Water Quality Research Program

Development of Unstructured Grid Linkage Methodology and Software for CE-QUAL-ICM

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Preface

The work reported herein was conducted as part of the Water Quality Research Program (WQRP), Work Unit 32808, "Model of Contaminant Transport and Fate at Corps Projects." The WQRP is sponsored by the Headquarters, U.S. Army Corps of Engineers (HQUSACE), and is assigned to the U.S. Army Engineer Waterways Experiment Station (WES) under the purview of the Environmental Laboratory (EL). Funding was provided under Department of the Army Appropriation 96X3121, General Investigation. The WQRP is managed under the Environmental Modeling, Simulation, and Assessment Center (EMSAC), Dr. John W. Barko, Director for EL. Mr. Robert C. Gunkel was Assistant Manager for the WQRP. Program Monitor during this study was Mr. Frederick B. Juhle, HQUSACE.

The Principal Investigator of Work Unit 32808 was Dr. Mark S. Dortch, Chief, Water Quality and Contaminant Modeling Branch (WQCMB), Environmental Processes and Effects Division (EPED), EL. The work reported herein was conducted by Dr. Raymond S. Chapman, Ray Chapman and Associates, Vicksburg, MS, and Mr. Terry K. Gerald, ASci, Inc., Vicksburg, MS, under contract to WES. This report was prepared by Dr. Chapman and Mr. Gerald. Dr. Dortch monitored the contract and reviewed, edited, and revised the report.

This study was conducted under the general supervision of Dr. Richard E. Price, Acting Chief, EPED, and Dr. John Harrison, Director, EL. This report was reviewed by Messrs. Thomas Cole and Ross Hall, WQCMB.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin.
This report should be cited as follows:


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1 Introduction

Background

CE-QUAL-ICM (Cerco and Cole 1995) is a three-dimensional (3-D) water quality model based on the finite volume approach. There are two versions of this model, a eutrophication version documented by Cerco and Cole (1995), and a toxic substance version referred to as ICM/TOXI documented by Wang et al. (1996). The project that funded the development of ICM/TOXI also funded the present study reported herein.

Neither version of CE-QUAL-ICM (ICM) solves for hydrodynamics, so this information must be supplied by a hydrodynamic model for driving transport in the ICM model. The ICM model is usually linked to output from CH3D-WES (Johnson et al. 1991), a 3-D finite difference hydrodynamic model based on a structured grid scheme. Structured grids assume that computational cells are ordered along columns and rows, whereas unstructured grids allow cells to be arranged in a nonordered fashion. Thus, unstructured grids allow greater flexibility for describing the geometry of the domain.

RMA10 (Norton, King, and Orlob 1973; Thomas and McAnally 1990) is a 3-D finite element hydrodynamic model frequently used by the U.S. Army Engineer Waterways Experiment Station (WES). RMA10 is based on an unstructured grid approach. There was a need for developing a linkage to the RMA10 model to allow greater flexibility provided by unstructured grids for conducting water quality and contaminant model studies.

Objective and Scope

The objective of this study was to develop software to provide linkage of RMA10 output to the ICM code and to test the success of the linkage for simple test cases. The software development consisted of basically three parts: (a) development of a code (MAPPER) to map the finite element grid configuration and geometry information into a file that can be interpreted by the ICM code; (b) development of an RMA10 postprocessor code (FEMCONVT) to convert RMA10 velocity and water surface information at nodes to flows and
cell areas and volumes for each ICM cell; and (c) modifications within ICM to conform to the RMA10 linkage. Linkage testing consisted of checking local and global volume and mass conservation and examining the transport against known solutions. It is important to maintain mass conservation in water quality models since they are based on the mass conservation principle.

This report is organized into chapters on Introduction, Implementation, Testing, and Summary and Recommendations. Appendixes A-C deal with the MAPPER, FEMCONVT, and ICM codes.
2 Implementation

The basic requirements for the design and development of an unstructured grid linkage methodology for ICM are as follows: (a) generating a geometry file that relates the elements and their geometric attributes for an unstructured grid hydrodynamic model, such as RMA10, to flow faces and computational cells of ICM; (b) assigning a tagging system to relate flows from the hydrodynamic model to ICM flow faces; (c) establishing a convention for positive/negative flow directions; and (d) computing integrated flows across and normal to each hydrodynamic element face. The linkage program MAPPER conducts the first three tasks, while the linkage program FEMCONVT conducts the last.

MAPPER

The linkage geometry and map files are derived from the RMA10 element connection file that is generated for a hydrodynamic run. A C language program (MAPPER.C) was written to generate this information. MAPPER.C is described and listed in Appendix A. Descriptions of the RMA10 node and element connectivity scheme were obtained from the RMA10 documentation (Thomas and McAnally 1990; Brigham Young University 1994). The element connection file, generated by an RMA10 preprocessor code, which resides within the WES Coastal and Hydraulics Laboratory (CHL), provides element and node numbering, the 3-D coordinates of each node within the grid, and boundary designation information. This file is read by MAPPER.C, which generates the geometry (GEO) and map (MAP) files required as input to ICM.

To accommodate unstructured grid hydrodynamics, the GEO file was modified so that a one-dimensional array of centroid-based grid distances, which are direction sensitive, is computed and replaces the original box lengths (i.e., BL(IB(F),QD(F))). The centroid-based grid lengths data consist of (a) distance from centroid of IB cell to flow face (BID); (b) centroid to centroid distance between IB and JB cells (BI); (c) centroid to centroid distance between the ILB cell and IB (BIL); and (d) centroid to centroid distance between the JB cell and JRB cell (BIR) (see Figure 1). The specification of the ILB, IB, JB, and JRB ICM cell numbers (Figure 1) is accomplished through examination of the element connection file. Specifically, when elements that share common mid-side nodes are identified, a cell face between boxes IB and JB is defined. Cells
Figure 1. Grid nomenclature

to the right or left of cells with a common flow face are determined by selecting the cell with the shortest centroid distance. For example, as shown in Figure 1, the centroid distance from Cells JB to JRB is shorter than the distance from Cells JB to J1; thus, Cell JRB is selected as the adjacent right cell, or the far downstream cell for the QUICKEST weighting, and BIR is the distance from JB to JRB.

Due to the fact that unstructured grids have no preferred grid direction, a convention has been adopted. A flow direction for the establishment of the GEO
and MAP files is assumed based upon the cell numbering scheme obtained from RMA10. In the horizontal direction, flow is defined to be positive when it passes from a smaller RMA10 element number to a larger RMA10 element number. In the vertical direction, flows are defined positive upward, which is the convention used in both RMA10 and ICM. When the flow field is read in from the HYD file, the actual flow directions relative to the assumed flow directions are determined so that the proper cells are sampled for the QUICKEST advection operators.

The general concept of the MAP file was unaltered; however, additional information was required to relate the RMA10 and ICM grids. The processor program MAPPER assigns ICM cell numbers to RMA10 element numbers and writes the ordered pairs as the first set of records in the MAP file. The correspondence between hydrodynamic elements and ICM cells is arbitrary in that the connection is accomplished via flow face definitions. This approach is adopted so that the existing convention for numbering cells and flow faces in ICM is unaltered.

The RMA10 element edges and ICM flow faces are related in the MAP file via a tag. In the horizontal direction, the flow faces between adjacent cells in ICM are tagged to mid-side nodes in RMA10, which are defined along element edges. Vertical flow faces in ICM are tagged to the top of each element in RMA10. These tags are used via translation arrays to relate RMA10 flow locations to the corresponding sequentially numbered ICM flow face numbers.

Boundaries within the RMA10 grid are specified via nodal codes that define land, inflow, and tidal or head boundaries. These codes are used in MAPPER to specify boundaries in the MAP file.

**FEMCONVT**

The Fortran language program FEMCONVT.f was written by Dr. R. C. Berger of the WES CHL to read a binary RMA10 hydrodynamic output file and convert nodal velocities and surface elevations into cell face areas (including planar surface areas), volumes, and flows, which are written to another output file (HYD file). A listing of FEMCONVT is provided in Appendix B. The output of FEMCONVT is segregated into horizontal and vertical components. In the horizontal direction, the information provided is time-varying horizontal flow face areas and flows for each mid-side node. The vertical part of the hydrodynamic output provides element number, element planar surface area, volume, and the vertical flow defined on the top face of each element.

**ICM Modifications**

The original advection operator in ICM was designed to work with structured grid hydrodynamic models such as CH3D-WES (Chapman 1988). As a result, the grid is described by rows and columns of grid cells and box lengths. These
box lengths are used to compute the QUICKEST multipliers used for transport. Due to the success realized during numerous applications of the QUICKEST transport algorithm in both the ICM and CE-QUAL-W2 models (Dortch, Chapman, and Abt 1991; Chapman 1992; Chapman and Cole 1992), a similar approach was adopted for the unstructured version of ICM. The unstructured grid modifications made to the original version of ICM are presented in Appendix C. For ICM to accommodate unstructured hydrodynamic models such as RMA10, the QUICKEST multipliers had to be recast in terms of element centroid to centroid distances. As previously discussed, the linkage processor program MAPPER generates the four length scales needed to develop the QUICKEST multipliers. Using these length scales, the QUICKEST multipliers were rewritten and checked to ensure that the advection multipliers summed to one, and the diffusive multipliers summed to zero.

**Linkage Procedure**

To complete a linkage of RMA10 and ICM, the steps outlined below must be completed.

a. A binary output file generated by RMA10, which contains the time-invariant grid and time-varying hydrodynamic data, must be obtained from the hydrodynamic modeling team. The name of this file is specified as RMA10 input, so it is arbitrary.

b. With regard to the time-invariant grid data, a program named R4ICR10.f, written and provided by CHL, is used to read the RMA10 binary file and generate a 3-D ASCII element connection file named R4ICR10.out. This file describes the juxtaposition of all elements and nodes in the RMA10 grid.

c. The linkage program MAPPER.C reads R4ICR10.out and generates the ICM MAP and GEO files. The number and position of ICM cells or boxes are determined by MAPPER automatically. Presently, a parameter statement within the MAPPER code defines “number_of_layers,” which must be set to the desired number of layers. This parameter can be used to limit the output to a single layer for debug purposes. When this parameter is set to the correct number of RMA10 layers, the complete MAP and GEO files are automatically generated. MAPPER input (i.e., R4ICR10.out) and output files for a simple 3 by 2 by 2 grid are presented in Appendix D.

d. The time-varying hydrodynamic data are also extracted from the same RMA10 binary output file. This is accomplished using the FEMCONVT.f program. This program has one interactive input, which is the RMA10 binary file name. All grid parameters are read from the RMA10 binary file. The output of this program is an ASCII ICM HYD file. At this time, FEMCONVT.f has several limitations:
• ASCII output should be written in binary to reduce space requirements for applications with large output files.

• Base elevation in feet relative to an RMA10 datum must be hardwired.

• FEMCONVT only works for quadrilateral elements.

• Parameter statements must be checked to ensure the code will accommodate the size of the grid.

• Vertical diffusivities required by ICM are not computed nor output.

• There is no provision for temporal or spatial averaging of hydrodynamic output.

e. Two additional parameters must be defined in the ICM file WQM_COM.INC. NFEMHFFP and NFEMVFFP are the maximum number of horizontal and vertical flow faces, respectively.
Testing

Volume Balance Testing

Initial testing of the linkage methodology using hydrodynamic flow information was performed on a simple 26 by 4 by 3 rectangular contracted channel comprised of quadrilaterals as shown in Figure 2. To test both local and global volume conservation, a single steady-state flow field was used. Given that the flow field has in fact converged to a steady-state solution, successive applications of the flow field using the steady-state distribution of element volumes as an initial state should result in no temporal change in volume. Using these data, ICM was run using a 1-hr hydrodynamic update for 0.2 days, or two hydrodynamic updates. As expected, global volume conservation was achieved. However, significant variations in local volume conservation were observed throughout the grid. This problem was further investigated by performing flow balances on individual cells. In regions where elements were orthogonal, flow imbalances on the order of 1 percent were found, where the error in flow balance is based on the difference in the sum of the flows scaled by the maximum flow in or out of that cell. In regions where elements were nonorthogonal, flow imbalances were on the order of 60 percent. Discussions with CHL suggested that this problem can be overcome or at least reduced to errors on the order of a few percent. Means of correcting the flow/volume imbalances are being pursued.

Given that RMA10 flow fields can be produced with small but possibly acceptable volume errors, two alternatives can be adopted that will result in a local volume balance. The simplest option is to use the flows from the RMA10 hydrodynamic processor, but not use the resulting volumes. Under this scenario, time-varying volumes are computed within ICM using the previously computed volume and the input flows, thereby ensuring volume and mass conservation. The downside of this option is that if a persistent net loss or gain is realized in one or more cells, problems could develop during long-term simulations. Specifically, cells could either dry out or become unrealistically large.

Alternatively, both RMA10 flows and volumes can be used by ICM. The RMA10 flow data would again be used within ICM to calculate conserving volumes for each hydrodynamic update interval. The difference in the RMA10 volumes and ICM volumes can then be used to determine the volume errors for
each cell. If the volume error is ignored, i.e., RMA10 volumes are used, the model will not conserve mass, but concentrations will be conserved. For example, if a water quality constituent of 10 ppm is introduced into a bay that
contains 10 ppm, the concentrations will all remain 10 ppm, but some mass of the constituent will be gained or lost.

Volume and mass conservation can be forced when using both RMA10 flows and volumes by introducing a volume error correction. However, under this option the concentrations will not remain conservative, or 10 ppm everywhere as in the previous example. The error correction for each hydrodynamic update interval is computed and added (or subtracted) incrementally over the ICM time-steps within that update interval. Thus, the ICM volume computed at the end of each hydrodynamic update interval will be identical to the corresponding RMA10 volume. The simplest way to implement this correction is to generate a source flow by dividing the total volume error for each hydrodynamic update interval by the hydrodynamic update time interval. As the ICM simulation proceeds, a volume source/sink can be added/subtracted by multiplying the source flow by the ICM time-step.

**Transport Testing**

To test the revisions to ICM for the unstructured grid QUICKEST multipliers, transport testing was done using a one-dimensional rectangular grid set up without and with the unstructured grid multipliers as derived from the GEO and MAP files generated by MAPPER. The RMA10 model was not used for these tests. This grid consisted of 25 boxes 100 m in length with 1-m² cell face areas. A constant flow rate of 0.1 m³/sec was specified with no horizontal diffusion. Specifying a constant source concentration at the inflow, the predicted square wave concentrations in both simulations (i.e., with structured and with unstructured grid) were identical as shown in Figures 3 and 4. The algorithm was tested for variable grid spacing by alternating between 100- and 50-m box lengths and repeating the simulations. Additionally, both positive and negative flows were tested. All runs yielded identical results, which confirmed correct implementation of QUICKEST.

Additional testing of transport was performed using a steady-state RMA10 hydrodynamic flow field. A rectangular channel RMA10 grid was used consisting of 10 elements along the channel, 4 elements across the channel, and 3 elements deep (see Figure 5). Output from RMA10 was used to drive ICM. Exact global mass conservation was verified via a simulation of a conservative tracer spot dump and simulation of a uniform tracer concentration throughout the grid and boundaries. In addition, a constant source square wave test was performed. Despite the coarseness of the grid, the expected characteristics of QUICKEST are preserved in that minimal undershoot and overshoot and smearing of the wave occur over about five grid points (see Figure 6).
Figure 3. Square wave test result with structured grid QUICKEST multipliers
Figure 4. Square wave test result with unstructured grid QUICKEST multipliers
Figure 5. Transport test grid
Figure 6. Square wave test result for RMA10-ICM transport test
4 Summary and Recommendations

A linkage methodology has been developed, implemented, and tested that allows CE-QUAL-ICM to use unstructured grid hydrodynamic information from the RMA10 finite element model. This has been accomplished through the development of two postprocessor programs, which provide flow and linkage information to ICM. Initial testing of volume conservation suggests that local volume conservation problems inherent within RMA10 limit the general skill of the linkage system; however, a procedure for correcting the volume errors within ICM is outlined. Irrespective, results of the present study suggest that further work towards eliminating volume conservation errors within RMA10 is warranted. In addition, a centroid-based QUICKEST advection scheme consistent with the unstructured form of RMA10 has been developed, implemented, and tested. Testing of the scheme shows that it is mass conservative and that it provides results consistent with the well-tested structured grid version of QUICKEST previously employed in ICM.

With respect to future refinements of the linkage methodology, in addition to either correcting for or eliminating the local volume conservation errors obtained from RMA10, the hydrodynamic processor FEMCONVT needs to be generalized to accommodate combinations of triangular and quadrilateral elements. Furthermore, additional work is required to integrate vertical eddy diffusivities within RMA10 so that cell face values can be provided to ICM. Subsequent to these and other more minor improvements outlined in Chapter 2, the complete linkage methodology should be tested using a real time-varying field application.
References


Appendix A
MAPPER Description and Source Code Listing

The following is a brief description of the internal steps followed by the program MAPPER.C that generates the MAP and GEO files needed by the ICM model. This program is run after the RMA10 program is executed. There is a program called R4ICR10.F written by the U.S. Army Engineer Waterways Experiment Station Coastal and Hydraulics Laboratory that extracts the two files used as input by MAPPER.C from the RMA10 binary output file. A listing of the MAPPER.C source code follows the description.

The step by step operations of MAPPER.C are listed below.

Read the node-to-element connection table. Allocates each "Element" as a column and assigns an ID.

Subroutine call: readElementConnectionFile()

Subroutine description: The routine opens and reads the element to node connection table file. This file provides information that uniquely relates an element or column identification number to the associated nodes. Additional information obtained from this file is the coordinates of each node. At this point, it is assumed that RMA10 node identification numbers are being used. This routine creates a unique "arc" for each side of the surface layer elements, which can be either trapezoidal or triangular.

Source of input file: Input file is generated by R4ICR10.f.

Read boundary information.

Subroutine call: readBoundaryArcFile()
Subroutine description: Routine reads a file that contains information about all "special" nodes in the RMA10 grid. These special nodes are nodes at which some physical parameters are specified such as head values, wall boundaries, open boundaries, interior boundaries, etc. This information, in addition to the node data from Step 1, completely describes the RMA10 grid structure.

Source of input file: Input file is generated by R4ICR10.f.

Relate each arc to the adjacent columns.

Subroutine call: mapColumnsToArcs()

Subroutine description: Routine determines the adjacent column identification numbers for each arc.

Relate each column to its neighbors.

Subroutine call: mapNeighborColumnsForEachColumn()

Subroutine description: Routine determines for each column, all the columns that share a common arc. Thus, a list is generated for each column that contains all of its neighbor columns.

Determine arc type.

Subroutine call: determineArcTypeF()

Subroutine description: Routine examines each arc and determines its type, which is defined to be (a) INTERNAL - arc that is internal to the grid, (b) BOUNDARY - arc lies at an open boundary, and (c) WALL - arc lies at the wall of the grid. The arc type is defined using the nodal boundary data.

Determine upstream and downstream columns.

Subroutine call: mapUpstreamAndDownstreamColumnsForEachColumnF()

Subroutine description: Routine defines adjacent columns.

Create a list of all elements in the 3-D grid.

Subroutine call: createElementList()

Subroutine description: Routine will generate a list of all elements in the RMA10 grid. First, it generates surface layer or column elements. Next, for
each column, it will define elements within that column from the surface down. The order of elements is that defined by RMA10.

Map neighboring elements.

Subroutine call: mapElementToNeighborElements()

Subroutine description: Routine determines neighboring elements. This is accomplished by using the column information previously defined.

Check for internal and boundary flow faces.

Subroutine call: generateHorizontalFlowFaceListF()

Subroutine description: Routine examines each arc, its type. If the type is "INTERNAL" or "BOUNDARY," it will create a flow-face for that arc; this is done in layer order starting at the surface then going down. For each defined flow face, the adjacent elements of that flow face are listed.

Determine far upstream elements for each horizontal flow face.

Subroutine call: mapHorizontalFlowFaces()

Subroutine description: Routine determines for each flow face its far upstream and far downstream element IDs using the adjacent element ID information.

Create the vertical flow face list.

Subroutine call: mapVerticalFlowFaces()

Subroutine description: Routine uses the column information defined above and creates a vertical flow face between each element. It also does the vertical mapping of upstream and downstream elements.

Define tags that relate RMA10 and ICM flow faces.

Subroutine call: setFlowFaceIdentifierTags()

Subroutine description: Routine examines each flow face and tags it with a unique identifier. This unique identifier is defined as (a) horizontally oriented flow face (the top center node ID of each flow face); and (b) vertically oriented flow face (the RMA10 element ID of the element below the flow face).
Number ICM flow faces.

Subroutine call: renumberAllFlowFacesForOutputF()

Subroutine description: Routine renumbers the flow face identifications consistent with the ICM convention.

Calculate surface areas and the centroid locations.

Subroutine call: calculateColumnSurfaceAreaAndCentroid()

Subroutine description: Routine will calculate surface area and centroid location using the surface node coordinates.

Calculate required distances between centroids.

Subroutine call: calculateDistanceBetweenCentroidsF()

Subroutine description: Routine calculates the following length scale information for each flow face:

(a) $\text{BIL} =$ Distance between far upstream element centroid and upstream element centroid.

(b) $\text{BI} =$ Distance between upstream element centroid and the downstream element centroid.

(c) $\text{BIR} =$ Distance between downstream element centroid and far downstream element centroid.

(d) $\text{BID} =$ Distance between flow face and the upstream element centroid.

Print "MAP FILE".

Subroutine call: printFlowFaceListF()

Subroutine description: Routine writes "MAP" file data.

Print "GEO FILE".

Subroutine call: printGeoFileF()

Subroutine description: Routine writes "GEO" file data.
/* PROGRAM NAME: MAPPER.c

PROGRAMMER: Terry K. Gerald

PURPOSE: Build the "MAP" file and the "GEO" file for ICM from an RMA10
finite element model grid.
*/

#include <stdio.h>
#include <string.h>
#include <math.h>

#define TRUE 1
#define FALSE 0
#define YES 1
#define NO 0
#define OK 1
#define SET 1
#define NOT_SET 2
#define GE 10
#define GNN 20
#define OTHERSTUFF 30
#define TRAPAZOID 100
#define TRIANGLE 200
#define NUMBER_OF_LAYERS 3
```c
#define MAXARGS 20

#define INTERNAL 70
#define BOUNDARY 80
#define WALL 90

#define VERTICAL 100
#define HORIZONTAL 200
#define INBETWEEN 300

/* ____________________________________________________________ */

typedef struct ELEMENT_BLOCK_STRUCT 
{  struct ELEMENT_BLOCK_STRUCT *pLastElementBlockPtr;
    struct ELEMENT_BLOCK_STRUCT *pNextElementBlockPtr;
    int elementId;
    int rotElementId;
    int columnId;
    int elementType;
    int arcCount;
    int layerId;
    int faceId[6];
    int commonNeighborElementId[4];
    int commonNeighbor2ElementId[4];
    int bottomFlowFaceId;
    struct ELEMENT_BLOCK_STRUCT *elementAbovePtr;
    struct ELEMENT_BLOCK_STRUCT *elementBelowPtr;
 } ELEMENT_BLOCK;
```

typedef ELEMENT_BLOCK *PELEMENT_BLOCK;

ELEMENT_BLOCK *pHeadElementListBlockPtr;

int globalElementCount = 0;

PELEMENT_BLOCK *lookupElementPtrArray = NULL;

typedef struct COLUMN_BLOCK_STRUCT
{
    struct COLUMN_BLOCK_STRUCT *pLastColumnBlockPtr;
    struct COLUMN_BLOCK_STRUCT *pNextColumnBlockPtr;
    int columnId;
    int columnIndex;
    int columnType;
    int arcCount;
    int numberOfLayers;
    int arcIds[4];
    int commonNeighborColumnCount;
    int commonNeighborColumnId[4];
    int commonNeighborArcId[4];
    int commonNeighbor2ColumnId[4];
    float surfaceArea;
    float centroidX, centroidY;

    PELEMENT_BLOCK elementPtr;
    PELEMENT_BLOCK surfaceElementPtr;
} COLUMN_BLOCK;

typedef COLUMN_BLOCK *PCOLUMN_BLOCK;

COLUMN_BLOCK *pHeadColumnListBlockPtr;
int globalColumnCount = 0;

PCOLUMN_BLOCK *lookupColumnPtrArray = NULL;

typedef struct NODE_BLOCK_STRUCT
{ struct NODE_BLOCK_STRUCT *lastNodeBlockPtr;
  struct NODE_BLOCK_STRUCT *nextNodeBlockPtr;
  int nodeId;
  float coordinates[3];
} NODE_BLOCK;

typedef NODE_BLOCK *PNODE_BLOCK;

PNODE_BLOCK pHeadNodeBlockPtr = NULL;

int globalNodeCount = 0;

PNODE_BLOCK *lookupNodePtrArray = NULL;

typedef struct ARC_BLOCK_STRUCT
{ struct ARC_BLOCK_STRUCT *pLastArcBlockPtr;
  struct ARC_BLOCK_STRUCT *pNextArcBlockPtr;
  int arcId;
  int nodeId[3];
  int adjacentColumn[2];
  int type;
} ARC_BLOCK;

typedef ARC_BLOCK *PARC_BLOCK;

PARC_BLOCK pHeadArcListBlockPtr = NULL;
int globalArcCount = 0;

typedef struct FLOWFACE_BLOCK_STRUCT {
    struct FLOWFACE_BLOCK_STRUCT *pLastFlowFaceBlockPtr;
    struct FLOWFACE_BLOCK_STRUCT *pNextFlowFaceBlockPtr;
    struct ARC_BLOCK_STRUCT *arcPtr;
    int identifierTag;
    int arcId;
    int flowFaceId;
    int modelFlowFaceId;
    int layerId;
    int farDownstreamElementId;
    int downstreamElementId;
    int upstreamElementId;
    int farUpstreamElementId;
    int type;
    int orientation;
    int adjacentColumn[2];
    int adjacentElement[2];
    float distanceBetweenCentroids;
    float upstreamDistanceBetweenCentroidAndFace;
    float downstreamDistanceBetweenCentroidAndFace;
    float distanceBetweenUpstreamCentroids;
    float distanceBetweenDownstreamCentroids;
} FLOWFACE_BLOCK;

typedef FLOWFACE_BLOCK *PFLOWFACE_BLOCK;

PFLOWFACE_BLOCK pHeadFlowFaceListBlockPtr = NULL;
PFLOWFACE_BLOCK pHeadSurfaceFlowFaceListBlockPtr = NULL;
PFLOWFACE_BLOCK pTailSurfaceFlowFaceListBlockPtr = NULL;
int globalFlowFaceCount = 0;

PFLOWFACE_BLOCK *lookupFlowFacePtrArray = NULL;

typedef struct BOUNDARY_NODE_BLOCK_STRUCT
{
  struct BOUNDARY_NODE_BLOCK_STRUCT *lastBoundaryNodeBlockPtr;
  struct BOUNDARY_NODE_BLOCK_STRUCT *nextBoundaryNodeBlockPtr;
  int boundaryNodeId;
} BOUNDARY_NODE_BLOCK;

typedef BOUNDARY_NODE_BLOCK *PBOUNDARY_NODE_BLOCK;

PBOUNDARY_NODE_BLOCK pHeadBoundaryNodeBlockPtr = NULL;

/* int globalBoundaryNodeCount = 0; */

typedef struct SURFACE_NODE_LIST_STRUCT
{
  int ndep;
  int nref;
} SURFACE_NODE_LIST;

typedef SURFACE_NODE_LIST *PSURFACE_NODE_LIST;

PSURFACE_NODE_LIST surfaceNodeList;

/ * function prototypes */
NODE_BLOCK
*allocateNewNodeBlockF();

BOUNDARY_NODE_BLOCK
*allocateNewBoundaryNodeBlockF();

ARC_BLOCK
*allocateNewSegmentArcBlockF();

ELEMENT_BLOCK
*allocateNewElementBlockF();

COLUMN_BLOCK
*allocateNewColumnBlockF();

FLOWFACE_BLOCK
*allocateNewFlowFaceBlockF();

PNODE_BLOCK
findNodePtrF(int);

PARC_BLOCK
findArcPtrF(int);

PCOLUMN_BLOCK
lookupColumnPtrF(int);
PELEMENT_BLOCK
lookupElementPtrF(int);

PFLOWFACE_BLOCK
lookupFlowFacePtrF(int);

int
iCheckIfCommonNodeInTwoArcsF(PARC_BLOCK, PARC_BLOCK);

void
readBoundaryArcFile();

int
ggetColumn(FILE *, char *, char *);

int
searchForNFIX(FILE *);

void
allocateNewElementByColumnBlockF(COLUMN_BLOCK *, int);

/**
   /* */

/**
   /* */

   /* MAIN ROUTINE */

void main()
{  
/* Read the node-to-element connection  
table. Allocates each "Element" as  
a column. Column ID is also read in. */
readElementConnectionFile();  

/* Read from an RMA10 output file, which  
nodes are BOUNDARY nodes */
readBoundaryArcFile();  

/* Relate to each arc in a column, the  
two columns on each side */
mapColumnsToArcs();  

/* Relate each column to its neighbors */
mapNeighborColumnsForEachColumn();  

/* Determine for each arc if it is an  
1) INTERNAL arc, 2) BOUNDARY arc or a  
3) WALL arc! */
determineArcTypeF();  

/* Map upstream and downstream columns */
mapUpstreamAndDownstreamColumnsForEachColumnF();  

/* Create all elements */
createElementList();  

/* Map for each element its neighbor  
elements */
mapElementToNeighborElements();  

/* Generate each horizontal flow-face  
utilizing the arc list */
generateHorizontalFlowFaceListF();

mapHorizontalFlowFaces();

mapVerticalFlowFaces();

setFlowFaceIdentifierTags();

renumberAllFlowFacesForOutputF();

calculateColumnSurfaceAreaAndCentroid();

calculateDistanceBetweenCentroidsF();

printFlowFaceListF();

print"MAP" file

/* Determine relationship between the flow-face and it's adjacent elements */

/* From the column lists generate the vertical flow-faces and determine their adjacent element ids */

/* Need to reference each flow-face with some type of information that RMA10 is aware of so the flow-faces can be ordered in way that preserves their geometric relationships to their elements. */

/* Renumber the flow-faces so that they are numbered increasing by layer instead of by column */

/* Calculate the geometry for each element */

/* Print the "GEO" file */
printGeoFileF();
}

/* ____________________________________________________________ */

NODE_BLOCK *allocateNewNodeBlockF()
{
    int i;
    NODE_BLOCK *aNodeBlock;

    static
    PNODE_BLOCK lastNodePtr;

    aNodeBlock = (PNODE_BLOCK)calloc(1,sizeof(NODE_BLOCK));
    aNodeBlock->lastNodeBlock.Ptr = NULL;
    aNodeBlock->nextNodeBlock.Ptr = NULL;
    aNodeBlock->nodeId = ++globalNodeCount;

    /* Set list ptrs */

    if(pHeadNodeBlockPtr == NULL)
    { pHeadNodeBlockPtr = aNodeBlock;
    }
}
else
{
    lastNodePtr->nextNodeBlockPtr = aNodeBlock;
    aNodeBlock->lastNodeBlockPtr = lastNodePtr;
}

lastNodePtr = aNodeBlock;

return(aNodeBlock);
}

arseilleNewBoundaryNodeBlockF()
{
    int i;
    BOUNDARY_NODE_BLOCK *aBoundaryNodeBlockPtr;

    static
    PBOUNDARY_NODE_BLOCK lastBoundaryNodePtr;

    aBoundaryNodeBlockPtr = (PBOUNDARY_NODE_BLOCK)malloc(1,sizeof(BOUNDARY_NODE_BLOCK));

    aBoundaryNodeBlockPtr->lastBoundaryNodeBlockPtr = NULL;
    aBoundaryNodeBlockPtr->nextBoundaryNodeBlockPtr = NULL;
/* Set list ptrs */
if(pHeadBoundaryNodeBlockPtr == NULL)
{
pHeadBoundaryNodeBlockPtr = aBoundaryNodeBlockPtr;
}
else
{
 lastBoundaryNodePtr->nextBoundaryNodeBlockPtr = aBoundaryNodeBlockPtr;
 aBoundaryNodeBlockPtr->lastBoundaryNodeBlockPtr = lastBoundaryNodePtr;
}
lastBoundaryNodePtr = aBoundaryNodeBlockPtr;

return(aBoundaryNodeBlockPtr);

/*
ARC_BLOCK *allocateNewArcBlockF()
{
    int i;
    ARC_BLOCK *aArcBlock;

    static
    PARC_BLOCK lastArcPtr;

    aArcBlock = (PARC_BLOCK)calloc(1,sizeof(ARC_BLOCK) );
    aArcBlock->pLastArcBlockPtr = NULL;
    aArcBlock->pNextArcBlockPtr = NULL;
*/
aArcBlock->arcId = ++globalArcCount;

aArcBlock->adjacentColumn[0] = -1;
aArcBlock->adjacentColumn[1] = -1;

/* Set list ptrs */

if(pHeadArcListBlockPtr == NULL)
{
    pHeadArcListBlockPtr = aArcBlock;
}
else
{
    lastArcPtr->pNextArcBlockPtr = aArcBlock;
    aArcBlock->pLastArcBlockPtr = lastArcPtr;
}

lastArcPtr = aArcBlock;

return(aArcBlock);
}

/*****************************/

ELEMENT_BLOCK *allocateNewElementBlockF()
{
    int i;
    ELEMENT_BLOCK *anElementBlockPtr;

    static ELEMENT_BLOCK *lastElementPtr;

    ...
anElementBlockPtr = (PELEMENT_BLOCK) calloc(1,sizeof(ELEMENT_BLOCK));

anElementBlockPtr->pLastElementBlockPtr = NULL;
anElementBlockPtr->pNextElementBlockPtr = NULL;
anElementBlockPtr->elementAbovePtr=NULL;
anElementBlock.Ptr->elementBelowPtr=NULL;

for(i=0; i<6; i++)
anElementBlockPtr->faceId[i] = -1;

globalElementCount++;

anElementBlockPtr->elementId= globalElementCount;

/* Set list ptrs */

if(pHeadElementListBlockPtr == NULL)
{ pHeadElementListBlockPtr = anElementBlockPtr;
  lastElementPtr = anElementBlockPtr;
}
else
{ lastElementPtr->pNextElementBlockPtr = anElementBlockPtr;
anElementBlockPtr->pLastElementBlockPtr = lastElementPtr;
  lastElementPtr = anElementBlockPtr;
}

return(anElementBlockPtr);
COLUMN_BLOCK *allocateNewColumnBlockF()
{

int i;
COLUMN_BLOCK *aColumnBlockPtr;

static
PCOLUMN_BLOCK lastColumnPtr;

aColumnBlockPtr = (PCOLUMN_BLOCK)calloc(1,sizeof(COLUMN_BLOCK));

aColumnBlockPtr->pLastColumnBlockPtr = NULL;
aColumnBlockPtr->pNextColumnBlockPtr = NULL;
aColumnBlockPtr->columnId = ++globalColumnCount;
aColumnBlockPtr->commonNeighborColumnCount = 0;

for(i=0; i<4; i++)
{   aColumnBlockPtr->commonNeighborColumnId[i] = -1;
aColumnBlockPtr->commonNeighborArcId[i] = -1;
aColumnBlockPtr->commonNeighbor2ColumnId[i] = -1;
}

/>* Set list ptrs */
if(pHeadColumnListBlockPtr == NULL)
{
    pHeadColumnListBlockPtr = aColumnBlockPtr;
}
else
{
    lastColumnPtr->pNextColumnBlockPtr = aColumnBlockPtr;
    aColumnBlockPtr->pLastColumnBlockPtr = lastColumnPtr;
}

lastColumnPtr = aColumnBlockPtr;
return(aColumnBlockPtr);

FLOWFACE_BLOCK *allocateNewFlowFaceBlockF()
{
    int i;
    FLOWFACE_BLOCK *aFlowFaceBlockPtr;

    static
    PFLOWFACE_BLOCK lastFlowFacePtr;

    aFlowFaceBlockPtr = (PFLOWFACE_BLOCK)calloc(1,sizeof(FLOWFACE_BLOCK) );
    aFlowFaceBlockPtr->pLastFlowFaceBlockPtr = NULL;
    aFlowFaceBlockPtr->pNextFlowFaceBlockPtr = NULL;
    aFlowFaceBlockPtr->arcPtr = NULL;
aFlowFaceBlockPtr->flowFaceId = ++globalFlowFaceCount;

aFlowFaceBlockPtr->adjacentColumn[0] = -1;
aFlowFaceBlockPtr->adjacentColumn[1] = -1;

aFlowFaceBlockPtr->adjacentElement[0] = -1;
aFlowFaceBlockPtr->adjacentElement[1] = -1;

/* Set list ptrs */

if(pHeadFlowFaceListBlockPtr == NULL)
{
    pHeadFlowFaceListBlockPtr = aFlowFaceBlockPtr;
}
else
{
    lastFlowFacePtr->pNextFlowFaceBlockPtr = aFlowFaceBlockPtr;
    aFlowFaceBlockPtr->pLastFlowFaceBlockPtr = lastFlowFacePtr;
}

lastFlowFacePtr = aFlowFaceBlockPtr;

return(aFlowFaceBlockPtr);

void calculateCentroidOfGeneralizedTriangle(x,y,cList)
    float x[3], y[3];
    float *cList;

{ float A, d, e;
 float x1,y1, x2,y2, x3,y3;
 float z1, z2, z3;

 /* First calculate arc midpoint locations */

 x1 = (x[1]+x[2]) / 2.0;
 y1 = (y[1]+y[2]) / 2.0;

 x2 = (x[2]+x[3]) / 2.0;
 y2 = (y[2]+y[3]) / 2.0;

 x3 = (x[3]+x[1]) / 2.0;
 y3 = (y[3]+y[1]) / 2.0;

 A = (x2*y3 - x3*y2) -(x1*y3 - x3*y1) + (x1*y2 - x2*y1);
 z1 = x1*x1 + y1*y1;
 z2 = x2*x2 + y2*y2;
 z3 = x3*x3 + y3*y3;

d = (z1*y3 - z1*y2 - z2*y3 + z2*y1 + z3*y2 - z3*y1) / (-2.0*A);

e = (-z1*x3 + z1*x2 + z2*x3 - z2*x1 - z3*x2 + z3*x1) / (-2.0*A);

cList[0] = d; cList[1] = e;
}

/* ----------------------------------------------- */

void calculateColumnSurfaceAreaAndCentroid()
{  
  PCOLUMN_BLOCK columnPtr;
  PARC_BLOCK arcPtr;
  PNODE_BLOCK nodePtr;

  int arcId;
  int i, j, iTemp;
  int nodeIds[4];
  int nodeCount;
  float x[5], y[5];
  float area;
  int lastCornerNode;
  float centroidX, centroidY;
  float cList[2];

  int foundlt;

  int nodeIdList[13], nodeIdListCount;

  columnPtr = pHeadColumnListBlockPtr;

  while(columnPtr != NULL)
  {
    nodeCount = 0;
    /* Each column has 4 potential arcs */

    nodeIdListCount = 0;

    for(i=0; i<4; i++)
if (columnPtr->arcIds[i] < 1) continue;
arcId = columnPtr->arcIds[i];
arcPtr = findArcPtrF(arcId);

/* Check if arc already encountered */
foundlt = NO;
for (j = 0; j < nodeldListCount; j++)
if (arcPtr->nodeld[0] == nodeldList[j])
    foundlt = YES;
if (foundlt == NO)
    nodeldList[nodeldListCount++] = arcPtr->nodeld[0];

foundlt = NO;
for (j = 0; j < nodeldListCount; j++)
if (arcPtr->nodeld[2] == nodeldList[j])
    foundlt = YES;
if (foundlt == NO)
    nodeldList[nodeldListCount++] = arcPtr->nodeld[2];

nodeCount = nodeldListCount;
for (i = 0; i < nodeldListCount; i++)
    nodelds[i] = nodeldList[i];

/* Now get coors of these nodes */
for (i = 1; i <= nodeCount; i++)
    { nodePtr = findNodePtrF(nodelds[i-1]);
x[i] = nodePtr->coordinates[0];
y[i] = nodePtr->coordinates[1];
}

/ * Check if type of element */
switch(nodeCount)
{
  case 3:
    calculateCentroidOfGeneralizedTriangle(x,y,cList);
    centroidX = cList[0];
    centroidY = cList[1];
    break;

  case 4:
    break;
}

columnPtr->surfaceArea = area;

columnPtr->centroidX = centroidX;
columnPtr->centroidY = centroidY;
columnPtr = columnPtr->pNextColumnBlockPtr;

/**
* float calculate_BI_F(PFLOWFACE_BLOCK flowFacePtr)
*
* PELEMENT_BLOCK  downstreamElementPtr, upstreamElementPtr;
* int               downstreamElementId, upstreamElementId;
* PCOLUMN_BLOCK     upstreamColumnPtr, downstreamColumnPtr;
* int               downstreamColumnId, upstreamColumnId;
* float             x, y, x1, y1, x2, y2;
* double            d2;
* float             d;
*
* upstreamElementId = flowFacePtr->upstreamElementId;
* upstreamElementPtr = lookupElementPtrF(upstreamElementId);
* if(upstreamElementPtr != NULL)
* {
*     upstreamColumnId = upstreamElementPtr->columnId;
*     upstreamColumnPtr = lookupColumnPtrF(upstreamColumnId);
* }
else
    upstreamColumnPtr = NULL;

downstreamElementId = flowFacePtr->downstreamElementId;
downstreamElementPtr = lookupElementPtrF(downstreamElementId);
if(downstreamElementPtr != NULL)
    {
        downstreamColumnId = downstreamElementPtr->columnId;
        downstreamColumnPtr = lookupColumnPtrF(downstreamColumnId);
    }
else
    downstreamColumnPtr = NULL;

if( (upstreamColumnPtr != NULL) && (downstreamColumnPtr != NULL) )
    {
        x1 = upstreamColumnPtr->centroidX;
        y1 = upstreamColumnPtr->centroidY;

        x2 = downstreamColumnPtr->centroidX;
        y2 = downstreamColumnPtr->centroidY;

        d2 = (x1-x2)*(x1-x2) + (y1-y2)*(y1-y2);
        d2 = sqrt(d2);

        d = d2;
    }
else
    d = 0.0;
return(d);
/* ____________________________________________________________________ */

float
calculate_BID_F( PFLOWFACE_BLOCK flowFacePtr )
{

PELEMENT_BLOCK              downstreamElementPtr, upstreamElementPtr;
int                      downstreamElementId, upstreamElementId;

PELEMENT_BLOCK              farDownstreamElementPtr, farUpstreamElementPtr;
int                      farDownstreamElementId, farUpstreamElementId;

PCOLUMN_BLOCK              downstreamColumnPtr, upstreamColumnPtr;
int                      downstreamColumnId, upstreamColumnId;

PCOLUMN_BLOCK              farDownstreamColumnPtr, farUpstreamColumnPtr;
int                      farDownstreamColumnId, farUpstreamColumnId;

float          x, y, x1, y1, x2, y2, xA1, yA1, xA2, yA2;
PARC_BLOCK        arcPtr;

int              lineType;

PNODE_BLOCK      node1Ptr, node2Ptr;

int              node1, node2;

float          mCentroid, yIntCentroid;
float          m1, m2, b1, b2, d;
float          xBar, yBar;
double          d2;
float          TOLERANCE = 0.001;
d = 0.0;

upstreamElementId = flowFacePtr->upstreamElementId;
upstreamElementPtr = lookupElementPtrF(upstreamElementId);
if(upstreamElementPtr != NULL)
{
    upstreamColumnId = upstreamElementPtr->columnId;
    upstreamColumnPtr = lookupColumnPtrF(upstreamColumnId);
}
else
upstreamColumnPtr = NULL;

downstreamElementId = flowFacePtr->downstreamElementId;
downstreamElementPtr = lookupElementPtrF(downstreamElementId);
if(downstreamElementPtr != NULL)
{
    downstreamColumnId = downstreamElementPtr->columnId;
    downstreamColumnPtr = lookupColumnPtrF(downstreamColumnId);
}
else
downstreamColumnPtr = NULL;

if( (flowFacePtr != NULL) && (upstreamColumnPtr == NULL) )
{
    arcPtr = flowFacePtr->arcPtr;
    node1 = arcPtr->nodeId[0];
    node2 = arcPtr->nodeId[2];

    node1Ptr = findNodePtrF(node1);
xA1 = node1Ptr->coordinates[0];
yA1 = node1Ptr->coordinates[1];
node2Ptr = findNodePtrF(node2);
xA2 = node2Ptr->coordinates[0];
yA2 = node2Ptr->coordinates[1];
x1 = (xA1 + xA2) / 2.0;
y1 = (yA1 + yA2) / 2.0;

x2 = downstreamColumnPtr->centroidX;
y2 = downstreamColumnPtr->centroidY;

d2 = (x1-x2)*(x1-x2) + (y1-y2)*(y1-y2);
d2 = sqrt(d2);
d = d2;
return(d);
}

if( (flowFacePtr != NULL) && (downstreamColumnPtr != NULL) )
{
    x1 = upstreamColumnPtr->centroidX;
y1 = upstreamColumnPtr->centroidY;
x2 = downstreamColumnPtr->centroidX;
y2 = downstreamColumnPtr->centroidY;

    /* Set line type */
    if( (y2-y1) < TOLERANCE )
        lineType = HORIZONTAL;
    else
        if( (x2-x1) < TOLERANCE )
            lineType = VERTICAL;
else
    lineType = INBETWEEN;

switch(lineType)
{ case HORIZONTAL:
    arcPtr = flowFacePtr->arcPtr;
    node1 = arcPtr->nodeId[0];
    node2 = arcPtr->nodeId[2];

    node1Ptr = findNodePtrF(node1);
    xA1 = node1Ptr->coordinates[0];
    yA1 = node1Ptr->coordinates[1];

    node2Ptr = findNodePtrF(node2);
    xA2 = node2Ptr->coordinates[0];
    yA2 = node2Ptr->coordinates[1];

    xBar = (xA1 + xA2) / 2.0;
    yBar = (yA1 + yA2) / 2.0;

    d2 = xBar - x2;
    if( d2 < 0.0) d2 = -d2;

    d = d2;
    break;

case VERTICAL:
    arcPtr = flowFacePtr->arcPtr;
    node1 = arcPtr->nodeId[0];
    node2 = arcPtr->nodeId[2];
node1Ptr = findNodePtrF(node1);
xA1 = node1Ptr->coordinates[0];
yA1 = node1Ptr->coordinates[1];

node2Ptr = findNodePtrF(node2);
xA2 = node2Ptr->coordinates[0];
yA2 = node2Ptr->coordinates[1];

xBar = (xA1 + xA2) / 2.0;
yBar = (yA1 + yA2) / 2.0;

d2 = yBar - y2;
if( d2 < 0.0) d2 = -d2;

d = d2;
break;

case IN BETWEEN:

m1 = (x2-x1) / (y2-y1);
b1 = y1-m1*x1;

/* Calculate equation of arc */
arcPtr = flowFacePtr->arcPtr;
node1 = arcPtr->nodeId[0];
node2 = arcPtr->nodeId[2];

node1Ptr = findNodePtrF(node1);
xA1 = node1Ptr->coordinates[0];
yA1 = node1Ptr->coordinates[1];
node2Ptr = findNodePtrF(node2);
xA2 = node2Ptr->coordinates[0];
yA2 = node2Ptr->coordinates[1];

m2 = (xA2-xA1) / (yA2-yA1);
b2 = yA1-m2*xA1;

/* Calculate intersection location of the two lines */

x = (b2-b1) / (m1-m2);
y = (m1*b2 - m2*b1) / (m1-m2);

d2 = (x-x2)*(x-x2) + (y-y2)*(y-y2);
d2 = sqrt(d2);
d = d2;
break;
}

return(d);
}
/* */

float calculate_BIL_F( PFLOWFACE_BLOCK flowFacePtr )
{

PELEMENT_BLOCK      upstreamElementPtr;
int                 upstreamElementId;

PCOLUMN_BLOCK       upstreamColumnPtr;
int                 upstreamColumnId;

PELEMENT_BLOCK      farUpstreamElementPtr;
int                 farUpstreamElementId;

PCOLUMN_BLOCK       farUpstreamColumnPtr;
int                 farUpstreamColumnId;

float               x1,y1, x2,y2;
float               d;
double              d2;

upstreamElementId = flowFacePtr->upstreamElementId;
upstreamElementPtr = lookupElementPtrF(upstreamElementId);
if(upstreamElementPtr != NULL)
{
    upstreamColumnId = upstreamElementPtr->columnId;
    upstreamColumnPtr = lookupColumnPtrF(upstreamColumnId);
}
else
    upstreamColumnPtr = NULL;

farUpstreamElementId = flowFacePtr->farUpstreamElementId;
farUpstreamElementPtr = lookupElementPtrF(farUpstreamElementId);
if( (upstreamColumnPtr != NULL) && (farUpstreamElementPtr != NULL) )
farUpstreamColumnId = farUpstreamElementPtr->columnId;
farUpstreamColumnPtr = lookupColumnPtrF(farUpstreamColumnId);

x1 = upstreamColumnPtr->centroidX;
y1 = upstreamColumnPtr->centroidY;

x2 = farUpstreamColumnPtr->centroidX;
y2 = farUpstreamColumnPtr->centroidY;

d2 = (x1-x2)*(x1-x2) + (y1-y2)*(y1-y2);
d2 = sqrt(d2);
d = d2;

else
d = 0.0;

return(d);

}/*

float calculate_BIR_F( PFLOWFACE_BLOCK flowFacePtr )

{PELEMENT_BLOCK  downstreamElementPtr;
 int        downstreamElementId;
PCOLUMN_BLOCK  downstreamColumnPtr;
 int        downstreamColumnId;*/
PELEMENT_BLOCK farDownstreamElementPtr;
int farDownstreamElementId;

PCOLUMN_BLOCK farDownstreamColumnPtr;
int farDownstreamColumnId;

float x1,y1, x2,y2;
float d;
double d2;

downstreamElementId = flowFacePtr->downstreamElementId;
downstreamElementPtr = lookupElementPtrF(downstreamElementId);
if(downstreamElementPtr != NULL)
{
    downstreamColumnId = downstreamElementPtr->columnId;
    downstreamColumnPtr = lookupColumnPtrF(downstreamColumnId);
}
else
    downstreamColumnPtr = NULL;

farDownstreamElementId = flowFacePtr->farDownstreamElementId;
farDownstreamElementPtr = lookupElementPtrF(farDownstreamElementId);
if( (downstreamColumnPtr != NULL) && (farDownstreamElementPtr != NULL) )
{
    farDownstreamColumnId = farDownstreamElementPtr->columnId;
    farDownstreamColumnPtr = lookupColumnPtrF(farDownstreamColumnId);
    x1 = downstreamColumnPtr->centroidX;
    y1 = downstreamColumnPtr->centroidY;
x2 = farDownstreamColumnPtr->centroidX;
y2 = farDownstreamColumnPtr->centroidY;

d2 = (x1-x2)*(x1-x2) + (y1-y2)*(y1-y2);
d2 = sqrt(d2);

d = d2;
} else
d = 0.0;

return(d);
}

/* ______________________________________________________________ */

void calculateDistanceBetweenCentroidsF()
{

FLOWFACE_BLOCK  *flowFacePtr;

    /* Examine each cell face and calculate the required distances */

flowFacePtr = pHeadFlowFaceListBlockPtr;

while( (flowFacePtr != NULL) && (flowFacePtr->orientation == HORIZONTAL) )
if (flowFacePtr->type == INTERNAL) || (flowFacePtr->type == BOUNDARY) )
{

    /* BIL = Distance between farUpstreamElement centroid and upstreamElement centroid. */
    BIL = Distance between farUpstreamElement centroid and upstreamElement centroid.

    BI = Distance between upstreamElement centroid and the downstreamElement centroid.

    BIR = Distance between downstreamElement centroid and farDownstreamElement centroid.

    BID = Distance between flowface and the downstreamElement. */

    /* Calculate BI! */

    flowFacePtr->distanceBetweenCentroids =
    calculate_BI_F(flowFacePtr);

    /* Calculate BID! */

    flowFacePtr->downstreamDistanceBetweenCentroidAndFace =
    calculate_BID_F(flowFacePtr);

    /* Calculate BIL! */
flowFacePtr->distanceBetweenUpstreamCentroids = calculate_BIL_F(flowFacePtr);

    /* Calculate BIR! */

    flowFacePtr->distanceBetweenDownstreamCentroids = calculate_BIR_F(flowFacePtr);

    } /* Go to next flow face */

    flowFacePtr = flowFacePtr->pNextFlowFaceBlockPtr;

    }

/* */

int iCheckIfTwoListsAreTheSameF(int listA[3], int listB[3])
{
    int i,j;
    int list1[3], list2[3];
    int tempInt;

    for(i=0; i<3; i++)
    list1[i] = listA[i];
/* Sort list1 */

for(i=0; i<3; i++)
for(j=i+1; j<3; j++)
if(list1[i] > list1[j])
{ tempInt = list1[i];
  list1[i] = list1[j];
  list1[j] = tempInt;
}

for(i=0; i<3; i++)
list2[i] = listB[i];

/* Sort list2 */

for(i=0; i<3; i++)
for(j=i+1; j<3; j++)
if(list2[i] > list2[j])
{ tempInt = list2[i];
  list2[i] = list2[j];
  list2[j] = tempInt;
}

if(list1[0] == list2[0]) && (list1[1] == list2[1]) && (list1[2] == list2[2])
return(TRUE);
else
return(FALSE);

PARC_BLOCK checkIfArcExistsF( int list[3] )
ARC_BLOCK    *arcPtr;
int numbersAreTheSame;
int i;

arcPtr = pHeadArcListBlockPtr;

while(arcPtr != NULL)
{
    for(i=0; i<3; i++)
    {
        numbersAreTheSame = iCheckIfTwoListsAreTheSameF(&arcPtr->nodeId[0],list);
        if(numbersAreTheSame)
        {
            return(arcPtr);
        }
    }
    arcPtr = arcPtr->pNextArcBlockPtr;
}

return(NULL);

void readElementConnectionFile()
{
    FILE *inputf;
    char dummyStr[80];
    COLUMN_BLOCK *currentColumnPtr;
NODE_BLOCK *currentNodePtr;
int i, lineType;
int arcCount;
int nodeInArc[3];
ARC_BLOCK *arcPtr;
int numberOfNodesInCell;
int nodeList[20];
int index;

/* Open the element to node connection table file */
inputf = fopen("r102.geo", "r");
if (inputf == NULL) {
    printf("Unable to open 'r102.geo'n");
    exit(0);
}

/* Read till end of file */
while(1) {
    fscanf(inputf,"%s", dummyStr);
    /* fofe returns a nonzero (TRUE) value after the FIRST read BEYOND the end of file! */
    if (feof(inputf)) break;

    lineType = OTHERSTUFF;
    /* strcmp returns 0 if args same */
    if( !strcmp(dummyStr,"GE") )
        lineType = GE;
    else
{ if( !strcmp(dummyStr, "GNN") )
    lineType = GNN;
}

switch(lineType)
{
    case GE:
        /* Note that we will number our elements as they are numbered in RMA10 for the surface layer. So we read the element ID from the connection file. */

        currentColumnPtr = allocateNewColumnBlockF();
        currentColumnPtr->numberOfLayers = NUMBER_OF_LAYERS;
        fscanf(inputf, "%d", &currentColumnPtr->columnId);
        for(i=0; i<8; i++)
            fscanf(inputf, "%d", &nodeList[i]);
        numberOfNodesInCell = 0;
        for(i=0; i<8; i++)
            if(nodeList[i] != 0)
                numberOfNodesInCell++;
        /* Repeat first node Id as last node */
        nodeList[numberOfNodesInCell] = nodeList[0];

        if(numberOfNodesInCell == 8)
        {
            currentColumnPtr->columnType = TRAPAZOID;
        }
currentColumnPtr->arcCount = 4;
}
else
    if(numberOfNodesInCell == 6)
        { currentColumnPtr->columnType = TRIANGLE;
          currentColumnPtr->arcCount = 3;
        }

switch(currentColumnPtr->columnType)
{
    case TRAPAZOID:
        
        index = 0;
        for(arcCount=0; arcCount<4; arcCount++)
        {
            for(i=0; i<3; i++)
            {
                if(i != 0) index++;
                nodeInArc[i] = nodeList[index];
            }

            arcPtr = checkIfArcExistsF( nodeInArc );

            if(arcPtr == NULL)
                { arcPtr = allocateNewArcBlockF();
                  arcPtr->nodeId[0] = nodeInArc[0];
                  arcPtr->nodeId[1] = nodeInArc[1];
                  arcPtr->nodeId[2] = nodeInArc[2];
                }

            currentColumnPtr->arcIds[arcCount] = arcPtr->arcId;
        }

    break;
case TRIANGLE:

    index = 0;
    for(arcCount=0; arcCount<3; arcCount++)
    {
        for(i=0; i<3; i++)
        {
            if(i != 0) index++;
            nodeInArc[i] = nodeList[index];
        }

        arcPtr = checkIfArcExistsF(nodeInArc);

        if(arcPtr == NULL)
        {
            arcPtr = allocateNewArcBlockF();
            arcPtr->nodeId[0] = nodeInArc[0];
            arcPtr->nodeId[1] = nodeInArc[1];
            arcPtr->nodeId[2] = nodeInArc[2];
        }

        currentColumnPtr->arcIds[arcCount] = arcPtr->arcId;
    }
    break;

break;
case GNN:

    /* Note that we will number our
     * nodes as they are numbered
     * in RMA10. So we read the node
     * id from the connection file. */

    currentNodePtr = allocateNewNodeBlockF();
    fscanf(inputf, "%d", &currentNodePtr->nodeId);
    for(i=0; i<3; i++)
        fscanf(inputf, "%f", &currentNodePtr->coordinates[i]);
    break;

fclose(inputf);
}

void

mapColumnsToArcs()
{

PCOLUMN_BLOCK columnPtr;
PARC_BLOCK arcPtr;
int arcId;
int i, iTemp;

columnPtr = pHeadColumnListBlockPtr;

while(columnPtr != NULL)
{
    /* Each column has 4 potential arcs */
    for(i=0; i<columnPtr->arcCount; i++)
    {
        if(columnPtr->arcIds[i] < 1) continue;
        arcId = columnPtr->arcIds[i];
        arcPtr = findArcPtrF(arcId);

        /* Set so the smaller column id is the
         * first in adjacent column list */

        if(arcPtr->adjacentColumn[1] == -1)
        {
            arcPtr->adjacentColumn[1] = columnPtr->columnId;
        }
        else
        {
            if(columnPtr->columnId > arcPtr->adjacentColumn[1])
            {
                arcPtr->adjacentColumn[0] = arcPtr->adjacentColumn[1];
                arcPtr->adjacentColumn[1] = columnPtr->columnId;
            }
            else
            { ...}}
arcPtr->adjacentColumn[0] = columnPtr->columnId;
}
}
columnPtr = columnPtr->pNextColumnBlockPtr;
}
}

/*
 * ____________________________________________________________________ */

int searchColumnListForNamedArc(PCOLUMN_BLOCK columnPtr,
   int arcId)
{
   PCOLUMN_BLOCK columnPtr2;
   int i, foundIt;

   columnPtr2 = pHeadColumnListBlockPtr;
   while( columnPtr2 != NULL)
   {
      if(columnPtr2 == columnPtr)
      { columnPtr2 = columnPtr2->pNextColumnBlockPtr;
         continue;
      }
   }
foundlt = FALSE;

for(i=0; i<columnPtr2->arcCount; i++)
{ if(columnPtr2->arcIds[i] == arcId)
  foundlt = TRUE;
}

if( foundlt )
  return(columnPtr2->columnId);

columnPtr2 = columnPtr2->pNextColumnBlockPtr;
}

return(-1);

/* _____________________________________________________________ */

int iCheckIfArcIsAFlowBoundaryF(PARC_BLOCK arcPtr)
{

  PBOUNDARY_NODE_BLOCK  boundaryNodePtr;
  int nodeld, i;
  int foundlt;

  for(i=0; i<3; i++)
  { boundaryNodePtr = pHeadBoundaryNodeBlockPtr;

foundIt = NO;

while( boundaryNodePtr != NULL)
{ nodeId = arcPtr->nodeId[i];
  if(boundaryNodePtr->boundaryNodeId == nodeId)
  { foundIt = YES;
    break;
  }

  boundaryNodePtr = boundaryNodePtr->nextBoundaryNodeBlockPtr;
}

if(foundIt == NO)
return(NO);

return(YES);

/* ______________________________________________________________ */

void determineArcTypeF()
{
  PARC_BLOCK arcPtr;
  int result;

  arcPtr = pHeadArcListBlockPtr;

  while(arcPtr != NULL)
  { if((arcPtr->adjacentColumn[0] != -1) && (arcPtr->adjacentColumn[1] != -1))
    arcPtr->type = INTERNAL;
else
    { result = iCheckIfArcIsAFlowBoundaryF(arcPtr);
      if(result == YES)
        arcPtr->type = BOUNDARY;
      else
        arcPtr->type = WALL;
    }
arcPtr = arcPtr->pNextArcBlockPtr;
}

void
mapNeighborColumnsForEachColumn()
{
  print("applicability: ", arcCount, arcId);
  int arcCount, arcId;
  int otherColumnId;
  int i, first, second, third;

  columnPtr = pHeadColumnListBlockPtr;
  while(columnPtr != NULL)
    { for( arcCount=0; arcCount<columnPtr->arcCount; arcCount++)
{ arcId = columnPtr->arcIds[arcCount];

otherColumnId = searchColumnListForNamedArc( columnPtr, arcId );

if(otherColumnId > 0)
{ columnPtr->commonNeighborColumnId[columnPtr->commonNeighborColumnCount] = otherColumnId;
  columnPtr->commonNeighborArcId[columnPtr->commonNeighborColumnCount++] = arcId;
}

columnPtr = columnPtr->pNextColumnBlockPtr;

} /*
 * \end{verbatim}
 */

int iCheckIfCommonNodeInTwoArcsF(PARC_BLOCK arcPtr1, PARC_BLOCK arcPtr2)
{
  int i;

  for(i=0; i<3; i++)
    if( (arcPtr1->nodeId[i] == arcPtr2->nodeId[0])
      ||
      (arcPtr1->nodeId[i] == arcPtr2->nodeId[1])
      ||
      (arcPtr1->nodeId[i] == arcPtr2->nodeId[2]) )
      return(YES);
    return(NO);
}
PARC_BLOCK
findOppositeArcInAColumnF(int columnId, int arcId)
{
    PCOLUMN_BLOCK columnPtr;
    PARC_BLOCK arcPtr, arcPtr2, arcPtr3;
    int nodeId, nodeId2, nodeId3;
    PNODE_BLOCK nodePtr, nodePtr2, nodePtr3;
    int i, result;
    int foundOppositeArc;
    int arcId2;
    float x1, y1, x2, y2;
    double dd;
    float d2, d3;

    columnPtr = lookupColumnPtrF(columnId);

    switch(columnPtr->columnType)
    {
    case TRAPAZOID:
        arcPtr = findArcPtrF(arcId);
        foundOppositeArc = NO;
        for(i=0; i<4; i++)
        {
            arcId2 = columnPtr->arcIds[i];
            if( arcId != arcId2)
            {
                arcPtr2 = findArcPtrF(arcId2);

...
result = iCheckIfCommonNodeInTwoArcsF(arcPtr, arcPtr2);
if(result == NO)
{
    foundOppositeArc = YES;
    break;
}

if(foundOppositeArc == YES)
    return(arcPtr2);
else
    return(NULL);

break;

case TRIANGLE:
    arcPtr = findArcPtrF(arcId);

    for(i=0; i<3; i++)
        if(columnPtr->arcIds[i]) break;

    if(i == 0)
    {
        arcPtr2 = findArcPtrF(columnPtr->arcIds[1]);
        arcPtr3 = findArcPtrF(columnPtr->arcIds[2]);
    }
    else
    if(i == 1)
    {
        arcPtr2 = findArcPtrF(columnPtr->arcIds[0]);
        arcPtr3 = findArcPtrF(columnPtr->arcIds[2]);
    }
    else
    if(i == 2)
\{ \text{arcPtr2} = \text{findArcPtrF} (\text{columnPtr} \rightarrow \text{arcIds}[0]); \\
\text{arcPtr3} = \text{findArcPtrF} (\text{columnPtr} \rightarrow \text{arcIds}[1]); \\
\}

\text{nodeld} = \text{arcPtr} \rightarrow \text{nodeld}[1]; \\
\text{nodeld2} = \text{arcPtr2} \rightarrow \text{nodeld}[1]; \\
\text{nodeld3} = \text{arcPtr3} \rightarrow \text{nodeld}[1]; \\

\text{nodePtr} = \text{findNodePtrF} (\text{nodeld}); \\
x_1 = \text{nodePtr} \rightarrow \text{coordinates}[0]; \\
y_1 = \text{nodePtr} \rightarrow \text{coordinates}[1]; \\

\text{nodePtr2} = \text{findNodePtrF} (\text{nodeld2}); \\
x_2 = \text{nodePtr2} \rightarrow \text{coordinates}[0]; \\
y_2 = \text{nodePtr2} \rightarrow \text{coordinates}[1]; \\

\text{dd} = (x_1 - x_2)^2 + (y_1 - y_2)^2; \\
dd = \sqrt{\text{dd}}; \\
d_2 = \text{dd}; \\

\text{nodePtr3} = \text{findNodePtrF} (\text{nodeld3}); \\
x_2 = \text{nodePtr3} \rightarrow \text{coordinates}[0]; \\
y_2 = \text{nodePtr3} \rightarrow \text{coordinates}[1]; \\

\text{dd} = (x_1 - x_2)^2 + (y_1 - y_2)^2; \\
dd = \sqrt{\text{dd}}; \\
d_3 = \text{dd}; \\

\text{if}(d_2 < d_3) \\
\text{\quad return} (\text{arcPtr2}); \\
\text{else} \\
\text{\quad return} (\text{arcPtr3});
return(NULL);
}

/* Catch-All */

void mapUpstreamAndDownstreamColumnsForEachColumnF()
{
    PCOLUMN_BLOCK columnPtr;
    int i, otherColumnId, otherArcId;
    PARC_BLOCK farArcPtr;

    columnPtr = pHeadColumnListBlockPtr;

    while(columnPtr != NULL)
    {
        for(i=0; i<columnPtr->arcCount; i++)
        {
            otherColumnId = columnPtr->commonNeighborColumnId[i];
            otherArcId = columnPtr->commonNeighborArcId[i];
            if(otherColumnId != -1)
            {
                farArcPtr = findOppositeArcInAColumnF(otherColumnId, otherArcId);
                if(farArcPtr->adjacentColumn[0] == otherColumnId)
                    columnPtr->commonNeighbor2ColumnId[i] = farArcPtr->adjacentColumn[1];
                else
                    columnPtr->commonNeighbor2ColumnId[i] = farArcPtr->adjacentColumn[0];
            }
            else
                columnPtr->commonNeighbor2ColumnId[i] = -1;
        }
    }
}
void createElementList()
{

ELEMENT_BLOCK *elementPtr;
ELEMENT_BLOCK *elementAbovePtr;
COLUMN_BLOCK *columnPtr;

int iMaximumNumberOfLayers;
int iCurrentCellLayerId;
int iNumberOfCells;
int i;
int lastElementId;

/* Determine maximum number of layers in column list */
iMaximumNumberOfLayers = 0;

columnPtr = pHeadColumnListBlockPtr;

while(columnPtr != NULL)
{
    if(columnPtr->numberOfLayers > iMaximumNumberOfLayers)
        iMaximumNumberOfLayers = columnPtr->numberOfLayers;

    columnPtr = columnPtr->pNextColumnBlockPtr;
}
/* Do surface layer first */

iCurrentCellLayerId = 1;
iNumberOfCells = 0;

/* Column IDs same as element IDs in surface layer. */

columnPtr = pHeadColumnListBlockPtr;

while(columnPtr != NULL)
{
    elementPtr = allocateNewElementBlockF();
    columnPtr->elementPtr = elementPtr;
    columnPtr->surfaceElementPtr = elementPtr;
    elementPtr->columnId = columnPtr->columnId;
    elementPtr->elementType = columnPtr->columnType;
    elementPtr->arcCount = columnPtr->arcCount;
    elementPtr->layerId = iCurrentCellLayerId;
    elementPtr->elementId = columnPtr->columnId;
    elementPtr->rma10ElementId = elementPtr->elementId;
    iNumberOfCells++;
    columnPtr = columnPtr->pNextColumnBlock.Ptr;
}

lastRma10ElementId = elementPtr->rma10ElementId;
for(iCurrentCellLayerId = 2; iCurrentCellLayerId <= iMaximumNumberOfLayers; iCurrentCellLayerId++)
{

columnPtr = pHeadColumnListBlockPtr;

while(columnPtr != NULL)
{
    if(iCurrentCellLayerId <= columnPtr->numberOfLayers)
    {
        elementPtr = allocateNewElementBlockF();

        elementPtr->columnId = columnPtr->columnId;
        elementPtr->elementType = columnPtr->elementType;
        elementPtr->arcCount = columnPtr->arcCount;
        elementAbovePtr = columnPtr->elementPtr;
        elementPtr->elementAbovePtr = elementAbovePtr;
        elementAbovePtr->elementBelowPtr = elementPtr;
        columnPtr->elementPtr = elementPtr;

        elementPtr->layerId = iCurrentCellLayerId;
        iNumberOfCells++;

        elementPtr->elementId = iNumberOfCells;
    }
}
}
columnPtr = columnPtr->pNextColumnBlockPtr;
}

columnPtr = pHeadColumnListBlockPtr;

while(columnPtr != NULL)
{
    elementPtr = columnPtr->surfaceElementPtr;
    while(elementPtr->elementBelowPtr != NULL)
    {
        elementPtr = elementPtr->elementBelowPtr;
    }
    while(elementPtr->elementAbovePtr != NULL)
    {
        elementPtr->rma10ElementId = ++lastRma10ElementId;
        elementPtr = elementPtr->elementAbovePtr;
    }
    columnPtr = columnPtr->pNextColumnBlockPtr;
}

void mapElementToNeighborElements()
/* Determine maximum number of layers in column list */

int iMaximumNumberOfLayers = 0;

columnPtr = pHeadColumnListBlockPtr;

while(columnPtr != NULL)
{
    if(columnPtr->numberOfLayers > iMaximumNumberOfLayers)
    {
        iMaximumNumberOfLayers = columnPtr->numberOfLayers;
        columnPtr = columnPtr->pNextColumnBlockPtr;
    }
    columnPtr = columnPtr->pNextColumnBlockPtr;
}

currentLayerId = 1;

while(currentLayerId <= iMaximumNumberOfLayers)
{
    columnPtr = pHeadColumnListBlockPtr;
}
while(columnPtr != NULL)
{
    elementPtr = columnPtr->surfaceElementPtr;

    while(elementPtr->layerId < currentLayerId)
        elementPtr = elementPtr->elementBelowPtr;

    if(elementPtr != NULL)
    {
        for(i=0; i<columnPtr->arcCount; i++)
        {
            otherColumnId = columnPtr->commonNeighborColumnId[i];
            if(otherColumnId != -1)
            {
                otherColumnPtr = lookupColumnPtrF(otherColumnId);
                otherElementPtr = otherColumnPtr->surfaceElementPtr;

                while(otherElementPtr->layerId < currentLayerId)
                    otherElementPtr = otherElementPtr->elementBelowPtr;

                if(otherElementPtr != NULL)
                    elementPtr->commonNeighborElementId[i] = otherElementPtr->elementId;
                else
                    elementPtr->commonNeighborElementId[i] = -1;
            }
        }

        farColumnId = columnPtr->commonNeighbor2ColumnId[i];
        if(farColumnId != -1)
        {
            farColumnPtr = lookupColumnPtrF(farColumnId);
            farElementPtr = farColumnPtr->surfaceElementPtr;

            while(farElementPtr->layerId < currentLayerId)
                farElementPtr = farElementPtr->elementBelowPtr;
        }
    }
}
if(farElementPtr != NULL)
    elementPtr->commonNeighbor2ElementId[i] = farElementPtr->elementId;
else
    elementPtr->commonNeighbor2ElementId[i] = -1;

    columnPtr = columnPtr->pNextColumnBlockPtr;
}

    currentLayerId++;
```c
int        result;
int        columnId;

/* Determine maximum number of layers in column list */

iMaximumNumberOfLayers = 0;

columnPtr = pHeadColumnListBlockPtr;

while(columnPtr != NULL) {
    if(columnPtr->numberOfLayers > iMaximumNumberOfLayers)
        iMaximumNumberOfLayers = columnPtr->numberOfLayers;

    columnPtr = columnPtr->pNextColumnBlockPtr;
}

currentLayerId = 1;

while(currentLayerId <= iMaximumNumberOfLayers) {
    arcPtr = pHeadArcListBlockPtr;

    while(arcPtr != NULL) {

        flowFacePtr = allocateNewFlowFaceBlockF();

        flowFacePtr->orientation = HORIZONTAL;

        flowFacePtr->layerId = currentLayerId;
```
flowFacePtr->arcPtr = arcPtr;

flowFacePtr->adjacentColumn[0] = arcPtr->adjacentColumn[0];
flowFacePtr->adjacentColumn[1] = arcPtr->adjacentColumn[1];

columnId = arcPtr->adjacentColumn[0];
if(columnId != -1)
{
  columnPtr = lookupColumnPtrF(columnId);
  elementPtr = columnPtr->surfaceElementPtr;

  while(elementPtr->layerId < currentLayerId)
  {
    elementPtr = elementPtr->elementBelowPtr;
  }

  if(elementPtr != NULL)
  {
    flowFacePtr->adjacentElement[0] = elementPtr->elementId;
  }
  else
  {
    flowFacePtr->adjacentElement[0] = -1;
  }
}

columnId = arcPtr->adjacentColumn[1];
if(columnId != -1)
{
  columnPtr = lookupColumnPtrF(columnId);
  elementPtr = columnPtr->surfaceElementPtr;

  while(elementPtr->layerId < currentLayerId)
  {
    elementPtr = elementPtr->elementBelowPtr;
  }

  if(elementPtr != NULL)
  {
    flowFacePtr->adjacentElement[1] = elementPtr->elementId;
  }
  else
  {
    flowFacePtr->adjacentElement[1] = -1;
  }
}
switch(arcPtr->type)
case INTERNAL:
    flowFacePtr->type = INTERNAL;
    break;

case BOUNDARY:
    flowFacePtr->type = BOUNDARY;
    break;

case WALL:
    flowFacePtr->type = WALL;
    break;
}

arcPtr = arcPtr->pNextArcBlockPtr;
}
currentLayerId++;
}

void mapHorizontalFlowFaces()
{
    PELEMENT_BLOCK elementPtr;
    PFLOWFACE_BLOCK flowFacePtr;
    PARC_BLOCK arcPtr, oppositeArcPtr;
}
int foundIt, i;
int targetElementId;

int leftElementId, rightElementId;
PELEMENT_BLOCK leftElementPtr, rightElementPtr;
int leftColumnId, rightColumnId;
int farLeftColumnId, farRightColumnId;
PCOLUMN_BLOCK farLeftColumnPtr, farRightColumnPtr;
PELEMENT_BLOCK farElementPtr;
int farLeftElementId, farRightElementId;

flowFacePtr = pHeadFlowFaceListBlockPtr;

while(flowFacePtr != NULL)
{
    switch(flowFacePtr->type)
    {
        case INTERNAL:
        {
            leftElementId = flowFacePtr->adjacentElement[0];
            rightElementId = flowFacePtr->adjacentElement[1];

            flowFacePtr->upstreamElementId = leftElementId;
            flowFacePtr->downstreamElementId = rightElementId;

            leftElementPtr = lookupElementPtrF(leftElementId);

            foundIt = NO;
            for(i=0; i<leftElementPtr->arcCount; i++)
            {
                targetElementId = leftElementPtr->commonNeighborElementId[i];
                if(targetElementId == rightElementId)
                { foundIt = YES;
                  break;
                }
if(foundlt == YES)
{
    flowFacePtr->farDownstreamElementId =
        leftElementPtr->commonNeighbor2ElementId[i];
}
else
    flowFacePtr->farDownstreamElementId = -1;

rightElementPtr = lookupElementPtrF(rightElementId);

foundlt = NO;
for(i=0; i<rightElementPtr->arcCount; i++)
{
    targetElementId = rightElementPtr->commonNeighborElementId[i];
    if(targetElementId == leftElementId)
    {
        foundlt = YES;
        break;
    }
}

if(foundlt == YES)
{
    flowFacePtr->farUpstreamElementId =
        rightElementPtr->commonNeighbor2ElementId[i];
}
else
    flowFacePtr->farUpstreamElementId = -1;

break;
case BOUNDARY:
    leftElementId = flowFacePtr->adjacentElement[0];
    rightElementId = flowFacePtr->adjacentElement[1];

    flowFacePtr->upstreamElementId = leftElementId;
    flowFacePtr->downstreamElementId = rightElementId;

    if(leftElementId == -1)
    {
        flowFacePtr->farUpstreamElementId = -1;
    }
    else
    { arcPtr = flowFacePtr->arcPtr;

        leftElementPtr = lookupElementPtrF(leftElementId);
        leftColumnId = leftElementPtr->columnId;

        oppositeArcPtr = findOppositeArcInAColumnF(leftColumnId, arcPtr->arcId);
        if(oppositeArcPtr->adjacentColumn[0] == leftColumnId)
        farLeftColumnId = oppositeArcPtr->adjacentColumn[l];
        else
        farLeftColumnId = oppositeArcPtr->adjacentColumn[0];

        farLeftColumnPtr = lookupColumnPtrF(farLeftColumnId);
        farElementPtr = farLeftColumnPtr->surfaceElementPtr;

        while(farElementPtr->layerId < leftElementPtr->layerId)
        farElementPtr = farElementPtr->elementBelowPtr;

        if(farElementPtr != NULL)
        farLeftElementId = farElementPtr->elementId;
        else
        farLeftElementId = -1;

        flowFacePtr->farUpstreamElementId = farLeftElementId;
if(rightElementId == -1)
    flowFacePtr->farDownstreamElementId = -1;
else
    { arcPtr = flowFacePtr->arcPtr;

    rightElementPtr = lookupElementPtrF(rightElementId);
    rightColumnId = rightElementPtr->columnId;

    oppositeArcPtr = findOppositeArcInAColumnF(rightColumnId, arcPtr->arcId);

    if(oppositeArcPtr->adjacentColumn[0] == rightColumnId)
        farRightColumnId = oppositeArcPtr->adjacentColumn[1];
    else
        farRightColumnId = oppositeArcPtr->adjacentColumn[0];

    farRightColumnPtr = lookupColumnPtrF(farRightColumnId);
    farElementPtr = farRightColumnPtr->surfaceElementPtr;

    while(farElementPtr->layerId < rightElementId->layerId)
        farElementPtr = farElementPtr->elementBelowPtr;

    if(farElementPtr != NULL)
        farRightElementId = farElementPtr->elementId;
    else
        farRightElementId = -1;

    flowFacePtr->farDownstreamElementId = farRightElementId;
    }
break;
case WALL:
    break;
}

flowFacePtr = flowFacePtr->pNextFlowFaceBlockPtr;
}
}

/* ___________________________ */

void mapVerticalFlowFaces()
{
    PELEMENT_BLOCK elementPtr;
    PFLOWFACE_BLOCK flowFacePtr;
    PCOLUMN_BLOCK columnPtr;
    PELEMENT_BLOCK farUpstreamElementPtr,
        upstreamElementPtr,
        downstreamElementPtr,
        farDownstreamElementPtr;

    /* For FEM RMA10 .................. 
        POSITIVE FLOW IS TAKEN TO BE 
        UP! IRREGARDLESS of other 
        conventions */
/* ICM will have vertical flow faces
   numbered from the bottom up with
   and POSITIVE flow taken to be up */

    columnPtr = pHeadColumnListBlockPtr;

    while(columnPtr != NULL)
    {
        elementPtr = columnPtr->surfaceElementPtr;
        while(elementPtr->elementBelowPtr != NULL)
        {
            elementPtr = elementPtr->elementBelowPtr;
        }
        downstreamElementPtr = elementPtr->elementAbovePtr;

        while(downstreamElementPtr != NULL)
        {
            farDownstreamElementPtr = downstreamElementPtr->elementAbovePtr;
            upstreamElementPtr = downstreamElementPtr->elementBelowPtr;
            farUpstreamElementPtr = upstreamElementPtr->elementBelowPtr;

            flowFacePtr = allocateNewFlowFaceBlockF();
            flowFacePtr->orientation = VERTICAL;
            flowFacePtr->type = INTERNAL;
            downstreamElementPtr->bottomFlowFaceld = flowFacePtr->flowFaceld;
            if(farUpstreamElementPtr != NULL)
            {
                flowFacePtr->farUpstreamElementId = farUpstreamElementPtr->elementId;
            }
            else
            {
                flowFacePtr->farUpstreamElementId = -1;
            }
            flowFacePtr->upstreamElementId = upstreamElementPtr->elementId;
            flowFacePtr->downstreamElementId = downstreamElementPtr->elementId;
        }
    }

if (farDownstreamElementPtr != NULL)
    flowFacePtr->farDownstreamElementId = farDownstreamElementPtr->elementId;
else
    flowFacePtr->farDownstreamElementId = -1;

downstreamElementPtr = downstreamElementPtr->elementAbovePtr;
}

columnPtr = columnPtr->pNextColumnBlockPtr;
}

/*----------------------------------------------------------------------------------------------------------------------------*/

PARC_BLOCK
findArcPtrF(int arcId)
{

PARC_BLOCK arcPtr;
arcPtr = pHeadArcListBlockPtr;
while (arcPtr != NULL)
{
    if (arcPtr->arcId == arcId)
        return(arcPtr);

arcPtr = arcPtr->pNextArcBlockPtr;
}
return(NULL);

PNODE_BLOCK
findNodePtrF(int nodeId)
{
PNODE_BLOCK nodePtr;
nodePtr = pHeadNodeBlockPtr;
while(nodePtr != NULL)
{
    if(nodePtr->nodeId == nodeId)
        return(nodePtr);
    nodePtr = nodePtr->nextNodeBlockPtr;
}
return(NULL);

/*/ ______________________________________________________________ */
/* DO NOT USE-- node numbering SKIPS around */

PNODE_BLOCK
lookupNodePtrF(int nodeId)
{

PNODE_BLOCK nodePtr;

if(lookupNodePtrArray == NULL)
{

lookupNodePtrArray =
(PNODE_BLOCK *)calloc(globalNodeCount+1,sizeof(PNODE_BLOCK));

nodePtr = pHeadNodeBlockPtr;

while(nodePtr != NULL)
{

lookupNodePtrArray[nodePtr->nId] = nodePtr;

nodePtr = nodePtr->nextNodeBlockPtr;
}
}

if(nodeId > globalNodeCount)
return(NULL);
else
return(lookupNodePtrArray[nodeId]);
}
PCOLUMN_BLOCK

findColumnPtr(int columnId)
{

PCOLUMN_BLOCK columnPtr;

columnPtr = pHeadColumnListBlockPtr;

while(columnPtr != NULL)
{

if(columnPtr->columnId == columnId)
    return(columnPtr);

    columnPtr = columnPtr->pNextColumnBlockPtr;
}

return(NULL);
}

PCOLUMN_BLOCK

lookupColumnPtrF(int columnId)
{

}
PCOLUMN_BLOCK columnPtr;

if (lookupColumnPtrArray == NULL) {
    lookupColumnPtrArray = (PCOLUMN_BLOCK *)(calloc (globalColumnCount+1, sizeof (PCOLUMN_BLOCK) ) );

    ColumnPtr = pHeadColumnListBlockPtr;

    while ( columnPtr != NULL ) {
        lookupColumnPtrArray[columnPtr -> columnId] = columnPtr;

        ColumnPtr = columnPtr ->pNextColumnBlockPtr ;
    }
}

if ( (columnId < 1) || (columnId > globalColumnCount ) )
    return (NULL);
else
    return ( lookupColumnPtrArray[columnId] ) ;

PELEMENT_BLOCK
LookupElementPtrF ( int elementId)
{
    PELEMENT_BLOCK elementPtr;
if(lookupElementPtrArray == NULL) {
    lookupElementPtrArray = (PELEMENT_BLOCK *)calloc(globalElementCount+1,sizeof(PELEMENT_BLOCK));
}

elementPtr = pHeadElementListBlockPtr;

while(elementPtr != NULL) {
    lookupElementPtrArray[elementPtr->elementId] = elementPtr;
    elementPtr = elementPtr->pNextElementBlockPtr;
}

if( (elementId < 1) || (elementId > globalElementCount))
    return(NULL);
else
    return(lookupElementPtrArray[elementId]);
}

/* ____________________________________________________________ */

PFLOWFACE_BLOCK
lookupFlowFacePtrF(int flowFaceId)
{ 
  PFLOWFACE_BLOCK flowFacePtr;

  if(lookupFlowFacePtrArray == NULL) {
    lookupFlowFacePtrArray =
      (PFLOWFACE_BLOCK *)calloc(globalFlowFaceCount+1,sizeof(PFLOWFACE_BLOCK));

    flowFacePtr = pHeadFlowFaceListBlockPtr;
    while(flowFacePtr != NULL) {
      lookupFlowFacePtrArray[flowFacePtr->flowId] = flowFacePtr;
      flowFacePtr = flowFacePtr->pNextFlowFaceBlockPtr;
    }
  }

  if( (flowId < 1) || (flowId > globalFlowFaceCount) )
    return(NULL);
  else
    return(lookupFlowFacePtrArray[flowId]);
}

/* --------------------------------------------------------- */
void setFlowFaceIdentifierTags()
{
    PFLOWFACE_BLOCK flowFacePtr;
    PARC_BLOCK arcPtr;
    int surfaceCenterNodeId;
    int topCenterNodeId;
    int layerFlowFacesIn;
    PELEMENT_BLOCK elementPtr;
    int elementId;

    flowFacePtr = pHeadFlowFaceListBlockPtr;

    while(flowFacePtr != NULL)
    {
        if(flowFacePtr->orientation == HORIZONTAL)
        {
            arcPtr = flowFacePtr->arcPtr;
            surfaceCenterNodeId = arcPtr->nodeId[1];
            layerFlowFacesIn = flowFacePtr->layerId;

            if(layerFlowFacesIn == 1)
                topCenterNodeId = surfaceCenterNodeId;
            else
                topCenterNodeId = surfaceNodeList[surfaceCenterNodeId].nref + (layerFlowFacesIn-1);

            flowFacePtr->identifierTag = topCenterNodeId;
        }
        else
            if(flowFacePtr->orientation == VERTICAL)
elementld = flowFacePtr->upstreamElementld;
elementPtr = lookupElementPtrF(elementld);
flowFacePtr->identifierTag = elementPtr->rmale10Elementld;

/* Check if upstream cell is a surface cell. If it is then the identifier is taken to be the flow face's downstream element's rma10Elementld. If the flow faces upstream element is not in the surface layer, then it must be in a layer beneath the surface layer. All vertical flow faces beneath the first vertical flow face in a column WILL HAVE THE WRONG SENSE OF FLUX when the fluxes are read in from the hydrodynamic file. This is because in RMA10 they number elements first in the surface, then they start numbering elements in the subsurface at the bottom layer then go up in the same column to the 2nd layer! The flux sense in BOTH models is taken to be from an element with the smaller element id to the larger element id. We will indicate a change in flux sign by making the identifier tag NEGATIVE */

flowFacePtr = flowFacePtr->pNextFlowFaceBlockPtr;
void renumberAllFlowFacesForOutputF()
{

  PFLOWFACE_BLOCK flowFacePtr;
  int modelFlowFaceId;
  char faceType, faceOrientation;

  flowFacePtr = pHeadFlowFaceListBlockPtr;

  modelFlowFaceId = 1;

  while(flowFacePtr != NULL)
  {
    switch(flowFacePtr->type)
    {
      case INTERNAL:
        faceType = 'I';
        break;

      case BOUNDARY:
        faceType = 'B';
        break;

      case WALL:
        faceType = 'W';
        break;
    }
  }
}
switch(flowFacePtr->orientation)
{
    case HORIZONTAL:
        faceOrientation = 'H';
        break;
    
    case VERTICAL:
        faceOrientation = 'V';
        break;
}

if( (faceType == 'B') || (faceType == 'T'))
{
    flowFacePtr->modelFlowFaceId = modelFlowFaceId++;
}

flowFacePtr = flowFacePtr->pNextFlowFaceBlockPtr;
}


int *retrieveAColumnsVerticalFlowFaceInfo( PCOLUMN_BLOCK columnPtr )
{
    PELEMENT_BLOCK elementPtr;
    PFLOWFACE_BLOCK flowFacePtr;
PELEMENT_BLOCK upstreamElementPtr;

int i, flowFaceId;
int columnFlowFaceCount = 0;
int *intList;
int intListItemIndex = 0;

elementPtr = columnPtr->surfaceElementPtr;
while(elementPtr->elementBelowPtr != NULL)
{
    columnFlowFaceCount++;
    elementPtr = elementPtr->elementBelowPtr;
}

I* Make first element in array be count of total size of array. */

intList = (int *)calloc(columnFlowFaceCount+1,sizeof(int));
intList[intListItemIndex++] = columnFlowFaceCount;

upstreamElementPtr = elementPtr->elementAbovePtr;

while(upstreamElementPtr != NULL)
{
    flowFaceId = upstreamElementPtr->bottomFlowFaceId;
    intList[intListItemIndex++] = flowFaceId;
    upstreamElementPtr = upstreamElementPtr->elementAbovePtr;
}

return(intList);
void printFlowFaceListF()
{

PELEMENT_BLOCK elementPtr;
FLOWFACE_BLOCK *flowFacePtr;
int flowFaceld;
FILE *outf;
char faceType, faceOrientation;
int modelFlowFaceld;
int upstreamElementld,
downstreamElementld,
farUpstreamElementld,
farDownstreamElementld;

PCOLUMN_BLOCK columnPtr;
int *intList;
int i, numberInList;

outf = fopen("FF.out", "w");

fprintf(outf," ICM FEM\n");
elementPtr = pHeadElementListBlockPtr;

while(elementPtr != NULL)
{
    fprintf(outf,"%8d %6d\n",
            elementPtr->elementld,
            elementPtr->elementId,
            elementPtr->modelFlowFaceld,
            elementPtr->upstreamElementId,
            elementPtr->downstreamElementId,
            elementPtr->farUpstreamElementId,
            elementPtr->farDownstreamElementId,
            elementPtr->columnPtr,
            elementPtr->intList,
            elementPtr->i,
            elementPtr->numberInList);
elementPtr->rma10ElementId);

    elementPtr = elementPtr->pNextElementBlockPtr;
}

fprintf(outf,"\n FFID  ILB  IL  JR  JRB  TYPE ORIENT  TAG\n");

flowFacePtr = pHeadFlowFaceListBlockPtr;

flowFaceld = 0;
while(flowFacePtr != NULL)
{
    switch(flowFacePtr->type)
    {
    case INTERNAL:
        faceType = 'I';
        break;

    case BOUNDARY:
        faceType = 'B';
        break;

    case WALL:
        faceType = 'W';
        break;
    }

    switch(flowFacePtr->orientation)
    {
    case HORIZONTAL:
        faceOrientation = 'H';
        break;

    case VERTICAL:
        faceOrientation = 'V';
        break;
    }
modelFlowFaceld = flowFacePtr->modelFlowFaceld;

if(flowFacePtr->farUpstreamElementId != -1)
    farUpstreamElementId = flowFacePtr->farUpstreamElementId;
else
    farUpstreamElementId = 0;

if(flowFacePtr->upstreamElementId != -1)
    upstreamElementId = flowFacePtr->upstreamElementId;
else
    upstreamElementId = 0;

if(flowFacePtr->downstreamElementId != -1)
    downstreamElementId = flowFacePtr->downstreamElementId;
else
    downstreamElementId = 0;

if(flowFacePtr->farDownstreamElementId != -1)
    farDownstreamElementId = flowFacePtr->farDownstreamElementId;
else
    farDownstreamElementId = 0;

if((flowFacePtr->type == BOUNDARY) || (flowFacePtr->type == INTERNAL))
{
    flowFaceld++;
    fprintf(outf, "%8d %6d %6d %6d %6d %c %c %6d\n",
            modelFlowFaceld,
            farUpstreamElementId,
            upstreamElementId,
            downstreamElementId,
            farDownstreamElementId,
faceType,
faceOrientation,
flowFacePtr->identifierTag);
}
flowFacePtr = flowFacePtr->pNextFlowFaceBlock.Ptr;
}

/* Write out the number of vertical
flow faces in a column info */

fprintf(outf, "\n SB NVF\n");

columnPtr = pHeadColumnListBlock.Ptr;
while(columnPtr != NULL)
{
    /* Function returns a list of vertical
    flow faces for each column. This
    list is dynamically allocated so
    need to release memory when we
    finish with it. */

    intList = retrieveAColumnsVerticalFlowFaceInfo(columnPtr);
    numberInList = intList[0];

    fprintf(outf, "%8d%8d\n", columnPtr->columnId, numberInList);
    free(intList);
    columnPtr = columnPtr->pNextColumnBlock.Ptr;
}
/* Write out the vertical
  flow faces in a column info */

fprintf(outf,"\n  SB  VFN LIST...\n");

columnPtr = pHeadColumnListBlockPtr;

while(columnPtr != NULL)
{
  /* Function returns a list of vertical
     flow faces for each column. This
     list is dynamically allocated so
     need to release memory when we
     finish with it. */

  intList = retrieveAColumnsVerticalFlowFaceInfo(columnPtr);
  numberInList = intList[0];

  fprintf(outf," %6d",columnPtr->columnId);
  for(i=1; i<=numberInList; i++)
  {
    flowFacePtr = lookupFlowFacePtrF(intList[i]);
    modelFlowFaceId = flowFacePtr->modelFlowFaceId;
    fprintf(outf," %6d",modelFlowFaceId);
  }
  fprintf(outf,\n");

  free(intList);

  columnPtr = columnPtr->pNextColumnBlock.Ptr;
}

fclose(outf);
void printGeoFileF()
{
    FILE *outf;
    PCOLUMN_BLOCK columnPtr;
    PELEMENT_BLOCK elementPtr;
    PELEMENT_BLOCK surfaceElementPtr, bottomElementPtr;
    PELEMENT_BLOCK elementAbovePtr;
    int elementAboveId;
    PFLOWFACE_BLOCK flowFacePtr;
    char faceType;

    float BIL, BI, BID, BIR;

    outf = fopen("geo.out","w");

    /* Write out for each column, the 
    surface element id and its corresponding bottom element id */

    fprintf(outf," SBN  BBN\n");

    columnPtr = pHeadColumnListBlockPtr;

    while(columnPtr != NULL)
elementPtr = columnPtr->surfaceElementPtr;
surfaceElementPtr = elementPtr;

while(elementPtr->elementBelowPtr != NULL)
    elementPtr = elementPtr->elementBelowPtr;

bottomElementPtr = elementPtr;

fprintf(outf,
    "%6d %6d\n",
    surfaceElementPtr->elementId,
    bottomElementPtr->elementId);

columnPtr = columnPtr->pNextColumnBlockPtr;
}
/* Now print out boxes above */

fprintf(outf,"\n BU\n");

elementPtr = pHeadElementListBlockPtr;

while(elementPtr != NULL)
{
    elementAbovePtr = elementPtr->elementAbovePtr;
    if(elementAbovePtr != NULL)
        elementAboveId = elementAbovePtr->elementId;
    else
        elementAboveId = 0;
    fprintf(outf,"%6d \n",elementAboveId);
elementPtr = elementPtr->pNextElementBlockPtr;
}

/* Now print out centroid ofsets */

fprintf(outf, "n BIL BI BID BIR type layer\n");

flowFacePtr = pHeadFlowFaceListBlockPtr;
while( (flowFacePtr != NULL) && (flowFacePtr->orientation == HORIZONTAL) )
{
    if( (flowFacePtr->type == BOUNDARY) || (flowFacePtr->type == INTERNAL) )
    {
        switch(flowFacePtr->type)
        { case INTERNAL:
            faceType = 'T';
            break;

            case BOUNDARY:
            faceType = 'B';
            break;

            case WALL:
            faceType = 'W';
            break;
        }

        BIL = flowFacePtr->distanceBetweenUpstreamCentroids;
        BI = flowFacePtr->distanceBetweenCentroids;
        BID = flowFacePtr->downstreamDistanceBetweenCentroidAndFace;
        BIR = flowFacePtr->distanceBetweenDownstreamCentroids;
    }
fprintf(outf,
    " %10.5e %10.5e %10.5e %10.5e %c %3d\n",
    BIL,BI,BID,BIR,faceType,flowFacePtr->layerId);

/* fprintf(outf," %15.9e %15.9e %15.9e %15.9e\n",BIL,BI,BID,BIR); */
}

flowFacePtr = flowFacePtr->pNextFlowFaceBlockPtr;

}

fclose(outf);

}

/* _____________________________________________________________ */

void readBoundaryArcFile()
{

FILE    *inile;
int     i, int1, int2, index;
char    lineBuffer[132];
in   NP, NE, NPM, NEM;
in   surfaceNodeId;
in   ndep, nref;

BOUNDARY_NODE_BLOCK *boundaryNodePtr;
infile = fopen("r4icr10.output","r");
if(infile == NULL)
    { printf("Unable to open 'r4icr10.output\n");
      fflush(stdout);
      exit(0);
    }

    /* Skip first 2 lines */
    fgets(lineBuffer,132,infile);
    fgets(lineBuffer,132,infile);

    fscanf(infile,"%d %d %d %d", &NP, &NE, &NPM, &NEM);

    if(NPM > 100000)
        { printf("number of nodes in surface layer is 100000!\n");
          printf("If thats true then take out this line and recompile!\n");
          fflush(stdout);
          exit(0);
        }

    surfaceNodeList =
        (SURFACE_NODE_LIST *)calloc(NPM+1,sizeof(SURFACE_NODE_LIST));

    /* Skip first next 4 lines */
    for(i=0; i<4; i++)
        fgets(lineBuffer,132,infile);

    for(i=0; i<NPM; i++)
        { fscanf(infile,"%d %d %d", &surfaceNodeId, &ndep, &nref);
          surfaceNodeList[surfaceNodeId].ndep = ndep;
          surfaceNodeList[surfaceNodeId].nref = nref;
        }
/* Skip first next 3 lines */
for(i=0; i<3; i++)
    fgets(lineBuffer,132,infile);

fscanf(infile,"%d %d",&int1, &int2);
while(!feof(infile))
{
    if(int1 < 374)
        if( (int2 == 31000) || (int2 == 200) || (int2 == 1200) )
            { boundaryNodePtr = allocateNewBoundaryNodeBlockF();
              boundaryNodePtr->boundaryNodeId = int1;
            }

    fscanf(infile,"%d %d",&int1, &int2);
}
/* ----------------------------------------------------------- */
Appendix B
FEMCONVT Source Code Listing
THIS PROGRAM CALCULATES THE FLUXES THROUGH THE
FACES OF A RMA10 BINARY
OUTPUT FILE. IT ALSO CALCULATES THEIR VOLUME.

Parameter (MNP=2000, MEL=2000, NLAYM=4)

CHARACTER CHFN*15
DIMENSION IDND(MNP, 8), NNPE(MEL), LIS(MNP), FLUX(MNP)
AREA(MNP)
DIMENSION LISE(MEL), VOL(MEL), VAREA(MEL), VFLUX(MEL)
DIMENSION CORD(MNP, 3), SPEC(MNP, 3), ALFA(MNP), NFIX(MNP)
AO(MNP), NSURF(MNP), NREF(MNP), NOP(MEL, 20)
NCORN(MEL), IMAT(MEL), TH(MEL), NFIXH(MEL), WIDTH(MNP)
DIMENSION XVEL(4, MNP), VVEL(MNP), DFCT(MEL)

DEFINITIONS

JNN = # OF THE MID-SIDE NODE USED TO NUMBER THE FACE
NODR = NODE ID FOR RIGHT END TOP
NODL = NODE ID FOR LEFT END TOP
NQD = NUMBER OF QUADRILATERALS ALONG THIS FACE
NTR = NUMBER OF TRIANGLES ALONG THIS FACE
IDND(I, J) = NODE CONNECTION TABLE AROUND A FACE; WHERE I IS THE
FACE NUMBER AND J IS THE LOCAL NODE NUMBER
NNPE(I) = THE NUMBER OF NODES MAKING UP THIS FACE 6 OR 8; I IS
THE FACE NUMBER
NES = THE NUMBER OF SURFACE ELEMENTS (I.E. PLANAR)
JNM = THE NUMBER OF VERTICAL FACES
LIS(1-JNM) = LIST OF THE VERTICAL FACE NUMBERS
FLUX(I) = THE FLUX FOR FACE LIS(I)
VOL(I) = THE VOLUME OF ELEMENT LISE(I)
LISE(1-JNV) = LIST OF ELEMENTS FOR VOLUMES AND VERTICAL FLUX
VAREA(I) = THE VERTICAL FLUX OUT OF THE TOP OF ELEMENT I

ELEV IS HARDWIRED TO THIS APPLICATION THIS NEEDS TO BE CHANGED
TO SOMETHING MORE GENERAL
c

open(unit=10,file='femconvT.out',status='UNKNOWN')

ELEV=100.000

c
C READ THE GEOMETRY PORTION OF THE FILE
C
I  WRITE(*,*) ' WHAT IS THE HYDRO FILE ?'
READ(*,'(A)',ERR=1) CHFN
OPEN(UNIT=60,FILE=CHFN,STATUS='OLD', form='unformatted')
READ (60) NP, NE, NPM, NES,
& ((CORD(J,K),SPEC(J,K),K=1,3), ALFA(J), NFIX(J), AO(J),
& NSURF(J), J = 1, NP), (NDEP(J), NREF(J), J = 1, NPM),
& ((NOP(J,K),K=1,20), NCORN(J), IMAT(J), TH(J),
& NFIXH(J), J = 1, NE), (WIDTH(J), J = 1, NP)
C FIRST SETUP THE TOPOLOGY OF THE FACES
DO 10 J = 1, NPM
   LIS(J)=0
   DO 20 I=1,8
      IDND(J,I) = 0
   20 CONTINUE
10 CONTINUE
DO 30 J=1,NP
   if(j.le.npm)then
      NNPE(J)=0
   else
      nnpe(j)=1
   endif
30 CONTINUE
C LOOP THROUGH ALL THE 2D SURFACE ELEMENTS IN THE GEOMETRY

JNM=0
DO 100 IE=1,NES
   DO 110 I=1,NCORN(IE),2
      JNN = NOP(IE,I+1)
      IF(NNPE(JNN).NE.0)GO TO 110
      JNE = (NDEP(JNN)+1)/2
      NODL=NOP(IE,I)
      IF((I+1).EQ.NCORN(IE))THEN
         NODR=NOP(IE,I-2)
      ELSE
         NODR=NOP(IE,I+2)
      END IF
      NELL = (NDEP(NODL)-1)/2
      NELR = (NDEP(NODR)-1)/2
      NQD=NELL
      IF((NELL.LT.NELR).OR.(NELL.EQ.NELR).AND.(NELL.LT.0))NQD=NELR
      NTR=JNE-NQD
      IF((NQD.NE.0).AND.(NTR.EQ.0))GO TO 120
      DO 120 J=1,NQD
         IF(J.EQ.1)THEN
            IDEL=JNN
         ELSE
            JNM=JNM+1
            LIS(JNM)=IDEL
            IDND(IDEL,1) = NODL
            IDND(IDEL,2) = NREF(NODL)+1
            IDND(IDEL,3) = NREF(NODL)+2
            IDND(IDEL,4) = NREF(IDEL)+1
            IDND(IDEL,5) = NREF(NODR)+2
            IDND(IDEL,6) = NREF(NODR)+1
            IDND(IDEL,7) = NODR
         END IF
      END DO 120
   END DO 110
110 CONTINUE
100 CONTINUE
NNPE(IDEL) = 8
ELSE
  IDEL = NREF(JNN) + J - 1
  JNM = JNM + 1
  LIS(JNM) = IDEL
  IDND(IDEL,1) = NREF(NODL) + (J-1)*2
  IDND(IDEL,2) = IDND(IDEL,1) + 1
  IDND(IDEL,3) = IDND(IDEL,2) + 1
  IDND(IDEL,4) = IDEL + 1
  IDND(IDEL,7) = NREF(NODR) + (J-1)*2
  IDND(IDEL,6) = IDND(IDEL,7) + 1
  IDND(IDEL,5) = IDND(IDEL,6) + 1
  IDND(IDEL,8) = IDEL
  NNPE(IDEL) = 8
END IF
120 CONTINUE
ENDIF

C
IF (NTR.NE.0) THEN
  DO 130 J = 1, NTR
    IF (NQD.EQ.0) THEN
      IF (J.EQ.1) THEN
        IF (NELL.GT.NELR) THEN
          IDEL = JNN
          JNM = JNM + 1
          LIS(JNM) = IDEL
          IDND(IDEL,1) = NODL
          IDND(IDEL,2) = NREF(NODL) + 1
          IDND(IDEL,3) = NREF(NODL) + 2
          IDND(IDEL,4) = NREF(IDEL) + 1
          IDND(IDEL,5) = NODR
          IDND(IDEL,6) = IDEL
          NNPE(IDEL) = 6
        ELSE
          IDEL = JNN
          JNM = JNM + 1
          LIS(JNM) = IDEL
          IDND(IDEL,1) = NODL
          IDND(IDEL,2) = NREF(NODL) + 1
          IDND(IDEL,3) = NREF(NODL) + 2
          IDND(IDEL,4) = NREF(IDEL) + 1
          IDND(IDEL,5) = NODR
          IDND(IDEL,6) = IDEL
          NNPE(IDEL) = 6
        END IF
      END IF
    END IF
  END DO 130
ENDIF
IDEL = JNN
JNM = JNM + 1
LIS(JNM) = IDEL
IDND(IDEL,1) = NODL
IDND(IDEL,2) = NREF(IDEL) + 1
IDND(IDEL,3) = NREF(NODR) + 1
IDND(IDEL,4) = IDEL + 1
IDND(IDEL,5) = NODR
IDND(IDEL,6) = IDEL
NNPE(IDEL) = 6
ENDIF
ELSE
IF(NELL.GT.NELR) THEN
  IDEL = NREF(JNN) + J - 1
  JNM = JNM + 1
  LIS(JNM) = IDEL
  NOPT = NQD + J - 1
  IDND(IDEL,1) = NREF(NODL) + NOPT*2
  IDND(IDEL,2) = IDND(IDEL,1) + 1
  IDND(IDEL,3) = IDND(IDEL,2) + 1
  IDND(IDEL,4) = IDEL + 1
  IDND(IDEL,5) = NODR
  IDND(IDEL,6) = IDEL
  NNPE(IDEL) = 6
ELSE
  IDEL = NREF(JNN) + J - 1
  JNM = JNM + 1
  LIS(JNM) = IDEL
  NOPT = NQD + J - 1
  IDND(IDEL,1) = NODL
  IDND(IDEL,2) = IDEL + 1
  IDND(IDEL,3) = NREF(NODR) + NOPT*2
  IDND(IDEL,4) = IDND(IDEL,5) + 1
  IDND(IDEL,5) = IDND(IDEL,5) + 2
IDND(IDEL,6) = IDEL
NNPE(IDEL) = 6
ENDIF
ENDIF
ELSE
NOPT = NQD+J-1
IDEL = NREF(JNN) + NOPT
JNM=JNM+1
LIS(JNM)=IDEL
IF(NELL.GT.NELR)THEN
  IDND(IDEL,1) = NREF(NODL)+NOPT*2
  IDND(IDEL,2) = IDND(IDEL,1)+1
  IDND(IDEL,3) = IDND(IDEL,2)+1
  IDND(IDEL,4) = IDEL+1
  IDND(IDEL,5) = NREF(NODR)+NQD*2
  IDND(IDEL,6) = IDEL
  NNPE(IDEL) = 6
ELSE
  IDND(IDEL,1) = NREF(NODL)+NQD*2
  IDND(IDEL,2) = IDEL+1
  IDND(IDEL,5) = NREF(NODR)+NOPT*2
  IDND(IDEL,4) = IDND(IDEL,5)+1
  IDND(IDEL,3) = IDND(IDEL,5)+2
  IDND(IDEL,6) = IDEL
  NNPE(IDEL) = 6
ENDIF
ENDIF
130 CONTINUE
ENDIF
110 CONTINUE
100 CONTINUE
\text{c}
\text{c Now calculate fluxes}
\text{c}
read(60,end=200)tet,np,ndf,
   ((xvel(k,j),k=1,ndf),vvel(j),j=1,np),
   (dfct(j),j=1,ne)
C
C THIS IS CURRENTLY SETUP FOR QUADRILATERAL ONLY
C
DO 210 I=1,JNM
   IFACE=LIS(I)
   X1=CORD(IDND(IFACE,1),1)
   Y1=CORD(IDND(IFACE,1),2)
   Z1=CORD(IDND(IFACE,1),3)
   X3=CORD(IDND(IFACE,3),1)
   Y3=CORD(IDND(IFACE,3),2)
   Z3=CORD(IDND(IFACE,3),3)
   X5=CORD(IDND(IFACE,5),1)
   Y5=CORD(IDND(IFACE,5),2)
   Z5=CORD(IDND(IFACE,5),3)
   X7=CORD(IDND(IFACE,7),1)
   Y7=CORD(IDND(IFACE,7),2)
   Z7=CORD(IDND(IFACE,7),3)
   U1=XVEL(1,IDND(IFACE,1))
   V1=XVEL(2,IDND(IFACE,1))
   H1=XVEL(3,IDND(IFACE,1))
   U2=XVEL(1,IDND(IFACE,2))
   V2=XVEL(2,IDND(IFACE,2))
   U3=XVEL(1,IDND(IFACE,3))
   V3=XVEL(2,IDND(IFACE,3))
   H3=XVEL(3,IDND(IFACE,3))
   U4=XVEL(1,IDND(IFACE,4))
   V4=XVEL(2,IDND(IFACE,4))
   U5=XVEL(1,IDND(IFACE,5))
   V5=XVEL(2,IDND(IFACE,5))
   H5=XVEL(3,IDND(IFACE,5))
   U6=XVEL(1,IDND(IFACE,6))

V6=XVEL(2,IDND(IFACE,6))
U7=XVEL(1,IDND(IFACE,7))
V7=XVEL(2,IDND(IFACE,7))
H7=XVEL(3,IDND(IFACE,7))
U8=XVEL(1,IDND(IFACE,8))
V8=XVEL(2,IDND(IFACE,8))

C
CORRECT THE COORDINATES FOR THE TRANSFORMATION

Z1=(Z1-AO(IDND(IFACE,1)))/(ELEV-AO(IDND(IFACE,1)))+XVEL(3,IDND(IFACE,3))
Z3=(Z3-AO(IDND(IFACE,3)))/(ELEV-AO(IDND(IFACE,3)))+XVEL(3,IDND(IFACE,3))
Z5=(Z5-AO(IDND(IFACE,5)))/(ELEV-AO(IDND(IFACE,5)))+XVEL(3,IDND(IFACE,3))
Z7=(Z7-AO(IDND(IFACE,7)))/(ELEV-AO(IDND(IFACE,7)))+XVEL(3,IDND(IFACE,3))

C
CALCULATE HORIZONTAL FLUXES

reference distances to a corner
X1 = X1 - X7
Y1 = Y1 - Y7
Z1 = Z1 - Z7
X3 = X3 - X7
Y3 = Y3 - Y7
Z3 = Z3 - Z7
X5 = X5 - X7
Y5 = Y5 - Y7
Z5 = Z5 - Z7

temporary variables for jacobians
X1Z1 = X1 * Z1
X3Z1 = X3 * Z1
X5Z1 = X5 * Z1
X1Z3 = X1 * Z3
X3Z3 = X3 * Z3
X5Z3 = X5 * Z3
X1Z5 = X1 * Z5
X3Z5 = X3 * Z5
X5Z5 = X5 * Z5

C
Y1Z1 = Y1 * Z1
Y3Z1 = Y3 * Z1
Y5Z1 = Y5 * Z1
Y1Z3 = Y1 * Z3
Y3Z3 = Y3 * Z3
Y5Z3 = Y5 * Z3
Y1Z5 = Y1 * Z5
Y3Z5 = Y3 * Z5
Y5Z5 = Y5 * Z5

C
FX = (U1*(-Y1Z3+Y3Z1-2.*Y3Z5+2.*Y5Z3)
+2.*U2*(-4.*Y3Z1+Y5Z1+4.*Y1Z3
-3.*Y5Z3-Y1Z5+3.*Y3Z5)
+U3*(Y3Z1+Y5Z1-Y1Z3+Y5Z3-Y1Z5-Y3Z5)
+2.*U4*(-3.*Y3Z1+Y5Z1+3.*Y1Z3
-4.*Y5Z3-Y1Z5+4.*Y3Z5)
+U5*(-2.*Y1Z3+2.*Y3Z1+Y5Z3-Y3Z5)
+2.*U6*(2.*Y1Z3-2.*Y3Z1-Y5Z1
-3.*Y5Z3+Y1Z5+3.*Y3Z5)
+U7*(-2.*Y1Z3-Y5Z1+Y1Z5+2.*Y3Z1
-2.*Y3Z5+2.*Y5Z3)
+2.*U8*(-3.*Y3Z1-Y5Z1+3.*Y1Z3
+Y1Z5+2.*Y3Z5-2.*Y5Z3))
/36.

C
\[
FY = (V1*(-X1Z3+X3Z1-2.*X3Z5+2.*X5Z3) \\
+2.*V2*(-4.*X3Z1+X5Z1+4.*X1Z3 \\
-3.*X5Z3-X1Z5+3.*X3Z5) \\
+V3*(X3Z1+X5Z1-X1Z3+X5Z3-X1Z5-X3Z3) \\
+2.*V4*(-3.*X3Z1+X5Z1+3.*X1Z3 \\
-4.*X5Z3-X1Z5+4.*X3Z5) \\
+V5*(-2.*X1Z3+2.*X3Z1+X5Z3-X3Z5) \\
+2.*V6*(2.*X1Z3-2.*X3Z1-X5Z1 \\
-3.*X5Z3+X1Z5+3.*X3Z5) \\
+V7*(-2.*X1Z3-X5Z1+X1Z5+2.*X3Z1 \\
-2.*X3Z5+2.*X5Z3) \\
+2.*V8*(-3.*X3Z1-X5Z1+3.*X1Z3 \\
+X1Z5+2.*X3Z5-2.*X5Z3)) \\
/36.
\]

\[
\text{FLUX}(I) = \text{FX} + \text{FY} \\
\text{AX} = 0.5*(Y1Z3-Y3Z1+Y3Z5-Y5Z3) \\
\text{AY} = 0.5*(X1Z3-X3Z1+X3Z5-X5Z3) \\
\text{AREA}(I) = \sqrt{\text{AX}^2+\text{AY}^2} \\
\text{if}((\text{lis}(i).gt.980).and.\text{(lis}(i).lt.990))\text{then} \\
\text{WRITE}(**,*) 'FX,FY', \text{FX}, \text{FY} \\
\text{WRITE}(**,*) \text{LIS}(I),\text{FLUX}(I),\text{AREA}(I) \\
\text{endif}
\]

210 CONTINUE
200 continue
C
C 3D ELEMENTS VOLUME CALCULATION
C
JNV = 0
DO 300 IE=1,NE
  IF (NCORN(IE).EQ.20)THEN \\
JNV = JNV+1 \\
LISE(JNV)=IE \\
IB1=NOP(IE,1) \\
IB3=NOP(IE,3)
IB5=NOP(IE,5)
IB7=NOP(IE,7)
IT1=NOP(IE,13)
IT2=NOP(IE,14)
IT3=NOP(IE,15)
IT4=NOP(IE,16)
IT5=NOP(IE,17)
IT6=NOP(IE,18)
IT7=NOP(IE,19)
IT8=NOP(IE,20)
if(ie.eq.569)then
  write(*,*),'ib',ib1,ib3,ib5,ib7
  write(*,*),'it',it1,it3,it5,it7
end if
X1=CORD(IB1,1)
X3=CORD(IB3,1)
X5=CORD(IB5,1)
X7=CORD(IB7,1)
Y1=CORD(IB1,2)
Y3=CORD(IB3,2)
Y5=CORD(IB5,2)
Y7=CORD(IB7,2)
ZB1=CORD(IB1,3)
ZB3=CORD(IB3,3)
ZB5=CORD(IB5,3)
ZB7=CORD(IB7,3)
ZT1=CORD(IT1,3)
ZT3=CORD(IT3,3)
ZT5=CORD(IT5,3)
ZT7=CORD(IT7,3)
ZB1=(ZB1-AO(IB1))/(ELEV-AO(IB1))
  *XVEL(3,IB1)+AO(IB1)
ZB3=(ZB3-AO(IB3))/(ELEV-AO(IB3))


\[ X3Yl = X3 \times Yl \]
\[ X5Yl = X5 \times Yl \]
\[ X7Yl = X7 \times Yl \]
\[ XlY3 = Xl \times Y3 \]
\[ X5Y3 = X5 \times Y3 \]
\[ X7Y3 = X7 \times Y3 \]
\[ X1Y5 = X1 \times Y5 \]
\[ X3Y5 = X3 \times Y5 \]
\[ X7Y5 = X7 \times Y5 \]
\[ X1Y7 = X1 \times Y7 \]
\[ X3Y7 = X3 \times Y7 \]
\[ X5Y7 = X5 \times Y7 \]

/*XVEL(3,IB3)+AO(IB3)
ZB5=(ZB5-AO(IB5))/(ELEV-AO(IB5))

/*XVEL(3,IB5)+AO(IB5)
ZB7=(ZB3-AO(IB7))/(ELEV-AO(IB7))

/*XVEL(3,IB7)+AO(IB7)
ZT1=(ZT1-AO(IT1))/(ELEV-AO(IT1))

/*XVEL(3,IT1)+AO(IT1)
ZT3=(ZT3-AO(IT3))/(ELEV-AO(IT3))

/*XVEL(3,IT3)+AO(IT3)
ZT5=(ZT5-AO(IT5))/(ELEV-AO(IT5))

/*XVEL(3,IT5)+AO(IT5)
ZT7=(ZT3-AO(IT7))/(ELEV-AO(IT7))

/*XVEL(3,IT7)+AO(IT7)

CALCULATE THE VOLUME OF AN ELEMENT

VOL(JNV)=(ZB1-ZT1)*(2.*X3Y1-2.*X7Y1-2.*X1Y3+X5Y3

+X7Y3-X3Y5+X7Y5+2.*X1Y7-X3Y7-X5Y7)/12.

+(ZB3-ZT3)*(2.*X3Y1-X5Y1-X7Y1-2.*X1Y3+

2.*X5Y3+X1Y5-2.*X3Y5+X7Y5+X1Y7-X5Y7)/12.

+(ZB5-ZT5)*(X3Y1-X7Y1-X1Y3+2.*X5Y3-X7Y3

-2.*X3Y5+2.*X7Y5+X1Y7+X3Y7-2.*X5Y7)/12.
\[ + (Z7-T7) \times (X3Y1+X5Y1-2.\times X7Y1-X1Y3+X5Y3 \\
- X1Y5-X3Y5+2.\times X7Y5+2.\times X1Y7-2.\times X5Y7)/12. \]

**CALCULATE THE VERTICAL FLUX AND AREA**

\[ W1 = VVEL(IT1) \]
\[ W2 = VVEL(IT2) \]
\[ W3 = VVEL(IT3) \]
\[ W4 = VVEL(IT4) \]
\[ W5 = VVEL(IT5) \]
\[ W6 = VVEL(IT6) \]
\[ W7 = VVEL(IT7) \]
\[ W8 = VVEL(IT8) \]

\[ \text{VAR}(JNV) = 0.5 \times (-X3Y1+X7Y1+X1Y3-X5Y3-X7Y5-X1Y7 \\
+ X5Y7+X3Y5) \]

\[ \text{TMP}1 = W1 \times ((X3Y1-X7Y1-X1Y3+X5Y3-X3Y5+X7Y5+X1Y7- \\
X5Y7)/12.+(-2.\times X3Y1+2.\times X7Y1+2.\times X1Y3-X5Y3- \\
X7Y3+X3Y5-X7Y5-2.\times X1Y7+X3Y7+X5Y7)/36.) \]

\[ \text{TMP}2 = W2 \times ((4.\times X3Y1-X5Y1-3.\times X7Y1+4.\times X1Y3+3.\times X5Y3+ \\
X7Y3+X1Y5-3.\times X3Y5+2.\times X7Y5+3.\times X1Y7- \\
X3Y7-2.\times X5Y7)/36.+ \\
(-4.\times X3Y1+X5Y1+3.\times X7Y1+4.\times X1Y3-3.\times X5Y3- \\
X7Y3-X1Y5+3.\times X3Y5-2.\times X7Y5-3.\times X1Y7+ \\
X3Y7+2.\times X5Y7)/12.) \]

\[ \text{TMP}3 = W3 \times ((X3Y1-X7Y1-X1Y3+X5Y3-X3Y5+X7Y5+ \\
X1Y7-X5Y7)/12.+ \\
(-2.\times X3Y1+X5Y1+X7Y1+2.\times X1Y3-2.\times X5Y3-X1Y5+ \\
2.\times X3Y5-X7Y5-X1Y7+X5Y7)/36.) \]

\[ \text{TMP}4 = W4 \times ((X5Y1-X7Y1-X5Y3+X7Y3-X1Y5+X3Y5+ \\
X1Y7-X3Y7)/18.+ \\
(-X3Y1+X7Y1+X1Y3-X5Y3+X3Y5-X7Y5- \\
X1Y7+X5Y7)/6.) \]

\[ \text{TMP}5 = W5 \times ((X3Y1-X7Y1-X1Y3+X5Y3-X3Y5+X7Y5+ \\
X1Y7-X5Y7)/12.+ \]
\[
(-X3Y1+X7Y1+X1Y3-2.*X5Y3+X7Y3+2.*X3Y5-
2.*X7Y5-X1Y7-X3Y7+2.*X5Y7)/36.\]

\[
\text{TMP6} = W6*((2.*X3Y1+X5Y1-3.*X7Y1-2.*X1Y3+3.*X5Y3-
X7Y3-X1Y5-3.*X3Y5+4.*X7Y5+3.*X1Y7+
X3Y7-4.*X5Y7)/36.+ (-2.*X3Y1-X5Y1+3.*X7Y1+2.*X1Y3-3.*X5Y3+
X7Y3+X1Y5+3.*X3Y5-4.*X7Y5-3.*X1Y7-
X3Y7+4.*X5Y7)/12.)
\]

\[
\text{TMP7} = W7*((X3Y1-X7Y1-X1Y3+X5Y3-X3Y5+X7Y5+
X1Y7-X5Y7)/12.+ (-X3Y1-X5Y1+2.*X7Y1+X1Y3-X5Y3+X1Y5+
X3Y5-2.*X7Y5-2.*X1Y7+2.*X5Y7)/36.)
\]

\[
\text{TMP8} = W8*((-X5Y1+X7Y1+X5Y3-X7Y3+X1Y5-X3Y5-
X1Y7+X3Y7)/18.+ (-X3Y1+X7Y1+X1Y3-X5Y3+X3Y5-X7Y5-
X1Y7+X5Y7)/6.)
\]

\[
\text{VFLUX(JNV)} = \text{TMP1} + \text{TMP2} + \text{TMP3} + \text{TMP4} + \text{TMP5} + \text{TMP6} + \text{TMP7} + \text{TMP8}
\]

ENDIF

300 CONTINUE

C THE VARIABLES YOU WANT OUT OF THIS ARE

write(10,5000) JNM

DO I=1,JNM
    J=LIS(I)
    WRITE(10,1000) J,AREA(I),FLUX(I) ! FACE,AREA OF FACE, FLUX
END DO

write(10,5000) JNV

DO I=1,JNV
    J=LISE(I)
WRITE(10,2000) I,VOL(I),VAREA(I),VFLUX(I) ! ELEMENT, VOLUME, AREA
  ! OF TOP, VERTICAL
  ! FLUX OUT TOP
END DO

close(10)

5000 format(i8)
1000 format(i8,2x,e15.9,2x,e15.9)
2000 format(i8,2x,e15.9,2x,e15.9,2x,e15.9)

END
Appendix C
Modifications to ICM Code
Several modifications were made to the original ICM source code to allow it to be driven by the RMA10 hydrodynamic model. The changes made are detailed below:

Modification 1:
The inline code for reading the map file:

```
***** Flow mapping data

OPEN (MAP, FILE=MAPFN, STATUS='OLD')
READ (MAP, 1110) (QD(F), ILB(F), JB(F), JRB(F), F=1, NQF)
READ (MAP, 1027) (NVF(SB), SB=1, NSB)
READ (MAP, 1100)
DO 10010 SB=1, NSB
   READ (MAP, 1130) (VFN(F, SB), F=1, NVF(SB))
10010 CONTINUE
READ (MAP, 1027) (OBP(F), F=1, NOBP)
CLOSE (MAP)
```

was changed and implemented as a subroutine:

```
subroutine readMap(MAPFN)
character*72 MAPFN

include 'model.inc'

integer HHtag(NFEMHFFP), HVtag(NFEMVFFP), Itag(NQFP),
   HHtagToItagMap(NFEMHFFP), HVtagToItagMap(NFEMVFFP),
   FemCellToIcmCell(NBP)
common /lookup/ HHtag, HVtag, Itag, HHtagToItagMap, HVtagToItagMap,
   HVtagToItagMap, FemCellToIcmCell
```
integer F, SB, ISB
integer icmCellId, femCellId

open(MAP, FILE=MAPFN, STATUS='OLD')

read(map, 1000)
do b=1,NBP
   read(map, 1500) icmCellId, femCellId
   FemCellToICMCCell(femCellId) = icmCellId
enddo

read(map, 1000)
read(MAP, 2000) (ILB(F), IB(F), JB(F), JRB(F), ITAG(F), F=1,NQF)

read(map, 1000)
read(MAP, 2010) (NVF(SB), SB=1, NSB)

read(map, 1000)
do SB=1,NSB
   READ (MAP, 2030) ISB, (VFN(F,SB), F=1,NVF(SB))
enddo

close(MAP)

return

1000 format(/)
1500 format(I8, I8)
2000 format(8X, 4I8, 15x, I6)
2010 format(8X, I8)
2020 format(/)
2030 format(I8, 9I8)

end
Modification 2:
The inline code for reading the geo file:

***** Geometric data

```
OPEN (GEO, FILE=GEOFN, STATUS='OLD')
IF (BINARY_HYDRO .OR. DEPTH_AVG_HYDRO) THEN
  READ (GEO, 1120) (BU(B), B=1, NB)
  READ (GEO, 1140) (SBN(SB), BBN(SB), SB=1, NSB)
ELSE
  READ (GEO, 1000)
  READ (GEO, 1150) (BL(B,1), BL(B,2), BL(B,3), V1(B), ZD(B), BU(B),
  B=1, NB)
  READ (GEO, 1170) (SBN(SB), BBN(SB), SB=1, NSB)
  DO 10015 SB=1, NSB
    SFA(SB) = V1(SBN(SB))/BL(SBN(SB),3)
  10015 CONTINUE
END IF
CLOSE (GEO)
```

was changed and implemented as a subroutine:

```
subroutine readGeo(GEOFN)
character*72 GEOFN
include 'model.inc'
integer f, sb

dimension BIL(NHQP), BI(NHQP), BID(NHQP), BIR(NHQP)
common /rma10/ BIL, BI, BID, BIR
```
c Data from map generator
   open (geo, file=GEOFN, status='OLD')

read(geo, 1000)

c Surface box id
read(geo, 1020) (SBN(SB), BBN(SB), SB=1, NSB)

read(geo, 1040)

c Upper box for each box
read(geo, 1025) (bu(b), b=1, nb)

read(geo, 1040)

c Centroid distances
   do f=1, NHQP
      read(geo, 1010) BIL(f), BI(f), BID(f), BIR(f)
   enddo

   NOTE !! following moved
   to hydro file.

c Box surface area
read(geo, 1030) (sfa(sb), sb=1, nsb)

   close (geo)

   return

1000  format(1x)
1010  format(4(2x, e11.6))
1020  format(I6, I7)
1025  format(I6)
1030  format(e15.9)
1040  format(/
   end
Modification 3:
The inline code for reading the time-invariant hydro data
from the hydro file:

***** Time-invariant hydrodynamic data

IF (BINARY_HYDRO) THEN
READ (HYD) SFA
READ (HYD) (BL(SB,1),SB=1,NSB)
READ (HYD) (BL(SB,2),SB=1,NSB)
READ (HYD) (A(F),F=1,NHQF)
READ (HYD) HMBV
READ (HYD) HMBV
ELSE IF (ASCII_HYDRO) THEN
READ (HYD,1000)
READ (HYD,1160) (A(F),F=1,NQF)
READ (HYD,1100)
ELSE IF (DEPTH_AVG_HYDRO) THEN
READ (HYD) SFA
READ (HYD) (A(F),F=1,NHQF)
READ (HYD) (BL(SB,1),SB=1,NSB)
READ (HYD) (BL(SB,2),SB=1,NSB)
READ (HYD) HMSBV
ELSE
WRITE(*,*) 'hydro file specified incorrectly'
STOP
ENDIF

was changed and implemented as a subroutine:

logical function initializeHydro()
include 'model.inc'
integer HHtag(NFEMHFFP), HVtag(NFEMVFPF), Itag(NQFP),
   HHtagToItagMap(NFEMHFFP), HVtagToItagMap(NFEMVFPF),
   FemCellToIcmCell(NBP)

common /lookup/ HHtag, HVtag, Itag, HHtagToItagMap,
   HVtagToItagMap, FemCellToIcmCell

integer HYD2
common /lookup2/ HYD2

integer node_id, hface_id, vface_id, box_id
real f_area, flux, volume, top_area, v_flux

integer i, f1, f2, b1

integer nHHtags1, nHVTags2, HHtagValue, HVtagValue,
   ItagIndex

integer unusedHFaceCount, unusedVFaceCount

logical end_of_file, readHydro

   face_id: id of flow face
   f_area: Flow face area
   flux: Flow face flux
   box_id: id of box
   volume: box volume
   top_area: area of box top
   v_flux: flux out of boxes top face
   Clear the following arrays

   do i=1,NFEMHFFP
     HHtagToItagMap(i) = 0
enddo

do i=1,NFEMVFFP
HVtagToItagMap(i) = 0
enddo

open(HYD2,FILE=HYDFN(1),STATUS='OLD',FORM = 'FORMATTED')

initializeHydro = .TRUE.

c Read in horizontal flow face
c data from rma10 output file

c( hyd2,100,end=50) nHHtags1

f2 = 0
do f1=1,nHHtags1
   read(hyd2,200,end=50) node_id, f_area, flux
   f2 = f2 + 1
   HHtag(f2) = node_id
endo

unusedHFaceCount = 0

do i = 1, f2

   HHtagValue = HHtag(i)
   ItagIndex = 0
   j = 0

continue
j = j + 1
if(j .gt. NHQP) goto 30

if(Itag(j) .eq. HHtagValue) then
    ItagIndex = j
goto 30
else
goto 20
endif

30 continue

c If HtagToItagMap(HtagValue) = 0 then
c not a "flow face" we are interested in!

    HHtagToItagMap(i) = ItagIndex
    if(ItagIndex .eq. 0) unusedHFaceCount = unusedHFaceCount+1

enddo

c Read in cell data and vertical

c flow face data
read(hyd2, 100, end=50) nHVtags2

f2 = 0
do b1=1,nHVtags2
    read(hyd2,300) box_id, volume, top_area, v_flux
    f2 = f2 + 1
    HVtag(f2) = box_id
endo}
close(HYD2)
unusedVFaceCount = 0

do i = 1, f2

    HVtagValue = HVtag(i)
    ItagIndex = 0
    j = NHQP-1

2000  continue

    j = j + 1
    if(j .gt. NQFP) goto 3000

    if(!tag(j) .eq. HVtagValue) then
        ItagIndex = j
        goto 3000
    else
        if(-!tag(j) .eq. HVtagValue) then
            ItagIndex = -j
        else
            goto 2000
        endif
    endif

3000  continue

c If HtagToItagMap(HtagValue) = 0 then not a "flow face" we are interested in!

c
HVtagToItagMap(HVtagValue) = ItagIndex
if(ItagIndex .eq. 0) unusedVFaceCount = unusedVFaceCount+1

enddo
write(*,*) ' finished tag mapping'

close(HYD2)

c Need to initialize HMV (Hydrodynamic

c model cell volume) array and A (ICM flow

c face area) array. Only way to do this is

c to read data in from hydro file.

open(HYD,FILE=HYDFN(1),STATUS='OLD',FORM = 'FORMATTED')

end_of_file = readHydro()
if(end_of_file) then
   initializeHydro = .TRUE.
else
   initializeHydro = .FALSE.
endif

close(2)

return

50 close(HYD)

return

100 format(i8)
200 format(I8,2x,e15.9,2x,e15.9)
300 format(I8,2x,e15.9,2x,e15.9,2x,e15.9)

end
Modification 4:
A subroutine for reading the time-variant hydro data was written
to read the RMA10 hydro output data. This routine replaces ICM's
HYDRO subroutine. New subroutine code follows:

```plaintext
logical function readHydro()
include 'model.inc'

integer HHtag(NFEMHFFP), HVtag(NFEMVFFP), Itag(NQFP),
.  HHtagToTagMap(NFEMHFFP), HVtagToTagMap(NFEMVFFP),
.  FemCellToIcmCell(NBP)

common /lookup/ HHtag, HVtag, Itag, HHtagToTagMap,
.  HVtagToTagMap, FemCellToIcmCell

logical firstHR
common /lookup3/firstHR
logical end_of_file
integer node_id, hface_id, vface_id, box_id
real f_area, flux, volume, top_area, v_flux
integer unusedHFaceCount, unusedVFaceCount
real sense
integer icm_box_id, fem_box_id
integer f
logical bTagMap

c NOTE the PARAMETER NFEMFFP MEANS ...
c Number of Finite Element Model Flow Faces Parameter
c NFEMFFP = nHtags1 + nHtags2

c face_id: id of flow face
c f_area: Flow face area
```
flux: Flow face flux

readHydro = .FALSE.

Read in horizontal flow face data from rma10 output file

unusedHFaceCount = 0
read(hyd, 100, end=50) nHtags1
do f=1, nHtags1
    read(hyd, 200, end=50) node_id, f_area, flux
    hface_id = HHtagToItagMap(f)
    if(hface_id .eq. 0)
        unusedHFaceCount = unusedHFaceCount + 1
    else
        a(hface_id) = f_area
        q(hface_id) = flux
    endif
endo

Read in cell data and vertical flow face data

unusedVFaceCount = 0
read(hyd, 100, end=50) nHtags2

icm_box_id: id of box in ICM
fem_box_id: id of box in RMA0
volume: box volume
top_area: area of box top
v_flux: flux out of boxes top face
do b=1,nHtags2
  read(hyd,300) fem_box_id, volume, top_area, v_flux
  icm_box_id = FemCellToIcmCell(fem_box_id)
  hmv(icm_box_id) = volume
  bl3(icm_box_id) = volume/top_area
  sfa(icm_box_id) = top_area
  vface_id = HVtagToIagMap(fem_box_id)
  if(vface_id .eq. 0)
    unusedVFaceCount = unusedVFaceCount + 1
  else
    q(vface_id) = v_flux
    a(vface_id) = top_area
  endif
endo
return

50      readHydro = .TRUE.
      return

100     format(i8)
200     format(I8,2x,e15.9,2x,e15.9)
300     format(I8,2x,e15.9,2x,e15.9,2x,e15.9)
end

Modification 5:
The BL array was originally implemented as a two-dimensional array: BL(NUMBER_OF_BOXES,3). This array holds the three lengths (width, length and height) for each cell. The finite-element version does not distinguish between the horizontal distances; therefore this array was replaced with the array BL3(NUMBER_OF_BOXES). This array contains the cell height. All original code references were changed to reflect this modification.
Modification 6:
The mainline initialization of the HMV and V1 arrays:

********** Initialize volumes

DO 10110 SB=1,NSB
   DO 10100 F=1,NVF(SB)
      HMV(IB(VFN(F,SB))) = HMBV(SB)
      V1(IB(VFN(F,SB))) = HMBV(SB)
   10100 CONTINUE
   HMV(JB(VFN(NVF(SB),SB))) = HMSBV(SB)
   V1(JB(VFN(NVF(SB),SB))) = HMSBV(SB)
10110 CONTINUE

was replaced with the following code:

********** Initialize volumes

do 10100 b=1,NBP
   v1(b) = hmv(b)
10100 continue

The FEM version of ICM reads in from the hydrodynamic input file the volume of each box and assigns it directly to the array HMV. There is no intermediate assignment to HMBV (volume of boxes below surface layer with the index being the surface box id) or to HMSBV (volume of boxes in surface layer).

Modification 7:
The mainline initialization of the BL array was eliminated:
********** Initialize box lengths

DO 10130 SB=1,NSB
   CDIR$ VECTOR
   DO 10120 F=1,NVF(SB)
       BL(IB(VFN(F,SB)),1) = BL(JB(VFN(NVF(SB),SB)),1)
       BL(IB(VFN(F,SB)),2) = BL(JB(VFN(NVF(SB),SB)),2)
       BL(IB(VFN(F,SB)),3) = HMV(IB(VFN(F,SB)))/SFA(SB)
   10120 CONTINUE
   BL(JB(VFN(NVF(SB),SB)),3) = HMV(JB(VFN(NVF(SB),SB)))/SFA(SB)
10130 CONTINUE

The Bl array was replaced with the BL3 array. The BL3 array is assigned by the subroutine READHYDRO and updated by the subroutine UPDATE.

Modification 8:
Subroutine calls made to HYDRO changed to calls of HYDRO2.
The original subroutine HYDRO was not modified. Instead, a new routine specific to RMA10 was written. This new routine handles the hydrodynamic data updates.

SUBROUTINE HYDRO2 (NXHYD)

SAVE

INCLUDE 'model.inc'

REAL NXDAY
INTEGER F, SB
LOGICAL END_OF_FILE, readHydro
DIMENSION MASS(0:NBP,NCP)
10000 IF (NWQMR.GE.NHMR) THEN

** Hydrodynamic column volumes, flows, and vertical diffusions

end_of_file = readHydro()

10020 IF (END_OF_FILE) THEN

** Open next hydrodynamic file

HYDPTR = HYD PTR+1
IF (DIAGNOSTICS) WRITE (DIA,*) 'Opening hydrodynamic ',
. 'file ',HYD PTR,' at day ',
. JDAY
CLOSE (HYD)
OPEN (HYD,FILE=HYDFN(HYD PTR),FORM='UNFORMATTED',
. STATUS='OLD')

end_of_file = readHydro()

NWQMR = 0
NHMR = 0

** Reinitialize HM and WQM volumes

do b=1,NBP
v2(b) = hmv(b)
enddo

IF (CONSERVE_MASS) THEN
DO 10047 B=1,NB
DO 10045 JC=1,NAC
    MASS(B,AC(JC)) = C1(B,AC(JC))*V1(B)
  10045 CONTINUE
    V1(B) = V2(B)
    V1S(B) = V1(B)
DO 10046 JC=1,NAC
    C1(B,AC(JC)) = MASS(B,AC(JC))/V1(B)
    C2(B,AC(JC)) = MAX(C1(B,AC(JC)),0.0)
  10046 CONTINUE
  10047 CONTINUE
ELSE
  DO 10048 B=1,NB
    V1(B) = V2(B)
  10048 CONTINUE
END IF

***** Reinitialize initial water column mass

IF (MASS_BALANCE) THEN

***** Reinitialize mass balance variables

S1FLXN = 0.
S1FLXP = 0.
S1FLXC = 0.
S2FLXN = 0.
S2FLXP = 0.
S2FLXC = 0.
ATMFLXN = 0.
ATMFLXP = 0.
BENFLXPN = 0.
BENFLXDN = 0.
BENFLXPP = 0.
BENFLXDP = 0.
BENFLXPC = 0.
DLWCKMN = 0.
DLWCKMC = 0.
BNDFLXN = 0.
BNDFLXP = 0.
BNDFLXC = 0.
BURIALFLXN = 0.
BURIALFLXP = 0.
BURIALFLXC = 0.
DLSEDKN = 0.
DLSEDKC = 0.
ISEDMN = 0.
ISEDMP = 0.
ISEDMC = 0.

*****
Reinitialize initial water column and sediment masses
*****

DO 10051 J=1,NAC
  JC = AC(J)
  CMASS(JC) = 0.0
  DO 10050 B=1,NB
     CMASS(JC) = CMASS(JC)+C1(B,JC)*V1(B)/1000.
  CONTINUE
10050 CONTINUE
10051 CONTINUE

IWCMN = ANCC*CMASS(4)+ANCD*CMASS(5)+ANCG*CMASS(6)
       +CMASS(10)+CMASS(11)+CMASS(12)+CMASS(13)
       +CMASS(14)
IWCMP = CMASS(15)+CMASS(16)+CMASS(17)+CMASS(18)
IWCMC = CMASS(4)+CMASS(5)+CMASS(6)+CMASS(7)+CMASS(8)
       +CMASS(9)
IWCMS = ASCD*CMASS(5)+CMASS(21)+CMASS(22)
DO 10058 BB=1,NBB
ISEDMN = ISEDMN+(CPON(BB,1)+CPON(BB,2)+CPON(BB,3) 
  +CNH4(BB)+CNO3(BB))*A(VFN(1,BB)) 
  *HSED(BB)/1.E6

ISEDMP = ISEDMP+(CPOP(BB,1)+CPOP(BB,2)+CPOP(BB,3) 
  +CPIP(BB))*A(VFN(1,BB))*HSED(BB)/1.E6

ISEDMC = ISEDMC+(CPOC(BB,1)+CPOC(BB,2)+CPOC(BB,3)) 
  *A(VFN(1,BB))*HSED(BB)/1.E6

10058 CONTINUE
END IF

END_OF_FILE = .FALSE.

ELSE

***** Reinitialize HM and WQM volumes

do b=1,NBP
v2(b) = hmv(b)
enddo

NHMR = NHMR+1

END IF

GO TO 10000
END IF

END IF

NWQMR = NWQMR+1
NXHYD = NXHYD+INT(AHMDLT)

******* Calculations

******* Dead sea case
IF (.NOT.FLOW) THEN
    DO 10100 F=1,NQF
    Q(F) = 0.0
10100 CONTINUE
END IF

IF (.NOT.XY_DIFFUSION) THEN
    DO 10110 F=1,NHQF
    DIFF(F) = 0.
10110 CONTINUE
END IF

IF (.NOT.Z_DIFFUSION) THEN
    DO 10120 F=NHQF+1,NQF
    DIFF(F) = 0.
10120 CONTINUE
END IF

****** Determine flow direction

DO 10130 F=1,NQF
    IF (Q(F).GE.0.0) THEN
        POSITIVE_FLOW(F) = .TRUE.
    ELSE
        POSITIVE_FLOW(F) = .FALSE.
    END IF
10130 CONTINUE

****** Adjust vertical diffusion

DO 10140 F=NHQF+1,NQF
    DIFF(F) = ZDFMUL*DIFF(F)
10140 CONTINUE
****** ASCII input FORMAT statements

1000 FORMAT(21X,E10.3,5X,E10.3)
1005 FORMAT(F8.0)
1010 FORMAT(/)
1020 FORMAT(13X,F13.0)
1030 FORMAT(/)

END

Modification 9:
The following mainline code for updating the geometry
variables:

****** Update WQM volumes

DO 10600 F=1,NQF
    V2(JB(F)) = V2(JB(F))+Q(F)*DLT
    V2(IB(F)) = V2(IB(F))-Q(F)*DLT
10600 CONTINUE

****** Update box lengths

DO 10620 SB=1,NSB
    DO 10610 F=1,NVF(SB)
        BL(IB(VFN(F,SB)),3) = V2(IB(VFN(F,SB)))/SFA(SB)
    10610 CONTINUE

    BL(JB(VFN(NVF(SB),SB)),3) = V2(JB(VFN(NVF(SB),SB)))/SFA(SB)
10620 CONTINUE
****** Update layer depths

```fortran
DO 10630 B=1,NB
   ZD(B) = 0.0
10630 CONTINUE
DO 10650 SB=1,NSB
   CDIR$ VECTOR
      DO 10640 F=NVF(SB),1,-1
         ZD(IB(VFN(F,SB))) = ZD(JB(VFN(F,SB)))
         +BL(JB(VFN(F,SB)),3)
      10640 CONTINUE
10650 CONTINUE
ELSE IF (DEPTH_AVG_HYDRO) THEN

****** Update WQM volumes

```fortran
DO 50600 F=1,NQF
   V2(JB(F)) = V2(JB(F)) + Q(F) * DLT
   V2(IB(F)) = V2(IB(F)) - Q(F) * DLT
50600 CONTINUE

****** Update box lengths

```fortran
DO 50620 SB=1,NSB
   BL(SB,3) = V2(SB) / SFA(SB)
50620 CONTINUE
END IF
```

was replaced with a call to the new subroutine UPDATE:

subroutine updateG(HYDC)
character*8 HYDC
integer f,sb

include 'model.inc'
integer f, b, sb

c Check type of hydrodynamics
if(HYDC.EQ. 'BINARY') goto 10
if(HYDC.EQ.'DEPTH_AV') goto 20
if(HYDC.EQ.'RMAHYDRO') goto 30

BINARY_HYDRO
10 continue

c Update WQM volumes
do f=1,NQF
   V2(JB(f)) = V2(JB(f))+Q(f)*DLT
   V2(1B(f)) = V2(1B(f))-Q(f)*DLT
enddo

c Update box lengths..Note that vertical box length changes every time step because box volume is changing every time step!

do b=1,nb
   bl3(b) = v2(b)/sfa(b)
enddo

Update layer depths
ZD(i) is depth below surface of top of box i!
c cell depth below equals cell depth above + thickness
do b=1,NB
   ZD(b) = 0.0
endo

do sb=1,NSB
   do f=NVF(sb),1,-1
      ZD(IB(VFN(f,sb))) = ZD(JB(VFN(f,sb)))
      +BL3(JB(VFN(f,sb)))
      enddo
endo
endo

return

DEPTH_AVG_HYDRO

continue

do b=1,NB
   ZD(b) = 0.0
endo

Set depth to box top

Update WQM volumes

do f=1,NQF
   V2(JB(f)) = V2(JB(f))+Q(f)*DLT
   V2(IB(f)) = V2(IB(f))-Q(f)*DLT
endo

Update box lengths

return

RMA10_HYDRO
Modification 10:
This modification concerned replacing the direction dependent algorithm for calculating the advection and diffusion multipliers with one using the centroid parameters. The following mainline code is the original algorithm:
***** Horizontal advection and diffusion multipliers

CDIR$ VECTOR
DO 10190 F=1,NHQF

****** Positive flows

IF (LEFTM1_BOUNDARY(F)) BL(ILB(F),QD(F)) = BL(IB(F),QD(F))
IF (LEFT_FLOWB(F)) THEN
    BL(IB(F),QD(F)) = BL(JB(F),QD(F))
    BL(ILB(F),QD(F)) = BL(JB(F),QD(F))
END IF
IF (RIGHT_FLOWB(F)) BL(JB(F),QD(F)) = BL(IB(F),QD(F))
SF1(F) = MIN(BL(IB(F),QD(F)),BL(JB(F),QD(F)))
SF2(F,1) = BL(IB(F),QD(F))**2
DEN1(F,1) = 0.25*(BL(ILB(F),QD(F))+2.*BL(IB(F),QD(F))
          +BL(JB(F),QD(F))*(BL(ILB(F),QD(F))
          +BL(IB(F),QD(F)))
DEN2(F,1) = -0.25*(BL(IB(F),QD(F))+BL(JB(F),QD(F))
           *(BL(ILB(F),QD(F))+2.0*BL(IB(F),QD(F))
           +BL(JB(F),QD(F)))
DEN3(F,1) = 0.25*(BL(IB(F),QD(F))+3.0*BL(IB(F),QD(F))
            +BL(JB(F),QD(F)))
T2(F,1) = BL(JB(F),QD(F))/(BL(IB(F),QD(F))+BL(JB(F),QD(F)))
T3(F) = BL(IB(F),QD(F))/(BL(IB(F),QD(F))+BL(JB(F),QD(F)))
TP1(F,1) = 0.5*(BL(IB(F),QD(F))-BL(JB(F),QD(F)))*SF1(F)
TP2(F,1) = 0.5*(BL(ILB(F),QD(F))+2.0*BL(IB(F),QD(F))
           -BL(JB(F),QD(F)))*SF1(F)
TP3(F,1) = 0.5*(BL(ILB(F),QD(F))+3.0*BL(IB(F),QD(F)))*SF1(F)

****** Negative flows

IF (LEFT_FLOWB(F)) BL(IB(F),QD(F)) = BL(JB(F),QD(F))
IF (RIGHT_FLOWB(F)) THEN

\[
\begin{align*}
\text{BL}(JB(F), QD(F)) &= \text{BL}(IB(F), QD(F)) \\
\text{BL}(JRB(F), QD(F)) &= \text{BL}(IB(F), QD(F)) \\
\end{align*}
\]

\[
\text{END IF}
\]

IF (RIGHTP1_BOUNDARY(F)) \text{ BL}(JRB(F), QD(F)) = \text{ BL}(JB(F), QD(F))

\[
\text{SF1}(F) = \text{MIN}([\text{BL}(IB(F), QD(F)), \text{BL}(JB(F), QD(F))])
\]

\[
\text{SF2}(F, 2) = \text{BL}(JB(F), QD(F))^{**2}
\]

\[
\text{DEN1}(F, 2) = 0.25*(\text{BL}(IB(F), QD(F)) + 2.0*\text{BL}(JB(F), QD(F))
\]

\[
+\text{BL}(JRB(F), QD(F)))*\text{BL}(IB(F), QD(F)) + \text{BL}(JB(F), QD(F))
\]

\[
\text{DEN2}(F, 2) = -0.25*(\text{BL}(JB(F), QD(F)) + \text{BL}(JRB(F), QD(F))
\]

\[
*\text{BL}(IB(F), QD(F)) + \text{BL}(JB(F), QD(F))
\]

\[
\text{DEN3}(F, 2) = 0.25*(\text{BL}(IB(F), QD(F)) + 2.0*\text{BL}(JB(F), QD(F))
\]

\[
+\text{BL}(JRB(F), QD(F)))*\text{BL}(IB(F), QD(F))
\]

\[
+\text{BL}(JB(F), QD(F))
\]

\[
\text{T1}(F) = \text{BL}(JB(F), QD(F))/(\text{BL}(IB(F), QD(F)) + \text{BL}(JB(F), QD(F))
\]

\[
\text{T2}(F,2) = \text{BL}(IB(F), QD(F))/(\text{BL}(IB(F), QD(F)) + \text{BL}(JB(F), QD(F))
\]

\[
\text{TP1}(F,2) = -0.5*(3.0*\text{BL}(JB(F), QD(F)) + \text{BL}(JRB(F), QD(F)))*\text{SF1}(F)
\]

\[
\text{TP2}(F,2) = 0.5*(\text{BL}(IB(F), QD(F)) - 2.0*\text{BL}(JB(F), QD(F))
\]

\[
-\text{BL}(JRB(F), QD(F)))*\text{SF1}(F)
\]

\[
\text{TP3}(F,2) = 0.5*(\text{BL}(IB(F), QD(F)) - \text{BL}(JB(F), QD(F)))*\text{SF1}(F)
\]

10190 CONTINUE

The above code was replaced with the following centroid parameter based algorithm:

\[
\text{DO 10195 F=1,NHQF}
\]

****** Positive flows

IF (LEFTM1_BOUNDARY(F)) BIL(F) = BI(F)

IF (LEFT_FLOWB(F)) THEN

\[
\text{BI}(F) = 2.0*\text{BID}(F)
\]

\[
\text{BIL}(F) = \text{BI}(F)
\]

END IF

IF (RIGHT_FLOWB(F)) THEN
\[ BI(F) = 2.0 \times BID(F) \]
\[ BIR(F) = BI(F) \]

END IF

\[ SF1(F) = BI(F) \]
\[ SF2(F,1) = BI(F) \times BI(F) \]
\[ DEN1(F,1) = (BIL(F) + BI(F)) \times BIL(F) \]
\[ DEN2(F,1) = -BI(F) \times BIL(F) \]
\[ DEN3(F,1) = BI(F) \times (BIL(F) + BI(F)) \]
\[ T2(F,1) = (BI(F) - BID(F)) / BI(F) \]
\[ T3(F) = BID(F) / BI(F) \]
\[ TP1(F,1) = (2.0 \times BID(F) - BI(F)) \times SF1(F) \]
\[ TP2(F,1) = (2.0 \times BID(F) - BI(F) + BIL(F)) \times SF1(F) \]
\[ TP3(F,1) = (BIL(F) + 2.0 \times BID(F)) \times SF1(F) \]

******* Negative flows

IF \((LEFT\_FLOWB(F))\) \(BI(F) = 2.0 \times BID(F)\)

IF \((RIGHT\_FLOWB(F))\) THEN
\( BI(F) = 2.0 \times BID(F) \)
\( BIR(F) = BI(F) \)
END IF

IF \((RIGHT\_P1\_BOUNDARY(F))\) \(BIR(F) = BI(F)\)

\[ SF1(F) = BI(F) \]
\[ SF2(F,2) = BI(F) \times BI(F) \]
\[ DEN1(F,2) = (BI(F) + BIR(F)) \times BI(F) \]
\[ DEN2(F,2) = -BI(F) \times BIR(F) \]
\[ DEN3(F,2) = (BI(F) + BIR(F)) \times BIR(F) \]
\[ T1(F) = (BI(F) - BID(F)) / BI(F) \]
\[ T2(F,2) = BID(F) / BI(F) \]
\[ TP1(F,2) = -(2.0 \times (BI(F) - BID(F)) + BIR(F)) \times SF1(F) \]
\[ TP2(F,2) = (2.0 \times BID(F) - BI(F) - BIR(F)) \times SF1(F) \]
\[ TP3(F,2) = (2.0 \times BID(F) - BI(F)) \times SF1(F) \]

10195 CONTINUE
Appendix D
MAPPER Input and Output Files for Example Grid

This appendix presents an example grid and the associated input and output files for MAPPER.C. The example consists of a 3 by 2 by 2 grid domain of 12.0 m³, with element dimensions 1.0 by 1.0 by 1.0 m. The node numbers are shown at the corners and facial mid-points, and the element numbers are indicated in the center of each element in Figure D1. Plan views are shown in Figure D1 for the two layers at the top, middle, and bottom of each layer. The node-element connectivity output file from RC4IC10.f is shown for the example grid in Table D1. This file provides the input required for MAPPER.C. The output files from MAPPER.C, MAP and GEO, are shown for the example grid in Tables D2 and D3, respectively. Following is a description of the steps to conduct this example, along with explanations for the input and output files.

MAPPER Input File Description

The hydrodynamic grid is initially generated by the FastTABS program, which is a preprocessor and postprocessor for two-dimensional (2-D) finite element models maintained by the U.S. Army Engineer Waterways Experiment Station Coastal and Hydraulics Laboratory. The user interactively constructs a grid within FastTABS that then outputs a mesh geometry file for later input into RMA. All information contained in this file is subsequently written by RMA to what is referred to as the RMA binary output file. This RMA output file ultimately will contain a complete geometric description of the grid in 3-D along with the time-varying hydrodynamic flow fields. The RC4IC10.f postprocessing program reads the RMA binary output file and creates the node-element connectivity file, which is the input file for MAPPER.C.

The node-element connectivity file (i.e., Table D1) is described as follows. Information in the first section of this file describes the 2-D mesh geometry of the grid. Each line begins with a line type code consisting of two or three letters. Code definitions follow below.
Figure D1. Plan view of example 3 by 1 by 2 grid (Sheet 1 of 3)
Figure D1. (Sheet 2 of 3)
Figure D1. (Sheet 3 of 3)

Appendix D  MAPPER Input and Output Files for Example Grid
### Table D.1. Node-Element Connectivity File for Example Grid from RC4IC10.f Output File

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VALUES FROM 3D BINARY GEOMETRY FILE (generated by ricr10.f)

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SURFACE

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NSURF 1200 means head boundary strip.
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</table>

! 1000 means wall Boundary strip

! 0 means internal strip
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### Table D.2. MAP File Generated for Example Grid

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Table D.3. GEO File Generated for Example Grid

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<td>0.0</td>
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</tr>
</tbody>
</table>
T1 thru T3: Titles. T1 and T2 are optional, T3 is necessary.

SI: Signifies English or SI units. English = 0, SI = 1.

$L$: logical unit numbers used by RMA specific routines.

GO: Used to input the nodes of a GO string (RMA term). Used as a reference line for a renumbering of node identifier numbers done by RMA internally.

GE: Element definitions.

<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The first integer is the element identifier.</td>
</tr>
<tr>
<td>2-9</td>
<td>The next eight integers define the nodal connectivity of the element. The node ordering is counter-clockwise beginning at a corner then sequentially around the perimeter. Eight integers are always used. Triangular elements that have only six nodes will have the remaining two integers set to zero.</td>
</tr>
<tr>
<td>10</td>
<td>Material identifier (internal to RMA)</td>
</tr>
<tr>
<td>11</td>
<td>A real value. Represents the direction of the eddy viscosity tensor for the element and is usually left as zero.</td>
</tr>
</tbody>
</table>

GNN: Corner node coordinates.

<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>Integer. Node identifier.</td>
</tr>
<tr>
<td>2</td>
<td>Real. X coordinate.</td>
</tr>
<tr>
<td>3</td>
<td>Real. Y coordinate.</td>
</tr>
<tr>
<td>4</td>
<td>Real. Z coordinate.</td>
</tr>
</tbody>
</table>

Midside nodes are not listed. They can be calculated from corner nodes.

Information in the second section Table D1 describes the depth dimension of the grid. This section begins with the specification of the following parameters:

NP - Total number of nodes in grid.

NE - Total number of elements in grid.

NPM - Total number of nodes in the surface plane.
NEM - Total number of elements in surface plane.

Next, the number of nodes beneath each surface node, including the surface node, and an integer indicating the numbering of this column of nodes are specified.

NDEP - Total number of nodes in a column. A column exists for each node in the surface plane.

NREF - Nodes in the surface plane are numbered sequentially. However, all other nodes are numbered in sequential order from the node beneath the surface node to the bottom within a node column. This integer is the starting node identifier for the first node beneath the surface plane node in a node column plus 1.

The final section of Table D1 indicates for each node within a node column whether it is internal to the grid or positioned on the boundary. The following definitions apply.

NSURF: An integer associated with each node column indicating the type of node column. Possible values are as follows:

0 - Internal node column.

1000 - Wall boundary exists at this node column.

1200 - Head boundary exists at this node column.

31000 - M2 tidal boundary exists at this node column.

MAPPER Output Files Descriptions

The program MAPPER.C reads the node-element connectivity file and generates the output files MAP and GEO files used as input by ICM. When MAPPER reads the node-element connectivity file, it builds an internal RMA grid. MAPPER is aware of how RMA numbers its nodes and elements. After completing the internal RMA grid, MAPPER can then write out the linkage and geometry data ICM needs. MAPPER will create the MAP and GEO files. The MAP file contains the RMA element to ICM cell correspondence and flow face definitions. The GEO file specifies the vertical relationship between ICM cells and lists the QUICKEST weighting distances.

ICM MAP File Description

The MAP file contains four sections of data. A brief explanation of each section follows below.
The first section lists the correspondence between ICM cell identifiers and RMA element identifiers. Note that the two models have different numbering schemes for their cells. This section establishes the relationship between the two numbering schemes. The FEMCONVT.F program, which reads the RMA binary output file, writes out data in terms of RMA internal element numbers and node numbers; therefore, the information in this section will allow a unique identification of each cell and flow face.

RMA numbers elements sequentially in the order of their creation for the surface layer. Next, it numbers its elements from the bottom up to the layer beneath the surface layer going from one column to the next in the order of the element numbering in the surface layer. The ICM numbering scheme sequentially numbers the cells within a layer starting with the surface layer then progressing to the layer beneath till the last layer has been processed. Definitions of the parameters for this section follow.

ICM - Unique ICM cell identifier.

FEM - Unique RMA cell identifier corresponding to the appropriate ICM cell.

The second section identifies each flow face in the grid. Definitions of the parameters for flow face definition follow.

FFID - Unique flow face identifier.

ILB - QUICKEST far upstream weighting cell identifier.

IB - Cell identifier for flow donor cell.

JB - Cell identifier for flow receiver cell.

JRB - QUICKEST far downstream weighting cell identifier.

TYPE - Character variable indicating type of flow face. B indicates Boundary. I indicates Internal flow face.

ORIENT - Character variable indicating direction orientation. H indicates face is oriented for horizontal flow. V indicates face is oriented for vertical flow.

LAYER - Indicates what layer the flow face is in.

The third section lists the number of vertical flow faces in a cell column beneath each surface cell. Definitions of the parameters for this section follow.

SB - Surface cell (box) identifier.

NVF - Number of vertical flow faces beneath the surface cell.
The fourth section lists the vertical flow face identifiers for each ICM cell column iterated in the third section. Definitions of the parameters necessary for this section follow.

SB - Surface cell (box) identifier.

VFN - List of all flow face identifiers oriented vertically beneath a surface cell.

**ICM GEO File Description**

The GEO file contains three sections of data. A brief explanation of each section follows below.

The first section identifies for each surface cell the bottom cell directly beneath it. Definitions of the parameters for this section follow.

SB - Surface cell (box) identifier.

BBN - Bottom cell identifier.

The second section identifies for each cell, in increasing order, the cell directly above it. Definition of the parameter for this section follows.

BU - Identifier of cell above. Cell identifier is implicit in line order.

The third section specifies the QUICKEST weighting distances for each flow face. Definitions of the parameters for this section follow.

BI - Centroid to centroid distance between IB cell and JB cell.

BID - Distance from centroid of IB cell to flow face.

BIL - Centroid to centroid distance between ILB cell and IB cell.

BIR - Centroid to centroid distance between JB cell and JRB cell.

TYPE - Character variable indicating type of flow face. B indicates Boundary. I indicates Internal flow face.

LAYER - Indicates what layer the flow face is in.
### REPORT DOCUMENTATION PAGE

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13. ABSTRACT (Maximum 200 words)

This study was conducted for the purpose of developing a methodology and associated software for linking hydrodynamic output from the RMA10 finite element model to the CE-QUAL-ICM finite volume water quality model. The ICM model is usually linked to hydrodynamic output from a finite difference hydrodynamic model, CH3D-WES. RMA10 uses an unstructured grid approach, whereas CH3D-WES is based on a structured grid scheme. A linkage to RMA10 was needed to provide greater flexibility for simulating water quality and contaminants. This report documents the development and testing of the RMA10-ICM linkage.

14. SUBJECT TERMS

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