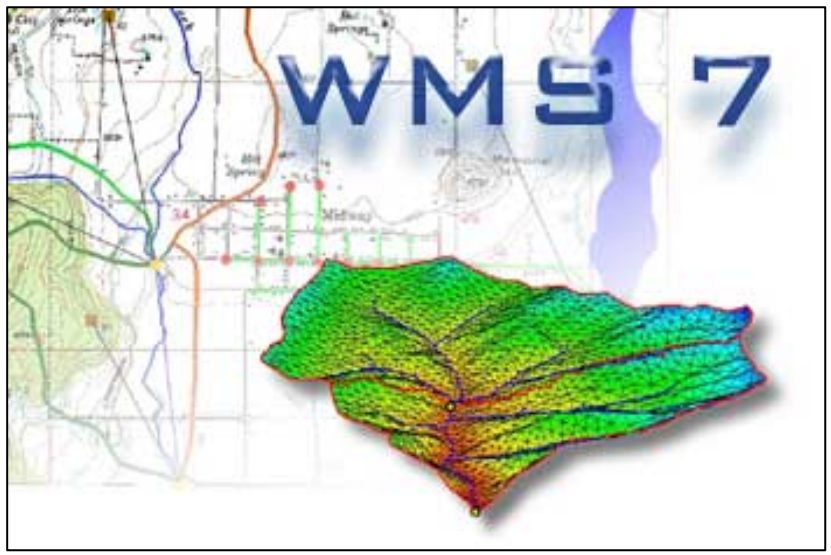
Integrating Geospatial and Watershed Data Using the Watershed Modeling System (WMS) to Evaluate Flooding Potential of the Clear Fork Watershed in KY and TN

Rick Mann, OSM, Knoxville Field Office



Presented by Stephen Parsons, OSM

December 7, 2004

OSM-TIPS Large Watershed Modeling Software Review Team

- OSM's Technical Innovation and Professional Services program began in 1986 to provide focused technology and training to OSM, State and Tribal SMCRA Partners
- TIPS formed the Large Watershed Modeling Software Review Team was created to search for and evaluate software to be used to evaluate impacts of mining on large watersheds.
- The Team consists of 9 State and OSM watershed specialists.

OSM-TIPS Large Watershed Team Seeking & Testing Software Capable of:

- Predicting Flooding and Floodplain Impacts Caused by Mining and Land Use Changes
- Predicting Changes in Sediment Loading caused by Mining, Road Construction, or Other Land Use Changes
- Predicting Water Quality Impacts and Changes Caused by Mining and Other Activities Within the Watershed
- Accounting for Water Losses and Gains Within the Watershed Caused by Mining or Other Activities
- Accounting for Ground Water Contributions and Interactions Under Baseflow Conditions
- Compatibility With Other TIPS and OSM Software Systems, including GIS

OSM-TIPS Large Watershed Modeling Software Review

Support targeted activities, including:

- **Predictive impact analyses in support of permitting activities (e.g., CHIA preparation, PHC evaluation)**
- **Assessing impacts on water quantity, quality, and seasonal variation**
- **Conducting NEPA & similar hydrologic impact studies**
- **Assessing impacts of discharges from AML sites**
- **Evaluate flood hazards/impacts associated with mining**
- **Provide defensible technical findings in litigation**

Large Watershed Model Review

- **Software considered include:**
  - **Watershed Modeling System (WMS)**
  - **BASINS**
  - **Watershed Characterization Modeling System (WCMS)**
  - **HEC-RAS and HEC-HMS**
  - **MIKE (11)-SHE**
  - **ARC-HYDRO**

Watershed Modeling System: WMS

- Developed by the Environmental Modeling Research Laboratory (EMRL) at Brigham Young University, Provo, UT
- EMRL development sponsored by U.S. Army Corp. of Engineers, EPA, Federal Highway Administration, and others
- Distribution, training, and support of Software is through Environmental Modeling Systems, Inc. (EMS-I)

WMS Geospatial Data Interface Capabilities (1)

- Provides a graphical user interface for various hydrologic models
- Interfaces with other TIPS supported software including:
  - AutoCAD
  - ArcView 3X
  - ArcGIS 8X
  - HEC RAS
- Supports a wide range of image formats
  - GeoTIFF
  - TIFF
  - JPEG
  - MrSID
- Allows the use and conversions between different coordinate or projection
- GIS information or modeling results can be imported or exported for use in other applications or by WMS

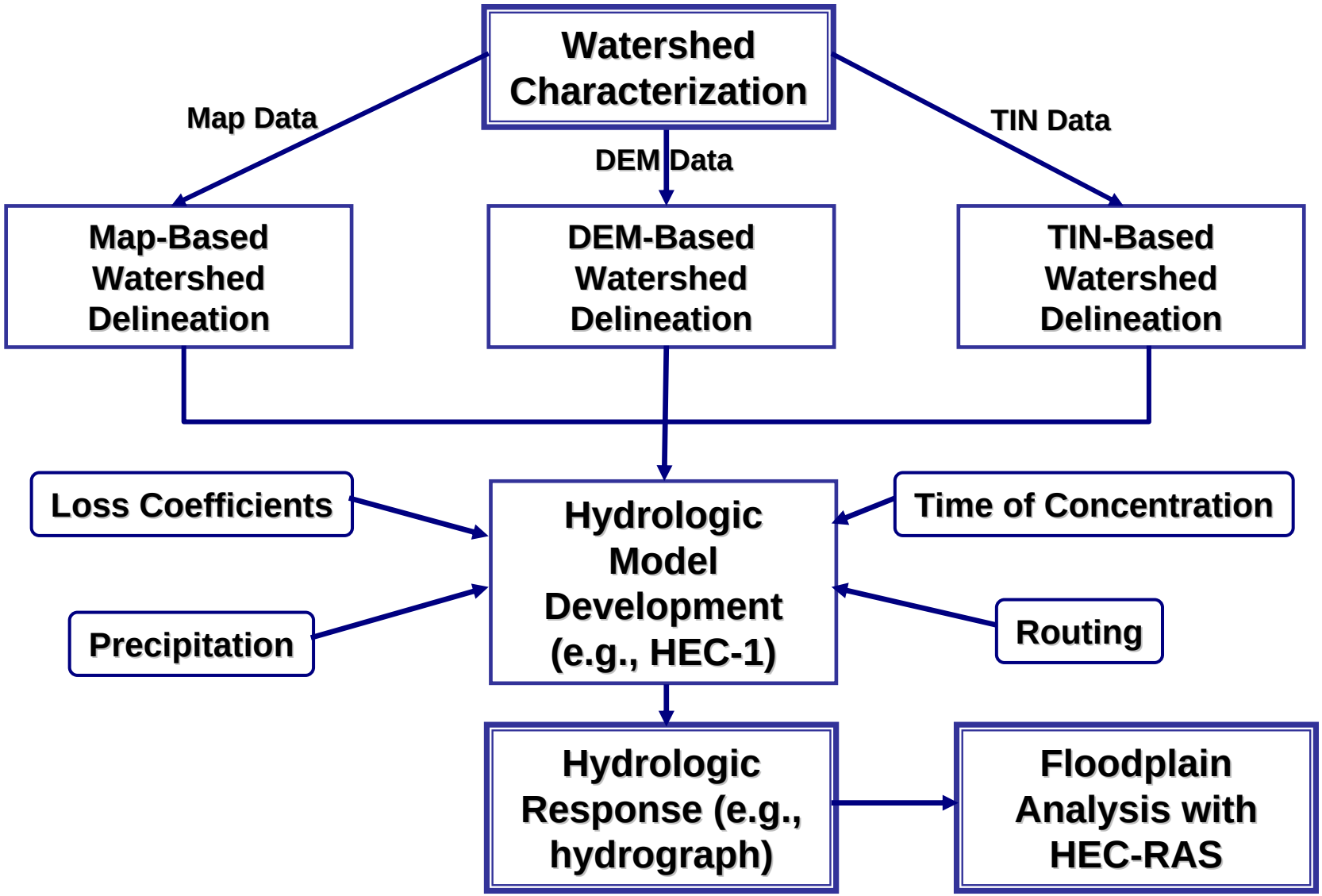
WMS Data Analysis Capabilities
(2)

- Allows automated watershed delineation using digital elevation data obtained from:
  - Digital Elevation Models (DEMs)
  - USGS National Elevation Dataset (NED)
  - Triangulated Irregular Networks (TINS)
  - ArcGIS Elevation Grids
  - Survey Data
- Automates the calculation of basin information needed to run the various hydrologic models
  - Composite Curve Numbers (Loss Coefficients)
  - Channel and Storage Routing, Time of Concentration/Lag Times
  - Basin Elevations, Slopes, Flow Lengths, etc.
- Allows for floodplain modeling and mapping based on digital terrain information and hydrologic model results

Hydrologic Models Supported

- HEC-1
- TR-20
- TR-55
- Rational Method
- MODRAT (Modified Rational Method)
- NFF (USGS National Flood Frequency Regional Eqn)
- HSPF (Hydrologic Simulation Program – Fortran)
- HEC-RAS (Pre- and Post-Processing Interface)
- GSSHA (Gridded Surface Subsurface Hydrologic Analysis)
- CE-QUAL-W2 (Enhanced Stream Water Quality Model)

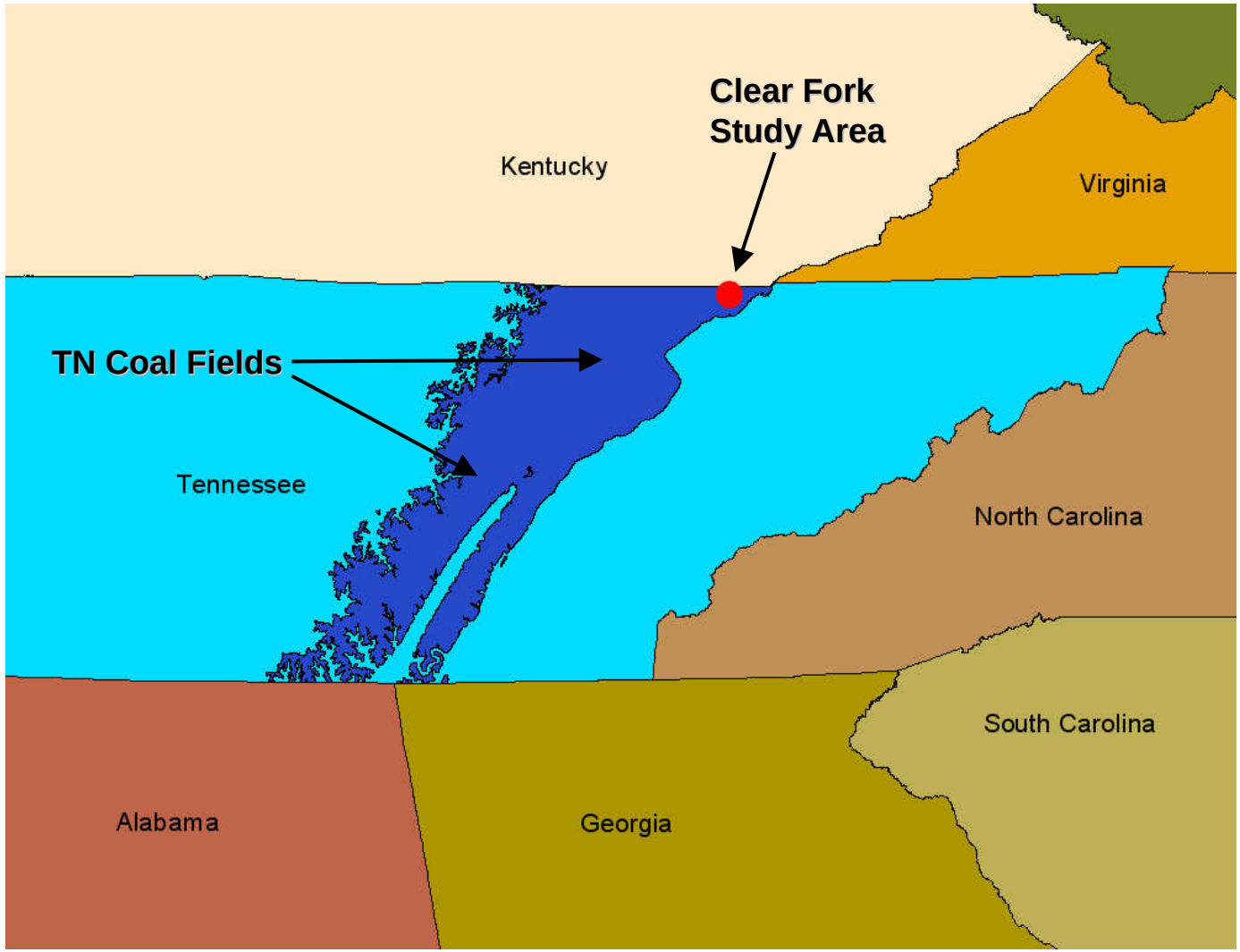
Example of WMS-to-HEC-RAS Work Flow



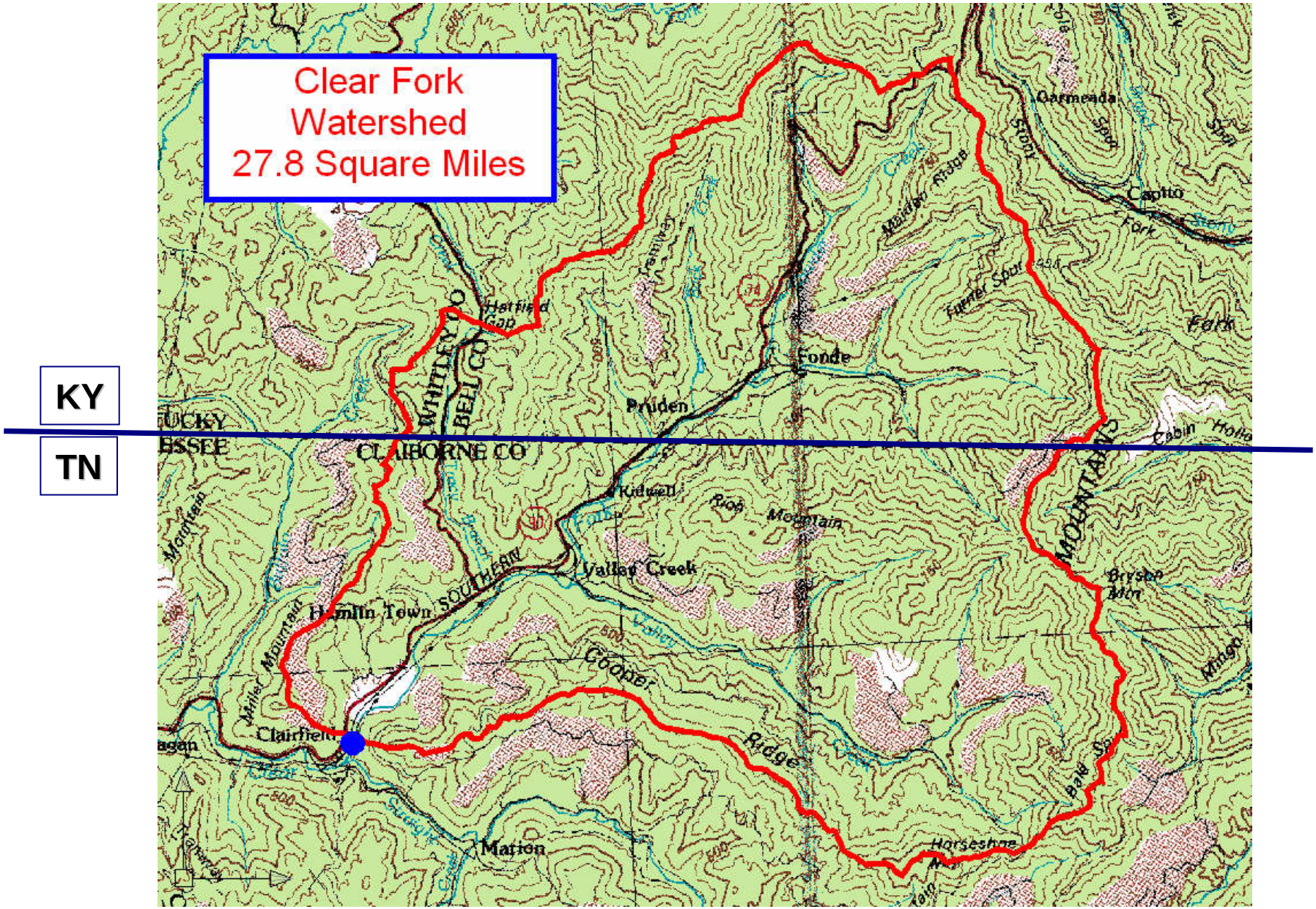
WMS Demonstration: Clear Fork Watershed, KY and TN

- Large concentration of proposed and existing surface mining
- OSM regulates coal mining in Tennessee
- Public water utility system potentially affected
- Residential area and school located in floodplain of Clear Fork Creek

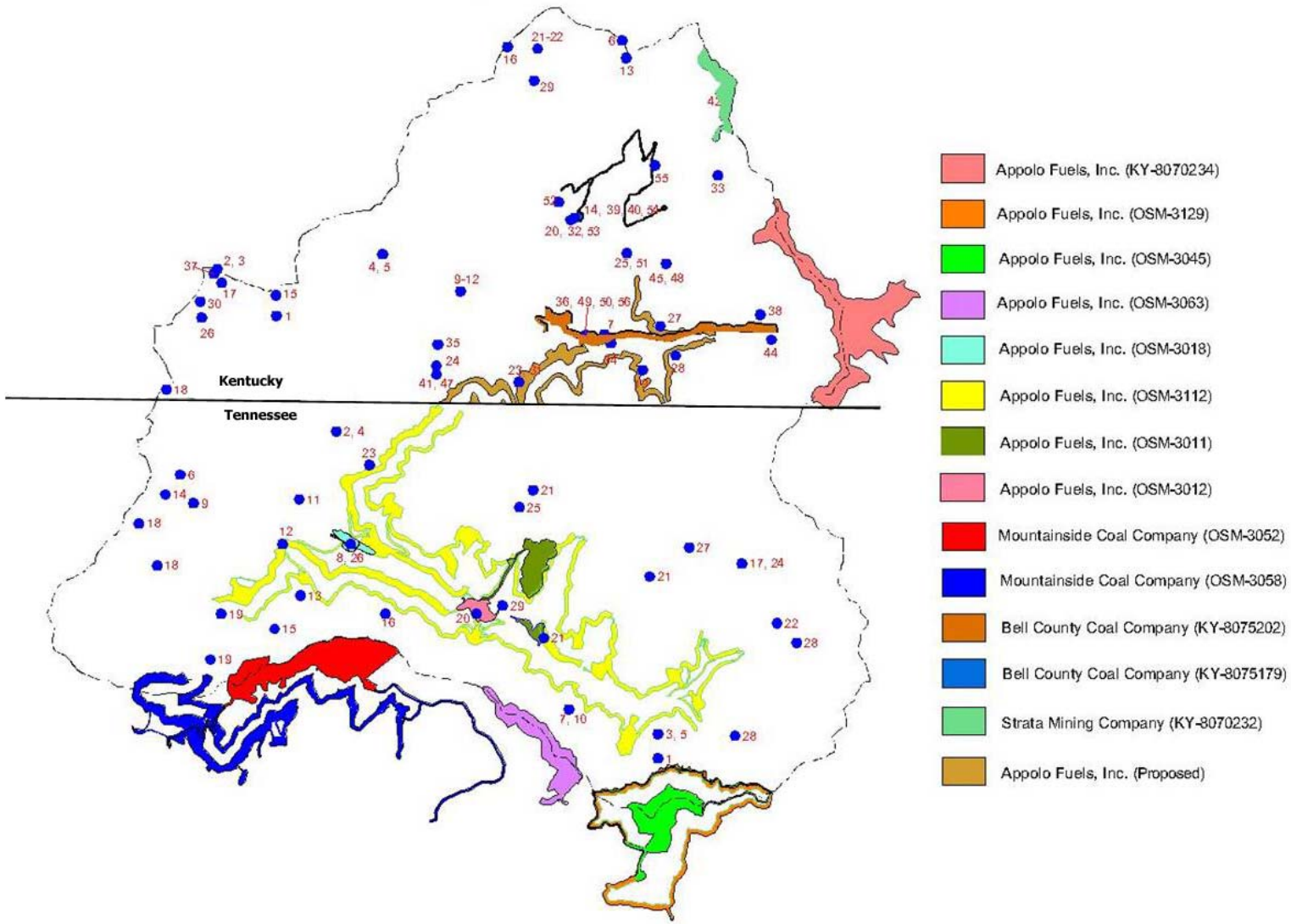
Clear Fork Study Area in Kentucky and Tennessee Part of the Cumberland River Drainage System



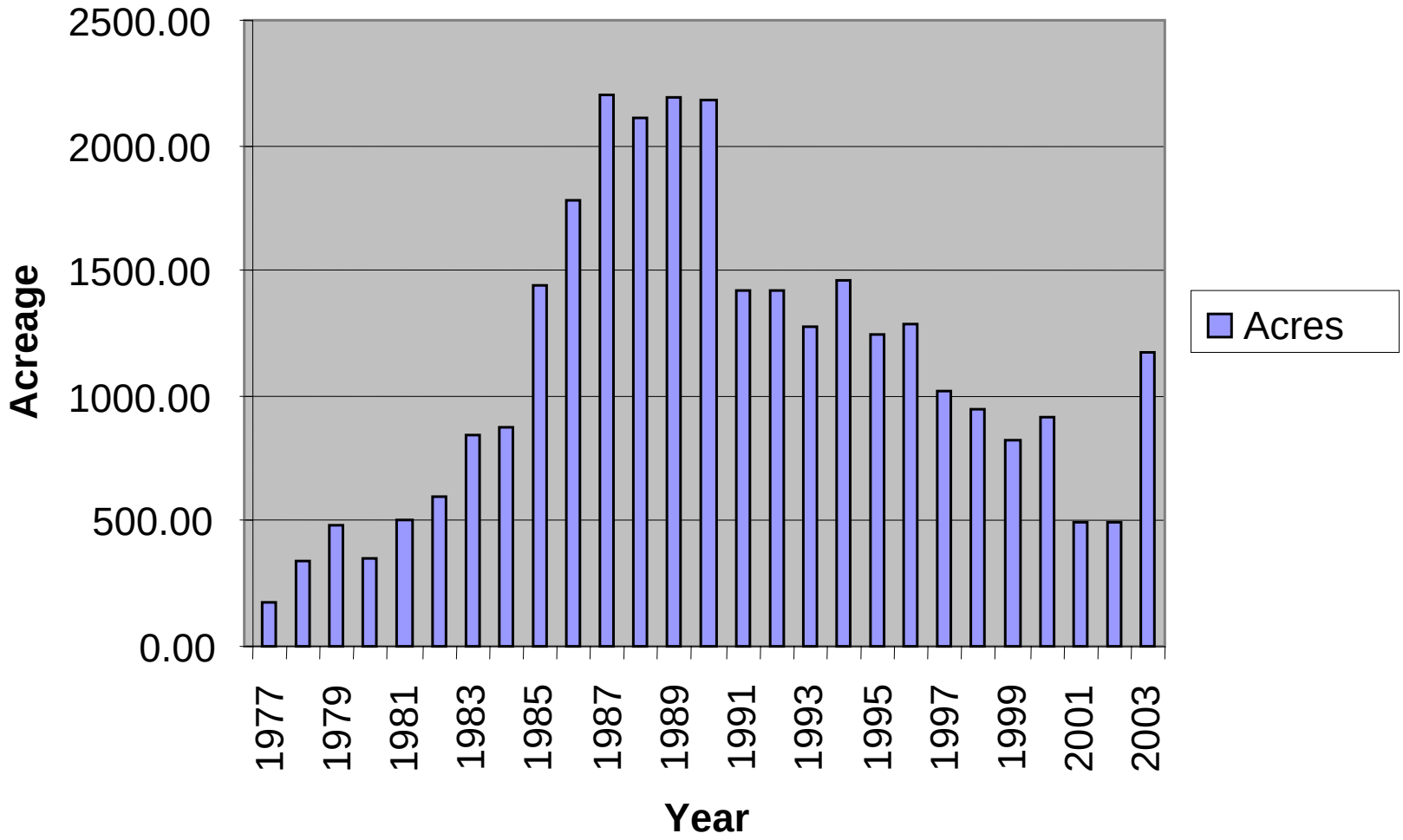
Clear Fork Watershed Watershed



Mining in Clear Fork Watershed



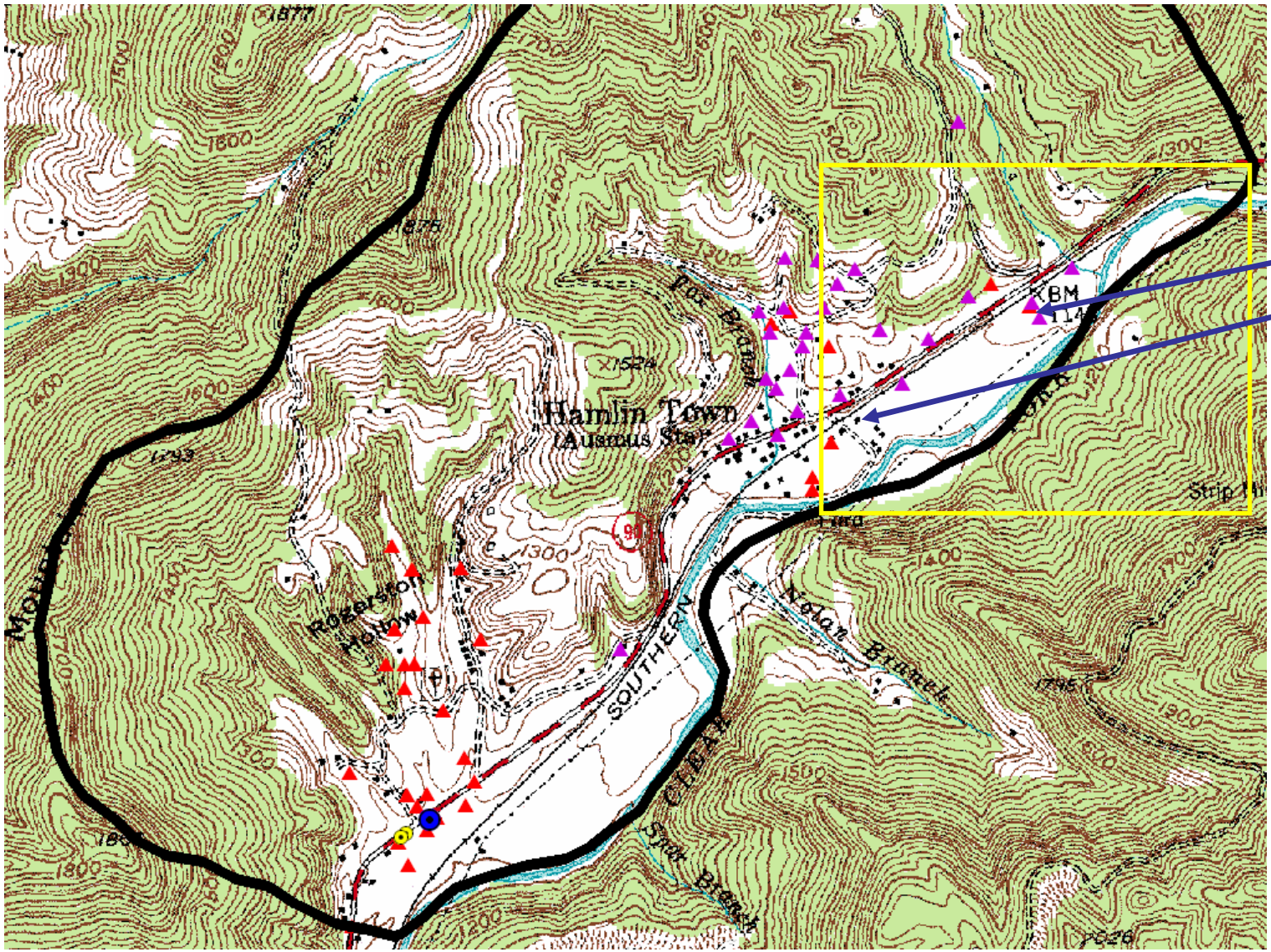
History of Permitted Surface Disturbance



Clear Fork Watershed Looking North into Kentucky

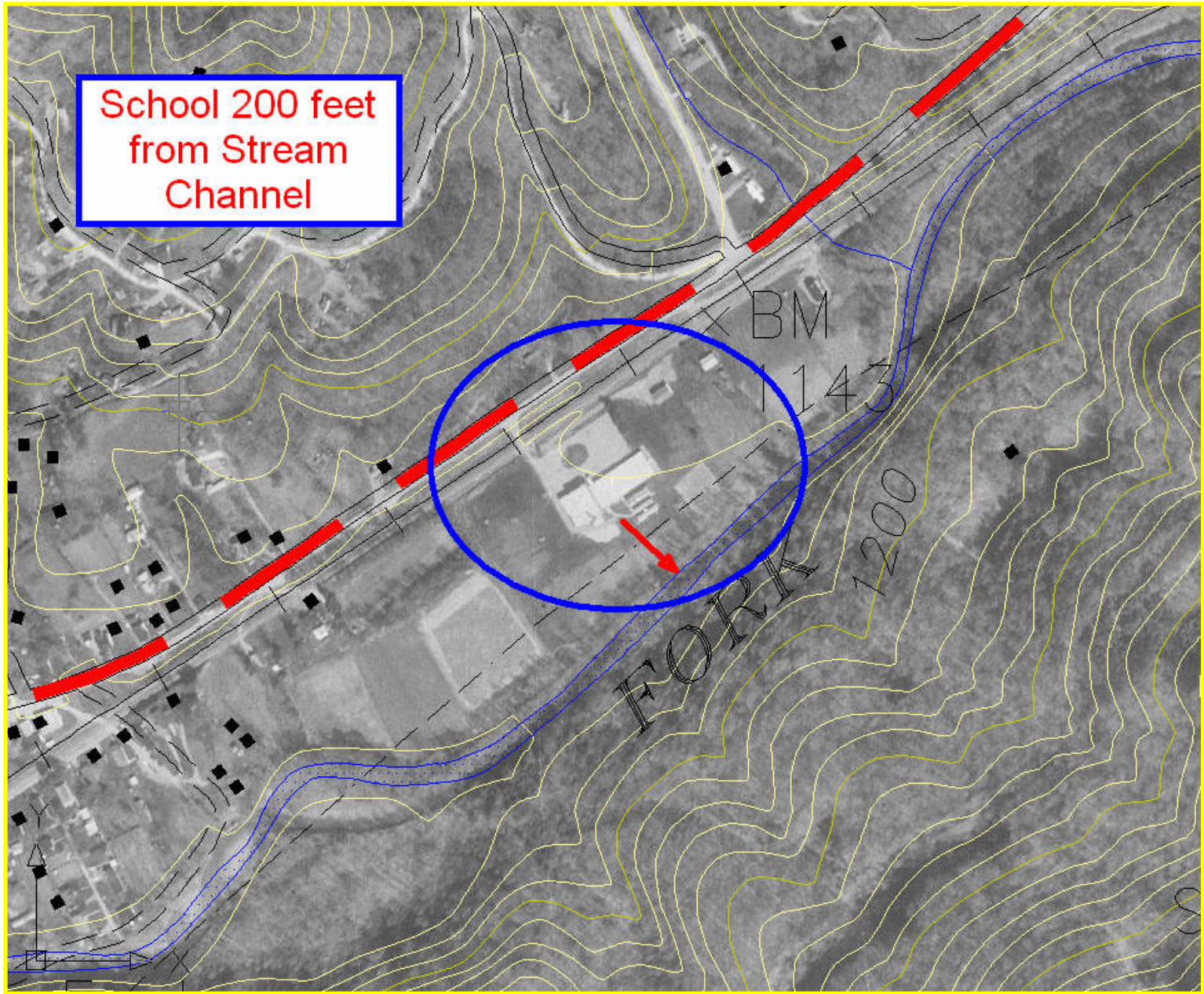
Clear Fork Watershed Looking Downstream From the Headwaters area in Kentucky

Reach of Concern in Lower Clear Fork Watershed



School and Residential Development

Position of School and Residents Relative to Stream

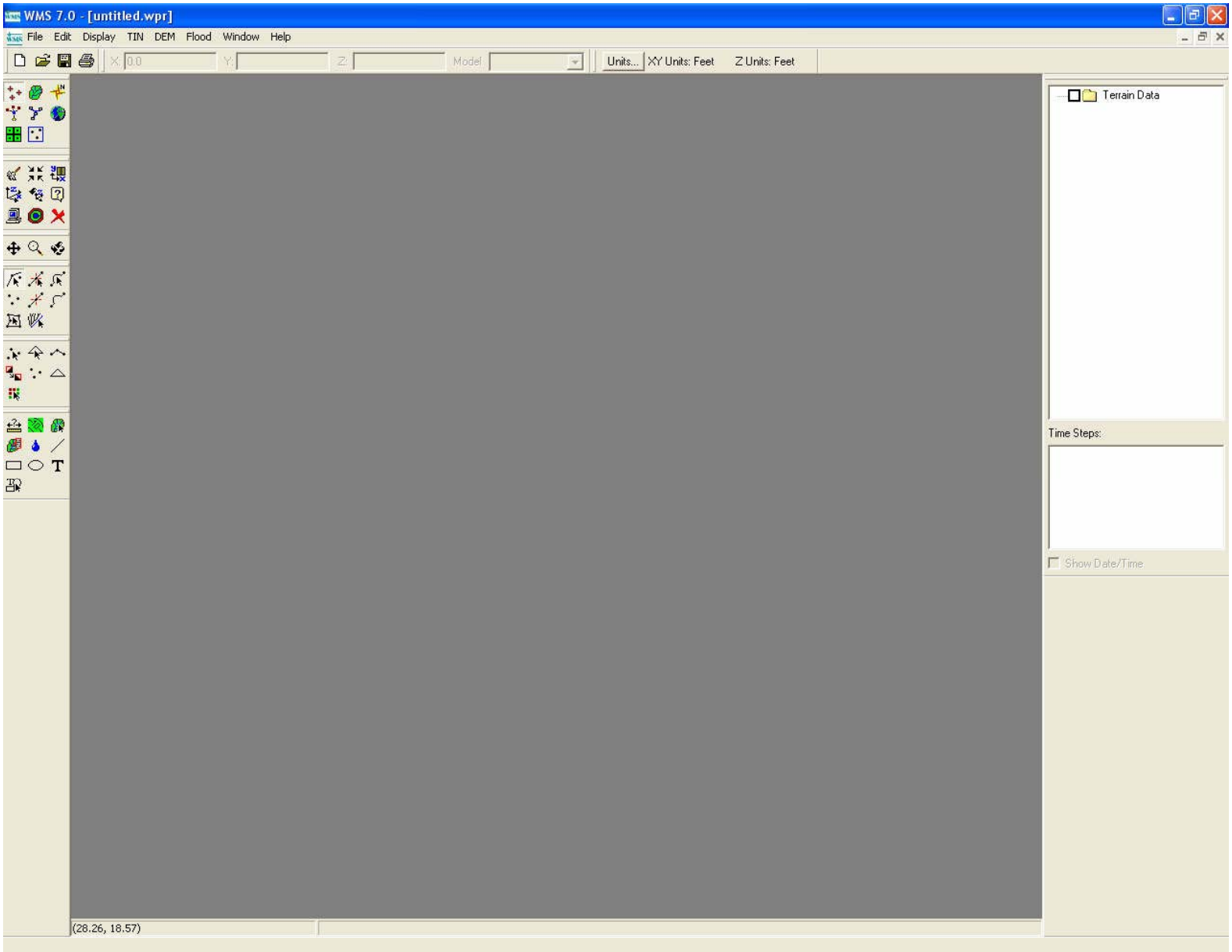


Clairfield Elementary School and Floodplain

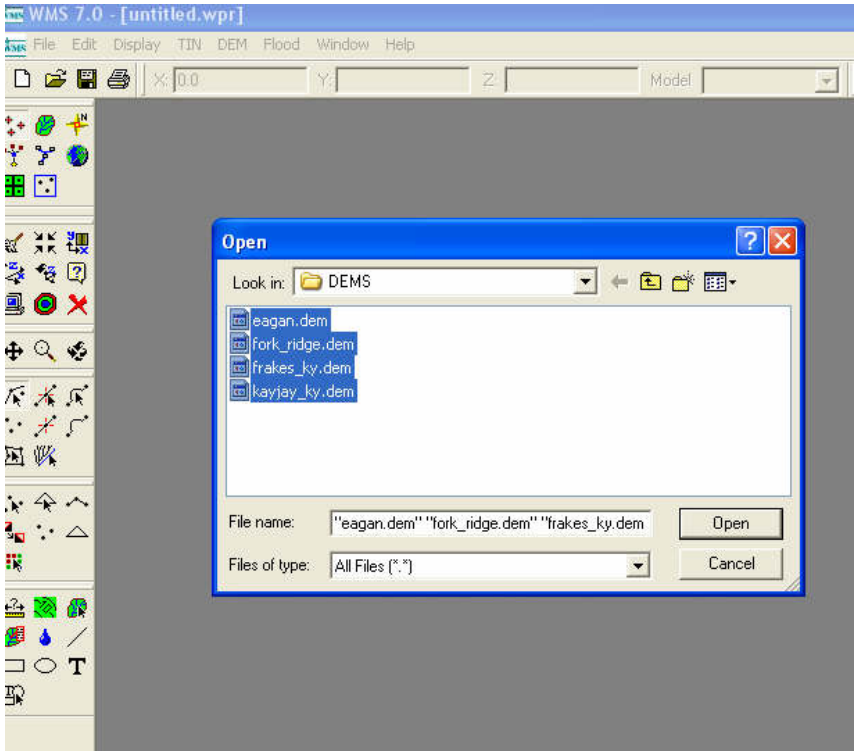
Clear Fork Looking Upstream Behind School

Clear Fork Looking Downstream Behind School

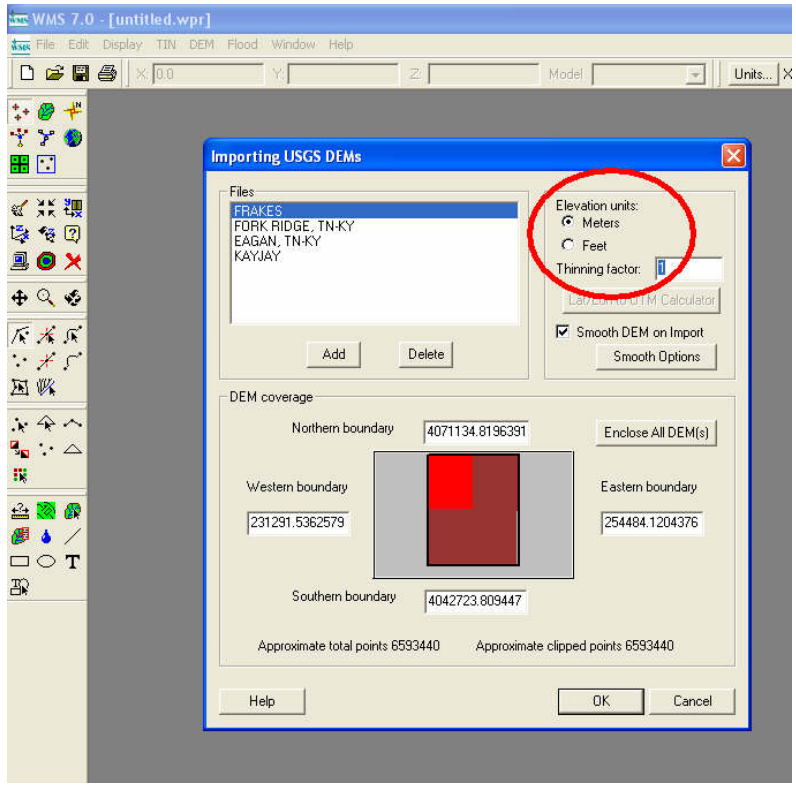
WMS Uses Standardized ESM-I Workspace Configuration



Bring in digital topographic data (DEMs in this case) as the basis for digital terrain model development

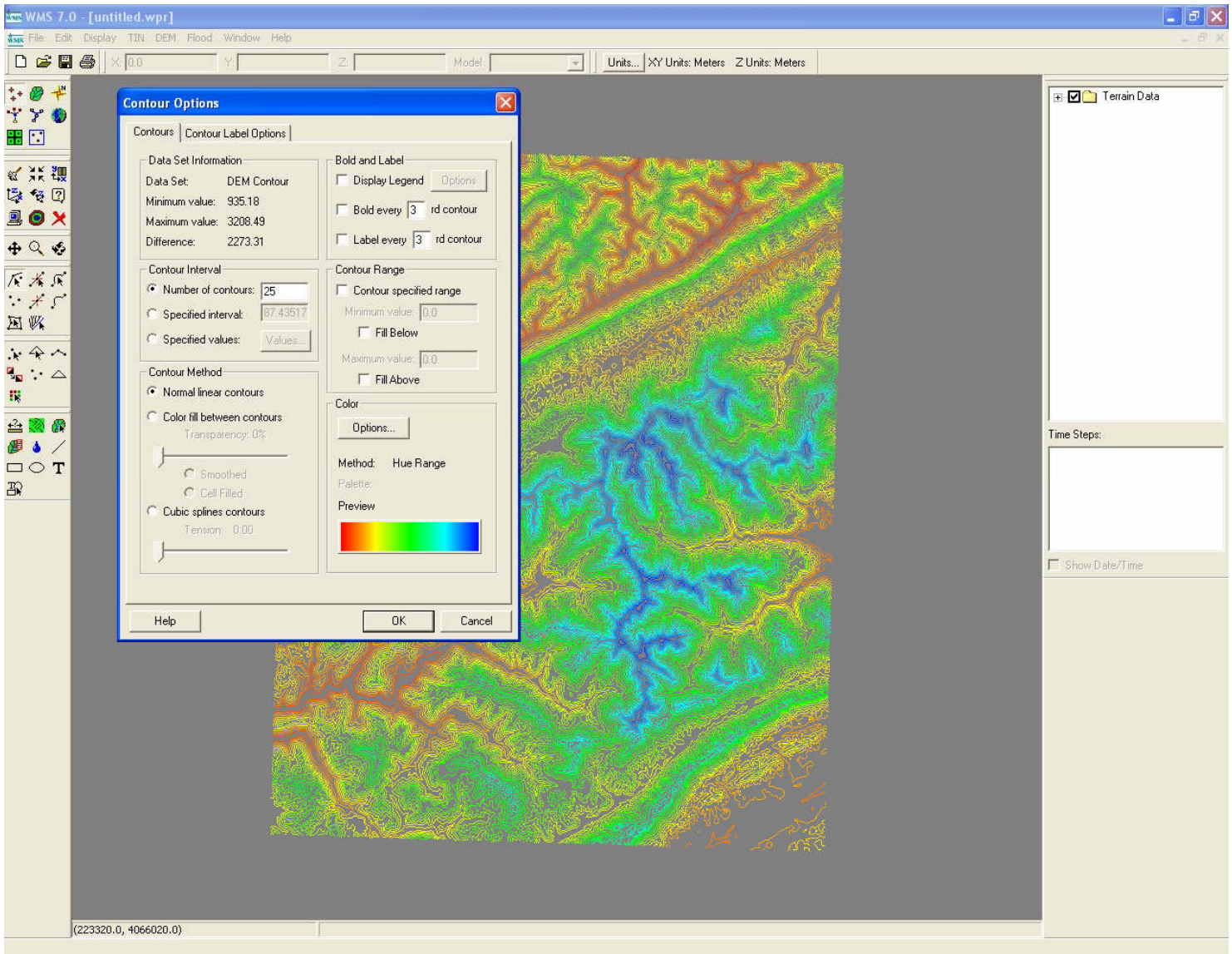


Open USGS DEMS

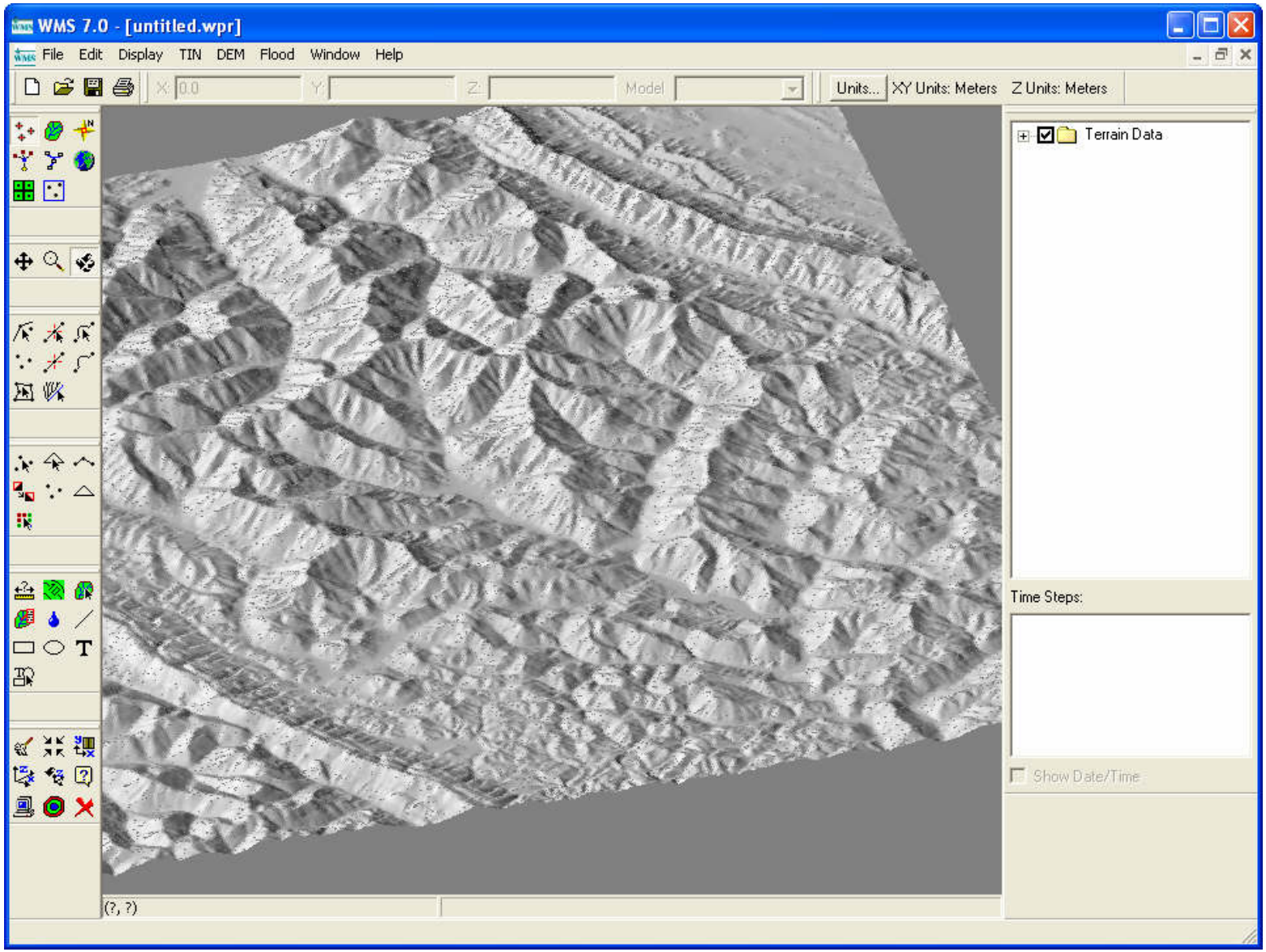


Set Elevation Units and Thinning Factors

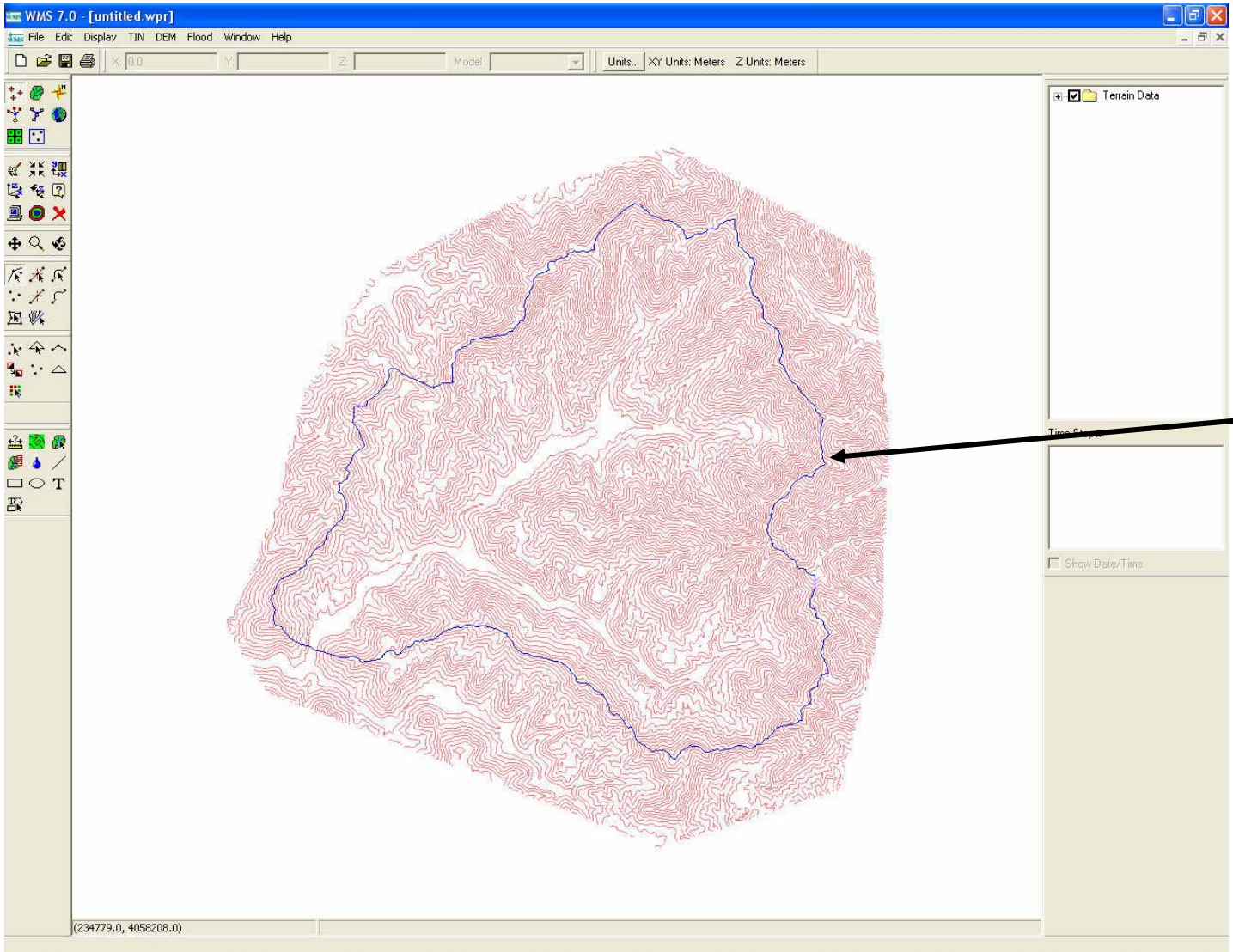
WMS Provides GIS Capabilities, e.g., User Defined Contouring Preferences



And, Shading and 3D Perspective View

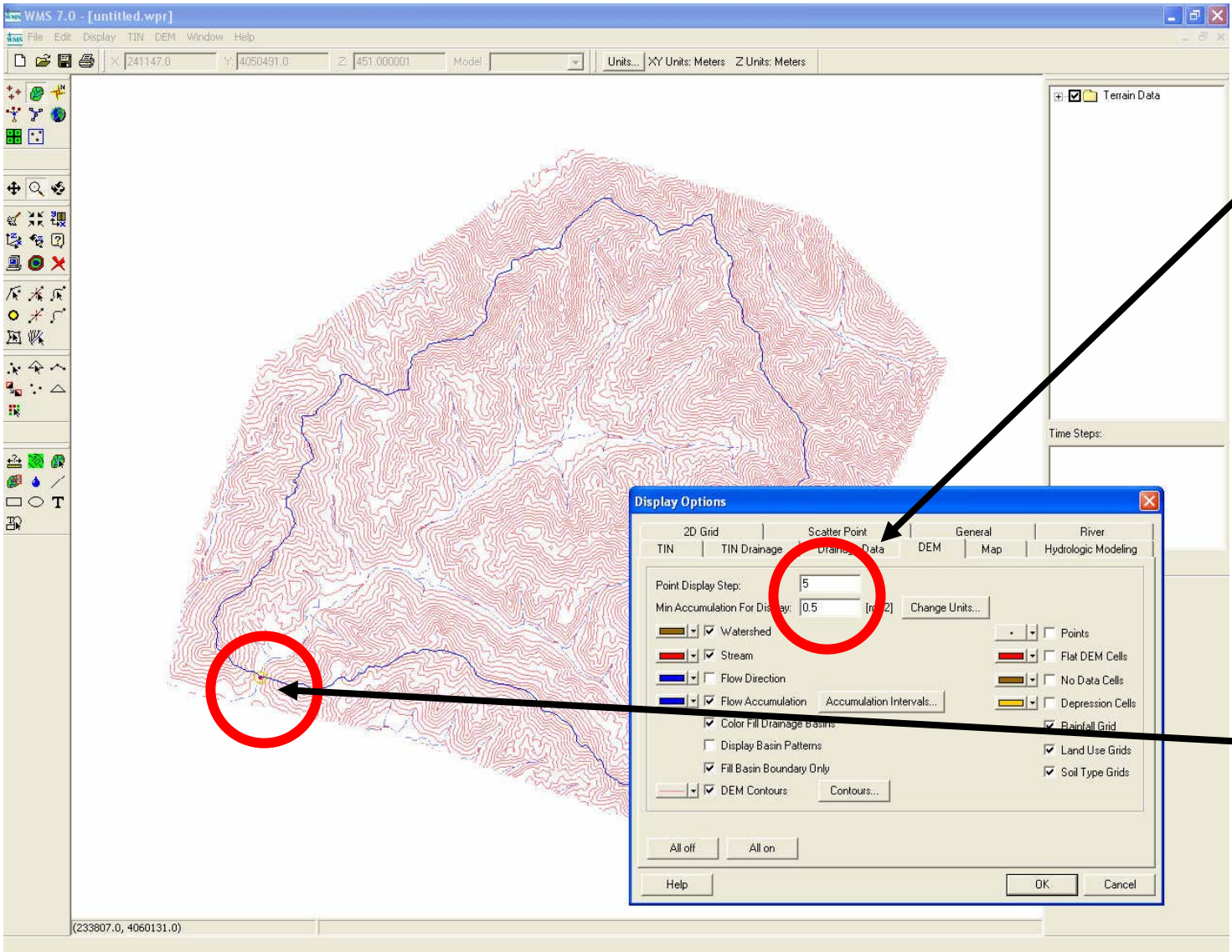


DEMs Can Be Clipped to Project Area to Improve System Performance



Watershed Boundary was Easily Brought into WMS as an AutoCAD DWG File and was used as a Reference for Trimming the Cumulative Impact Area out of the DEM

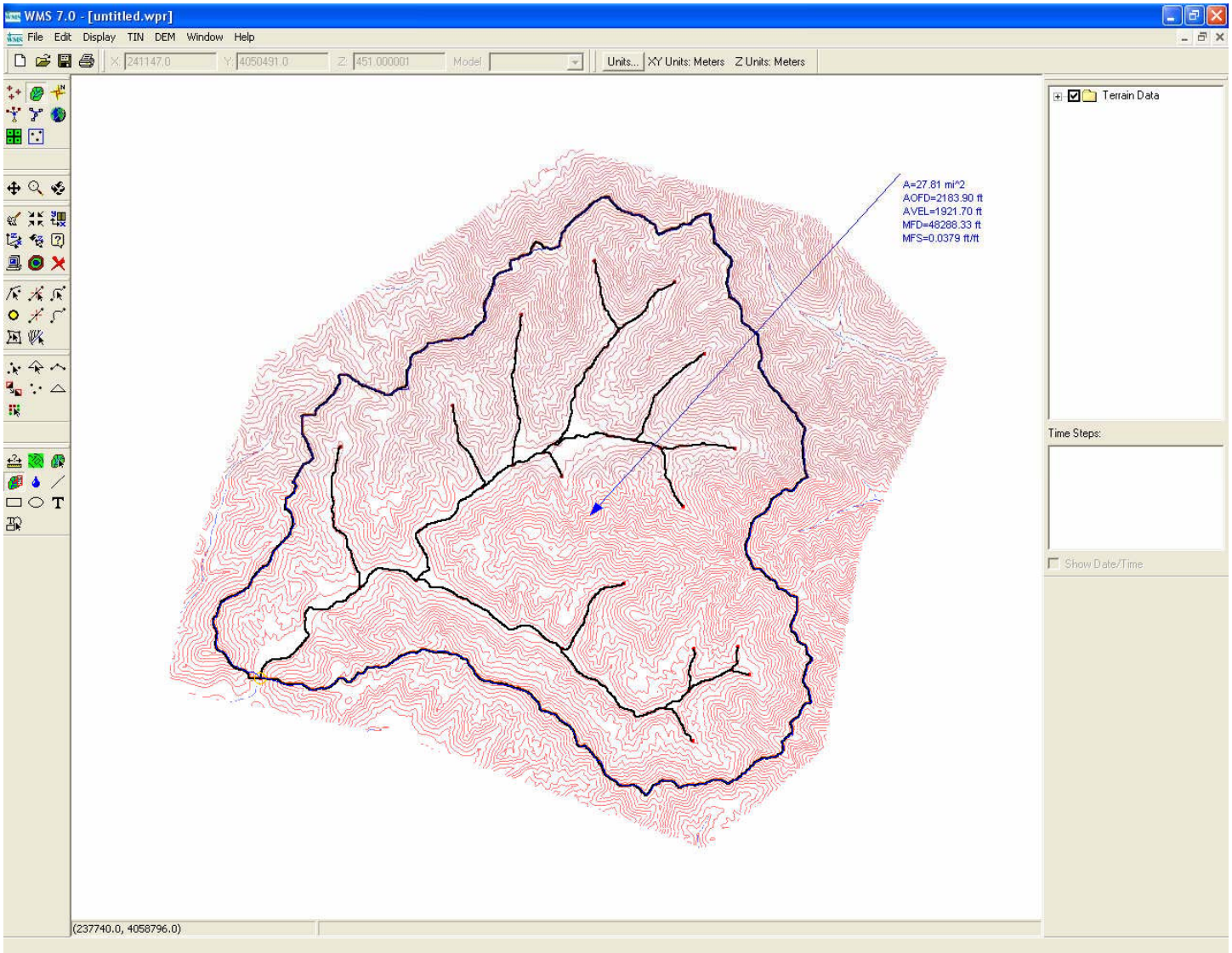
Automatically Calculate Flow Accumulations and Delineate Stream Channels for Specified Drainage Area Using TOPAZ



Specify **Accumulation Threshold**, the drainage area at which WMS begins generating flow arcs

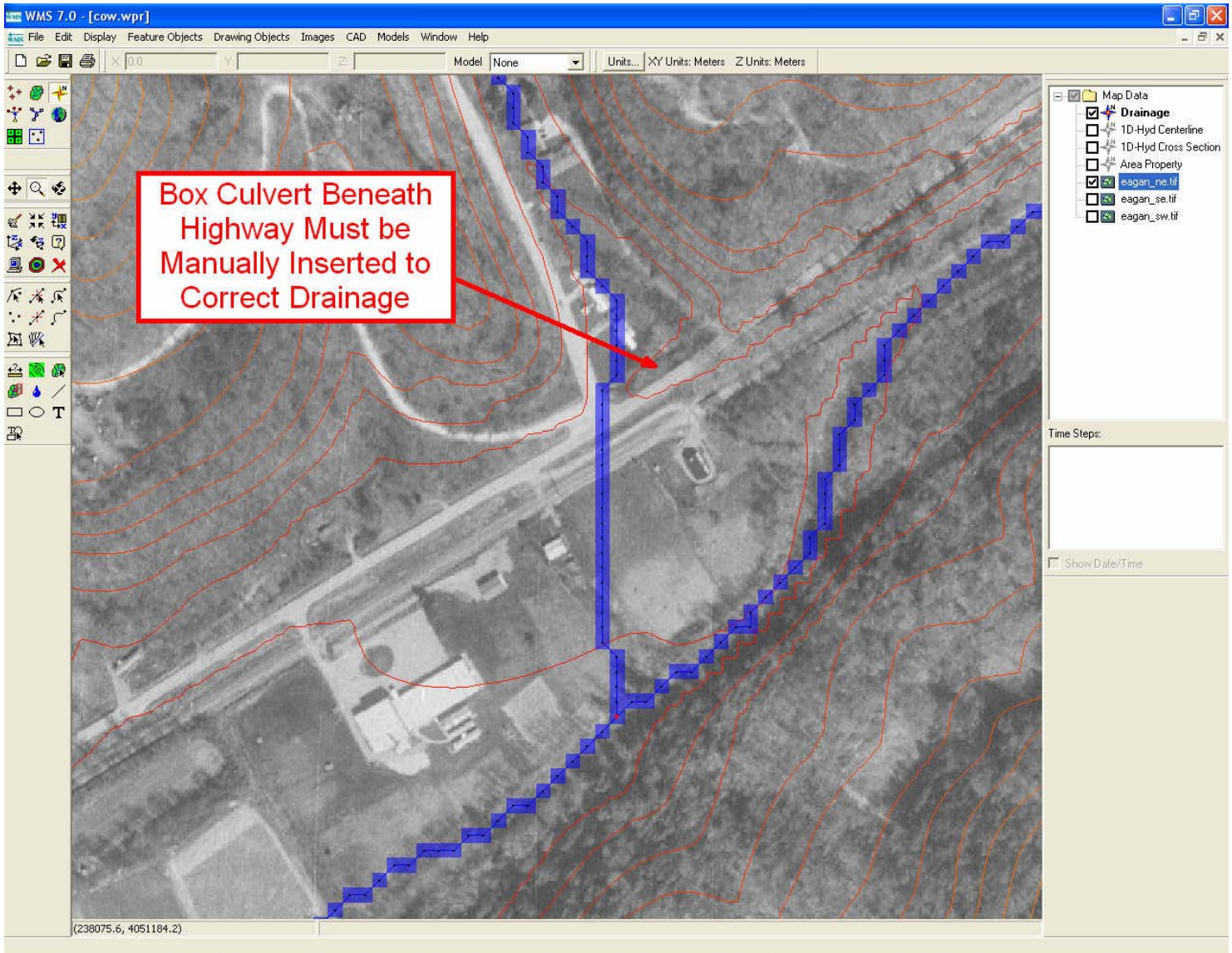
Specify the **Drainage Outlet** for the watershed basin on the resulting stream arc

TOPAZ / WMS Computes Stream Arcs and Basin Boundary

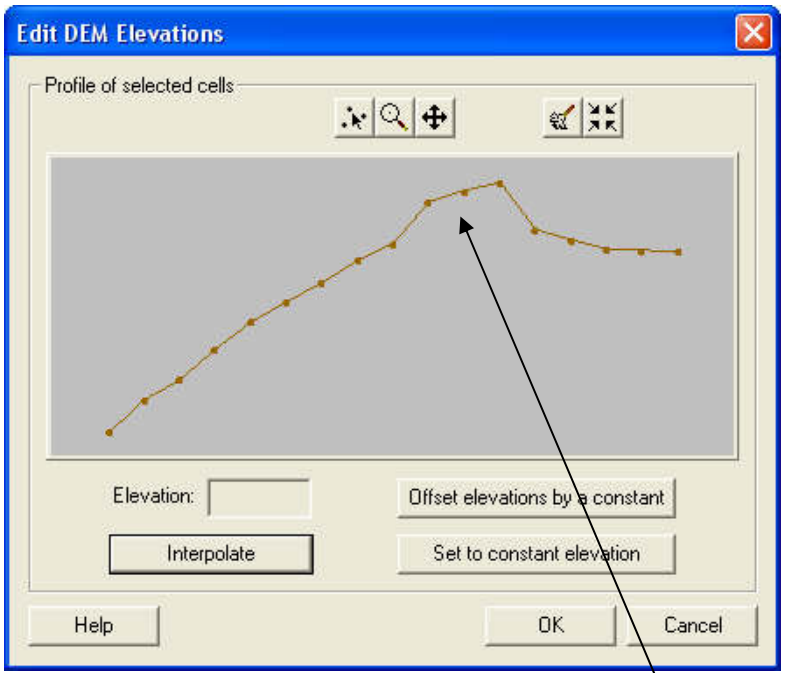


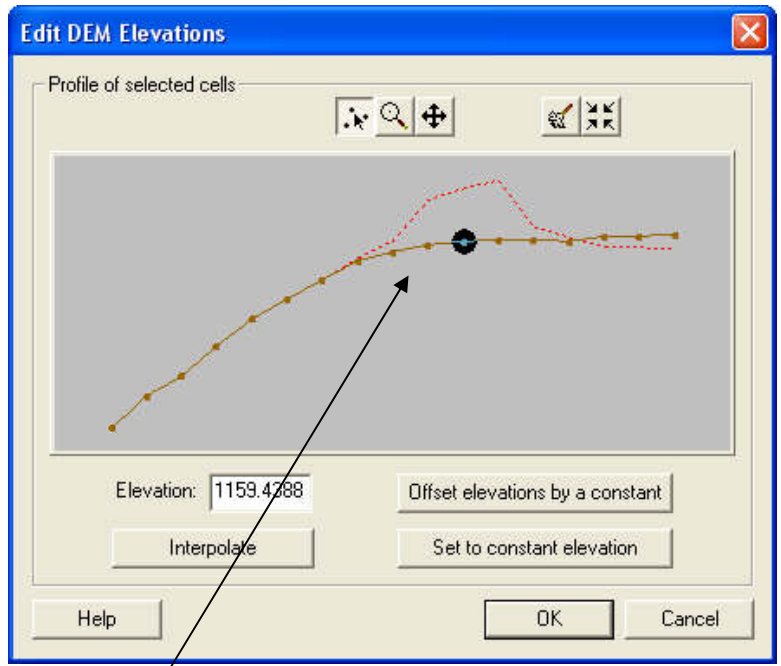
Generated Feature Objects are Used in the Hydrologic Models

Stream Arcs Can Be Edited in WMS to Correct Errors, e.g., Diversions by Culverts, Embankments, Roadways or Ditches



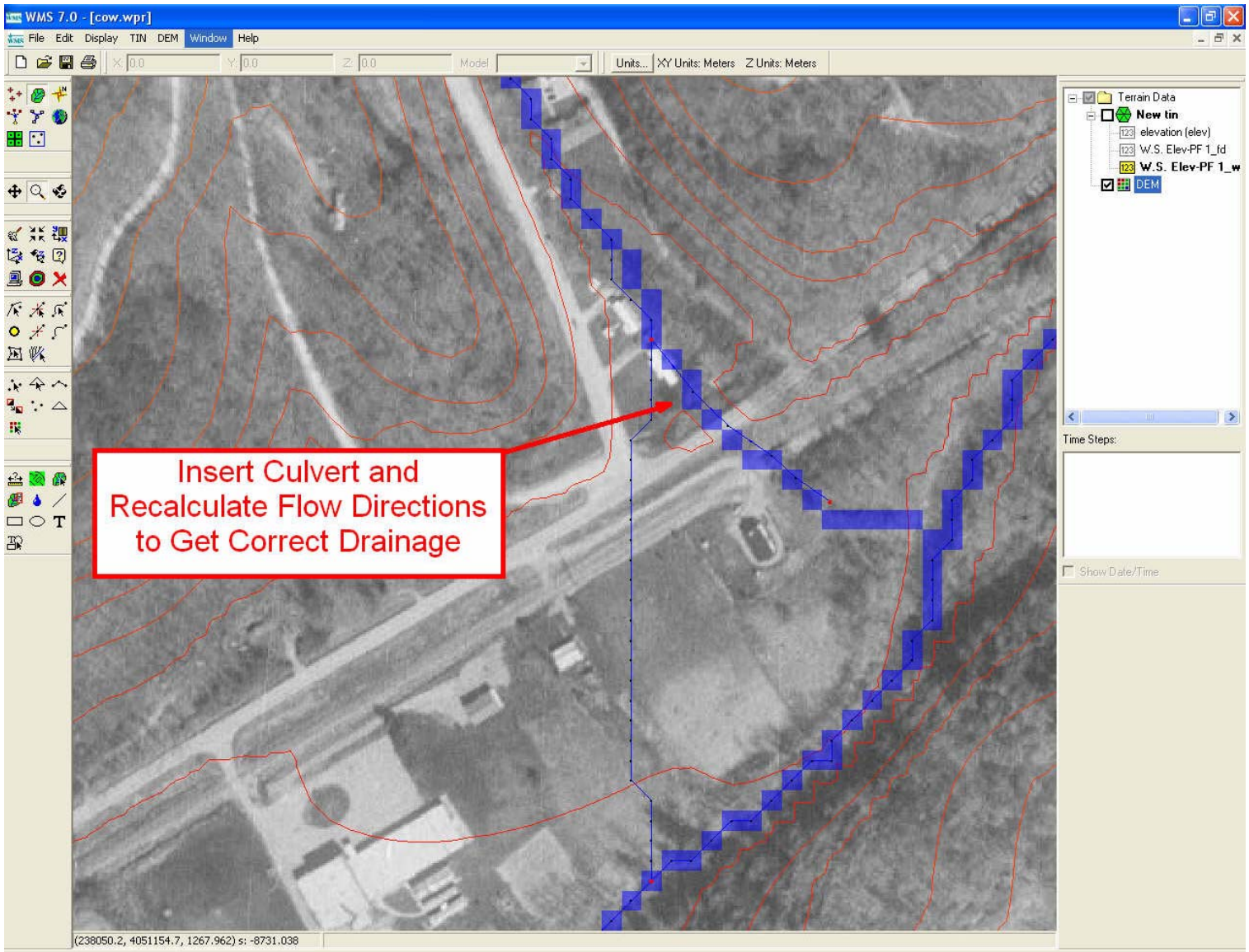
The Box Culvert was Added by Editing the Stream Section Directly Adjacent to the Road Crossing



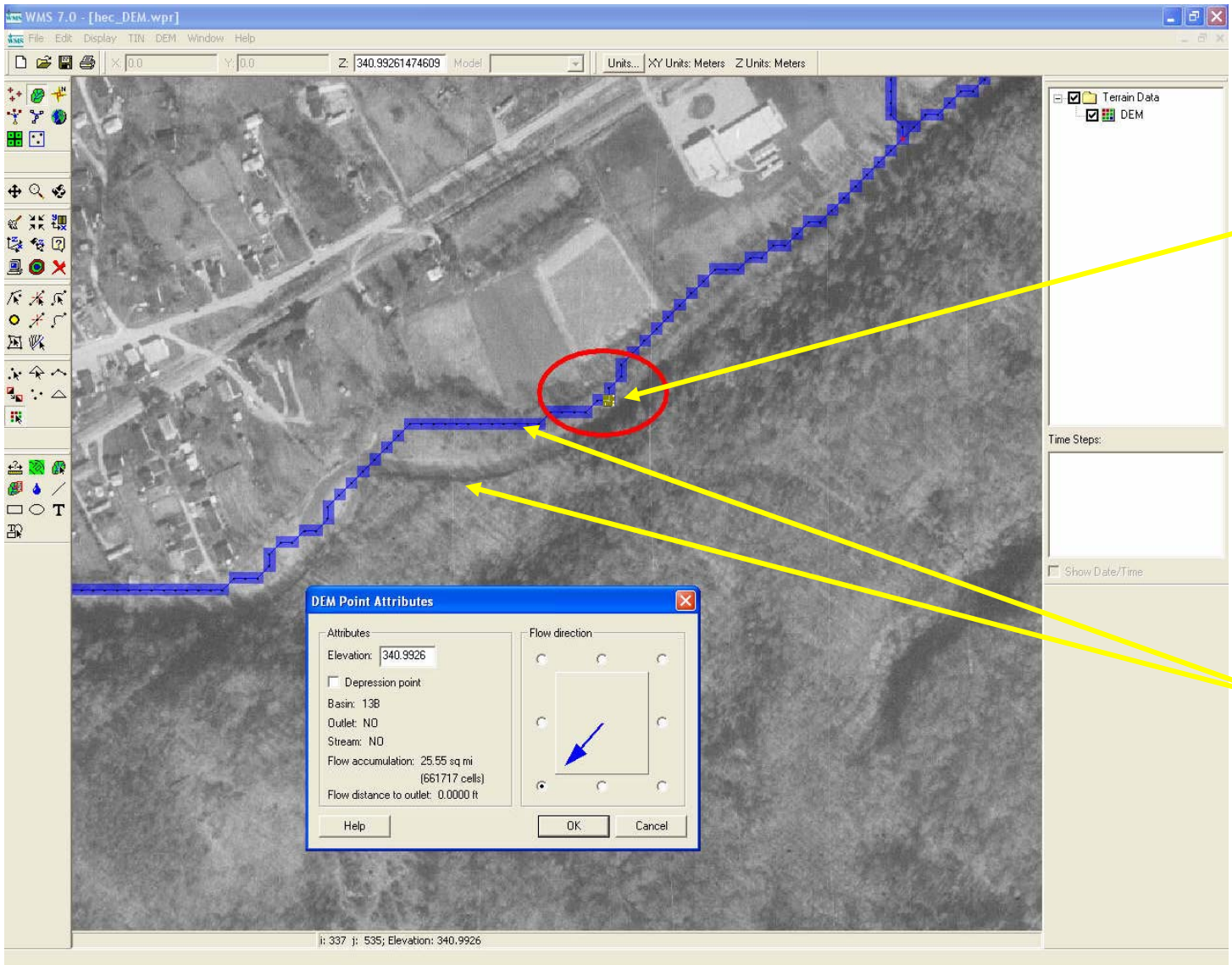


Road Embankment Detected by the DTM Which is Removed or Lowered along the Stream

Once the Culvert is Inserted, the Drainage Can be Recalculated Based on the Revised Topography



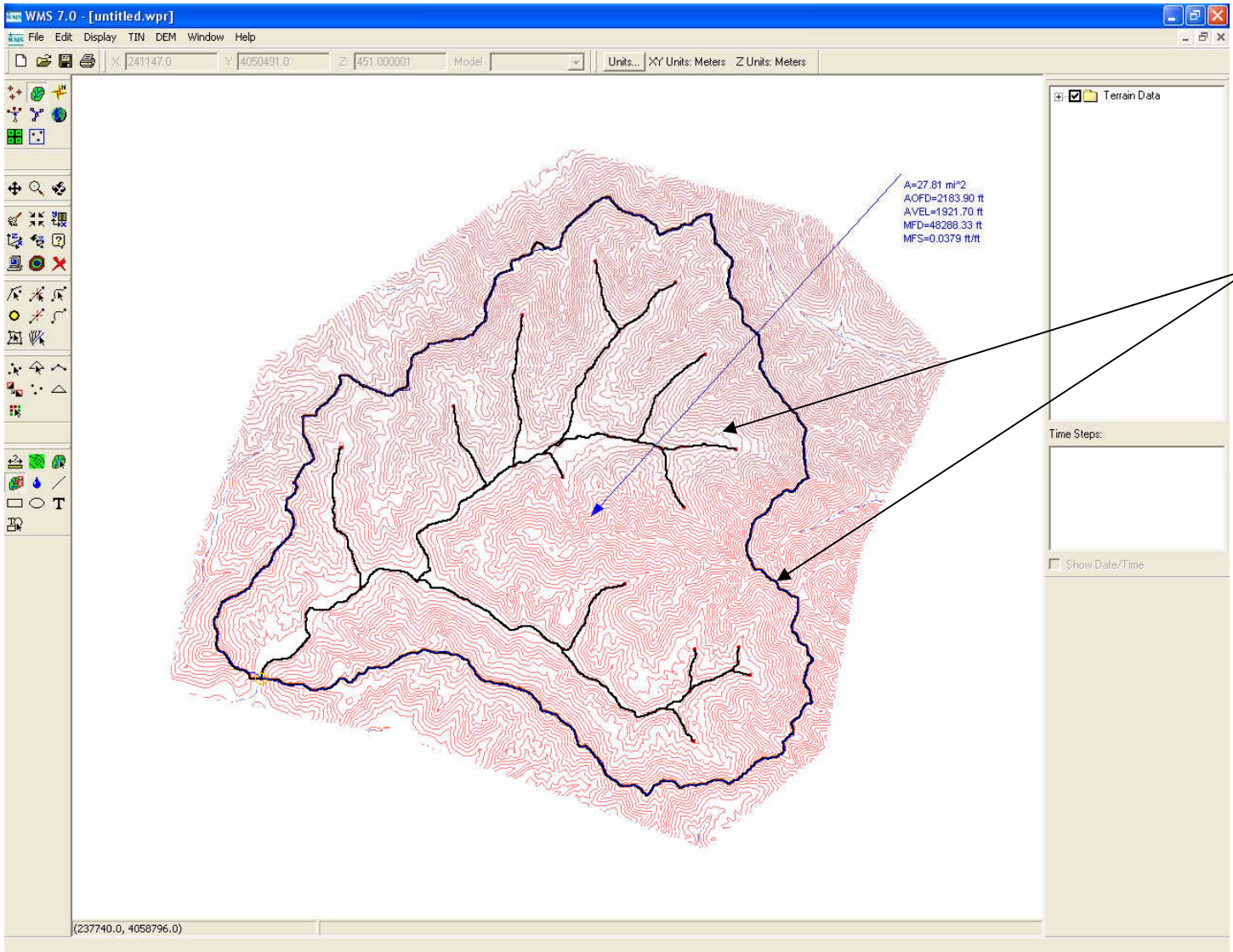
Flow Path Can Also be Edited to Correct DEM Irregularities or Lack of Data Points, Especially in Low Gradient Areas



You Can Specify Individual Pixels and Change the Flow Direction or Redigitize the Stream

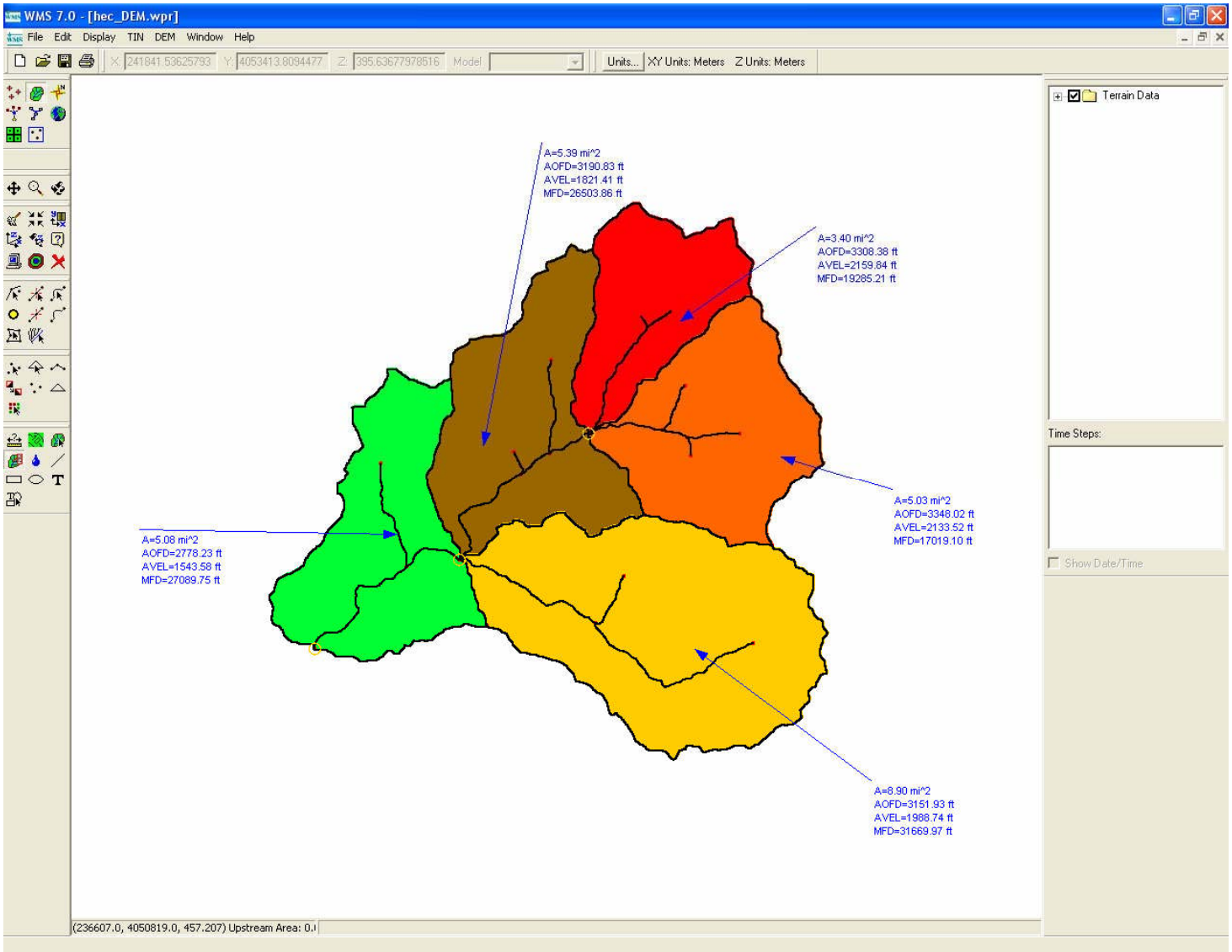
Calculated Stream Channel is Not within Actual Stream

Corrected Stream Arcs and Generated Feature Objects are Recomputed & Used in the Hydrologic Models

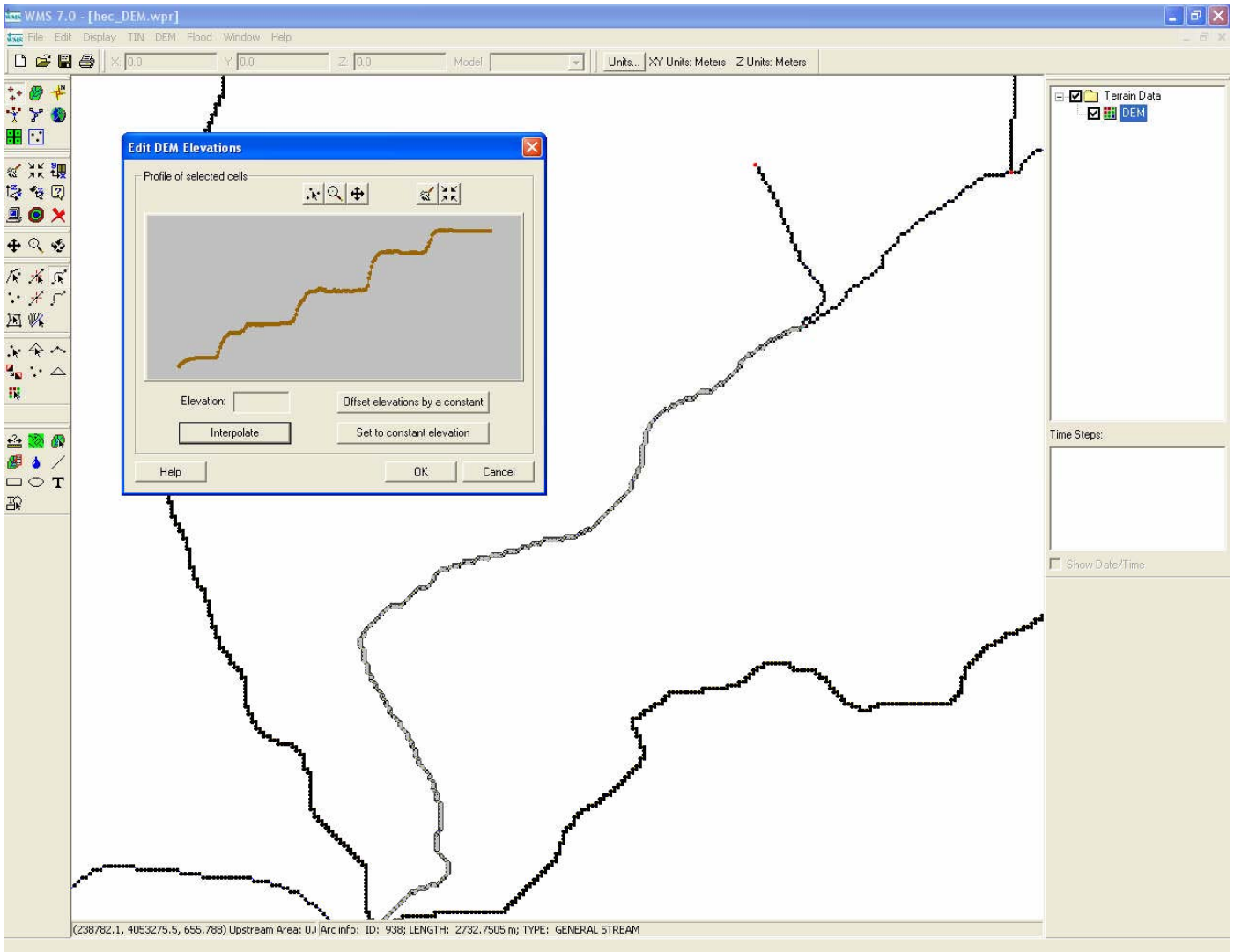


Feature Objects (Basin Boundary and Stream Arcs) can be Imported into WMS or Exported for Use in Other Applications

Watershed Topology of the Watershed can be Defined by adding Outlets to Major Sub-Basins

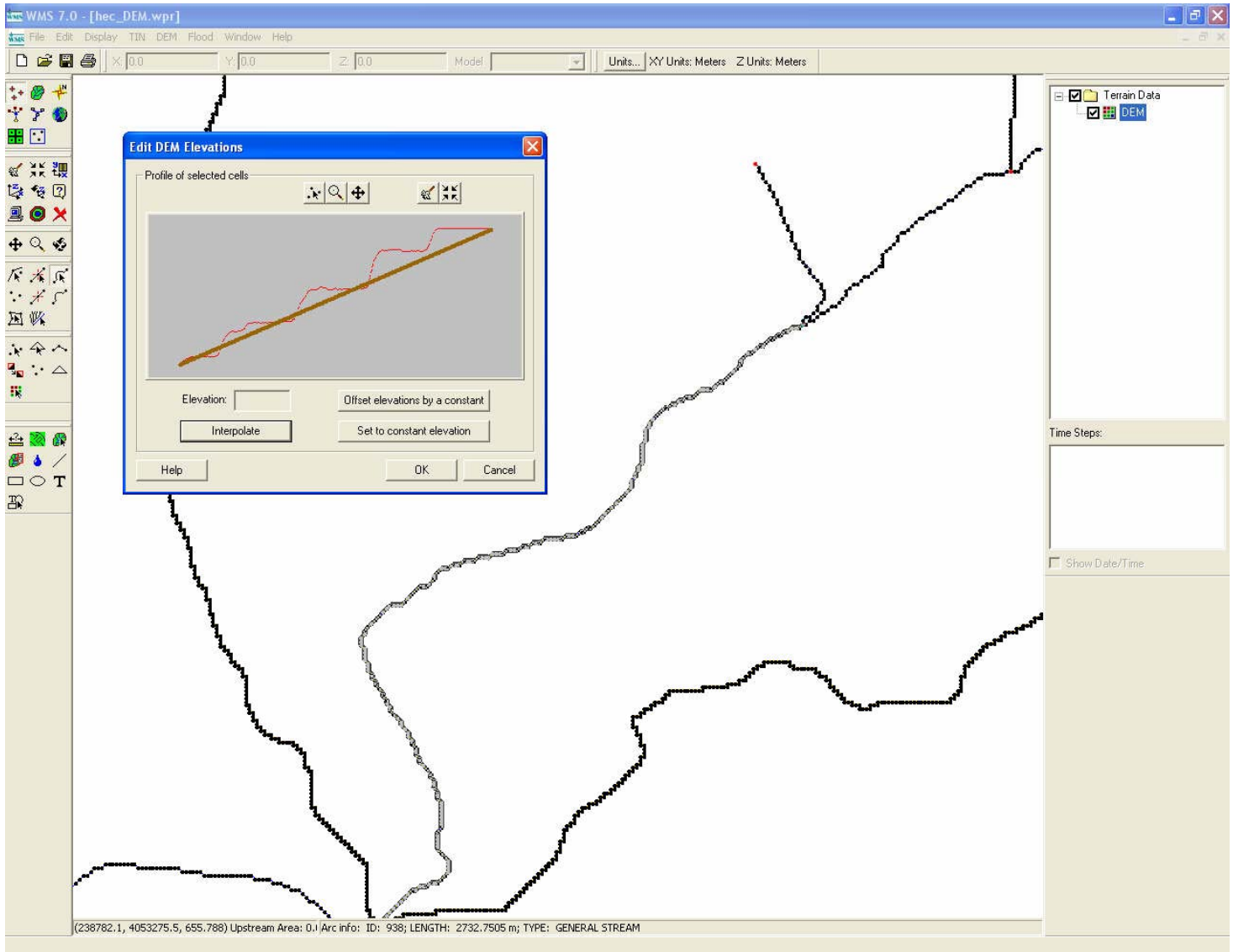


Stream Channel Profiles Can be Edited Prior to Running Hydrologic Models to Smooth Irregularities Caused DEM Cell Spacing

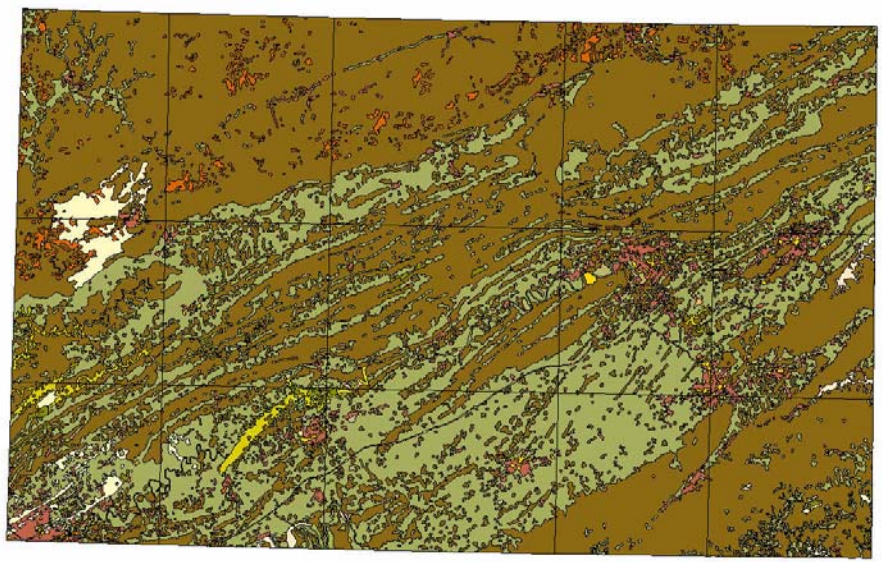


Stream Arcs can be Broken into Smaller Sections before Interpolating or Smoothing the Data and Then Joined Back to Prevent Over Interpolation

WMS Displays the Proposed Interpolated Stream Channel Profile for the Selected Stream Arc

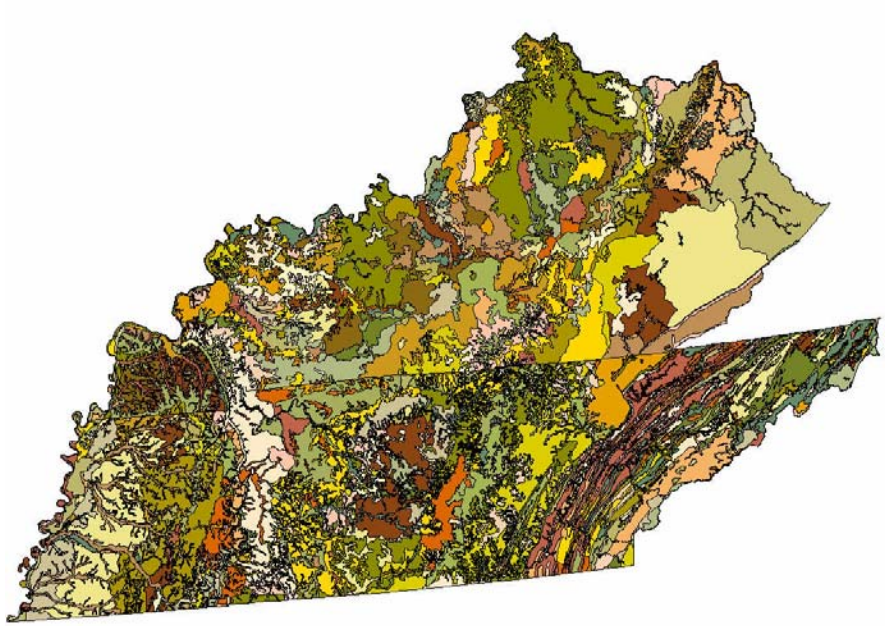


WMS Allows You to Utilize ArcView Shape Files or ArcGIS Coverages to Overlay Land Use and Soils Maps to Assign Curve Numbers within the Watershed



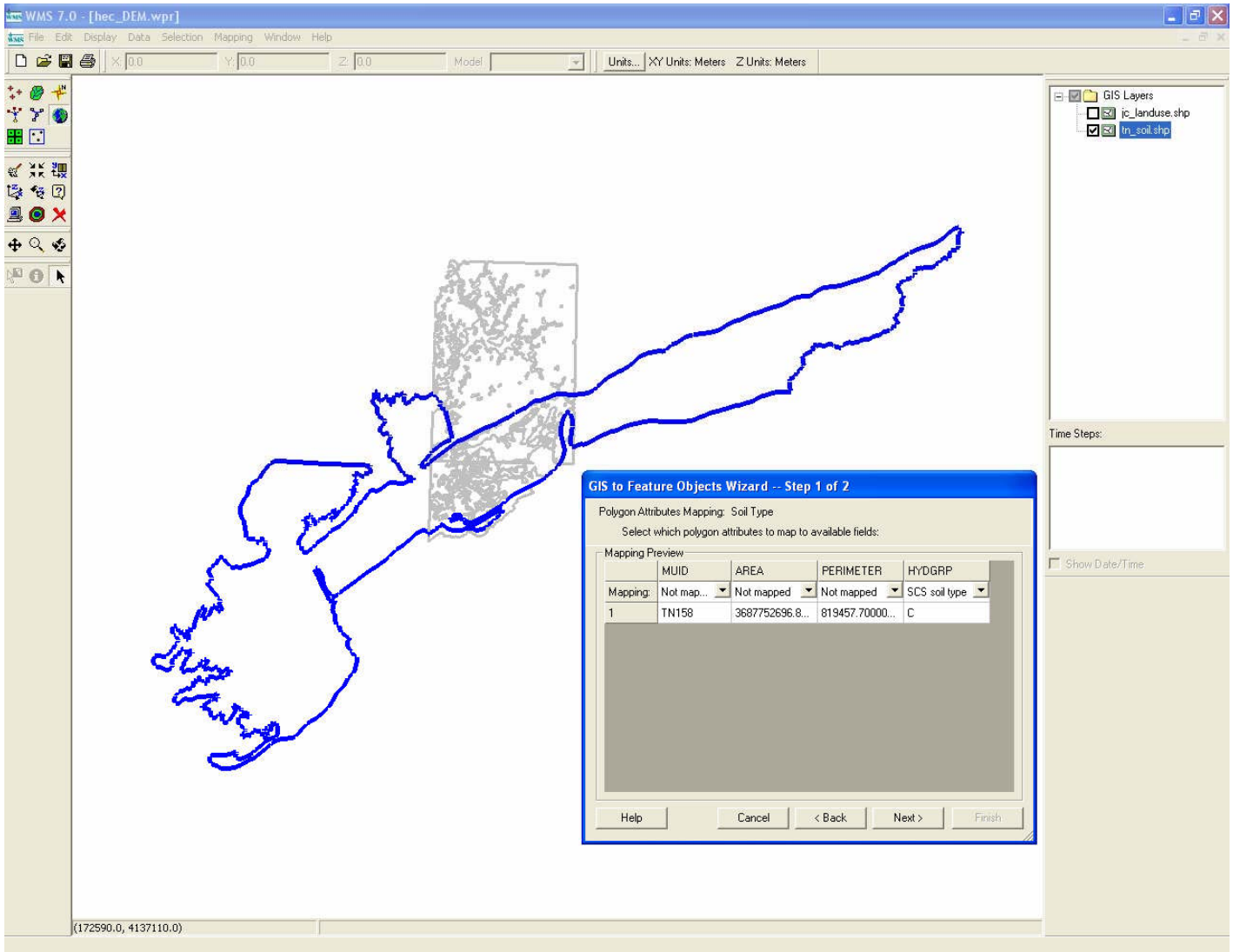
Land use data is available from multiple sources or can be developed from local aerial photography

This is from EPA Landuse / Landcover GIRAS Spatial Database (1:250,000)

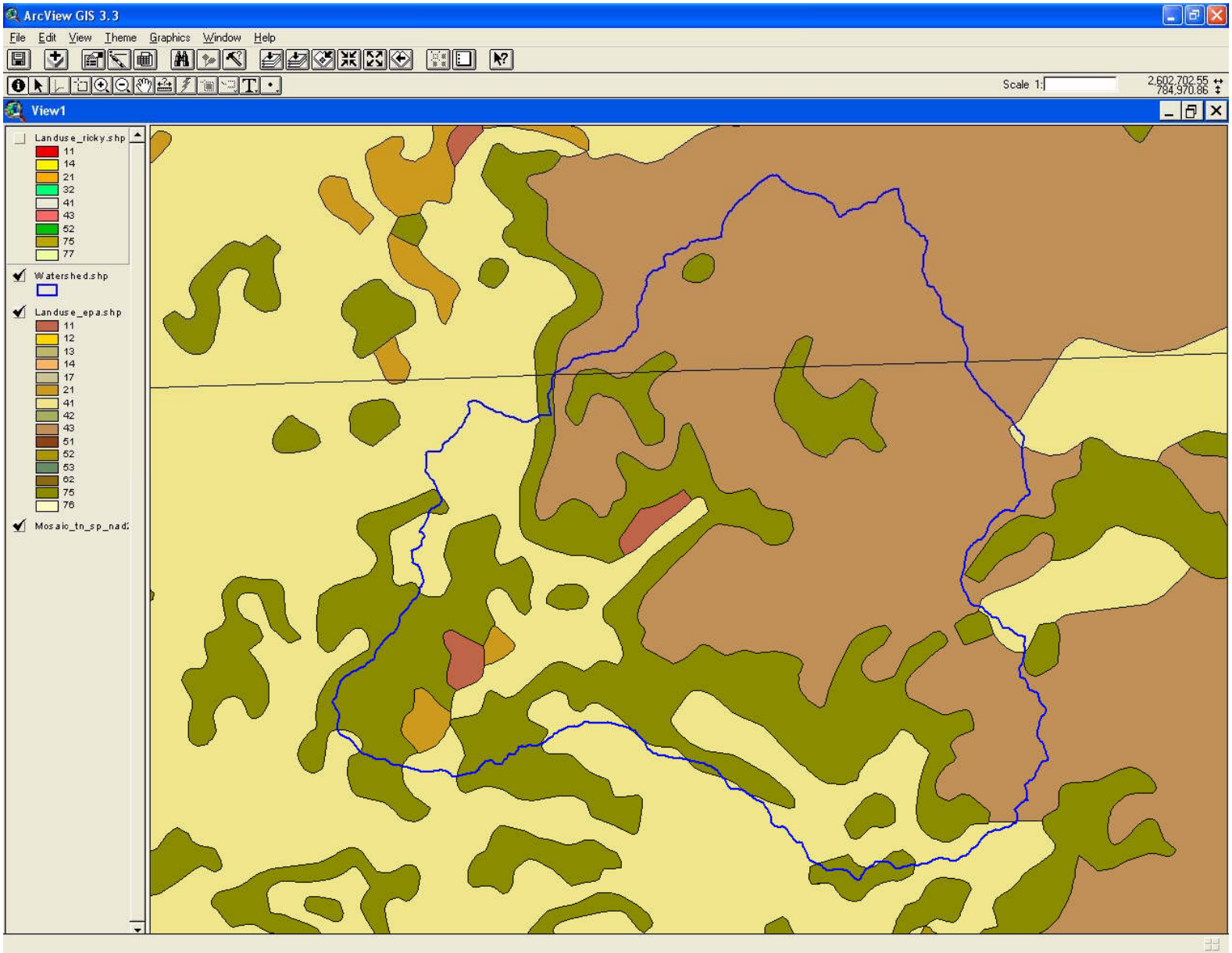


STATSGO (1:250,000) and SSURGO (1:12,000 to 63,360) soils data is available from NRCS in digital format

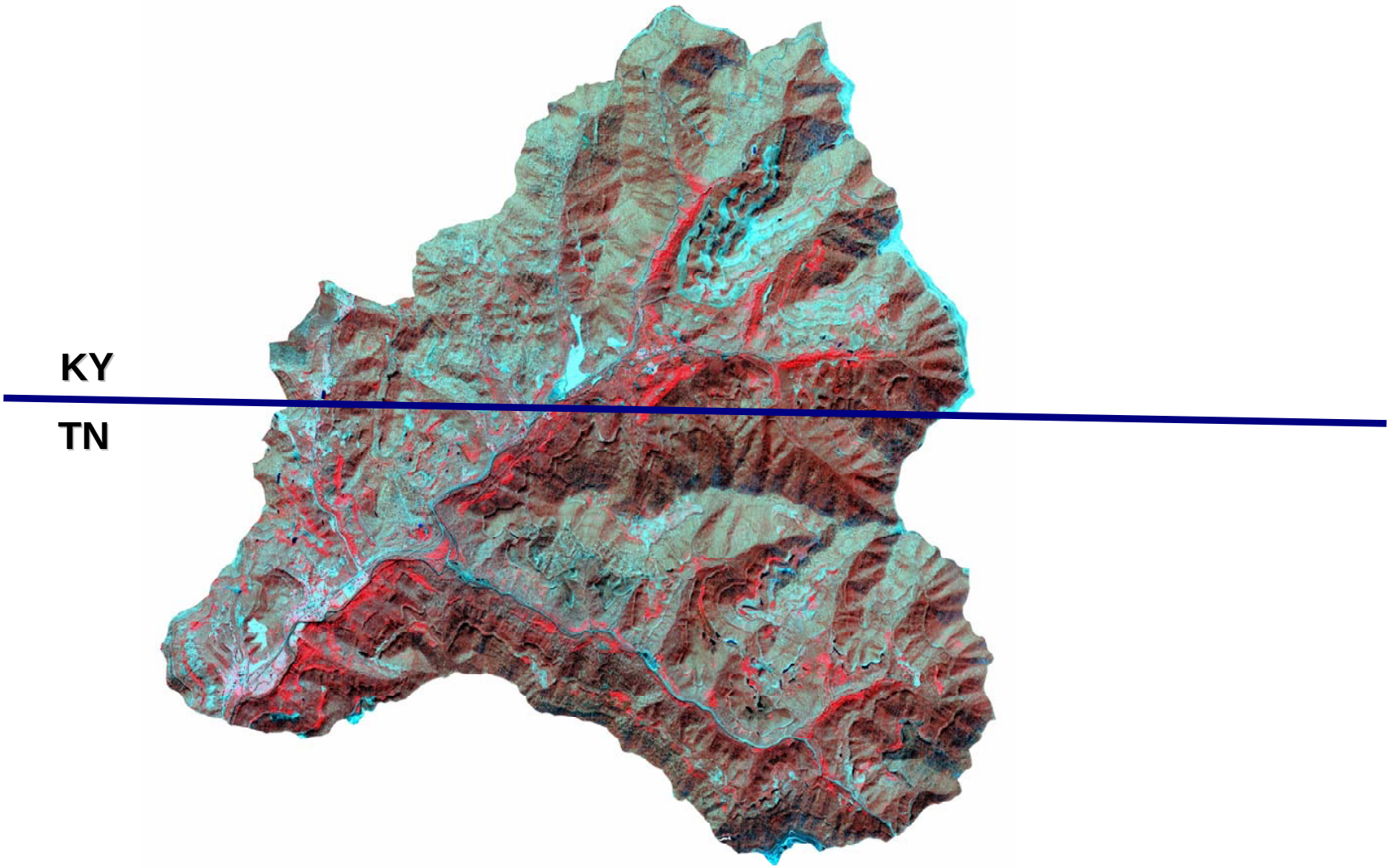
Link the Attribute Tables from the Shape Files or Coverages for the Watershed and Attach the Information to the Resulting Feature Objects



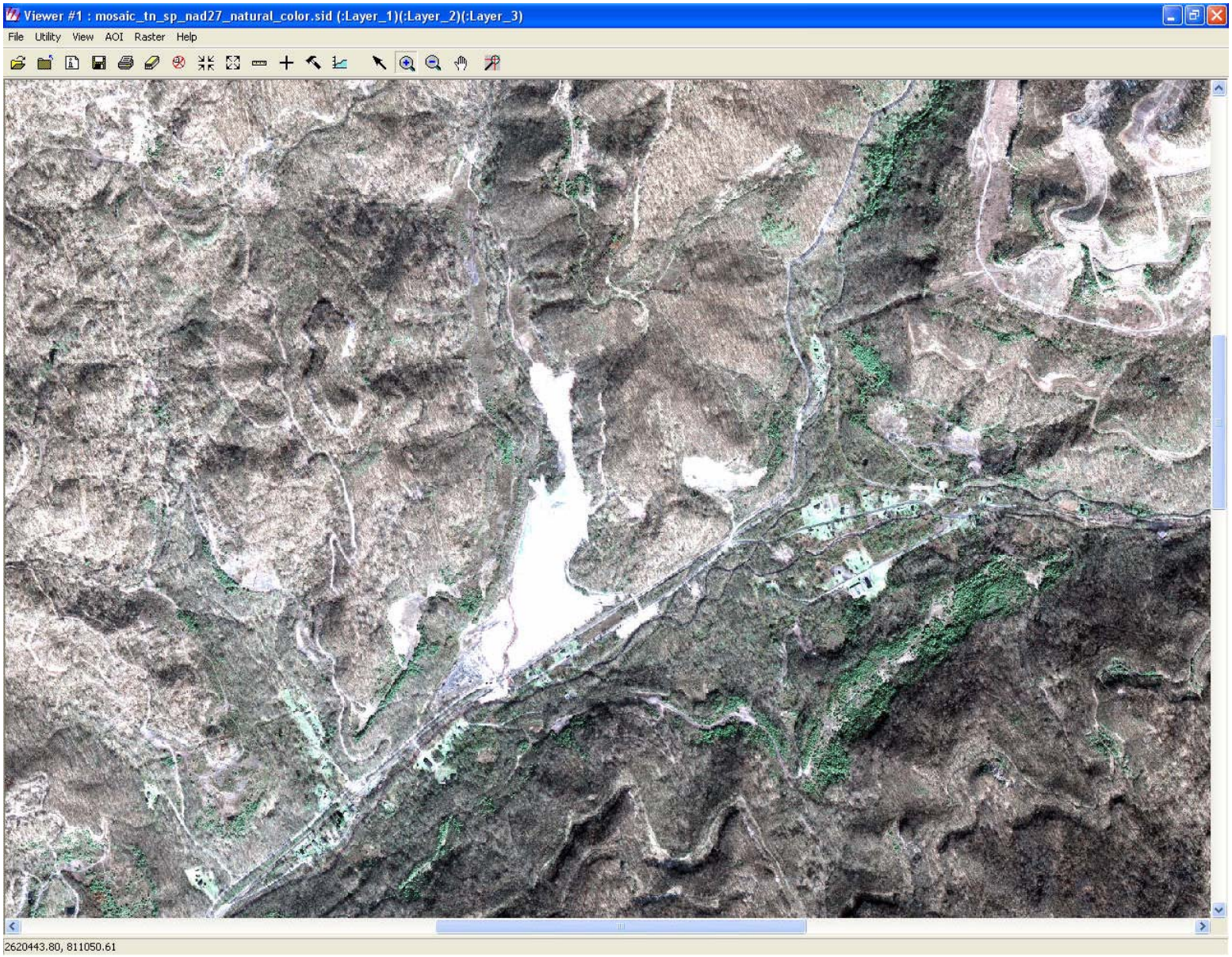
However, Available Land Use and Soils Information was Limited



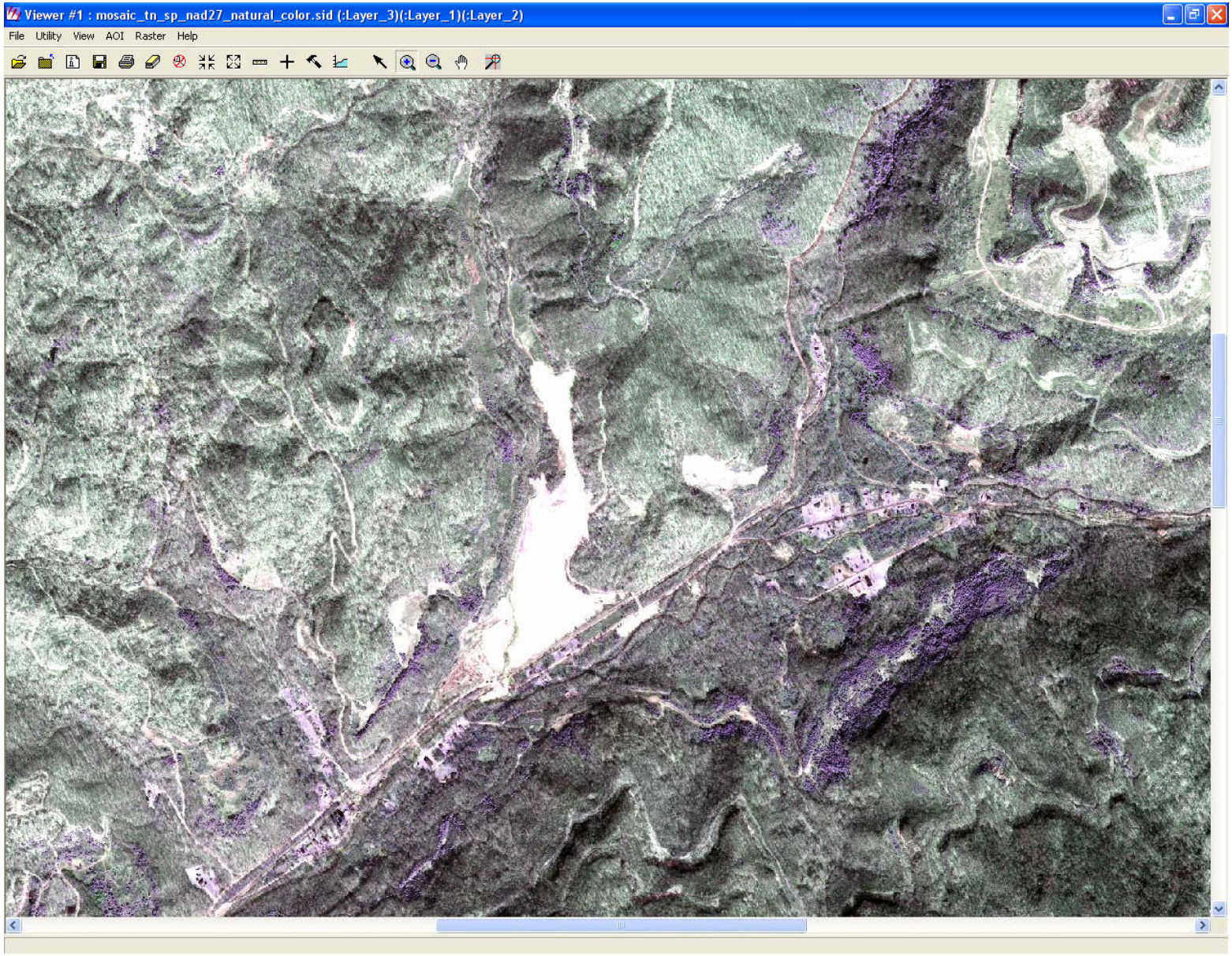
TIPS purchased IKONOS Satellite Imagery to Identify Existing Conditions To Assist in Evaluating Land Uses in the Watershed



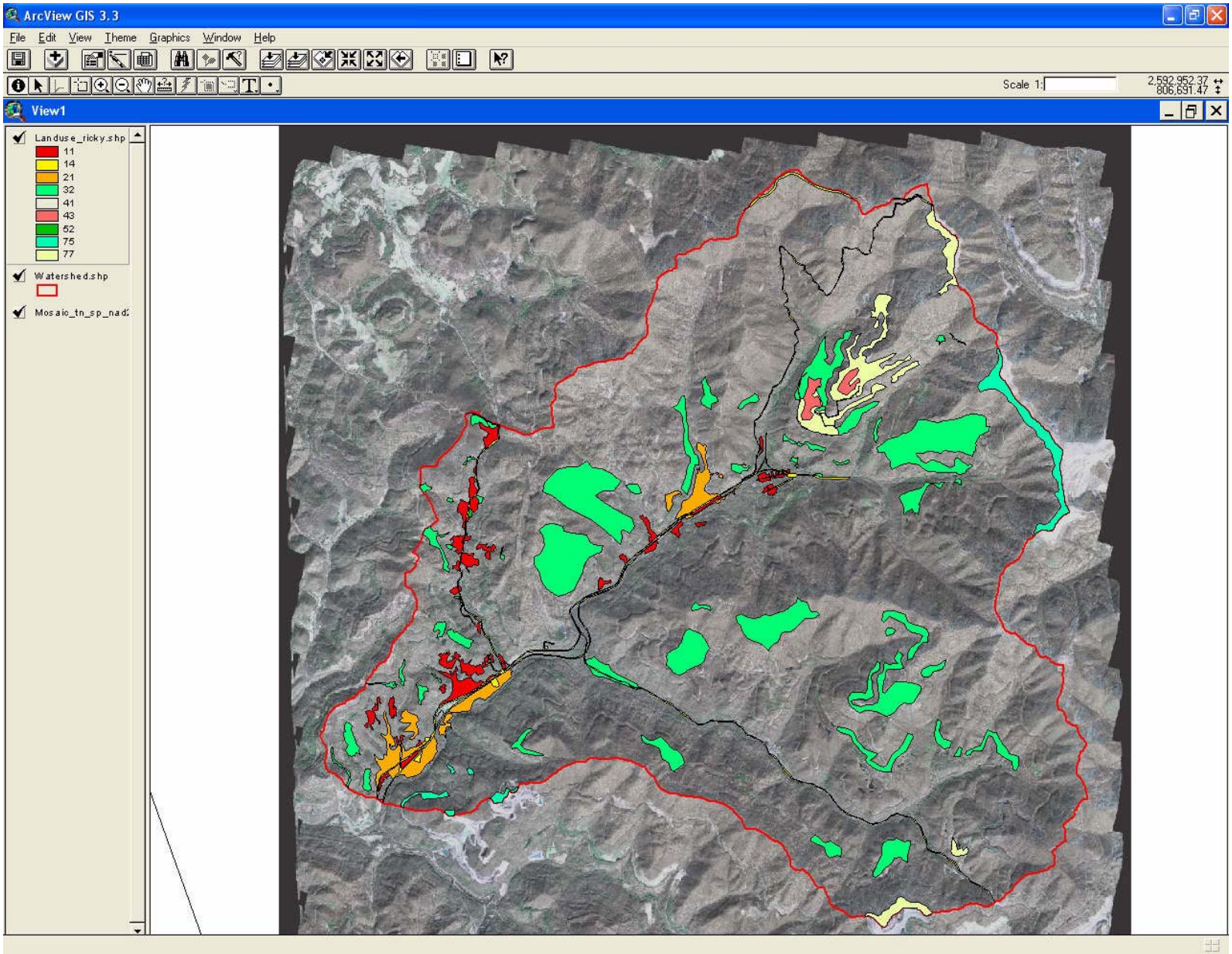
Anderson Level-2 land use classification was attempted with ERDAS Image and ARCGIS Spatial Analyst.



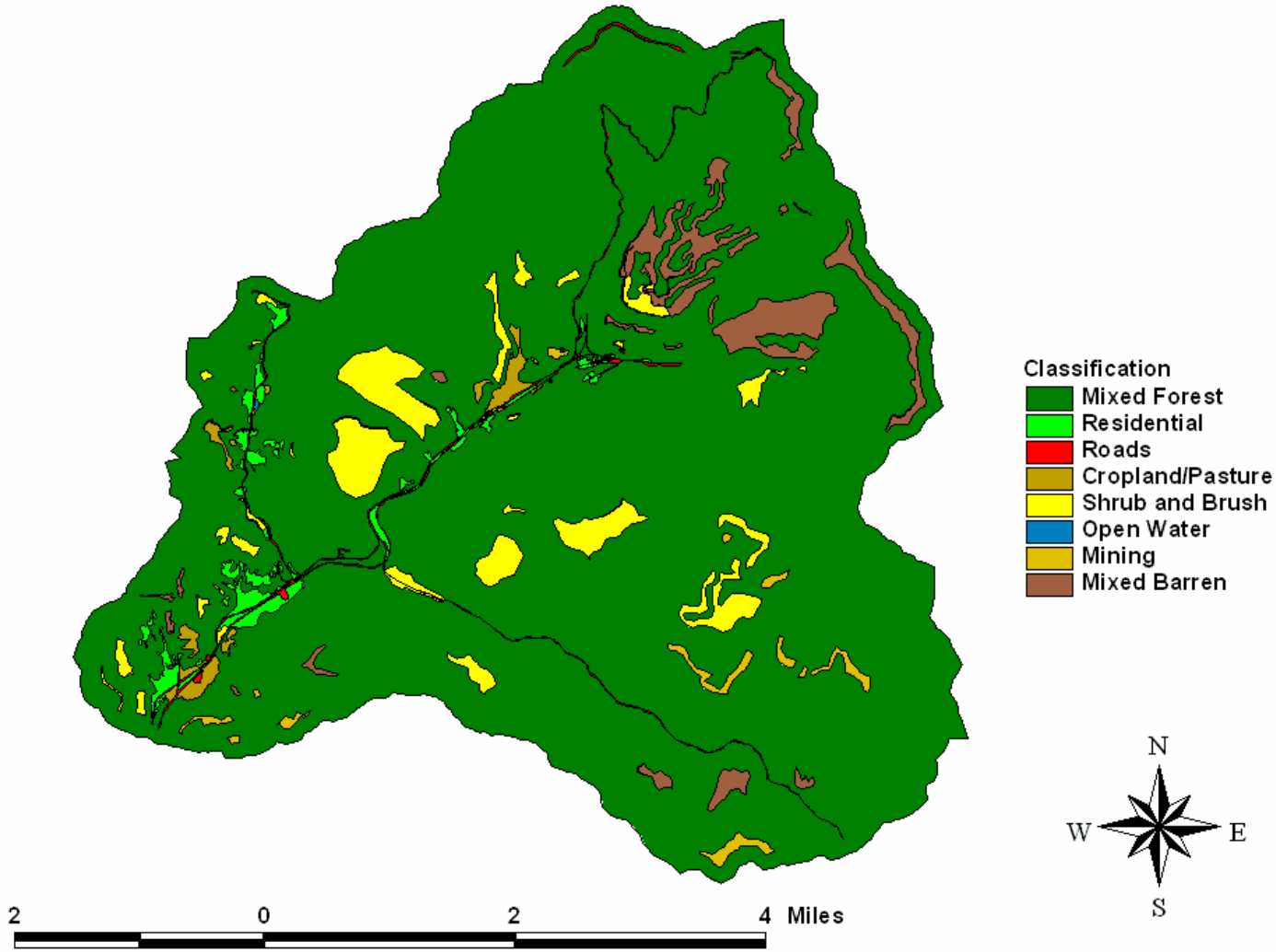
Shadows and Snow Cover along With Poor Definition Failed to Produce a Useful Classification



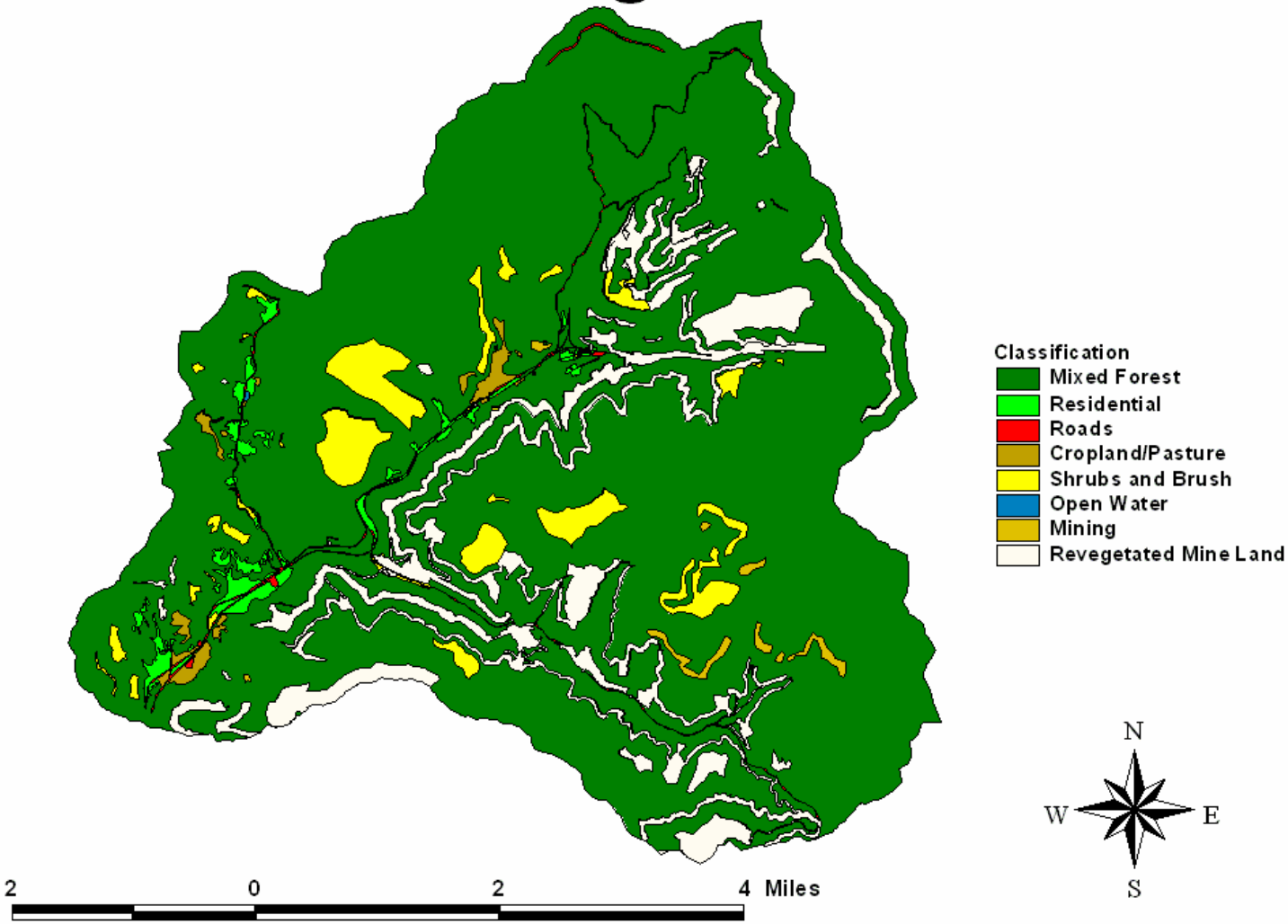
As a result, Land Use was Done by Standard “Heads Up” Digitizing



Premining Land Use



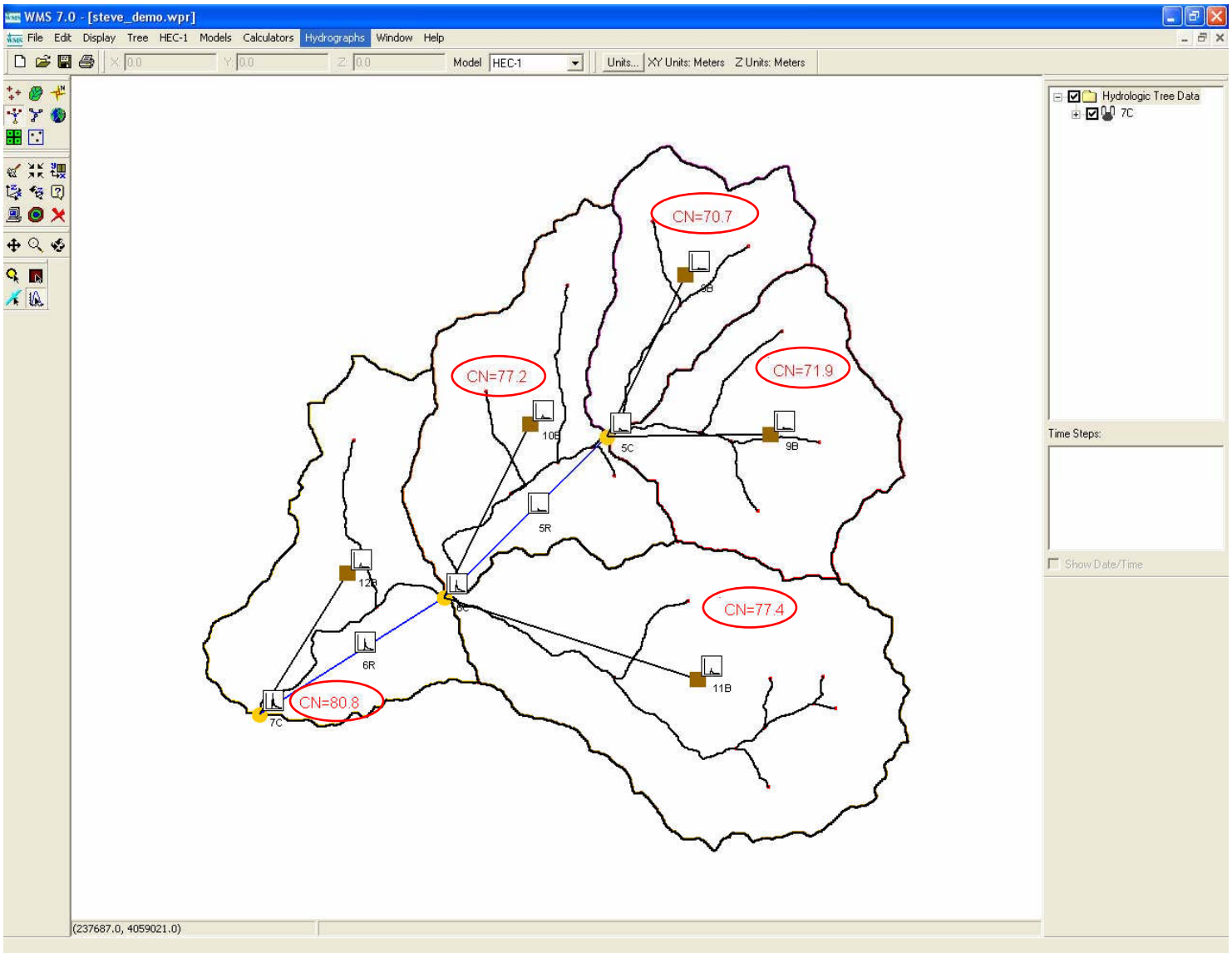
Postmining Land Use



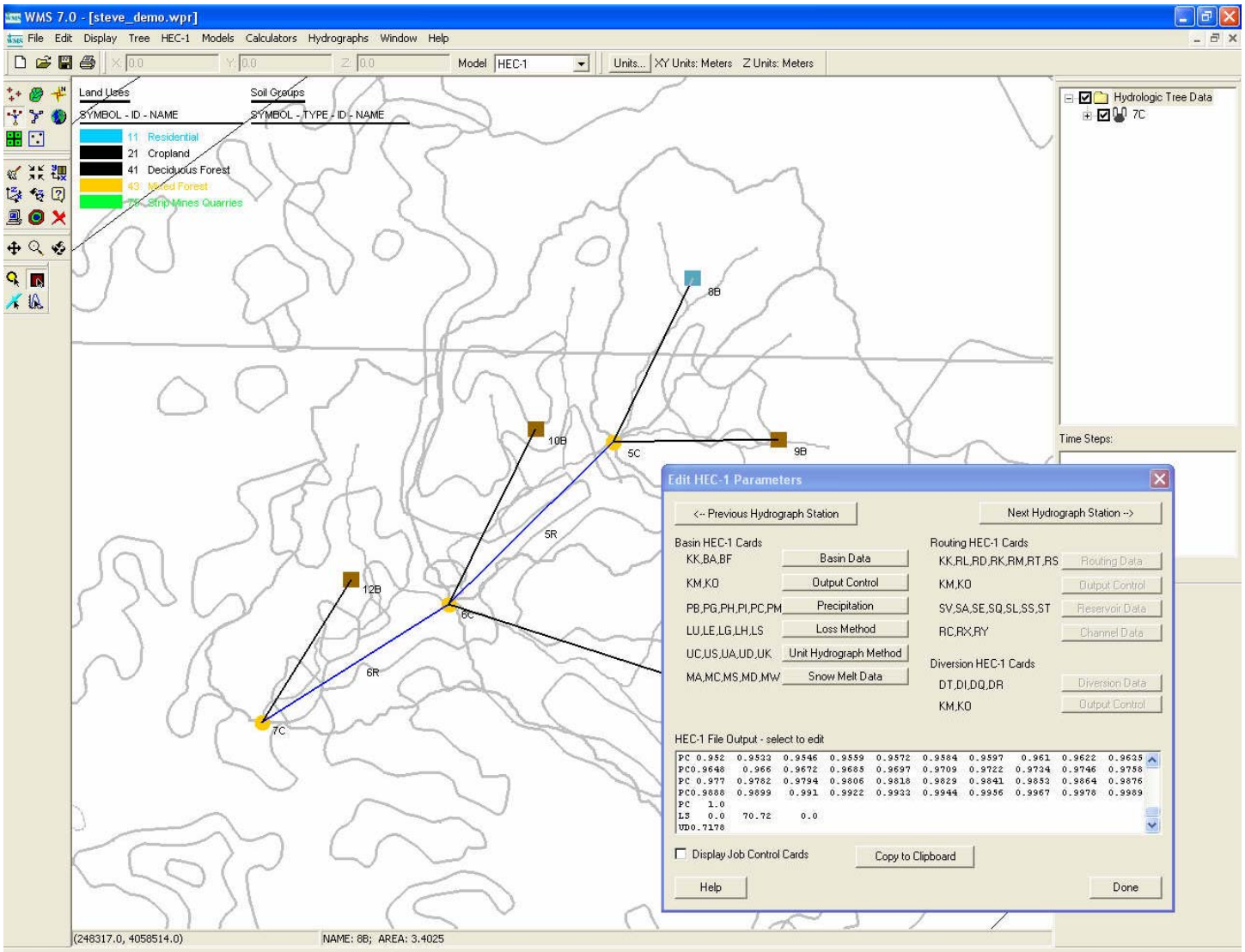
Assigning Curve Numbers

- The best available Land Use and Soils data was overlaid to delineate areas of equal curve number within the Clear Fork watershed
- WMS calculates area-weighted curve numbers for each sub-basin

WMS Will Recalculate the Weighted Curve Numbers for Each Basin Which has Been Defined Based on Soils and Land Use

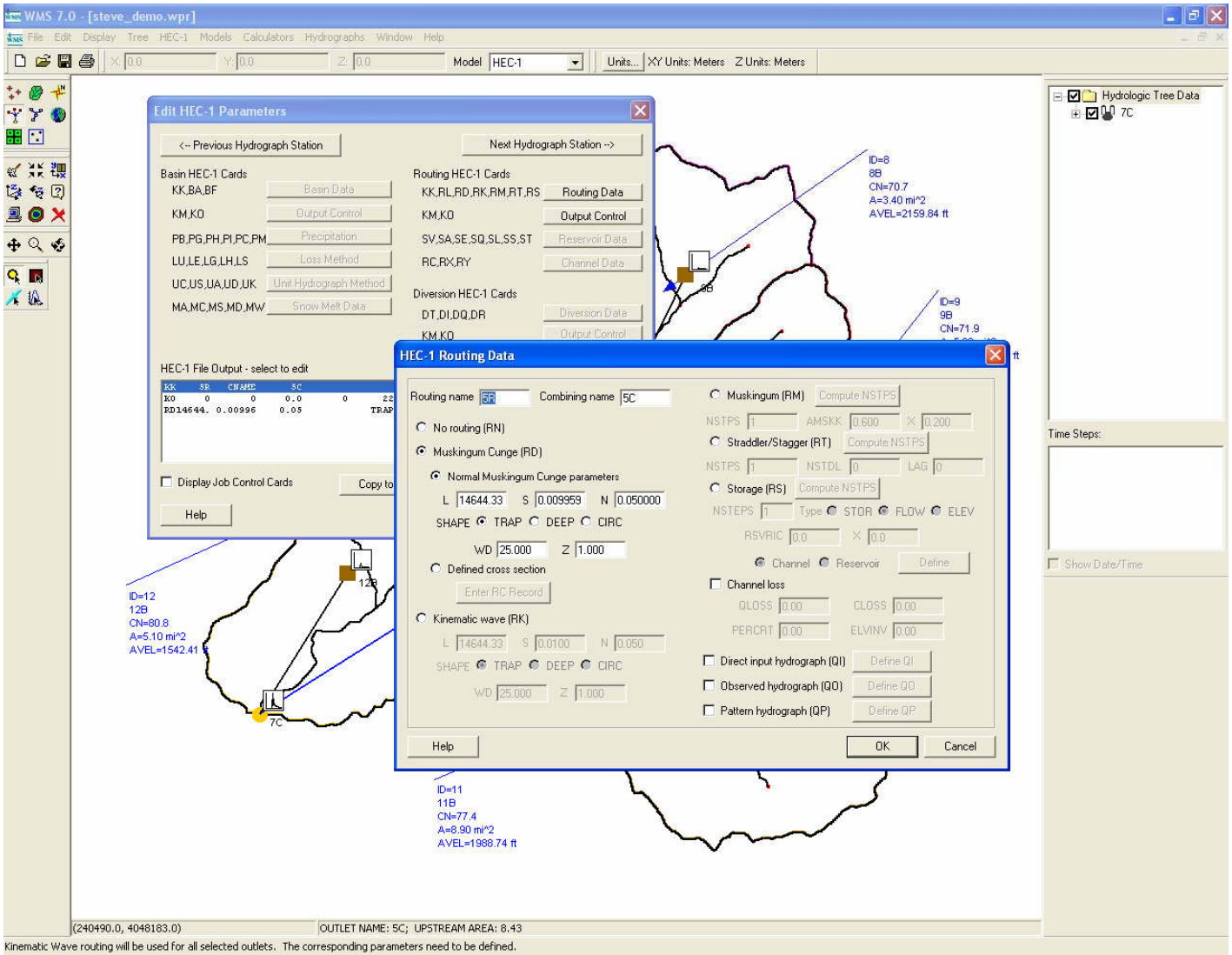


WMS Allows Interactive Entry of Parameter Information Needed for the Hydrologic Simulation by Clicking on the Individual Basin Icon

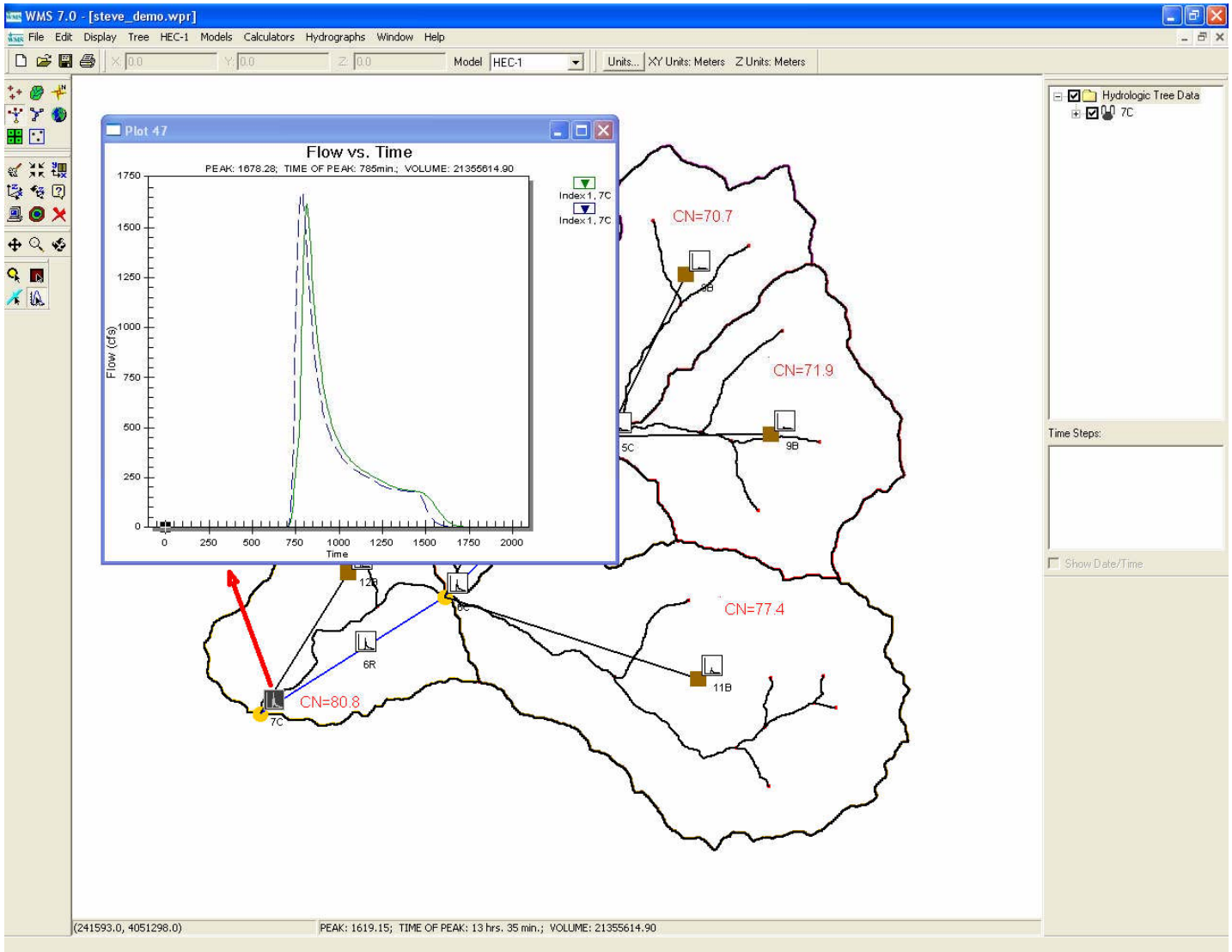


In this HEC-1 Simulation You Can Enter Information Relative to Storm Type, Precipitation, Loss Equations, Unit Hydrograph Method, Etc. for each Basin

WMS Allows You to Route the Flow Hydrograph to account for Lag Time and Attenuation between the Upper and Lower Reaches of the Watershed

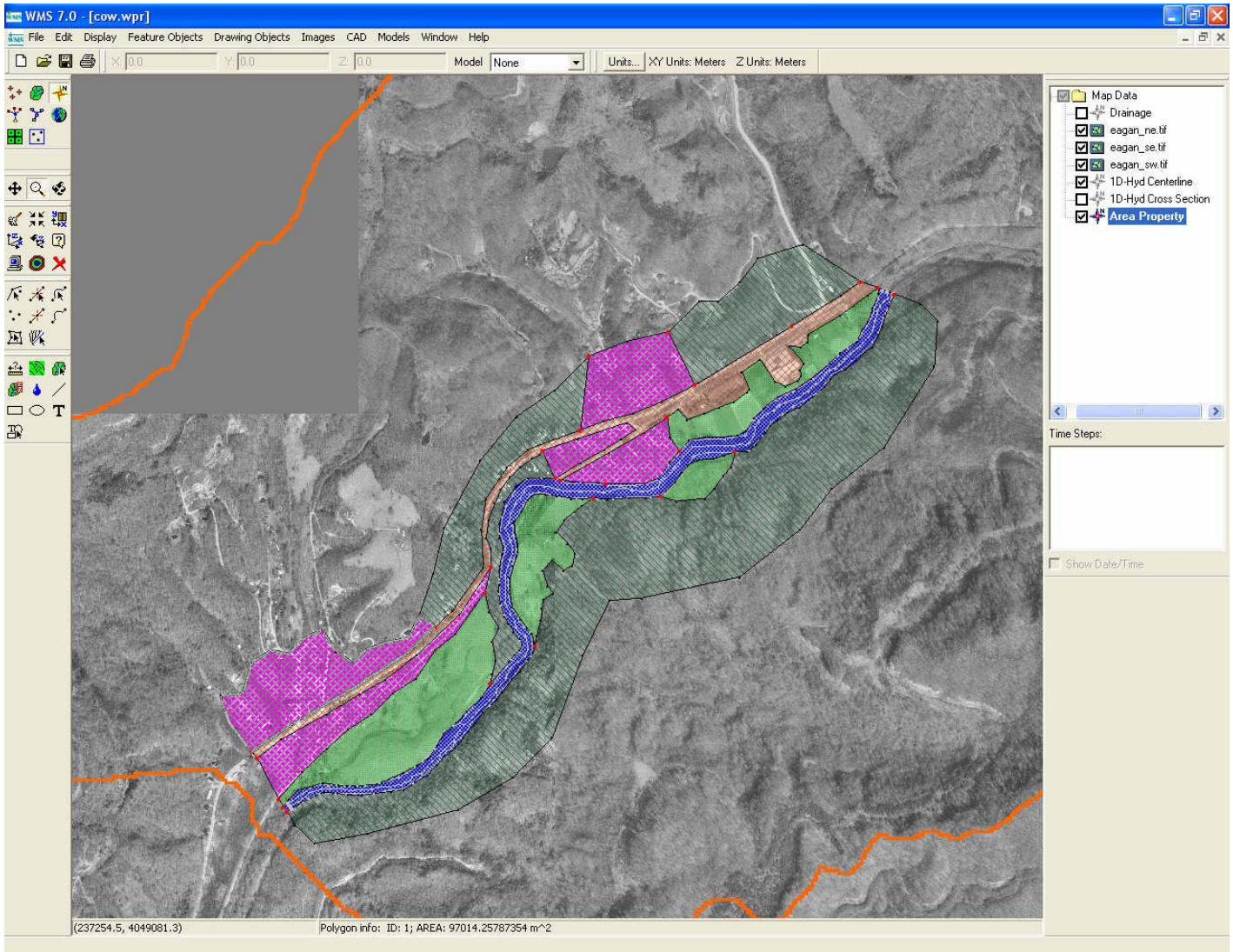


Results Can be Plotted Against Previous Simulations to Compare Results of the Various Settings or Methods Used

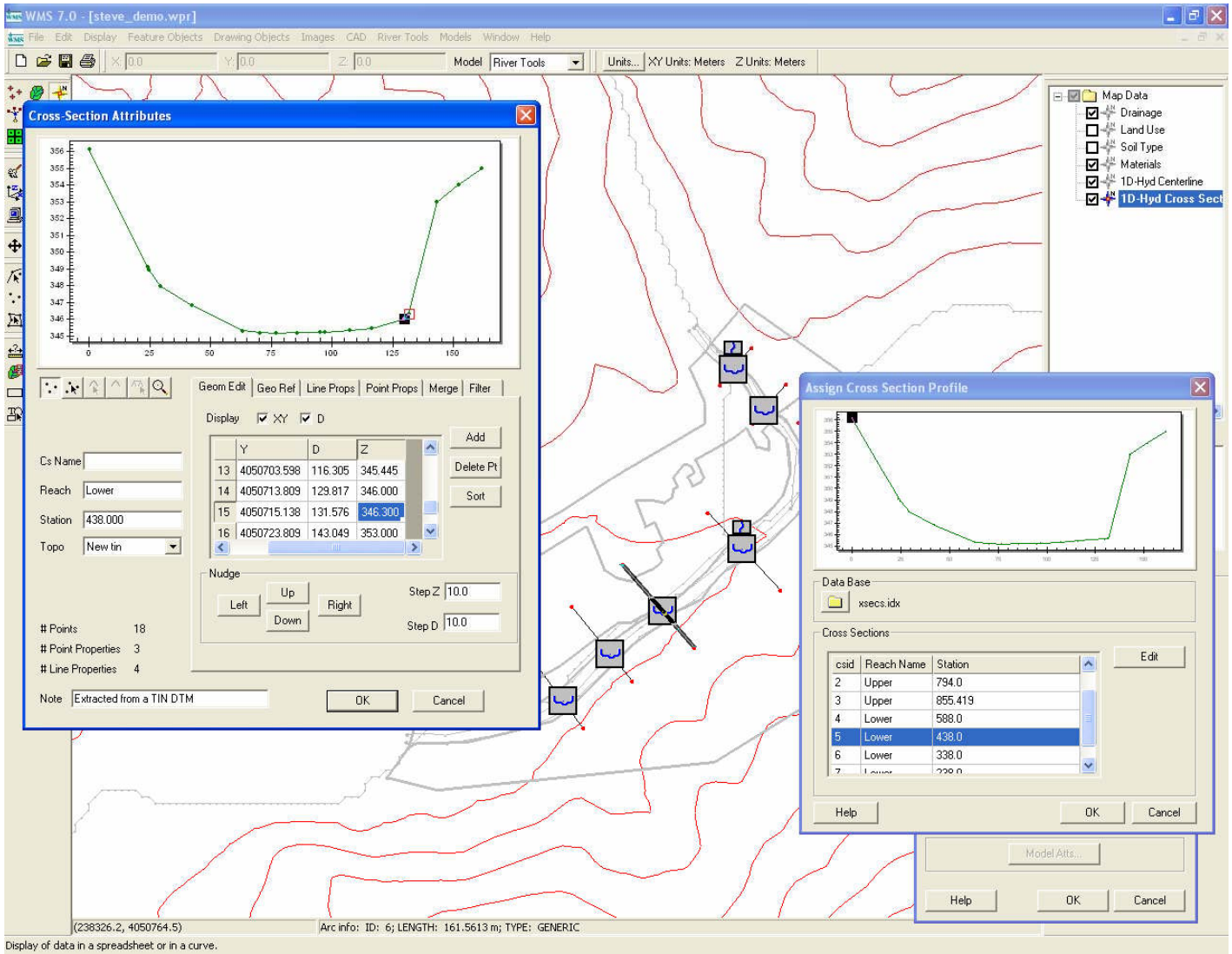


After Peak Flows Are Calculated, Cross Sections and Profiles can be Delineated in WMS for Export to HEC-RAS to Determine Flood Depth and Extent

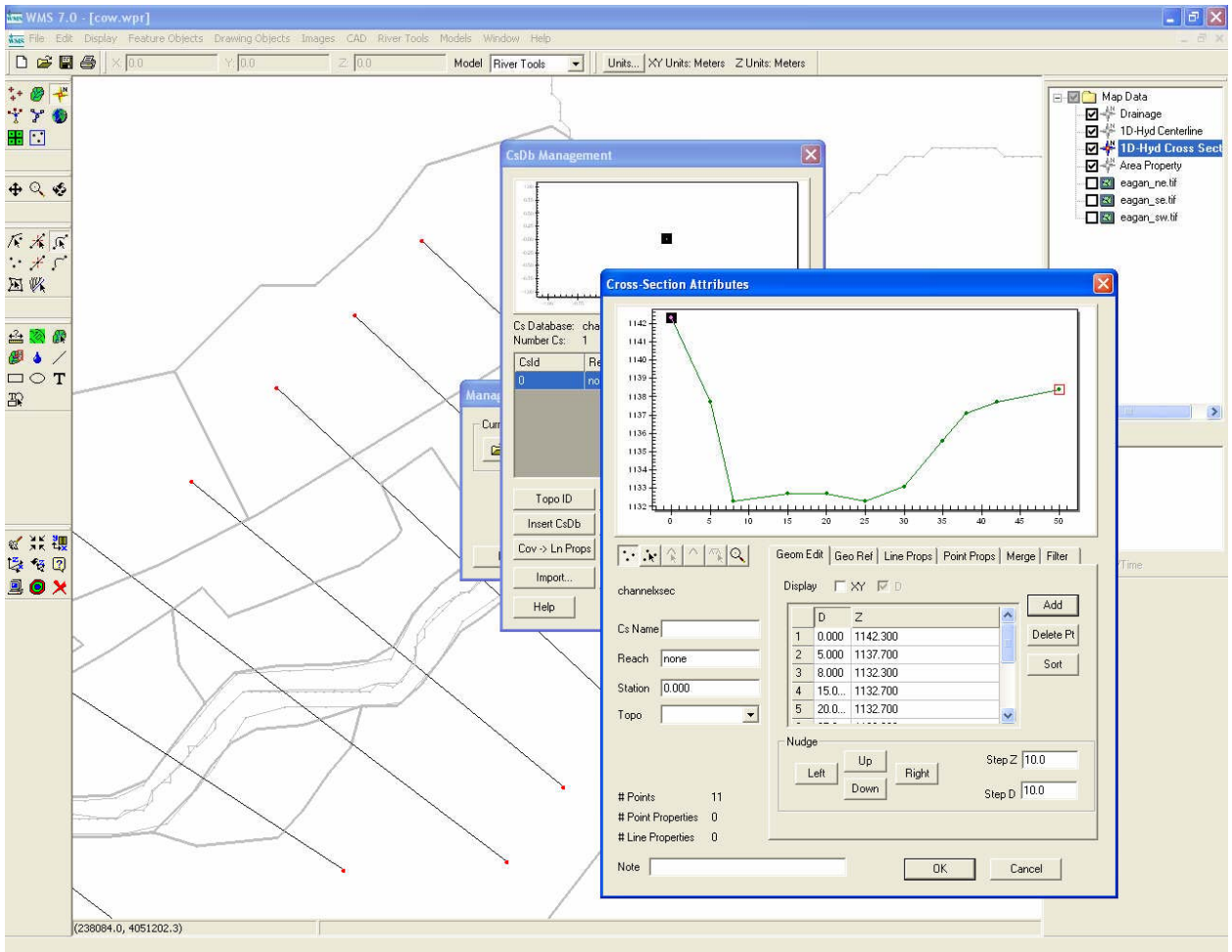
Mannings Roughness Values for Materials in the Cross Sections Can be Mapped in WMS For Exporting to HEC-RAS



Cross Sections Can be Previewed and Edited Prior to Exporting to HEC RAS

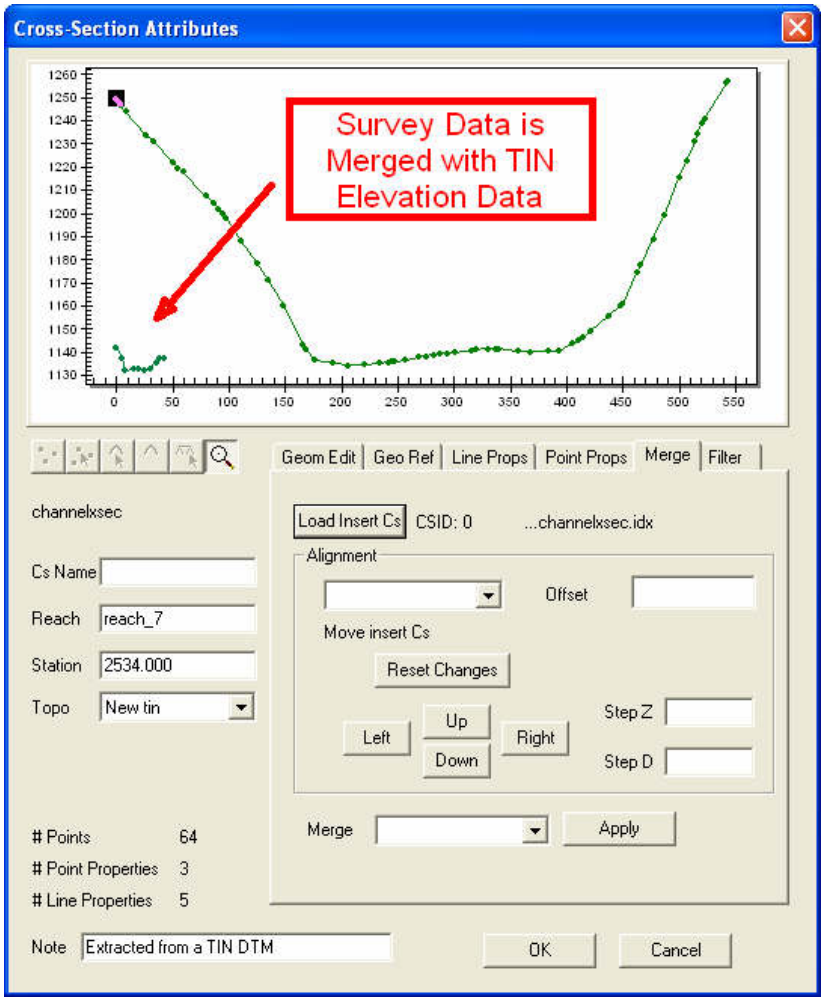


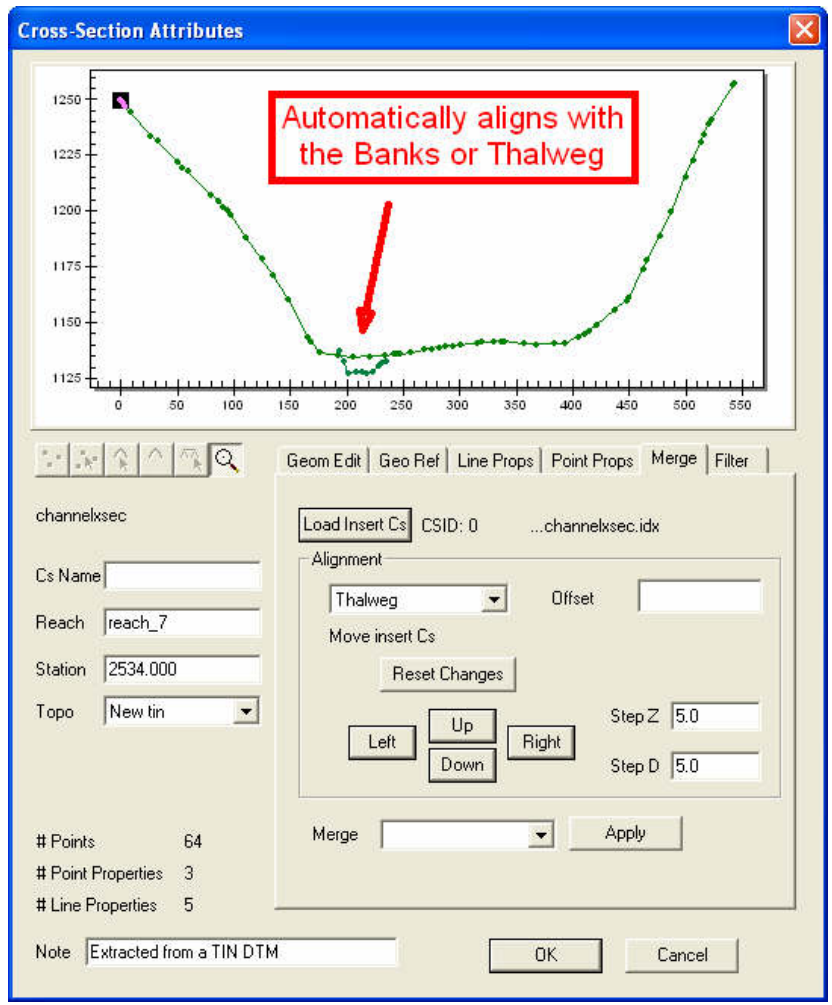
Surveyed Cross Sections Can also be Merged With DTM Data Generated from TINs or DEMs to More Accurately Represent the Stream or Floodplain



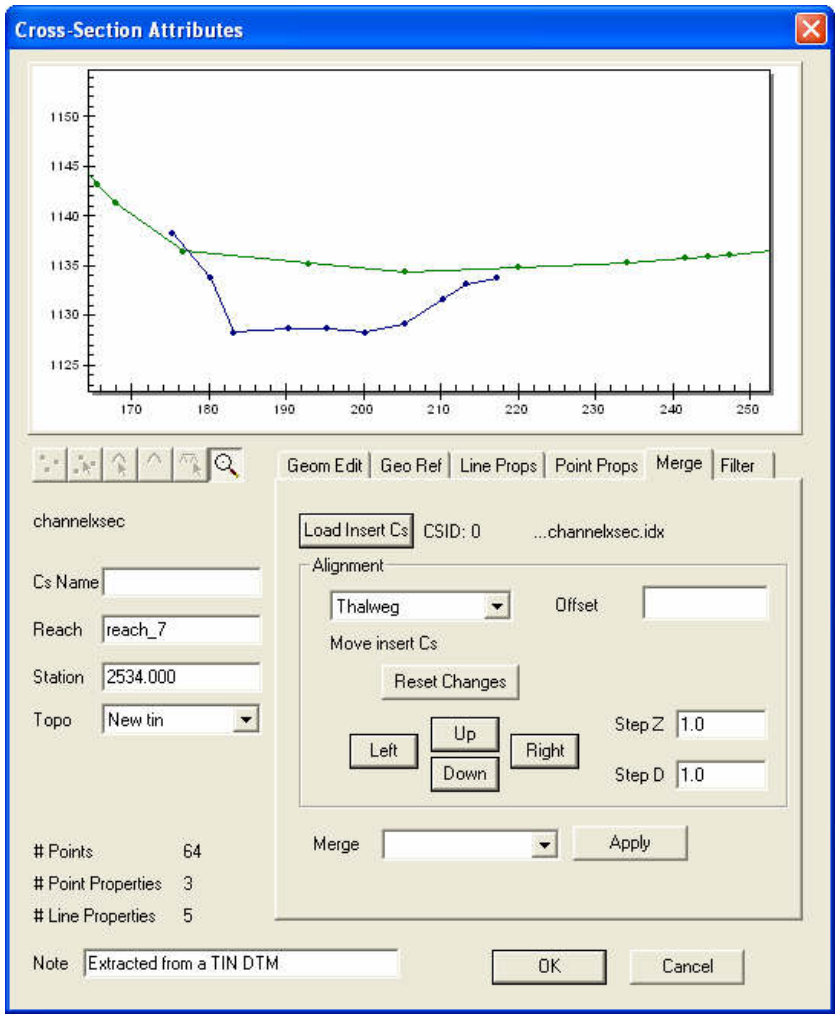
Here 10 Survey Points Across the Stream From Bank to Bank were Manually Entered Into WMS

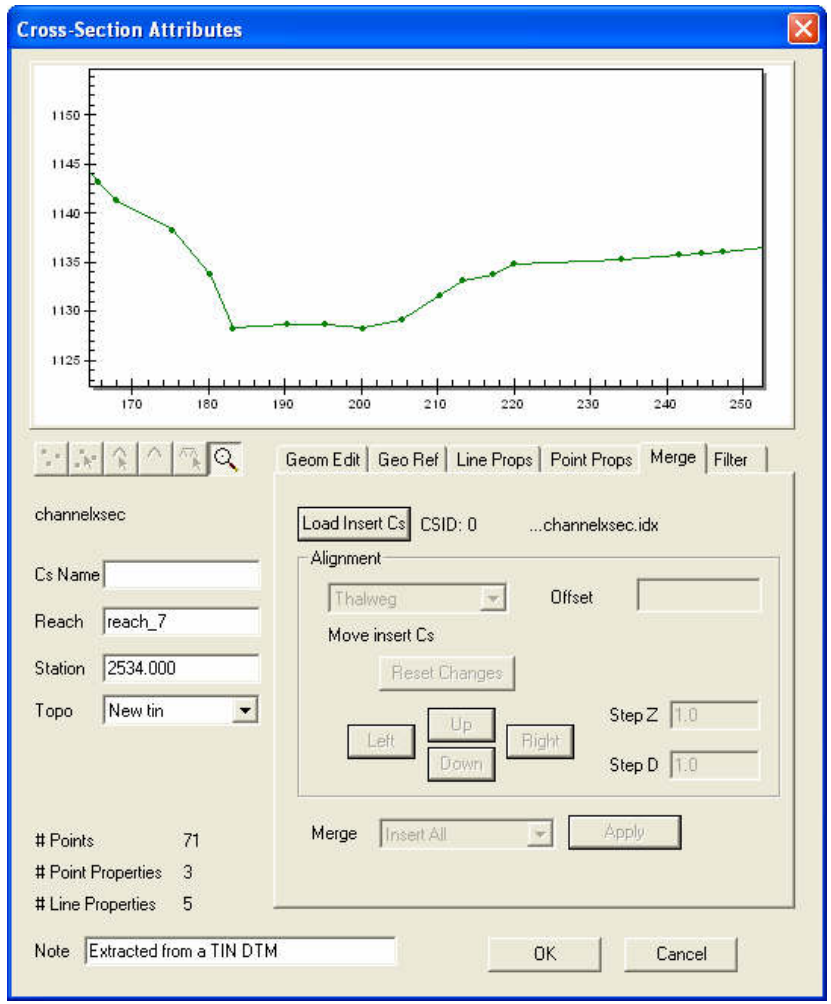
The Data from the DTM and the Survey Can Then Be Merged into a Single Cross Section



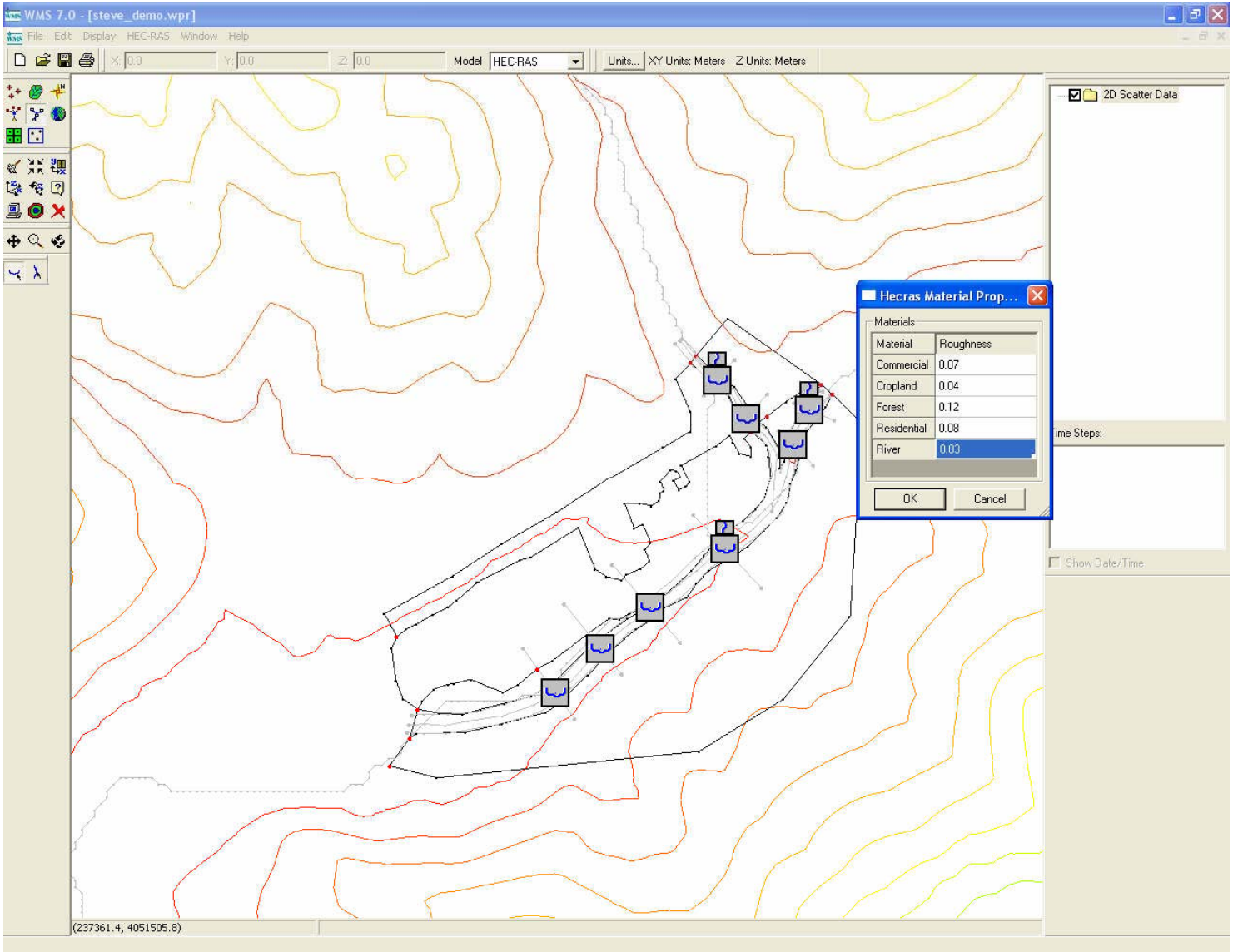


Once the Alignment has Been Verified, The Data Can Then Be Merged or Blended into the Cross Section File

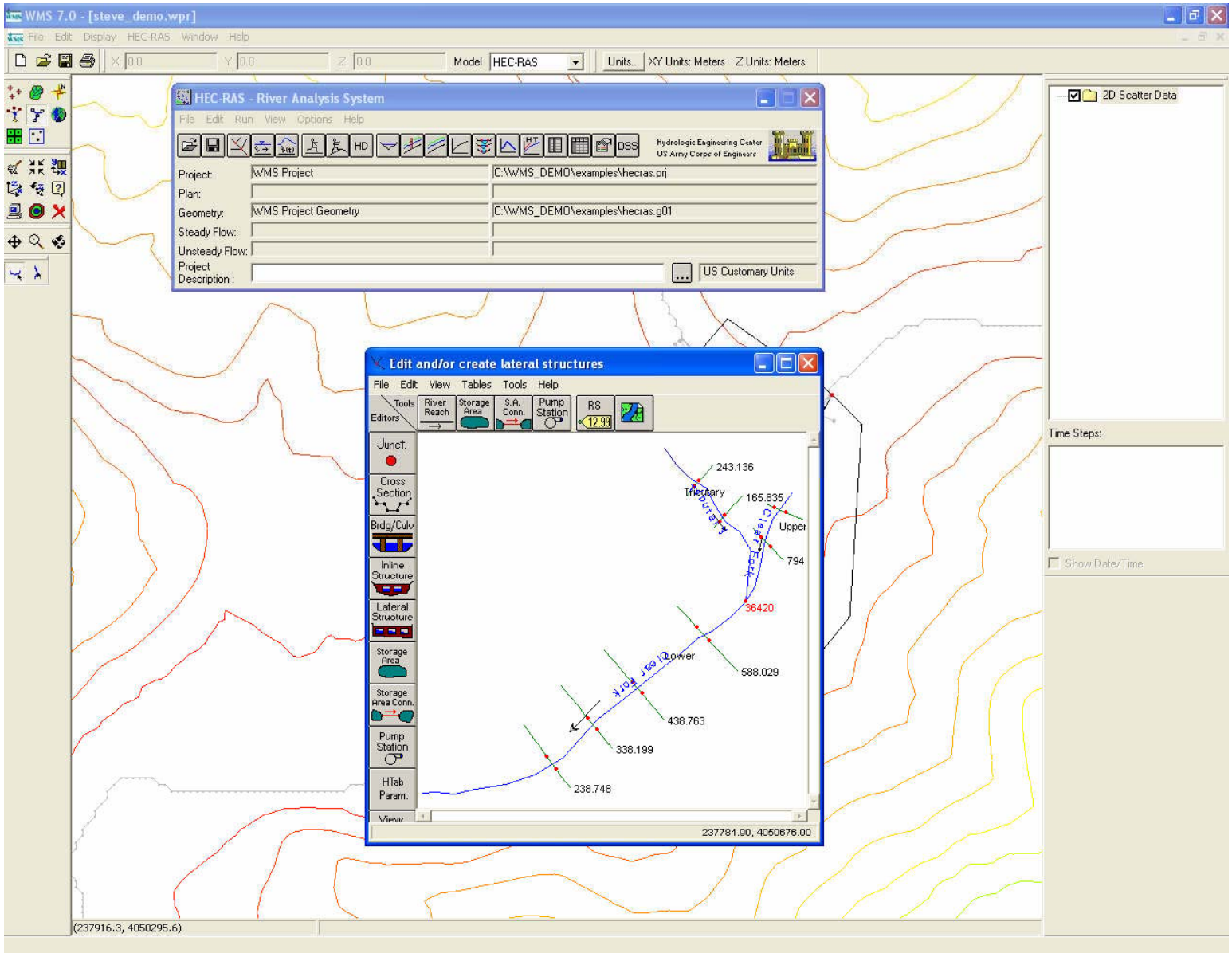




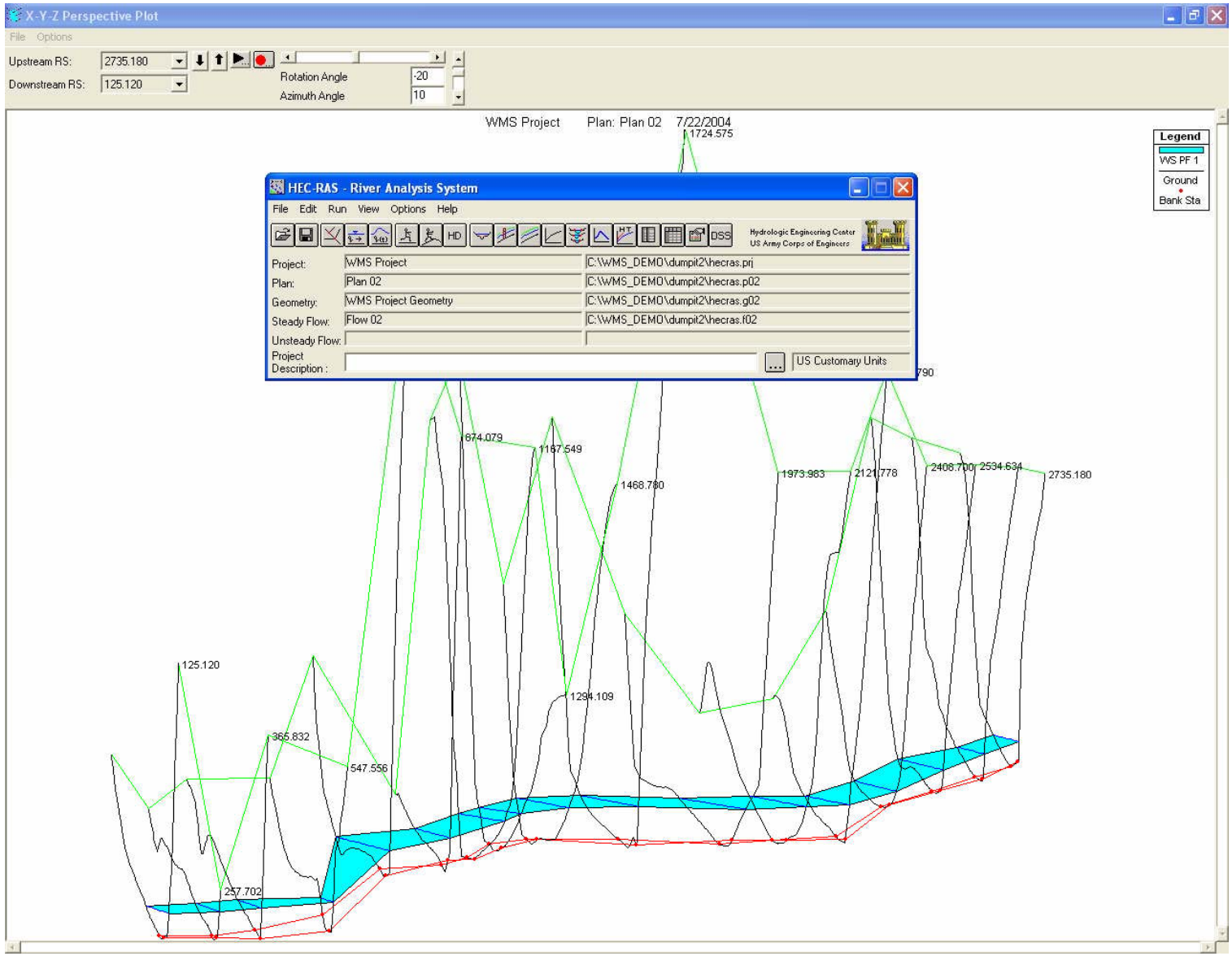
WMS Will Then Convert the Cross Sections and Profiles to a HEC RAS Geometry File for Export



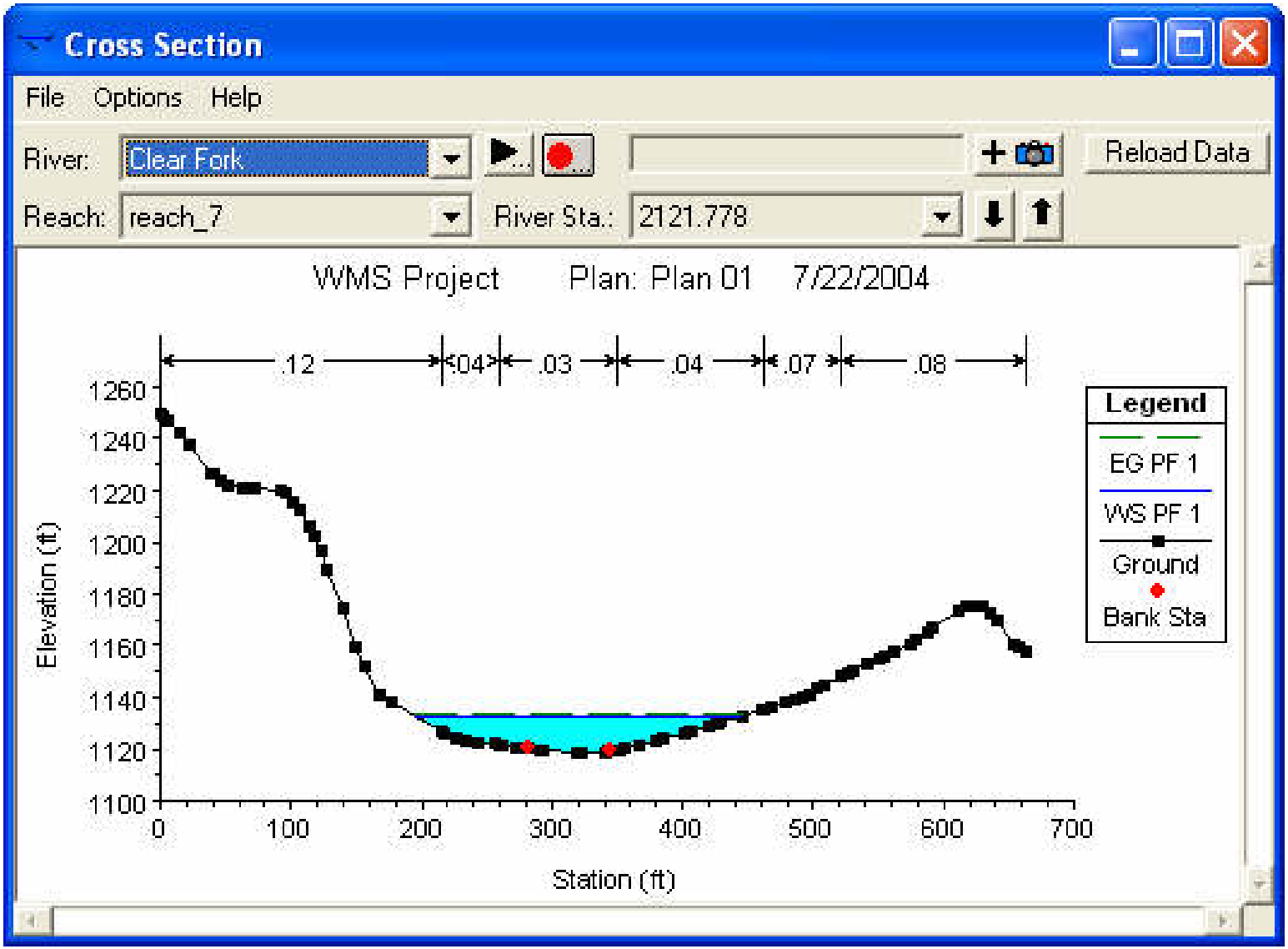
Once Exported, HEC RAS will Automatically Launch and Allow For Calculation of the Flow Analysis



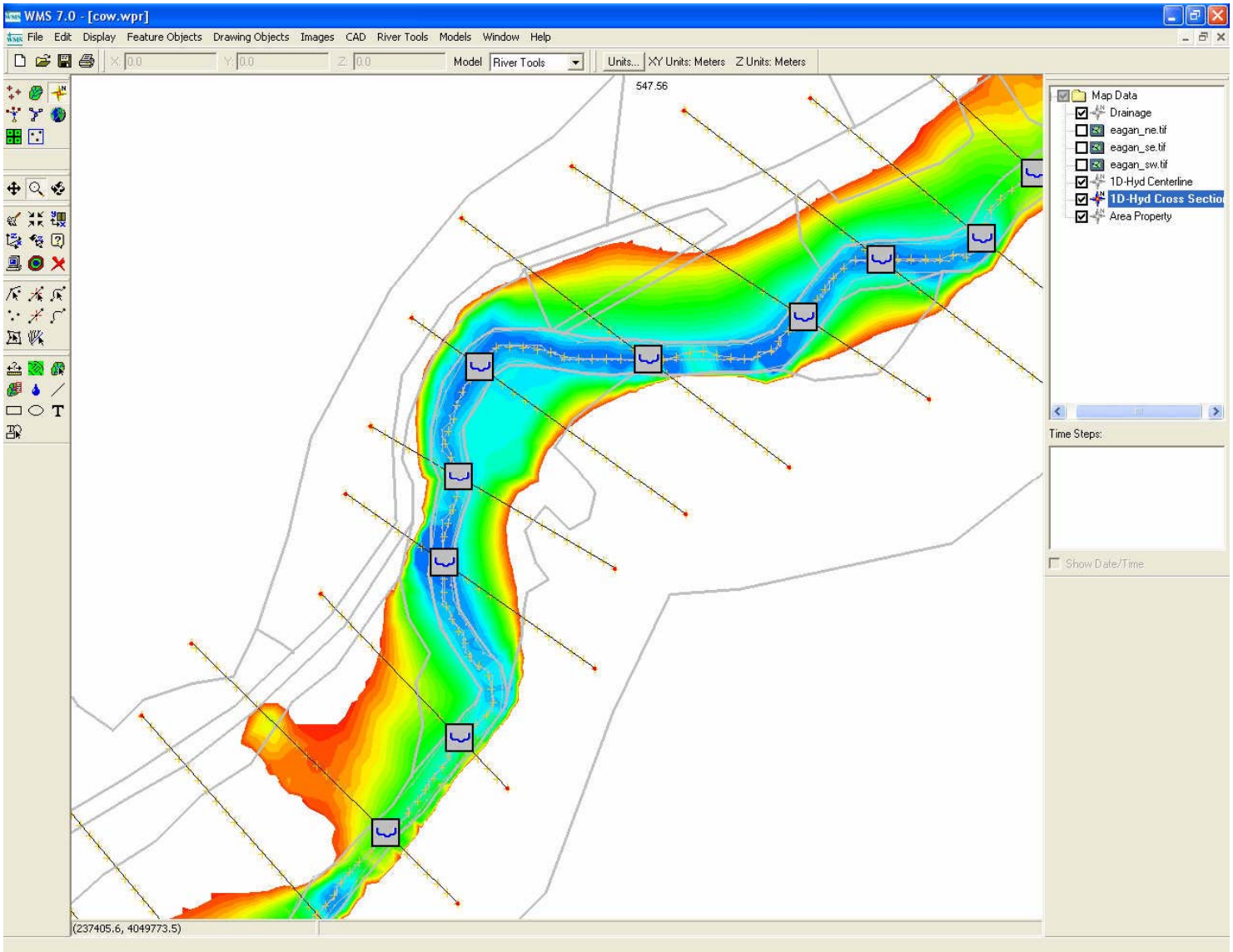
HEC RAS will Allow You to Preview The Stream Profile in 3D



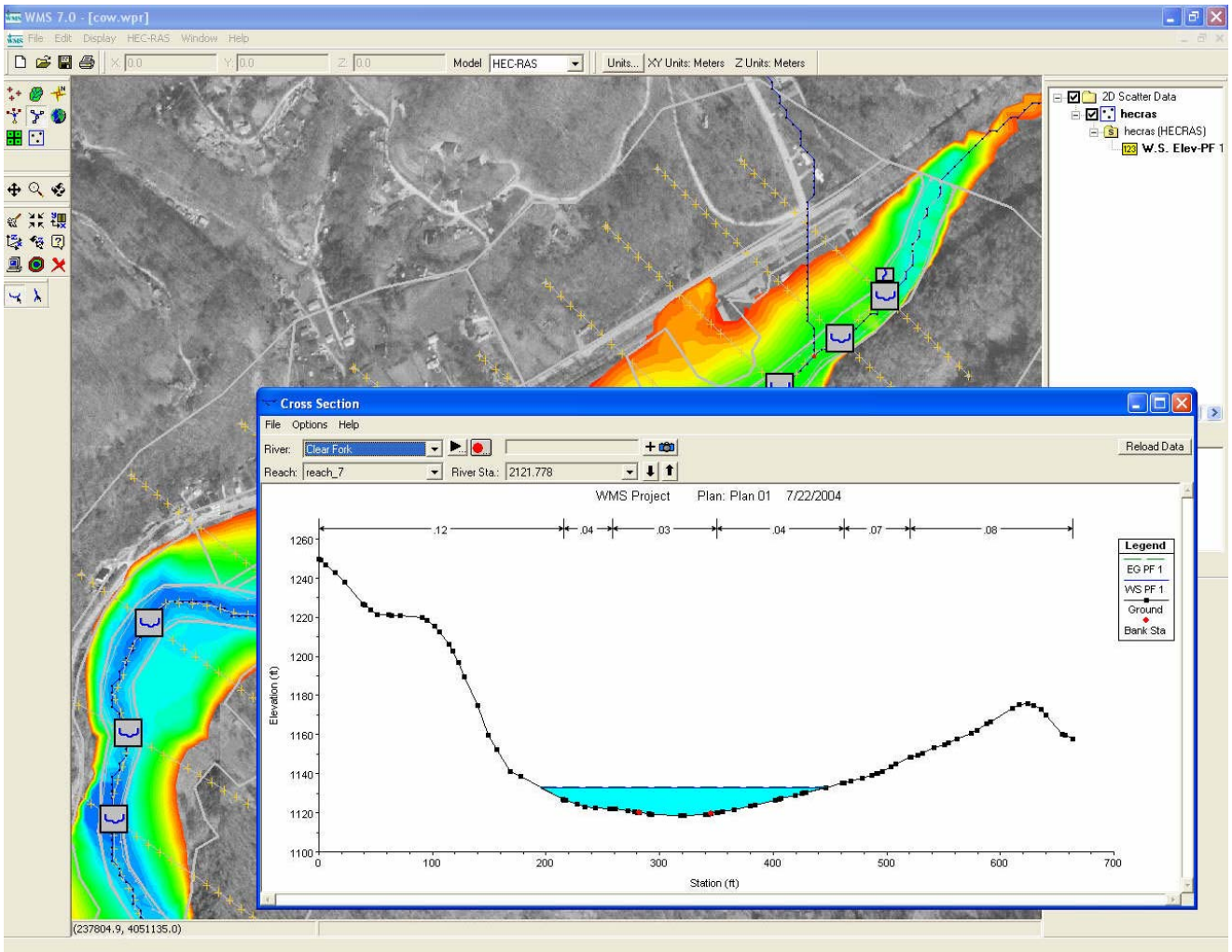
You Can Also Preview the Cross Sections and Calculated Flood Depths in Either WMS or HEC RAS



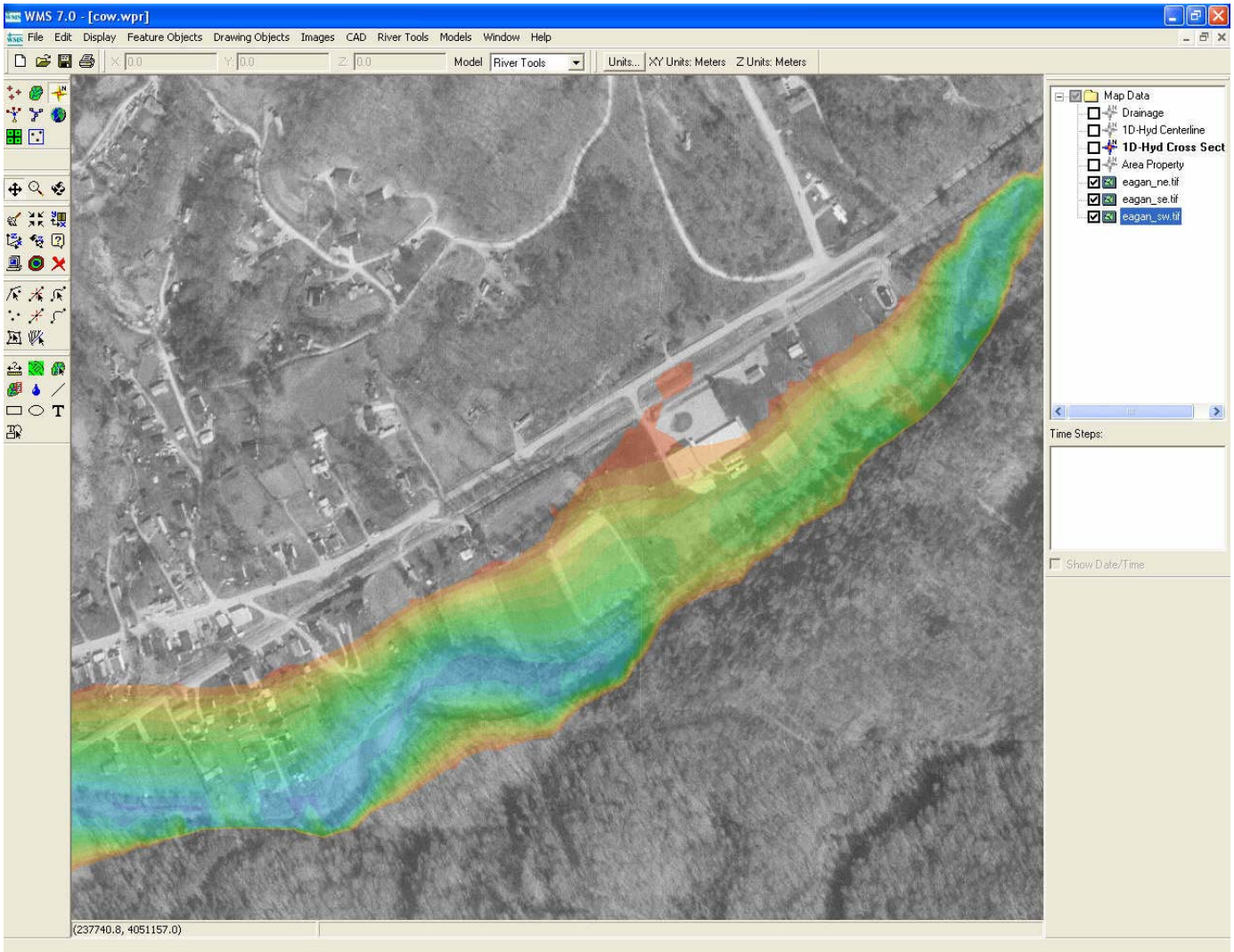
WMS Will Then Import the Resulting HEC RAS Project File and Delineate a Floodplain Map Based On the Cross Sectional Information



WMS Allows You to Quickly Plot the Cross Sections or Profiles Anywhere Along the Floodplain



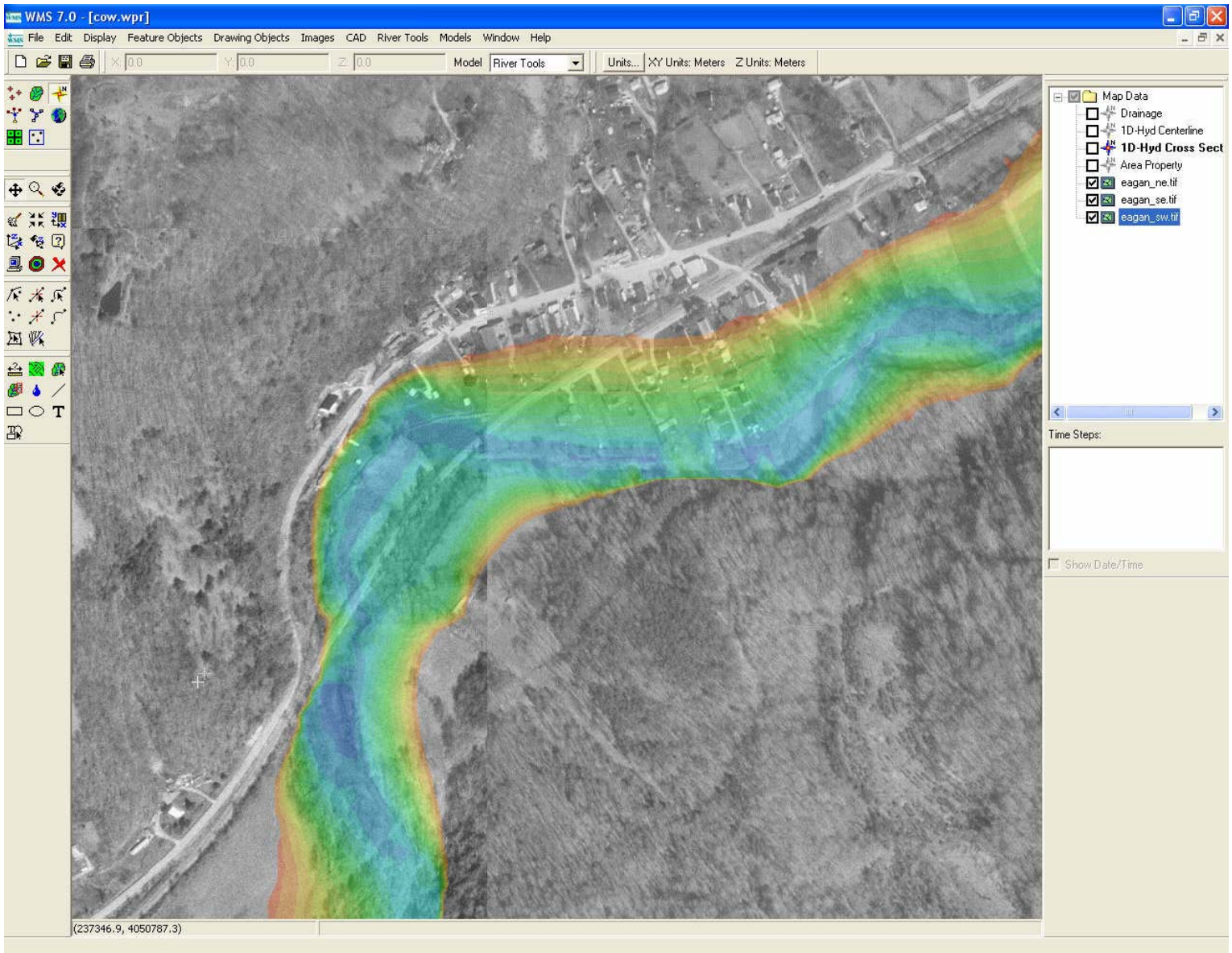
By Using Color Filled Contours and Transparency, The Floodplain can Identify Potentially Affected Structures



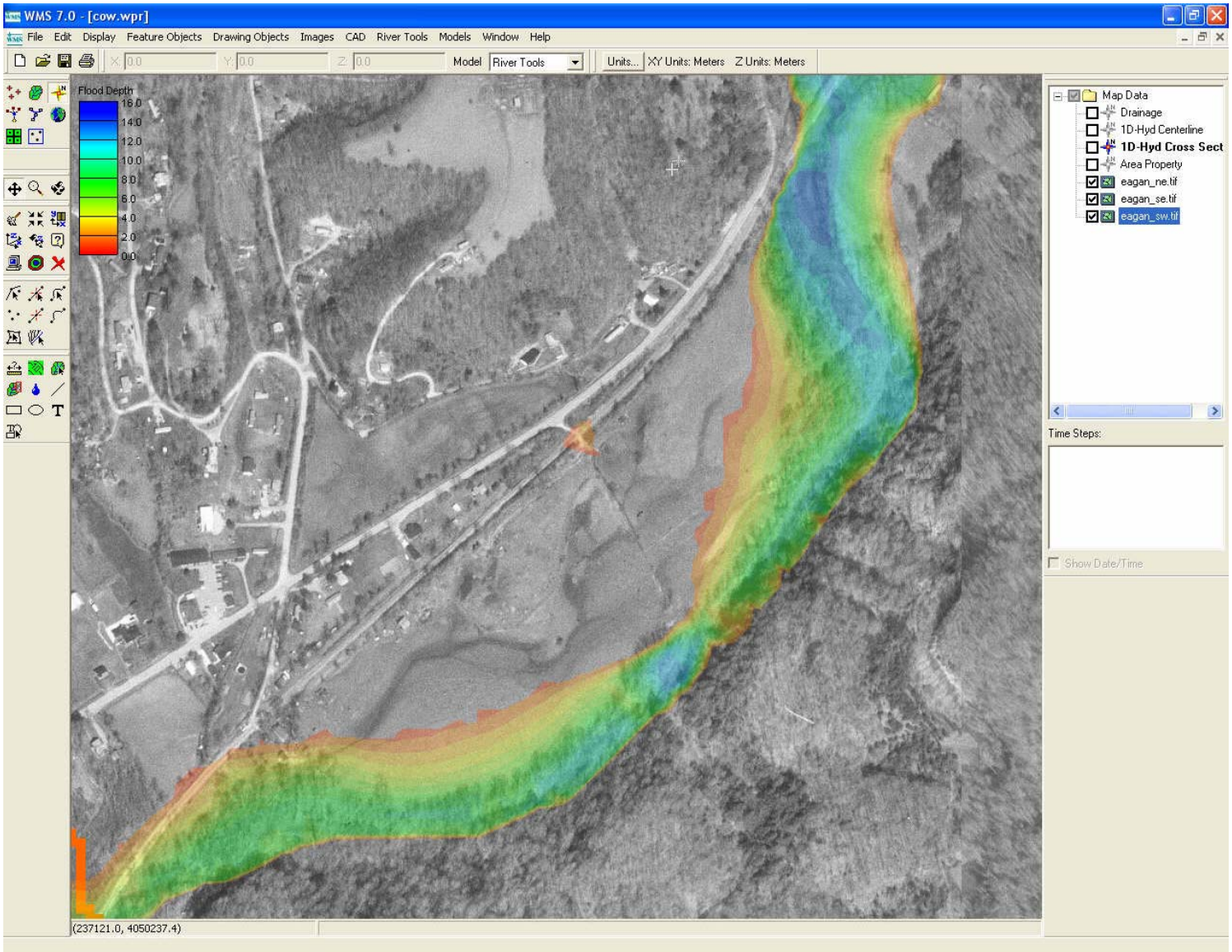
This Floodplain was based on 6,000 CFS which was an estimated 10 year, 24 hour event

Depth of water contours are Based on 1 foot intervals

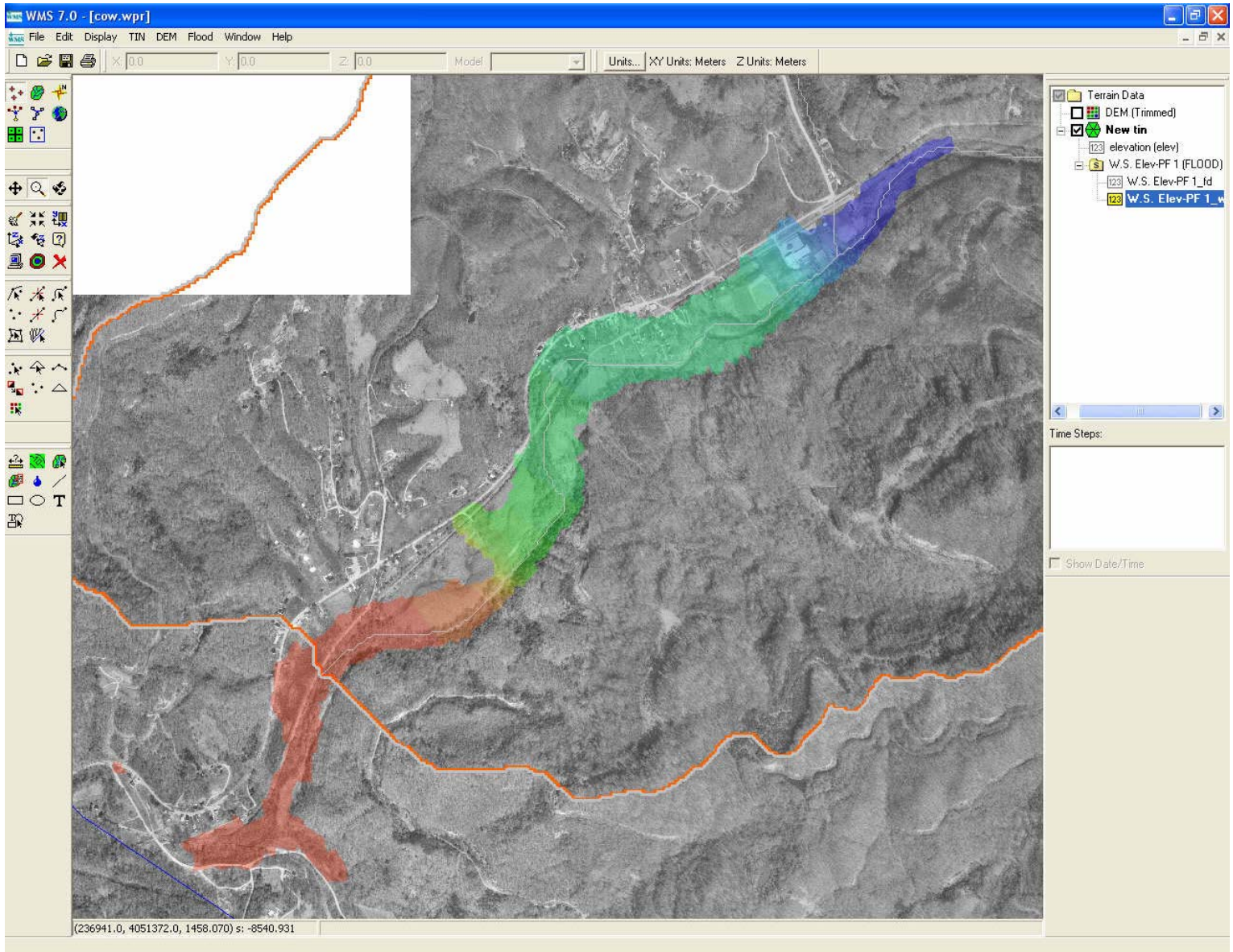
Midsection of Floodplain Evaluation



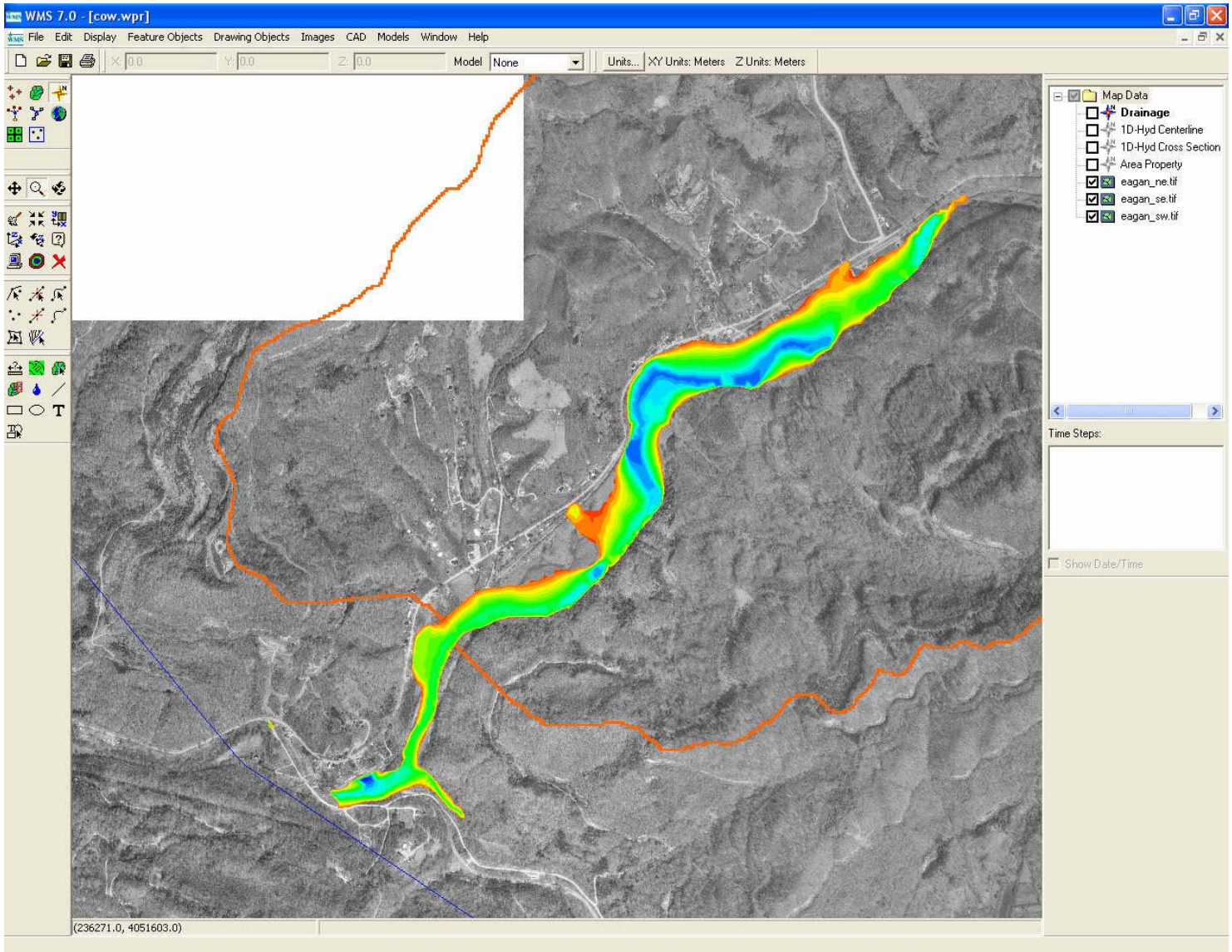
Lower Section of Floodplain Evaluation



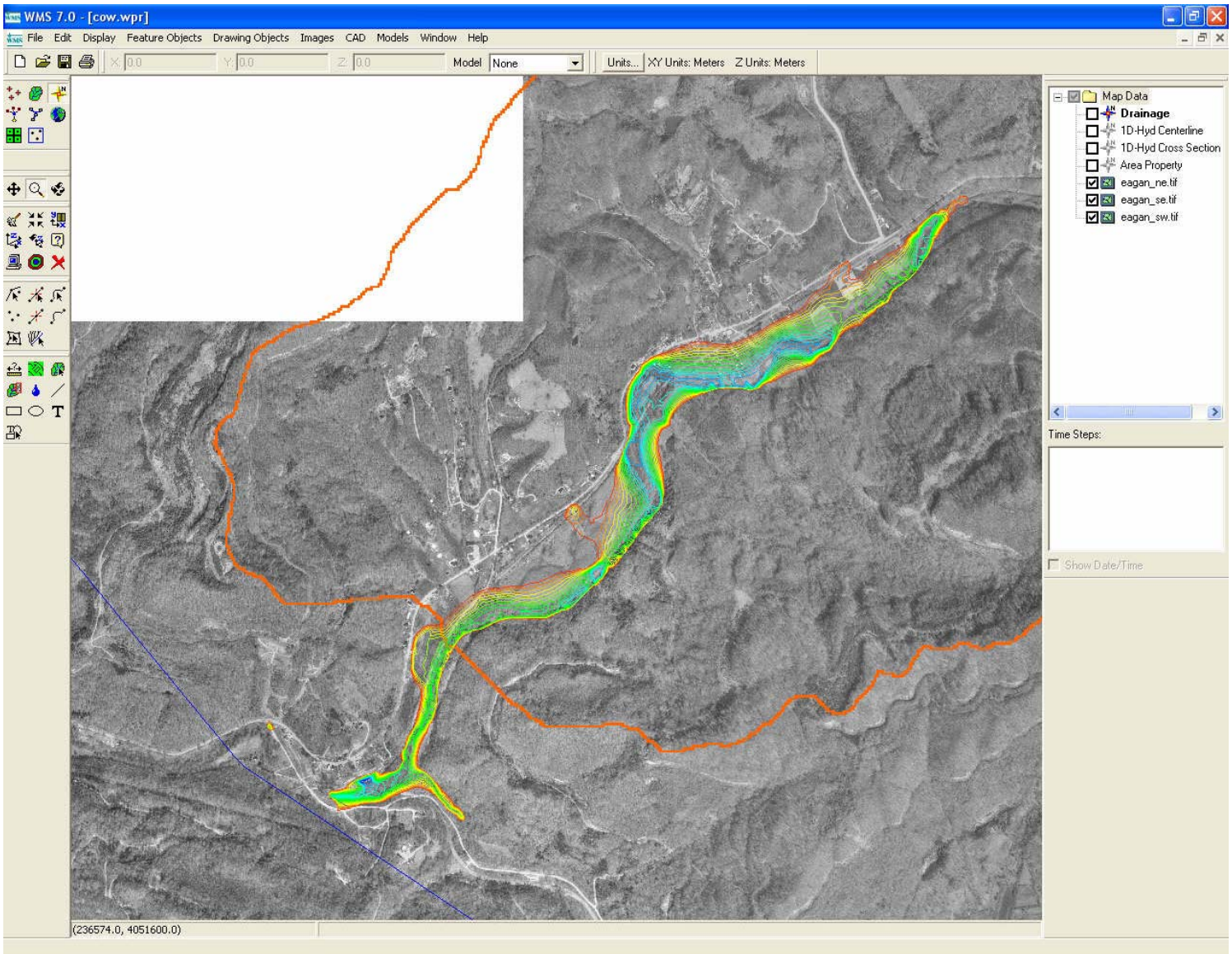
WMS also Calculates an Elevation Grid for the Flood Surface



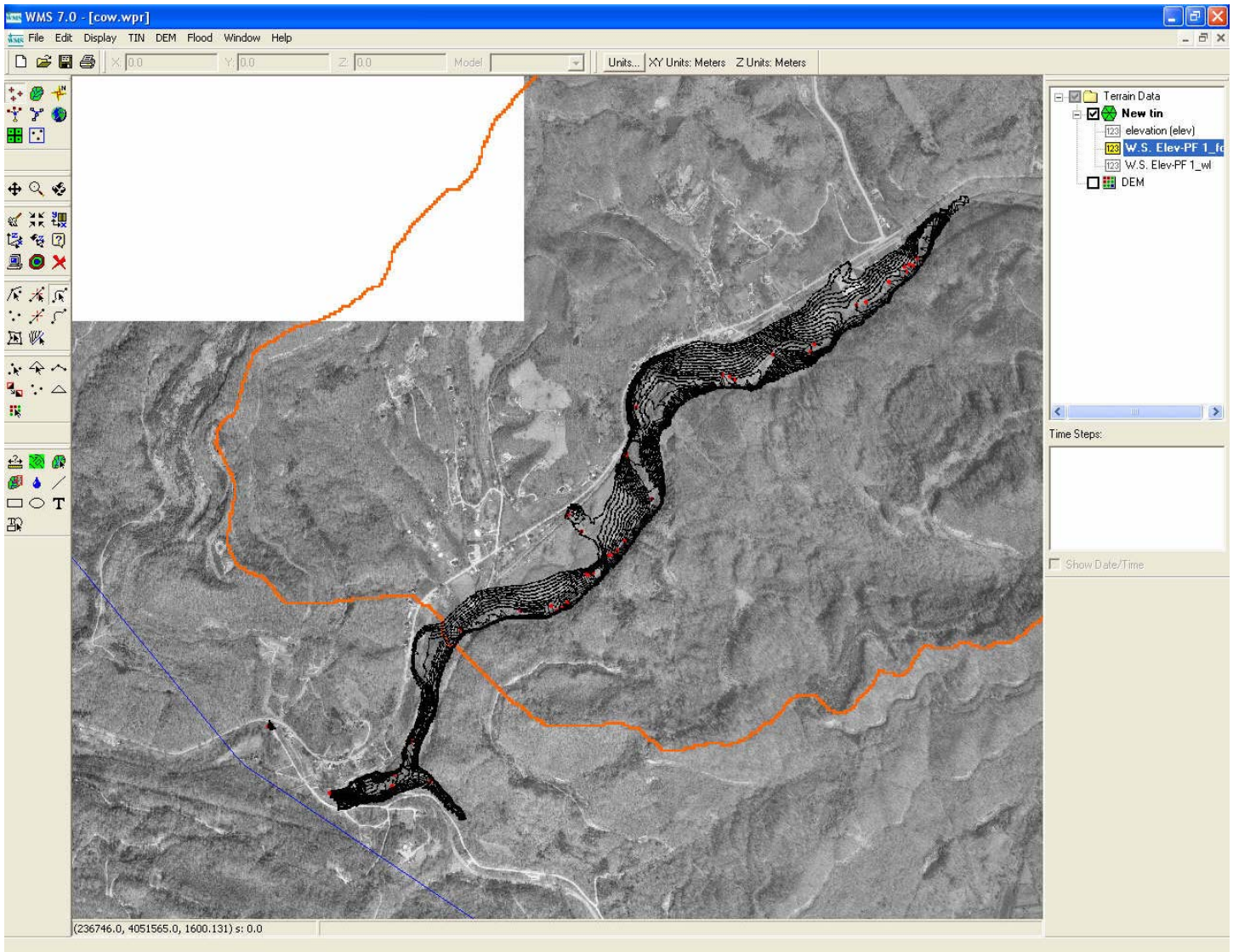
Floodplain Maps or other Feature Objects Generated can be Exported to ESRI, AutoDesk, or ASCII Format Files



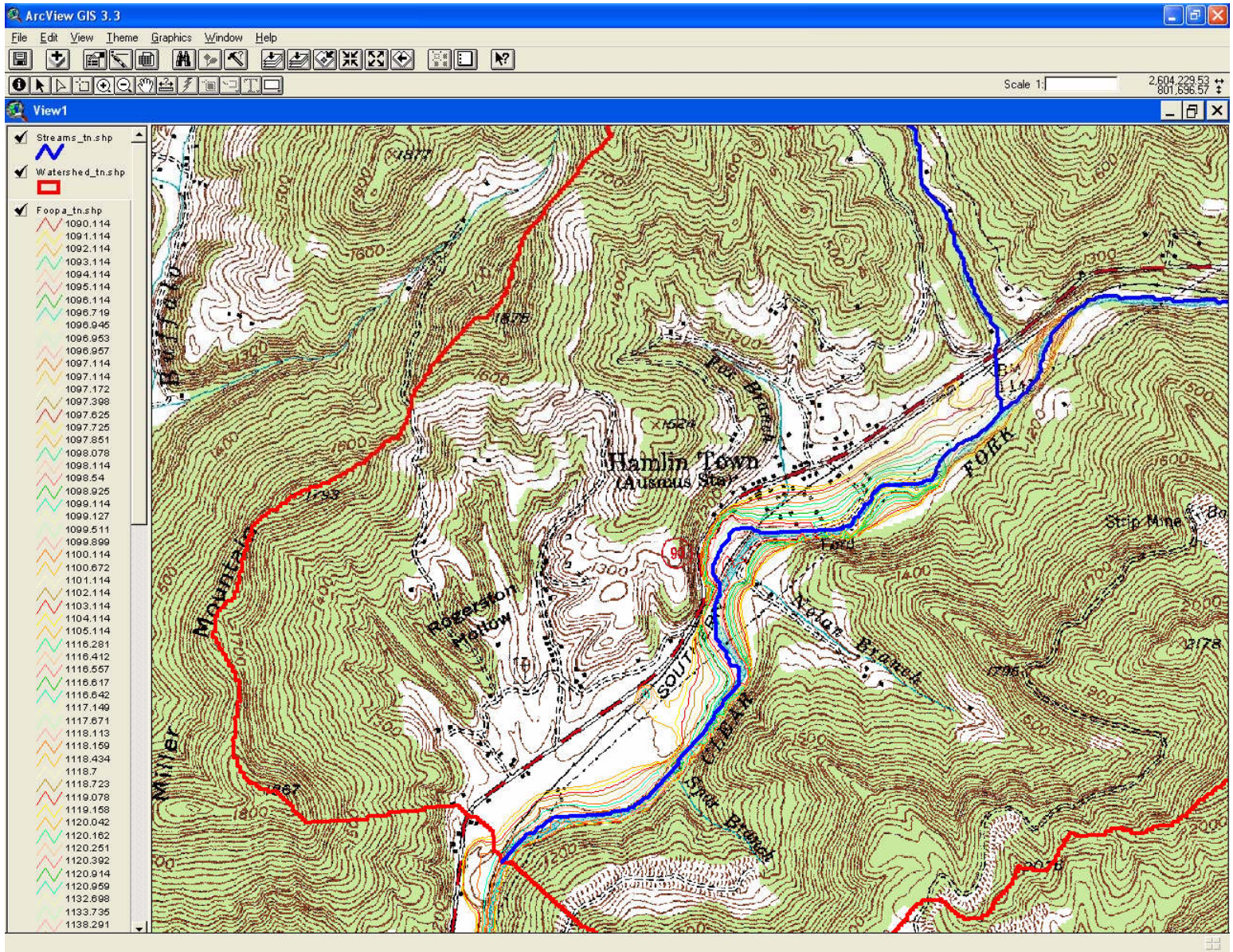
WMS Converts the Flood Depth Contour Lines to Feature Objects



Feature Objects Can Then be Exported to ESRI Shape Files



The Results Can Then Be Used in ArcMAP or ArcView



WMS Problems Identified During Initial Testing

- Some stability problems were noted during testing – especially during coordinate conversions, TIN generation, and simulations
- No “Undo” option which requires frequent “Saves”
- On-screen digitizing somewhat limited (panning and zooming not available)
- Multiple coordinate systems were often problematic (This project had 7 coordinate systems)
- AutoCAD Drawings Must be version 2002 or older
- Current version of HEC RAS not supported – Must be 3.1.1 or older
- Most capabilities of the software seem to be covered in existing TIPS or public domain software systems (However does offer a good graphical user interface)
- DEM data typically too coarse for floodplain delineation in low order watersheds

Conclusion and Summary

- WMS Interfaces Well With Other TIPS Supported Software (ArcView, ArcGIS, AutoCAD, HEC RAS)
- Automates Watershed Delineations and stream Channel Generation
- Allows for Export of Modeling Results and Features Objects to Other Software applications
- Uses Common Hydrologic Models to Generate Peak Flow Estimates
- Allows for Front End and Post-Processing for Other Hydrologic Models (GSSHA, HEC-RAS, CE-QUAL-W2)