Potential CHIA application for WATER

(Water Availability Tool for Environmental Resources)

USGS Kentucky Water Science Center

U.S. Department of the Interior
U.S. Geological Survey

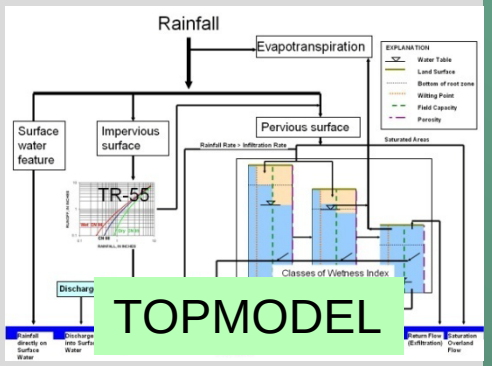
The Configuration of the WATER Application

WATER

Simple Interface

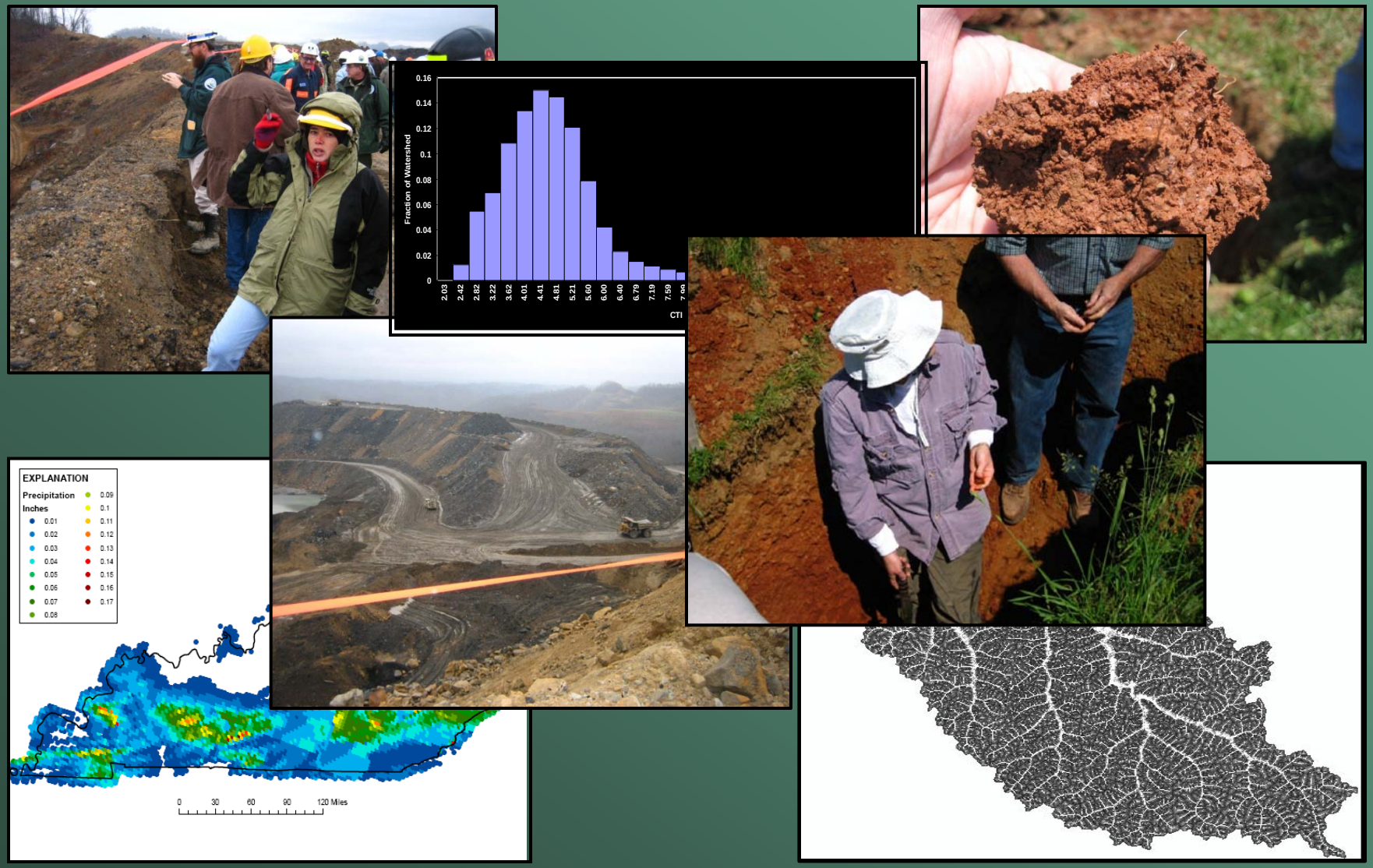
WATER draws from MANY data layers produced by MANY scientists

"Any Extension"



Output from "Any Extension"

Many decisions by multiple experts must go (and have gone) into the application and processing of datasets and layers in WATER to produce accurate, consistent, and scientifically defensible results.



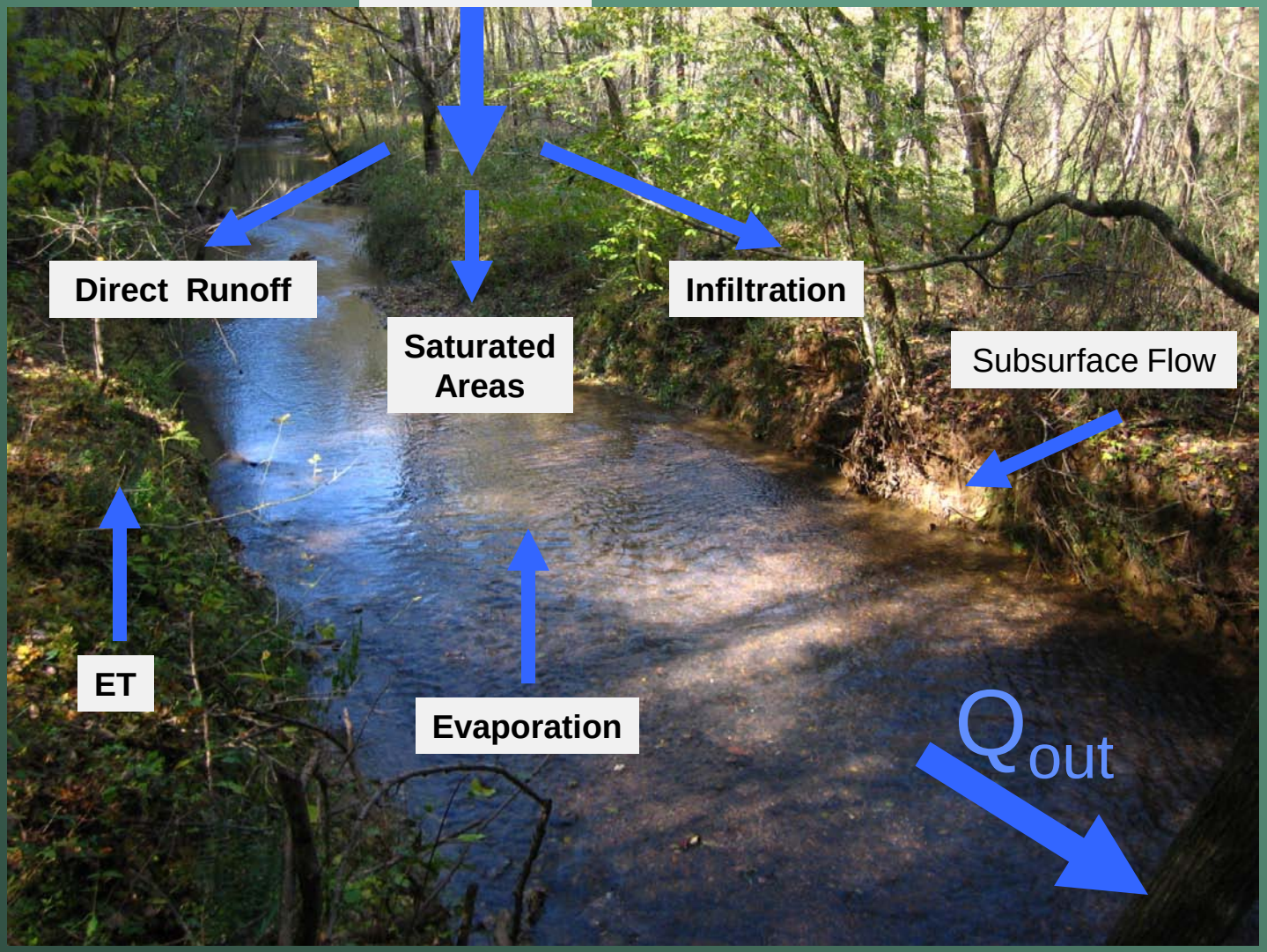
Brief discussion on the TOPMODEL extension in WATER

- TOPography-based hydrological MODEL
- Developed by Beven and Kirkby, 1979
- "Physically-based watershed model that simulates the variable-source-area concept of streamflow generation." (Wolock, 1993)
- Quasi-distributed approach – breaks the watershed up into landscape components that are identified by the topographic wetness index

Beven, K.J. and M.J. Kirkby. 1979. A physically based, variable contributing area model of basin hydrology. *Hydrological Sciences Bulletin*, v. 24, pp. 43-69.
Wolock, David M. 1993. Simulating the variable-source-area concept of streamflow generation with the watershed model TOPMODEL. *USGS WRI 93-4124.*

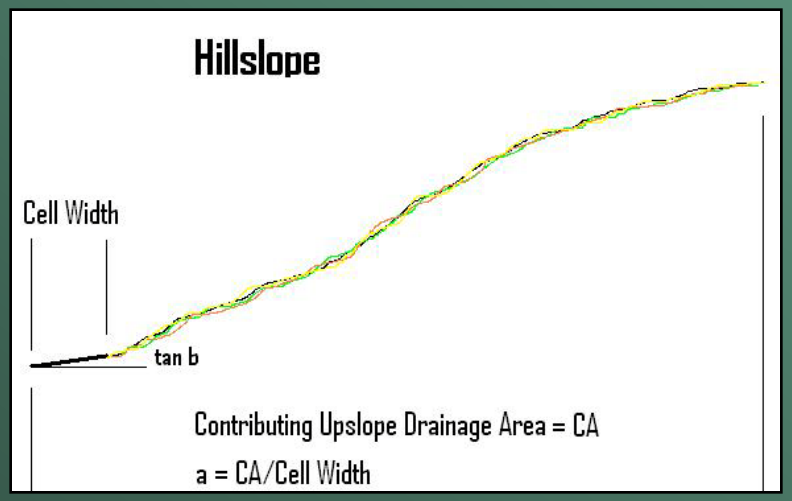
TOPMODEL Water Budget Components

Water Cycle



TOPMODEL topographic wetness index

$$TWI = \ln\left(\frac{upslope\ contributing\ area}{\tan\ slope}\right)$$



Grid cells with the same TWI are hydrologically similar

Calculations need not be performed on every single grid cell (quasi distributed).

High values of TWI → High potential for saturation
Low values of TWI → Low potential for saturation

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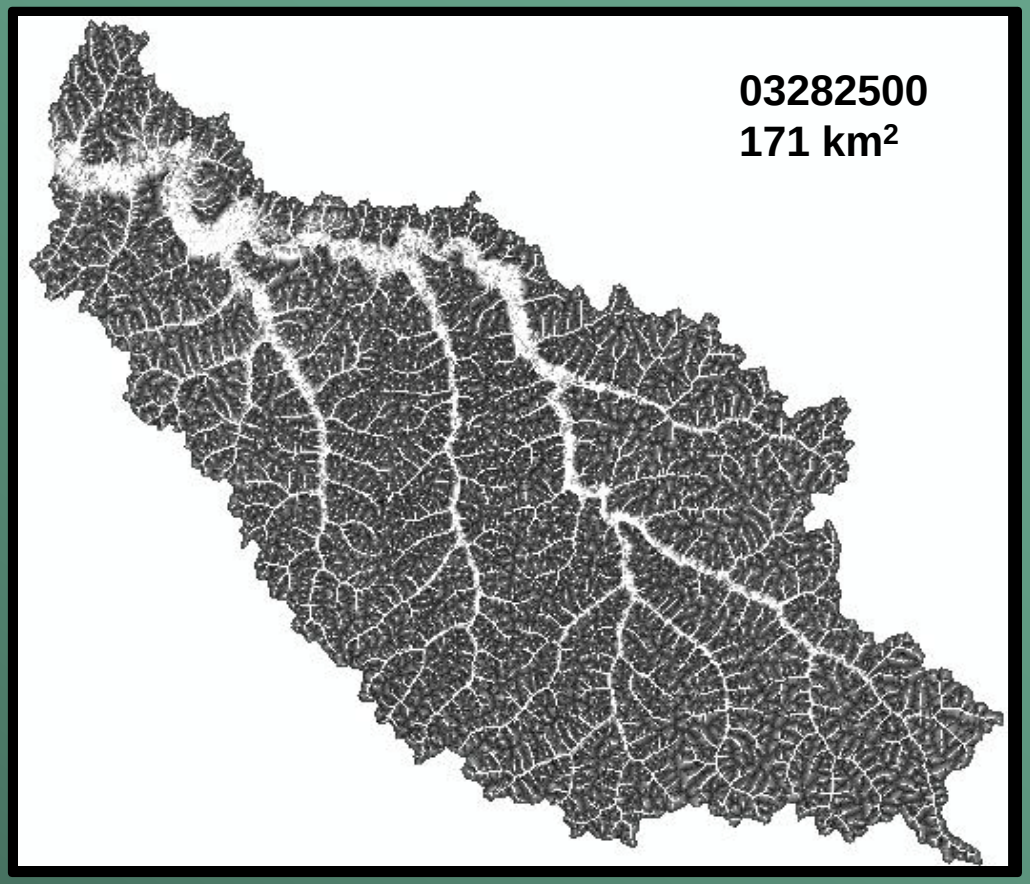
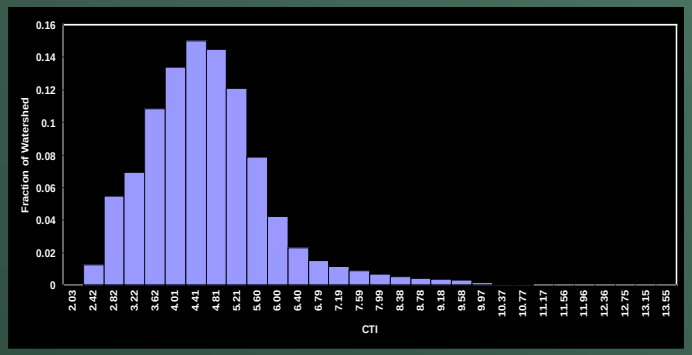
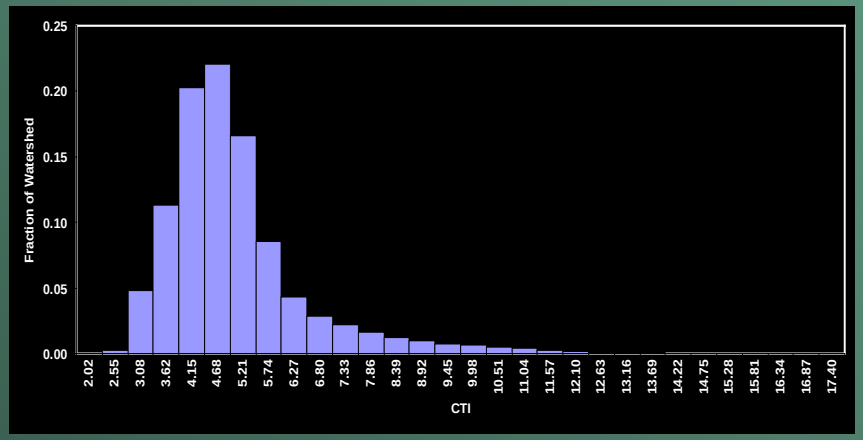
Quasi-distributed Approach



03207965
17 km²





WATER Data Library

Historical Climate and gridded NEXRAD data

→ **Precipitation and Temperature Estimates for Each Basin**

Topographic Wetness Index → **Histogram**

DEM → **Topographic Wetness Index**

DEM → **Streams (synthetic)** → **Topographic Wetness Index**

From Spatial Layers
Site ID
Area
Total cells
Lake area
Uplake Area
Soil Characteristics
Root Zone
Stream cells
Latitude
Impervious areas
Withdrawals
Discharges

→ **TOPMODEL Extension**

- **Estimated hydrograph**
- **Time series**
  - **Saturated areas**
  - **Stream length**

DATA SOURCES

- **KY Dam Safety Commission**
- **Soil Survey Geographic Data**
- **TR-55 Impervious Erosion Curve**
- **National Land Cover Data 2001**
- **KY Pollutant Discharge Elimination System**
- **KY Division of Water**
- **NOAA NWS**

Soil Characteristics

SSURGO Variables	Calculated "m"
▪ Hydraulic conductivity (moderately high or higher) ▪ Available Water Capacity ▪ Field Capacity ▪ Porosity ▪ Depth (based on conductivity) And….. ▪ Scaling Parameter "m" computed from processed SSURGO data ▪ *m* = readily drained soil porosity/rate of decrease with depth	Conductivity Multiplier $\frac{K_{sat}\text{-}High\ surface}{K_{sat}\text{-}Low\ depth}$ Scaling Parameter $f = \frac{\ln(conductivity\ multiplier)}{soil\ depth}$ $m = \frac{porosity - field\ capacity}{f}$

Basic TOPMODEL equation:

$$S_x = \bar{S} + m\left(T\overline{WI} - TWI_x\right)$$

S – saturation deficit
TWI – topographic wetness index
m –controls range of variability in saturation deficit

as *m* ↑, variability in *S* ↑ and water table gradient ↑

due to <u>increased</u> effect of topography -

this attenuates peak flow and steadies base flow

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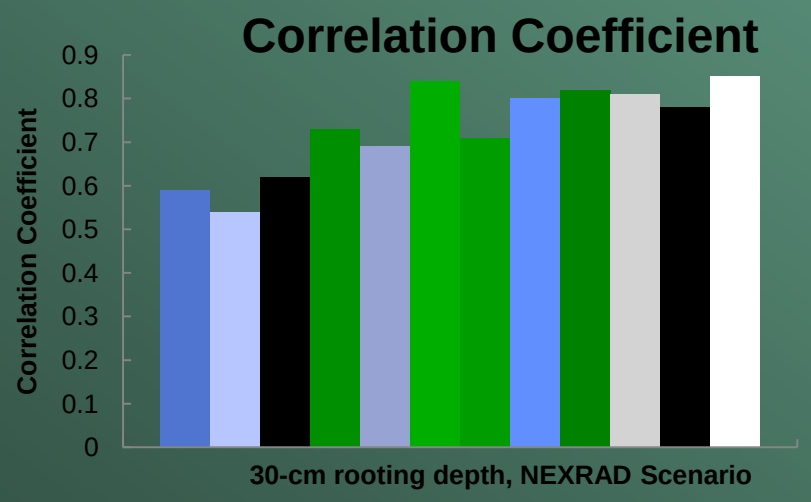
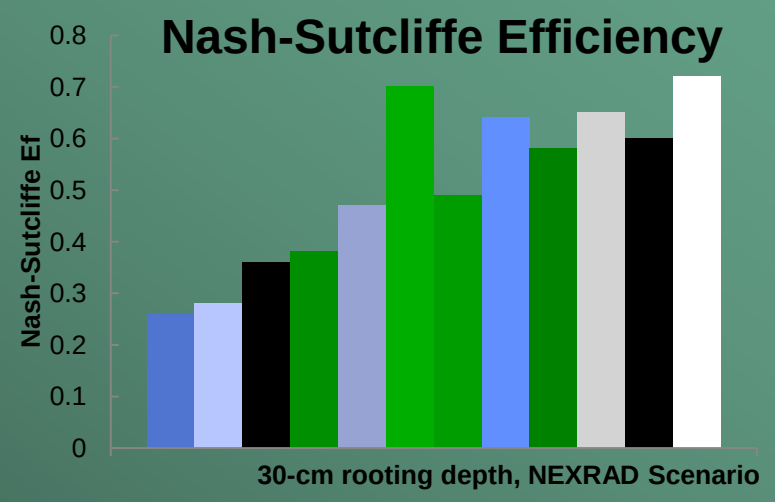
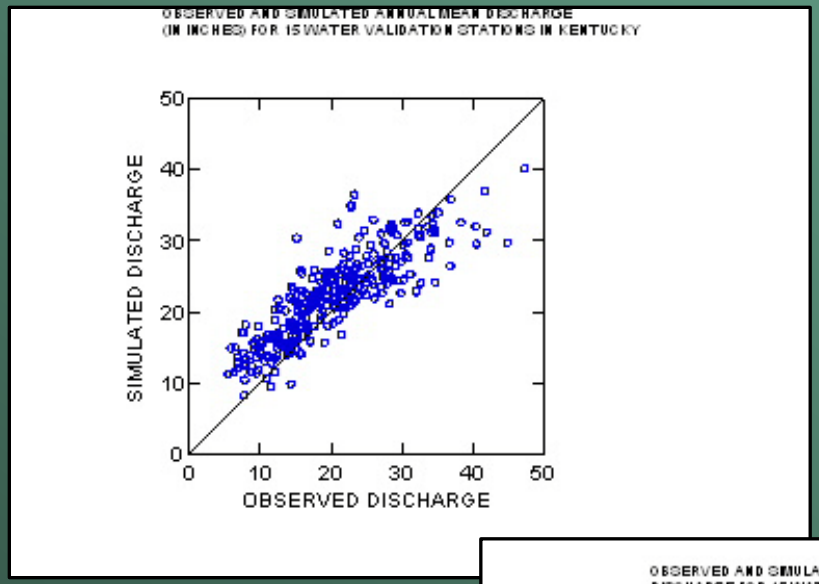
Statistical Validation - How well does it work over all flows?

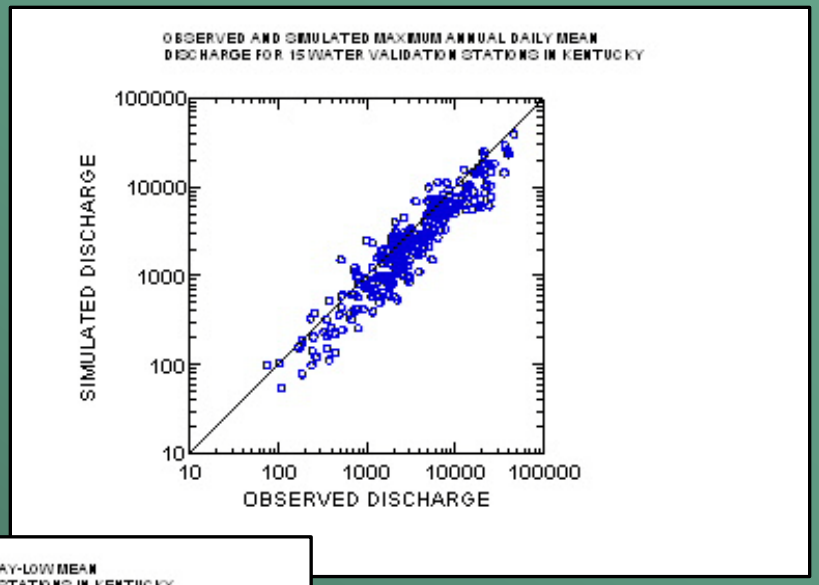


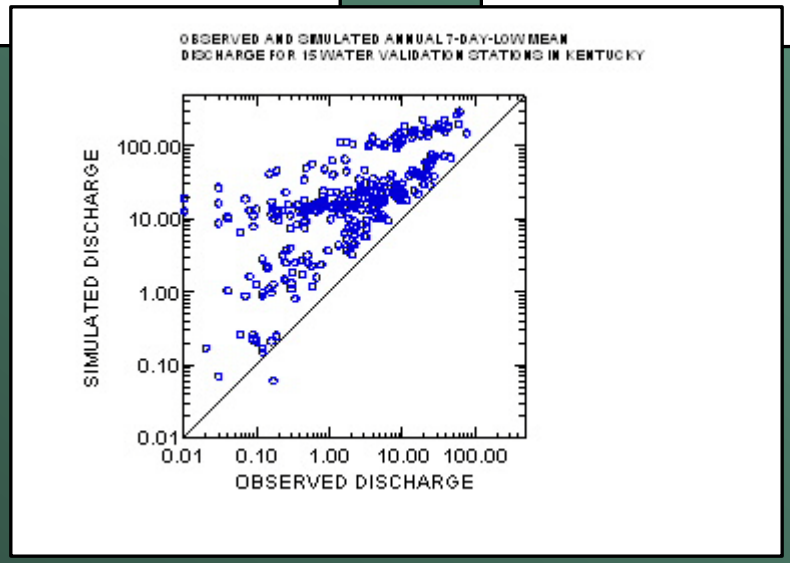


Statistical Validation

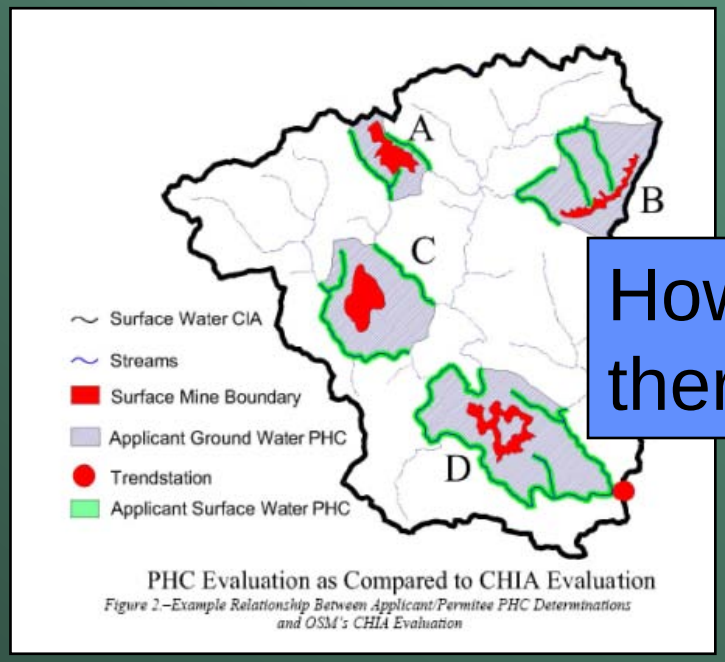
How well does it work by flow regime?



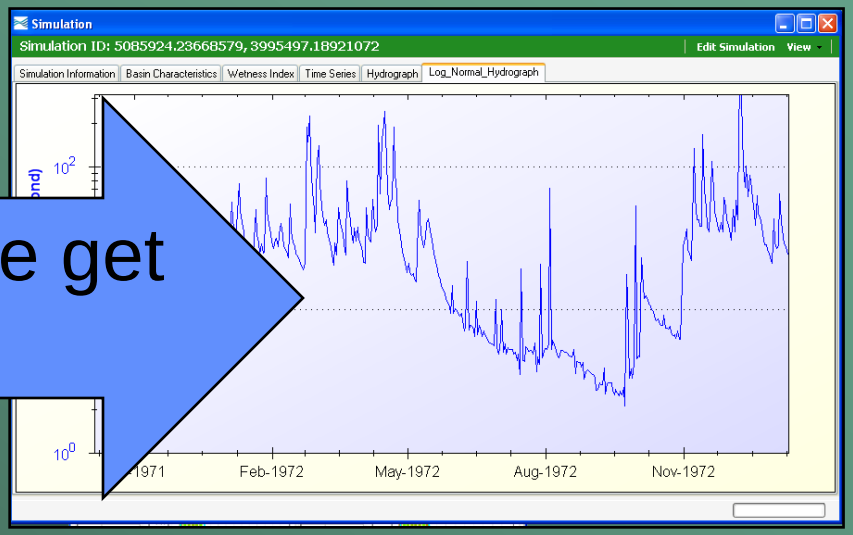




CHIA specific modifications



How do we get there?



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Current upgrades being funded through USGS Midwest Area Mining Initiative.

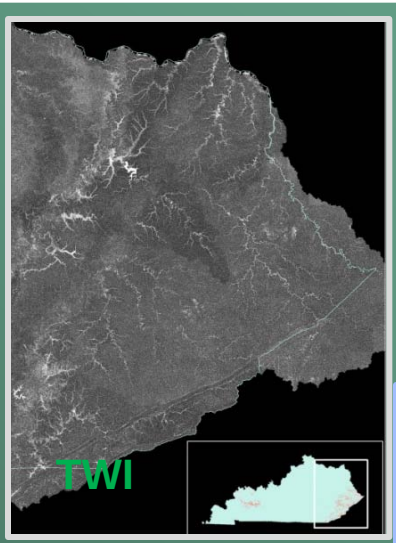
3 objectives:

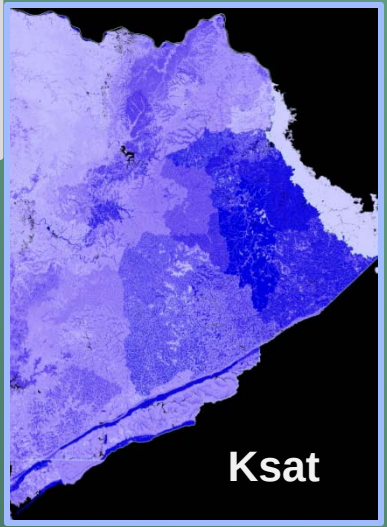
- Full implementation of PEST for improved accuracy and regionalization (internal use for development of various extensions)
- Build foundation for PHREEQC and run pilot basin
- Add function to implement EarthWorks output from latest version of SEDCAD to automatically modify DEM - more work is needed beyond this.

USGS

Implementation of Parameter Estimation capability (PEST)

- PEST (Doherty, 2008)
  - Better accommodate uncertainties or heterogeneities in basin parameters.
  - Facilitates scenario testing of hydrologic responses obtained by significant changes in parameters.
  - Helps Identify Most Sensitive Parameters – Minimizes parameter correlation.
  - Relative Error Analysis – Estimates variability contributed from individual parameters.





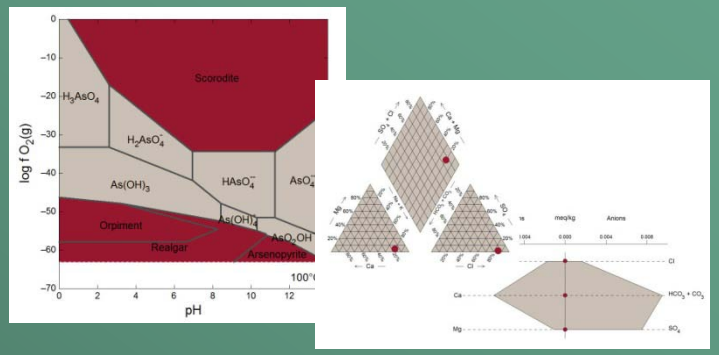
USGS

Implementation of PHREEQC

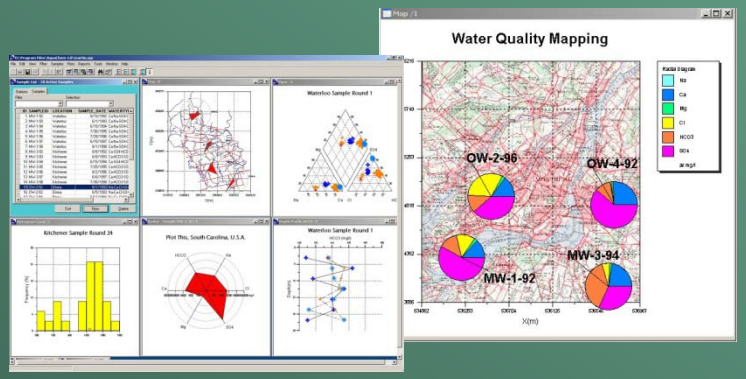
A USGS Computer Program for Speciation, Batch-Reaction, One-Dimensional Transport, and Inverse Geochemical Calculations (Parkhurst and Appelo, 1999)

- For example, PHREEQC enables:
  - Forward and inverse geochemical speciation modeling:
    - "What minerals are anticipated to dissolve?"
    - "What minerals will precipitate?"
    - "What geochemical reactions or rock/water/soil interactions produced these water-chemistry characteristics?"
  - Mixing models:
    - "If water with composition A mixes with water with composition B, what is composition of product (water C)?"
  - 1-Dimensional Reactive Transport modeling:
    - "How does the water chemistry change as it moves along a stream or through an aquifer?"

Potential graphical outputs

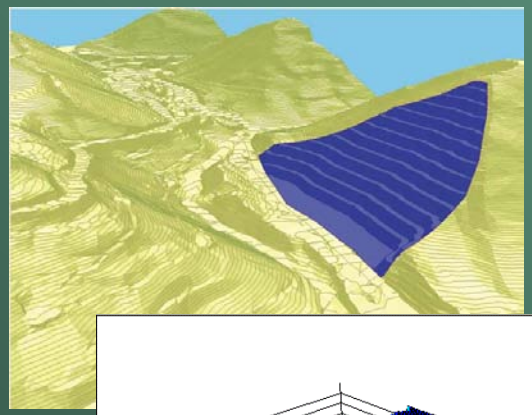


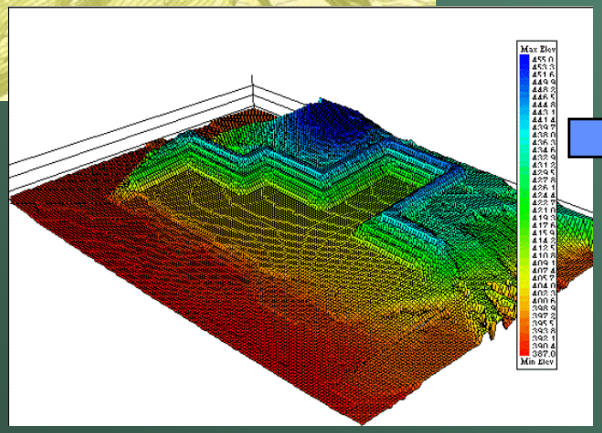
Images of similar output from Geochemist 's Workbench ™ application



Images of PHREEQC output from Aquachem™ application

Implementation of commonly used AutoCAD formats into WATER





USGS will be working with Dr. Richard Warner (UK) to incorporate output from latest version of SEDCAD into WATER (EarthWorks Package).

Example output from Carlson Software's Mining 2010 package and EarthWorks

http://www.carlsonsw.com/PL_CS_Mining.html#pillarcutting
http://www.donraymond.com/itiproducts.htm

Use of GIS and WATER to Identify and Delineate of Ephemeral, Intermittent and Perennial Channels in the Cumberland Plateau of Eastern Kentucky –

Using GIS and the USGS program WATER, spatial data related to topography, soils, geology, rainfall, and field-collected geomorphic data will be used to develop flow duration curves and point-of-origin delineation criteria. This model will be extrapolated to watersheds located in the University of Kentucky's Robinson Forest for field verification and assessment.

Funded through UK Precision Resource Management Special Grant

Principal Investigators – UK College of Agriculture

Carmen T. Agouridis, Ph.D., P.E.; Richard C. Warner, Ph.D.; Christopher D. Barton, Ph.D.;Teri C. Dowdy, GISP

Collaborator

Tanja N. Williamson Ph.D., Project Chief

United States Geological Survey, Kentucky Water Science Center

USGS

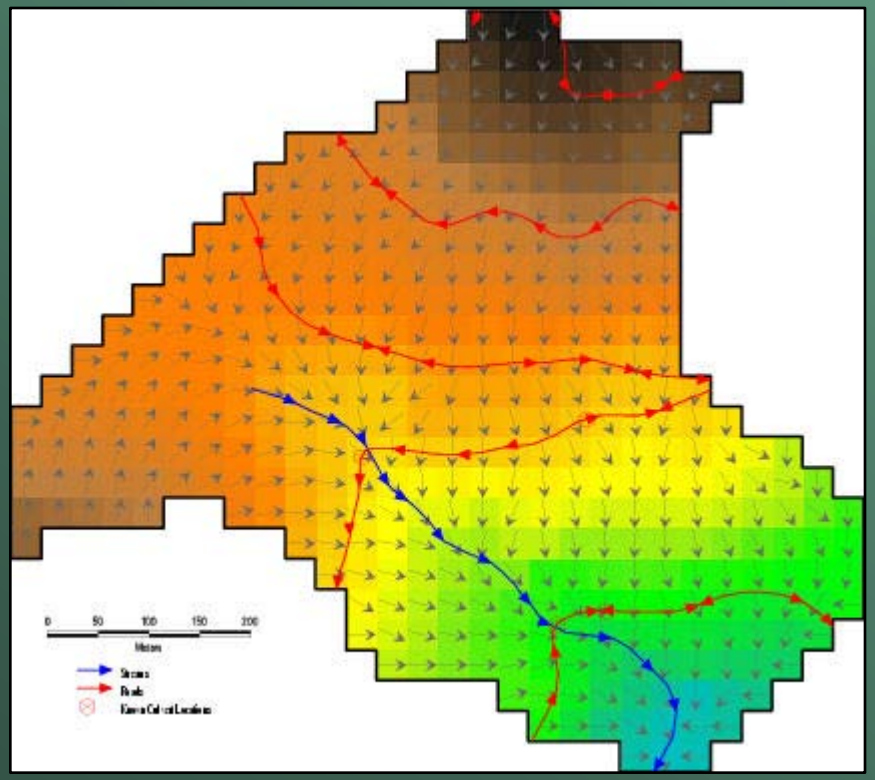
Tasks and processes that need to be implemented

- Complete PHREEQC and SEDCAD™ programming started under USGS program
- Build fully distributed application
- Build function to incorporate data from outside databases
- Implement MapWindow™ open-source code
- Process mined vs. unmined basins to test methods – this is new science!

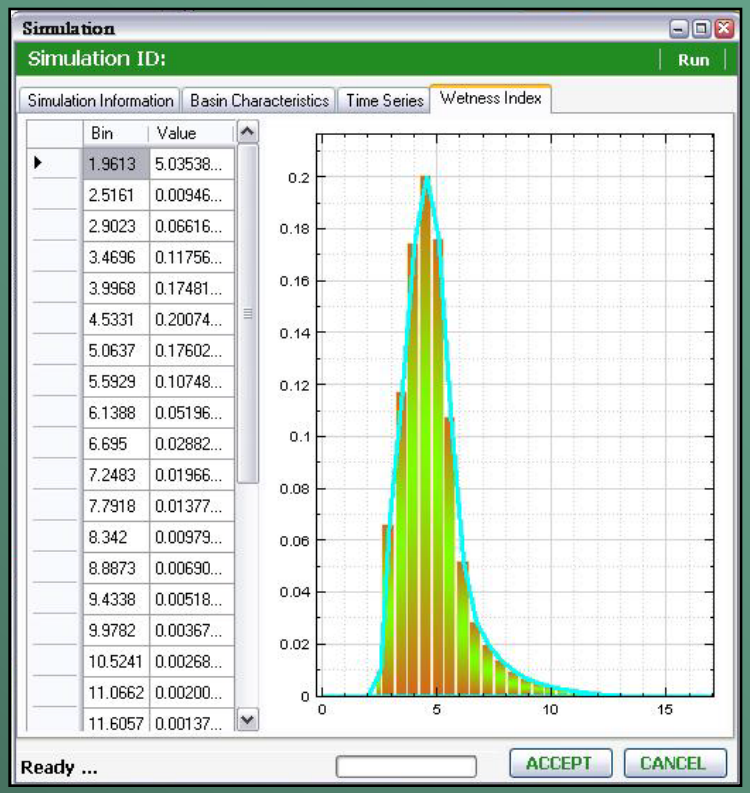
USGS

Incorporate fully distributed approach

Fully Distributed

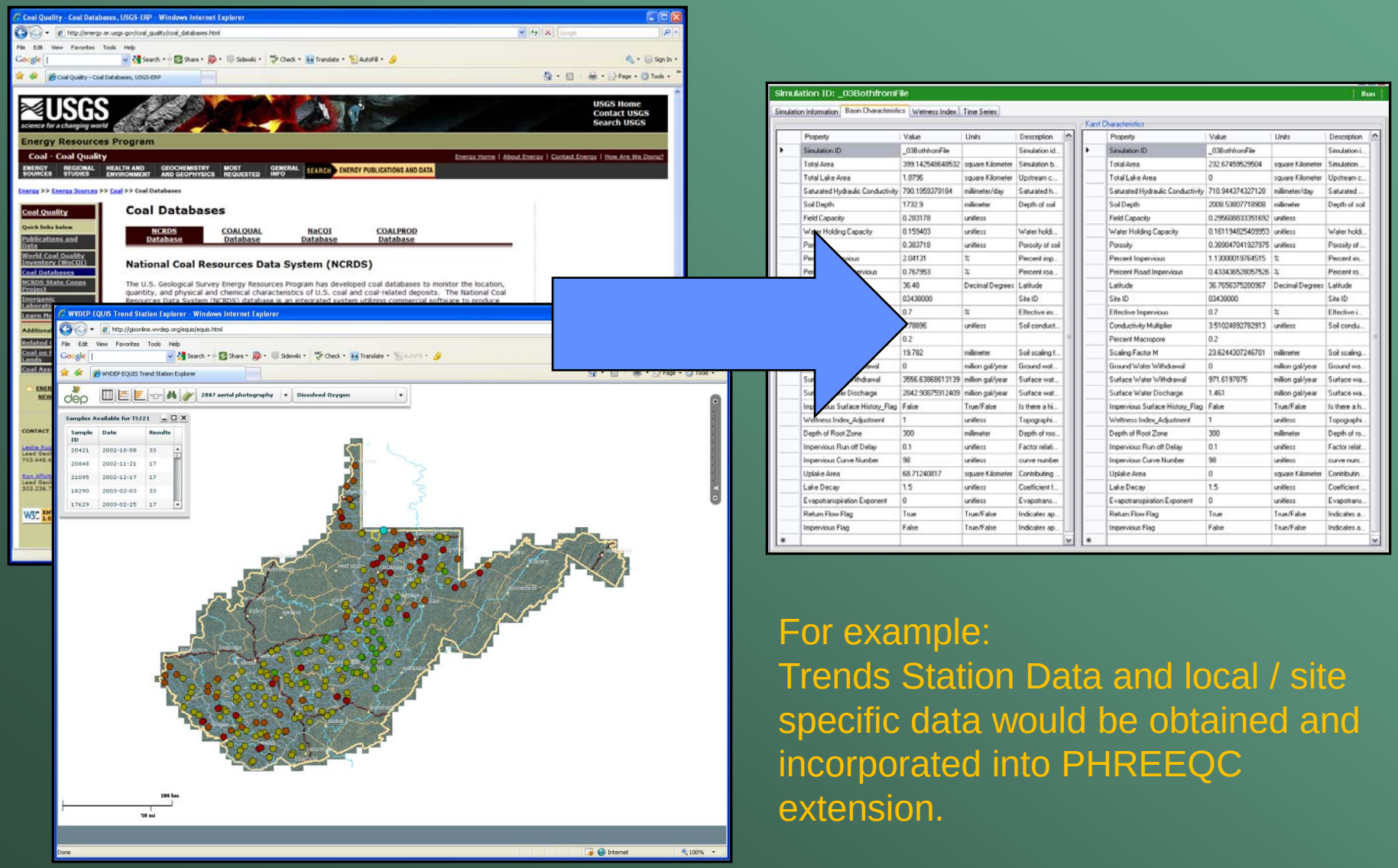


Quasi Distributed



Critical for routing and other analyses

Incorporate additional data / databases



For example:
Trends Station Data and local / site specific data would be obtained and incorporated into PHREEQC extension.

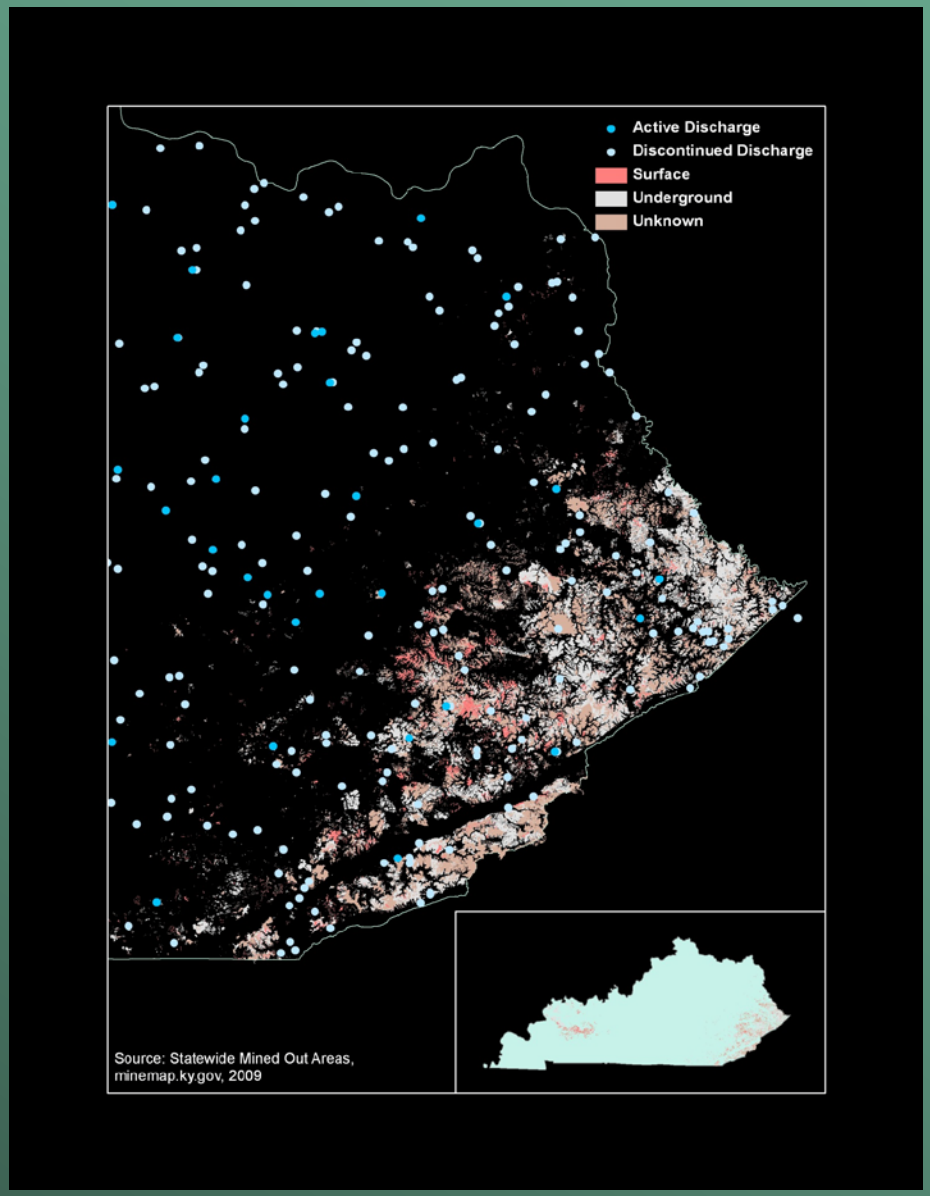
Implement MapWindow open-source code

MapWindow is an open source "Programmable Geographic Information System" that supports manipulation, analysis, and viewing of geospatial data and associated attribute data in several standard GIS data formats. MapWindow is a mapping tool, a GIS modeling system, and a GIS application programming interface (API) all in one convenient redistributable open source form.

MapWindow was developed to address the need for a GIS programming tool that could be used in engineering research and project software, **without requiring end users to purchase a complete GIS system**, or become GIS experts.

Validation of WATER for CHIA applications

- Previously proposed methods test in Kentucky ----
- Apply WATER to unmined watersheds in Eastern Appalachian Coalfield regions
  - baseline hydrologic response
  - compare various settings
    - hydrogeologic
    - climatic
- Apply WATER to mined watersheds in Eastern Appalachian Coalfield regions
  - ≥ 30% surface disturbance
  - simulate mining impact
- Characterize changes in hydrologic response of the test watersheds
  - statistically evaluate changes in basin hydrology with time
  - compare responses between unmined and mined watersheds
  - determine whether relation between percent mining-disturbance and hydrologic change is quantifiable
    - stormwater-runoff response
    - baseflow or ground-water recharge



Tasks and processes that would improve functionality but are not critical

- Build function to incorporate NEXRAD / climate data automatically.
- Make WATER web based.

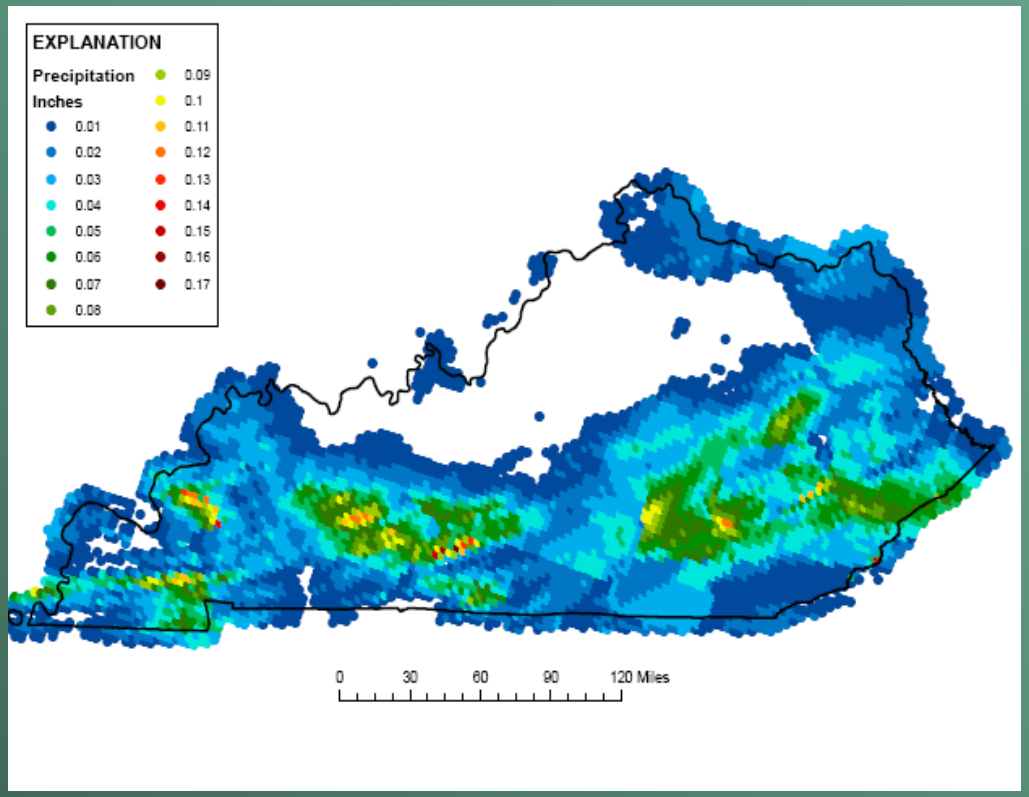
USGS

Incorporate / automate climate data –

Rainfall intensity is critical to any process-based application

- Current WATER platform uses static, gridded climate data (aggregated coop station and NEXRAD).

- NOAA NWS and USGS personnel processed >98,500 hourly .XMRG (NEXRAD) files for WATER (2000 to 2006). This data is available via a database and could be automated; however, this is quite involved and may not be worth the price in computing power / speed.



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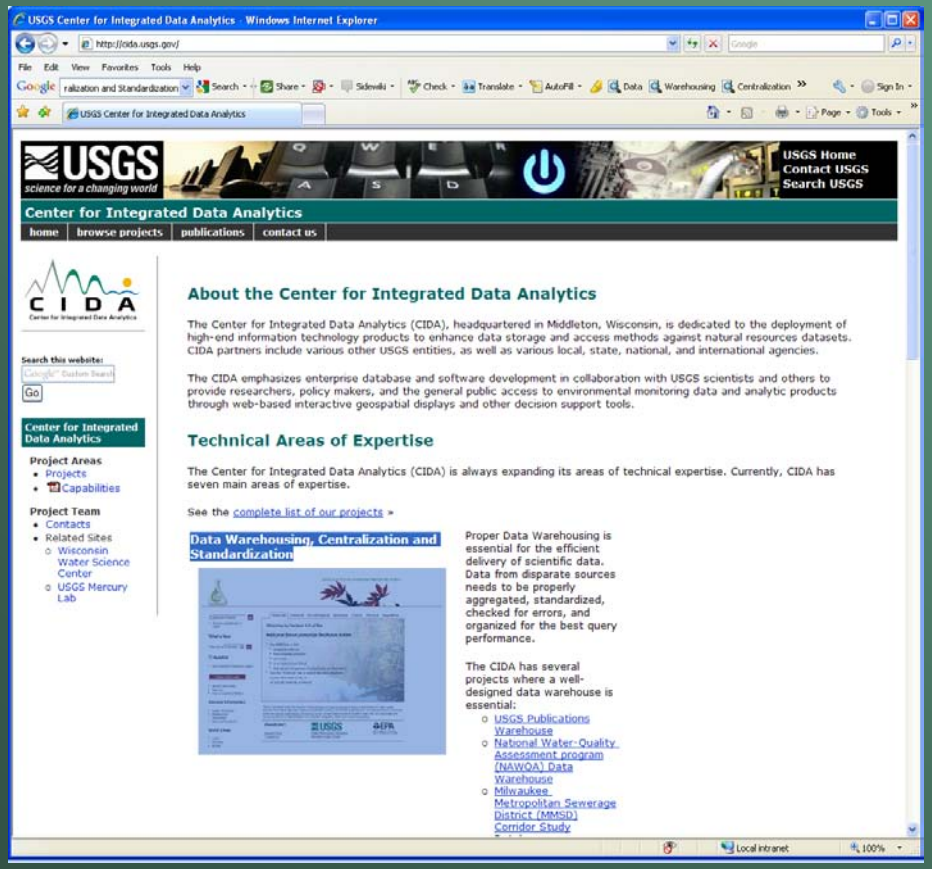
Migrate to web-based application



Web-based applications involve maintenance, but guarantee up-to-date products / versions and allow data-intensive programs to run from anywhere.

USGS

QUESTIONS?