Hydrologic Modeling System (HEC-HMS) Adaptions for the Province of Ontario

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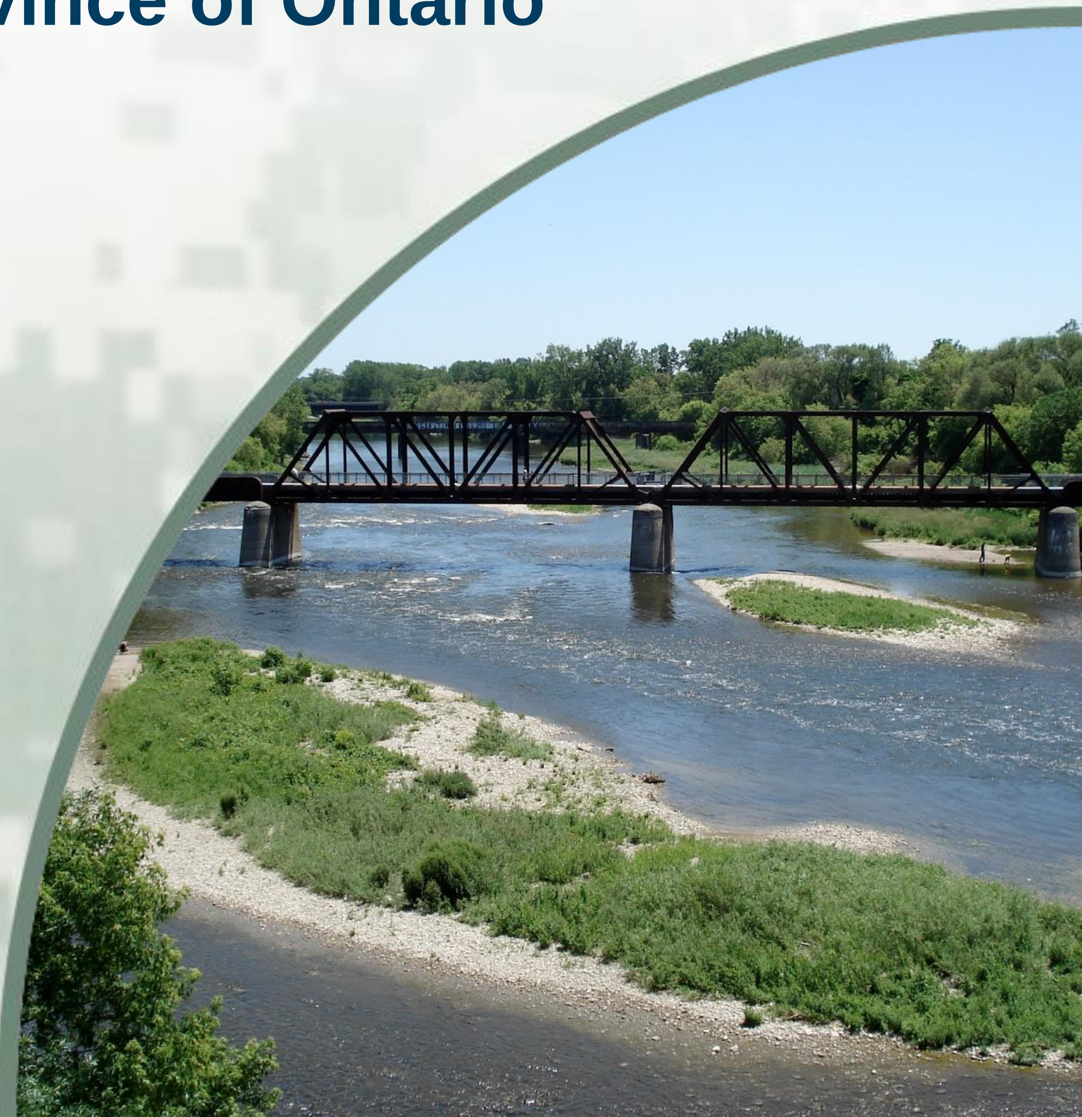
Floodplain Mapping Knowledge Transfer Workshop
Vaughan, Ontario

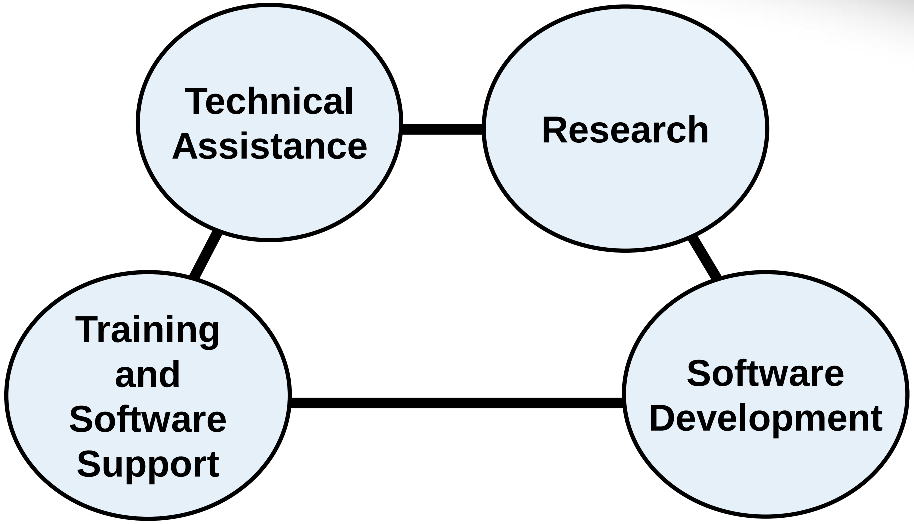


US Army Corps of Engineers®

Hydrologic Engineering Center

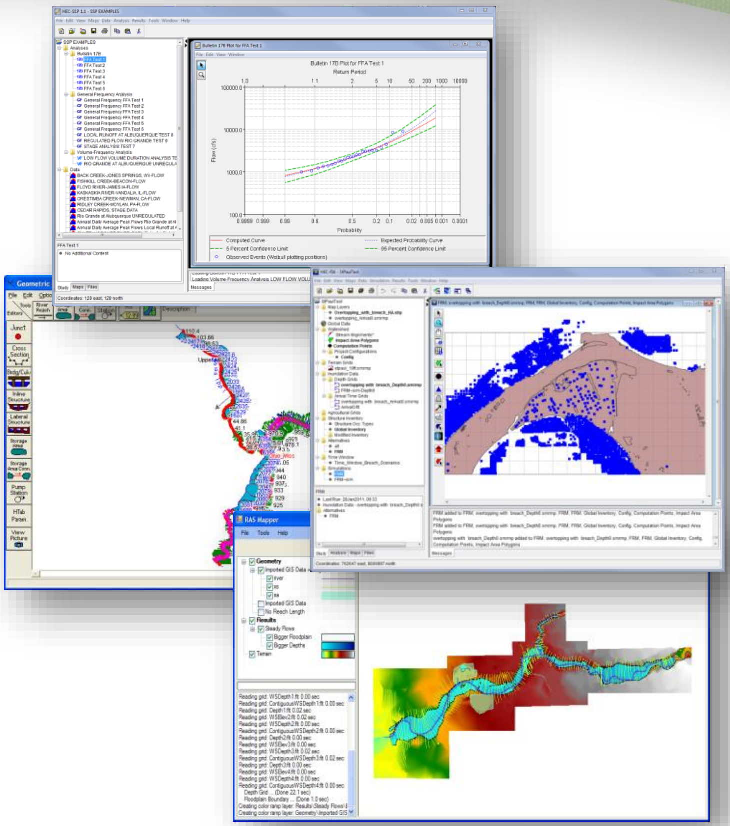
How We View Our Role In The World

- HEC exists to help the Corps of Engineers perform its civil works mission in a world-class manner:
  - The work of the Corps is performed at the field office level.
  - HEC products and services are for field use and application.
  - Generic software can be used anywhere, worldwide.
  - Software is used worldwide for five major reasons.
- The primary goal is to take "State-of-the-Art" and turn it into "State-of-the-Practice."



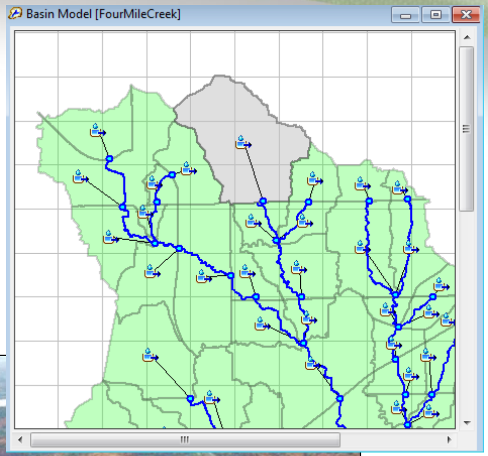
HEC Software Activities

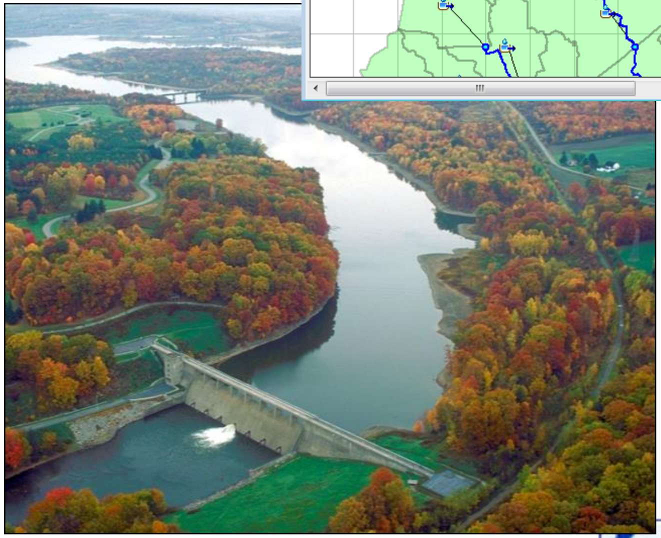
- Solve problems in a general manner to support multiple end uses.
- Complete product line for hydrologic engineering and planning analysis:
  - Hydrologic statistics and simulation.
  - Reservoir systems.
  - Riverine hydraulics.
  - Consequences and life loss.
  - Flood risk management.
  - Real-time forecasting.
- Continually drive the software forward with new features to meet emerging needs:
  - Corps of Engineers R&D programs.
  - Special application projects.



Hydrologic Modeling System

- A fully-featured riverine hydrologic modeling system for a wide range of water resource study goals.
- Integrated work environment with tools for data entry, mapping, simulation, parameter estimation, and results visualization.
- The full scope of the hydrologic cycle is encompassed with meteorology, land surface, river channel, and structures.
- Current release is Version 4.3.
- Over 47,000 software downloads of all versions during 2018.

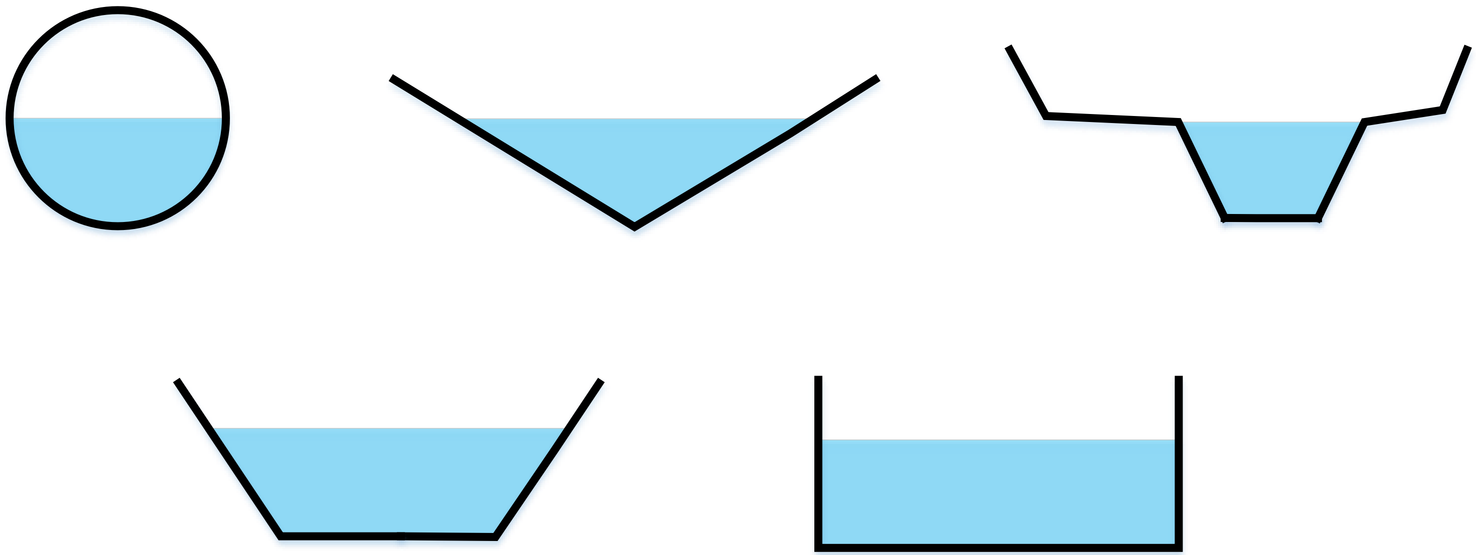




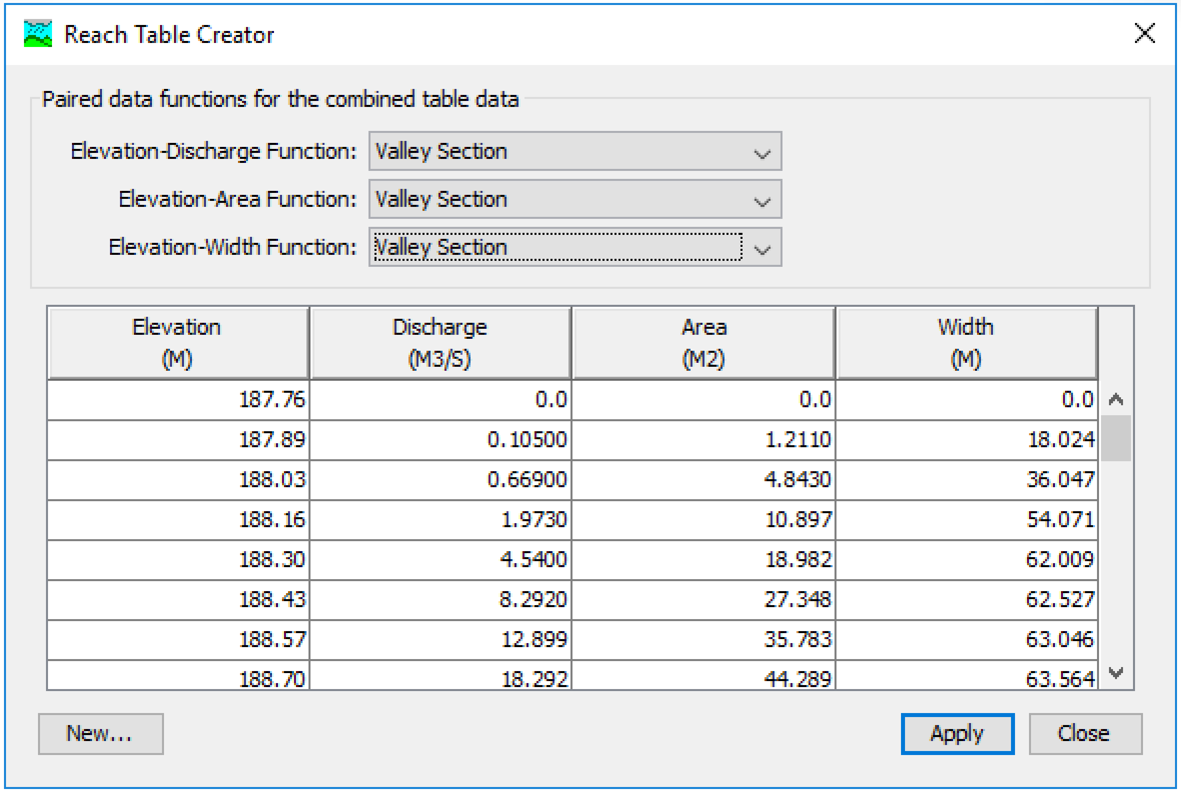
Important Topics

1. Muskingum Cunge channel routing with complex cross sections.
2. Green Ampt infiltration in a layered soil profile.
3. Baseflow.
4. Snowmelt.
5. GIS toolkit.

Muskingum Cunge Routing



Muskingum Cunge Routing



Elevation (M)	Discharge (M3/S)	Area (M2)	Width (M)
187.76	0.0	0.0	0.0
187.89	0.10500	1.2110	18.024
188.03	0.66900	4.8430	36.047
188.16	1.9730	10.897	54.071
188.30	4.5400	18.982	62.009
188.43	8.2920	27.348	62.527
188.57	12.899	35.783	63.046
188.70	18.292	44.289	63.564

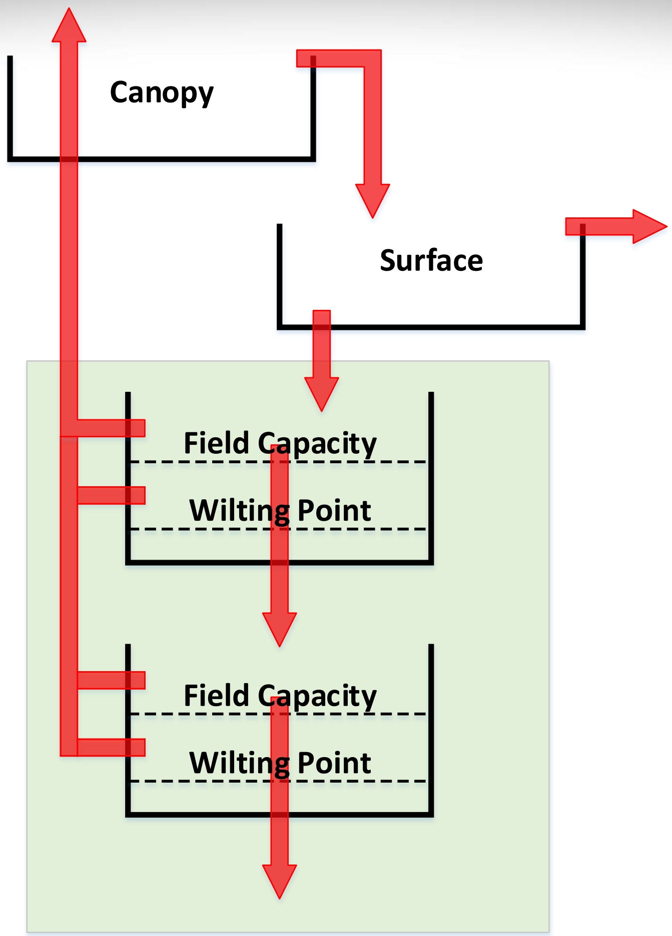
Muskingum Cunge Routing

- Routing coefficients:
  - Moving from using fixed coefficients C_1, C_2, and C_3 recalculated every 24 days…
  - To using variable coefficients recalculated every spatial step and temporal step.
- Selecting the spatial step DX:
  - Moving from the user manually specifying the number of DX in the reach…
  - To having the choice of manually specifying DX or automatically calculating it from the index wave celerity and simulation time interval.
- Selecting the temporal step DT:
  - Moving from DT always set equal to the simulation time interval…
  - To having the choice of manually specifying DT or automatically calculating it from the DX, wave celerity, and simulation time interval.
- Index wave celerity:
  - Index wave celerity can be entered directly.
  - There is also an option to specify an index flow, then have the celerity calculated.
- This feature was included in Version 4.3, released November 2018.

Green Ampt Infiltration

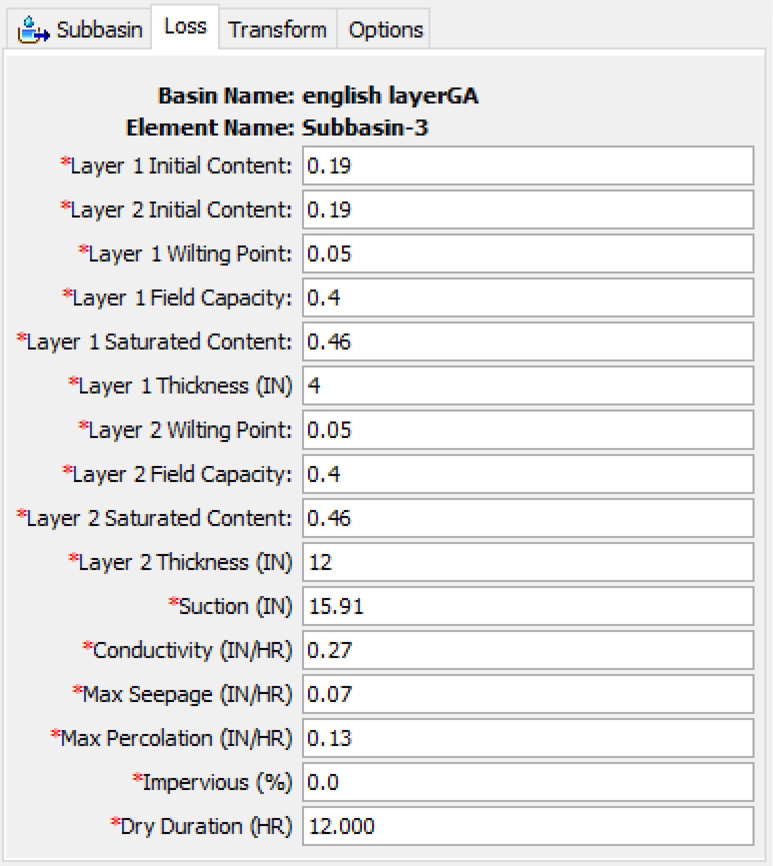
- HEC-HMS implements Green Ampt infiltration with an old algorithm designed for individual storm events.
- GAWSER implements a different approach to Green Ampt infiltration that includes two layers and soil moisture drying between storm events.
- GAWSER team will contribute expert advice:
  - Documentation of the GAWSER algorithm.
  - Applications experience, especially parameter estimation.
- HEC-HMS team will implement a new infiltration method based on the work of the GAWSER team:
  - Old "Green Ampt" method for event simulation.
  - New "Layered Green Ampt" method for multi-event and continuous.
- GAWSER team and others will be Beta testing for Version 4.4.

Green Ampt Infiltration



Green Ampt Infiltration

- The meteorologic model should be configured with precipitation and evapotranspiration. Add snowmelt in cold climates.
- Initial Conditions:
  - Layer 1 initial content.
  - Layer 2 initial content.
- Parameters:
  - Saturated water content.
  - Field capacity, wilting point.
  - Layer thickness.
  - Wetting front suction.
  - Saturated hydraulic conductivity.
  - Maximum seepage, percolation.
  - Percent impervious area.
  - Dry period duration (for reset).



Green Ampt Infiltration

- Fill canopy interception. Precipitation that exceeds the canopy storage capacity will overflow and be added to the surface.
- Precipitation storage on the surface:
  - Infiltrate to soil profile.

$$f = K_{SAT}\left(1 + h_f \frac{\theta_{SAT}^1 - \theta_{init}^1}{F}\right)$$

  - Calculate the precipitation remaining in surface depression.
  - Water exceeding surface storage capacity becomes precipitation excess.
- Layer 1:
  - Add infiltration to the layer storage.
  - Infiltration is limited to maximum seepage rate when saturated.
  - Seepage occurs only when storage exceeds field capacity.

Green Ampt Infiltration

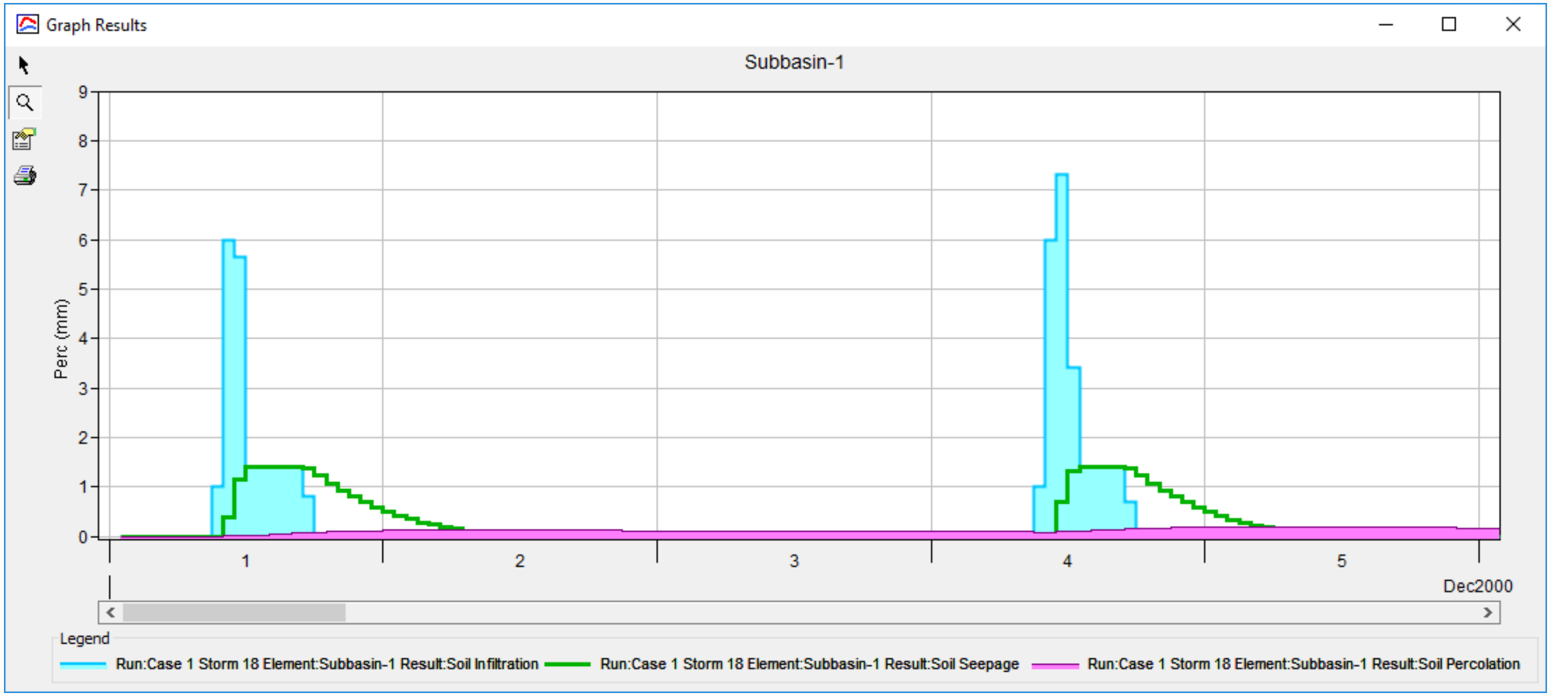
- Seepage only occurs if Layer 1 storage exceeds field capacity.
- Percolation only occurs if Layer 2 storage exceeds field capacity.

$$R_{SEEP} = Seep_{MAX}\left(1 - \frac{\theta_{SAT}^{1} - \theta^{1}}{\theta_{SAT}^{1} - \theta_{FC}^{1}}\right)$$

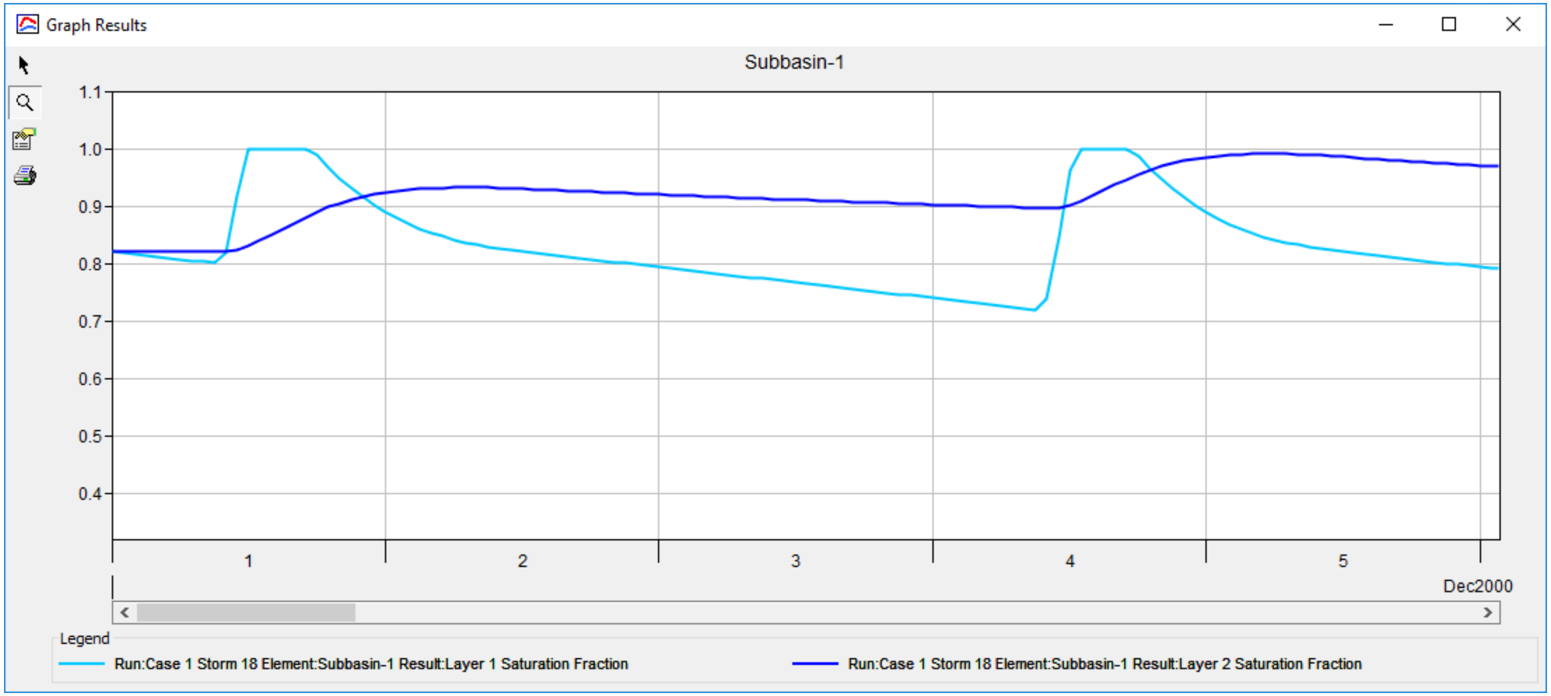
$$R_{PERC} = Perc_{MAX}\left(1 - \frac{\theta_{SAT}^{2} - \theta^{2}}{\theta_{SAT}^{2} - \theta_{FC}^{2}}\right)$$

- Seepage is limited when Layer 2 is saturated.
- Percolation can be split between contribution to linear reservoir baseflow, and aquifer recharge
- Evapotranspiration is computed by the plant canopy component.

Green Ampt Infiltration



Green Ampt Infiltration



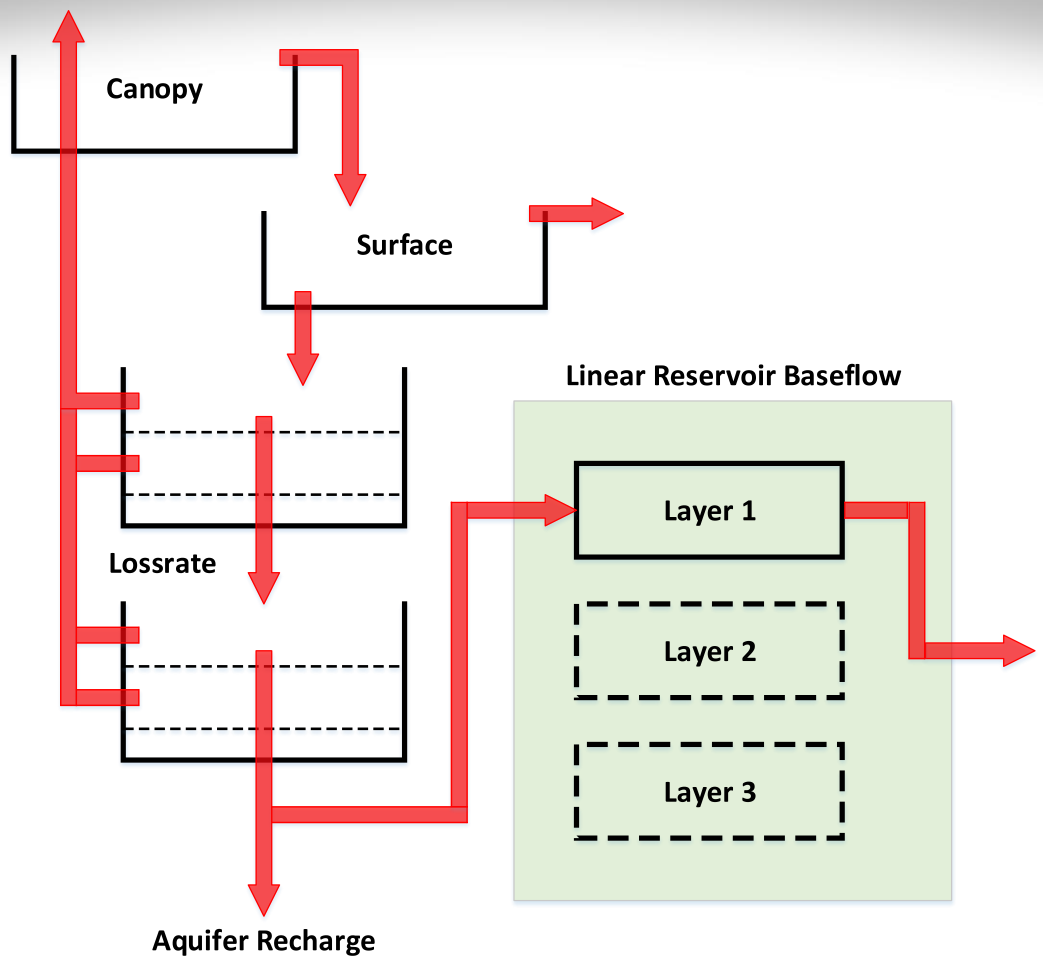
Green Ampt Infiltration

- Implementation is mostly complete.
- Interception and potential evapotranspiration by the canopy component.
- Surface precipitation capture, delayed infiltration, and dry duration provided by the surface component.
- Parameters are integrated with the simulation framework:
  - Optimization trials – automatic parameter estimation.
  - Forecast alternatives – zone adjustments for real-time operations.
  - Uncertainty analyses – sampling during a Monte Carlo simulation.
- Validation Testing – Demonstrate that the equations have been implemented correctly. Show that results are comparable to GAWSER.
- Application Testing – Pilot testing for applications in flood forecasting, floodplain regulation, and water balance studies.

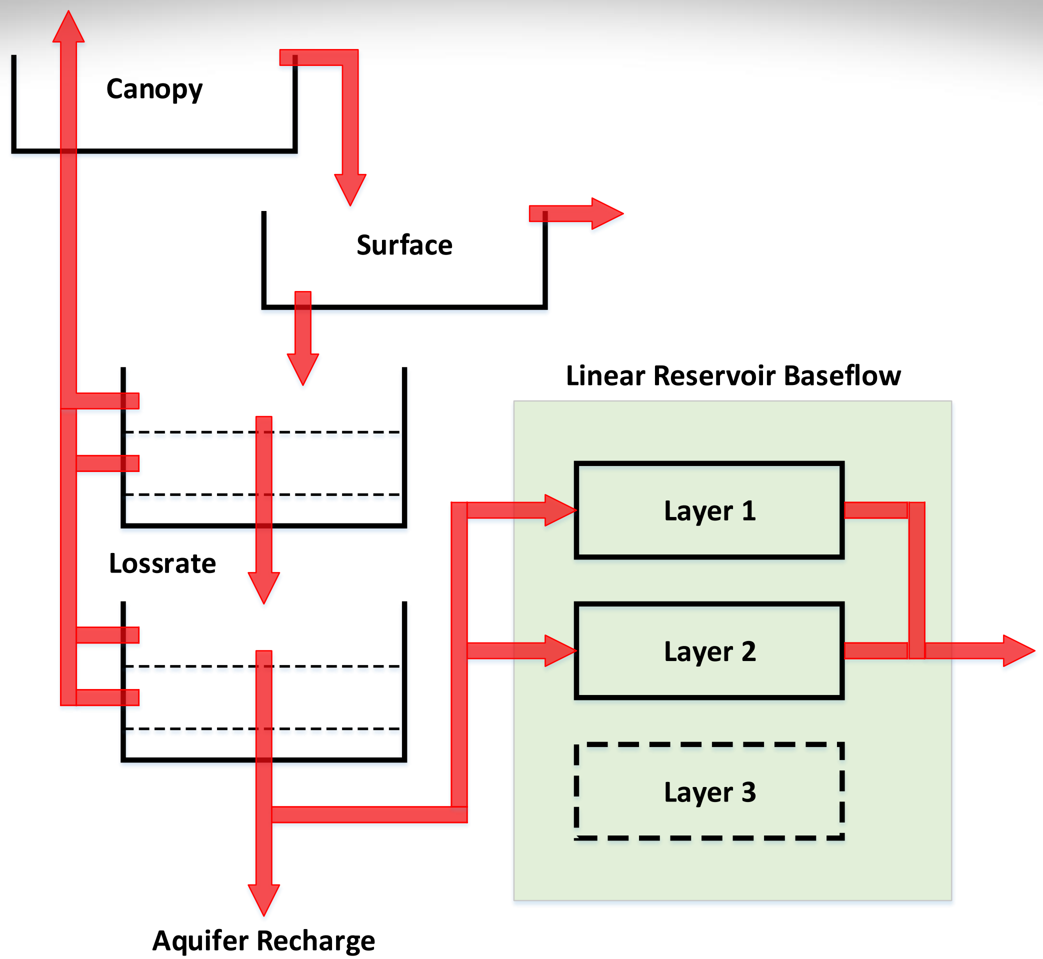
Linear Reservoir Baseflow

- HEC-HMS includes the linear reservoir baseflow method designed for water balance studies. It allows one or two layers. Percolation is split equally, and there is no aquifer recharge.
- GAWSER also includes a linear reservoir baseflow method, but it includes three layers. Percolation is allocated to baseflow and aquifer recharge.
- HEC-HMS team will enhance the linear reservoir baseflow method while providing backward compatibility:
  - Add a third linear reservoir layer.
  - Add ratios to control the allocation of percolation water to the layers.
  - Allow unallocated water to recharge the aquifer.
- GAWSER team and others will be Beta testing for Version 4.4.

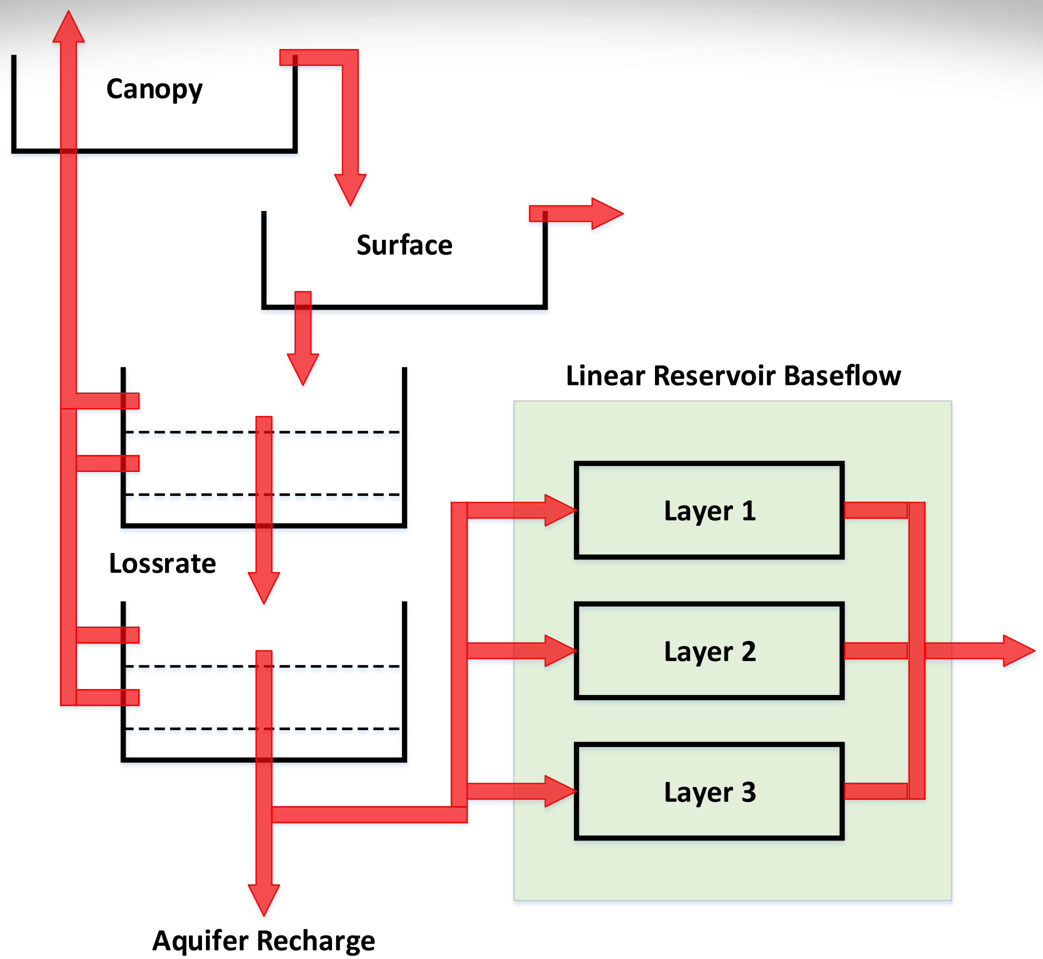
Linear Reservoir Baseflow



Linear Reservoir Baseflow

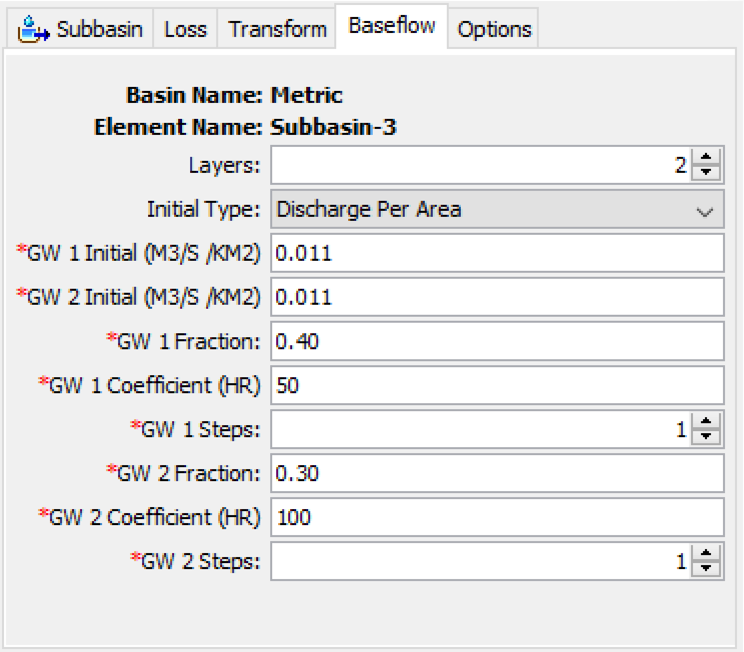


Linear Reservoir Baseflow



Linear Reservoir Baseflow

- Configuration:
  - Number of layers.
  - Manner of specifying initial conditions.
- Initial conditions:
  - Initial outflow from each layer.
- Parameters:
  - Fraction of percolated water that enters each layer.
  - Storage coefficient in hours for the linear reservoir.
  - Number of routing steps for the linear reservoir.



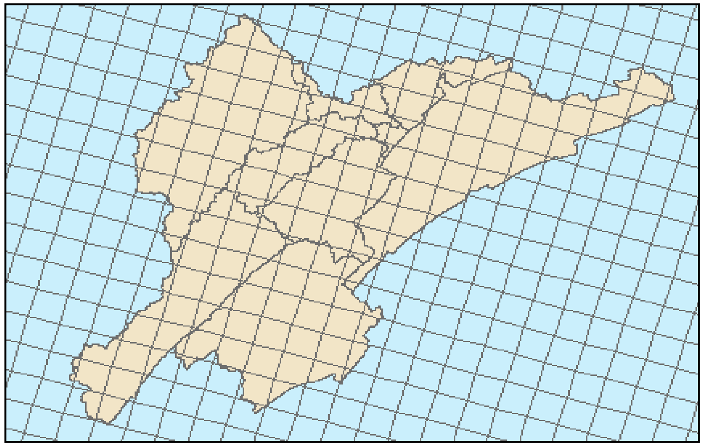
Snowmelt

- HEC-HMS includes a temperature index snowmelt method designed mountainous watersheds that accumulate deep snowpacks.
- GAWSER includes a temperature index snowmelt method designed for shallow, transient snowpacks typical of Ontario and surrounding Provinces.

- A new snowmelt method will be implemented in HEC-HMS, following closely the method from GAWSER.
- The new implementation will support an elevation band approach, or gridded approach.
- Anticipated for Version 4.5.

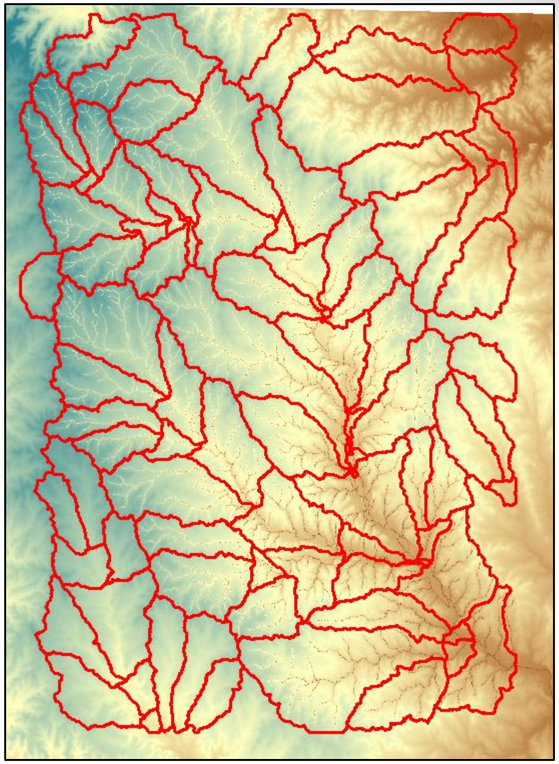
GIS Toolkit

- Create square grid cell meshes for use with atmospheric data:
  - Hydrologic Rainfall Analysis Project.
    - NOAA products including weather radar.
  - Standard Hydrologic Grid.
    - Albers equal-area conic.
  - Universal Transverse Mercator (UTM).
    - Only supported format for worldwide use.
  - All meteorology components use the same coordinate system.
- Overlay grid cell meshes with subbasins to map gridded meteorology to vertical processes on the land surface.
  - Each subbasin can use a different coordinate system and/or different cell size.
- Key feature for Version 4.4.



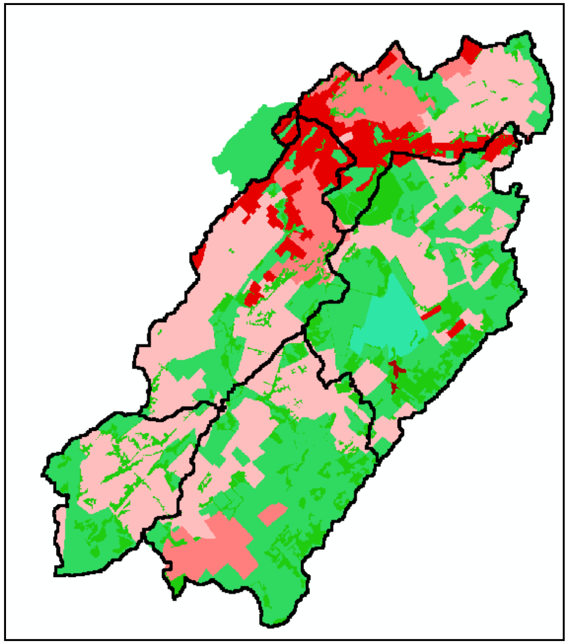
GIS Toolkit

- Terrain visualization in the basin map.
- Optional, sink filling to force surface flow all the way to the outlet.
- Automatic delineation of subbasin and reach elements directly from the terrain:
  - Improved algorithm for "saddles" and "flat valleys."
  - Specified area threshold for catchments.
  - Break points for creating junctions.
- Merging and splitting delineated subbasins and reaches.
- Key feature for Version 4.4.



GIS Toolkit

- Eventually, treat background maps as a source of data for calculating model parameters and initial conditions:
  - Soils, land use, surface condition, vegetation cover, snow survey, and many others.
- Integrate data derived from the terrain:
  - Slope, aspect, flow length, and others.
- User-supplied supplemental data such as lookup tables and pedotransfer functions.
- Intersect and combine all the data to calculate lumped or gridded parameter values.
- Anticipated for Version 4.5.



HEC-HMS on the Internet

www.hec.usace.army.mil/software/hec-hms