Frontiers in Hydrology-San Juan Puerto Rico
June 19-24, 2022

Development of an Engineering with Nature (EWN) Design Tool – Part 1
Current GSSHA Flow, Sediment, and Constituent Fate and Transport Capabilities

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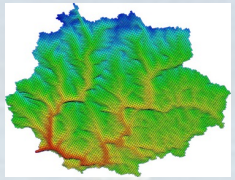
Gridded Surface Subsurface Hydrologic Analysis (GSSHA)

- GSSHA is a complete watershed simulation and management model used for hydrologic, hydraulic, sediment and quality simulation and management.
- GSSHA is a fully distributed, physics based model that utilizes a grid to represent the watershed.
- GSSHA is a product of the US Army ERDC
  - Maintained
  - Supported
  - Distributed
- GSSHA works on a uniform spatial grid.
- Basic equations of mass, energy, and momentum conservation are solved with finite volume and finite difference techniques.
- Point processes are solved at the grid level.
- Point responses are integrated to get the system response.

$$\frac{\partial h}{\partial t} = \frac{\partial \bar{q}^{-}}{\partial x} + \frac{\partial \bar{q}^{-}}{\partial y}$$

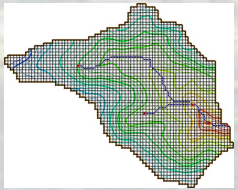
$$\bar{q} = \frac{1}{n} d^{5/3} S_{fx}^{1/2} \bar{i} + \frac{1}{n} d^{5/3} S_{fy}^{1/2} \bar{j}$$

$$S_{fx} = S_{ox} - \frac{dh}{dx}; S_{fy} = S_{oy} - \frac{dh}{dy}$$



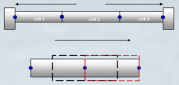
Hydraulic Structures

- Types
  - Broad crested weirs
    - Horizontal
    - Parabolic
  - Culverts
    - Circular
    - Rectangular
  - Active control structures
    - Rule curve
    - Scheduled discharge
  - Generic structure rating curve
- Reservoirs or detention basins can also be added to your network.



- Infiltration
  - Richards Equation
    - 3 primary soil layers
    - infinite subdivisions of each layer
  - Green and Ampt, 1 layer
  - Two-layer Green and Ampt w/ Soil Moisture Redistribution
  - Three layer Green and Ampt model with soil moisture accounting
- Evapotranspiration
  - Deardorff bare earth
  - Penman – Montieth

- Connected set of pipes, manholes, inlet grates
- Tile drains are porous pipes that drain groundwater in agricultural areas.

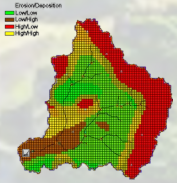


- GSSHA has the capability to simulate constituent fate and transport in surface water components of the model.
  - Soil column
  - Overland
  - Streams
- Kinetics
  - First order
  - Nutrient Simulation Model (NSM)
    - Not currently in release model
- Dissolved and sorbed phases

$$\frac{\partial}{\partial x}\left(K_x b \frac{\partial E_{xx}}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_y b \frac{\partial E_{xx}}{\partial y}\right) = S \frac{\partial E_{xx}}{\partial t}$$

- Single-layer free surface groundwater equation
- Provides recharge -> groundwater flow
  -> stream, seep interaction
- Allows for environmentally important flows (low flows, wetlands) to be modeled
- Important for modeling saturation excess runoff

- Event based erosion and deposition model (not USLE-based)
  - Overland
  - Streams
- User-defined sediment properties



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Development of an Engineering with Nature (EWN) Design Tool – Part 2
"Clearwater Water Quality Modules Integration with GSSHA"

Billy E. Johnson – LimnoTech Inc.
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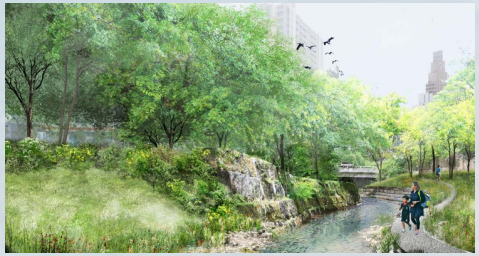
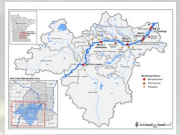
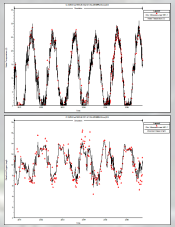


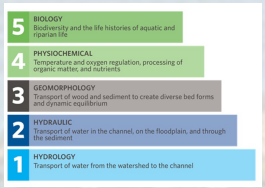
- **ClearWater (Corps Library for Environmental Analysis and Restoration of Watersheds)** is a library of environmental simulation software that leverages the capabilities of existing water resource simulation models to assess environmental impacts and design solutions to manage and restore aquatic ecosystems. ClearWater consists of a set of water quality and vegetation simulation modules as well as an engine and user interface components that link the capabilities with external models.

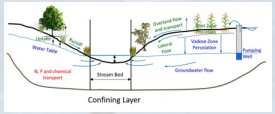
1. Environmental Modules:
   - NSMs: Nutrient Simulation Modules (I and II)
   - TSM: Temperature Simulation Module
   - MSM: Mercury Simulation Module
   - CSM: Contaminant Simulation Module
   - SSM: Solids Simulation Module
   - RVSM: Riparian Vegetation Simulation Module
2. A water quality engine that computes the transport processes and integrates the ClearWater modules with the water resources models (e.g., HEC-RAS, GSSHA, HEC-ResSim, HEC-HMS, and AdH)
3. Graphical User Interface (GUI) components for environmental modeling:
   - Controls and tables to input/import set up an environmental model
     - Boundary & initial conditions, variables, parameters, etc.
   - Plots
   - Reports





Engineering With Nature®

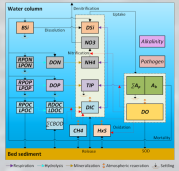




Riparian Vegetation Simulation Module (RVSM)

The Riparian Vegetation Simulation Module (RVSM) simulates the lifecycle of vegetation, including seed dispersal, seedling establishment, and plant growth and mortality in response to dynamic physical conditions. RVSM includes eleven vegetation roughness computation methods

Note: Vegetation Simulation Module – Generalized Vegetation Module (Terrestrial, Riparian, and Aquatic) is under development.



Nutrient Simulation Module) NSM II

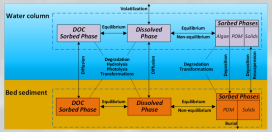
Level I (NSMI.dll)
- State variables: Algae, Benthic Algae, Organic Nitrogen, Ammonia, Nitrate, Organic Phosphorus, Total Inorganic Phosphorus, Organic Carbon, CBOD, DO
- Derived outputs: DIN, TKN, TN, DIP, TP, DOC, POC, CBOD5

Level II (NSMII.dll)
- State variables: Multiple Algae Groups, NO3, NH4, DON, LPON, RPON, TIP, DOP, LPOP, RPOP, DIC, LDOC, RDOC, LPOC, RPOC, DO, COD, Pathogen, Alkalinity
- Derived outputs: Chlorophyll-a, DIN, TKN, TN, DIP, TP, DOC, POC, TOC, CBOD5, pH
- DiToro's bed sediment diagenesis model

Multi-Media Kinetics
- Water Column
- Underlying Sediment Layer

Multi-Phase Partitioning (Equilibrium and Non-Equilibrium)
- Water
- DOC (Dissolved Organic Carbon)
- Organic Matter
- Inorganic Solids

Eight (8) Biochemical Transformation Processes
- Ionization (5 Species)
- Degradation
- Hydrolysis
- Photolysis (Photodegradation)
- Volatilization
- User Defined Extra Reaction (Second Order)
- Transformations and Daughter Products



Contaminant Simulation Module (CSM)

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