Watershed Analysis & Hydrologic Modeling

U.S. Fish & Wildlife Service
National Conservation Training Center

CSP 7306

Syllabus

Class Duration: This is a 1 week course meeting for 4.5 days. The class meets Monday to Thursday from 8am to 5pm and Friday from 8am to noon.

Class Schedule: Monday 8am on October 27 to noon Friday October 31, 2014.

Lecture Location: National Conservation Training Center, Shepherdstown, WV.

Instructors:

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Overview:
Analyzing spatial issues is a necessary component of watershed management. Geographic Information Systems (GIS) is a useful tool to characterize spatial components of a stream, river or larger water body as well as the landscape, terrain attributes, and drainage patterns. Beyond characterization and data collection, watershed analysis includes using statistical modelling, hydrological principals and continuity equations, and terrain derivatives to provide insights to questions about water quality, quantity, aquatic habitat, restoration, and conservation. In this course titled "Watershed Analysis and Hydrological Modeling", the goal is to incorporate these multifaceted aspects into a single framework to aid in aquatic resources monitoring, protection and restoration for sustainable management of aquatic resources. To meet this overall goal, the course will incorporate the following learning objectives.

Learning Objectives:
At the end of this course, students will be able to:

1. Understand storage components, fluxes, and controls on and within the hydrologic cycle and dominant drivers of hydrologic change;

2. Understand and use the newer spatial datasets and analysis tools for watershed management;

3. Incorporate the surface hydrological analysis functions in GIS to answer questions related to stream flow, drainage area, finding potentially affected streams, and estimating water quality;

4. Interpolate information for larger water bodies including depth, temperature, substrate, and fish densities using geostatistical techniques;

5. Make ranking or prioritization decisions with models that use spatial data as criteria inputs;

6. Understand all data limitations when integrating GIS functionality with models and concepts for aquatic resource management

To accomplish these objectives, the course will integrate lectures and lab sessions. Lectures will cover the necessary background of issues and the labs will give students the opportunity to develop GIS and data analysis skills to solve spatial problems from the ground up. The models and concepts introduced in lecture will have hands-on exercise components to reinforce learning so students will be comfortable in applications with their own datasets.

Who should attend?
GIS professionals and/or fishery biologists interested in extending their GIS proficiency in the area of watershed analysis and hydrological modeling. Completion of an introductory GIS course or proficiency in ArcGIS software is suggested.

Software:
The main software used in this course is ESRI ArcGIS version 10.2 with the appropriate extensions. The NHD Plus Accumulation Tool will be installed in the computers used in the course. It is available online at http://www.horizon-systems.com/NHDPlus/NHDPlusV2_tools.php#NHDPlusV2 Catchment Attribute Allocation and Accumulation Tool (CA3TV2). A student time-out version of ArcGIS 10.2 will be given to students of the class for use on their own personal computers if they wish. In addition, the open source statistical software framework R will be used to condition and analyze hydrologic and climatic datasets.

Topics

DAY 1: MONDAY

1. Introduction

- Instructors, class
- Course goals and objectives

2. Understanding the hydrological cycle
   - Landscape and climate controls on hydrology
   - Implications of environmental change
   - Watershed management
   - Connecting the watershed hydrology to GIS

2. Elevation data
   - Background – source for overland flow analysis
   - How they are created and processed
   - Different types of elevation data and resolutions
   - Acquiring elevation data for anywhere in the US

3. Processing elevation data
   - Elevation data limitations for hydrological analysis
   - Preparing elevation data for use in hydrological modeling and analysis
   - ArcGIS hydrology commands
   - Vector and raster stream differences

4. Watershed delineation
   - Watersheds versus USGS HUCs
   - Manual process with GIS
   - Automated process by points, segments
   - Off stream catchment delineation

5. Stream flow estimation
   - Drainage area ratio method
   - Acquiring a snapshot of USGS gauge data
   - Confidence intervals for the ratio method
   - Limitations, assumptions

DAY 2: TUESDAY

6. Statistical analysis of hydrology data
   - Goals and procedures
   - Conditioning hydrological data for modeling
   - Using R and HydroTSM

7. Creating a spatially explicit runoff grid
   - Overview to building a relationship between rainfall and stream flow
   - Stream flow gauge selection and summarization
   - Gridded precipitation data acquisition
   - Delineating watersheds for USGS gauge location
   - Summarizing precipitation by gauge watershed extent
   - Developing a runoff equation
   - Applying runoff equation to create a spatially explicit runoff grid
   - Stream flow grid creation and comparison to ratio method

8. Identifying potentially impacted streams and watersheds
   - Overland flow of hydrological cycle
   - Point and non-point sources
   - Weighted flow accumulation command
   - Applications of where to sample water quality

DAY 3: WEDNESDAY

9. In-stream time of travel
   - Elk river contaminant spill, Charleston WV
   - Raster based time steps
   - Bankfull equations
   - Flow length conversion command

10. Modeling water quality
    - Expected mean concentration modeling
    - Loading rates for land cover
    - Downloading land cover data
    - Processing land cover as a weight grid
    - Loading values for total nitrogen, phosphorous, and suspended solids
    - Annual loading grid
    - Annual concentrations
    - Applications, limitations

11. National Hydrography Data (NHD) use and applications
    - Watershed boundaries
    - Streamlines
    - Local versus cumulative analysis

- NHDlus accumulation tool

DAY 4: THURSDAY

12. Terrain analysis to aid in watershed modeling
    - Deriving fluvial landform characteristics
    - Floodplain delineation
    - Soils extraction from ESRI
    - Watershed dimensions
    - Moisture indices for wetland prediction
    - Riparian area delineation with a cost path modeling approach

13. Multi-criteria analysis for adaptive watershed management
    - Ranking/prioritizing challenges
    - Watershed criteria selection
    - Evaluation matrix creation
    - Payoff matrix normalization
    - Weight solicitation techniques
    - Compromise programming
    - Sensitivity analysis

14. Surface interpolation and modeling for fishery habitat
    - Habitat conditions in streams, rivers and lakes
    - Interpolation techniques for water depth and temperature
    - Geostatistical analysis

DAY 5: FRIDAY

15. Indicators of Hydrological Alternation (IHA)
    - Introduction of IHA and ecological metrics
    - Defining hydrologic regimes for aquatic resources
    - Human impacts on hydrological conditions

16. Continued challenges for GIS use in watershed management
    - Summarizing our current state of knowledge and limitations
    - Intellectual and theoretical
    - Practical and organizational
    - Economic
    - Social and cultural
    - Closing the loop between field sciences and GIS

17. Useful online data sources for aquatic and watershed management (HANDOUT)
    - Surface and ground water data
    - Water quality
    - Weather and climate
    - Climate change
    - Crowd sourcing

18. Class evaluations

Texts and Readings:

There is not one assigned text for this class but sections of the following books will be made available for the lecture topics that are covered. In addition, journal articles will be used to highlight applications and models presented in the class.

Bolstad, P. 2008. GIS Fundamentals: A first text on Geographic Information Systems, third edition. Eider Press, White Bear Lake, MN.

Fisher, W. L. and F. J. Rahel, editors. 2004. Geographic Information Systems in Fisheries. American Fisheries Society, Bethesda Maryland.

Gurnell, A. M. and D. R. Montgomery. 2000. Hydrological Applications of GIS, Advances in Hydrological Processes. John Wiley and Sons, New York, NY.

Heuvelink, G. B. 1998. Error Propagation in Environmental Modelling with GIS. Taylor and Francis, New York, NY.

Johnston, K., J. M. Ver Hoef, K. Krivoruchko, and N. Lucas. 2001. Using ArcGis Geostatistical Analyst. Environmental System Research Institute, Redlands, CA.

Longley, P. A. and M. Batty. 1996. Spatial Analysis: Modeling in a GIS Environment. John Wiley and Sons, New York, NY.

Longley, P. A. and M. Batty. 2003. Advanced Spatial Analysis. ESRI Press, Redlands, CA.

Malczewski, J. 1999. GIS and Multicriteria Decision Analysis. John Wiley and Sons, New York, NY.

Maidment, D., and D. Djokic. 2000. Hydrologic and Hydraulic Modeling Support with GIS. Environmental System Research Institute, Redlands, CA.

Masser, I. and F. Salge. 2000. Spatial Models and GIS New Potential and New Models. Taylor and Francis, Philadelphia, PA.

Mitchell, A. The ESRI Guide to GIS Analysis Volume 1: Geographic Patterns and Relationships. 1999. ESRI, Inc. Redlands, CA.

Mowrer, T., and R. Congalton. 2000. Quantifying Spatial Uncertainty in Natural Resources, Theory and Applications for GIS and Remote Sensing. Sleeping Bear Press, Chelsea, MI.

Rogerson, P. 2001. Statistical Methods for Geography. Sage Publications, Thousand Oaks, CA.

Shaw, G. and D. Wheeler. 1994. Statistical Techniques in Geographical Analysis. David Fulton Publishers, London.

Schedule

Start	End	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**
8:00 AM	8:30 AM	Introduction	Review / questions	Review / questions	Review / questions	Review / questions
8:30 AM	9:00 AM	Understanding the hydrological cycle	Stream flow estimation	Estimating water quality - EMC	MCA – Compromise Programming	Data sources & tools; climate, water resources, climate change
9:00 AM	9:30 AM					
9:30 AM	10:00 AM	GIS Use in Watershed Mgmt				
10:00 AM	10:30 AM	Break	Break	Break	Break	Break
10:30 AM	11:00 AM	Elevation data	Analysis & conditioning of hydrological using R	Estimating water quality – Fate Transport	Terrain analysis for watershed modeling	National Hydrology Data use and applications
11:00 AM	11:30 AM					
11:30 AM	12:00 PM					Class evaluations
12:00 PM	12:30 PM	Lunch	Lunch	Lunch	Lunch	
12:30 PM	1:00 PM					
1:00 PM	1:30 PM					
1:30 PM	2:00 PM	Processing elevation data	Creating a spatially explicit runoff grid	In-stream time of travel	Terrain analysis continued	
2:00 PM	2:30 PM					
2:30 PM	3:00 PM					
3:00 PM	3:30 PM	Break	Break	Break	Break	
3:30 PM	4:00 PM	Watershed delineation	Identifying potentially affected streams	Multi-criteria analysis for adaptive watershed management - Weighting	Surface interpolation for fishery habitat	
4:00 PM	4:30 PM					
4:30 PM	5:00 PM					