**: Main subroutine that controls simulation of sediment remedial actions.
- **rembankero.for**: Subroutine called by *rembedctrl.for* to simulate bank removal/stabilization.
- **setlayrem.for**: Subroutine called by *rembedctrl.for* that determines and returns the deepest sediment layer that will be subjected to removal (based on the user-input removal depth).
- **remcalrls.for**: Subroutine called by *rembedctrl.for* that computes the release rate of solids and PCBs during remediation, and residual mass for PCBs in backfill or capping material.
- **remout.for**: Subroutine called by *hdmt2t.for* to write *rem.restart* file used in "hot start" simulations that include remediation.

Revised Existing EFDC Subroutines

- **input.for**: Code was added to read two additional Card Images (C96 and C97) in the main EFDC input file (*EFDC.INP*); this routine was also modified to read new input files *REMMAP.INP*, *REMSCHEDULE.INP*, and *REM.RESTART* (if "hot start" of the remediation module is utilized).
- **hdmt2t.for**: Code was added to call *remout.for*.
- **ssedtox.for**: Code was added to call *rembedctrl.for* and to simulate the release of solids and PCBs during dredging (if specified by the user).
- **setfpocb.for**: Code was modified to include one additional class of non-cohesive solids (NCx).
- **efdc.cmn**: Code was modified to include new variables used in the new sediment remediation code.
- **efdc.par**: Modified parameters to reflect inclusion of one additional class of non-cohesive solids (NCx) for simulation of armoring.

New Input Files

- **REMMAP.INP**: This input file specifies the I and J coordinates of grid cells to be remediated, and for each grid cell specifies the sediment remedial technology, depth of removal or cap thickness, the depth to be used in vertical averaging for sediment residual calculations, and flags for the options of simulating bed armoring and/or bank removal/stabilization. An excerpt from a generic example of this model input file is provided below.

```
C file REMMAP.INP - sediment remediation mapping file
C
C Define remedial technology and remedial depth for
C model cells that are subjected to remediation
C
C   IREM,JREM - CELL I,J TO BE REMEDIATED
C   REMTYPE    - REMEDIAL TECHNOLOGY DEFINED IN EFDC.INP C97
C   REMDEPTH   - DEPTH (METERS) OF REMOVAL; CAP THICKNESS (METERS)
C   RESDEPTH   - DEPTH (METERS) OF VERTICAL AVERAGING FOR RESIDUAL CALCULATION
C   REMARMOR   - OPTION FOR ARMOR LAYER ( 1; SHOULD BE USED ONLY FOR ECAP AND REMOVAL)
C   REMBANK    - OPTION FOR BANK REMOVAL/STABILIZATION ( 1)
C
C   NREM       - NUMBER OF CELLS SUBJECTED TO REMEDIATION
C      IREM       JREM    REMTYPE  REMDEPTH  RESDEPTH  REMARMOR    REMBANK
C
  [illegible]
     [illegible]
     [illegible]
     [illegible]
     [illegible]
     [illegible]
     [illegible]
     [illegible]
     [illegible]
     [illegible]
     [illegible]
     [illegible]
     . . .
```

- **REMSCHEDULE.INP**: This input file specifies the start and end times for sediment remedial actions for each model grid cell that is subject to remediation. An excerpt from a generic example of this model input file is provided below.

```
C FILE REMSCHEDULE.INP - SEDIMENT REMEDIATION TIME SERIES SCHEDULE
C    NREMBLK  : NUMBER OF REMEDIAL TIME BLOCK
C    TCREMSER : MULTIPLICATION CONVERSION FACTOR NEEDED TO CONVERT THE TIME UNITS TO SEC
C    NRMCL    : NUMBER OF CELLS WITHIN A GIVEN TIME BLOCK
C    TRMBEG   : BEGINNING TIME OF A GIVEN REMEDIAL TIME BLOCK
C    TRMEND   : END TIME OF A GIVEN REMEDIAL TIME BLOCK
C    IRMSCH:    CELL I
C    JRMSCH:    CELL J
C
C    NREMBLK    TCREMSER
C         NRMCL    TRMBEG      TRMEND
C              IRMSCH    JRMSCH
C
[illegible]   86400
     1   9497.000   9500.676
         8      303
     1   9500.676   9504.346
         8      302
     1   9504.346   9507.807
         7      302
     1   9507.807   9511.213
         6      302
     1   9511.213   9514.559
         5      302
     1   9514.5[illegible]9   9517.104
         4      302
     1   9517.104   9519.965
         5      302
   . . .
```

- **EFDC.INP**: Two additional "Card Images" (C96 and C97) have been added to this input file to control the options for sediment remediation:
  - C96 is the general control of the sediment remediation module, and is used to (1) activate the sediment remediation module; (2) specify the desired number of simulated remedial technologies (maximum = 10); and (3) specify whether a given simulation is a "cold start" or "hot start" run.
  - C97 specifies options with regard to release rates and residual concentrations for each remedial technology. There are two general types of active remediation technologies specified for the Housatonic River model: (1) removal with replacement (TECHTYPE = -1); and (2) capping (TECHTYPE = 1). A third option (TECHTYPE = 0) was included in the code to allow the user to simulate bank removal/stabilization along with no action or MNR for the sediments of a given grid cell. For each specified technology, RLSCF1 represents the user-specified fraction of solids and PCB released during remediation. RSDCF1 and RSDCF2 are coefficients used to calculate the post-remediation PCB concentration.

An example of C96 and C97 from this model input file is provided below.

```
C96 CONTROLS FOR REMEDIATION MODULE
*
*   ISREM:        1 FOR SEDIMENT REMEDIAL OPERATIONS
*   NREMTECH:   NUMBER OF AVAILABLE REMEDIAL TECHNOLOGIES (MAX 10)
*   ISCIREM:      1 TO READ REMEDIATION RESTART FILE (REM.RESTART)
*
C96 ISREM  NREMTECH  ISCIREM
      [illegible]       [illegible]         0
------------------------------------------------------------------------------------
C97 SPECIFICATION OF ATTRIBUTES FOR AVAILABLE REMEDIAL TECHNOLOGIES
*
*    REMTECH:    NAME OF REMEDIAL TECHNOLOGY
*    TECHTYPE:     -1 FOR REMOVAL WITH REPLACEMENT
*                   1 FOR CAPPING
*                   0 FOR NO ACTION
*    RLSCF1:     RELEASE RATE = NATIVE SED CONC * RLSCF1
*    RSDCF1:     RESIDUAL CONC = NATIVE SEDIMENT CONC * RSDCF1 + RSDCF2
*    RSDCF2:
*
C97 REMTECH  TECHTYPE  RLSCF    RSDCF1   RSDCF2     COMMENTS
    TLC          1        0.00     0.00     0.021      THIN LAYER CAPPING
    ECAP         1        0.00     0.01     0.000      ENGINEERED CAPPING ALONE
    DRYMCH      -1        0.0[illegible]     0.00     0.021      REMOVAL IN DRY (MECHANICAL)
    WETMCH      -1        0.0      0.01     0.000      REMOVAL IN WET (MECHANICAL)
    WETHYD      -1        0.02     0.01     0.000      REMOVAL IN WET (HYDRAULIC)
    MNR          0        0.00     [illegible].00     0.000      MONITORED NATURAL RECOVERY
```

Appendix. Key FORTRAN variables used in the Housatonic River sediment remediation modules.

<u>Index Variables</u>

KBR:	index for either the deepest sediment layer removed, or the topmost cap layer
ISCHST:	index for the remedial time block
NCTRM:	index for current remediation time block

<u>Constants</u>

NREMTECH:	number of available remedial technologies
NREMBLK:	number of remediation time blocks
TCREMSER:	multiplicative factor to change time units to seconds in remediation schedule file

<u>Switches</u>

ISREM:	switch (set = 1) to activate sediment in the remediation module
ISCIREM:	switch (set = 1) to read remediation restart file (REM.RESTART)
IRMSTOP:	flag indicating if all remedial actions listed in the schedule file are complete

<u>One-Dimensional Arrays (size = NREMTECH)</u>

ITCH:	index for the remedial technologies specified in C97
REMTECH:	names of defined remedial technologies
TECHTYPE:	types of remedial technologies
RLSCF1:	coefficient for controlling rate of release (as a fraction)
RSDCF1:	coefficient for calculating post-remediation concentration (as a fraction)
RSDCF2:	coefficient for calculating residual concentration (as a constant)

<u>One-Dimensional Arrays (size = LCM)</u>

IRMARMOR:	switch (set = 1) to activate bed armoring
IRMBANK:	switch (set = 1) to activate bank removal/stabilization
IRMSTFLAG:	switch (set = 1) for on-going remediation in a given cell
REMDEPTH:	removal depth or cap thickness [meters]
RSDDEPTH:	vertical averaging depth [meters] for calculating post-remediation concentration
IRMBLK:	switch (set = 1) for on-going remediation of a given time block (controlled ISCHST)
TRMBEG:	start time of remedial time blocks (controlled by ISCHST)
TRMEND:	end time of remedial time blocks (controlled by ISCHST)
NRMIJ:	number of grid cells within each remediation time block (controlled by ISCHST)
IRMSCH:	(I) indices for all grid cells to be remediated
JRMSCH:	(J) indices for all grid cells to be remediated

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LRM:	(L) indices for grid cells to be remediated within a given time block (controlled by NRMIJ)
TOXBRSDL(NTOX):	residual TOX for backfill or cap material

Two-Dimensional Arrays

SEDFRLS (L, NSED):	release of cohesive solids flux [grams/meter^2-second]
SNDFRLS (L, NSND):	release of non-cohesive solids flux [grams/meter^2-second]
TOXFRSL (L, NTOX):	release of TOX flux [milligrams/meter^2-second]

QEA
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TECHNICAL MEMORANDUM

EFDC Remediation Code

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- As a result of cap addition, the sediment bed elevation (i.e., sediment/water interface) is increased in the model by the same amount as the user-specified cap thickness. Results of test simulations conducted with the code have not indicated any issues with hydrodynamic model instability associated with this instantaneous change in bed elevation. However, as stated above, the specific set of conditions for the CMS Proposal alternatives has not been simulated with this code. If during such simulations model instabilities are encountered, additional future refinements of the code will be required.

Bed Armoring

Armoring of an engineered cap (when used to replace removed sediment, or when added to the bed without prior removal) is simulated in the model through the use of an additional class of non-cohesive solids (NCx). This additional solids class, the properties of which are specified by the user as inputs (Card C41 in *EFDC.INP*), should contain the same specific volume (SDEN) and specific gravity (SSG) as the other solids classes in the calibrated model; however the particle diameter (SNDDIA) for NCx should be set to a value large enough to prevent erosion of the placed material (e.g., 7 mm). Simulation of the armor layer is achieved in the model code by first aggregating the masses of all cohesive and non-cohesive solids in the topmost sediment layer after cap material placement; this resulting mass is then assigned to the NCx solids class for that same surface layer, while the masses of the other solids classes in that layer are then set to zero. The approach for cap armoring described above allows for deposition and subsequent erosion of new solids on the surface of the armor layer after placement (but no movement of the armor layer itself).

Bank Removal/Stabilization

Simulation of bank erosion in EFDC is specified using two model input files. The first file (*BEMAP.INP*) contains a time series of the total bank solids load for all eroding banks; the second (*BESER.INP*) is a "mapping" file that contains a list of grid cell IDs for all eroding banks (there are actually two grid cell IDs specified at each eroding bank location: one for the channel cell and one for the adjacent floodplain cell). For each pair of grid cells in the mapping file, a fraction is assigned that represents the percentage of the total bank erosion load that is contributed by that particular location.

Bank stabilization at a particular grid cell is simulated in the remediation code by simply removing the appropriate grid cell ID pair from the bank erosion mapping array when that cell is remediated. Following this modification, a revised list of bank erosion cells is output to a model "restart" file (*BEMAP.RESTART*) at the end of the simulation; this file is then used to replace the original mapping file (*BEMAP.INP*) for subsequent "hot starts" of the model.

Remediation Schedule

As described in the CMS Proposal, a realistic schedule of the remedial actions will be developed for the model projections that uses production rate information specific to the particular technology being used (see Table 5-2 in the CMS Proposal for proposed production rates, with additional justification provided in Section 8 of GE's May 11, 2007 CMS Proposal Supplement). The production rates, in conjunction with model grid cell surface areas, will be used to estimate a remediation start and end time (in days) for each model grid cell; these start and end times are specified by the user in the remediation schedule input file (*REMSCHEDULE.INP*). Because the EFDC model is run year-by-year in "hot start" mode, the remediation progress at the end of a given year's simulation (i.e., where the remediation has left off) is recorded in a model restart file (*REM.RESTART*).

Code Additions and Changes

QEA has developed a number of new "remediation" subroutines to facilitate simulation of the remedial technologies described above. Incorporation of these new routines into the existing EFDC model provided by EPA necessitated some changes to existing EFDC subroutines. The sections below briefly summarize: (1) the new routines developed by QEA; (2) the changes made to existing EFDC subroutines; and (3) the new input files required by the additional subroutines. A listing and brief description of key variables used in the Housatonic River sediment remediation code are provided in the Appendix to this Memorandum.

New Remediation Subroutines

- **rembedctrl.for**: Main subroutine that controls simulation of sediment remedial actions.
- **rembankero.for**: Subroutine called by *rembedctrl.for* to simulate bank removal/stabilization.
- **setlayrem.for**: Subroutine called by *rembedctrl.for* that determines and returns the deepest sediment layer that will be subjected to removal (based on the user-input removal depth).
- **remcalrls.for**: Subroutine called by *rembedctrl.for* that computes the release rate of solids and PCBs during remediation, and residual mass for PCBs in backfill or capping material.
- **remout.for**: Subroutine called by *hdmt2t.for* to write *rem.restart* file used in "hot start" simulations that include remediation.

Revised Existing EFDC Subroutines

- **input.for**: Code was added to read two additional Card Images (C96 and C97) in the main EFDC input file (*EFDC.INP*); this routine was also modified to read new input files *REMMAP.INP*, *REMSCHEDULE.INP*, and *REM.RESTART* (if "hot start" of the remediation module is utilized).
- **hdmt2t.for**: Code was added to call *remout.for*.
- **ssedtox.for**: Code was added to call *rembedctrl.for* and to simulate the release of solids and PCBs during dredging (if specified by the user).
- **setfpocb.for**: Code was modified to include one additional class of non-cohesive solids (NCx).
- **efdc.cmn**: Code was modified to include new variables used in the new sediment remediation code.
- **efdc.par**: Modified parameters to reflect inclusion of one additional class of non-cohesive solids (NCx) for simulation of armoring.

New Input Files

- **REMMAP.INP**: This input file specifies the I and J coordinates of grid cells to be remediated, and for each grid cell specifies the sediment remedial technology, depth of removal or cap thickness, the depth to be used in vertical averaging for sediment residual calculations, and flags for the options of simulating bed armoring and/or bank removal/stabilization. An excerpt from a generic example of this model input file is provided below.

```
C file REMMAP.INP - sediment remediation mapping file
C
C Define remedial technology and remedial depth for
C model cells that are subjected to remediation
C
C  IREM,JREM - CELL I,J TO BE REMEDIATED
C  REMTYPE   - REMEDIAL TECHNOLOGY DEFINED IN EFDC.INP C97
C  REMDEPTH  - DEPTH (METERS) OF REMOVAL; CAP THICKNESS (METERS)
C  RSDDEPTH  - DEPTH (METERS) OF VERTICAL AVERAGING FOR RESIDUAL CALCULATION
C  REMARMOR  - OPTION FOR ARMOR LAYER (= 1; SHOULD BE USED ONLY FOR ECAP AND REMOVAL)
C  REMBANK   - OPTION FOR BANK REMOVAL/STABILIZATION (= 1)
C
C  NREM      - NUMBER OF CELLS SUBJECTED TO REMEDIATION
C     IREM      JREM   REMTYPE  REMDEPTH  RSDDEPTH  REMARMOR   REMBANK
C
  941
        10       305    DRYMCH    0.6096    0.6096       1        1
        10       304    DRYMCH    0.6096    0.6096       1        0
        10       303    DRYMCH    0.6096    0.6096       1        0
         9       303    DRYMCH    0.6096    0.6096       1        0
         8       303    DRYMCH    1.2192    1.2192       1        0
         8       302    DRYMCH    1.2192    1.2192       1        0
         7       302    DRYMCH    1.2192    1.2192       1        0
         6       302    DRYMCH    1.2192    1.2192       1        0
         5       302    DRYMCH    1.2192    1.2192       1        0
         4       302    DRYMCH    1.2192    1.2192       1        0
         3       302    DRYMCH    1.2192    1.2192       1        1
         . . .
```

- **REMSCHEDULE.INP**: This input file specifies the start and end times for sediment remedial actions for each model grid cell that is subject to remediation. An excerpt from a generic example of this model input file is provided below.

```
C FILE REMSCHEDULE.INP - SEDIMENT REMEDIATION TIME SEIRES/SCHEDULE
C   NREMBLK : NUMBER OF UNIQUE TIME BLOCKS
C   TCREMSER: MULTIPLICATIVE CONVERSION FACTOR NEEDED TO CONVERT THE TIME UNITS TO SEC
C   NRMIJ :   NUMBER OF GRID CELLS WITHIN A GIVEN TIME BLOCK
C   TRMBEG :  BEGINNING TIME OF A GIVEN REMEDIAL TIME BLOCK
C   TRMEND :  END TIME OF A GIVEN REMEDIAL TIME BLOCK
C   IRMSCH:   CELL I
C   JRMSCH:   CELL J
C
C   NREMBLK   TCREMSER
C       NRMIJ  TRMBEG   TRMEND
C          IRMSCH   JRMSCH
C
939  86400
    1  9497.000  9500.676
       8     303
    1  9500.676  9504.346
       8     302
    1  9504.346  9507.807
       7     302
    1  9507.807  9511.213
       6     302
    1  9511.213  9514.339
       5     302
    1  9514.339  9517.104
       4     302
    1  9517.104  9519.965
       3     302
    . . .
```

- **EFDC.INP**: Two additional “Card Images” (C96 and C97) have been added to this input file to control the options for sediment remediation:
  - C96 is the general control of the sediment remediation module, and is used to (1) activate the sediment remediation module; (2) specify the desired number of simulated remedial technologies (maximum = 10); and (3) specify whether a given simulation is a “cold start” or “hot start” run.
  - C97 specifies options with regard to release rates and residual concentrations for each remedial technology. There are two general types of active remediation technologies specified for the Housatonic River model: (1) removal with replacement (TECHTYPE = -1); and (2) capping (TECHTYPE = 1). A third option (TECHTYPE = 0) was included in the code to allow the user to simulate bank removal/stabilization along with no action or MNR for the sediments of a given grid cell. For each specified technology, RLSCF1 represents the user-specified fraction of solids and PCB released during remediation. RSDCF1 and RSDCF2 are coefficients used to calculate the post-remediation PCB concentration.

An example of C96 and C97 from this model input file is provided below.

```
C96 CONTROLS FOR REMEDIATION MODULE
*
*  ISREM:     1 FOR SEDIMENT REMEDIAL OPERATIONS
*  NREMTECH:  NUMBER OF AVAILABLE REMEDIAL TECHNOLOGIES (MAX=10)
*  ISCIREM:   1 TO READ REMEDIATION RESTART FILE (REM.RESTART)
*
C96 ISREM  NREMTECH  ISCIREM
      1       6         0
-------------------------------------------------------------------------------
C97 SPECIFICATION OF ATTRIBUTES FOR AVAILABLE REMEDIAL TECHNOLOGIES
*
*   REMTECH:   NAME OF REMEDIAL TECHNOLOGY
*   TECHTYPE:  = -1 FOR REMOVAL WITH REPLACEMENT
*              =  1 FOR CAPPING
*              =  0 FOR NO ACTION
*   RLSCF1:    RELEASE RATE = NATIVE SED CONC * RLSCF1
*   RSDCF1:    RESIDUAL CONC = NATIVE SEDIMENT CONC * RSDCF1 + RSDCF2
*   RSDCF2:
*
C97 REMTECH  TECHTYPE  RLSCF1   RSDCF1  RSDCF2     COMMENTS
    TLC         1       0.00     0.00    0.021     THIN LAYER CAPPING
    ECAP        1       0.00     0.01    0.000     ENGINEERED CAPPING ALONE
    DRYMCH     -1       0.00     0.00    0.021     REMOVAL IN DRY (MECHANICAL)
    WETMCH     -1       0.01     0.01    0.000     REMOVAL IN WET (MECHANICAL)
    WETHYD     -1       0.02     0.01    0.000     REMOVAL IN WET (HYDRAULIC)
    MNR         0       0.00     1.00    0.000     MONITORED NATURAL RECOVERY
```

Appendix. Key FORTRAN variables used in the Housatonic River sediment remediation modules.

Index Variables

KBR:	index for either the deepest sediment layer removed, or the topmost cap layer
ISCHST:	index for the remedial time block
NCTRM:	index for current remediation time block

Constants

NREMTECH:	number of available remedial technologies
NREMBLK:	number of remediation time blocks
TCREMSER:	multiplicative factor to change time units to seconds in remediation schedule file

Switches

ISREM:	switch (set = 1) to activate sediment in the remediation module
ISCIREM:	switch (set = 1) to read remediation restart file (REM.RESTART)
IRMSTOP:	flag indicating if all remedial actions listed in the schedule file are complete

One-Dimensional Arrays (size = NREMTECH)

ITCH:	index for the remedial technologies specified in C97
REMTECH:	names of defined remedial technologies
TECHTYPE:	types of remedial technologies
RLSCF1:	coefficient for controlling rate of release (as a fraction)
RSDCF1:	coefficient for calculating post-remediation concentration (as a fraction)
RSDCF2:	coefficient for calculating residual concentration (as a constant)

One-Dimensional Arrays (size = LCM)

IRMARMOR:	switch (set = 1) to activate bed armoring
IRMBANK:	switch (set = 1) to activate bank removal/stabilization
IRMSTFLAG:	switch (set = 1) for on-going remediation in a given cell
REMDEPTH:	removal depth or cap thickness [meters]
RSDDEPTH:	vertical averaging depth [meters] for calculating post-remediation concentration
IRMBLK:	switch (set = 1) for on-going remediation of a given time block (controlled ISCHST)
TRMBEG:	start time of remedial time blocks (controlled by ISCHST)
TRMEND:	end time of remedial time blocks (controlled by ISCHST)
NRMIJ:	number of grid cells within each remediation time block (controlled by ISCHST)
IRMSCH:	(I) indices for all grid cells to be remediated
JRMSCH:	(J) indices for all grid cells to be remediated

LRM:	(L) indices for grid cells to be remediated within a given time block (controlled by NRMIJ)
TOXBRSDL(NTOX):	residual TOX for backfill or cap material

Two-Dimensional Arrays

SEDFRLS (L, NSED):	release of cohesive solids flux [grams/meter^2-second]
SNDFRLS (L, NSND):	release of non-cohesive solids flux [grams/meter^2-second]
TOXFRSL (L, NTOX):	release of TOX flux [milligrams/meter^2-second]