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Project Summary

Maintenance and Testing of Hydrological Simulation Program—FORTRAN (HSPF)

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The Hydrological Simulation Program FORTRAN (HSPF) is a mathematical model that simulates hydrology and water quality in natural and man-made water systems. This report describes the work involved in maintaining and testing HSPF over a period of one year following its initial development. An account is given of the chronology of major events during the maintenance work. The testing included work with hypothetical data and checks against outputs produced by three predecessor models, the ARM, NPS, and HSP-QUALITY models. Through this process, it was determined that the HSPF model functioned as designed.

This Project Summary was developed by EPA's Environmental Research Laboratory, Athens, GA, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The purpose of the work described in this report was to maintain and test the Hydrological Simulation Program—FORTRAN (HSPF) developed under a U.S. Environmental Protection Agency (EPA) contract.

HSPF is a mathematical model for simulating the hydrologic and water quality processes in and under the land surfaces of a watershed and in the associated streams and lakes. The roots of HSPF go back to the Stanford Watershed Model, which was one of the first rainfall-runoff computer models and was developed under National Science Foundation sponsorship. Many newer models have been developed from it; among the best known is the Hydrocomp Simulation Program, which incorporated a sophisticated time series management system. Hydrocomp also developed a water quality model that simulates the accumulation of constituents on a watershed surface, their washoff into streams and lakes and the biochemical transformations that occur in such water bodies.

The "Lands" section of the Stanford Watershed Model was also used as the basis for the Agricultural Runoff Management (ARM) Model, which was also developed under EPA contract. The ARM model simulates sediment production, as well as the behavior of pesticides and nutrients, on agricultural lands. The EPA also sponsored the development of the Non-Point Source (NPS) Model, which simulates the washoff of constituents from land surfaces by relations with washed-off sediment.

Although all the above models originated from the Stanford Watershed Model, they have each undergone development in their own specialized directions. Each is a powerful tool for use in its area of specialization, but it is not easy to use them together in situations where their combined strength is required. With the goal of overcoming this problem, EPA sponsored the development of a "comprehensive package for the simulation of watershed hydrology and water quality," which later became known as HSPF. The objective was to incorporate the capabilities of all of the above models in a single, consistently designed set of well-documented software, written as far as possible in ANSI FORTRAN (1966 version). This was part of EPA's program to develop engineering tools to help pollution control officials achieve water quality goals through watershed management.

Objective

The objective of this project was to provide a comprehensive initial test of HSPF and correct any errors or shortcomings found in the code. A new release of the program was to be prepared at the end of the project. In addition, utility modules that would enhance the power of the system were to be added to the system. These modules included an interface with a digital plotter, a neatly formatted summary output table, a statistical analysis package, and a module to perform time series calculations.

Approach

The purpose of the testing program was to check that HSPF correctly implemented the modeling algorithms outlined in the User's Manual. These algorithms are, for the most part, similar to those embodied in the predecessor models, but the manner in which they are included are very different since HSPF has a radically different structure. Thus, most of the testing consisted of comparing HSPF output against similar runs of ARM, NPS, and HSP-QUALITY. If the results were similar, it would be reasonable to expect that the algorithms were correctly implemented. Differences would have to be investigated to determine whether HSPF was in error. This was a different approach than usually taken where model output is compared against observed data but it was reasoned that the predecessor models had already been checked this way.

Tests were conducted in three phases. First, very simplistic hypothetical data sets were constructed and simulation output was compared against manual calculations. Then the NPS and HSP-QUALITY simulations performed for the Northern Virginia Planning District Commission (NVPDC) were reproduced using HSPF. Finally, the agricultural runoff module of HSP was compared to ARM simulations of a Michigan State University test watershed. This site also allowed testing of the snowmelt algorithms.

Results

The manual calculations were very useful. They were easy to set up and permitted many aspects of the model to be checked quickly.

The NVPDC comparison showed that it is sometimes difficult to produce identical results with HSPF because of its radically different structure. This produced a cumbersome HSPF input sequence and resulted in lower execution efficiency than if the sub-basins had been segmented in a manner more appropriate for HSPF. The results pointed out some subtle differences between HSPF and predecessor models but, for the most part, comparable results could be produced by reasonable adjustments to accommodate the differences in implementation. A significant difference was found in the phytoplankton simulations due to a different definition of "water body depth" used in the light extinction equations.

The Michigan State University simulations produced similar results. Minor discrepancies in the snowmelt simulations were attributable to slight differences in implementation of the algorithms. In many of these cases, it was believed that the HSPF code more closely represents natural processes. Comparisons of the water balance routines resulted in a correction to the manner in which HSPF handled snowmelt. Good agreement was found in the sediment simulations. Pesticide and nutrient simulations showed a difference that was attributed to differences in computation sequencing in the two models. HSPF was modified to more closely coincide with the ARM model where it was deemed appropriate. The testing program did raise questions about the adequacy of the way the near-surface region of the soil is simulated in both ARM and HSPF.

Conclusions and Recommendations

The care that went into the design, coding, and documentation of HSPF was deemed to be worthwhile. It is relatively easy for a well-trained person to use the system, and bugs have been easy to locate and fix. New modules were easy to add. It was also found, however, that the model was more costly to operate than its predecessor models, largely because of the flexibility built into the design.

The testing program found that the algorithms described in the User's Manual were correctly implemented. When checked against predecessor models, HSPF produced similar output, with these notable exceptions:

1. Simulation of nutrient behavior in pervious land segments (PERLND module) did not agree with the results produced by the ARM model. This is attributable to:
   a. Intermittent calculation of reaction fluxes in ARM Model runs
   b. Problems inherent in having a thin surface layer, with moisture storage dependent only on overland flow depth (a feature of both ARM and HSPF)
2. Simulation of phytoplankton in streams and reservoirs. Because HSPF and HSP-QUALITY use different definitions of "water body depth" in the light extinction equation, they produce radically different light-limiting phytoplankton growth rates.

Recommendations for future development of the model include:

1. Elimination of half-word integers, to make it easier to install on a variety of machines.
2. Development of a special version for large-memory installations, designed to minimize disc input/output and associated costs.
3. Improved trapping of user's errors, by the Run Interpreter.
4. Study of the feasibility of having a dynamically varying internal time step for certain processes - fine when there is rapid variation, coarse when there is not. This would save computer time.

Two problems in the agricultural chemical simulation system of the PERLND module need to be solved:

1. The MSTLAY section needs to be reformulated, so that the system will give results that are not a direct function of the time step, thus freeing this part of HSPF from the 5 and 15 minute time steps to which it (and ARM) is limited.
2. The problems posed by the use of a thin surface layer, with moisture storage totally dependent on overland flow depth, must be overcome.

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The complete report, entitled "Maintenance and Testing of Hydrological Simulation Program—FORTRAN (HSPF)," (Order No. PB 82-237 033; Cost: $10.50 subject to change) will be available only from:
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