Chapter 3

PARTICIPANT MODELS

Contents

At initiation of the Review in June 1997, there were six participant models. But only three continued to participate. These three models are identified by the sponsoring agency or organization.

3.1 Contra Costa Water District

Identifier CCW

Hydrodynamic Model Fischer Delta Model DELFLO

Primary Documentation Anon. (1984)

Transport Model DELSAL

Primary Documentation Anon. (1984)

Contact K.T. Shum

3.1.1 Data File Submissions

- H1-H5
  - December 1998
- H6-H8
  - August 2000
- M1-M4
  - none
- H9-H11
  - August 2000
- Missing Responses
  - M1, M2, M3, M4
- Data Format Compliance
  - Excellent

3.1.2 Numerical Algorithm

The DELFLO numerical algorithm is the Method of Characteristics. The friction formula is Manning.

The specific implementation adopts a uniform Eulerian grid, with locally-constant-slope characteristic paths from the previous time, and linear interpolation for water surface elevation and flow at the previous time. This is a variation on a text book "three-point method of characteristics" algorithm, e.g. Abbott (1979) §4.2, Cunge et al. (1980) page 58 and Hoffman (1992) §15.10.

The truncation error of the "three-point method of characteristics" algorithm (Hoffman 1992, pages 727-8) is $O(\Delta t, \Delta x^2, \Delta x^2/\Delta t)$. The third part is especially noteworthy, identifying implicit numerical diffusion for large Δx (especially) or small Δt. This is not necessarily a problem where there is excellent space resolution of expected response patterns, but the results need to be carefully evaluated for any application that seeks to stretch the familiar response envelope.

The DELSAL numerical algorithm is a Lagrangian box (Fischer 1972), a finite volume approach along the local plug-flow advection path. The Fischer algorithm was the breakthrough contribution in numerical solutions of Equation 2.4.4, establishing the fundamental preference for moving coordinate algorithms over those based on an Eulerian coordinate system.

3.2 Department of Water Resources, California

Identifier DWR

Hydrodynamic Model DSM2 HYDRO

Primary Documentation DeLong et al. (1997)

Transport Model DSM2 QUAL

Primary Documentation Jobson and Schoellhamer (1987)

Contact Parviz Nader

Online Documentation http://wwwdelmod.water.ca.gov

3.2.1 Data File Submissions

- H1-H5
  - September 1998
  - revised October 1999
  - revised March 2000
- M1-M4
  - missing M3
  - September 1998
  - revised October 1999
  - revised March 2000
- H6-H8
  - October 1999
  - revised March 2000
- H9-H11
  - 21 August 2000

  - revised 22 August 2000
  - revised 29 August 2000

- Missing Responses
  - M3
- Data Format Compliance
  - Poor.

    Particular problems were
    * Computational time step was reported incorrectly as 1 s
    * Direction of x axis was reversed
    * Network numbering was completely changed
    * H series data files had truncated lines
    * Numerous revisions
    * Gravitational acceleration reported as 32.02 ft/s^2

    Data analysis code has numerous **if (DWR) then ...** exceptions, and a substantially disproportionate effort[1] was necessary to read and interpret these data files.

3.2.2 Numerical Algorithm

The DSM2 numerical algorithm is the Finite Difference Method. The friction formula is Manning.

The specific implementation is a variation on the classical Preissmann (1961) box algorithm on a uniform grid, originally adopted in his pioneering numerical solutions of Equations 2.4.1 and 2.4.2. It remains an excellent choice of finite difference algorithm. Text book discussions of this algorithm are Abbott (1979) pages 182-188 and Cunge et al. (1980) pages 64-66.

The manner of time integration is especially noteworthy. A local variable or parameter, $f(x,t)$, is time-integrated as (DeLong et al. 1997, page 8)

$$\int_{t_n}^{t_n+\Delta t} f(x,t)\,dt \approx \Big[\theta f(x,t_n{+}\Delta t) + (1{-}\theta) f(x,t_n)\Big]\Delta t \tag{3.2.1}$$

where θ is a time-weighting parameter. Abbott (1979) notes that the time-centered scheme, $\theta = 0.5$, is non-dissipative, but that heavy numerical damping is introduced for $\theta > 0.5$. DeLong et al. (1997), page 21, suggest θ as "0.5 to 1.0, normally about 0.6", but caution that the "use of θ to dampen numerical oscillations occurring in results is not recommended"; θ is a DSM2 input parameter.

[1]The following commentary was provided by DWR (2 February 2001): "DSM2 is a very complex model, and I/O routines alone require several thousand lines of code. Conforming to Dr. Sobey's requested output format was very time-consuming. In several cases, we chose to deviate from the specified output format. While we appreciate the extra effort required by Dr. Sobey to interpret test problem results, we believe the conclusions inappropriately emphasize the difficulties he encountered. We believe that the report should focus more on model performance and less on the reviewer's difficulties in interpreting model results."

3.3 Resource Management Associates

Identifier RMA

Hydrodynamic Model RMA2

Primary Documentation King et al. (1975)

Transport Model RMA11

Primary Documentation King and Norton (1978)

Contact John DeGeorge, Stacie Grinbergs

Online Documentation http://www.rmanet.com/rma2.htm, http://www.rmanet.com/rma11.htm

3.3.1 Data File Submissions

- H1-H6
  - September 1997
  - revised February 2000
  - revised August 2000
- M1-M4
  - September 1997
  - revised August 2000
- H6-H8
  - February 2000
- H9-H11
  - August 2000
- Missing Responses
  - none
- Data Format Compliance
  - Excellent

3.3.2 Numerical Algorithm

The RMA2/RMA11 numerical algorithm is the Finite Element Method. The friction formula is Manning. The specific implementation adopts a mix[2] of linear and quadratic elements in x.

While the numerical Method of Characteristics (CCW) and the Finite Difference method (DWR) are based directly on the field equations (Equations 2.4.1 through 2.4.4), the Finite Element Method is based on weighted integrals of these field equations, respectively

$$\iint W_j \left[b\frac{\partial \eta}{\partial t} + \frac{\partial Q}{\partial x} - q \right] dx\, dt \tag{3.3.1}$$

$$\iint W_j \left[\frac{\partial Q}{\partial t} + \frac{\partial}{\partial x}(\frac{Q^2}{A}) + gA\frac{\partial \eta}{\partial x} + \frac{\tau_0}{\rho}P \right] dx\, dt \tag{3.3.2}$$

$$\iint W_j \left[\frac{\partial}{\partial t}(AC) + \frac{\partial}{\partial x}(QC) - \frac{\partial}{\partial x}\left(E_x A \frac{\partial C}{\partial x} \right) - S \right] dx\, dt \tag{3.3.3}$$

where a sufficient number of different weighting functions $W_j, j = 1,2,\ldots$ are chosen to mathematically close the problem formulation. This is called the weak formulation of the physical problem, as distinct to the strong form (the field equations, Equations 2.4.1 through 2.4.4). The classical text book discussion of the Finite Element Method is Zienkiewicz (1977).

Two general concerns with FEM are prevalent, namely the weak[3] formulation and the additional computational overhead associated with the weighted integration over the solution domain. Nevertheless, FEM has proven to be an appropriate numerical solution algorithm for the present system of field equations.

3.4 Revised Submissions

Finally, it is noted that there were multiple submissions from some participants. These were mostly in response to problems identified at workshops in February 1999 and March 2000, where preliminary results of the review were presented and discussed. Hydrodynamic and transport modeling is a challenging task. The physical problem is complex and the detail is voluminous. The probability of error is high. The challenge is to recognize them!

[2]The following description was provided by RMA (DeGeorge, 19 January 2001): "The RMA finite element hydrodynamic model uses a different order representation for pressure terms and velocity terms. Pressure terms (water surface elevation) are represented using a linear basis functions over an element, while velocity terms are represented using a quadratic basis functions. This mixed approximation was found to be necessary for stability of the formulation and is common in finite element CFD applications. One-dimensional cross-sectionally averaged elements use three computational nodes, two corner nodes and a mid-side node. The velocity is represented by a quadratic fit through all three nodes. The water surface elevation is represented by a linear fit between the corner nodes only. Each element has a trapezoidal section (defined by bottom width and side-slopes) that varies linearly between corner nodes." In the terminology of Chapters 4 through 18, the spacing of flow nodes is Δx, and the spacing of water surface elevation nodes is $2\Delta x$.

[3]The following commentary was provided by RMA (DeGeorge, 19 January 2001): "It is true that the weak form does not ensure that the original differential equations will be satisfied at each computational node. Rather, using the weak form solves for the "best" approximation to the solution of the governing equation over each element in the computational space."

3.5 Model Documentation

Given that one objective of a comparative review must be information on candidate models, the varying format, detail, vintage and availability of existing model documentation is a relevant concern. In addition, the listed primary documentation is in the "grey" literature, documents that are not readily accessible.

Several years ago, the International Association for Hydraulic Research recognized the growing penetration of numerical models into hydraulic engineering practice, and the consequent need to examine and support the validity of models and the results they produce. They initiated a study to answer the following questions:

- In which situations can a particular model be justifiably applied, and how well do computational results represent the actual physics?
- To what extent has this been tested?
- What are the estimated accuracies of predictions, and what is the basis for these estimates?
- What are the inherent uncertainties in model calculations and how can they be controlled?
- What has been done to ensure that the model represents the state of the art in conceptual understanding, numerical implementation, and software engineering?

The result Dee et al. (1994) was a set of *Guidelines for documenting the validity of computational modelling software*.

Assimilation of information on the competing model systems would be significantly enhanced by the preparation of model documentation that follows these guidelines.

The documentation in this recommended format should be easily available. A copy of the current documentation should be deposited with the University of California's Water Resources Center Archives. This would ensure that the documentation would appear in major online library catalogs such as World Cat (OCLC) and Melvyl (University of California). The BDMF might also consider hosting on-line versions of this documentation.

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