Hydrologic Modeling Tools for Cumulative Hydrologic Impact Assessment of West Virginia Coal Mine Permits

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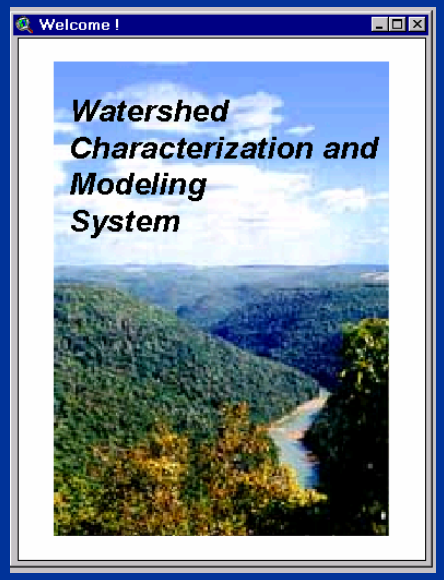


Natural Resource Analysis Center
West Virginia University
Jerald J. Fletcher, Director

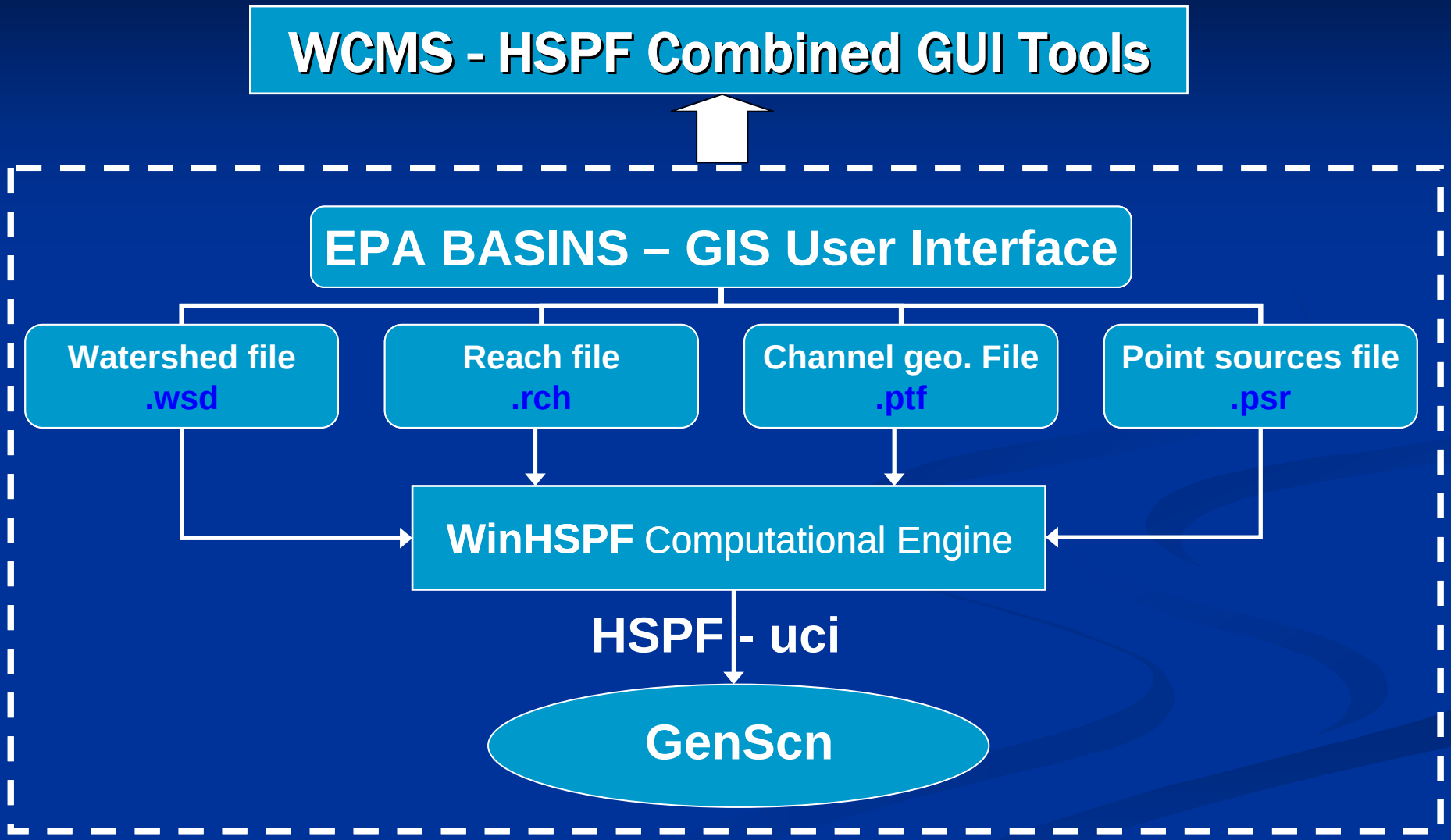
WVDEP CHIA Project

- Cooperative Effort Between WVDEP, OSM, and NRAC (Natural Resource Analysis Center) at West Virginia University.
  - Develop New WCMS Modeling Tools to Support CHIA on Mine-Impacted Watersheds in West Virginia.
  - Integrate HSPF (Hydrological Simulation Program – Fortran) with WCMS.

Hydrologic Model Selection: HSPF

- Widespread Acceptance and Use (EPA, USGS, USACE).
- HSPF is Included in EPA BASINS.
- Continuous Time Simulation of Stream Flow and Stream Water Quantity.
- Model Components Simulate Both Land Surface and Subsurface Hydrology, and Water Quality.
- Maintenance and Development is Sponsored by EPA and USGS.

Simplification of EPA BASINS Functionality Within WCMS



HSPF/CHIA Application Modules

- **PERLND** (Simulate a Pervious Land Segment).
- **RCHRES** (Perform Computations for a Stream Reach or Reservoir)
- **ACIDPH** (Implements the NRAC Mine Drainage Model, **ACCAL4**)
  - **ACIDPH** Operates Within the **RCHRES** Component.
  - Changes in Fe, Al, Mn, pH, Acidity, and Alkalinity are Simulated in Each **RCHRES** of the Watershed Stream Drainage Network.

CHIA/HSPF Mine Drainage Model

- Changes in Fe, Al, Mn, pH, Acidity, and Alkalinity are Modeled Within Each RCHRES, According to Geochemical Balance Equations.
  - Sulfate and Electrical Conductivity are Modeled Using a Mass Balance.
- Geochemistry Balances use Activity Instead of Concentrations for Calculating Metal Precipitation (Based on Ion Strength).
  - Activity Coefficient is Derived from the Debye-Huckel Equation and is similar to EPA's MINTEQA2 model.
- Most Ferrous Iron in Mine Drainage is Quickly Converted to Ferric Form; Therefore, Ferric Iron is Modeled and Assumed to Approximate Total Iron.
- Total Acidity is Modeled Using Both Metal Ion Concentrations and pH.

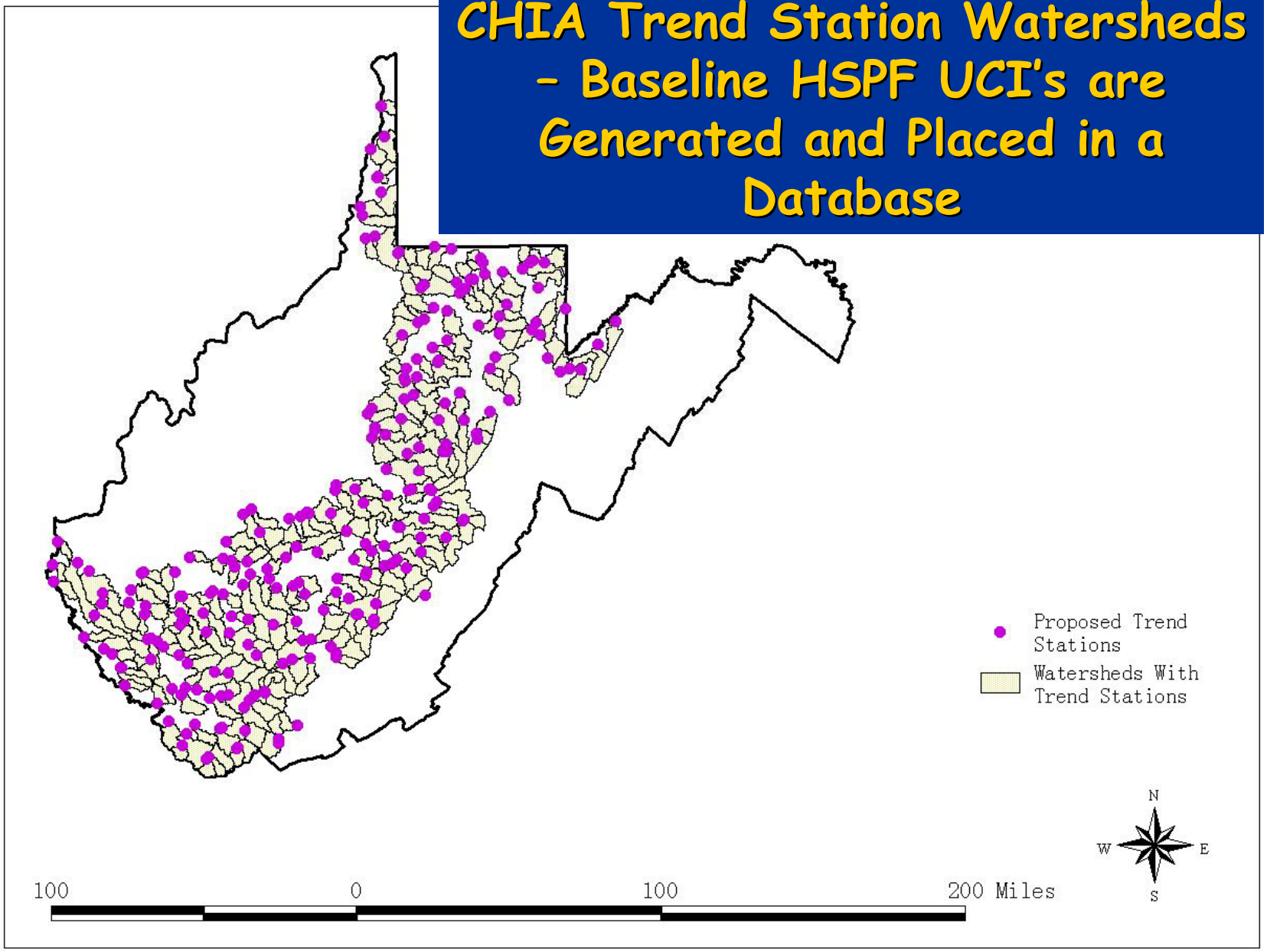
HSPF Data Input Requirements

- Land Use/Land Cover Classifications (11 used).
- Digital Elevation Model and 1:24K NHD Stream Network.
  - WCMS Tools Divide the Watershed into Subbasins.
- Daily Temperature Maximum & Minimum.
  - Used by HSPF to Model Snow and Evapotranspiration.
- Hourly Precipitation (Supplied by ZedX Inc.).
  - 5 km Grid Coverage of West Virginia (1949-2002).
- Mine Drainage Water Quality Parameters.

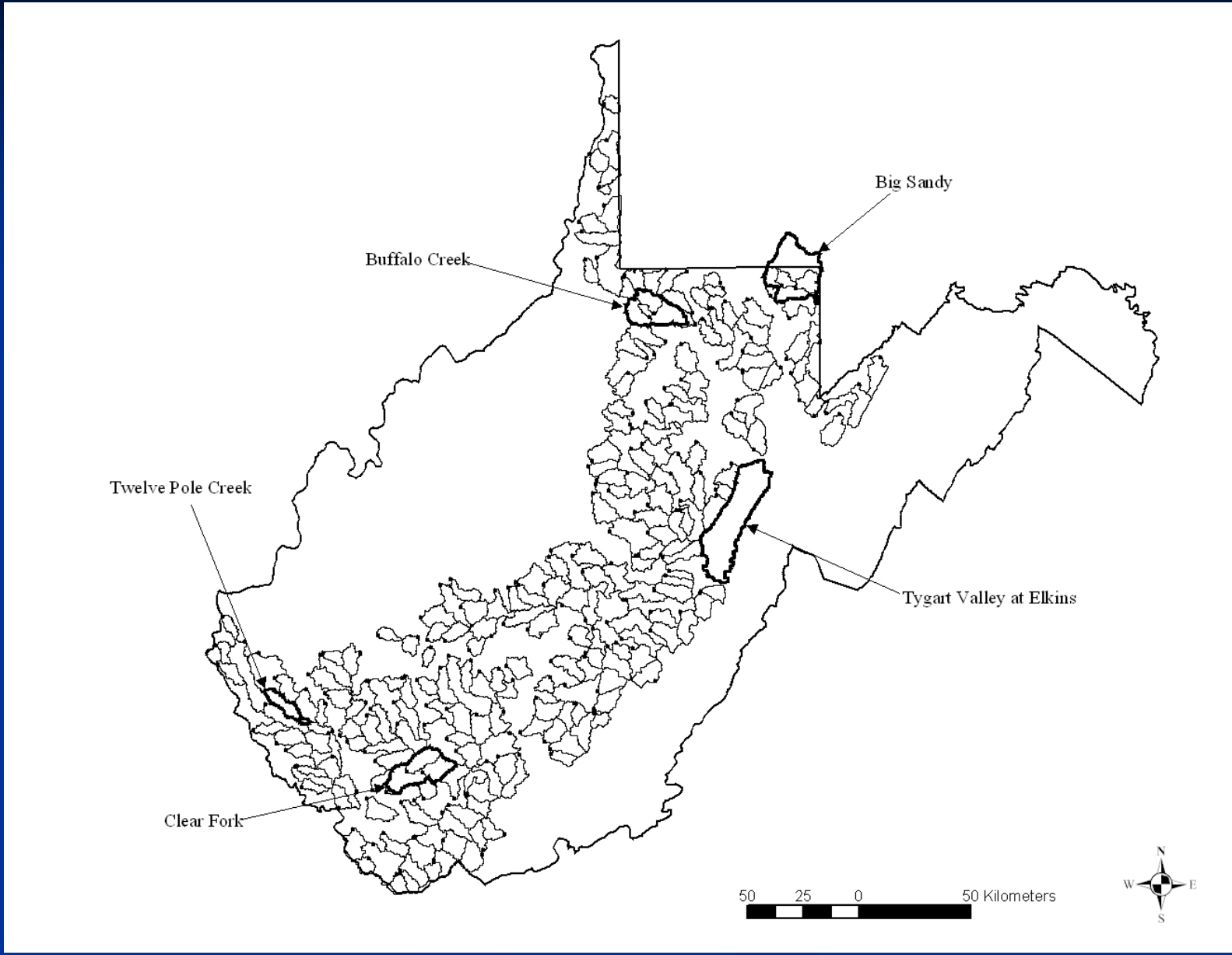
HSPF Calibration for CHIA

- HSPF is to be Fitted to Approximately 235 Trend Station Watersheds (TSW's).
- TSW's are Defined by Steam Water Quality Sampling Points.
- TSW's Do Not Coincide with USGS Stream Gaging Stations.
- Calibration Strategy Adopted Follows Donigian (2002) and Dinicola (1990, 2001).
- 5 Calibration Watersheds & 5 Verification Watersheds were Selected.

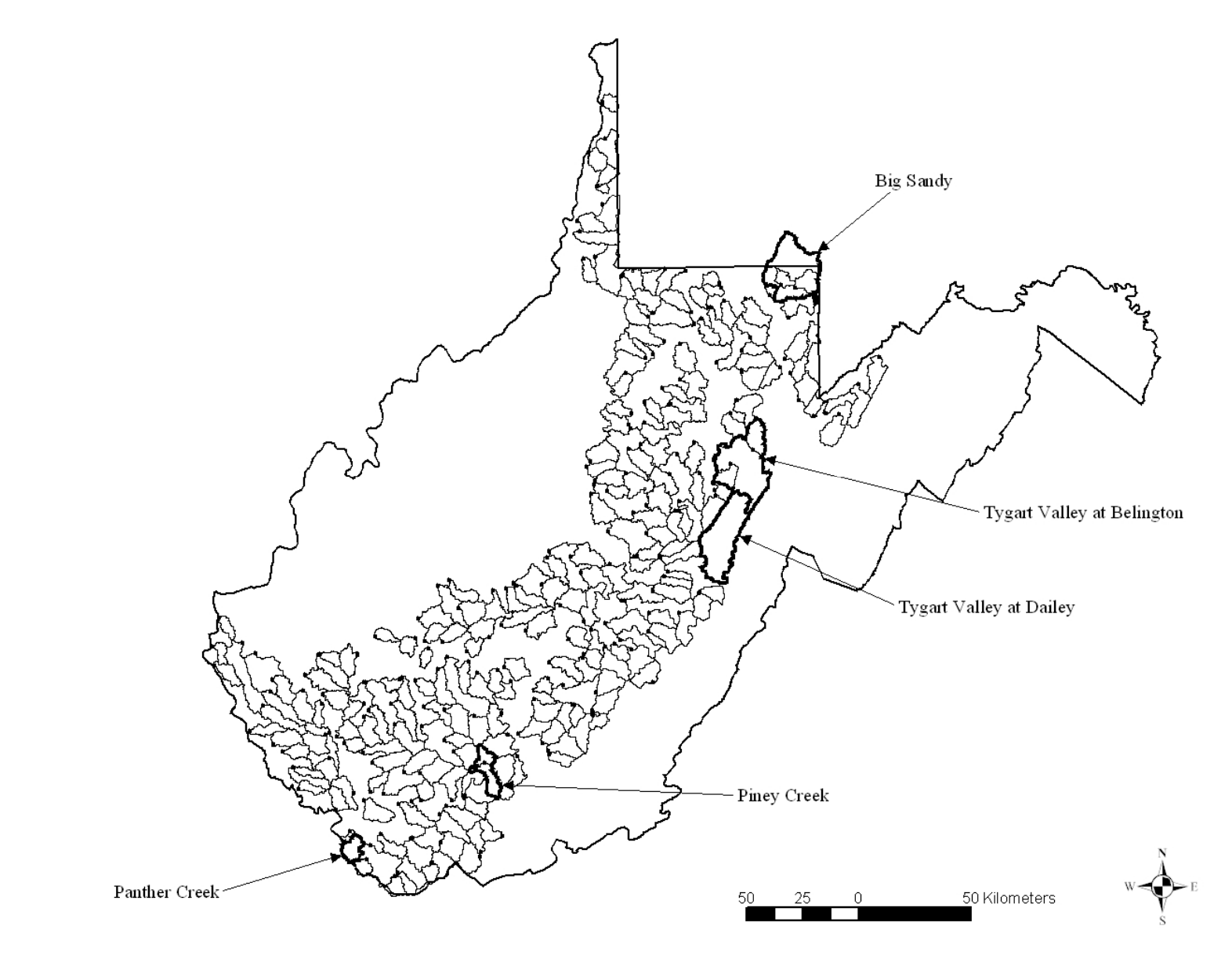
CHIA Trend Station Watersheds – Baseline HSPF UCI's are Generated and Placed in a Database



CHIA Project Calibration Watersheds



CHIA Project Verification Watersheds



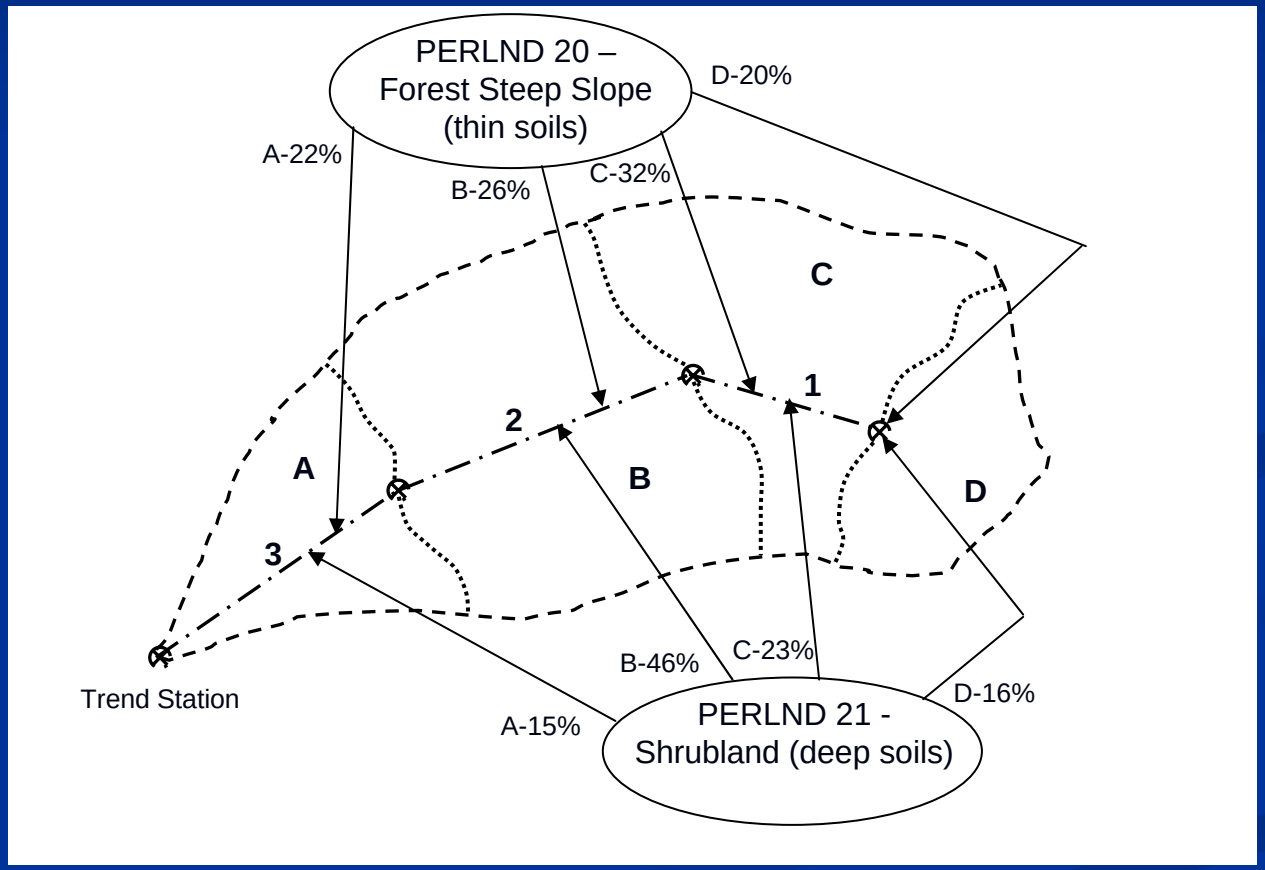
Land Use/Cover Classifications (1993 GAP Data)

1. Forest
   - Steep Slope
   - Moderate Slope
   - Mild Slope
2. Barren
3. Mined
4. Pasture/Grassland
5. Row Crop/Agriculture
6. Shrubland
7. Surface Water
8. Urban/Developed
9. Wetland

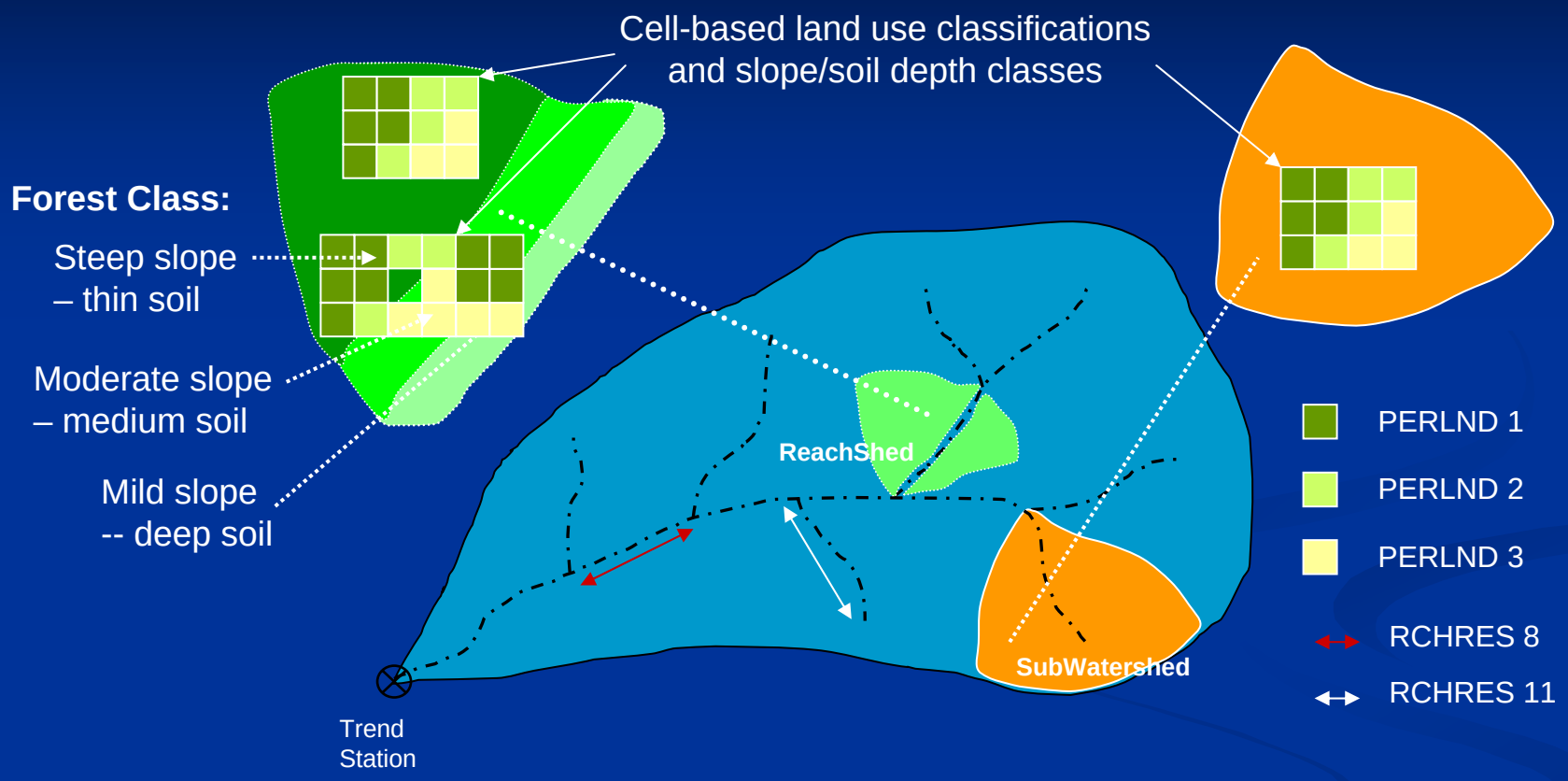
Slope Distribution for Forest Classification

Watershed	Total Area (acres)	Total Forested Area (acres)	% Forested	% Mild Forest	% Moderate Forest	% Steep Forest
Twelve Pole Creek	23646	20402	86	10	16	74
Buffalo Creek	72257	57590	80	19	28	53
Tygart Valley at Elkins	172642	137950	80	16	22	62
Clear Fork	79862	71455	89	7	10	83
Big Sandy	123027	96713	79	61	29	10

Grouping Land Use/Cover Classifications Across Subbasins in HSPF

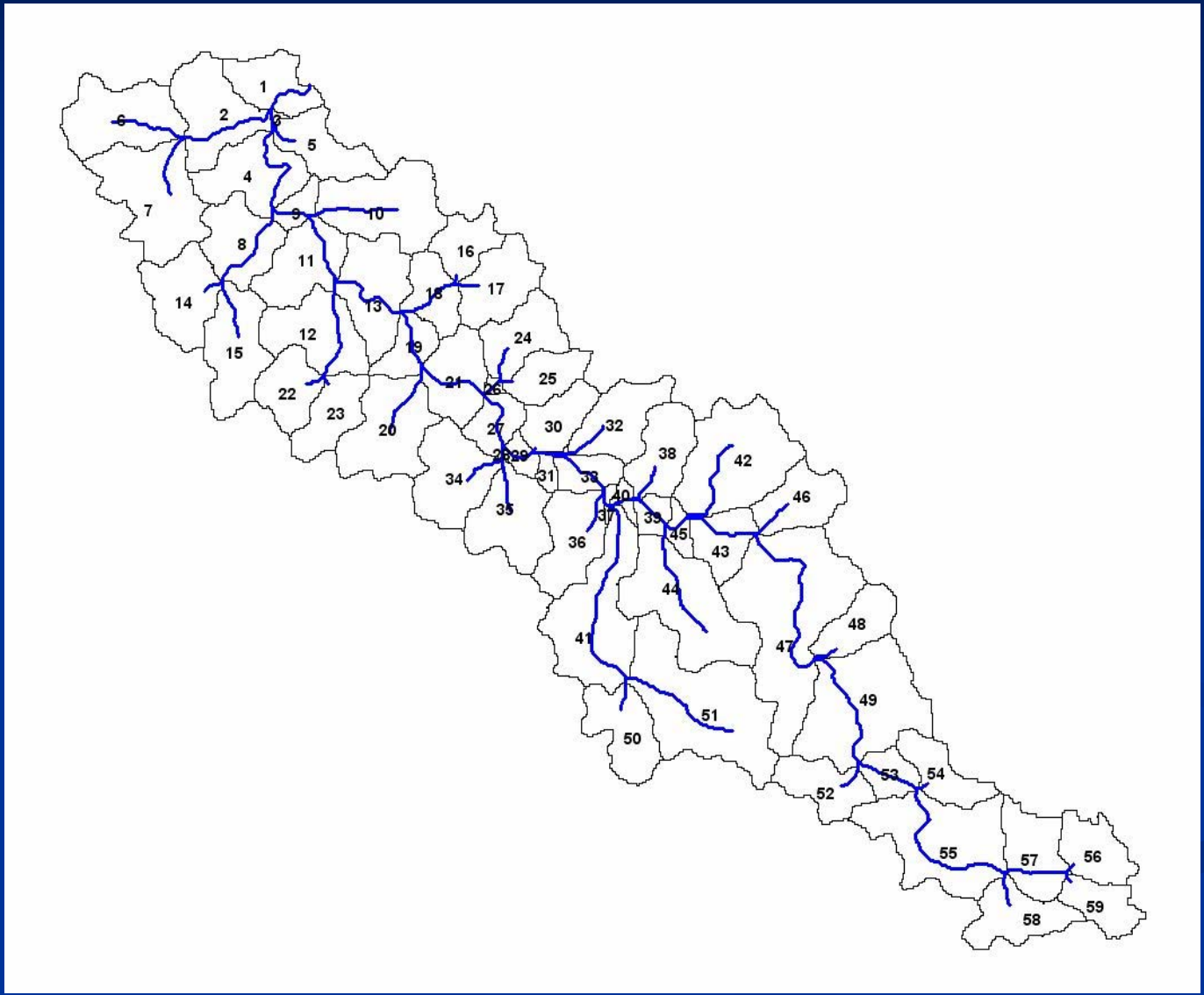


Grouped PERLNDs (11 classes)

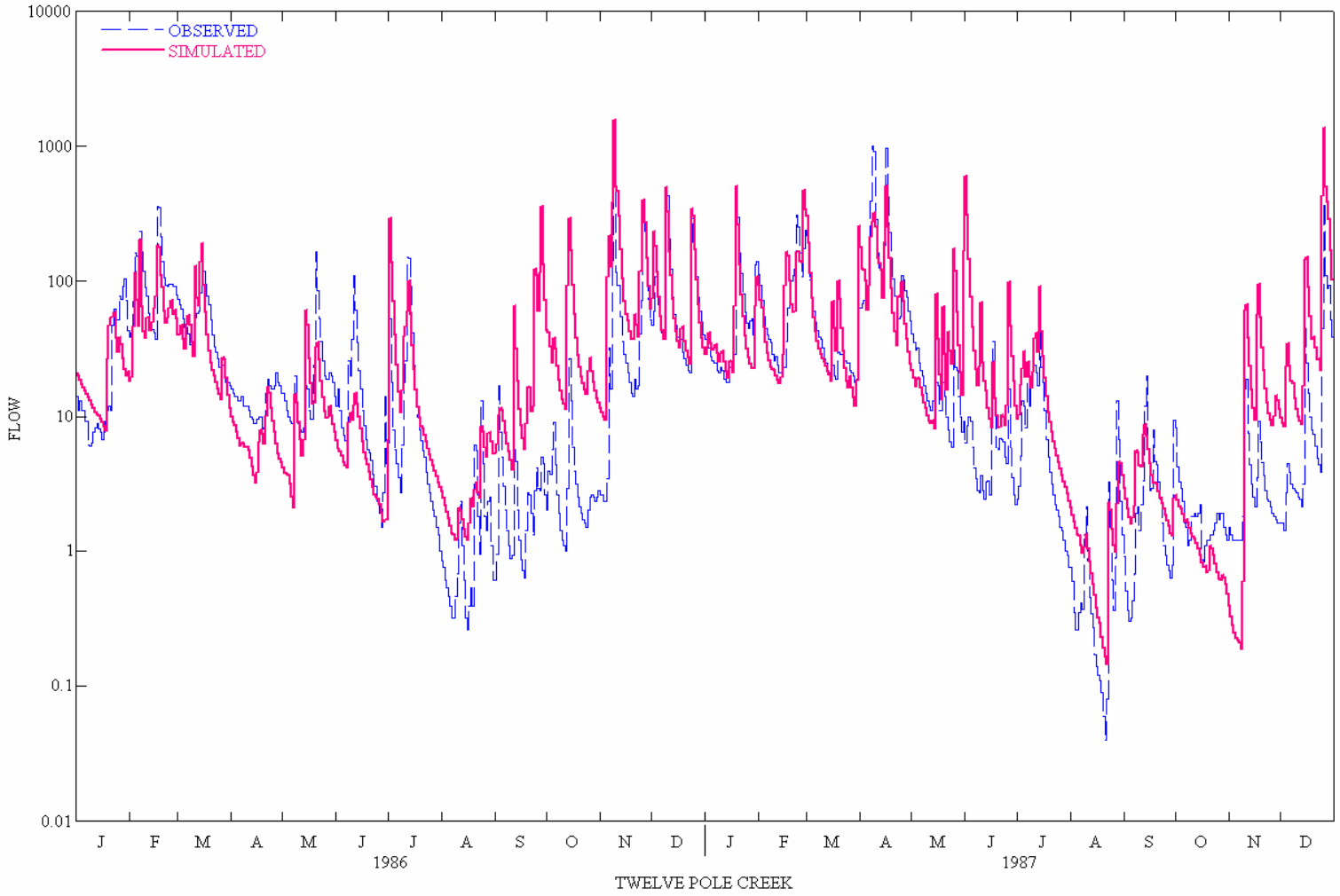


Segmentation Based on NHD Stream Drainage Network Representation in WCMS.

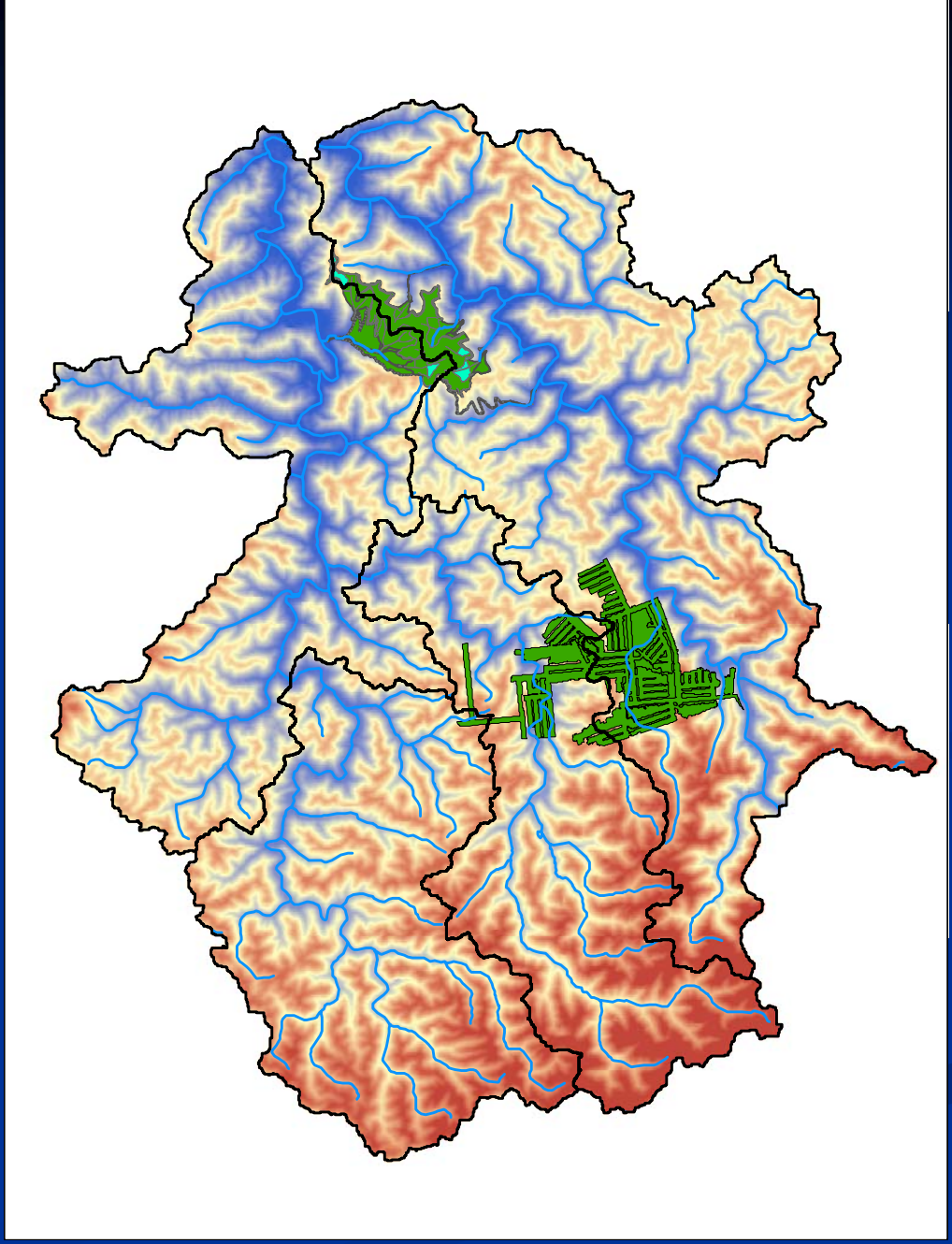
Twelve Pole Creek with WCMS/NHD Watershed Subdivision



Twelve Pole Creek HSPF Simulated Outflow and Gaged Outflow

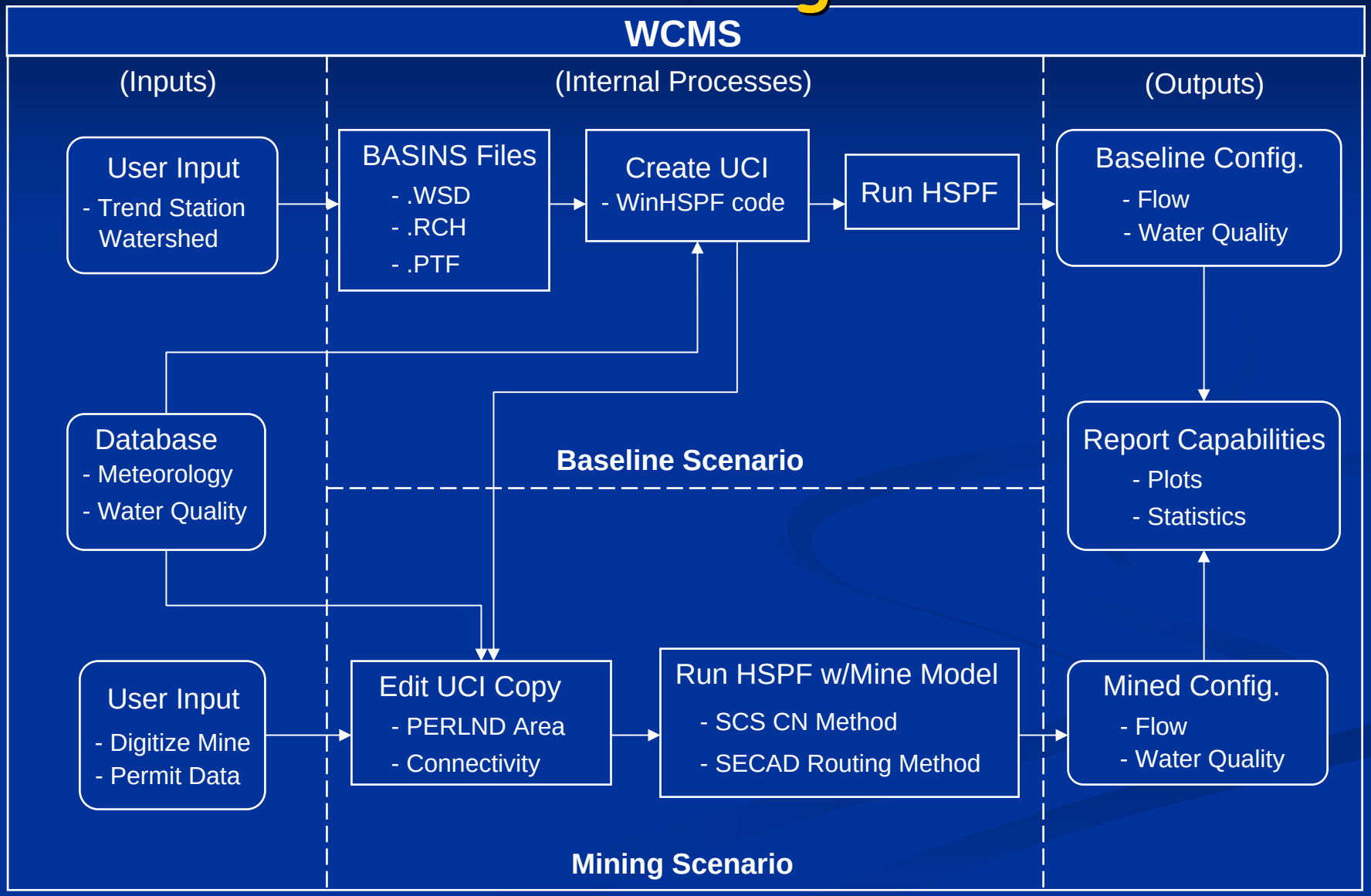


WCMS HSPF Modeling Tools for Surface and Underground Mines



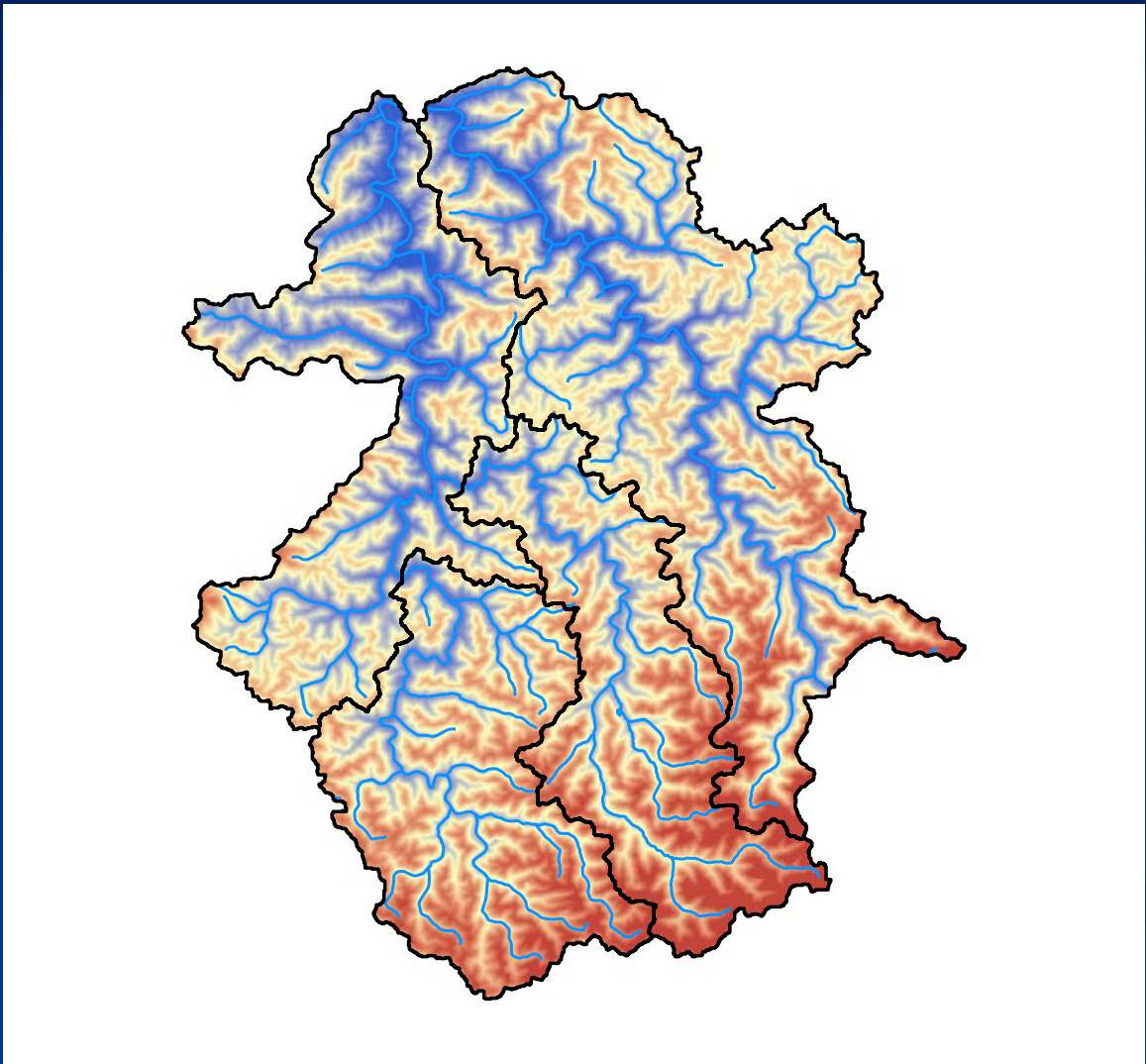
Surface Mine HSPF Modeling Procedures for Trend Station Watershed CHIA's

WCMS-HSPF Modeling Procedure: Baseline and Mining Scenarios



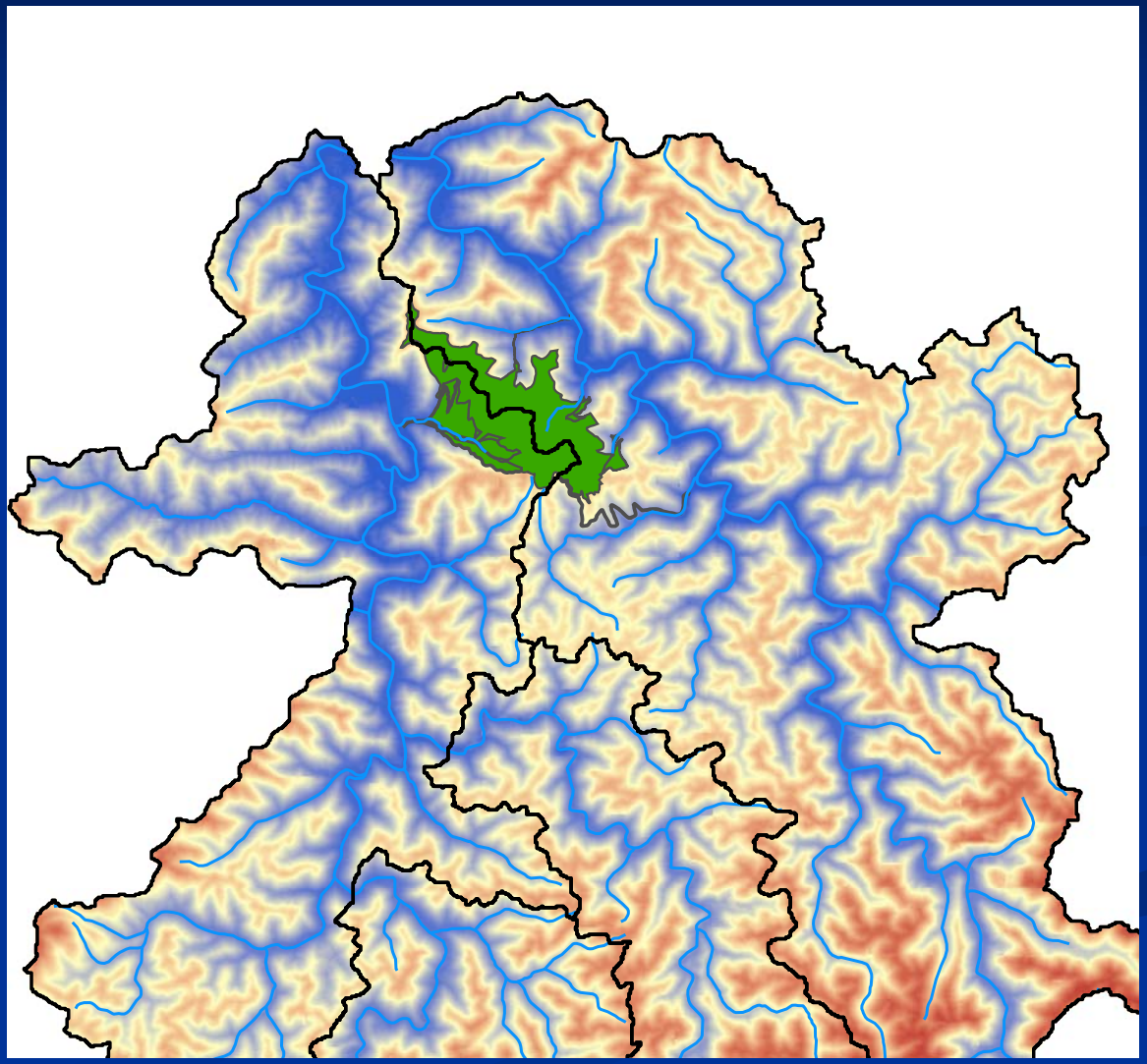
Step 1: Locate Mine Site Trend Station Watersheds

- UCI's for Each Trend Station are Stored in the Database.
- The Mine Site may Impact two or more Trend Station sheds.



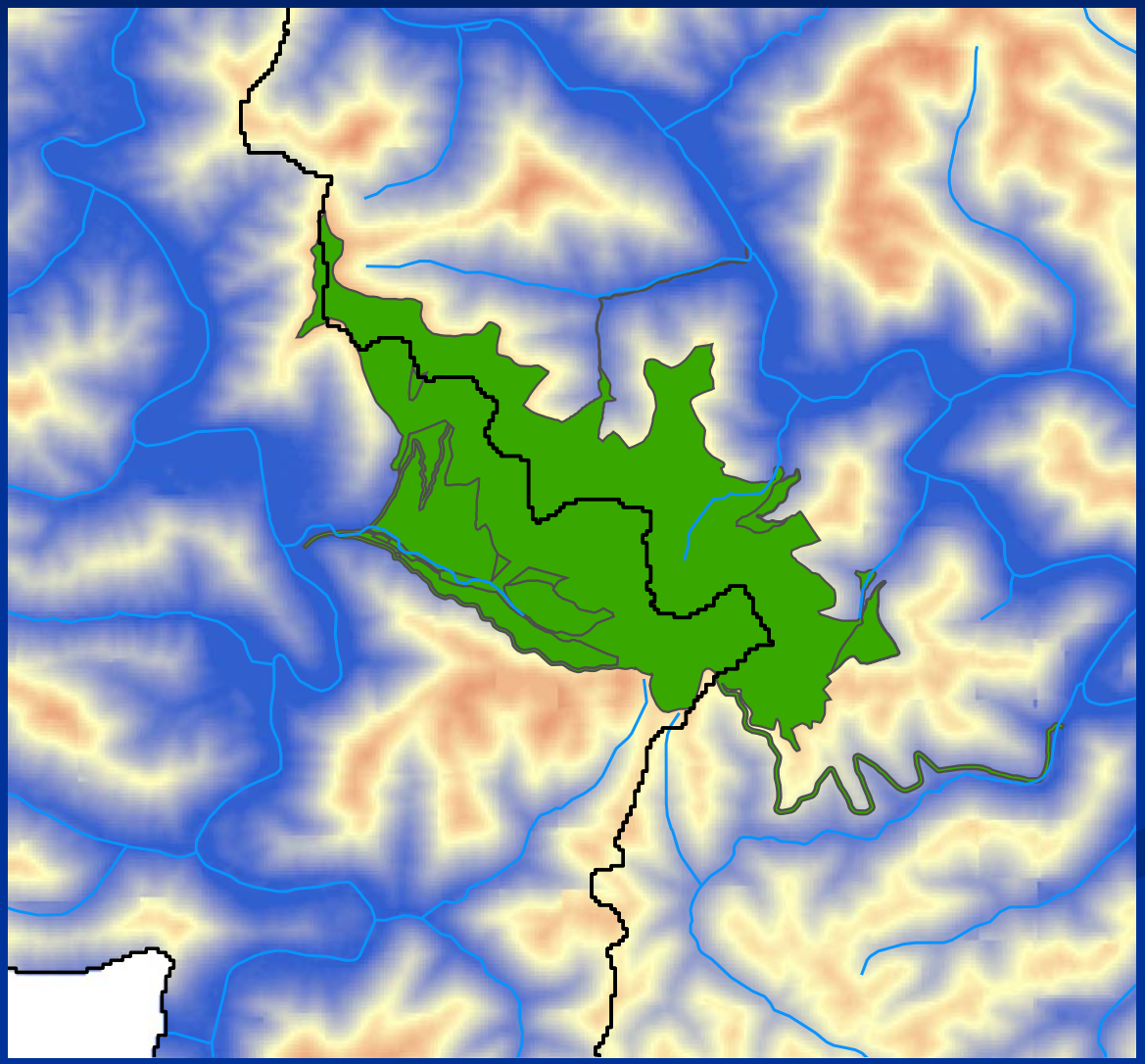
Step 2: Digitize the Mine Permit Boundary

- Area Enclosed by the Boundary Should Only Include those Areas under Hydrologic Control (NPDES).
- Outflows from the Area Enclosed are Assumed to Pass Through Sediment Control Structures.



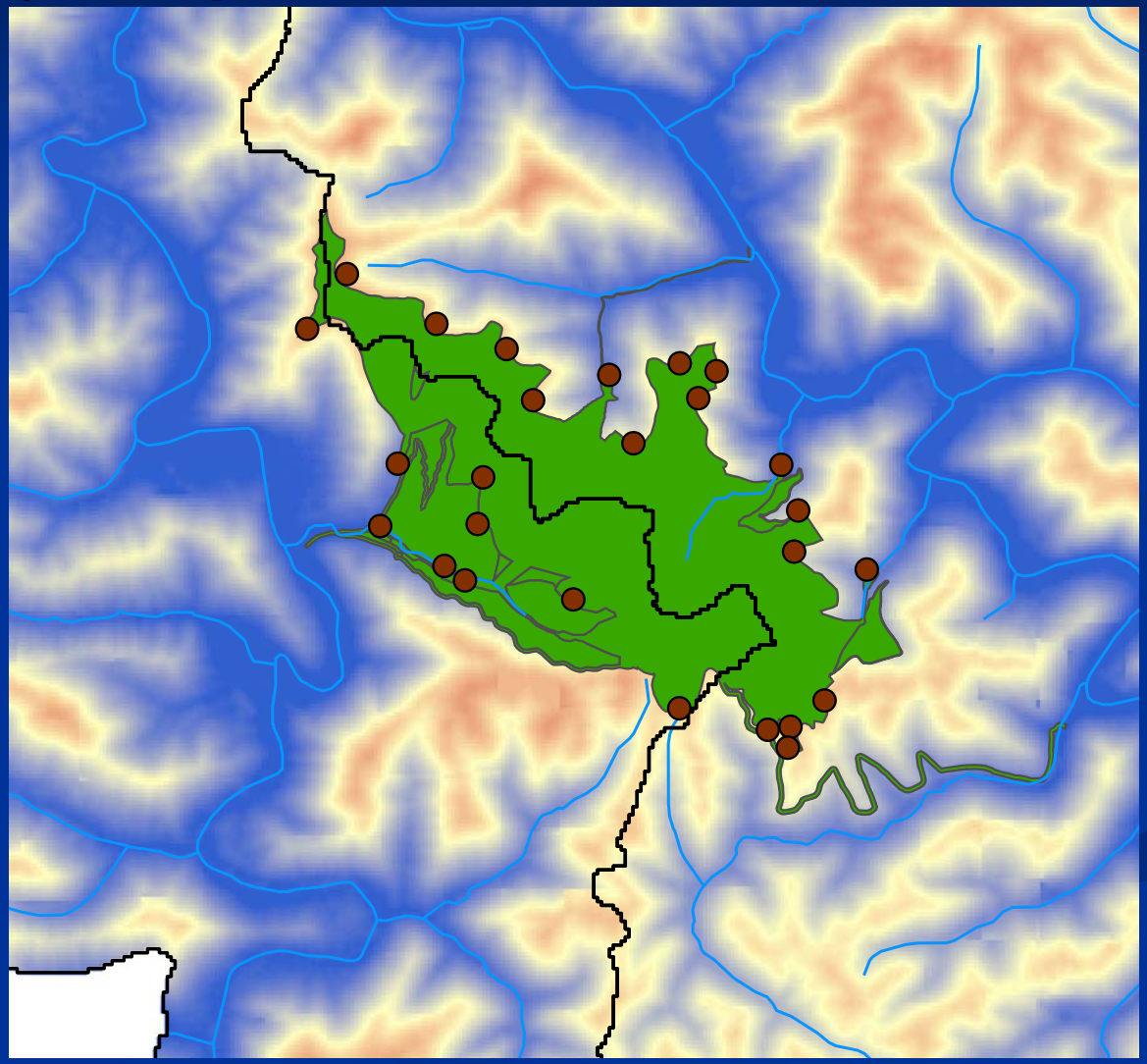
Step 3: Access Trend Station UCI's, to Cut-out the Mined Area

- Mine Boundary is Cut-out of a Copy of the Corresponding Trend Station uci's by Direct Editing of the PERLND Areas.
- The Entire Cut-out Editing Process is Accomplished with WCMS Tools.
- The Baseline Trend Station uci Remains Unchanged.



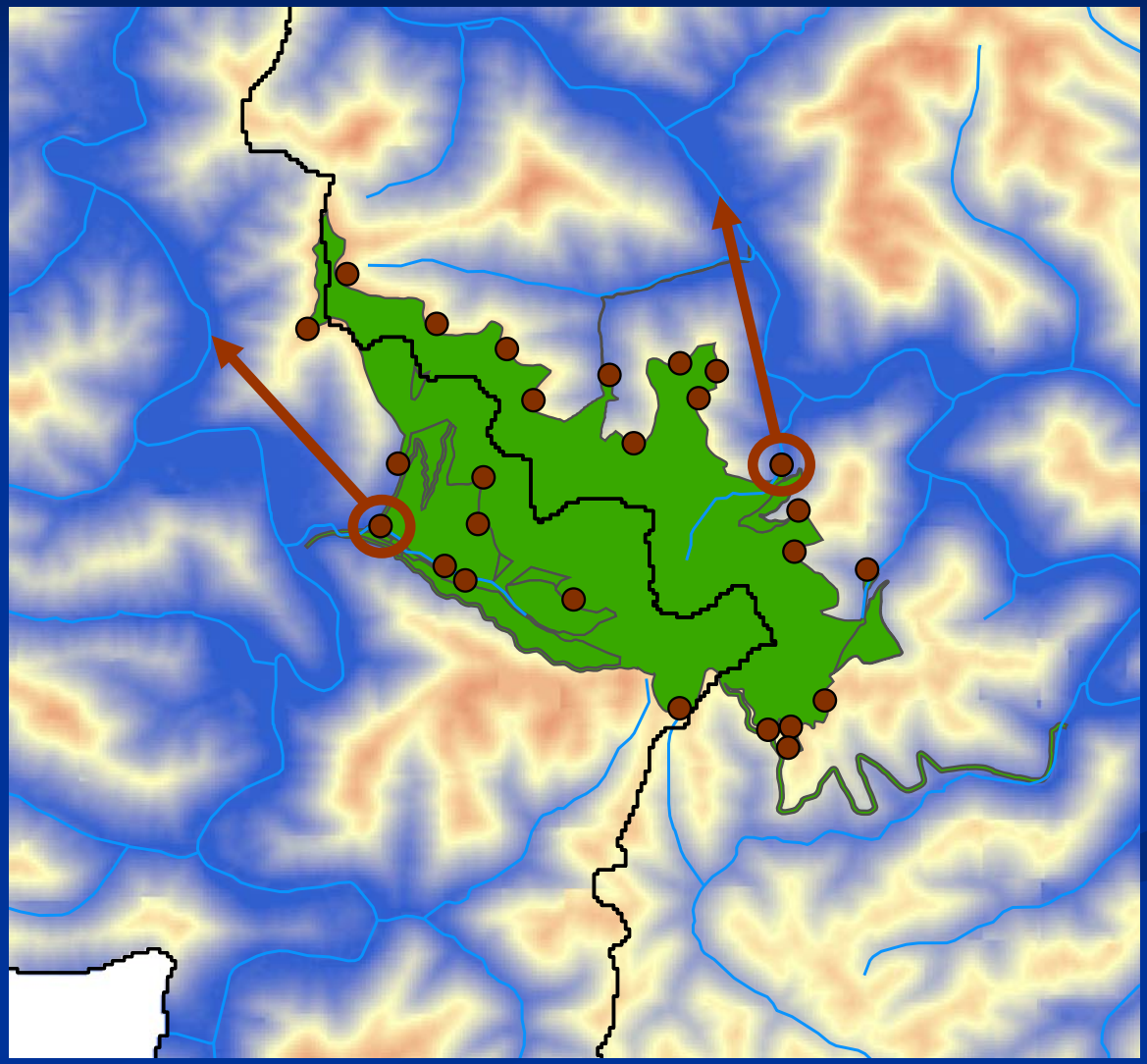
Step 4: Examine the NPDES Outflow Locations – Lump Together as Desired

- Decide Whether to Model Individual NPDES Outflows, or to Combine Some of Them.
- Select the Most Appropriate Stream Segment(s) Into Which the Outflow(s) are to be Placed.



Step 5: Combine NPDES Outflows (if desired) and Select Receiving Stream Segment(s)

- Select the WCMS Mine Segment Modeling Tool.
- Point to the Receiving Stream Segment for Each Outflow, and Enter the Mine Segment Hydrologic Parameters.
- Total of Mine Segment Areas Must Match Cut-out Area in Step 3.



Physical Mine Segmentation:

- Drainage Area(s)

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- Sediment Ponds (or Ditches)

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NPDES Points

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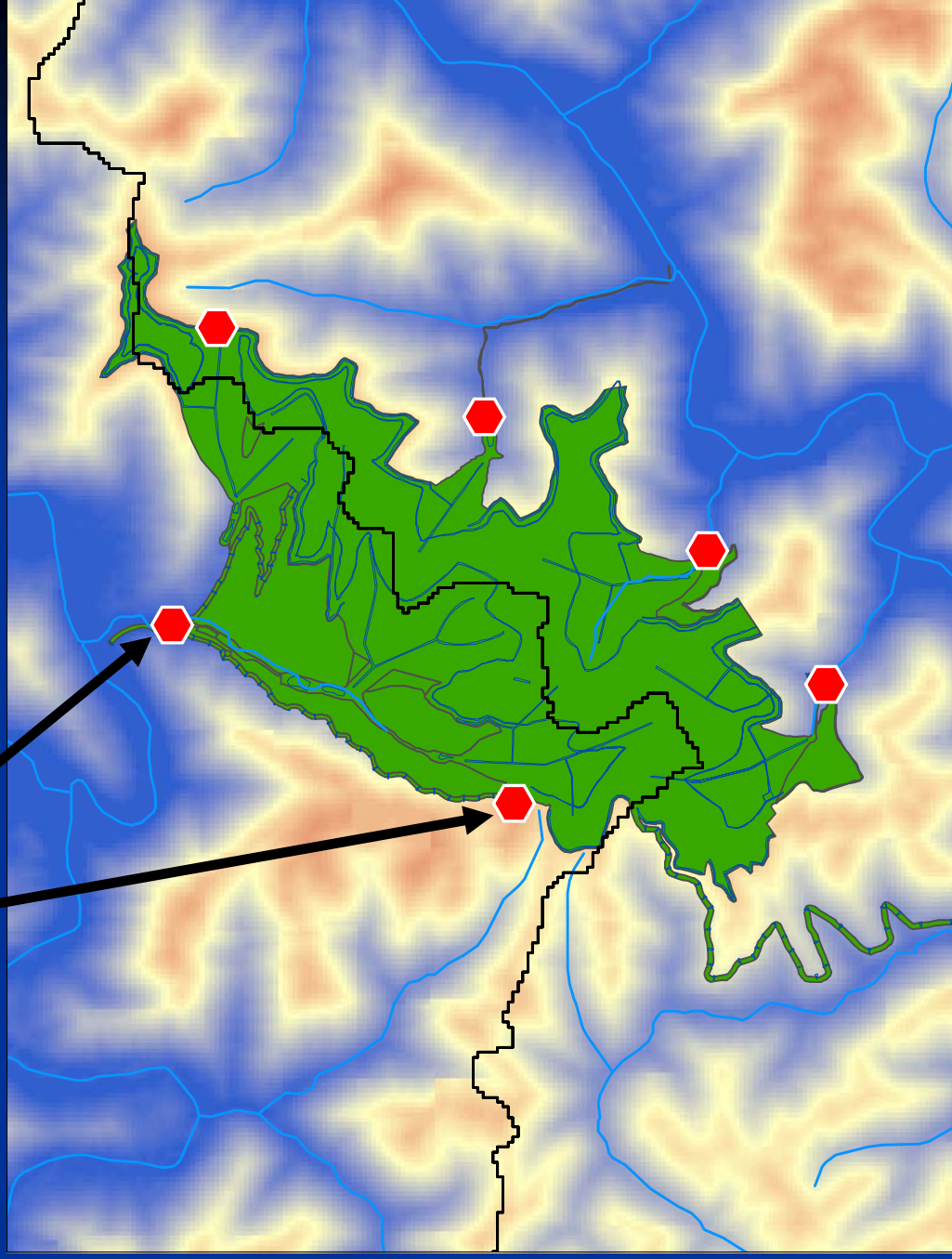
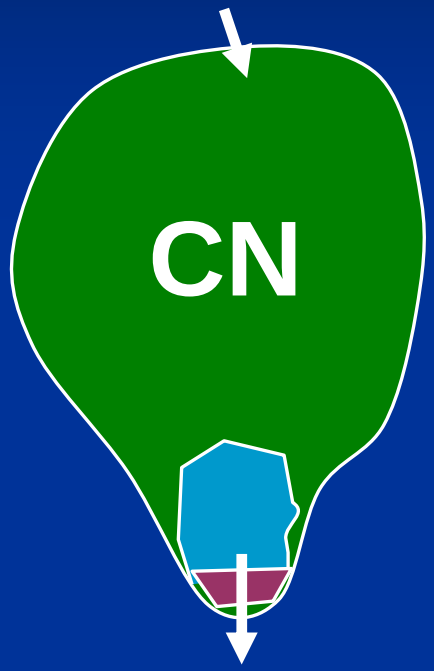
Stream Segment



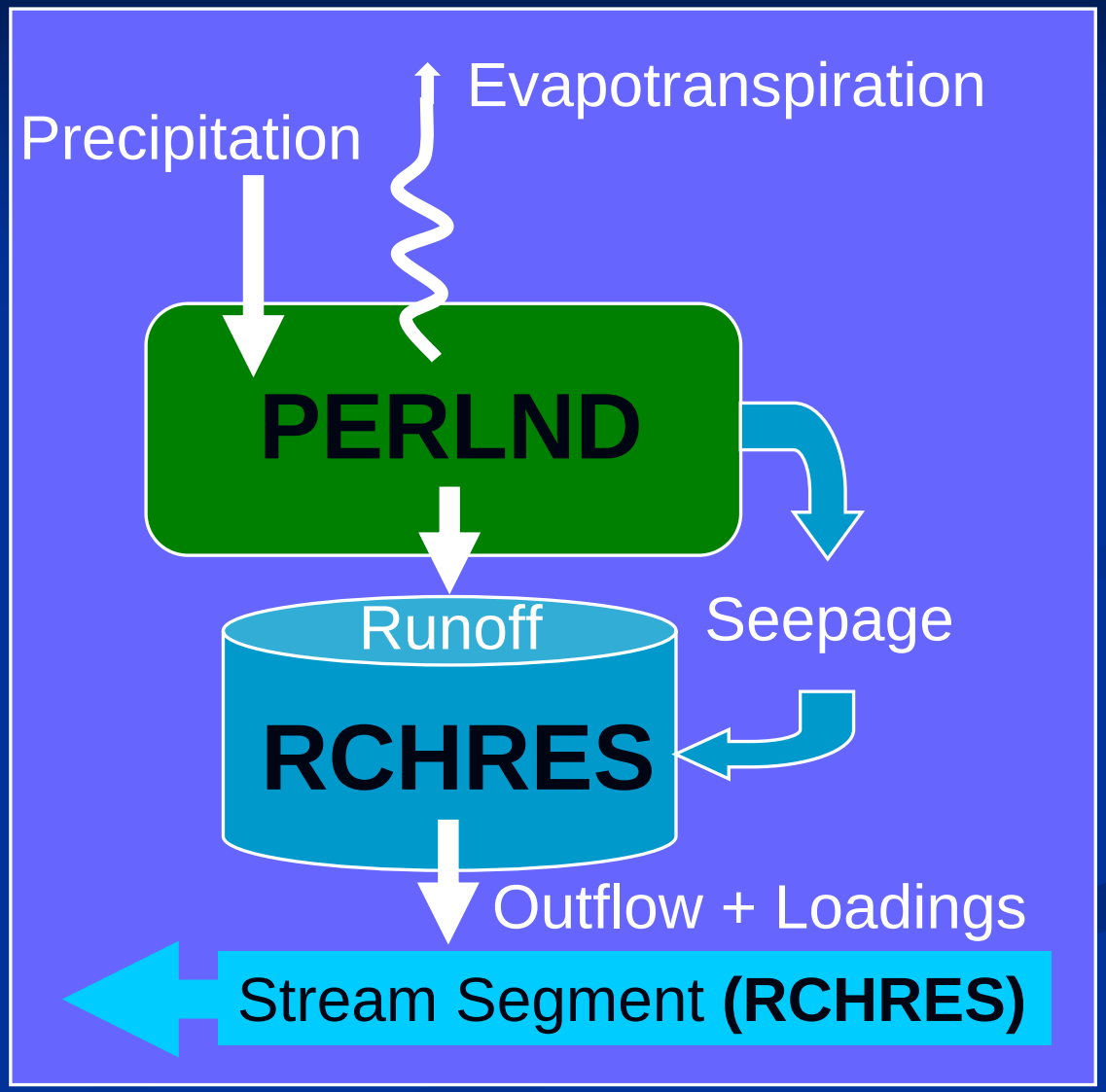
Mine Segment HSPF Model

Drainage Area



Storage Versus Outflow

+ Water Quality Loadings



Mine Segment Model Input Data Requirements

- Minimal Data Input Option:
  - Drainage Area
  - Weighted Curve Number (CN)
  - Design Storm Frequency
  - NPDES Discharge

- Complete Data Input Option:
  - Drainage Area
  - Weighted Curve Number (CN)
  - Design Storm Frequency
  - Watershed Slope
  - Hydraulic Length
  - Sediment Structure Storage versus Outflow Table
  - NPDES Discharge

Underground Mine HSPF Modeling Concept for Trend Station Watershed CHIA's

Deep Mine Segmentation

Surface Recharge Areas

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Mine Cavity Storage

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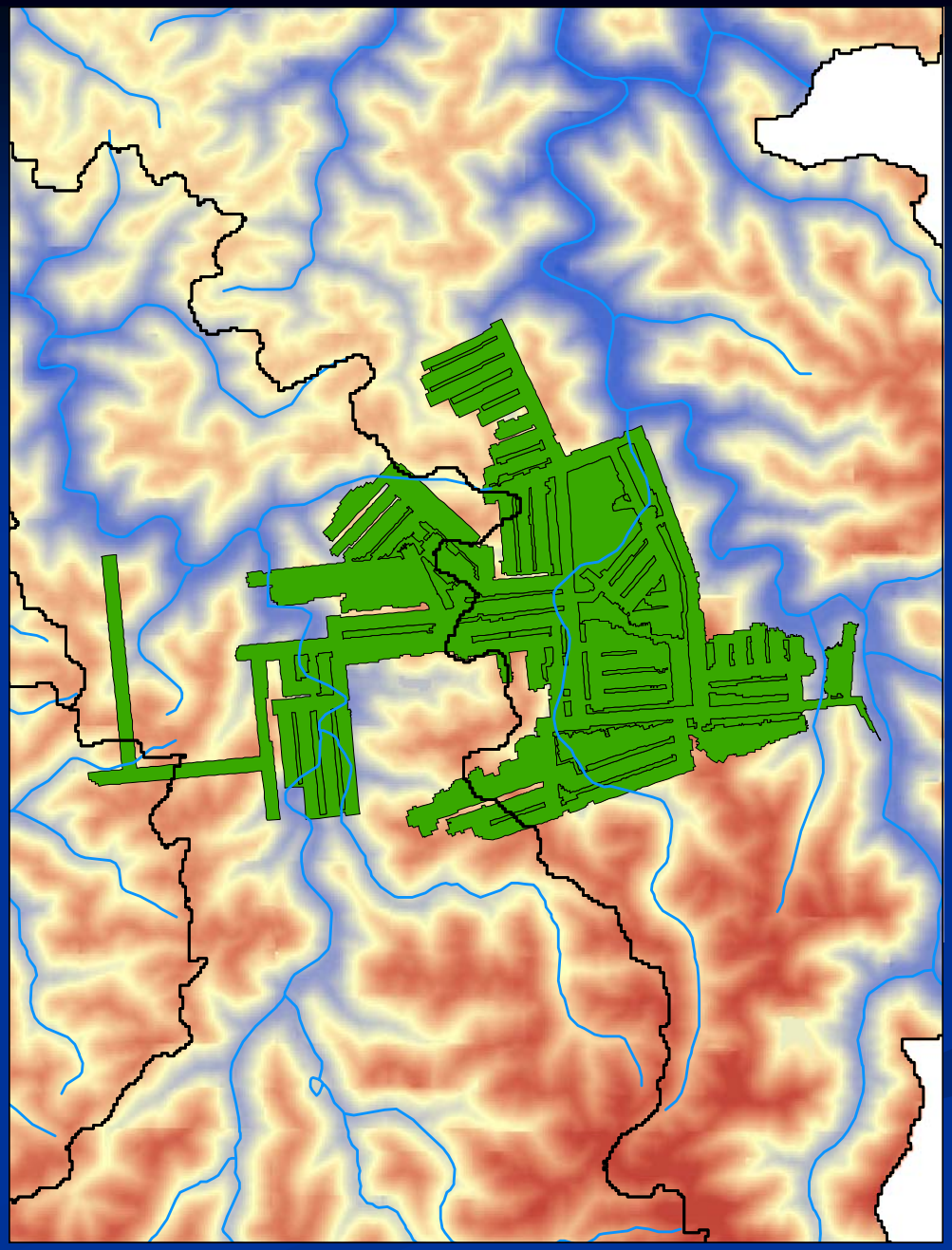
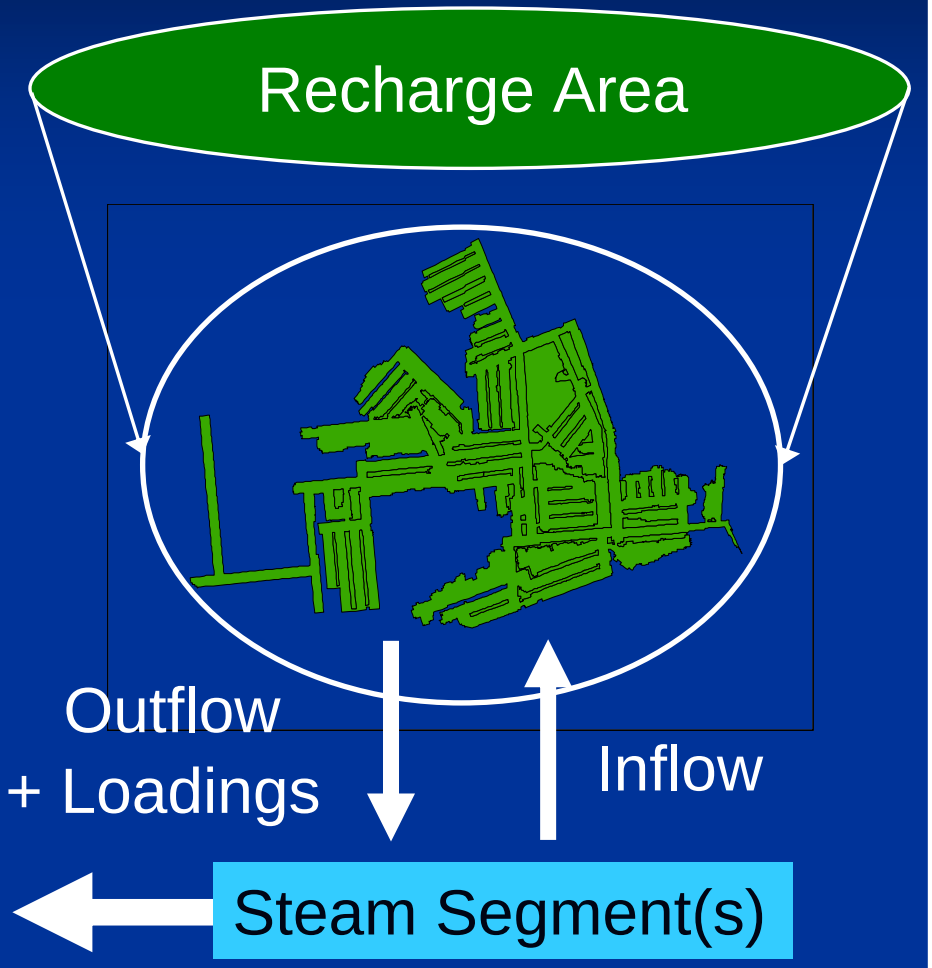
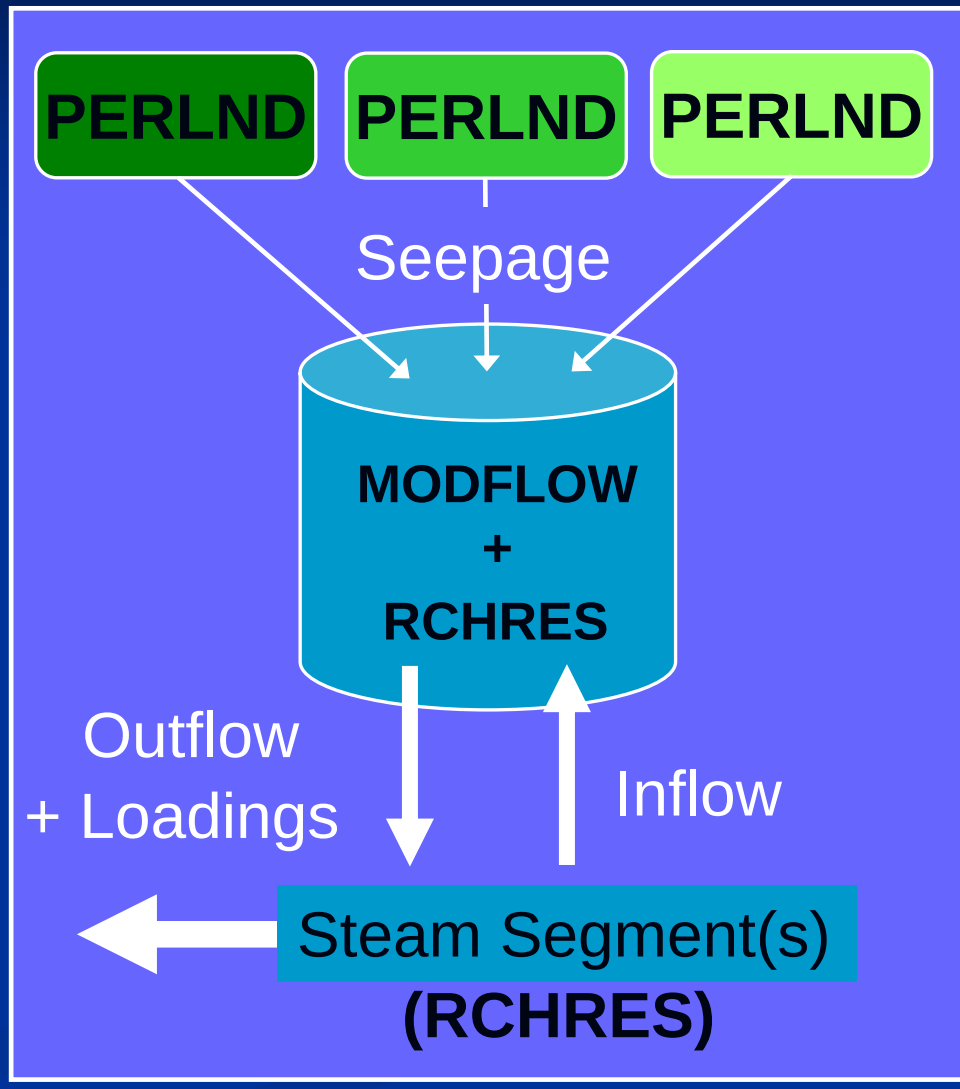
Stream Segment Inflow - Outflow



Underground Mine HSPF Model





Future Directions

- Complete WCMS User Interface Tools for HSPF/CHIA Modeling.
- Complete the Implementation and Testing of the HSPF Surface Mine Hydrologic Model.
- Complete the Implementation and Testing of the ACIDPH Model.
- Start the Conceptual Development Process for the Underground Mine Model.
  - Utilization of the New HSPF/MODFLOW Combined Model