



ENVIRONMENTAL AND ECONOMIC RESEARCH AND DEVELOPMENT PROGRAM

Assessing Long-term Hydrological Impacts of Climate Change Across Wisconsin

Executive Summary
August 2012

PREPARED BY:

ADAM C. MEDNICK;
THERESA M. POSSLEY NELSON;
DREUX J. WATERMOLEN

THE RESEARCH WITHIN THIS STUDY WAS CONDUCTED IN COOPERATION WITH
AND PUBLISHED BY:

THE WISCONSIN DEPARTMENT OF NATURAL RESOURCES
BUREAU OF SCIENCE SERVICES
PO. BOX 7921
MADISON, WI 53707-7921



focus on energysm

Partnering with Wisconsin utilities



The Wisconsin Department of Natural Resources provides equal opportunity in its employment, programs, services, and functions under an Affirmative Action Plan. If you have any questions regarding this plan, please write to Equal Opportunity Office, Department of Interior, Washington, D.C. 20240.

This publication is available in alternative format (large print, Braille, audio tape, etc.) upon request. Please call (608) 266-0531 for more information.

Executive Summary

Report Date: July 31, 2011

Project Title: “Assessing Long-Term Hydrologic Impacts of Climate Change across Wisconsin”

Investigators: Adam C. Mednick, Theresa M. Possley Nelson, PE, and Dreux J. Watermolen

Institution: Bureau of Science Services, Wisconsin Department of Natural Resources

Research

Category: Environmental and Economic Impacts of Climate Change in Wisconsin Potentially Attributable to Electric or Natural Gas Use

Project

Period: January 1, 2010 – May 31, 2011

The object of this study was to generate statewide, high-resolution estimates of historical and projected-future changes in direct runoff and non-point source (NPS) water pollution under alternative climate and land-use scenarios. This type of information can help inform the development and refinement of climate adaptation strategies, as part of the Wisconsin Initiative on Climate Change Impacts (WICCI), as well as local and regional planning efforts. Decision-makers, planners, and the public have lacked geographically detailed information on the relative magnitude of changes in runoff and NPS pollution that have occurred in the recent past, as well as those that are projected to occur in the future under different climate and land-use scenarios.

Working with collaborators at Purdue University, we developed a customized version of the long-term hydrologic impact assessment (L-THIA) modeling system, capable of estimating runoff and NPS loadings using high-resolution precipitation projections from “downscaled” general circulation models (GCMs), generated for WICCI by researchers at the University of Wisconsin. The initial intent was to develop an L-THIA 3.0 extension to the Environmental System Research Institute’s *ArcGIS* software package; however, data processing limitations within *ArcGIS* required us to develop a series of separate model routines using the Python programming language. Model parameters were calibrated using streamflow data from six gauged watersheds. Default event-mean concentration (EMC) coefficients were substituted with more regionally appropriate values.

Once completed, the customized L-THIA modeling system was run to predict average growing season runoff and NPS pollutant loadings for five successive decades: 1957-1966, 1967-1976, 1977-1986, 1987-1996, and 1997-2006. In addition, we modeled average runoff and NPS pollutant loadings for the future period of 2046-2055, under 18 combined land-use and climate scenarios. Climate scenarios included the Intergovernmental Panel on Climate Change’s “B1,” “A1B,” and “A2” scenarios, representing best-, middle-, and worst-case scenarios, respectively. Land-use scenarios include no change, the reversion of Conservation Reserve Program (CRP) lands to cropland, the maintenance of CRP/adoption of additional conservation practices, urban expansion, urban expansion with 25% adoption of low impact development (LID) practices, and urban expansion with 50% adoption of LID practices.

The results of the L-THIA model runs for the historic period indicate a distinct pattern of hydrologic change that has occurred over the past fifty years, with growing-season direct runoff increasing substantially in the southeastern, central, and west-central portions of the state, while decreasing across the northern region and much of the east-central and southwestern portions of the state. The results of model runs based on downscaled future GCMs indicate that while growing-season rainfall totals are projected to decrease by 3-5% between now and 2050, runoff totals are projected to increase by 20%, 27%, and 28%, respectively, under climate scenarios B1, A1B, and A2.

Model results also indicate that the spatial pattern of change varies considerably depending on the scale of analysis, with significant small-scale variation in runoff and NPS pollution projected at the sub-watershed and stream catchment scale. In some areas of the state, adaptation strategies based on alternative land-use and land management scenarios were shown to be capable of offsetting significant proportions of additional runoff and NPS pollution projected to occur under future climate scenarios, particularly in agricultural or urbanizing watersheds.

This study adds to our current understanding of the impacts of electricity and natural gas use in Wisconsin by illustrating historic and possible future hydrologic impacts of a changing regional climate at a spatial resolution previously unattainable. L-THIA model outputs include historical and projected-future average direct runoff and NPS loadings under alternative climate and land-use scenarios. These are contained in statewide data tables that can be linked to publically available geographic information system (GIS) files. Model outputs and associated GIS-based maps can be used by decision-makers, planners, and the public to help inform energy policy as well as adaptation planning at regional and local scales, and can be used to target areas for more detailed hydrologic analysis, such as future changes in the frequency and intensity of major flood events.

Future directions could include expanding the temporal window of analysis from the historical growing season to projected future growing seasons and beyond in order to account for late winter/early spring runoff, including snowmelt. Additional analyses could include modeling runoff and NPS pollutant loading based on the full range of downscaled GCMs, as well as modeling monthly runoff to evaluate seasonal changes. In addition, we could substitute statewide rainfall-runoff parameters and EMC coefficients with separate sets of regionally-optimized values, in order to better account for variation in watershed conditions. A key future direction would be the creation and dissemination of a publically available L-THIA 3.0 GIS software extension to automate more of the modeling process and enable regional and local adaptation planners to conduct these types of analyses themselves.

Disclaimer: Points of view expressed in this report do not necessarily reflect the views or policies of Focus on Energy. Mention of trade names and commercial products does not constitute endorsement of their use.

Table of Contents

Executive Summary	1
List of Tables	4
List of Figures	5
Abbreviations and Acronyms	6
Introduction	7
Current Literature	9
Methods	11
Input Data	12
Customized L-THIA Modeling System	15
Model Scenarios	20
Findings	24
Discussion and User Considerations	32
Conclusions	33
Sources Cited	35
Acknowledgments	38

List of Tables

1. Previous Long-term Hydrologic Impact Studies	10
2. Final Calibration Curve Numbers	17
3. Monthly Runoff Calibration/Validation Results	19
4. Event-Mean Concentration (EMC) Coefficients	19
5. L-THIA Model Runs by Land-use and Climate Scenario	20
6. Low Impact Development Practices Simulated in Scenarios 5 and 6	23
7. Direct Runoff Volume by Basin, Assuming No Land-use Change	26
8. Non-Point Loadings of Selected Pollutants by Basin, Assuming No Land-use Change and an “A1B” Future Climate	28
9. Direct Runoff Volume by Basin, under Alternative Land-use Scenarios and an “A1B” Future Climate	30

List of Figures

1. Conceptual Model of Climate and Land-use Related Impacts	7
2. Global vs. Downscaled Model Resolutions, and Climate Stations	8
3. Rainfall-Runoff Curve Numbers	12
4. L-THIA Model Inputs	13
5. Customized L-THIA Modeling System Showing Input Data	15
6. Runoff Calibration Watersheds	16
7. L-THIA Direct Runoff vs. USGS Total Runoff, 1951-1980 Average	18
8. Average Inches of Rainfall per Growing Season (May through September)	21
9. Land Transformation Model (LTM), East-Central Wisconsin	22
10. Historic Changes (ca. 2000–ca. 1960) in Growing-Season Rainfall and Estimated Direct Runoff	24
11. Primary Drainage Basins in Wisconsin. Highlighted Basins are Projected to Experience >50% Increase in Growing Season Runoff by ca. 2050	25
12. Projected Future Changes (ca. 2050–ca. 2000) in Direct Runoff Volume at Different Hydrologic Scales, Assuming “A1B” Climate and No Land-use Change	27
13. Projected Changes (ca. 2050–ca. 2000) in Selected Pollutant Loadings, Assuming “A1B” Climate and No Land-use Change	29
14. Projected Changes (ca. 2050–ca. 2000) in Direct Runoff Depth in Inches, Assuming “A1B” Climate, under Alternative Land-use Scenarios	31

Abbreviations and Acronyms

avg. – average

CN – curve number

CRP – Conservation Reserve Program

EMC – event-mean concentration

ESRI – Environmental System Research Institute

ft³/acre – cubic feet per acre

GCMs – general circulation models

GIS – geographic information system

HSG – hydrologic soil group

HUC – hydrologic unit code

lbs/acre – pounds per acre

LID – low impact development

L-THIA – Long-term Hydrological Impact Assessment modeling system

LTM – Land Transformation Model

m – meter

mg/L – milligrams per liter

ml – milliliter

NLCD – National Land Cover Data

NPS – non-point source

NRCS – Natural Resources Conservation Service

SCS – Soil Conservation Service

SSURGO – Soil Survey Geographic data

STATSGO – State Soil Geographic data

SWAT – Soil and Water Assessment Tool

TR-55 – *Technical Release 55* (USDA SCS 1986)

µg/L – micrograms per liter

USDA – United State Department of Agriculture

USGS – United States Geological Survey

VIC – Variable Infiltration Capacity model

WICCI – Wisconsin Initiative on Climate Change Impacts

WISCLAND - Wisconsin Initiative for Statewide Cooperation on Landscape Analysis and Data

Acknowledgments

We thank Bernie Engel and Larry Theller, Purdue University, and Kyoung Jae Lim, Kangwon National University, South Korea, for their assistance in developing the modified L-THIA model. Andy Kalcic, Purdue University, developed the Python script. James Hunter, Morgan State University, provided assistance with L-THIA LID. Bryan Pijanowski, Purdue University, provided land use/cover data from the LTM. We thank Daniel Vimont, Chris Kucharik, Shawn Serbin, Michael Notaro, and David Lorenz, all from the University of Wisconsin-Madison, for sharing the WICCI climate data and helping us understand the appropriate use of those data. Tim Whiteaker, University of Texas at Austin, helped us understand ArcGIS's NetCDF limitations. Jerry Sullivan and Kim Ness, Wisconsin DNR, assisted our GIS analyses in numerous ways.