Geospatial Tools to Support Watershed Environmental Monitoring and Reclamation: Assessing Mining Impacts on The Upper Susquehanna-Lackawanna American Heritage River

Dale Bruns and Tom Sweet

- PA GIS Consortium
- Sweet Solutions
- Wilkes University (GeoEnv. Sci. & Eng. Dept.; Coll. Of Sci. & Eng.)

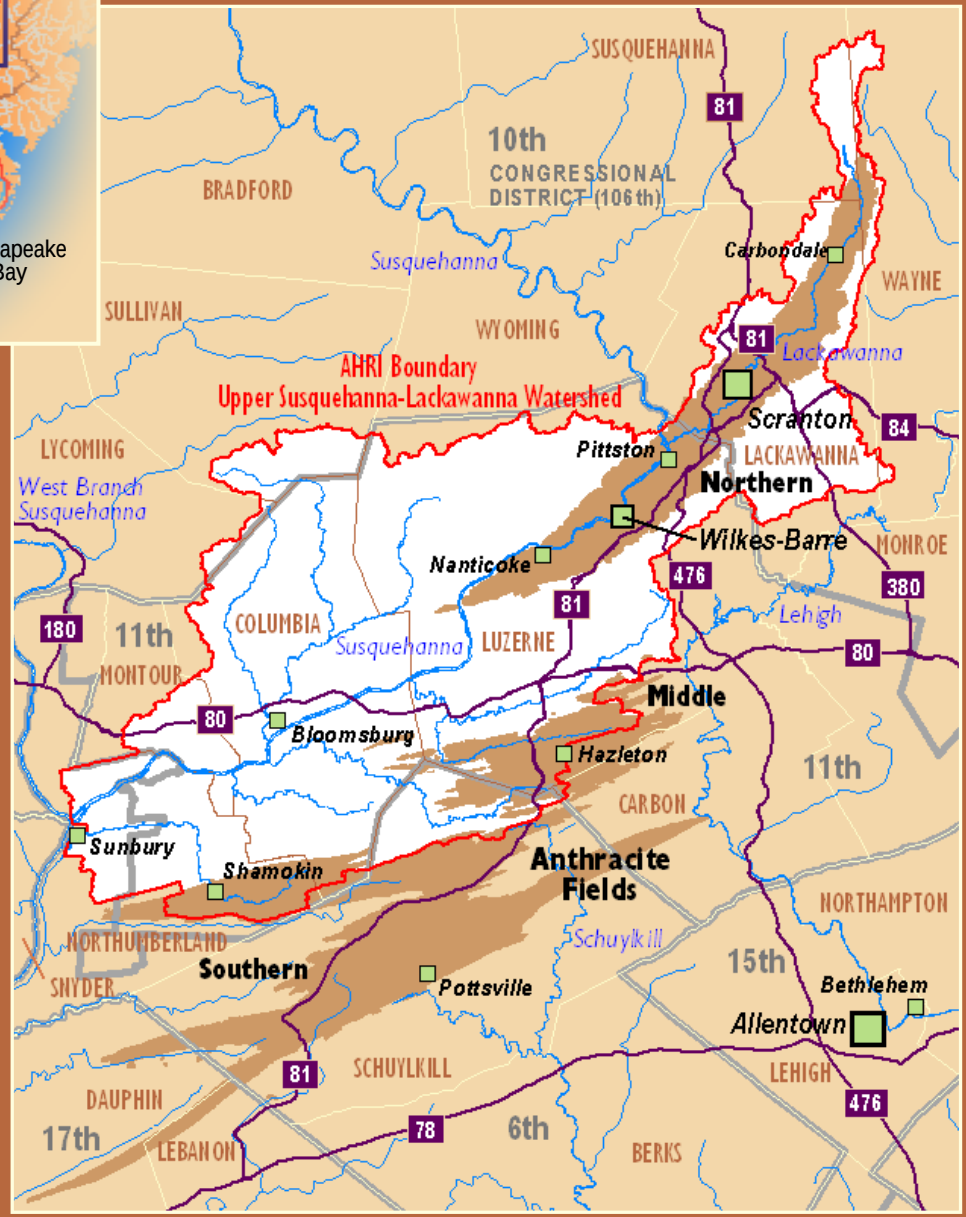
Overview of Presentation

- Background on American Heritage River (AHR)
  - Environmental problems
  - Use of GIS and data needs
- GIS in environmental monitoring design
  - Environmental design principles
  - Applications to AHR
- RiverNet and EPA EMPACT
  - Real-time instrumentation and telemetry
  - Web based GIS
  - RiverNet Data Portal
  - Data trends and analysis
  - Conclusions

Project Location

- Susquehanna River drains the largest U.S. river basin on the Atlantic coast
- Susquehanna River contributes to over half of the freshwater inflow to the Chesapeake Bay
- 120,000 acres of Abandoned Mine Lands within the Upper Susquehanna-Lackawanna River Basin
- 3600 square miles - watershed delineation with Anthracite Fields

Upper Susquehanna-Lackawanna Watershed's Relationship to the Chesapeake Bay Ecosystem

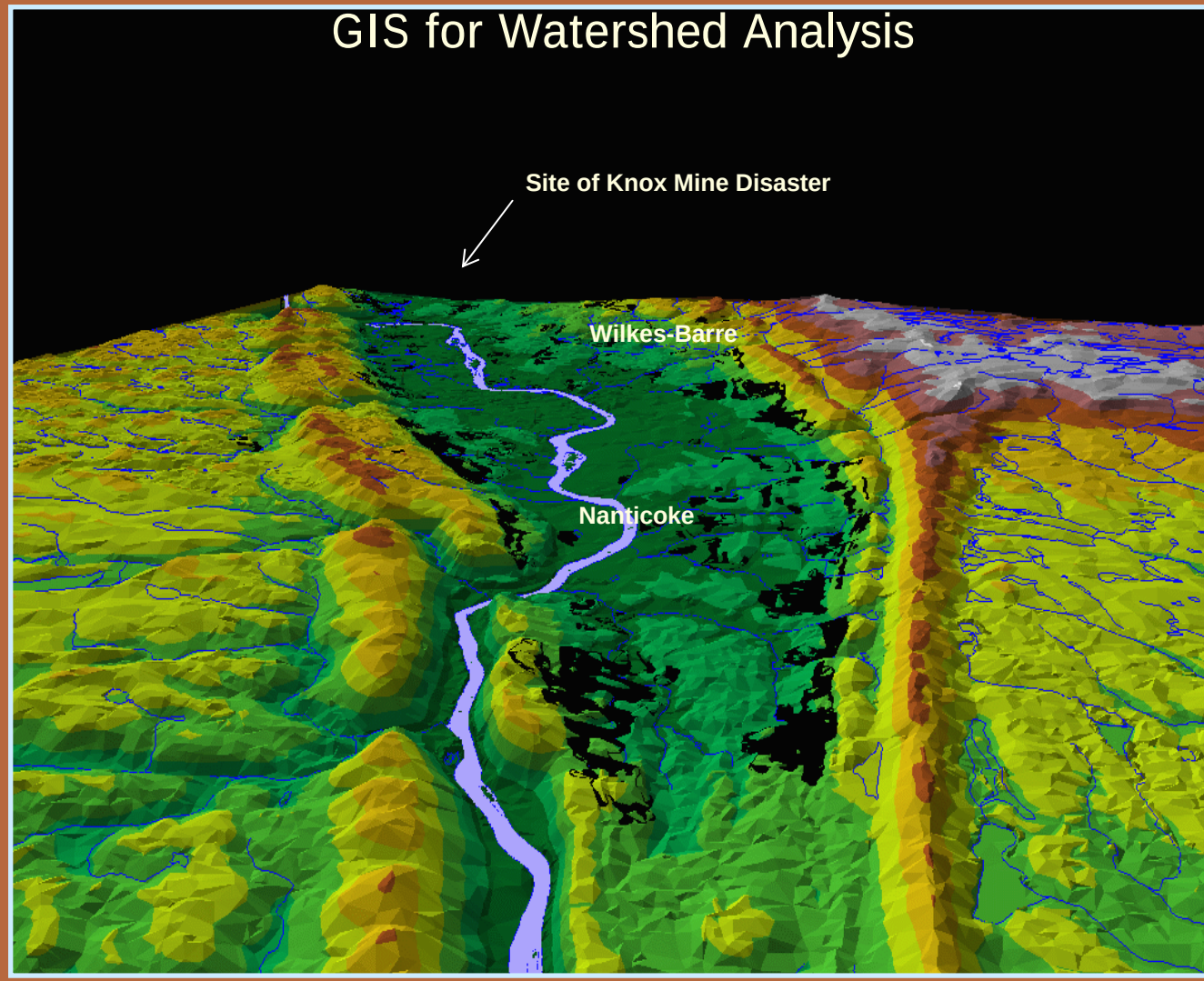


Environmental Problems

- Watershed suffers from more than 150 years of physical disturbance, sedimentation, acid mine drainage, and untreated urban runoff
- Clean up costs: $2.5 billion
- Specific Problem Areas (Land Use)
  - Abandoned Mine Lands
  - Non-point AMD and AMD Outfalls
  - Combined Storm Overflows (CSOs)

GeoSpatial Technologies for Environmental Montoring and Reclamation

- **Characterize and Assess**
  - Ecological conditions (2000 sq. mi. area)
  - Anthracite Fields
    - strip mines
    - mine pool
    - culm banks
    - acid mine outfalls
- **Technologies**
  - GIS and GPS
  - Remote Sensing and Digital Photogrammetry
- **Watershed Analysis**
  - provide first step to testing watershed indicators of pollution



Filmclip:
Knox Mine Disaster

Persistent Water Quality Problems

Severely degraded stream with urban debris and mining sediments

Mapping mine outfall locations with GPS technologies

GPS locations of water quality problems

Proposed Phases of Watershed Plan

- Phase I (focus on existing data)
  - Inventory and Compilation (GIS Data)
  - Watershed Indicators
- Phase II (Data acquisition and analysis)
  - Photogrammetry, remote sensing, GPS
  - water quality and hydrologic monitoring
  - modeling: hydrology, AMD and chemistry
- Phase III (support engineering design)
  - reclamation, data management, monitoring

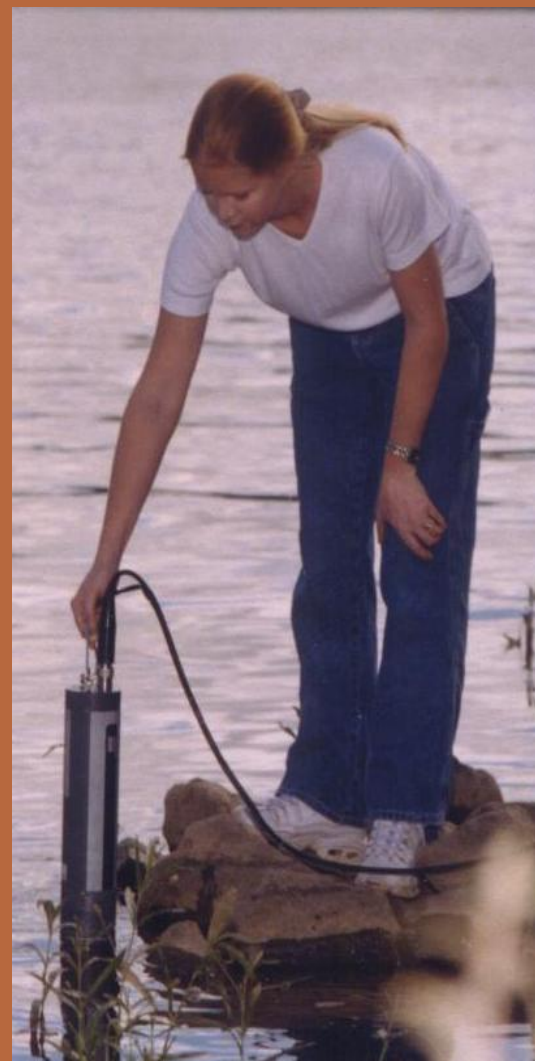
EPA EMPACT: objectives and partners

- Monitor water quality parameters in AHR watershed
- Use Real-Time water quality instruments (YSI)
- Make data available to community via GIS and Internet based software
- Conduct environmental education and public outreach activities

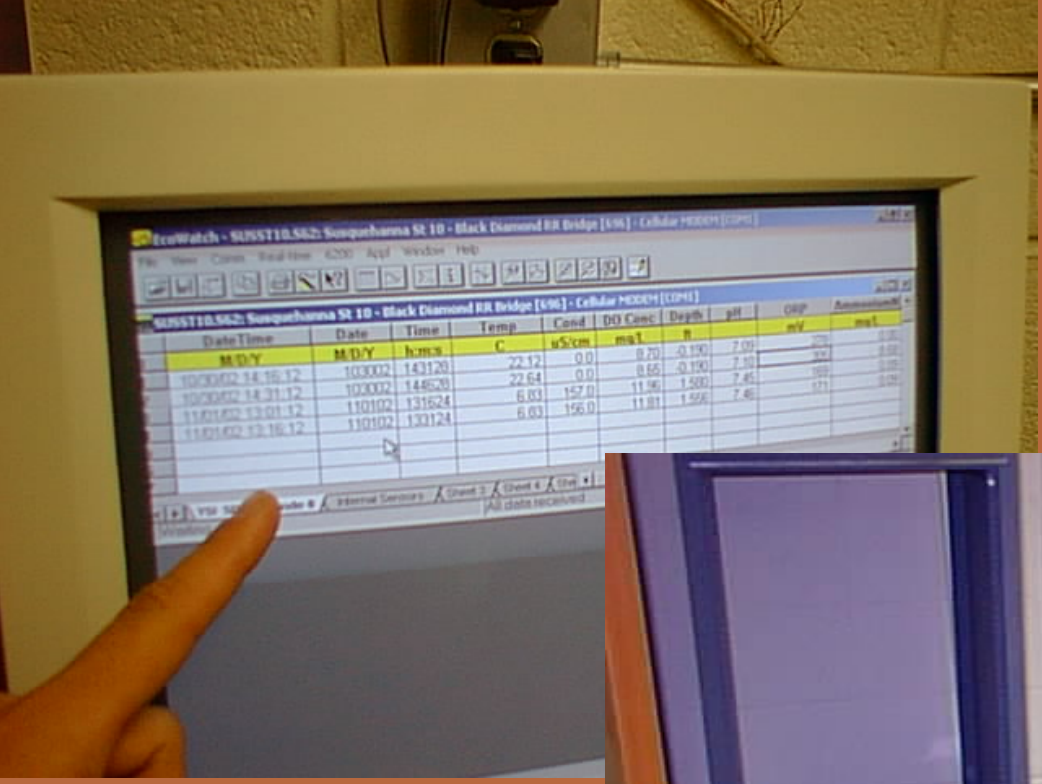
Watershed groups: Lackawanna and Nescopeck; PA DEP, EC, Chamber, EPCAMR, PEC; EPA and USDA RGIS

Update on YSI water quality monitoring

Real-time monitor (8 parameters); control box; solar panel



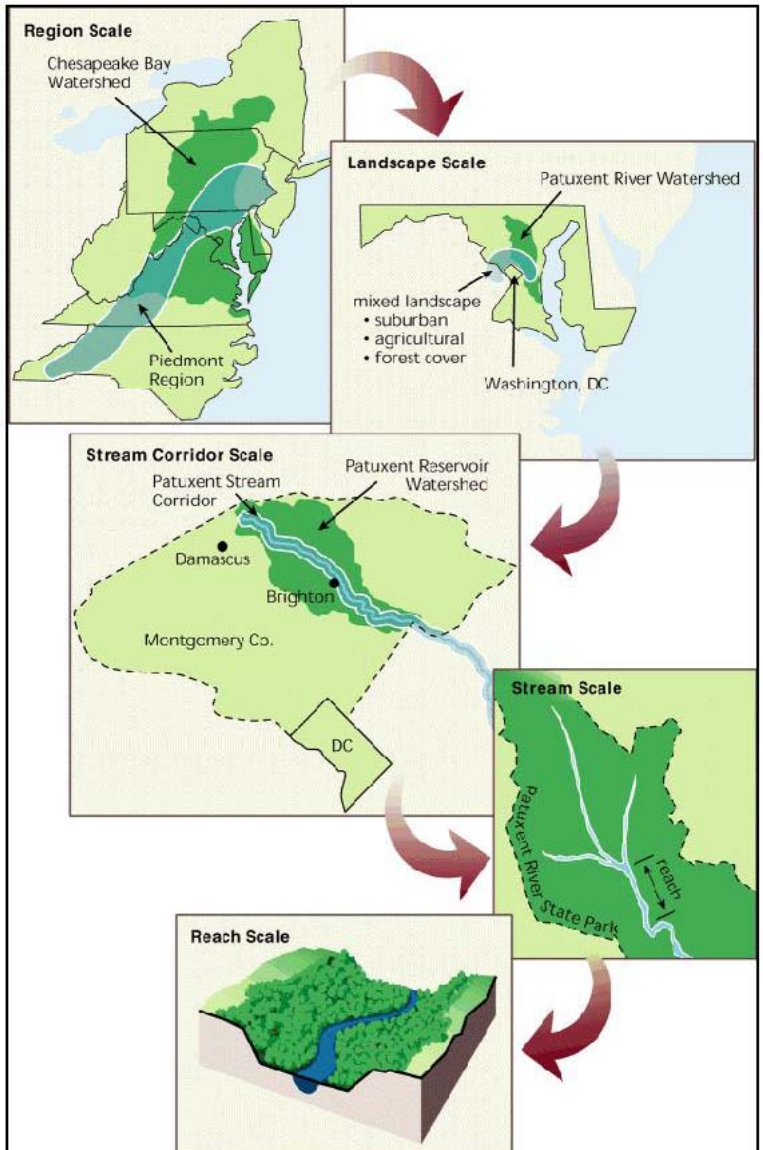
Telemetry download to server



- Manually linked to ArcIMS

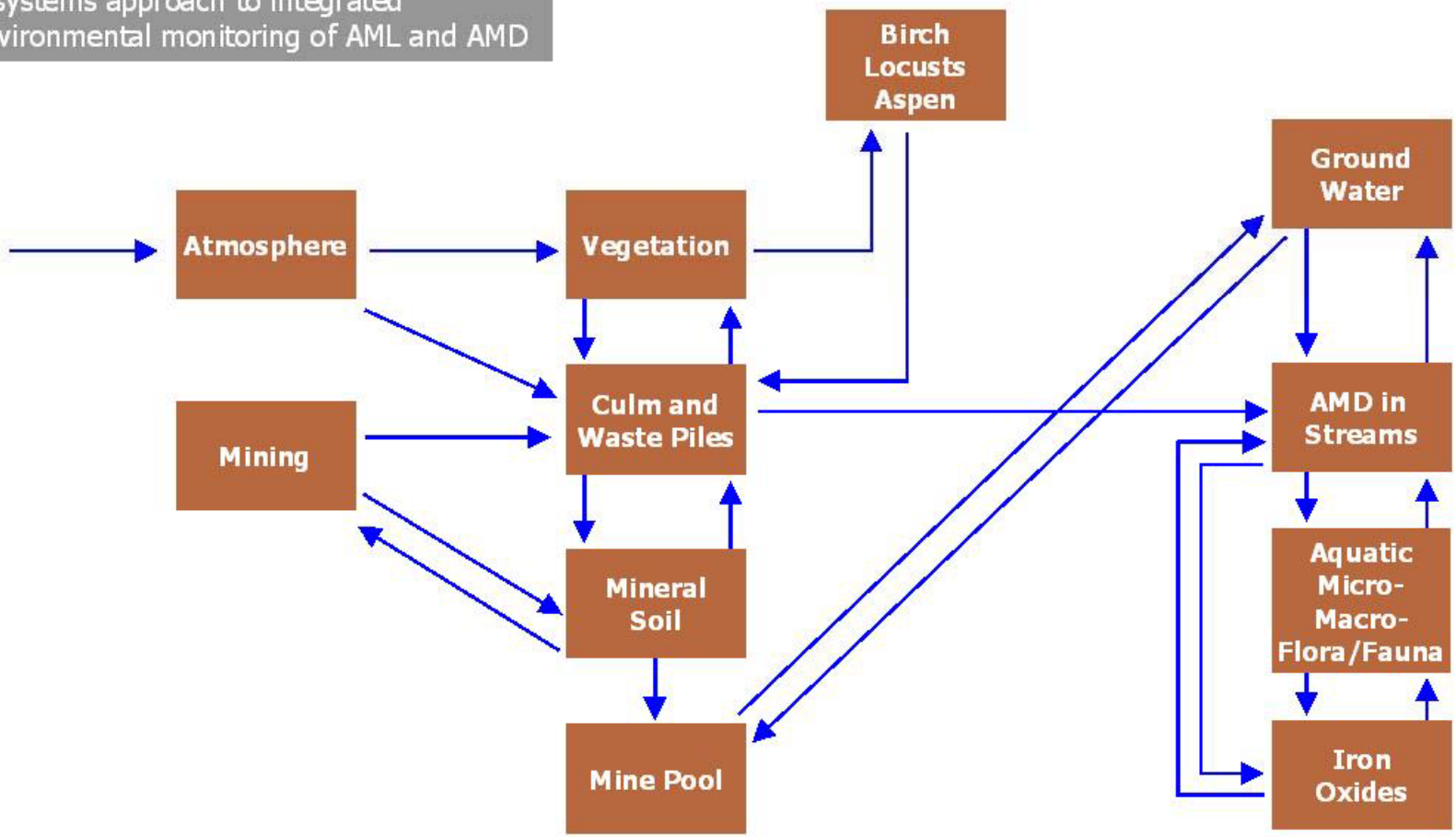
Ecosystems at Multiple Scales

from Landscape to Watershed to Stream Reach



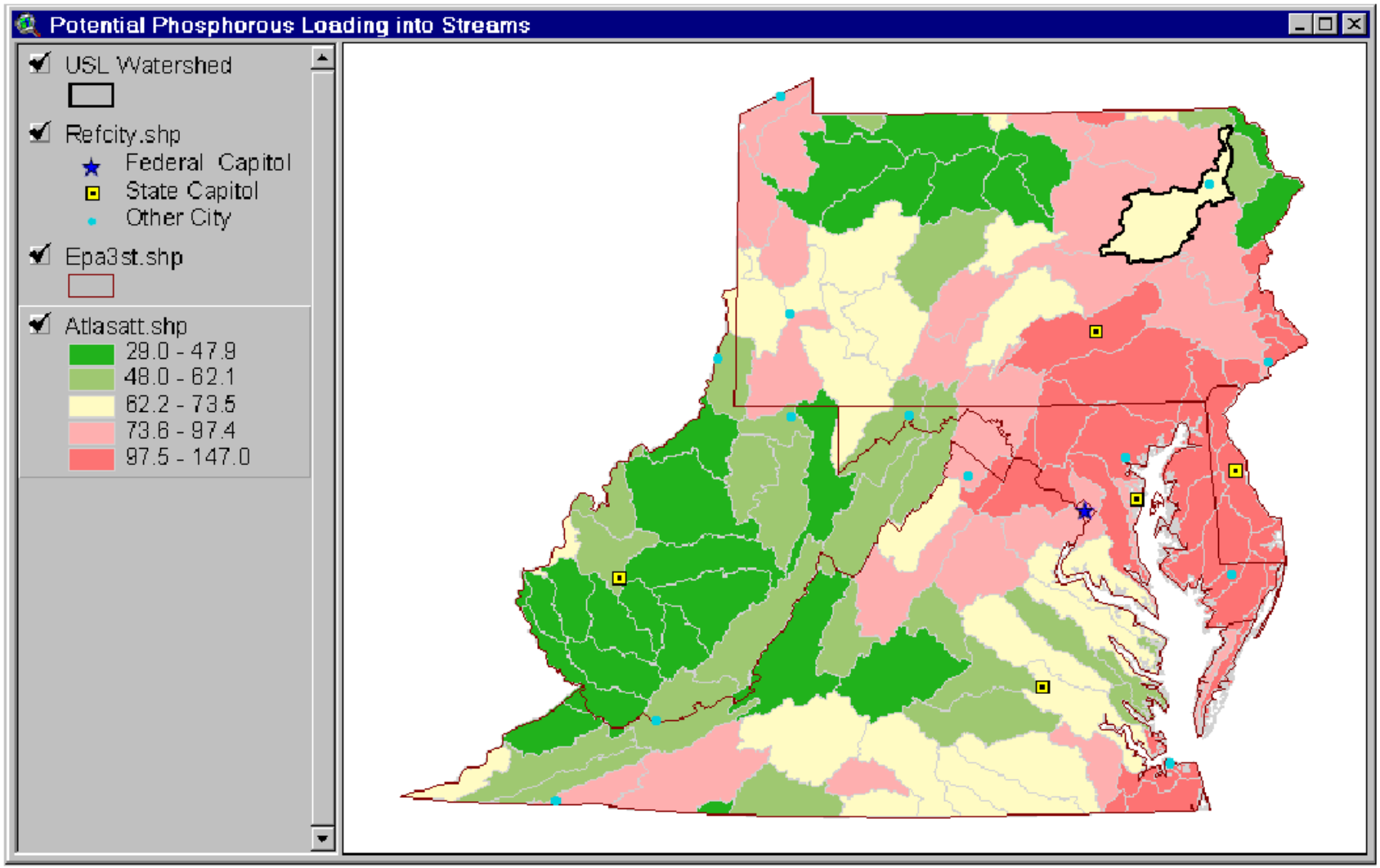
Conceptual Approach to Monitoring of Watershed-River-Stream Ecosystems Receiving Coal Mining Impacts

A systems approach to integrated environmental monitoring of AML and AMD



Arrows represent critical environmental pathways and interactions.

EPA's Mid-Atlantic Ecological Assessment: Phosphorous Loading

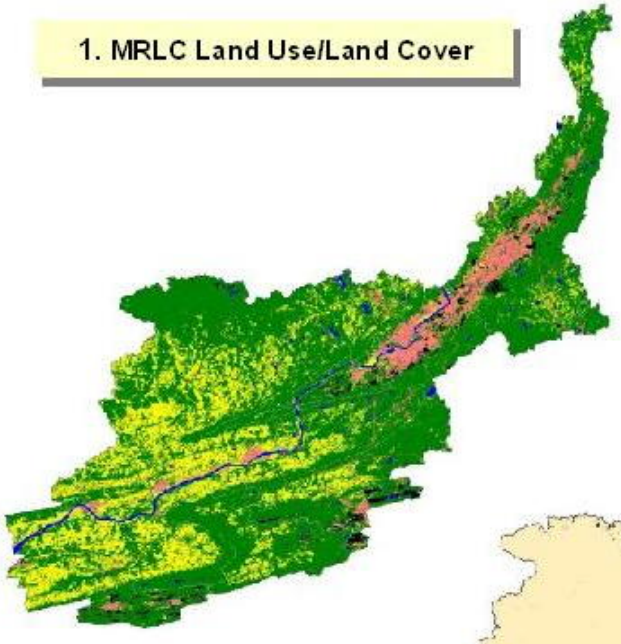


Map Image captured from "View" Window of EPA's Landscape Atlas ArcView Project CD-ROM. The USL Watershed Boundary has been highlighted for this illustration. "Refcity.shp" legend labels have been expanded in "View" Table of Contents. No other modifications have been made.

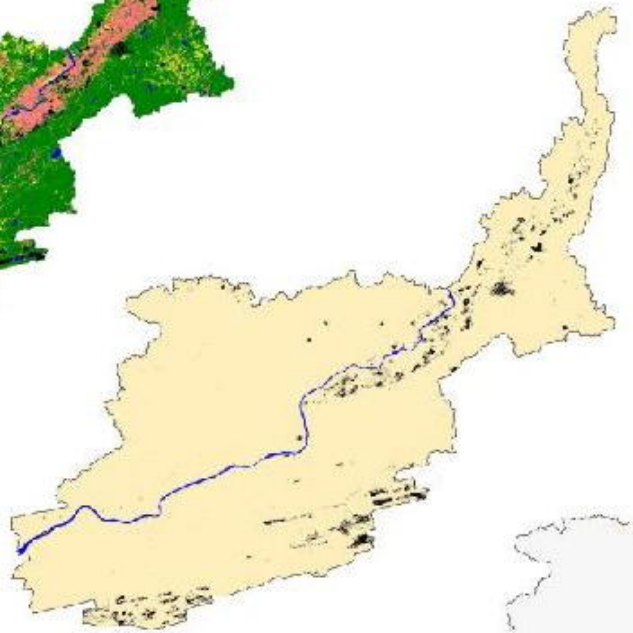
GIS Analysis of Watershed Characteristics

Upper Susquehanna-Lackawanna Watershed -- An American Heritage River

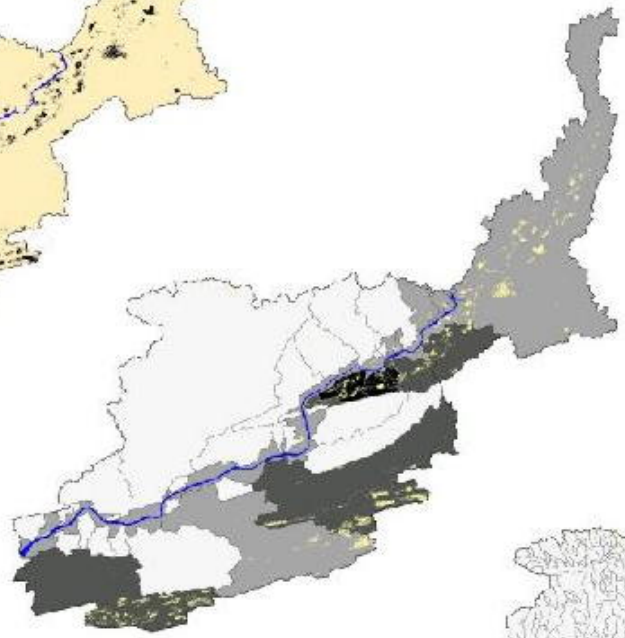
1. MRLC Land Use/Land Cover



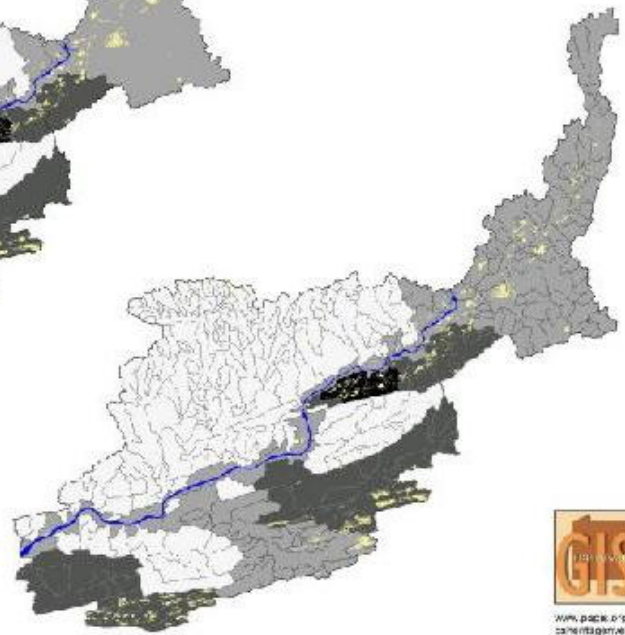
2. Distribution of Abandoned Mine Lands (shown in black from MRLC) relative to the mainstem Susquehanna River



3. GIS Classification of Tributary Watersheds
   BLACK = Highest Percent Mining
   WHITE = Lowest Percent Mining
   YELLOW = Abandoned Mine Lands



4. Small Watersheds for Data Mining, Fusion and detailed GIS Analyses



Total Watershed Area Analysis on 2000 Sq. Miles (Source: MRLC)

Colors relate to watershed 1 (MRLC Land Use / Cover)

LAND COVER	% of TOTAL
FOREST	67%
AGRICULTURE	23%
URBAN	6%
MINING	2%
WATER	2%

LOCATION MAP

YSI Site Selections

EPA EMPACT Study Area

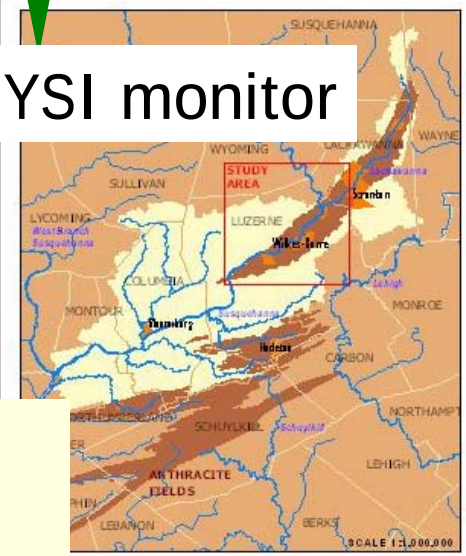
Wyoming Valley

Northern Anthracite Field

- Water Quality Sampling Site
- CSO Location (Combined Sewer Overflow)
- Borehole Site
- Strip Mined Area
- Minepool Boundary

Reference tributary site: Toby Creek

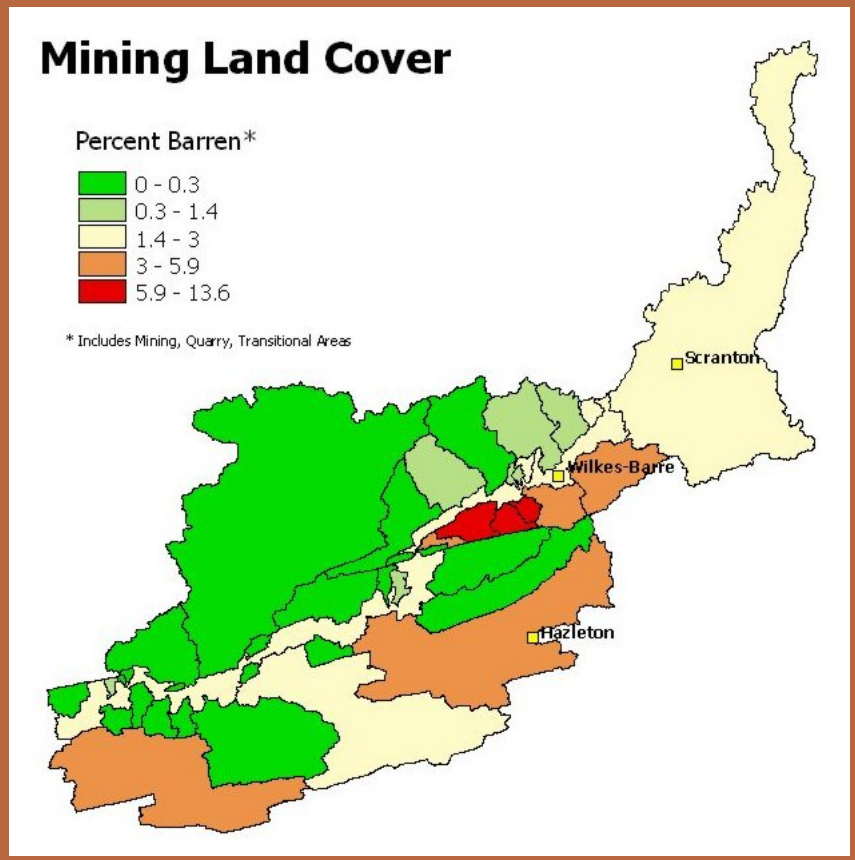
YSI monitor

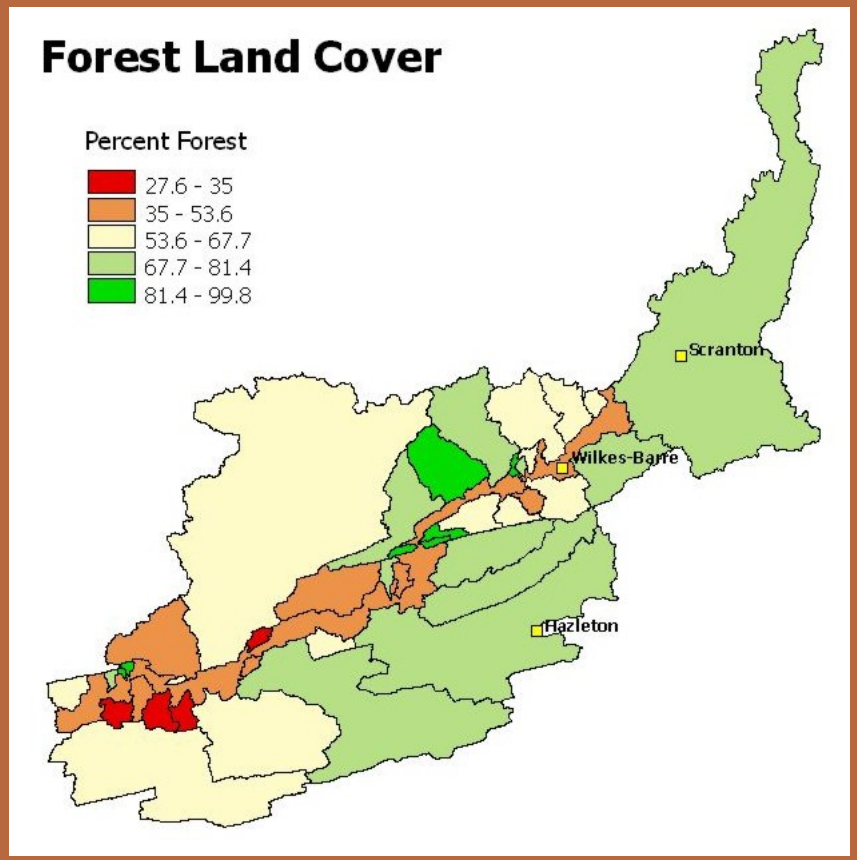


American Heritage River Initiative: US-L Watershed

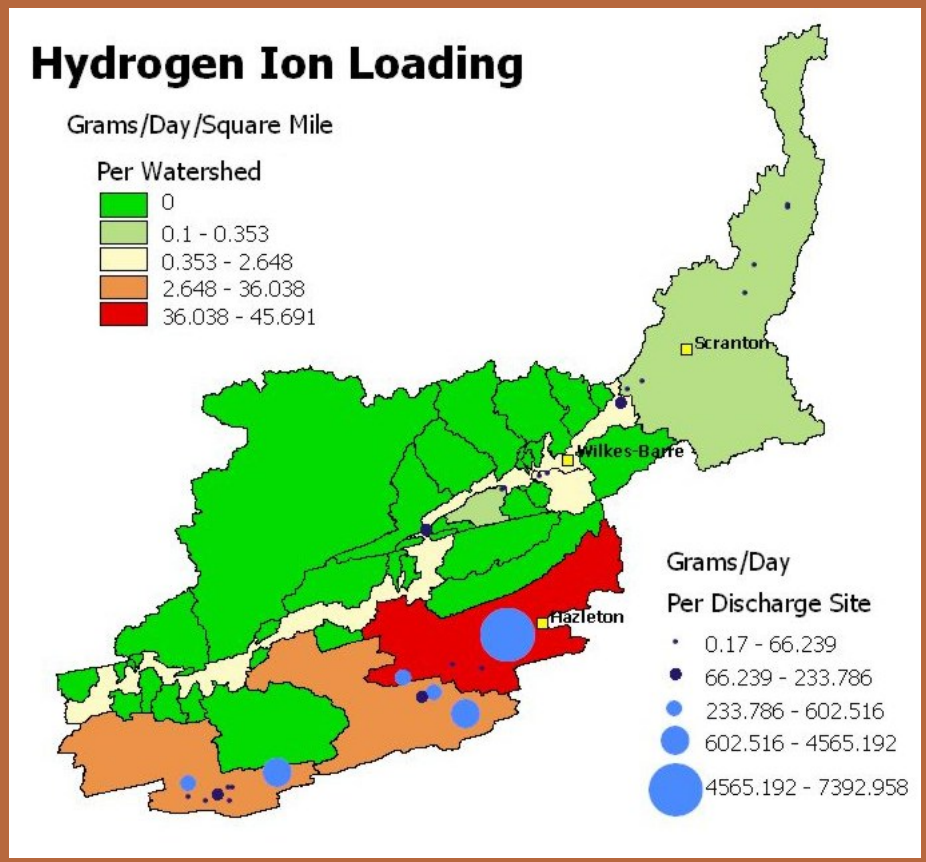
AML impacted tributary site: Nanticoke Creek

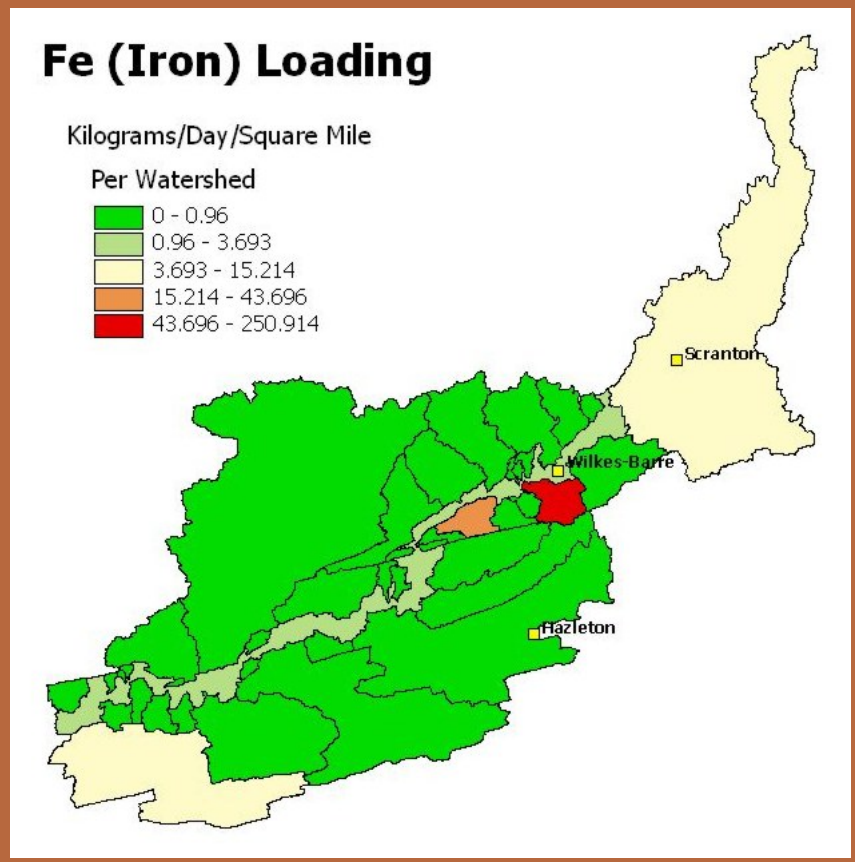
Delineated Tributary Sub-Watersheds



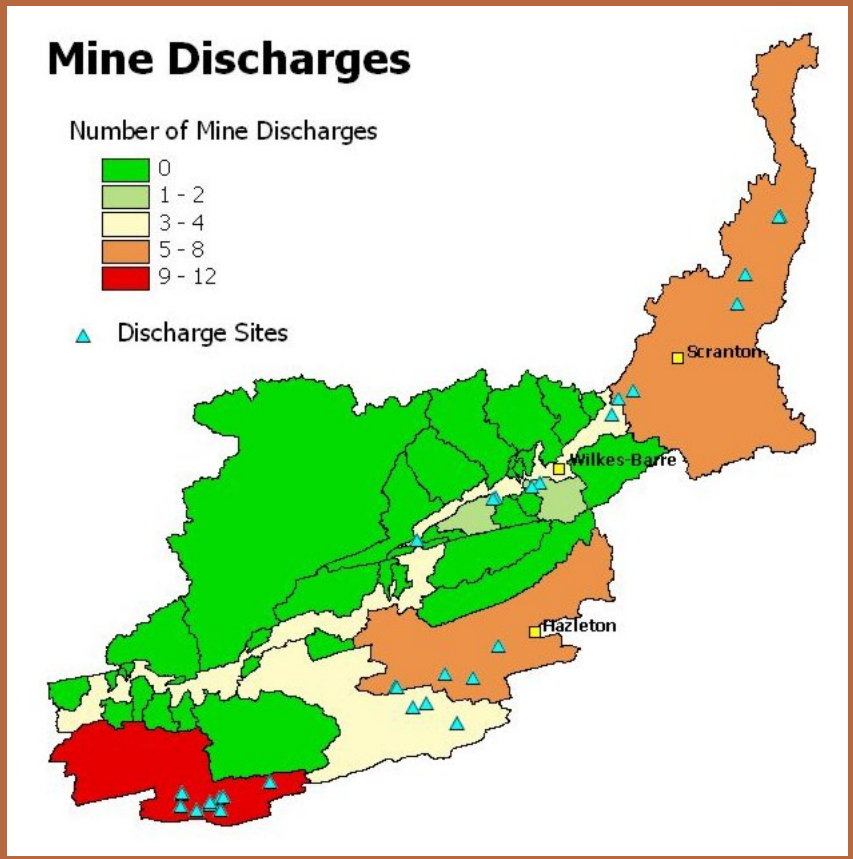


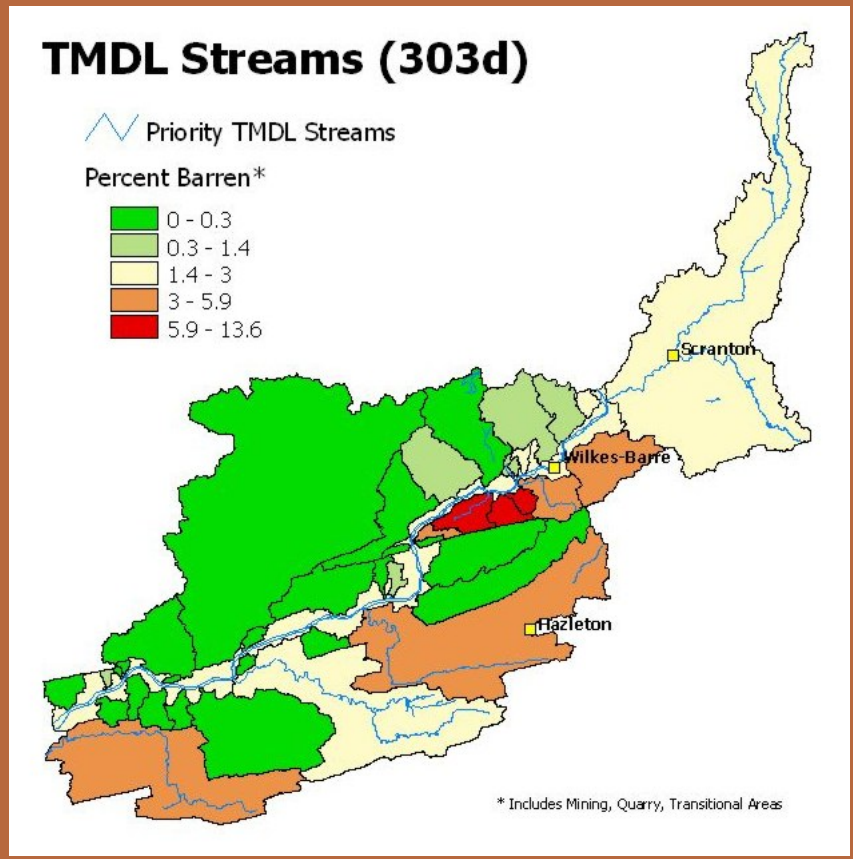
Delineated Tributary Sub-Watersheds



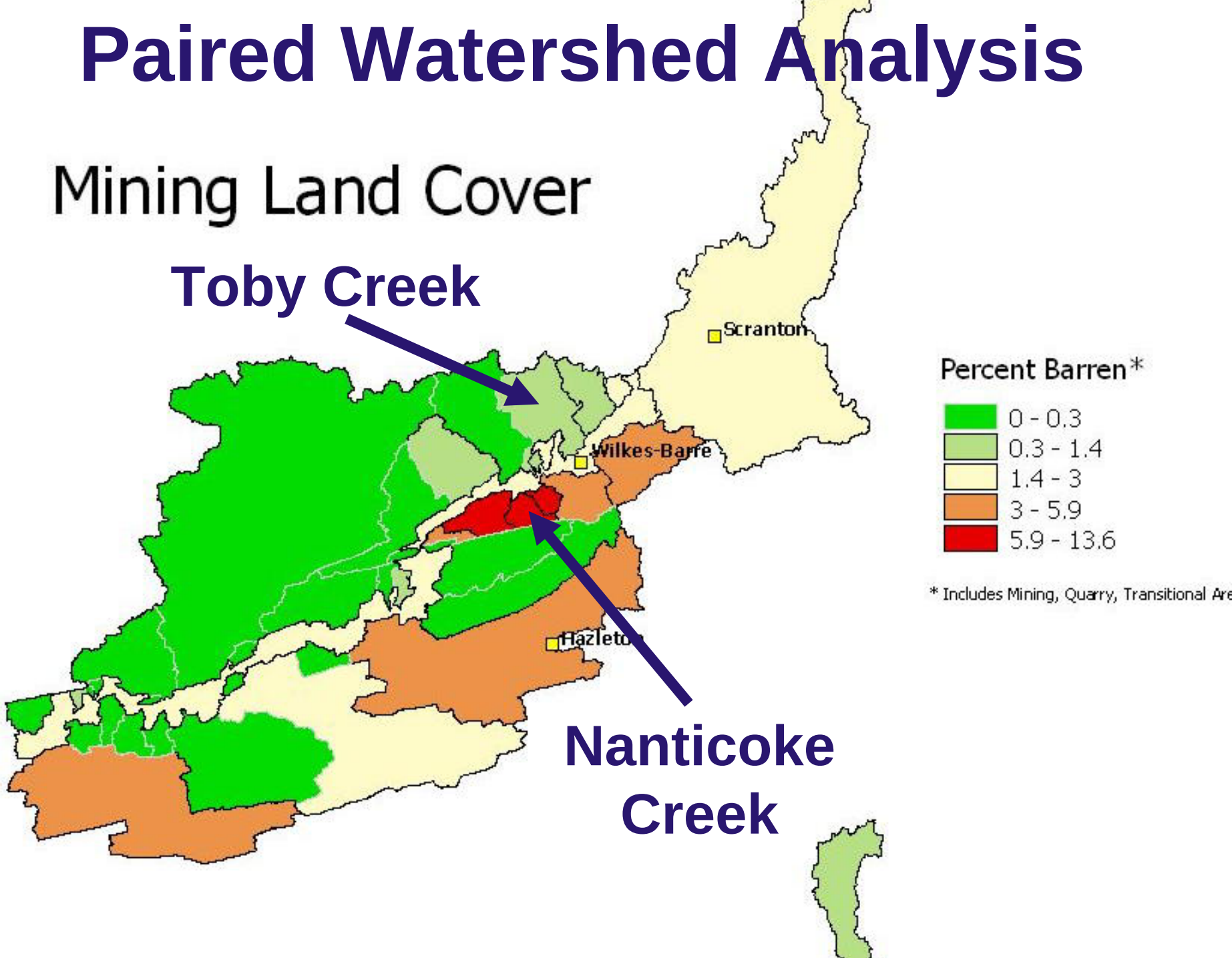


Delineated Tributary Sub-Watersheds





Paired Watershed Analysis



Watershed Characteristic	Toby Creek	Nanticoke Creek
Watershed area	36 square miles	8 square miles
% Forest land cover	61.3	67.3
% Grassland land cover	19.6	8.6
% Urban land cover	16.4	12.2
% Mining land cover	0.6	10.3
% Wetlands land cover	2.1	1.6
Number of AMD outfalls	0	0
Iron loading from outfalls	0	0
Hydrogen loading from outfalls	0	0
Number of CSOs	1	4

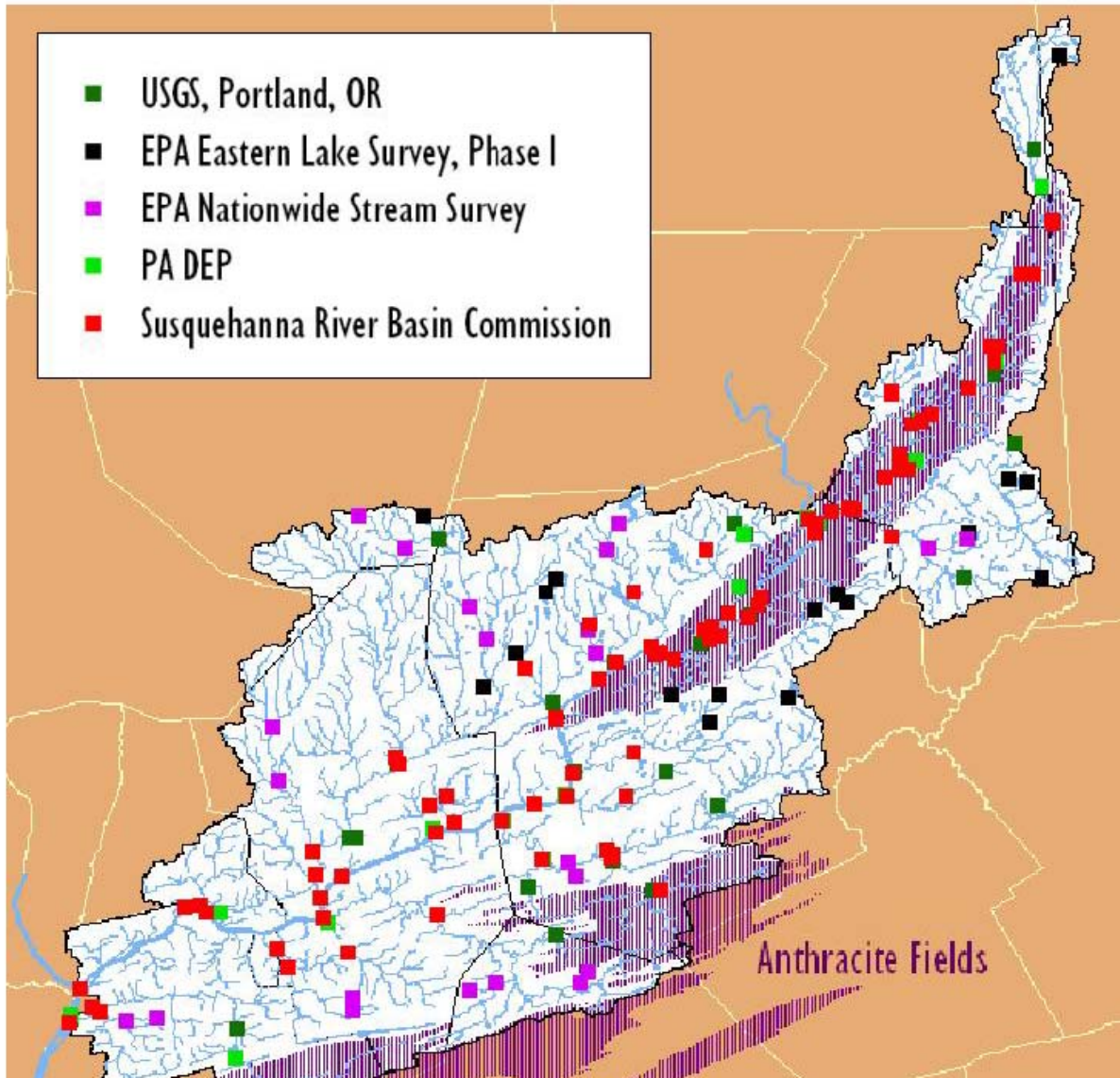
Paired Watershed Analysis

Table 2. Water quality data from real-time monitors (Jan. 2003 - July 2004, readings at 15 min. interval for Toby Creek; June – Nov. 2003 and, readings at 30 min. interval for Nanticoke Creek).

Conductivity (uS/cm)	Toby Cr	Nanticoke Cr	Reference (EPA BASINS)			
Mean	155	740	**Toby Cr:**	**Mean**	**Std Dev.**	**Obs.**
Standard Deviation	43.9	167.5	1970-1974	163	69.7	7
Observations	38371	7717	1975-1979	164	51.2	40
df	7931		1980-1984	216	45.8	56
t Stat	-304.7		1985-1989	204	41.7	37
Significance (one-tail)	P < 0.001		**Nanticoke Cr: no data**			
t Critical one-tail	1.65		**Criterion:** none listed			

PENNSYLVANIA GIS CONSORTIUM

BASINS: Water Quality Sampling Sites by Agency



Paired Watershed Analysis

TDS (mg/L)	Toby Cr	Nanticoke Cr	Reference (EPA BASINS)			
Mean	117	622	**Toby Cr:**	**Mean**	**Std Dev.**	**Obs.**
Standard Deviation	30.6	137.2	1970-1974	no data collected		
Observations	38372	7717	1975-1979	126	46.5	29
df	7871		1980-1984	140	65.1	56
t Stat	-321.57		1985-1989	207	264.7	37
Significance (one-tail)	P < 0.001		**Nant. Cr (80-84):** 1772		none	0
t Critical one-tail	1.65		**Criterion:** 500 mg/L as monthly average			

Paired Watershed Analysis

Redox Potential (mV)	Toby Cr	Nanticoke Cr	Reference (EPA BASINS)
Mean	440	120	**Toby Cr:** **Mean** **Std Dev.** **Obs.**
Standard deviation	92.9	136.4	1970-1974 no data collected
Observations	36688	7717	1975-1979 no data collected
df	9275		1980-1984 no data collected
t Stat	196.4		1985-1989 no data collected
Significance (one-tail)	P < 0.001		**Nanticoke Cr: no data**
t Critical one-tail	1.65		**Criterion:** none listed

Paired Watershed Analysis

Diss. Oxygen (mg/L)	Toby Cr	Nanticoke Cr	Reference (EPA BASINS)			
Mean	11	7	**Toby Cr:**	**Mean**	**Std Dev.**	**Obs.**
Standard deviation	2.5	2.8	1970-1974	10	1.4	14
Observations	39373	7717	1975-1979	11	2.9	28
df	10141		1980-1984	9	3.4	25
t Stat	116.60		1985-1989	8	1.8	36
Significance (one-tail)	P < 0.001		**Nanticoke Cr:**	8	0.6	2
t Critical one-tail	1.64		**Criterion:** 6 mg/L minimum daily ave.			

Paired Watershed Analysis

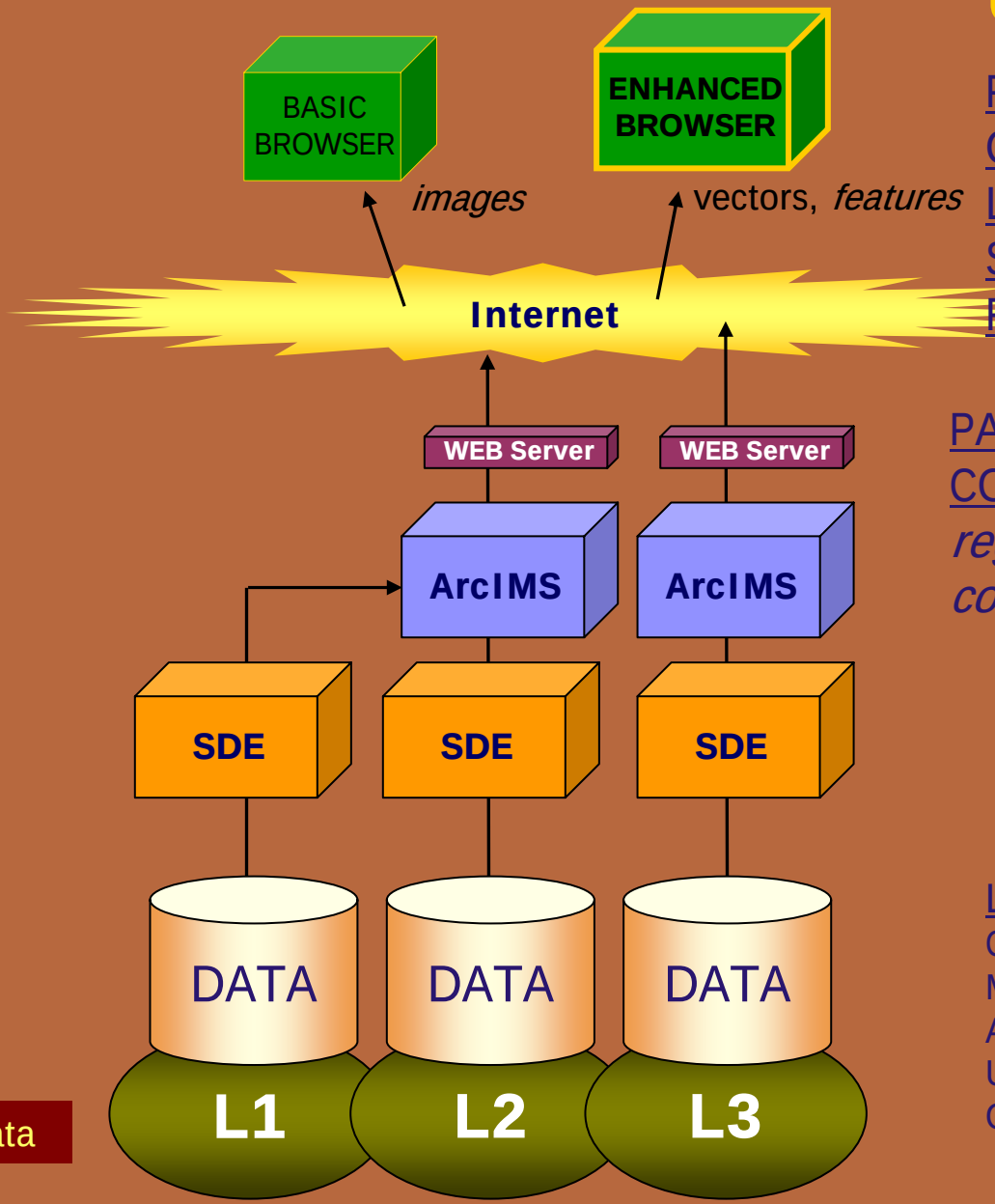
Table 2. Water quality data from real-time monitors (continued).

pH	Toby Cr	Nanticoke Cr	Reference (EPA)			
Mean	7.35	6.72	**Toby Cr:**	**Mean**	**Std Dev.**	**Obs.**
Standard deviation	0.15	0.18	1970-1974	7.12	0.59	12
Observations	39373	7717	1975-1979	7.58	0.46	23
df	9895		1980-1984	6.99	0.82	30
t Stat	289.43		1985-1989	7.06	0.36	24
Significance (one-tail)	P < 0.001		**Nant. Cr (80-84):** 6.98		0.04	2
t Critical one-tail	1.65		**Criterion:** 6.0 to 9.0			

Data Distribution Strategy

Regional Model: Distributed GIS

(locally maintained and regionally coordinated)



Large Scale/Local Data

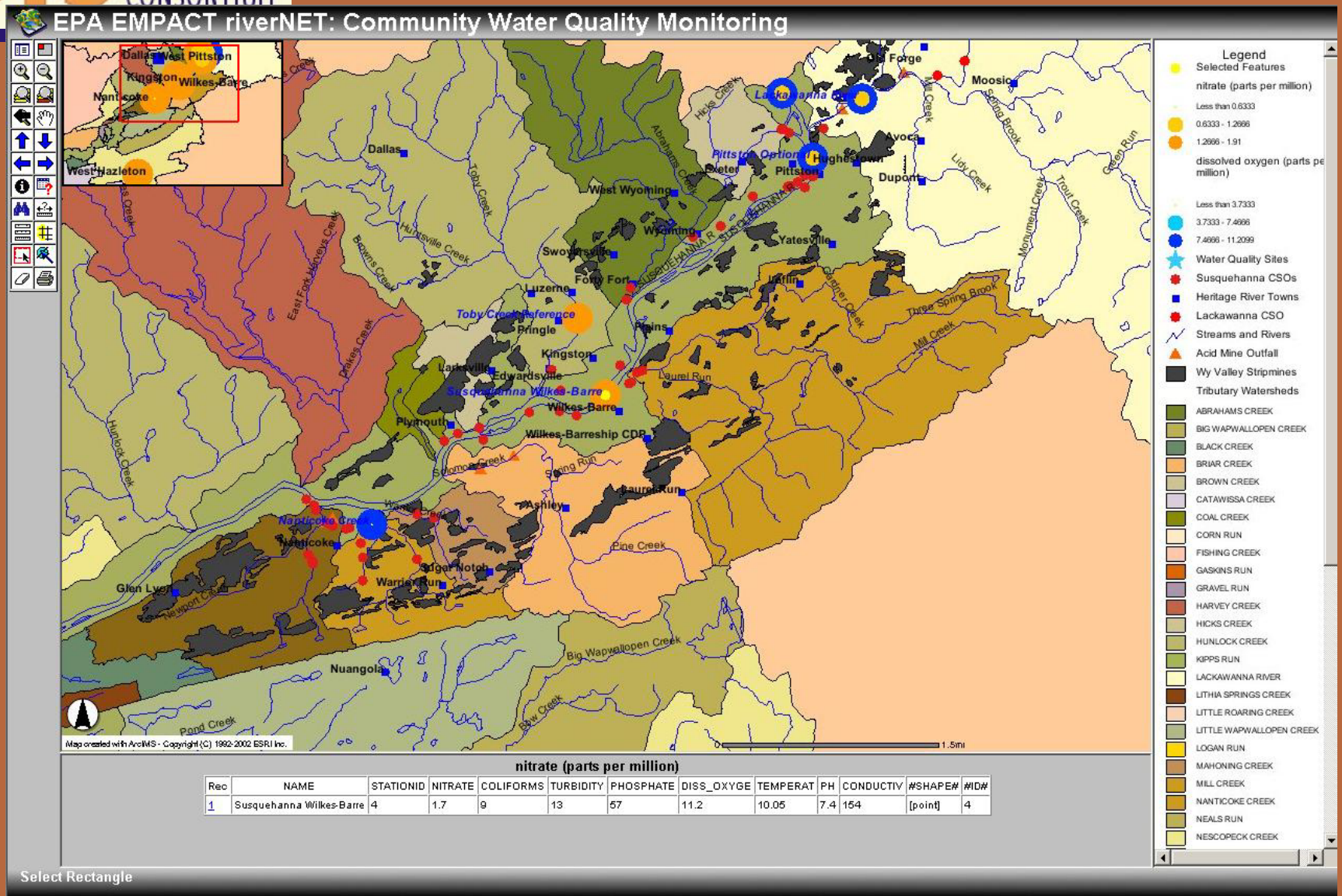
Users

PUBLIC
OTHER
LOCAL
STATE
FEDERAL

PA GIS CONSORTIUM
regional coordination

LOCAL
County
Municipality
Agency
University
Other

EPA EMPACT RIVERNET – WEB BASED GIS MAP SERVICE SHOWING WATERSHED INFORMATION AND WATER QUALITY DATA



RiverNET

Realtime Internet Visualization and Environmental Reporting Network

Main Sections

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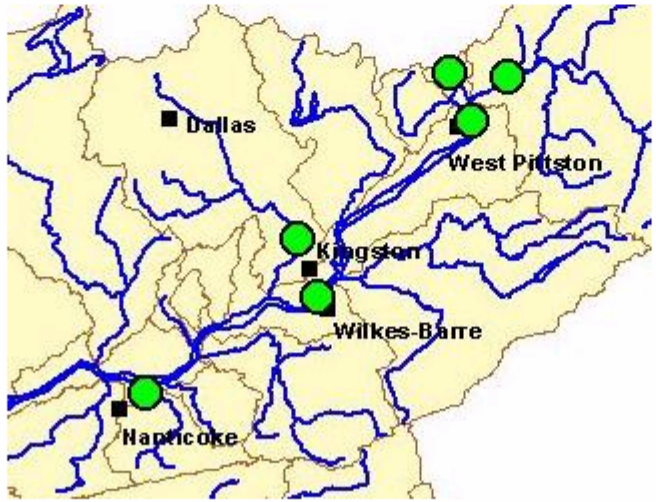
Project Summary

RiverNET is an environmental research project focused on monitoring water quality parameters in the Upper Susquehanna/Lackawanna American Heritage River Waterhed. The project uses real-time water quality monitoring equipment and community-based GIS to visualize water quality via the Internet as it happens.

Monitor Locations

Click on the stations for more information.



RiverNET

Realtime Internet Visualization and Environmental Reporting Network

Toby Creek Reference

Site Information

This sampling site is located just above the Dallas Area Municipal Authority plant on Route 309 in Kingston Township, PA. Security to this site is provided by the location within the DAMA property. The YSI water monitor is situated in the stream in a protective flow-through chamber and is held in place by several tether cables. The telemetry and power equipment are mounted on nearby poles. Permanent installation of this site took place in March 2003.

Toby Creek is used as our reference-control stream, receiving very little impact from Combined Sewer Overflows and no Abandoned Mine Drainage discharges. Almost the entire watershed is located in a sub-urban to rural area. The majority of the lower reach of the stream lies within the urban corridor of the Wyoming Valley and is channeled underground through a concrete culvert.

Current Conditions

Conditions for Toby Creek Reference were last observed September 28, 2003 01:16:12

Temperature	17.06°C
Conductivity	113µs/cm
Dissolved Oxygen Concentration	9.2mg/L
Depth	0.396
pH	7.311
ORP	454.9 volts
Ammonium Concentration	0.042 mg/L
Nitrate Ion Concentration	50.241 mg/L
Chloride Concentration	26.521 mg/L
Turbidity	20.5

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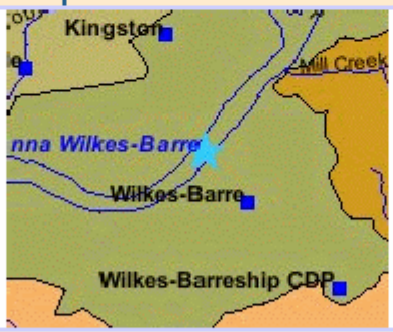
Current Conditions

Introduction

This page is a quick reference to RiverNET monitoring sites.

Available Stations

Susquehanna Wilkes-Barre



City: Wilkes-Barre
Water Body: Susquehanna River
Watershed: Susquehanna River

Toby Creek Reference

City: Kingston Twp
Water Body: Toby Creek
Watershed: Toby Creek

RiverNET

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Table Specifications

Station ID: Toby Creek Reference

If you wish to generate a table of one type of chemical or other recorded data over several stations instead, please click here.

What chemicals and other observed information do you want in the generated table?

- [ ] Ammonium Concentration
- [x] Chloride Concentration
- [ ] chlorophyll
- [ ] Conductivity
- [ ] Depth
- [ ] Disolved Oxygen Concentration
- [ ] Nitrate Concentration
- [ ] REDOX Potential
- [x] pH Scale
- [ ] Temperature
- [x] Turbidity

Start Date:
January 01 2000

End Date:
January 01 2004

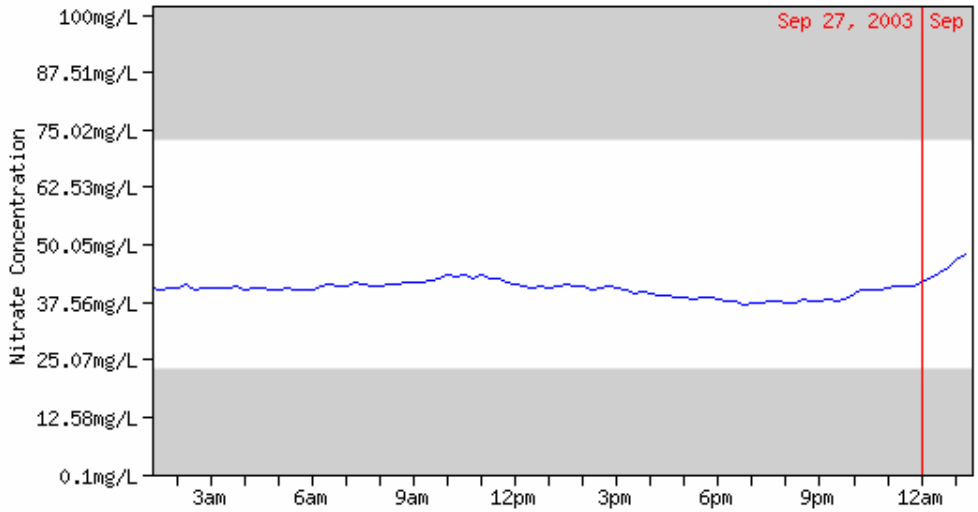
RiverNET

Realtime Internet Visualization and Environmental Reporting Network

Fatal error: Maximum execution time of 30 seconds exceeded in **/home/rivernetadmin/public_html/includes/timedate_functions.php** on line **13**

Observation Time	Chloride Concentration (mg/L)	pH	Turbidity (NTU)
04/06/2003 03:00 AM	69.131	7.431	3.8
04/06/2003 03:00 AM	68.881	7.431	4.701
04/06/2003 03:00 AM	69.081	7.431	3.8
04/06/2003 03:01 AM	68.891	7.431	3.8
04/06/2003 03:16 AM	69.071	7.421	3.8
04/06/2003 03:31 AM	69.201	7.431	4.201
04/06/2003 03:46 AM	68.881	7.421	3.8
04/06/2003 04:01 AM	69.191	7.421	3.5
04/06/2003 04:16 AM	69.151	7.421	3.8
04/06/2003 04:31 AM	69.431	7.421	3
04/06/2003 04:46 AM	69.301	7.421	3.6
04/06/2003 05:01 AM	69.431	7.421	3.3
04/06/2003 05:16 AM	69.411	7.421	3.701
04/06/2003 05:31 AM	69.491	7.421	3
04/06/2003 05:46 AM	70.231	7.421	3.3
04/06/2003 06:01 AM	70.271	7.421	3.1
04/06/2003 06:16 AM	70.241	7.431	3.3
04/06/2003 06:31 AM	70.361	7.441	11.4
04/06/2003 06:46 AM	70.901	7.451	3.701
04/06/2003 07:01 AM	71.301	7.461	3.1
04/06/2003 07:16 AM	71.351	7.47	2.701

Nitrate Ion Concentration



Ammonium represents the ammonia ion and nitrate is the most oxidized form of nitrogen present in water. Nitrogen is essential for all living things as it is a component of proteins. Nitrogen exists in the environment in many forms and changes forms as it moves through the nitrogen cycle. Ammonia concentrations are usually found at very levels while the easily oxidized form nitrate can be higher, as much as 10 mg/L. The primary sources of these chemicals in surface waters in the Susquehanna River watershed are CSO's and fertilized farmlands.

Chloride Concentration

RiverNET

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The Archives

I need to write a good introduction

Archived Data

There are several methods of getting river data, including the generation of customized tables and graphs. Select an option in the list below to get your data now.

- Generate a table of chemical conditions for one station - Here you can build a table of any number the record atributes for any one monitoring site. The outputted table can be formatted into an easy to read HTML table, or exported in a plain text, comma delimiteed format to be loaded into any number of spreadsheet and data processing applications.

- Generate a table of data from multiple stations - From here you can compare how a particular recorded value changes both over time and from one monitoring site to another. **Still under construction**

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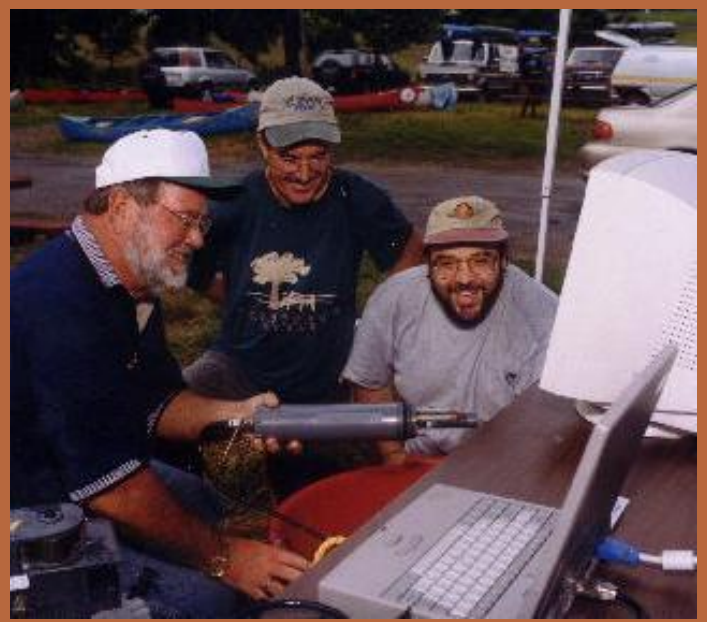
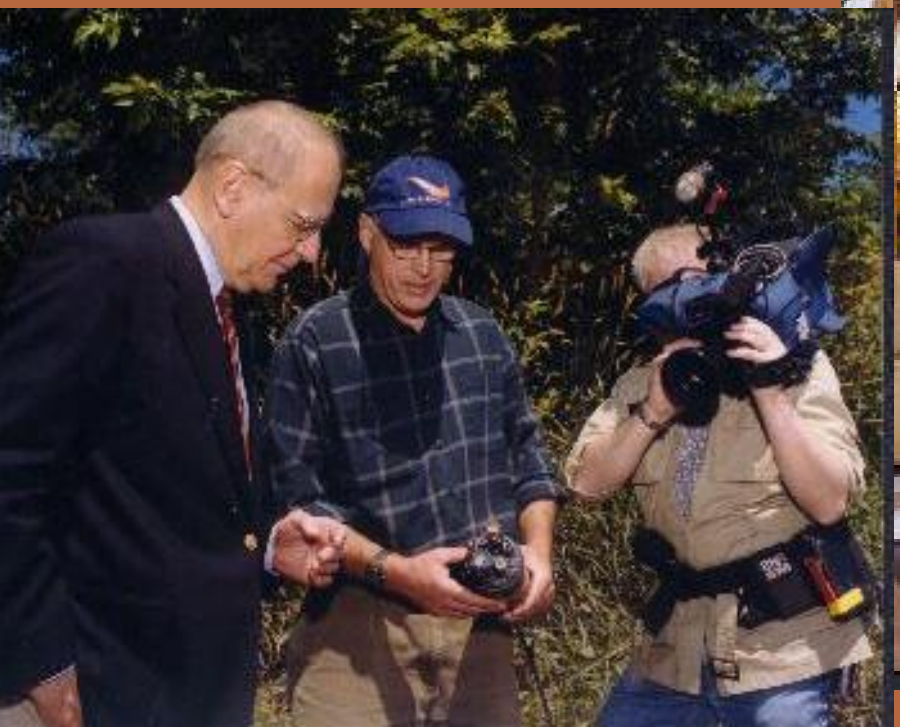
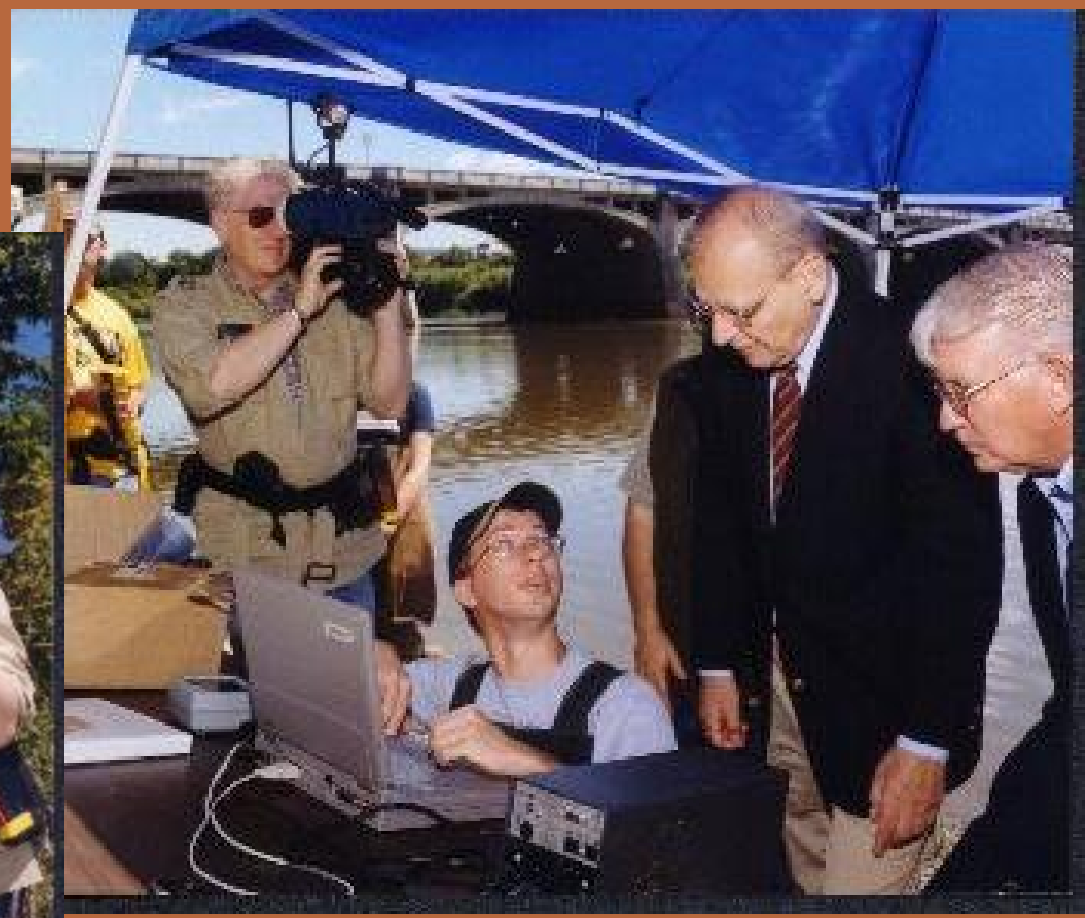
Environmental Education and Outreach:
River Fest on River Front Parks



Environmental Education and Outreach: Press Release at River Front Parks





THE CITIZENS' VOICE

TUESDAY
July 3, 2001
Wilkes-Barre, PA

72 Pages

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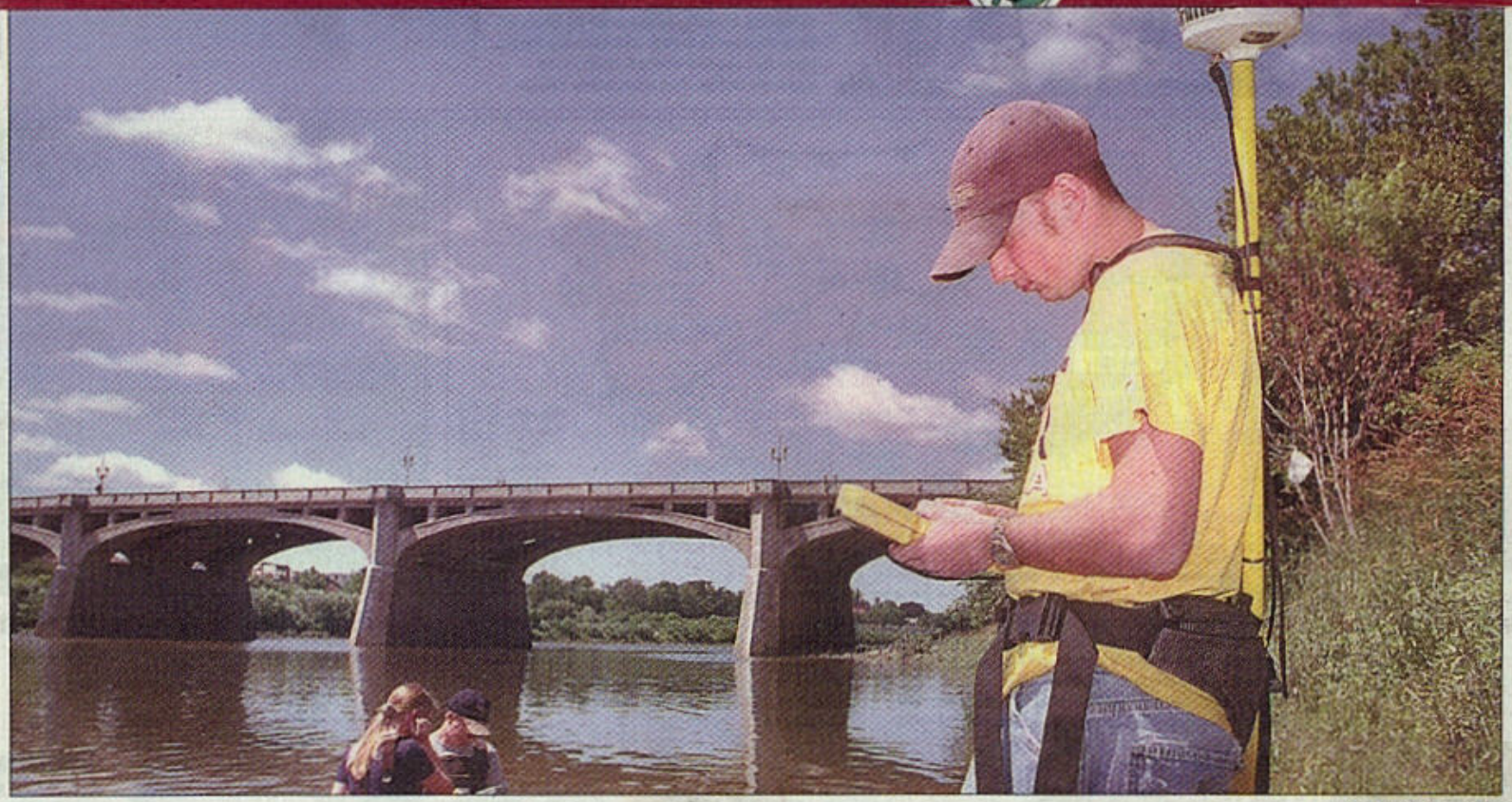


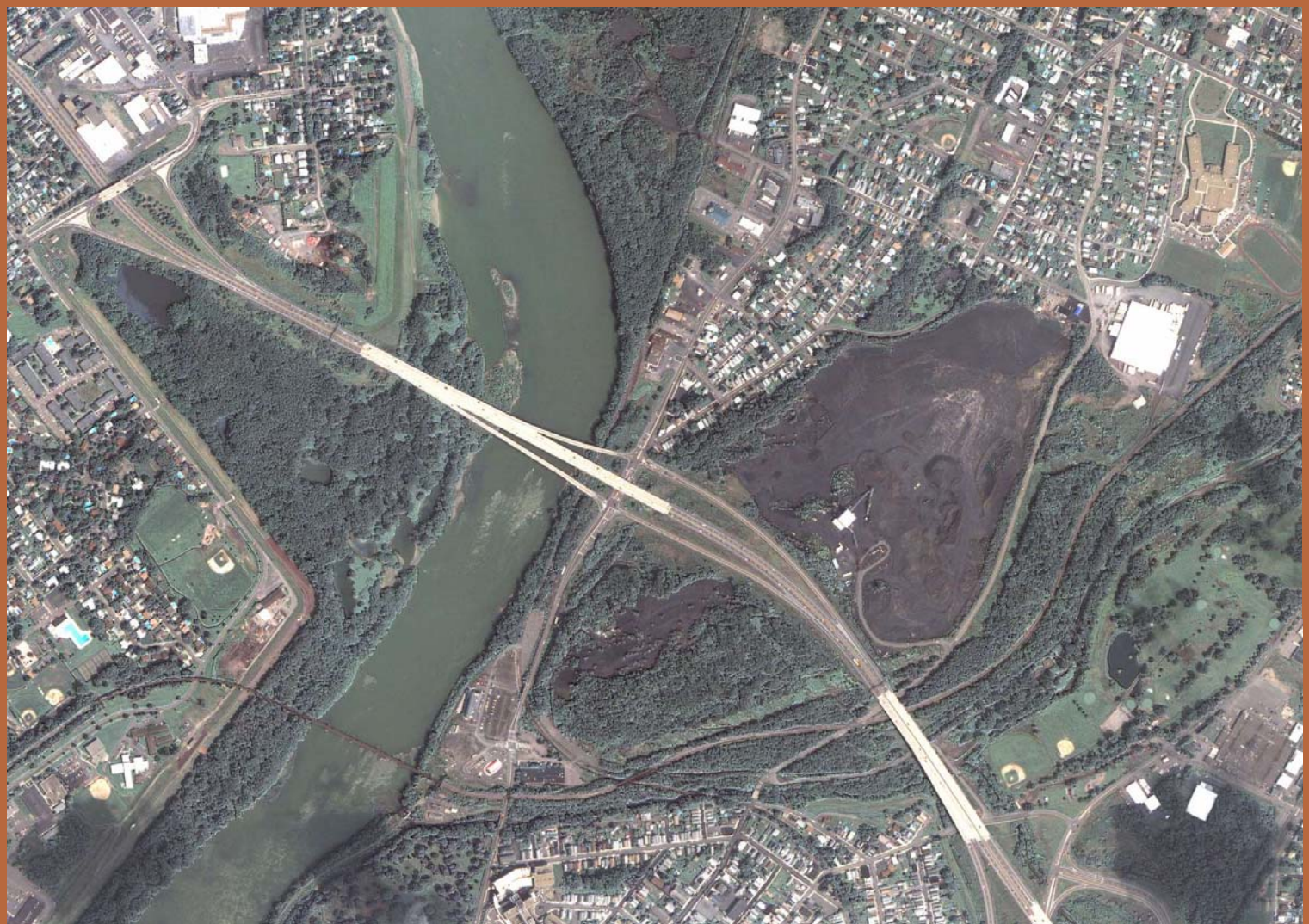
WARREN RUDA/CITIZENS' VOICE

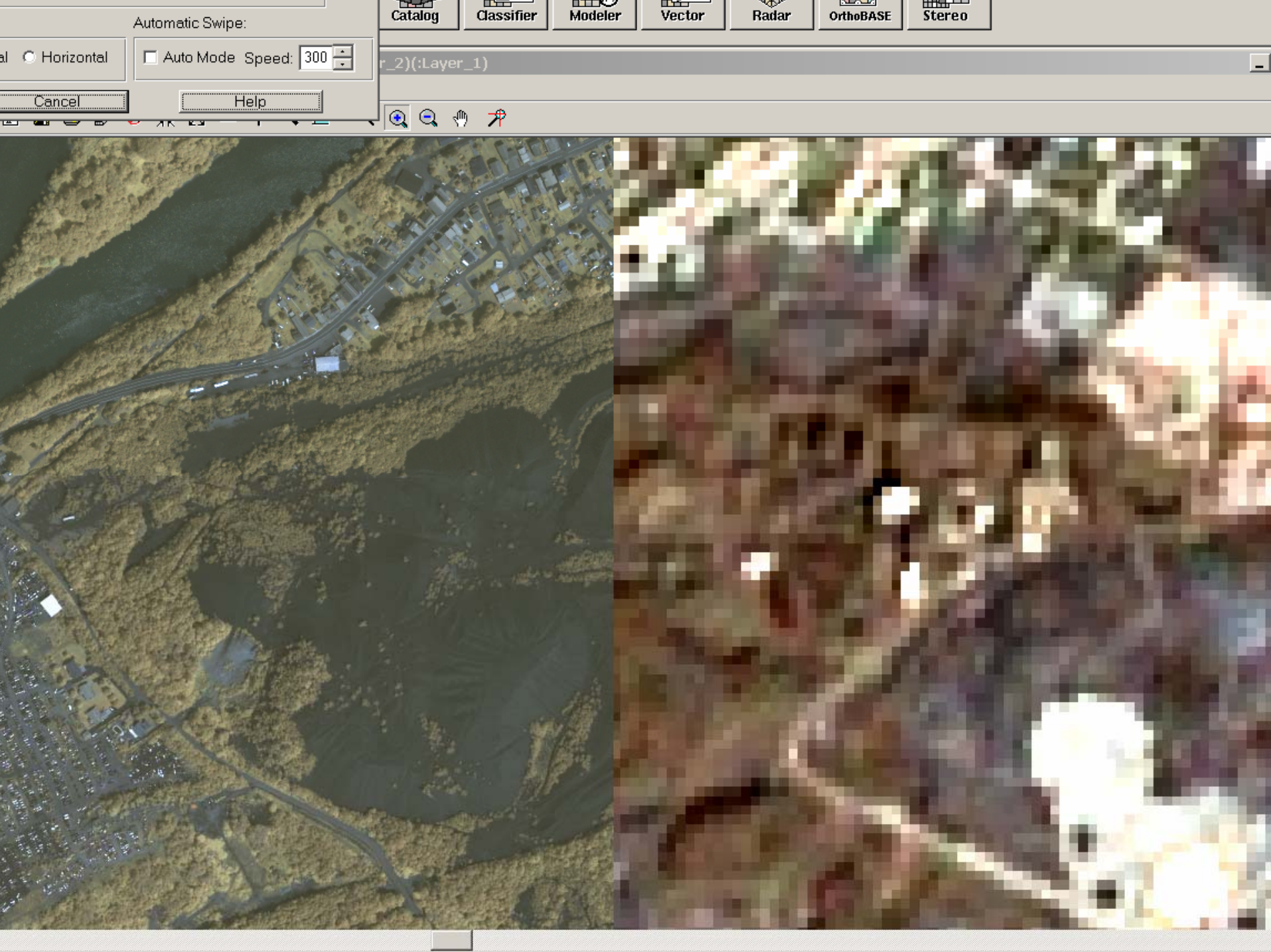
Mark Hendry, right, a Wilkes University student, stands on shore with GPS unit. In water are Stacy Rizzo and Chris Watkins.

Taking a closer look at the Susquehanna River

Page 3

Future directions—
Applications of Quick Bird imagery: floodplain, mining, reclamation, and highway corridors

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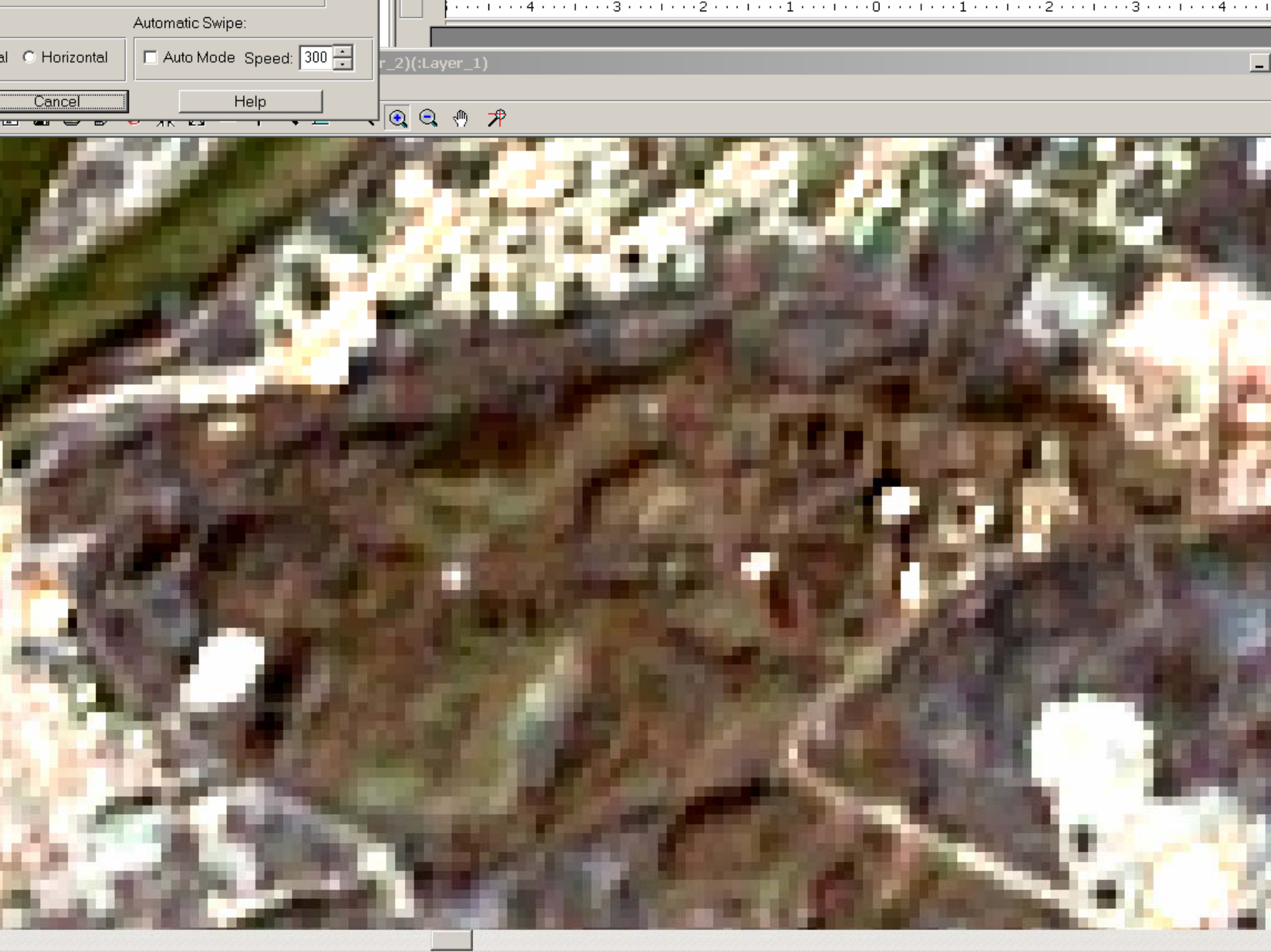
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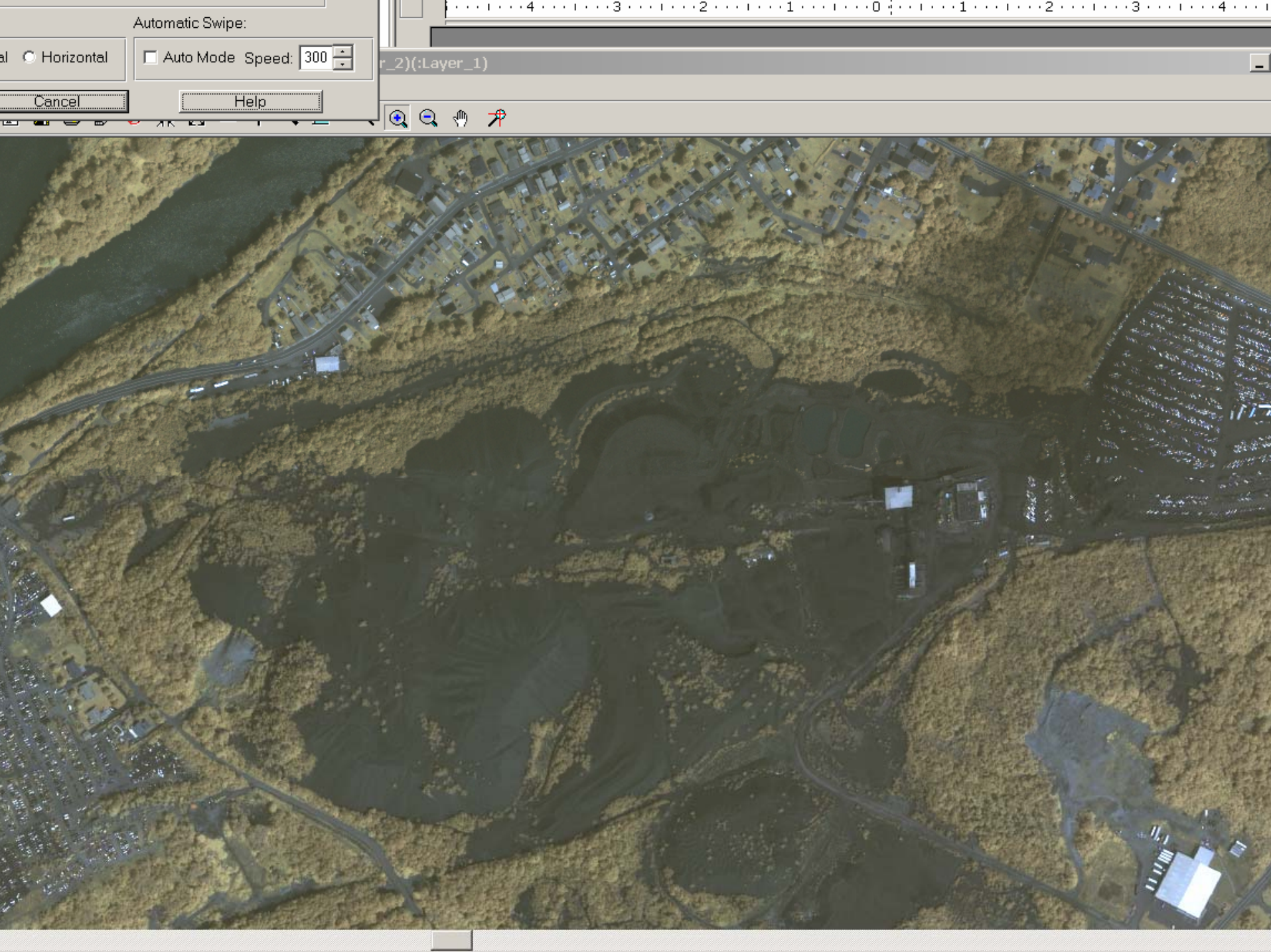
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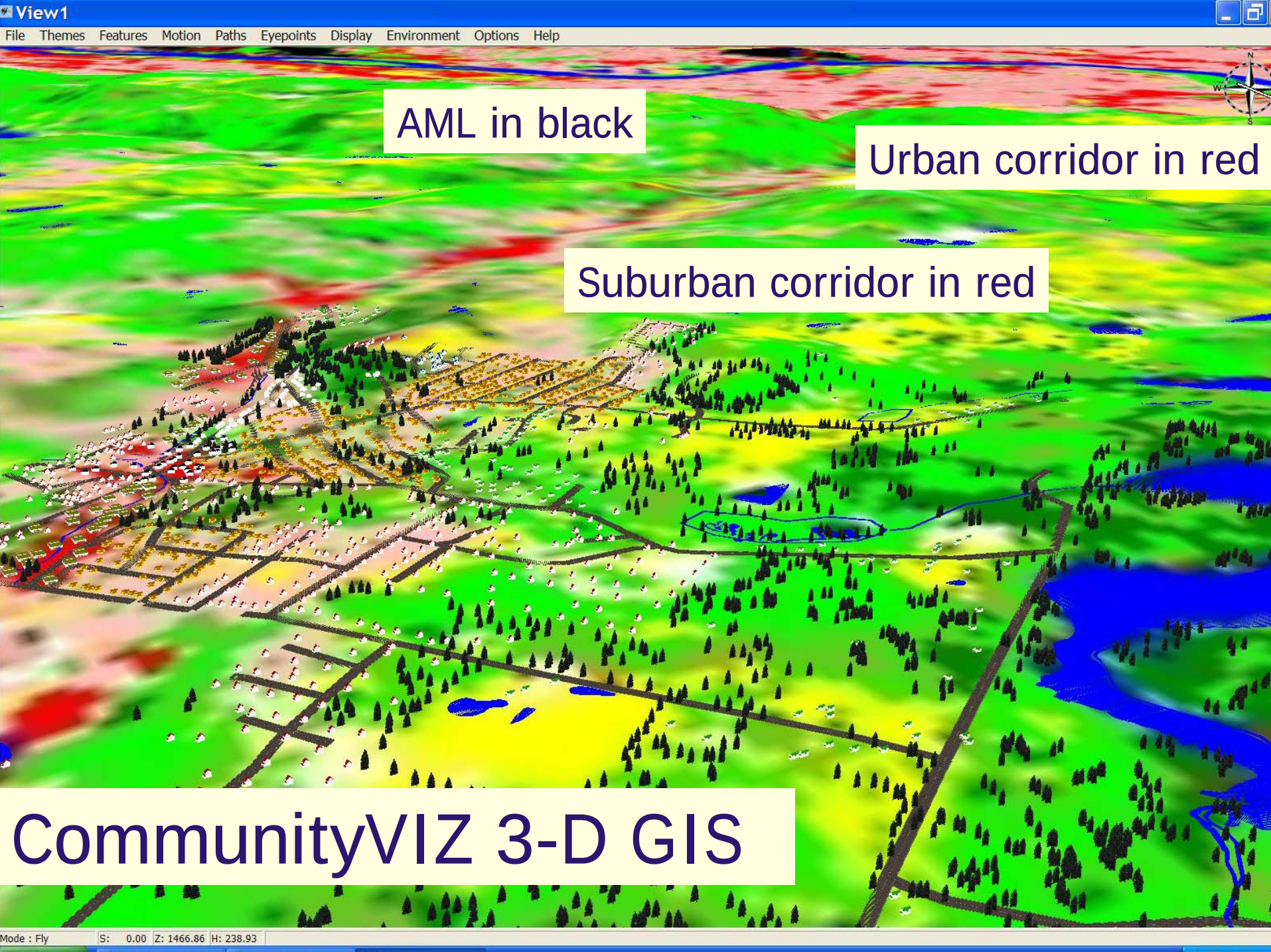
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Urban corridor in red
Suburban corridor in red
CommunityVIZ 3-D GIS
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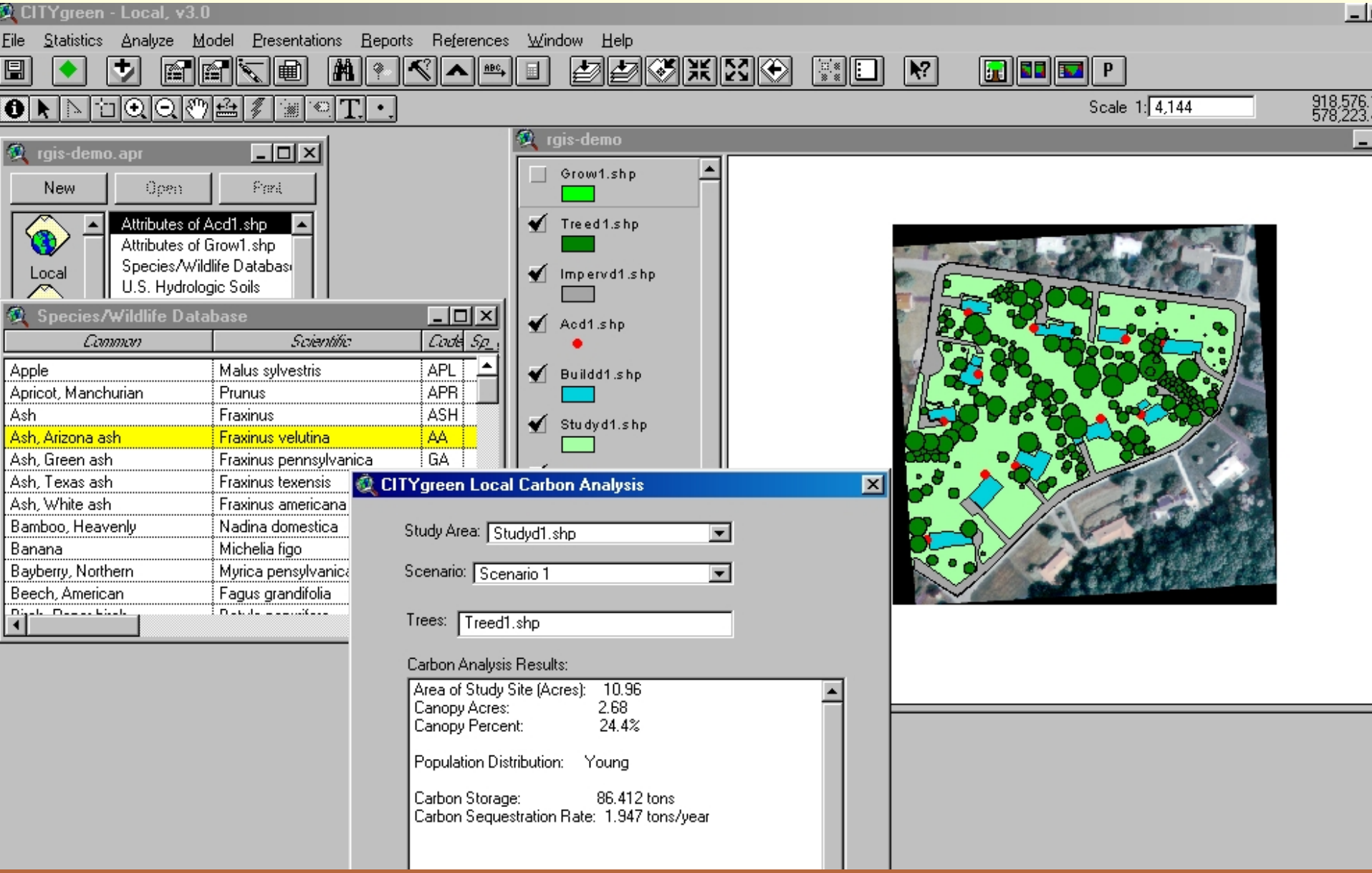
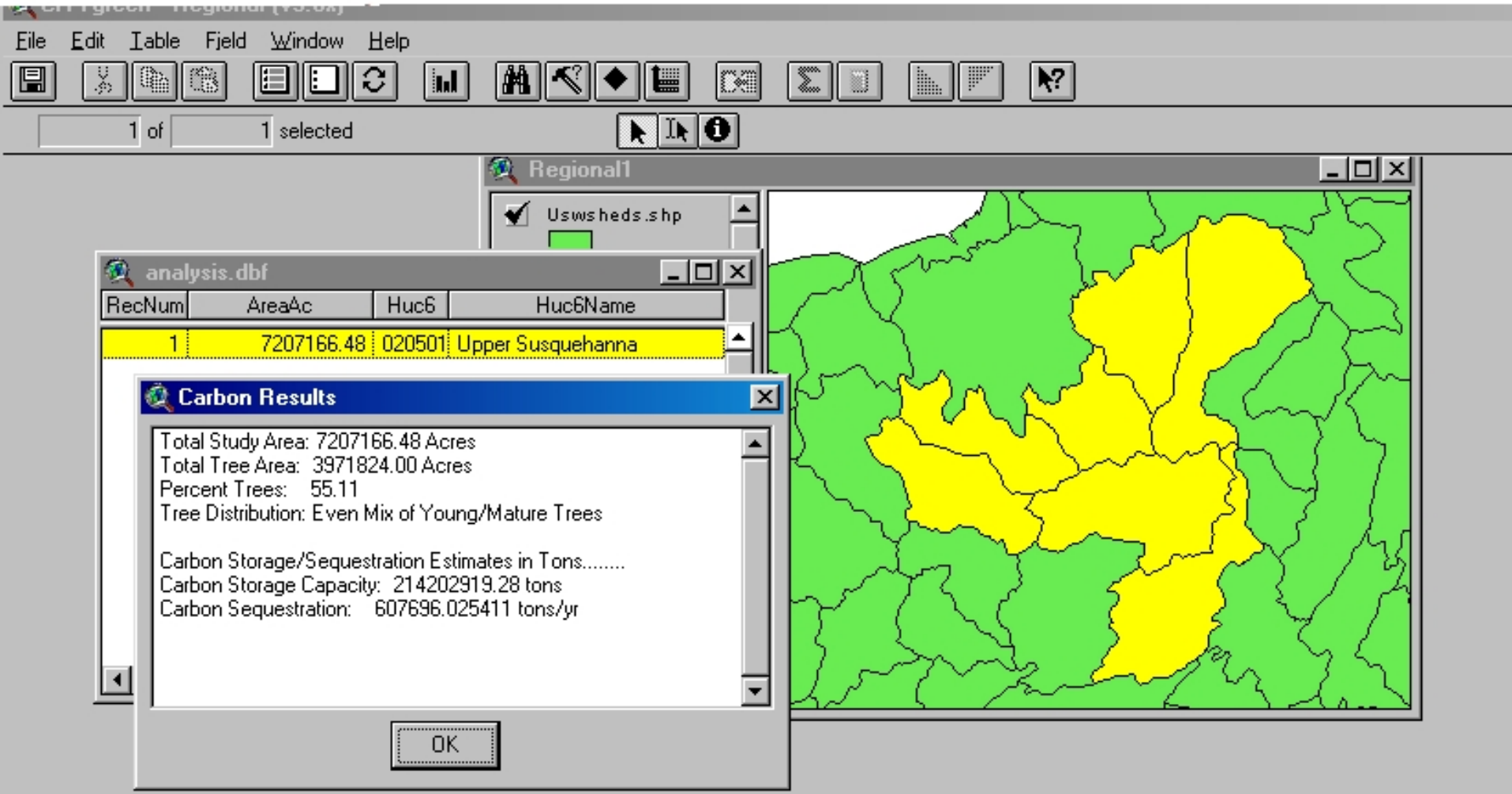
H: 238.93

CITYgreen: Trees and carbon sequestration analysis

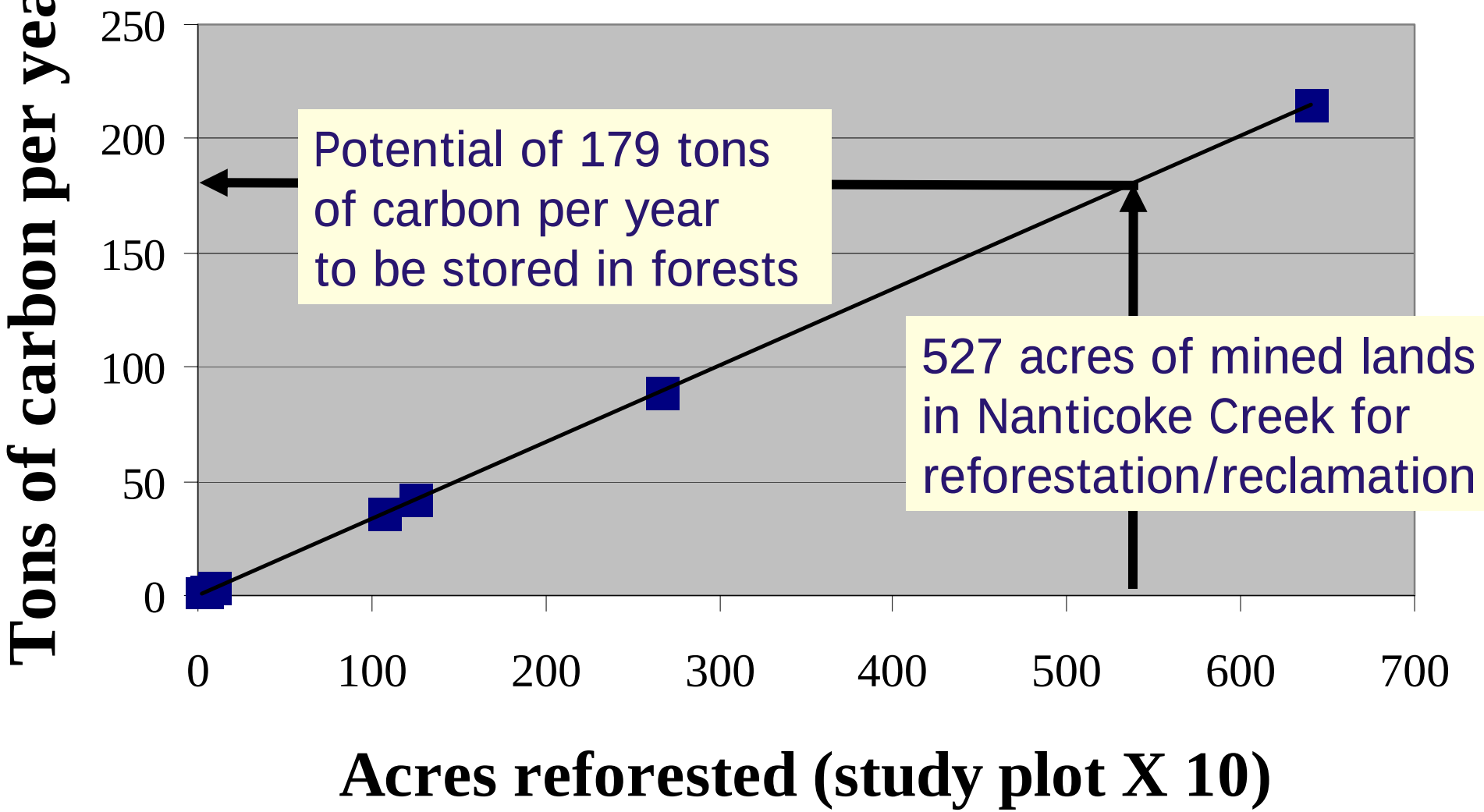


CITYgreen: Regional carbon sequestration analysis



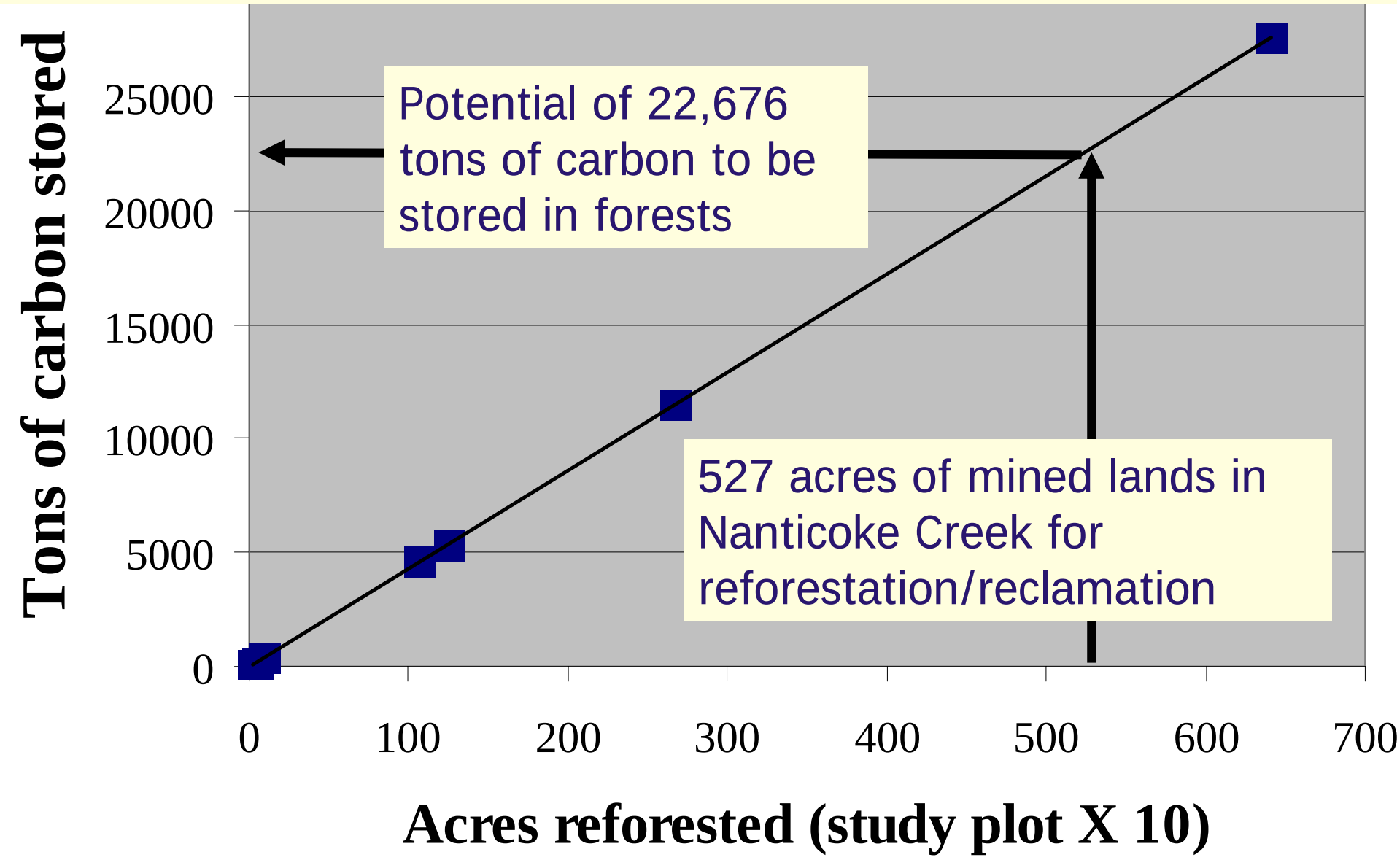
CITYgreen Predictions: Benefits of Reforestation

Regression equation: tons of C stored per year = 0.34 x (acres of forest)



CITYgreen Predictions: Benefits of Reforestation

Regression equation: tons of C = 43 x (acres of forest)



Benefits and Conclusions of EMPACT

- **Benefits - Fit the AHR Master Plan**
  - Support and participation of the public, local govt. & environ. Groups
    - Data available to public; public outreach and environ. education
    - WVSA, Wilkes University, PA GIS Consortium, AHR
    - two watershed groups, EC, Chamber, PA DEP, EPCAMR, PEC
- **Conclusions – GIS analysis supports monitoring design**
  - Statistical analysis supports both AML (and CSO issues)
  - AMD – limited historical data from 1970s,1980s, 1990s (BASINS)
  - Paired watershed analysis successful in data analysis
  - CommunityVIZ, CITYgreen, and Quick Bird imagery hold potential

Acknowledgements

- Congressman Paul Kanjorski and Staff
- Department of Interior
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  - OSM
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- USGS
- U. S. Army Corps of Engineers
- PA DEP
- Wilkes University
- ESRI (Chris Cappelli)
- Sweet Solutions
- Marconi Systems/ADR
- Digital Globe
- EPA EMPACT

Contact information: pagis.org