Hinkson Creek
Collaborative Adaptive Management

Physical Habitat Assessment
Phase II: Field Component

Draft Final Report

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University of Missouri Research Team

Principle Investigator:

Jason A. Hubbart, Ph.D.

Graduate Research Assistants:

Lynne Hooper
Gregory Hosmer
Michael Hogan

Hinkson CAM Science Team Collaborators

Paul Blanchard, Ph.D., Missouri Department of Conservation
Joe Engeln, Ph.D., Missouri Department of Natural Resources
Robert Jacobson, Ph.D., United States Geological Survey
Dave Michaelson, Missouri Department of Natural Resources

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1.0 Project Summary

To quantify current physical habitat in Hinkson Creek the Hinkson Creek Collaborative Adaptive Management (CAM) team partners (Boone County, City of Columbia, and University of Missouri-Columbia) funded a two-tiered study called the Physical Habitat Assessment (PHA) in 2013. Phase I of the study was conducted by Missouri Resource Assessment Partnership (MoRAP), and presented in a report dated July 31, 2013. The MoRAP study used GIS models to delineate various features of the Hinkson Creek Watershed. The end product of Phase I is a fine-resolution dataset that describes certain geomorphological features of the creek, adjacent floodplains and riparian areas, and can be used by land managers and agencies for making more informed land use and/or restoration decisions. Phase II of the PHA included a field component, the results of which are described in this report. One of the goals of Phase II was to generate observed data that are comparable to some features described in Phase I. The results of this comparison are presented in section 7.2 of this report. An additional goal of Phase II was to provide measurements of physical habitat at consistent spatial intervals along the entire length (56 km) of Hinkson Creek that can be analyzed using current land use and land cover data in the watershed (see MoRAP report dated July 31, 2013). The results of analyses of the PHA Phase II data are presented in section 7.0 of this report.

Data sets developed during Phase II of the PHA include the following: descriptive statistics for all bank and channel measurements, channel width with stream distance, bankfull width with stream distance, bank height with stream distance, percent canopy cover with stream distance, substrate particle size class distribution, percent substrate embeddedness with stream distance, percent channel unit type for Hinkson Creek, and major tributary confluence bank and channel measurement comparison.

2.0 Introduction

As a member-partner of the Hinkson Collaborative Adaptive Management (CAM) Science Team, the University of Missouri-Columbia was charged to conduct Phase II of the PHA. At the request of the Collaborative Adaptive Management (CAM) team partners (Boone County, City of Columbia, and University of Missouri-Columbia), Dr. Jason Hubbart led the effort and assembled a field crew consisting of three graduate research assistants who collected physical and photographic data in Hinkson Creek. A Field Protocol was prepared, and data were collected over the entire length of Hinkson Creek from headwaters to mouth, including additional detailed data at each of the eight major confluences of Hinkson Creek (Figure 1).

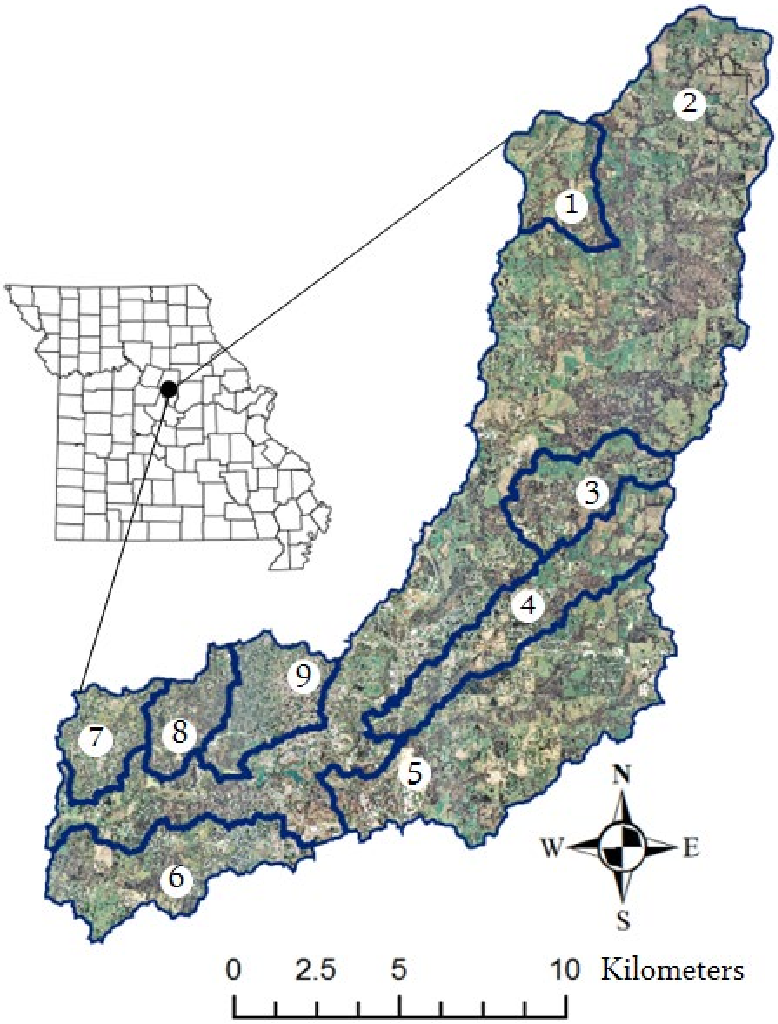

Figure 1. Hinkson Creek Watershed in Boone County, Missouri, including Hinkson Creek and 8 major tributary basins: 1) Varnon Branch, 2) Hinkson Creek, 3) Nelson Creek, 4) Hominy Branch, 5) Grindstone Creek, 6) Mill Creek, 7) Merideth Branch, 8) County House Branch, and 9) Flat Branch Creek.

3.0 Data Collection

During Phase I of the PHA, Missouri Resource Assessment Partnership (MoRAP) used GIS and remote sensing tools to generate a fine resolution data set delineating various geomorphological features of the Hinkson Creek Watershed. Data sets developed by MoRAP included: (1) stream centerline update, (2) spatially explicit sample points at 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. Some of the data generated by MoRAP (PHA Phase I) will be used as a basis of comparison with observed data from PHA Phase II presented in this report (see section 7.3). MoRAP also provided the PHA field team with coordinates for the set of 50 m survey points along the length of Hinkson Creek. The data provided by MoRAP are publicly available and can be used in conjunction with a map viewer. For more information, please visit: http://maps.showmeboone.com/viewers/RM_Hinkson_GIS_Technical_Report_Final_2013/.

Data for Phase II of the PHA were collected as delineated in the Physical Habitat Assessment Field Protocol, dated January 25, 2014. The PHA Phase II protocol was developed in the Interdisciplinary Hydrology Laboratory Directed by Dr. Jason Hubbart, with consultation and feedback from members of the CAM Science Team. The majority of the Phase II protocol used in the field is included in the following text. A complete copy of the original field protocol will be forwarded to the web administrator of http://helpthehinkson.org/ upon request, and posted therein.

4.0 Physical Habitat Assessment (Phase II) Field Protocol

4.1 Global Positioning System Data

The PHA Phase II survey was conducted at pre-determined survey points at 100 m intervals, starting at the mouth of Hinkson Creek at its confluence with Perche Creek and continuing upstream to the first second-order confluence at the headwaters of Hinkson Creek. Coordinates for the 100 m survey points were provided by MoRAP PHA Phase I, and were pre-loaded into a global positioning system (GPS) unit used by the field team. The field team travelled to the coordinates of each survey point, and recorded the coordinates provided by MoRAP and the coordinates of the center of the stream channel for each point on the data sheet(s) (see example at end of protocol). In addition, coordinates were collected at each survey point to mark the position of the stream banks and streambeds. Major objects including woody debris piles, public utilities, engineered structures, eroded gullies, bank failures, debris piles, and any other obvious habitat altering features were photographed with a camera that recorded GPS coordinates in the properties of the picture. Additional survey points were established at the confluence of each of the following tributaries as they were encountered on the survey path from the mouth to the first second order confluence at the headwaters of Hinkson Creek: Meredith Branch (MB), County House Branch (CH), Mill Creek (MC), Flat Branch Creek (FB), Grindstone Creek (GC), Hominy Branch (HB), Nelson Creek (NC), and Varnon Branch (VB). Coordinates were collected at confluence survey points and recorded in the same manner as the 100 m survey points.

4.2 Survey Point Naming Convention

GPS waypoints were named using a two letter code for the feature and the nearest survey point number. For example, the waypoint for survey point one was be named SP1 (i.e. Survey Point 1). Each survey point was sequentially numbered from the first point at the mouth of Hinkson Creek through the final point near the first second order confluence at the headwaters. The survey point number was recorded on the data sheets with the corresponding MoRAP and field team GPS coordinates. For those survey points that were at the confluence with tributaries, data were collected and stored separately to avoid confusion with the 100 m survey points.

4.3 Description of Survey Points

Each survey point was located in the center of the stream channel and served as the center point of a study plot. The study plot consisted of a principal transect running from bank to bank through the survey point perpendicular to the direction of stream flow. Upstream and downstream transects delineated the beginning and end of the plot and were located 5 meters upstream and downstream of the principal transect. Upstream and downstream transects were parallel to the principal transect and extended from bank to bank (Figure 2a).

For purposes of the survey, the field protocol called for the survey cross section of the study plot at any confluence to be set in Hinkson Creek 5 m downstream of the downstream bank of the confluence with the tributary so that the study plot was as close to the confluence as possible. This placement of the survey transect proved to be impractical in the field, as the width of the channel tended to be greater at the confluences, and the effects on physical habitat from the tributary flow were not evident at the 5 m distance. After consultation with Dr. Hubbart, the field team set three transects for each confluence: one upstream of the confluence in Hinkson Creek, one downstream of the confluence in Hinkson Creek, and a third in the tributary. Transects were located 20 m to 50 m from the center point of the confluence, with all three distances being measured and recorded (Figure 2b). All bank and channel measurements described in this field protocol were collected at each of the three transects.

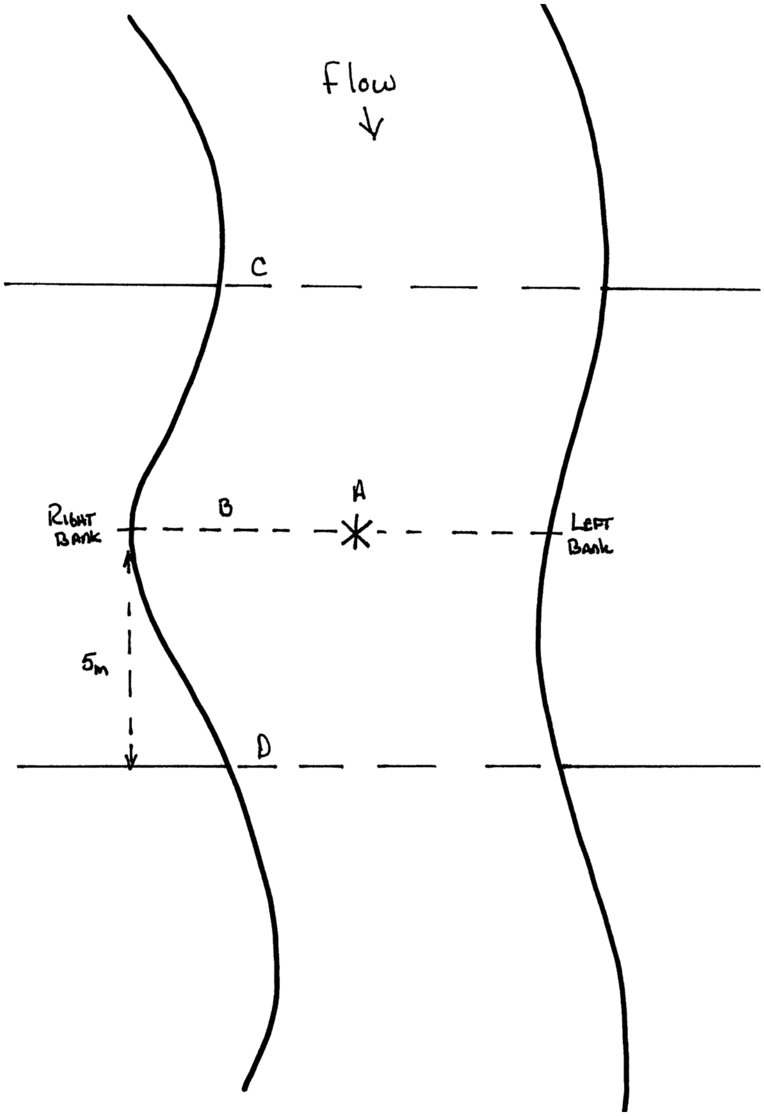

Figure 2a. Layout of study plots used for habitat measurements. A: Plot Center. B: Principal Transect. C: Upstream Transect D: Downstream Transect.

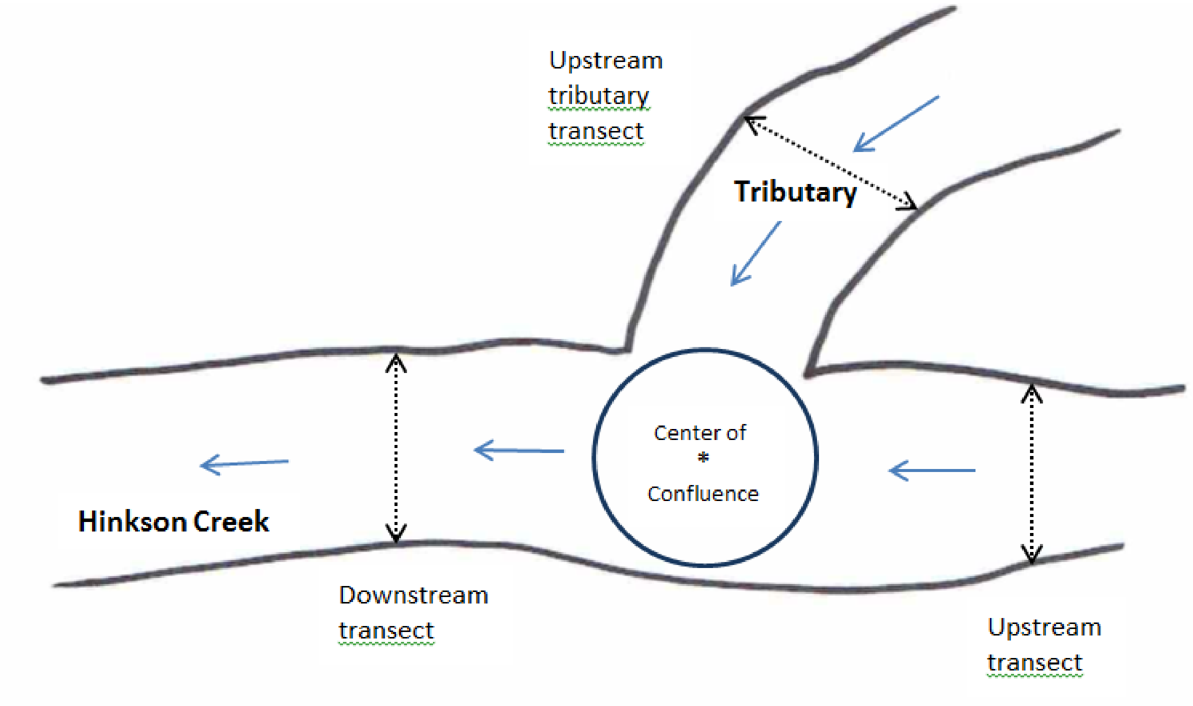

Figure 2b. Layout of three measured transects at confluence sites.

4.4 Photographic Journal

A digital camera was used to create a photographic journal of each study plot. A mandatory set of photos were collected from the survey point as follows: directly down at a distance of 1 m from the streambed (streambed composition), directly upstream (normal with the channel), then turning clockwise a perpendicular (90 degree angle) photograph of the left bank, downstream (parallel with the channel), a perpendicular photograph of the right bank, and a final photo directly upwards to capture canopy cover. Photographs of the stream banks captured the extent of vegetative cover present. A photograph of the survey point number (either written on a dry erase board or from the face of the GPS unit) was taken immediately before the first (streambed) photo in the series and again before photos taken at any transect between survey points (survey point – transect number, e.g. SP1-3) so that the photographs could be catalogued later.

At confluence survey points, additional photographs were taken to document physical characteristics at the confluence, including the standard channel photographs described above, and a 360 degree panorama from the center of the confluence and at each of the three transects surveyed.

4.5 Special Features

GPS coordinates are embedded in the properties of photographs to document the presence of any of the following special features: bank stabilization structures, including rip-rap, gabion baskets, and other engineered structures; infrastructure not adequately mapped in GIS resources, including pipes, outfalls, discharge control structures, and utilities with any related infrastructure;

disturbance features including erosion gullies, debris fans, slumps, bank failures, and woody debris piles; cattle tracks found on either bank or in the substrate; large trash dumps in or near the stream. Special features photographs are named using the survey point number, followed by a hyphen and the distance downstream from the survey point (where applicable), the date, the type of feature, and the streambank. A sample file name is SP40-8_2014-07-16_erosion_and_woody_debris_rb.

4.6 Canopy Measurements

Canopy cover was estimated following the method described by Peck et al. (2006). A convex densiometer (Lemmon 1957) was used after modification to prevent overlap from measurements taken close together. The modification consisted of creating a "V" comprised of tape on the face of the densiometer with the vertex pointing towards the viewer such that 17 line intersections exist within the V (Mulvey et al. 1992). The number of line intersections covered by canopy was recorded on the data sheet. During the winter months, the number of line intersections covered by branches was recorded on the data sheet, and a notation was made as to the presence or absence of leaves. Canopy cover was determined by quantifying the percentage of points covered by canopy (Peck et al. 2006).

4.6.1 Procedure for Canopy Cover Measurements

1. A field team member stood on the principal transect at mid channel facing upstream.
2. The densiometer was positioned 1 m above the streambed, and levelled using the bubble level. The densiometer was then positioned so that the face of the field team member was reflected just below the apex of the taped "V" (Figure 3).
3. The number of grid intersection points within the "V" that were covered by a tree, a leaf, or a high branch were counted (0 to 17) and recorded in the appropriate place on the datasheet.
4. The field team member then faced the left descending bank (left, facing downstream). Steps 2 and 3 were repeated, and the value was recorded in the appropriate place.
5. Steps 2 and 3 were repeated again facing downstream and again facing the right bank, and the values were recorded in the appropriate places.
6. Steps 2 and 3 were repeated at the channel's edge on the left bank at the end of the principal transect, and again on the right bank, and the values were recorded in the appropriate places.

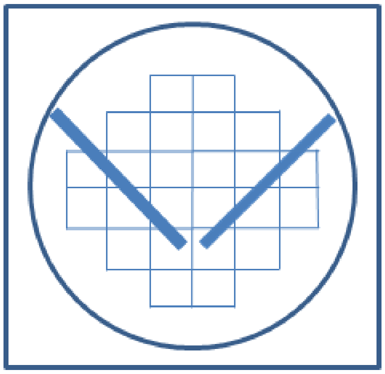

Figure 3. Diagram of taping of “v” on face of convex densiometer.

4.7 Bank Angle, Stream Width and Channel Depth

At the principal transect running through each survey point, measurements of channel width, wetted width of the stream, bank angle, bankfull width, and bank height were recorded (Figure 4). Bank angle was measured on both banks and calculated as the average slope of the bank extending 2 m from the bottom (top of gravel) to the top of the bank. Normally, slope was between 0º and 90º; however, by definition undercut banks had an angle greater than 90° because the edge of the water was underneath the overhanging bank.

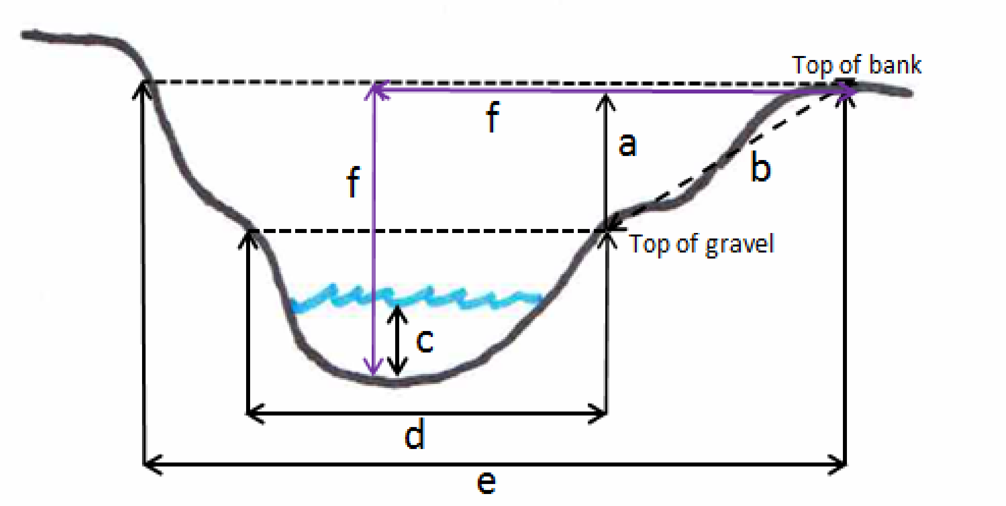

Figure 4. Cross-section view of measured channel dimensions: a) bank height, b) bank slope, c) thalweg depth, d) channel width, e) bankfull width, and f) relative thalweg depth (vertical) and thalweg position (horizontal).

Bankfull flows are events large enough to erode the streambed and banks, and frequent enough to prevent substantial growth of terrestrial vegetation (Peck et al. 2006). Annual peak flows are used to compare channel morphology measurements on a consistent basis, relative to flows thought to have a consistent 1.5-2.0 year return interval (Leopold et al. 1964). Common indicators of bankfull level included the top of pointbars, changes in vegetation from aquatic to terrestrial, changes in slope, changes in bank material (e.g. from coarse gravel to sand), bank undercuts, or stain lines on bedrock or boulders (Harrelson et al. 1994). More detailed descriptions of these indicators can be found in Harrelson et al. (1994). Determination of bankfull levels at times required some discussion among crew members and if possible, multiple indicators that "agreed" with each other were used. Bankfull width was measured as the distance between banks at the bankfull level perpendicular to stream flow. All measurements in this section were made using a laser level and/or laser range finder.

4.7.1 Procedure for measuring bank angle:

1. An extension pole was laid on the bankfull bank at the end of the principal transect so that the base of the pole was at the bottom of the bank (top of the line of gravel from the streambed). The extension pole was extended 2 m up toward the top of the bank. A clinometer was placed on the extension pole and the bank angle was read and recorded in degrees (0-90°). If the bank was undercut (>90°), the measurement was made from the water's edge along the underside of the undercut, and the clinometer reading was subtracted from 180° and recorded.
2. If the bank was undercut, the undercut depth was recorded by placing a meter stick horizontally parallel to the stream, and the distance from the back of undercut to the edge of the bank was measured.
3. If there was a large boulder or a log at the transect point, the measurement point was moved ($\leq$ 5 m) to a nearby point which was more representative.
4. Step 1 (and Step 2 if necessary) was repeated on the opposite bank.

4.7.2 Procedure for measuring Channel Width, Wetted Width, Bankfull Width, Bank Height, Channel Depth, and Relative Thalweg Depth and Thalweg Position (Figure 4):

1. Using a laser range finder, the distance from the bottom of the bank (the top of the gravel from the streambed) was measured across the stream channel from one bank to the other (channel width). Also using a laser range finder, the distance from one side of the stream to the other (wetted width) was measured. If there was a split in the channel due to a bar or island, the following wetted width values were recorded where possible and applicable: entire width of wetted portion of stream, wetted width nearest to left bank, wetted width of center stream channel, wetted width nearest to right bank. Values for channel width and wetted width(s) were recorded on the data sheet.
2. To measure bankfull width, the bankfull level on the streambank with the highest terrace was located. For a description of bankfull indicators see Harrelson et al. (1994). While squatting at the top of the streambank with the lowest terrace (presumed bankfull), the

laser range finder was used to measure the width to the bankfull level on the opposite streambank.

3. Whether the right bank or left bank (descending) was used for bank measurements was determined at each survey point by which bank had the lower elevation (bankfull bank), and was indicated on the data sheet. Bank height was measured as the distance from the bottom of the bankfull bank (frequently determined by the top of the line of gravel from the streambed) to the top of the stream bank, using a laser level and an extension pole with a receiver.
4. Thalweg depth was measured by positioning the meter stick or extension pole on the stream bed at the deepest part of the channel and reading the depth of the water. In the event that the water was more than chest deep, the depth finder and battery with float were deployed for measuring thalweg depth.
5. Relative thalweg depth and thalweg position were measured relative to the bankfull bank. Relative thalweg depth was measured using a laser level and an extension pole with a receiver. The extension pole was set at the bottom of the stream in the thalweg, and raised or lowered until the receiver was on a horizontal plane with the laser level stationed at the top of the bank. Thalweg position was measured using a laser rangefinder to measure the distance between the top of the bankfull bank and the laser receiver on the extension pole.

4.8 Longitudinal Thalweg Depth Profile

The thalweg is the path of the stream that follows the deepest point of the channel (Armantrout 1998). This is also the last part of the channel to become dry during a drought. Though this is not a topographic profile, a longitudinal profile of thalweg depth yields information about habitat complexity and channel form variability. The thalweg was measured at each survey point and every 10 m in between survey points. At the location of each thalweg measurement a field crew member recorded the thalweg depth, the channel unit according to Table 1, the substrate size classification (Table 2), and the presence or absence of periphyton. More detailed descriptions of the channel form can be found in Table 7.3 in Peck et al. (2006).

Table 1. Channel unit types and codes used in data recording in Hinkson Creek. Adapted from Peck et al. (2006).

Channel Unit	*Code*	*Description*
Plunge Pool	PP	Pool at base of plunging cascade or falls.
Trench Pool	PT	Pool-like trench in the center of the stream.
Lateral Scour Pool	PL	Pool scoured along a bank.
Impoundment Pool	PD	Pool formed by impoundment above dam or constriction.
Pool	P	Pool (unspecified type).
Glide	GL	Water moving slowly, with smooth unbroken surface. Low turbulence.
Riffle	RI	Water moving with small ripples, waves and eddies – waves not breaking, surface tension not broken. Sound: babbling, gurgling.
Dry Channel	DR	No water in the channel or flow is under the substrate (hyporheic).

* Due to the local topography of Hinkson Creek, cascades are unlikely to occur, and thus this category was omitted from the Channel Unit Code on the data sheet in order to conserve space.

4.8.1 Procedure for Measuring Thalweg Profile

1. The depth of the water was measured at the deepest part of the channel along the principal transect. This depth (cm) was recorded under station "1" on the data sheet.
2. The channel unit was identified and the channel unit code was recorded on the data sheet.
3. The size classification of a random substrate particle was determined at the thalweg and the appropriate code from Table 2 was recorded.
4. Where possible, the presence or absence of periphyton on the substrate at the thalweg was determined and noted on the data sheet.
5. Using the string line marked at 10 m intervals, the field team continued downstream following the thalweg, and Steps 1 and 2 were repeated every 10 m between survey points. The data from steps 1 through 4 were recorded on the data sheet under stations 2-10, respectively.
6. After the depth at the 90 m mark was recorded, the field team moved to the next coordinate provided by MoRAP and started a new data sheet.

4.9 Substrate Characterization (Pebble Count)

The method for substrate particle size characterization described here was adapted from Peck et al. (2006) and Wolman (1954). The procedure required estimation of the diameter size class of 15 substrate particles at each study plot. Five particles were sampled from each of the principal transect, the upstream transect, and the downstream transect. On each transect, particles were sampled from the left and right banks, and from 25, 50, and 75% of the distance across the width of the channel. Particle size was estimated according to the size classes listed in Table 2.

Table 2. Particle size classes and codes used on data sheets.

Diameter (mm)	*Size Equivalent*	*Code*	*Substrate Type*
>4000	Larger than a car	RS	Bedrock (Smooth)
>4000	Larger than a car	RR	Bedrock (Rough)
>4000	Larger than a car	RC	Concrete/Asphalt
1000 to 4000	Meterstick to Car	XB	Large Boulder
256 to 1000	Basketball to Meterstick	SB	Small Boulder
64 to 256	Tennis ball to Basketball	CB	Cobble
16 to 64	Marble to Tennis ball	GC	Coarse Gravel
2 to 16	Ladybug to Marble	GF	Fine Gravel
0.06 to 2	Gritty - up to Ladybug	SA	Sand
<0.06	Smooth, Not gritty	FN	Silt/Clay/Muck
Any size	NA	HP	Hardpan (Firm, Consolidated Fine Substrate)
Any size	NA	WD	Wood
Any size	NA	OT	Other - (Write comment)

4.9.1 Procedure for measuring substrate:

1. The procedure started on a bank of the rincipal Transect. Using a meter stick, the first particle that the meter stick came into contact with was selected. If the substrate was sand or finer material, multiple particles were picked up and size class was determined by texture.
2. The size of the selected particle was estimated (or particles for finer material) according to Table 2, and the size class was recorded on the data sheet.
3. The percent vertical embeddedness of the particle in the substrate (what percentage of the particle is not visible) was estimated to the nearest 5%. Note that sand and silt are by definition 100% embedded, and bedrock or claypan are 0% embedded. The percent vertical embeddedness was recorded on the data sheet.
4. The field team member moved to the next station along the principal transect and repeated Steps 1 to 3, recording the data in the appropriate locations on the data sheet. Five particles were sampled on the principal transect.

5. Steps 1 to 4 were repeated at the upstream transect and the downstream transect (see Figure 1).

5.0 Subject Matter Expertise/Science Team Collaboration

The field protocol for Phase II of the PHA was accepted and approved by the CAM Science Team in July of 2013. In the fall of 2013, CAM Science Team members Dr. Paul Blanchard (Missouri Department of Conservation), Dr. Robert Jacobson (United States Geological Survey), Dr. Joe Engeln and Dave Michaelson (both from Missouri Department of Natural Resources) met in the field with Dr. Jason Hubbart and Lynne Hooper for a demonstration and discussion of methods for PHA Phase II data collection following which, the PHA Phase II field protocol were finalized and approved by the CAM Science Team during this meeting.

6.0 Data Development Methodologies

6.1 Projection

MoRAP used a standard projection (see Phase I report) in their Phase I analyses of Hinkson Creek Watershed, including the determination of survey points for the study area, which consisted of the entire length of Hinkson Creek (56 km). The survey points provided by MoRAP were loaded into the GPS units used by the PHA field team in Phase II. The same standard projection was used in any comparison analyses performed in ArcGIS.

6.2 Phase I Analyses Comparable to Phase II Observed Data

Comparable data from MoRAP PHA Phase I to PHA Phase II include bankfull width measurements and stream center point coordinates. The remaining analyses provided by MoRAP in Phase I are not directly comparable to the Phase II data. For example, MoRAP provided a stream centerline update in their Phase I report dated July 31, 2013. The centerline was manually edited using LiDAR hillshade and 2011 aerial photographs. The data collected during the PHA Phase II cannot be compared to the MoRAP centerline because point coordinates in Phase II were only collected at 100 m intervals, and any attempt made at interpolation at this spatial resolution would be incorrect. Some data analyzed during Phase I were not collected during Phase II (land use / landcover, valley delineation and sinuosity, among others), or were measured from a different position than a measurement during Phase II. An example of the latter includes the geographic coordinates for the presumed bankfull bank in Phase I located at the top of the bank, and were recorded at the bottom of the bank in Phase II as per the field protocol.

7.0 Results and Discussion

7.1 Data Analyses

A summary of the types of data collected during the PHA Phase II is provided in Table 3. These data will be supplied to Boone County, Missouri with the final Phase II report in spreadsheet format (i.e. .xlsx). Data will then presumably be available to land managers and managing agencies as requested or needed to help guide watershed management and restoration decisions.

Table 3. Measurements collected for Physical Habitat Assessment database.

Coordinates	Bank Measurements	Channel Measurements	Substrate Qualification	Thalweg Profile
Survey point	Bank slope (both)	Wetted width	Pebble count	Thalweg depth
Right bank	Undercut	Channel width		Substrate particle size
Left bank	Bankfull width	Canopy cover		Periphyton p/a
Streambed*	Bank height**	Thalweg depth		Channel unit
		Relative thalweg depth		
		Thalweg position		

* If different from survey point. Also if site included a split channel, coordinates of sub-channels may be provided.
** Bank height was measured on the presumed bankfull bank.

The following sections provide a summary of the data collected during Phase II of the PHA. In the interest of consistency an attempt was made to generate data analyses that are reasonably comparable to the data presented in the Phase I PHA and summarized in the MoRAP report dated July 31, 2013. Comparisons are largely based on descriptive statistics or measurements at survey points as a function of stream distance.

7.2 Comparison of Observed Data to GIS Data

A point file of observed stream center point coordinates was opened in ArcMap and compared to a point file of stream center points (the survey points) generated by MoRAP. Using ArcGIS tools, the distance between the modelled and observed points was calculated at each survey point. The maximum distance between stream points was 93.44m. This maximum was a very extreme outlier, and was presumably influenced by the presence of two bridges side by side immediately upstream of the survey point that may have blocked satellite signals. On this basis, this outlier was removed from the data comparison pool. The new maximum distance between MoRAP and observed points was 39.93m, minimum distance 0.00m, mean distance 4.18m, median of data set 2.99m (data are right-skewed), and standard deviation 4.25m (Table 4).

Bankfull width data generated by MoRAP were copied as a column from the attribute table of the Hinkson Creek 50m survey points file, and pasted into an Excel spreadsheet side by side with a column of the observed bankfull width measurements. The MoRAP data corresponding to every 100m were converted to meters (data were in feet) for an exact comparison with the survey points. Comparison of the data yielded a maximum distance between points of 55.22m, a minimum of 0.01m, an average of 4.72m, median of and a standard deviation of 6.15m (Table 4).

The purpose of this comparison was for validation of the data generated by the MoRAP GIS modelled data for the HCW relative to observed data. The accuracy of the handlheld GPS unit used by the field team was ±3m. This range of accuracy explains the majority of the difference in the average distance between modelled and observed data. Other factors that may have affected the accuracy of the modelled and observed measurements include: human error (in both the modelling and observed scenarios), bank channel movement (the images and DEM files used by MoRAP predate at least one significant flooding event on Hinkson Creek in May of 2013), and interference with GPS satellite signal by land forms, weather, or the fact that the field team was down in the stream channel (for the point comparison).

Table 4. Descriptive statistics of differences between GIS modelled and observed center of stream points and bankfull width at survey points.

Statistic	**Center of stream points**	**Bankfull width measurements**
Maximum	39.93m	55.22m
Minimum	0.00m	0.01m
Mean	4.18m	4.72m
Median	2.99m	2.76m

7.3 Bank and Channel Measurements

At every 100m survey point, measurements were collected of bank and channel variables including bank angle (left and right), channel width, wetted width, bankfull width, and bank height. Bank angle exhibited the greatest variability, with a maximum of 100°, minimum of 0°, mean of 35.0°, and standard deviation of 16.1°. Channel width and bankfull width varied from a maximum of 70.0 m and 74.0 m respectively, to a minimum of 0.8 m and 1.8 m, respectively, near Hinkson Creek headwaters. Bank height reached a maximum of 5.8m near the mouth of Hinkson Creek at Perche Creek, with a minimum of 0.3 m, mean of 2.8 m, and standard deviation of 1.0 m. Please see Table 4 for a complete listing of descriptive statistics of bank and channel measurements.

Table 4. Descriptive statistics of bank and channel measurements for entire length of Hinkson Creek

Statistic	**Bank angle Left**	**Bank angle Right**	**Channel width**	**Wetted width**	**Bankfull width**	**Bank height**
Maximum	100°	96°	70.0m	24.9m	74.0m	5.8m
Minimum	2°	0°	0.8m	0m	1.8m	0.3m
Mean	34.6°	35.5°	15.4m	9.8m	24.2m	2.8m
Standard Deviation	15.8°	16.4°	8.2m	5.5m	9.4m	1.0m

Hinkson Creek is a multi-use watershed, with various dominant land uses. Agriculture is the dominant land use type in the upper reaches, while the urban center of Columbia is close to the center of the watershed and continues toward the mouth of the stream (MoRAP report July 31, 2013). For the purposes of exploring differences in measured bank and channel parameters with stream distance (and hence land use), Figures 5 through 8 are presented below. A legend of reference sites for Figures 5 through 9 and Figure 11 is presented as Table 5.

Table 5. Legend of reference sites shown in Figures 5 through 8, listed from headwaters to mouth. Sites that do not have an asterisk (*) are macroinvertebrate and water quality monitoring sites used by the Missouri Department of Natural Resources.

MDNR SITE #	LOCATIONS REFERENCED ON STREAM DISTANCE GRAPHS
	* E. Old Highway 124
	* Mt. Zion Church Road
	* Highway HH
8	Downstream of Rogers Rd. bridge
7	Upstream of Hinkson Creek Rd. bridge
6.5	Upstream of Highway 63 connector
6	East Walnut Street bridge
5.5	Downstream of Broadway and upstream of Old Highway 63
5	Upstream of Capen Park footbridge (upstream Grindstone Confluence)
4	Downstream of Rock Quarry Rd. bridge
3.5	Upstream of Recreation Dr. (MU intramural fields)
3	Downstream of Forum Blvd.
2	Upstream of MKT bridge near Twin Lakes Recreation Area
1	Downstream of Scott Blvd.

In streams that are affected by human land use, certain changes in physical parameters are observable (and expected) with stream distance. For example, while channel width is expected to increase with stream distance in natural stream systems, it also increases in altered systems (e.g. urban stream syndrome, Walsh et al. 2005). Increased overland flow resulting from deforestation, agriculture, and increases of impervious surface with urbanization can lead to channel incision. After incision, stream banks slump and collapse, and stream channels widen (Shepherd et al. 2011, Paul and Meyer 2001, Piégay and Schumm 2003). Figure 5 shows a slight trend of increasing channel width with stream distance. The absence of a strong positive trend could be interpreted in a couple of ways: 1) there is not a strong positive relationship between stream distance and channel width in Hinkson Creek, or 2) the positive relationship between channel width and the effects of human land use change with stream distance are just beginning to be observed in Hinkson Creek (Hubbart and Zell 2013).

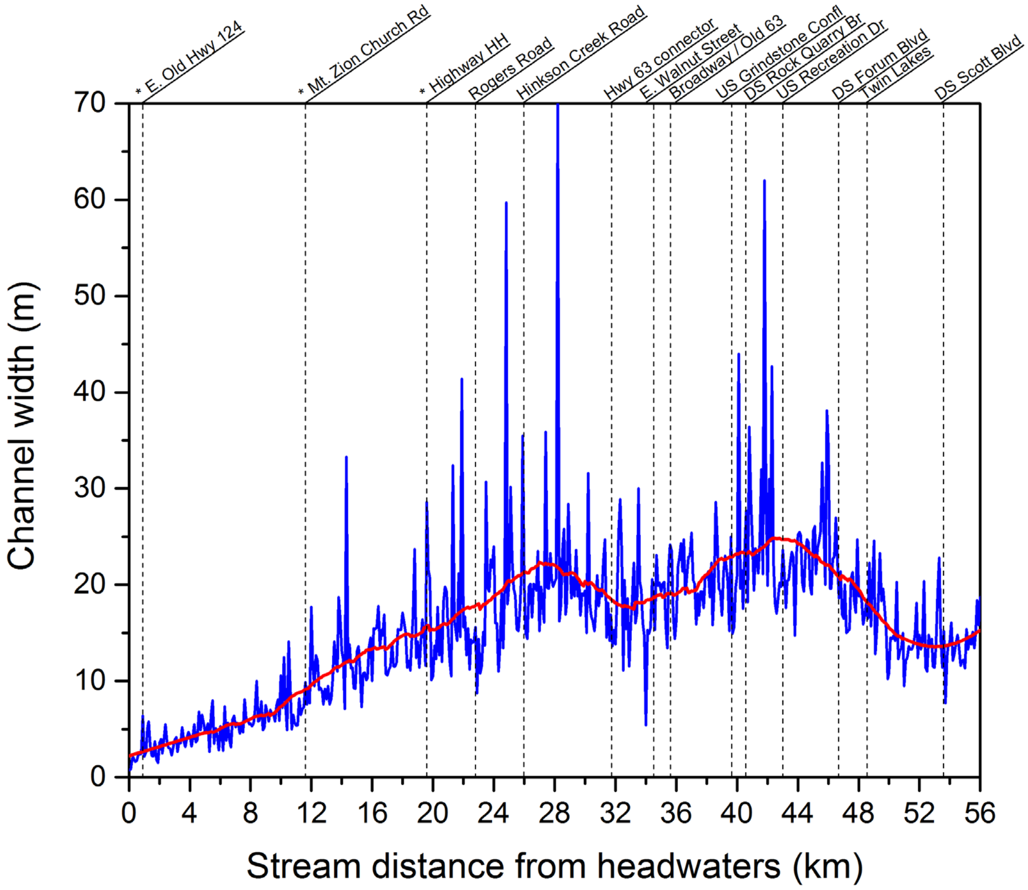

Figure 5. Channel width as a function of stream distance from the headwaters for the entire length of Hinkson Creek. 100pt moving average in red.

Wetted width in Hinkson Creek is highly variable. It would therefore not be expected that there would be a strong relationship between wetted width measured during the Phase II PHA and channel width because wetted width is highly dependent on discharge characteristics at the time of measurement whereas channel width and bankfull width are more persistent and relate to persistent hydrologic conditions. A comparison of channel width and wetted width with stream distance is shown below (Figure 6).

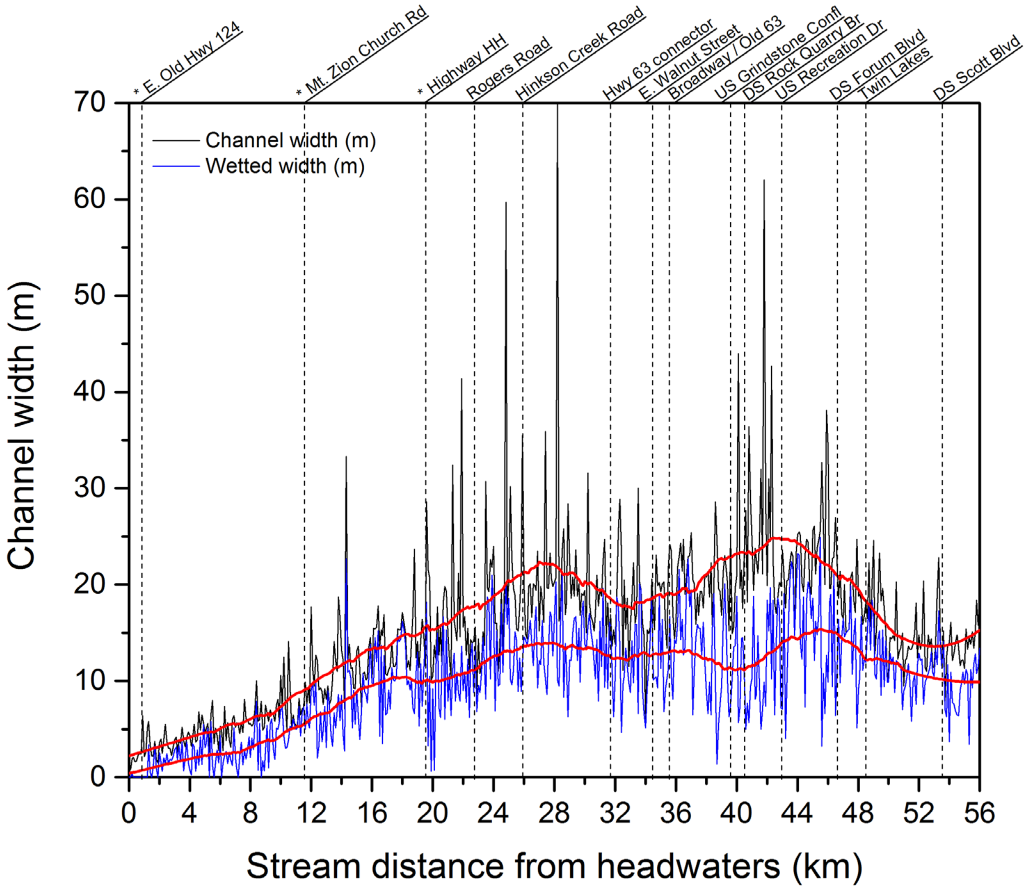

Figure 6. Channel width and wetted width as a function of stream distance for Hinkson Creek, with 100pt moving average in red.

Bankfull width measured from the top of the bankfull bank across the channel to the bankfull height on the opposite bank shows a slightly stronger positive relationship with stream distance than channel width (Figure 7). One possible explanation for this trend is that channel incision may be occurring in response to land use changes upstream (Booth and Jackson 1997).

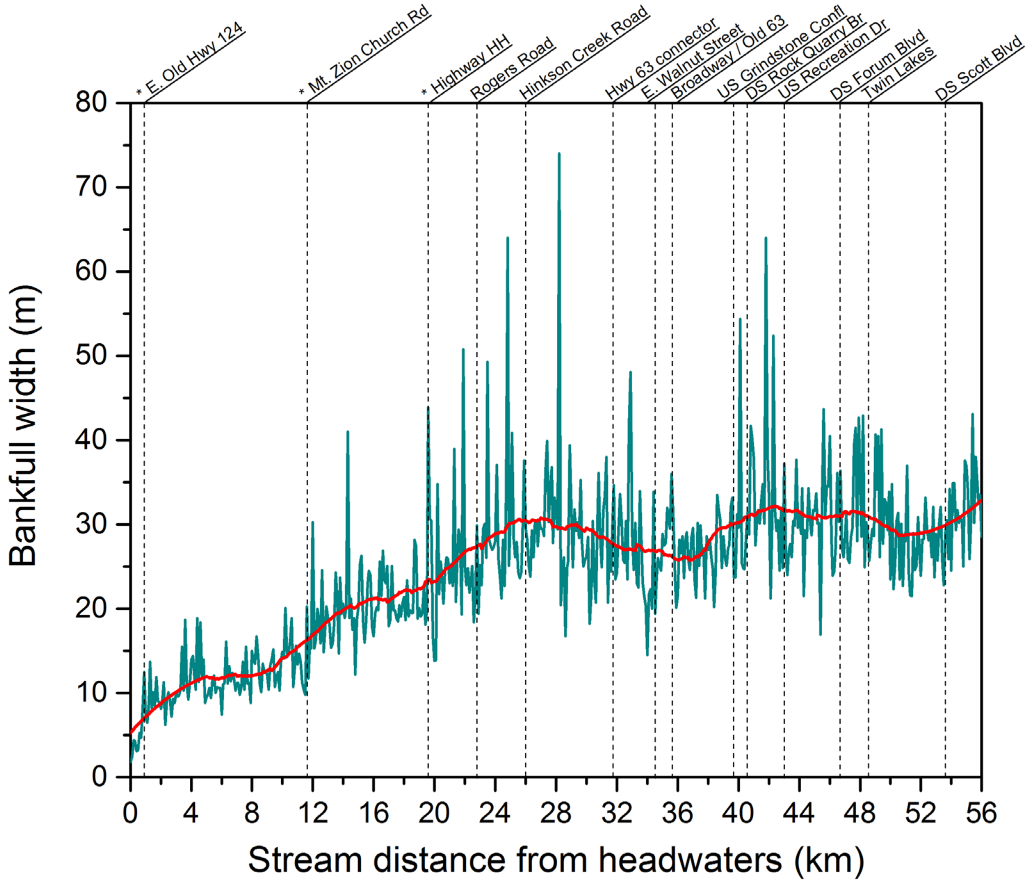

Figure 7. Bankfull width with stream distance in Hinkson Creek. 100pt moving average in red.

The graph in Figure 8 exhibits the strongest positive relationship (bank height increases as stream distance increases) of the bank and channel measurements illustrated between stream distances 42 km to 56 km. There is a rapid increase in bank height with stream distance in the lower reaches of the stream (from 3.44 m high at 42 km to 5.54 m high at 56 km), suggesting that suggesting that bank erosion due to channel incision may be ongoing in the channel below the City of Columbia (Hubbart et al. 2011, Huang 2012). Bank erosion and channel incision may be indicative of cumulative effects, including (but not limited to) alteration of stream hydrologic processes, loss of bottomland hardwood forests, and increased impervious surfaces (Hubbart et al. 2011, Hubbart and Zell 2013).

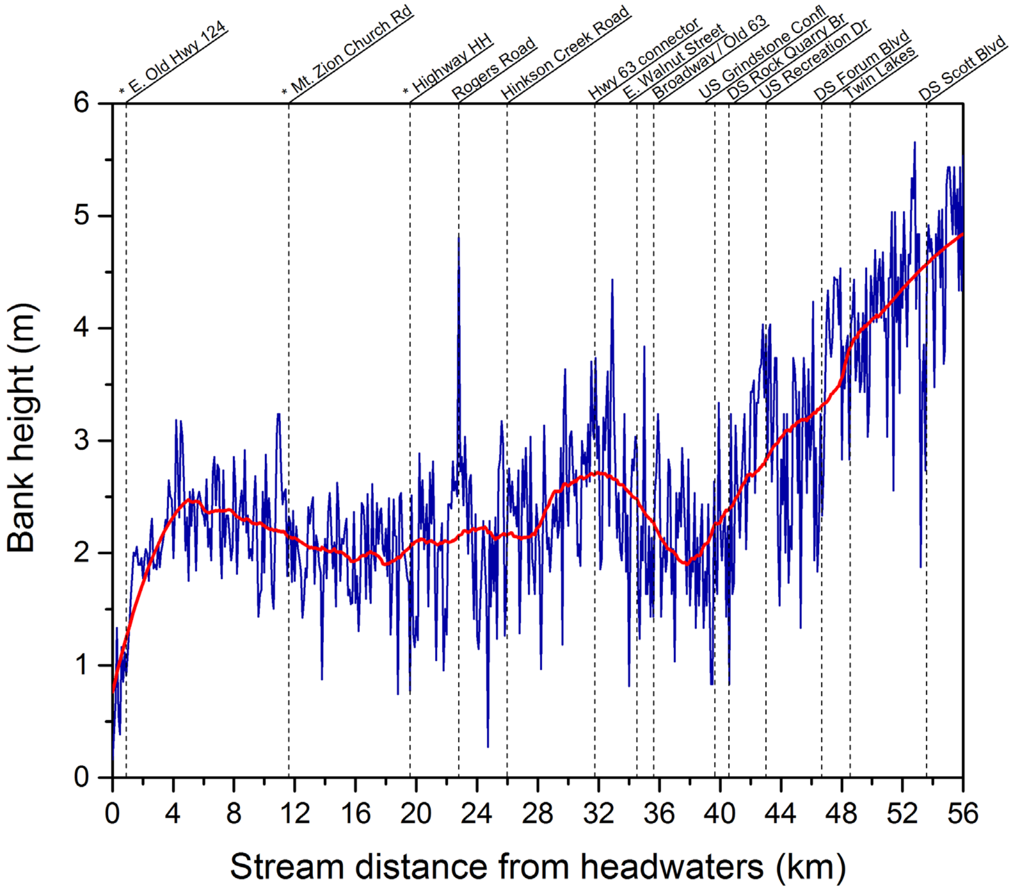

Figure 8. Bank height with distance downstream from headwaters, Hinkson Creek. 100pt moving average red.

7.4 Relative thalweg depth and thalweg position measurements

The thalweg is the deepest point in the stream channel. The thalweg does not maintain a consistent position laterally across the stream, but varies due to stream geomorphology and shifting substrate moved by stream flows. Thalweg depth is simply a point measurement of the deepest point in the stream channel at a given moment in time. Thalweg depth was measured in Hinkson Creek at the 100 m survey points, and then approximately every 10m between survey points. Thalweg depth varied from a maximum of 330 cm (10.83 feet) to a minimum of 0cm near the headwaters when the channel was dry (Table 5).

Measurements during Phase II of the PHA included relative thalweg depth and thalweg position. Relative thalweg depth measures the height from the thalweg to the top of the bankfull bank. Thalweg position is the distance from the thalweg to the top of the bankfull bank to the thalweg on a horizontal plane (Figure 4). Descriptive statistics for relative thalweg depth and thalweg position are listed in Table 5, along with the percentage of measurements where the presumed bankfull bank was the right or left bank. The general trend was an increase in relative thalweg depth with stream distance, such that the minimum of 0.2 m was found near the headwaters, and the maximum of 8.6 m was at a survey point near the mouth of Hinkson Creek.

Table 5. Descriptive statistics of thalweg measurements taken at each principal transect.

Statistic	Thalweg depth*	Relative thalweg depth	Thalweg position	Bankfull bank	Percentage of sites
Maximum	330cm	8.6m	68.3m	Right bank	52.9%
Minimum	0cm	0.2m	0.2m	Left bank	46.2%
Mean	50.3cm	3.4m	13.7m	Unrecorded sites (4)	0.9%
Standard deviation	38.7cm	1.2m	7.8m		

*Descriptive statistics are for all thalweg depths measured during thalweg profile.

7.5 Canopy cover

Average canopy cover was calculated for each 100 m survey point by averaging the six canopy cover measurements (at left bank, at center of stream: facing upstream, facing left bank, facing downstream, facing right bank, and at right bank) and dividing that average number by 17 (the maximum number of points that could be covered on the modified convex densiometer) to calculate average percent canopy cover per site. The percent canopy cover at the 100 m survey points ranged from a maximum of 100%, to a minimum of 0%, with a mean of 59.5% and standard deviation of 27.4%. A graph of the average percent canopy cover with stream distance illustrates the variability from site to site from headwaters to mouth in Hinkson Creek (Figure 9).

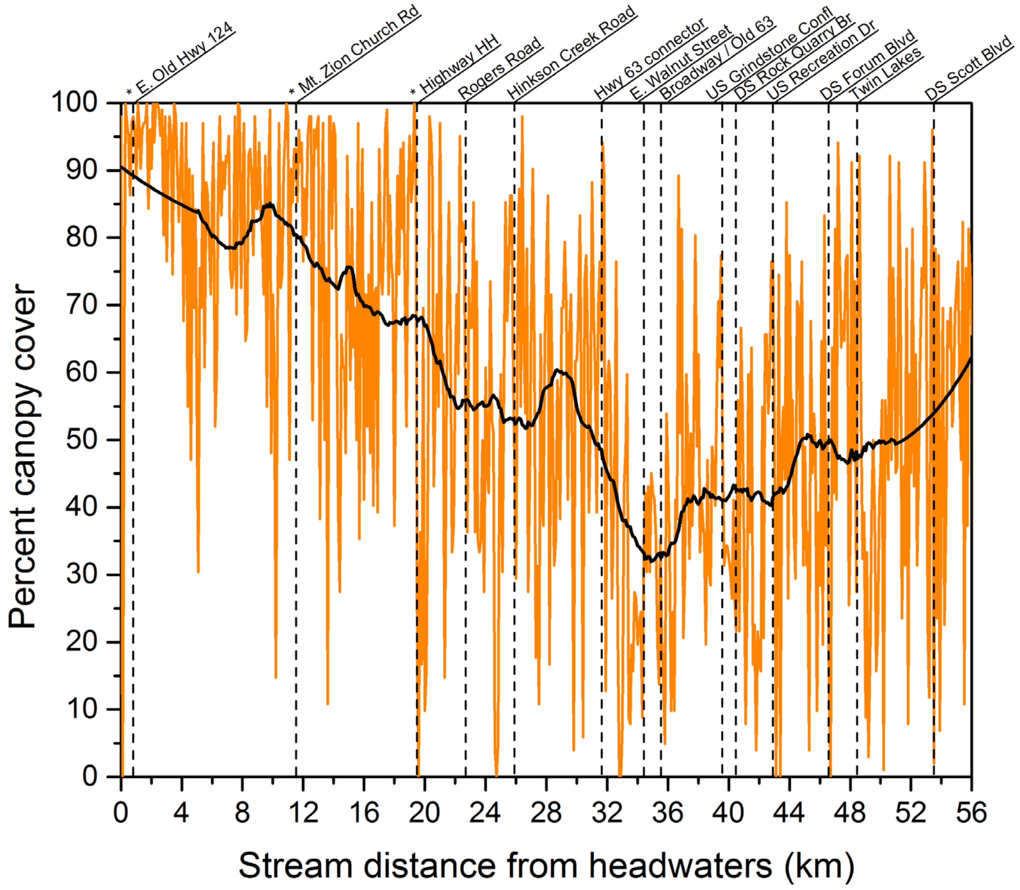

Figure 9. Percent canopy cover on each 100 m transect (average) with stream distance from headwaters, Hinkson Creek. 100pt moving average in black.

7.6 Substrate particle size and percent embeddedness

Substrate particles were collected during pebble count procedures (15 particles per 100 m survey plot), and then one additional particle was collected at the thalweg every 10 m between survey points. For ease of analysis, the particles were grouped into size classes. Small particles consist of fines (silt, clay), sand, and fine gravel (2 to 16 mm). Intermediate particles ranged from 16 to 1000 mm, and included vegetation (i.e. leaves, coarse particulate organic matter) and wood (i.e. logs, roots). The large size class included particles larger than 1000 mm, along with bedrock, both rough and smooth. The graph presented in Figure 10 below shows percentages of substrate particles broken down into individual particle size components. Substrate size is important for suitable microhabitat for aquatic organisms including macroinvertebrates such as clingers that require interstitial spaces between gravel particles in the substrate for habitat (Rabeni et al. 2005). Particle size composition was grouped into size classes in Table 6.

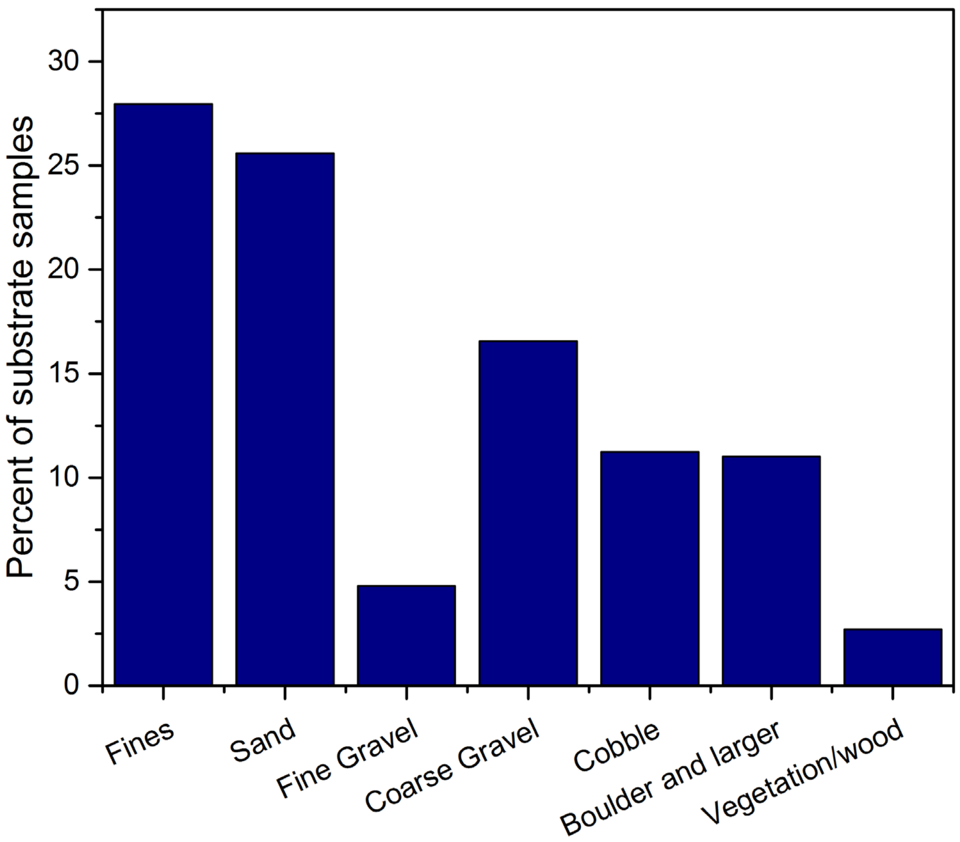

Figure 10. Substrate particles by size class (see Table 2) for all particles examined as a part of the Hinkson Creek physical habitat assessment, Phase II.

Table 6. Breakdown of size classes for sampled particles in pebble count and along thalweg profile.

Small		**Intermediate**		**Large**		**Other**
Sand	25.6%	Coarse gravel	16.5%	R bedrock	4.8%	0.24%
Fines*	28.0%	Cobble	11.2%	S bedrock	1.7%	
Sm gravel	4.8%	Sm boulder	3.3%	Xl boulder	0.8%	
		Vegetation	1.8%	Riprap	0.4%	
		Wood	0.8%	Lg concrete	0.06%	
Total:	58.4%		33.6%		7.76%	0.24%

*silt and clay

Substrate characteristics are the most significant habitat selection criteria for specific families of macroinvertebrates (Richards et al. 1993). However, substrate particle size is not the only characteristic of the streambed that is important for macroinvertebrate habitat. Embeddedness of the substrate due to deposition of fine sediment (i.e. sand, silt and clay) can fill interstitial spaces regardless of the particle size class composition (Rabeni et al. 2005). Average percent embeddednesss was calculated from percent embeddedness of the 15 particles collected during the pebble count at each 100 m survey transect. Average percent embeddedness is graphed as a function of stream distance in Figure 11 below. Average percent embeddedness at survey transects ranged from a maximum of 100% to a minimum of 10%, with a mean of 72% and standard deviation of 21%. The average percent embeddedness at a survey transect was calculated to be 100% fifty-one times along the length of Hinkson Creek, or approximately 9% of the survey transects. A highly embedded streambed significantly reduces habitat available for virtually all macroinvertebrates except those that are burrowers (Rabeni et al. 2005). Based on the results from the PHA Phase II, Hinkson Creek appears to have reduced habitat heterogeneity available for macroinvertebrate habitat.

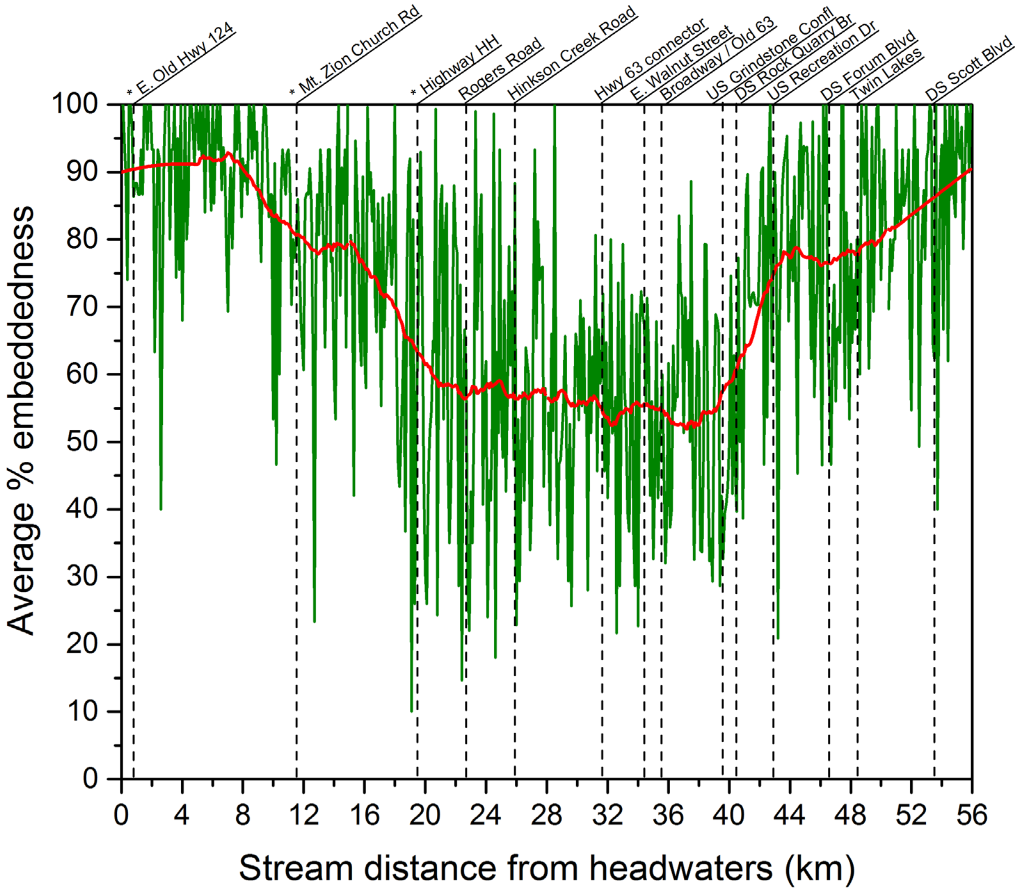

Figure 11. Average percent embeddedness for sampled particles (5) at each survey transect with stream distance from headwaters of Hinkson Creek. 100pt moving average in red.

7.7 Channel unit classification

Alluvial streams are expected to exhibit certain morphological characteristics, including a sequence of channel unit types, particularly riffles and pools. The riffle-pool sequence is expected at regular intervals along the stream continuum. The Missouri Department of Natural Resources (MDNR) procedure for Semi-Quantitative Macroinvertebrate Stream Bioassessment states that riffles are expected to occur at a distance of 7 to 10 stream widths (wetted width) due to the effects of sinuosity and the influence of point bars on streamflow velocity (MDNR 2003). The results of Phase II of the PHA showed that trench pools are the dominant form of channel unit at 70% of channel unit types recorded (survey point, and then every ten meters between survey points). Given the MDNR standard, and the average wetted width of 9.8m in Hinkson Creek, a riffle would be expected approximately every 68.6 to 98m. Using the more conservative estimate, 816 riffles would be expected along the length of Hinkson Creek (14.6% of channel unit classifications given total measurements of 5,583). Using this calculation, the results in Figure 12 are slightly above expected riffle-pool frequency in Hinkson Creek. The breakdown of channel unit types is listed in table form in Table 7.

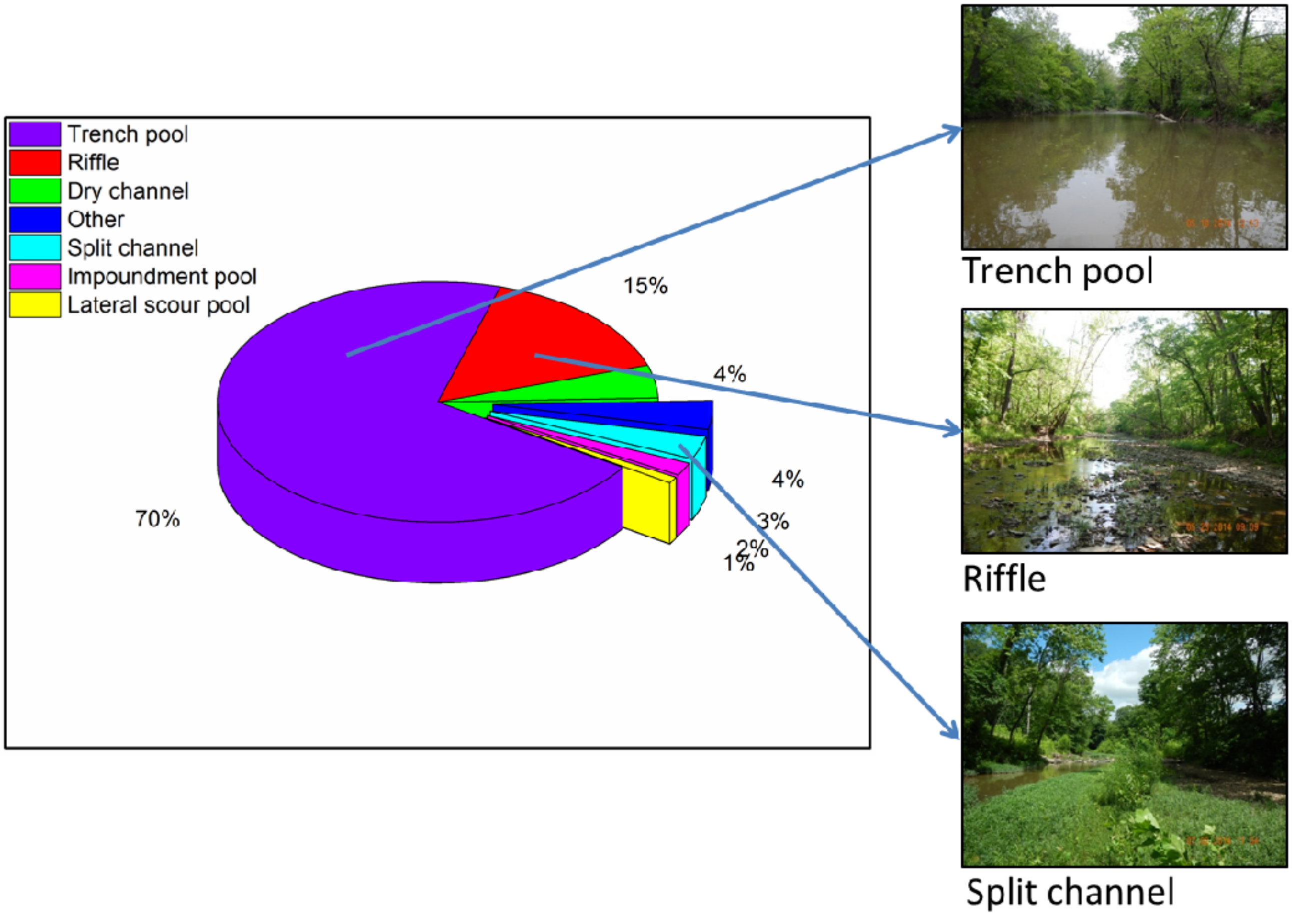

Figure 12. Breakdown of channel unit types in Hinkson Creek.

Table 7. Channel unit breakdown at principal transects and 10 m transects along thalweg profile.

Channel unit	Percent of total count
Trench pool	70%
Riffle	15%
Dry channel	4%
Split channel	3%
Impoundment pool	2%
Lateral scour pool	1%
Other	4%

7.8 Confluences

The point along the stream where a tributary enters the stream is called a confluence. Previous work showed that the effects of tributary convergence on stream morphology can be observed above and below a confluence (Benda et al. 2004). In Hinkson Creek, detailed bank and channel measurements were made at each of the eight major confluences. Three transects were used, one above and one below the confluence on Hinkson Creek, and then the last above the confluence on the tributary. The measurements from the three transects were averaged and confluence data are presented in Table 9. At the time of this work, bankfull width at the confluences was on average greater than average bankfull width along Hinkson Creek (average bankfull width 24.2 m).

Table 8. Summary of bank height and channel measurements for average of three transects at each major confluence of Hinkson Creek.

	Confluence*							
Measurement	**MB**	**MC**	**CH**	**FB**	**GC**	**HB**	**NC**	**VB**
Thalweg depth	43cm	49cm	1.34m	41cm	44cm	60cm	35cm	35cm
Bank height	4.92m	4.28m	4.30m	3.72m	2.55m	2.78m	2.70m	2.14m
Wetted width	6.21m	8.33m	11.30m	12.23m	9.10m	12.6m	12.21m	15.07m
Bankfull width	23.67m	24.80m	27.90m	37.97m	35.83m	26.6m	23.87m	22.8m
Channel width	9.18m	8.77m	13.57m	24.17m	21.8m	16.9m	14.4m	15.73m

*MB = Meredith Branch, MC = Mill Creek, CH = County House Branch, FB = Flat Branch Creek, GC = Grindstone Creek, HB = Hominy Branch, NC = Nelson Creek, VB = Varnon Branch

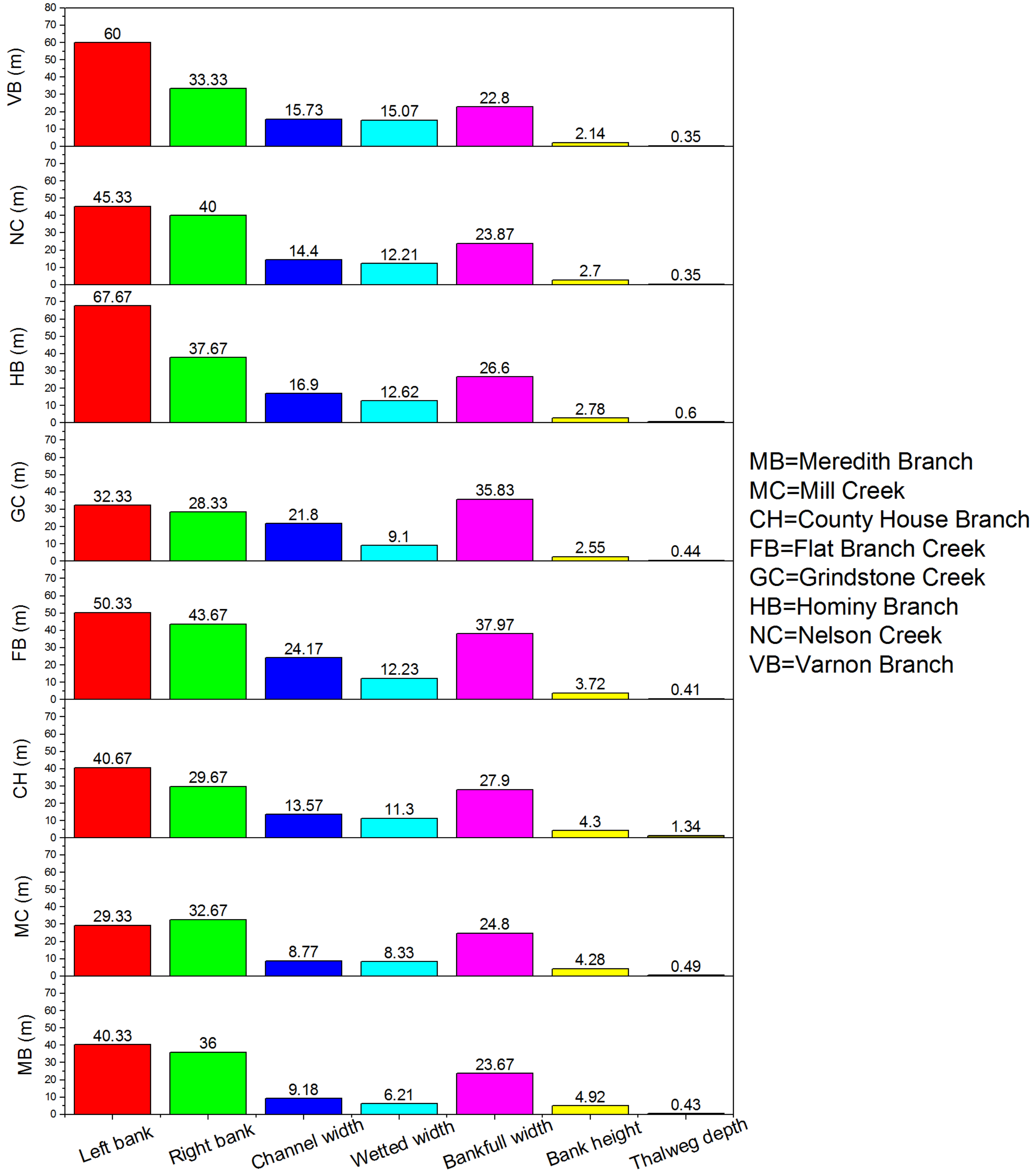

Figure 13. A comparison of averaged transect measurements (see Section 4.0 Field Protocol for how metrics are calculated) at the confluence of each of the eight major tributaries of Hinkson Creek. All measurements are in meters, with the exception of the left bank and right bank angles which are in degrees.

7.9 Photographic database

Standard channel photographs for each survey point will be presented to Boone County, Missouri at the time that this report is finalized and submitted, or as soon as a practicable mode of transferal is proposed. Presumably the photographic database will be uploaded to the project server and will be available to watershed stakeholders. The photographic database will also include photographs of special features (e.g. bank erosion, riprap, outlet pipes) for the survey point, and the 100 m section between survey points. For ease of cataloging, the photographs for the special features are named to include the survey point number, the date, the type of special feature, and whether the feature was noted on the right or left bank of the stream.

7.10 Statistical analysis of cross section accuracy

As per the field protocol, every tenth field day, one half day was spent resurveying every other survey point from the first field day in the sequence. If less than five sites were surveyed on the first field day, then all of the sites from the first field day in the sequence were resurveyed. The original bank and channel measurements were compared to the resurveyed measurements, and the differences were examined using descriptive statistics, including maximum, minimum, mean, median and standard deviation. Initial and return visit site data were arranged in columns and compared using the Student’s T-Test to check for statistical relatedness (CI = 0.05) (Sokal and Rohlf 1981, Zar 1996). At the 0.05 level of significance, none of the metrics were statistically different between the two survey dates, and the lowest p-value of all of the metrics compared was 0.54 (Figure 14, Table 9) indicating very strong relationships between initial surveys and resurveys.

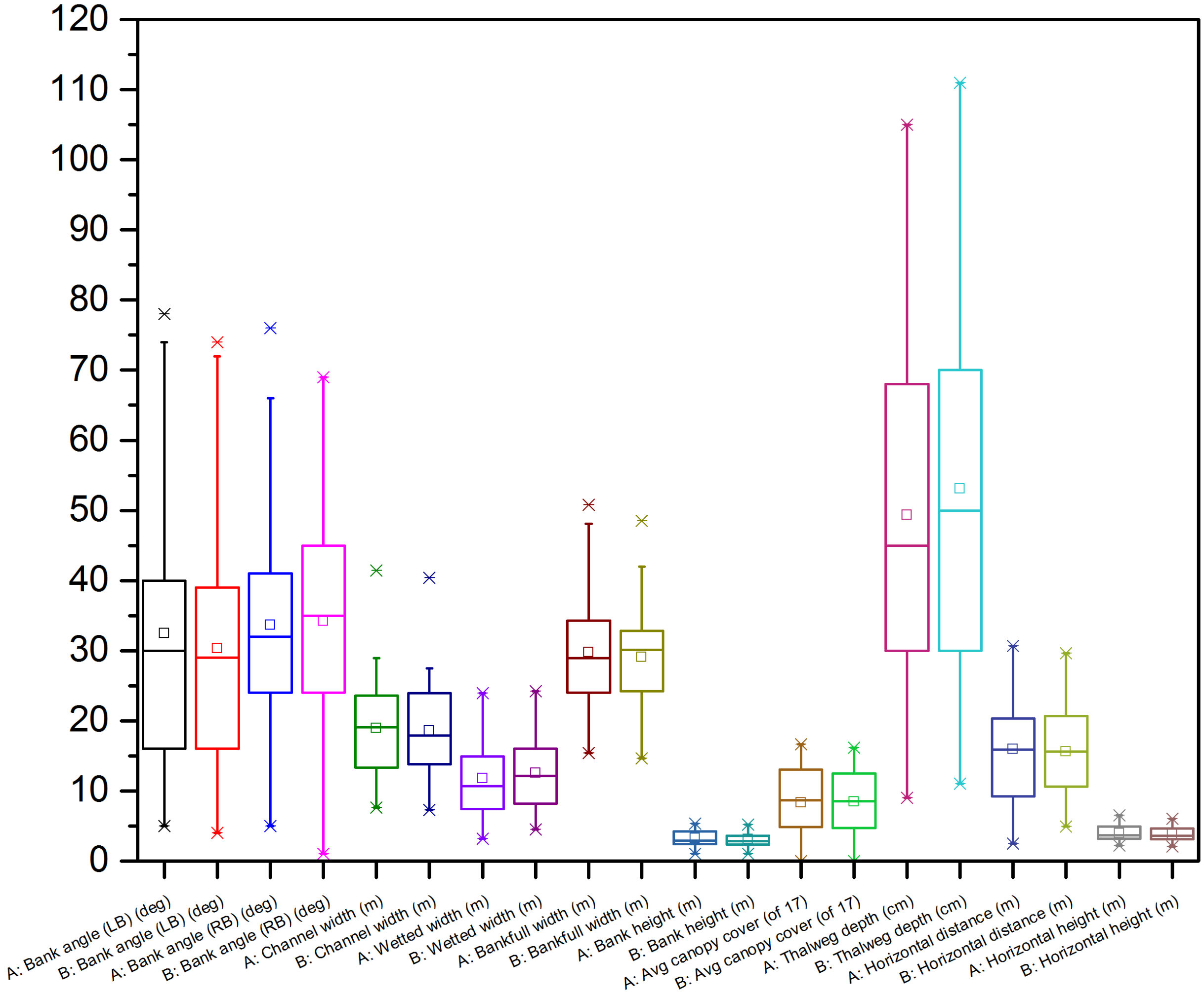

Figure 14. Box and whisker plot of comparison of initial survey metric (A) and resurveyed metric (B) at resurvey points. The median value of each measurement is shown by the horizontal line through the box, and the mean value of each measurement is shown by the small box near the horizontal line. Outliers are denoted by asterisks. If the two sets of measurements were statistically difference, there would be greater vertical distance between the larger boxes and the horizontal lines and small boxes.

Table 9. Descriptive statistics of comparison of initial surveys to resurveys.

Metric	Mean	Standard Deviation	Minimum	Median	Maximum
A: Bank angle (LB) (deg)	32.46	18.60	5.00	30.00	78.00
B: Bank angle (LB) (deg)	30.34	18.28	4.00	29.00	74.00
A: Bank angle (RB) (deg)	33.66	15.30	5.00	32.00	76.00
B: Bank angle (RB) (deg)	34.20	16.29	1.00	35.00	69.00
A: Channel width (m)	18.96	6.91	7.60	19.10	41.40
B: Channel width (m)	18.57	6.63	7.30	17.90	40.40
A: Wetted width (m)	11.77	5.45	3.20	10.70	23.90
B: Wetted width (m)	12.56	5.30	4.50	12.10	24.20
A: Bankfull width (m)	29.75	7.85	15.40	28.90	50.80
B: Bankfull width (m)	29.07	7.12	14.60	30.10	48.50
A: Bank height (m)	3.22	1.17	1.04	2.90	5.30
B: Bank height (m)	3.07	1.07	1.01	2.85	5.19
A: Avg canopy cover (of 17)	8.31	4.46	0.00	8.67	16.67
B: Avg canopy cover (of 17)	8.44	4.96	0.00	8.50	16.17
A: Thalweg depth (cm)	49.36	27.81	9.00	45.00	105.00
B: Thalweg depth (cm)	53.11	27.75	11.00	50.00	111.00
A: Horizontal distance (m)	15.96	7.45	2.50	15.90	30.70
B: Horizontal distance (m)	15.61	6.24	4.90	15.60	29.60
A: Horizontal height (m)	3.94	1.11	2.17	3.64	6.50
B: Horizontal height (m)	3.81	1.11	2.09	3.60	6.00

8.0 Closing Statements

The products presented from this research are the first phase of information generated from the data collected (i.e. the data product). Results have applicability for land use managers and agency planners in the Hinkson Creek Watershed. The photographic and numeric databases can be used to identify potential “hotspots” of hydrologic disturbance, and may indicate sites that would benefit from restoration efforts. Some of the data collected in the PHA Phase II will be further developed in the Master’s thesis of Lynne Hooper that should be available via the University of Missouri libraries website after June 1st, 2015. The large dataset generated by the PHA will be an invaluable resource for current, ongoing and future management activities and policy initiatives in the Hinkson Creek Watershed and provides a rich baseline data set that will be valuable for future assessments.

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