LECTURE 7
MODELING

Youngstown State University

CEEN 4800/6965 - Special Topics
Geographic Information Systems and Hydrologic & Hydraulic Modeling
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OUTLINE

- **Definitions**
- **Modeling**
  - **Model types**
  - **Hydrologic modeling**
  - **Hydraulic modeling**
- **GIS Movie No. 11**
  - **Spatial analysis and modeling**
- **Section 8: Modeling**
  - **Chapter 20: Creating Models**
    - **ModelBuilder**
    - **Exercise 20a: Starting a model (Computer lab)**
    - **Exercise 20b: Building a model (Computer lab)**
    - **Exercise 20c: Enhancing a model (Homework 5)**

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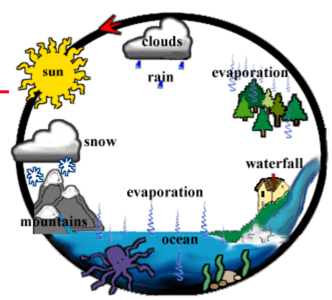
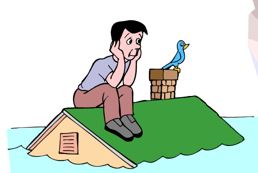
DEFINITIONS

HYDROLOGY

- Hydrology is the science that encompasses the occurrence, distribution, movement and properties of the waters of the earth and their relationship with the environment within each phase of the hydrologic cycle.
- Hydrology: Science of water's:
  - Occurrence
  - Distribution, and
  - Movement





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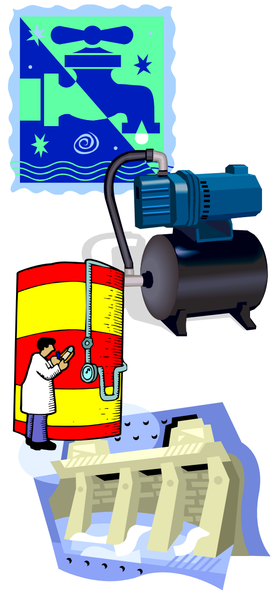
HYDRAULICS

- The physical science and technology of the static and dynamic behavior of fluids
- The branch of engineering that focuses on the practical problems of collecting, storing, measuring, transporting, controlling, and using water and other liquids.
  - Pumps, valves, siphons, spillways
- It differs from
  - Fluid mechanics, which is more theoretical and includes the study of gases as well as liquids;
  - Hydrology, which is the study of the properties, distribution, and circulation of the Earth's water.



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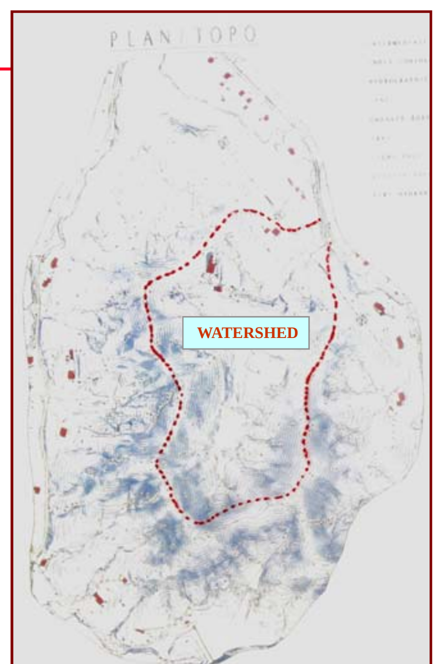
WATERSHEDS

- Watershed: area of land draining into a stream at a given location
- Sewershed: drainage area of sewer system
- Watershed divide: a line dividing
  - land draining towards the given stream, and
  - land draining away from that stream
- Manual delineation of watersheds is done by drawing drainage divides on topographic (contour) maps, which is cumbersome
- Automatic delineation of watersheds is done using Digital Elevation Models (DEMs) and Geographic Information Systems (GIS) software
  - ArcGIS Spatial Analyst Extension



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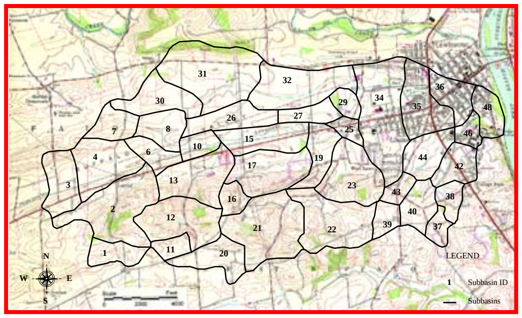
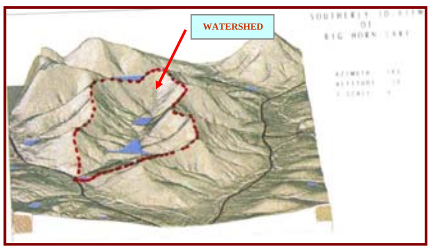
WATERSHED EXAMPLES

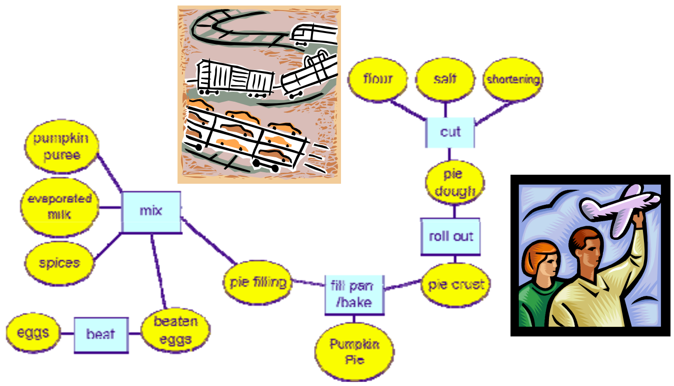




MODELING

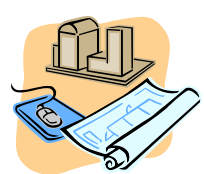
WHAT IS A MODEL?

- An approximate representation of reality
- Example: a recipe, a model train or plane



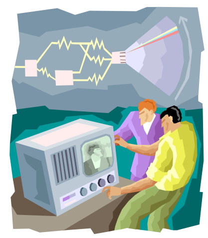
MODEL CLASSIFICATION

1. Physical models
   - Scale models
   - Analog models
2. Mathematical models
   - Hydrologic models
     - Rainfall-runoff modeling
     - Watersheds
     - Example: US Army Corps of Engineers' HEC-HMS software
   - Hydraulic models
     - Flow routing in pressure pipes
     - Water systems
     - Example: US EPA's EPANET software
   - Hydrologic and hydraulic models
     - Rainfall-runoff modeling
     - Flow routing in gravity and pressure pipes (force mains)
     - Wastewater and stormwater systems
     - Sewers and storm drains
     - Example: US EPA's Storm Water Management Model (SWMM)



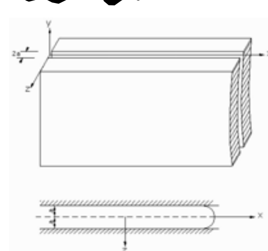
MATHEMATICAL MODEL

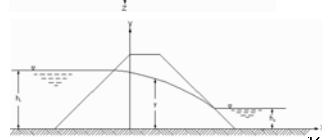
- Mathematical model: an abstract model that uses mathematical language to describe the behavior of a system.
- A computer program that reads user input data to provide output results
- Mathematical models are used in:
  - Natural sciences and engineering disciplines
    - Physics, biology, and civil engineering
  - Social sciences
    - Economics, sociology and political science
- Engineers, Physicists, computer scientists, and economists use mathematical models most extensively.



HYDROLOGIC MODEL CLASSIFICATION

1. Physical
   - Scale: Reduced scale replicas of prototype
     - Ex: a dam spillway
   - Analog: <u>Another</u> physical system having properties similar to those of the prototype
     - Ex: Hele-Shaw model uses the movement of a viscous fluid between two closely spaced parallel plates to model seepage in an embankment

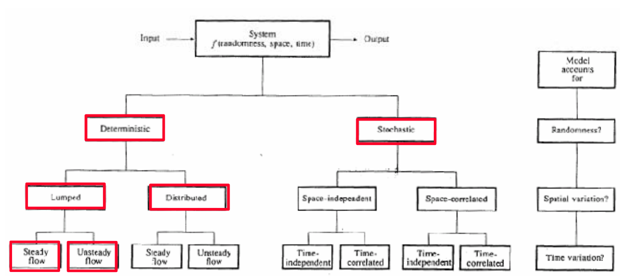




HYDROLOGIC MODEL CLASSIFICATION

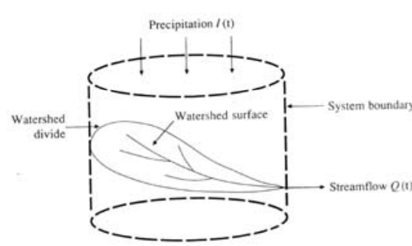
2. Hydrologic Mathematical Models

- Deterministic: Model variables have a fixed (known) value
  - Make forecasts
  - Ex: Daily evaporation models
- Stochastic: Model variables are random and described by probability distributions
  - Make predictions
  - Ex: Daily precipitation models
- Lumped: hydrologic processes do not vary spatially within the watershed
- Distributed: hydrologic processes vary spatially within the watershed
- Steady: flow rate does not change with time
- Unsteady: flow rate changes with time



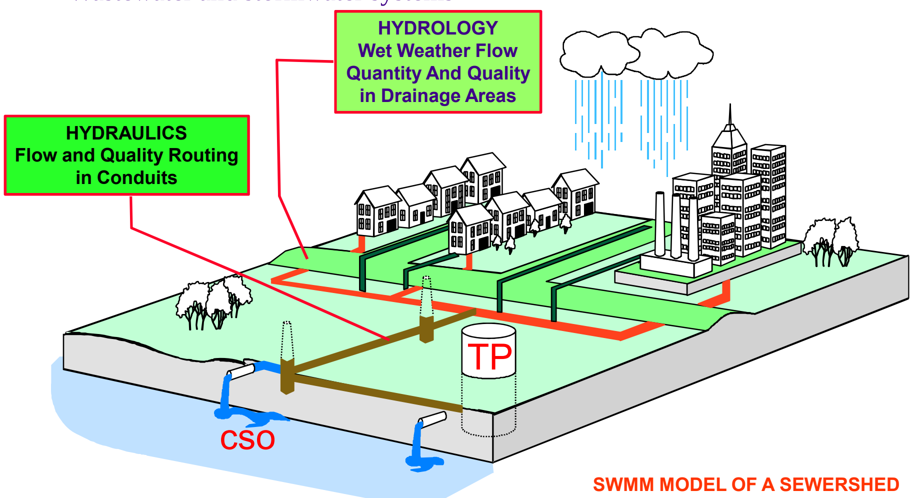
MODEL EXAMPLES

- Example 1: Watershed rainfall-runoff process as a hydrologic system
- Model Q(t) = Ω . I(t)
- I (t) = model input (rainfall) at time t
- Q (t) = model output (runoff) at time t
- Ω = transfer function (omega)



MODEL EXAMPLES

- Example 2: Storm Water Management Model (SWMM)
  - A hydrologic and hydraulic model
  - Wastewater and stormwater systems



SWMM MODEL OF A SEWERSHED
Sewershed rainfall-runoff and hydraulic routing process

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MODEL EXAMPLES

- Example 3: Rational Method *Q = CIA*
- *Used for estimating flow in sewer pipes for designing sewer size*
  - *Q* = peak flow (output)
  - *I* = rainfall intensity (input)
  - *A* = drainage area (input)
  - *C* = runoff coefficient (transfer function)
    - 0.9 for concrete, 0.15 for lawns

Example 1:
What is the peak discharge through a single culvert draining a forested watershed in Austin (TX) of 150 acres with average slope during a 10-year storm with a rainfall intensity of 6 in/hr?
Q = CiA
From Table 15.1.1, C = 0.36
Q = 0.36 x 6 x 150
Q = 324 cfs

TABLE 15.1.1
Runoff coefficients for use in the rational method

	Return Period (years)						
Character of surface	**2**	**5**	**10**	**25**	**50**	**100**	**500**
Developed							
Asphaltic	0.73	0.77	0.81	0.86	0.90	0.95	1.00
Concrete/roof	0.75	0.80	0.83	0.88	0.92	0.97	1.00
Grass areas (lawns, parks, etc.)							
Poor condition (grass cover less than 50% of the area)							
Flat, 0–2%	0.32	0.34	0.37	0.40	0.44	0.47	0.58
Average, 2–7%	0.37	0.40	0.43	0.46	0.49	0.53	0.61
Steep, over 7%	0.40	0.43	0.45	0.49	0.52	0.55	0.62
Fair condition (grass cover on 50% to 75% of the area)							
Flat, 0–2%	0.25	0.28	0.30	0.34	0.37	0.41	0.53
Average, 2–7%	0.33	0.36	0.38	0.42	0.45	0.49	0.58
Steep, over 7%	0.37	0.40	0.42	0.46	0.49	0.53	0.60
Good condition (grass cover larger than 75% of the area)							
Flat, 0–2%	0.21	0.23	0.25	0.29	0.32	0.36	0.49
Average, 2–7%	0.29	0.32	0.35	0.39	0.42	0.46	0.56
Steep, over 7%	0.34	0.37	0.40	0.44	0.47	0.51	0.58
Undeveloped							
Cultivated Land							
Flat, 0–2%	0.31	0.34	0.36	0.40	0.43	0.47	0.57
Average, 2–7%	0.35	0.38	0.41	0.44	0.48	0.51	0.60
Steep, over 7%	0.39	0.42	0.44	0.48	0.51	0.54	0.61
Pasture/Range							
Flat, 0–2%	0.25	0.28	0.30	0.34	0.37	0.41	0.53
Average, 2–7%	0.33	0.36	0.38	0.42	0.45	0.49	0.58
Steep, over 7%	0.37	0.40	0.42	0.46	0.49	0.53	0.60
Forest/Woodlands							
Flat, 0–2%	0.22	0.25	0.28	0.31	0.35	0.39	0.48
Average, 2–7%	0.31	0.34	0.36	0.40	0.43	0.47	0.56
Steep, over 7%	0.35	0.39	0.41	0.45	0.48	0.52	0.58

Note: The values in the table are the standards used by the City of Austin, Texas. Used with permission.

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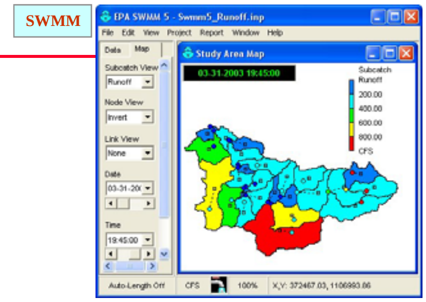
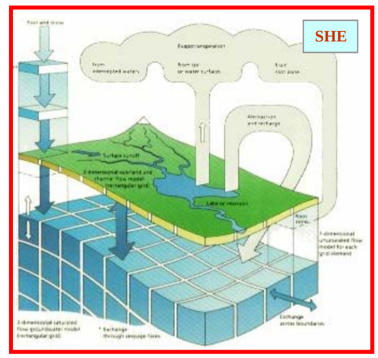
MODEL EXAMPLES



- Lumped:
  - HEC-HMS
  - SWMM
- Distributed:
  - Système Hydrologique Européen SHE (European Hydrological System)
  - A deterministic, distributed, and physically based modeling system for describing the major flow processes of the entire land phase of the hydrological cycle.



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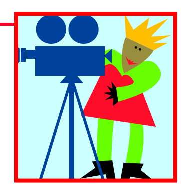
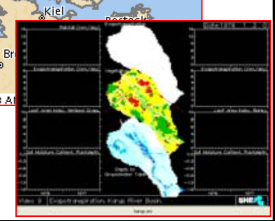
DISTRIBUTED MODEL: MIKE SHE



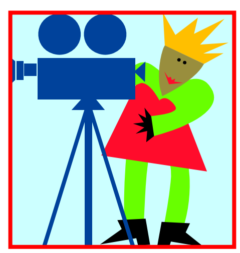
- Spatial and temporal variations in evapotranspiration (ET) rate
- Karup (Denmark) catchment, 425 km^2, single unconfined sandy aquifer
- Evapotranspiration strongly depends on development stage of crops and depth to groundwater table
- Additional info: Danish Hydraulic Institute (DHI), www.dhigroup.com



MODEL BUILDER

GIS MOVIE

- Analyzing Data
  - Spatial Analysis
  - Modeling water quality due to fertilizer application
- 5:30 minutes



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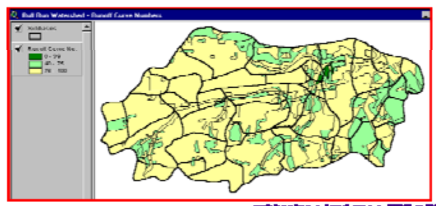
GEOPROCESSING

- Recall Lecture 5A: Spatial Analysis And Geoprocessing

GEOPROCESSING

- Geoprocessing = spatial analysis
  - What's the population of a given sewershed?
    - Overlay of sewershed and census block layers
  - What's the runoff curve number of a given watershed?
    - Overlay of watershed, land use, and soil layers

TO ESTIMATE RUNOFF CURVE NUMBERS



subbasins + land use + HSG = RCN

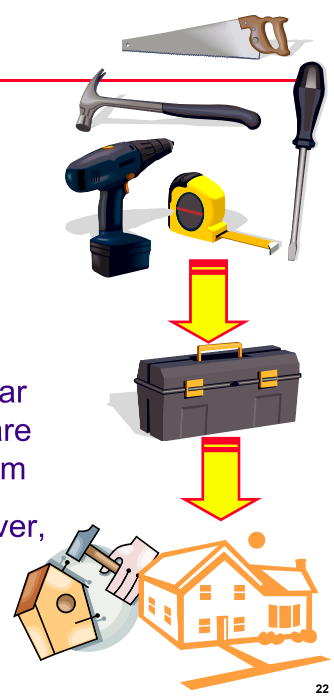
Known from NRCS runoff curve number table

Land Use	% Imp.	Runoff Curve Number for Hydrologic Soil			
		A	B	C	D
High density residential	51	69	80	87	90
Medium density residential	28	56	71	81	86
Low density residential	16	49	66	78	83

MODELBUILDER

- A utility for automating geoprocessing
- Does not build a mathematical model
- Models (automates) GIS work flow

- Individual tools (Dissolve, Clip, Buffer & Union) are useful for completing particular tasks but their real power is when they are used together to solve a complex problem
- Individual tools (saw, hammer, screwdriver, and tape) are useful for completing particular tasks but you should use your entire toolbox to build a house



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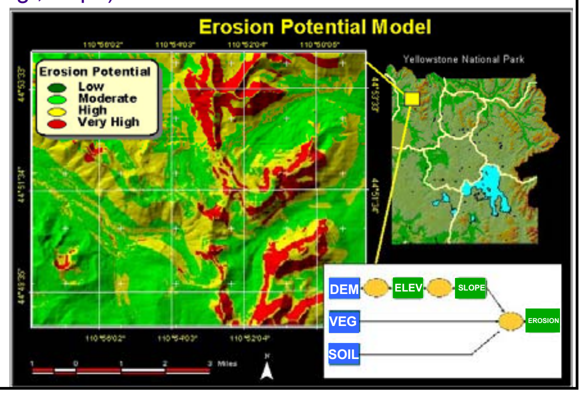
MODELBUILDER BENEFITS

- Model = A workflow diagram
- Automate work flow by linking processes together
- Show the process used to create output
- Document methods & procedures in a model and share it with others
- Save the model so it can be run again
  - Huge time saving for repetitive spatial analyses
  - Change an input parameter (e.g., slope) and rerun the entire model with one click
  - Model and run what-if scenarios (decision support system)

CALCULATE SNYDER UNIT HYDROGRAPH



ACCESSING MODELBUILDER

- Start ArcCatalog
- Open ArcToolBox
- Right-click ArcToolBox ArcToolbox & choose New Toolbox. Type a name for the toolbox.
- Right-click your new toolbox and choose New model. Click the model, choose Properties, click the General tab & give it a name

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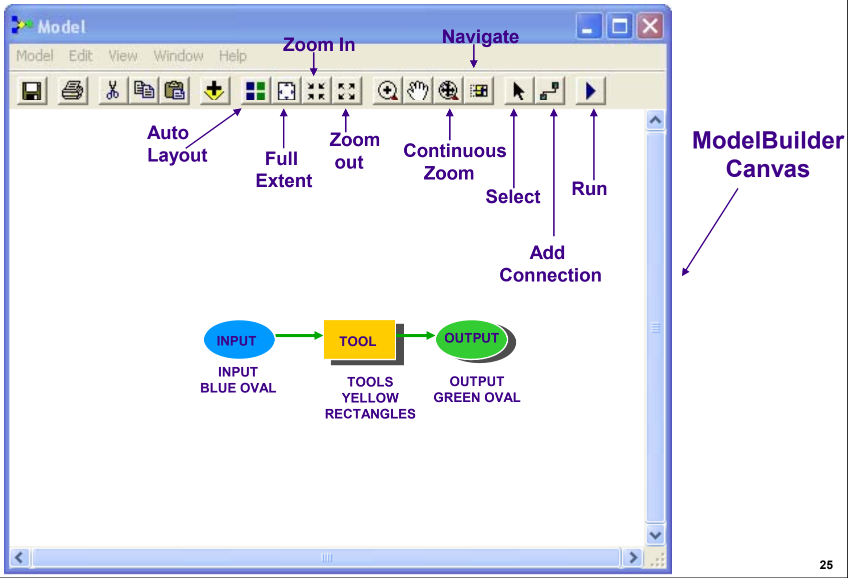
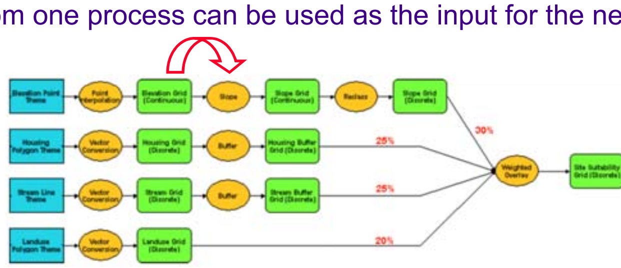
THE MODELBUILDER INTERFACE

ModelBuilder window: where you edit, test and run models



THE MODELBUILDER INTERFACE, CONT.

- Auto Layout button: organizes your model elements into easily readable linear patterns
- Navigate tool: lets you navigate through the model from one element to the next, forward or backward
- Add Connection tool: used to add connections between data & the tool that will accept that data as an input
- Run button: runs the processes that have not already been run.
  - Output from one process can be used as the input for the next process



SUITABLE SITES FOR A WASTE DUMP

THE MODELBUILDER INTERFACE, CONT.

- Model elements have 3 states

1. Not ready to run (parameters aren't defined)

2. Ready to run (all elements are colored)

3. Already run (elements are colored and shaded)

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START BUILDING YOUR MODEL!

- First, plan what you want to do
  - What data will you need?
  - What processes will you run on each dataset?
- If the ModelBuilder Window is closed, right-click the model and choose Edit to open for editing
- Add data layers to the canvas using the *or* drag them in from ArcCatalog
- Drag tools onto the canvas from ArcToolbox
- Connect data layers to tools using the tool

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LAB EXERCISES

- ModelBuilder
- Exercise 20a: Starting a model
- Exercise 20b: Building a model
- Remember, you do not have the "write" permission on the C drive of the lab computers. Therefore, copy the exercise data to a drive where you have the write permission. Before starting the exercise, create a folder ESRIPress on your N drive (YSU's student account server) or memory stick (E drive). Copy exercise data folder (Chapter20) from the C:\ESRIPress\GTKArcGIS folder to the ESRIPress folder on N or E drive. In exercise steps, replace C:\ with N:\ or E:\.

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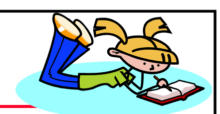
HOMEWORK 5



- Exercise 20c: Enhancing a model
  - Q1. After completing Step 26, submit a screenshot of the "Harvest Profitability" model shown on page 571.
  - Q2. After completing Step 27, answer the following question:
    What's the mean stand value for harvest stands?

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