HINKSON CREEK COLLABORATIVE ADAPTIVE MANAGEMENT RESEARCH PROPOSAL: FY2015

Combined Flow and Suspended Sediment Proposal

Total Budget (Not to Exceed):
$280,000.00 (Please see Budget Details)

Submitted To:
Hinkson Creek Watershed Collaborative Adaptive Management
Stakeholders, Actions and Science Teams

Date:
March 19, 2014

Project Title:
Hinkson Creek: Quantifying Stream Flow and Suspended Sediment Response to Urbanization using a Scale-Nested Experimental Watershed Study Design

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Background

Hinkson Creeks listing on the Clean Water Act (CWA) 303(d) list as impaired due to unknown pollutants in 1998 (MDNR, 2011; USEPA, 2011) came about due to many problems suspected by State and Federal agencies, and local residents including (but not limited to), (1) larger and more frequent floods, (2) lower base flows; (3) increased soil erosion in construction and development areas with subsequent transport of the soil to streams (i.e. altered suspended sediment regimes); (4) water contamination from urban storm water flows; (5) degradation of habitat for aquatic organisms due to the concerns listed above; and (6) degradation of aquatic habitat due to the physical alteration of stream channels and adjacent streamside (riparian) corridors (MDNR, 2009). In November of 2008, with initial funding ($634,000) provided by the MDNR 319 program and USDA Ag Experimental Station, the PI began instrumenting Hinkson Creek with a nested-scale experimental watershed study design (Hubbart et al. 2010) to investigate the suspected problems that led to the 1998 listing and improve understanding of contemporary land-use and urbanization effects on hydrologic processes (stream response, water yield), water quality, and biological community health. Nested watershed study designs use a series of sub-basins inside a larger watershed to examine environmental variables. Sub-basins are often determined based on dominant land use and characteristics of the hydrologic system. A nested watershed study design enables quantitative characterization of influencing patterns and processes observed at each location (Hubbart et al., 2010). Each nested monitoring site of Hinkson Creek is designed to monitor water stage and a complete suite of climate variables. Multiple additional water quality variables (e.g. suspended sediment, nitrogen, phosphorus, chloride, pH, and other constituents) have been monitored at the nested sites since shortly after implementation of the study. A United States Geological Survey gauging station (USGS-06910230) has collected stage data intermittently since 1966 and provides flow data for site 4 (Figure 1).

Urbanization can significantly impact stream hydro-ecosystems. In particular by means of stream flow response to precipitation and runoff events. Increased impervious surface areas in urban watersheds, including roadways, rooftops, and parking lots, act to reduce or eliminate soil infiltration and increase the amount of stormwater runoff delivered to stream channels (Bledsoe and Watson 2001, Rose and Peters 2001, Jennings and Jarnagin 2002, Burns et al. 2005, Cianfrani et al. 2006, Xiao et al. 2007). Watershed imperviousness also reduces stormwater transit time, shortening the “lag time” between peak precipitation and peak flow (Galster et al. 2008). Vegetation removal and urban development also increases runoff volumes due to reduced evapotranspiration and canopy interception of precipitation (Hornbeck et al. 1997, Rose and Peters 2001, Im et al. 2003).

Stormwater flow serves as an important transport mechanism for non-point source pollutants, including suspended solids, nutrients, turf fertilizers, bacteria, and trace metals (Tsihrintzis and Hamid 1998, Xiao et al. 2007). Impervious surfaces serve as conduits for flow, replacing soils and vegetation that would otherwise attenuate runoff and transport of pollutants (Tabacchi et al. 2000). Urban peak discharge events also degrade water quality through physical alterations to the stream channel. Channels typically broaden and deepen in response to increased volume, velocity, and frequency of peak discharge in urban environments (Bledsoe and Watson 2001, Galster et al. 2008), leading to channel instability and accelerated channel erosion (Olsen et al. 1997). Changes in the timing, frequency, and magnitude of stream flow have significant impacts on freshwater ecosystem function (Postel 2000). Channel simplification as a consequence of increased peak discharge frequency also degrades stream habitat diversity and biotic integrity (Cianfrani et al. 2006). In nearly every region, peak discharge magnitude has been shown to increase in response to watershed urbanization. In the southeastern United States, Rose and Peters (2001) documented 30 to 100 percent increases in the magnitude of peak flows in urban watersheds relative to rural watersheds. Despite available information, little is known in urbanizing watersheds of the central U.S. where there is similarly no multi-use (including urban) experimental watershed studies underway from which to draw inference. Thus, the experimental watershed study design implemented in the HCW will provide a great deal of information both locally and regionally in terms of urban land-use effects on peak flow and other stream response characteristics.

A primary transport material of receiving waters is suspended sediment. Suspended sediment is a primary cause of freshwater impairment (USEPA, 2006) affecting the biological, chemical, and physical health of aquatic ecosystems (Uri, 2001). Excess sediment is associated with a host of aquatic ecosystem impacts including reduced transmission of sunlight, which can inhibit photosynthesis and primary productivity (Campbell et al., 2005). Too much suspended sediment can abrade or clog the gills of aquatic organisms, inhibit the feeding efficiency of filter feeders (i.e. mussels), obstruct sight-feeders (i.e. applies to most fish species), and adversely affect macroinvertebrate communities by filling streambed interstitial void spaces (Owens et al., 2005). Suspended sediment also serves as a transport mechanism for many water quality constituents (Keyes and Radcliffe, 2002).

Objectives

The objectives of this project are to improve understanding of the impairment of Hinkson Creek and to assess implications for recovery strategies. Study outcomes will identify land-use related impacts to flow, thus informing the CAM process, respond to original concerns (re: 1998 303(d) listing) in Hinkson Creek related to altered flow processes, and better inform the appropriateness of the formerly proposed volume-based flow reduction TMDL approach. The experimental watershed study design (presented above) in the HCW and associated flow and sediment data collected over the past four years will be used to improve quantitative understanding of stream responses to water –input events (i.e. precipitation) and the transport of sediment and sediment loading in Hinkson Creek. This analysis is a substantial undertaking and investment. For example, flow and precipitation data have been collected at 5-minute intervals during the entire time period (approximately 421,000 data points) and multiple grants have been obtained by the PI to maintain instrumentation and a graduate student labor force (~$1.5million). Sub-objectives of the current proposed analyses include estimating the interactions of land use type (forested, agriculture, sub-urban, urban) on stream response characteristics such as peak discharge, event flow hydrographs (or effective water input), storm duration, hydrograph rise, response lag, time to peak, response time, time of concentration and other stream responses characteristics (Dingman, 2002) (as appropriate, as analyses progress) will be evaluated at and between each nested monitoring site. These relationships where practicable will be evaluated with observed suspended sediment concentrations. Observed data and analyses will then be used to calibrate a hydrological model (such as the soil water assessment tool, SWAT), and/or a water resources planning and management analytical tools (e.g. StreamStats, USGS). A calibrated hydrological model will allow us to assess sensitivity of Hinkson Creek streamflow characteristics to a wide range of past and future land-use changes in the watershed.

Study Rationale

1. Quantifying stream response to rainfall events and associated transport of suspended sediment will provide understanding of how these processes vary with stream distance and land-use in Hinkson Creek. Thus, the potential causes of water quality concerns related to physical habitat will become more apparent through this study.
2. This study, coupled to the Physical Habitat Assessment (PHA) results, will help inform decisions on possible actions to improve habitat and water quality in Hinkson Creek by showing where important changes in suspended sediment dynamics occur relative to location (i.e. land-use) in the watershed.

By comparing Hinkson Creek flow data with that from other streams in both urbanized and rural settings, it may be possible to estimate how altered Hinkson Creek has become as a result of land-use practices (e.g. urbanization). This provides a critical measure for determining what might be possible in terms of "restoration" of Hinkson Creek and to better estimate *realistic* extents of action needed to mitigate current and future development impacts.

Methods

Streamflow Metrics

Discharge at gauge sites 1, 2, 3, and 5 will be measured at designated stream cross-sections using the velocity-area method (Rantz 1982, Jones 1997, Dingman 2002, Chen and Chiu 2004). Cross-section discharge estimates will be used to create rating curve equations that will adjust stage measurements (5-minute intervals) from gauge sites. Stream response characteristics will be assessed based on a suite of metrics that may include but are not limited to mean annual flows, 7-day low flows in winter and summer, peak discharges due to rainfall as well as number of flow days with high and extreme flow rates greater than the mean plus one or two standard deviations, respectively (Novotny and Stefan, 2007), or upper confidence limits (CL) to detect significant differences in peak discharge (e.g. 90% CL) as per methods such as Beschta et al. (2000). There may also be some basis for considering precipitation and/or flow return periods in the analysis. Simple regression analysis (Hirsch et al., 1993), and/or statistics such as (but not limited to) Mann-Kendal non-parametric tests will be used to detect significant trends over time and between streamflow monitoring sites. The current work should not be considered all-encompassing or exhaustive, but will be <u>focused on the most meaningful information that will most effectively assist the CAM process</u>.

Suspended Sediment

Suspended sediment concentrations have been quantified using two standardized methods, 1) mass (or gravimetric, mg/l) concentration by wet sieving (ASTM, 1999: Edward and Glysson, 1999; Davis, 2005), and 2) laser diffraction analysis (ul/l). Wet sieving produces Total Suspended Sediment (TSS), or Suspended Sediment Concentration (SSC) information. The main difference between the TSS and SSC method is that TSS generally analyzes an aliquot of a total sample, whereas SSC analyzes the entire sample. Recent advances in suspended sediment monitoring include *in situ* fully automated devices that sense and log suspended sediment and particle size classes (Gray and Gartner, 2009). Laser diffraction instruments often provide volumetric estimates of sediment concentration as opposed to a mass concentration (Agrawal and Pottsmith, 2000) because the optical power distribution is converted to an area distribution. The LISST-Streamside (Sequoia Scientific Inc.), used in the current work utilizes laser diffraction technology to estimate suspended sediment and particle size class concentration metrics (Hubbart and Freeman, 2010). Both methods were used in the current work because each method has its advantages. For example, questions of sediment loading and yield may be most appropriately addressed using mass/gravimetric methods since the studies concern transfers of mass between systems (Walling 1999; Walling and Fang 2003; Wass and Leeks 1999). Conversely, water quality questions, such as the effects of excess sediment concentrations on aquatic biota, may be more aptly addressed via volumetric methods since the method quantifies relative proportions of a given constituent within a water body (Nichols, 2013).

Regardless of the method used, sample collection and laboratory analyses are expensive, and labor intensive (Gray and Gartner, 2009). The collection and labor involved with laboratory analysis will be complete on March 1, 2014. This proposal includes analysis of these data to provide information on how suspended sediment concentrations, loads, and particle-size distributions vary over time in Hinkson Creek.

Study Outcomes: Product(s) and Recommendations for CAM Process

Distinct products are listed as follows for flow and sediment. However, it is worth mentioning that sediment analysis cannot be concluded without flow, so combination of the two studies is a logical course of action.

Flow

Results of data analysis will provide quantitative estimates of stream response characteristics (such as those listed above) in Hinkson Creek. Products will include:

- Annual estimates of stream response metrics at all 5 nested monitoring sites in the HCW.
- Seasonal and event based estimates of stream response metrics at all 5 nested monitoring sites in the HCW.
- Modeled vs. observed stream response metrics (for example, peak flow) processes using a process based model such as (but not limited to) the Soil Water Assessment Tool (SWAT).

Stream response metrics will be compared to land use types in the overall watershed and in each respective sub-catchment (n=5, Figure 1) of the HCW. Modeling results will be very important for this phase of the work to understand land-use impacts on flow processes. Study results will be synthesized with respect to overall implications for the severity and causes of impairment of Hinkson Creek. Results from Hinkson Creek will be compared with similar studies in other urban areas to provide insight on controlling factors.

The combination of flow dynamics, land use characteristics, and hydroclimatic data will provide detailed, quantitative information that will provide evidence to support, or refute hypotheses about causes for altered stream flow regimes in Hinkson Creek. That information will help guide decision makers in terms of management plans in terrestrial and aquatic environments to mitigate any detected alterations. Study outcomes will identify land-use related impacts to flow dynamics that will inform the CAM process and respond to original concerns in Hinkson Creek related to altered flow processes. Results will also help target most effective locations for BMP implementation projects, and better inform the appropriateness of the formerly proposed volume-based flow reduction TMDL approach.

Suspended Sediment

Results of flow analysis will provide transport relationships to improve quantitative estimates of:

1. Annual suspended sediment loads at all 5 nested monitoring sites in the HCW.
2. Quantitative estimates of fine particle size class concentrations between sites, as an indicator of sediment source or the type of sediment-related stress. For example, urban stormwater runoff may contribute disproportionate quantities of fine sediment to receiving water bodies, while simultaneously starving watercourses of total sediment concentration.
3. Modeled vs. observed suspended sediment loading using the Soil Water Assessment Tool (SWAT).

Total loading and particle size class analysis results will be compared to land use practices in the overall watershed and in each respective sub-catchment (n=5, Figure 1) of the HCW to provide relations between existing land use and suspended sediment. Modeling will be important in this phase of the work to help describe land-use practice impacts to sediment dynamics through 1) providing estimates of background sediment yield under pre-urban conditions and 2) providing a means to assess sensitivity of sediment loading to various land-use scenarios. Study results will be synthesized with respect to overall implications for the severity and causes of impairment of Hinkson Creek. Results from Hinkson Creek will be compared with similar studies in other urban areas to provide insight on controlling factors.

The combination of sediment loads, concentrations, and size distributions, compared with land use characteristics and hydroclimatic data, will provide detailed, quantitative information that will provide evidence to support, or refute hypotheses about causes for altered suspended sediment regimes in Hinkson Creek and thus guide decision makers accordingly in terms of management plans to mitigate any detected alterations in the receiving water body. Thus, study results will inform the CAM process by identifying whether or not suspended sediment is a problem in Hinkson Creek, and if so, where, and by how much.

Products will include annual reports to CAM teams and at least 6 publications in the peer reviewed literature addressing the numbered bullets above.

Not to Exceed Budget

The proposed work will support a post-doctoral research associate (PDA) in the Interdisciplinary Hydrology Laboratory of the PI. The PDA will post-process and analyze data, conduct modeling and report results that will supply improved understanding of land-use impacts on stream response, and management recommendations in Hinkson Creek.

Post-doctoral research associate stipend, benefits and analysis and modeling software, office supplies, consumables: $70k/yr x 4 yrs = $280k

Tentative Budget

	Year 1	Year 2	Year 3	Year 4	Total
Salary Post-Doc	$ 45,000.00	$ 47,250.00	$ 49,612.50	$ 52,093.13	$ 193,955.63
Benefits	$ 15,916.50	$ 16,712.33	$ 17,547.94	$ 18,425.34	$ 68,602.10
Analyis and Modeling Software	$5,000	$3,000	$1,000	$0	$ 9,000.00
Travel	4000	3000	1800	0	$ 8,800.00
Total Direct Costs	$ 69,916.50	$ 69,962.33	$ 69,960.44	$ 70,518.46	$ 280,357.73
				Grand Total:	**$ 280,357.73**
Funding Source and Amount					
University of Missouri	$ 69,916.50	$ 23,320.78	$ 23,320.15	$ 23,506.15	$ 140,063.58
City of Columbia		$ 23,320.78	$ 23,320.15	$ 23,506.15	$ 70,147.08
Boone County		$ 23,320.78	$ 23,320.15	$ 23,506.15	$ 70,147.08
				Grand Total:	**$ 280,357.73**

Based on the tentative budget above, each of the three CAM partners are requested to fund approximately $23,320 for year each year following the first year (2, 3, and 4).

Tentative Schedule

Tasks/Accomplishments	Year 1				Year 2				Year 3				Year 4			
	F	W	Sp	Su	F	W	Sp	Su	F	W	Sp	Su	F	W	Sp	Su
Post-Doc Secured for Project	X	X														
Data post processing		X	X	X	X	X	X	X	X	X	X	X	X	X		
Report #1, Article #1, and 2 Submission				X	X											
Report #2, Article #3, and 4 Submission								X	X							
Report #3, Article #5 and 6 Submission												X	X			
Work Completed															X	X

Reports are distributed to CAM teams.
Timeline assumes post-doc appointment at noted date (could be delayed depending on qualified applicants)

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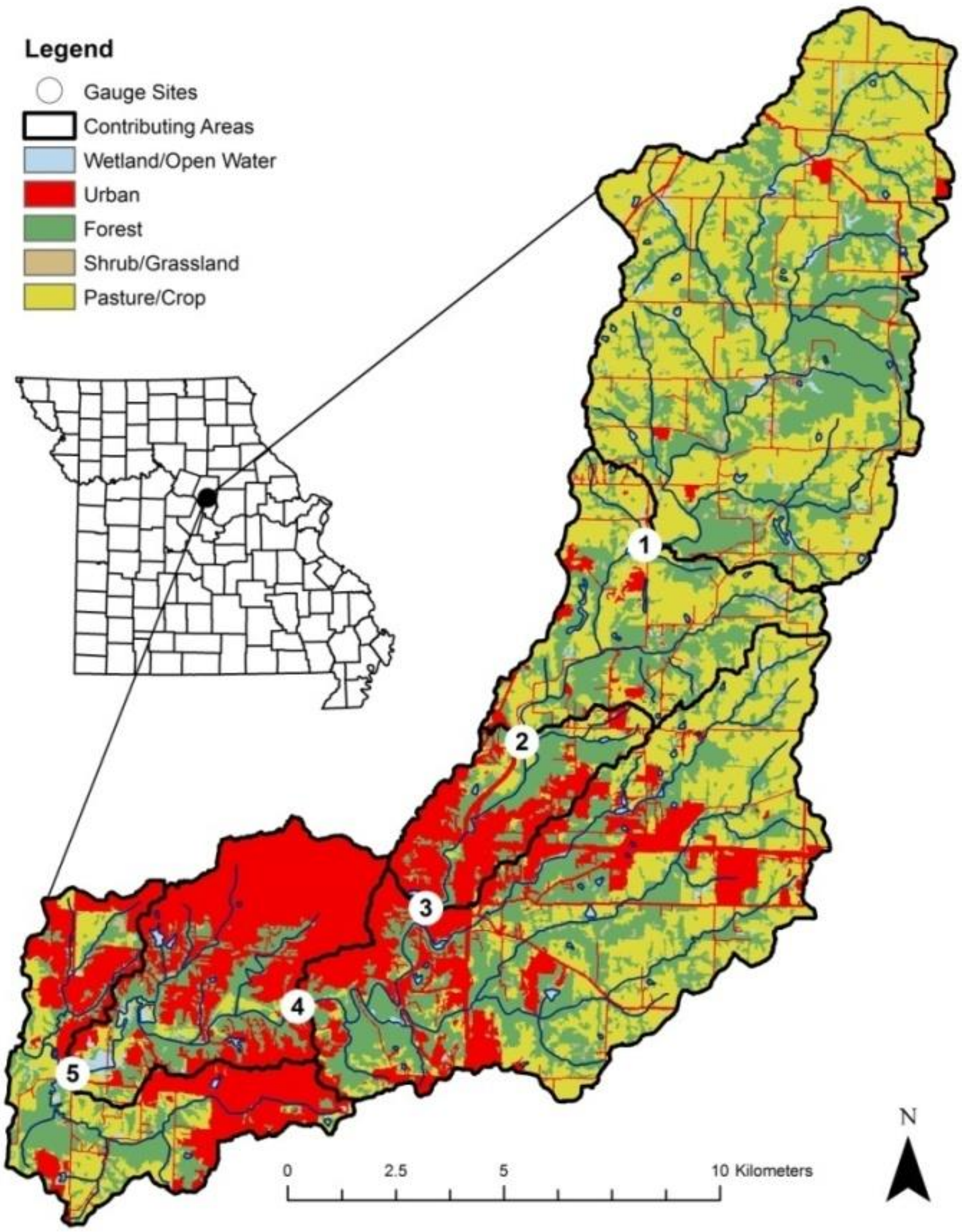

Figure 1. Hinkson Creek Watershed (HCW) nested-scale experimental watershed study design (site 4 is the USGS gauging station).