Hinkson Creek Watershed Restoration Project

Collaborative Adaptive Management (CAM)

Physical Habitat GIS Data Development Technical Report

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Table of Contents

1 Executive Summary

As part of the Hinkson Creek Restoration project, we used GIS and Remote Sensing techniques to create basic information on the geomorphology of Hinkson Creek and the distribution of land cover within the valley and watershed. Basic input data, which included air photos, LiDAR, a stream center line, and fine spatial resolution land cover for about 75% of the watershed, were provided by partners (Boone County and City of Columbia). Staff from our partners, which included members of the Hinkson CAM Science team, viewed progress and provided input on interim products so that modifications could be made at regular intervals. The Hinkson Creek Restoration team partners (Boone County, City of Columbia, and University of Missouri) will use this information for a variety of initiatives, including selection of field data sampling sites and stand-alone analyses, such as the influence of land cover on the geomorphology and biology of the stream. The information is fine-resolution and will serve as input for analyses at multiple scales of resolution.

Data sets developed include: (1) stream centerline update, (2) spatially explicit sample points at 50 m (and multiples of 50 m) intervals on the centerline of the stream, (3) bankfull boundaries on the stream, (4) valley boundaries along the stream, (5) new fine spatial resolution land use/landcover (LULC) for 25% of the study area, (6) attribution of physical data to spatially specific points within the stream at multiple scales (i.e., LULC composition, bankfull width, valley width, slope, sinuosity, and distance to valley wall), (7) sand/gravel bar delineation, and (8) Hinkson Creek road crossings.

2 Data Development

2.1 Introduction

Missouri Resource Assessment Partnership (MoRAP) was contracted to create a number of geospatial datasets, requested by the Hinkson Collaborative Adaptive Management (CAM) Science Team, which would aid in the analysis of the physical, ecological, and geomorphic conditions of Hinkson Creek and its eight main tributaries. The study area extends from the headwaters of Hinkson Creek to its confluence with Perche Creek and includes the following watersheds: County House Branch, Flat Branch, Grindstone Creek, Hinkson Creek, Hominy Branch, Merideth Branch, Mill Creek, Nelson Creek, and Varnon Branch (Figure 1).

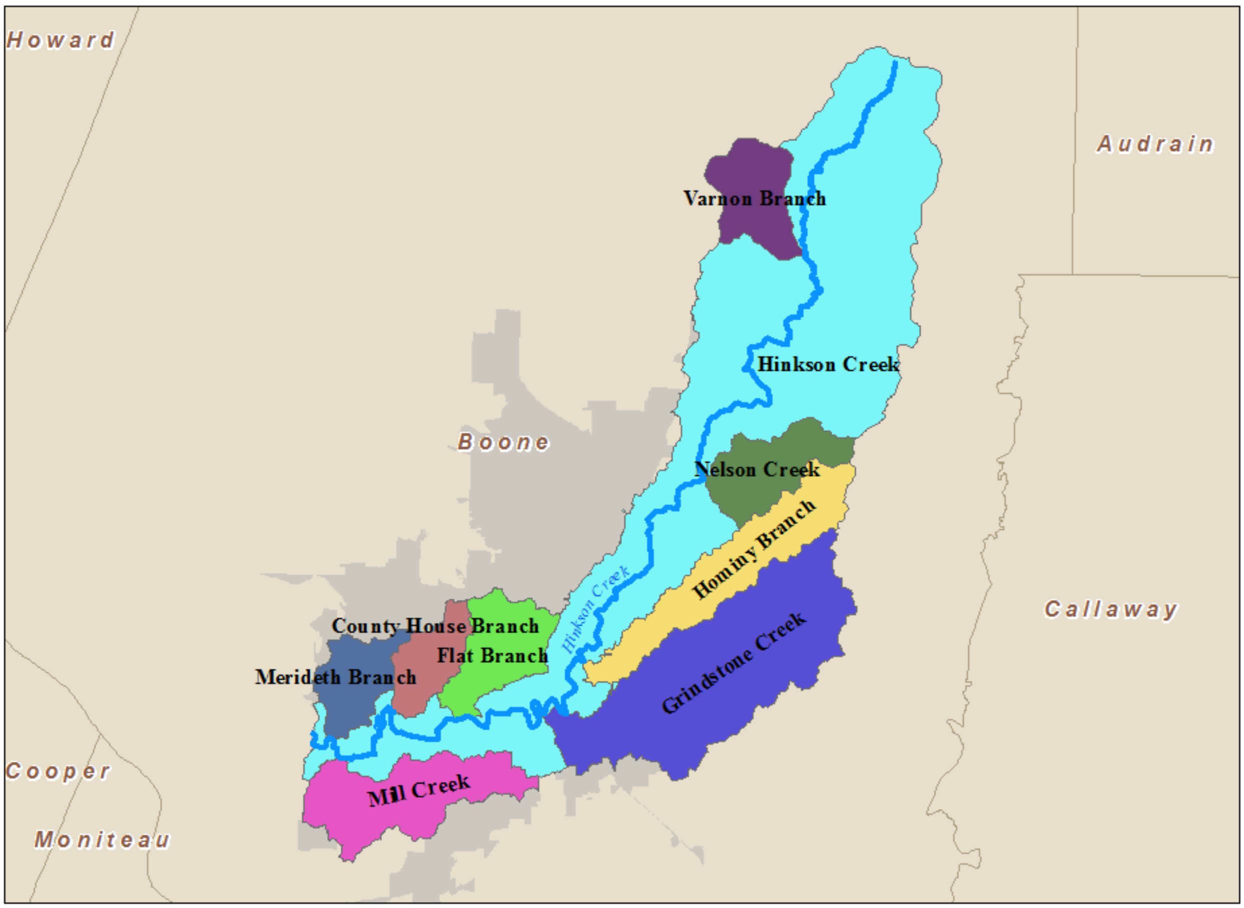

Figure 1. Watersheds that define the study area cover much of the Columbia metro area in central Boone County, Missouri.

2.2 Data Collaboration

Boone County and the City of Columbia shared critical geospatial data with MoRAP (Table 1). The shared data was used only for this project and a GIS data agreement was signed prior to MoRAP receiving data.

2.2.1 Data Used

Table 1. List of GIS data provided by partners to develop physical habitat products.

Data Name	Source	Description	Use
2009 1 foot DEM	Boone County	Digital elevation raster model derived from 2009 LiDAR data	Stream centerline update, bankfull, valley delineation, sand and gravel bar delineation, and % slope
2009 1 foot Hill Shade	Boone County	Hill shade raster derived from 2009 1 foot DEM	Stream centerline update, bankfull, valley delineation, sand and gravel bar delineation, and % slope
Hydro_lines	Boone County	Hydrography lines based on 2007 ortho-imagery	Source for Hinkson Creek centerline, though centerline was updated by MoRAP
2011 6 inch Leaf-off Aerial Photography	Boone County	6 inch, leaf-off, 3-band, true color, aerial photography	Stream centerline update, sand or gravel bar delineation, MoRAP LULC, Hinkson road crossings
2007 Natural Resources Inventory (NRI)	City of Columbia	6 class vector Land Use/Land Cover data set for City of Columbia	Used to determine LULC and impervious surface composition throughout study area and as training data source for MoRAP LULC of study area not covered by NRI
Watersheds	City of Columbia	Watershed vector layer used to define study area	Study area delineation and LULC statistics
2010 1 meter leaf-on NAIP	MSDIS	1 meter, leaf-on, 4-band, CIR, NAIP. Used original, non-compressed, quads	MoRAP LULC

2.3 Subject Matter Expert/Science Team Collaboration

Multiple meetings with subject matter experts Dr. Robb Jacobson - United States Geological Survey, Dr. Paul Blanchard – Missouri Department of Conservation, and Dr. Jason Hubbart – University of Missouri were conducted to identify GIS data products that would be useful to the overall Hinkson Creek restoration effort. Additionally, meetings with a wider audience were held to review GIS data during the data development process to ensure that the data was on track with what was requested and that all parties had similar expectations. By working in a collaborative manner and conducting meetings throughout the data development process, we were able to capitalize on expert information to improve the final products.

2.4 Data Development Methodologies

2.4.1 Study Area Extent

The study area consists of 57,338 acres in central Boone County, Missouri and is centered on Hinkson Creek. The watersheds included are: County House Branch, Flat Branch, Grindstone Creek, Hinkson Creek, Hominy Branch, Merideth Branch, Mill Creek, Nelson Creek, and Varnon Branch (see Figure 1).

2.4.2 Projection

The standard projection used for all datasets was Missouri State Plane Central, NAD 83, FIPS 2402, U.S. Survey feet. Distances in tables are feet unless otherwise noted.

2.4.3 Stream Centerline Update

The Hinkson Creek stream centerline (Hydro_Lines) provided by Boone County was based on 2007 ortho-imagery and upon visual inspection, discrepancies between the centerline and stream channel in the 2009 LiDAR hillshade (provided by Boone County) and the 2011, 6 inch, leaf-off aerial photography (provided by Boone County) were observed. As a result, MoRAP manually edited the Hinkson Creek stream centerline at a 1:1000 scale to reflect its location based on 2009 LiDAR hillshade and the 2011 imagery (Figure 2). Additionally, in some locations the 2009 LiDAR and 2011 imagery did not match due to bank and stream channel geomorphologic changes. In these situations, the stream centerline was modified to more closely correspond with LiDAR, which was used to develop several other datasets.

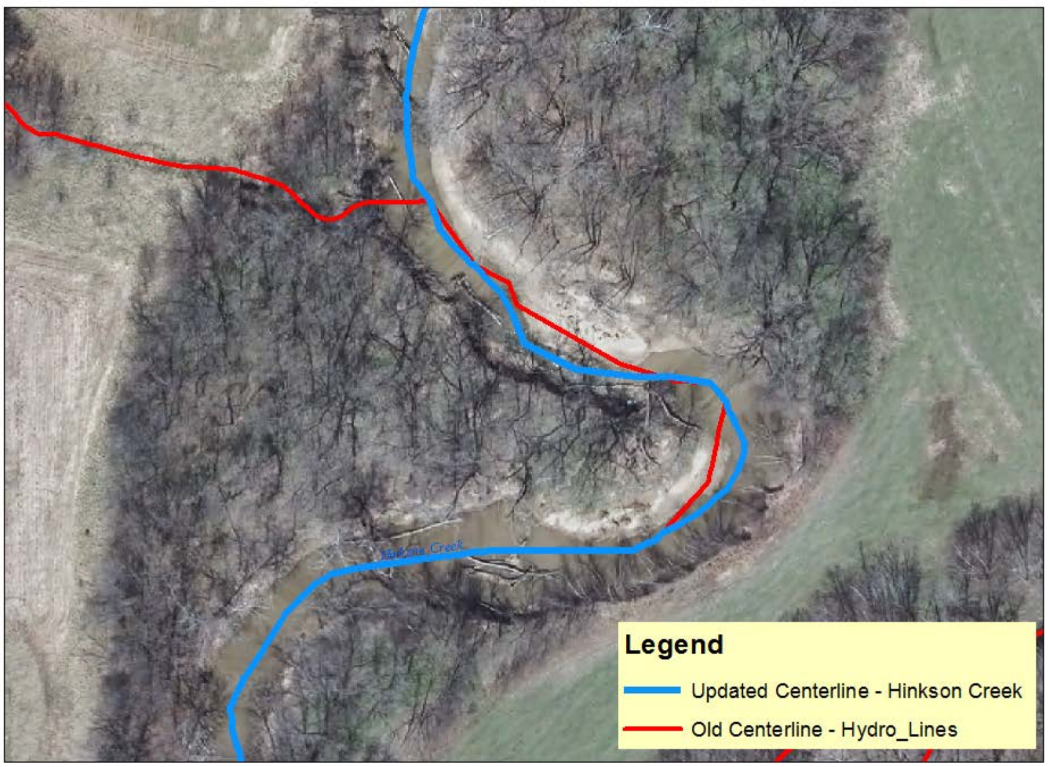

Figure 2. The centerline for Hinkson Creek was updated (blue) in places where 2007 line work (red) did not reflect stream conditions in 2011.

2.4.4 Top of Bank/Bankfull

A bankfull, or top of bank, dataset was created to identify the slope break between the narrower stream channel and the broader floodplain. Theoretically, this is the point at which water will flow over the banks into the surrounding floodplain. It should be noted that top of bank, as determined via GIS data, may not represent modern hydrologic bankfull width because of down cutting of the channel and limitations of the spatial resolution of the imagery. Hydrologic bankfull width is the channel width at bankfull discharge.

Several methods of delineating bankfull were explored, including the automated River Bathymetry Toolkit (RBT). The data for the study area proved to be too cumbersome for the RBT and the results on sample areas were not satisfactory. MoRAP was able to develop a straightforward and effective method of delineating bankfull. Image objects, or polygons, were created for a buffered extent of the Hinkson Creek centerline based on elevation and slope from the 2009 1 foot LiDAR DEM using Ecognition software. Polygons were generated to encompass textural, tonal, and statistical homogeneity in the data. Due to data file size restrictions, the study area was divided into 22 tiles and image objects were created for each tile. The image object tiles were merged together to create one file encompassing the total study area.

Polygons that delineated top of bank/bankfull were manually selected at a scale of 1:1000. All polygons between steep slope breaks at the top of banks on both sides of the creek were selected (Figure 3). Two foot elevation contours based on the LiDAR DEM were also used to aid in top of bank/bankfull delineation where one bank was higher than the other. This was especially useful in cases where one of the banks was a bluff or high valley wall with a continuous steep slope on one side of the creek. In these instances the elevation break point on the lower bank was used to determine where the bankfull line should be placed on the higher bank.

Image objects were based on raster data, resulting in squared and pixelated-looking polygons. To improve aesthetic appearances, a smoothing technique was applied to the polygons after bankfull delineation was complete (Figure 3 A and B). The polygon shapefile was smoothed in ArcMap using the PAEK smoothing algorithm with a 25 feet tolerance, and all other defaults were retained. This smoothing technique was also applied to valley boundaries and sand/gravel bar boundaries, which were also developed using image objects based on raster data.

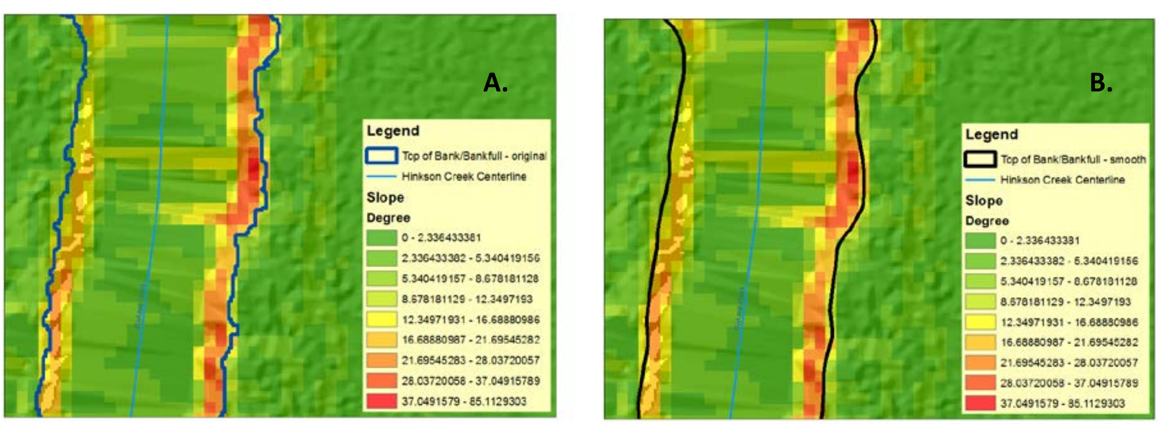

Figure 3. A) The original, pixel based polygon delineation of bankfull where the surrounding valley begins to slope down into stream channel. B) Smoothed bankfull polygon.

2.4.5 Valley Delineation

The initial Hinkson Creek valley delineation concept was designed to define the stream valley from bluff to bluff, including the entire bottomland area and all recent as well as historic floodplain terraces. After initial review by, and advice from, the subject matter experts, a second version of the valley was delineated based on modern constrictions to flow (e.g. levees, roads, etc.; Figure 4).

The constricted modern floodplain concept attempts to limit the delineation to the modern active floodplain and accounts for the impacts of modern structures such as levees, built-up roads, and bridge abutments. This delineation was somewhat subjective, but a single MoRAP staff member did all of the delineation to ensure consistency. Results were viewed and vetted by members of our subject matter expert panel.

The valley boundaries delineated in this project are distinct and different from the FEMA floodplain dataset. The FEMA dataset was developed to identify flood hazards and will be a useful tool in future analyses. The valley bottom datasets created here are not intended for use in flood hazard assessment.

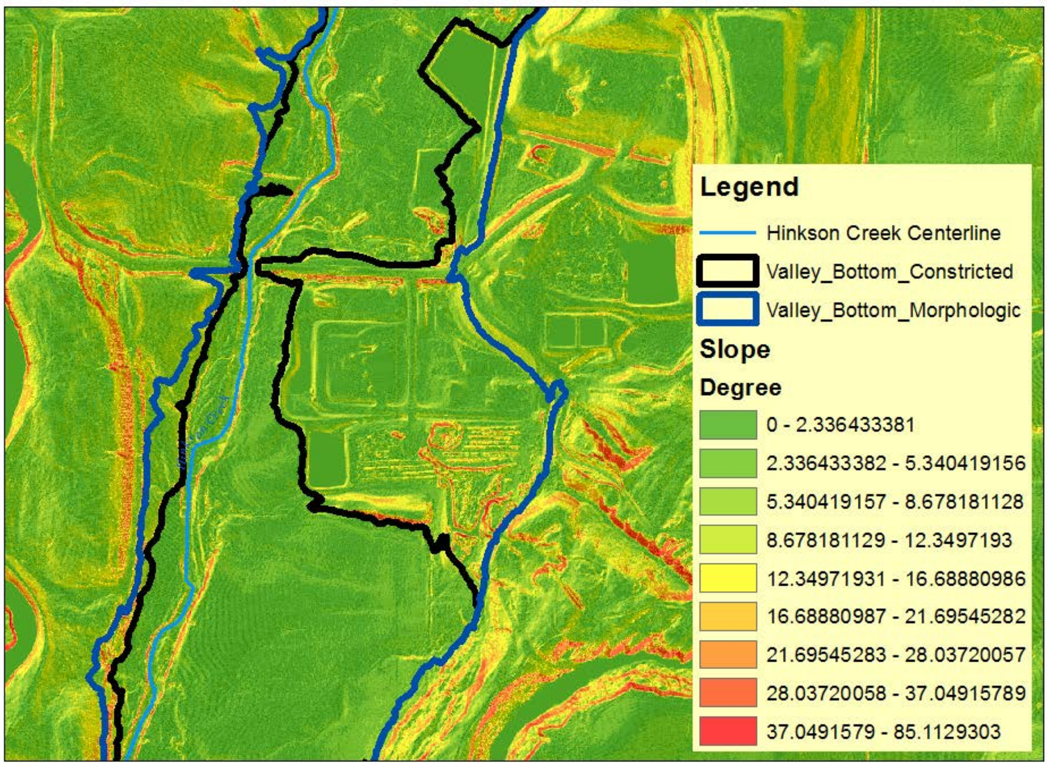

Figure 4. Location within the valley where constricted (black) valley is narrowed due to levees and elevated road beds. Morphological valley (blue) is considerably wider in some areas.

2.4.5.1 Morphological Valley Delineation

The morphological valley boundary broadly circumscribes the bottomland between bluffs (Figure 5). The same image objects created for top of bank/bankfull were used to delineate the morphological valley. Image objects that intersected with alluvial bottomland/valley soils defined by digital county soil surveys were initially selected. The valley boundary was refined using a subjective manual process, generally at a scale of 1:1000. The image objects were compared against the 2009 1 foot LiDAR hillshade and slope to identify the final boundary of the valley. Valley boundary identification was clear at bluff/bottomland intersections. However, a more subjective approach was often required in areas with more subtle valley slope breaks. In such cases, the valley boundary line was often drawn where incised lateral drainages on slopes intersected with smooth, flat valley bottoms.

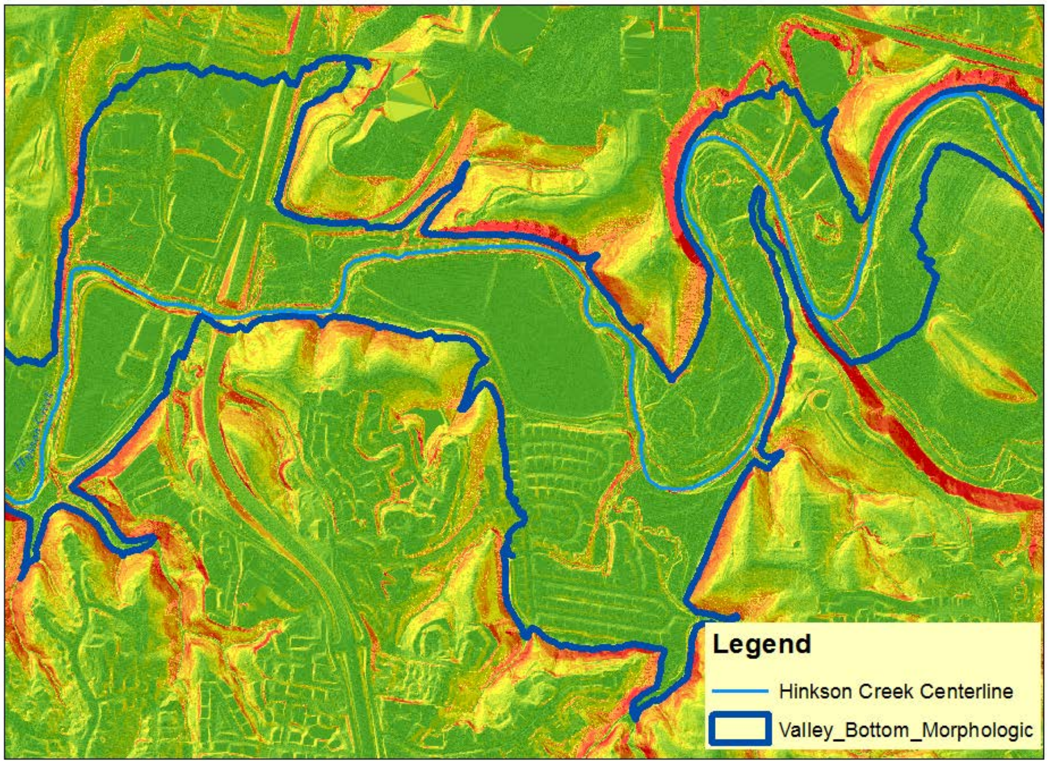

Figure 5. Morphological valley delineating bluff to bluff boundary.

2.4.5.2 Constricted Valley Delineation

The constricted valley is often defined by anthropomorphic built-up impedances, such as roads, bridges, trails, levees, and neighborhoods. In some areas without built-up impedances, the constricted valley boundary is drawn at gentle inflections in the landscape that may correspond with the boundary between modern versus older floodplain terrace soils. The same image objects generated for top of bank/bankfull and morphological valley boundary were used to delineate the constricted valley (Figure 6). This process was also a manual and subjective process that was completed at an average scale of 1:1000.

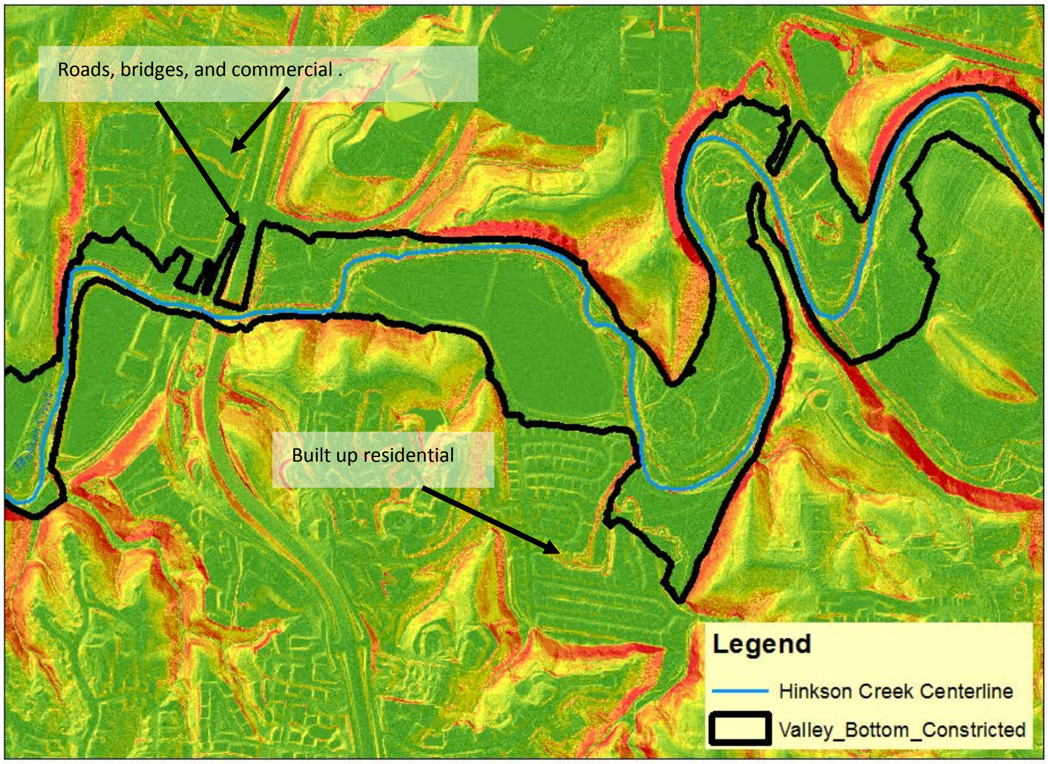

Figure 6. Valley is constricted due to roads, bridges, and built up residential and commercial properties.

2.4.6 Sand or Gravel Bar Delineation

Sand or gravel bars within Hinkson Creek channel were delineated based on 2011 6 inch, 3-band, true color, leaf-off aerial photography provided by Boone County (Figure 7). Image objects were generated based on the 2011 photography using Ecognition software. Due to data file size restrictions, the imagery was divided into seven tiles. Image objects, or polygons, were generated based on the textural and tonal homogeneity of the imagery. The image object tiles were merged into a single file for sand or gravel bar delineation. Polygons that circumscribed sand or gravel bars were manually selected and modified at a scale of 1:1000, as needed, by scanning the entire length of Hinkson Creek from the confluence to the headwaters. No distinction between sand versus gravel bars was possible due to limitations of the imagery. Accordingly, the resultant dataset is a record of sand or gravel bars that existed in the spring of 2011.

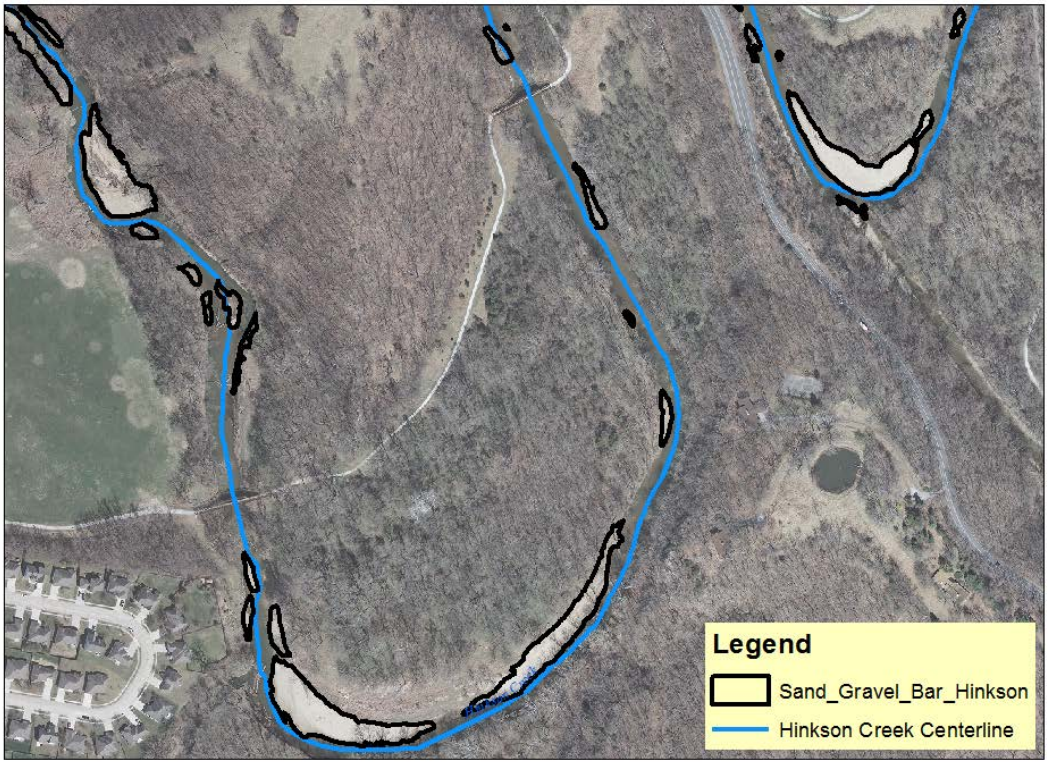

Figure 7. Sand or gravel bars were identified based on 2011 6 inch, 3-band, true color, leaf-off imagery.

2.4.7 Land Use/Landcover - LULC

Land Use/Landcover (LULC) data were used to determine the composition of vegetation and impervious surface within the study area. LULC from the City of Columbia's 2007 Natural Resources Inventory (NRI), a 6 class vector LULC based on 2007 6 inch, 4-band, leaf-on, aerial photography covered approximately 75% of the study area. The remaining 25%, mainly north of the city of Columbia, was not covered by high spatial resolution LULC. MoRAP developed a NRI-like LULC to fill in the gap (Figure 8).

The MoRAP NRI-like LULC is based on 2011 6 inch, 3-band, leaf-off aerial photography (provided by Boone County), 2010 1 meter, 4-band, leaf-on NAIP imagery, 2009 LiDAR DEM derivatives slope and aspect, and a LiDAR digital surface model (DSM). All datasets used in classification were resampled to 1 meter spatial resolution. A supervised classification approach was employed to map the 6 NRI LULC classes (forest, grass, impervious, sparsely vegetated, crop, and water). A total of 3,000 training samples from the NRI dataset, 500 per class, were used to classify and map LULC in raster format. Image objects were generated using Ecognition software based on the 2011 and 2010 imagery to approximate the shape and size of the NRI polygons. Each polygon was attributed with the majority LULC value based on the raster LULC dataset. The NRI and MoRAP NRI-like LULC vector datasets were merged together to create a seamless, high spatial resolution vector LULC dataset that covers over 99% of the study area (Figure 9). There were approximately 100 acres not covered by LULC due to lack of data at the time of classification.

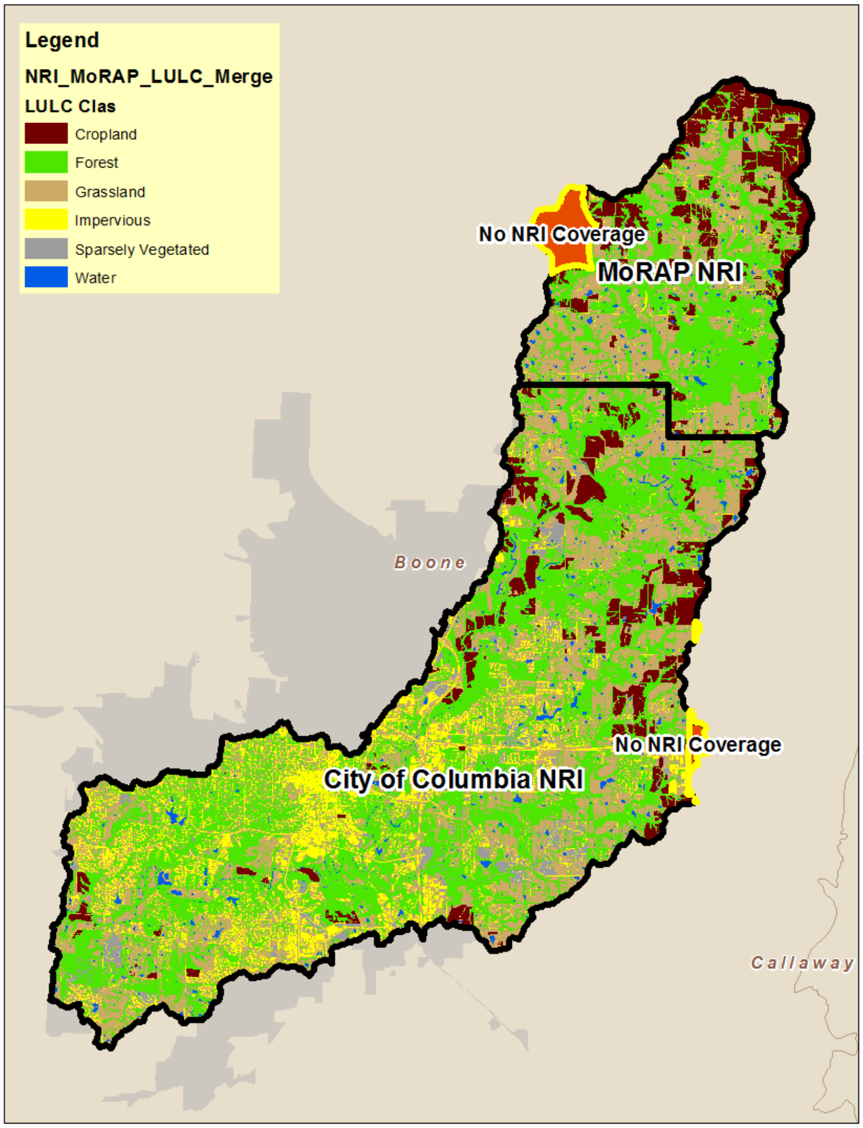

Figure 8. MoRAP created NRI-like LULC for the northern portion of the study area. The areas in red indicate where no LULC exists.

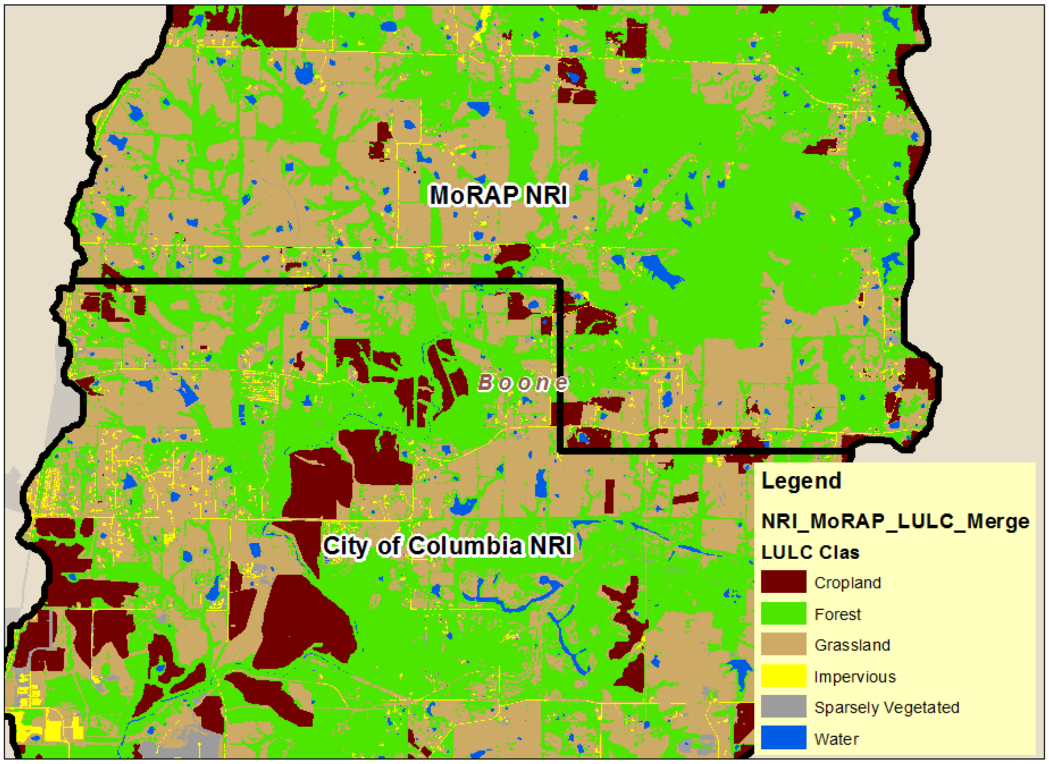

Figure 9. The addition of the MoRAP created LULC provided a virtually seamless LULC for the study area.

2.4.8 Stream Points

Points were generated along the Hinkson Creek centerline at 50 meter intervals to facilitate data summaries and on-the-ground sampling (Figure 10). Ground data will be collected at intervals defined by points generated here, and field data can be compared with GIS-generated data. Attributes applied to the points were percent slope, sinuosity, bankfull width, morphological and constricted valley width, and distance to valley wall. Summaries were provided at intervals of 50, 100, 250, 500, 1000, 2000, and 4000 meters. All points at an interval greater than 50 meters were based on the 50 meter points. Physical stream attributes at multiple scales allow fine- and broad-scale views of the stream. The unique identification number for each set of points begins at 0 at the confluence of Perche and Hinkson Creeks and increases incrementally upstream to the headwaters.

Figure 100. Shown are points at 50 meter intervals along the Hinkson Creek centerline, beginning at the confluence with Perche Creek. Physical attributes were summarized for these points (i.e. slope, sinuosity, bankfull width, valley width, etc.).

2.4.8.1 Percent Slope

Slope is a measure of stream gradient or steepness and was based on the surface water elevation of the stream at the time of LiDAR DEM (provided by Boone County) data acquisition, March 18 and 19, 2009. Average stream discharge during the period of data acquisition was 19 cubic feet per second (waterdata.usgs.gov). Percent slope between stream points along the centerline was calculated at all point intervals. Calculation of slope began at the confluence of Hinkson and Perche Creeks and ended at the headwaters. Slope was calculated by first extracting the elevation for each point from the LiDAR DEM, then calculating the elevation difference between the adjacent points to determine the rise value. The elevation difference was divided by the stream distance to produce a percent slope value.

% slope = (elevation difference/stream line distance) x 100

2.4.8.2 Sinuosity

Sinuosity is a measure that indicates the degree to which a stream meanders. It is the ratio between the stream distance and Euclidean, or straight-line, distance between two points. A value of 1 indicates a straight stream. As values increase a more sinuous, or meandering, stream is indicated (Figure 11). Sinuosity was calculated between points at all stream point intervals and began at the confluence of Hinkson and Perche Creeks and ended at the headwaters (Figure 12).

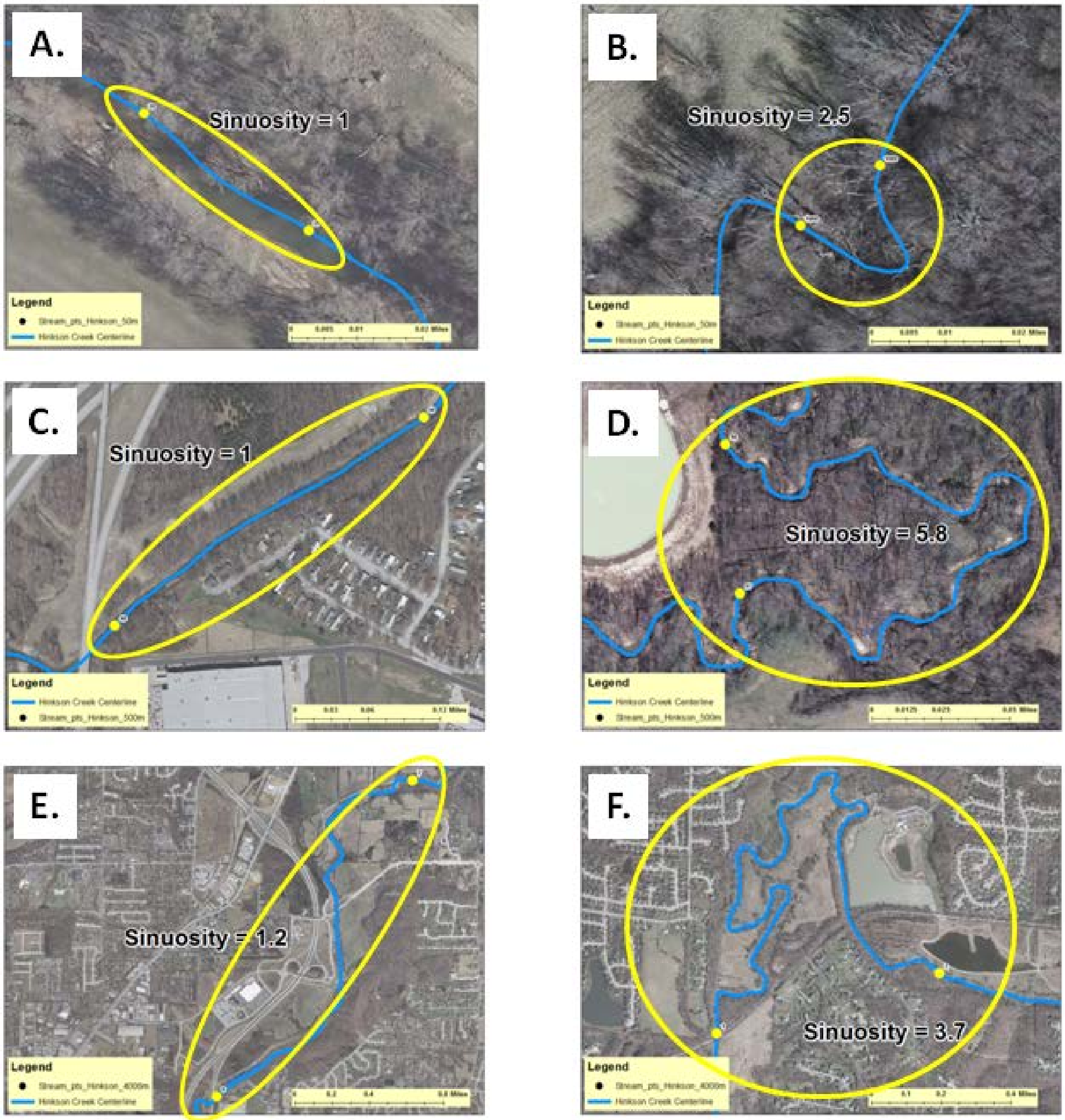

Figure 11. Shown is sinuosity at various scales. A) Sinuosity value of 1 between 50 meter points, indicating a straight section of the creek. B) Maximum sinuosity value of 2.5 within the 50 meter point dataset. C) Sinuosity value of 1 between 500 meter points. D) Maximum sinuosity value of 5.8 within the 500 meter point dataset. E) Sinuosity value of 1.2 between 4000 meter points. F) Maximum sinuosity value of 3.7 within the 4000 meter point dataset.

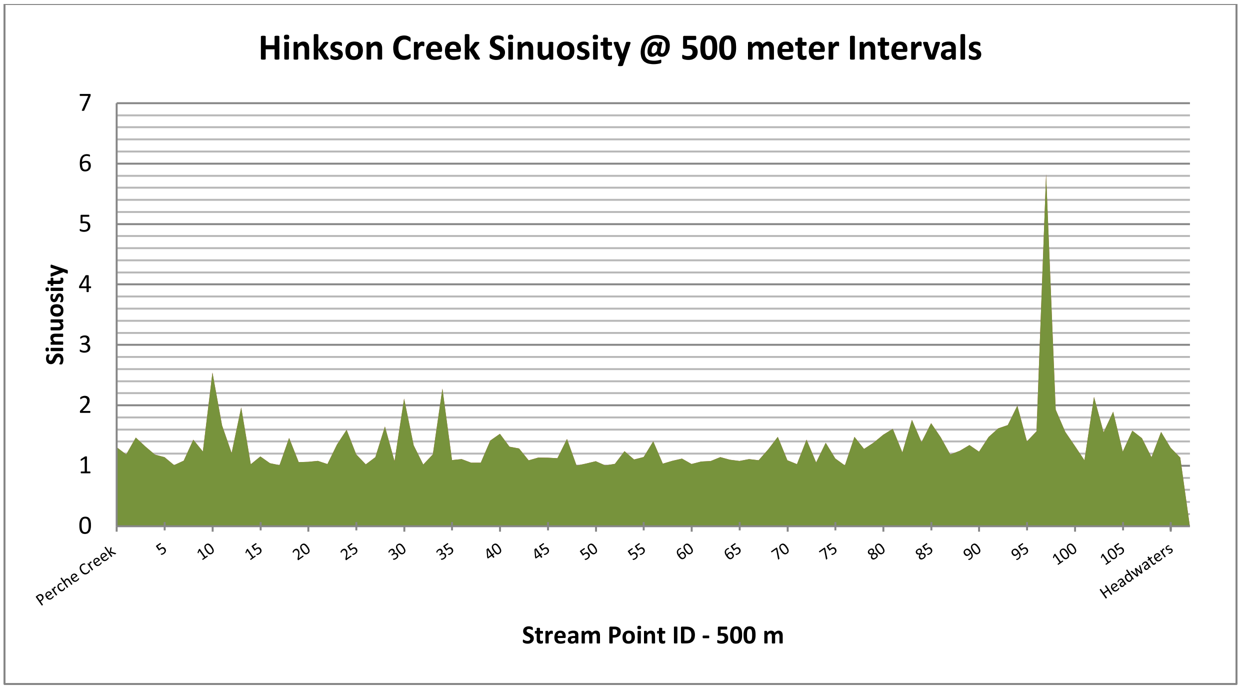

Figure 122. Longitudinal plot of sinuosity measures of Hinkson Creek at 500 meter point intervals. See Figure 23 for locator map of points at 500 meter intervals.

2.4.8.3 Bankfull and Valley Width

Top-of-bank/bankfull and valley widths were measured at each point for all point intervals. A transect perpendicular to the stream centerline was generated for each point and clipped to bankfull, morphological valley, and constricted valley boundaries (Figures 13, 14, 15, and 16). The Geospatial Modeling Environment (GME) "sampleperpointsalonglines" function was used to generate points perpendicular to the stream centerline at 50 meter intervals. Transects were generated at a distance of 300 feet on each side for bankfull width and 10,000 feet for valley widths. A Python script was written to convert the endpoints for transects into polylines. The polylines were clipped to bankfull, morphological valley, and constricted valley boundaries. Extraneous lines remaining as a result of clipping the polylines to boundaries were removed. Line distance, in feet, was calculated for the remaining polylines. A spatial join was performed to apply transect lengths for bankfull and valley widths to each set of stream points.

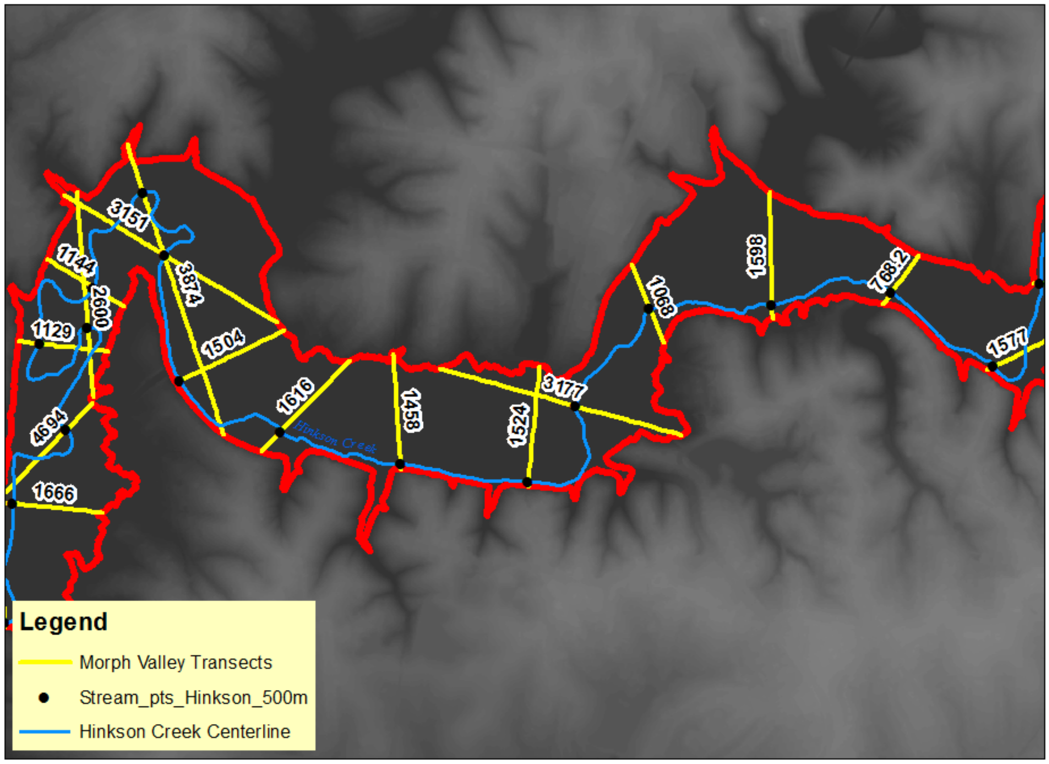

Figure 133. Transects perpendicular to the stream centerline were calculated for each point and clipped to morphologic and constricted valley boundaries and the bankfull boundary to calculate width and then applied to each point. Shown are transects clipped to the morphological valley boundary with width distances in feet on the transect lines. Due to stream sinuosity within the valley, these values may be more or less meaningful.

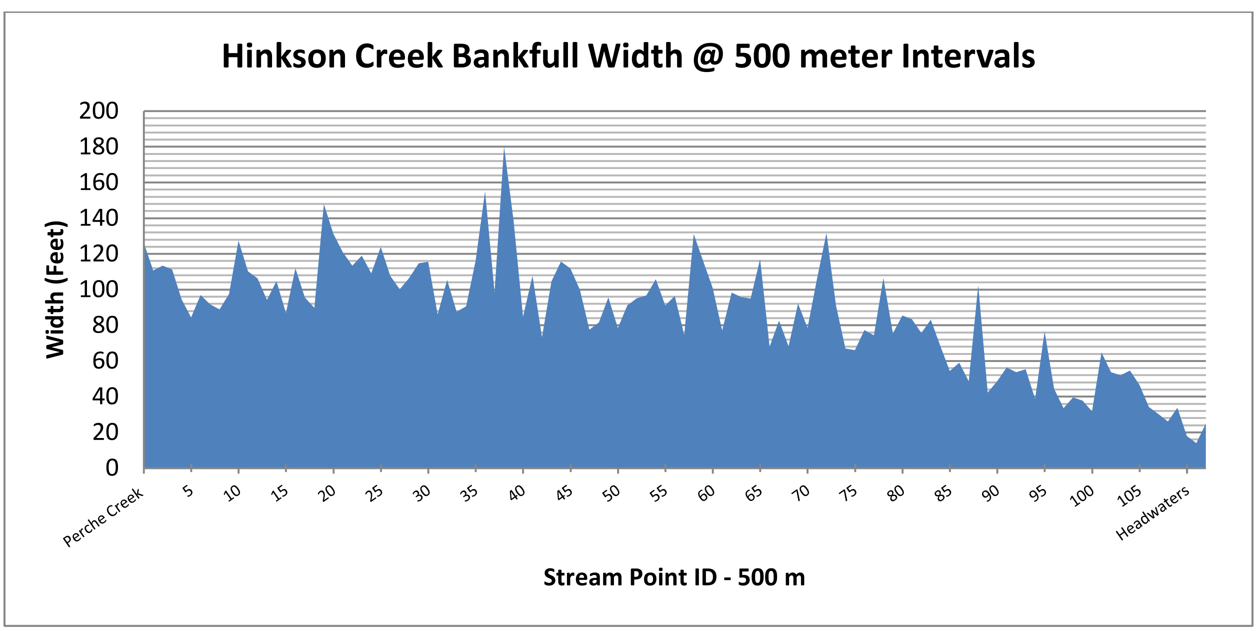

Figure 14. Longitudinal profile of Hinkson Creek bankfull width at 500 meter intervals shows decreasing width from the confluence at Perche Creek upstream to the headwaters. See Figure 23 for locator map of points at 500 meter intervals.

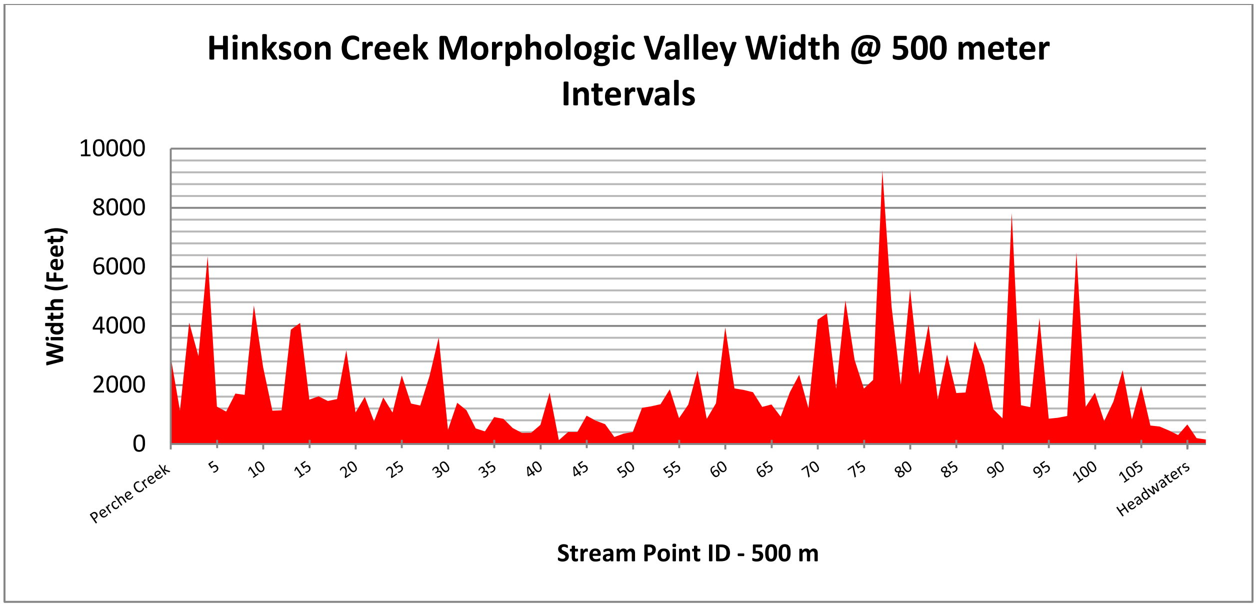

Figure 145. Width of Hinkson Creek morphologic valley at 500 meter intervals. See Figure 23 for locator map of points at 500 meter intervals.

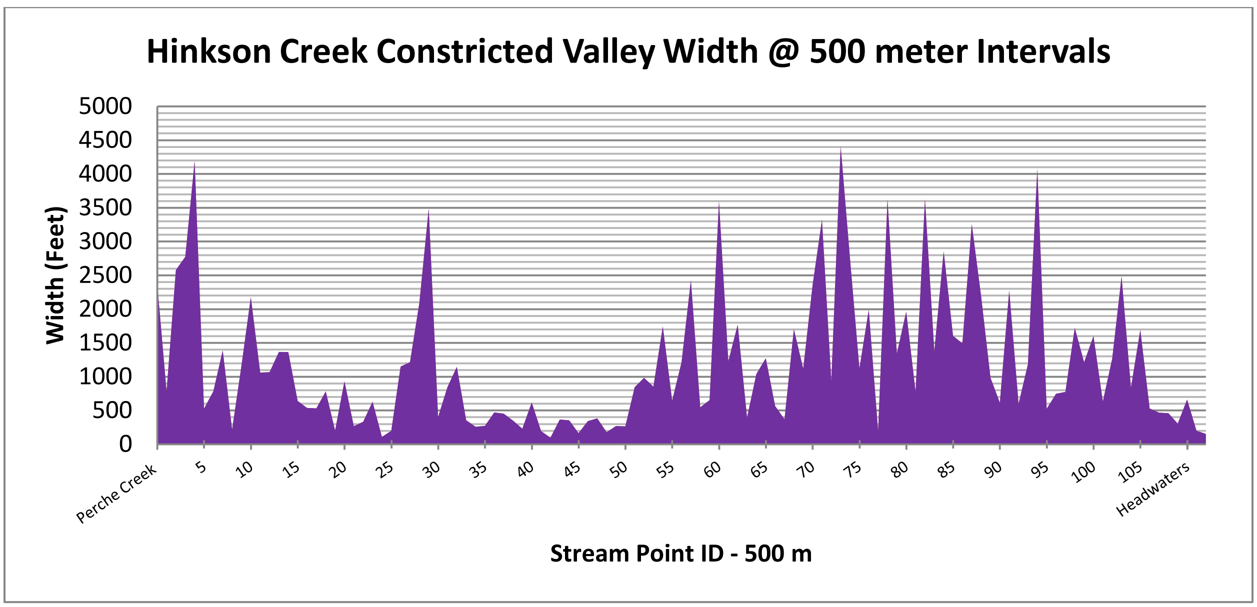

Figure 156. Width of Hinkson Creek constricted valley at 500 meter intervals. See Figure 23 for locator map of points at 500 meter intervals.

2.4.8.4 Distance to Valley Wall

Distance to morphologic and constricted valley walls were calculated and applied to points for all point intervals. Transects used to measure valley width were split at the stream centerline, and the length of the remaining transects for each side of the stream was calculated (Figures 17, 18, and 19). Two distance values were assigned for each point, one for distance to valley wall/boundary edge on one side of the stream, and one for distance on the opposite side. Right and left sides of the stream were assigned as if navigating upstream from the confluence of Hinkson and Perche Creeks.

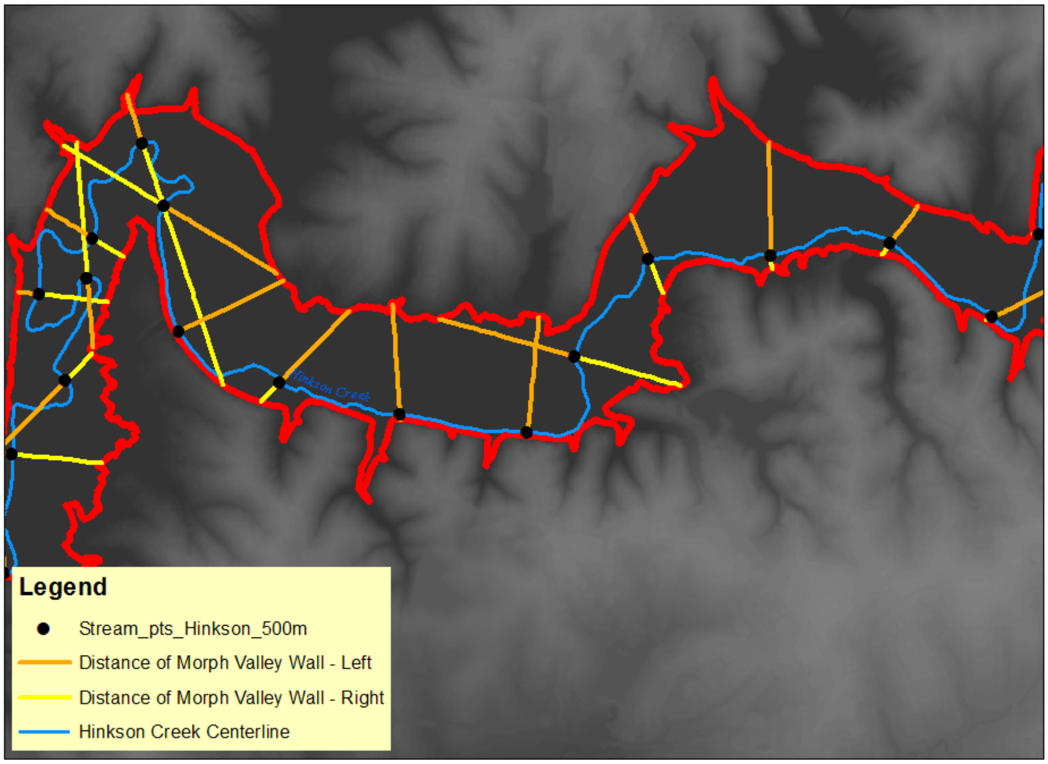

Figure 167. Perpendicular transects used to calculate valley widths were split using the stream centerline. Distance from centerline to right and left side valley boundaries were calculated and applied to each point. Due to sinuosity within the valley, these values may be more or less meaningful.

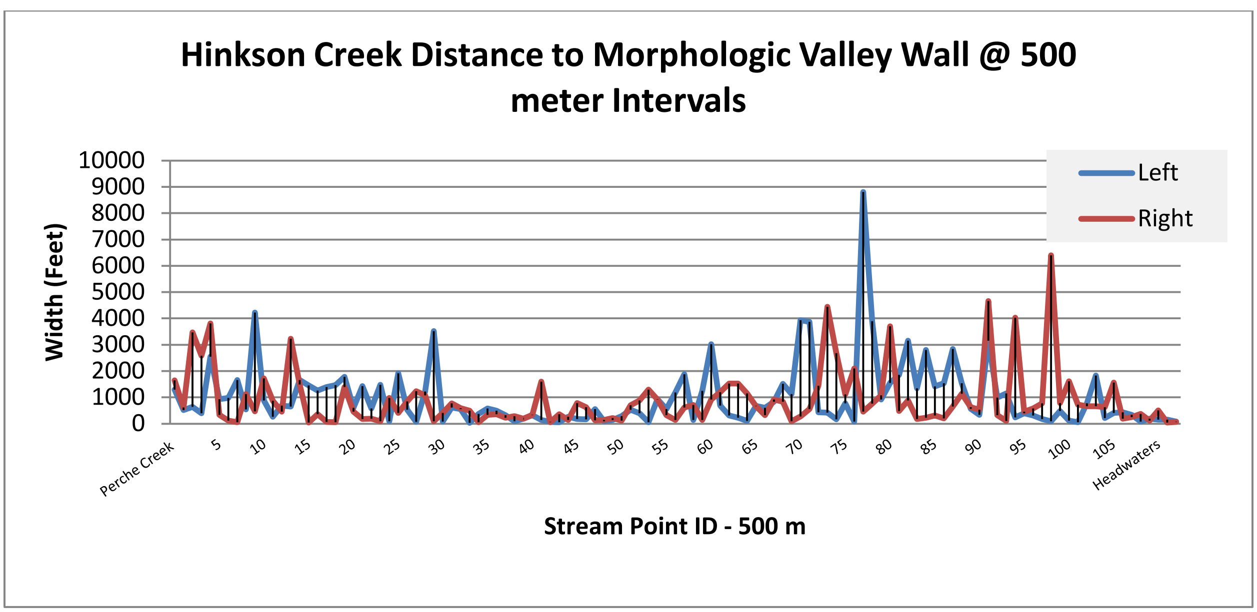

Figure 18. Distance to morphologic valley wall from Hinkson Creek centerline at 500 meter intervals. Red line represents distance from right side of stream to valley boundary and blue line represents distance from left side of stream to valley boundary based on navigation upstream from confluence of Hinkson and Perche Creeks. See Figure 23 for locator map of points at 500 meter intervals.

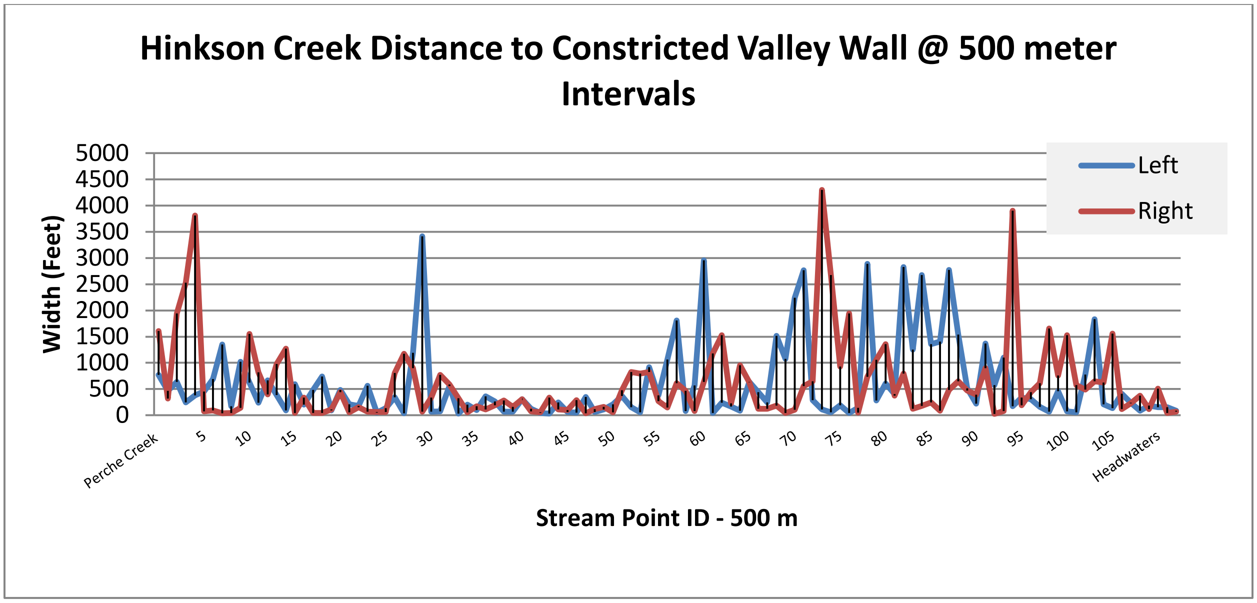

Figure 19. Distance to constricted valley wall from Hinkson Creek centerline at 500 meter intervals. Red line represents distance from right side of stream to valley boundary and blue line represents distance from left side of stream to valley boundary based on navigation upstream from confluence of Hinkson and Perche Creeks. See Figure 23 for locator map of points at 500 meter intervals.

2.4.8.5 Thiessen Polygon LULC Summary

Thiessen polygons represent areas, or zones, around a set of points where any location associated with a given point is closer to that point than any other point. A set of Thiessen polygons was generated for stream points at all intervals in order to associate the surrounding LULC with a spatially specific location within the stream. The polygons were clipped to both the morphologic and constricted valley boundaries and LULC composition was summarized (total area and % area of each class) for every polygon within each dataset. This resulted in two sets of polygons for each stream interval. A caveat to comparing LULC values for a given point is that the size of the area within polygons associated with any given point can vary greatly. The shorter the stream centerline interval between points, the more varied in size the area within polygons. Polygons based on 50 meter interval stream points have a coefficient of variance (CV) of roughly 0.91 (Figure 20). They become less variable at 500 meters, where CV was 0.49 (Figure 21). The lowest CV of 0.41 occurred at 2000 meters.

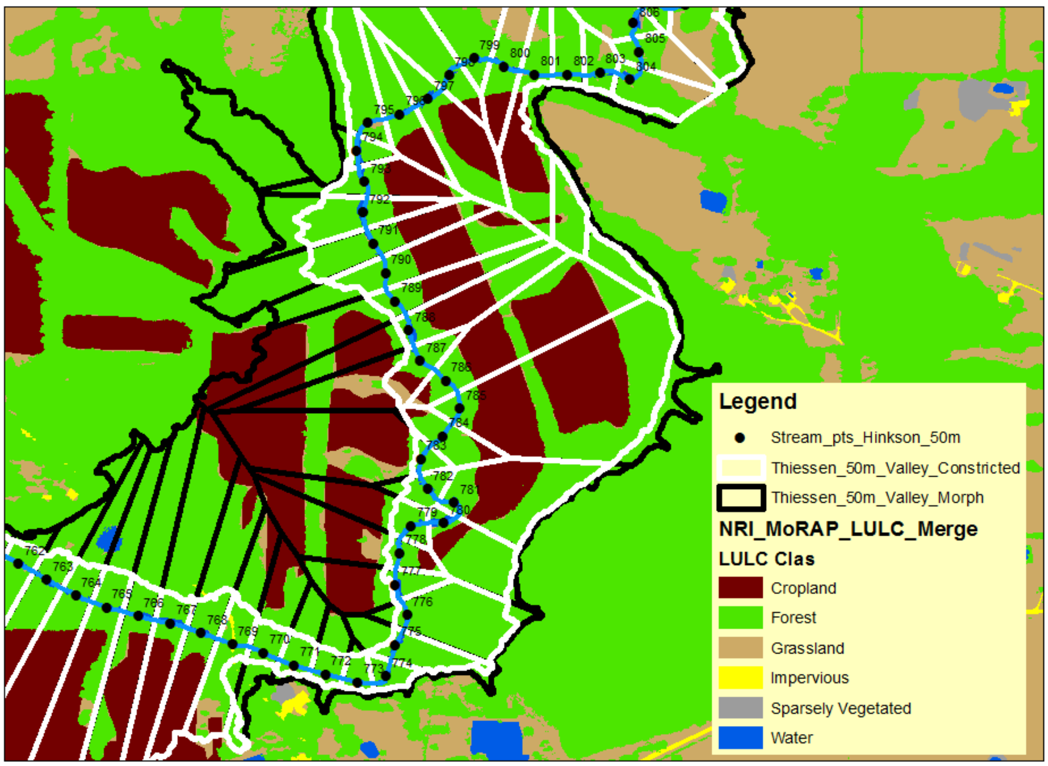

Figure 20. Theissen polygons based on stream points at 50 meter intervals vary greatly in size. Thiessen polygons were clipped to morphological (black) and constricted (white) valley boundaries.

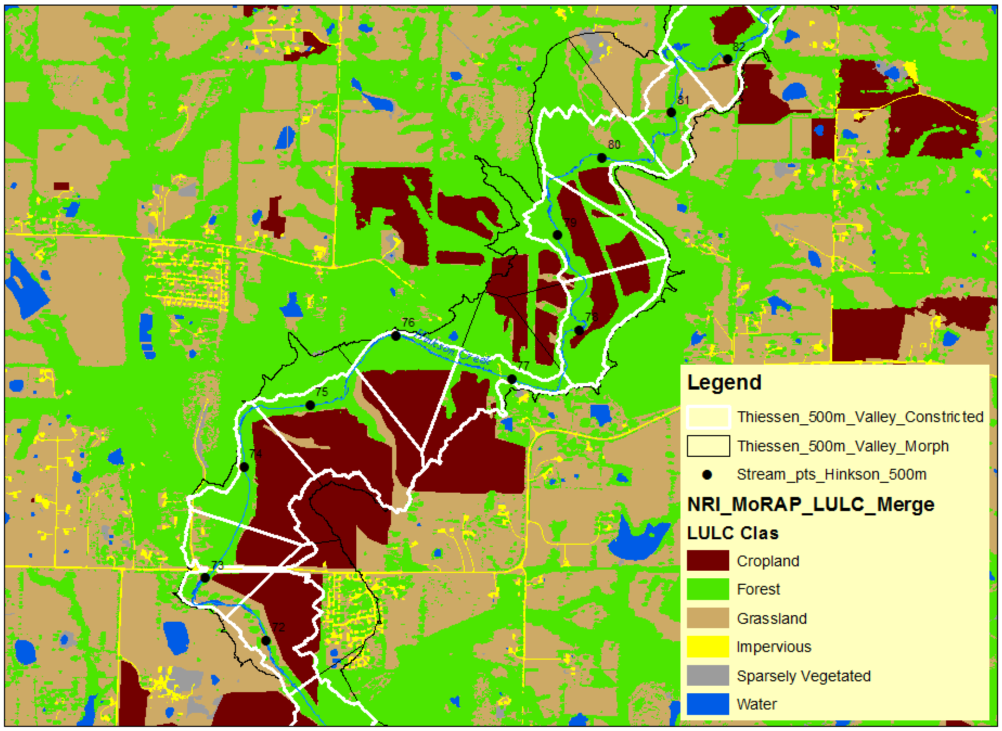

Figure 21. Theissen polygons based on stream points at 500 meter intervals were much more uniform in size compared to 50 meter intervals (Figure 20). Thiessen polygons were clipped to morphologic (black) and constricted (white) valley boundaries.

2.4.9 Hinkson Road Crossings

A point file was created indicating where roads, bridges, trails, cart paths, etc. cross Hinkson Creek (Figure 22). A point was manually placed on the stream centerline at the location of a stream crossing based on visual inspection of the 2011 6 inch, leaf-off imagery provided by Boone County at a scale of 1:1000. This is a record of stream crossings visible in 2011 aerial photography.

Figure 172. A point file of road crossings was manually created by marking any road, bridge, trail, or low water crossing along the stream centerline visible in Spring 2011.

3 Results

3.1 LULC Analysis

3.1.1 LULC – Theissen Polygons - Morphologic Valley

Land Use/Landcover (LULC) values can be analyzed in a number of ways to help evaluate contribution to stream conditions at multiple scales. LULC summarized by Thiessen polygons at 500 meter stream intervals, clipped to the morphologic valley extent, show spikes in impervious at the lower reaches of Hinkson Creek (Figures 23 and 24). Forest and grass comprise the majority of LULC throughout much of the valley, except at the lower reach where impervious cover increases and at the upper middle portion of the reach, between points 61 and 72, where crop increases (Figures 23 and 24).

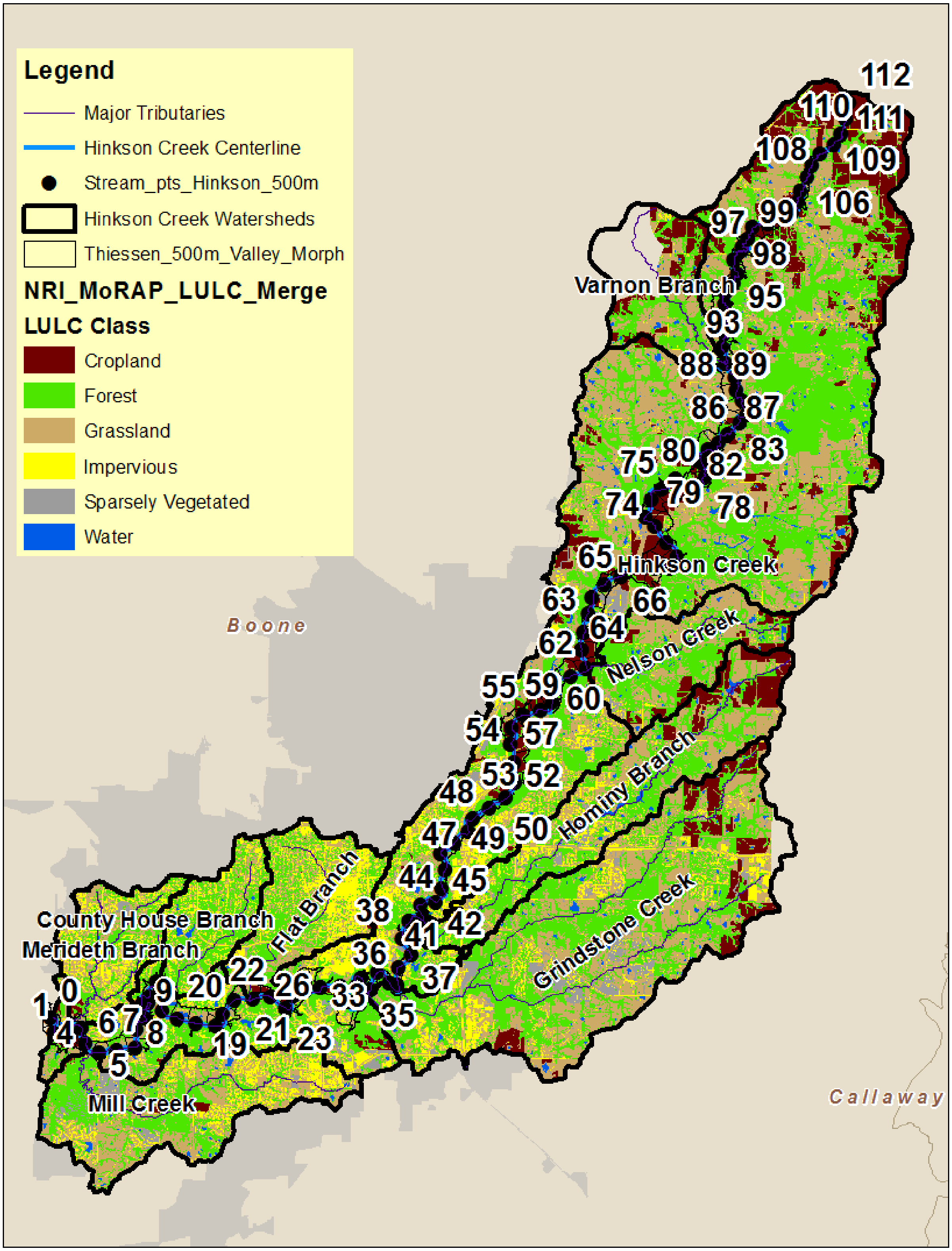

Figure 183. Numbers represent unique ID of stream points and Thiessen polygons at 500 meter intervals along stream centerline.

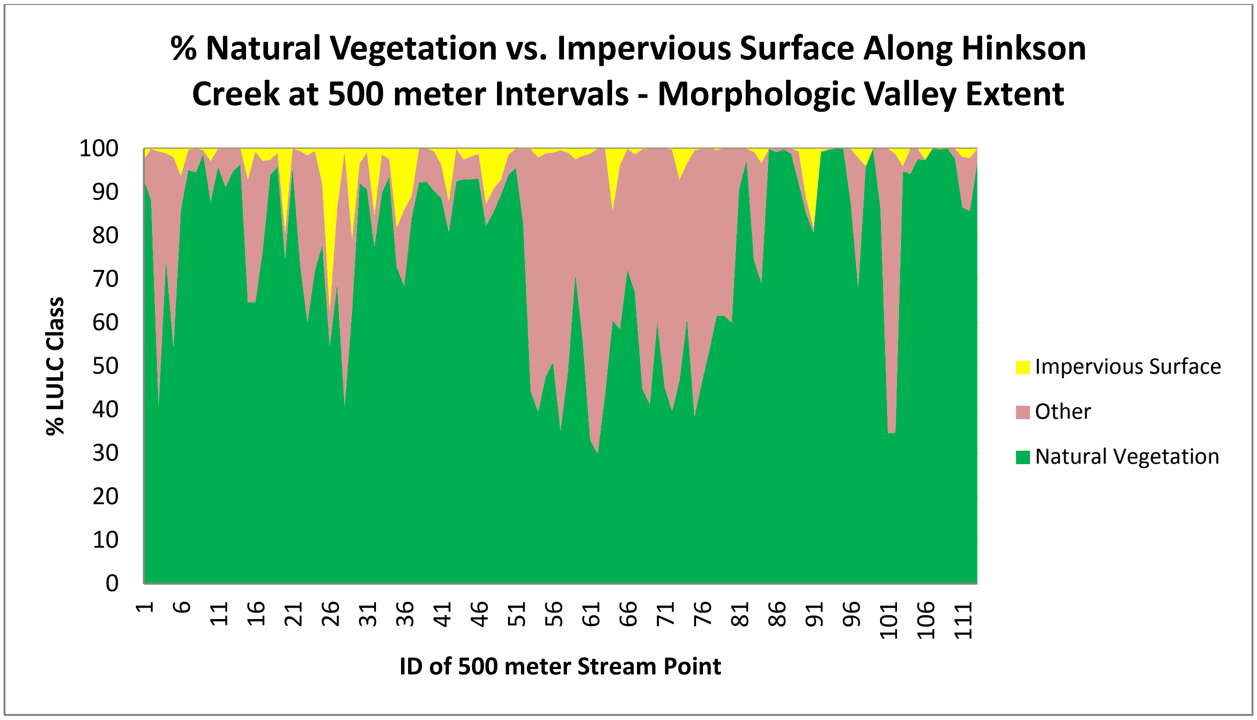

Figure 194. Chart illustrating LULC composition within Thiessen polygons at 500 meter intervals within the morphologic valley. Spikes in impervious surface mostly occur along lower portions of stream, between points 16 and 51. While natural vegetation (grass and forest) drops just below the mid-point of the stream, it typically comprises the majority of LULC within the morphologic valley. Points along the x-axis correspond to spatially explicit points along Hinkson Creek (Figure 25), beginning at the confluence and ending at the headwaters.

3.1.2 LULC – Watershed

At a broader scale, LULC composition within each watershed is illustrated in Figures 25, 26, and 27. Hinkson Creek watershed has the most total area in all cover classes (Figure 26) based on its overall larger size. Forest and grass are the predominant cover types in all watersheds. Flat Branch watershed has the highest percentage of impervious of all watersheds, at 31%, followed by Meredith Branch, at 23%.

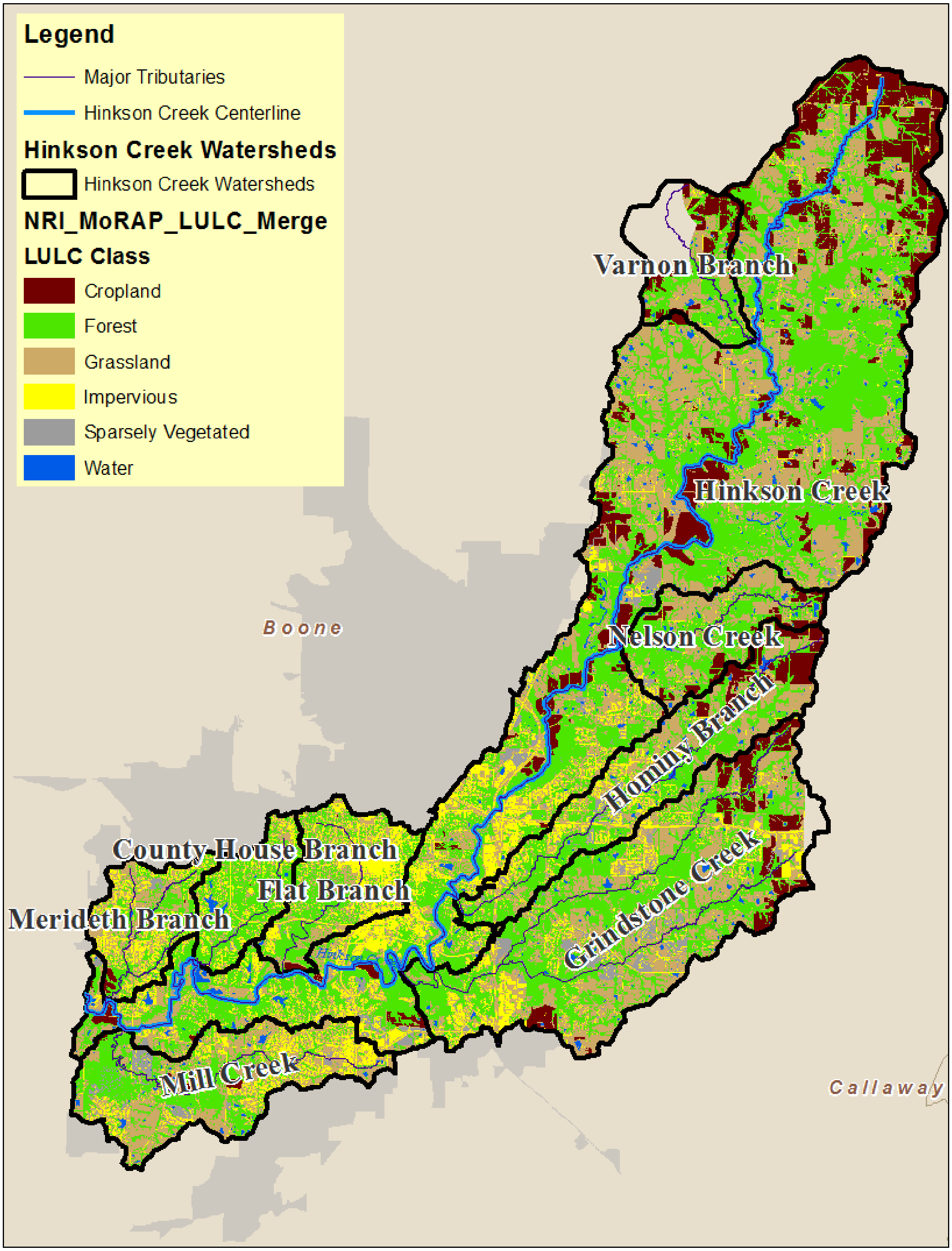

Figure 205. Watersheds and LULC within Hinkson Creek study area.

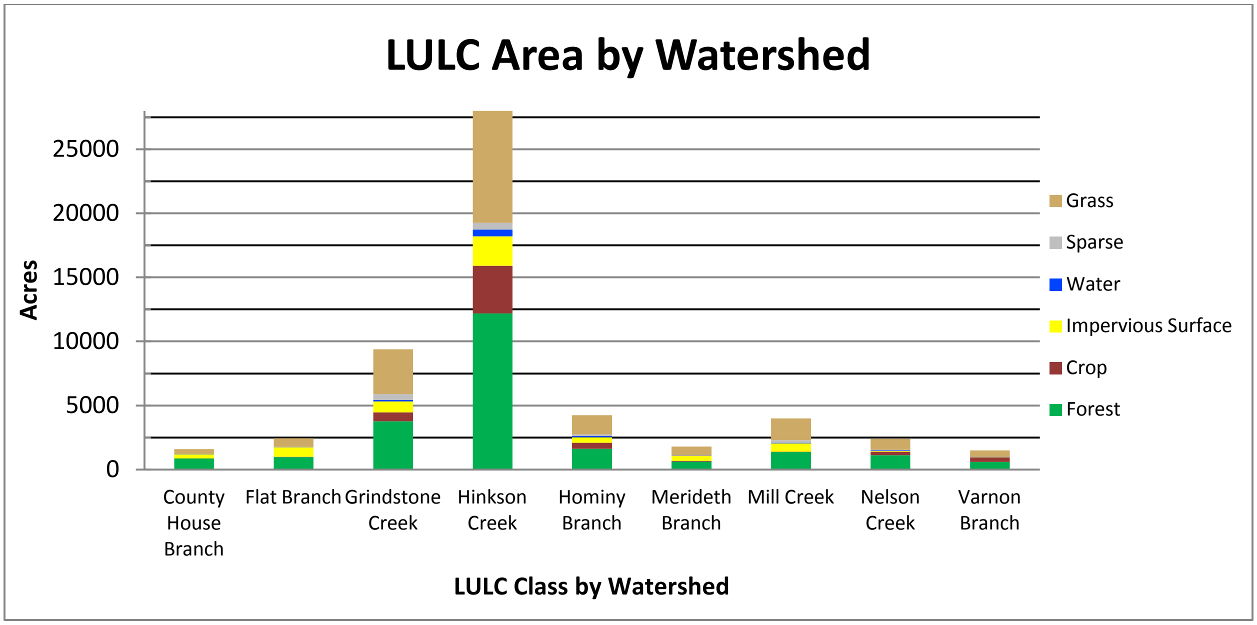

Figure 216. Area of LULC within each watershed in acres.

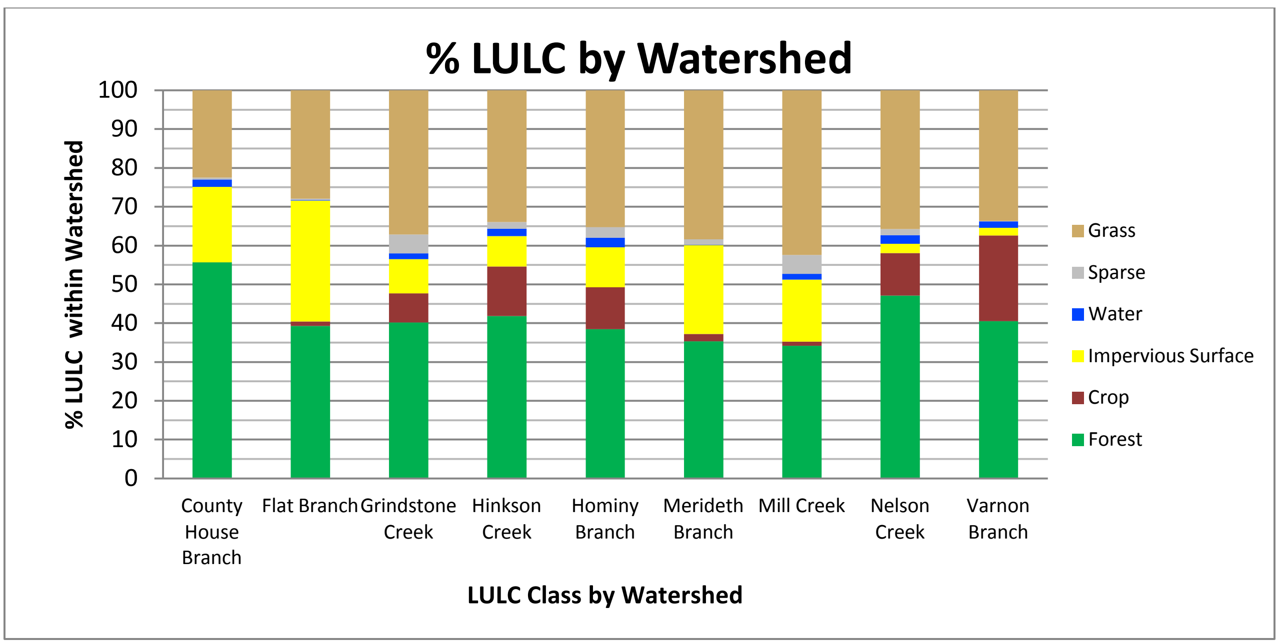

Figure 227. Percent LULC class within each watershed.

3.1.3 LULC – Cumulative Upstream Catchments

To quantify the cumulative upstream composition of LULC at each major tributary, the watershed was divided into hydrologic drainage catchments that roughly correspond with the watershed layer. The Hinkson Creek watershed was subdivided at the confluence of major tributaries. Break lines were drawn based on Hinkson Creek basin hydrologic catchments generated from 30 m DEMs (Figure 28). Catchments were numbered from 1 to 8, starting at the headwaters, with each major tributary resulting in a break point.

Figure 29 shows the percent LULC within each catchment. Forest and grass comprise the majority cover in all catchments, while percent crop decreases and impervious increases downstream. Catchment 5 (Flat Branch) is 28% impervious, which is the highest percentage of all the catchments. Catchment 1 (Varnon Branch) has the highest percentage of crop, at 30%. The highest percentage of forest is found in catchment 6 (County House Branch), at 54% of the catchment. The percent cover by catchment portrays a more accurate longitudinal LULC trend, following the course of Hinkson Creek, than the watersheds. This is due to the subdivision of the Hinkson Creek watershed at major tributaries.

Cumulative upstream LULC depicts the composition of LULC above each major tributary. Forest, grass, and impervious steadily increase downstream, while the percentage of crop levels off at catchment 4, the Grindstone Creek confluence (Figure 30). A spike in impervious occurs between catchments 2 (Nelson Creek) and 3 (Hominy Branch), where the total jumps from 0.8% to 3.3%, and continues to increase up to the confluence with Perche Creek. The second highest spike in impervious occurs between catchments 4 (Grindstone Creek) and 5 (Flat Branch), where the value increases from 5% to 7.3%. Ninety-five percent of all crop occurs between catchments 1 (Varnon Branch) and 4 (Grindstone Creek), and 70% of crop is accounted for in catchments 1 (Varnon Branch) and 2 (Nelson Creek). The most significant jump in forest and grass cover is from catchment 1 (Varnon Branch) to 2 (Nelson Creek), with 13% and 11% increases, respectively.

Percent LULC cover type relative to total area of a given cover type helps to identify the spatial distribution of cover types by catchment. Figure 31 shows that roughly 32% of all forest is within catchment 2 (Nelson Creek), 36% of all crop is within catchment 1 (Varnon Branch), and 60% of impervious surface is within catchments 3 through 5. Catchment 3 (Hominy Branch) has the highest value for impervious at 23%. More than 31% of grass exists in catchment 2 (Nelson Creek). These values are influenced by the size of the catchments, but nonetheless paint a picture of the distribution of land cover within the study area.

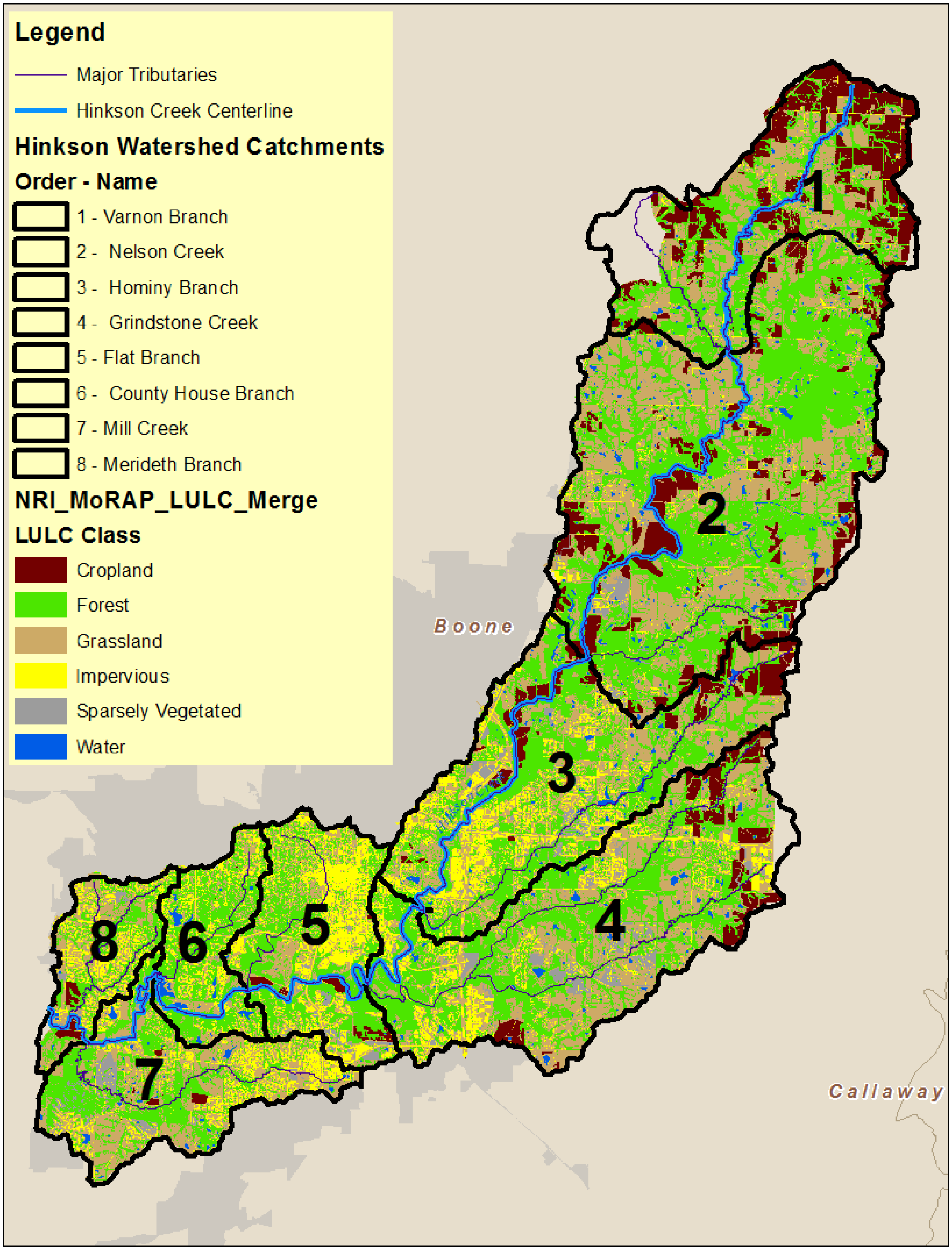

Figure 28. "Catchments" developed to calculate cumulative upstream LULC composition statistics at major tributaries of Hinkson Creek. Watersheds were divided at major tributaries based on fine scale catchments and lumped into broader watershed catchments. Catchments were numbered starting at #1 for the headwaters and increasing downstream.

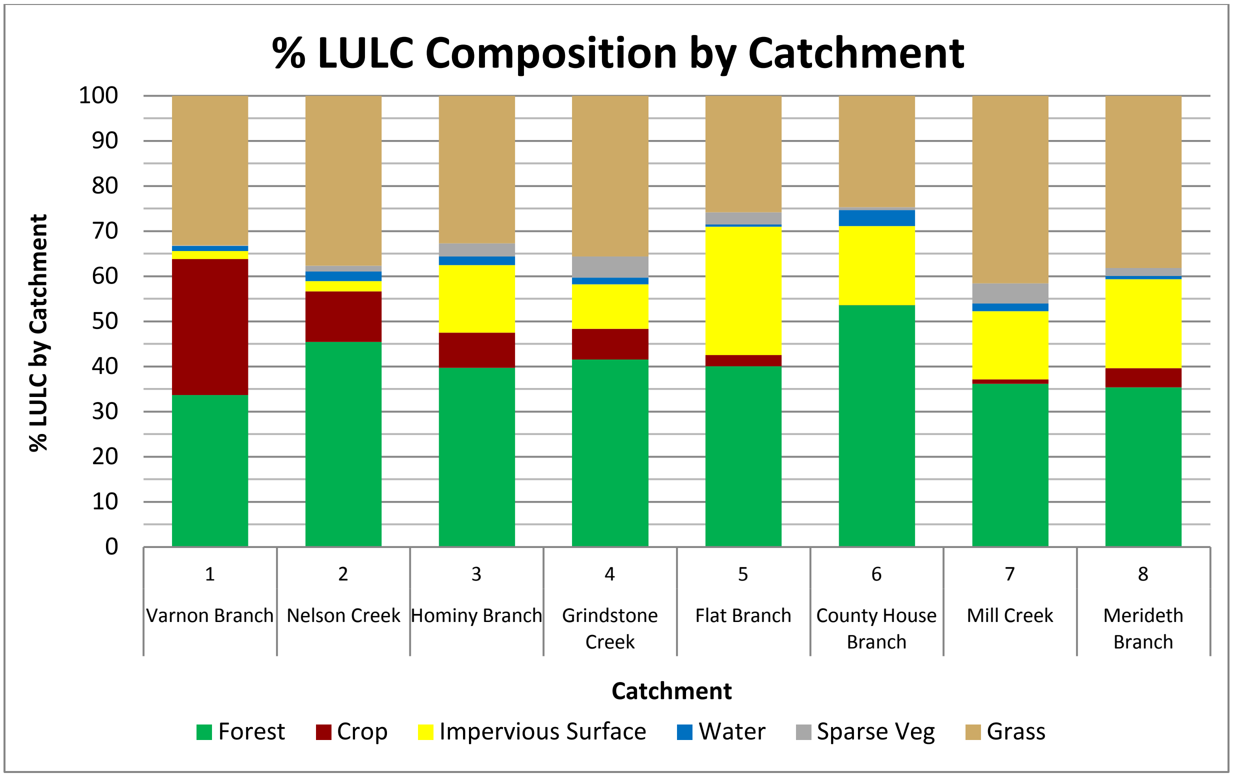

Figure 29. Percent LULC composition within each catchment. Note the dominance of the forest and grass cover types in all catchments, the increase in impervious cover from catchments 3 to 8, and decrease in crop cover type from catchments 1 through 8.

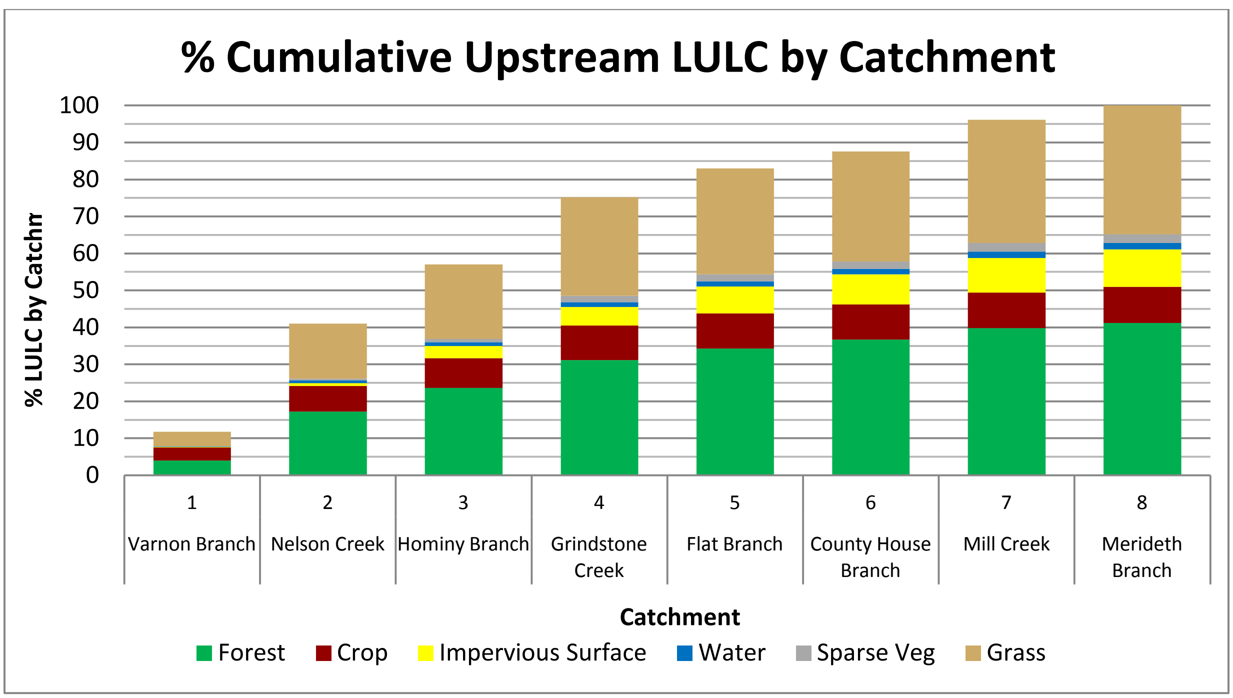

Figure 30. Percent cumulative upstream LULC by catchment shows the contribution of each catchment toward total land cover values for the entire watershed, progressively moving downstream. Note the gradual addition of all forest, grass, and impervious in a downstream direction. Crop, water, and sparse vegetation cover level off before catchment 8.

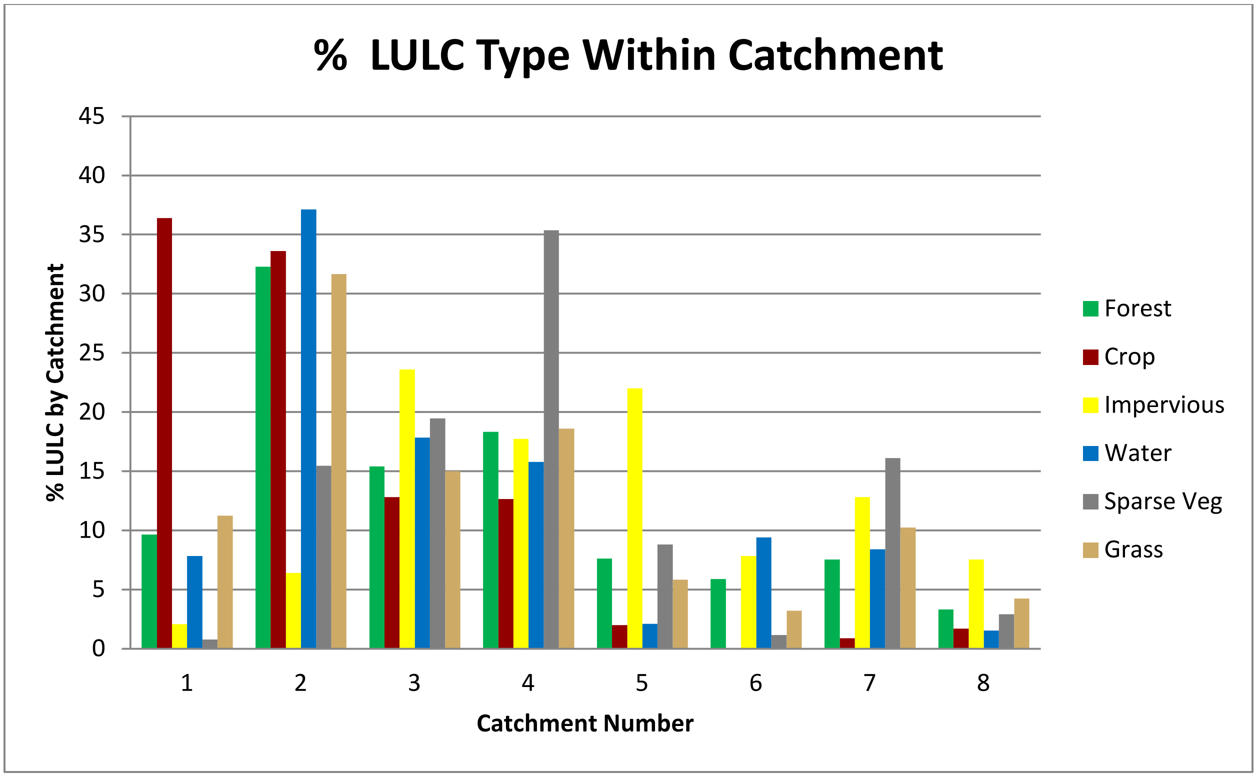

Figure 31. Percent of each LULC type by catchment relative to total area for each LULC type. This chart illustrates the percentage of the total area of a single cover type that exists within each catchment. Note that over 35% of all crop exists in catchment 1 and over 60% of all impervious surface can be found in catchments 3 thru 5.