Annual Report
Urbanization Impacts on NH Streamwater Thermal Loading
PI: J.M. Jacobs

1. Problem

Research suggests that watershed urbanization may have a significant impact on the thermal regime of the stream that drains the impacted area (Krause et al. 2004, Wheeler et al. 2005). Paul and Meyer (2001) list urbanization as a major cause of impairment in streams and rivers, second only to agriculture. In studies dating from the late 1960's, documented urbanization impacts to stream temperature include increases of 5-6°C (Pluhowski 1968, Pluhowski 1970).

Recent research indicates that impervious areas may increase stream temperature following a rainfall event (Nelson and Palmer 2007, Herb et al. 2008, Thompson et al. 2008). In addition, stream crossings, such as culverts, are also suspected to impact stream water temperature. Though temperature impacts are not yet documented, stream crossings impact the macroinvertebrate community (Khan and Colbo 2008) and the geomorphic properties downstream of the crossing. Both are indicative of a change in the thermal regime of the stream.

2. Objectives

The purpose of this research is to study the impacts on urbanization on small streams as they relate to water temperature, with a particular focus on the effects of stream crossings and impervious surfaces. The overall objective will be met by addressing the following three specific objectives:

Objective 1: To develop a database of thermal impacts from storm runoff that includes temperature measurements for typical New Hampshire streams.

Objective 2: To determine the timing and magnitude of thermal differences upstream and downstream of storm runoff.

Objective 3: To model culvert and impervious area impacts on stream temperature.

3. Methods

The overall approach is to monitor temperature upstream and downstream of the stormwater contributing feature. High resolution profiles of temperature using Fiber Optic Distributed Temperature Sensing (FODTS) and ancillary meteorological and vegetation shading data will be measured during one intensive field campaign (IFC). These data will be used to develop a database of thermal impacts from storm runoff that includes temperature measurements for typical New Hampshire streams (Objective 1).

3.1. Continuous Stream Monitoring

Experimental data necessary to test the hypotheses were collected within multiple study streams, at urbanized reaches within the streams. The target streams include mainly 1st and 2nd order streams that have a wide range of impacts (Table 1). Each study site has a unique combination of impervious area, stream crossings, land use, and riparian zone. Study streams all are within close proximity of a road crossing. Impervious area within the study reaches ranges from 3 to 47%.

At the 9 study sites listed in Table 1, hydrologic instruments monitored stream temperature upstream and downstream of potential thermal inputs continuously for at least one year. Several sites have multiple sensors that were used to measure additional downstream locations. To the extent possible, ancillary measurements including stream stage or flow were monitored. Atmospheric conditions were obtained from NOAA's Durham (Kingman Farm) site.

Table 1: Study locations throughout Coastal New Hampshire.

Stream Name	Location	Impervious Area (%)	Road Crossings	Watershed Area (km^2)	Collection Dates
Berry Brook	Dover, NH	47	4	1.06	2/09-12/09
Chesley Brook	Durham, NH	6	1	3.93	4/09-12/09
College Brook	Durham, NH	30	7	1.83	12/07-12/09
Gerrish Brook	Dover, NH	5	1	4.06	7/08-11/08
Great Brook	Kingston, NH	3	7	6.51	7/08-11/08
Hodgson Brook	Portsmouth, NH	38	8	9.26	7/08-12/09
Lee Five Corners Brook	Lee, NH	9	4	1.32	4/09-12/09
Reservoir Brook	Durham, NH	29	9	1.30	7/09-12/09
Wednesday Hill Brook	Lee, NH	15	1	1.14	10/08-12/09

3.2. Stream Thermal Sampling IFC

The 2009 IFC was conducted in Hodgson Brook. Because equipment were available beyond the originally planned one week period, a 50 day FO DTS survey was conducted along with enhanced temperature, water level, and streamflow measurements. During the IFC, a series of temperature measurements were made along the cable with a 1 m spatial, a 1 minute temporal resolution, and a 0.1°C accuracy with 0.01°C resolution. A total of 13 rainfall events were observed during the IFC.

4. Major Findings and Significance

Stream temperature data from upstream and downstream of urban areas were compared. Results showed differing upstream and downstream thermal characteristics (**Figure 1**). Baseflow analyses showed that impervious areas were associated with increased daily average temperatures (**Figure 2**). In addition, distinct "temperature surges" were identified during certain rainfall events. Temperature surges were found to occur more often and with greater magnitude in more urban areas, particularly those downstream of road crossings (**Figure 3**). Warm temperature pulses were identified during intense rainfall periods in the Hodgson Brook IFC (**Figure 4**). Overall, the experimental data showed that both culverts and impervious areas influenced stream temperatures during either baseflow or stormflow conditions.

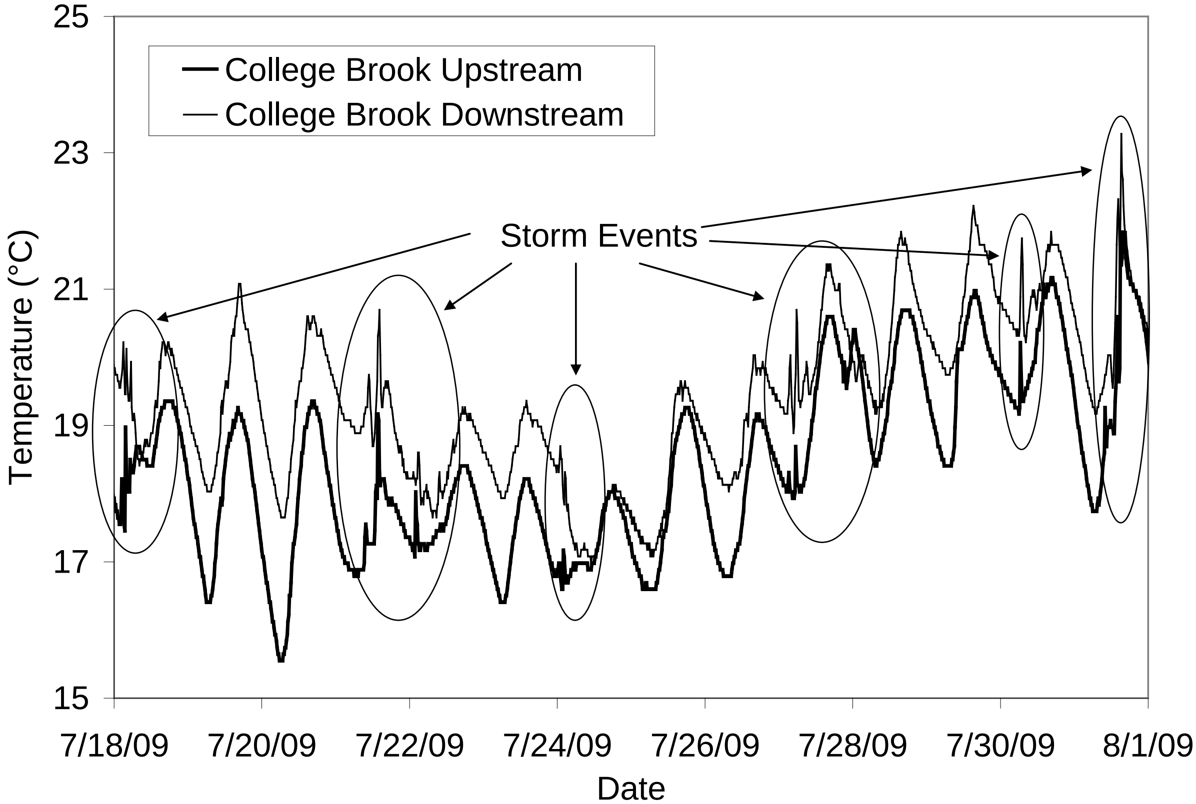

Figure 1: College Brook stream temperature time series.

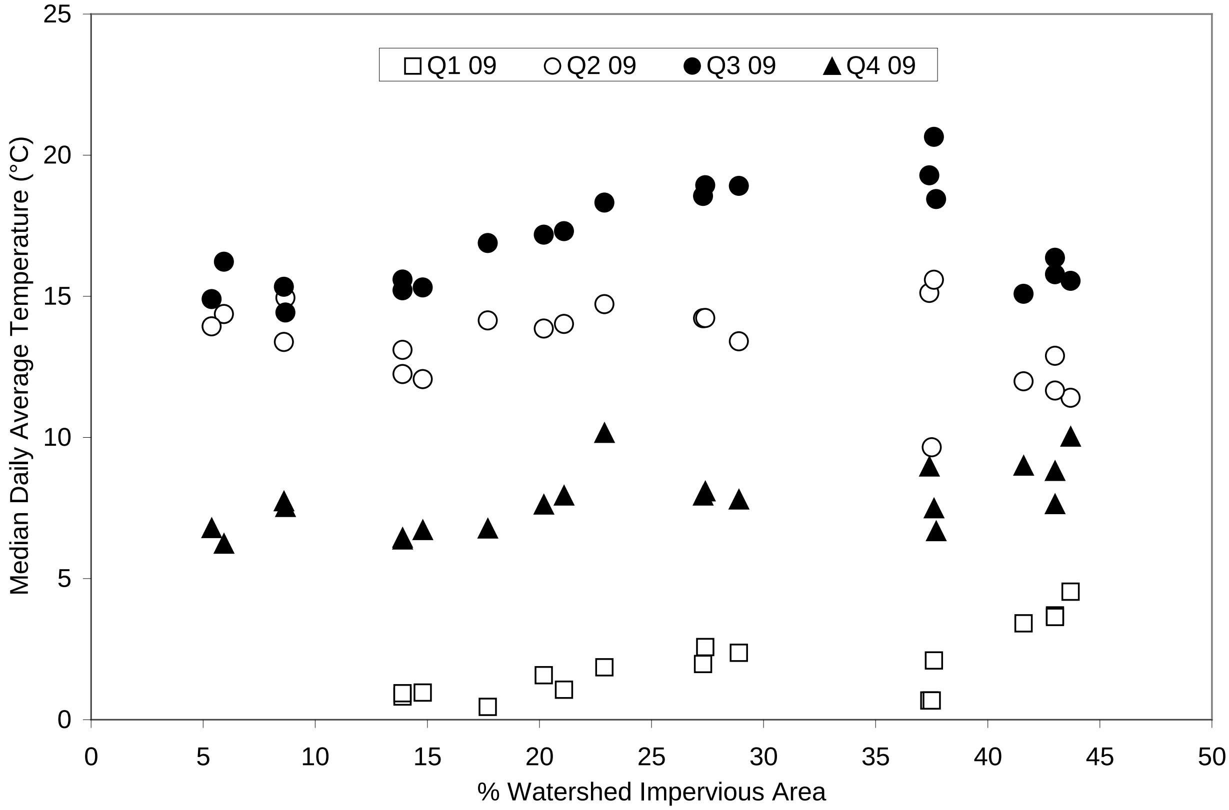

Figure 2: Impervious area versus quarterly median daily average temperature.

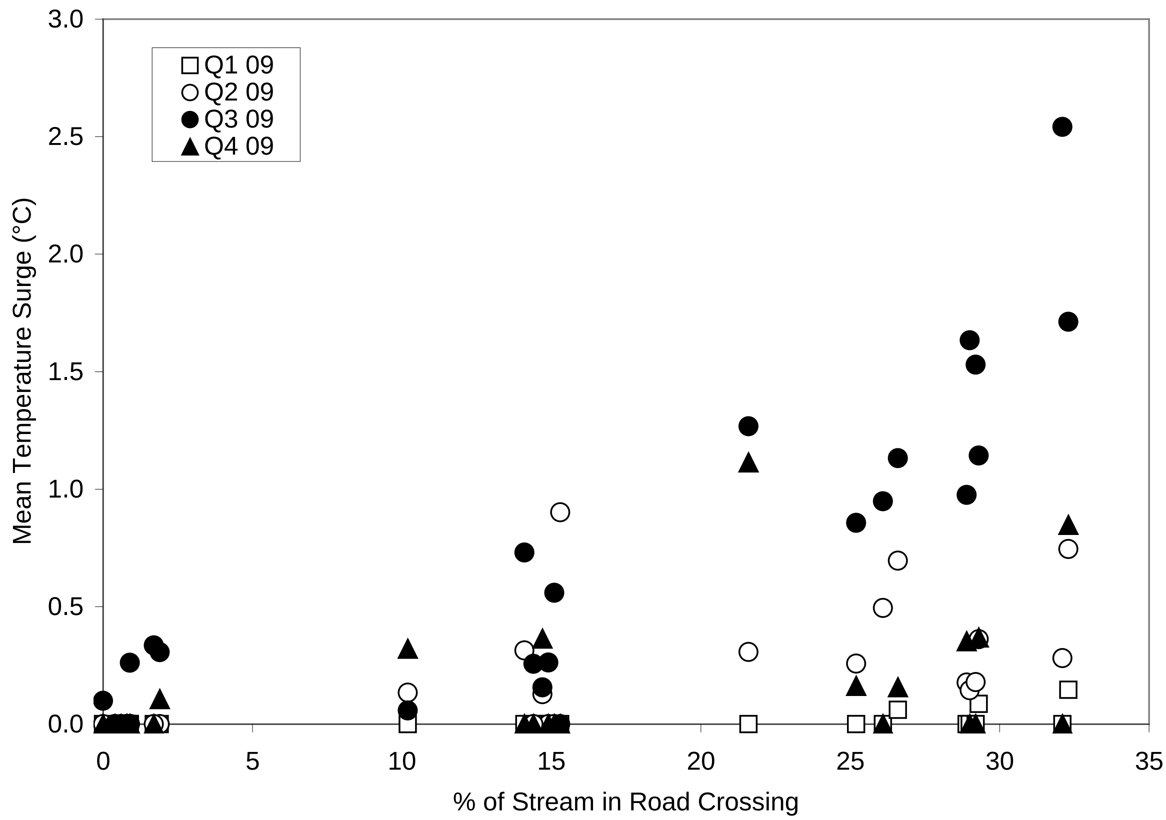

Figure 3: % of stream in a road crossing versus quarterly mean temperature surge.

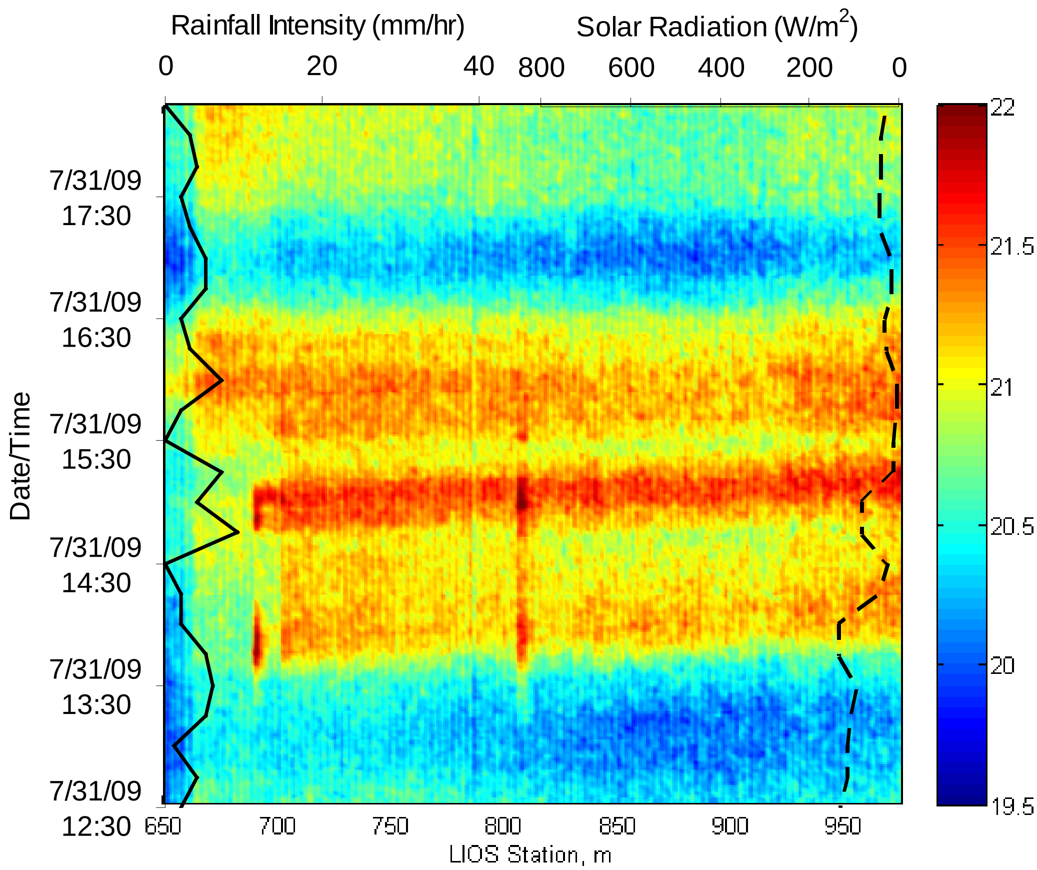

Figure 4: Hodgson Brook spatiotemporal stream temperature plots for storm 5 of 13. Storm drains are located at 680 m FO DTS. Runoff from parking lot located at 810 m FO DTS. Rainfall and solar radiation during the storm are also shown. The color bar corresponds to the stream temperature (°C).

Stream temperatures were modeled for several of the monitored stream reaches. The objective was to determine the primary energy fluxes driving urban stream temperatures. Results showed that solar radiation was generally the largest energy influx, while net longwave radiation and latent heat were the largest energy effluxes. Culverts underneath road crossings substantially changed streams' energy fluxes, often resulting in cooling temperatures inside culverts. In areas with large amounts of impervious area canopy density was often reduced, increasing solar radiation. **Figure 5** shows the average energy fluxes and stream temperatures from 7/15/09 to 8/13/09.

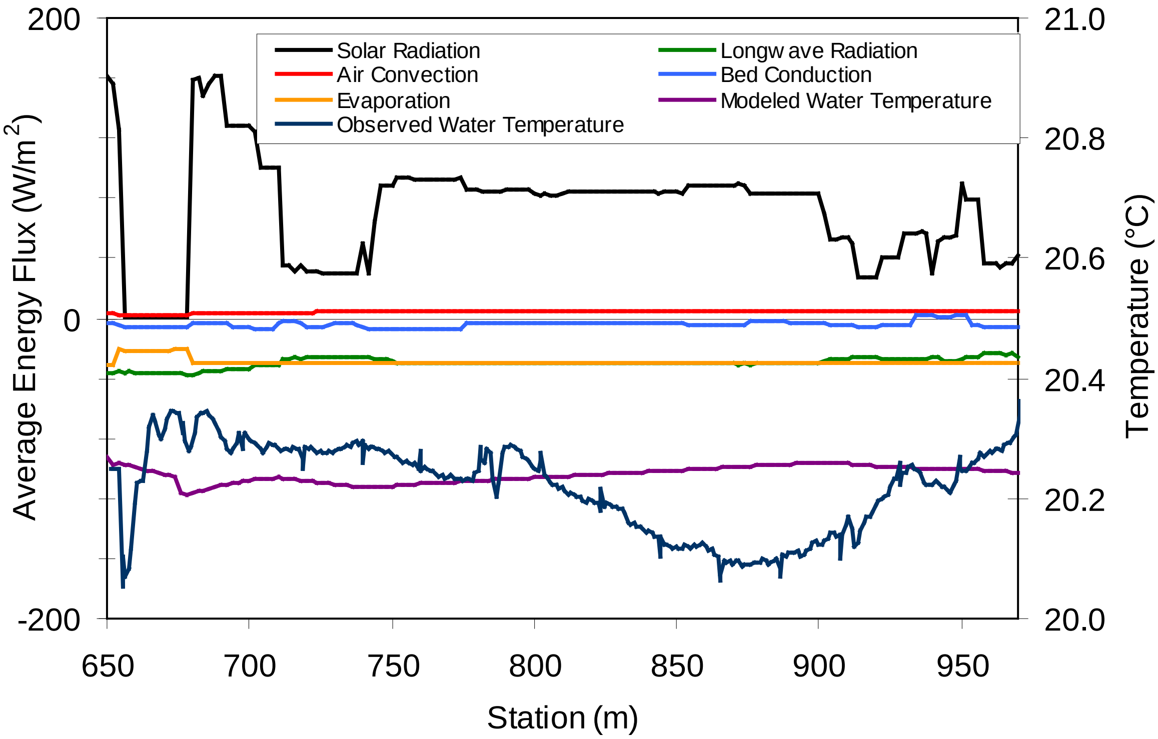

Figure 5: Hodgson Brook longitudinal profile of average energy fluxes and temperatures from 7/15/09 to 8/13/09.

5. Publications, Presentations, and Awards

Lemay, G. "Stream Temperature Impacts of Culverts and Impervious Areas" Civil Engineering Alumni Conference. University of New Hampshire. April 30 and May 1, 2010.

Lemay, G. "Stream Temperature Impacts: Lamprey Case Study" Lamprey River Symposium. University of New Hampshire. January 8, 2010.

Jacobs, J.M., T. Richard, and R. Abele. 2010. Summer Water Temperatures in NH and MA Coldwater Streams. New England Association of Environmental Biologists Conference. March 17-19. Newport, Rhode Island.

Lemay, G. and Jacobs, J.M. "Impacts of Culverts and Impervious Areas on Stream Temperature in Coastal NH Streams" North Atlantic Chapter of the Society for Environmental Toxicology and Chemistry Annual Conference. Durham NH. June 10-12, 2009.

Jacobs, J.M. "Stream Temperature What's Hot, What's Not!" Natural Resources Seminar. University of New Hampshire. April 24, 2009. Invited Speaker.

Lemay, G. and Jacobs, J.M. "Impacts of Impervious Areas and Culverts on Stream Temperature" Lamprey River Symposium. University of New Hampshire. January 16, 2009.

Jacobs, J.M. "Lamprey River Tributaries" Lamprey River Symposium. University of New Hampshire. January 16, 2009.

Jacobs, J.M. “Stream Temperature Tricks and Treats”, EPA Regional Science Council. November 5, 2008. Boston, Massachusetts. Invited Speaker.

Jacobs, J.M. “Environmental System Characterization Using Temperature Measurements”, New England Regional Temperature Meeting. July 24, 2008. Turners Falls, Massachusetts. Invited Speaker.

Jacobs, J.M. “Fiber Optics Distributed Temperature Sensing: Technology and Scientific Inquiry” Environmental Research Group Seminar. University of New Hampshire. March 7, 2008. Invited Speaker.

Jacobs, J.M. “Stream Temperature Sensing: Technology and Scientific Inquiry” Department of Civil and Environmental Engineering Seminar. Tufts University. April 15, 2008. Invited Speaker.

6. Publications from Previous N/A

7. Outreach or Information Transferred

In addition to the presentations during the past year, numerous extension opportunities have occurred. They are briefly summarized below.

Organization	Topic
NH Fish and Game	Collaboration of monitoring efforts and review of NH coldwater fish datasets
MA Fish and Wildlife	Information exchange and development of collaborative agreements
USEPA Region I	Relationship between instream flow, water quality efforts and stream water temperature
Office of Water Resources MA Dept of Conservation and Recreation	Groundwater depletion effects on stream temperature
MA Riverways Group	Groundwater depletion effects on stream temperature
Hodgson Brook Watershed Group	Development of collaborative efforts in the watershed. Site potential for FODTS study
UNH Statistical Hydrology Course	Data were used in the PIs’ Statistical Hydrology course in Spring 2009 (12 graduate students)
Hodgson Brook Watershed Group	Development of collaborative efforts in the watershed. Site collaborator for FO DTS study

8. Students Supported

This project is partially supporting Gary Lemay, a Masters student in Civil Engineering. He will complete his M.S. degree in June, 2010. Additional students have gained research experience through this project including graduate students Danna Truslow, Nick DiGennaro, Carrie Vuyovich, Ram Ray and undergraduations Logan Kenney (Civil Engineering), Rusty Jones (ESci), and Heidi Borchers (Environmental Engineering). In addition to G. Lemay, graduate students James Sherrard and Carrie Voyuvich participated in the 2009 IFC and were trained in FO DTS best methods. Project participants who are not students include Matt Lavigne and Prof. M. Choi from Hanyang University, Seoul, South Korea.

9. References

Herb, W. R., B. Janke, O. Mohseni, and H. G. Stefan. 2008. Thermal pollution of streams by runoff from paved surfaces. Hydrological Processes 22:987-999.

Khan, B., and M. H. Colbo. 2008. The impact of physical disturbance on stream communities: lessons from road culverts. Hydrobiologia 600:229-235.

Krause, C. W., B. Lockard, T. J. Newcomb, D. Kibler, V. Lohani, and D. J. Orth. 2004. Predicting influences of urban development on thermal habitat in a warm water stream. Journal of the American Water Resources Association 40:1645-1658.

Nelson, K. C., and M. A. Palmer. 2007. Stream temperature surges under urbanization and climate change: data, models, and responses. Journal of the American Water Resources Association 43:440-452.

Paul, M. J., and J. L. Meyer. 2001. Streams in the urban landscape. Annual Review of Ecology and Systematics 32:333-365.

Pluhowski, E. J. 1968. Effects of urban development on the hydrology of Long Island, New York.

Pluhowski, E. J. editor. 1970. Urbanization and Its Effect on the Temperature of the Streams on Long Island, New York. U.S. Department of the Interior, Washington DC.

Thompson, A. M., K. Kim, and A. J. Vandermuss. 2008. Thermal characteristics of stormwater runoff from asphalt and sod surfaces. Journal of the American Water Resources Association 44:1325-1336.

Wheeler, A. P., P. L. Angermeier, and A. E. Rosenberger. 2005. Impacts of new highways and subsequent landscape urbanization on stream habitat and biota. Reviews in Fisheries Science 13:141-164.