GSSHA Basics
Basic Overland Flow Model

Overland Flow Represented as Sheet Flow

- Water running over the land surface
  - Broad, shallow flow
  - Interacts with small-scale topography (retention)

Generation Mechanisms

- Infiltration excess (Hortonian)
- Saturation excess
- Exfiltration (Groundwater discharge)
  - Seep, Spring
- Storm surge
- Out-of-bank stream flow

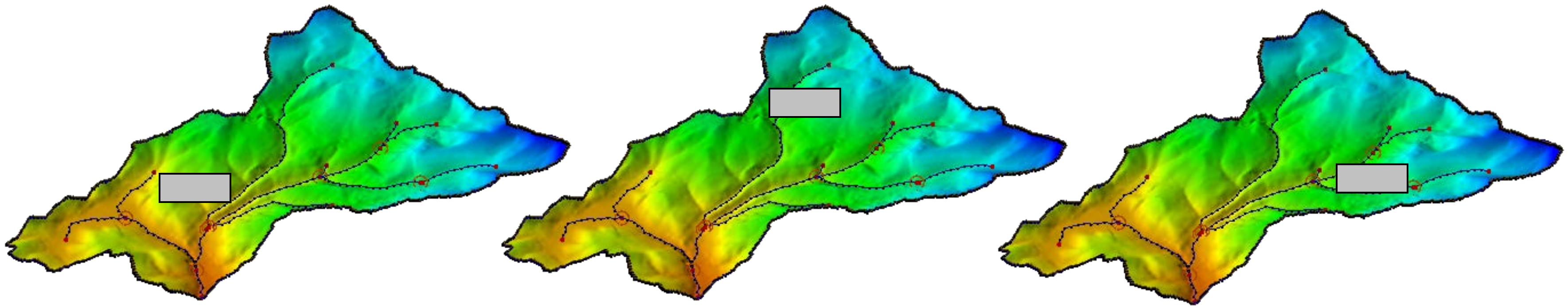
Overland Flow Model v. Runoff Transformation

Overland Flow Runoff Model

- Model spatial interactions
  - Spatial-specific data

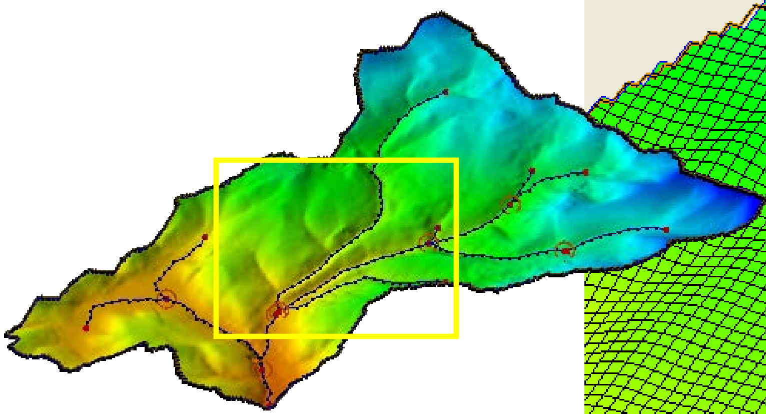
Runoff Transformation

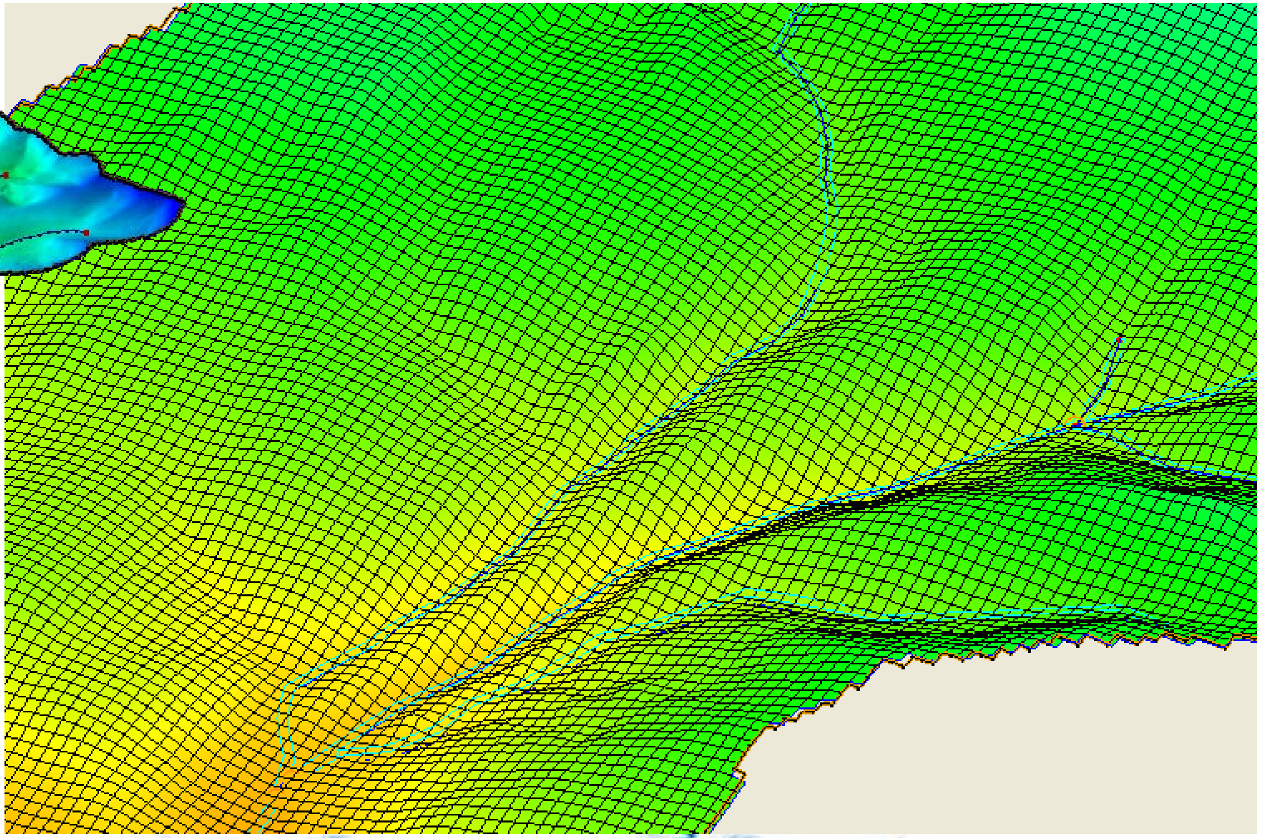
- Lump together spatial interactions (across sub-basin)
  - Spatial-general data



Overland Flow in GSSHA

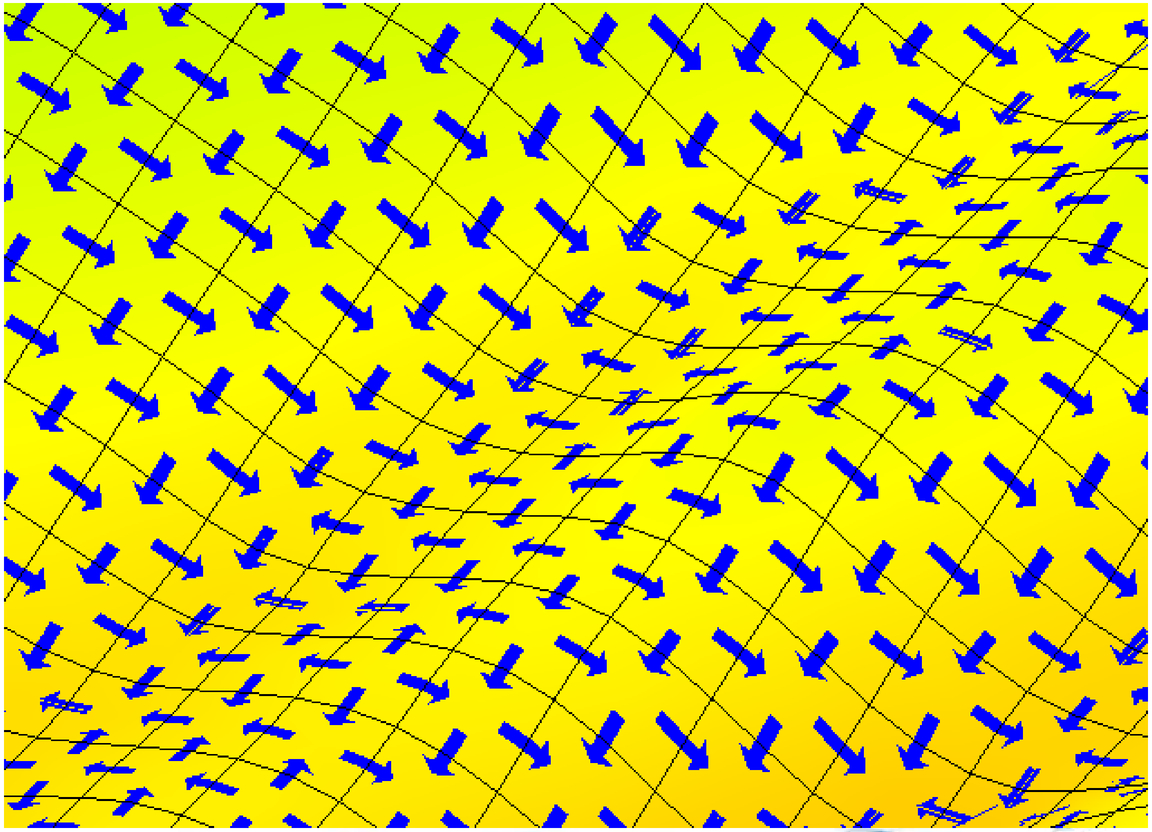
- 2D grid of interconnected cells





Overland Flow in GSSHA

- Four-point flow



Diffusive Wave Equation

In X Direction

$$\frac{\partial h}{\partial x} = S_{ox} - S_{fx}$$

h = depth
S_{ox} = land slope x direction
S_{fx} = water surface slope x direction

In Y Direction

$$\frac{\partial h}{\partial y} = S_{oy} - S_{fy}$$

h = depth
S_{oy} = land slope y direction
S_{fy} = water surface slope y direction

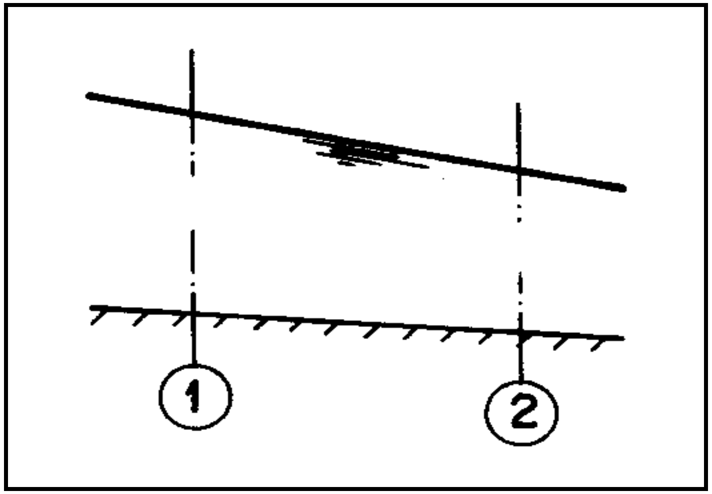
Friction Slope in Finite Difference Form

In X direction

$$S_{fx} = S_{ox} - \left(\frac{h_i - h_{i-1}}{\Delta x} \right)$$

In Y direction

$$S_{xy} = S_{oy} - \left(\frac{h_j - h_{j-1}}{\Delta y} \right)$$



Substitute into Manning Equation

Flow in the x direction

$$q_x = \frac{1}{n} h_i^{2/3} S_{fx}^{1/2}$$

Flow in the y direction

$$q_y = \frac{1}{n} h_j^{2/3} S_{fy}^{1/2}$$

Continuity Equation

$$\frac{\partial h}{\partial t} + \frac{\partial q_x}{\partial x} + \frac{\partial q_y}{\partial y} = 0$$

In finite difference form

$$h_{ij}^{n+1} = h_{ij}^{n} + \frac{\Delta t}{\Delta x}\left(qx_{i-1} - qx_{i} + qy_{j-1} - qy_{j}\right)$$

Solution

- Finite volume
- Forward weighted (dependent on flow direction)
- Explicit
  - One-pass, time-variable solution
  - Compute q_x, q_y, then update heads
- ADE
  - One-pass, time-variable solution
  - Compute q_x, update heads, compute q_y, update heads
- ADE-PC
  - Two-pass ADE
  - Uses a weighted average of the steps to compute the new heads

Basic Model Requirements

- Land surface elevation → DEM
- Manning's roughness
- Retention depth
  → Land Use
- Rainfall input →
  - Uniform
  - Gage
  - Radar
- Outlet location and slope → DEM
- Cell Size
- Time Step
  → User defined

Cell Size Selection

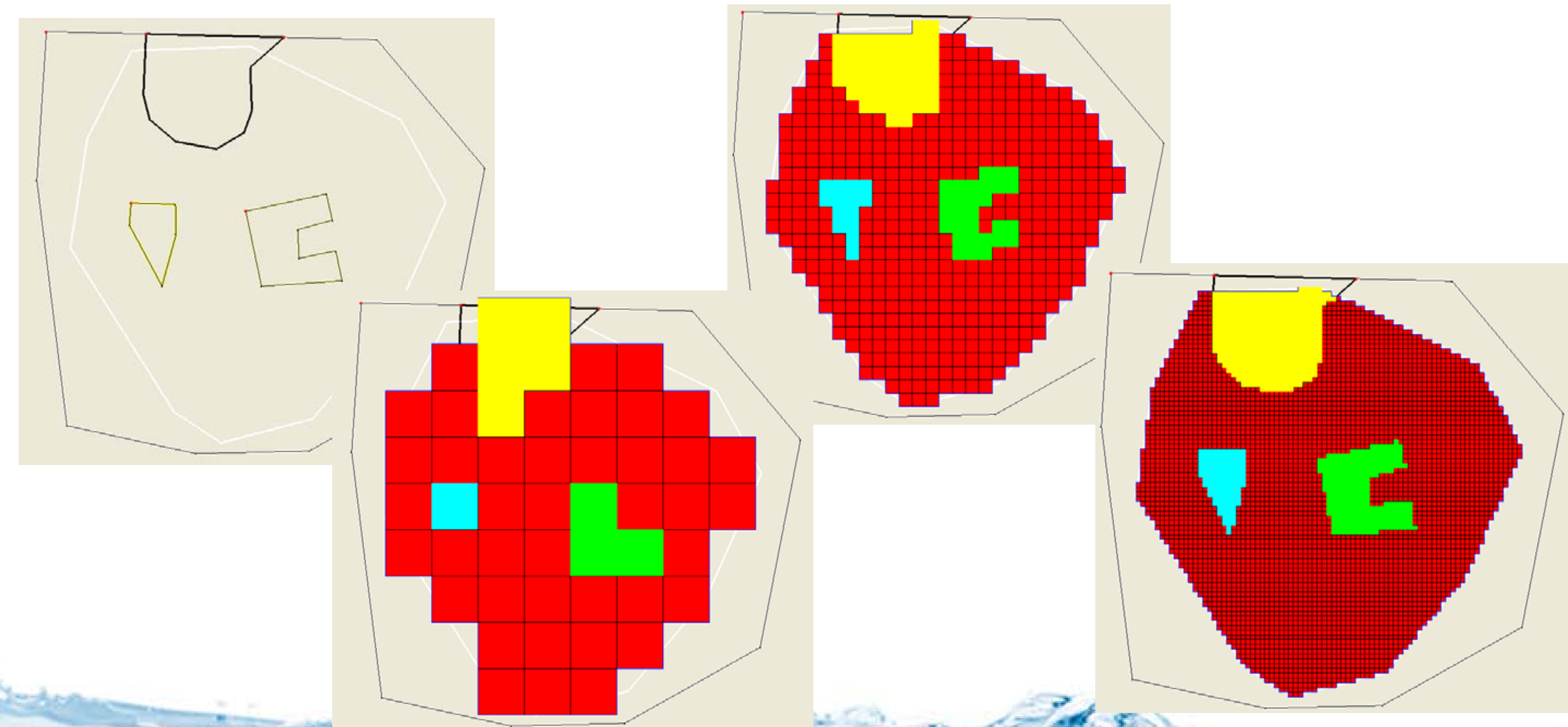
- The grid is the basis of the model.
- Information at the subgrid level is lost.
- Things to consider.
  - What is the resolution of your input data?
    - Don't make grid size smaller than the resolution of your DEM
  - What features are you trying to capture?
  - What is the purpose of your model?
  - What are the dominant processes?
  - Computational burden.
    - Watershed size
    - Computing power

Cell Size Selection: Computational Requirements

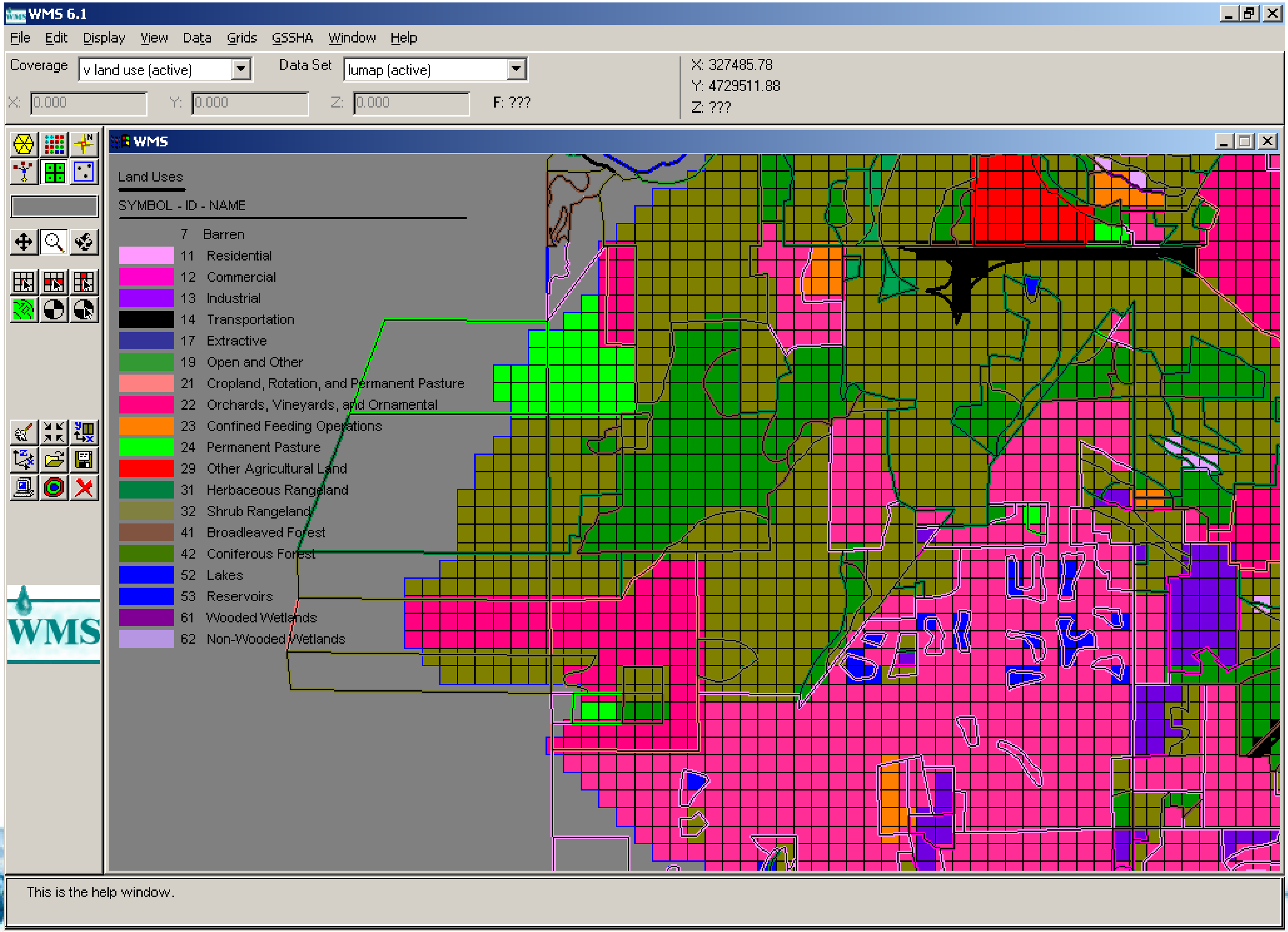
- 100 ac
  - 10m = ~4000 cells
  - 50m = ~160 cells
  - 100m = ~40 cells
  - 200m = ~10 cells
- 100 mi²
  - 10m = ~2,600,000 cells
  - 50m = ~104,000 cells
  - 100m = ~26,000 cells
  - 200m = ~6,500 cells
- 10 mi²
  - 10m = ~260,000 cells
  - 50m = ~10,400 cells
  - 100m = ~2600 cells
  - 200m = ~650 cells
- 1000 mi²
  - Ouch!
  - 10m = ~26,000,000 cells
  - 50m = ~1,040,000 cells
  - 100m = ~260,000 cells
  - 200m = ~65,000 cells

Cell Size Selection: Data Requirements

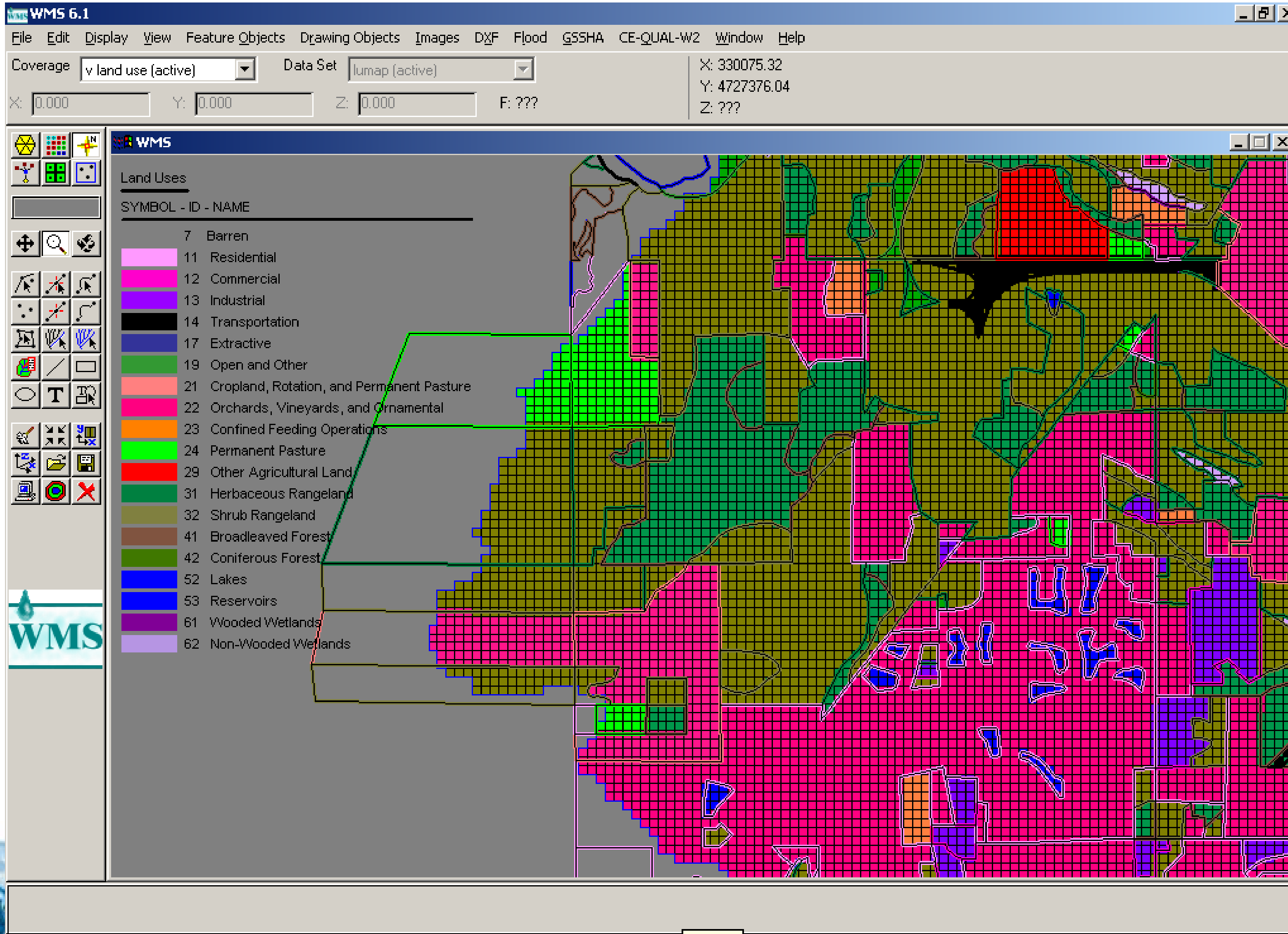
- Must consider scale of important features



Land Use with 100m Grid

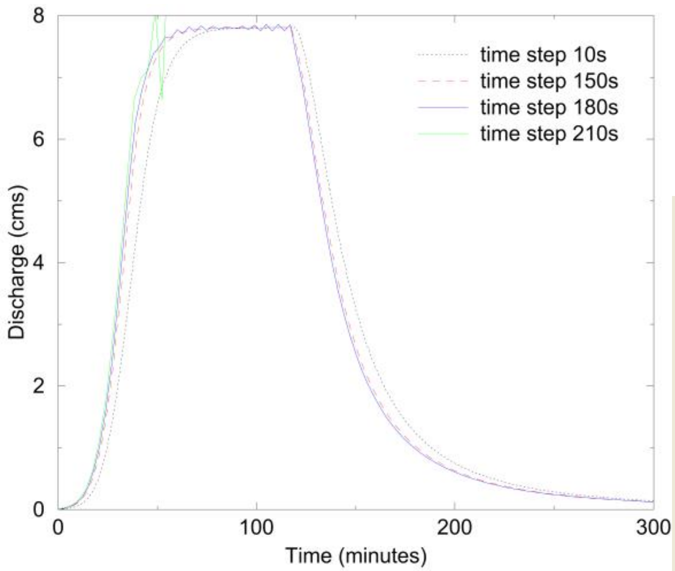


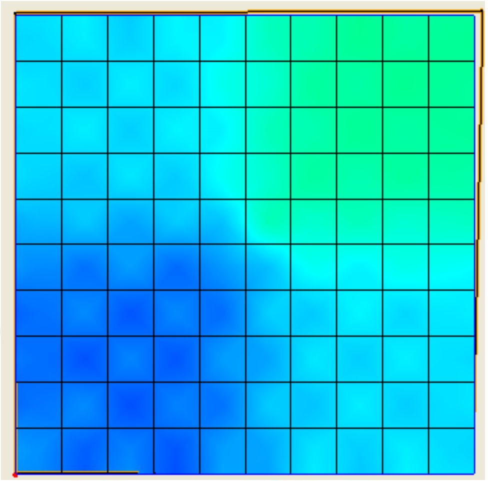
Land Use with 50m Grid



Time Step Selection

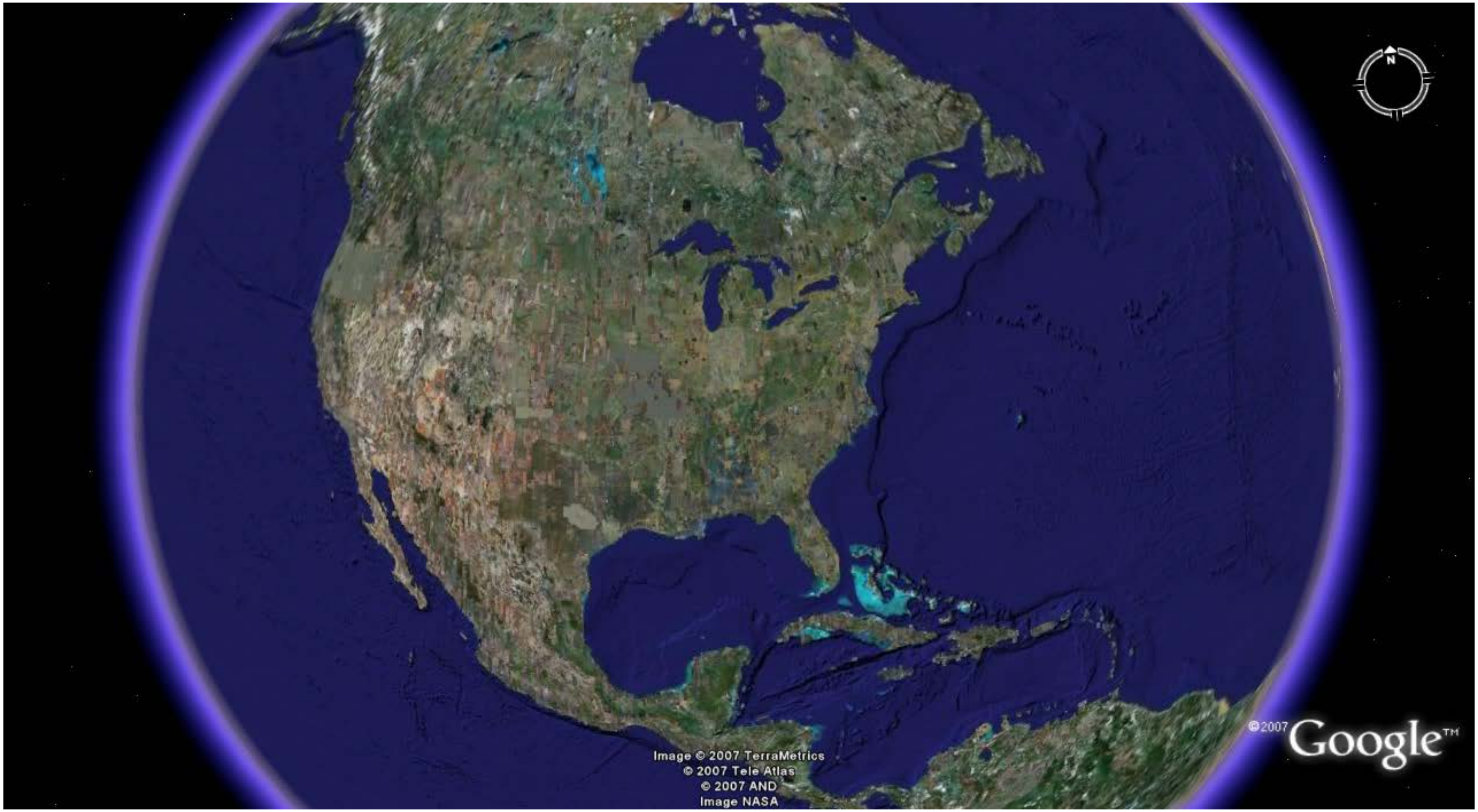
- There is an important relationship between flow velocity, cell size, and the model time step. The flow velocity cannot exceed the grid velocity: $\Delta x / \Delta t$





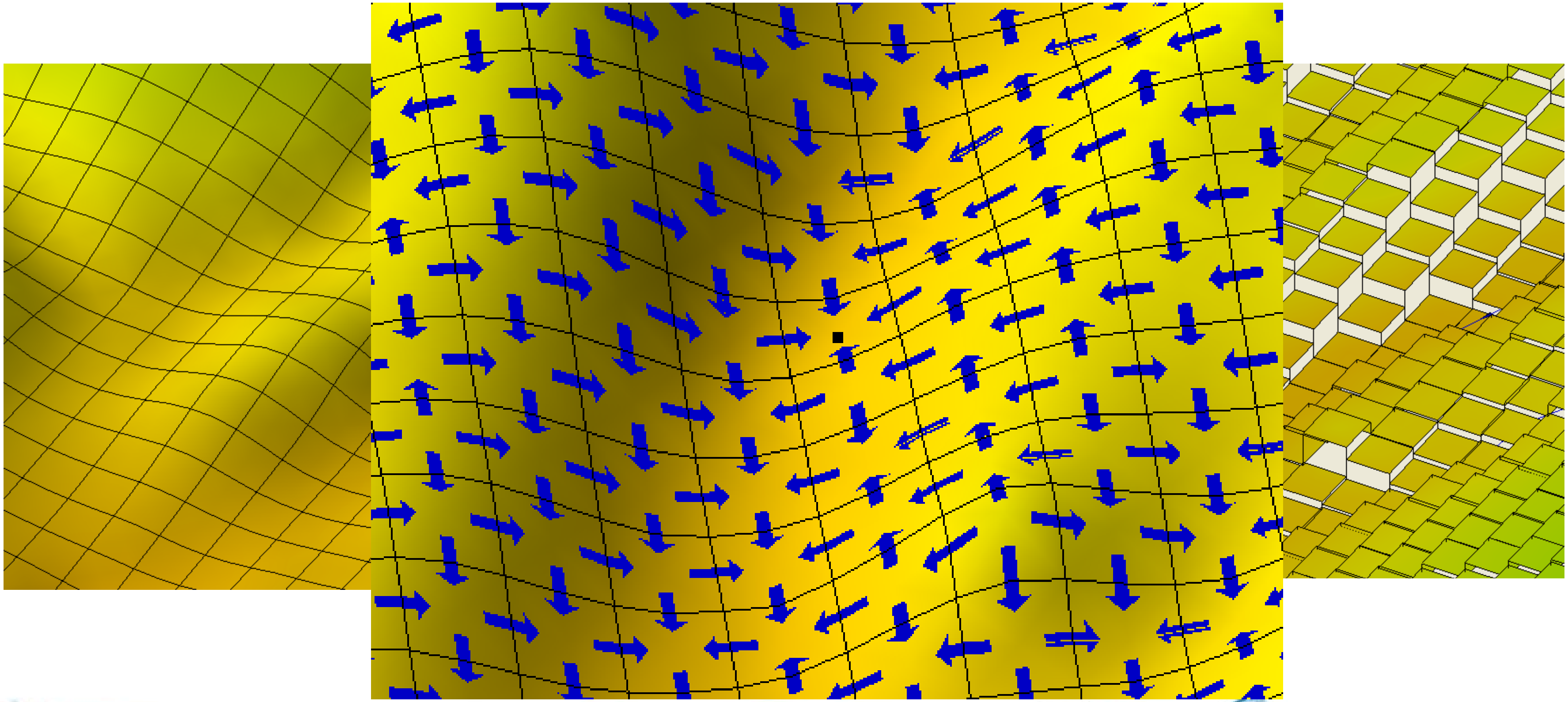
- For stability the time step must satisfy the courant criteria.
- For accuracy and efficiency the time step should be maximized.
- Time step is determined by a convergence study.
- Indications time step is too large.
  - Model crashes
  - Oscillations in hydrograph
  - Checker-boarding
  - Mass balance errors

Hypothetical Storm Surge Charleston

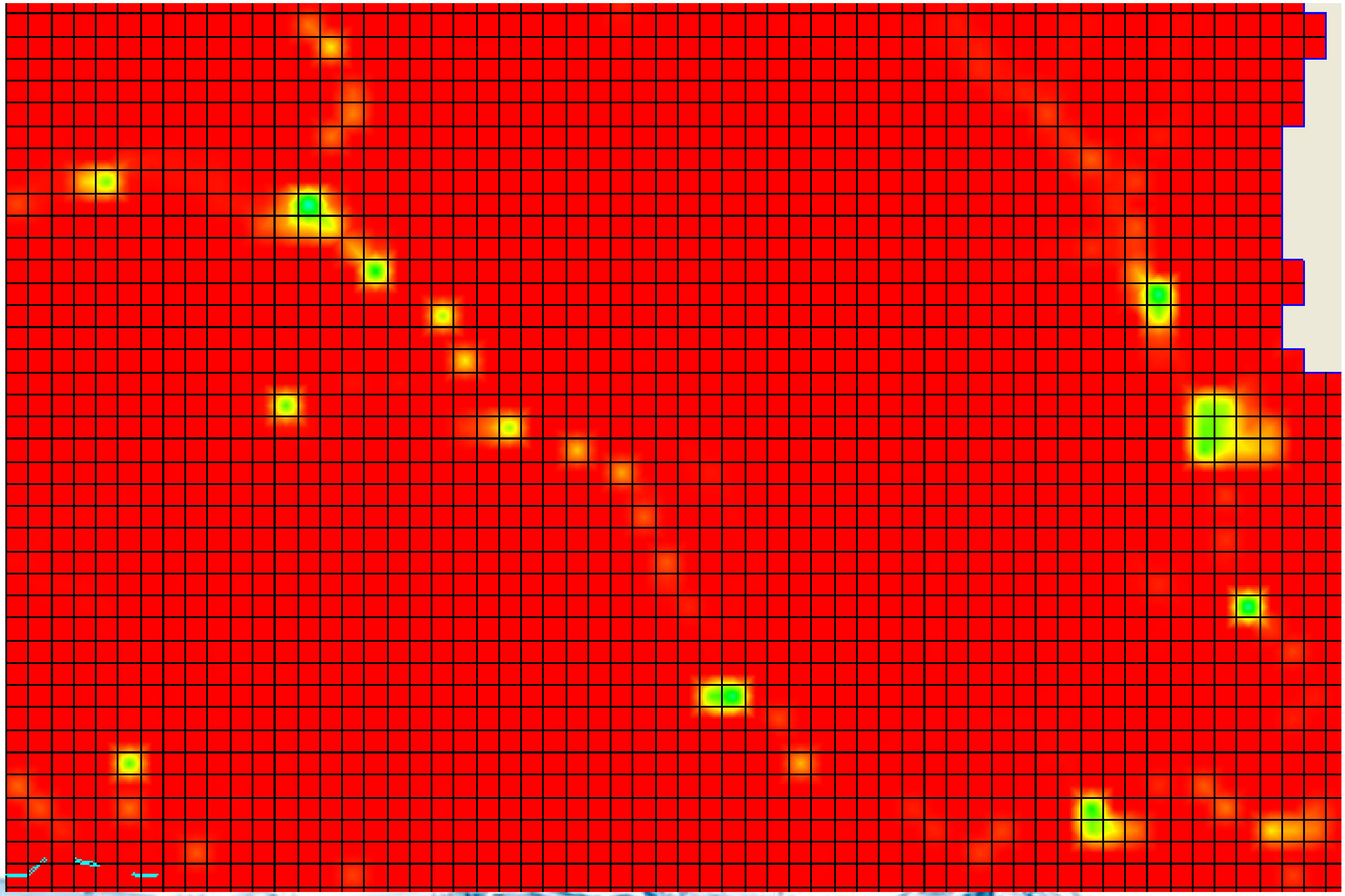


A Problem You Will Run Into

- Digital Dams



Digital Dams



Start simple and build on success

- Build the basic model
  - Start with overland flow, uniform roughness, and uniform precipitation
  - Work out digital dams
  - Add land use, spatial roughness
  - Add retention depth
- Add processes and detail to satisfy the demands of your project
- You have to conceptualize your physical system and build a model that simulates the system properly.
- Don’t include needless detail that adds nothing to your solution.