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Urban Ecosystems: Alterations to Peakflow, Microclimate, and the Natural Environment

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Introduction:

- More than half of the world's population lives in urbanized ecosystems.
- Continued human population growth over the next several decades will place unprecedented demand on urban water resources, resulting in escalating water quality and supply challenges.
- Urbanization exacts significant impacts on stream ecosystems including increased magnitude and frequency of peak flows, altered microclimates and reduced biodiversity.
- Stormwater flow serves as an important transport mechanism for non-point source pollutants, and impervious surfaces serve as preferential flow paths, replacing soils and vegetation that would otherwise attenuate runoff and pollutants.
- Stream channels typically broaden and deepen in response to increased volume, velocity and frequency of peak flows, leading to increased channel instability, accelerated erosion, and subsequent loss of habitat.
- The following research will lead to quantification and improved understanding of developmental/urbanization impacts to fresh water resources and natural resource sustainability in dynamic urbanizing landscapes.

Hinkson Creek Watershed (HCW) Description:

- Watershed area: approximately 230.8 km^2.
- The HCW flows approximately 42 kilometers southwesterly to it's confluence with Perche Creek, and is situated in the transitional zone between Glaciated Plains and Ozark Natural Divisions (Thom and Wilson 1980).
- Land use in the upper portion of the watershed is largely rural pastureland and wooded areas. The lower portion of the watershed lies within the urbanized section of the city of Columbia.
- Soils are prairie-forest transitional, poor to well drained, and are easily erodible in part due to steep slopes (Perkins 1995). Soil types in the upper and lower HCW are loamy till with a well developed clay pan and thin cherty clay and silty to sandy clay respectively (Chapman et al. 2002).
- Vegetation is characterized as a mixed deciduous oak forest . Riparian zones contain willows (*Salix, spp*), birch (*Betula, spp*), cottonwood (*Populus, spp*), and sycamore (*Plantanus, spp*). Alluvial fans are covered with elm (Ulmus, spp), maple (*Acer, spp*), basswood (*Tilia, spp*), and woody shrub (*spp*).

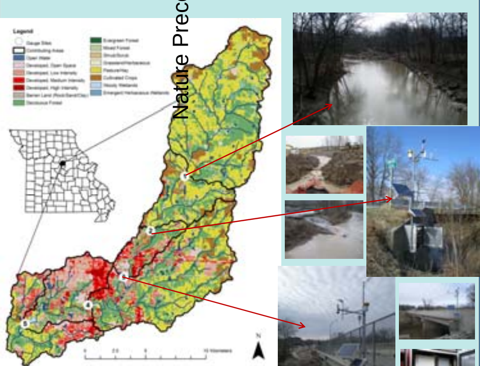


Figure 1. Hinkson Creek Watershed (HCW) Located in Central Missouri

Hinkson Creek Watershed Climate and Hydrology

- The Transitional climate of Missouri includes influences from winter dominant continental polar air masses, and summer prevalent maritime and continental tropical air masses. This translates to broad fluctuations in temperature (12.8 ºC avg/yr) and precipitation (1016 mm/yr). Heaviest rainfall typically arrives in the late spring and early summer with 70% of the total precipitation falling in the period from April through August. Annual snowfall is around 508 mm (Nigh and Shroeder, 2002).
- Elevation ranges from 177 meters at the confluence of Perche Creek to 274 meters above sea level in the headwaters. A U.S. Geological Survey gauging station (S.N. 06910230) is located on Hinkson Creek (Figure 1, Site #4).
- Average discharge measured at the gauging station from Oct. 1966 to date is approximately 1.42 m^3/s, with a range of 0.38 m^3/s in 1980 to 3.14 m^3/s in 1973.

Methods (Preliminary Analyses):

- Installation of five permanent hydroclimate monitoring sites commenced during the winter of 2008/2009.
- A Nested-Scale Watershed Study Design approach was used to establish permanent gauging locations.

Table 1. Variables sensed, sensors, and sensing intervals at each of five heavily instrumented hydroclimate monitoring sites in the HCW.

Variables Sensed (all 5 sites)	Units	Sensor Model	Sensing Interval
Accubar Constant Flow Bubbler	mm	Sutron, 56-0133	10s
Suspended Sediment	ul/l	Sequoia Scientific, Inc. LISST	30min
Air Temperature	°C	Vaisala, HMP45C	30sec
Soil Temperature	°C	CS 107	30sec
Relative Humidity	%	Vaisala, HMP45C	30sec
Wind Speed	m/s	Met-One 034B	30sec
Wind Direction	Deg	Met-One 034B	30sec
Vegetation/Snow Depth	cm	SR50A, Sonic Range Sensor	30sec
Soil Volumetric Water Content	%	CS 616	30sec
Precipitation (SNOTEL)	mm	TE525WS Rain Gage	30sec
Radiation	W/m^2	LI200X, LI-COR Pyranometer	30sec

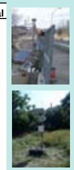


Table 2. Total and cumulative contributing (ha), and land-use (%) areas for the HCW (assuming 15 land-use divisions) for each of five gauge sites in the Hinkson Creek Watershed, Missouri (GIS work by Daniel Scollan).

Site	Contributing Areas Area (ha)	Open Water Area (%)	Developed, Open Space Area (%)	Developed, Low Intensity Area (%)	Developed, Med. Intensity Area (%)	Developed, High Intensity Area (%)
1	7742.3	0.5	4.2	0.5	0.0	0.0
2	2358.5	0.6	5.0	1.8	1.2	0.4
3	1327.4	0.4	14.4	19.0	13.8	4.8
4	6526.8	0.7	8.1	9.6	5.5	1.6
5	2630.1	1.0	18.7	31.2	12.2	4.8
Cumulative	20585.1	0.6	8.1	8.7	4.3	1.5

Site	Contributing Areas	Barren Land	Deciduous Forest	Evergreen Forest	Mixed Forest	Shrub/Scrub
1	7742.3	0.0	34.3	0.6	1.2	0.5
2	2358.5	1.4	34.7	0.8	2.2	1.1
3	1327.4	0.1	29.6	0.4	1.9	0.6
4	6526.8	0.4	33.9	1.0	1.6	0.3
5	2630.1	0.1	22.4	0.1	0.6	0.2
Cumulative	20585.1	0.3	32.4	0.7	1.4	0.5

Site	Contributing Areas	Grassland/ Herbaceous	Pasture/ Hay	Cultivated Crops	Woody Wetlands	Emergent Herbaceous Wetlands
1	7742.3	1.1	44.9	10.3	1.9	0.1
2	2358.5	0.7	36.7	12.2	1.3	0.0
3	1327.4	0.1	10.2	4.3	0.4	0.0
4	6526.8	0.6	28.0	7.6	0.9	0.0
5	2630.1	0.4	5.3	1.0	2.1	0.0
Cumulative	20585.1	0.8	31.3	8.1	1.4	0.0

- Contributing areas and land-use cover classes were determined in ESRI ArcGIS 9.3 using 10 m DEM data from the National Elevation Dataset (NED) data and 30 m land-use cover data from the National Land Cover Dataset (NLCD).

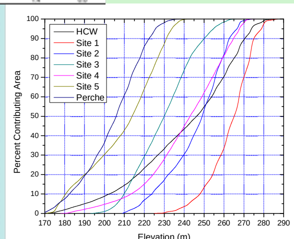


Figure 2. Hinkson Creek Watershed (HCW) hypsometric curves showing relative contributing area (m) to each of the 5 permanently located monitoring stations. Also shown, are hypsometric curves for the entire HCW, as well as the remaining watershed below site 5.

Results and Discussion (Preliminary Analyses):

- Continuous stream stage and climate data collected at permanently located monitoring sites were used to quantify peak flow and climate differences between different land-use types of the watershed.

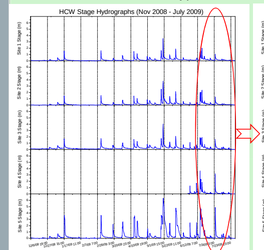


Figure 3. Stage hydrographs representing 5 HCW gauging sites from Nov 16th, 2008 to July 29th, 2009.

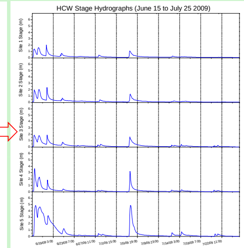


Figure 4. Stage hydrographs representing 5 HCW gauging sites from June 15th to July 25th, 2009.

- Preliminary results indicate that the forest headwaters of the HCW tend to attenuate peak flows of small precipitation events (< 0.80 mm), whereas events of similar magnitude in urban settings cause relatively higher spikes in water flow and corresponding flashier rising and falling limbs of the hydrograph.

Stage Statistics (November 16th 2008 through July 29th 2009)

	Site 1 stage(m)	Site 2 Stage(m)	Site 3 stage(m)	Site 4 stage(m)	Site 5 Stage(m)
Average stage (m)	0.178	0.178	0.248	0.205	0.429
Minimum Stage (m)	0.000	0.000	0.000	0.000	0.000
Maximum Stage (m)	3.534	3.790	4.032	3.626	6.325
Std Dev Stage (m)	0.237	0.284	0.278	0.376	0.879

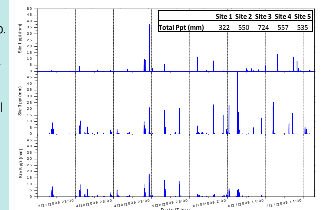
Stage Statistics (June 15th through July 25th 2009)

	Site 1 stage(m)	Site 2 Stage(m)	Site 3 stage(m)	Site 4 stage(m)	Site 5 Stage(m)
Average stage (m)	0.238	0.243	0.260	0.225	0.559
Minimum Stage (m)	0.073	0.060	0.026	0.014	0.020
Maximum Stage (m)	2.031	2.346	1.897	3.626	4.876
Std Dev Stage (m)	0.254	0.312	0.323	0.434	1.051

Table 3. descriptive statistics reflecting stage data collected at 5 permanent gauging sites on Hinkson Creek, central Missouri.

- Maximum stage (m) at site 5 is approximately 150% higher than the average maximum stage at all other sites from Nov 08' to July 09'.
- Maximum stage (m) at site 5 is approximately 1.25 times higher than site 4 during the time period June 15th – July 25th. While expected (i.e. study design, nested scale), these stage depths are accompanied by extreme flooding:

- Majority of precipitation falls in the City proper of Columbia, Mo.
  - ~60% more
- This is a common phenomena in urban settings, but has been rarely quantified.
- The HCW watershed study will quantify these environmental alterations.



	Site 1	Site 2	Site 3	Site 4	Site 5
Total Ppt (mm)	322	550	724	557	535

Figure 5. Precipitation measured at sites 1, 3, and 5 from March 2nd to July 25th, 2009.

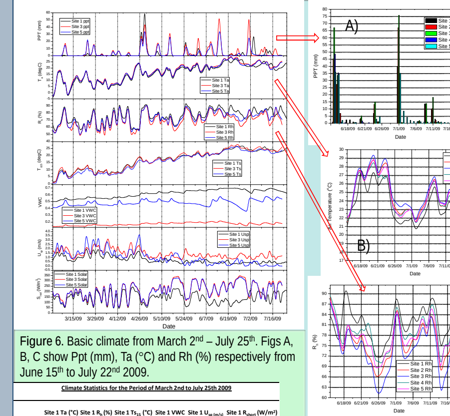


Figure 6. Basic climate from March 2nd – July 25th. Figs A, B, C show Ppt (mm), Ta (°C) and Rh (%) respectively from June 15th to July 22nd 2009.

Climate Statistics for the Period of March 2nd to July 25th 2009

	Site 1 Ta (°C)	Site 1 R_h (%)	Site 1 Ts_{15} (°C)	Site 1 VWC	Site 1 $U_{sp\,(m/s)}$	Site 1 R_{short} (W/m^2)
Average	16.12	75.62	17.03	0.62	0.73	143.16
Minimum	-7.40	21.36	0.97	0.50	0.00	0.00
Maximum	34.29	100.00	29.42	0.72	3.59	1036.00
Std Dev	8.56	20.60	7.06	0.06	0.65	229.72

	Site 2 Ta (°C)	Site 2 R_h (%)	Site 2 Ts_{15} (°C)	Site 2 VWC	Site 2 $U_{sp\,(m/s)}$	Site 2 R_{short} (W/m^2)
Average	16.86	71.39	16.48	0.39	1.40	199.75
Minimum	-7.01	20.82	1.14	0.28	0.00	0.00
Maximum	36.13	99.60	27.11	0.49	6.29	1004.00
Std Dev	8.58	20.76	6.48	0.03	1.09	270.25

	Site 3 Ta (°C)	Site 3 R_h (%)	Site 3 Ts_{15} (°C)	Site 3 VWC	Site 3 $U_{sp\,(m/s)}$	Site 3 R_{short} (W/m^2)
Average	17.21	69.70	16.94	0.17	1.42	213.32
Minimum	-6.76	19.98	0.64	0.14	0.00	0.00
Maximum	36.57	100.00	29.33	0.24	5.79	1011.00
Std Dev	8.52	20.78	7.09	0.02	0.96	287.86

	Site 4 Ta (°C)	Site 4 R_h (%)	Site 4 Ts_{15} (°C)	Site 4 VWC	Site 4 $U_{sp\,(m/s)}$	Site 4 R_{short} (W/m^2)
Average	16.84	72.06	15.14	0.35	0.79	145.92
Minimum	-7.17	20.64	0.33	0.21	0.00	0.00
Maximum	35.71	100.00	29.67	0.56	3.15	982.00
Std Dev	8.35	20.64	7.13	0.09	0.61	233.06

	Site 5 Ta (°C)	Site 5 R_h (%)	Site 5 Ts_{15} (°C)	Site 5 VWC	Site 5 $U_{sp\,(m/s)}$	Site 5 R_{short} (W/m^2)
Average	16.82	72.35	15.90	0.48	1.01	210.05
Minimum	-7.04	19.72	0.42	0.35	0.00	0.00
Maximum	36.42	100.00	28.72	0.63	7.29	986.00
Std Dev	8.61	21.23	7.13	0.05	1.21	287.98

- Average air temperatures in t[he] urban region exceed the fores[t] region by at least 15% during winter months, holding importa[nt] implications for snow melt and runoff, peak flow and ecosyste[m] processes.
- Enhanced climate variables i[n] the Urban Environment.

Table 4. Average climate from June 1[5] July 22nd at 5 climate monitoring sites located in the HCW, Columbia, Misso[uri]

Conclusions/Future Directions:

- With larger precipitation events (> 1.0 mm), the time from peak rainfall to [peak] flow may be decreased by as much as 13% in urban settings accompanied by at least 4 cm higher peak flows and 15-20% greater flow volume.
- Continued monitoring/analyses will more precisely identify the mechanism[s] and quantify the impact of human anthropogenic alterations in the HCW a[nd] other complex urban ecosystems.
- Outcomes of this work will provide critical information and tools (models) t[hat] will insure the continued sustainable management of urban natural resourc[es].

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"Physical Processes Govern Biological Systems" (Hubbart 2007)

Metadata, citation and similar papers a