Indiana Water Resources Research Center
Annual Technical Report
FY 2005

Introduction

This report covers the activities of the Indiana Water Resources Research Center for the period March 1, 2005 to February 28, 2006. The report is provided to meet requirements and obligations under the 104 (B) program. The objectives of the fiscal year 2005 program of the Indiana Water Resources Research Center (IWRRC) have been: (1) to engage the water community in the State of Indiana as related to water research and educational; (2) to develop a suite of research programs that encompass several water issues; and (3) to strengthen interactions with State and Federal Agencies. Briefly, this year we have supported three externally reviewed 104(B) projects, help organize two water related workshops, reestablished our external and internal advisory board, reestablished a functional website (www.iwrrc.org) submitted six proposals, three funded, two rejected and one still in submission, to other agencies, facilitated the submission of two proposals to the 104(G) program and worked with the Army Corps of Engineers on a contract to support research. The IWRRC 104(B) research program includes work on algae contamination of drinking water supplies and two projects on residential development and hydrological systems. I have been and will be spending, a great deal of time trying to leverage our limited resources into as many projects as possible. This is being done primarily to create our outreach program. I will interconnect IWRRCs statewide programs with EPI-net a new national program about pathogens in the environment. I am the lead PI for EPI-net and operation will be based out of my office at Purdue University. Both efforts are based on water protection so the synergy should be strong.

Research Program

Project 01: Program Administration and State Coordination

In general, the administrative portion of the project has been used to support the management of the IWRRC's research projects. These projects have the ultimate goal of improving the quality of water resources in the State of Indiana. The funds in the administrative portion of the project also have allowed the IWRRC director a means to invest time in the efforts to integrate with state and federal agencies. The IWRRC director has worked with state and federal environmental agencies, the governments of Indiana's cities and counties and key citizen groups on water education and water resources planning activities. In this way, the results from the research projects can be transferred to interested individuals in the state.

A significant portion of the Directors time is spent in coordination of larger water related research efforts. Of note is the Living Laboratories on the Wabash (LLOW) project. The IWRRC is playing a major role in directing efforts that will focus attention on Indianas greatest river. Initial efforts are focused on the Wabash River near Lafayette. These efforts will expand in time to include the entire river.

The goal of the LLOW team is to establish a living laboratory that will integrate discovery, learning and outreach and act as a model for other river communities in Indiana and elsewhere. This will be accomplished through graduate and undergraduate research and service-learning projects, development of a community participation process and public educational programs, and improved participation and coordination between local, state and federal agencies.

LLOW Project Focus for 2005: The immediate focus of the Living Laboratories On the Wabash (LLOW) Project will be to develop a plan of work to establish a discovery, learning and outreach project for the 1,410 acre floodplain along the Wabash River between U.S. Highways 52 and 231 (see attached map). Partnering with the Wabash River Enhancement Corporation (WREC) and the Center for Earth and Environmental Science (CEES) at IUPUI, the LLOW team will use C4E funding for the following. Outreach objective (1) Facilitate WRECs strategic planning process - To successful guide large scale riverfront transformations WREC will need to develop strong leadership: that is, committed board members with clear goals, and with the authority to make decisions and to work toward the common good over time. Currently WREC has finalized a mission statement. Facilitated by Professor Wilson, the board will develop a strategic plan that is informed by specialists and precedents, incorporates public input, and addresses short and long-term funding issues. a. research and visit similar programs;

Learning the projects learning objectives are to increase the number of faculty and students at Purdue involved in experiential learning through an increase number of service-learning courses and to engage students in the design and implementation of environmental projects. (1) Support Development of Service-learning coursework To assist WREC in their strategic planning process and building on Purdues initiative to institutionalize Service-learning, LLOW team will support faculty in the development of service-learning courses. Examples of service-learning projects include sustainable land use plan for North 9th Street, urban tree inventory, Wabash Neighborhood Revitalization Plan, riverfront visual assessment, and public perception survey.

Discovery (2) Develop research agenda and projects; a. Community-based research (3) Coordinate internal and external resources

These efforts will be undertaken in order to define how best to improve the quality of our environment, reduce flood damage and protect and restore natural resources while simultaneously promoting economic development. Additionally, our team will assist WREC with short-term organizational and implementation strategies allowing WREC full access to the Purdue University community. This effort will culminate with the submission of at least three proposals to federal agencies.

Grant Applications Submitted thorough/with IWRRC:

a. (Funded) Advanced Concepts and Technologies International, LLC Improved Detection & Remediation of NBC/CBRN/TIC/TIM Contaminants in Potable Water. Developed with Drs. Inez Hua and Chad Jafvert. IWRRC provided organizational and management input. $325,000

b. (Funded) IDEM-319Development and Demonstration of Outcomes-Based Evaluation Framework for the Indiana Nonpoint Source Program. Developed with Jane Frankenberger, Linda Prokopy, and Shorna Broussard. $230,000 c. (Funded) Center for the Environment. $70,000. Living Laboratories on the Wabash (LLOW). Developed with Kim Wilson, Linda Prokopy, Larry Nies and Dan Sheperson.

d. (In submission) USDA Conservation Effects Assessment Program. $660,000. Watershed-Scale Evaluation of BMP Effectiveness and Acceptability: Eagle Creek Watershed, Indiana. Developed with Jane Frankenberg, Lenore Tedesco, Jerry Shively, Linda Prokopy.

e. (Not Funded, will be resubmitted) NOAA-Oceans and Human Health Initiative, External Grants Program. Development of a rapid identification method allowing pathogen tracking to enhance coastal water protection. Developed with the University of Toledo, Von Sigler. $450,000

f. (Not Funded) EPACreating sustainable drinking water supplies for Central Indiana: Innovations to achieve reductions in watershed and reservoir nutrient levels. Developed with Central Indiana Water Resources Partnership; IUPUI Center for Earth and Environmental Science, Indianapolis Department of Waterworks Town of Zionsville Sewage Department Hamilton County Soil and Water conservation District and Upper White River Watershed Alliance $500,000.

External Board of Advisors Membership: Dr. Lenore Tedesco, Director Center for Earth and Environmental Science, Indianapolis IN Dr. Jack Wittman, President, Wittman Hydrosciences, Bloomington IN Dr. John C. Steinmetz, Director, Indiana Geological Survey Indiana University Bloomington IN Dr. Dennis Wichelns, Executive Director, The Rivers Institute at Hanover College, Hanover IN Ms. Christine Livingston, Watershed Coordinator, Save the Dunes, Michigan City, IN Dr. Jim Stewart, Section Chief USGS Indianapolis Dr. Linda Lee, Interim Director Center for the Environment, Purdue University Ms. Martha Clark-Mettler, Director Watersheds Program IDEM, Indianapolis IN

Faculty Advisory Committee: Dr. Linda Lee, Interim Director Center for the Environment, Purdue University Dr. Jane Frankenberger, Agriculture and Biological Engineering Dr. Larry Nies, Civil and Environmental Engineering Dr. Inez Hua, Civil and Environmental Engineering Dr. Dev Niyogi, Agronomy Department, and State Climatologist

The Effects of Landscape Transformation in a Changing Climate on Indiana’s Water Resources

Basic Information

Title:	The Effects of Landscape Transformation in a Changing Climate on Indiana’s Water Resources
Project Number:	2005IN173B
Start Date:	3/1/2005
End Date:	2/28/2006
Funding Source:	104B
Congressional District:	5th
Research Category:	Climate and Hydrologic Processes
Focus Category:	Floods, Groundwater, Hydrology
Descriptors:	None
Principal Investigators:	Jon Harbor, Jon Harbor

Publication

1. Davis, C.E. Understanding and Managing the Impacts of Climate Change in a Complex Environmental System: The Effects of Increasing Precipitation and Land Use Change on Streamflow. Dissertation. Advisor: Jon Harbor. Expected graduation: May 2007.
2. Goss, A.M., C. E. Davis, D. Tripathy. The Effects of Landscape Transformation in a Changing Climate on Indianas Water Resources. Indiana Water Resources Association Symposium, West Lafayette, IN, June 2006.
3. Goss, A.M. Assessing the Historical Impacts of Landscape Transformation on Water Fluxes in Muskegon River Watershed for Environmental Monitoring and Assessment. Dissertation. Advisor: Jon Harbor Expected graduation: May 2007.

THE EFFECTS OF LANDSCAPE TRANSFORMATION IN A CHANGING CLIMATE ON INDIANA'S WATER RESOURCES

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PROBLEM AND RESEARCH OBJECTIVES

Indiana's landscape has been rapidly changing in the last fifty years - a change that often has unintended consequences on the state's water resources. The nine-county Greater Indianapolis area (Boone, Hamilton, Hancock, Hendricks, Johnson, Madison, Marion, Morgan, and Shelby counties) has undergone a dramatic population increase in the past several decades, which has increased the demand for local water resources (Figure 1). The growth rate (16.4%) of Greater Indianapolis exceeded the national average (13.2%) for the period 1970 to 2000, with Hamilton County showing a 404% increase (U.S. Census Bureau, 2000). Combined with this increase in demand, it is well understood in general terms that the urban development accompanying population increases also shifts the balance between surface and groundwater, with direct impacts on both water supply and flooding. Nationally, interactions between land use change and hydrologic processes are recognized as a major scientific and management challenge (National Science Foundation, 2003; DeFries and Eshleman, 2004) and in Greater Indianapolis, as well as other Indiana cities, managing growth based on an understanding of past and future impacts of land use change on water quality and quantity is critical if we are to sustain the economic and environmental health of the state.

Urbanization affects local hydrology by increasing impervious surface area, which reduces infiltration and results in more direct surface runoff. Urbanization also affects flood timing and magnitude, streamflow regime, stream channel and soil erosion, aquatic habitats, and groundwater recharge. Nationally, flooding causes approximately $3.1 billion in damages (Pielke Jr. and Downton, 2000) and can spread disease through direct pollutant runoff and overloading of treatment facilities (Ford *et al.*, 1998). Effective management of excess rainfall and runoff is an important issue to consider for Indiana's economy and environmental health. Surface water quality is impaired not only by the elevated amount of pollutants present in an urbanized area, but also through the channelization of runoff directly into the streams by the paved surfaces. Water carries pollutants into the soil as it infiltrates, which allows for natural degradation of contaminants by microbial processes. When pollutant-laden runoff is prevented from infiltrating, the contaminants are directly transported to streams, where the degradation process is much slower, if present at all.

Another impact of urbanization is its ability to significantly alter baseflow ─ the sustained flow in a stream that comes from groundwater discharge or seepage. This discharge often maintains streamflow during seasonal dry periods and has important ecological and environmental functions. Precipitation that infiltrates into the subsurface becomes groundwater, providing baseflow to streams. Decreased infiltration rates and increased groundwater withdrawals from aquifers underlying urban areas have the potential to reduce baseflow in streams and water level in lakes and wetlands. Lowered baseflow can impose limitations on long-term availability of groundwater and can adversely affect stream resilience to drought conditions.

Greater Indianapolis' water supply comes from a combination of public reservoirs and public and private groundwater wells and is threatened by increasing urbanization. Not only has the water demand increased (Arvin and Spaeth, 2000), but the amount of water reaching regional aquifers may be decreasing due to increased impervious surfaces. Reservoirs used for drinking water supply may also be affected by increased stresses, such as extreme floods and droughts, reduced groundwater recharge, and elevated pollutant loads. In order to support planning for growth in Greater Indianapolis, the past and future impacts of urbanization on natural hydrologic functions must be ascertained.

This study furthers our understanding of watershed processes and the relationship between urbanization, precipitation, streamflow, and groundwater. Through the integration of urban land use scenarios with historical water fluxes and climatic data, the project will provide an assessment of impacts to stream discharge, baseflow, and hydrograph peaks (flooding).

The lack of studies focusing on the integrated details of watershed hydrology, urbanization, and climate change makes this project important because it focuses on improving our understanding of process interactions in a complex environmental system responding to climate change. Integrating models that address urbanization, hydrology fluctuations, as well as climate change scenarios enable the assessment of future consequences of land use change and climate scenarios on water resources, and consequently, to address policy questions related to the sustainability of current resources. This provides a basis for predicting future streamflow, baseflow, and hydrologic variations resulting from climate change, urbanization, and the combination of the two.

The U.S. EPA Office of Research, through its "Water and Watersheds" program, has identified the need for greater emphasis on watershed management based on improved understanding of how human activities impact water resources (EPA, 1998). The research conducted in this project includes an investigation of how human modifications of landscape, combined with observed and modeled climate scenarios, affect water cycling at various scales in the Greater Indianapolis area. We investigate this issue through combining recreations of historical land use ("backcasts") with hydrologic models that predict surface and subsurface water flows in the Greater Indianapolis area. Through analysis of human impacts on water resources in this region, for which land use change is a proxy, the influence of climate change on the hydrology of this region can be indirectly assessed.

Our primary objectives are:

(1) To determine the historical relationships among urbanization, climate, and hydrology (specifically, streamflow, peak flows, and baseflow) in the Greater Indianapolis area

(2) To evaluate the implications of past relationships for informing decisions about future change

(3) To create an approach that can be applied across the entire state of Indiana for more comprehensive water resource management.

METHODOLOGY

To quantify the interactions between historical hydrology and land use in Greater Indianapolis, we employed both actual and projected precipitation, streamflow, and baseflow values for three urbanizing watersheds. The watersheds were selected based on the availability of continuous streamflow and precipitation data. Modeled data were coupled with estimated urban, agricultural, forest, and shrubland/grassland areas for pre-1940 and present using U.S. Census and National Agricultural Statistics Service (NASS) datasets for selected watersheds in Greater Indianapolis. We used Purdue University's web-based L-THIA watershed delineation tool (Choi *et al.*, 2002) and combined these delineations with the USGS National Hydrography Dataset (NHD) (USGS, 2004). Historical hydrologic data were combined with modeled historical land cover data and water fluxes to determine the relative impacts of urbanization and climate change on streamflow, baseflow, and flooding. Distinguishing the impacts of natural from human-induced impacts on streamflow and baseflow was predicted through analyzing the changes to hydrology while land use and climatology remain static. Historical peak annual and seasonal discharge records were examined for the three Greater Indianapolis watersheds to determine whether these events have changed over time and if there is a trend in the data record. Flood frequencies and magnitudes were also calculated from the historical streamflow record to determine whether the risk of flooding has changed over time.

Quantifying Interactions between Hydrology and Land Use

Streamflow and baseflow variations are a result of the combined impacts of natural and anthropogenic influences. For this study, we focused on climate change and land cover change (primarily urbanization) as the primary factors impacting streamflow and baseflow in Greater Indianapolis over the past 60 years. Three stream gauges and accompanying watersheds were identified for analysis: Fall Creek near Fortville, Fall Creek near Millersville, and Little Eagle Creek at Speedway (Figure 2). Historical and predicted streamflow, baseflow, and precipitation were statistically examined to (1) quantify the relative influences of natural and anthropogenic variation on streamflow and baseflow and (2) to evaluate the amount of variation in streamflow, baseflow, and precipitation in Greater Indianapolis.

Determining the change in streamflow, baseflow, and precipitation data required statistical trend analysis of whether the data is increasing, decreasing, or remaining stationary over a given period of time. Use of the Mann-Kendall Rank Correlation Test allowed for both the detection of monotonic trends and the significance determination of the trends. The Mann-Kendall test is a common method for determining the presence of trends in hydrologic data (Lins and Slack, 1999; Stogner, 2000; Pilon and Yue, 2002) since it is a non-parametric test, resistant to the skewing influences of outliers (Helsel and Hirsch, 1992). The identified trends were used to consider future implications of land transformation and climate change on Greater Indianapolis water resources. Regression techniques were used to determine the relative amount of streamflow and baseflow variation accounted for by climate and urbanization.

Completing the Land Use Record

In order to input historical estimates of land cover into a hydrology model, the operational unit of the historical data used to derive estimates must be converted to the resolution of the hydrology model. Historical land use scenarios spanning 60 years a selected watershed in Greater Indianapolis were developed based on demographic and land use databases at the minor civil division (MCD) and county level. The VIC (Variable Infiltration Capacity) model calculates water fluxes within grid cells using percent cover of each land use type defined within the model.

The VIC model is an energy and water balance system (Liang *et al.*, 1994; Liang *et al.*, 1996; Cherkauer *et al.*, 2003). In comparison to other Soil-Vegetation-Atmosphere Transfer

Schemes (SVATS), VIC is able to model variability in soil moisture capacity as a probability distribution, as well as parameterize baseflow, so that it is separated from quick storm response (Zhao *et al*., 1980; Dumenil and Todini, 1992). The model relies on a vegetation library file that provides information, such as leaf area index and albedo, for each land use type. These figures were derived and provided to the model for urban areas. Evapotranspiration, surface runoff, and baseflow were then computed for each cover type and summed over all cover types within a grid cell. The outputs include energy and water balance flux information, as well as outflow hydrographs. Four land use types were used to characterize the historical landscape of the study area: urban (impervious), agricultural, shrubland/grassland, and forest.

Large-scale land use data for the study area is limited by the availability of reliable remotely sensed data which emerged in 1978 with the Landsat TM satellite images. Using a technique pioneered by Goss *et al.* (2005), United States Census data was used for estimates of urban growth in the time period before present-day. Total housing units data for each time period were derived from the "Year Built" statistic (referred to as "QT-H7 Year Structure Built and Year Householder Moved Into Unit" or "Occupied Housing Units" within the Summary File 4 dataset for the 2000 Census) (U.S. Census Bureau, 2000). The number of houses built before 2000 (used to represent "present" because it is the last available Landscan TM image) in each township was calculated. Using the number of houses built during each time step, the amount of impervious area that existed during that time step could be estimated for the operational unit of the hydrology model used.

The National Agriculture Statistics Service (NASS) Census of Agriculture served as a proxy for agricultural data. On a county basis, it reports the number of acres that are agricultural (called "Land in Farms") (U.S. Census Bureau, 1980). Decadal values were normalized by the ratio of Land in Farms in 2000 to agricultural land cover in 2000 (taken from Landsat TM data) for each county. These values were corrected by area-weighting the spatial relationship between each county and each VIC grid cell, which provided the percent agricultural for each VIC grid cell.

The percent of each VIC grid cell that was covered by the remaining two land uses/covers—shrubland/grassland and forest—was created through employing a transition matrix for the watershed from 1978 to 1998. The ratios of change from and to each of the four land uses were combined with the estimated urban and agricultural values for 1940 to generate estimates of shrubland/grassland and forest for VIC grid cells. In this way, the output of the model was land cover for 1940, a time for which reliable historical land use data is not available.

Completing the Streamflow and Baseflow Records

50 years of continuous data are often recommended to determine and analyze trends in hydrologic data (Lettenmaier *et al*., 1994; Stogner, 2000; McCabe and Wolock, 2002). The entire period of historical streamflow and corresponding precipitation data available for the three study sites was used in this analysis. Fall Creek at Fortville and Fall Creek at Millersville had 63 and 75 years of available data, respectively. Although Little Eagle Creek had only 45 years of streamflow data, this was deemed sufficient. Since all three watersheds were gauged, daily streamflow data was obtained from the U.S. Geological Survey website (USGS, 2006) and daily precipitation data was accessed through the National Climatic Data Center website (NCDC, 2006).

Baseflow can be separated from the historical streamflow data using various hydrograph separation techniques. The Web-based Hydrograph Analysis Tool (WHAT) is a convenient method for baseflow separation (Engel and Lim, 2004). This automated hydrograph separation method is based on flow peak and flow minimum detection from continuous stream flow data and produces results comparable with another widely-used program - HYSEP (Sloto and Crouse, 1996).

Analysis of frequency and magnitude of extreme hydrologic events

Extreme value distributions from the historic precipitation and streamflow data were used to determine the magnitude of rainfall and discharge events with various recurrence intervals. Due to the increased amount of impervious surfaces, rapidly urbanizing areas are at risk for unexpected flooding events, requiring this flood frequency analysis for the Greater Indianapolis area. This analysis was also used on the precipitation data record to consider the potential effects of climate change on extreme precipitation events. To best determine the change over time, the flood frequency analysis was used in combination with a 10-year moving window. Use of moving window analysis for a set length of time reduces the influence of record length on extreme event statistics.

RESULTS AND DISCUSSION: HISTORICAL PRECIPITATION

Mann-Kendall trend analysis indicated no statistically significant trends in peak annual daily precipitation or total annual precipitation for the three study sites (Tables 1 and 2). Seasonal precipitation analysis, however, did show that autumn precipitation in the Little Eagle Creek watershed is increasing. Peak autumn daily precipitation and total autumn precipitation both show statistically significant increasing trends in the Little Eagle Creek watershed. Linear regression was also conducted on total annual precipitation and resulted in essentially no change (P value is 0.46, 0.61, and 0.44 for Fall Creek near Fortville, Fall Creek near Millersville, and Little Eagle Creek at Speedway respectively).

The timing of peak precipitation events was also examined to determine whether peak precipitation events were correlated with peak discharge events. As expected, most peak precipitation events occur in the summer months of June and July, while peak streamflow events tend to occur in the late-winter (February) and spring (May) due in part to snow melt. At Little Eagle Creek and Fall Creek near Fortville, approximately 30% of peak daily precipitation events were directly correlated to peak daily streamflow events. This correlation is a bit lower (23%) for Fall Creek near Millersville. These findings indicate that over two-thirds of peak daily precipitation events do not directly cause peak streamflow events. Many peak streamflow events were the result of extended rainy periods, rather than a single heavy rainfall event. Further examination of the relationship between seasonal precipitation and streamflow indicates that the peak events are occurring in concert with one another more frequently in the later part of the record (Figure 3).

Precipitation statistics were examined to determine whether high-magnitude, low-frequency precipitation events are changing over the period of record for the three sites. Due to the varying record lengths available, a moving-window analysis was used to obtain precipitation statistics for uniform record lengths. The Extreme Value Type 1 distribution was chosen because of its suitability for modeling storm rainfall (Chow et al., 1988). It was found that for the 24-hour events of all recurrence intervals, there has been no consistent change over the period of record. This suggests that high-magnitude precipitation events are not becoming more frequent or intense.

RESULTS AND DISCUSSION: HISTORICAL BASEFLOW

Baseflow in all the three urbanized watersheds in the greater Indianapolis region has increased significantly over the years as shown in Figure 4 to 6. Similar increasing trends in baseflow are also found using the Mann-Kendall test for all the three watersheds (significance level is 0.009, 0.007, and 0.0005 in the watersheds of Fall Creek near Fortville, Fall Creek near Millersville, and Little Eagle Creek at Speedway respectively). 10-year moving averages of baseflow also show a definite increase in trend (Figures 7 to 9). It is also important to note that, as expected, the direct runoff has increased appreciably in all the watersheds (Linear regression P value is 0.41, 0.05, and 0.001 in the watershed of Fall Creek near Fortville, Fall Creek near Millersville, and Little Eagle Creek at Speedway respectively). Increase in direct runoff results from increased impervious area associated with progressive urbanization.

Even if there is a significant increase in annual baseflow in all the three urbanized watersheds, there is hardly any change in annual precipitation. Thus, in order to further examine the influence of urbanization on the three watersheds, the normalized baseflow (normalized with respect to precipitation) were analyzed for their trends. As shown in Figures 10 to 12, the normalized baseflow in all the three watersheds again showed significant increasing trends. Similar increasing trends in baseflow were also found using the Mann-Kendall test for all the three watersheds (significance level is 0.001, 0.003, and 0.0001 in the watersheds of Fall Creek near Fortville, Fall Creek near Millersville, and Little Eagle Creek at Speedway, respectively). 10-year moving averages of baseflow also show a definite increase in trend (Figures 13 to 15). The results clearly indicate that progressive urbanization had played a major in the increase in baseflow in all the three watersheds as opposed to influence of climate (as detected through precipitation).

RESULTS AND DISCUSSION: HISTORICAL STREAMFLOW

Mann-Kendall trend analysis for the three watersheds indicates that substantial changes have occurred in peak annual and peak seasonal streamflow, although not all trends are statistically significant (Table 3). Little Eagle Creek has experienced the greatest change in peak streamflow, with statistically significant increasing trends in peak annual, peak summer, and peak autumn streamflow (Figures 16 to 18). Both Fall Creek sites had statistically significant increasing trends in peak autumn streamflow and Fall Creek near Millersville also showed a statistically significant increasing trend in peak summer streamflow.

Further investigation into autumn streamflow indicated that a low percentage (approximately 10%) of peak annual events occur in autumn at all sites, so the changes observed in peak annual streamflow are probably not driven by the autumnal increases. This is important for local water resource mangers, as a shift from the typical late-winter/early-spring peak discharge to autumn would result in very different management practices. Heavy streamflow occurring early in the growing season is important for crop productivity, as well as providing the basis for drinking water and recreational reservoirs. Since the peak autumn streamflow trends were so strong at all three sites, further investigation is needed to determine if this matches a regional pattern of streamflow change.

RESULTS AND DISCUSSION: FLOOD MAGNITUDE

Extreme value distributions from the historic data were used to determine the magnitude of high discharge events with various recurrence intervals. Rapidly urbanizing areas are at risk for unexpected flash flooding events, requiring this analysis for Greater Indianapolis. A 10-year moving window analysis indicated that flood magnitude has not experienced a dramatic change over the period of record. This could largely be the result of dams in the upper reaches of the watersheds, which serve to regulate the discharge of water at both sites.

RESULTS AND DISCUSSION: MODELED LAND COVER CHANGE AND WATER FLUXES

The use of a distributed hydrologic model enables the identification of spatial trends in water fluxes within a watershed that could not be detected by simply examining a point value of baseflow or streamflow at a basin's outlet.

The spatial pattern of modeled monthly baseflow is similar throughout the year. The southern half of the watershed showed little response to the change in land cover input (Figure 19). Most of the northern portion of the watershed demonstrated a slight increase. However, one cell modeled a dramatic difference between the two land uses. The baseflow generated from the 2000 land cover input was 43% lower than the baseflow generated from the 1940 land cover (from ~925 mm to ~650 mm per month). The yearly average baseflow over the 50 year period was ~2,500 mm (100 inches) higher with the 2000 land cover than with the 1940 land cover.

Modeled evaporation showed similar spatial trends from October to June. The southern portion of the watershed had similar values between both land cover inputs with slightly higher evaporation values in the middle of the watershed (Figure 20). The northern portion of the watershed modeled slightly lower evaporation values, except for the east central cell which produced consistently higher evaporation each month on the order of 75% (a maximum difference of ~23 mm).

Excluding this cell, the monthly average evaporation was lower for the 2000 land cover input than for the 1940 land cover in the months of July, August, and September. The largest differences were in the northern half of the cell, reaching over 100% reduction from 1940 values to 2000 values. These values represent a difference in evaporation of ~10 mm (0.4 inches).

Most of the watershed modeled similar runoff values with the two land covers through the winter and early spring (Figure 21). These values deviated through the rest of the year reaching maximum deviation in October and November. Most of the watershed produced lower runoff values for the 2000 land cover than for the 1940 land cover, yet most of the difference between cells was within 50%. The east central cell with higher precipitation inputs, produced some of the largest differences between the two land covers, in some months 70% less runoff (13 mm vs. 8 mm) was produced with the 2000 land cover than the 1940 runoff. The total runoff generated by cells within the watershed was slightly larger with the 1940 land cover than the 2000 land cover (3114 mm and 2833 mm respectively).

The land cover change estimated by the above method bases estimates of urban area on the ratio between housing units and urban cover in 2000. This produced an increase in urban area over the 50 year time period on the order of 80 km^2 within the watershed (Figure 22). While urban is a small percentage of the total land cover, this change represents a 230% increase in urban area over the 60 year time period. Agricultural and forest coverage both decreased substantially (220 km^2/20% and 130 km^2/55% respectively). The largest change by area in land cover occurred within shrubland, which increased by 275 km^2 or 30%. This land cover change scenario helps to explain the lack of an increase in runoff. Generally, agriculture produces more evapotranspiration and runoff than shrubland within the VIC framework. A decrease in forest cover and increase in urban cover should increase runoff, yet the increase in shrubland attenuated this change.

SIGNIFICANCE OF THE PROJECT

This project provides water resource managers with information they need to evaluate and manage critical changes in water resources related to land use and climate change. This work has important implications for both science and society through its consideration of climate change, land use, and watershed management, and helps further our understanding of watershed processes and the relationship between urbanization, precipitation, streamflow, and groundwater. Through the integration of urban land use scenarios with historical water fluxes and climatic data, this project provides an assessment of impacts to stream discharge and baseflow. The work outlined here provides a basis for predicting future streamflow, baseflow, and hydrologic variations resulting from climate change, urbanization, and the combination of the two.
The key benefits of this project are:

(1) Quantification of past and predicted water cycle fluxes in Greater Indianapolis, including an understanding of the causal relationships
    a. There is no significant trend in precipitation over the period of record.
    b. Streamflow is increasing, with the most dramatic increases in autumn.
    c. Baseflow is increasing over the period of record.
    d. Land cover changes within the Fall Creek near Fortville watershed were estimated. Urban cover has more than doubled since 1940 while agricultural and forest cover has decreased. Shrubland and grassland cover has increased.
    e. These estimated changes have caused modeled baseflow to increase, runoff to decrease, and evaporation to decrease. The spatial distribution of these water fluxes enriches the historical streamflow and baseflow records at the watershed's outlet.

(2) Provide water resource managers with integrated information necessary for sustainable growth in Greater Indianapolis

(3) Creation of a comprehensive framework that is transferable to the rest of Indiana and the U.S.

(4) Public education regarding the important societal implications of altered water resources in Greater Indianapolis

The information generated in this study can be used in developing approaches to minimize the effects of upstream urban land uses on downstream processes, and will also be used in a reevaluation of current watershed planning. A better understanding of the water and energy fluxes between land, atmosphere, and hydrology enables the development of strategies to mitigate the impacts of future landscape transformation and climate change. Engineering design, such as that for bridges and culverts, normally based on out-dated streamflow and precipitation records may be shown to be noncompliant and obsolete in the context of current data. Knowledge of current streamflow regimes and prediction of future effects on flood frequency and magnitude will allow for better planning and mitigation of damage, and a better understanding of how environmental systems respond to both climate change and urbanization. An improved understanding of how Indiana watersheds function and how human activities (such as urbanization) impact water resources enables environmental agencies, such as the Indiana Department of Natural Resources and the Division of Water, to manage water resources more effectively.

STUDENTS

Carrie Davis, Ph.D Candidate

Alison Goss, Ph.D. Candidate

Dibyajyoti Tripathy, Ph.D. Candidate

DISSERTATION TITLES, PAPERS, AND ABSTRACTS

Davis, C.E. Understanding and Managing the Impacts of Climate Change in a Complex Environmental System: The Effects of Increasing Precipitation and Land Use Change on Streamflow. Dissertation. Advisor: Jon Harbor. Expected graduation: May 2007.

Goss, A.M. Assessing the Historical Impacts of Landscape Transformation on Water Fluxes in Muskegon River Watershed for Environmental Monitoring and Assessment. Dissertation. Advisor: Jon Harbor Expected graduation: May 2007.

Goss, A.M., C. E. Davis, D. Tripathy. The Effects of Landscape Transformation in a Changing Climate on Indiana's Water Resources. Indiana Water Resources Association Symposium, West Lafayette, IN, June 2006.

> Abstract: *Water resources are critically influenced by changes in land use and climate. As landscapes are converted from agriculture to urban and suburban development, natural hydrologic processes are altered. Impervious surfaces decrease the amount of water infiltrating into the soil to become groundwater and increase the amount of runoff reaching streams. Similarly, climate change that increases the frequency of large rainstorms alters the amount of runoff and groundwater, even if average annual rainfall remains constant. The Greater Indianapolis area has been experiencing increased urbanization in the past several decades, which is affecting the local water quality and quantity. As population increases, the stresses placed on water resources also increase. This project quantifies the impacts that past and future land use and climate change have on Greater Indianapolis water resources, providing critical information for local water resource planners and managers who are working to protect the water resources that are vital for the economic and environmental health of Indiana.*

Tripathy, D. Assessing Land Use Change Impacts on Groundwater Resources. Dissertation. Advisor: Jon Harbor. Expected graduation: May 2007.

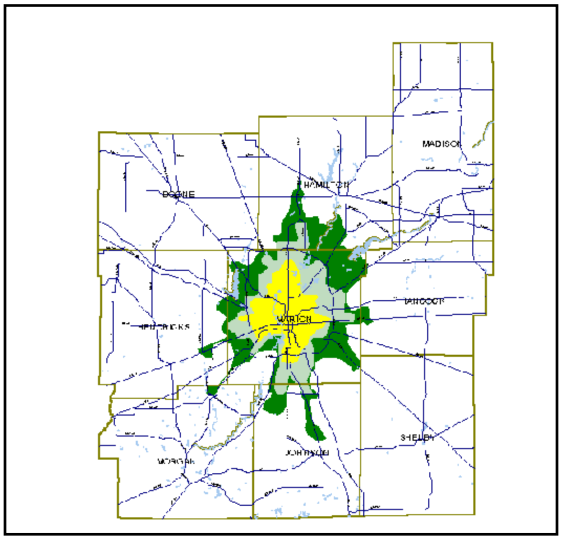


Figure 1. Historical growth of the Indianapolis urban area in the nine-county Greater Indianapolis area. Yellow indicates the contiguous developed area in 1963, grey shows the urban growth through 1895, and the green area is the contiguous developed area in 1999. In 1963, the Indianapolis metro area was completely contained in Marion County. (From Stumpf, 1999)

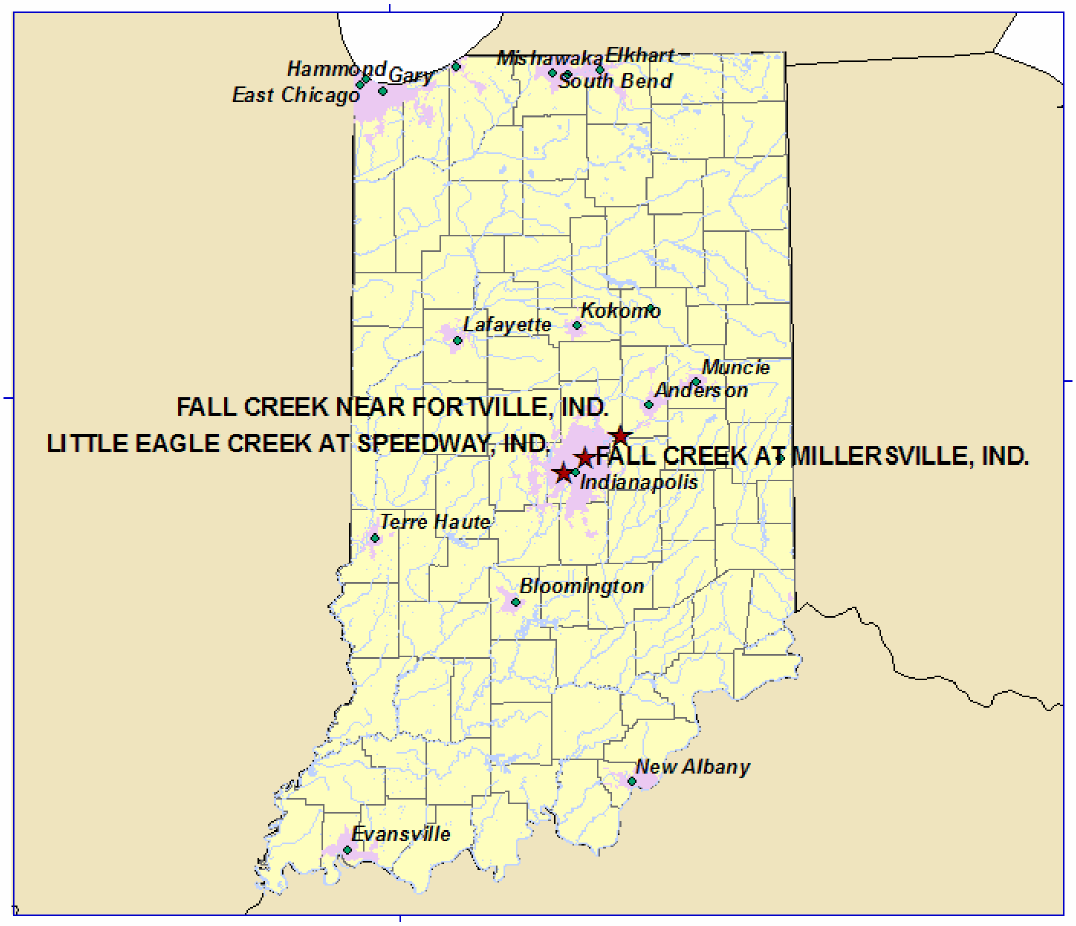


Figure 2. Location of streamflow gauges and watersheds analyzed in this study.

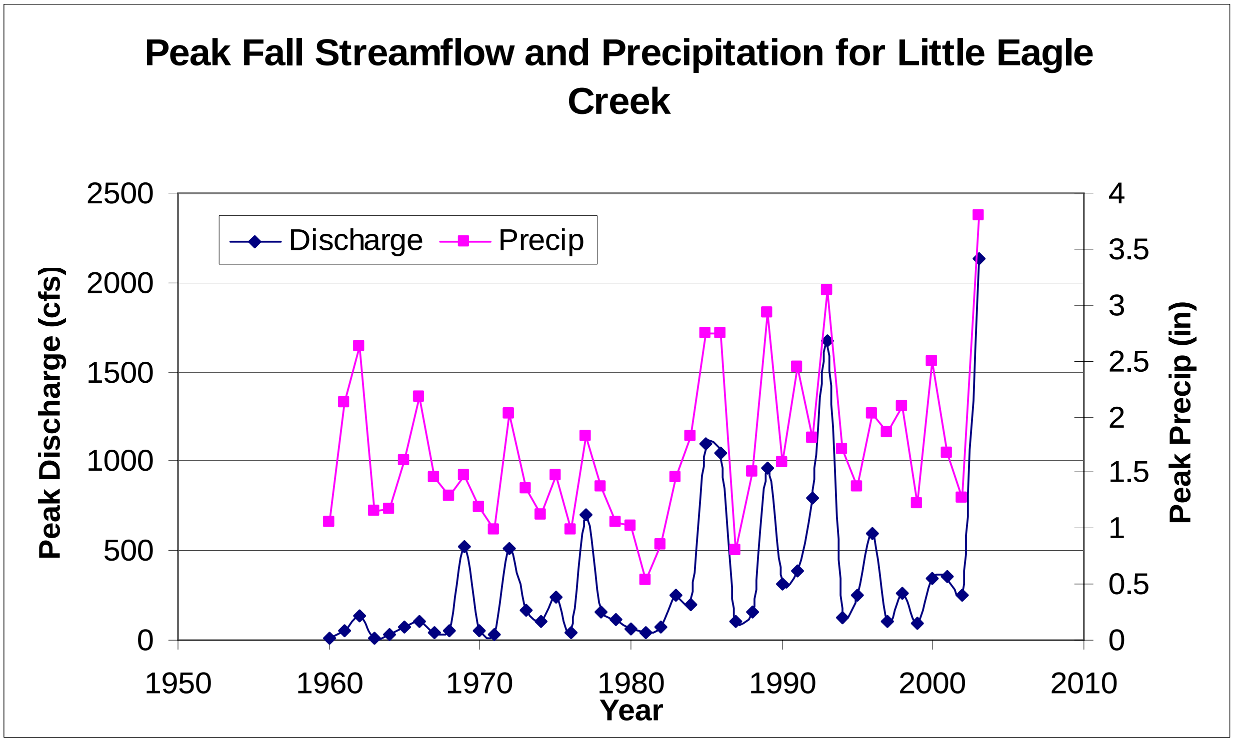


Figure 3. Relationship between peak autumn precipitation and streamflow for Little Eagle Creek. Prior to 1980, precipitation and streamflow appear to be changing in opposite directions, with precipitation decreasing and streamflow increasing. After 1980, however, the peaks are more aligned, indicating a greater relationship between peak autumn precipitation and peak autumn streamflow.

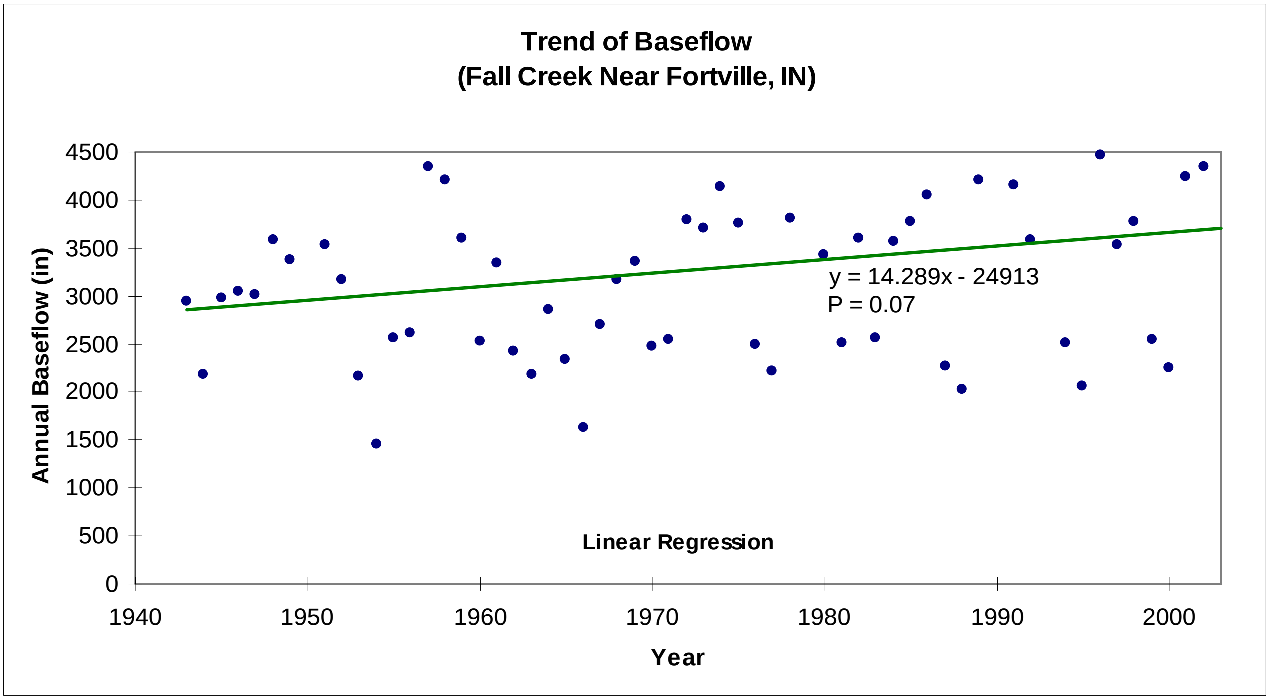


Figure 4. Increasing trend of baseflow in the watershed of Fall Creek near Fortville, IN.

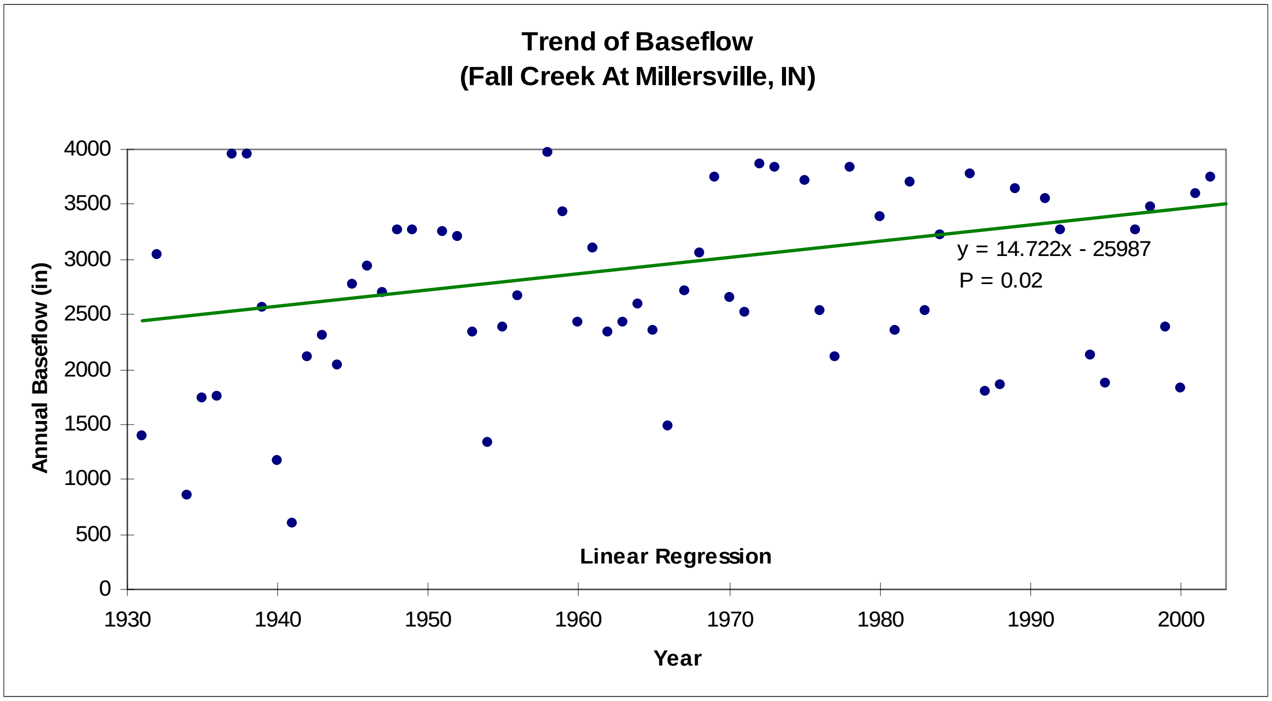


Figure 5. Increasing trend of baseflow in the watershed of Fall Creek near Millersville, IN.

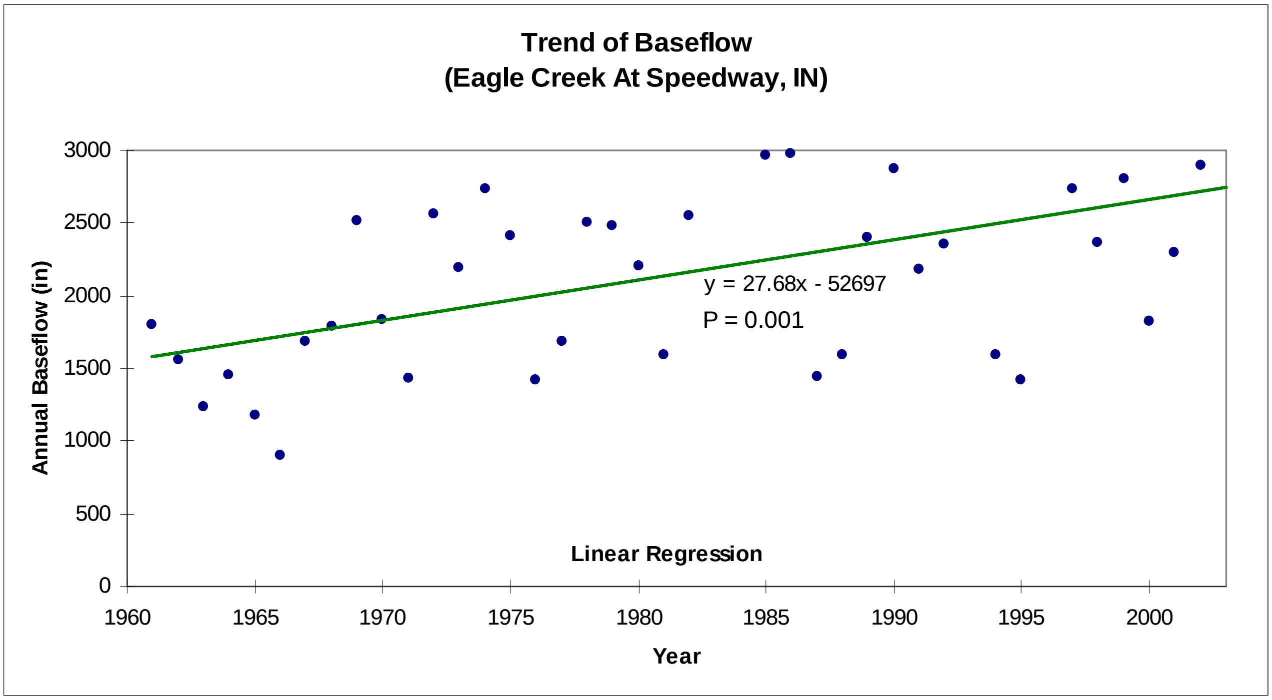


Figure 6. Increasing trend of baseflow in the watershed of Little Eagle Creek at Speedway, IN.

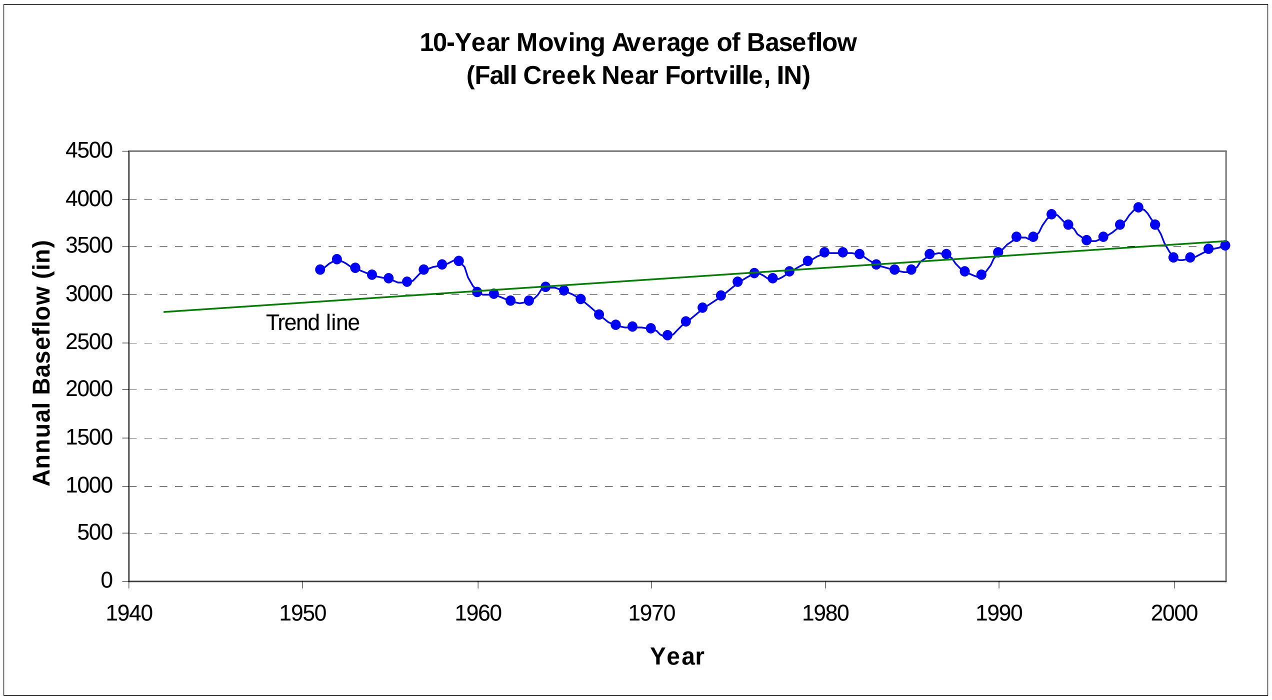


Figure 7. Increasing trend of baseflow in the watershed of Fall Creek near Fortville, IN.

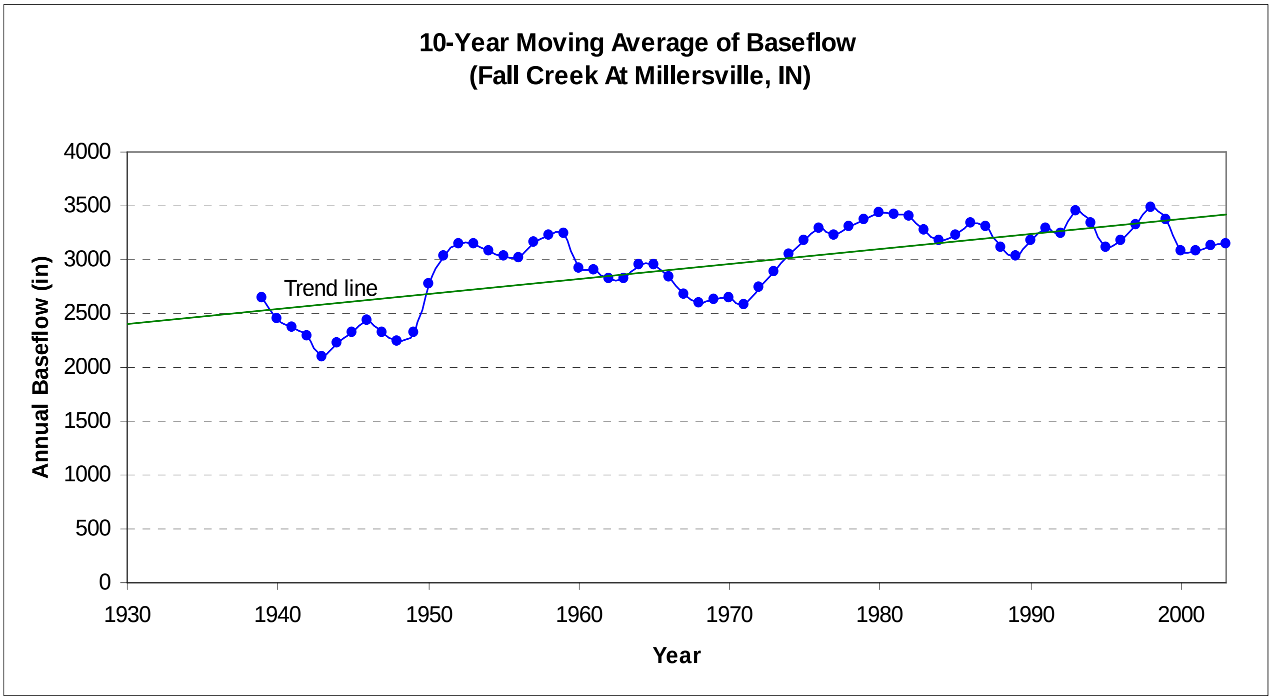


Figure 8. Increasing trend of baseflow in the watershed of Fall Creek near Millersville, IN.

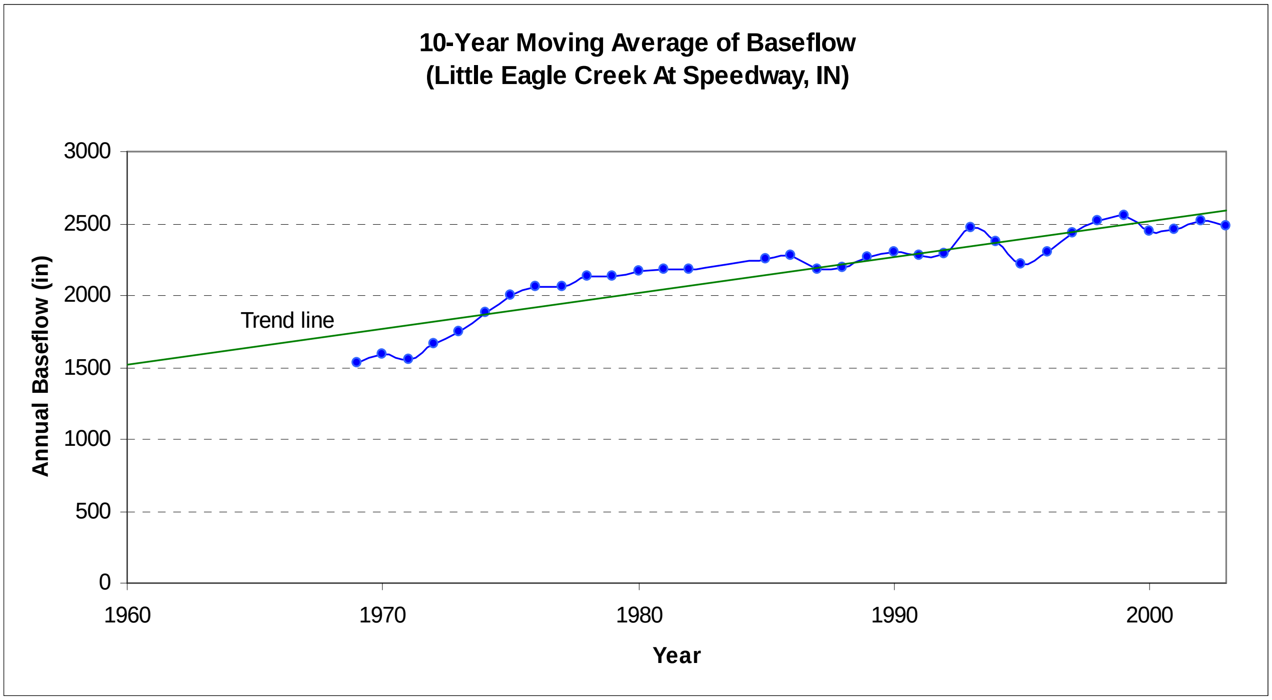


Figure 9. Increasing trend of baseflow in the watershed of Little Eagle creek at Speedway, IN.

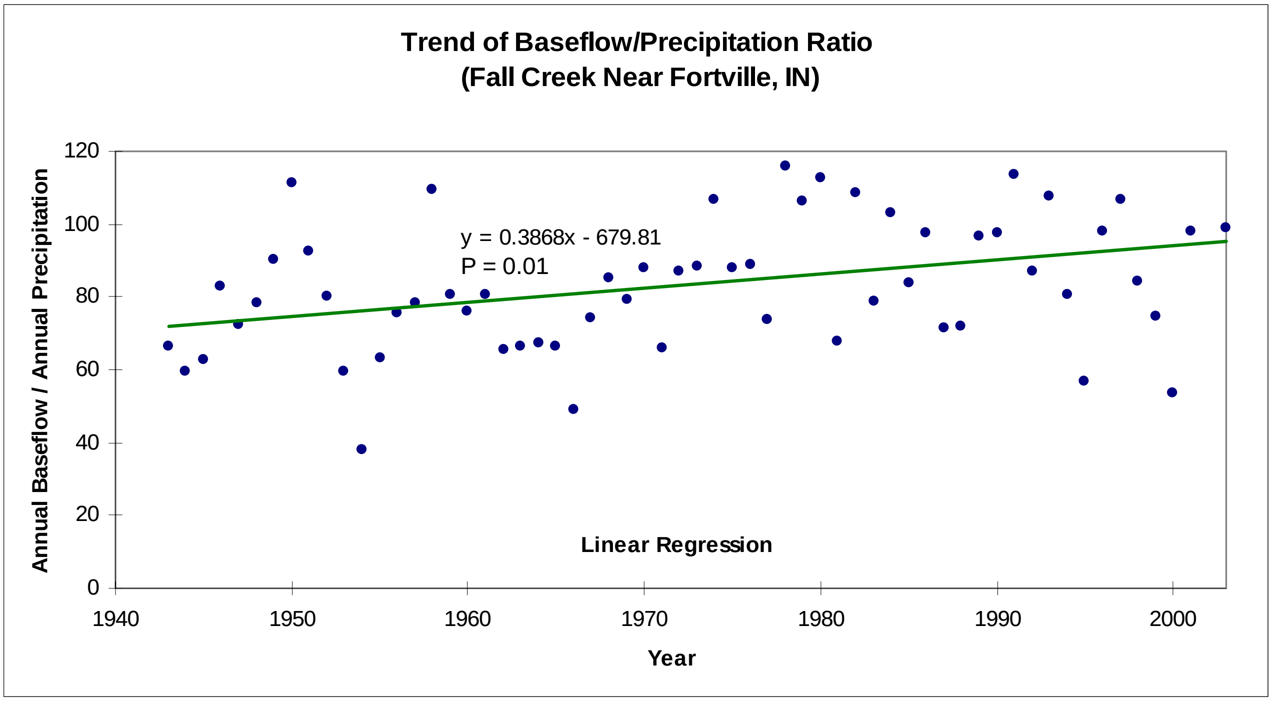


Figure 10. Increasing trend of baseflow in the watershed of Fall Creek near Fortville, IN.

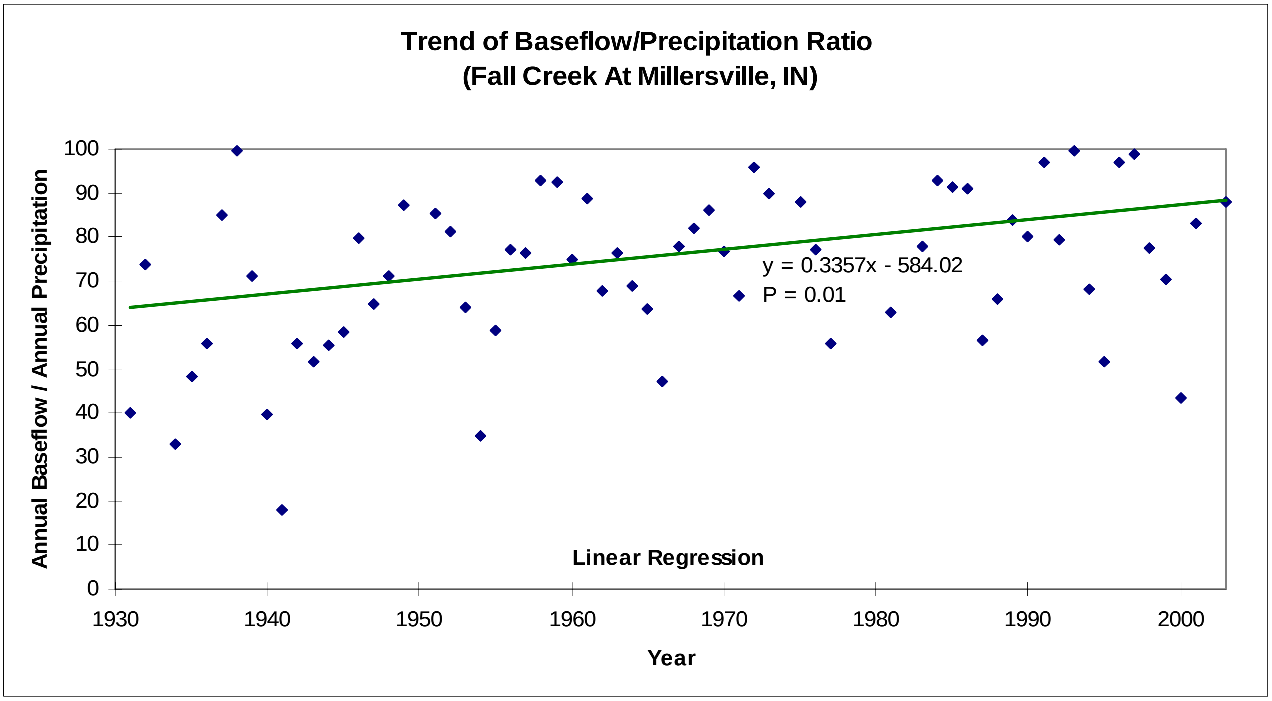


Figure 11. Increasing trend of baseflow in the watershed of Fall Creek near Millersville, IN.

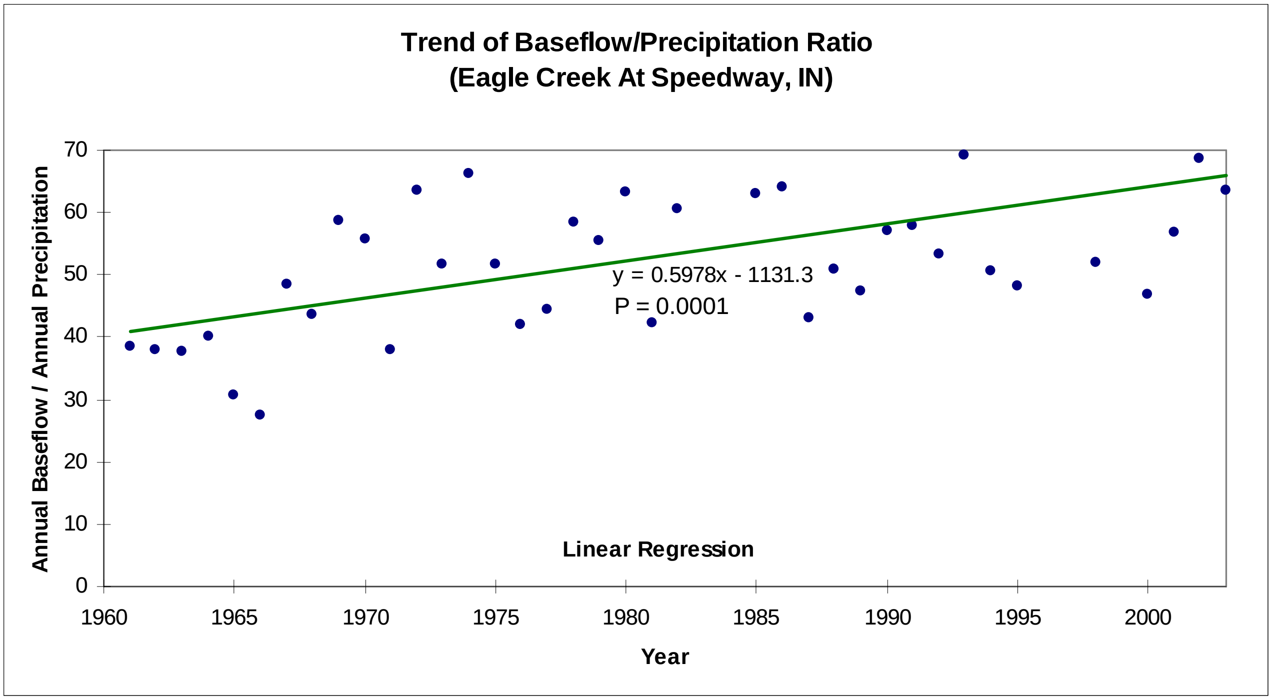


Figure 12. Increasing trend of baseflow in the watershed of Little Eagle creek at Speedway, IN.

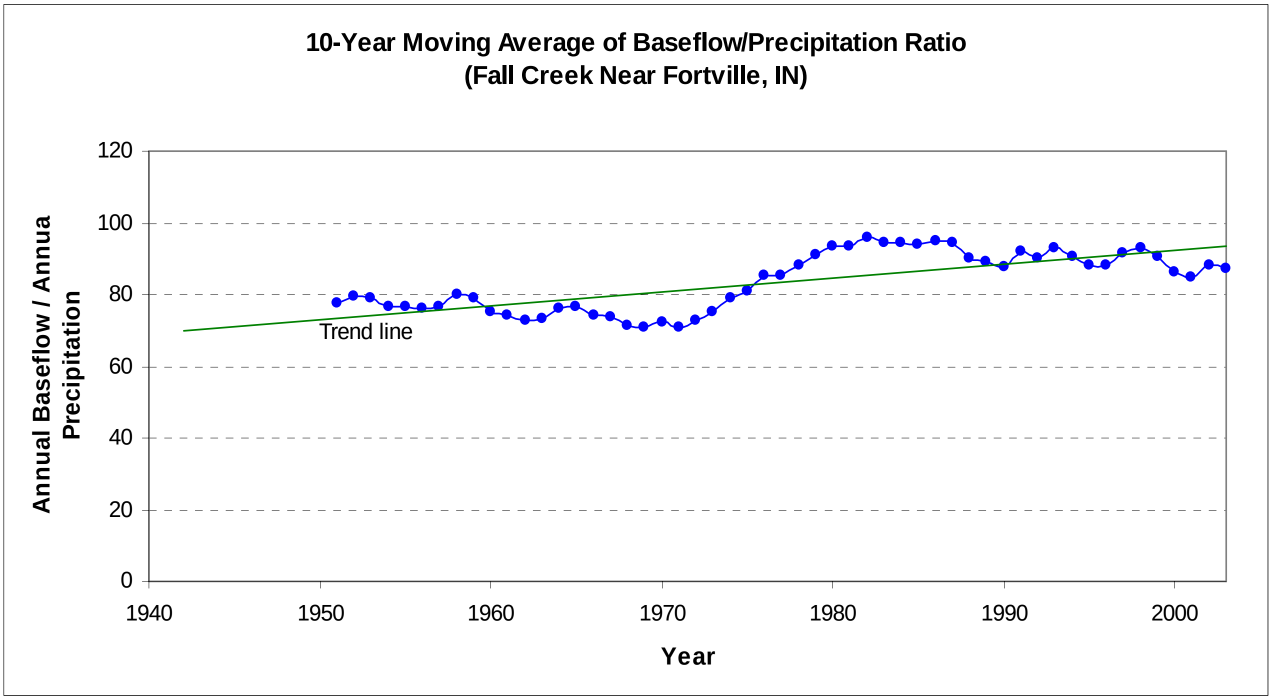


Figure 13. Increasing trend of baseflow in the watershed of Fall Creek near Fortville, IN.

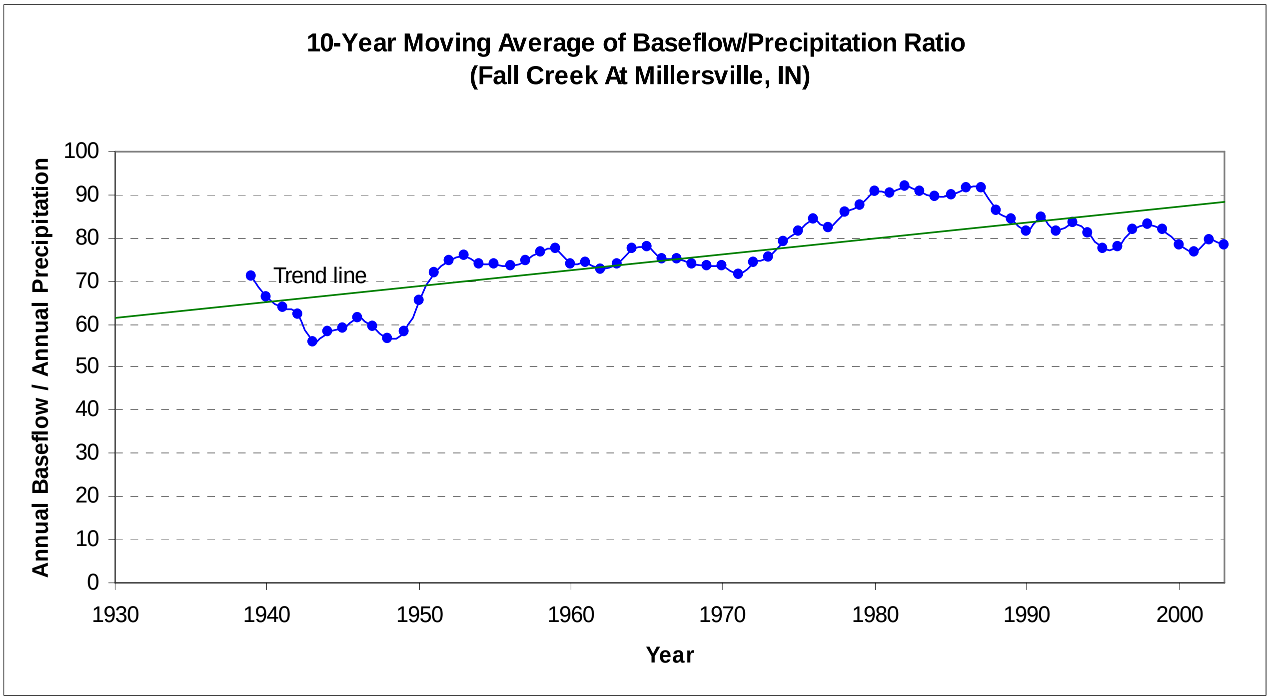


Figure 14. Increasing trend of baseflow in the watershed of Fall Creek near Millersville, IN.

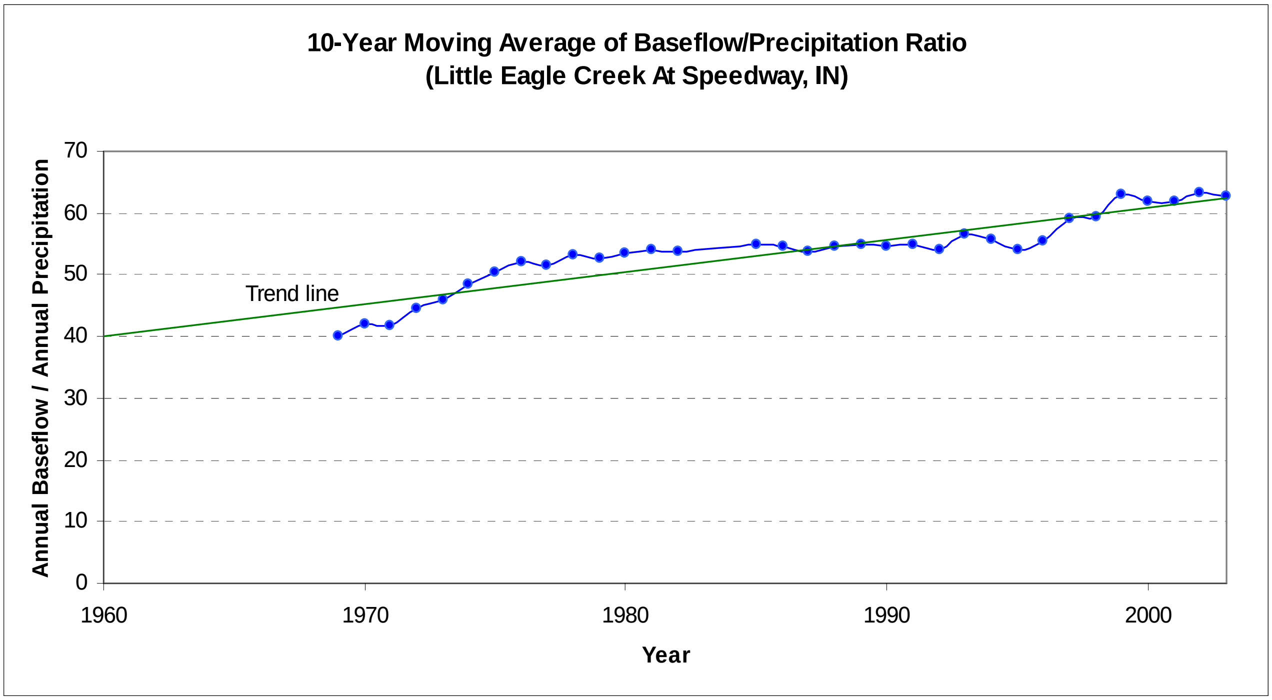


Figure 15. Increasing trend of baseflow in the watershed of Little Eagle creek at Speedway, IN.

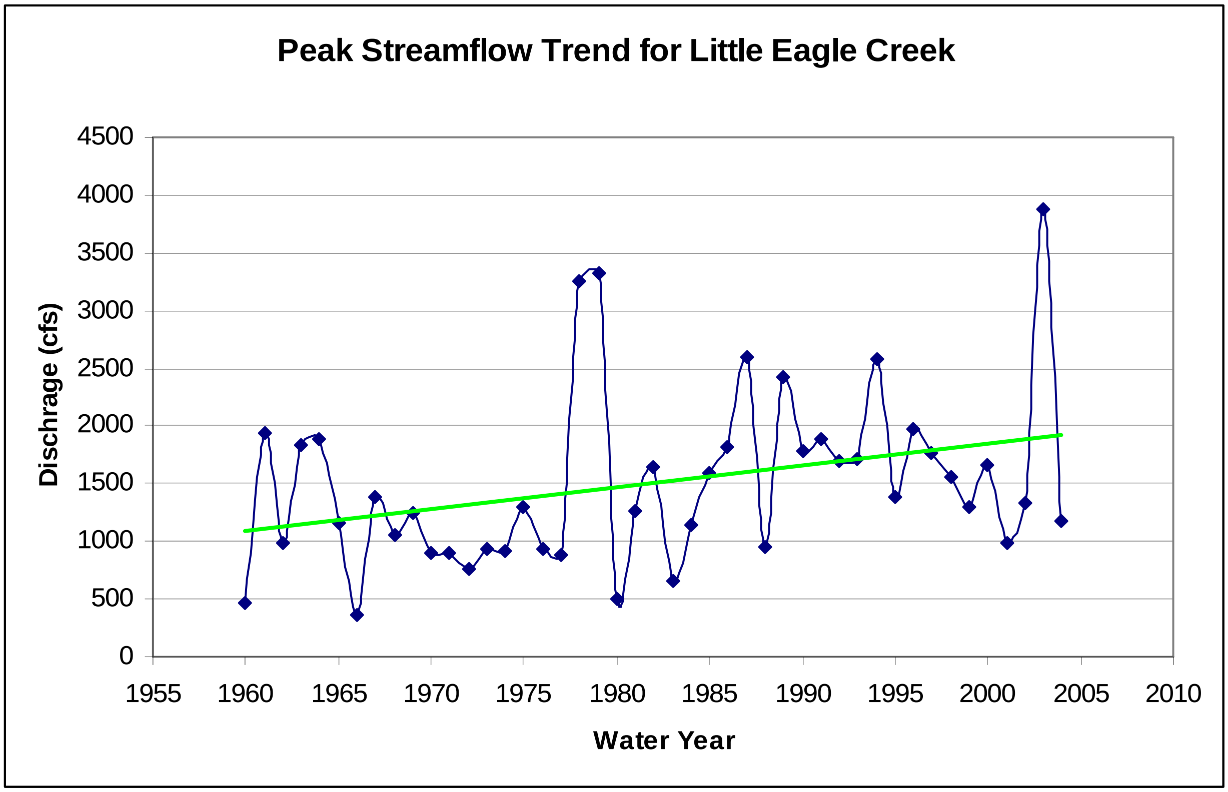


Figure 16. Statistically significant increasing trend in peak annual daily streamflow at Little Eagle Creek.

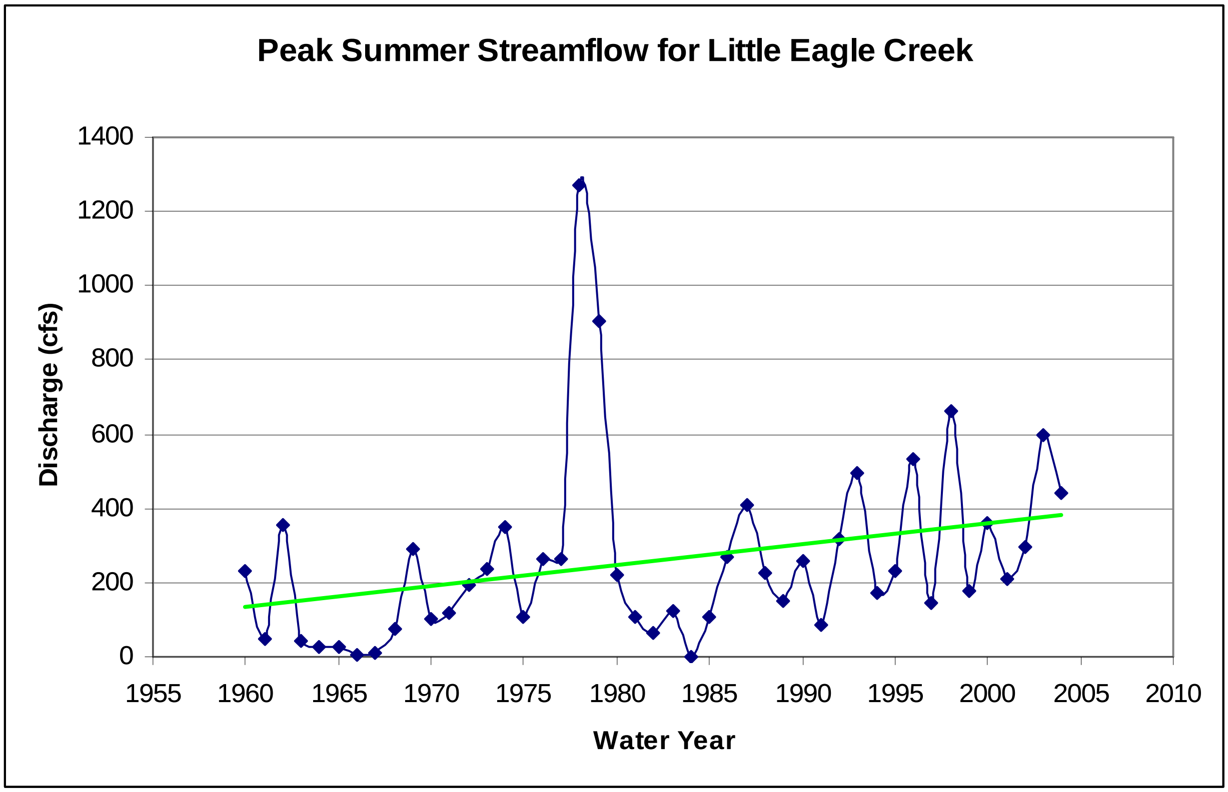


Figure 17. Statistically significant increasing trend in peak summer streamflow at Little Eagle Creek. Removal of the outlying points in 1978 and 1979 still results in a significant increasing trend.

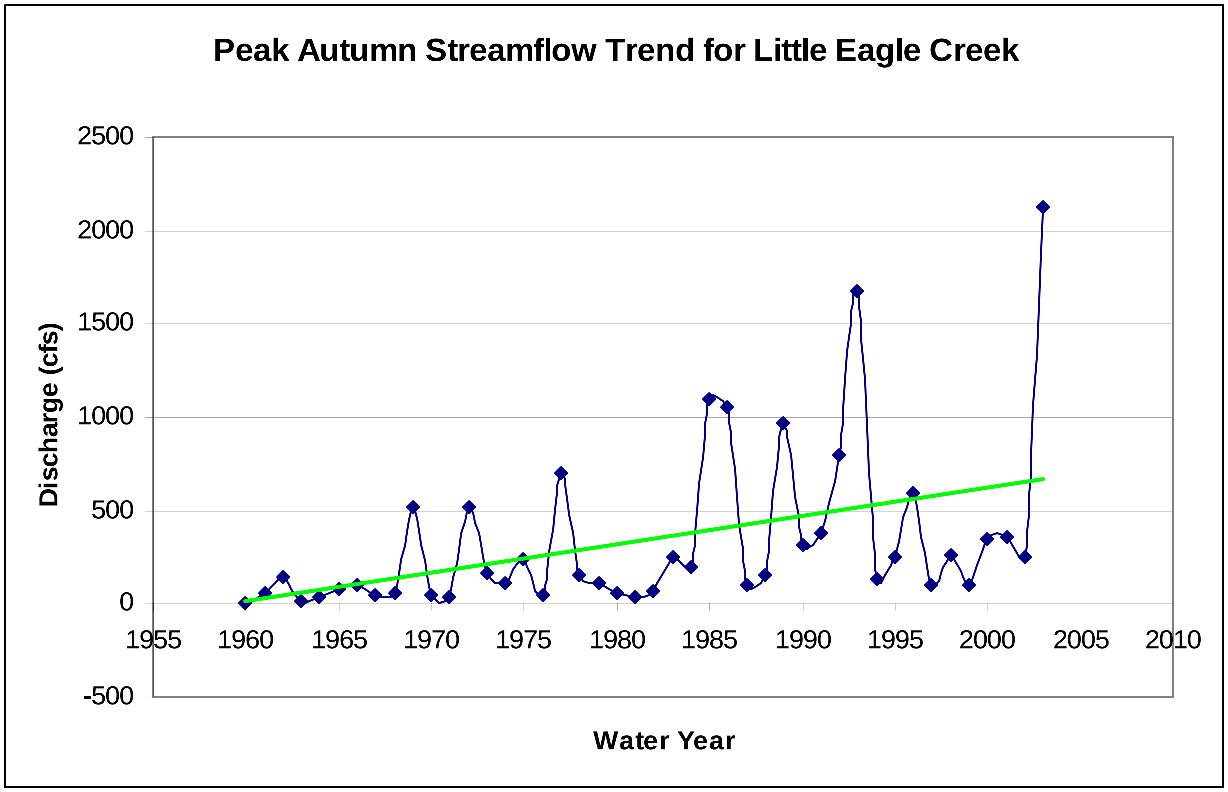


Figure 18. Statistically significant increasing trend in peak autumn streamflow at Little Eagle Creek.

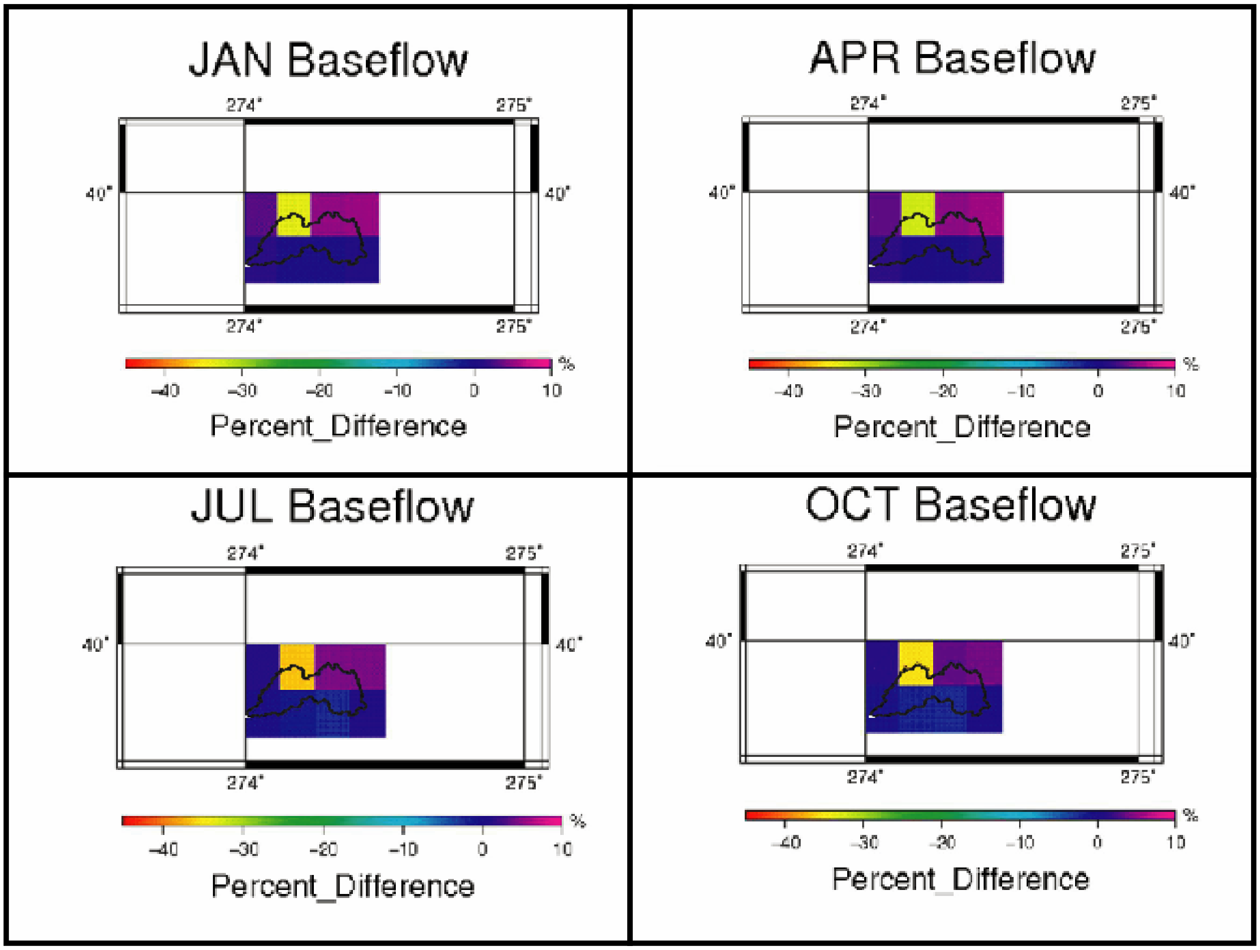


Figure 19. Percent difference between baseflow generated using 1940 and 2000 land use.

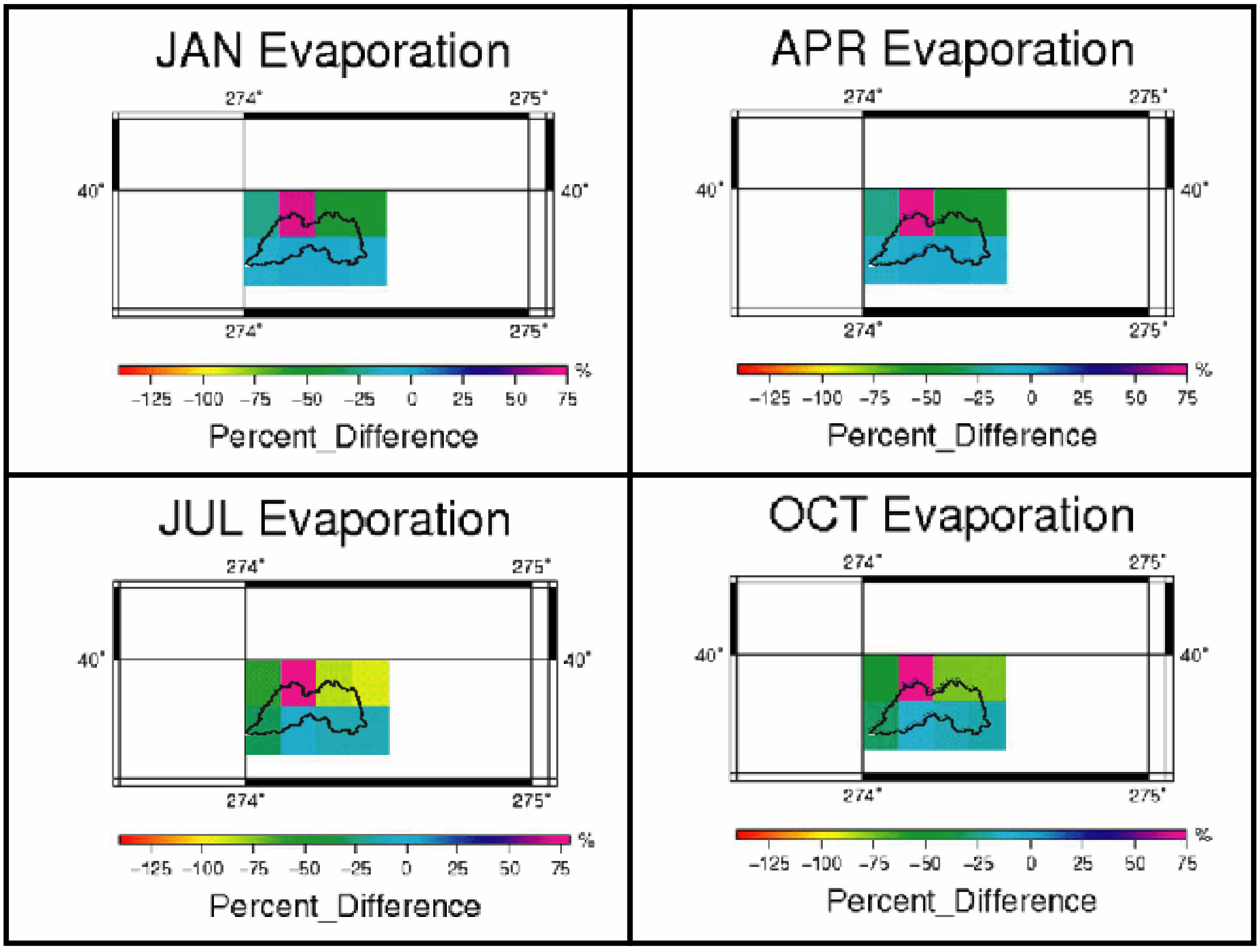
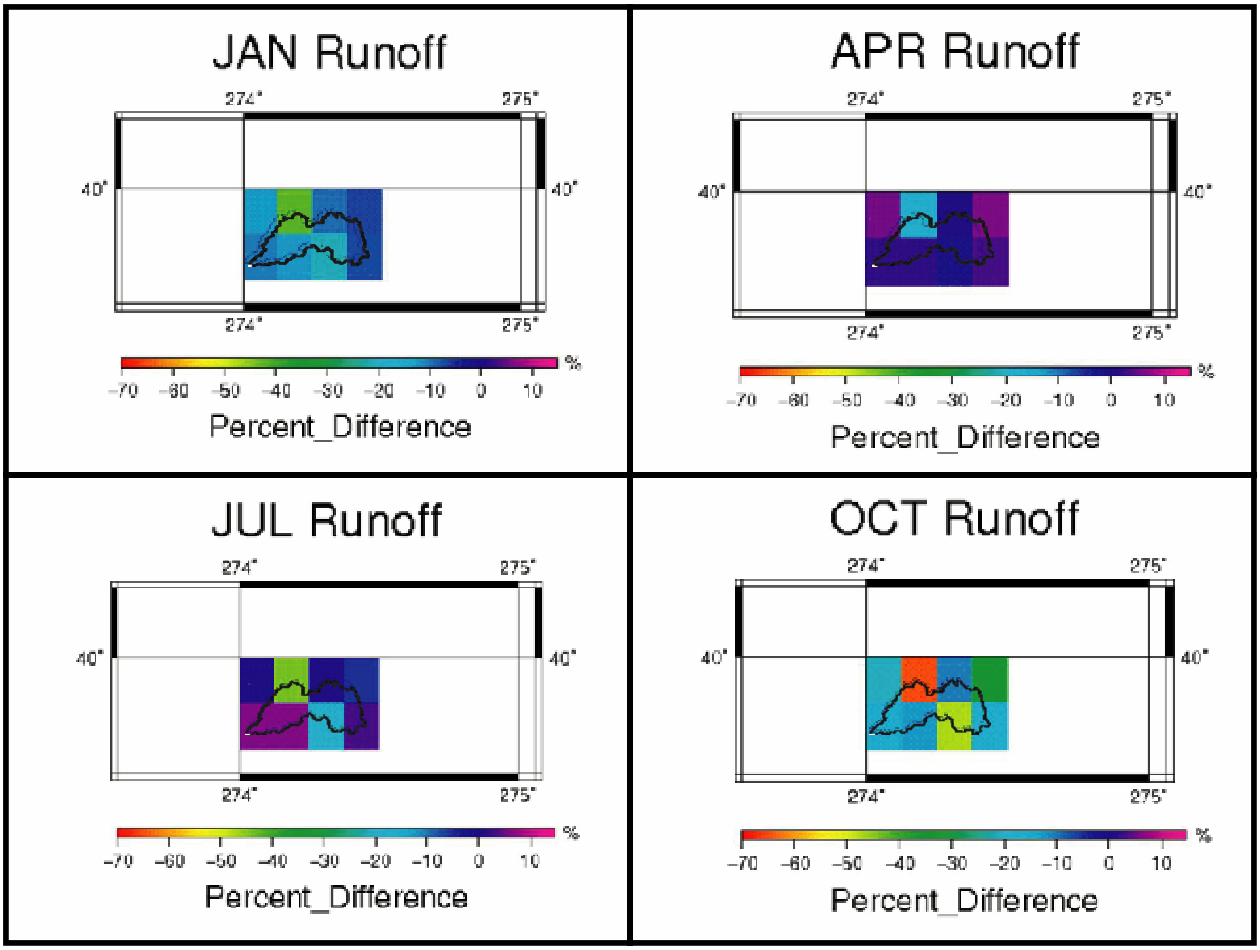


Figure 20. Percent difference between evaporation generated using 1940 and 2000 land use.



JAN Runoff

APR Runoff

JUL Runoff

OCT Runoff

Figure 21. Percent difference between surface runoff generated using 1940 and 2000 land use.

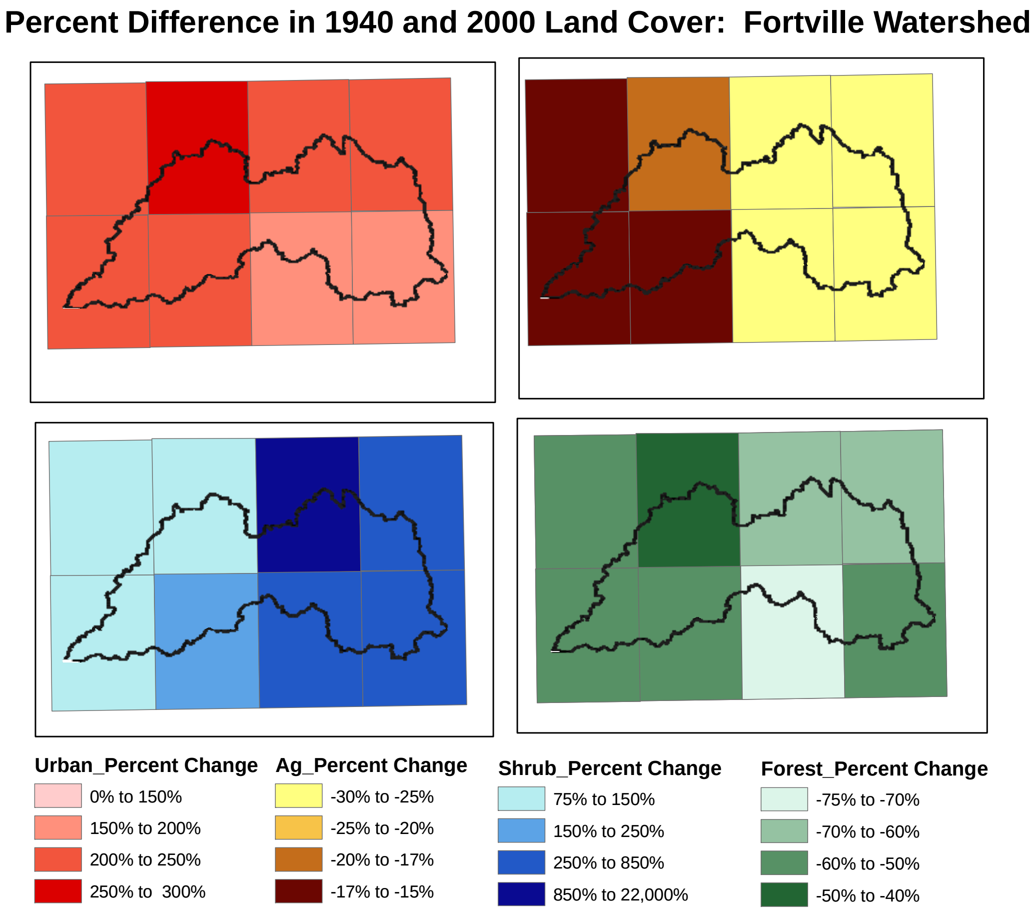


Figure 22. Estimated percent land cover change from 1940 to 2000 within the watershed draining to Falls Creek near Fortville, Indiana.

TABLE 1. Significance level of peak precipitation trends for the study sites. Values approaching zero are the most significant increases, while the values closer to one indicate decreases. Although not significant, peak annual precipitation is increasing, while peak autumn precipitation is increasing. The bold values indicate statistical significance at the α=0.05 level.

	PEAK ANNUAL	**PEAK WINTER**	**PEAK SPRING**	**PEAK SUMMER**	**PEAK AUTUMN**
LITTLE EAGLE CREEK	0.641	0.737	0.081	0.50	**0.045**
FALL CREEK NEAR FORTVILLE	0.739	0.636	0.763	0.504	0.393
FALL CREEK NEAR MILLERSVILLE	0.727	0.373	0.601	0.717	0.251

TABLE 2. Significance level of total precipitation trends for the study sites. Values approaching zero are the most significant increases, while the values closer to one indicate decreases. The bold values indicate statistical significance at the α=0.05 level.

	TOTAL ANNUAL	**TOTAL WINTER**	**TOTAL SPRING**	**TOTAL SUMMER**	**TOTAL AUTUMN**
LITTLE EAGLE CREEK	0.292	0.896	0.19	0.146	**0.04**
FALL CREEK NEAR FORTVILLE	0.739	0.636	0.736	0.504	0.393
FALL CREEK NEAR MILLERSVILLE	0.727	0.373	0.601	0.717	0.251

TABLE 3. Significance level of peak streamflow trends for the study sites. Values approaching zero are the most significant increases, while the values closer to one indicate decreases. The bold values indicate statistical significance at the α=0.05 level. Peak annual streamflow is increasing at all sites, with peak summer and peak autumn streamflow showing the highest overall significance levels.

	PEAK ANNUAL	**PEAK WINTER**	**PEAK SPRING**	**PEAK SUMMER**	**PEAK AUTUMN**
LITTLE EAGLE CREEK	**0.019**	0.404	0.570	**0.001**	**0.0001**
FALL CREEK NEAR FORTVILLE	0.179	0.633	0.546	0.338	**0.020**
FALL CREEK NEAR MILLERSVILLE	0.182	0.273	0.187	**0.026**	**0.004**

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Rapid Detection of Toxic and Taste and Odor Causing Cyanobacteria in Indiana Surface Water

Basic Information

Title:	Rapid Detection of Toxic and Taste and Odor Causing Cyanobacteria in Indiana Surface Water
Project Number:	2005IN174B
Start Date:	5/15/2005
End Date:	1/30/2006
Funding Source:	104B
Congressional District:	4th
Research Category:	Water Quality
Focus Category:	Surface Water, Toxic Substances, Water Quality
Descriptors:	
Principal Investigators:	Carole A Lembi, Carole A Lembi

Publication

1. Britton, C. H., R. E. Pruitt, and C. A. Lembi. 2005. A rapid, quantitative detection assay of cyanbacteria. Abstract booklet produced by the Aquatic Plant Management Society, July 10-13, 2005, San Antonio, TX, page 35.

Title: Rapid Detection of Toxic- and Taste and Odor-causing Cyanobacteria in Indiana Surface Waters

Principal Investigator: Carole A. Lembi, Department of Botany and Plant Pathology, 915 W. State Street, Purdue University, W. Lafayette, IN 47907; phone 765-494-7887; FAX 765-494-0663; email lembi@purdue.edu
Co-Principal Investigator: Robert Pruitt, Department of Botany and Plant Pathology, 915 W. State Street, Purdue University, W. Lafayette, IN 47907; phone 765-496-6794; FAX 765-494-0663; email pruittr@purdue.edu

Problem and Research Objectives: The invasion of *Cylindrospermopsis raciborskii*, a toxin-producing cyanobacterium, into Indiana and other Midwestern waters has caused great concern among state agencies and drinking water providers. At the present time, water treatment involves the use of copper-containing compounds to temporarily reduce the *C. raciborskii* populations. A statement from the Indiana Natural Resources Commission (2003) indicates the concern of the state of Indiana regarding copper: **"In 1989 and for several years since 2000, all major surface sources of drinking water for the city of Indianapolis have been chemically treated to reduce populations of blue-green algae, at a high cost to the utility and its customers, as well as incurring the risks to the ecosystem associated with the use of herbicides."**

The ability to rapidly detect small numbers of *C. raciborskii* and *P. limnetica* cells before they reach peak populations could greatly reduce the amount of copper used in-water and the amounts of activated carbon and chlorine used at the drinking water treatment plant. It could also greatly enhance ecological studies of these organisms, including their responses to nutrient reduction strategies. Early and rapid detection at the current time is not possible because 1) the filaments are extremely small (the width of a *C. raciborskii* filament is only 2-3 µm wide), making detection with light microscopy extremely difficult, even for experts, 2) other phytoplanktonic species can easily be confused with the two, and 3) sending water samples for identification to a lab such as Phycotech is expensive (>$150/sample) and time-consuming and beyond the financial ability of managers of surface waters not used for drinking.

The purpose of this project is to develop a quantitative detection method for *Pseudanabaena limnetica* and *Cylindrospermopsis raciborskii* using 5'-exonuclease PCR, which measures the release of a fluorescent dye attached to an oligonucleotide probe in response to amplification of a specific target sequence. This method provides a quantitative measure of the target DNA found in the sample as well as a greater degree of specificity than methods that quantify the total amount of DNA amplification by using a dye that binds non-specifically to all DNA amplified. A properly developed and calibrated assay can be used to accurately calculate the concentration of the cyanobacterial cells present in collected water samples. The project has two primary objectives:

Objective 1 is to verify or determine the DNA sequences for a number of PCR products amplified from *Cylindrospermopsis raciborskii* and to utilize this information to design species-specific 5'-exonuclease PCR assays.

Objective 2 is to validate these new assays using highly purified DNA from cyanobacterial cultures, crude DNA from cyanobacterial cultures, and crude DNA prepared from cyanobacterial cultures mixed with environmental water samples.

Methodology and Principal Findings:

Objective 1: Regions of the cyanobacterial genome that were specific to *C. raciborskii* were found using gene databanks and computer alignment programs. We decided to use a conserved region within the *nif*H gene (associated with nitrogen fixation). We then tested four different DNA extraction methods (with a number of variations) to determine the most reliable method to obtain Real Time PCR-quality DNA from lake water samples. We finally settled on the MoBio UltraClean Soil DNA Isolation Kit. We found that this extraction kit was reliable and sensitive enough to detect cell concentrations within a range of 5000 to 100,000 cells/mL

Using Primer3 software, we focused on a region within the *nif*H gene and tested primers for that fragment for their specificity to *C. raciborskii* over other cyanobacteria (*Anabaena, Microcystis, Pseudanabaena*) using Sybr Green analysis. The *C. raciborskii* sample amplified after the fewest cycles, showing that the *C. raciborskii* primers were most specific for *C. raciborskii* DNA. In order to more stringently follow the guidelines for ABI's quantitative PCR protocol, we used PrimerExpress software to find a more suitable primer/probe set. Alignment of the primer/probe to known DNA sequences, as well as conventional PCR analysis, allowed us to do this.

Objective 2: Now that we have found a method to extract quality cyanobacterial DNA directly from the lake water and have developed the species-specific primers and probe, we have begun to test the sensitivity and the accuracy of our assay. However, a problem of contamination has arisen during PCR. After attempting to resolve the contamination by switching water sources, buffers, ordering new primers, etc. we have still been unsuccessful in locating the cause of bands in the negative controls. Most recently, the PCR product has been successfully cloned into *E. coli*. From this, sequencing is being conducted to identify whether or not our negative control product is indeed *C. raciborskii* contamination or if it happens to be a random product of similar size. Once the contamination source has been identified, we will be able to resume our calculations of sensitivity and efficiency for the assay.

Significance of the Project: The funding provided by the IWRRC allowed us to begin the process of isolating, identifying, and quantifying the populations of *Cylindrospermopsis raciborskii* in lake water using DNA. Initially, the hardest part was finding a DNA isolation technique that would work in our study lake (Lake Lemon in Monroe Co.), because water constituents such as tannic and humic acids appeared to be inhibiting the assay. This is why we eventually settled on a soil DNA isolation procedure, which effectively removes these types of contaminants. Currently, we are working to solve a second problem that involves a PCR contaminant.

Once the procedures have been developed for *C. raciborskii*, we will then extend them to *Pseudanabaena limnetica*, a cyanobacterium that has caused major taste and odor causing problems in drinking water reservoirs. The early detection of this organism could be of great benefit to water treatment facilities throughout the U.S.

An additional benefit of the IWRRC funding was that it allowed us to sample, on a monthly basis, the *C. raciborskii* populations in Lake Lemon, IN. We now have depth distribution data and water quality parameters at two locations in the lake each month since June 2005. This will be the first time a population of this potentially toxic alga has been monitored, even over the winter months, in a temperate lake in the U.S. In addition, we have begun isolating strains of *C. raciborskii* from Lake Lemon and other Indiana lakes, which, with DNA and toxin characterization, will allow us to eventually study the geographic distribution and potential for toxin production of individual strains in the state.

Student: Clay Britton (graduate student; Ph.D. candidate) was supported on this project and conducted all of this research.

Abstract: Britton, C. H., R. E. Pruitt, and C. A. Lembi. 2005. A rapid, quantitative detection assay of cyanbacteria. Abstract booklet produced by the Aquatic Plant Management Society, July 10-13, 2005, San Antonio, TX, page 35.

Characterizing hydrologic response in urbanizing watersheds in Indiana: Determination of changes in runoff coefficients

Basic Information

Title:	Characterizing hydrologic response in urbanizing watersheds in Indiana: Determination of changes in runoff coefficients
Project Number:	2005IN177B
Start Date:	3/1/2005
End Date:	2/28/2006
Funding Source:	104B
Congressional District:	9th
Research Category:	Climate and Hydrologic Processes
Focus Category:	Climatological Processes, Ecology, Floods
Descriptors:	
Principal Investigators:	Susan Grimmond, Jack Wittman

Publication

1. None yet
2. http://www.indiana.edu/~ecohydro/MCRR/

IWRRC Report

Title: Characterizing hydrologic response in urbanizing watersheds in Indiana: Determination of changes in runoff coefficients

Submitted by:

Professors **Sue Grimmond** and **Kelly Caylor**, Atmospheric Science Program, Department of Geography, Indiana University, Student Building 120, Bloomington, IN, 47401

Dr. Jack Wittman, Wittman Hydro Planning Associates, Inc.
President, Monroe Country Drainage Board

Funding Period: March 1, 2005 – February 28 2006

Problem:

When agricultural, or undeveloped areas, are converted to subdivisions and commercial development, roads are built, vegetation is removed, and an engineered drainage network is established. The water cycle for the catchment, or watershed, is altered in a way that increases the amount of water that runs off and decreases the amount stored in the catchment. When natural vegetative cover is removed during development and replaced by yards that drain into local streams or pipe networks, the reduction in landscape storage for precipitation assures that more runoff will occur throughout the year in response to rainfall events. The swails and gutters help to accelerate the stream response so that the peak flow occurs soon after the end of a storm. In many different watersheds around the country, rainfall-runoff data show the degree to which there are changes in both the magnitude and the timing of runoff caused by development (Konrad, 2003). Research done in surrounding states (Illinois, Michigan, and Wisconsin) indicates that there is a threshold density and distribution of residential development that may be a tipping point for stormwater impacts.

Over the past two years the Indiana Department of Environmental Management has developed a new rule and guidance material for implementing phase two of the Clean Water Act (Rule 13). This new rule is designed to reduce the water quality impairments caused by stormwater inflows to Indiana's streams and rivers. The basic premise is that the diffuse development that occurs in watersheds in urban and urbanizing areas needs to account for the increases in stormwater runoff that is caused by the impervious areas in the watersheds of the state. These new rules are to be implemented by the designated MS4 operator with limited background and in most cases, very limited funding. While it is not uncommon for Indiana's municipal governments to bear the burden of a new state regulation, it is unusual that this rule is being imposed on local governments that have no basis upon which to make informed judgments. The stormwater management plans that the counties and local governments are writing require an understanding of the performance and appropriateness of different best management practices. The critical information needed is the relation between development patterns and hydrologic response in a sub-watershed.

Research Objectives

The objective of this study is to investigate runoff ratios of urbanizing areas in Monroe County, Indiana and to put in place a long-term monitoring study to monitor a broader suite of hydrological variables and to evaluate and develop. To reflect this, the objectives of the study are formulated in two parts:

Short-term objective:

- To gather runoff and rainfall data, with land cover and land use information, through time in areas that are urbanizing to evaluate how rainfall runoff ratios change with urbanization in a Midwestern area.

Longer term objectives:

- To document all aspects of the urban water balance within urbanizing watersheds, including rainfall, piped water supply, runoff, evapotranspiration, and change in soil moisture.
- To evaluate models of the urban water balance which have potential to inform planning decisions related to regional water demand and low flow water quality, as well as storm water management.

This report focuses on the short-term objectives only and the collection of data to date.

Methodology

During the early part of the project period, while conversations with Monroe County Drainage Board (MCDB) were occurring about the most feasible areas for discharge measurements to occur, rain gauges were installed in a number of different areas in Monroe County (MC) (Figure 1). After practical considerations of the flow measurements and future development in MC were taken into account, it was decided to constrain the data collection efforts to the Ellettsville area of MC (Figure 1d). As this is the area of ongoing effort, this report is primarily concerned with work in this area. Additional information can be provided on the other sites and data upon request.

- Several tipping-bucket rain gauges have been placed in an urbanizing area close to Ellettsville (Figure 1) to measure rainfall intensity and amount (Table 1).
- Two pressure sensors and staff gauges have been installed in nearby streams (Figures 1 and 2) to measure flow rates of the streams, and therefore the corresponding discharge that will enable us to model the runoff rates based upon the rainfall data.
- A summary of the sites and data collected at each site is provided in Table 1 below. More details and panoramic images for each of the sites are provided by

following site links at the MCRR project web site: http://www.indiana.edu/~ecohydro/MCRR/

Table 1: Raingauge sites that are part of the Ellettsville data set

Site	Details
Elletsville Fire House (EFH)	Ellettsville Fire House (EFH) N Coordinate: 39°13’46.3” W Coordinate: 86°37’7.9” Elevation (m): 210.9 LULC type (not official): Urban – Medium Density Grass lot Raingauge make: Sierra-Misco Environment LTD. Model: 2501 Serial #: 1398C Radius (mm): 107.95 Manufacturer tip rate (mm/tip): 0.1 Calibrated tip rate (mm/tip): 0.2291
Langvardt House (LH)	N Coordinate:39°13’33.6” W Coordinate:86°34’58.8” Elevation (m): 253.0 LULC type (not official): Suburban – Low Density Raingauge make: Texas Electronics, Inc. Model: TR-525M Serial #: 20180 Radius (mm): 122.5 Manufacturer tip rate (mm/tip): 0.1 Calibrated tip rate (mm/tip): 0.1141
Elletsville Utilities (EU)	N Coordinate: 39°14’19.3” W Coordinate: 86°37’22.8” Elevation (m): 205.7 LULC type (not official): Utilities – Grass lot Raingauge make: Climatronics Corp. Model: 100508 Serial #: 960 Radius (mm): 76.2 Manufacturer tip rate (mm/tip): 0.1 Calibrated tip rate (mm/tip): 0.2940
Wittman House (WH)	N Coordinate: 39°10’00.5’’ W Coordinate: 86°31’31.5’’ Elevation (m): 265.5 LULC type (not official): Suburban – Low

	Density Raingauge make: Texas Electronics, Inc. Model: TR-525M Serial #: 10572-492 Radius (mm): 122.5 Manufacturer tip rate (mm/tip): 0.1 Calibrated tip rate (mm/tip): 0.0966
Wal-mart (WM)	N Coordinate: 39°08’32.9” W Coordinate: 86°34’25.9” Elevation (m): 248 LULC type (not official): Urban – Medium Density Grass lot Raingauge make: Texas Electronics, Inc. Model: TR-525M Serial #: 10571-492 Radius (mm): 122.5 Manufacturer tip rate (mm/tip): 0.1 Calibrated tip rate (mm/tip): 0.1345
Stout’s Creek (SC)	N Coordinate: 39°11’12.4” W Coordinate: 86°34’14.8” Elevation (m): 238.7 LULC type (not official): Agricultural - Pasture Raingauge make: Qualimetrics, Inc. Model: 6011-B Serial #: 1265 Radius (mm): 104.03 Manufacturer tip rate (mm/tip): 0.1 Calibrated tip rate (mm/tip): 0.1119

Some characteristics of the study area: slopes and elevation (Figure 3); hypsometric curve (Figure 4); and probable land-cover in 1997 (Figure 5).

Principal Findings

A web site for the project has been created where data are reported in real-time: http://www.indiana.edu/~ecohydro/MCRR/. Archives of all previous data are included here on the web site too. These are not reproduced here.

Rating curves for the stream gauging sites are presented at: http://www.indiana.edu/~ecohydro/MCRR/index.php/archives/category/data/rating-curves/

Data collection is ongoing. Analyses are now being initiated of rainfall-runoff ratios and relations to levels of urbanization/nature of land-cover change.

Significance

Results will be used to document effects of urbanization on urban runoff, with implications for water supply and quality. Best Management Practices for minimizing and mitigating negative effects will evaluated and demonstrated to developers.

Publications

Web site: http://www.indiana.edu/~ecohydro/MCRR/

Students

Many students were involved in this project and were an integral part of its success.

Graduate Students:

- Valerie Anderson, Department of Geography, Indiana University
- Bin Deng, Department of Geography, Indiana University

Undergraduate Students:

- Ryan Aylward, Department of Geography, Indiana University
- Jenny Davis, Environmental Sciences Program, Indiana University
- Holly Rauwolf, Department of Geography, Indiana University
- Jake Irvin, Department of Geography, Indiana University
- Nate Langwald, Department of Geography, Indiana University
- Adam Souder, Department of Geography, Indiana University
- Justin Wood, Department of Geography, Indiana University

These students have worked on the project on an hourly-basis and/or also completed course projects (notably in the Field Methods and Instrumentation Course: G350 and GIS courses) and independent studies. In addition, 5 students in G405/505 Hydroloclimatology are using the data from the MCRR project and the sites as a basis for conducting their own independent class research projects.

Invaluable support has also been provided by Steve Scott, Field & Instrument Scientist, Department of Geography, Indiana University and Angela Martin, Field & Instrument Scientist, Department of Geography, Indiana University

Figure 1. Location of Monroe County within Indiana, the associated cities and towns (red) in relation to the raingauge sites. In (b) the adjacent counties are listed in cyan (c) . The raingauge sites and water bodies. (d) Detail of the Ellettsville rain gauges sites

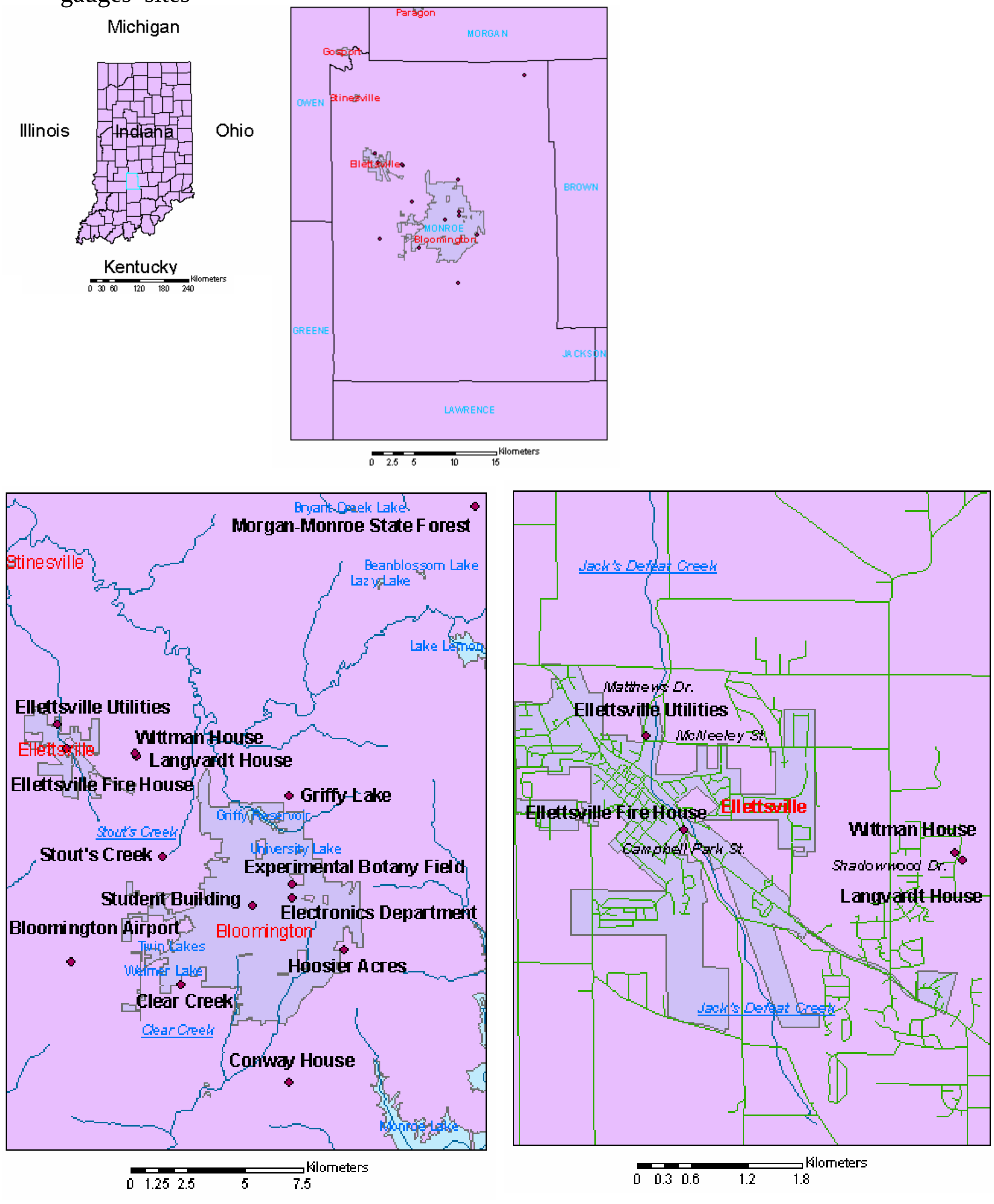


Figure 2: Stream location and gauging sites TBC- Turtle Back Creek and JDC: Jack Defeat’s Creek on the

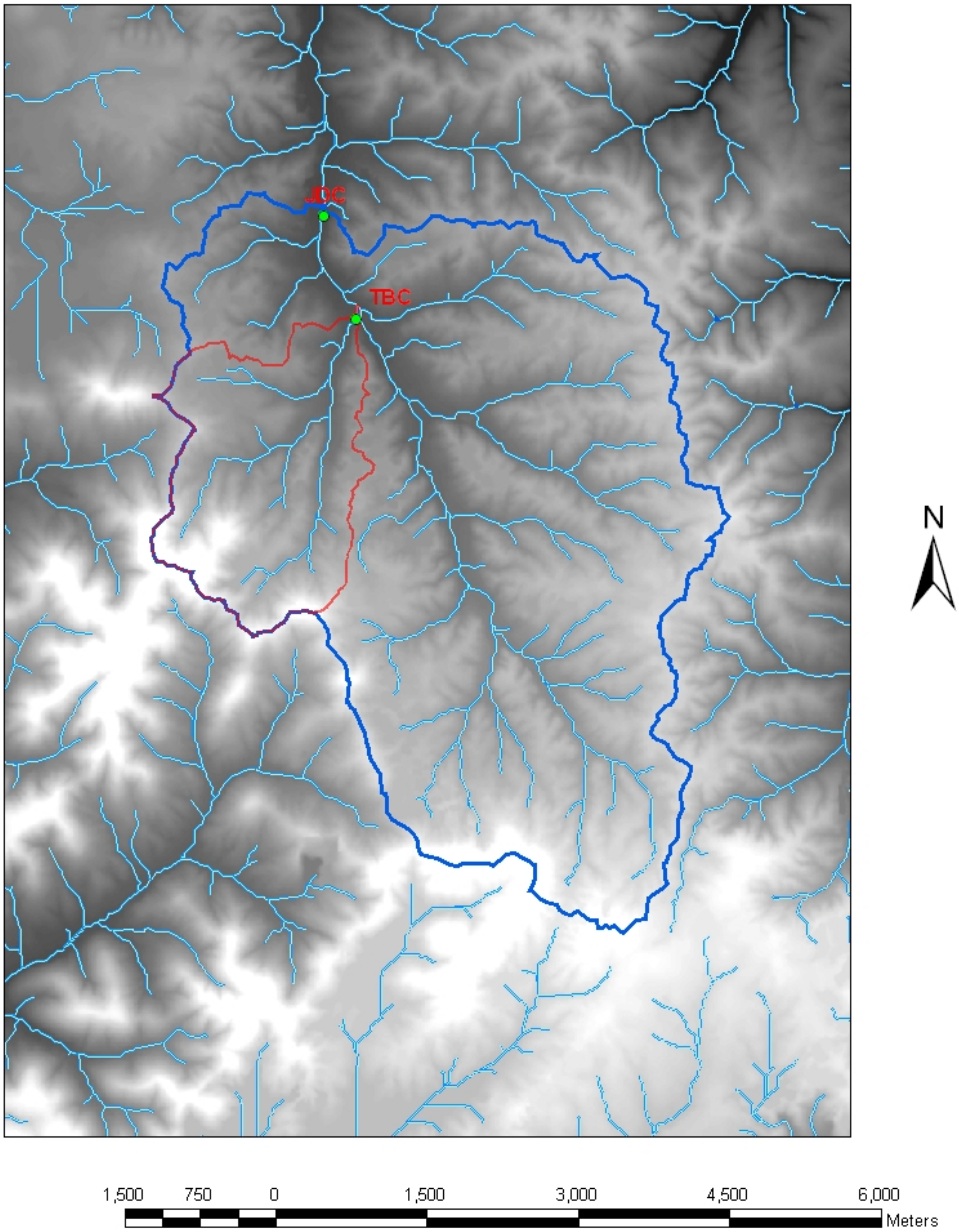


Figure 3: Slope and elevation within the catchment areas

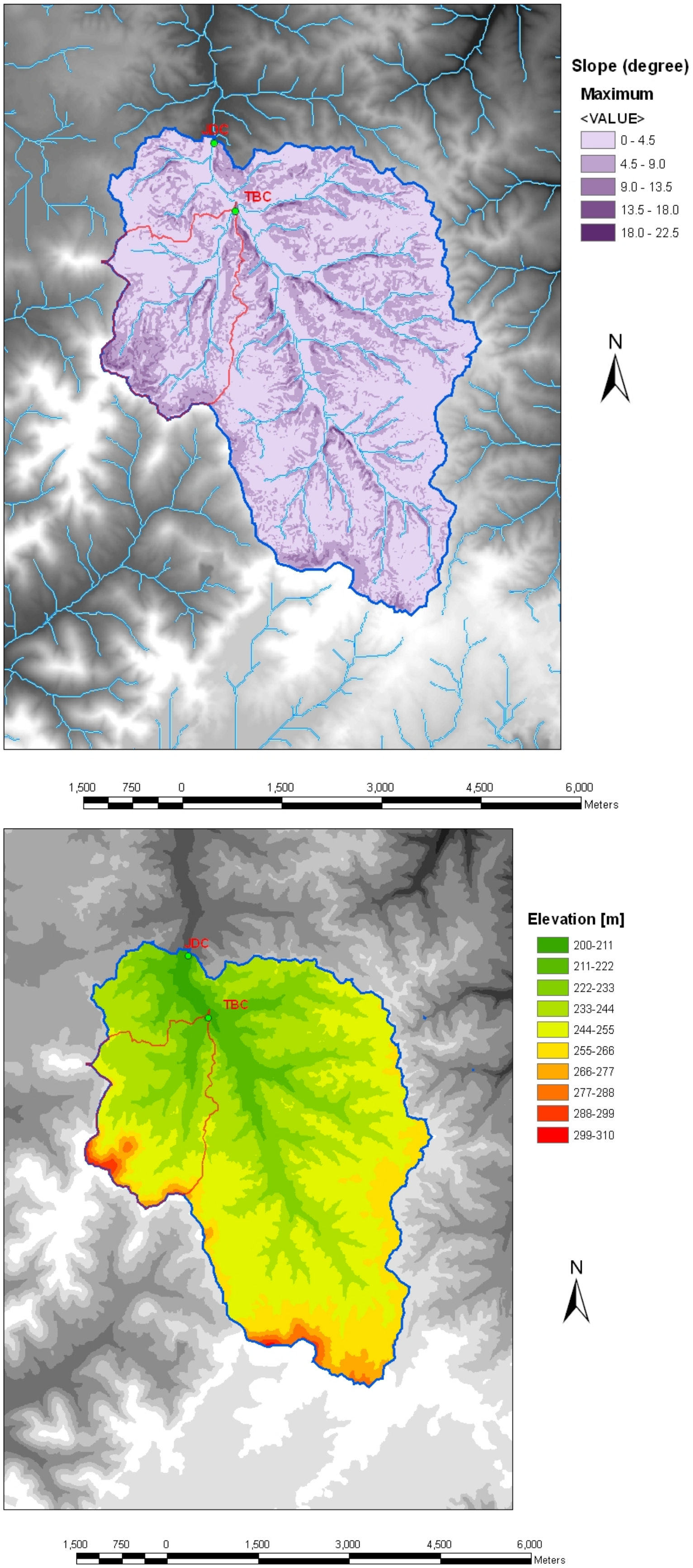


Figure 4: Hypsometric curves for JDC and TBC watersheds

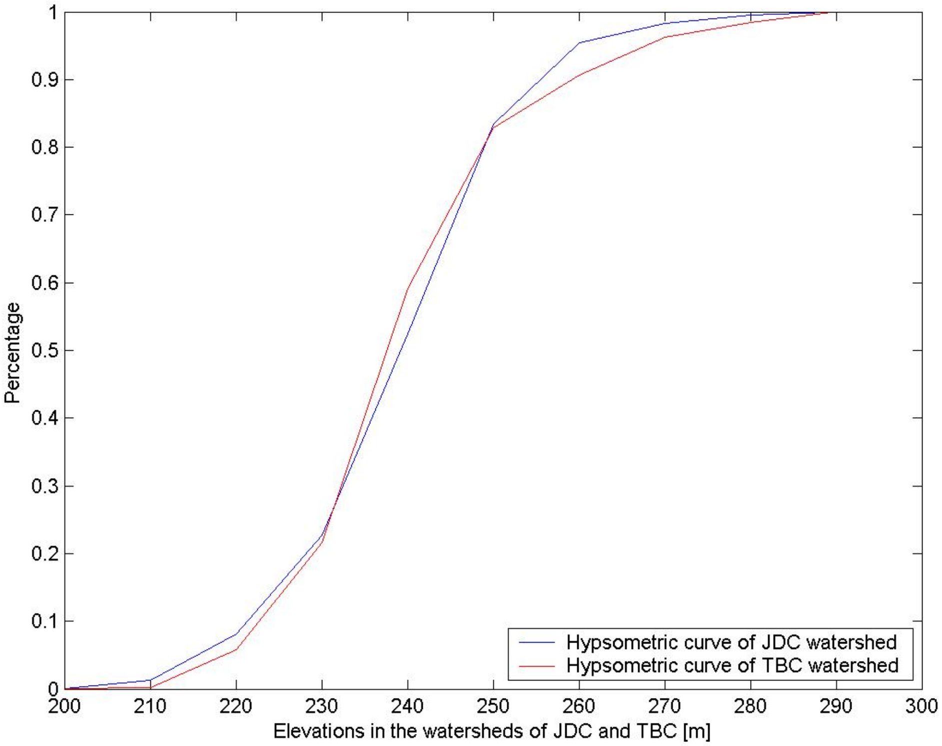
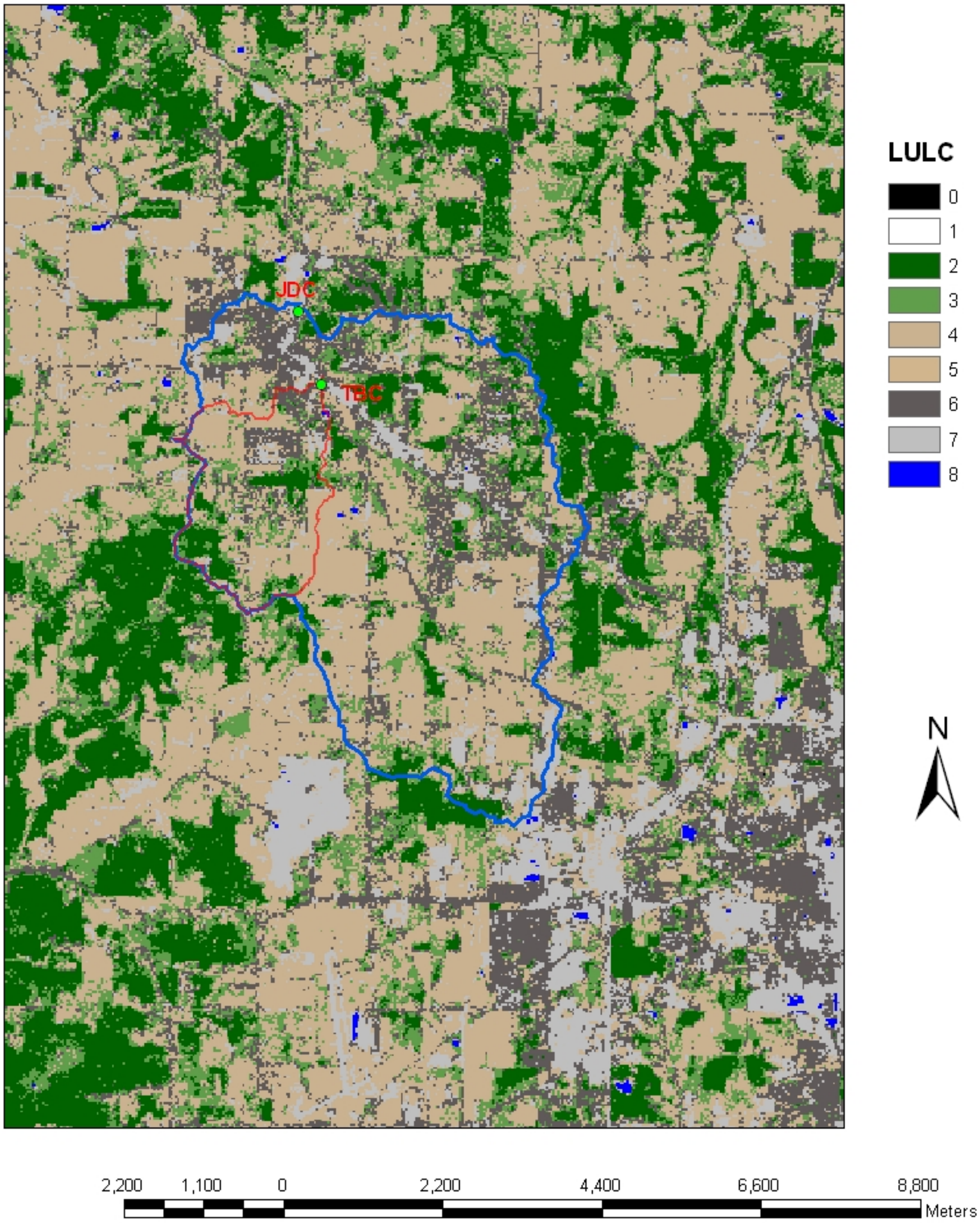


Figure 5: Probable land use land cover in the area based on the 1997 Indiana Land Use Land Cover (LULC) map. 2: Tree; 3-5: Grass/Agriculture/Soil 6-7: Built 8: water



Information Transfer Program

The IWRRC director has worked with state and federal environmental agencies, the governments of Indiana's cities and counties and key citizen groups on water education and water resources planning activities. In this way, the results from the research projects can be transferred to interested individuals in the state. The IWRRC director has participated in important national meetings related to water and environmental protection.

Our new website can be found at: www.iwrrc.org

Grant No. 05HQGR0177 Integrating ACOE Sediment Runoff Predictive Tool into DW-L-THIA System

Basic Information

Title:	Grant No. 05HQGR0177 Integrating ACOE Sediment Runoff Predictive Tool into DW-L-THIA System
Project Number:	2005IN209S
Start Date:	9/1/2005
End Date:	8/31/2006
Funding Source:	Supplemental
Congressional District:	4th
Research Category:	Water Quality
Focus Category:	Sediments, Water Quality, None
Descriptors:	
Principal Investigators:	Bernard Engel

Publication

Title: Sediment runoff predictive tool using the DW-L-THIA system

PROBLEM AND RESEARCH OBJECTIVES

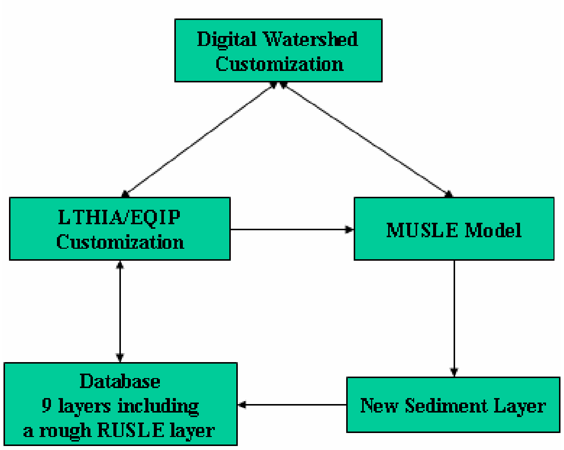
Sediment and nutrient loadings from nonpoint sources are major contributors to water pollution in the Great Lakes region and throughout the world. Sediment loadings cause two highly adverse economic impacts on our ecosystem: lost productivity from unnecessary erosion and the costs of dredging for navigational and environmental purposes. To control and reduce these loadings to our rivers, lakes, and streams, public agencies and private land owners need effective tools for targeting practices that reduce the volume of sediment leaving the land.

The goal of this effort is to create a tool for the Army Corps of Engineers (ACOE) Chicago District that integrates a GIS-based sediment runoff predictive tool into Digital Watershed (DW) and the Long-Term Hydrologic Impact Assessment (L-THIA) system and its associated tools so the resulting modeling and decision support tool can be easily accessed and used by a wide variety of expertise levels in determining the effects of development and different agricultural practices to the sediment loadings within two tributaries to Lake Michigan in Northwest Indiana; Burns Ditch/Little Calumet East Branch and Trail Creek in the first phase of the project. The tool could be generalized for other watersheds in the Great Lakes region in a second phase of the project so a broader user base can take advantage of the tools. This proposal is targeted towards the first phase of the project.

METHODOLOGY AND PRINCIPAL FINDINGS

The proposed work builds from a substantial base of web-based decision support tools that have been developed at Michigan State University and Purdue University. In this effort, we are to integrate the MUSLE model for two tributaries to Lake Michigan in Northwest Indiana (Burns Ditch/Little Calumet East Branch and Trail Creek) into the integrated Digital Watershed and L-THIA system (including SEDSPEC and watershed delineation tool) in the first phase of the project so end users can delineate watershed on the fly and run the model for different scenarios online in real time. The construction of the MUSLE model and its integration into the DW-L-THIA system will NOT be based on the existing ACOE SWAT modeling effort.

The following is the system diagram:



Principal tasks and findings:

- We conducted a regional meeting with NIRPC (Northern Indiana Regional Planning Commission) members and others identified by ACOE Chicago District. These will be the stakeholders of the project.
- We have successfully implemented interoperable linkage between the MSU Digital Watershed and Purdue EQIP system. The key finding is that only vector data in the form of ESRI shapefiles can be efficiently passing among the sites. With increasingly finer resolution raster data layers, hence data size, data transfer via HTTP is infeasible at this time. We also implemented dynamic data projection conversion in this effort.
- We have established a mechanism to obtain and share the K, L, S, C, and P raster layers for MUSLE equation calculation between the Purdue and MSU web sites. The runoff factor is to be calculated using the event runoff volume and peak runoff rate produced by the online SEDSPEC model on the Purdue site, and subsequently delivered to the MSU site for MUSLE calculation
- We are still firming up the strategy for representing erosion BMPs by modifying the C and P factors in the MUSLE equation.
- We are also mindful of the user friendliness of the web-GIS application and we will work with stakeholders to ensure of that with interactive help and interface modifications.

SIGNIFICANCE of the PROJECT

As a result of its diffuse and pervasive nature, reducing nonpoint source pollution requires the collaborative efforts of several federal agencies including the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Agriculture’s (USDA) Natural Resources Conservation Service (NRCS) in addition to the ACOE. According to the EPA, approximately 40% of water bodies in the U.S. fail to meet clean water standards. Consequently, the EPA is currently engaged in a process to establish total maximum daily loads (TMDLs) for sediment and nutrient loadings for these water bodies. Under the Clean Water Act Section 319 Nonpoint Source National Monitoring Program and wetland protection programs, the EPA funds and programs support efforts to reduce the negative impacts of runoff from agricultural, urban, and industrialized areas. Similarly, the NRCS has provided $51 million in federal funds to support agricultural best management practices (BMPs) this past year in the effort to reduce the movement of pollutants into our waterways.

The ACOE Great Lakes Tributary Modeling Program, under Section 516(e) of the Water Resources Development Act of 1996, is an important initiative which complements other programs designed to reduce sediment delivery to rivers and streams. This program has funded numerous modeling efforts intended to encourage watershed planning and other local actions to control sediment movement and impacts. However, to achieve optimal reduction of pollutant loadings in water quality-impaired watersheds and to maintain water quality in others, there is a need for easy-to-use tools that provide accurate assessment of best conservation practices applied at various sites in these watersheds. This project utilizes existing programming capabilities to build such easy-to-use tool for erosion potential evaluation. Significant developments include interoperability among separate Web sites hosting different computing resources, extensible application framework for future program and user base expansion.

STUDENTS

Currently, Dr. Tong Zhai (Post-Doc research assistant) with Purdue University, ABE Department is working on Purdue portion of the project involving the following activities:

- restructuring existing L-THIA and EQIP Web GIS interface and program elements to fit current project layout
- implementing interoperability between Purdue and MSU Web-GIS sites
- constructing new program components to allow users to change landuse and/or apply BMPs on the fly and deliver updated landuse and BMP boundaries to the MSU site for MUSLE calculation
- overall Web site design

A publication is being developed detailing the technical aspects of the system. Subsequent papers focusing on usability, validation, and other issues are also in the planning stage.

Core Outreach Program IWRRC

Basic Information

Title:	Core Outreach Program IWRRC
Project Number:	2005IN210B
Start Date:	3/1/2005
End Date:	2/30/2006
Funding Source:	104B
Congressional District:	
Research Category:	Water Quality
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	Ron F. Turco

Publication

IWRRC Administrative Outreach Program

The IWRRC has taken an aggressive approach to outreach efforts in the State of Indiana.

Projects and Meetings

1. Use of Long-Term Ecological Research for Enhancing Water Quality in the Great Lakes Region. Workshop and Field tour, September 2005. Co-sponsored with CEES, Indianapolis and USDA CSREES.
    a. Approximately 130 individuals from across the state and region attended the meeting and tour. We had nine presentations on Thursday and five tour stops on Friday. The presentations highlighted the interface that exists between the rural and urban environments and the types of data that needs to be collected in order to understand the impacts of each. Our meeting was started by our keynote speaker (Andy Miller) from the Baltimore LTER who provided a new number of new ideas about how study these interface areas. The subsequent field tour highlighted efforts in the Indianapolis area looking at similar urban-rural interfaces.
    b. The meeting was also a watermark event in that we demonstrated the how we could put together a very success event with outstanding attendance and interaction. The field tour was well received.
    c. Fallout from the meeting continues to be realized. We developed a working group that led development of proposal submitted to the Conservation Effects Assessment Program (CEAP) of the USDA (see below).
    d. The meeting highlighted the need for the IWRRC to select a targeted region of the state in which to work. As result, the IWRRC director worked with a group at Purdue to submit a proposal to Purdue's Center for the Environment (C4E) to support a seed project entitled "Living Laboratories on the Wabash (LLOW)" see below for details. The effort has focused IWRRC attention on the Wabash River and led to a relationship between IWRRC, Purdue's Center for the Environment (C4E) and Wabash River Enhancement Corporation (WERC). Our working title for the effort is "Improving the Health of the Wabash"
    e. As part of the LLOW project we are hosting a series of workshops.

2. Meeting with the Lake LaSalle homeowners and water management group to help them establish priorities for improving the water quality in Lake LaSalle. Lake LaSalle is located south of Indianapolis and is representative of many of Indiana's small lakes.
3. Reoccurring meetings with staff at Indiana Save the Dunes. As part of wetlands enhancement program and pathogen tracking programs we are continuing to work with Save the Dunes. This interaction led to the development of a proposal with University of Toledo submitted to NOAA on pathogen tracking, water quality and wetlands.
4. Meeting with Purdue Pesticides Program Office. Working with Dr. Fred Whitford to establish an outreach effort center on water protection emphasizing pesticide management, rural water quality and protection. This relationship will be strengthened in the coming years.
5. Meetings with Dr. Brad Lee, Purdue's septic system expert. I am working on plan to elevate the role of the IWRRC in water protection as related to septic

systems management. Indiana, like most of the Midwest, is dependent on septic systems for waste handling. We are developing a program to better educate the professional installer. This relationship will be strengthened in the coming years.

6. Reoccurring meetings with Dr. Lenore Tedesco Director of IUPUI-Center for Earth and Environmental Sciences (CEES). These meetings led to the development of our first workshop, a proposal for submission to EPA and a strategy for working with the state's environmental programs.
7. Working with the Wabash River Enhancement Corporation (WERC) in developing a strategy for improving the Wabash River. This relationship now underpins our major effort in the state, the Health of the Wabash.

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	4	0	0	0	4
Masters	12	0	0	0	12
Ph.D.	0	0	0	0	0
Post-Doc.	0	0	0	0	0
Total	16	0	0	0	16

Notable Awards and Achievements

Publications from Prior Projects

1. 2003IN112B ("Soil and Mineralogical Processes Involved in Septic System Failure") - Articles in Refereed Scientific Journals - Brad D. Lee, Byron J. Jenkinson, James A. Doolittle, Richard S. Taylor, and J. Wes Tuttle. 2006. Electrical Conductivity of a Failed Septic System Soil Absorption Field. Vadose Zone J. 5: 757-763
2. 2005IN-ADMIN ("Program Administration Project") - Other Publications - Lee, B.D. 2006. Home and Environment WebSite for Septic Systems. http://www.ces.purdue.edu/HENV/SepticSystems.htm (Much of this work was supported by IWRRC)
3. 2003IN112B ("Soil and Mineralogical Processes Involved in Septic System Failure") - Conference Proceedings - Hart, K.S., B.D. Lee, P.J. Schoeneberger and D.P. Franzmeier. 2005. Hydraulic conductivity across a toposequence on the Wabash moraine, northeast Indiana. In Agronomy abstracts, ASA, Madison, WI. Krenz, J.L., B.D. Lee, D.G. Schulze, P.J. Schoeneberger, D.P. Franzmeier, S.K. Sears, and H. Vali. 2005. Illitic soil mineralogy: Bluffton Till Plain and associated moraines in northeast Indiana. In Agronomy abstracts, ASA, Madison, WI.
4. 2004IN160B ("Norms, public opinion, and preservation of non-charismatic aquatic and riparian species") - Conference Proceedings - Raymond, L. and Laura Schneider 2005. Who Wants to Save That? Legitimating Policies To Protect Non-Charismatic Species. Poster to be presented at the 2005 annual meeting of the American Political Science Association, September 2005, Washington D.C.
5. 2005IN169B ("Stormwater Guidance and Implementation in Indiana: Perspectives on the new Rule 13") - Dissertations - Karstedt, Wenke, 2005. A Comparison of Stormwater Management in the US and Germany. MS Dissertation Indiana University.