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ILLINOIS NATURAL HISTORY SURVEY
PRAIRIE RESEARCH INSTITUTE

Hierarchical Framework for Wadeable Stream Management and Conservation: Final Report

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16 March 2017

INHS Technical Report 2017 (14)

Prepared for: Illinois Department of Natural Resources
State Wildlife Grant Program
(Project Number T-75-R-001)

Unrestricted: for immediate online release.

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Final Summary Report

Project Title:
Hierarchical Framework for Wadeable Stream Management and Conservation.

Project Number: T-75-R-001

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Final Project Report Submitted: 16 March 2017

Updated: 31 May 2017

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Goals/ Objectives: (1) Develop Ecological Drainage Units for Illinois Streams; (2) Define Aquatic Ecological Systems for Illinois Streams; (3) Develop and Classify Illinois' Stream Valley Segments; (4) Define Natural Community Types for Illinois Streams; and (5) Develop and submit a list of candidate sites for INAI listing under Category I (High Quality and Significant Natural Communities) and revised Category VI (Unusual Concentrations of Fauna) criteria for streams.

Executive Summary

Hierarchical Framework for Wadeable Stream Management and Conservation.

This project produced a series of attributed GIS feature classes that describe nested classification units consisting of Ecological Drainage Units and Aquatic Ecological Systems that can be used for conservation and management planning for stream systems at a variety of landscape scales. Valley Segment Types were also developed for the 1:100,000 scale GIS that was available when the project was started but have not yet been redeveloped for the finer scale system (1:24,000).

We also examined existing Illinois Natural Areas Inventory (INAI) Natural Community Types (NCT), and Subtypes, associated with streams and identified areas that meet the physical descriptions of these NCTs based on stream size and gradient. We discuss the identification of natural features in terrestrial and stream systems within the initial development of the INAI and how this lead to differences in their evaluation and separation into different Categories (Category I: High Quality Natural Communities; Category VII: Outstanding Aquatic Features). An approach for defining and evaluating natural features for stream systems that is more similar to that used for terrestrial NCTs is presented.

Information from recent and historical surveys of fish, mussels, and other invertebrate taxa was assembled for use in identifying potential Illinois Natural Areas Inventory (INAI) sites using existing criteria for streams. We identified stream reaches that contained current element of occurrence records for Illinois Endangered and Threatened fish and mussels including those that were not currently listed on the INAI that may qualify as Category II sites (Specific Suitable Habitat of Endangered and Threatened Species) and give recommendations for their further evaluation. These data were also used to identify stream reaches that may qualify for the INAI as Category VI (Unusual Concentration of Flora and Fauna). Additional guidance is provided for implementation of existing criteria that use mussel species richness, the mussel classification index, and the fish index of biotic integrity as criteria for qualifying as Category VI INAI sites.

Acknowledgements

This work was conducted under a State Wildlife Grant from the Illinois Department of Natural Resources (T-75-R-1). The following organizations assisted these efforts by providing data and/or logistical support: Office of Resource Conservation of the Illinois Department of Natural Resources, Bureau of Water of the Illinois Environmental Protection Agency, Illinois Natural History Survey of the Prairie Research Institute University of Illinois, University of Michigan Natural History Museum. We would especially like to thank the following for their contributions: Ann Holtrop (IDNR), Andrew Hulin (IDNR), Don Bricker (IDNR), John Wilker (IDNR), Bob Szafoni (IDNR), Matt Short (IEPA), Roy Smogor (IEPA), Yong Cao (INHS), Brian Anderson (INHS), Alison Stodola (INHS), Ed DeWalt (INHS), Dana Infante (MSU), Mary Khoury (TNC).

Hierarchical Framework for Wadeable Stream Management and Conservation.

Narrative:

Initial project our work focused on obtaining and integrating existing data for biological assemblages with our current GIS infrastructure and reviewing existing classification efforts within Illinois (e.g., National Fish Habitat Partnership [Esselman et al. 2011]; Upper Mississippi River Basin Assessment [Khoury et al. 2011]). Fish and mussel data were prepared for formalizing Ecological Drainage Units (EDU) and developing Aquatic Ecological System (AES) units during the first 18 months of the project. We also expanded our taxonomic scope beyond fish and mussels by adding information from the Illinois Natural History Survey (INHS) collections database for aquatic macroinvertebrates (Ephemeroptera, Plecoptera, and Trichoptera or collectively EPT) and the IEPA basin survey aquatic macroinvertebrate collections throughout Illinois.

This project was designed to produce attributed GIS feature classes that describe a series of nested classification units that can be used for conservation and management planning for stream systems at a variety of landscape scales. Despite having essentially completed our database integration (Job 1), delineation of EDUs (Job 2), AESs (Job 3), and VSTs (Job 4) for the 1:100,000 scale linework system available during the first 24 months of the project we were committed to transitioning this work to the finer resolution GIS system that was being developed by IDNR since this scale was more appropriate for management prioritization and tracking associated with the IWAP's Streams Campaign. This decision ultimately greatly expanded the amount of time required for several parts of the project.

Our work shifted toward transitioning the GIS data layers that formed the nested classification and the existing data for biological assemblages to comply with the updated 1:24,000 scale stream lines, the 10m DEM, and the associated watershed summaries. We focused considerable effort on assisting IDNR in development and QA/QC of the refined stream network for watersheds draining into or within Illinois. GIS geodatabases containing representations of stream reaches in all Illinois EDUs were reviewed and adjusted to better reflect existing conditions.

We had developed the Illinois' Ecological Drainage Units (EDUs) using fish and mussel distribution similarities based on the 1:100,000 linework. However, shifts in the EDU boundaries required us to revise these polygons to fit the watershed boundaries associated with the 1:24,000 linework. Since none of the biological data used to develop the EDUs was located at the edges of these polygons there was no need to redevelop the EDUs. However, small shifts in individual stream reach watershed polygons necessitated a review and correction of the entire boundary of each EDU.

Initial efforts to define AES polygons uncovered two unexpected but related issues with our 1:100,000 scale GIS database system. A large number of very small areas (often less than one-meter-wide but sometimes miles long) within the state had not been incorporated into the system. Secondly, some watershed polygons were found to have been misattributed to adjacent watersheds. These areas were generally at the boundaries of the processing units (major watersheds for 1:100,000 linework and EDUs for 1:24,000 linework) that were used in the initial database development. Although these areas contained no attributes and did not contribute to any existing watershed polygon their absence distorted the assigned character of the watersheds where they should have been assigned. Some watershed polygons were also found to have been misattributed to adjacent watersheds or attributed to more than one watershed polygon. This error appears to have occurred when curved watershed delineations were rasterized leading to overlaps between the curved and straightened watershed polygons. Identifying, incorporating, and attributing these areas was an unexpectedly large task that was undertaken first at the 1:100,000 scale during the initial attribution stages and then again at the 1:24,000 scale as we transitioned to the finer resolution data.

In addition, Valley Segment Types (VSTs) had been delineated based on stream size, summer temperatures, and low flow water yield for the 1:100,000 linework. However, VSTs were not refit onto the 1:24,000 linework since some of the 1:100,000 stream reaches represent multiple reaches at 1:24,000 and many 1:24,000 stream reaches were never attributed since they are not represented at 1:100,000. Transitioning requires VSTs to be completely redeveloped for the 1:24,000 scale linework and has not been completed at this time.

Fish and mussel data were updated annually for application within Ecological Drainage Units (EDUs) and summarization within the Aquatic Ecological Systems (AES). We also consolidated and mapped biological information associated with existing criteria for INAI listing of wadeable streams. Threatened and Endangered species locations, fish Index of Biotic Integrity and Mussel Classification Index values, and Mussel Species Richness from recent statewide surveys that meet existing criteria for INAI listing were consolidated and mapped. Additional efforts were made toward developing standard methods for classifying and rating INAI Category I and Category VI sites and recommendations for improving current practice are identified in this report.

Two 12 month no-cost extensions were requested and granted for this project to assist with transferring the spatial hierarchy to the revised stream network and associated watersheds to the ArcHydro Infrastructure developed in T-60-D-1. Stream linework, local watersheds, EDU, and AES boundaries have been revised and made compatible with the new system. Although valley segments were typed at the 1:100,000 scale we were unable to reapply this typing to the 1:24,000 scale during the extended project time period. We believe that this typing would still be a useful and valuable tool for conservation management and planning within the Streams Campaign of Illinois' Wildlife Action Plan.

Job 1: Compile and update databases.

Compilation and integration of biological assemblage data with hydrologic, geomorphic, and geologic data within our existing GIS system was completed for data available through 2012. However, we initiated work with staff associated with the Statewide Streams Application (SSA, T-60-D-1) to assure that outputs from our project would transfer to their finer resolution GIS application (1:24,000 stream linework, 10m DEM).

Integration of biological assemblage data with our existing GIS system began with fish and mussel records and expanded to take advantage of additional available information on aquatic insects. Data sources for fish include IDNR Monitoring (Fisheries Database, Natural Heritage BIOTICS Database) and Collections Data (INHS, University of Michigan Natural History Museum). Fisheries data integration was initially completed with 3,995,952 IDNR records available statewide from 1910-2011 and later expanded to include additional records collected through 2013. These records are from 100s of stations located throughout the state. Mussel data through the 2015 from the INHS Collections and IDNR Mussels database (T-53) has also been added to this data system. Additional aquatic macroinvertebrate data were made available by the Illinois Environmental Protection Agency that were collected as part of their Intensive Basin Survey Program.

We worked with INHS research teams to include information on stoneflies (DeWalt et al. 2009), caddisflies and mayflies (DeWalt et al. 2011). We hired a graduate student from the entomology department (UIUC) to georeference and QA/QC all EPT records in the INHS collections database. When this work began the INHS collections database contained 4,592 total sample locations for Illinois EPT taxa. Over 4,500 EPT taxa records were georeferenced and added to the system. Although these data were added to the database system they were not used in further work associated with this project.

Job 2: Develop Ecological Drainage Units (EDUs).

Two major efforts that include Illinois streams (National Fish Habitat Action Plan (NFHAP), Upper Mississippi River Conservation Assessment) use EDUs developed by The Nature Conservancy (TNC). After consultation with the investigators that developed these plans/assessments (Dana Infante, Coordinator NFHAP Michigan State University Inland Assessment Group; Mary Khoury, The Nature Conservancy Great Lakes Project) we decided to use these boundaries as a starting point for our assessment. Spatial data for these EDUs have been secured from NFHAP and TNC and this information has been added to our existing GIS system.

Within the NFHAP and TNC EDU classifications some portions of the Wabash/Ohio River drainages in Illinois are currently lumped into a single EDU. A similar situation occurs with the Pecatonica River network being included in an EDU with the Apple River rather than with the Rock River to which it is a tributary stream. The suitability of these units has not been rigorously evaluated. We have been notified that any Illinois specific EDUs developed from this project will be incorporated into the NFHAP data structure (Dana Infante, personnel communication).

The USGS 8-digit Hydrologic Unit Codes (HUC8) were used as the baselayer for delineating EDUs. Biological information for fish and mussels within draft EDUs has been compiled, summarized, and mapped. We summarized species richness for native fish (Figure 2.1) and mussels (Figure 2.2) at HUC-8 watersheds statewide. Next, prevalence of each fish and mussel species were spatially linked to USGS HUC8s by compiling a state-wide georeferenced database using existing community samples. Fish community samples were compiled in a recent study (T-68) including samples from Illinois Department of Natural Resources Fisheries Division (IDNR Lake Stations, IDNR River Miles/Stations, IDNR Stream Stations, IDNR Stations-NRM), IDNR Natural Heritage Database (Biotics), Illinois Natural History Survey (Long Term ElectroFishing (LTEF) Program, INHS Collections, Long-Term Resource Monitoring Program (LTRMP)), and the fisheries collection of the University of Michigan Museum of Zoology (UMMZ). Mussel community samples were from Illinois Natural History Survey recent state-wide study (T-53; 2009-2011 survey collection). HUC8s that were split by state boundaries were merged with the most appropriate nearby HUC8 based on drainage (i.e., Sugar - Pecatonica, Upper Rock - Lower Rock, and Middle Wabash/Little Vermilion - Vermilion/Wabash). For the initial set of analyses (MDS and CLUSTER, PRIMER v6), fish and mussel assemblages were analyzed separately and examined with and without common and/or rare species presence. Little difference was observed when common and/or rare species were removed from analyses, so all species were included in the final analysis.

The resulting data matrix (all native species presence by HUC8) was used as the input data for a series of multivariate analyses that assessed the relative similarity of fish and mussel assemblages among HUC8s. Native fish and mussel assemblages were analyzed separately and together to compare relative similarity among HUC8s using non-metric multidimensional scaling and clustering dendrograms (MDS and CLUSTER, PRIMER v6). Draft EDUs were developed from HUC8s with relatively similar fish and mussel assemblages (Bray-Curtis 70% similarity; PRIMER v6). Draft EDUs were then analyzed separately to assess similarity of HUC8s within the defined EDUs and dissimilarity among EDUs to verify appropriate placement of HUC8s (SIMPER, PRIMER v6). Aquatic Subregions for Illinois (Laurentian Great Lakes, Upper Mississippi, Lower Mississippi, and Teays-Old Ohio; http://www.feow.org/ecoregions/browse) were also referred to during the development of EDUs. Eleven EDUs (Figure 2.3) were defined for Illinois based on similarity analyses and drainage boundaries (Great Lakes, Upper Illinois River, Illinois River, Rock River, Mississippi River North, Mississippi River Central, Mississippi River South, Kaskaskia River, Middle Wabash River, Wabash River, and Ohio River).

EDUs were defined using drainage affinity and presence of fish and mussel species (Figure 2.3). The eleven EDUs we have defined for Illinois differ only slightly from the EDUs currently being used by the National Fish Habitat Partnership. However, we believe that these refinements better reflect existing and historical patterns of ecological connectivity. These EDUs have been incorporated as formal part of Illinois' Statewide Streams Application (T-60-D-1) and were used as natural processing units for stream flow direction and attribution (Figure 2.4).

Job 3: Define Aquatic Ecological Systems (AES).

AES polygons were developed from 30-meter DEM local watersheds within the 1:100,000 stream arc coverage for Illinois. A total of 1,195 AES polygons were delineated for watersheds draining to Illinois rivers and streams. We planned to attribute bedrock and surficial geology, soils, landform, and groundwater potential based on a model describing potential subsurface water movement (Baker et al. 2003) for each AES polygon for use to distinguish AES types. Following this we plan to use a cluster analysis (MDS and CLUSTER, Primer v6; Clarke & Gorlev 2006) to group hydrologic units sharing similar proportions of selected physical variables (geology, soils, landform, groundwater inputs) into AES types. Unfortunately, delays in the conversion from 1:100,000 to 1:24,000 prevented this from occurring before the end of the project period. We plan to complete this task as time allows in the future.

All stream segments classified as headwaters or small streams (VST size code 1 and 2) were removed from the stream network (Figure 3.1). Valley Segment Type size codes > 3 (drainage area > 81 km^2) and selected null values (stream segments not coded but connected to larger streams) were used to create a digital stream network that contained only streams classified as medium stream, large stream, or large river (Figure 3.2). AES polygons were given a unique identifier that corresponded with the major stream segment that it contained. We developed an automated process within GIS to delineate AES polygons. During these efforts errors such as unidentified gaps and overlaps between polygons were discovered within and between some AES polygons. These were inspected individually and merged with the most appropriate AES polygon based on patterns of drainage. We also identified unattributed "slivers" and other small areas that were not included in the existing database system. These unattributed areas were generally relatively small (e.g., one-foot-wide and a mile long) relative to total watershed size and occurred along the boundaries of the original processing units used to develop summaries for the existing database system. These areas were merged into adjoining AES polygons based on drainage patterns with the help of existing stream lines and the DEM. AES polygons were delineated for watersheds draining to Illinois streams and rivers (Figure 3.3). We also plan to attribute bedrock and surficial geology, soils, landform, and groundwater potential based on a model describing potential subsurface water movement (Baker et al. 2003) for each AES polygon. A cluster analysis (MDS and CLUSTER, Primer v6; Clarke & Gorlev 2006) will be used to group hydrologic units sharing similar percentages of selected physical variables (geology, soils, landform, groundwater inputs) into AES types.

Integration of AES polygons proved to be complicated because watershed boundary polygons developed with the 1:100,000 streamlines and those from the 1:24,000 map scales do not consistently overlap. Unfortunately we were unable to simply apply the work conducted at 1:100,000 to the 1:24,000 watersheds during the project timeframe. We suggest that the process of attributing AES polygons be reapplied with the finer resolution linework and 10-meter DEM shifted watershed delineations that includes smaller stream reaches in the network. We plan to redevelop the AES polygons using the finer resolution data as time allows and to conduct a cluster analysis (MDS and CLUSTER, Primer v6) on these data to group hydrologic units sharing similar percentages of selected physical variables (geology, soils, landform, groundwater inputs) into AES types once the 1:24,000 stream linework transition is completed.

Job 4: Classify stream segments as valley segment types (VSTs).

The existing valley segment groupings were reviewed and attributed to the statewide stream linework (1:100,000) at the beginning of the project. This initial valley segment delineation was developed in 2007 with the approach described in Brenden et al. (2008) using catchment area, link number, catchment slope, and two surficial geology summaries associated with different expectations for infiltration and runoff (bedrock, coarse sand). This classification used regional expectations to categorize catchment attributes. We hoped to focus on conditions within Illinois for the revised classification and used existing data summaries and analysis (Holtrop et al. 2006, Hinz et al. 2011, Seelbach et al. 2011) to develop Illinois specific categories describing summer stream temperature, stream size, and low flow water yield (Table 4.1).

Stream size (width, drainage area, link magnitude), modeled exceedance flows, and modeled water temperatures were used to classify stream arcs in Illinois. To approximate stream size we used width measurements from IDNR FAS database and field data from T-25 (Sass et al. 2010). We also attributed stream arcs with size and gradient classes as defined within INAI guidelines (Natural Areas Program 2006) and used the regional upper stream size thresholds for the Illinois Fish IBI to define wadeable stream segments in Illinois (Table 4.2, Figure 4.1). We examined our stream size class breaks using the distributions of fish species with preference for small (brook stickleback, Southern Redbelly Dace), medium (Largescale Stoneroller, Fantail Darter, Orangethroat Darter, Redfin Shiner, Silverjaw Minnow), or large (Freshwater Drum, Smallmouth Buffalo, Bullhead Minnow, Emerald Shiner, Longnose Gar) stream channels. Size classes associated with these species were similar to those previously developed.

Similarly, we examined thresholds between stream gradient and fish distributions of species with habitat preferences associated with low gradients (Black Bullhead, Blackstripe Topminnow, Grass Pickerel, Sand Shiner, Silverjaw Minnow) or higher gradients (Southern Redbelly Dace, Central Stoneroller, Largescale Stoneroller, Striped Shiner, Orangethroat Darter). There appears to be a threshold at 0.1% slope between primarily lentic (i.e., low gradient) and lotic (i.e., high gradient) fish species assemblages in Illinois streams.

Finally, thermal classes were examined using representative fish distributions for coolwater species (Southern Redbelly Dace, Fantail Darter, Blacknose Dace, Common

Shiner, Brook Stickleback), warm transitional species (Smallmouth Bass, Stonecat), and warmwater species (Red Shiner, Longear Sunfish, Green Sunfish, Blackstripe Topminnow, Yellow Bullhead, Gizzard Shad) identified for Illinois in a previous project (Hinz et al. 2011). Thermal breaks associated with these species were similar to those previously defined.

We further examined relationships between drainage area, link magnitude, and stream width to develop an attribution of stream size and gradient for stream reaches statewide using INAI defined criteria for size and gradient (Figure 4.2). After completing attribution of the existing INAI guidelines using size and gradient we explored alternative attributes for stream classification (Figure 4.3, Figure 4.4, Figure 4.5).

Based on these earlier efforts to describe summer water temperatures, stream size, and low flow water yield in Illinois we input characterizations of stream reaches with the Valley Segment Affinity Search Technique (VAST; Brenden et al. 2008) to delineate valley segments by joining stream reaches with similar characteristics (Figure 4.6). We used catchment area, link number, catchment slope, and two surficial geology summaries (bedrock and coarse sand) associated with different expectations for infiltration and runoff in developing this valley segment delineation. Stream arcs based on the 1:100,000 scale stream linework were then attributed with unique valley segment identifiers throughout the state. We then developed polygons for characterization of each valley segment defined with VAST.

These efforts were conducted using the 1:100,000 stream linework and associated summaries. Integration of these valley segment delineations with the finer resolution data has been problematic. Summaries of the 1:24,000 based stream segments were incompletely compiled when this work was undertaken. GIS summaries of stream segment watershed characteristics are not directly applicable to the 1:24,000 stream linework. Therefore, we plan to redevelop this analysis in the future, as time allows, using the finer resolution data summaries.

Job 5: Define Natural Community Types (NCTs).

The initial terrestrial classification within the INAI used soil moisture, topographic position, and vegetation as “natural features” to distinguish natural communities (White 1978). However, no similar natural features were identified for stream systems. Instead the INAI described stream ecosystems solely based on stream size. The existing INAI Stream Community Class (Natural Areas Program 2006) includes 4 Community Subclasses (small stream, medium stream, large stream, major river) and 3 potential Community Types within these subclasses (high gradient, medium gradient, low gradient). Boundary conditions (e.g., size ranges) for these Community Subclasses and Community Types are not defined within documentation of the INAI (e.g., White 1978, Natural Areas Program 2006). However White (1978), while describing Natural Community Types, noted that “streams must be permanent, not intermittent or ephemeral (flowing only after a rain) to be considered as distinct natural communities instead of features of another community”. Therefore, these types of stream reaches (i.e., intermittent, ephemeral) are not included within the Stream Community Class of the INAI. Unfortunately, there has been no official statewide designation of flow status (e.g., perennial, intermittent, ephemeral) that covers all stream reaches in Illinois.

Existing Stream Community Subclasses and Community Types

We investigated using drainage area, stream order, and link number (also known as link magnitude) for the purposes of attributing Community Subclass to Illinois stream reaches based on their size. A wide range of different drainage areas, and link numbers, were observed for streams with the same stream order (based on 1:100,000 stream linework). Additionally, the range of link numbers for similar drainage areas appears to differ between basins. Because these differences may be associated with natural drainage patterns based on surficial geology and patterns of precipitation, or be based on modifications within the watershed (e.g., addition of drainage ditches), that differ between EDUs we chose not to use stream order and instead used link number (which had greater resolution) as a measure of stream size to identify Stream Community Subclasses for stream reaches statewide (Figure 3.1). While this attribution follows the existing INAI system and identifies Stream Community Subclasses it does little to assist with identifying qualifying features for these Stream Subclasses that could be used to evaluate Natural Community Quality.

High quality natural communities are expected to show little or no degradation from their expected condition and are evaluated based on “natural features” associated with their natural community type (Natural Areas Program 2006). Rather than using physical features of the landscape such as soil moisture or soil depth as “natural features” as was done for terrestrial ecosystems, species were given status as “natural features” for stream ecosystems (White 1978). Locations of species “so rare as to merit special preservation efforts” were considered as natural features for qualifying stream reaches for INAI listing. For example, seven significant natural features and forty-four exceptional natural features were identified based on the presence of fish species (White 1978). This approach is vastly different from that used for terrestrial systems. As such stream reaches that were identified using this approach were considered Category VII (Outstanding Aquatic Features) rather than Category I (High Quality Natural Communities). Category VII locations have since been moved to Category VI (Unusual Concentrations of Flora and Fauna) or Category II (Habitat for Endangered or Threatened Species) (Natural Areas Program 2006).

Terrestrial evaluations of natural community quality for the INAI include a comparison of observed vegetation composition and structure with expected conditions for the natural community being evaluated. This evaluation focuses on the presence of vascular plants including “conservative species” (Natural Areas Program 2006). A similar approach for evaluating stream communities would be to compare the presence of fish or invertebrate taxa with an expectation of their presence based on an unimpacted condition. There have been several approaches developed for assessing stream conditions in this way including the Index of Biotic Integrity (e.g., Karr 1981, Fausch et al. 1984) and direct comparisons of observed to expected conditions (e.g., Wright et al. 1993, Clarke et al. 1996, Cao & Hawkins 2011). Illinois' fish IBI (Smogor 2000) has been used to identify Category VI stream communities for qualifying for the INAI (Natural Areas Program 2006) and will be discussed under Job 6 (see below).

Instead of using the observation of individual species as "natural features" for stream ecosystems as was done in the initial INAI (White 1978) we considered the potential of using several different measures of biodiversity as natural features. These assemblage-based measures would more closely approximate the use of vegetation associated with the terrestrial assessments. We investigated the use of species richness to index regional biodiversity in a way that would allow assessment of the quality of biologically based "natural features" within stream reaches (i.e., develop expected biological conditions based on richness).

We assembled information on fish, mussels, and aquatic insects to help define natural features based on species assemblages in Illinois streams and summarized these for each EDU (Table 5.1). We then applied the observed statewide fish and mussel richness, and regional (EDU) fish and mussel richness expectations, as a standard reference level (expected value) for Category VI ("Unusual Concentrations of Flora and Fauna"). Regional fish and mussel richness were estimated statewide using recent survey data and were summarized at the EDU (Table 5.2a,b) and by stream size class. We further differentiated fish (Figure 5.1) and mussel (Figure 5.2) richness levels by stream size (i.e., Stream Subclass; Table 5.3a,b). This is a relatively simple method of developing expected values for aquatic taxa. Another approach for defining high quality is to use a high percentile based on all available scores (e.g., richness >90% of all scores; Figure 5.3). We also applied this approach to macroinvertebrate samples collected by the Illinois Environmental Protection Agency through their Intensive Basin Survey Program (Figure 5.4). Use and selection of a percentile criterion will, by definition, identify a fixed fraction of stream reaches that meet the criterion. While this will identify the highest richness areas that have been sampled it also allows the minimum richness that meets the standard to shift as additional samples are collected. We suggest investigating more robust methods of developing richness expectations for natural communities within Illinois streams in the future (e.g., Cao et al. 2015) to obtain a fixed standard.

These richness expectations can be used to assess the condition of the fish or mussel assemblage based on a sample, or series of samples, from a stream reach within the appropriate INAI Stream Community Subclass (based on stream size) and Community Type (based on gradient) or using an alternative Typing (e.g., EDU, AES, VST). Assemblage condition measures of this nature could also be used to assess the quality of stream ecosystem Subclasses or gradient based "community types."

While this approach holds great promise it is currently limited by its dependence on the density and distribution of available biological samples to determine the regional or local reference expectations. Unfortunately, the distribution of historic and contemporary aquatic sampling stations in Illinois' rivers & streams, while extensive, is neither randomly nor systematically derived and sample densities vary greatly between watersheds.

Several important taxonomic treatments have been completed in the past for aquatic fauna in Illinois based primarily on museum collection records (e.g., Frison 1935, Ross 1944, Smith 1979, Cummings & Mayer 1992). These contain information about preserved specimen locations but much of the state remains unsampled or undersampled. Despite this long history of biological sampling in Illinois streams there have been few recent efforts to systematically inventory aquatic fauna on a statewide basis. The two major exceptions are the Critical Trends Assessment Program (CTAP; Molano-Flores 2002) and recent efforts to conduct statewide surveys for mussels (Stodola et al. 2014). CTAP was established to characterize Illinois ecosystems (including streams) using a random sampling design and to track the status of these systems over time. CTAP stream sampling emphasized EPT taxa for biological assessment at 149 sites in Illinois. However, due to program constraints we lack parallel information for fish, mussels, and other aquatic taxa (e.g., crayfish, snails) at most of these locations. The mussel conservation work has been conducted under a series of SWG funded projects that began with conducting surveys in 2009 (Stodola et al. 2014), performed conservation assessments (Douglass and Stodola 2014), and are now focused on developing restoration options for at risk species. Directed statewide surveys for other aquatic taxa have not been undertaken recently except for a few species (e.g., Henry et al. 2009, Metzke and Holtrop 2014) or in rare habitats (e.g., Vandermyde & Shults 2015). Developing and implementing a broad scale statewide survey of stream fauna that includes multiple taxa would assist with defining current species distributions, refine regional and local species richness expectations, and aid with conservation assessments of rare and common species.

We also examined the potential use of NatureServe subnational (state) rankings of fish and mussel species for defining Category I or Category VI INAI sites in a manner similar to what is used for Cave Communities in the INAI. Caves are evaluated using the presence of taxa with imperiled or critically imperiled ratings (Natural Areas Program 2006). Unfortunately, while this approach also has promise the Illinois NatureServe rankings have not been updated since they were initially developed (< 1997) and are painfully out of date. Information from other projects (e.g., T-68, T-55, T-82) could be used to update the state S rankings but this is beyond the scope of this project. We suggest that updating S-ranks be prioritized for SGCN in Illinois.

Additional efforts to develop Category I criteria for stream communities requires completion of AES and stream reach characterization. While we completed the delineation of AESs based on the 1:100,000 linework characterizations using the updated 1:24,000 linework were incomplete at the time this report was written (see Appendix II).

Additional considerations for INAI Stream Subclasses and Community Types

INAI standards & guidelines use the CLASS CULTURAL for areas that have been heavily modified by, or for, human use. The “cultural” designation implies that the area is highly influenced by current or historic human use (either direct use or by activities within or near the area). These areas are generally not considered to be capable of supporting “natural communities” and are thus not eligible for listing on the INAI under Category I (High Quality Natural Communities).

Past attempts at identifying high quality aquatic systems (e.g., Smith 1971, Hite & Bertrand 1989, Page et al. in Phillippi and Anderson 1989, Burr and also Page in Page & Jeffords 1991) appear to have considered that all Illinois streams are in the “developed” or “cultural” class and have been disturbed to such an extent that undisturbed “natural” habitats (and thus high quality natural communities as defined by INAI Category I) are not observed. Despite this awareness of watershed modification there was a recognition that high quality species assemblages remained within the State of Illinois. These efforts thus used the presence of high species richness (generally of fish and/or mussels), rare fish or mussel species (primarily E&T species), or “unusual” assemblages of fish (high fIBI, or “rare” species) or mussels (MCI) to indicate locations that require conservation (including protection) efforts to maintain their quality.

At present there are no “cultural” designations for Illinois streams. We suggest that many stream reaches in Illinois meet the standard used to designate terrestrial landscapes with the CLASS CULTURAL based on conditions within their watersheds. Human activities have modified streams and their watersheds in numerous ways including but not limited to: hydrologic modification (including dams and other water level controls), channelization and leveeing, water table depression (e.g., withdrawal wells and near surface drainage), inter-basin and intra-basin transfer (e.g., effluent discharges and canals), surface water storage (e.g., wetland removal or construction, landscape leveling, mining pits, construction of ponds and reservoirs), flow patterns (e.g., drainage ditches and storm sewer systems), nutrient transfer (e.g., fertilizer additions and sewage effluent discharges), shifts in landcover (e.g., forest to grassland, grassland to farmland), and a host of other accidental and purposeful biological interventions (e.g., invasive species introduction and invasive species management, “pest” and “predator” control, intensive animal husbandry operations, forestry management, agroforestry, lawn maintenance, monocropping, industrial crop production). Such activities have most certainly altered the condition of the chemical, hydrologic, and physical character of Illinois watersheds and the streams that flow through them. However, there are currently no criteria to designate watersheds or stream reaches as “cultural” or “natural” in Illinois.

If stream classification is to follow a similar developmental pattern as that of the INAI’s terrestrial component which is based on landscape characteristics (e.g., “cultural” [urban, agricultural], or “natural” [prairie, forested, wetland, mountain, desert]), then source water (e.g., springs, runoff, diversion), and size (e.g., primary headwater → Great River) would more closely follow the terrestrial landscape treatment (1. “natural” or “cultural”, 2. NCT assessment) than the existing system that uses size as the primary determinant of Natural Community Subclass and gradient to identify NCT. Developing such a classification was beyond the scope of this project.

Job 6: Produce a list of candidate sites for INAI using existing data.

We mapped locations that would qualify as INAI sites under existing criteria for Category II or Category VI (Natural Areas Program 2006) based on high mussel species richness (Figure 6.1), mussel classification index score (Figure 6.2), presence of endangered or threatened mussel species (Figure 6.3) or fish species (Figure 6.4), and high fish IBI scores (Figure 6.5). Based on the large number of sites identified we recommend that field visits and further evaluation of site condition is conducted prior to the nomination of any of these locations as INAI sites. It may also be appropriate to more rigorously define Category II and Category VI with additional criteria that thoroughly describe the requirements of "specific suitable habitat" and status as "unusual concentrations" for the purposes of the INAI.

Specific Suitable Habitat of Endangered and Threatened Species

INAI Category II ("Specific Suitable Habitat of endangered and threatened species") is designed to identify and protect viable populations and critical habitat of E&T species. Such habitats are defined as "those physical and biological features of the landscape that a species requires to survive and reproduce" (Natural Areas Program 2006, p.17). This is similar to the "Essential Habitat" described in the Illinois Endangered Species Act (520 ILCS 10/2) as the "specific ecological conditions required by an endangered or threatened species for its survival and propagation, or physical examples of these conditions." Current INAI guidelines require the site to be occupied by at least one State or Federally listed endangered or threatened species as evidenced by a recent (<10 years old) Element Occurrence Record. Element Occurrence Records require verification of species identification and location information associated with the observation to be accepted. Unfortunately, a single observation of an endangered or threatened species does not, by itself, indicate the presence of a viable population or specific suitable habitat. Some taxonomic groups (i.e., snakes, birds, bats) have additional guidelines designed to consider life history requirements by identifying evidence of reproduction or wintering habitat as verification of specific suitable habitat (Natural Areas Program 2006, p. 18). Similar evidence should be required for each E&T species at observed locations prior to consideration for qualification as Category II. We suggest that guidelines for INAI Category II be revised to include a more thorough assessment of potential sites. Criteria could include verification of a minimum number of individuals inhabiting the site over a specified time interval (a fixed number of years or perhaps related to their generation time) and evidence of successful reproduction. Regardless of which factors are ultimately deemed necessary for a site to qualify as INAI Category II, the characteristics of "specific and suitable habitat" and of "essential habitat" should be described, and if possible unified, in conservation management and/or species recovery plans for the E&T species prior to qualifying any site as INAI Category II for the listed species.

Unusual Concentrations of Flora and Fauna

Qualification as INAI Category VI ("Unusual Concentration of Flora and Fauna") for stream reaches is currently assessed using mussel and fish assemblages. Other aquatic invertebrate assemblages are not generally considered for Category VI at this time. Stream reaches may qualify as Category VI by having a minimum of ten (10) live mussel species (Figure 6.6), a Mussel Classification Index Score of twelve (12) or more ("unique or highly valued resource", Figure 6.2), or a Fish Index of Biotic Integrity Score of fifty-six (56) or greater (Figure 6.5). A few other conditions are noted in the guidelines that may qualify under Category VI including the presence of coolwater fish communities, wintering habitats of uncommon fish species, or breeding habitat of rare species (Natural Areas Program, p. 21). With perhaps the exception of the presence of coolwater fish communities these other conditions describe, in part, "specific and suitable habitat" for rare species that might be better evaluated as part of Category II.

Mussels

Since statewide historic mussel richness patterns do not appear to have ever been similar between major watersheds within Illinois (Figure 2.2), or for different stream sizes (Bol et al. 2007), the statewide criterion of ten (10) live mussel species may be inappropriate for evaluating mussel communities in some parts of the State of Illinois. Relatively high richness reaches in historically low richness watersheds may be underrepresented, and those in historically high richness watersheds overrepresented, using the current criterion. We suggest that a richness criterion that is basin and size specific (Figure 5.2) be used instead of a statewide richness value (Figure 6.6) if a simple mussel richness measure is used to assess Category VI. Additional information based on sampling adequacy (Huang et al. 2011) and distribution modeling (Cao et al. 2015) for mussels could be used to further adjust this type of criterion for specific stream types if desired.

The Mussel Classification Index (MCI) was designed to identify a "resource value" based on the mussel assemblage observed at a sampling station (Appendix VII of Natural Areas Program 2006). The MCI is the sum of four factors that represent species richness, the presence of intolerant species, overall mussel abundance, and the extent of recruitment among the species that are present. Stream reaches with high mussel resource values are considered to have high richness or abundance, some intolerant species, and evidence of recruitment for some species. While the MCI was developed using mussel collection information primarily from central Illinois streams it has been applied throughout the State of Illinois. Unfortunately, there has been no formal evaluation or further development of the MCI at this time. If further use of the MCI is desired we suggest that it be redeveloped, or at least recalibrated, using statewide mussel survey information (e.g., Douglass & Stodola 2014, Stodola et al. 2014, Cao et al. 2015) that has been collected since its initial development.

Fishes

The fish IBI has also been updated (Smogor 2000) and the scoring substantially changed (Smogor 2005) since the Category VI qualifying criteria were initially developed. An evaluation of these changes suggests that scores with the same magnitude may no longer reflect the same similarity to reference conditions between different parts of the State of Illinois. As such we identified stream reaches containing samples that scored with the equivalent IBI rating that the current IBI criteria met (e.g., “exceptional”, IBI>51; Figure 6.7) which adds a considerable number of sites.

Considerations for High Quality Natural Communities in Streams

One of the goals of this project was to develop a stream based classification system with associated natural community types so that stream reaches could be evaluated as high quality natural communities (i.e., Category I). Category I of the INAI was initially developed to include ecological areas with high quality terrestrial and wetland natural communities as their significant qualifying feature (White 1978). The Illinois landscape was divided with a terrestrial based classification system that described broadscale patterns and expectations for natural communities (White 1978). Streams and lakes were not evaluated as part of the Category I survey but were listed as aquatic areas instead (Category VII; White & Corbin 1978; see also Job 5 above). Aquatic areas (later known as High Quality Streams) are no longer a separate Category in the INAI and sites that had previously been tracked as Category VII have been moved primarily to Category VI since their qualifying feature was based on the characteristics of their fish or mussel assemblage (Natural Areas Program 2006).

Evaluation of potential INAI Category I locations consists of two major steps. The first is to determine the type of natural community the location represents and the second is an evaluation of its quality. Each of these tasks is difficult without specific and detailed standardized criteria. INAI guidance states that “A specific set of criteria separates one community type from another. These criteria can include a community’s location (natural division), soils, soil moisture, soil parent material, hydrology, and plant species composition.” (Natural Areas Program 2006). We have attempted to transfer this guidance to lotic systems. We used the physical habitat structure of stream reaches (i.e., size, thermal regime, flow regime) to delineate valley segment types. These types describe the physiochemical, geographical, geological, and hydrological components that define the habitat template on which local flora and fauna depend. While we completed this delineation for the 1:100,000 scale during this project it should be reapplied to the 1:24,000 based streamlines.

Once the physical habitat conditions have been described the thing still missing from the evaluation of natural community types is the expression of the living organisms on this habitat template. For terrestrial natural communities the surface vegetation is used for this purpose. In lotic systems this is impractical. Macrophytes are more commonly associated with stream edges, riparian zones, and wetland systems rather than as major instream components (except in a few circumstances such as some headwaters, freshwater estuaries or floodplain features that are usually treated as wetlands) while microbenthos (e.g., algae and bacteria) and terrestrial inputs regularly form the base of the system of energy transfer. Thus instead of using plant species composition and structure to assist with separating natural community types in streams we recommend shifting the biological portion of the assessment to fish, mussel, and macroinvertebrate assemblages.

This currently occurs, in part, during the assessment of Category VI rather than the Category I assessment (except for Caves that uses the presence of rare species to indicate high quality communities; see pages 73-74, Natural Areas Program 2006). However, if standards using biological criteria were accepted as evidence of the quality of Natural Community Types then there is no reason to restrict stream reaches from being assessed for potential under Category I. An Index of Biotic Integrity, or Observed/Expected species richness assessment, that is designed to differentiate undisturbed reference conditions (or other agreed upon conditions) might be acceptable for this purpose. However, the difficulty in defining such reference conditions in Illinois may be problematic. We suggest continuing the development of a finely calibrated Biological Condition Gradient Model (Davies & Jackson 2006) for Illinois streams with indicators capable of describing Tier 1 and Tier 2 stream reaches which are essentially the equivalent of Grade A and Grade B Natural Community Types.

Job 7: Prepare manuscripts and reports.

This final performance report and four annual reports were prepared and submitted to the project sponsor. To date a total of four presentations of this work have been delivered (40th Natural Areas Conference [Chicago, Illinois 2013], Joint Aquatic Sciences Meeting [Portland, Oregon 2014], and the 51st [Rend Lake, Illinois 2013] and 52nd [Bloomington, Illinois 2014] Annual Meetings of the Illinois Chapter of the American Fisheries Society).

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Table 4.1. Stream segment attributes used to develop Valley Segment Types. Stream Size is the total upstream drainage area at the downstream end of the stream segment (Holtrop et al. 2006), Mean Daily July Temperature is based on predicted temperatures from a state-wide multiple linear regression model (Hinz et al. 2011), and Low Flow Yield was defined as the annual 90% exceedance flow discharge [m^3s^{-1}] / drainage area [km^2] based on a state-wide multiple linear regression model (Seelbach et al. 2011).

Code	Stream Size (stream size class name)
1	< 15 km^2 (headwaters)
2	15-80 km^2 (small streams)
3	81-600 km^2 (medium streams)
4	601-35,000 km^2 (large streams)
5	> 35,000 km^2 (major rivers)
Code	**Mean Daily July temperature (thermal class name)**
1	<21.5 °C (cool)
2	21.5-23.5 °C (warm transitional)
3	>23.5 °C (warm)
Code	**Modeled Low Flow Yield**
1	0 - 0.00000242 m^3s^{-1}/km^2
2	0.00000243 - 0.00015835 m^3s^{-1}/km^2
3	> 0.00015835 m^3s^{-1}/km^2

Table 4.2. Stream Size Class was recalculated using the same class breakpoints using the revised GIS information based on the 1:24,000 stream linework and the 10m resolution DEM.

Stream Size Classes		
Stream type	**Size Class**	**Drainage Area (km^2)**
Headwaters	1	< 15
Small streams	2	15-80
Medium streams	3	81-600
Large streams	4	601-35,000
Major Rivers	5	> 35,000

Table 5.1. Percentage of stream reaches in each Ecological Drainage Unit which were evaluated for fish species richness.

EDU	Reaches with Richness	Stream Reaches*	Percent Evaluated
Great Lakes	49	626	7.83%
Illinois River	1337	76094	1.76%
Rock River	174	14639	1.19%
Mississippi River North	265	11874	2.23%
Mississippi River Central	246	12774	1.93%
Mississippi River South	281	13524	2.08%
Kaskaskia River	152	20640	0.74%
Middle Wabash River	209	14211	1.47%
Wabash River	144	15067	0.96%
Ohio River	209	10223	2.04%
Statewide total	**3066**	**189672**	**1.62%**

*Includes only stream reaches within the Illinois state boundary

Table 5.2. Distribution of classified stream reaches by richness class for Illinois Ecological Drainage Units. Richness classes were derived for each EDU based on the observed richness in sampled reaches for Fish (4a) and Mussels (4b). Richness Class 1 contains reaches with species richness > 90% of all measured reaches, Richness Class 2 contains reaches with species richness > 50% but < 90% of all measured reaches. Richness Class 3 contains reaches with species richness at or below 50% of the richness value of all measured reaches.

5.2a. Fish

	Richness Class		
EDU	**1**	**2**	**3**
Great Lakes	12.24%	32.65%	55.10%
Upper Illinois	9.77%	38.01%	52.22%
Lower Illinois	9.65%	37.61%	52.74%
Rock River	8.09%	42.20%	49.71%
Mississippi River North	10.21%	39.57%	50.21%
Mississippi River Central	7.62%	40.48%	51.90%
Mississippi River South	8.81%	39.46%	51.72%
Kaskaskia River	11.26%	36.42%	52.32%
Middle Wabash River	10.63%	38.65%	50.72%
Wabash River	11.35%	39.72%	48.94%
Ohio River	13.02%	38.02%	48.96%

5.2b. Mussels

	Richness Class		
EDU	1	2	3
Great Lakes	11.11%	11.11%	77.78%
Upper Illinois	10.20%	37.39%	52.41%
Lower Illinois	9.70%	37.93%	52.37%
Rock River	8.25%	35.05%	56.70%
Mississippi River North	9.89%	36.26%	53.85%
Mississippi River Central	13.16%	26.32%	60.53%
Mississippi River South	9.09%	36.36%	54.55%
Kaskaskia River	10.34%	36.21%	53.45%
Middle Wabash River	8.95%	34.63%	56.42%
Wabash River	9.38%	35.94%	54.69%
Ohio River	13.04%	46.09%	40.87%

Table 5.3a. Stream reaches in Illinois that have been sampled for fish during the period 2000-2014 based on available data sources (IDNR Fisheries Database, INHS Fisheries Collections Database). **Note:** Not included in these totals are additional samples from the Kaskaskia River EDU that were collected in 2013-2015 as part of another program (Hinz & Metzke 2015).

		Stream Size Class					
EDU	**Stream reaches**	**1**	**2**	**3**	**4**	**5**	**ALL**
Great Lakes	Number Sampled	17	20	8	4	-	49
	Number of Reaches	471	120	23	12	-	626
	Percent sampled	3.6%	16.7%	34.8%	33.3%	-	88.4%
Upper Illinois	Number Sampled	22	168	138	162	-	490
	Number of Reaches	11,054	1,575	827	619	-	14,075
	Percent sampled	0.2%	10.7%	16.7%	26.2%	-	53.7%
Lower Illinois	Number Sampled	65	122	179	171	157	694
	Number of Reaches	49,655	7,004	3,327	1,766	267	62,019
	Percent sampled	0.1%	1.7%	5.4%	9.7%	58.8%	75.7%
Rock	Sampled	29	59	47	38	-	173
	Number of Reaches	11,916	1,499	672	551	1	14,639
	Percent sampled	0.2%	3.9%	7.0%	6.9%	0.0%	18.1%
Mississippi North	Number Sampled	3	25	31	48	128	235
	Number of Reaches	9,019	1,106	828	340	581	11,874
	Percent sampled	0.0%	2.3%	3.7%	14.1%	22.0%	42.2%
Mississippi Central	Number Sampled	15	18	36	8	133	210
	Number of Reaches	10,506	1,260	590	52	366	12,774
	Percent sampled	0.1%	1.4%	6.1%	15.4%	36.3%	59.4%
Mississippi South	Number Sampled	72	73	40	17	59	261
	Number of Reaches	11,000	1,383	736	229	176	13,524
	Percent sampled	0.7%	5.3%	5.4%	7.4%	33.5%	52.3%
Kaskaskia	Number Sampled	21	34	63	33	-	151
	Number of Reaches	16,515	2,119	1,453	552	1	20,640
	Percent sampled	0.1%	1.6%	4.3%	6.0%	0.0%	12.0%
Middle Wabash	Number Sampled	9	53	81	64	-	207
	Number of Reaches	11,290	1,580	862	479	-	14,211
	Percent sampled	0.1%	3.4%	9.4%	13.4%	-	26.2%
Wabash	Number Sampled	14	33	36	58	-	141
	Number of Reaches	12,101	1,709	732	525	-	15,067
	Percent sampled	0.1%	1.9%	4.9%	11.0%	-	18.0%
Ohio	Number Sampled	41	47	29	7	68	192
	Number of Reaches	8,291	1,006	586	126	214	10,223
	Percent sampled	0.5%	4.7%	4.9%	5.6%	31.8%	47.4%
ALL	Number Sampled	381	652	688	610	545	2,876
	Number of Reaches	151,818	20,361	10,635	5,252	1,606	189,672
	Percent sampled	0.3%	3.2%	6.5%	11.6%	33.9%	55.5%

Table 5.3b. Stream reaches in Illinois that have been sampled for mussels during the period 2000-2014 based on available data sources (IDNR Mussel Database, INHS Mussel Collections Database).

EDU	Stream reaches	Stream Size Class					
		1	2	3	4	5	ALL
Great Lakes	Number Sampled	2	9	1	-	-	12
	Number of Reaches	471	120	23	12	-	626
	Percent sampled	0.4%	7.5%	4.3%	0	-	12.3%
Upper Illinois	Number Sampled	35	93	128	97	-	353
	Number of Reaches	11,082	1,580	820	593	-	14,075
	Percent sampled	0.3%	5.9%	15.6%	16.4%	-	38.2%
Lower Illinois	Number Sampled	17	87	185	127	48	464
	Number of Reaches	49,735	7,038	3,296	1,729	221	62,019
	Percent sampled	0.03%	1.2%	5.6%	7.3%	21.7%	35.9%
Rock River	Number Sampled	6	39	67	82	-	194
	Number of Reaches	11,920	1,499	672	548	-	14,639
	Percent sampled	0.1%	2.6%	10.0%	15.0%	-	27.6%
Mississippi North	Number Sampled	1	6	38	18	29	92
	Number of Reaches	9,251	1,153	854	316	300	11,874
	Percent sampled	0.01%	0.5%	4.4%	5.7%	9.7%	20.3%
Mississippi Central	Number Sampled	2	7	17	2	14	42
	Number of Reaches	10,611	1,290	578	55	240	12,774
	Percent sampled	0.02%	0.5%	2.9%	3.6%	5.8%	13.0%
Mississippi South	Number Sampled	11	26	16	14	10	77
	Number of Reaches	11,046	1,390	738	237	113	13,524
	Percent sampled	0.1%	1.9%	2.2%	5.9%	8.8%	18.9%
Kaskaskia River	Number Sampled	4	19	65	32	-	120
	Number of Reaches	16,515	2,119	1,453	552	1	20,640
	Percent sampled	0.02%	0.9%	4.5%	5.8%	0	11.2%
Middle Wabash	Number Sampled	7	49	110	91	-	257
	Number of Reaches	11,290	1,580	862	479	-	14,211
	Percent sampled	0.1%	3.1%	12.8%	19.0%	-	34.9%
Wabash River	Number Sampled	4	22	48	54	-	128
	Number of Reaches	12,106	1,710	758	493	-	15,067
	Percent sampled	0.03%	1.3%	6.3%	11.0%	-	18.6%
Ohio River	Number Sampled	19	35	30	10	21	115
	Number of Reaches	8,373	1,019	592	128	111	10,223
	Percent sampled	0.2%	3.4%	5.1%	7.8%	18.9%	35.5%
Statewide	Number Sampled	108	392	705	527	122	1,854
	Number of Reaches	152,400	20,498	10,646	5,142	986	189,672
	Percent sampled	0.1%	1.9%	6.6%	10.2%	12.4%	31.2%

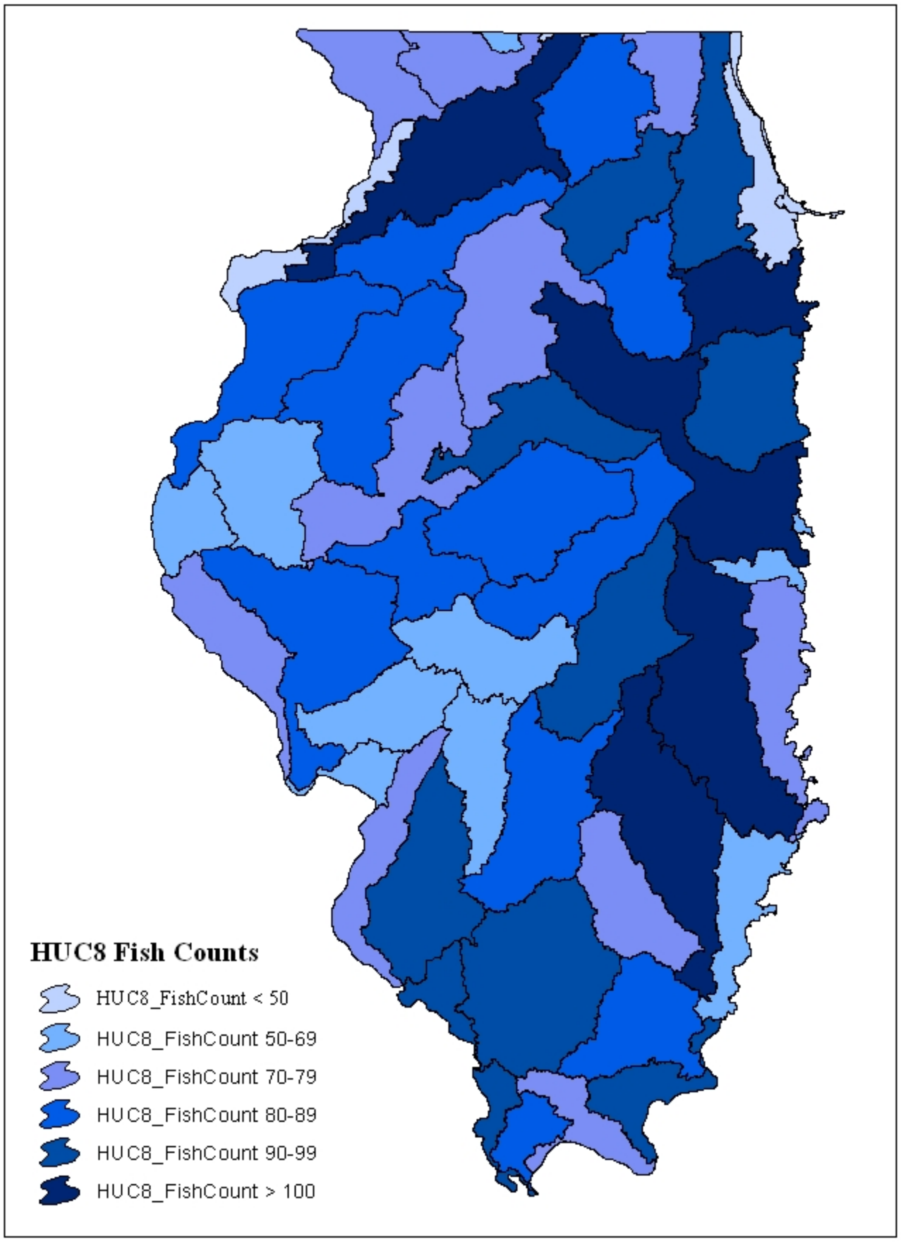

Figure 2.1. Number of native fish species within HUC8 watersheds in Illinois.

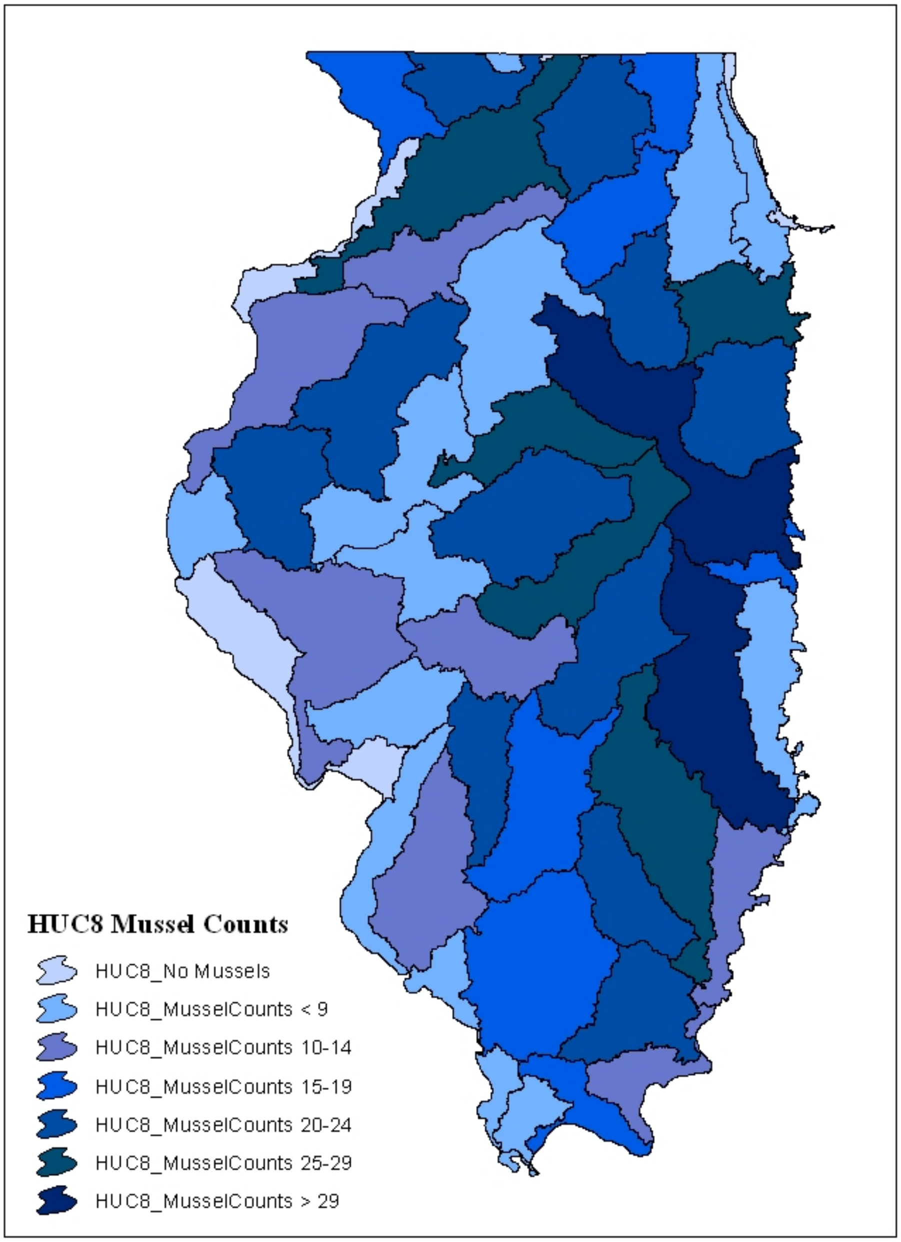

Figure 2.2. Number of native mussel species within HUC8 watersheds in Illinois. Areas with "No Mussels" have not been as extensively surveyed and do not include mussel records from the Mississippi River Mainstem or Lake Michigan.

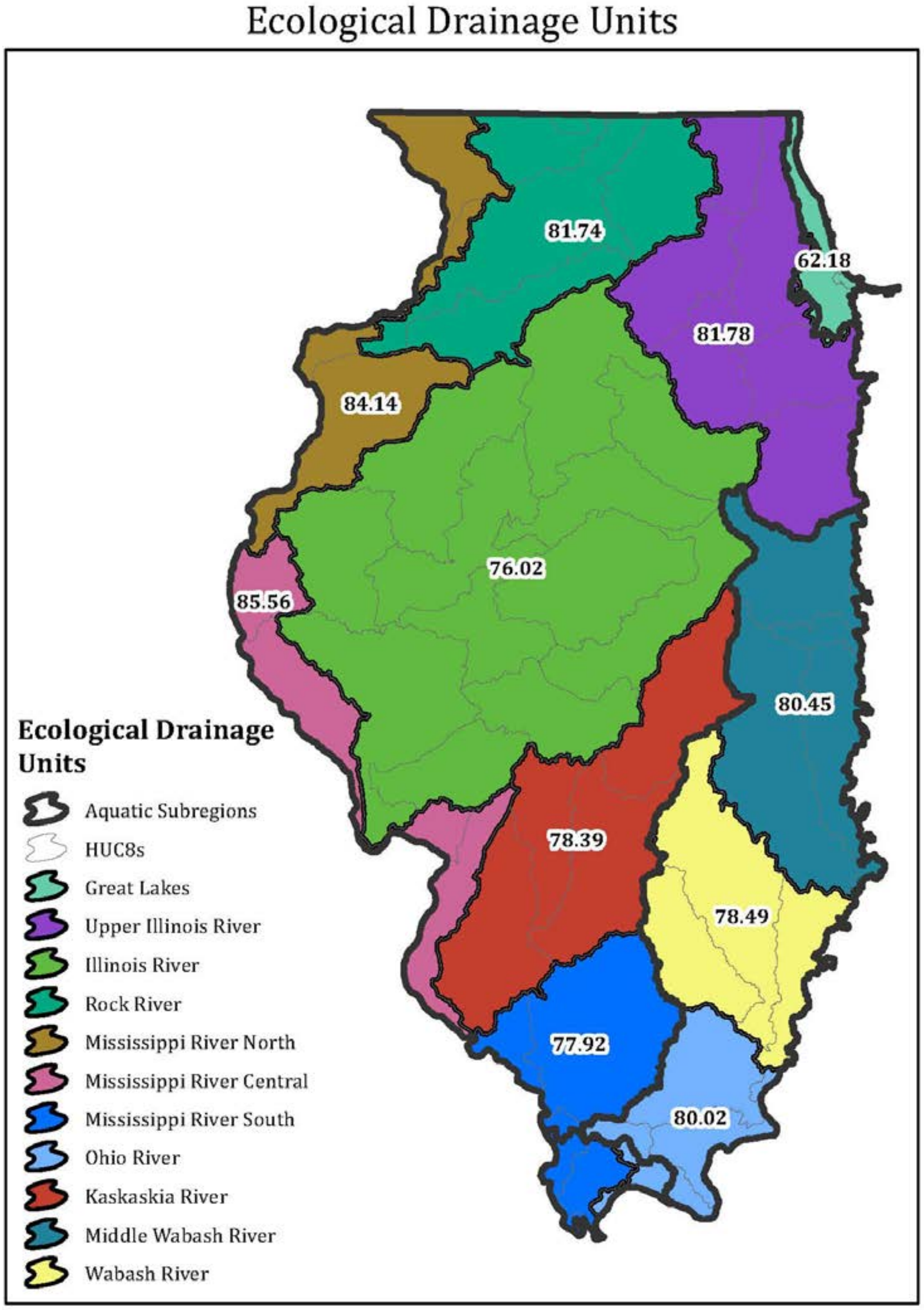

Figure 2.3. Ecological Drainage Units (EDU) for Illinois were derived using drainages and HUC8s with relatively similar fish and mussel species assemblages. Values correspond to the Bray-Curtis similarity of the combined fish and mussel assemblages between HUC8s within each EDU (SIMPER, Bray-Curtis 70% similarity; PRIMER v6).

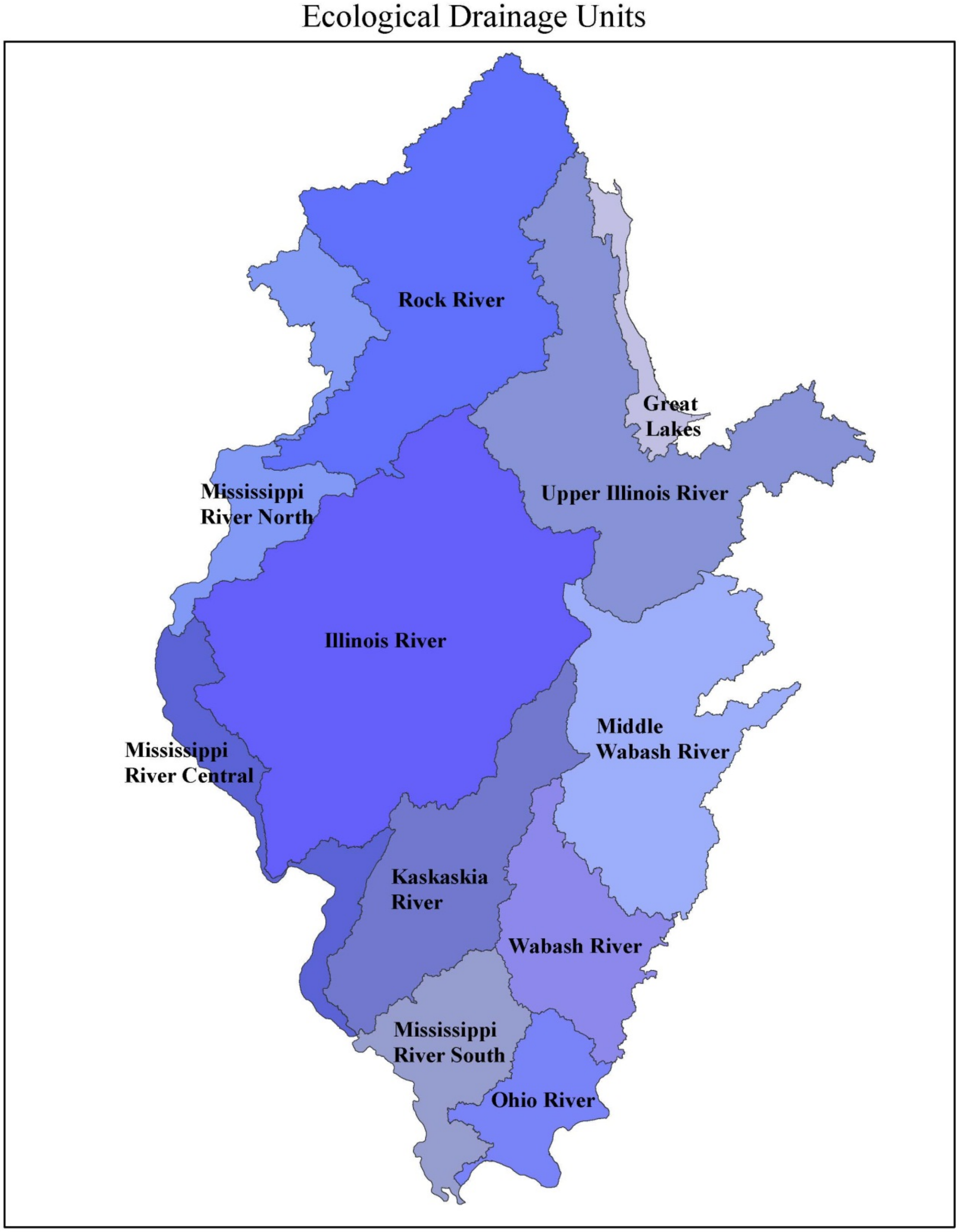

Figure 2.4. Ecological Drainage Units (EDUs) for Illinois were derived using drainages and HUC8s with relatively similar fish and mussel species assemblages.

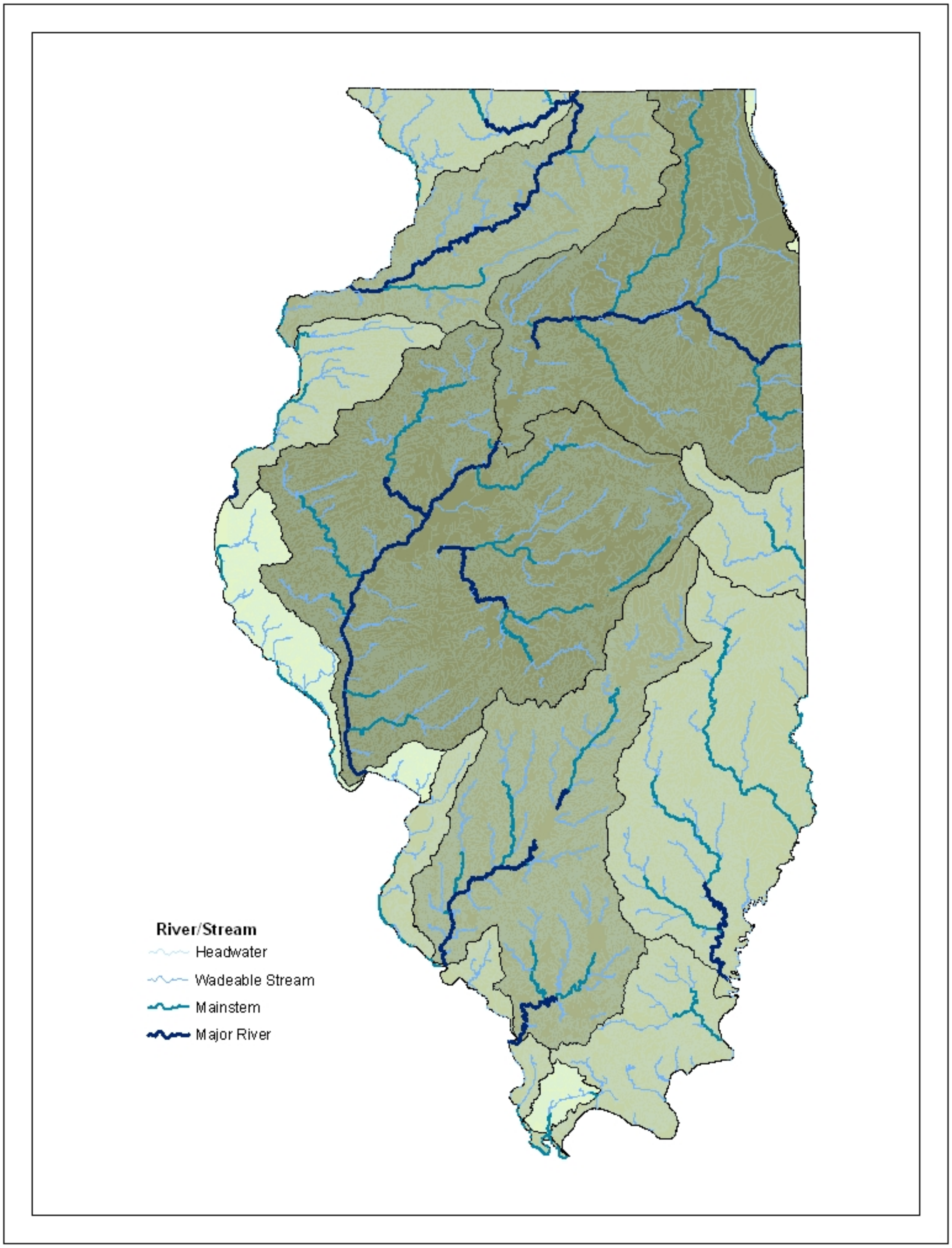

Figure 3.1. Community Subclasses for Illinois Rivers based on stream size (link number). Classes are "Headwater" link number = 1-20, "Wadeable Stream" link number = 21-180, "Mainstem" link number = 181-725, "Major River" link number >725. Large Reservoirs and Great Rivers (Mississippi, Ohio, Wabash) are not classified at this time.

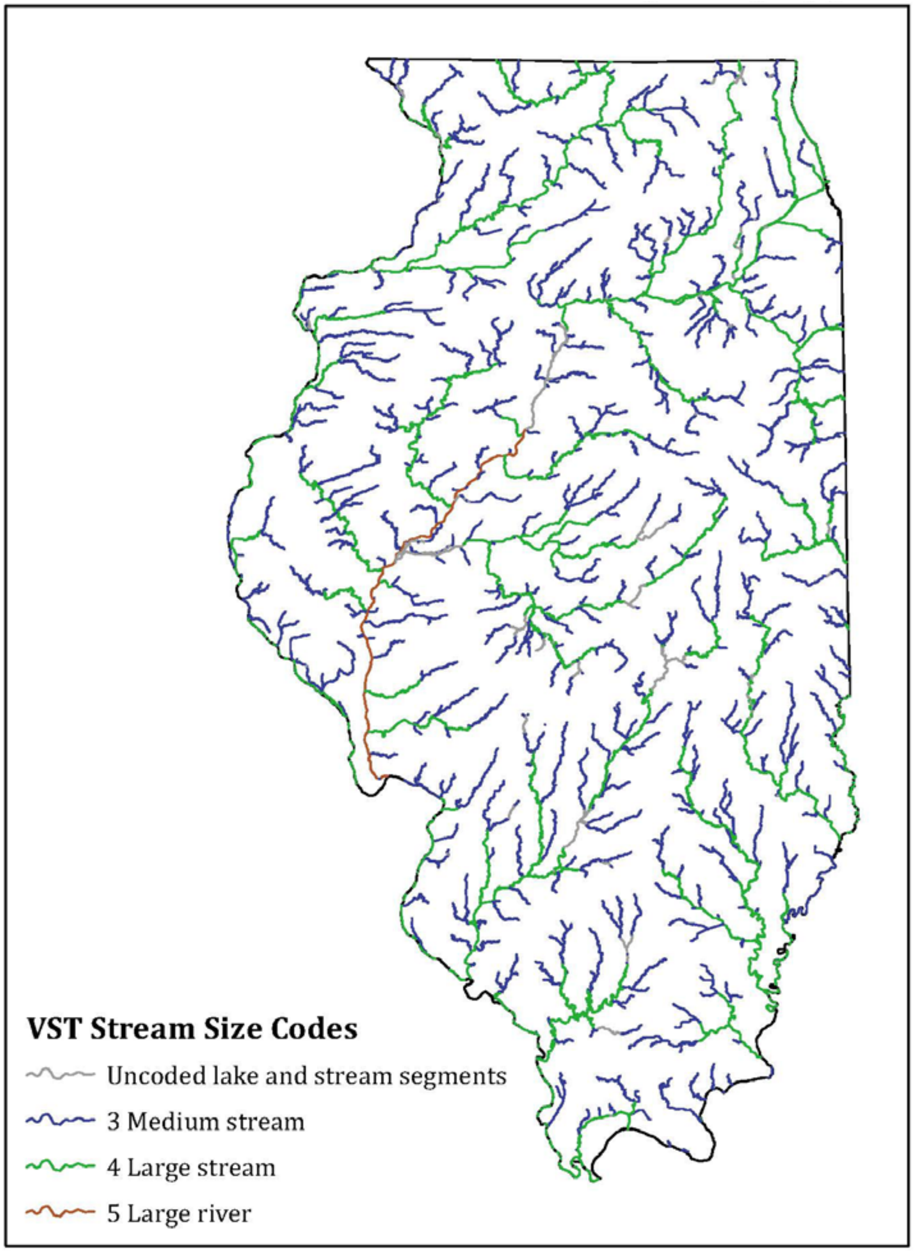

Figure 3.2. Illinois stream network containing only medium sized and larger stream segments used for developing watershed boundaries associated with Aquatic Ecological Systems. Great River (i.e., Mississippi River, Ohio River, Wabash River) segments on Illinois' borders with other states have not been coded for these efforts.

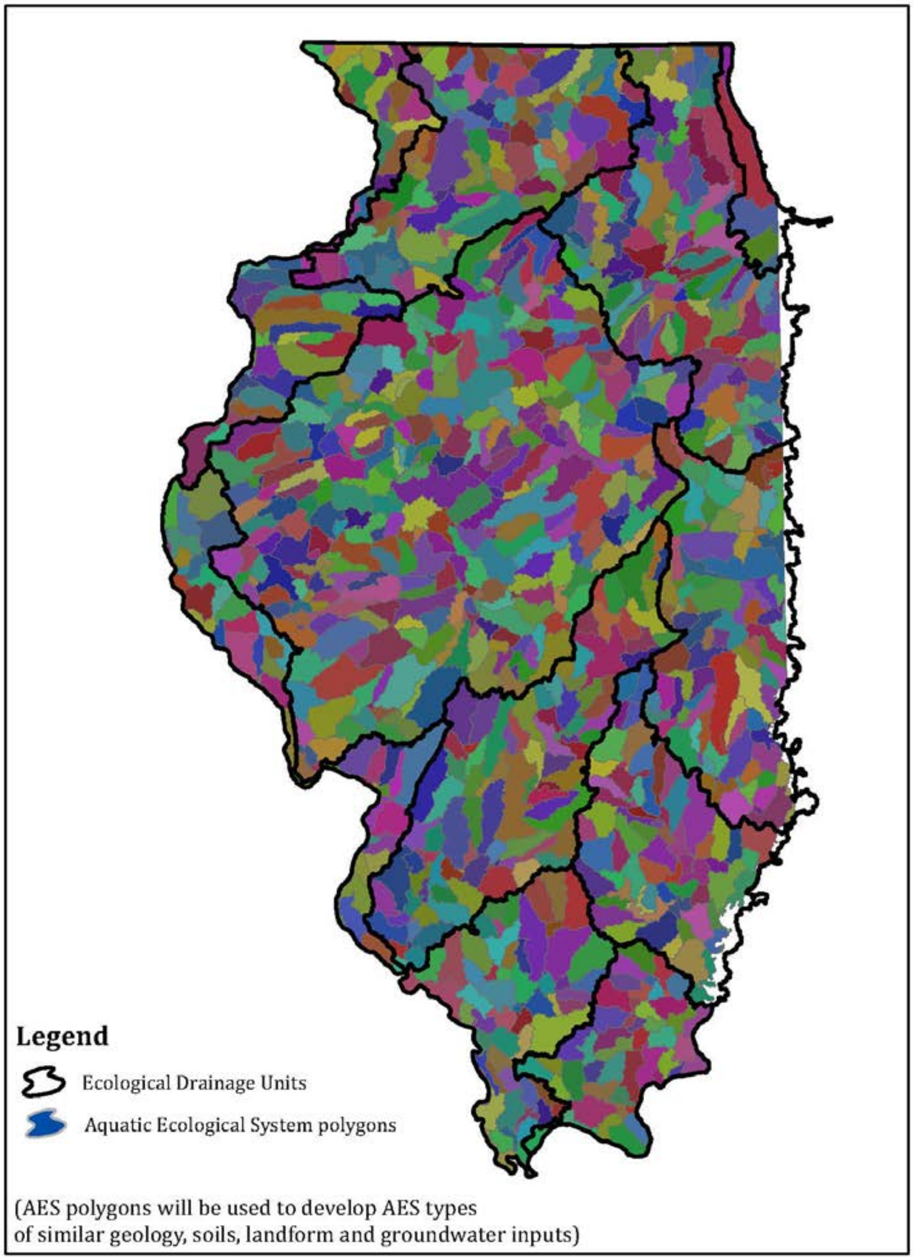

Figure 3.3. Watershed boundaries for Aquatic Ecological Systems for Illinois streams. Great River (i.e., Mississippi River, Ohio River, Wabash River) segments on Illinois' borders with other states have not been coded for these efforts.

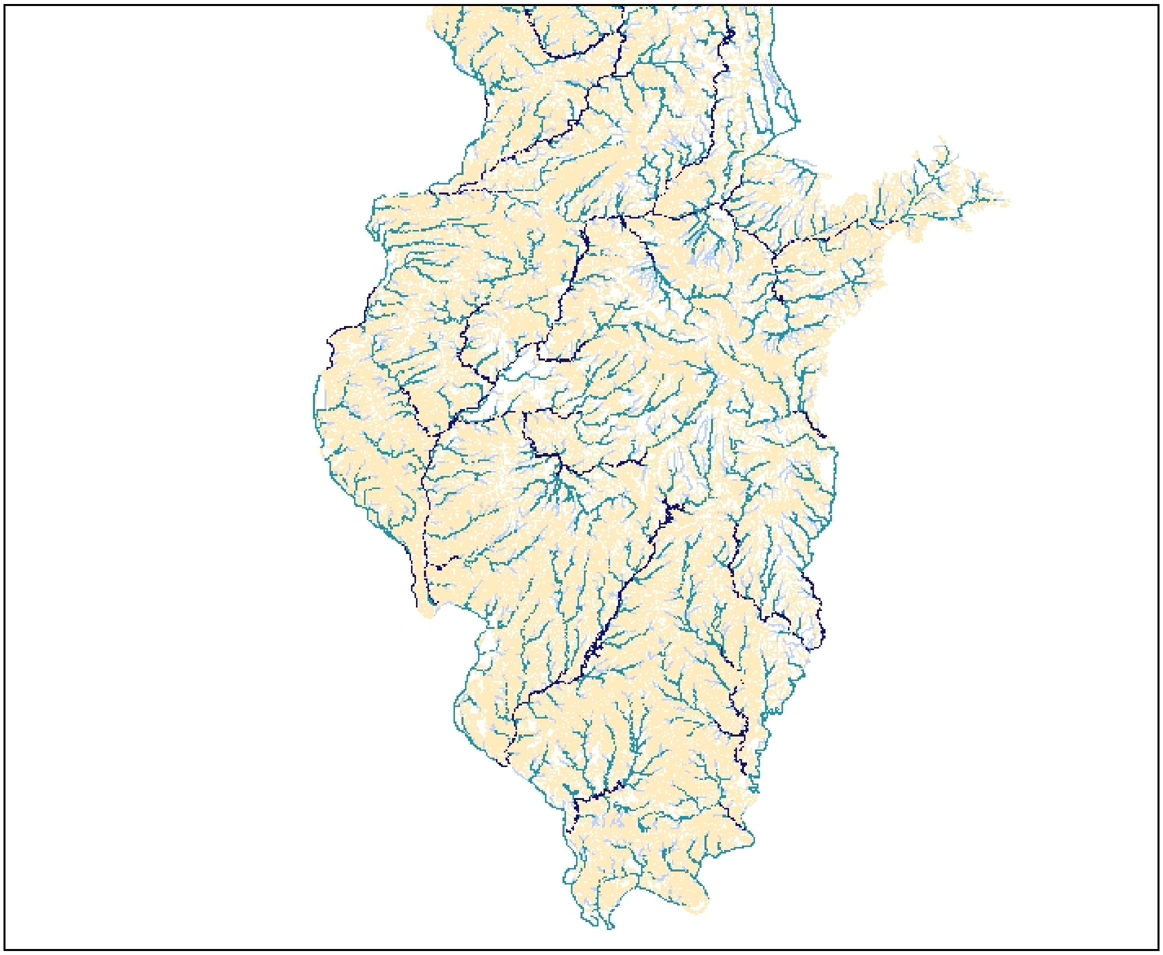

Figure 4.1. Size classification based on INAI Framework developed using association between drainage area and stream width. Very small streams (<10 ft, 0-37 km^2) are tan, small streams (10-20 ft, 38-80 km^2) are light blue, medium streams (21-100 ft, 81-2150 km^2) are green, and large streams (>100 ft, > 2150 km^2) are dark blue. [Note: Major Rivers (i.e., Mississippi, Ohio, Wabash) are not fully classified on this Figure; some portions of Indiana are included where they connect with Illinois' waters.]

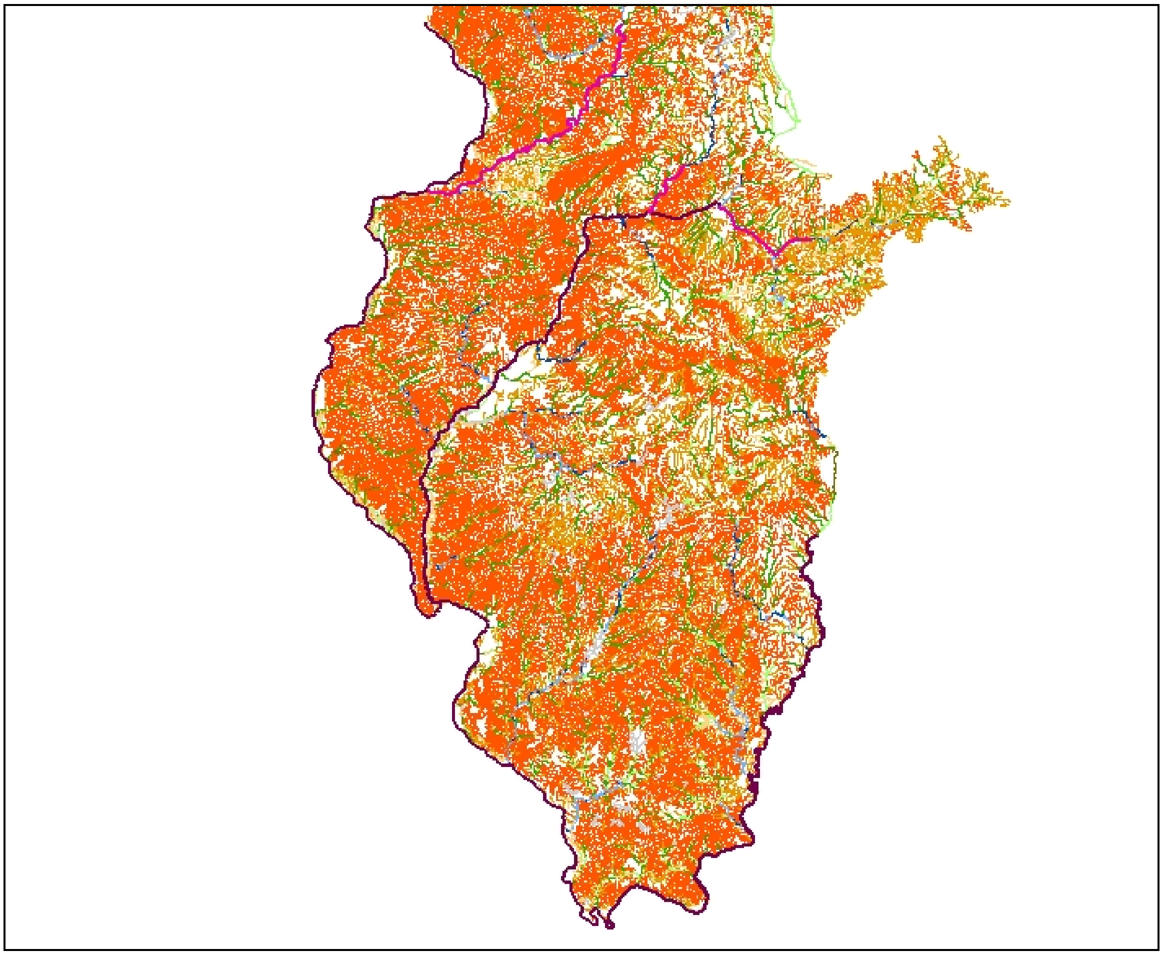

Figure 4.2. Size and Gradient Classification as defined within the current INAI framework. Colors represent different combinations of size and gradient.

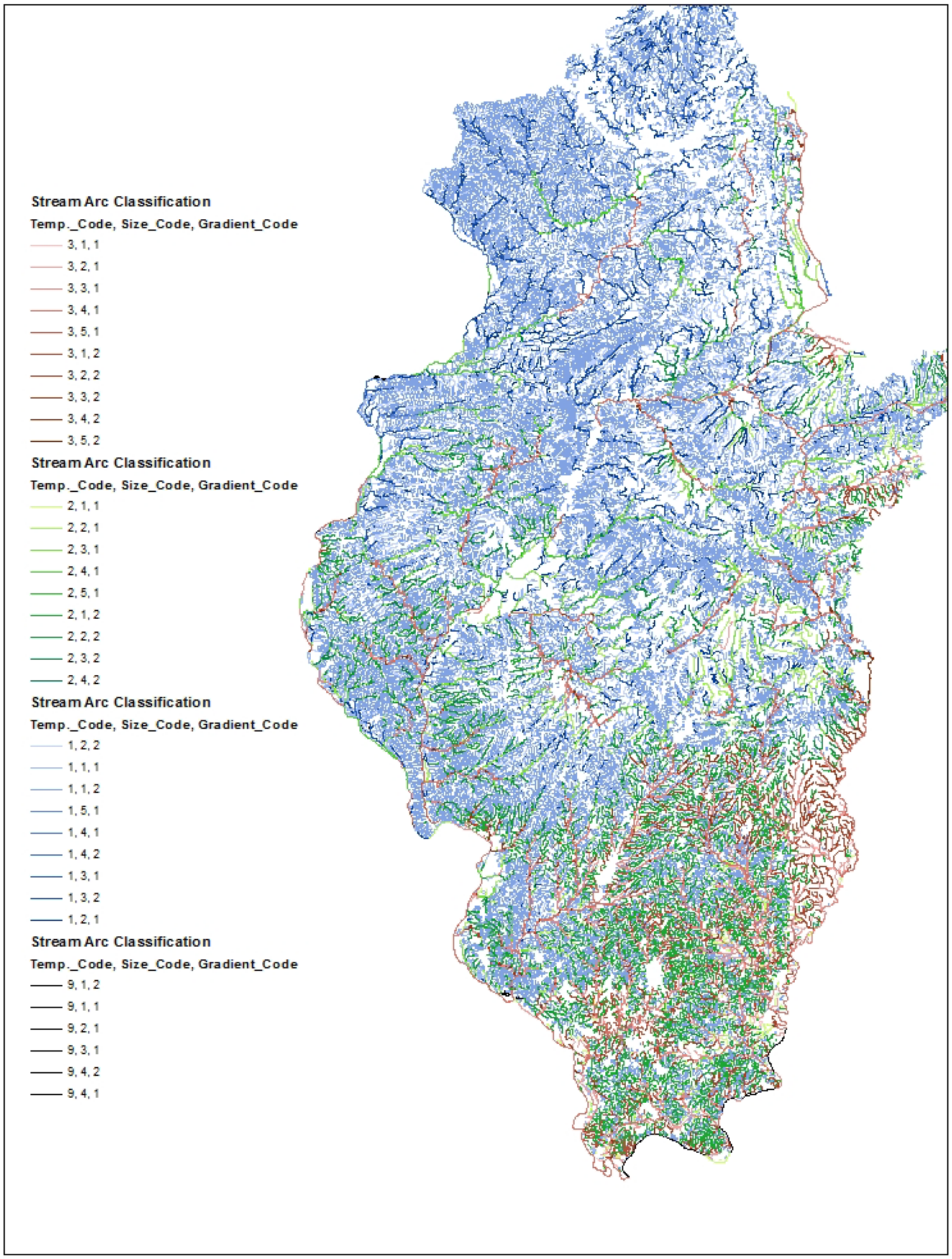

Figure 4.3. Draft Classification of stream reaches based on temperature, size, and gradient. This is essentially the existing INAI classification with a thermal attribute added.

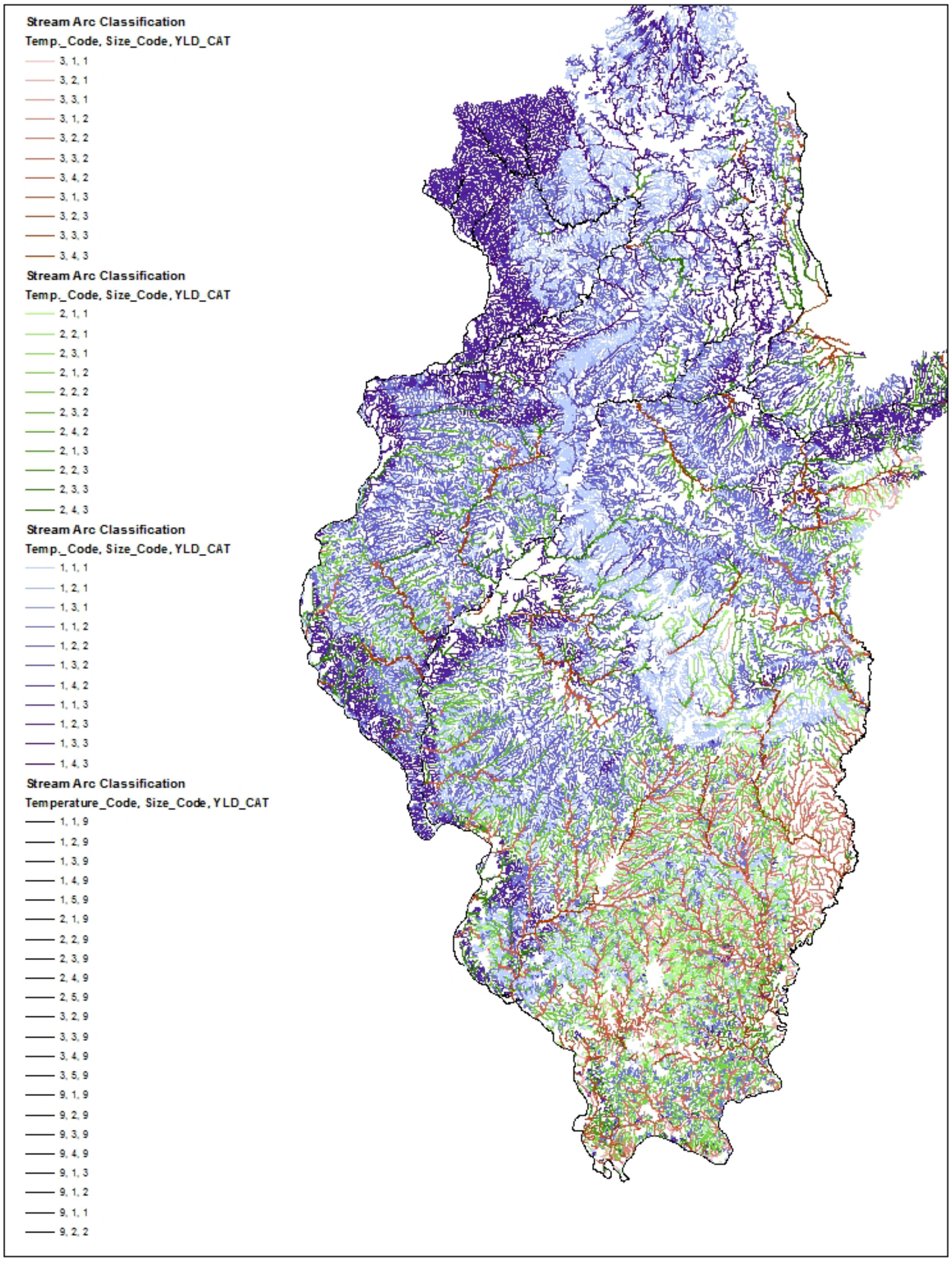

Figure 4.4. Stream classification based on summer temperature, stream size, and water yield.

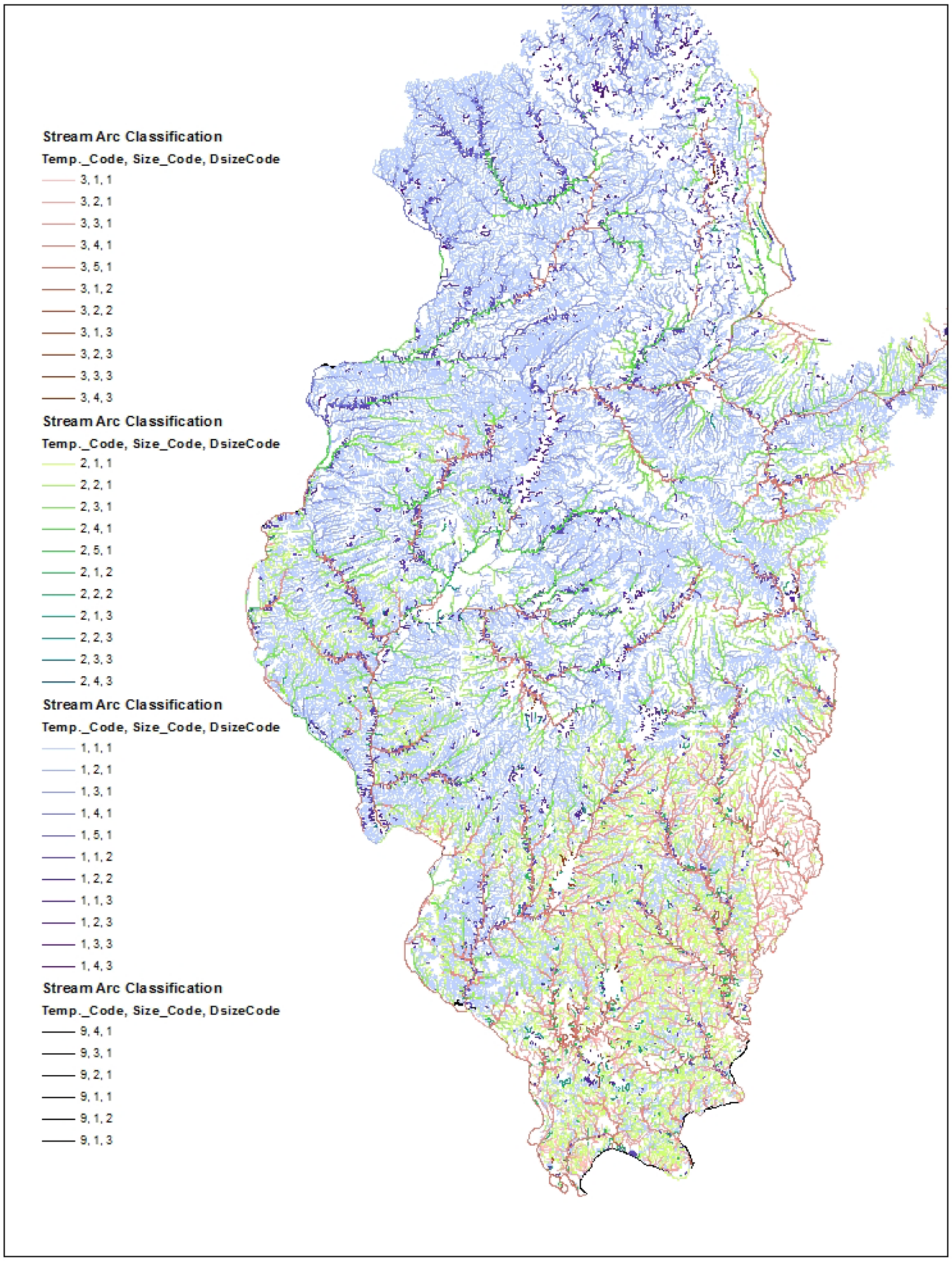

Figure 4.5. Stream classification based on temperature, stream size, and size of downstream segment.

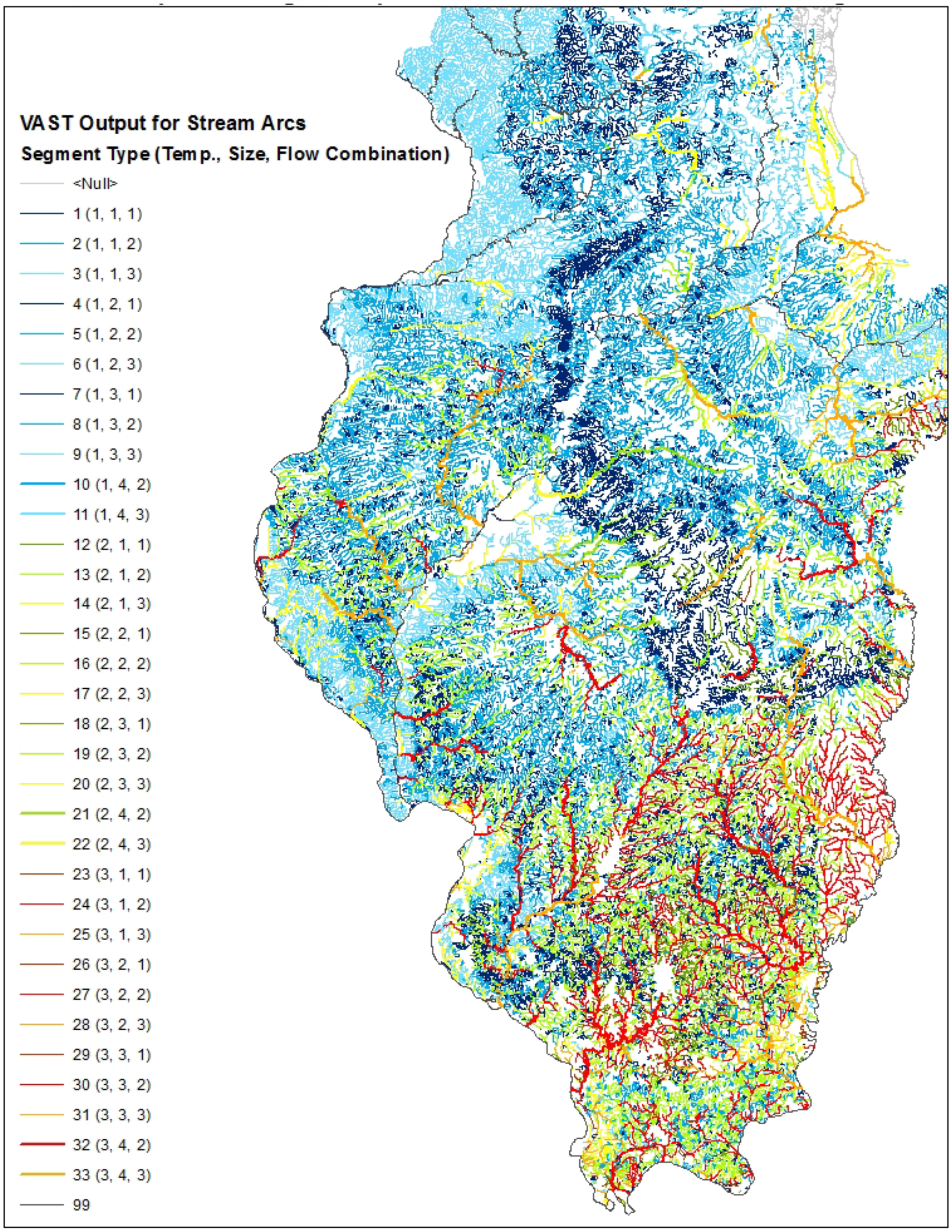

Figure 4.6. Valley Segment Types (VST) based on characteristics of mean daily summer temperature, stream size, and low flow yield developed using the valley affinity search technique (VAST, Brendon et al. 2008). Temperature, Size, and Flow characteristics are described in Table 1.

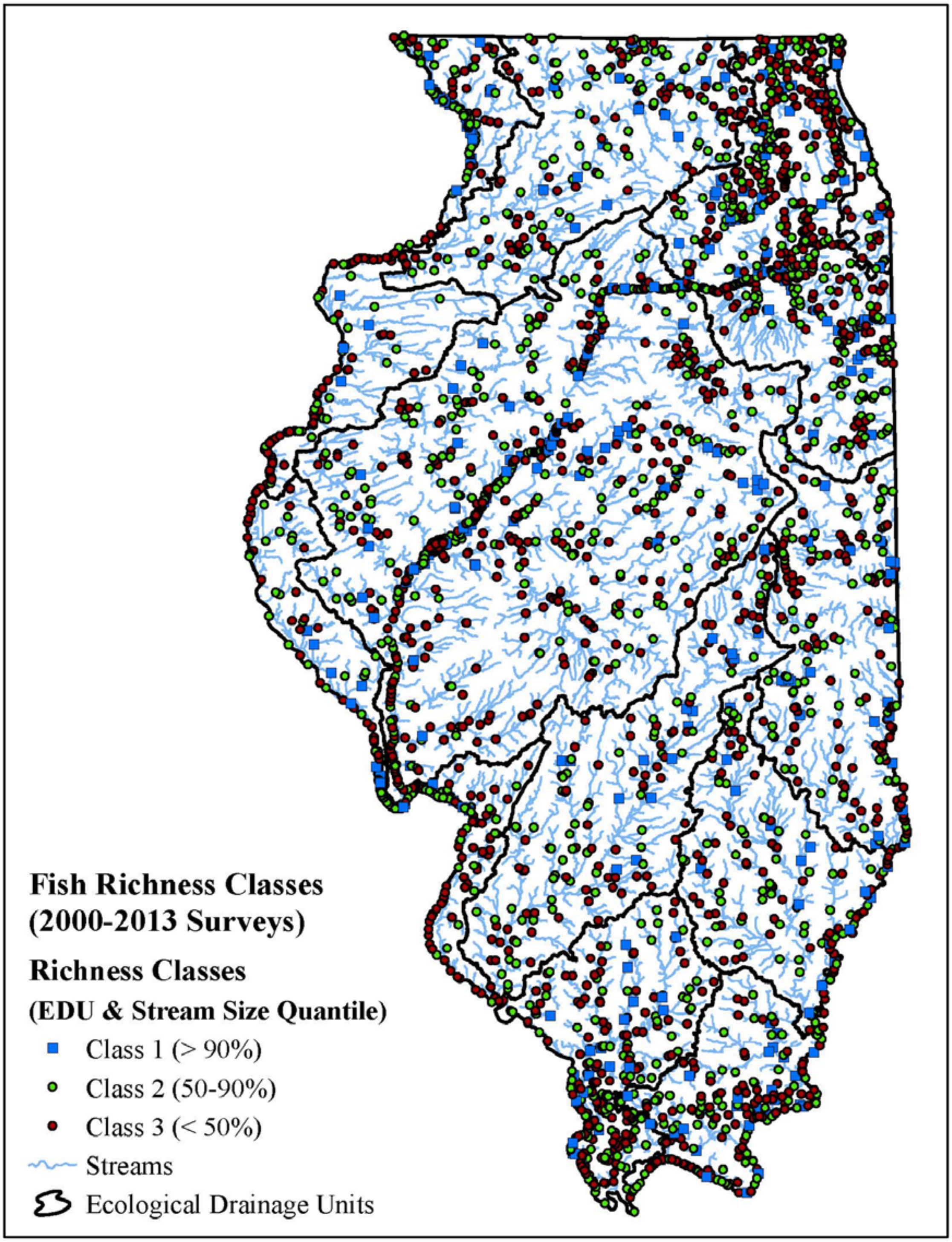

Figure 5.1. Fish Richness Classes standardized by EDU and stream size. Class 1 reaches include locations with fish richness greater than 90% of all sampled reaches for the stream size class within the EDU. Class 2 contains reaches with fish richness equal to or greater than 50% and less than 90% of all sampled reaches for the stream size class within the EDU. Class 3 contains reaches with fish richness less than 50% of all sampled reaches for the stream size class within the EDU.

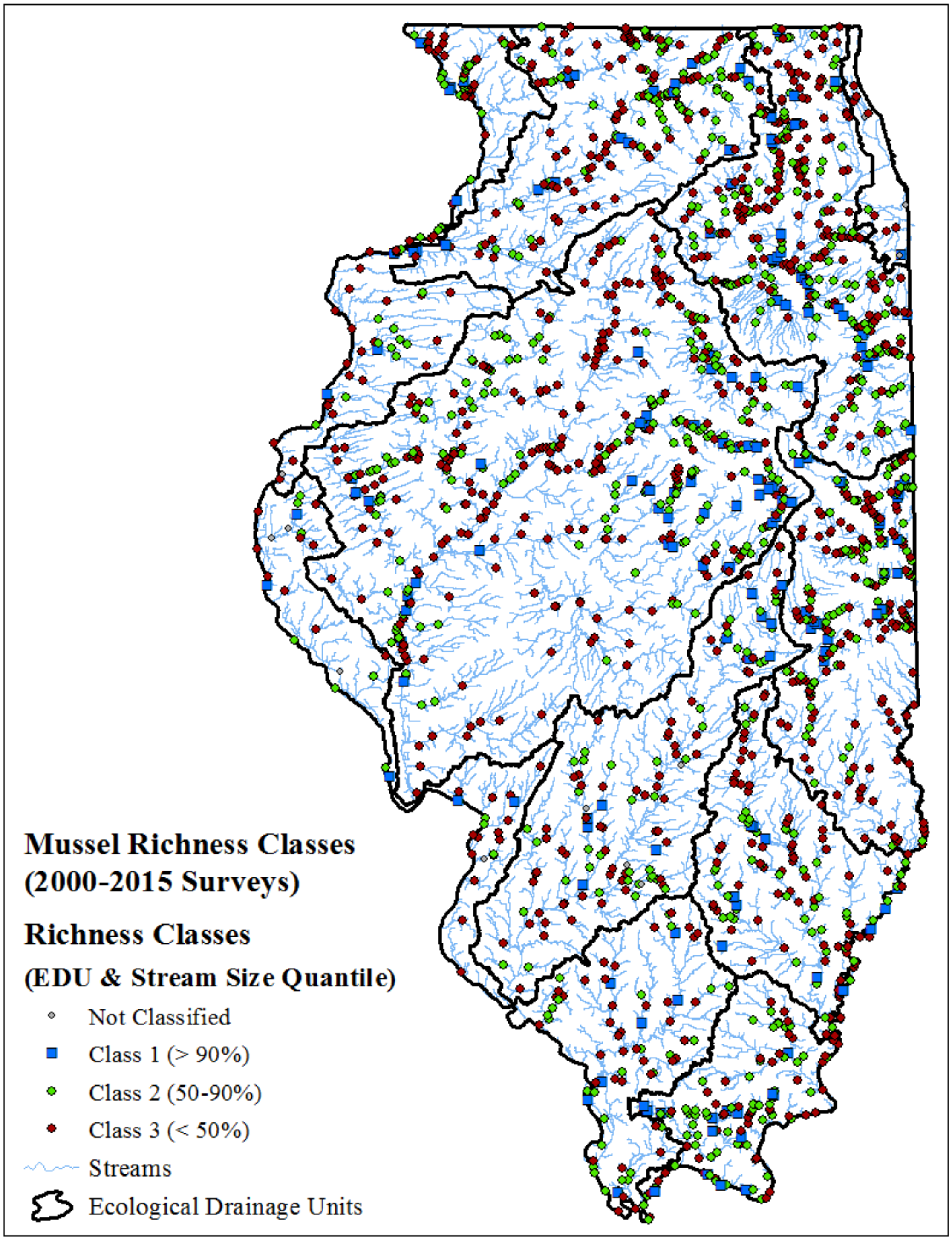

Figure 5.2. Mussel Richness Classes standardized by EDU and stream size. Class 1 reaches include locations with mussel richness greater than 90% of all sampled reaches for the stream size class within the EDU. Class 2 contains reaches with mussel richness equal to or greater than 50% and less than 90% of all sampled reaches for the stream size class within the EDU. Class 3 contains reaches with mussel richness less than 50% of all sampled reaches for the stream size class within the EDU.

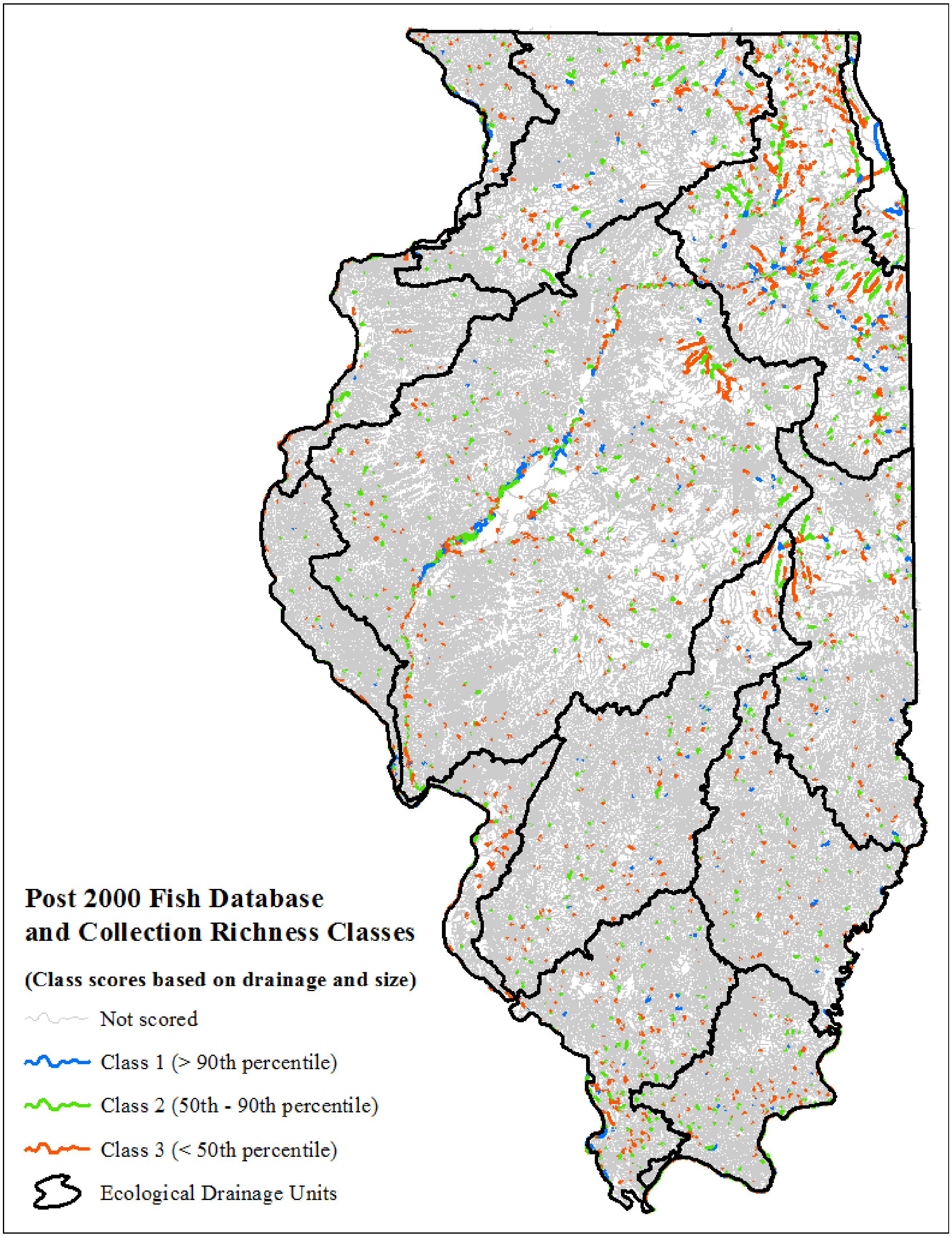

Figure 5.3. Native Fish Species Richness as a percentile of all sampled reaches within each EDU. Reaches with the highest richness values might qualify as the INAI Category VI criteria for "Unusual concentration of flora or fauna". This analysis was based on all community samples collected during the period 2000-2014.

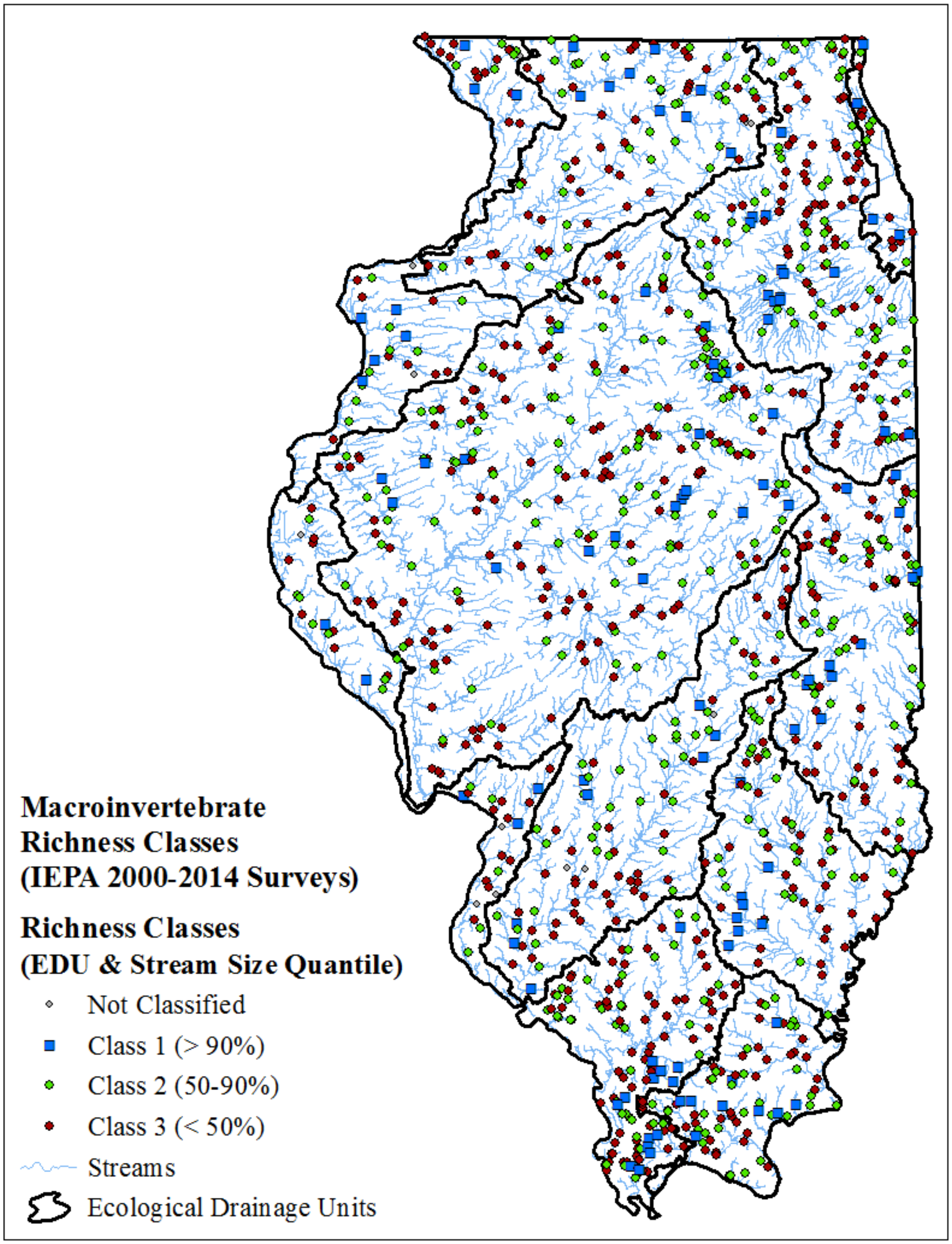

Figure 5.4. Aquatic Macroinvertebrate Richness Classes standardized by EDU and stream size. Class 1 reaches include locations with richness greater than 90% of all sampled reaches for the stream size class within the EDU. Class 2 contains reaches with richness equal to or greater than 50% and less than 90% of all sampled reaches for the stream size class within the EDU. Class 3 contains reaches with richness less than 50% of all sampled reaches for the stream size class within the EDU.

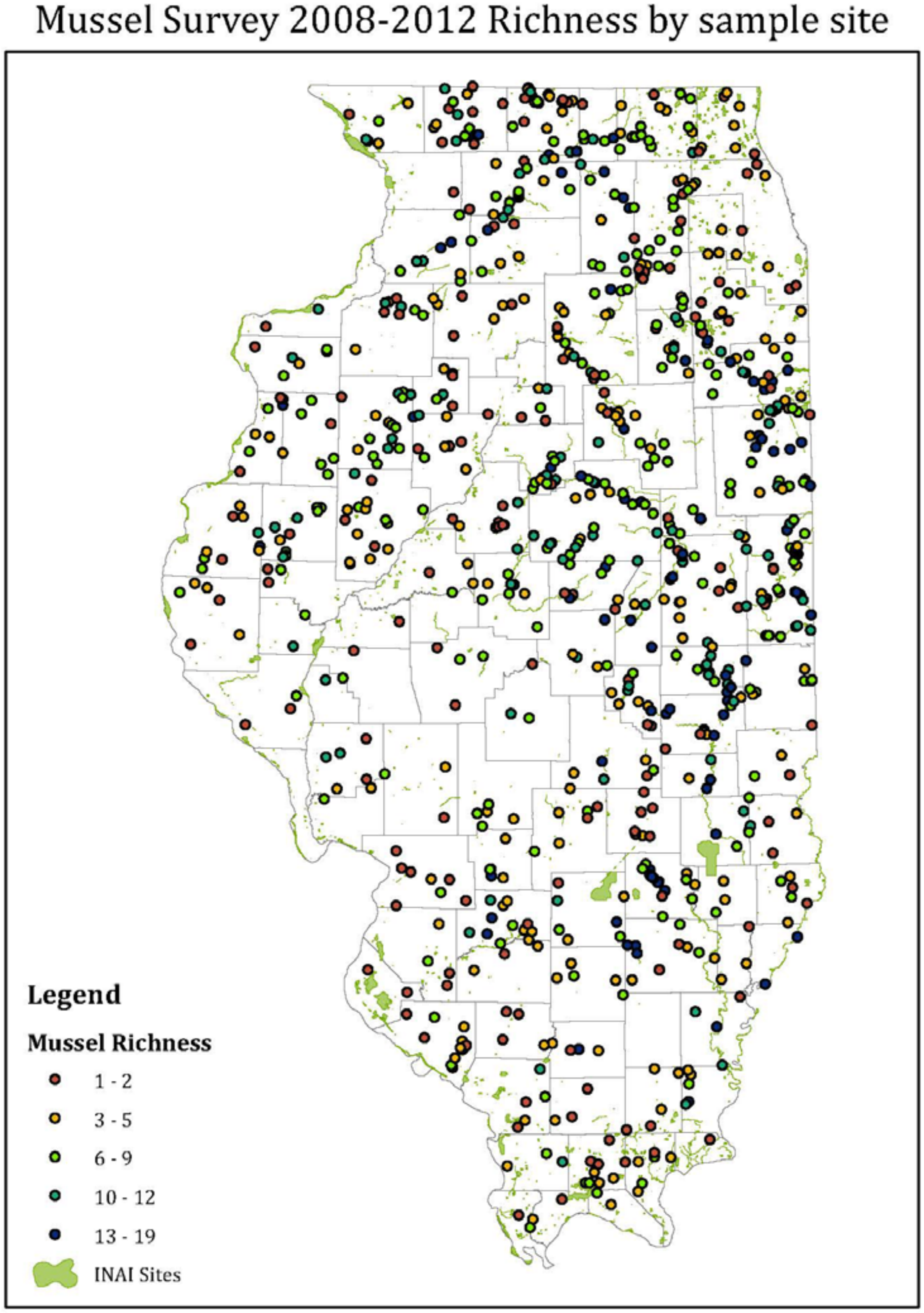

Figure 6.1. Mussel species richness. Sites with ten or more mussel species qualify at Category VI under current INAI assessment criteria.

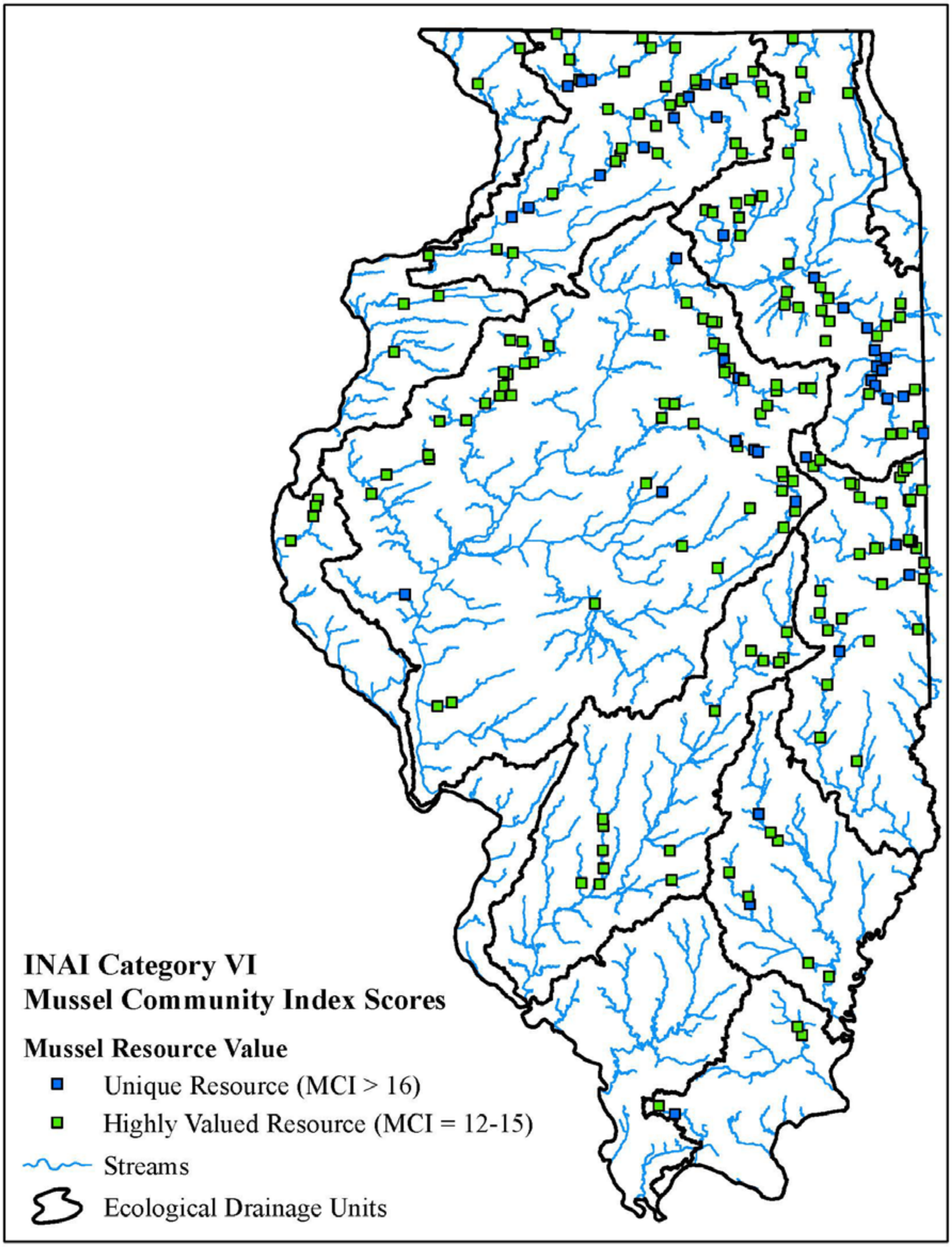

Figure 6.2. Reaches identified with Mussel Classification Index Scores that would qualify as the INAI Category VI criteria for "Unusual concentration of flora or fauna" under existing criteria. This analysis was based on all community samples collected during the period 2000-2014.

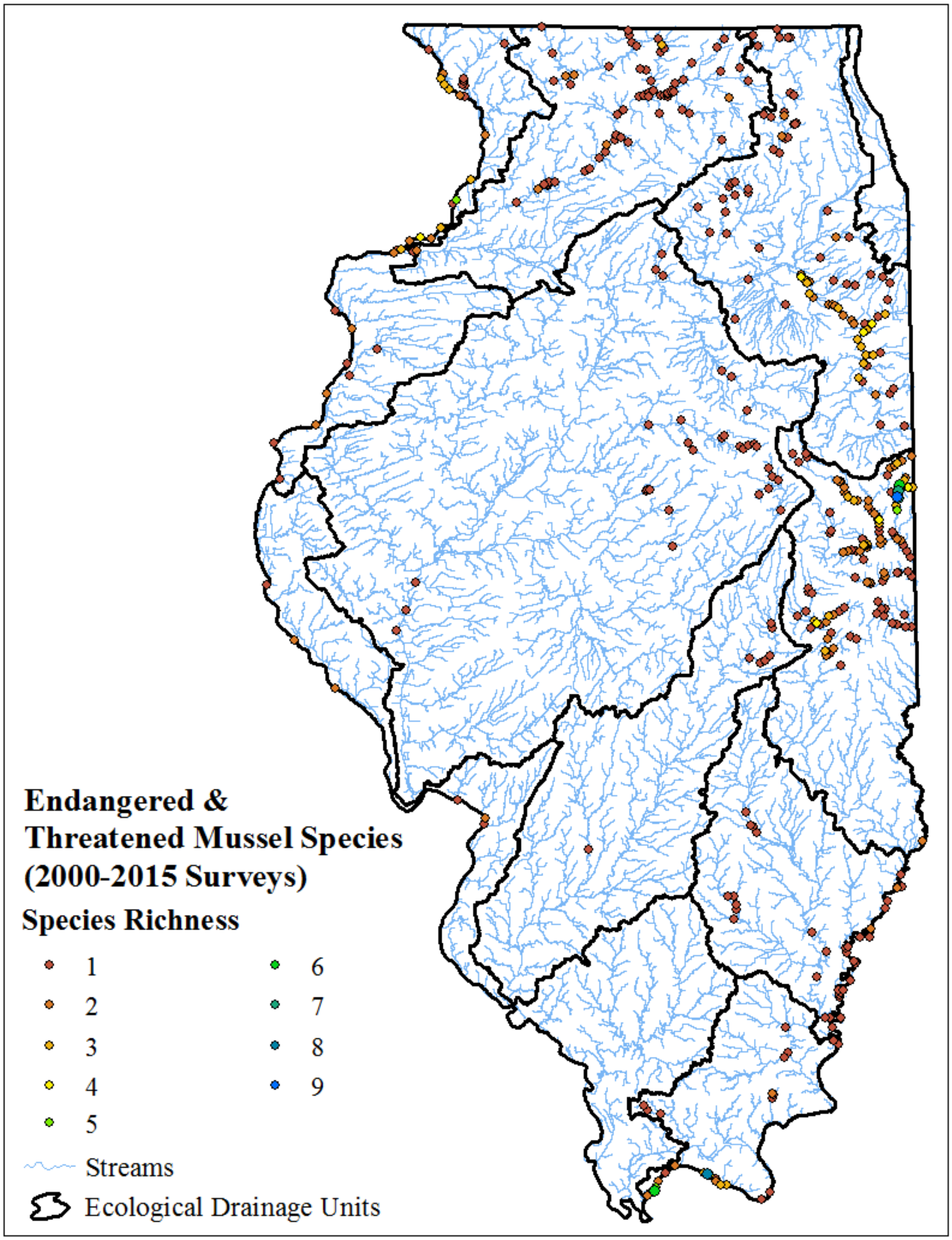

Figure 6.3. Locations of stations with Illinois endangered or threatened mussel species based on recent statewide mussel community sampling.

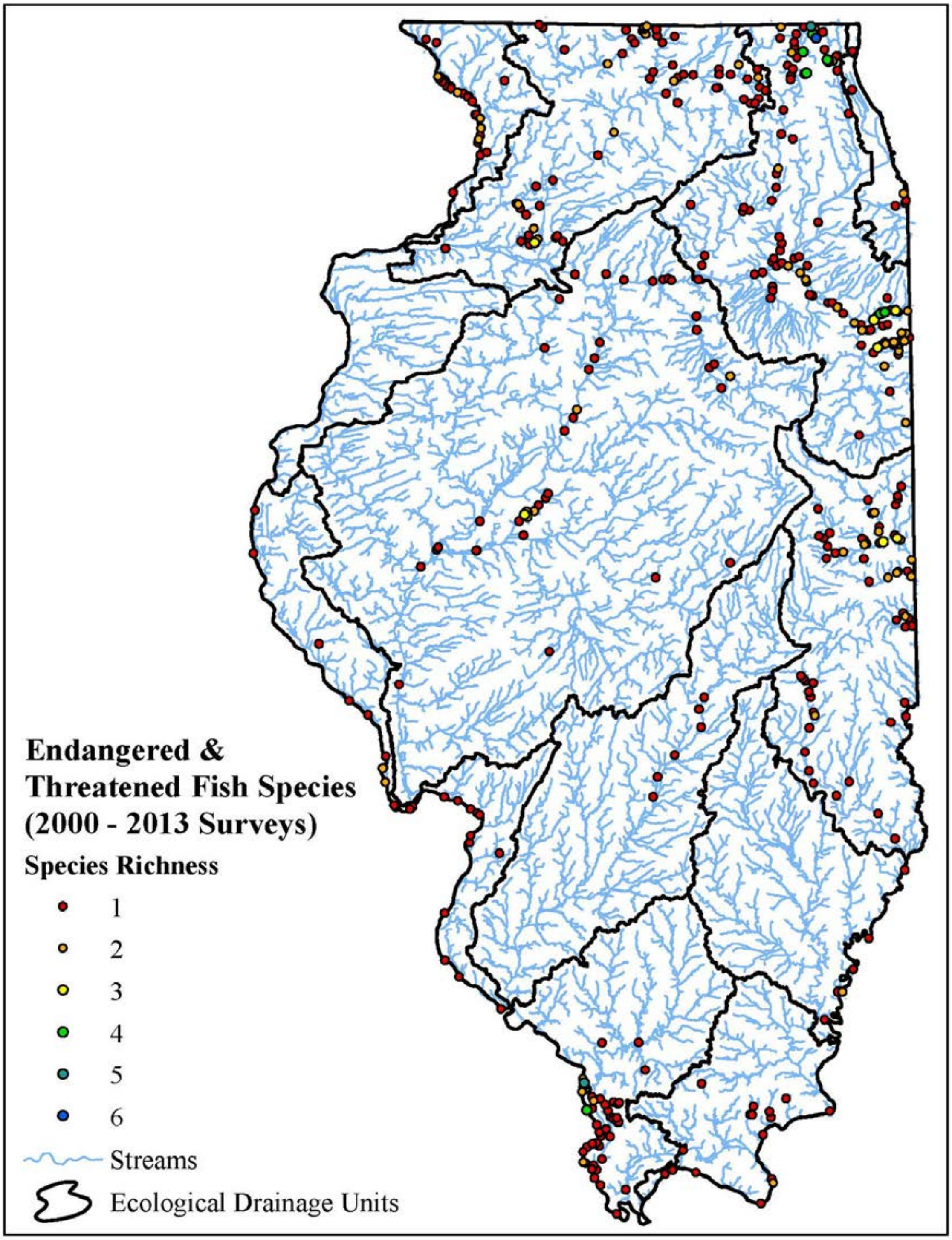

Figure 6.4. Locations of Illinois Endangered & Threatened Fish Species based on recent records (2000-2013 survey records).

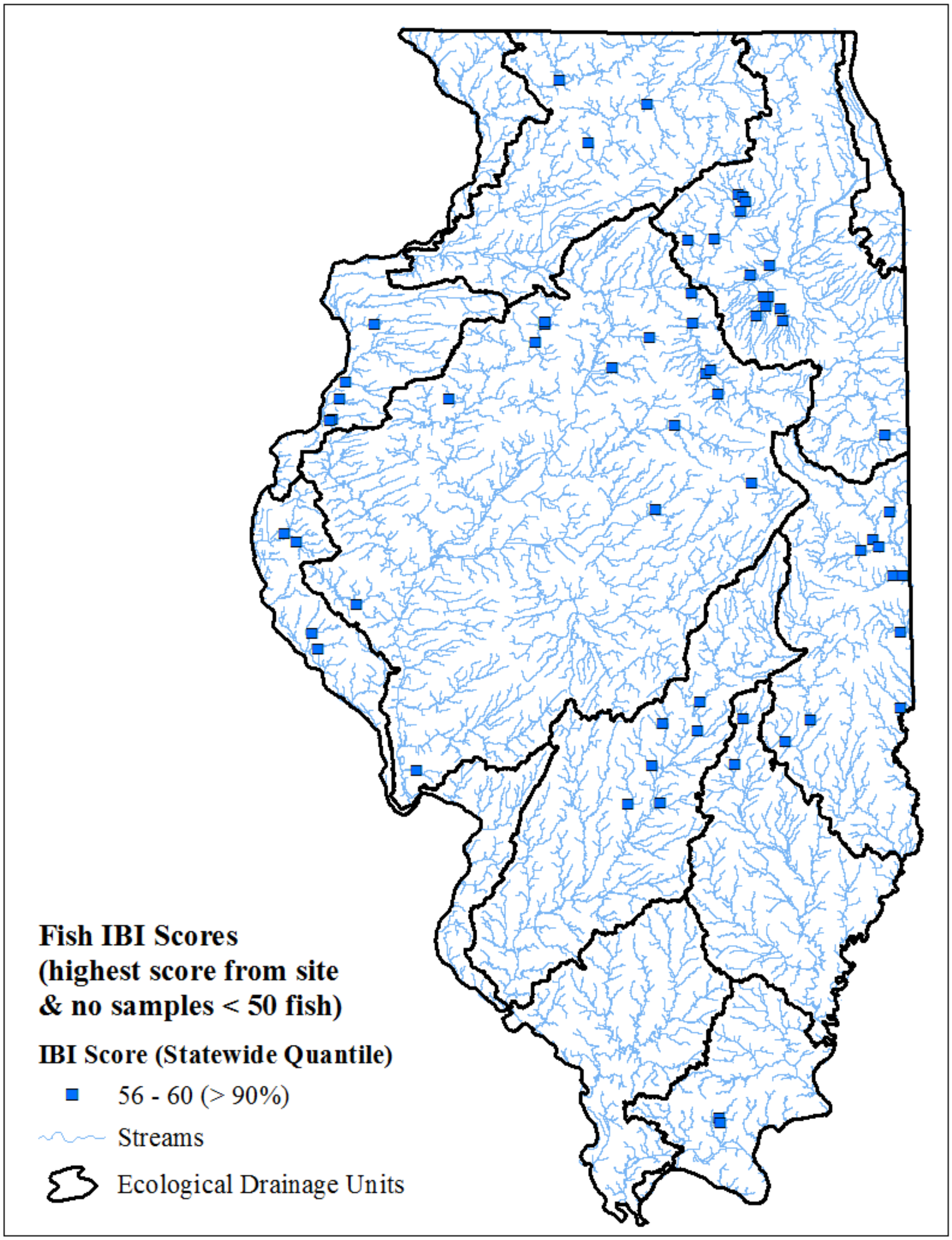

Figure 6.5. Locations of stations with Fish Index of Biotic Integrity scores that meet or exceed the INAI Category VI criteria for "Unusual concentration of flora or fauna" based on all IDNR fish samples collected during the period 2000-2012. Sites with IBI scores >55 qualify at Category VI under current INAI assessment criteria.

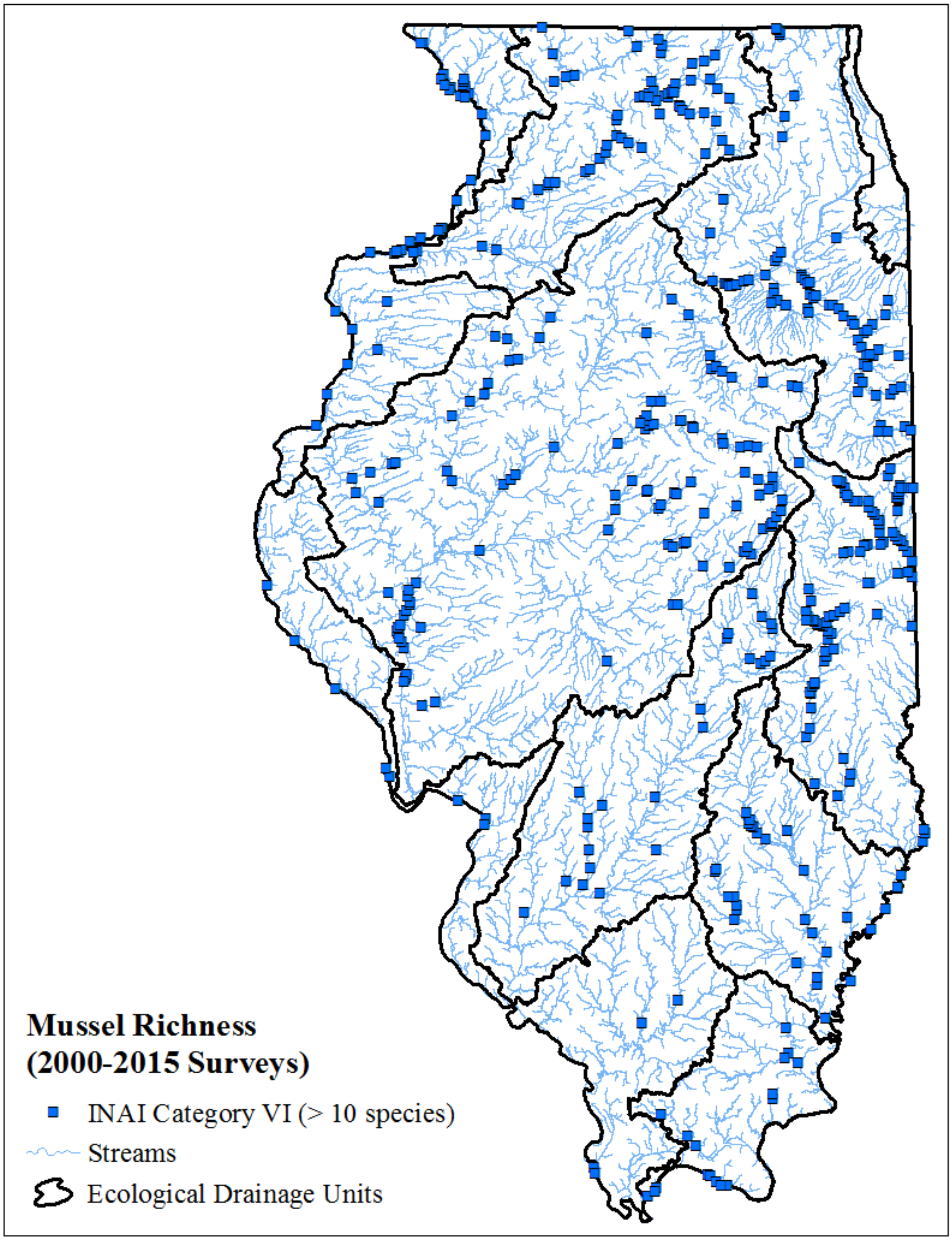

Figure 6.6. Locations of stations with mussel species richness that meet or exceed the existing INAI Category VI criteria ("unusual concentrations of flora or fauna"). Richness values based on recent statewide community mussel sampling.

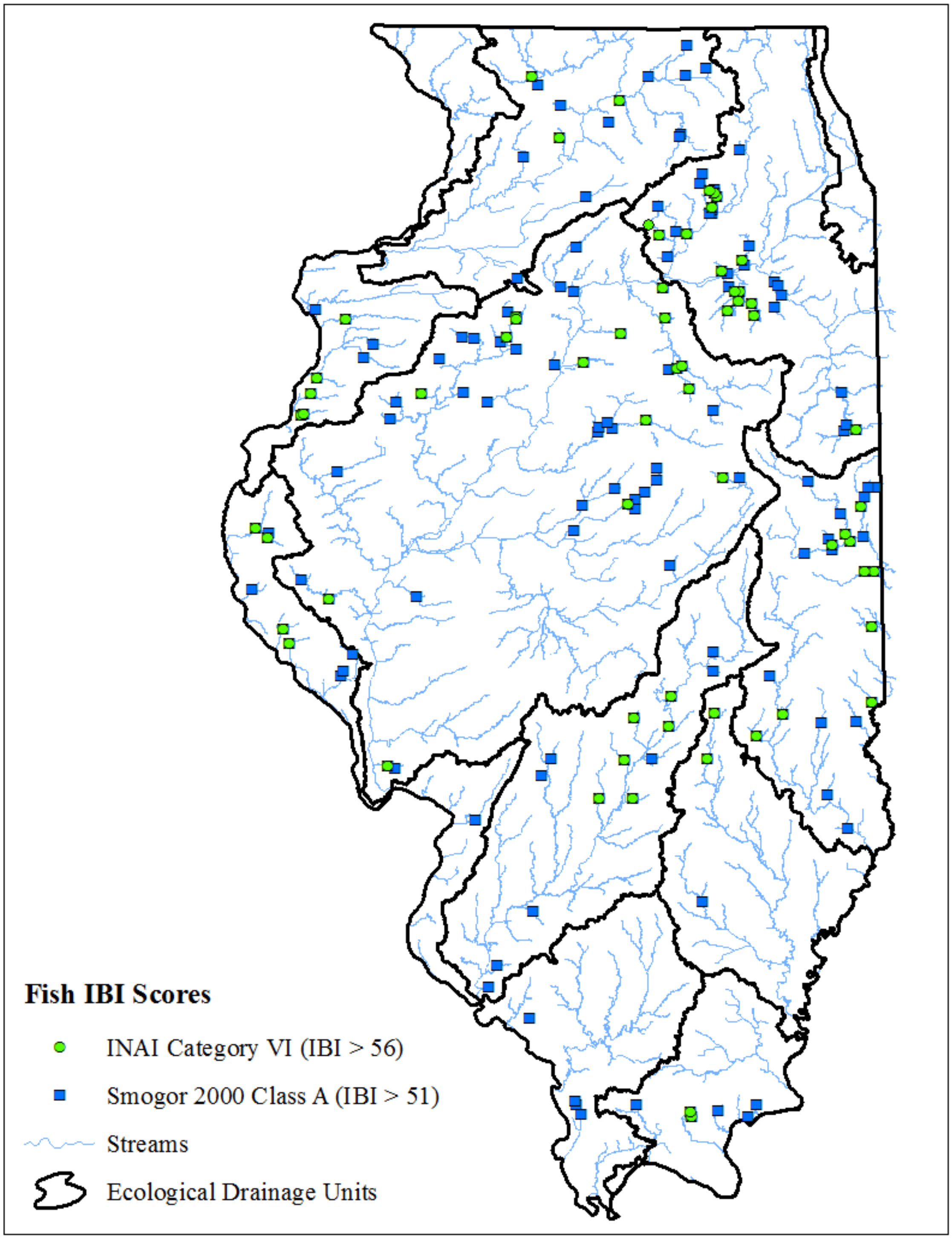

Figure 6.7. Recent stream survey record locations with Fish IBI scores in the "exceptional" class (IBI>51) and those with the current INAI Category VI criteria based on the older fish IBI that had different scoring scale (2000-2013 survey records).

Appendix I

Examples of Differences from original Illinois Digital Stream Network

Figure AI.1. Original digital stream network developed for Illinois Streams in 2005 based on NHD 1:100,000 linework (red) and 2014 stream network developed with staff from T-60-D-1 (blue). The 2014 stream network also expands the coverage to include portions of the Middle Wabash River EDU that drain into Illinois.

Figure AI.2. Original digital stream network developed for Illinois Streams in 2005 based on NHD 1:100,000 linework (red) and 2014 stream network developed with staff from T-60-D-1 (blue) for a portion of the Wabash River EDU showing detail of additional stream lines in the 2014 stream network.

Figure AI.3. Aqueduct. We defined Aqueducts as portions of the digital stream network that flow over other stream segments in man-made structures.

Figure AI.4. Culvert. We defined culverts as portions of the digital stream network that flow through levees.

Figure AI.5. Flow Split. We defined flow splits as portions of the digital stream network where water from a single channel flows into two separate channels.

Figure AI.6. Sinks. We defined sinks as points, or polygons, with drainages that are disconnected from any portion of the stream network that eventually flows out of the EDU.

Figure AI.7. Siphon. We defined siphons as portions of the digital stream network that cross under other stream segments through a pipe.

Figure AI.8. Strip mines. Surface mining and associated post-mining restoration activities form complicated and often novel landscapes, which may not reflect previous conditions.

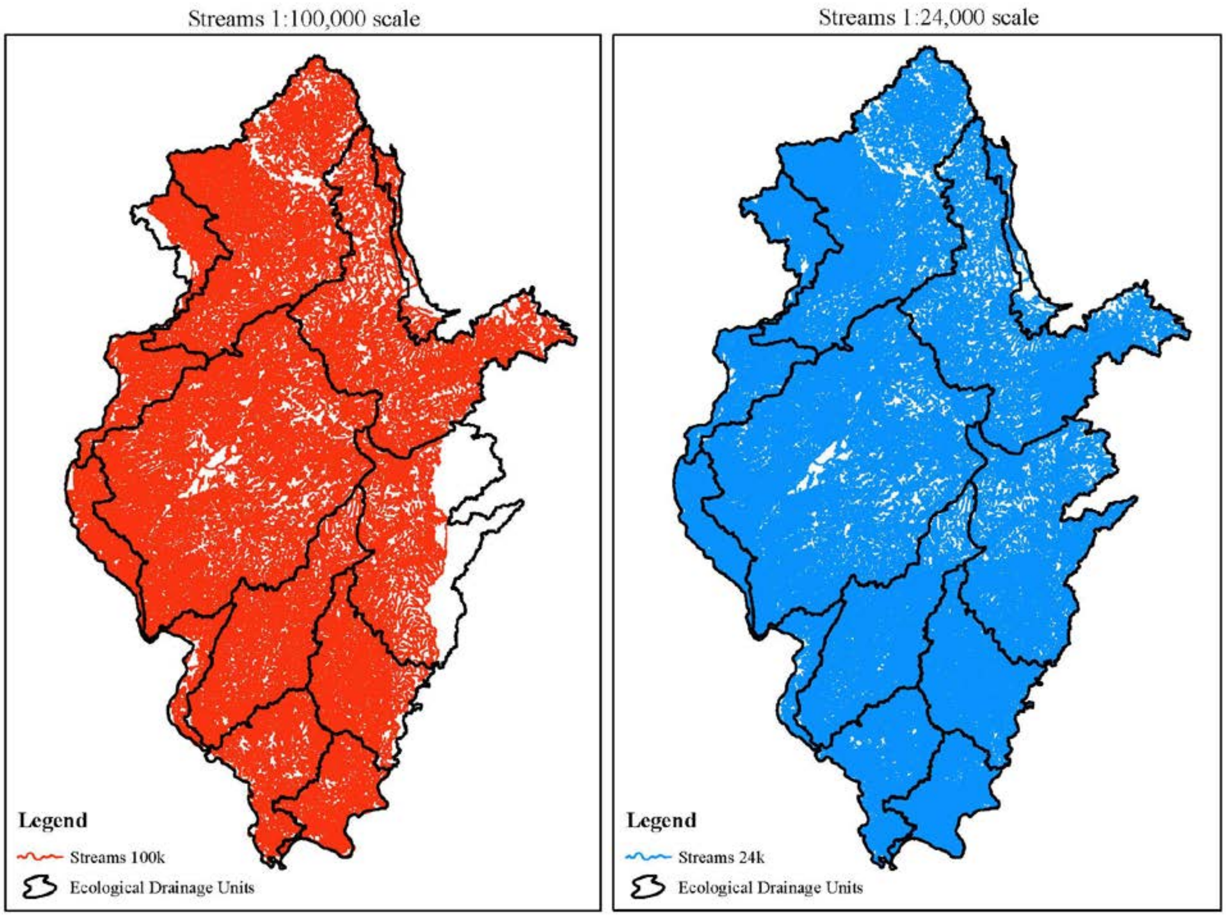

Figure AI.1. Original digital stream network developed for Illinois Streams in 2005 based on NHD 1:100,000 linework (red) and 2014 stream network developed with staff from T-60-D-1 (blue). The 2014 stream network also expands the coverage to include portions of the Middle Wabash River EDU that drain into Illinois.

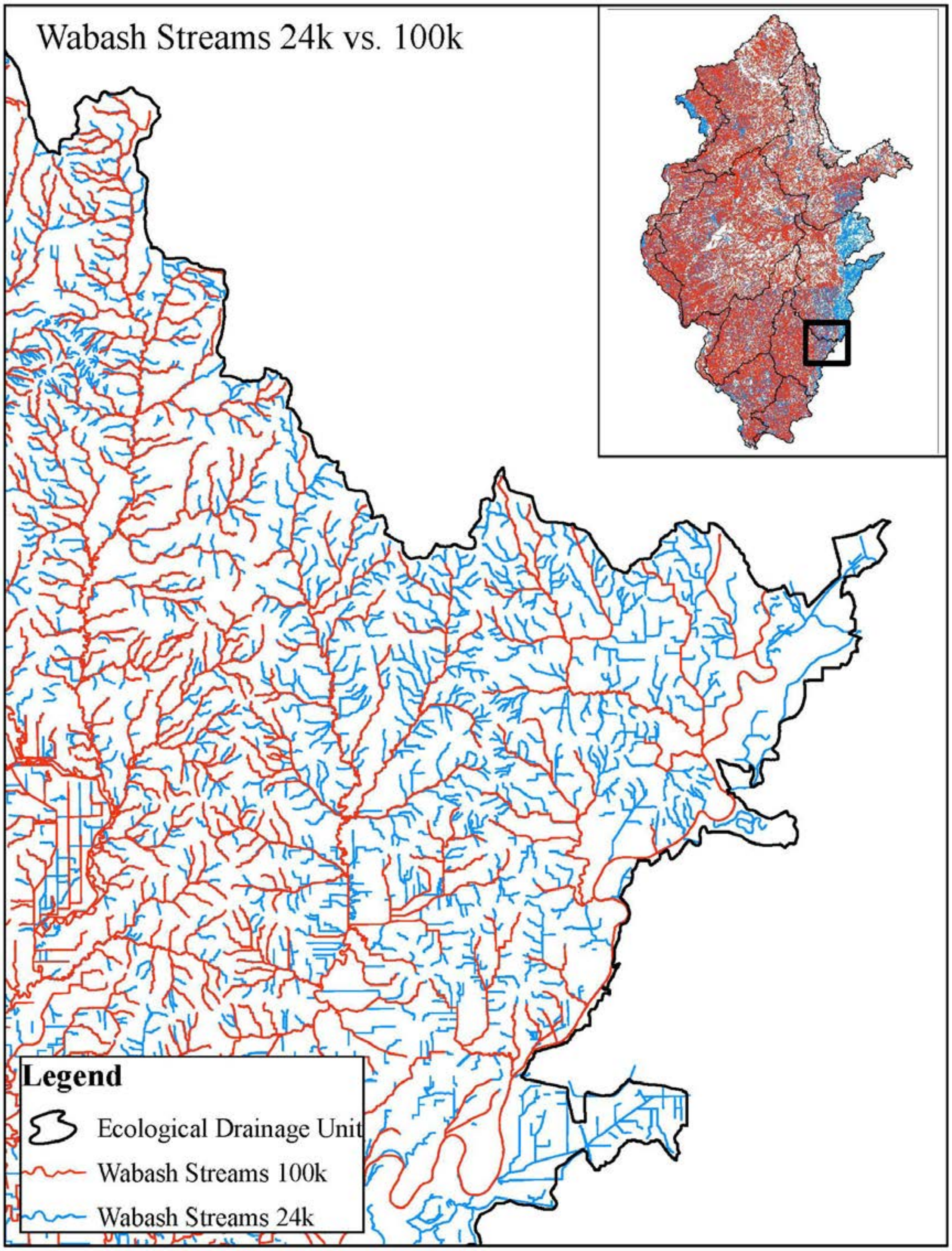

Figure AI.2. Original digital stream network developed for Illinois Streams in 2005 based on NHD 1:100,000 linework (red) and 2014 stream network developed with staff from T-60-D-1 (blue) for a portion of the Wabash River EDU showing detail of additional stream lines in the 2014 stream network.

Figure AI.3. Aqueduct. We defined Aqueducts as portions of the digital stream network that flow over other stream segments in man-made structures. The 2005 stream network (red lines) merged the streams at their apparent confluence. However, there is no confluence on the landscape. Instead, the canal flows over the stream in an aqueduct (yellow line) while the other channel continues uninterrupted as reflected in the 2014 stream network (blue lines).

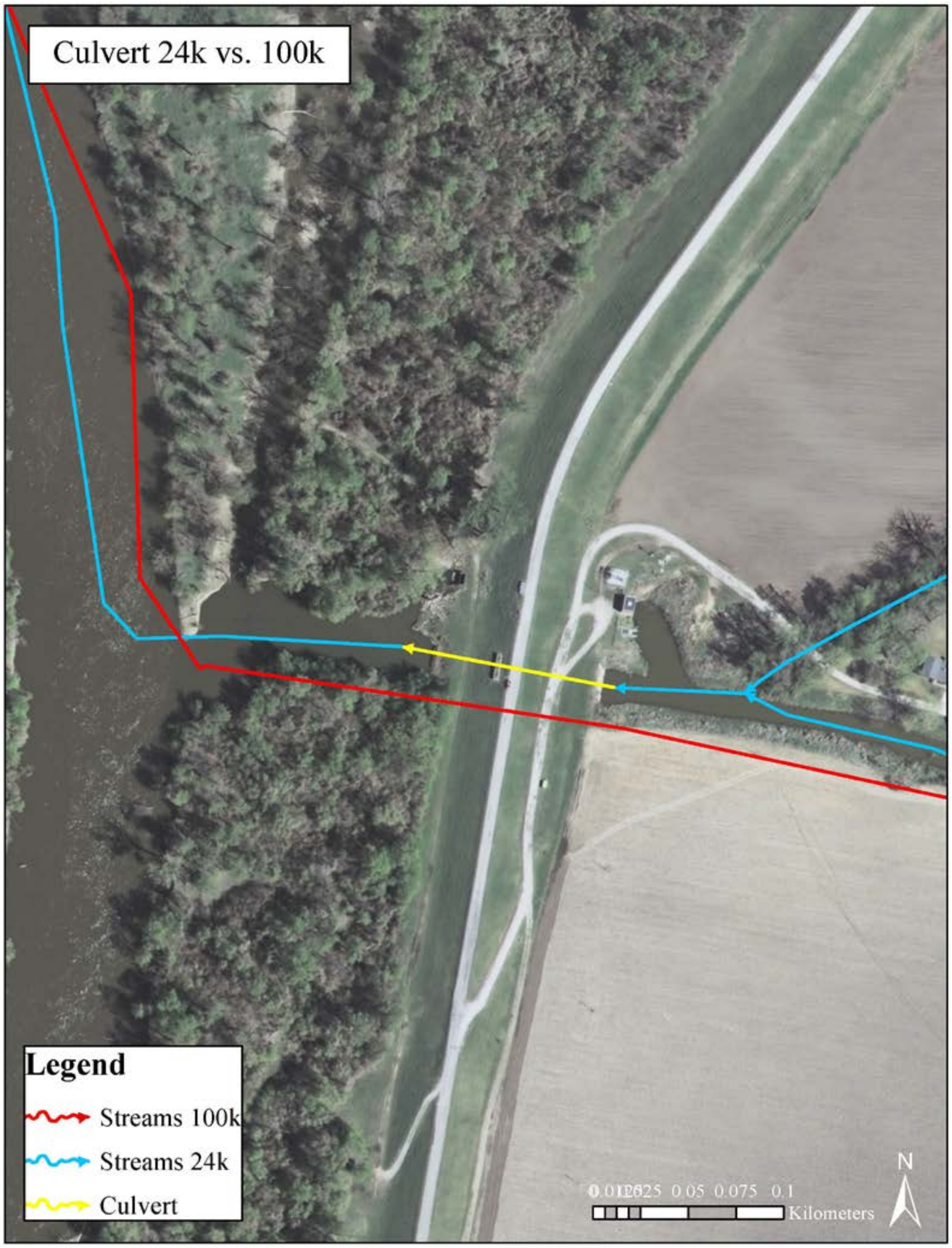

Figure AI.4. Culvert. We defined culverts as portions of the digital stream network that flow through levees. In cases where the stream network crossed over levees water would need to flow uphill based on the digital elevation map (DEM). What we observe on the ground is water flowing under the levee through a culvert. The 2005 stream network (red lines) essentially ignored these inconsistencies with the DEM or removed these connections. The 2014 stream network (blue lines) maintains these connections and allows ArcHydro to function normally in its use of the DEM.

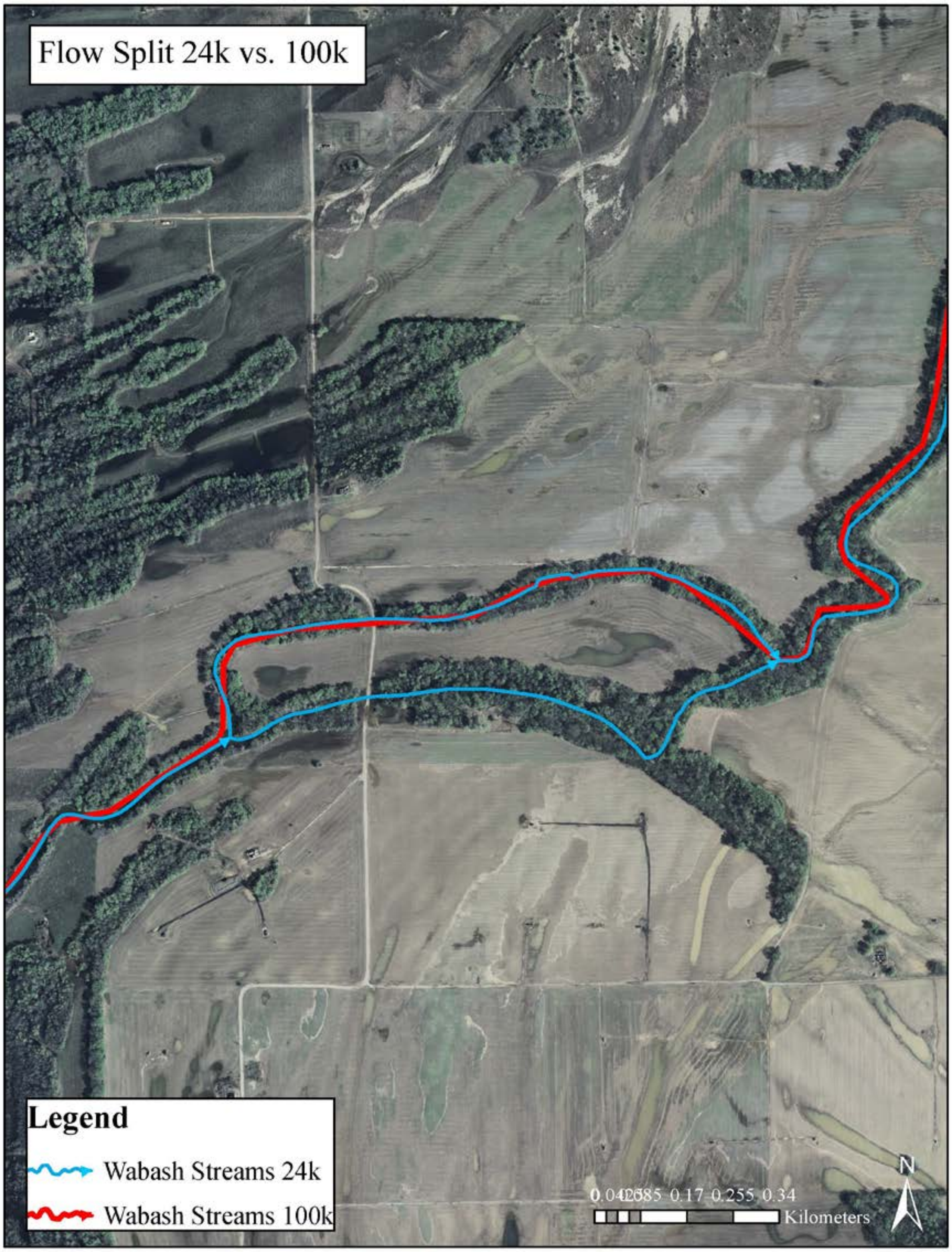

Figure AI.5. Flow Split. We defined flow splits as portions of the digital stream network where water from a single channel flows into two separate channels. The 2005 stream network (red lines) required water to flow along a single path necessitating the removal of some existing stream connections. With the switch to an ArcHydro framework we were able to include these existing connections in the 2014 digital stream network (blue lines).

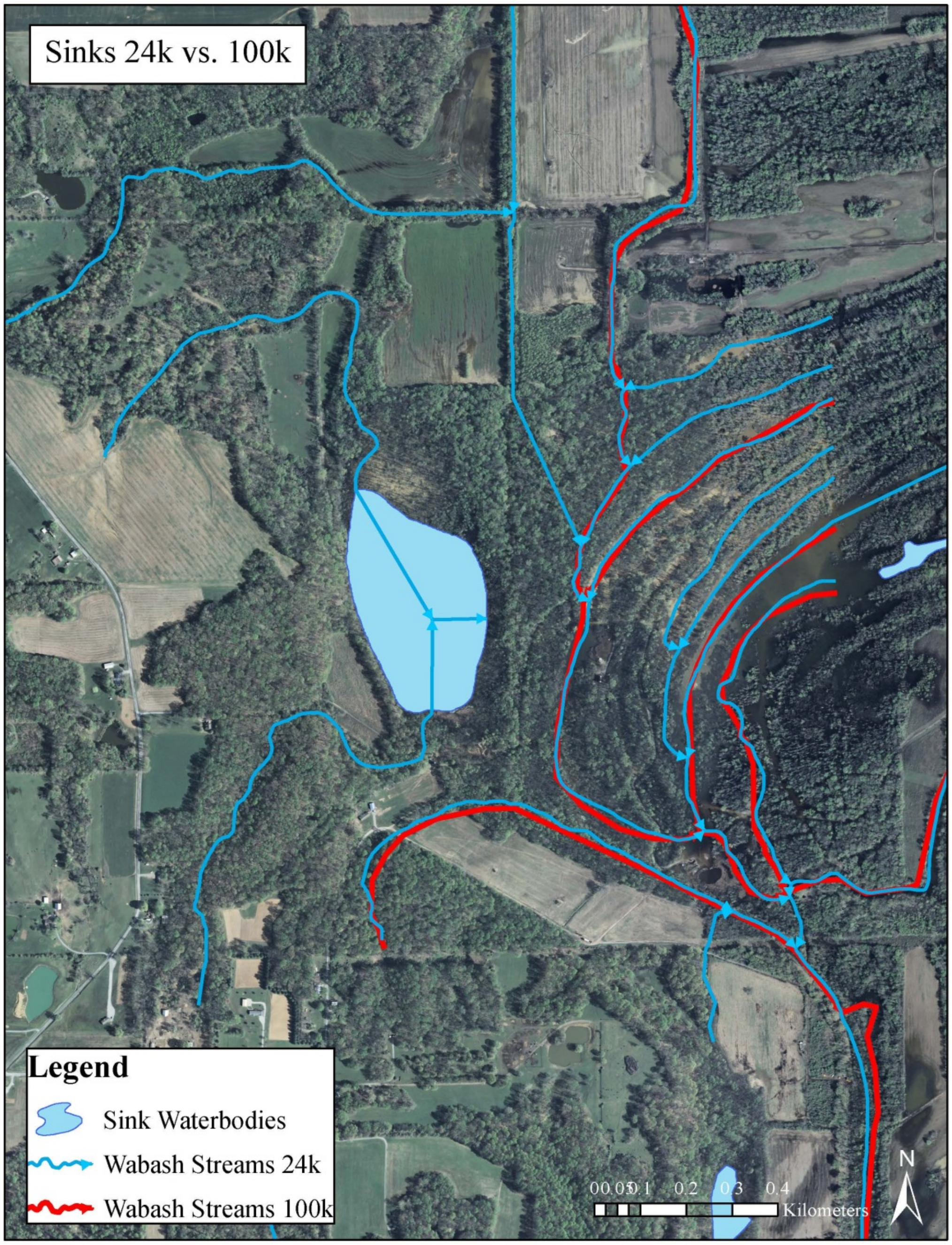

Figure AI.6. Sinks. We defined sinks as points, or polygons, with drainages that are disconnected from any portion of the stream network that eventually flows out of the EDU. These are essentially isolated drainages. The 2005 stream network filled all sinks so that water would contribute directly to the stream network (red lines). The 2014 digital stream network (blue lines) has isolated drainages, such as the sink waterbody shown here, that do not contribute to adjacent drainages.

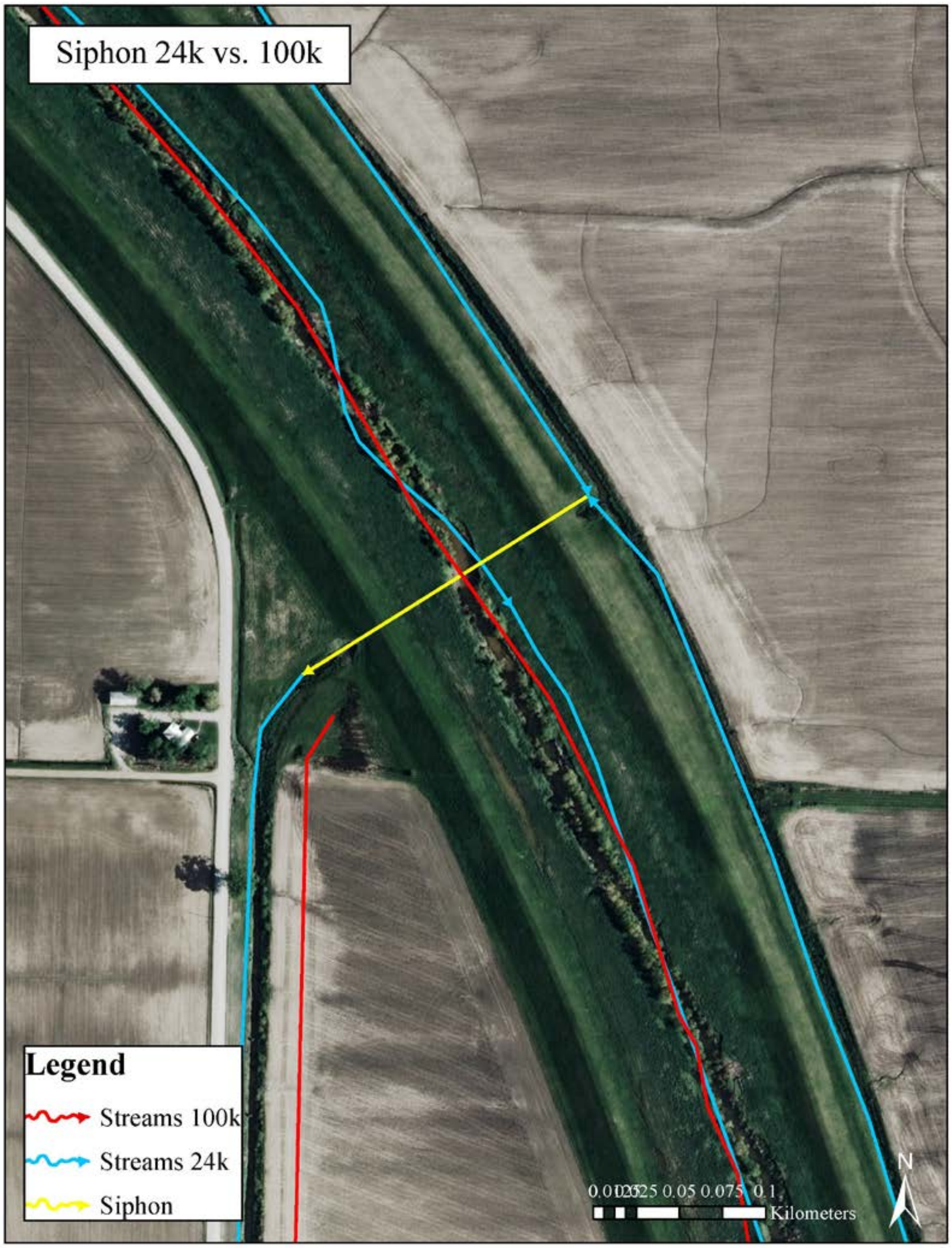

Figure AI.7. Siphon. We defined siphons as portions of the digital stream network that cross under other stream segments through a pipe. The 2005 stream network (red lines) did not contain these types of connections. Although rare, the 2014 revised stream network (blue lines) contains situations such as the one shown here where there is a connection underneath a channel running between two levees.

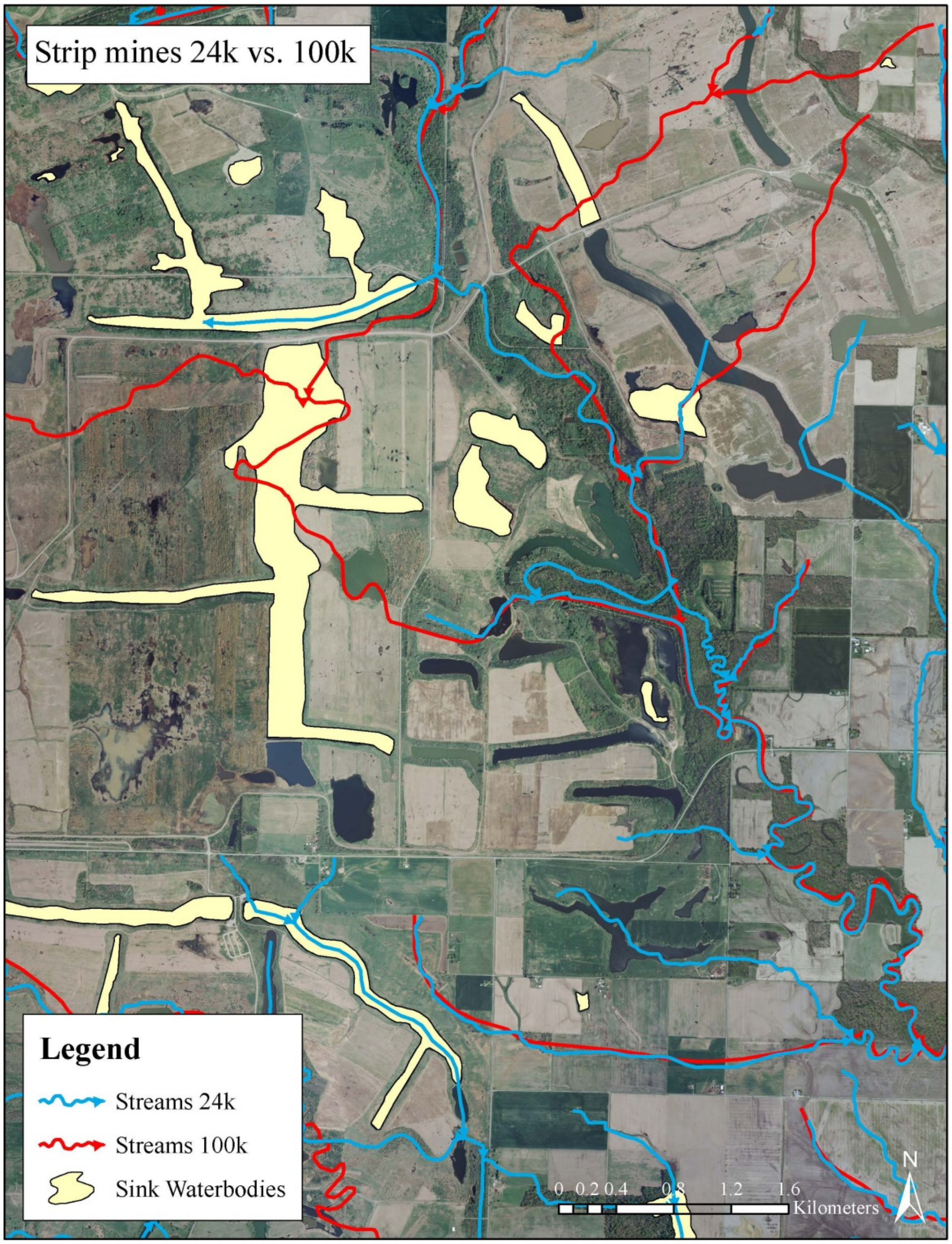

Figure AI.8. Strip mines. Surface mining and associated post-mining restoration activities form complicated and often novel landscapes which may not reflect previous conditions. The 2005 digital stream network (red lines) was based in large part on an interpretation of USGS topographical maps that rarely match the currently existing landscape in areas of Illinois with a history of surface mining. The 2014 revised stream network (blue lines) now better reflects existing drainage including changes in surface flow patterns and the inclusion of many waterbodies that now act as sinks.

Appendix II: Mapping Complications

Development and classification of Aquatic Ecological Systems (AES) was delayed for the refinement of stream network (1:24,000 stream linework, 10m DEM) and development of watershed summaries for streams draining into or within Illinois. While assisting IDNR and ESRI (Holtrop 2015) to refine the stream network and develop watershed summaries, several problems were identified.

Potential problems identified while preparing the higher resolution stream linework included high density stream areas (Figure AII.1), stream lines appearing to cross but not connected (Figures AII.2-3), highly modified areas that no longer resembled topographic maps that the initial linework was based upon (Figure AII.4), and stream lines requiring identification as main or secondary paths at flow splits to summarize watersheds appropriately and avoid looping errors (Figures AII.5-6).

Areas with data gaps were also identified after watersheds were generated using the refined stream linework and higher resolution Digital Elevation Model (DEM). Several large data gaps were observed in areas with sparse surface stream networks (Figure AII.7) in the Great Lakes Ecological Drainage Unit (EDU) and other data gaps where observed where missing DEM information occurred between EDU boundaries (Figure AII.8). Overlapping stream watersheds were also observed in some areas at EDU boundaries, especially in areas with low elevation or at EDU outlets (Figure AII.9).

Watershed accumulation errors were identified by reviewing total watershed summaries generated by the Statewide Stream Assessment processing (Figure AII.10). Accumulation errors occurred when adjacent streams split by secondary paths both accumulated the same upstream characteristics resulting in the watershed attributes being counted twice when these segments rejoined the main streamline.

All stream network and watershed accumulation issues have been resolved, however, watershed summaries generated by Statewide Stream Assessment have yet to be corrected for watersheds with data gaps and/or overlap issues.

In the short term, boundaries of watersheds with data gaps and overlapping issues were edited for accurate AES classification (i.e., separate summary analysis was conducted).

Literature Cited:

Holtrop, A.M., and R. Collins. 2015. Development and expansion needs of existing information systems: State Wildlife Grant T-60 Final Report.

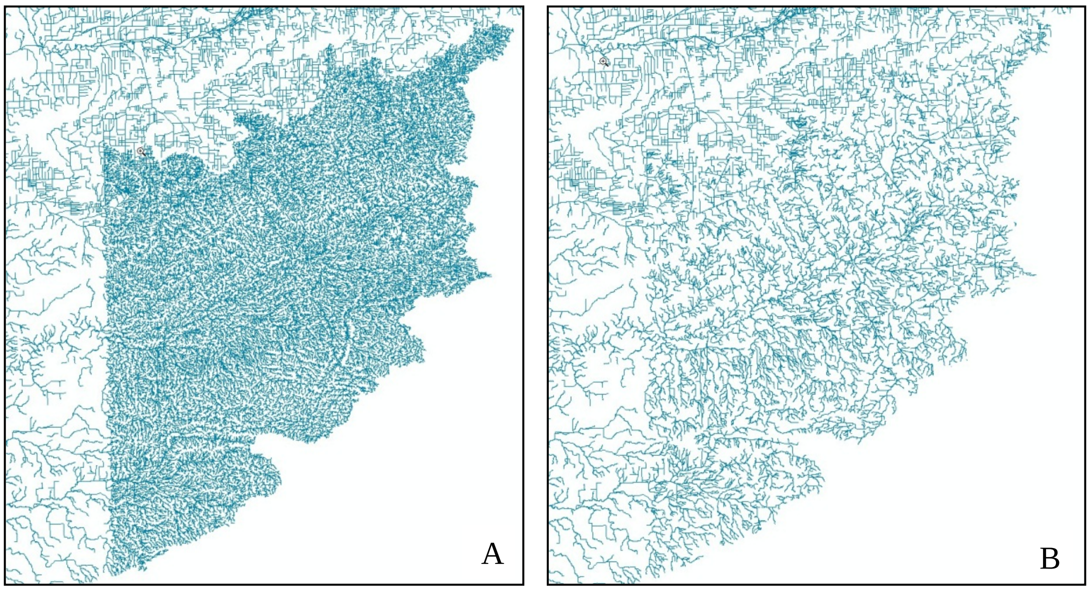

Figure AII.1. Stream density inconsistencies: A) an area with higher density stream lines; and B) same area after stream lines were reduced by removing very small first order stream channels (e.g., agricultural waterways).

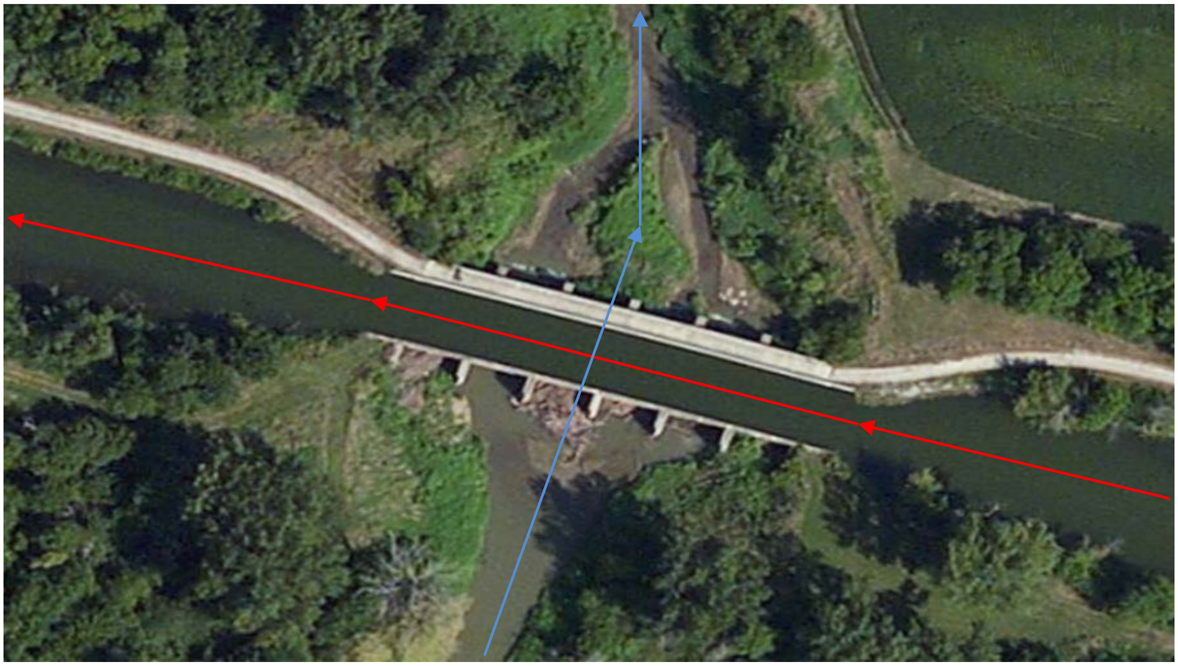

Figure AII.2. Example of condition where a stream (blue line and arrows) appears to cross an artificial stream channel (red line and arrows) flowing on an Aqueduct. Aqueduct stream lines were flagged to be excluded from the SSA watershed summaries.

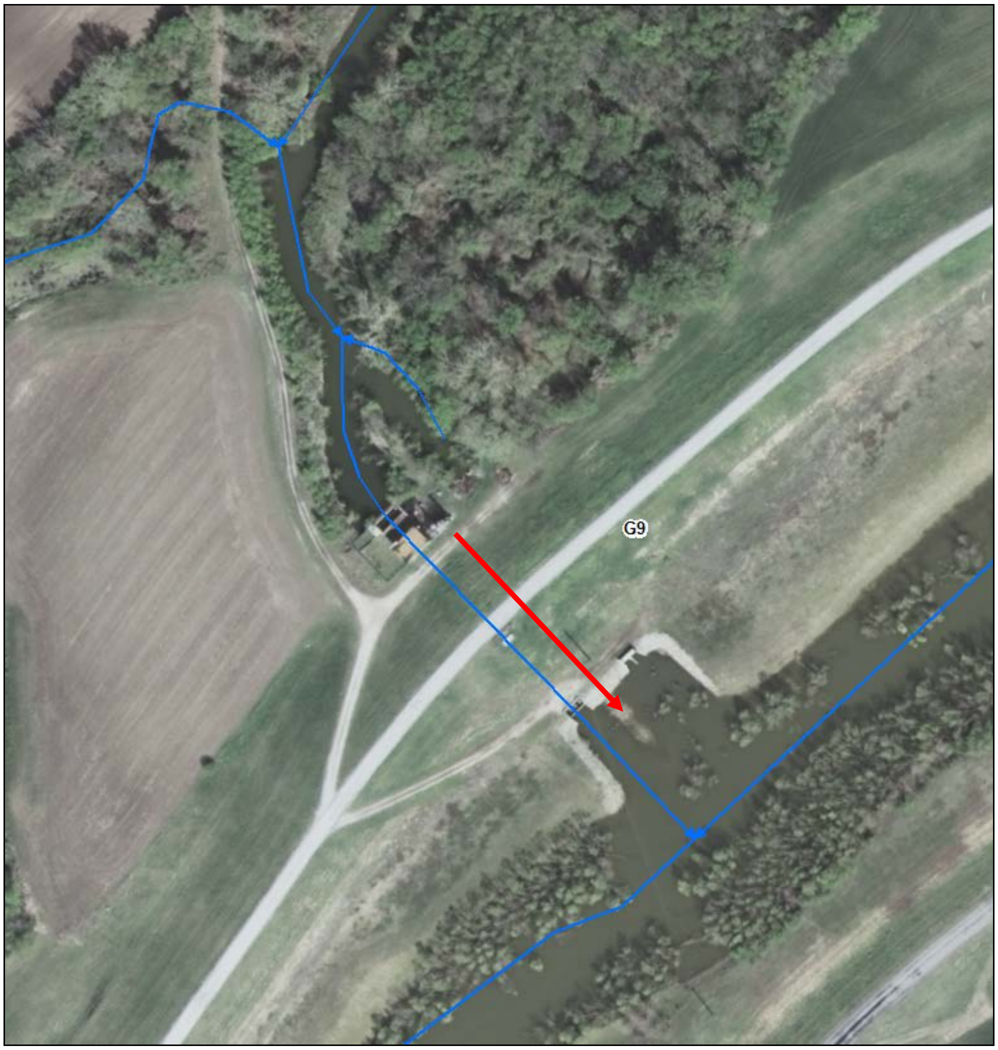

Figure AII.3. Stream line connectivity problems occurred when streams (blue arrows) pass under a levee through a water control structure or culvert (red arrows). Water control structures or culvert stream lines were flagged to stop accumulating watershed characteristics upstream of the structure outflow for SSA stream watershed summaries.

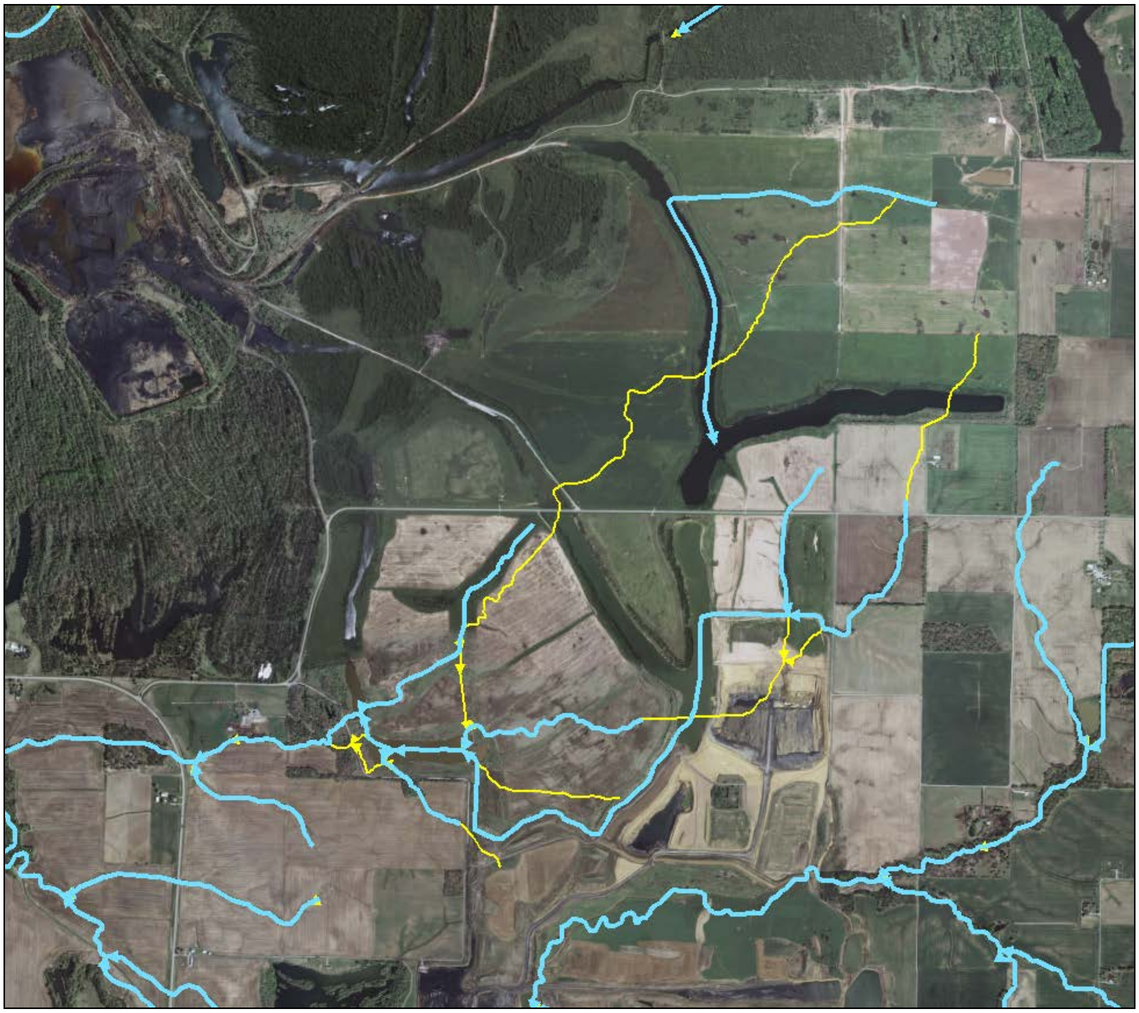

Figure AII.4. Stream line errors in strip mined areas. Existing stream linework (yellow arrows) was edited (blue arrows) to reflect current conditions based on NAPP 2011 imagery.

Figure AII.5. Stream order assignment error associated with secondary paths that increase the order of stream segments improperly. Stream order assignment issues occurred when a stream was classified as a secondary path (orange line) and was identified as an order 1 segment flowing independently into the main stream path (blue lines) instead of as a branch of the upstream reach during the GIS stream order assignment model. The GIS model was adjusted to correctly assign stream order.

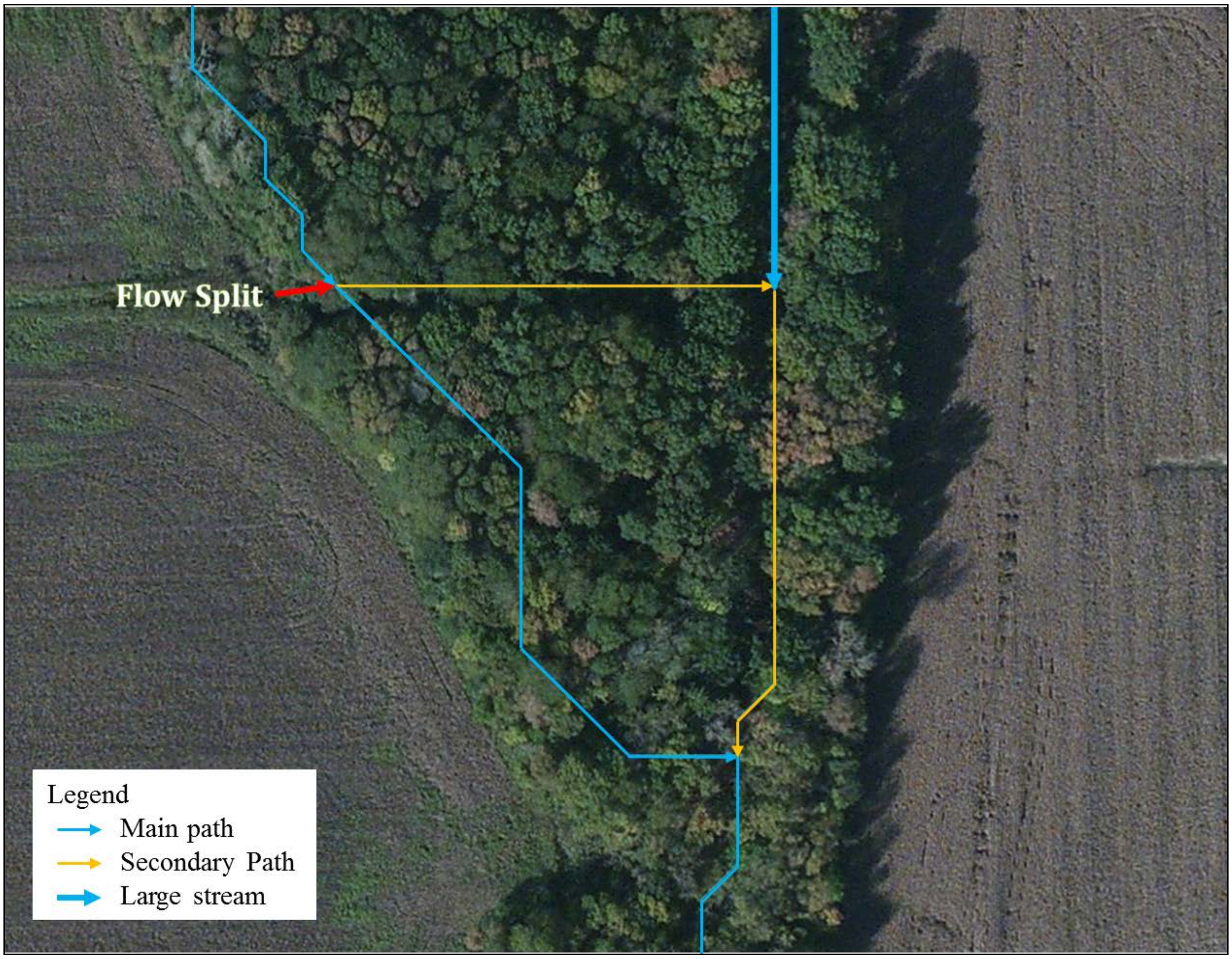

Figure AII.6. Stream segments were classified as main paths (blue lines) or secondary paths (orange lines) at flow splits (red arrow). The secondary path classification extends until it returns to the main path from which it originally split and does not accumulate upstream characteristics to avoid duplicate watershed calculations. Thick blue lines were classified as a large stream based on upstream watershed characteristics (i.e., total watershed area). The classification process resulted in the other main path (i.e., large stream) being inadvertently classified as secondary, and thus not accumulate upstream characteristics. Consequently, the stream is no longer classified as large stream downstream of the flow split. The secondary path classification was adjusted to extend to the main path which it originally split or a large stream. Misclassifications were manually corrected.

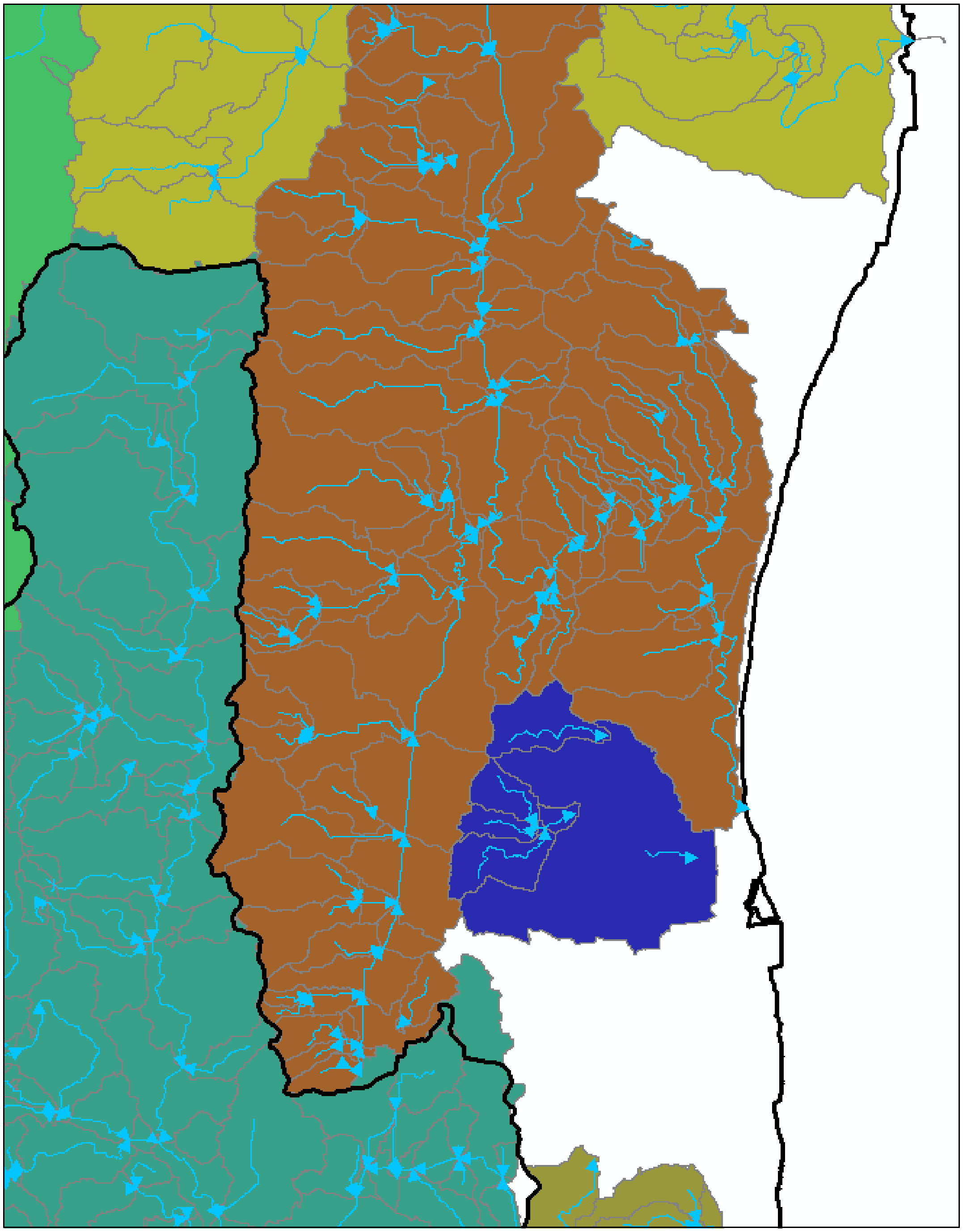

Figure AII.7. Map of data gaps in the Great Lakes Ecological Drainage Unit (black outline) where subwatersheds were not generated (white background within EDU) during the Statewide Stream Assessment (SSA). Subwatersheds (gray outline) that were generated using the Digital Elevation Model and stream lines (blue arrows) are symbolized by AES polygons (different fill color). These data gaps occur primarily in areas of high urban land use and were not included in the SSA watershed summary.

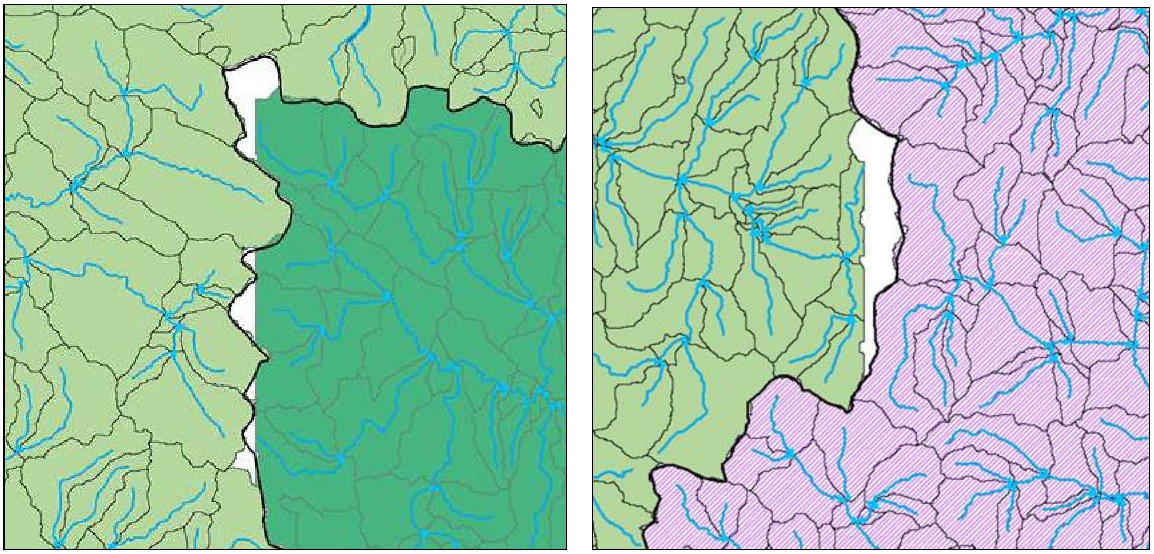

Figure AII.8. Data gaps between Ecological Drainage Unit boundaries (thick black line). The Digital Elevation Model used to generate subwatersheds (gray lines) was clipped for both EDUs and excluded clipped portions (white) of subwatershed characteristics from SSA stream watershed summaries. Subwatershed polygons were edited to fill data gaps for accurate AES classification.

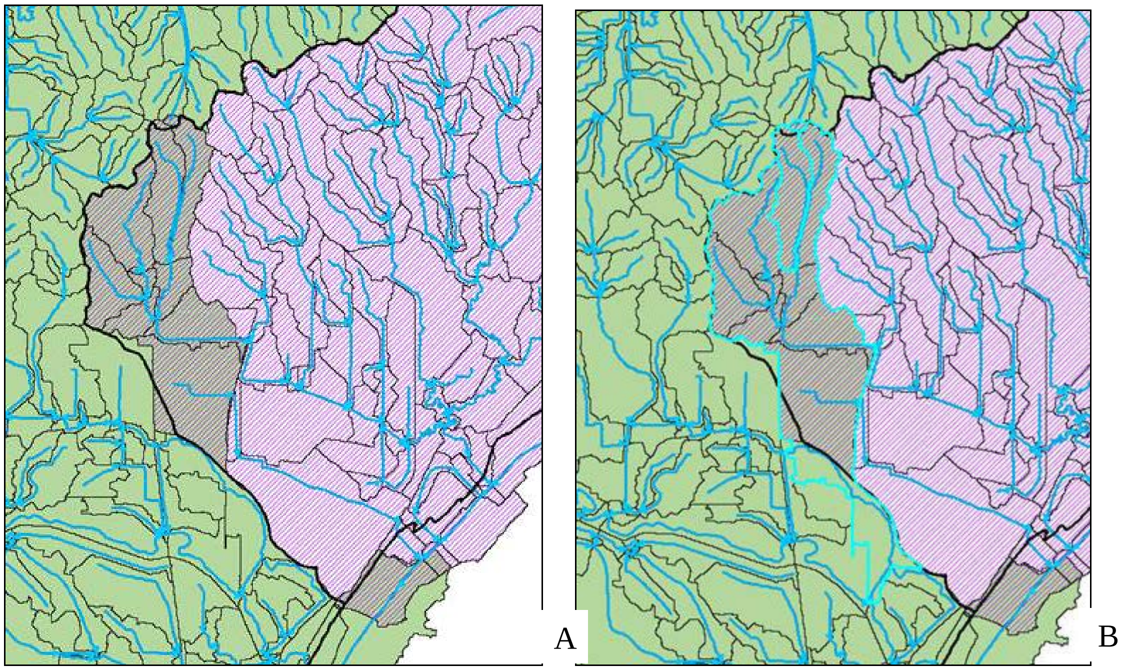

Figure AII.9. Overlapping subwatersheds: A) Subwatersheds overlapping between Ecological Drainage Unit (EDU; thick black line) boundaries. Mississippi River South (green polygons) and Ohio River (purple dashed polygons) subwatersheds were generated from the Illinois Digital Elevation Model and stream lines (blue arrows). B) One Mississippi River South subwatershed (light blue outline) overlaps with nine Ohio River subwatersheds. Overlapping subwatersheds were included multiple times in the Statewide Stream Assessment watersheds resulting in stream characteristics for overlapping areas to be counted multiple times and in some cases summarized multiple times. Overlapping subwatershed polygons were manually edited to remove the portions of the watershed that overlapped at the EDU boundary for accurate AES classification.

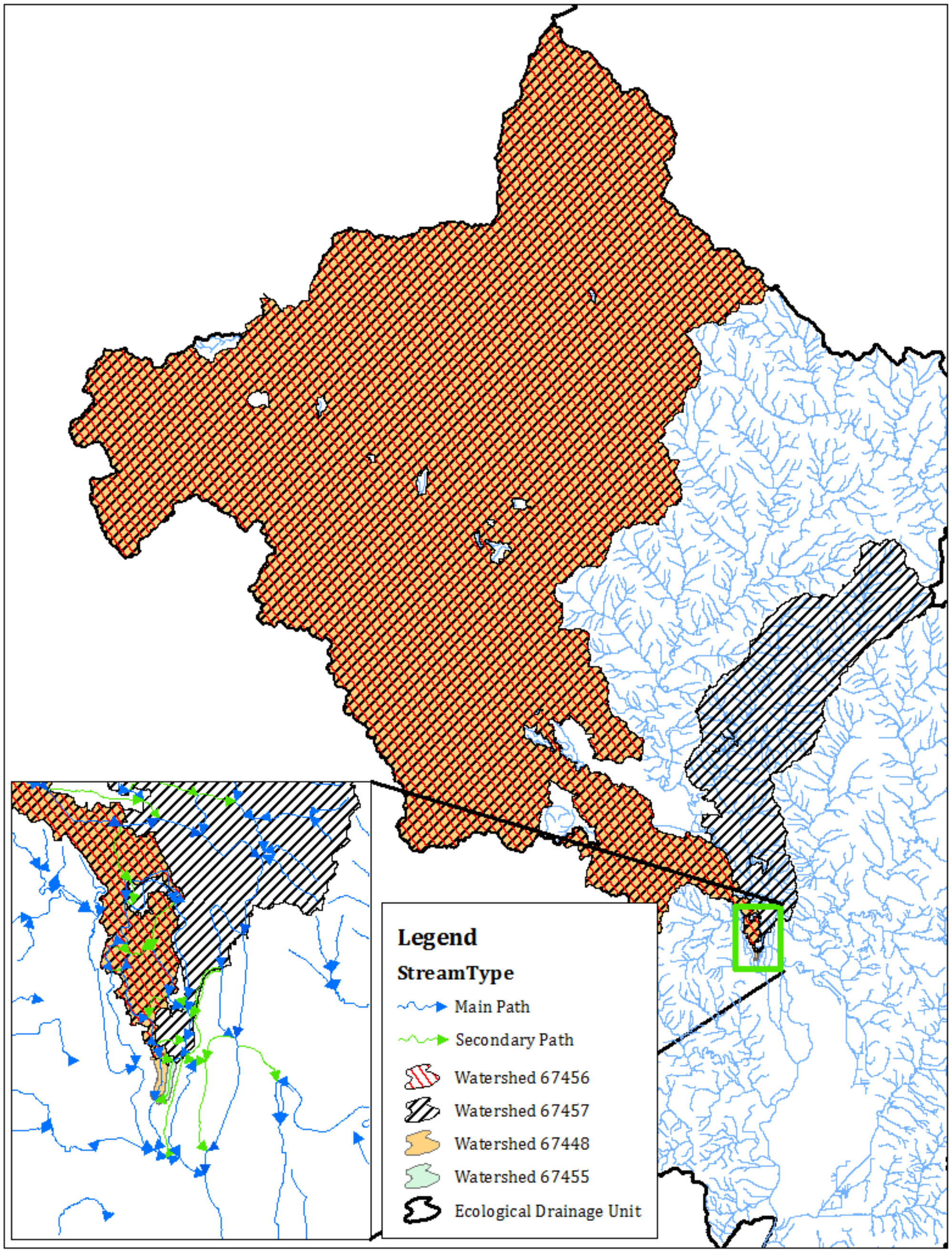

Figure AII.10: An area where adjacent streams split by secondary paths accumulate the same upstream characteristics resulting in duplicate watershed summaries. Watershed 67457 (black hatched) is accumulating the same stream characteristics as Watershed 67448 (light orange); however, Watershed 67457 should not be accumulating upstream characteristics at secondary paths (green arrows). Watershed accumulation model was adjusted to flag secondary paths to stop accumulation of upstream characteristics where it was not appropriate.