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of Engineers ®

Hydrologic Engineering Center

Hydrologic Modeling System HEC-HMS

Release Notes

Version 3.5
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Hydrologic Modeling System HEC-HMS, Release Notes

Introduction

Version 3.4 of the Hydrologic Modeling System (HEC-HMS) was completed in August 2009 and released for general use shortly thereafter. The capabilities of the subbasin have been expanded with the addition of a general canopy representation and a general surface depression representation. A gridded version of the Green Ampt lossrate model has also been added. The development team has also continued careful and systematic testing of the program since the last release. The results of that testing in combination with reports from users have allowed the identification and repair of various problems. Some of these affected simulation results and are described in detail later in this document. Some problems that did not affect results but caused problems in the program interface have been repaired without being specifically documented. The result is this Version 3.5 release. It is currently available for the Microsoft Windows® operating system, the Sun Microsystems Solaris™ operating system, and also the Linux® operating system.

The program has been designed to be easy to use. However, an understanding of how the program works is critical to producing accurate results. It is suggested that a new user read the *Quick Start Guide* (Version 3.5 April 2010). The guide briefly describes the basic features of the program in enough detail to begin using it. The guide also includes a step-by-step tutorial.

Installation

The installation program and all documentation are available on the HEC website at http://www.hec.usace.army.mil/. This new release is installed independently of any previous versions of the program so you will need to remove Version 3.4 if you do not want to use it anymore. However, you may keep different versions of the program installed for parallel use or testing if you choose to do so. This new version will automatically open projects developed with any previous version of the program. However, once a project has been opened in Version 3.5, it may not be possible to open it with older versions of the program.

The new installation package is designed to be easy to use. It will take you through the steps of selecting a directory for the program files and making other settings. Use the following steps to install the program on the Microsoft Windows® operating system:

1. Download the installation package from the HEC website to a temporary folder on the computer. If the software was provided to you on a CD-ROM or other media, insert it in the appropriate drive.

2. Run the installation program. In Windows Explorer, double-click the icon for the installation program. You must have administrator privileges to run the installer.

3. Follow the on-screen prompts to install the program.

Instructions for installing the program on the Sun Microsystems Solaris™ operating system and the Linux® operating system can be found in Chapter 2 of the User's Manual.

New Capabilities

A number of new capabilities have been added to the program. Complete descriptions are given below.

Canopy and Surface

The subbasin element has been expanded with new capabilities for representing canopy interception and surface depression storage. Previously it was only possible to represent the canopy or surface if the soil moisture accounting lossrate method was selected. However, it is now possible to include a canopy or surface component in the subbasin, along with the original components for lossrate, transform, and baseflow.

Two methods are available for selection in the canopy component of the subbasin: simple and gridded simple. The simple method allows the specification of a storage volume. Precipitation must fill the storage and then any additional precipitation becomes through-fall to the surface. The water in canopy storage is evacuated at the potential evapotranspiration rate computed in the meteorologic model. The gridded simple method is the same, but allows the parameter values for the canopy to vary for each grid cell in the subbasin when the ModClark transform method is used.

Two methods are available for selection in the surface component of the subbasin: simple and gridded simple. The simple method allows the specification of a surface depression storage volume. Precipitation or through-fall lands in the storage and can immediately infiltrate. Surface runoff will not begin until the surface storage is full, and precipitation exceeds the infiltration rate. Water in storage can infiltrate after the precipitation stops. Any water in storage after precipitation stops, and before it infiltrates, will be evacuated at the potential evapotranspiration rate computed in the meteorologic model after the canopy is dry. The gridded simple method is the same, but allows the parameter values for surface storage to vary for each grid cell in the subbasin when the ModClark transform method is used.

Gridded Green Ampt Lossrate

This release includes the new Gridded Green Ampt lossrate method. The new method is based on the Green Ampt lossrate method that has been included since the first release of the program. The new method can be used to specify separate parameter values for each cell in the subbasin. The parameter values are stored as parameters grids. A separate grid is used for the initial water content, saturated water content, hydraulic conductivity, wetting front suction, and impervious area. Each grid cell in the subbasin can have separate parameter values and separate precipitation, allowing for the simulation of watersheds with heterogeneous soil properties, and non-uniform precipitation.

Import Simulation Run

It is now possible to import a simulation run. A simulation run can be selected from a different project and imported into the current project. The program will automatically import the basin model, meteorologic model, and control specifications used in the simulation run. Optionally, the user can also import all of the time-series data, paired data, and grid data used in the basin model and meteorologic model. When the import process is complete, the simulation run added to the current project is an exact duplicate of the original.

Muskingum Cunge Routing

The Muskingum Cunge reach routing method can be used to simulate the translation and attenuation of a flood wave in a channel. Past versions of the program have used a fixed time interval to perform the routing. The time interval could be the time interval specified in the *Control Specifications*. However, in order to maintain numeric stability, it was more common for the program to select an internal time interval less than the time interval in the *Control Specifications*. The internal time interval would be used to perform the routing and then results would be interpolated to the reporting interval from the *Control Specifications*.

This method of selecting the internal time interval could be inefficient if the simulation time interval was very long. A short internal time interval might be needed because of a very steeply rising hydrograph. An adaptive time interval option has been added. The adaptive algorithm allows the internal time interval to be very short during a steeply rising hydrograph. During periods of gradually varied flow or steady flow, the internal time interval could be as long as the time interval in the *Control Specifications*.

The user can choose a fixed or adaptive time interval. Selecting the fixed time interval will result in the behavior found in all previous versions of the program. Performance may be improved for long simulations by using the adaptive time interval option in the reach routing *Component Editor*.

Specified Diversion

The diversion element includes a number of options for computing the flow leaving the channel: inflow function, lateral weir, and pump station. A fourth option is now available that allows the user to specify a time-series of diversion flows. The flows must be specified in a discharge gage within the Time-Series Data Manager. The discharge gage can then be selected at the diversion element. The flows specified in the discharge gage will be diverted from the channel unless the specified flow exceeds the inflow to the diversion. In this case, the diversion will be limited to the inflow. With this new method, the outflow from the diversion element will be the total inflow minus the diversion specified in the selected discharge gage.

Background Map Scale Control

Previous versions of the program included background maps, and the maps were drawn at all zoom scales. It is now possible to configure a map to only display at some zoom scales. The drawing is configured separately for each map. Options include drawing a map at all zoom scales, drawing a map when the scale is zoomed in smaller than a threshold, or drawing a map when the scale is zoomed out larger than a threshold. This control can be used to have background maps with varying levels of detail for use at appropriate zoom scale levels.

Changes in Operation

A number of existing capabilities in the program have changed. Complete descriptions are given below.

Grid Data

Some of the modeling components in the program utilize gridded data, such as the gridded precipitation method. Each precipitation grid includes information on

the origin and extent of the grid, and the coordinate system it uses. Previous versions of the program did not verify the precipitation data in any way. Beginning with this new version, all grid data is checked to make sure that it is internally consistent. This means all grids in the simulation sequence must have the same coordinate system, origin, and extent. If any of the grid data required in the simulation is inconsistent, then the simulation will stop with an error message.

Canopy and Surface

The canopy and surface layers have been removed from the soil moisture accounting lossrate method. These features can now be found as the canopy method and the surface method in the subbasin element. When old basin models are opened with the current version of the program, any subbasins with soil moisture accounting lossrate method will have the parameters for the canopy and surface layers automatically moved to the new canopy and surface components.

Project Options

The settings previously found in the *Project Options* have been moved to the *Program Settings*, and the *Project Options* no longer exist. Use the *Program Settings* to select the default methods for precipitation, lossrate, unit system, and other methods.

Green Ampt Lossrate

The Green Ampt lossrate method has been included in the program since the first release. The method parameters in previous versions included: initial loss, moisture deficit, conductivity, wetting front suction, and impervious area. The initial loss was not actually part of the infiltration calculations in the soil, and was best used for representing canopy interception. The addition of the canopy method in the subbasin replaces this feature of the Green Ampt lossrate method. The initial loss parameter has been removed from the Green Ampt lossrate method. When old basin models are opened with the current version of the program, any subbasins with Green Ampt lossrate method will have the initial loss moved to a new canopy method. Additionally, the moisture deficit parameter has been replaced with two parameters: saturated content, and initial content. This parameter change will make the parameter terminology more consistent with other parts of the program. When old basin models are opened with the current version of the program, any subbasins with Green Ampt lossrate method will have the moisture deficit converted to the new parameters. The saturated content will be set to 0.46. The initial content will be set equal to 0.46 minus the old moisture deficit. The remaining parameters for conductivity, wetting front suction, and impervious area are unchanged.

This change in operation may lead to changed simulation results. The Green Ampt lossrate method includes the concept of a time to ponding as part of the infiltration calculation. All precipitation infiltrates into the soil until the time to ponding is reached. After that time, the infiltration rate decreases until the soil approaches saturation. After saturation, the infiltration rate is equal to the saturated hydraulic conductivity. Previous versions would remove the initial loss from the first time interval of precipitation, and then distribute the remainder of the precipitation uniformly over the time interval. This remaining precipitation would go towards satisfying the infiltration during the time to ponding. Said another way, the counting of the time to ponding begin at the beginning of the first time interval. Now, the initial loss is captured within the canopy component.

No precipitation reaches the ground surface until the canopy storage is filled. Precipitation then overflows to the soil surface and begins infiltrating while the time to ponding is satisfied. This new method of operation delays the onset of the time to ponding. This delay will also slightly delay the onset of surface runoff. Ultimately, the volume of infiltrated precipitation is virtually identical, but the timing of runoff will be slightly delayed.

Soil Moisture Accounting

The canopy, surface, and lossrate calculations are linked during a simulation. When the soil moisture accounting lossrate method is used, dynamic feedback occurs between the three components. Precipitation fills the canopy, overflows to the surface, and infiltrates into the soil. Potential evapotranspiration is used first by the canopy, then by the surface, and finally by the soil. Both precipitation and potential evapotranspiration are coupled between the three components. Furthermore, adaptive time step control is utilized to make certain that the coupling of the three components properly accounts for precipitation movement and properly distributes utilization of the potential evapotranspiration demand to the three components. It was found that the adaptive time step control frequently used a shorter sub-interval of time than was necessary to maintain mass balance. The algorithm has been adjusted to use a longer sub-interval of time when possible, while still maintaining mass balance and accurate infiltration rates. These changes improve performance, reducing simulation duration by a factor of 20 under some conditions.

This change in operation may lead to changed simulation results. The adaptive time step control has been changed to increase the efficiency of the simulations when the soil moisture accounting method is used. This causes very slight changes in the results at the end of each time interval in the simulation. Previous results correctly conserved mass and calculated the correct infiltration rate for the conditions present at each sub-interval of the adaptive time step control algorithm. The same is also true after this change in the adaptive time step control. However, results are now very slightly different because the algorithm is no longer taking shorter time steps than necessary. The change in results is expected to have relatively minor impacts on computed subbasin outflow rates.

Reservoir and Diversion Pump

The reservoir element may include a pump when the outflow structures routing method is used. The pump is designed to turn on when the water in the reservoir reaches a high elevation, and to turn off when the water is reduced to a low elevation. One of the parameters for the pump was the "Discharge Elevation." Conceptually, the elevation should actually be the highest elevation of the discharge line leading from the pump to the discharge point. The parameter has been renamed "Line Elevation" to indicate the correct modeling philosophy. The diversion element includes a similar option with the pump station diversion method. The same modeling philosophy applies and the parameter name has also been changed.

It was also found that the pump used in the reservoir element and in the diversion element did not correctly calculate the head under some conditions. The original design did not consider the possibility that the reservoir pool elevation could be above the highest elevation on the pump discharge line. Likewise, the design as implemented in the diversion element did not consider the possibility that the channel stage could be above the highest elevation on the pump discharge line. In these cases the discharge from the pump would be less

than expected. The algorithm used in the pump to determine the total head has been corrected.

This change in operation may lead to changed simulation results. The changes in computed results are limited to model configurations where the reservoir pool elevation could be higher than the line elevation. Also, the changes in computed results can happen at a diversion where the channel stage is higher than the line elevation. In these limited situations, previous versions of the program under-estimated the pump discharge. With the corrections now in place, the pump discharge will be increased in these situations.

Temperature Index Snowmelt

The temperature index snowmelt method includes an equation for calculating the cold content antecedent temperature index. The previous equation used to calculate the ATI was:

$$CC_{ATI}^{t+1} = CC_{ATI}^{t} + \left(T - CC_{ATI}^{t}\right)DF_{CCATI}{}^{\Delta t_{DAYS}}$$

where CC_{ATI} is the cold content antecedent temperature index, T is the air temperature, DF_{CCATI} is the ATI-coldrate coefficient, and Δt_{DAYS} is the time interval in days. It was found that this equation computed different ATI values when the time interval of the control specifications changed. The differences occurred because the equation did not properly account for time intervals different from a daily time interval. The following equation is now used that correctly accounts for different time intervals:

$$CC_{ATI}^{t+1} = CC_{ATI}^{t} + \left(T - CC_{ATI}^{t}\right)\left(1 - \left(1 - DF_{CCATI}\right)^{\Delta t_{DAYS}}\right)$$

where the symbols are defined above. The temperature index snowmelt method also includes an equation for calculating the cold content. The previous equation used to calculate the cold content was:

$$CC^{t+1} = CC^{t} + \Delta t_{HOURS}\left(T - CC_{ATI}^{t+1}\right)\frac{CR}{24}$$

where CC is the cold content, CR is the calculated cold rate, Δt_{DAYS} is the time interval in hours, and the remaining symbols are defined above. It was found that this equation computed different cold content values when the time interval of the control specifications changed. Similar to the case with the cold content ATI, the differences in cold content occurred because the equation did not properly account for time intervals different from a daily time interval. The following equation is now used that correctly accounts for different time intervals:

$$CC^{t+1} = CC^{t} - CR^{t+1}\frac{\left(T - CC_{ATI}^{t}\right)}{\log\left(1 - DF_{CCATI}\right)}\left(1 - \left(1 - DF_{CCATI}\right)^{\Delta t_{DAYS}}\right)$$

where the symbols are defined above.

This change in operation may lead to changed simulation results. In general, the computed cold content will be greater than in previous program versions. Increased cold content will result in less snowpack melt at the beginning of an event if rain falls on the snowpack. After the corrections that have been implemented as described above, a more-accurate calculation will now be made of the amount of rain that can be frozen into the snowpack.

DSS Output Results

Previous versions of the program store all time-series computed during a simulation in the project DSS file. This is the same file where manually-entered time-series data and paired data is stored. If a project has the name "Anacostia" then the project DSS file would have the name "Anacostia.dss." Storing results in this manner was simple because only one DSS file was required. However, there is a limit of 8Gb on a DSS file and some simulations could exhaust this limit.

It is now possible for the user to specify the output DSS file for each simulation run, optimization trial, and depth-area analysis. By default the results will be stored in the project DSS file. Optionally, the user may change the output file for one or more simulation components. The output file can be changed in the *Component Editor*.

Problems Repaired

The reservoir would compute the wrong storage if the storage-discharge curve was incomplete. This problem was specific to the "storage curve" routing method, and was accidentally introduced at Version 3.4. If the storage in the reservoir exceeded the largest storage value in the storage-discharge curve, the simulation would continue when it should stop with an error condition. The error checking has been corrected so that excessive storage in the reservoir causes the simulation to stop with an explanatory error message.

The reservoir would not calculate the correct downstream tailwater stage if diversion flow was included. One of the options for tailwater condition on the reservoir is to take the total flow at the element downstream of the reservoir and apply a rating curve. If the diverted flow from a diversion element was connected to the downstream element, the regular outflow from the diversion element was used as the contribution to calculating stage instead of the diverted flow. The diverted flow was correctly passed through the channel network, but the computed stage would be incorrect. The stage calculation is now performed correctly.

The auxiliary flow release from a reservoir element would not appear in results correctly when it was connected downstream to a junction. The graph and time-series tables at the junction have been enhanced to show the auxiliary flow, if it is present.

The auxiliary flow release from a reservoir element would not operate correctly unless it was connected to a downstream element. The auxiliary flow has been enhanced so that it functions correctly regardless of the downstream connection. When unconnected, the auxiliary discharge computes the release and the water is removed from the basin model. When connected, the auxiliary discharge computes the release and discharges water to the correct downstream element.

The temperature index snowmelt method did not correctly account for the mass balance of melted snowpack and incoming rain, as they related to cold content. The algorithm has been redesigned to create clear pathways for rain, snow, and melt water to interchange and maintain mass balance. The interaction of precipitation and melted snowpack with cold content and the liquid water holding capacity are now tightly controlled. All mass transfers are now computed correctly within the snowpack, and to the ground surface.

The gridded temperature index snowmelt method could incorrectly process grid cell data if the subbasin area did not match the area of the grid cells within the subbasin. When the areas were not equal, a correction operation was performed twice when it should only be performed once. The cell data is now correctly processed only once for a simulation run.

The temperature index snowmelt method, when working with elevation bands, did not check the elevation on the temperature gage. The elevation is required to correctly calculate the lapsed temperature for each band. If the elevation was missing, the temperature gage would still be used and the lapsed temperature would be incorrect. The elevation on the temperature gage is now checked, and if missing, the simulation aborts with an error message.

The temperature index snowmelt method includes a parameter for the "cold limit." This parameter is shown with units of millimeters per day or inches per day, depending on the selected unit system. It was found that internally the value was treated as if it were specified per hour. The internal usage of the value has been corrected to be consistent with the display units specified per day.

The initial constant lossrate method included a very rare problem that has been corrected. Previously it was possible for a volume error to occur in the 0.00000000000001 decimal place. When this rare problem occurred it would stop a simulation with an error message. The algorithm was adjusted to detect the calculation error and avoid it. Calculations are now correct at all times.

Some parameters in the Green Ampt lossrate method were not saved correctly. All parameters are now saved correctly at all times.

The unit hydrographs associated with using the Clark, SCS, and Snyder transform methods are written to the output DSS file. They are not displayed in the interface, but can be inspected by the informed user. Those hydrographs would be wrong, even though the actual calculations performed in memory were correct. Only the version stored on disk was in error. The unit hydrographs stored to the output DSS file are now correct, but still are not displayed in the interface.

The straddle-stagger channel routing method includes a parameter for the lag and a parameter for the duration. If the duration was longer than the lag, then routing calculations would be erroneous. Parameter checking has been added to require the duration to be less than two times the lag. If the duration is longer than twice the lag, the simulation will stop with an error message. Also, if the duration is less than the lag, only the flow lag is performed and the duration is not applied. If the duration is less than the lag, the simulation will proceed after issuing a warning message.

The time of the peak flow was not calculated correctly in the optimization summary table that shows the objective function results. The problem has been corrected. The time of peak flow is now shown to the nearest minute, which is the resolution of the simulation.

Copying a project could lead to lost data. The problem only occurred when external data was stored in a remote directory, but required two more conditions. First, the remote directory must have started with the same folders as the target location for the project copy. Second, the final folders in the two directories had to be different. All directory comparisons are now performed from beginning to end in order to eliminate all possible problems.

A global summary table would not print correctly when it was long enough to require multiple pages. One or more of the pages would not print. The printing has been corrected so that all pages print correctly.

The *Component Editor* for precipitation gages did not operate correctly when switching between incremental and cumulative data entry. The first cell in the table should be editable if entering cumulative data. The first cell should be non-editable if entering incremental data. Switching between incremental and cumulative data caused the first cell to be incorrect. The problem has been repaired so that the first cell is always in the correct editing state.

Annual patterns may be used in the temperature index snowmelt method. They provide an optional way to specify groundmelt that changes during the year and adjustments to meltrate during the year. The data was not checked correctly, so that using patterns always caused the simulation to stop with an error condition. The parameter checking of the patterns is now performed correctly and will only stop a simulation when there is actually a problem with the pattern data.

The program includes a feature for importing basin and meteorologic models. The import feature includes the option to import time-series data, paired data, and grid data used in the basin or meteorologic model. A problem could occur when using the feature to import the data with the model. The problem has been corrected so that any necessary data is correctly imported with the basin or meteorologic model.

Copying a basin model took so long that it would appear the program had stopped responding. The problem was traced to an inefficient process for copying the basin model elements. The inefficient code section has been optimized to improve performance. Basin models are now copied very fast.

Future Plans

Land surface erosion and channel sediment transport is under development. Initially two simple methods will be provided for simulating land surface erosion as part of subbasin calculations. Eventually more complex methods will be added to the subbasin. A simplified channel transport capability will be added to reach elements. It will handle erosion and deposition within the channel in addition to transport down the channel, all in a simplified approach appropriate for hydrologic simulation. It is not anticipated to include a movable bed. Additional components will also be provided at source, diversion, and reservoir elements to include the movement of sediment throughout the element network.

Several features will be added to the reservoir element. Methods for simulating direct precipitation are being considered, along with percolation. Capability will be developed to specify a new type of spillway gate using a family of elevation-discharge curves. Plans are also underway to provide additional options for controlling the opening and closing of spillway gates. Finally, we are investigating ways to simulate the infiltration-runoff response of exposed ground when the pool is drawn down.

Significant upgrades to the basin map are also in the planning stage. An option is being developed to represent subbasins and reservoirs with polygons instead of a simple icon. Similarly, the reach would be represented with a line that follows the actual stream location. This will increase the spatial context of the basin model and create opportunities for visualizing parameter data or simulation results directly in the map through color-coded animations of the polygons.

Documentation

The *Hydrologic Modeling System HEC-HMS: Quick Start Guide* (Version 3.5 April 2010) provides a brief description of the program for new users. It describes the different parts of the interface and the basic steps necessary to obtain simulation results. A tutorial takes the user through the creation of a new project and shows how to obtain results. The guide has been updated to reflect changes in the interface.

The *Hydrologic Modeling System HEC-HMS: User's Manual* (Version 3.5 April 2010) contains extensive information on installing and using the program. Details on the use of each of the features and capabilities in the program are included. The manual has been updated with information describing new features added to the program for this Version 3.5 release. The updates are generally confined to Chapter 7 in select locations describing the subbasin element capabilities.

The *Hydrologic Modeling System HEC-HMS: Validation Guide* (Version 3.5 April 2010) contains information on the procedures used to certify the software for release. The manual describes the tests that have been established and the procedures used for determining the correct result for each test. An accompanying data kit includes all of the project data necessary to replicate the tests performed at HEC prior to certifying a new release for distribution.

The *Hydrologic Modeling System HEC-HMS: Technical Reference Manual* (March 2000) continues to accurately describe the mathematical models included in the program. New simulation capabilities have been added to the program and are not included in the manual. The manual is currently undergoing a major revision to expand documentation of existing mathematical models and fully describe the newly added models.

The *Hydrologic Modeling System HEC-HMS: Applications Guide* (March 2008) also continues to accurately describe how to apply the program to various engineering problems. The guide is undergoing revision to add guidance on how to use new features of the program and will be released when completed.

Support Policy

Technical support for program users within the Corps of Engineers is provided through an annual subscription service. Subscribing offices can expect full support from HEC staff in the routine application of the program. Users are strongly urged to consult with HEC staff on the technical feasibility of using the program before beginning a project with unique requirements such as grid cell hydrology, snow melt, or continuous simulation. Extended support for large or complex projects can be arranged under a separate reimbursable project agreement.

Support can not be provided to users outside the Corps of Engineers. Several companies and organizations offer varying levels of support, some through a fee-for-service support similar to the support provided to subscribing Corps offices. Such service agreements are between the user and the vendor and do not include HEC staff. Vendors can be located through internet searches.

Reporting of suspected program errors is unrestricted and we will reply to all correspondence concerning such errors. We are continuously working to improve the program and possible bugs should always be reported. Reports

should include a written description of the steps that lead to the problem and the effects that result from it. If we cannot reproduce the reported problem, we may ask you to send a copy of your project.

Request support or report program errors through the following channels:

- Call 530.756.1104, 7:30 am to 4:30 pm PT Monday through Friday.

- Fax 530.756.8250 any time.

- Write to U.S. Army Corps of Engineers, Institute for Water Resources, Hydrologic Engineering Center, 609 Second Street, Davis, CA 95616 USA.

- Send email to *hec.hms@usace.army.mil* on the internet.

- Visit our web site at http://www.hec.usace.army.mil.