

LECTURE #1

INTRODUCTION TO BASINS AND TMDLS



A vertical photograph of a waterfall cascading over dark rocks, with water splashing and creating white foam at the bottom. The image is positioned on the left side of the slide.

WHAT IS EPA'S BASINS?

Better Assessment Science Integrating Point and Nonpoint Sources

Integrated GIS, data analysis and modeling system designed to support watershed based analysis and TMDL development

- **Data:** national data sets with options to import local data
- **Tools:** provide quick access to analysis techniques for watershed assessment
- **Models:** provide more detailed analysis and predictive evaluations to support studies

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WHAT IS THE PURPOSE OF BASINS?

To assist in watershed management and TMDL development by integrating data, tools, and models.

Examples of uses:

- Characterizing water quality data
- Identifying pollution sources
- Investigating Load Allocations
- Climate Change Assessment



BASINS DEVELOPMENT PHILOSOPHY

Builds on existing, documented technology

- Integrates existing models (i.e., HSPF, SWAT)
- Incorporates national derived data layers (i.e., PCS, STORET...)

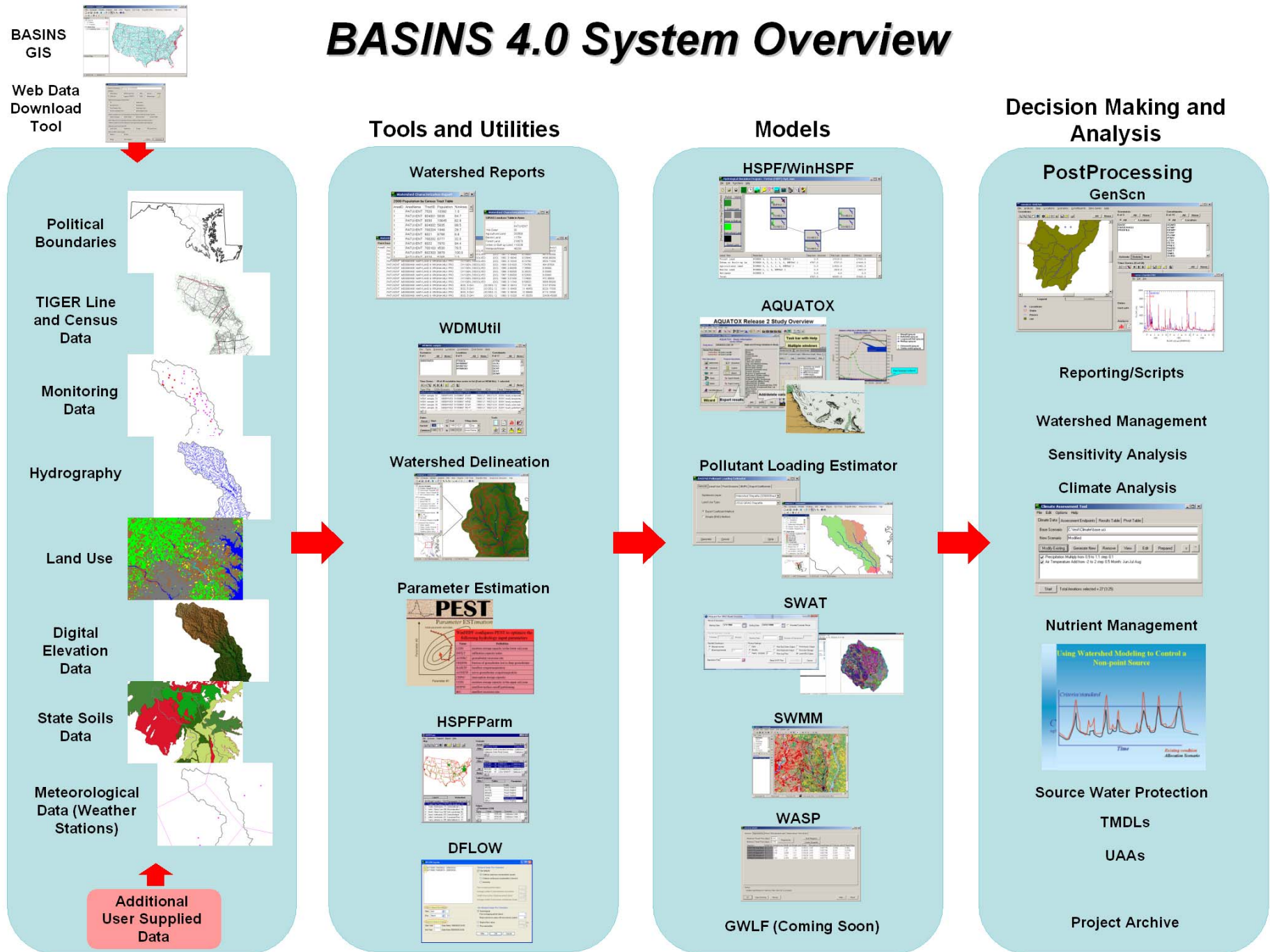
Ease of use

- GIS technology supports organization, display, selection, and analysis of information
- Windows technology provides graphical user interfaces (GUI) that facilitate interaction with the data and analytical tools
- Automatic linkage streamlines the flow of information

Open Platform

- Open Source
- Extensible architecture based on robust objects

BASINS 4.0 System Overview



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WHAT IS BASINS AGAIN?

- Multipurpose environmental analysis system
- Developed by EPA's Office of Water
- Designed for performing watershed and water quality-based studies
- Implemented through a customized GIS interface

Or, a software framework that holds and links data, tools, and models



BASINS VERSIONS

- 1.0 – May 1996
- 2.0 – January 1999
- 3.0 – June 2001
- 3.1 – August 2004 incremental release
- 4.0 – March 2007

Update 1 – November 2007

Update 2 – August 2008

Update 3 – May 2010



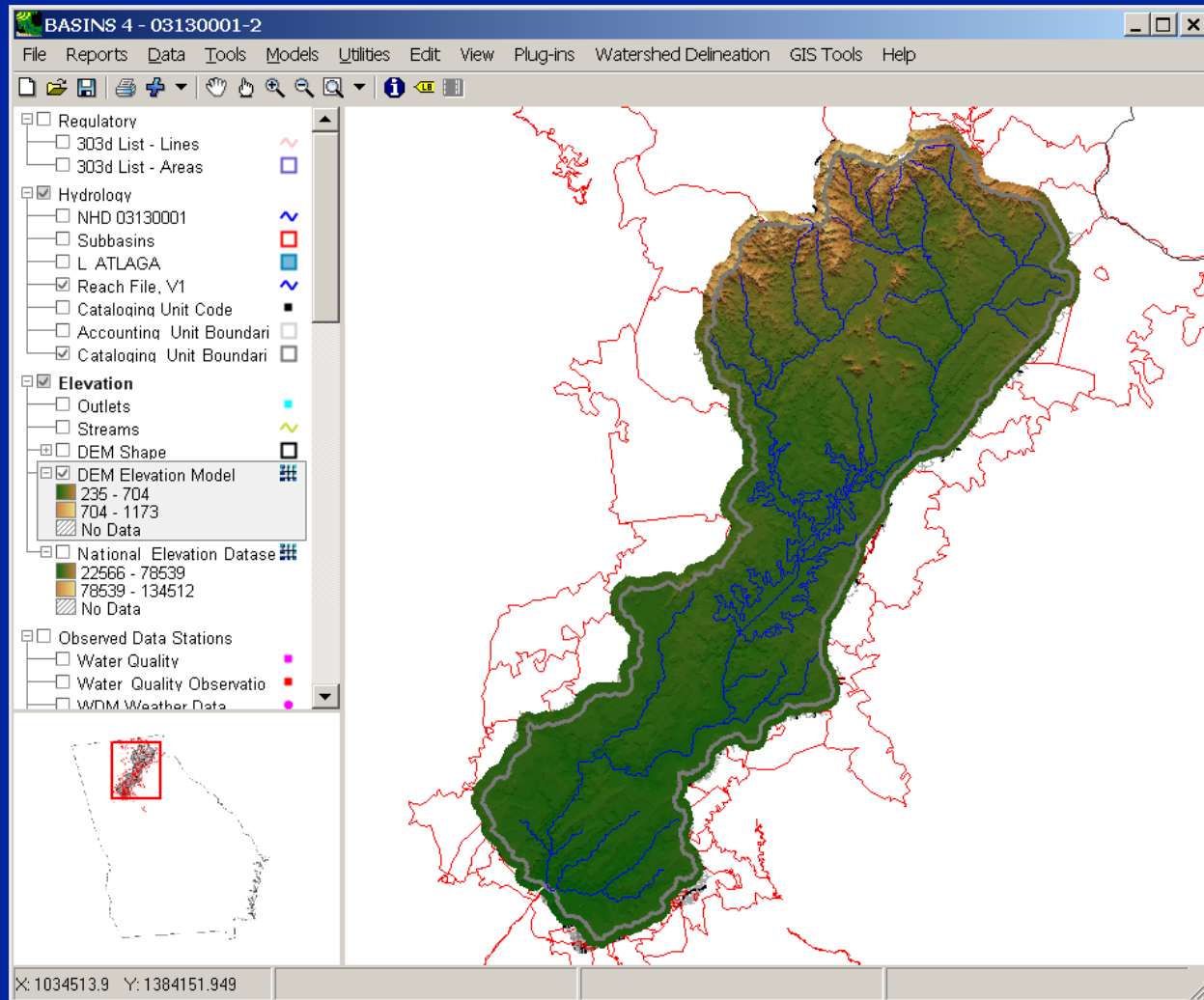
BASINS 4.0

- Builds off BASINS 3.1
- Significant restructuring to be GIS platform independent
- Accommodating both ArcView 3.x and ArcGIS
- Based on a non-proprietary, open-source GIS foundation (MapWindow)

MAPWINDOW BACKGROUND

- Originally developed at the Utah Water Research Laboratory at Utah State University
- Developed to assist in watershed management related activities and funded by a variety of agencies and organizations including the Idaho National Engineering Laboratory.
- Development and maintenance of core GIS components and additional plug-ins at Idaho State University, Utah State University, AQUA TERRA Consultants, and many others.
- www.mapwindow.org

BASINS 4.0 GIS INTERFACE



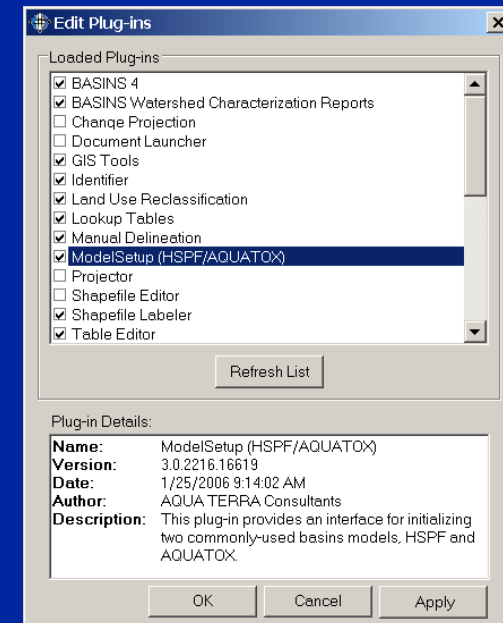


OPEN SOURCE ADVANTAGES

- No need to purchase expensive proprietary GIS products
- Source code for all components, including the foundational GIS software, will always be available to end users and the federal government
- Provides greater stability and transparency
- Open framework readily allows for inclusion of additional models and tools

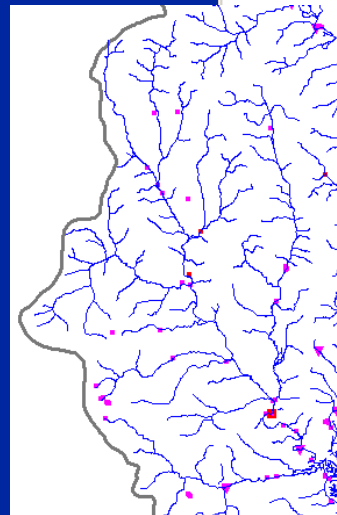
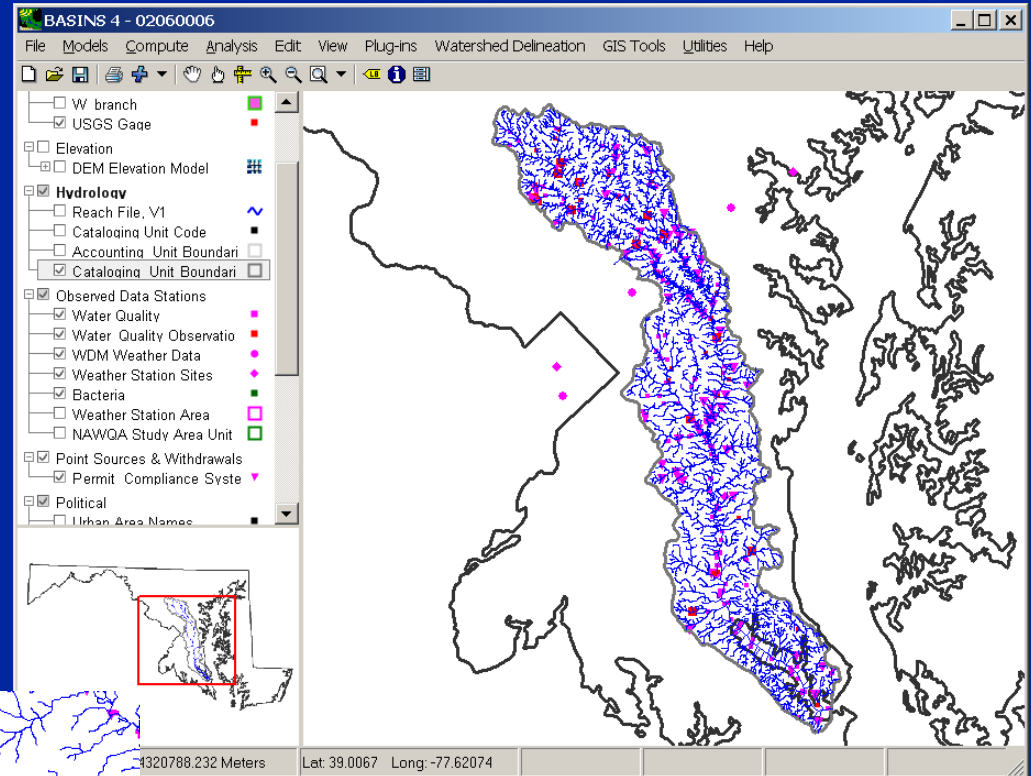
MAPWINDOW GIS FUNCTIONALITY

- Ability to add components using a plug-in extension interface
- Active and supportive international developer community
- Supports both vector and raster data manipulation in most common file formats



BASINS DATA

Select data layers to display



Zoom to area of interest

Data included:

- Streams - Reach File 1, NHD
- Watershed boundaries
- Point source locations
- Monitoring locations



BASINS SPATIALLY-DISTRIBUTED DATA

- Land use and land cover (shape and grid)
- Urbanized areas
- Reach file 1
- National Hydrography Data (NHD)
- Major roads
- TIGER Line Files (detailed roads and census boundaries)
- USGS hydrologic unit boundaries (accounting and catalog units)
- EPA region boundaries
- State boundaries
- County boundaries
- DEM (shape and grid)
- National Elevation Dataset (NED)
- Ecoregions
- NAQWA study unit boundaries
- Soil (STATSGO)

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BASINS ENVIRONMENTAL MONITORING DATA

- Bacteria monitoring station summaries
- Permit compliance system (PCS) sites and computed annual loadings
- Meteorological data
- USGS NWIS daily values, water quality, and streamflow measurements
- Modernized STORET

BASINS DATA DOWNLOAD TOOL

- Automatically downloads selected data from the web
- Projects shape and grid data
- Imports layers into the BASINS project

Download Data

Region to Download: Hydrologic Unit 02060006

BASINS

DEM Shape GIRAS Land Use NED Census 303(d)
 DEM Grid Legacy STORET NHD Meteorologic

National Hydrography Dataset Plus

All Catchments
 Elevation Grid Hydrography
 Flow Direction Grid Hydrologic Units
 Flow Accumulation Grid Streamgage Events

Station Locations from US Geological Survey National Water Information System

Daily Discharge Water Quality Measurements Ground Water

Data Values from US Geological Survey National Water Information System

Station Locations must be selected on the map before data value download

National Land Cover Data 2001

Land Cover Impervious Canopy 1992 Land Cover

EPA STORET Water Quality

Stations Results

Merge Clip to Region

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BASINS WATERSHED CHARACTERIZATION REPORTS

- Permitted Point Source Facilities Table
- 1990 Population and Sewerage by Census Tract
- 2000 Population and Census Tract Table
- 303d Listed Segment Tables
- Landuse Distribution Table
- Point Source Discharge Concentration and Loading Table
- Water Quality Observations Stations Table
- Plus custom reports through scripts



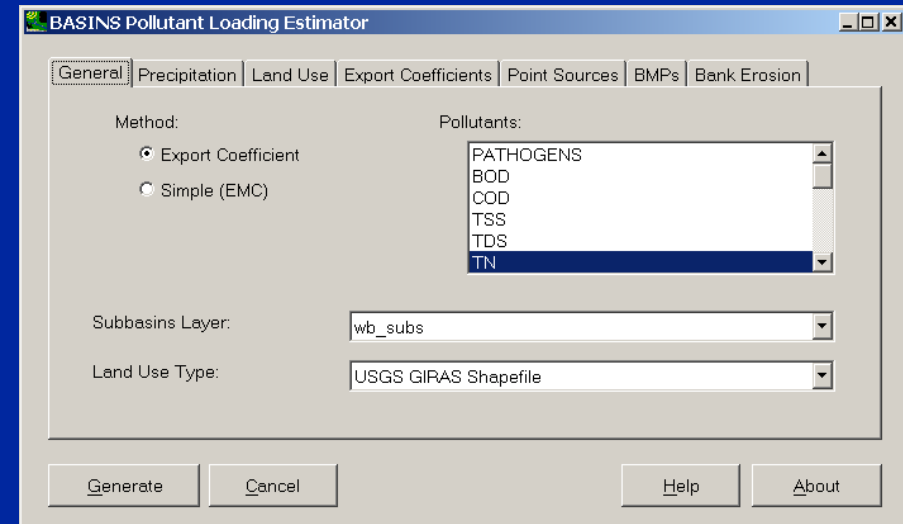
MODELING CAPABILITIES IN BASINS

- **Models to address multiple objectives**
 - Source assessment
 - Receiving water evaluation
- **Models which operate on various scales**
 - Local scale
 - Watersheds
 - Basins
- **Models which can be applied at various levels of complexity**
 - Screening
 - Detailed

BASINS MODELS

PLOAD

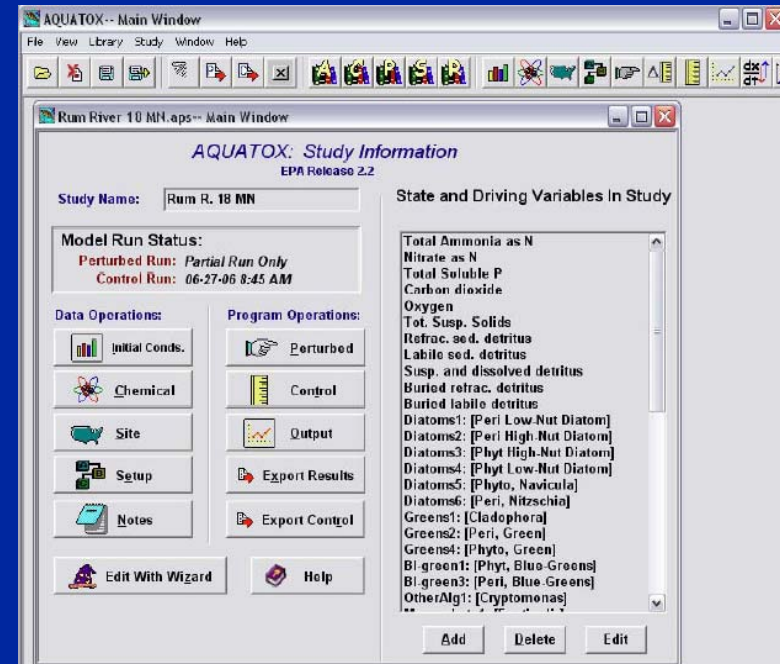
- Screening tool
- Provides estimates of nonpoint sources of pollution on an annual average basis
- Models any user-specified pollutant
- Uses either the export coefficient or simple method approach



BASINS MODELS

AQUATOX

- Simulation model for aquatic systems
- Predicts the fate of various pollutants, such as nutrients and organic chemicals, and their effects on the ecosystem, including fish, invertebrates, and aquatic plants
- Core model distributed separately from BASINS



BASINS MODELS

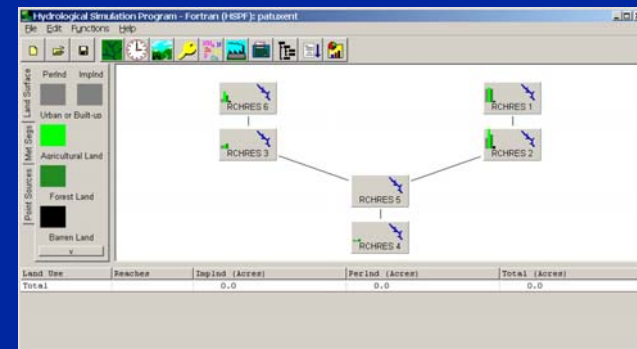
HSPF / WinHSPF (Hydrologic Simulation Program, FORTRAN)

- Continuous simulation watershed model with fixed, user-selected, time steps
- Predicts loadings and instream water quality in mixed land use watersheds for:

- Nutrients
- Toxics
- Bacteria
- Sediment

- Data provided to

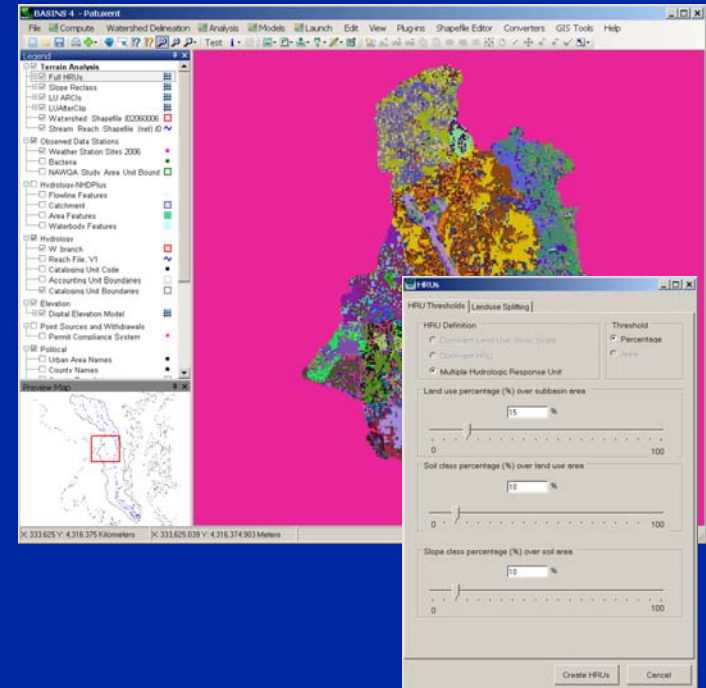
Windows interface through a BASINS plug-in



BASINS MODELS

SWAT – USDA's Soil and Water Assessment Tool

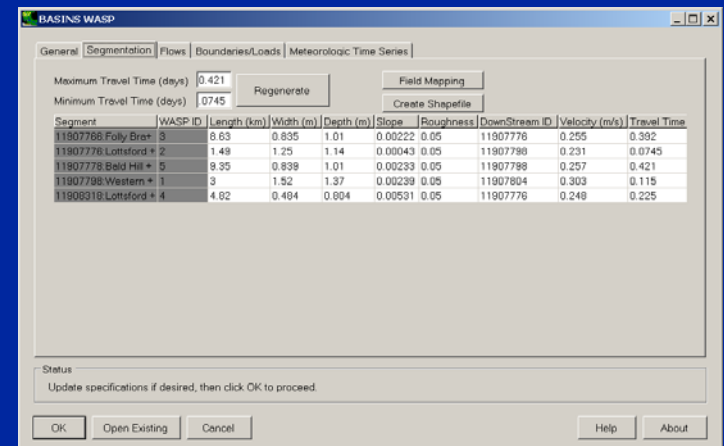
- Physical based, watershed scale model
- Developed to predict impacts of land management practices on water, sediment, and agricultural chemical yields in large complex watersheds
- BASINS 3.1 version closely tied to ArcView's scripting language; BASINS 4.0 compatible version included in May 2010 update
- Expedites set-up process for SWAT users, and provides BASINS with another sophisticated watershed model



BASINS MODELS

EPA's WASP – Water Quality and Analysis Simulation Program

- Dynamic compartment-modeling program for aquatic systems
- Supports development of TMDLs and waste load allocations
- Plug-in development a collaborative effort among the BASINS development team and EPA Region 4
- Expedites set-up process for WASP users, and provides BASINS with an established dynamic water quality model



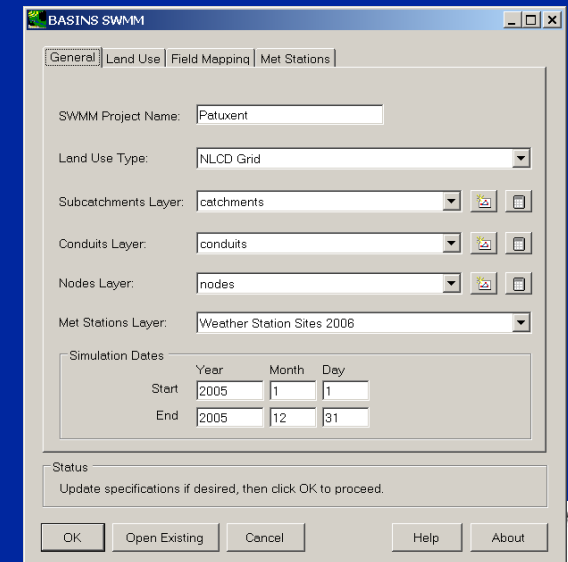
The screenshot shows the 'BASINS WASP' software window with the 'Segmentation' tab selected. It displays a table of segment data with columns for Segment, WASP ID, Length (km), Width (m), Depth (m), Slope, Roughness, DownStream ID, Velocity (m/s), and Travel Time. The table contains five rows of data for different segments.

Segment	WASP ID	Length (km)	Width (m)	Depth (m)	Slope	Roughness	DownStream ID	Velocity (m/s)	Travel Time
11907766 Folly Branch	5	8.63	0.835	1.01	0.00222	0.05	11907776	0.255	0.392
11907776 Lottsford # 2	2	1.49	1.25	1.14	0.00043	0.05	11907798	0.231	0.0745
11907778 Bald Hill # 5	5	9.35	0.839	1.01	0.00233	0.05	11907798	0.257	0.421
11907780 Western # 1	3	1.52	1.37	1.37	0.00239	0.05	11907804	0.303	0.115
11906318 Lottsford # 4	4	4.82	0.484	0.804	0.00531	0.05	11907776	0.248	0.225

BASINS MODELS

EPA's SWMM – Stormwater Management Model

- Dynamic rainfall-runoff simulation model for primarily urban areas / drainage systems
- Can also estimate the production of pollutant loads
- BASINS Plug-in development a collaborative effort among the BASINS and SWMM development teams
- Expedites set-up process for SWMM users, and provides BASINS with a premier urban drainage model



The screenshot shows the 'BASINS SWMM' software window with the 'General' tab selected. The interface includes the following fields and options:

- SWMM Project Name:** Patuxent
- Land Use Type:** NLCD Grid
- Subcatchments Layer:** catchments
- Conduits Layer:** conduits
- Nodes Layer:** nodes
- Met Stations Layer:** Weather Station Sites 2006
- Simulation Dates:**

	Year	Month	Day
Start	2005	1	1
End	2005	12	31
- Status:** Update specifications if desired, then click OK to proceed.

Buttons at the bottom include: OK, Open Existing, Cancel, Help, and About.

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MODELS ‘COMING SOON’ TO BASINS

GWLF – Generalized Watershed Loading Functions from Penn State

- “Mid-level” model, based on GWLF (Haith and Shoemaker, 1987)
- Previously implemented in ArcView (AVGWLF)
- Simulates runoff, sediment, and nutrient loads
- BASINS plug-in is being developed by Penn State

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CONNECTION BETWEEN BASINS AND HSPF

BASINS/GIS data layers provided for HSPF setup

- DEM (grid)
 - *Used to determine the boundaries of the subwatersheds when delineating.*
- Land Use (NLCD or GIRAS)
 - *Used to calculate land use distributions within each subwatershed.*
 - *Each land use is parameterized separately.*
- Reach File, Version 1; NHD/NHDPlus
 - *One representative reach is selected for each subwatershed.*
 - *Shapefile is used to determine some of the necessary inputs associated with the stream network setup within the model*



CONNECTION BETWEEN BASINS AND HSPF

BASINS data provided for HSPF

- Permit Compliance System (PCS)
 - *Nodes for PCS sites are added when delineating the subwatersheds.*
 - *PCS loading information input to HSPF.*
- BASINS Meteorological Data
 - *Meteorological data provided for over 16,000 stations throughout the U.S.*
- STORET Data
 - *Users can download water quality data from the EPA STORET website.*
- USGS Data
 - *Users can download discharge, water quality observations, and streamflow measurements from the USGS NWIS website.*

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HOW BASINS ASSISTS IN TMDL DEVELOPMENT: BACKGROUND

Clean Water Act Objective:

- “It is a national goal that the discharge of pollutants into the navigable waters be eliminated by 1985.”
- Total Maximum Daily Load (TMDL) focused on protection of surface water resources
 - Streams
 - Reservoirs
 - Estuaries
- The ultimate goal of the TMDL process is to meet the water quality standards and ultimately improve habitat in a watershed.

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THE TMDL PROGRAM

- **The TMDL program**

- Requires states to develop TMDLs for waters on the 303(d) list

- *Section 303(d) requires the identification and prioritization of waters not meeting in-stream water quality standards*

- The TMDL includes a distribution of pollutant loading (allocation) that results in attainment of water quality standards

- **Five key steps to TMDL development**

- Identify water quality-limited waters (303(d) list)

- Prioritize water quality-limited waters

- Develop the TMDL plan for each water quality limited stream segment

- Implement the water quality improvement for each segment

- Assess water quality improvement for each segment

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TMDL FOCUS

To determine the amount of pollution the water is capable of assimilating while maintaining its intended beneficial uses.

EPA TMDL EQUATION

Citizens

Politicians
and
Scientists

Managers and Engineers

$$\text{TMDL} = \text{WLA} + \text{LA} + \text{MOS}$$

(total max.
daily load)

(point source waste
load allocation)

(nonpoint load
allocation)

(margin of
safety)

↑
State water
quality standard
for the pollutant
given the
stream's
designated
beneficial use

TMDL development phase

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WHAT ARE EPA'S EXPECTATIONS AND RECOMMENDATIONS?

- **Scientific proof**
 - Must use credible tools for data analysis
- **Data**
 - CWA requires the use of credible and defensible data for decision making
 - Monitoring
 - Monitoring is required to prove the TMDL is appropriate and requirements are being met.

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MODELING IN THE TMDL PROCESS

1. What is the current loading in the stream?
2. What is the maximum loading a stream can receive without exceeding the assimilative capacity?
3. What will be the loading under proposed load allocations?

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ASSIMILATIVE CAPACITY TECHNICAL TOOLS

Point Sources

- Linkage between discharges and waterbody response
- Simple dilution models, steady-state water quality simulations (QUAL2E), dynamic water quality simulation (WASP) depend on pollutant type and waterbody

Nonpoint Sources

- Linkage between all sources and waterbody response
- Nonpoint source is wet-weather driven and critical condition may be at medium or high flow condition
- Watershed-receiving water response models (HSPF, SWMM, any linked watershed and receiving model)

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TMDL TYPES

- **Point sources and low flow condition**
 - Use steady state model
 - Use an appropriate design flow
 - Determine the magnitude of the impairment and endpoint
 - Develop scenarios of point source waste load allocations that will meet the allowable assimilative capacity

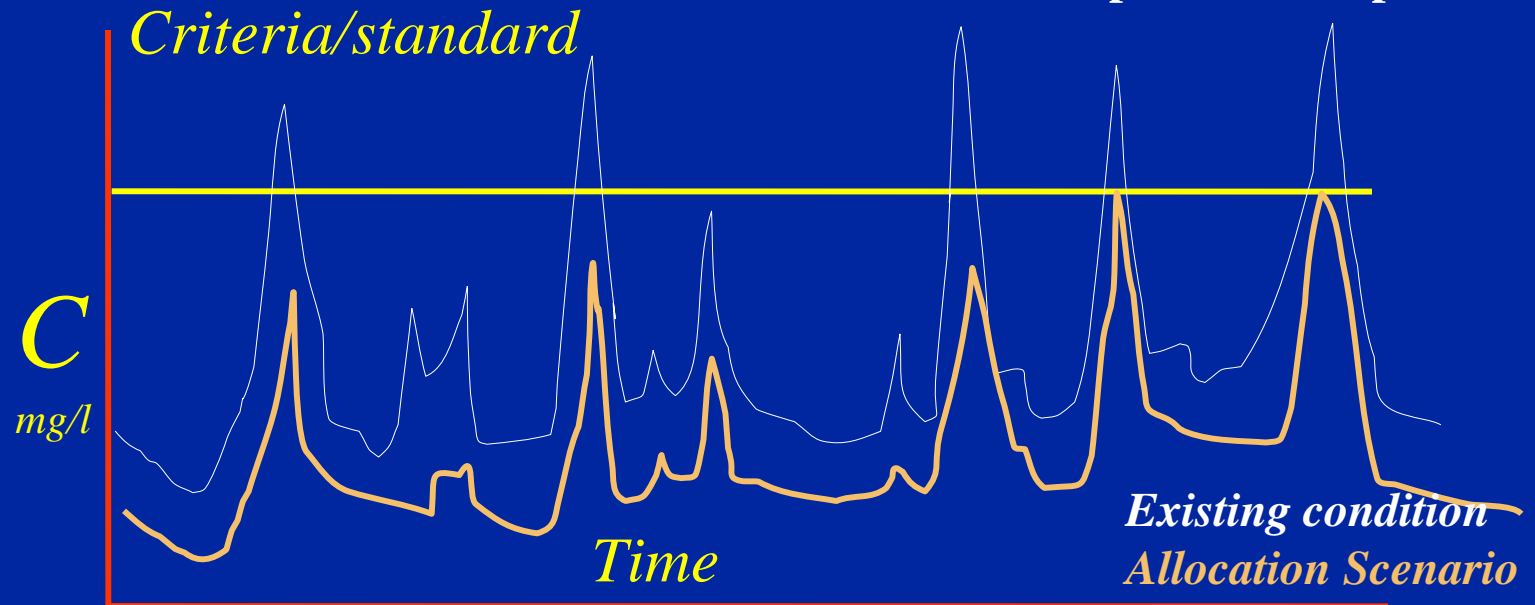
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TMDL TYPES

- **Point and nonpoint sources**
 - Probably need a time varying model
 - Include all sources and define when and where impairments occurs (critical condition)
 - Calculate loading under existing condition
 - Calculate loading under allocation scenarios that meet the target/standard
 - May need to negotiate with stakeholders

NONPOINT SOURCE TMDLS

Modeling Approach:
Use Continuous Simulation (HSPF)
Define critical/representative period



Scenario obtained through control of:

- 20% loading from Ag
- 15% from pastureland
- 20% urban
- 12% from point sources

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ISSUES IN TMDL DEVELOPMENT

- Scarcity of data in space and time
- Uncertainty in data and models
- Limitations in data analysis tools
- Difficulty with stakeholder involvement and input
- Limited expertise
- Limitations of models

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WHERE DOES BASINS FIT INTO THE TMDL PROCESS?

- Minimizes data collection
- Provides data visualization tools
- Provides simple data analysis tools
- Provides water quality models and data for populating models
- Models provide a framework for scenario generation and TMDL allocations.
- Communication with stakeholders through GIS and modeling output