# Delaware River Watershed Riparian Forest Assessment

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# Executive Summary

Research along the Kansas River following the 1993 flood suggests that riparian forests outperform other land cover types (i.e., grass, row crops) in stabilizing streambanks and reducing downstream sediment delivery (Geyer et al., 2003, 1997). Because of riparian forest correlation to reduced sediment loading, as well the ability to provide other ecological services such as stream shading/cooling, increased soil infiltration, flood attenuation, carbon sequestration, and wildlife habitat, properly functioning riparian forests are a critical component of the watersheds above Kansas' numerous surface water reservoirs. In addition to ecological benefits, properly functioning riparian forests provide watershed landowners and residents with a wide variety of sustainable income sources (e.g., quality timber, fuel wood), increased recreational opportunities (e.g., hunting, wildlife viewing), and aesthetics.

The goal of this assessment was to determine the location, extent, composition, functioning condition, and ownership of riparian forests within the Delaware River Hydrologic Unit Code 8 (HUC 8) watershed (10270103). The assessment did not cover the entire HUC 8, but focused specifically within eight smaller HUC 12 watersheds as well as the riparian area along the main stem of the Delaware River (Figure 1). These nine assessment areas were selected with assistance from the Delaware River Watershed Restoration and Protection Strategy (WRAPS) group and represent WRAPS priority areas for sediment and streambank erosion.

Using geographic information systems (GIS), remote sensing, and on-the-ground forest assessment and inventory, riparian forests in the assessment watersheds were categorized into three functioning condition classes: forests in need of protection (i.e., properly functioning), forests in need of management (i.e., functioning at risk), and forests in need of establishment (i.e., nonfunctioning). Functioning condition class was assigned by examining the ratio of forest width (from top bank) to stream active channel width (ACW) and percent forest canopy coverage within the riparian area. Forest stand data and qualitative riparian area observations (e.g., invasive species presence, degradation evidence) were also collected from on-the-ground inventory plots within each watershed. Field data and observations were used to validate GIS / remote sensing data, as well as provide guidance for future direction of voluntary forestry programs and technical assistance aimed at achieving the greatest water quality impact for the Delaware River watershed.

Riparian areas with no trees are expected to generate the highest amount of downstream sediment delivery to reservoirs, in comparison to the other two condition classes. These areas that lacked riparian forest cover were classified as "forests in need of establishment," and were found to represent 46 percent of the total riparian area (2ACW) within assessed watersheds.

In general, riparian forests within assessed areas exhibited a lack of active forest management. This absence of management is evidenced by the current overstory forest species composition, which was found to be dominated by species with lower economic value such as hackberry (*Celtis occidentalis*), honeylocust (*Gleditsia triacanthos*), and elm (*Ulmus spp.*). Interestingly, in many watersheds, black walnut (*Juglans nigra*), a species with high economic value, was the greatest single-species contributor to both basal area per acre (BA) and trees per acre (TA). However, in relation to the cumulative numbers of competing lower-value tree species, black walnut was in the minority for overall canopy composition.

Regeneration composition (combination of seedlings and saplings) was even more dominated by lower-value species, with elm and hackberry alone representing 73 percent of the total regeneration on average. Tree species of high economic value (e.g., walnut, oak (*Quercus spp.*)) represented only 4 percent of the overall regeneration, and never represented more than 10 percent of the regeneration present within a single watershed, again indicating an absence of management. Commonly observed threats to forest health/sustainability within on-the-ground riparian inventory plots included heavy livestock use, ice storm damage, and lack of active forest management.

The assessment information will be compiled into a GIS database that will assist the Delaware River WRAPS achieve sediment and nutrient water quality goals outlined within their nine-element watershed plan. The database also will allow WRAPS to more effectively collaborate with project partners (e.g., Kansas Forest Service, K-State Research and Extension) and relevant natural resource agencies (e.g., Natural Resources Conservation Service) to promote riparian forestry practices and programs to project-identified landowners in priority watersheds.

This study was associated with the Sediment Baseline Research Study (SBRS), a Kansas Water Office-led interagency effort investigating factors that influence sediment loading within three northeast Kansas HUC 12 watersheds. Delaware assessment project partners contributed riparian functioning condition data for Banner Creek and Otter/Clear creeks (Atchison County Lake) HUC 12 watersheds to the Kansas Water Office as part of their role in the study. More information on SBRS can be found in the Projects section of the Kansas Water Office website (*www.kwo.org*).

# Introduction

Forests that line Kansas waterways are known as *riparian* forests, and are vital for clean water. Riparian, simply put, is an area where land meets water — examples include riverbanks, lakeshores, and areas next to wetlands. Riparian comes from the Latin word *riparius*, meaning "frequenting riverbanks" or "the bank of a river." Riparian areas in Kansas have many different appearances – from native tallgrass prairie meadows lining the headwater streams of the Flint Hills, to big-timber floodplain forests along rivers such as the Republican, the Neosho, the Kansas, the Missouri, and the Delaware. Riparian areas, and the forests they support, provide tremendous benefits to both landowners and the environment. From a forestry perspective, certain riparian areas (with their rich soil and available water) are the prime sites for timber production in Kansas. Thus, properly functioning riparian forests provide watershed landowners and residents with a diversity of sustainable income sources (e.g., quality timber, fuelwood), and aesthetics. With trees, food, and water all in one location, riparian areas also can provide landowners with excellent wildlife habitat — leading to outstanding hunting, fishing, and other recreational opportunities. From a water quality perspective, healthy riparian areas buffer waterways by absorbing pollutants flowing off the landscape. Forested riparian areas also help to stabilize streambanks, which can prevent large quantities of soil from entering streams. In Kansas, streambank stabilization may be the most important role for riparian forests, in terms of water quality.

Research along the Kansas River following the 1993 flood suggests that riparian forests outperform other land cover types (i.e., grass, row crop) in stabilizing streambanks and reducing downstream sediment delivery (Geyer et al., 2003, 1997). By protecting streambanks, forests also act to reduce the loading of sediment-associated nutrients (i.e., phosphate) to waterways. Because of their correlation to reduced sediment and nutrient loading, as well their ability to provide other ecological services such as stream shading/cooling, increased soil infiltration, filtration of pollutants from surface runoff, carbon sequestration, flood attenuation, and wildlife habitat, properly functioning riparian forests are a critical component of the Delaware River watershed.

The goal of this project was to determine the location, extent, functioning condition, and species composition of riparian forests along the main stem of the Delaware River, and within eight hydrologic unit code 12 (HUC 12) sub-watersheds within the larger Delaware River HUC 8 watershed (10270103) (Figure 1): Cedar Creek (0102), Muddy Creek (0109), Grasshopper Creek (0202), Otter Creek (0203), Little Grasshopper Creek (0204), Negro Creek (0205), Straight Creek (0303), and Banner Creek (0305). This information has been compiled into a GIS database that will be used by researchers, watershed stakeholders, and forestry professionals to allocate resources and guide forestry cost-share and technical-assistance programs, such as Environmental Quality Incentives Program (EQIP), and Continuous Conservation Reserve Program (CCRP), for water quality purposes. It also will help the Delaware River WRAPS achieve specific pollutant reduction goals (e.g., sediment, phosphorus), and get best management practices (BMPs) implemented on the landscape — in the form of riparian forest buffers and riparian forest management.

Secondary goals of this project include gathering baseline riparian forest information for the watershed and the region. Currently, detailed information on riparian forests in Kansas simply does not exist. Thus, information gathered in studies such as this will help foresters answer the following critical questions: Where are our riparian forests located; what condition are they in; how many acres exist; and what tree species are present? Answers to these questions will help natural resource managers more effectively care for our state's riparian forest resources for water quality improvement and protection.

This study sets the stage for WRAPS-funded Kansas Forest Service riparian forestry technical assistance over the next 3 years (FY14-16). Using information gained from this project, Kansas Forest Service foresters will know "where is the most cost-effective area in the watershed to work in order to improve water quality"?

A smaller portion of the overall assessment project focused on identifying the location of animal feeding operations (AFOs), streambank erosion sites, and ephemeral gullies within the riparian area. This information, while relevant, was beyond the scope of this report, and thus not included. More information on this analysis is available from the Kansas Forest Service on request.

# GIS Methodology

Note: A highly detailed, technical GIS methodology is available from the Kansas Forest Service.

This project focused on eight Hydrologic Unit Code 12 (HUC-12) watersheds within the overall Delaware River HUC 8 watershed (Table 1). In addition to the eight HUC 12 watersheds, the project also focused on the main stem of the Delaware River. Watersheds were selected for assessment by the Kansas Forest Service in conjunction with the Delaware River WRAPS and the Kansas Water Office.

## Defining the riparian assessment area

This project focused on assessing riparian forests within the Delaware River watershed. Thus, the first step was to define the riparian area. For this project, the riparian area was defined as the intersection of:

- **A 2 active channel width (ACW) distance from the top of the streambank**, based on "Stream Visual Assessment Protocol v.2" (SVAP2, USDA-NRCS 2009) and the "Riparian Area Management: Process for Assessing Proper Functioning Condition" guidance (USDI-BLM 1998).

and…

- **Soils indexed to NRCS Conservation Tree and Shrub Groups (CTSG) 1 and 2** based on the Soil Survey Geographic Database (SSURGO) for Kansas (USDA-NRCS 2009).

Thus, the riparian area (we assessed) was defined as anywhere that the appropriate soils for tree and shrub growth were found within a 2ACW zone from the top of the streambank.

**Table 1.** *Assessment Hydrologic Unit Codes (HUCs).*

| Watershed Name | HUC 8 Code |
|---|---|
| Delaware River * | 10270103 |
| **Watershed Name** | **HUC 12 Code** |
| Cedar Creek | 102701030102 |
| Muddy Creek | 102701030109 |
| Grasshopper Creek | 102701030202 |
| Otter Creek | 102701030203 |
| Little Grasshopper Creek | 102701030204 |
| Negro Creek | 102701030205 |
| Straight Creek | 102701030303 |
| Banner Creek | 102701030305 |

**The riparian area along the main stem of the Delaware River was focused on, and not the entire HUC 8 watershed.*

*Why 2ACW was used:* Active channel width (ACW) is also known as bankfull width, and can be described as the width of the water in a stream channel at bankfull discharge. In unaltered/natural watersheds, bankfull discharge is defined as the volume of water flowing through a channel just before it spills over onto its floodplain. However, in post-settlement watersheds, where extensive land cover alterations have resulted in channel incision, streambank tops do not define the bankfull width. Again, because of incision, most modern bankfull width measurements are taken between two points well within the channel itself. Bankfull discharge is important, as it is the flow level where most of the channel-forming activity takes place. In Kansas, bankfull discharge typically occurs on a 1.2- to 1.7-year interval. Thus, taking a birds-eye view of the Delaware River soon after one of these runoff events, the observed width of the water would be the ACW. The SVAP2 (a stream-assessment guide produced by the USDA) states that natural vegetation should extend at least 2ACW on each side of the stream for the riparian area to function well.

*Why CTSG 1 and 2 soils were used:* Groups 1 and 2 represent productive, floodplain soils. It is soils within CTSG 1 & 2 that represent the greatest potential for forest/tree growth and management. In addition, these soils, because of their proximity to waterways, represent the area where trees would be most effective for water quality enhancement.

The riparian assessment area (i.e., the overlap of 2 ACW width and CTSG 1 and 2 soils) for the assessed watersheds can be viewed in Figures 1 through 11 (pages 25 – 35).

## Determining riparian forest canopy cover

All forest located within the 2ACW target population was identified using an object-based classification of four-band, 2008 NAIP imagery with ENVI software. After segmentation into polygons using a supervised classification, forest polygon boundaries were overlaid on Bing Maps imagery and edited to match observable boundary edges.

LANDFIRE Existing Vegetation Type (EVT) data were used to identify land use other than forest which occurred within the 2ACW target population. Since riparian forest delineation was the goal of this project, only areas misidentified by EVT as forest were edited and assigned the correct land use (e.g., pasture rather than forest). EVT was allowed to stand-alone for non-forested areas.

Riparian forest canopy cover, which was essential for assigning functioning condition class, was accomplished using Normalized Difference Vegetation Index (NDVI). NDVI was calculated from the red and near infrared bands (NIR) of 2008 NAIP imagery according to the equation: NDVI = (NIR – Red) ÷ (NIR + Red). The values of NDVI ranged from "no cover" or "very low greenness" to "high cover" or "high greenness," with "high greenness" assumed to be healthy forests exhibiting full canopy cover. NDVI was only calculated for the forest polygons extracted from object-based classification.

## Assigning riparian forest functioning condition class

Using NDVI thresholds, the riparian forest target population was classified into three functioning condition classes for the 0.5 ACW, 1ACW, and 2ACW extents: *forest in need of establishment*, *forest in need of management*, and *forest in need of protection*. Classes were defined using the following NDVI thresholds: *forest in need of establishment* (NDVI 0-130), *forest in need of management* (NDVI 131-210), and *forest in need of protection* (NDVI 211-255). Thresholds were developed by correlating remote NDVI readings and a wide range of in-field canopy coverage measurements.

*Forest in need of establishment* areas were cropland, developed areas (e.g., roads), pastures, native grasslands, bare patches, or "no cover" or "very low greenness" forest NDVI values that occurred where riparian forest should or could occur. *Forest in need of management* areas were "less dense" or "low to low-medium cover" forest NDVI values, and generally were comprised of stands of shrubs and seedlings, less dense forest, or the outside perimeters of riparian forests along pastures or crop fields. Finally, *forest in need of protection* areas represented "medium to high cover" forest NDVI values and corresponded with more densely wooded riparian areas. Examples of each functioning condition class can be seen in photos 1-3.

It should be noted that within forest stands, water and sandbars associated with the stream were sometimes classified as areas in need of establishment. Water and wetland values from the EVT layer were not classified into a functional category.

**Photo 1.** *Riparian areas in need of establishment lack woody vegetation and are expected to generate the highest amount of downstream sediment delivery.*

**Photo 2.** *Riparian areas with sparse forest cover were classified as "areas in need of management," and represented relatively low acreage within study watersheds.*

**Photo 3.** *Riparian areas with a significant forest cover were classified as "areas in need of protection," and were most prevalent within the Banner Creek watershed.*

# Riparian Forest Inventory Methodology

## Sampling design

Forest data were collected at a total 183 field inventory plots spread across the assessed areas. Forest data were collected to verify the GIS assumptions and collect vital information on riparian forest composition and structure. To collect the data, a selected representative sample design was used. Plots were located in areas identified as *forest in need of protection* by GIS. A landowner list was assembled, and contacts were made to seek access permission. It was difficult to randomly distribute plots across the watersheds as landowner permission was required for site access.

## Plot layout and forest data collection

Rectangular plots were established with a long axis perpendicular to the stream of 50 feet or 1 ACW, whichever was greater, (Figure 12). The width of the plot was 30 feet, resulting in a plot area of at least 1,500 square feet. Within this plot a number of individual tree measurements and observations were recorded, including diameter at breast height (dbh), tree height, and tree crown class by species. Crown class is essentially a way to measure the "hierarchy" of the forest. The amount of sunlight hitting the crown and tree height are the two factors that determine a tree's crown class. General notes were recorded for each tree as well, and included: disease presence, form, and degradation presence (e.g., storm damage, vines, decay). Within plots, all trees above 5 inches dbh were classified as mature trees and measured. Seedling and sapling regeneration was recorded from two circular sub-plots within the main plot (Figure 12). Regeneration plots had a radius of 5.3 feet (1/500 acre), with one sub-plot located within the half of the main plot nearest the stream, and one sub-plot located in the half of the main plot furthest from the stream, on the opposite side of the transect line. Regeneration plots were randomly stratified. Seedlings were classified as any small specimens of tree species present up to 4.5 feet tall and having a diameter of less than 1 inch. Saplings were recorded in the plots if they were more than 1 inch but less than 5 inches in dbh.

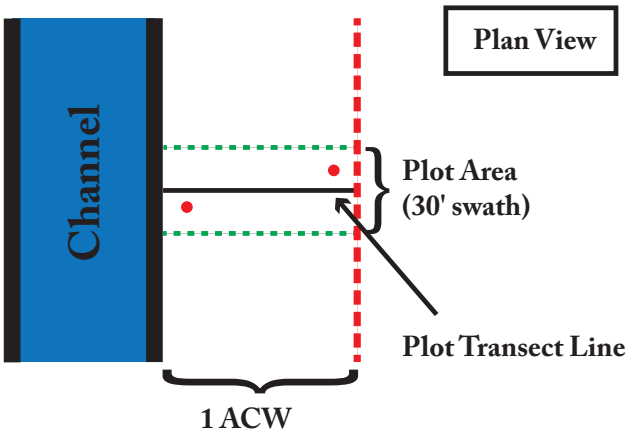


**Figure 12.** *Forest inventory plot layout, with red circles representing regeneration sub-plots. Not to scale.*

Stream ACW, forest width from the top of the streambank, and forest canopy coverage were recorded at plots as well. Qualitative data also were recorded, such as evidence of livestock use, evidence of woodland management (marking, harvesting, or planting trees), and dominant ground cover (grassy, broadleaved herbaceous, brushy, woody debris). The second ACW beyond the plots was visually classified as forest, grass, or crop field.

## Calculations

The collected forest data were used to calculate the following, which provide a good estimation of forest structure and composition for the three watersheds:

a. Basal area per acre (BA)
b. Trees per acre (TA)
c. Regeneration (seedlings and saplings) per acre (RA)
d. Quadratic mean diameter (QMD)

Species BA is a key measure of dominance and defined as the cross-sectional area at breast height and is computed through the formula by Avery and Burkhart (1994):

$$BA(ft^2) = \frac{\pi\ dbh^2}{4\ (144)} 0.005454\ dbh^2$$

where *BA* is the basal area of the tree, *dbh* is the diameter at breast height, and $\pi$ is the mathematical constant 3.14159.

For each plot, the sum of the total BA per tree species was multiplied by the appropriate expansion factor (e.g., 29.04 for 1,500 square foot plots) to yield BA per acre. The same expansion factors were used to calculate estimates of TA. The expansion factor for RA was 500. QMD is defined as the diameter of the tree of average BA for that particular species. In less technical terms, it provides more weighting to trees of larger diameter.

## Categorization of tree species according to timber value

It was important to consider the tree species composition from a commercial view point for the watersheds. Therefore, in consultation with Kansas Forest Service District Forester David Bruton, the species found in the assessed watersheds were categorized into three groups, based on current timber market value. Group 1 (high value) was composed of all oaks and walnut. Group 2 (moderate value) was composed of ash (*Fraxinus, spp.*), black cherry (*Prunis serotina*), cottonwood (*Populus deltoides*), hackberry (*Celtis occidentalis*), hickory (*Carya, spp.*), and silver maple (*Acer saccharinum*). Group 3 (low value) was composed of all other species.

# GIS Results

## Riparian area acreage

Within HUC 12 watersheds, the mean acreage of the 2 Active Channel Width (2ACW) riparian area was 962 acres and ranged from 502 acres (Negro Creek) to 1,344 acres (Straight Creek) (Table 2). The main stem of the Delaware River had a total 2 ACW riparian area of 3,750 acres (Table 2).

## Total riparian forest acreage

Within HUC 12 watersheds, the mean acreage of riparian forest (i.e., the sum of *forest in need of management acres and forest in need of protection acres*) within the 2ACW riparian area was 530 acres, and ranged between 253 acres (Negro Creek) and 713 acres (Straight Creek) (Table 3). The main stem of the Delaware River had a total 2 ACW riparian forest area of 1733 acres (Table 3).

The percent riparian forest area within the 2 ACW riparian area ranged between 46 percent (Main Stem Delaware) and 62 percent (Grasshopper Creek), with a mean of 56 percent (Table 3).

## Riparian forest functioning condition class

Within all HUC 12 watersheds, as well as along the main stem of the Delaware River, the majority of the 2 ACW riparian area was comprised of *forest in need of establishment* and *forest in need of management* functioning condition classes (Figure 13). *Forest in need of protection* represented between 27 and 45 percent of riparian areas, with a mean representation of 33 percent.

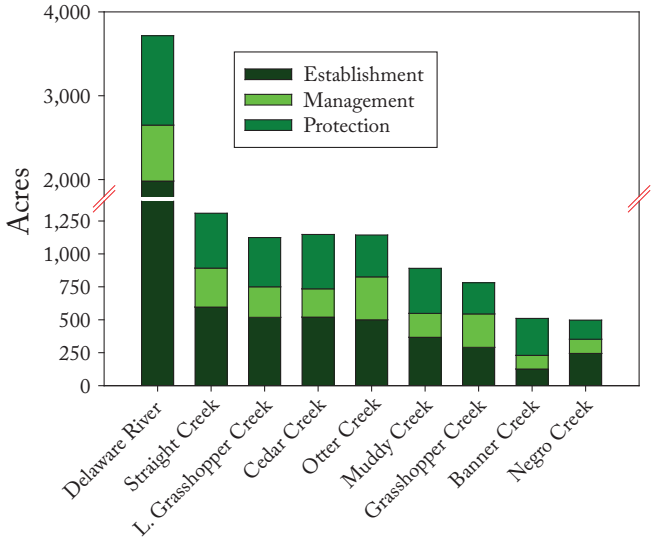


**Figure 13.** *Riparian forest functioning condition class acreage by watershed.*

Of the HUC 12 watersheds, Straight Creek exhibited the greatest total acreage of *forest in need of establishment* (596 acres), while Banner Creek exhibited the lowest total acreage of that condition class (126 acres). Within the Banner Creek riparian area, *forest in need of establishment* represented only 20 percent of the total acreage, lowest among the HUC 12 watersheds. The highest proportion of *forest in need of establishment* within the total riparian area occurred in the Negro Creek watershed, where 48 percent of the riparian area was classified as such.

The main stem of the Delaware River had more acres classified as *forest in need of establishment* (1,981 acres) than any of the HUC 12 watersheds. Along the main stem, *forest in need of establishment* represented 53 percent of the total riparian area also greater than any of the HUC 12 watersheds.

Within the HUC 12 watersheds, acres classified as *forest in need of management* ranged from 103 acres (Banner Creek) to 326 acres (Otter Creek), with a mean of 215 acres. For this condition class, representation within total watershed riparian areas ranged from 16 percent (Banner Creek) to 32 percent (Grasshopper Creek).

The main stem of the Delaware River had more acres classified as *forest in need of management* than any of the HUC 12 watersheds, with 668 acres. This condition class represented 18 percent of the total riparian area along the main stem.

Acres classified as *forest in need of protection* ranged between 145 acres (Negro Creek) and 416 acres (Straight Creek), with a mean of 316 acres within the HUC 12 watersheds. Otter Creek exhibited the lowest proportion of *forest in need of protection* within the total riparian area (27 percent), while Banner Creek exhibited the highest (45 percent).

As with all other functioning condition classes, the main stem of the Delaware had more acres classified as *forest in need of protection* (1,066 acres) than any of the HUC 12 watersheds. The proportion of *forest in need of protection* acres to the total riparian area along the Delaware River (28 percent) was lower than the mean for the HUC 12 watersheds (33 percent), however.

Riparian forest location and functioning condition class geographic distribution for each assessed watershed can be viewed in Figures 2 through 11.

**Table 2.** *Acreage of 2 ACW riparian area by watershed.*

| Watershed | Riparian Acreage (2 ACW) |
|---|---|
| Main Stem Delaware River (10270103)* | 3,750 |
| Straight Creek (0303) | 1,344 |
| Little Grasshopper Creek (0204) | 1,168 |
| Cedar Creek (0102) | 1,166 |
| Otter Creek (0203) | 1,163 |
| Muddy Creek (0109) | 925 |
| Grasshopper Creek (0202) | 795 |
| Banner Creek (0305) | 631 |
| Negro Creek (0205) | 502 |
| HUC 12 Watershed Mean** | 962 |

**Represents 2 ACW acreage along the main stem of the Delaware River, not entire watershed.*
*** HUC 12 watershed mean excludes the main stem of the Delaware River.*

**Table 3.** *Acreage of riparian forest by watershed, as well as riparian forest area as a percent of total riparian area.*

| Watershed | Riparian Area Forest Acreage (Management + Protection) | Riparian Forest Area / Total Riparian Area (%) |
|---|---|---|
| Main Stem Delaware River (10270103)* | 1,733 | 46 |
| Straight Creek (0303) | 713 | 53 |
| Otter Creek (0203) | 644 | 55 |
| Cedar Creek (0102) | 628 | 54 |
| Little Grasshopper Creek (0204) | 606 | 52 |
| Muddy Creek (0109) | 524 | 57 |
| Grasshopper Creek (0202) | 490 | 62 |
| Banner Creek (0305) | 384 | 61 |
| Negro Creek (0205) | 253 | 50 |
| Mean | 530** | 56*** |

**Represents riparian forest acreage along the main stem of the Delaware River, not entire watershed.*
***Mean excludes main stem of the Delaware River.*
****Mean includes main stem of Delaware River.*

# Riparian Forest Field Inventory Results

## Basal area per acre (BA) and trees per acre (TA)

Field plots were only established on sites categorized as "forest in need of protection." Within the HUC 12 watersheds, Negro Creek was found to have the highest basal area per acre (BA) for all species combined (172 square feet), while Muddy Creek was found to have the lowest (108 square feet) (Figure 14). Mean BA for all HUC 12 watersheds was 138 square feet. The main stem of the Delaware was found to have a higher mean BA (185 square feet) than any of the HUC 12 watersheds.

Trees per acre (TA) followed a similar trend, with Negro Creek once again exhibiting the highest mean (237), and Muddy Creek exhibiting the lowest (162) (Figure 14). The mean TA for all HUC 12 watersheds was found to be 191. The main stem of the Delaware River exhibited a mean TA of 215, which was greater than the TA of all HUC 12 watersheds with the exception of Negro Creek.

## Species composition (BA and TA) within watersheds

For all HUC 12 watersheds combined, the majority (65 percent) of BA was comprised of the combination of hackberry, black walnut, honeylocust, and elm. Oak represented 8 percent of total BA within HUC 12 watersheds, with Osage orange (*Maclura pomifera*), ash, mulberry (*Morus* spp.), hickory, and the "other" category making similar, minor contributions (2 to 10 percent) (Figure 15). Along the main stem of the Delaware, the combination of silver maple and hackberry made up the majority (57 percent) of BA (Figure 16). A breakdown of BA by species within individual watersheds, as well as along the main stem of the Delaware River, can be found in Table 4.

Similar to BA, the majority of HUC 12 TA (67 percent) was again represented by hackberry, black walnut, honeylocust, and elm (Figure 17). Oak

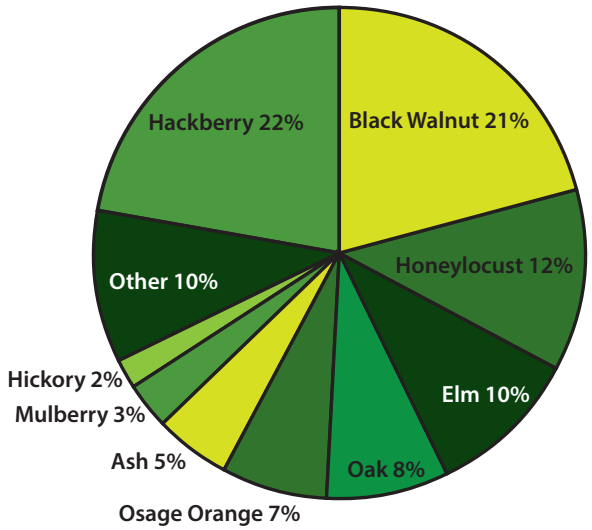


**Figure 15.** *Basal area per acre (BA) composition by species for all HUC 12 watersheds combined.*

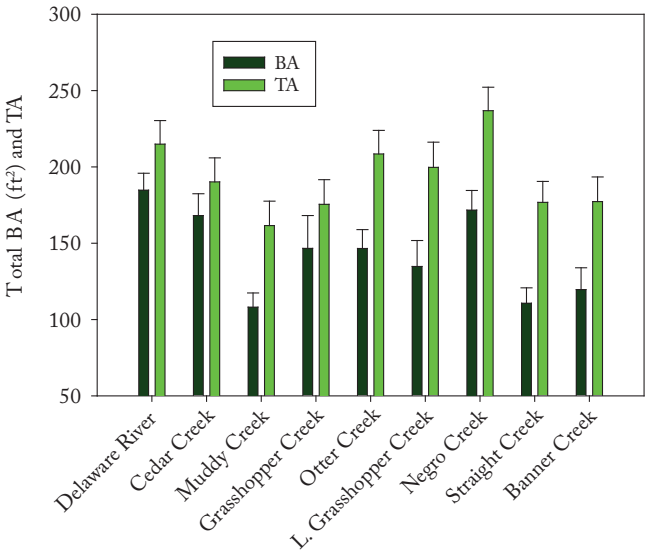


**Figure 14.** *Total basal area per acre (BA) and trees per acre (TA) (all species combined) by watershed.*

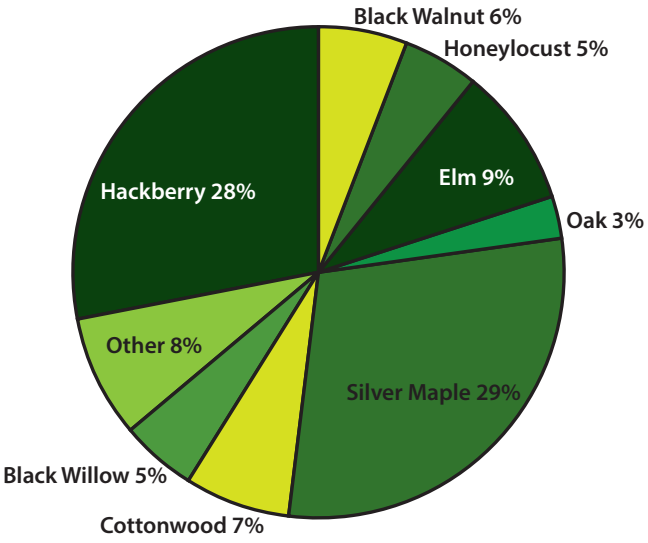


**Figure 16.** *Basal area per acre (BA) species composition for main stem Delaware River.*

**Table 4.** *Top three species (rank) that comprise basal area per acre (BA) and trees per acre (TA) by watershed.*

| | Watershed | #1 Species (% of Total) | #2 Species (% of Total) | #3 Species (% of Total) |
|---|---|---|---|---|
| Basal Area per Acre (BA) | Delaware River | S. Maple (29) | Hackberry (28) | Elm (9) |
| | Cedar Creek | H. Locust (28) | Hackberry (22) | B. Walnut / Oak (22) |
| | Muddy Creek | B. Walnut (30) | Hackberry (17) | Elm (11) |
| | Grasshopper Creek | B. Walnut (18) | Oak / Hackberry (13) | S. Maple (12) |
| | Otter Creek | B. Walnut (31) | Hackberry (16) | H. Locust (15) |
| | L. Grasshopper Creek | O. Orange (28) | Hackberry (18) | B. Walnut (15) |
| | Negro Creek | Hackberry (38) | B. Walnut (30) | Ash (8) |
| | Straight Creek | Hackberry (26) | H. Locust / B. Walnut (19) | Elm (11) |
| | Banner Creek | Oak (22) | Hackberry (19) | B. Walnut (13) |

| | Watershed | #1 Species (% of Total) | #2 Species (% of Total) | #3 Species (% of Total) |
|---|---|---|---|---|
| Trees per Acre (TA) | Delaware River | Hackberry (31) | S. Maple (25) | Elm (14) |
| | Cedar Creek | Hackberry (28) | Elm (27) | H. Locust (15) |
| | Muddy Creek | B. Walnut (23) | Elm (20) | Hackberry (15) |
| | Grasshopper Creek | Elm (25) | B. Walnut (16) | Hackberry (14) |
| | Otter Creek | B. Walnut (20) | Hackberry (14) | O. Orange (11) |
| | L. Grasshopper Creek | O. Orange (29) | Elm (25) | H. Locust (15) |
| | Negro Creek | Hackberry (41) | B. Walnut (25) | Elm (9) |
| | Straight Creek | Hackberry (26) | Elm (22) | H. Locust (15) |
| | Banner Creek | Elm (21) | Hackberry (19) | Hickory (12) |

represented 4 percent of total TA within HUC 12 watersheds, with Osage orange, ash, mulberry, hickory, and "other" making similar, minor contributions (3 to 8 percent) (Figure 17). Along the main stem of the Delaware River, hackberry, silver maple, and elm made up the majority (70 percent) of TA (Figure 18). A breakdown of TA by species within individual watersheds and along the main stem of the Delaware River can be found in Table 4.

## Regeneration per acre (RA) (seedling and sapling combined)

Cedar Creek was found to have the highest RA (5,387) of any HUC 12 watershed, while Muddy Creek was found to have the lowest (1,609) (Figure 19). The mean RA for all HUC 12 watersheds was found to be 3,680. The main stem of the Delaware River was found to have a mean RA of 3,113, which was higher than only three of the HUC 12 watersheds (Muddy, Negro, and Banner Creeks).

Two species alone (hackberry and elm) represented 74 percent of the total RA across all HUC 12 watersheds (Figure 20). High-value species (oak and black walnut) represented only 3 percent and 1 percent, respectively, of the total RA across all HUC 12 watersheds.

A similar situation was found along the main stem of the Delaware River, where hackberry and elm alone represented 71 percent of the total RA (Figure 21). High-value species (oak and black walnut) represented only 7 percent and 1 percent, respectively, of the total RA along the main stem of the Delaware River. A breakdown of RA by species within individual watersheds and along the main stem of the Delaware River can be found in Table 5.

Within all inventory plots, seedlings were found to be far more prevalent than saplings, with the former out-numbering the latter by a ratio of 10:1.

## QMD

Quadratic Mean Diameter (QMD) is the diameter of the tree of average BA recorded during the project. For this study, cottonwood, sycamore, and oak exhibited the largest QMDs (26 inches, 23 inches, and 17 inches respectively), while black cherry and buckeye represented the smallest (7 inches and 6 inches respectively).

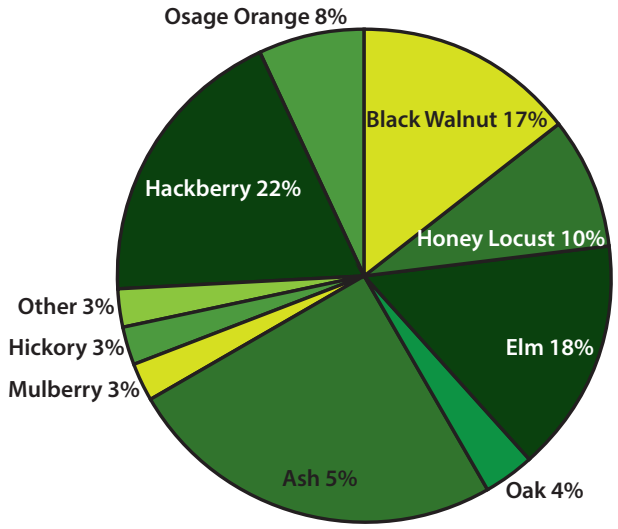


**Figure 17.** *Trees per acre (TA) composition by species for all HUC 12 watersheds combined.*

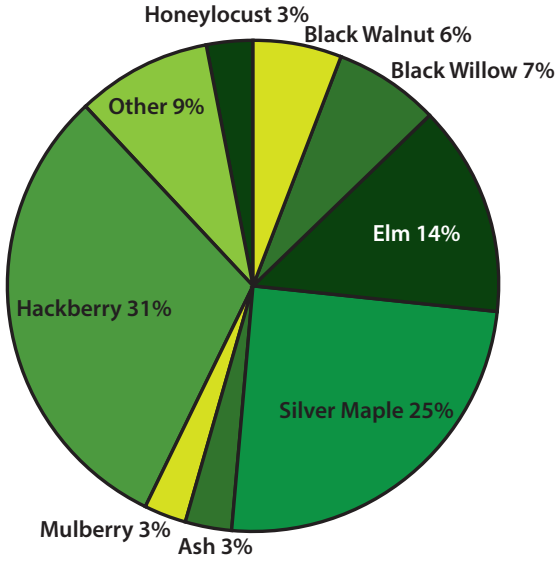


**Figure 18.** *Trees per acre (TA) composition by species for main stem of Delaware River.*

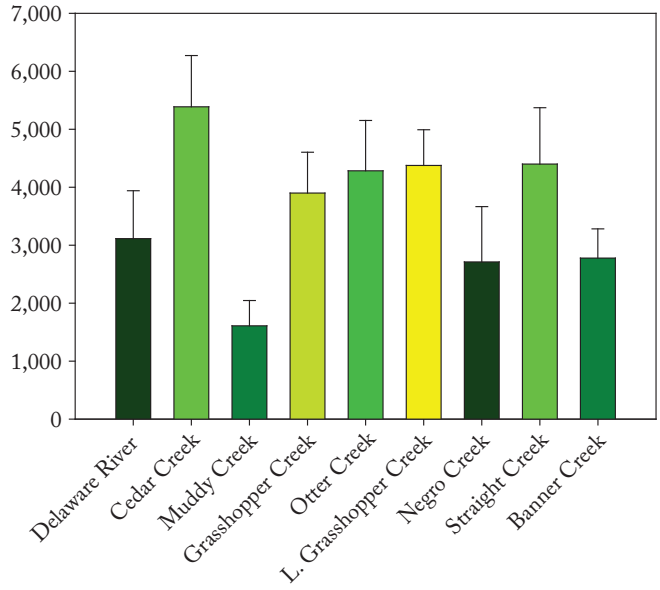


**Figure 19.** *Total regeneration per acre (RA) (seedlings and saplings combined) by watershed.*

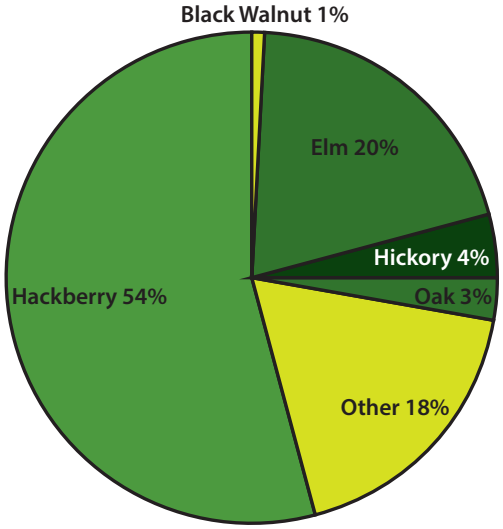


**Figure 20.** *Regeneration per acre (RA) composition by species for all HUC 12 watersheds combined.*

All other species recorded in the study exhibited QMDs between 8 inches and 14 inches (Figure 22).

QMD can assist land managers in developing effective strategies for forest management, including the scheduling of Timber Stand Improvement (e.g., TSI thinning) and timber harvest. As an example, consider the QMD of black walnut (the state's most commercially valuable timber species), which was found to be 13 inches for this study (Figure 23). This indicates that black walnut trees are generally at a size that would receive the greatest benefit from a release. Releases are commonly in the form of TSI practices, where adjacent, competing, less-desirable tree species are removed to enhance the growth of desired specimens.

The QMD of black walnut was found to be greatest in the Cedar Creek HUC 12 watershed (15 inches) (Figure 24).

## Categorization of overstory species according to timber value

It is important to consider tree species composition from a commercial view point. Therefore, in consultation with Dave Bruton (Kansas Forest Service District

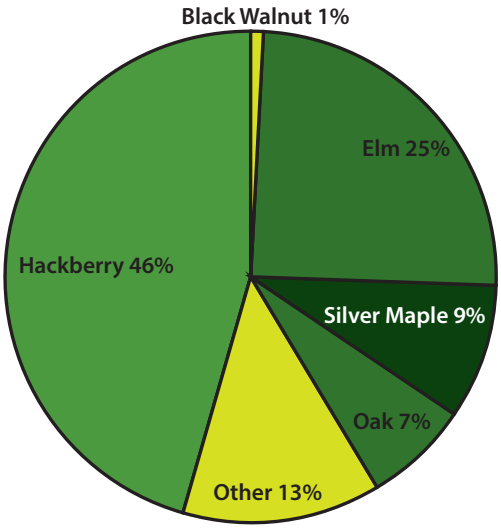


**Figure 21.** *Regeneration per acre (RA) composition by species for main stem Delaware River.*

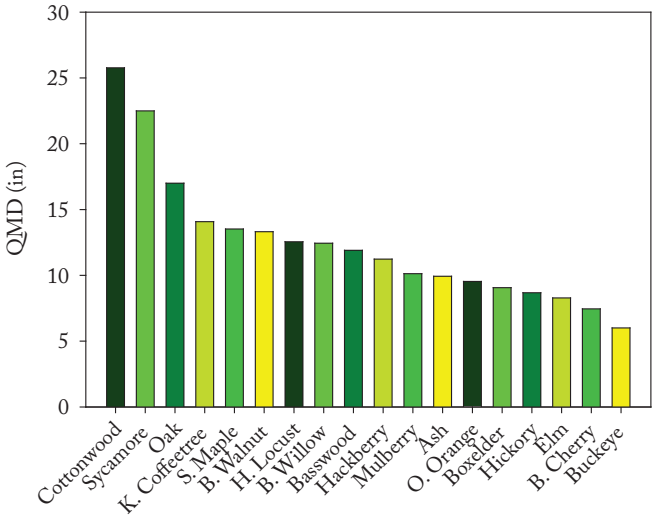


**Figure 22.** *Quadratic mean diameter (QMD) for select species documented in assessment.*

Forester), the species recorded in the study were categorized into three groups, based on the timber market value. Group 1 (high value) was composed of all oaks and walnut. Group 2 (moderate value) was composed of ash, black cherry, cottonwood, hackberry, hickory, and silver maple. Group 3 (low value) was composed of all other species.

Within all HUC 12 watersheds and along the main stem of the Delaware River, both BA and TA were heavily dominated by species value groups 2 and 3 (Figures 25 and 26). For the HUC 12 watersheds, Species value group 1 BA was greatest within Negro Creek and Otter Creek watersheds (52 square feet), and lowest within Little Grasshopper Creek (22 square feet) (Figure 25). It is of note that Little Grasshopper also exhibited the highest species value group 3 (lowest-value) BA (83 square feet) of the assessment. The main

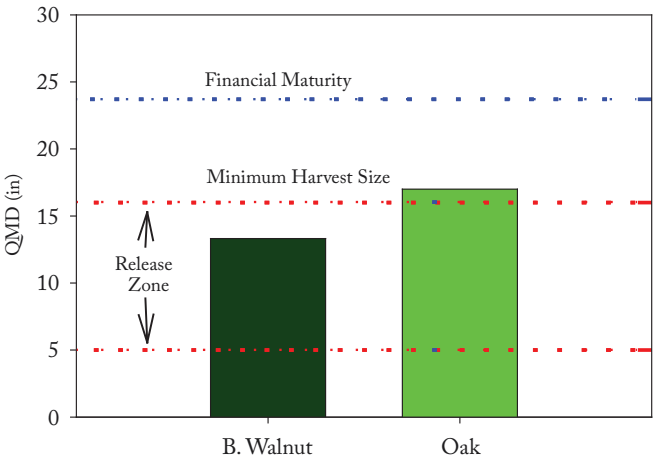


**Figure 23.** *Black walnut and oak quadratic mean diameter for assessed areas.*

**Table 5.** *Top three species (rank) that comprise regeneration (seedlings and saplings combined) by watershed.*

| | Watershed | #1 Species (% of Total) | #2 Species (% of Total) | #3 Species (% of Total) |
|---|---|---|---|---|
| RA | Delaware River | Hackberry (46) | Cottonwood (25) | S. Maple (9) |
| | Cedar Creek | Hackberry (61) | Elm (29) | H. Locust (4) |
| | Muddy Creek | Hackberry (70) | Elm (9) | Ash (7) |
| | Grasshopper Creek | Hackberry (42) | B. Cherry (15) | Elm (13) |
| | Otter Creek | Hackberry (55) | Elm (19) | Ash (9) |
| | L. Grasshopper Creek | Hackberry (78) | Elm (14) | H. Locust (4) |
| | Negro Creek | Hackberry (79) | Buckeye (11) | Elm (3) |
| | Straight Creek | Hackberry (49) | Elm (32) | Ash (6) |
| | Banner Creek | Hickory (28) | Hackberry (26) | Elm (8) |

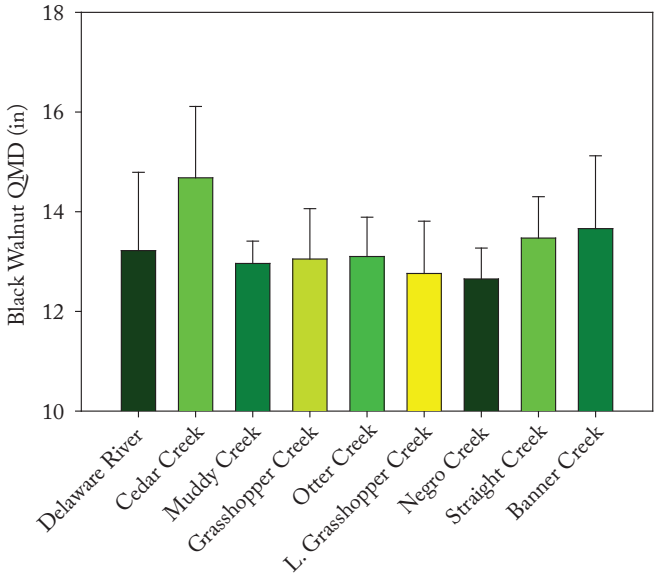


**Figure 24.** *Black walnut quadratic mean diameter (QMD) by HUC 12 watershed and main stem Delaware River.*

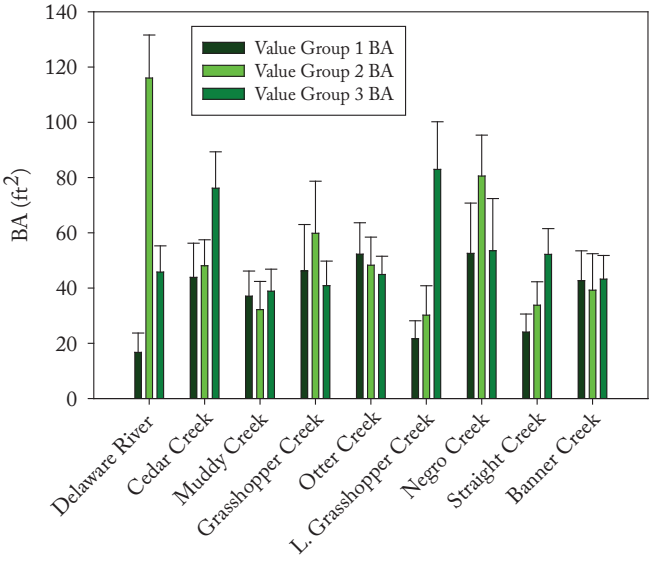


**Figure 25.** *Basal area per acre (BA) by species value group.*

stem of the Delaware River exhibited a mean species value group 1 BA of 17 square feet, which was less than that of any HUC 12 watershed.

For the HUC 12 watersheds, species value group 1 TA was greatest within Negro Creek (60) and lowest within the Little Grasshopper Creek watershed (25) (Figure 26). It is of note that Little Grasshopper also had the most species value group 3 (lowest-value) TA (147) of the assessment. The main stem of the Delaware River exhibited a mean species value group 1 TA of 16, which was less than that of any HUC 12 watershed.

## Categorization of regeneration species according to timber value

Compared to both BA and TA, RA was clearly dominated by species value group 2 (Figure 27). Value group 1 represented no greater than 7 percent of the total RA within any HUC 12 watershed, or along the main stem of the Delaware River. Within the HUC 12 watersheds, value group 1 RA was greatest in Banner Creek (222), and lowest within Little Grasshopper (31). Little Grasshopper was also found to have the lowest value group 1 BA and TA of any HUC 12 (Figures 25 and 26). The main stem of the Delaware River exhibited a mean of 241 for species value group 1, greater than that of any assessed HUC 12. This is interesting, because the main stem of the Delaware River had lower mean BA and TA for value group 1 species than any assessed HUC 12.

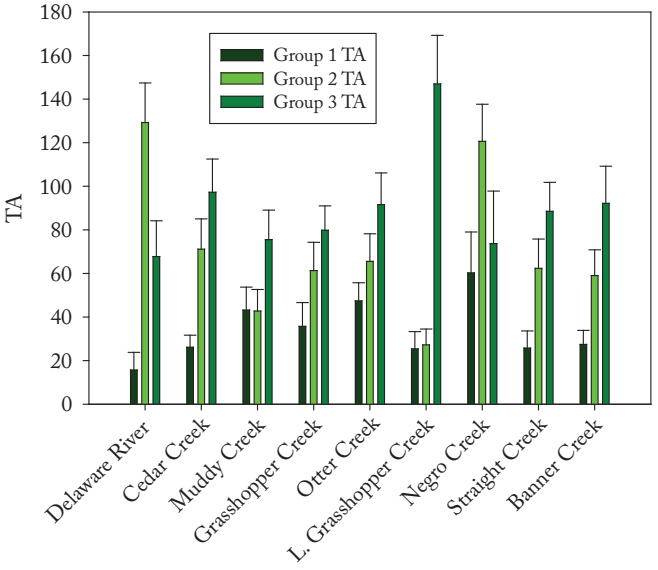


**Figure 26.** *Trees per acre (TA) by species value group.*

## Qualitative data

Livestock use (e.g., manure, trails, visible livestock) within plots ranged between 0 percent and 37 percent, and was not as prevalent within current assessment field plots as other forest assessments performed within Kansas (e.g., Tuttle Creek riparian forest assessment). An exception would be Banner Creek, where 72 percent of field plots had evidence of livestock use (the highest of the assessment) (Table 6). Livestock evidence was not recorded at all within Cedar Creek, Grasshopper Creek,

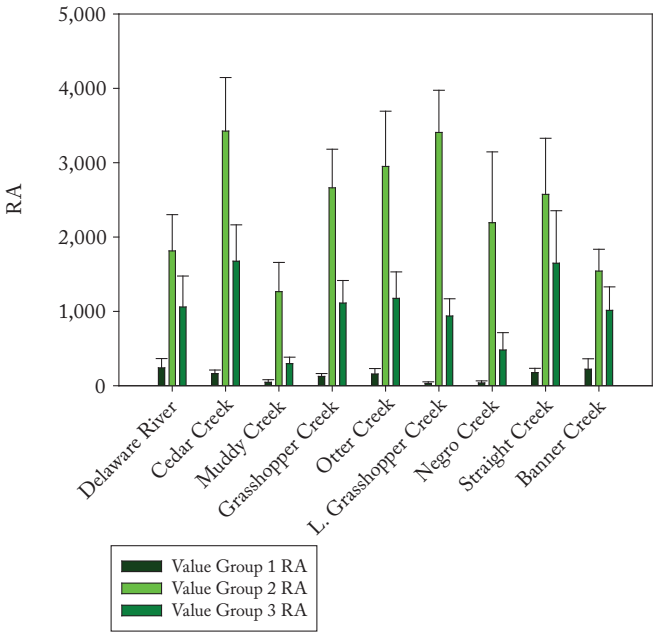


**Figure 27.** *Watershed RA by species value group.*

and Negro Creek HUC 12 watersheds, as well as along the main stem of the Delaware River.

Forest management was most prevalent within the Negro Creek watershed, where 77 percent of field plots exhibited some evidence of management (Table 6). It is of note that Negro Creek also exhibited the greatest BA and TA for species of value group 1 for any watershed. Within the HUC 12 watersheds, Grasshopper Creek exhibited the least amount of forest management, only being recorded within 5 percent of field plots. The only watershed where forest management was not evidenced at all was along the main stem of the Delaware River.

While in plots, foresters classified the land use present beyond the first ACW into three groups: forest, grass, or row-crop. Because all field plots were performed in areas identified by GIS as forest in need of protection, it was not surprising that forest was the predominant land use within the 2ACW area beyond plots (Table 6). An exception was the main stem of the Delaware, where cropland was the land use for 70 percent of the 2ACW inventory plots (Table 6).

**Table 6.** *Qualitative Plot Data*

| | | % Plots with | | % Plot Second ACW Land Use | | |
|---|---|---|---|---|---|---|
| *Watershed* | *# Plots* | *Livestock* | *Forest Management* | *Forest* | *Grass* | *Crop* |
| Delaware River | 23 | 0 | 0 | 30 | 0 | 70 |
| Cedar Creek | 20 | 0 | 30 | 75 | 5 | 20 |
| Muddy Creek | 16 | 19 | 44 | 88 | 12 | 0 |
| Grasshopper Creek | 20 | 0 | 5 | 85 | 5 | 10 |
| Otter Creek | 30 | 20 | 23 | 90 | 0 | 10 |
| L. Grasshopper Creek | 16 | 31 | 25 | 81 | 19 | 0 |
| Negro Creek | 13 | 0 | 77 | 100 | 0 | 0 |
| Straight Creek | 27 | 37 | 26 | 82 | 7 | 11 |
| Banner Creek | 18 | 72 | 11 | 72 | 28 | 0 |

# Summary and Conclusions

## Riparian forest functioning condition class

A majority of the riparian area within HUC 12 watersheds, as well as along the main stem of the Delaware River, was found to be comprised of *forest in need of establishment* and *forest in need of management*. In most cases, the combination of *forest in need of establishment* and *forest in need of management* acreage represented approximately two thirds of the total riparian area, which indicates that a majority of waterways lack an adequate wooded riparian corridor. The lone exception to this was the Banner Creek watershed, where the majority of the riparian acreage was classified as *forest in need of protection*.

Of all project focus areas, the main stem of the Delaware River exhibited the largest percentage of riparian acres classified as *forest in need of establishment*. With the exception of Banner Creek, HUC 12 riparian area acreages were fairly consistent in terms of classification — with approximately 40 to 50 percent of their riparian areas classified as *forest in need of establishment*, 20 to 30 percent classified as *forest in need of management*, and 30 to 40 percent classified as *forest in need of protection*.

## BA, TA, RA

Although 32 tree species were documented during the assessment, a handful of species consistently represented the majority of the BA and TA within HUC 12 watersheds. Of these, hackberry and black walnut were frequently the top two species making up both BA and TA in HUC 12 watersheds. For the main stem of the Delaware River, hackberry and silver maple were the two most prevalent species in terms of BA and TA. Also commonly documented (though generally not as prevalent as hackberry and black walnut) were elm, honeylocust, ash, Osage orange, and oak.

Within all HUC 12 watersheds, and along the main stem of the Delaware River, the ratio of BA to TA was consistently less than 1.

For all HUC 12 watersheds combined, as well as along the main stem of the Delaware River, two species alone (hackberry and elm) represented approximately 73 percent of the total recorded regeneration.

## Species value groups

The combination of species value groups 2 and 3 was found to heavily dominate both BA and TA within HUC 12 watersheds, as well as along the main stem of the Delaware River. In general, RA was clearly dominated by Group 2 species, with two species alone (hackberry and elm) representing the vast majority of RA within many watersheds. Species value Group 1 represented no greater than 7 percent of the total RA within any HUC 12 watershed, or along the main stem of the Delaware River.

It is of concern that Group 2 and Group 3 species dominate RA, as these lower-value species represent the next generation of forest. Riparian forests that consistently lack Group 1 species (i.e., oak, black walnut) have a tendency to be viewed as "wasteland" areas by landowners. Riparian forests with a larger component of Group 1 species may encourage more active forest management. Landowners who are actively engaged in managing their riparian woodlands may be less likely to be degrade (e.g., allow excessive cattle use) or remove these areas (e.g., convert to row crop).

## QMD

Cottonwood and sycamore represented the largest species documented during the assessment, based on QMD. Of interest to management potential is the QMD of species value Group 1, especially that of black walnut. For the overall assessment, the QMD of black walnut was found to be 13". This indicates that a majority of black walnut within assessed riparian areas is currently within the "zone of release" (Dave Bruton, District Forester, Kansas Forest Service, personal communication). This suggests crop-tree release and/or TSI efforts within the near future would be of great benefit to black walnut within assessed watersheds. These practices would reduce competition from less-desirable species, increase growth of desired species, and shorten the time needed to reach harvestable size and financial maturity.

## Qualitative data

With the exception of Banner Creek, evidence of cattle within riparian areas categorized at "forest in need of protection" was not very common (less than 37 percent). Riparian cattle evidence was completely absent within the plots of three HUC 12 watersheds (Cedar Creek, Grasshopper Creek, Negro Creek), as well as the main stem of the Delaware River. Evidence of forest management was documented more frequently. It should be noted that a majority of the observed forest management efforts were fairly old, and limited in scale (e.g., limited fuelwood cuttings). Current forest management activities (e.g., recent harvest, thinning,

tree marking) were rare. It is of note that forest management evidence was not recorded in any plot along the main stem of the Delaware River.

Within the riparian area of HUC 12 watersheds, forest was found to be the predominate landcover in the second ACW adjacent to the field assessment plots. Along the main stem of the Delaware River, however, the predominate land cover in the second ACW was found to be cropland. It is of note that the main stem Delaware River had the highest percentage of riparian area classified as *forest in need of establishment*.

# Management Recommendations

## Main stem Delaware River

Because a majority of the riparian area associated with the Delaware River was classified as *forest in need of protection*, it would seem logical that a large-scale effort to promote the establishment of riparian forest buffers would be beneficial. It should be noted, however, that the majority of streambanks adjacent to main stem Delaware River riparian areas (especially those classified as *forest in need of establishment*) are nearly vertical and can range from 20 to 30 feet in height. Thus, simply planting forest buffers will not immediately reduce streambank erosion. Therefore, if buffers are to be promoted, they need to occur in association with streambank stabilization practices.

Riparian forests along the main stem Delaware were found to be relatively narrow (70 percent of plots were adjacent to row-crop). Thus, widening narrow areas of existing forest to a width of at least 2 ACW should be encouraged. However, this will be challenging due to the value of this area for annual crop production, and current high commodity prices.

Because of existing streambank characteristics, it may be more effective to focus on the protection of existing riparian forest, rather than extensive tree planting for buffer establishment or augmentation of narrow areas.

Adequate cost-share programs exist for landowners interested in the practice of forest stand improvement, which not only acts to protect existing forest from degradation over a 10- to 15-year period, but also engages landowners in forest management, allows landowners to place a value on riparian areas through sustainable timber harvest, and creates wildlife habitat and associated recreational opportunities (e.g., hunting). The main stem Delaware River exhibited the greatest Group 1 species regeneration, yet some of the lowest BA and TA values for Group 1. Thus, forest stand improvement could act to hasten the recruitment of Group 1 regeneration into the overstory.

## HUC 12 watersheds

In general, 40 to 50 percent of riparian acreage within assessed HUC 12 watersheds was classified as forest in need of establishment. This relatively high percentage and the fact that these smaller sub-watersheds have channel dimensions and bank heights (especially in the headwater regions) that would allow riparian forest buffers to be an effective streambank stabilization tool, warrant a proactive effort to increase the adoption and installation of riparian forest buffers. It is recommended that buffers be implemented to a width of at least 2 ACW, and existing (i.e., *in need of management*) forests be widened to this 2 ACW mark. Thus focusing on HUC 12 watersheds for buffer implementation is recommended.

The lone exception, once again, would be the Banner Creek watershed, where only 25 percent of the riparian area was classified as forest in need of establishment. Here, buffer promotion should be secondary to protecting / enhancing existing riparian forest through practices such as forest stand improvement, and reducing livestock use.

Where channel dimensions are appropriate, cedar tree revetments may be used in combination with riparian forest buffers to stabilize highly erosive streambank sites.

Although the establishment of riparian forest buffers is a priority, enhancement and protection of existing riparian forest should not be ignored. Thus, a proactive effort to promote forest stand improvement practices would work to accomplish the following:

1. Increase the ratio of BA to TA, which was found to be less than 1 in all HUC 12 watersheds.
2. Reduce the abundance of shade tolerant, lower-value species such as hackberry and elm.
3. Create canopy gaps and encourage inter-planting of Group 1 trees, to reduce the heavy regeneration dominance of shade-tolerant, lower-value species such as hackberry and elm.
4. Release black walnut, to increase growth and reduce the time needed to reach financial maturity.

Although livestock evidence was not especially common within most assessed HUC 12s, focusing on riparian livestock exclusion in a number of watersheds (Banner, Muddy, Otter, Little Grasshopper and Straight Creeks) would be of benefit to riparian woodlands and water quality. Livestock exclusion should be considered a top priority to improve water quality and riparian forest health in Banner Creek, where livestock evidence was present on 72 percent of plots.

Although cost-share dollars are available to landowners for riparian forestry practices via programs such as CCRP and EQIP, creation of an alternative "program" and/or funding source may help to increase the adoption and success of riparian forestry practices. This program could be based on the ongoing Riparian Forest Buffer Restoration Initiative (a current Kansas Department of

Agriculture – Division of Conservation / Kansas Forest Service agreement).

The initiative provides adequate funding for landowners to hire a turnkey forestry contractor to perform buffer site preparation, tree planting, and three years of buffer maintenance (e.g., weed control). The initiative also provides a 10-year soil rental rate payment. The initiative has led to the successful establishment of forest buffers by taking the time/labor burden off of landowners, and ensuring that new plantings receive the needed three years of weed control. The initiative is currently limited in scope and is only available to landowners participating in large scale, rock-work streambank stabilization practices.

To offer this amount of funding to a broader range of landowners, it is recommended to work with entities such as WRAPS, FSA, and NRCS, to investigate whether WRAPS BMP dollars can be used to augment current CCRP / EQIP payments.

# A Note on Emerald Ash Borer

Emerald ash borer (EAB) is an exotic invasive beetle from eastern Russia and northeastern Asia that likely was brought to the United States in infested packing material. It was first detected in Kansas in 2012, in Wyandotte County. This beetle threatens our urban and riparian forests by killing North American ash species (*Fraxinus spp*.) and their cultivars. To date in the United States, emerald ash borer has destroyed more than 25 million ash trees. Ash was found to be a component of riparian forests within all assessed watersheds. Thus, all watersheds are threatened to lose a portion of their riparian timber composition in the near future, which may have implications for streambank stability, stream temperature, and wildlife habitat. Landowners may wish to remove a greater percentage of ash during Forest Stand Improvement and harvesting efforts, and may wish to discontinue using ash in riparian tree planting projects. More information on emerald ash borer can be found online at *www.kansasforests.org*.

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# Acknowledgments

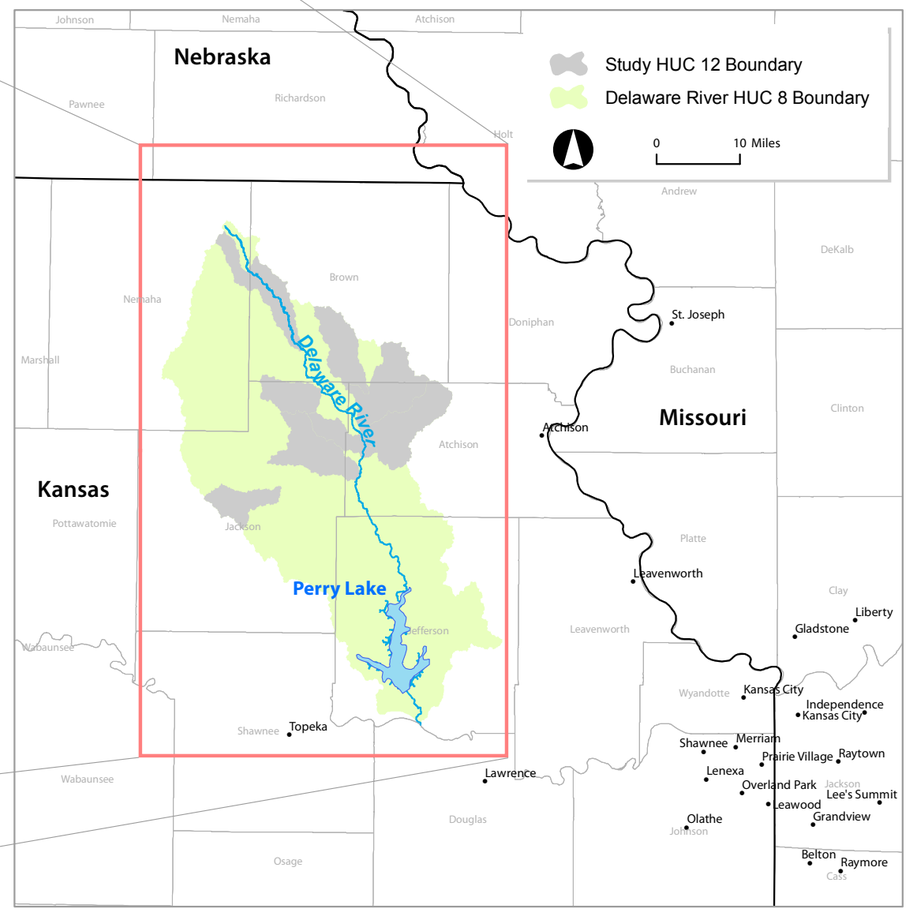
The authors would like to thank the many individuals whose assistance and dedication made this project possible: Bob Atchison, Dave Bruton, Rob Daniels, John Bond, Harold Klaege, Andy Lister, Jude Kastens, for assistance in methodology development; Marlene Bosworth, Gary Satter and the Delaware WRAPS stakeholder leadership team; Wally Leander, and the AT, BR, JA, NM County Conservation Districts for assistance with landowner contacts; Kory Nickell for assistance in field work; Darci Paull for overview map creation; and the many landowners that allowed data collection on their properties.

# Appendix A: Tree Species List

| Common Name | Scientific Name |
|---|---|
| Ash (includes Green, White) | *Fraxinus, spp.* |
| Black walnut | *Juglans nigra* |
| Cottonwood | *Populus deltoides* |
| Elm (includes American, Red) | *Ulmus, spp.* |
| Hackberry | *Celtis occidentalis* |
| Hickory (includes Mockernut, Bitternut, Shagbark) | *Carya, spp.* |
| Mulberry (includes Red, White) | *Morus, spp.* |
| Oak (includes Black, Bur, Chinkapin, N. Red, White) | *Quercus, spp.* |
| Osage Orange | *Maclura pomifera* |
| Silver Maple | *Acer saccharinum* |
| American Sycamore | *Platanus occidentalis* |
| *Basswood | *Tilia americana* |
| *Black Cherry | *Prunus serotina* |
| *Black Locust | *Robinia pseudoacacia* |
| *Black Willow | *Salix nigra* |
| *Boxelder | *Acer negundo* |
| *Buckeye (Western) | *Aesculus glabra* |
| *Catalpa | *Catalpa speciosa* |
| *Eastern Redcedar | *Juniperus virginiana* |
| *Honeylocust | *Gleditsia triacanthos* |
| *Kentucky Coffeetree | *Gymnocladus dioicus* |
| *Paw Paw | *Asimina triloba* |
| *Redbud | *Cercis canadensis* |

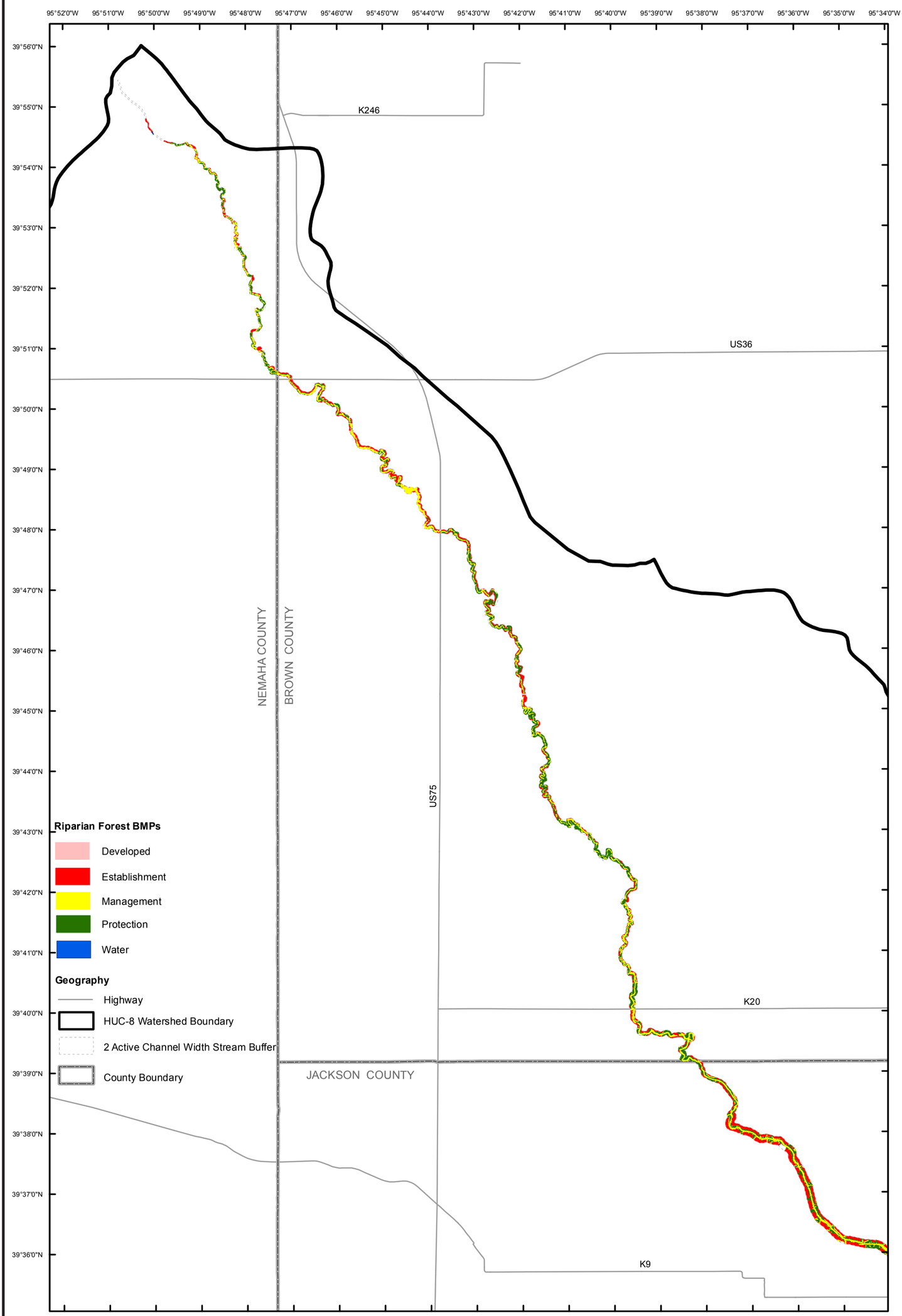
**Grouped as "Other"*

# Delaware River Riparian Forest Assessment Study Area


Sources:
USGS National Hydrography Dataset
U.S. Census Bureau

**Figure 1. Delaware River Riparian Forest Assessment Study Area**




Sources:
Forest Classification of 2008 NAIP Imagery
Normalized Difference Vegetation Index (NDVI)
Active Channel Width Determination of NHDPlus Streams
NE Kansas Regional Curves
Bing Imagery Identification of Risk Factors

**Riparian Forest Classification**
**Upper Main Stem Delaware River**
**Delaware River Basin**

0 10,000 Feet N

1 inch = 8,333 feet

**Figure 2. Riparian Forest Classification Upper Main Stem Delaware River Basin**

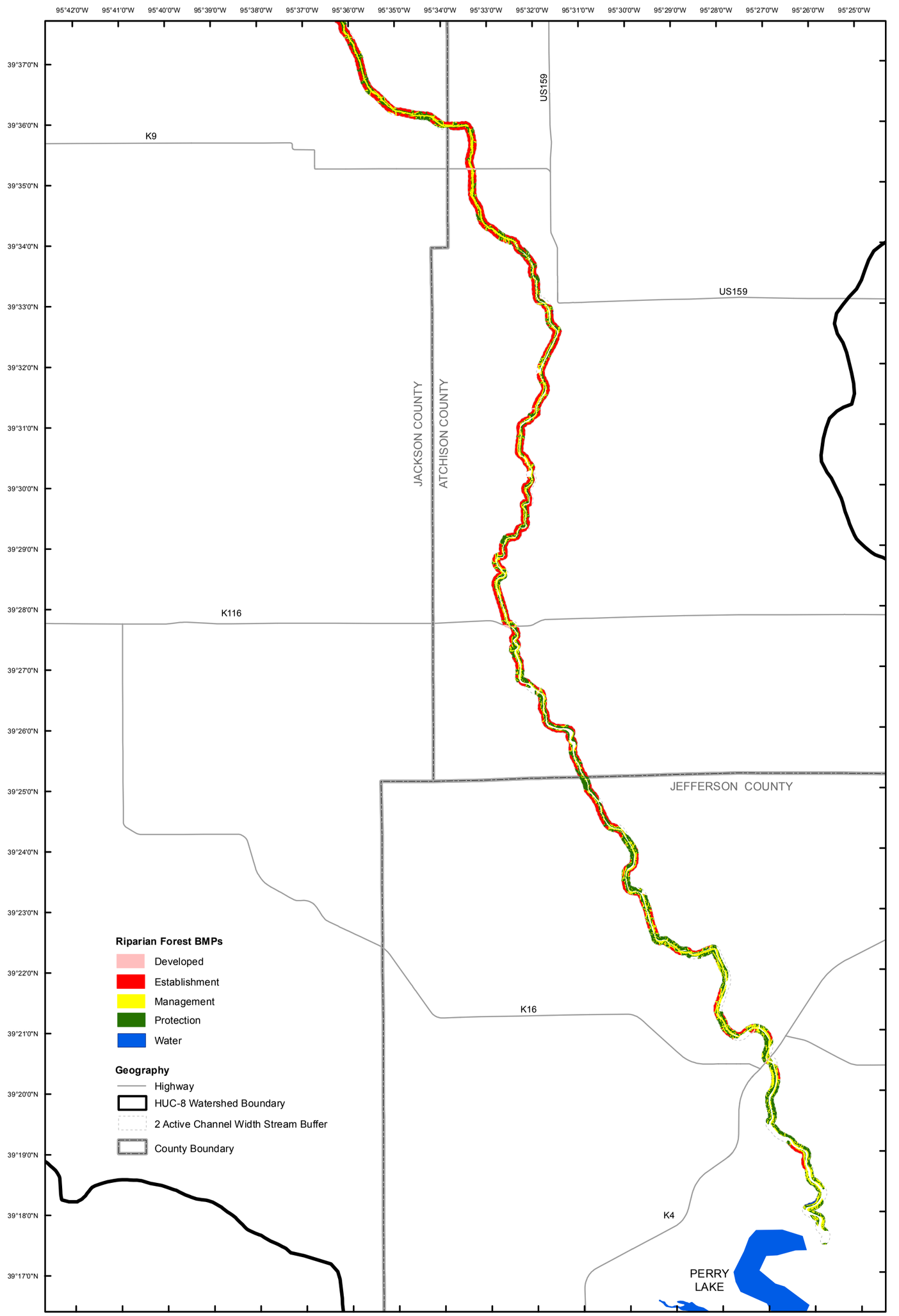



**Figure 3. Riparian Forest Analysis Area: Second Cow Creek Watershed**

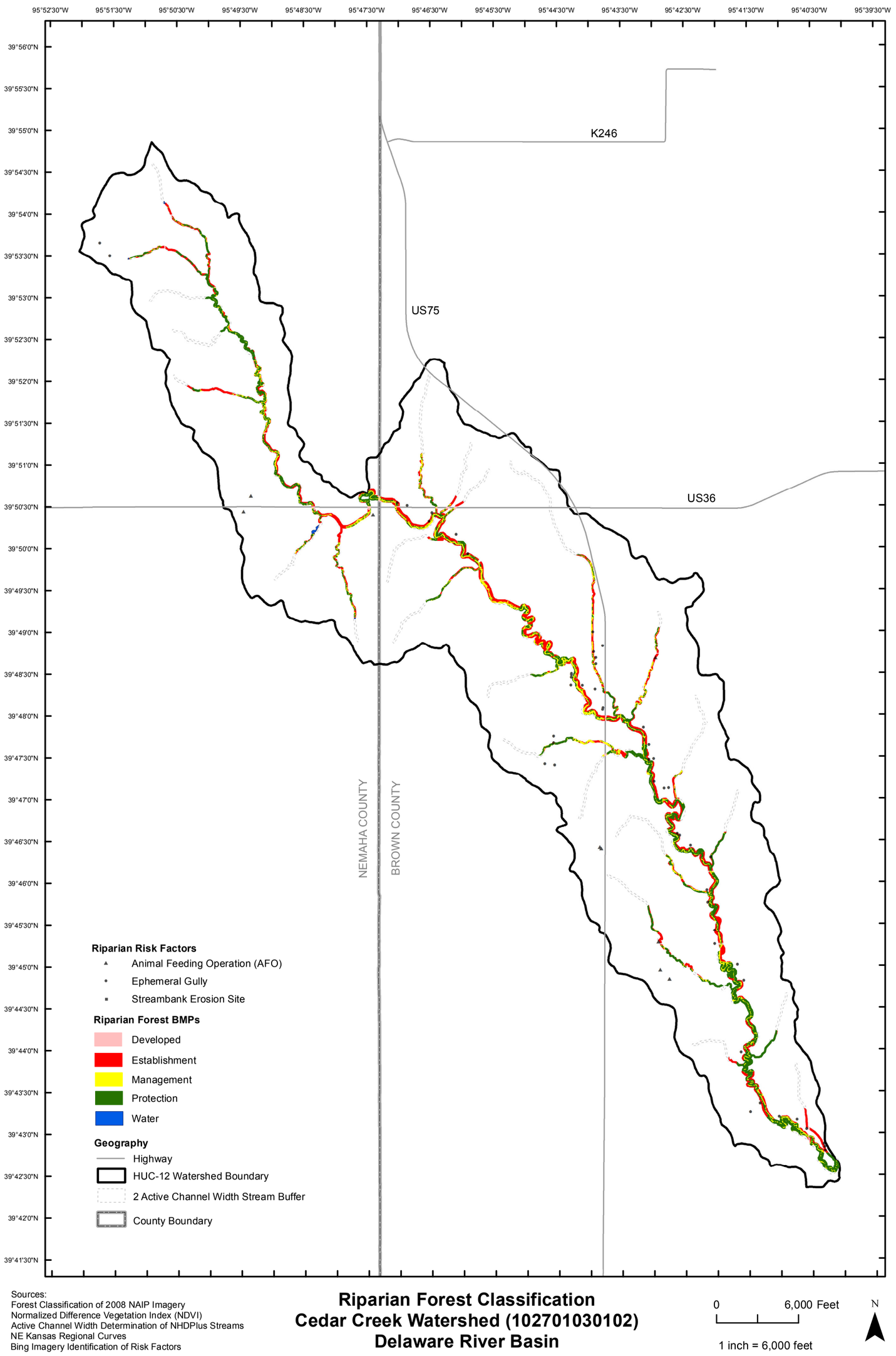
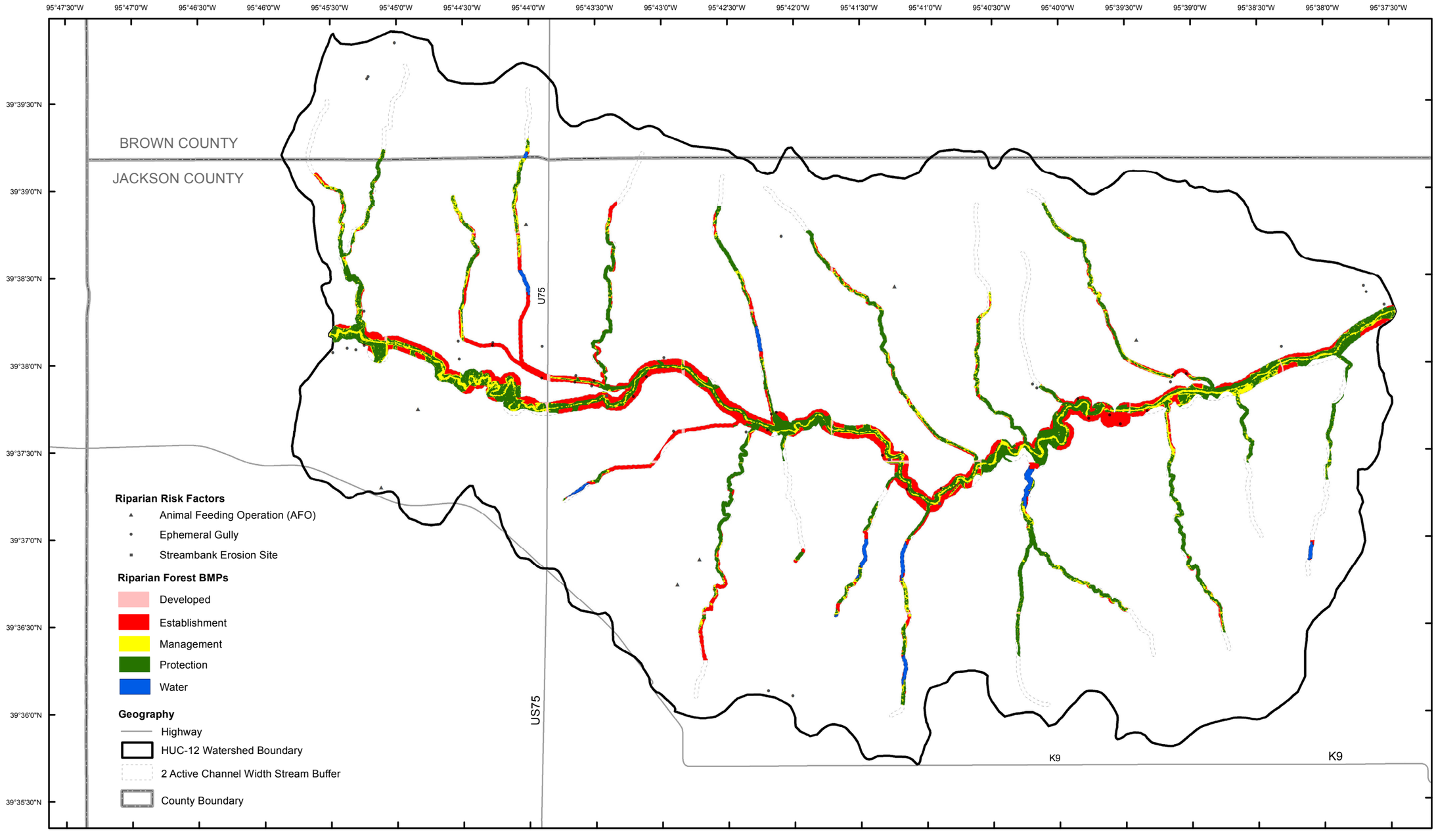



**Figure 4. Riparian Forest Classification Cedar Creek Watershed / Delaware River Basin**




Sources:
Forest Classification of 2008 NAIP Imagery
Normalized Difference Vegetation Index (NDVI)
Active Channel Width Determination of NHDPlus Streams
NE Kansas Regional Curves
Bing Imagery Identification of Risk Factors

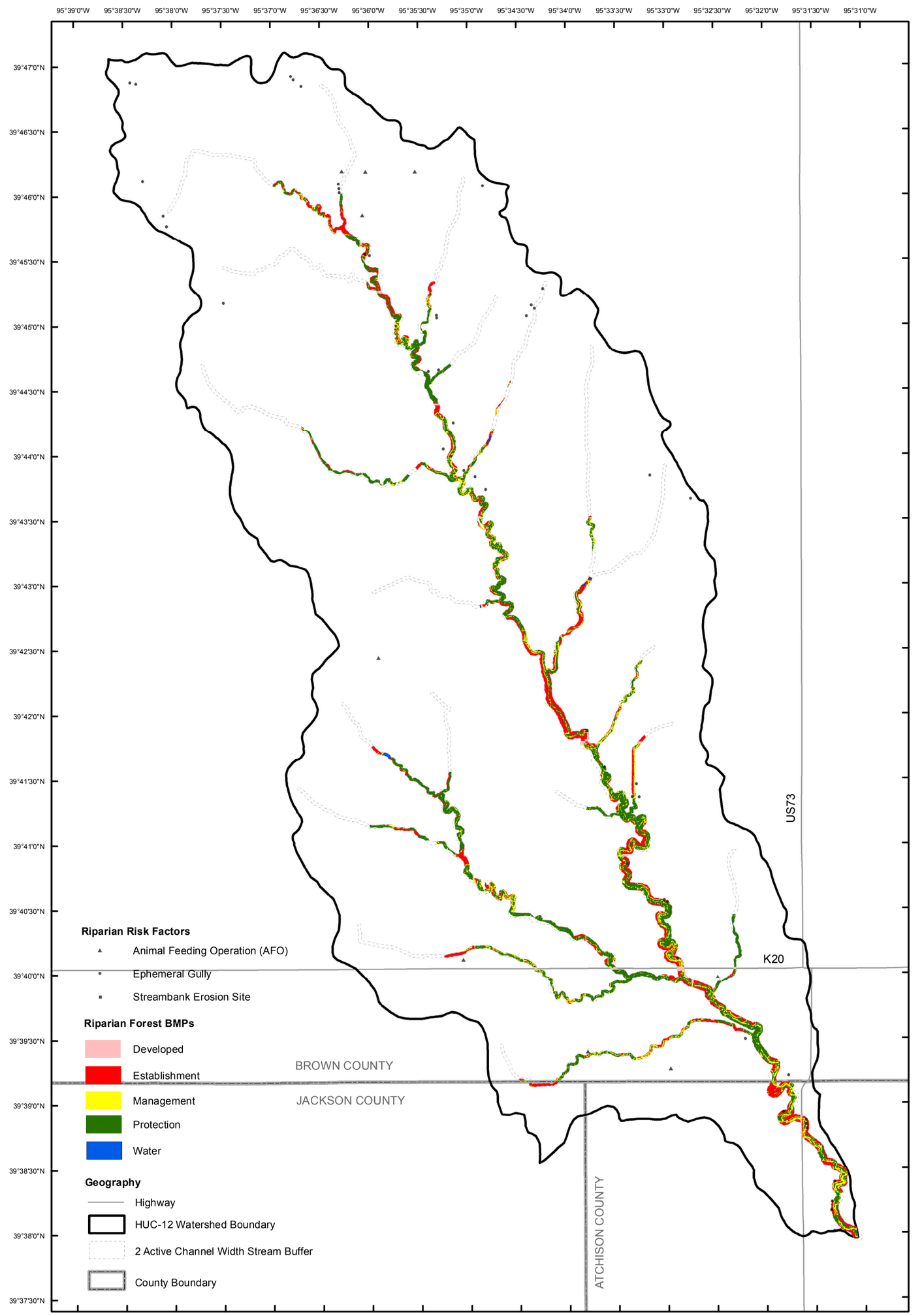
**Riparian Forest Classification**
**Muddy Creek Watershed (102701030109)**
**Delaware River Basin**

0 6,000 Feet

1 inch = 3,000 feet

N

**Figure 5. Riparian Forest Classification Muddy Creek Watershed / Delaware River Basin**




Sources:
Forest Classification of 2008 NAIP Imagery
Normalized Difference Vegetation Index (NDVI)
Active Channel Width Determination of NHDPlus Streams
NE Kansas Regional Curves
Bing Imagery Identification of Risk Factors

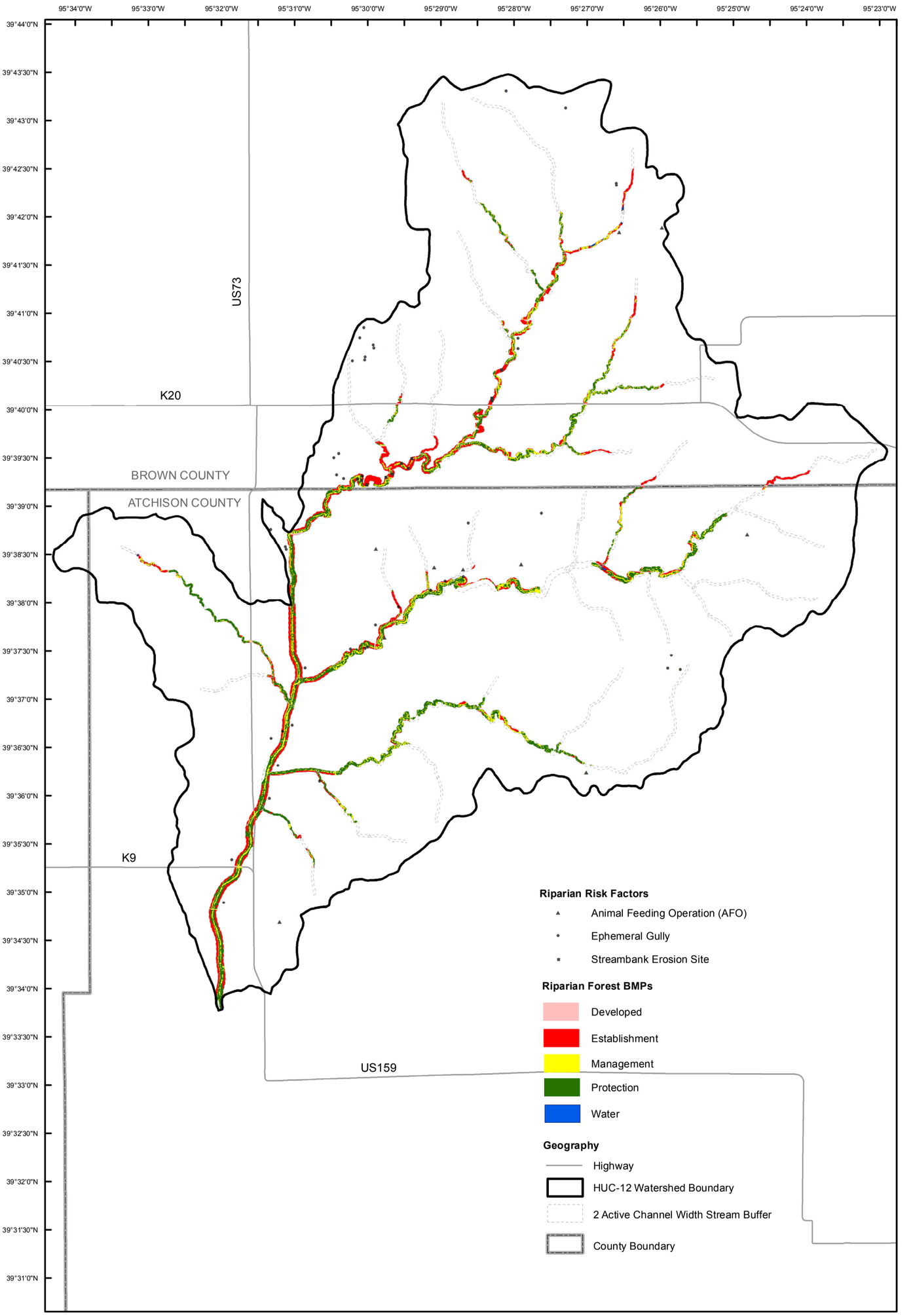
**Riparian Forest Classification**
**HW Grasshopper Watershed (102701030202)**
**Delaware River Basin**

0 4,000 Feet

1 inch = 4,000 feet

N

**Figure 6. Riparian Forest Classification HW Grasshopper Watershed / Delaware River Basin**




Sources:
Forest Classification of 2008 NAIP Imagery
Normalized Difference Vegetation Index (NDVI)
Active Channel Width Determination of NHDPlus Streams
NE Kansas Regional Curves
Bing Imagery Identification of Risk Factors

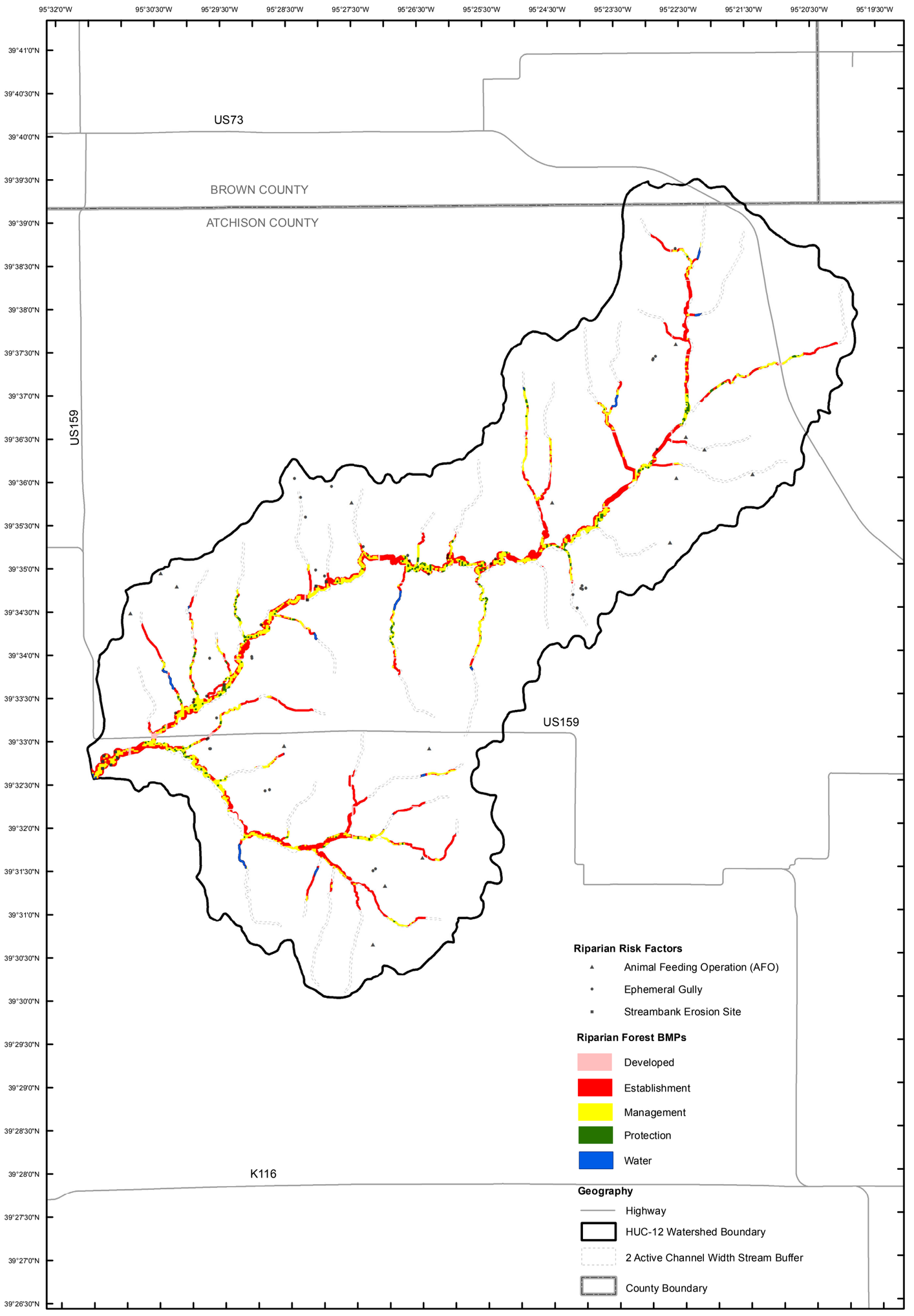
**Riparian Forest Classification**
**Outlet Grasshopper Cr. Watershed (102701030203)**
**Delaware River Basin**

0 5,400 Feet

1 inch = 5,400 feet

N

**Figure 7. Riparian Forest Classification Outlet Grasshopper Cr. Watershed / Delaware River Basin**



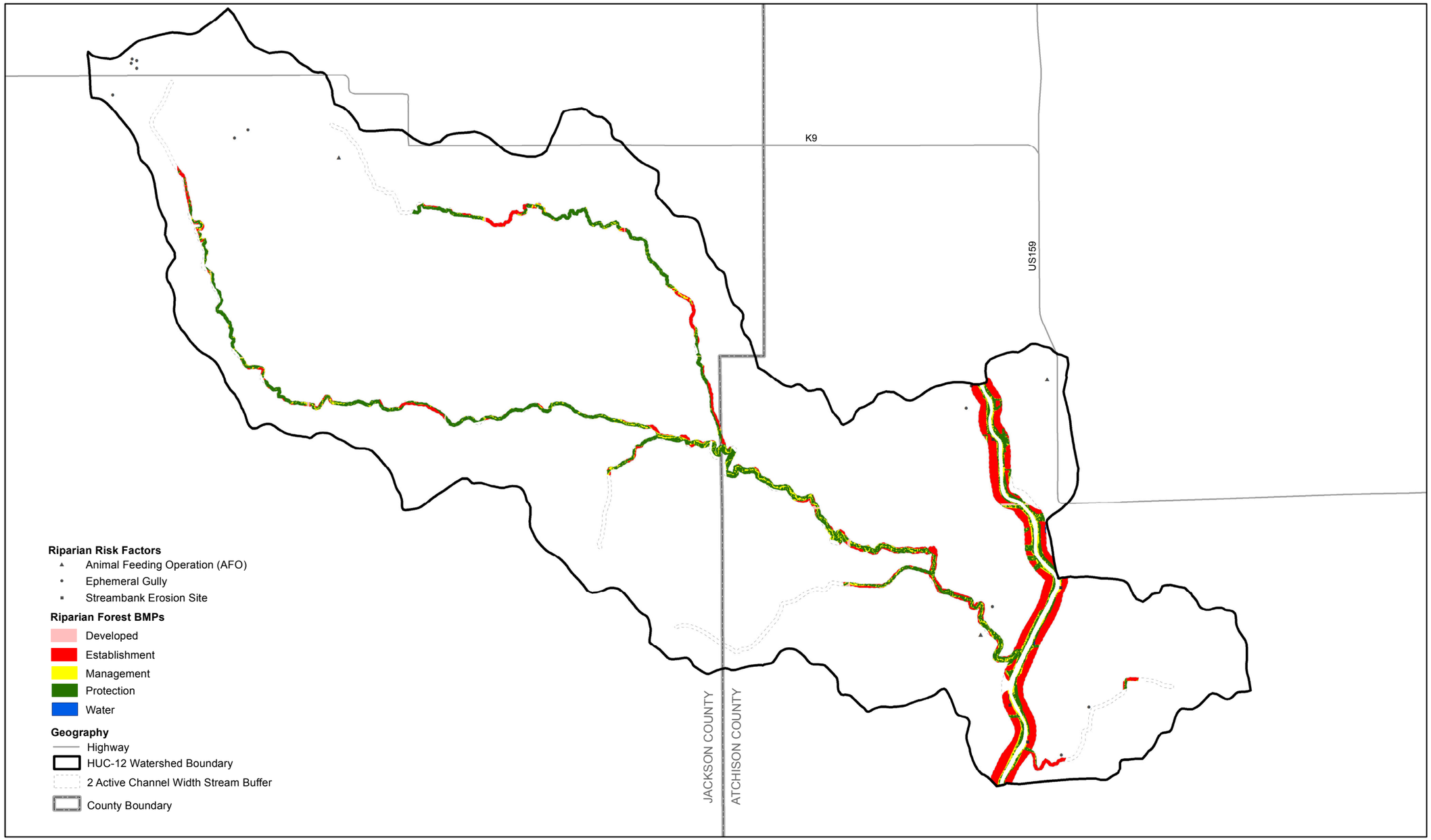

Sources:
Forest Classification of 2008 NAIP Imagery
Normalized Difference Vegetation Index (NDVI)
Active Channel Width Determination of NHDPlus Streams
NE Kansas Regional Curves
Bing Imagery Identification of Risk Factors

**Riparian Forest Classification**
**Little Grasshopper Cr. Watershed (102701030204)**
**Delaware River Basin**

0 6,000 Feet N

1 inch = 6,000 feet

**Figure 8. Riparian Forest Classification Little Grasshopper Cr. Watershed / Delaware River Basin**




Sources:
Forest Classification of 2008 NAIP Imagery
Normalized Difference Vegetation Index (NDVI)
Active Channel Width Determination of NHDPlus Streams
NE Kansas Regional Curves
Bing Imagery Identification of Risk Factors

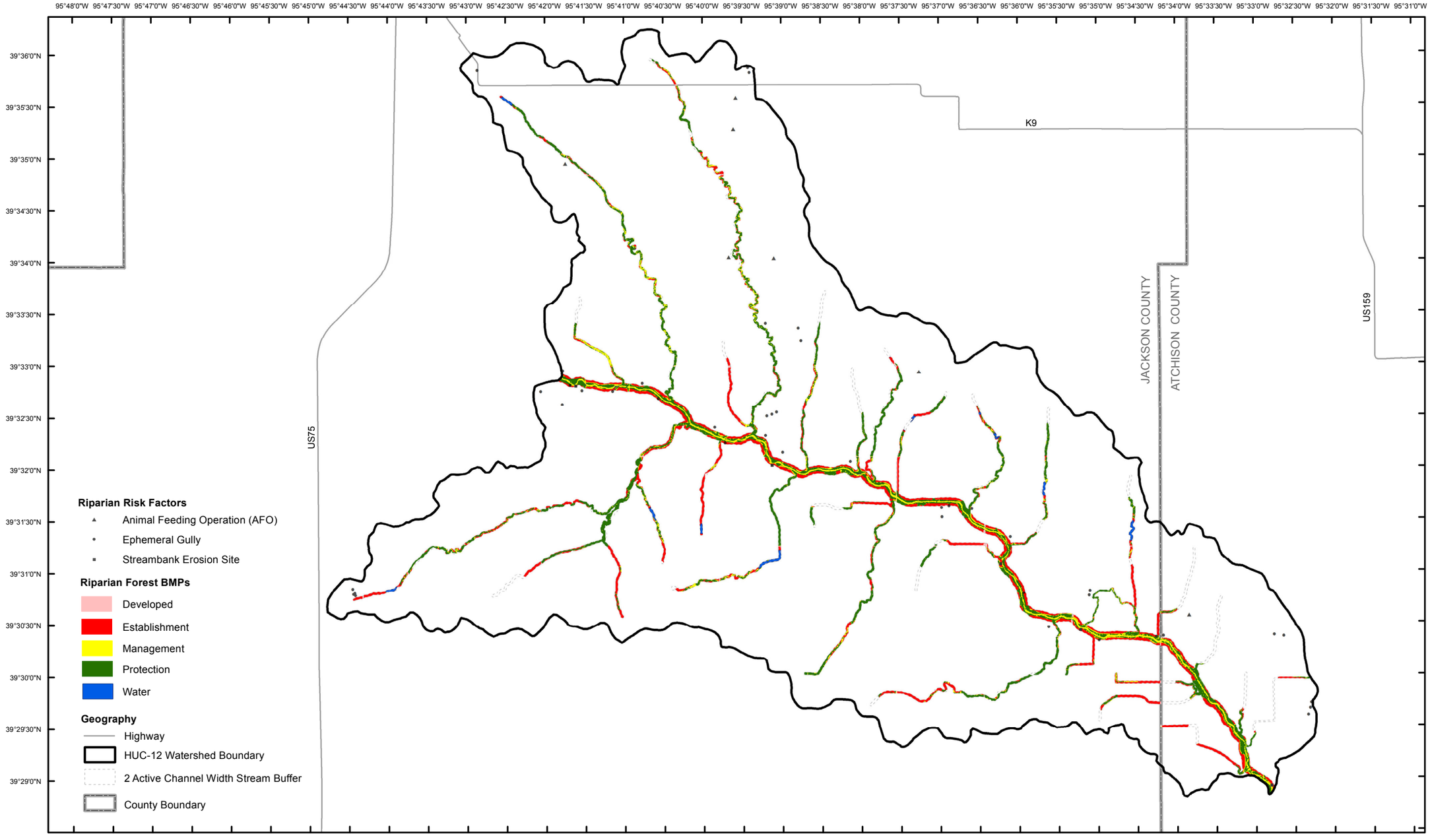
**Riparian Forest Classification**
**Negro Creek Watershed (102701030205)**
**Delaware River Basin**

0 6,000 Feet

1 inch = 3,333 feet

N

**Figure 9. Riparian Forest Classification Negro Creek Watershed / Delaware River Basin**




Sources:
Forest Classification of 2008 NAIP Imagery
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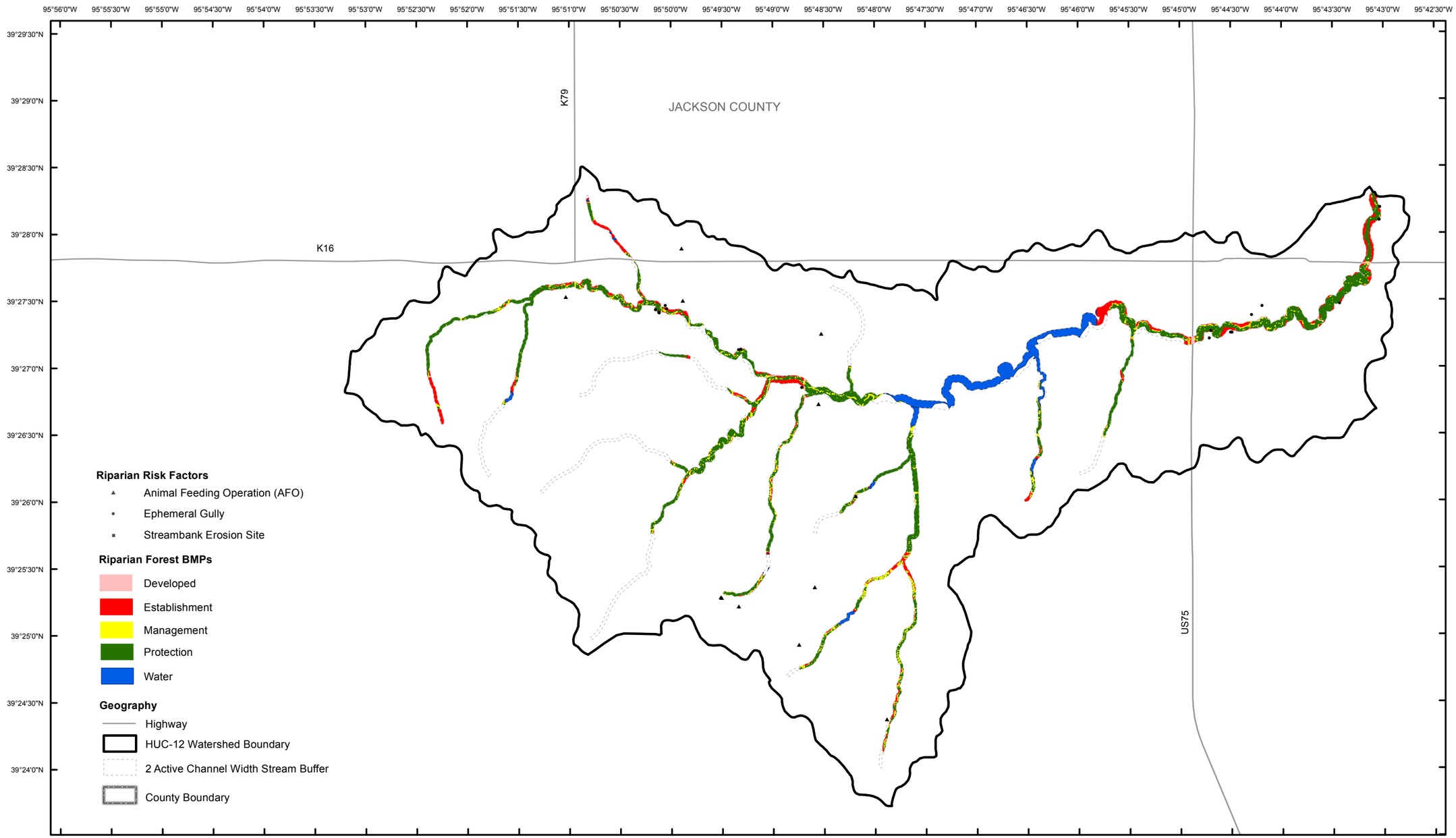
**Riparian Forest Classification**
**Outlet Straight Cr. Watershed (102701030303)**
**Delaware River Basin**

**Figure 10. Riparian Forest Classification Outlet Straight Cr. Watershed / Delaware River Basin**




Sources:
Forest Classification of 2008 NAIP Imagery
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Active Channel Width Determination of NHDPlus Streams
NE Kansas Regional Curves
Bing Imagery Identification of Risk Factors

**Riparian Forest Classification**
**Banner Creek Watershed (102701030305)**
**Delaware River Basin**

0 8,000 Feet
1 inch = 4,000 feet
N

**Figure 11. Riparian Forest Classification Banner Creek Watershed / Delaware River Basin**

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The Kansas Department of Health and Environment has provided financial assistance to this project through an EPA Section 319 Non-Point Source Pollution Control Grant (EPA Grant #C9007405 17).

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