



# Hydrogeologic-Framework Mapping of Shallow, Conduit-Dominated Karst—Components of a Regional GIS-Based Approach

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# Karst Hydrology Initiative Project

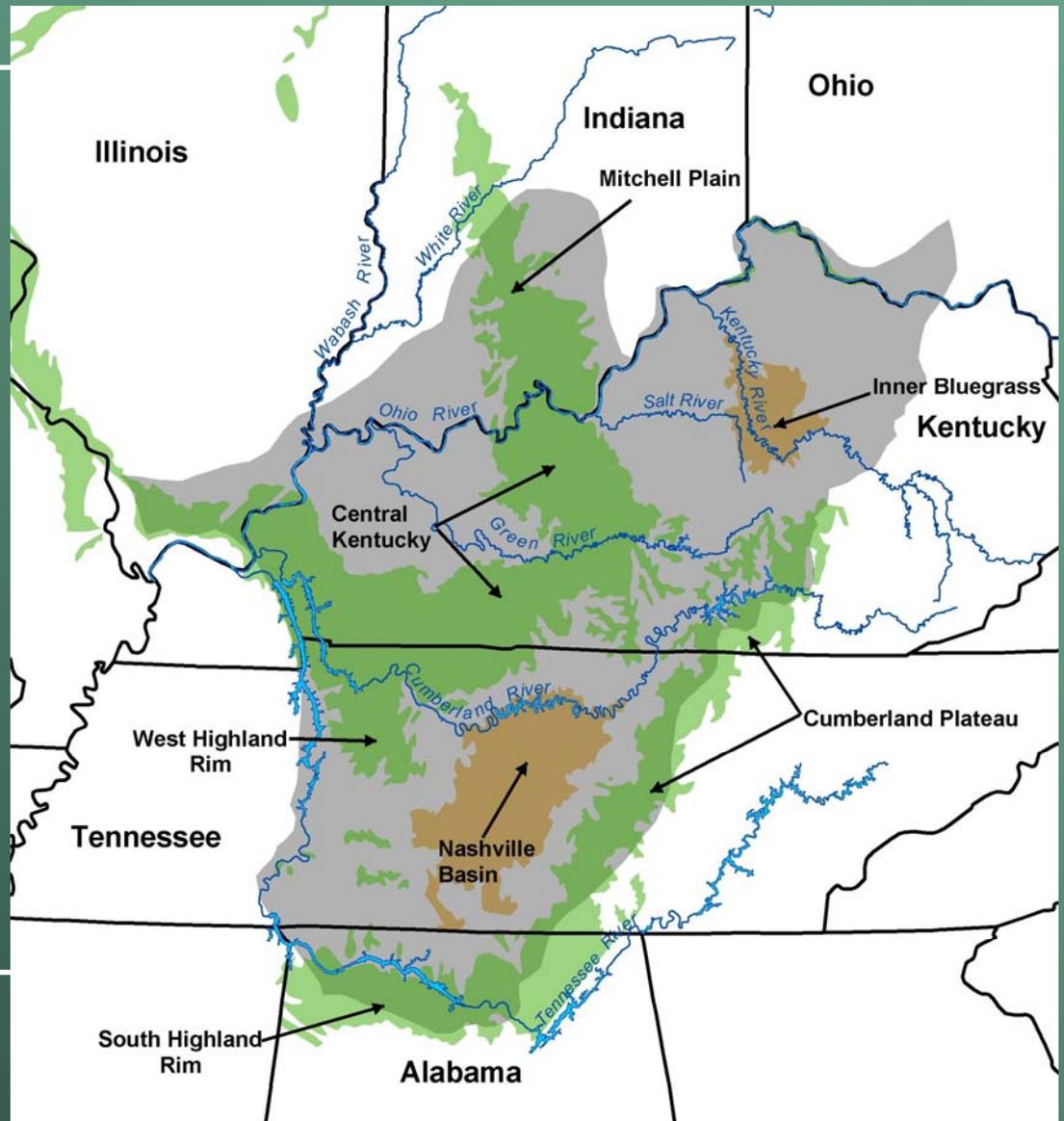
## USGS Ground-Water Resources Program

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- Objective is to develop GIS-based methods and tools needed to better synthesize karst hydrogeologic mapping data & better characterize karst hydrology.
  - The focus of the project is on shallow, conduit-dominated karst aquifers, such as those characteristic of the Interior Low Plateaus physiographic region of the central United States.
  - These types of aquifers are exceptionally difficult to characterize using conventional methods of aquifer testing, hydrogeologic mapping, and computer modeling.
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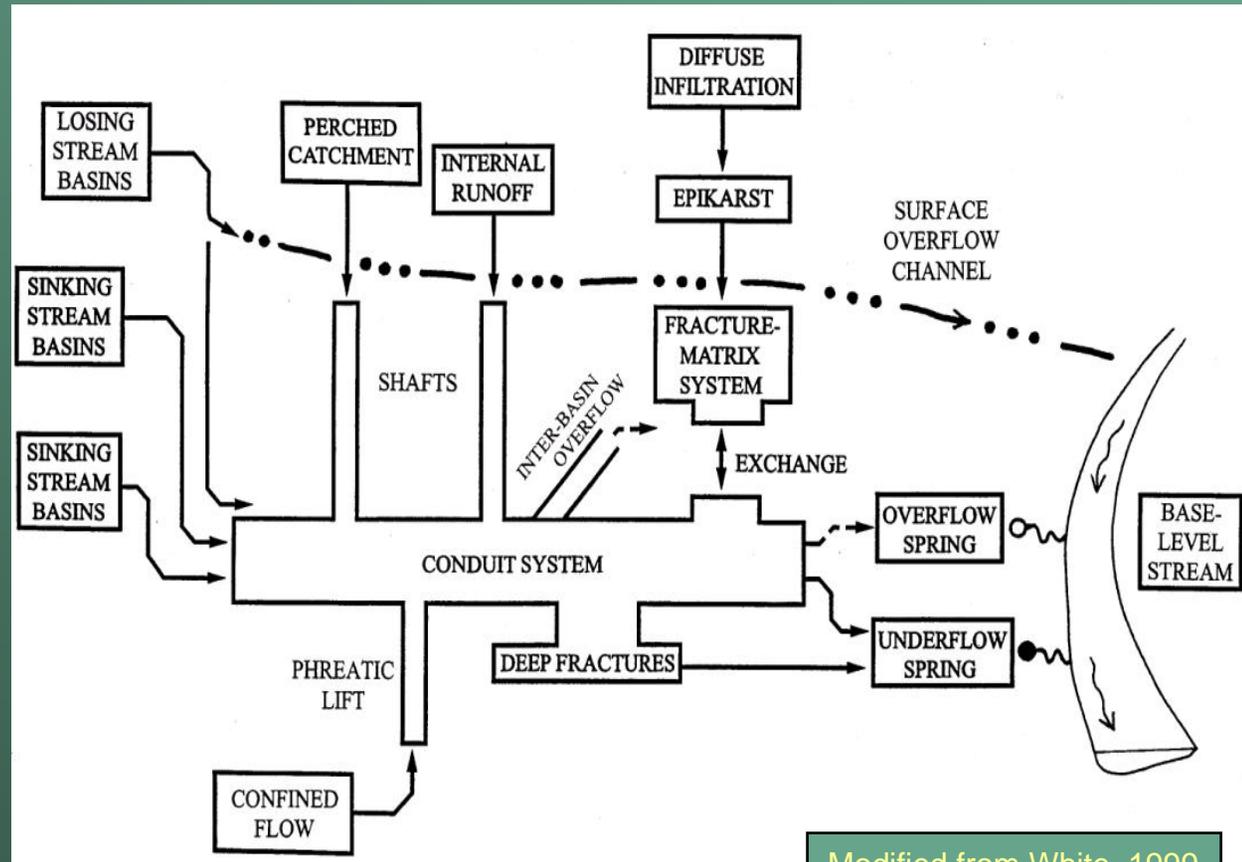
# KHI Project Regional Study Area

- Interior Low Plateaus physiographic region.
- Includes large parts of Indiana, Kentucky, Tennessee, & Alabama.
- Mapping work focused in seven major karst areas or hydrogeologic settings.
- The karst aquifers are developed mainly in Mississippian, and to a lesser extent, Ordovician carbonate rocks.



# Hydrogeologic Characteristics of the Regional Karst Aquifers

- Organized as confluent networks of subsurface conduits.
- Consist of multiple recharge, storage, and flow components.
- Drain a specific geographic area and often discharge to at least one perennial (underflow) spring.
- Distributary flow routes (to overflow springs) near discharge boundaries also common.
- Surface water and ground water are highly interconnected and compose a single dynamic flow system.



Modified from White, 1999

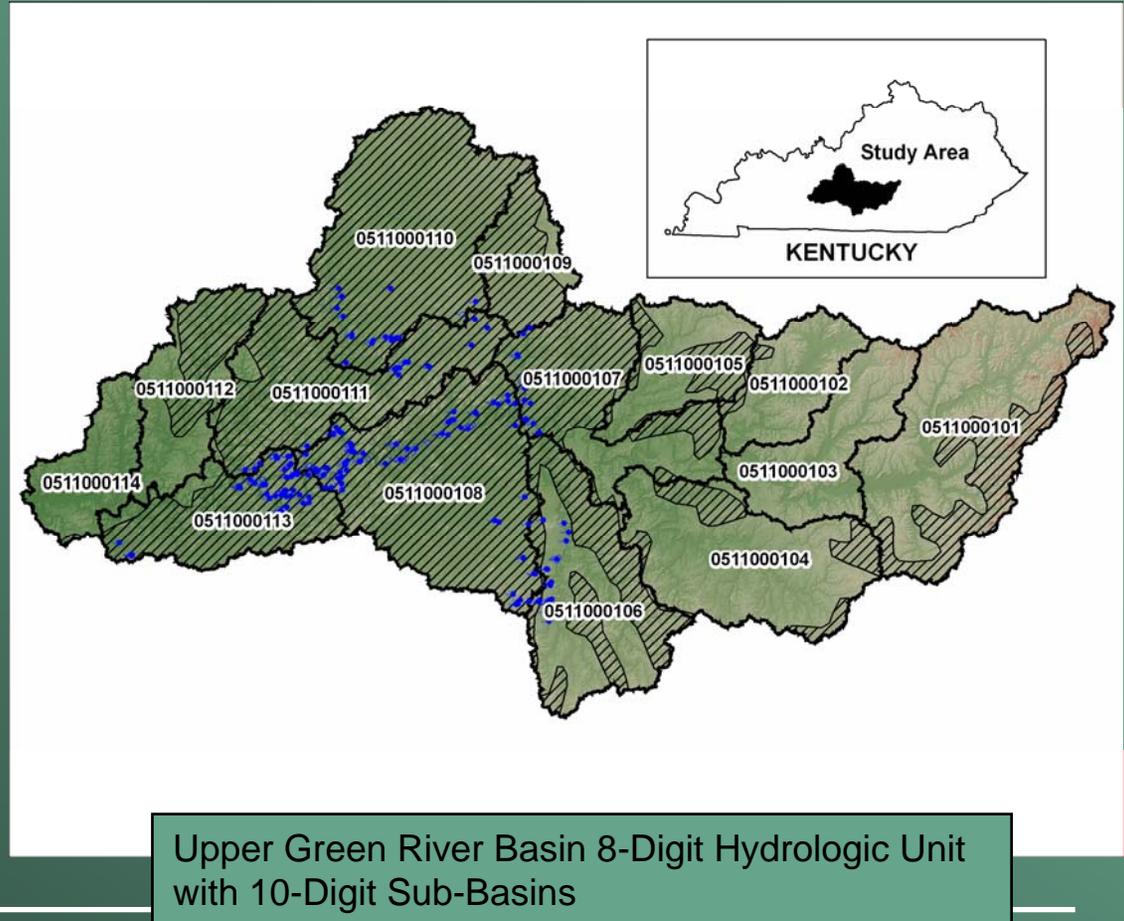
# Components of the GIS-Based Regional Mapping Approach:

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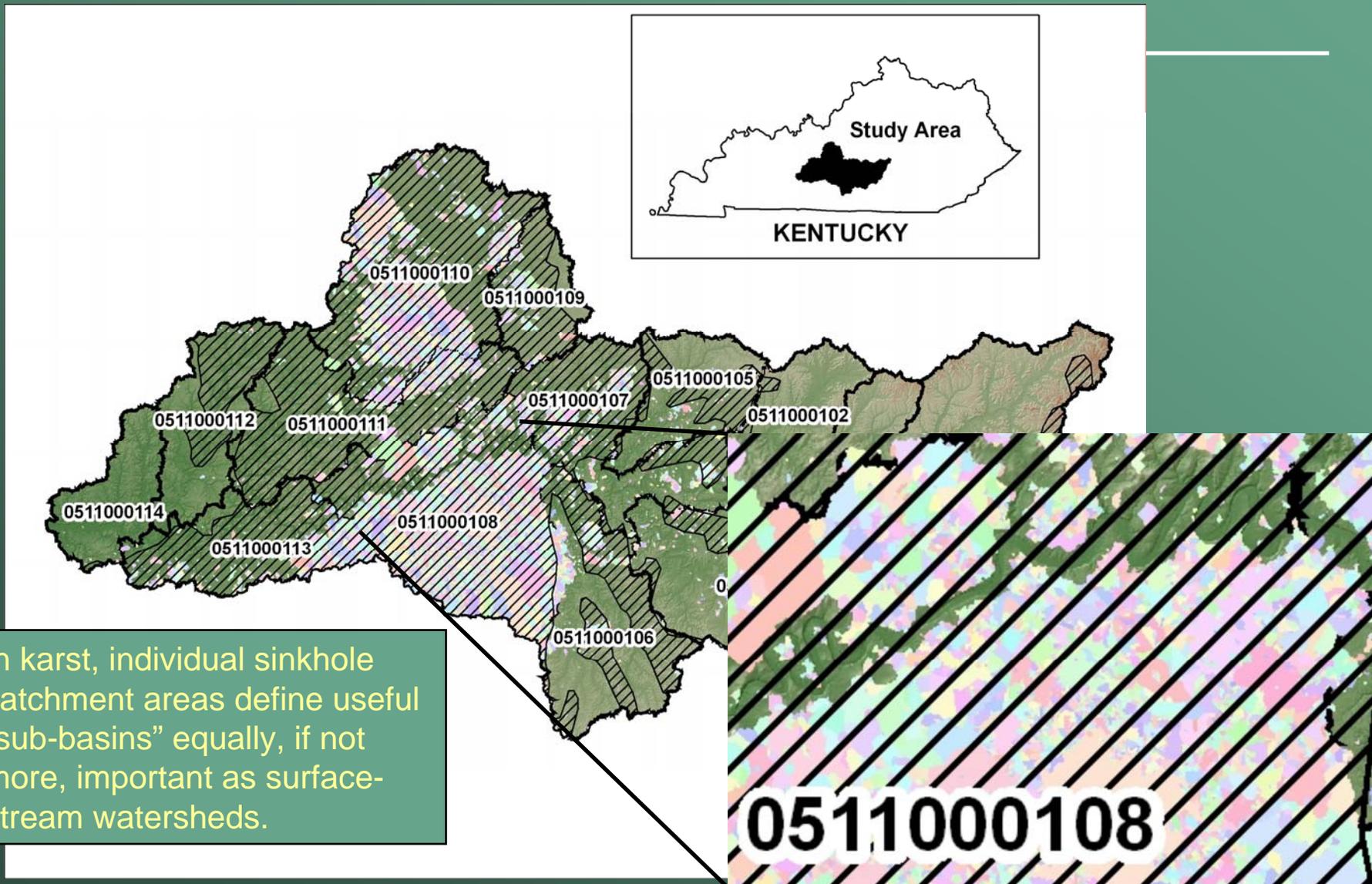
- GIS layers or data coverages that include these mapping components:
  - Sinkhole locations and catchment areas— defined by semi-automated processing of digital elevation model datasets (DEMs).
  - Karst springs— identified in the USGS National Water Information System (NWIS) and various state agency databases.
  - Identifiable sinking or losing streams & relic stream valleys.
  - Other hydrographic features such as perennial “blue line” streams and ponds or lakes.
  - Major watershed (surface drainage) divides— 8 & 10-digit hydrologic unit (HU) boundaries.
  - Subsurface flow paths inferred from reported dye-tracer tests.
  - Boundaries of karst drainage basins inferred by dye-tracer tests and other hydrogeologic-mapping techniques.

# Regional Mapping Approach: Cataloguing Karst Features by Surface Watersheds

- Emphasizes the surface water and ground water interconnection in karst.
- Facilitates transfer & use of data by the National Hydrographic Dataset, Streamstats, and other USGS programs.
- Facilitates correction and refinement of Hydrologic Unit Code (HUC) boundaries.
- Compatible with the watershed management approach favored by State and Federal regulatory programs.



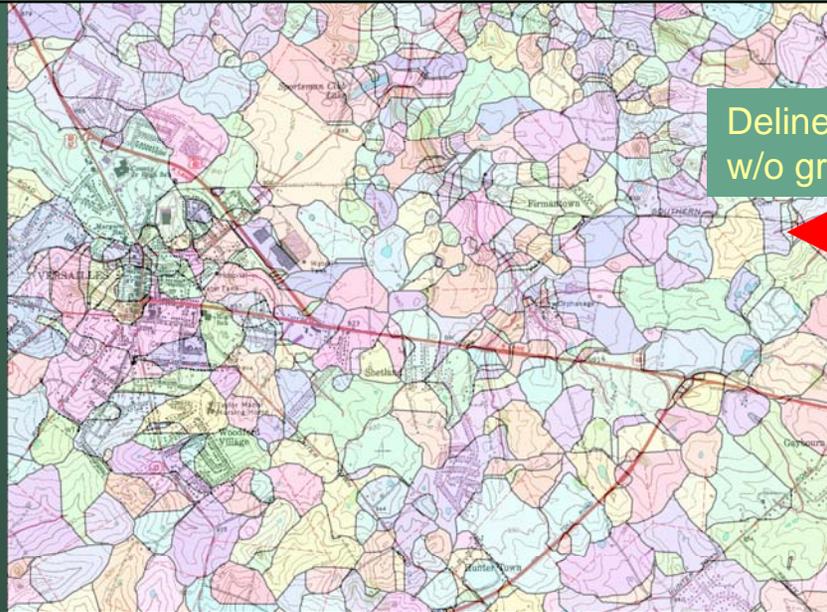
# Example Dataset: Sinkhole Catchments



In karst, individual sinkhole catchment areas define useful “sub-basins” equally, if not more, important as surface-stream watersheds.

# Delineation of Sinkhole Catchments from DEMs

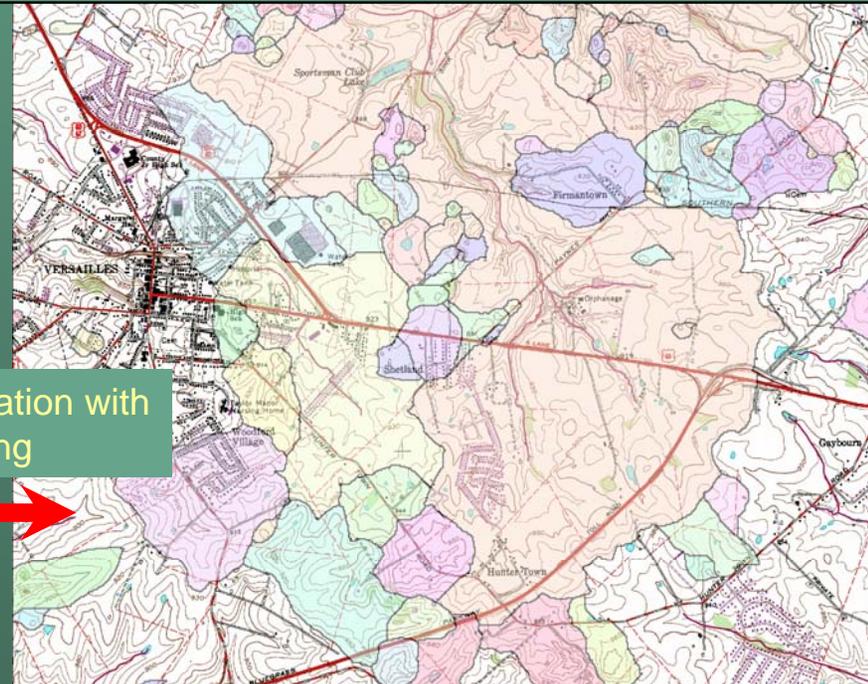
(1) Topographic depressions in the DEMs are identified and artificially filled using GIS-processing tools, and a grid of the difference between the filled and unfilled depressions is developed.



Delineation  
w/o grouping



(3) Grid cells associated with these throats are grouped together by assigning them unique numeric values that lump throats together into clusters and tie the clusters to an associated topographic depression.



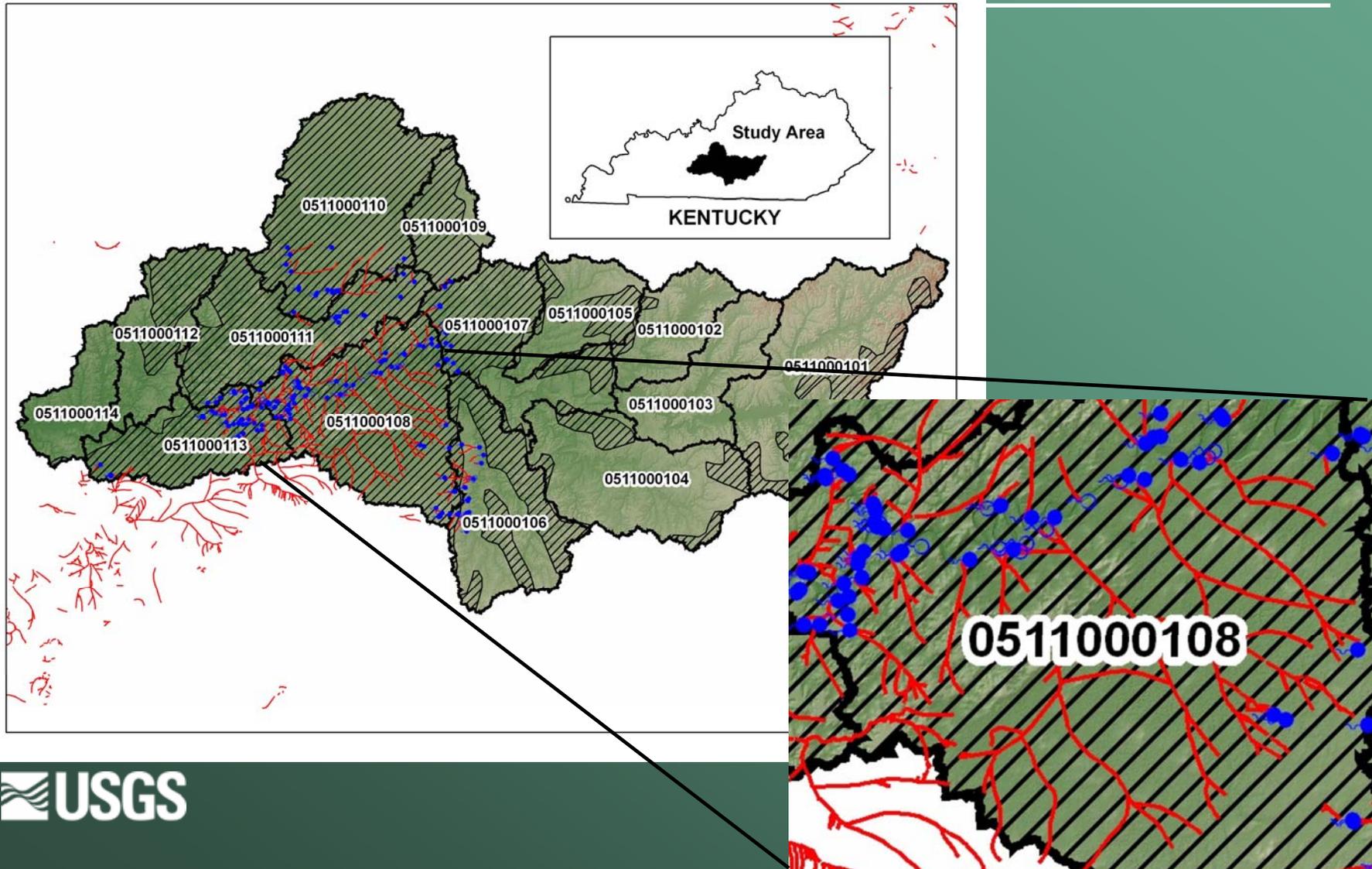
Delineation  
with  
grouping



(2) “Throats,” or locations within the depressions that are internally drained, are identified using a GIS “SINK” tool.

(4) Grouped topographic depressions and throats are then used as input data to define sinkhole catchment areas using a GIS “WATERSHED” delineation tool.

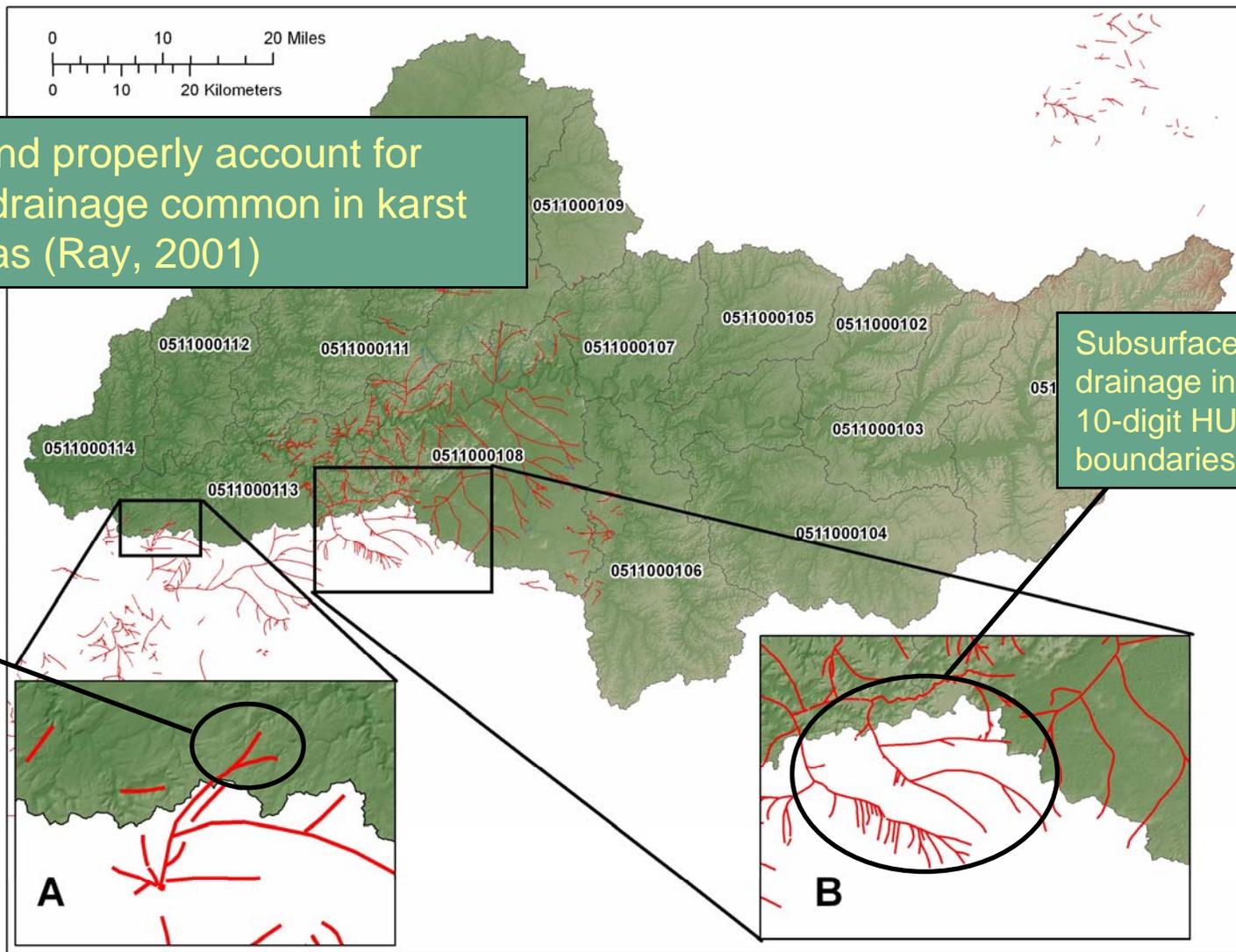
# Example Dataset: Springs and Dye-Trace Flow Paths



# Example Application: Correction of Hydrologic Unit (HU) Boundaries

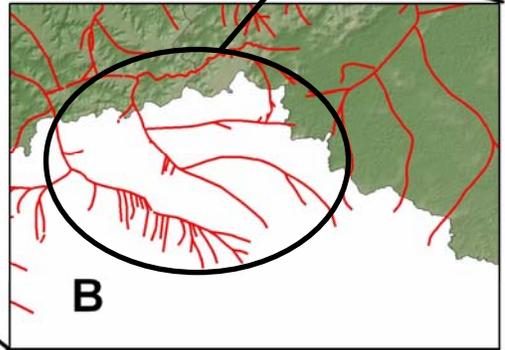
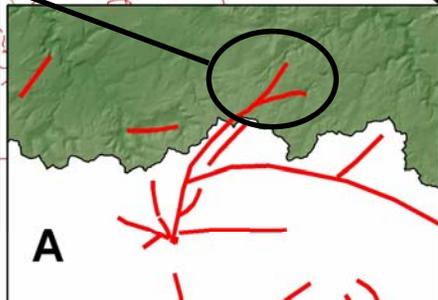
0 10 20 Miles  
0 10 20 Kilometers

To identify and properly account for “misbehaved” drainage common in karst areas (Ray, 2001)



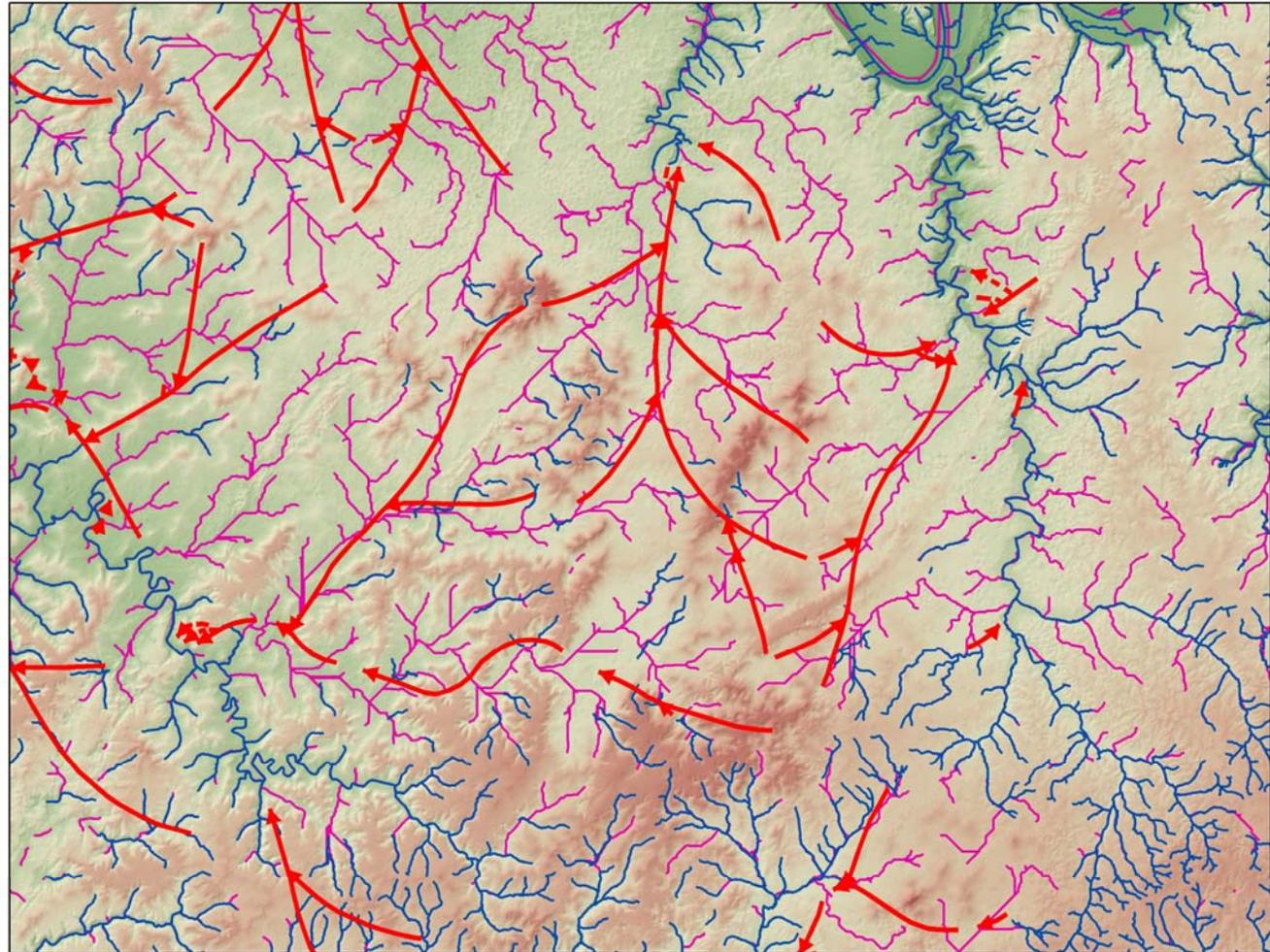
Subsurface drainage into 10-digit HU boundaries

Subsurface drainage out of 10-digit HU boundaries



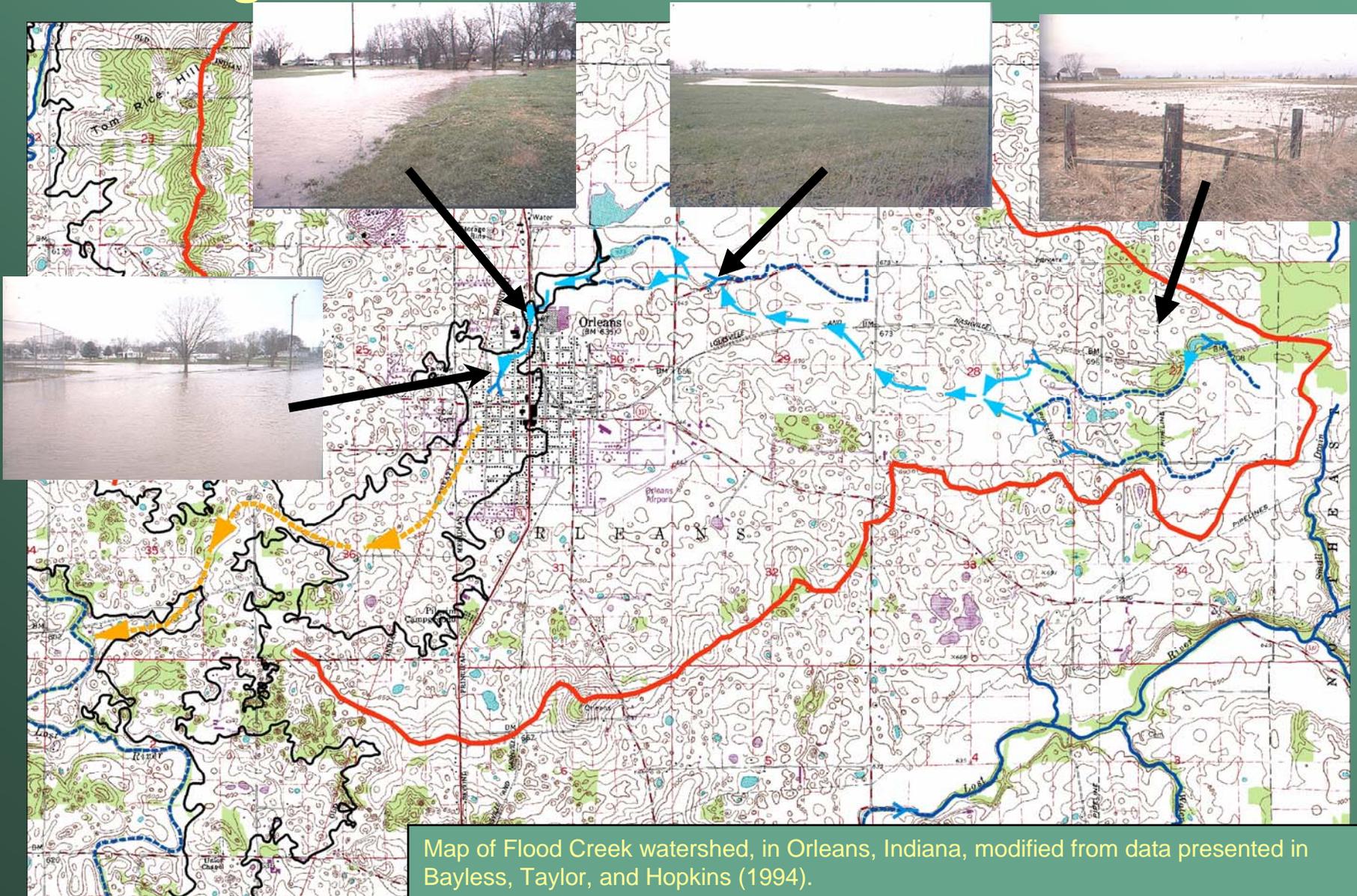
# Example Application: Investigation of Relic Stream Valleys & Their Hydrogeologic Significance

- Relic streams are geomorphic features representing former surface streams whose flow was captured & diverted underground by karst development.
- Often no apparent evidence of the former stream channel is present because of landscape erosion and sinkhole development.
- The features are useful in the interpretation and prediction of subsurface conduit locations & groundwater flow directions.
- They help explain the geographic pattern & history of karst drainage development.
- They may be favorable sites for drilling water-supply wells.



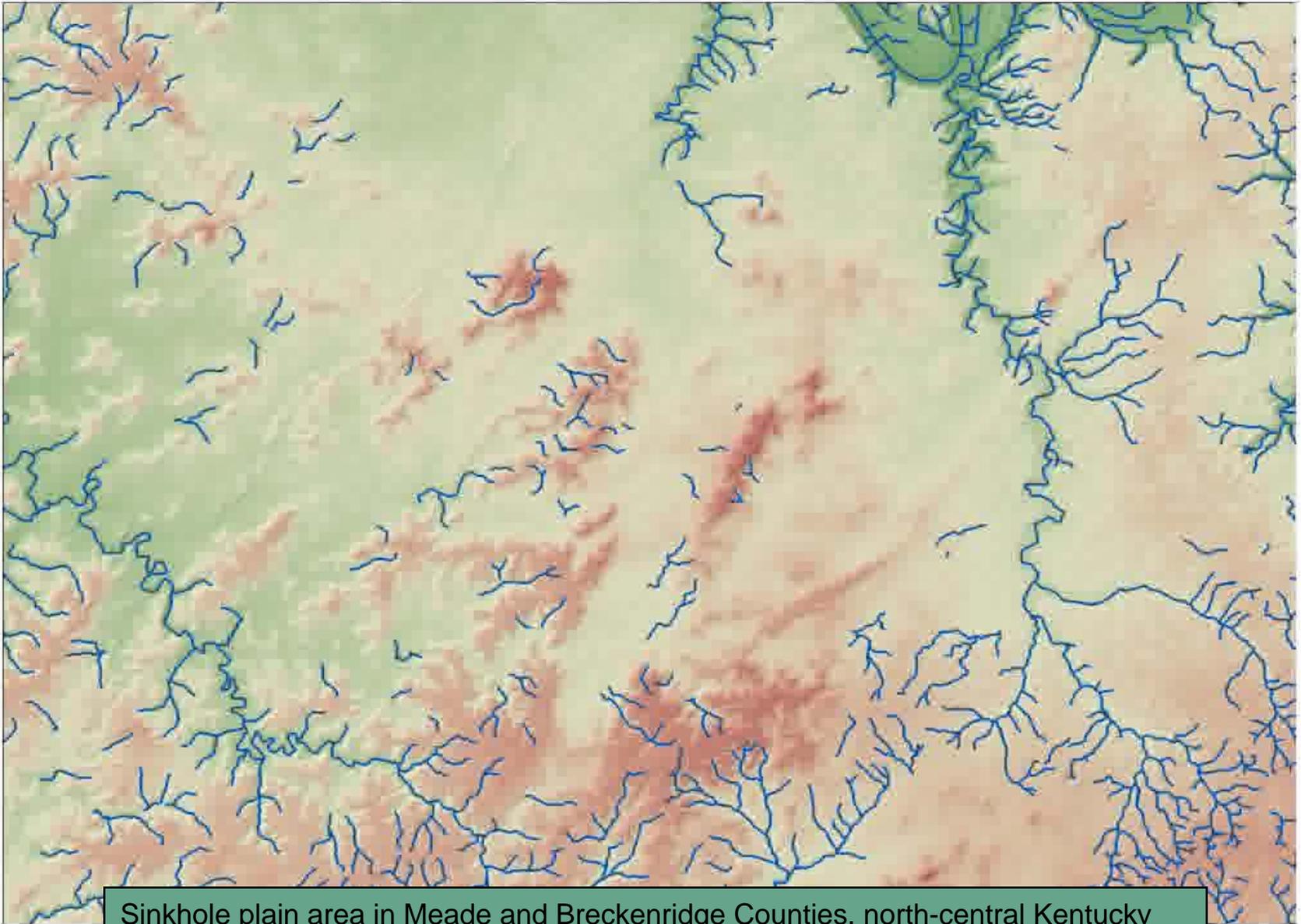
Red lines are dye-tracer flow paths reported by Taylor and McCombs (1998), and Ray (written comm., 2004).

# Relic Stream Valleys—An Overlooked Karst Flooding Hazard?



Map of Flood Creek watershed, in Orleans, Indiana, modified from data presented in Bayless, Taylor, and Hopkins (1994).

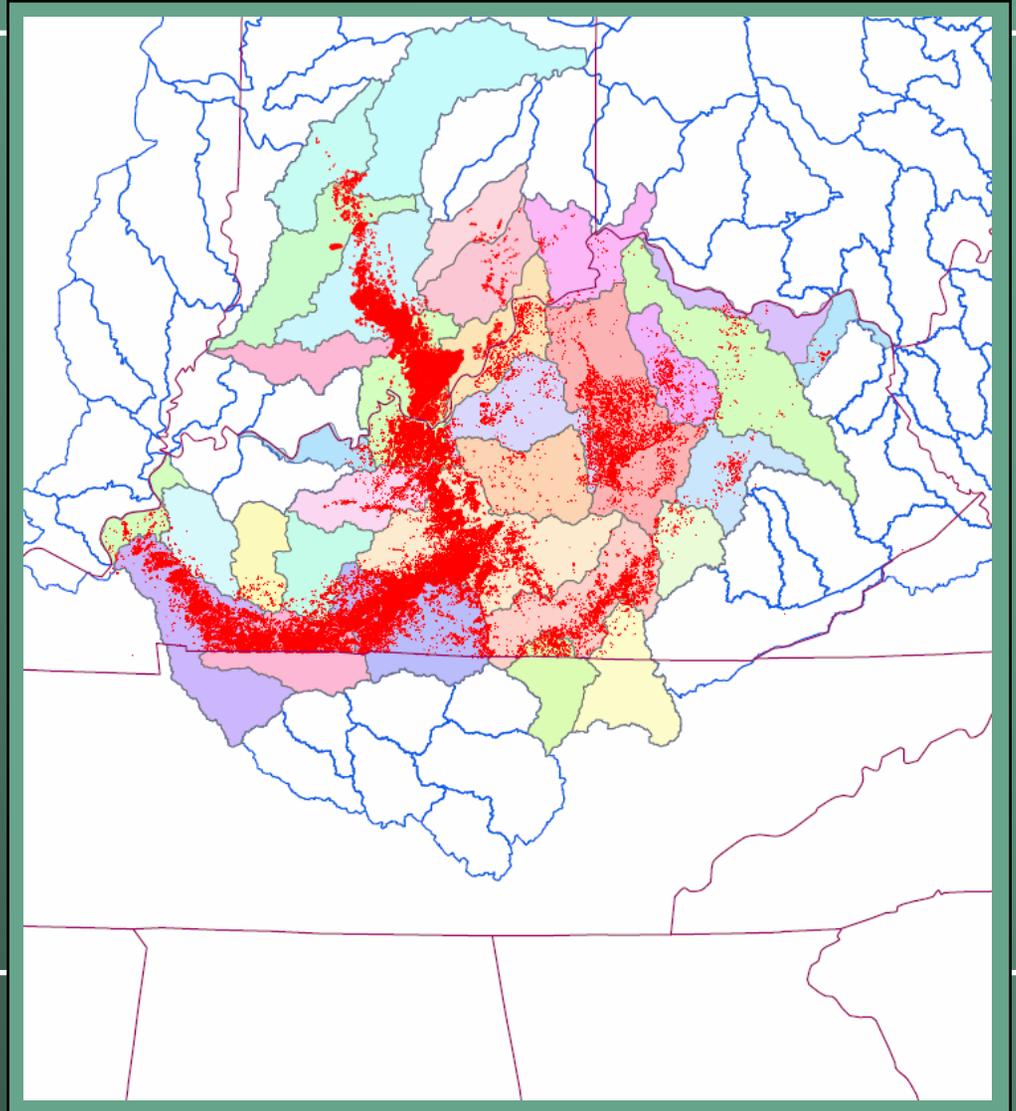
# Delineation of Relic Stream Valleys from DEMs



Sinkhole plain area in Meade and Breckenridge Counties, north-central Kentucky

# Status of Regional Karst Mapping and Database Construction:

- Sinkhole catchments and relic streams have been delineated in KY and IN, and are undergoing final editing.
- These features are also done for about 40-50% of watersheds in TN in the regional study area.
- GIS layers for spring locations and dye-tracing data have been compiled for KY, IN, and TN— data mining & compilation is ongoing.
- DEM processing and karst mapping work just starting in northern AL karst (South Highland Rim).



# KHI Project Outcomes:

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- **Regional Karst GIS Database:**

- Assembled as print-publishable map files (PMFs) that can be viewed and manipulated using ArcMap or ArcReader GIS software.
- Data organized by 8-digit Hydrologic Units compatible with watershed management framework.
- Internet accessible.
- Provides “pre-processed” GIS coverages of important karst hydrogeologic features, including springs, dye traces, sinkhole catchments and relic stream valleys.

- **Report:**

- Summarizes the state of knowledge about the region’s karst areas and features, based on presently available & publicly accessible data.
  - Helps identify “data gaps”—areas where detailed regional-to-local scale information about karst hydrogeology is sparse or lacking.
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# The End—Thank You

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Sinking stream in Rockcastle County, Kentucky