Introduction to GIS and Water Resources

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Types of Applications
Surface Water – Watershed Management

- Current Watershed Conditions
- Change in Watershed Conditions
- Mapping of Hazards
  - Erosion, Landslides, Floodplains, Pollutants
- Support Hydrologic Modeling
- Watershed Assessment and Analysis
- Watershed Planning

San Pedro River, AZ – AGWA Example

Kepner et al., EPA-NERL/ESD http://www.epa.gov/nerl/land-sci/san-pedro.htm

Human Use Index (HUI = 100 * Total Area in Human Use / Total Area)

Human Use Index

Legend
- Forest
- Grassland
- Agriculture
- Barren
- Oak Woodland
- Desertschub
- Urban
- Mesquite Woodland
- Riparian
- Water

Change in Land Cover Extent


Human Use Index

- 0 - 1.336
- 1.336 - 3.361
- 3.361 - 5.544
- 5.544 - 11.41
- 11.41 - 20.183

Area near Sierra Vista, AZ

Fast-growing city

Courtesy Bill Kepner, US-EP A
Hydrologic Modeling

• **Goal**: Find stream discharge, $Q$, at a location for a given precipitation.

• GIS is used to summarize terrain and hydrologic characteristics of the watershed for input to a model.

• Many ways to calculate $Q$.
  – Statistical methods
    • USGS regression equations (NFF, StreamStats)
  – “Physical” modeling (rainfall-runoff models)
    • HEC-HMS, SWAT, AGWA

**AGWA Conceptual Design: Inputs and Outputs**

- Watershed Delineation using Digital Elevation Model (DEM)
- Watershed Discretization (model elements)
- Intersect model elements with
  - Land Cover
  - Soils
  - Precipitation
  - Rain (Observed or Design Storm)

Output results that can be displayed in AGWA:

<table>
<thead>
<tr>
<th>KINEROS Outputs</th>
<th>SWAT Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel Infiltration (m/hr)</td>
<td>Precipitation (mm)</td>
</tr>
<tr>
<td>Plane Infiltration (mm)</td>
<td>ET (mm)</td>
</tr>
<tr>
<td>Runoff (mm or m³)</td>
<td>Percolation (mm)</td>
</tr>
<tr>
<td>Sediment yield (kg)</td>
<td>Channel Disch. (m³/day)</td>
</tr>
<tr>
<td>Peak flow (m³/s or mm/hr)</td>
<td>Transmission loss (mm)</td>
</tr>
<tr>
<td>Channel Scour (mm)</td>
<td>Water yield (mm)</td>
</tr>
<tr>
<td>Sediment discharge (kg/s)</td>
<td>Sediment yield (t/ha)</td>
</tr>
</tbody>
</table>

**Simulated Runoff From the Small Watershed Near Sierra Vista**

KINEROS model runs for rainfall events:

- 5-year, 30-minute rainfall
- 100-year, 60-minute rainfall

**Spatial and Temporal Scaling of Results**

- Using SWAT and KINEROS for integrated watershed assessment
- Land cover change analysis and impact on hydrologic response

**Output – Tools for Water Quality Planning**

Currently being used for watershed-based planning in AZ and to assess impacts of energy development in WY.
Characterizing the Watershed

- complex topography
- land cover/use
- soils
- high spatial variability
- complex watershed response

Drainage System

- Watershed Boundaries (Drainage Divides)
- Pour Points (Outlets)

GIS Tools for Describing Surface Water Movement

- Flow Direction
- Flow Accumulation
- Stream Order
- Stream Line
- Stream Link
- Flow Length
- Snap Pour
- Watershed Snap Pour

DEM Errors – Sinks and Spikes

- Sinks: when sinks are (or are not) sinks – lakes, depressions, ...
  - Global fill
  - Dealing with internal basins
  - Selective fill
    - Depth
    - Area

Flow Direction

- Elevation
- Flow Direction
- Direction Coding

GIS Background: Flow Direction

- Original Surface
- Flow Direction Surface
Flow Accumulation

GIS Background: Flow Accumulation

Creating Vector Streams

Stream Link
- Assign a unique value(s) to each stream segment.
  - Can be used as input to Watershed

Stream Ordering

Watershed
- Delineate the contributing area to a cell or group of cells.
- Input
  - Pour Point
  - Flow Accumulation
  - Flow Direction
SnapPour

- Snap the “pour point” of a watershed to the cell of highest flow accumulation within a neighborhood.
  - Prevents accidental creation of tiny watersheds on channel side slopes.

Flow Length

- Calculate the length of the upstream or downstream flow path from each cell.

Summarizing Watershed Characteristics

(Zonal Statistics)

- A zone is all the areas/cells with the same value.
- Calculate a statistic within the zones for each cell in a raster.
- Input zones can be feature or raster.
- Output as a raster, summary table, or chart.
  - Max flow length per watershed
  - Average slope per watershed
  - Average curve number per watershed

Zonal Overlay (cont.)

Where is this functionality?

- ArcInfo GRID Functions
- ArcView 3.x Spatial Analyst
  - Avenue requests
  - Sample extension
- ArcGIS Spatial Analyst 10.x
  - Tools in the Spatial Analyst Toolbox
  - Hydrology ToolKit

GIS Hydrologic Modeling Tools

- Automated Geospatial Watershed Assessment
  - http://www.tucson.ars.ag.gov/agwa/
- ArcSWAT
  - http://swatmodel.tamu.edu/software/arcswat/
- ArcAPEX
  - http://apex.tamu.edu/
- HEC – GeoRAS; HEC – GeoHMS