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Improved Thermal Predictions in CE-QUAL-W2

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Abstract

Recent modifications to the transport scheme within the two-dimensional hydrodynamic and water quality model **CE-QUAL-W2** have resulted in a significant improvement in the prediction of temperature distributions by reducing numerical diffusion. These changes allow for a more accurate description of wind effects in the model. This paper briefly describes the modifications to **CE-QUAL-W2** and presents results of two simulations both with and without the improvements to the transport algorithm.

Introduction

CE-QUAL-W2 is a two-dimensional, laterally averaged, hydrodynamic and water quality model (WES,1986) widely applied by the U. S. Army Corps of Engineers, universities, and the private sector. The experience gained through numerous applications of the model has led to the identification of a number of potential model improvements.

One improvement recently addressed is the removal of excessive numerical diffusion generated by the original upwind advective transport scheme. The reduction in numerical diffusion was of primary importance because of difficulties encountered when modeling temperature dynamics. In order to calibrate temperature profiles, previous applications have relied mainly on a wind sheltering coefficient ranging from 0 to 1 which is applied to reduce the observed winds.

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For example, the DeGray Lake application (Martin, 1978) used a wind sheltering coefficient of 0.3 throughout the summer stratification period. Since the wind shear formulation in **CE-QUAL-W2** is a function of the square of the wind speed, wind shear was reduced by over 90%. The effects of numerical diffusion were overcome by essentially eliminating one of the most important physical processes responsible for vertical temperature distribution - wind shear.

The problems associated with upwind numerical diffusion have been reduced by implementing 1) the explicit third-order **QUICKEST** advective transport scheme (Leonard, 1979) in both the horizontal and vertical dimensions, and 2) options for time-weighted implicit vertical advection. The purpose of this paper is to briefly describe improvements to the transport scheme and present comparisons of model applications with and without the improved transport scheme.

Transport Modifications

A modification of the third-order **QUICKEST** finite difference scheme has been implemented in both the horizontal and vertical dimensions (Chapman, 1988). A nonuniform grid version was developed using a three-point Lagrangian interpolation function (Henrici, 1964) to estimate constituent values at grid cell interfaces. Specifically, advective multipliers for each of three upstream weighted grid cells have been derived in terms of cell lengths and the local cell interface velocity. An advantage of this technique is that time varying and time invariant contributions to the interpolation functions can be segregated so that multiple constituents can be transported with a minimum of computational effort.

An option for implicit vertical transport set up for a variable grid size has also been implemented. This option employs a fully implicit diffusion algorithm and a time-weighted, central difference, implicit advection scheme. A unique feature of the implicit vertical advection option is that the explicit part of the time-weighted scheme is **QUICKEST** which increases overall accuracy. In addition, the implicit vertical transport relaxes the stability requirements allowing for larger timesteps which the model automatically calculates and adjusts during a simulation.

Demonstration Simulations

Two simulations are presented to demonstrate the improvement in thermal predictions using the new transport algorithm in **CE-QUAL-W2**. These test simulations revisit existing applications of DeGray Lake, Arkansas and Oahe

Lake, South Dakota, both of which are Corps of Engineer reservoirs. The details concerning the physical setting and computational set-up of the applications can be found in Martin (1987) and Cole et al. (1992) for Degray and Oahe Lakes, respectively. Verification years for the two sites are used to contrast the model predictions obtained using the new transport scheme and the original upwind difference method.

Results of the DeGray and Oahe Lake simulation with and without the new transport scheme are presented in Figures 1 and 2. The upper series of temperature profiles used **QUICKEST** transport horizontally and fully implicit transport vertically with a wind sheltering coefficient of 0.9 throughout the simulation. The lower series used the original upwind differencing scheme with the same wind sheltering coefficient. The differences for both applications are dramatic showing very clearly why previous applications resorted to the use of wind sheltering coefficients in order to reduce the amount of vertical mixing. Results from the other two vertical transport options (fully explicit **QUICKEST** and time-weighted) yielded similar reductions in numerical diffusion.

Conclusions

Although previous applications of **CE-QUAL-W2** have produced reasonable temperature predictions, the results were obtained at the expense of correctly specifying wind shear, one of the most important physical processes involved in temperature dynamics. The reduction in numerical diffusion accomplished by the new transport scheme allows for a more realistic specification of wind inputs into the model thus improving the models predictive capabilities.

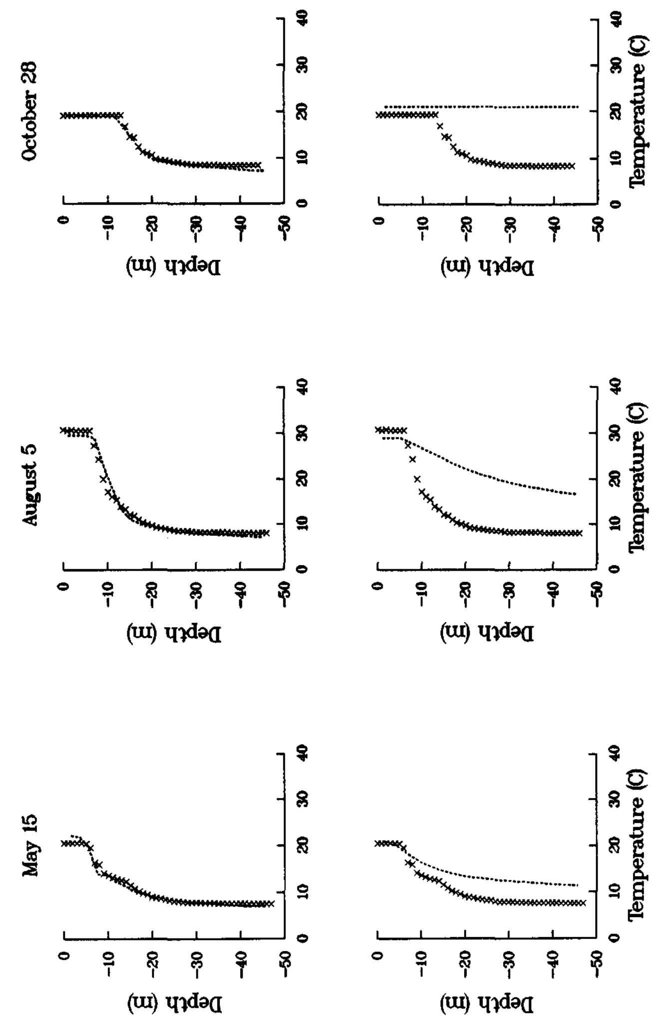

Figure 1. Predicted (-----) vs. observed (xxxxx) temperature profiles for DeGray Reservoir. The upper row represents results obtained with the modified transport scheme. The bottom row represents results obtained with upwind differencing. Both simulations used a wind sheltering coefficient of 0.9.

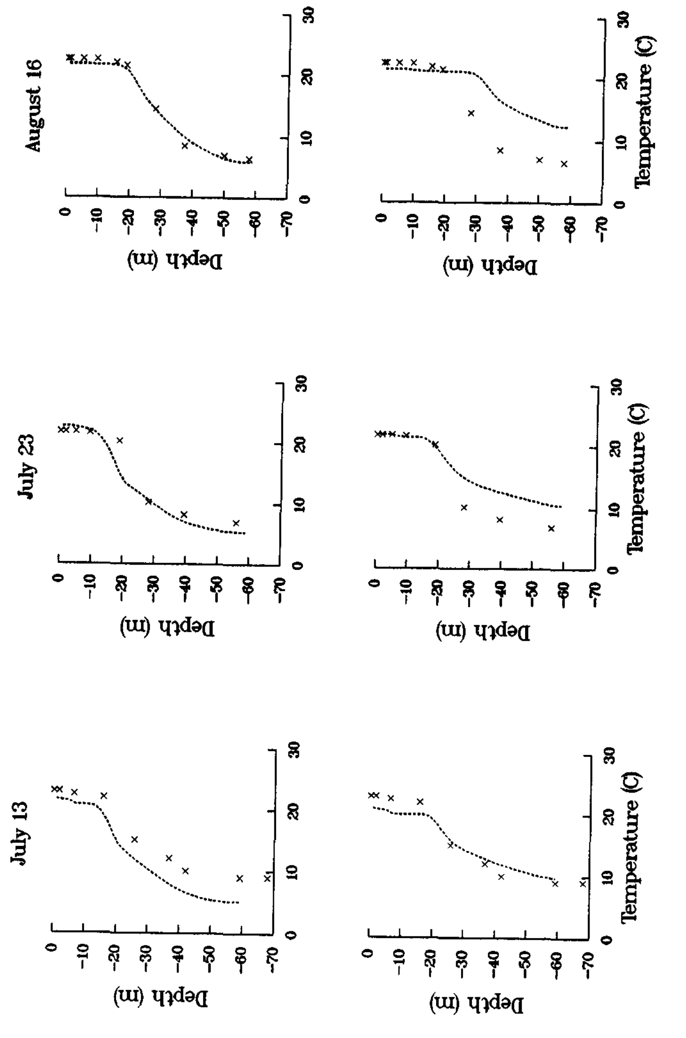

Figure 2. Predicted (-----) vs. observed (xxxxx) temperature profiles for Lake Oahe. The upper row represents results obtained with the modified transport scheme. The bottom row represents results obtained with upwind differencing. Both simulations used a wind sheltering coefficient of 0.9.

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Appendix 1: References

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