

**THE EFFECTS OF URBANIZATION ON
BAIRD CREEK,
GREEN BAY, WISCONSIN**

by

Jessie C. Fink

A thesis submitted in partial fulfillment of
the requirements for the Degree of

**MASTER OF SCIENCE
in
ENVIRONMENTAL SCIENCE AND POLICY**

University of Wisconsin-Green Bay

May, 2005

Approved:

Major Professor

Dean of Graduate Studies

Committee Members:

Tara Reed

Patricia Terry

ACKNOWLEDGEMENTS

This project would not have been possible without the assistance of many individuals who donated their time and expertise. First, I would like to extend my deepest appreciation and admiration to Dr. Kevin Fermanich for his effort, guidance, and understanding. His wisdom and timely encouragement were key to the successful completion of this thesis. I would also like to thank Dr. Patricia Terry and Dr. Tara Reed for their valuable insight and support through the document preparation phase.

I also wish to extend my sincere appreciation to Dr. Tim Ehlinger for advice on research approach and for assistance with installation and operation of the sonde equipment. Also, this project relied on the work of the laboratory technicians at UW-Milwaukee, especially Lori Schacht DeThorne, Jen Grzesik, and Mary Clifford.

I am also grateful to Paul Baumgart for his expertise in water sampling, analyzing data, and GIS manipulation. Many thanks are also owed to Amanda Bowman for guiding me through the convoluted maze of GIS projections and preventing me from throwing my computer out the window on numerous occasions. Jon Habeck and Jon Motquin also deserve credit for sampling assistance. Others who contributed to the successful completion of this project include Dave Graczyk, Dale Robertson, Paul Reneau and Troy Rutter of the U.S. Geological Survey and the laboratory staff at the Green Bay Metropolitan Sewerage District. I would also like to recognize the generosity of Arjo Wiggins Appleton, Ltd., who provided funding for this project.

My most sincere thanks are extended to the City of Green Bay Parks, Recreation, and Forestry Department for permitting access to Baird Creek and the installation of my sampling equipment. I also wish to express my appreciation for the data assistance provided by the City of Green Bay Public Works Department, Applied Ecological Services, the Baird Creek Preservation Foundation, the Village of Howard Public Works Department, and the Brown County Planning Department.

Last but not least, I would like to thank my family and friends for their support. A very special thanks goes to Cathy Davis who made me go to aerobics, joined with me in “mental health” breaks, and even (on a cold, wet December day) helped take streamflow measurements. Finally, I wish to express my deepest gratitude to my husband Eric. He supported my decision to pursue this degree, helped carry water samples in the rain on numerous occasions, and endured listening to all my frustrations. Without his patient support, none of this would have been possible.

ABSTRACT

THE EFFECTS OF URBANIZATION ON BAIRD CREEK, GREEN BAY, WISCONSIN

Jessie C. Fink

The Baird Creek watershed in Green Bay, Wisconsin, is rapidly changing from agricultural to urban land use between Northview Road and Interstate 43. To assess how urbanization is impacting the aquatic ecosystem of Baird Creek and to assist the City of Green Bay and the Baird Creek Preservation Foundation in making informed land management decisions within the watershed, this project established the following research questions: (1) Do differences exist in the water quality of the agricultural and urbanizing tributaries of Baird Creek? (2) Has the channel morphology of Baird Creek and its tributaries changed in response to hydrologic alterations in the urbanizing watershed? (3) Is the L-THIA watershed development assessment tool a viable model for assessing the impact of future development in the Baird Creek watershed?

Land use, percent impervious cover, and current construction activity were first assessed for the subwatersheds of Baird Creek. Storm event and low-flow sampling was conducted from April to December 2004 at three locations on Baird Creek: an agricultural tributary, a tributary transitioning to urban land use, and the main channel downstream of the confluence. Water samples were analyzed for total suspended solids (TSS), total phosphorus, and total dissolved phosphorus. Continuous temperature, pH, dissolved oxygen, turbidity, conductance, and depth data were recorded at each location. A relationship was established between turbidity measurements and TSS concentrations, which were used as a surrogate for sediment. Changes in channel morphology were assessed at twelve sites previously measured in 2002. Finally, data from water quality sampling and projected future land use was used to evaluate the L-THIA watershed assessment model as a tool to predict changes in pollutant export due to development.

Overall, the study found that urbanization is adversely impacting Baird Creek. Statistical analysis showed that event concentrations of sediment and total phosphorus were significantly higher on the urbanizing tributary than the agricultural branch. Also, although the urbanizing portion of the watershed comprised only 18.5% of the total land area, it contributed 60-70% of the total sediment load during a period of summer storm events. The channel morphology assessment showed that the cross-sectional area and bankfull width of sites located on urbanizing tributaries increased dramatically between the 2002 and 2004 surveys, but fewer impacts were seen at the sites downstream on the main channel. Finally, an evaluation of the L-THIA model as a potential development assessment tool indicated that care must be taken to fully understand the hydrological processes being modeled in order to avoid underestimating impacts of development.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS.....	ii
ABSTRACT.....	iii
TABLE OF CONTENTS	iv
LIST OF TABLES.....	vii
LIST OF FIGURES.....	ix
LIST OF PLATES	xi
LIST OF ACRONYMS	xii
CHAPTER 1 – INTRODUCTION.....	1
Project Background	1
Overview of the Baird Creek Watershed.....	2
Existing and Future Land Use	3
The Baird Creek Greenway: A Unique Environmental Resource.....	4
Literature Review	6
Impervious Cover	8
Drainage Density and Channel Structure.....	10
Sediment Loads in Urban Watersheds.....	12
Research Overview.....	14
Problem Statement.....	15
Study Limitations	16
Organization of this Document	16
CHAPTER 2 – CHARACTERIZING LAND USE DYNAMICS.....	18
Introduction.....	18
Methodology	20
Establishing Watershed Boundaries	20
Changes in Land Use	21
Estimating Impervious Surface Coverage.....	26
Results and Discussion	28
Conclusions	40
CHAPTER 3 – WATER QUALITY	43
Introduction.....	43
Historical Trends in Sediment and Phosphorus Loads	44
Research Objectives.....	45
Methodology	46
Water Quality	47
Water Quantity	51
Sediment and Phosphorus Load Calculation.....	52
Statistical Analysis	53

Results and Discussion	54
Precipitation	55
Discharge	57
Sediment and Phosphorus Concentrations	62
Load Comparisons	67
Conclusions	71
Connection to In-stream Biota Populations	72
Implications for Land Use Management.....	74
Study Limitations and Opportunities for Future Research	75
CHAPTER 4 – ESTABLISHING A RELATIONSHIP BETWEEN SEDIMENT CONCENTRATIONS AND TURBIDITY	76
Introduction.....	76
Benefits and Limitations of Using Turbidity to Predict Sediment Loads.....	77
Research Objectives.....	78
Methodology	79
Results and Discussion	80
Establishing Sediment-Turbidity Relationships for the Sampling Locations ..	80
Determining the Effect of Streamflow on Sediment-Turbidity Relationships..	84
Comparing TSS-Turbidity Relationships between Sites	84
Comparing Sediment Loads for Turbidity-Derived Predictions to Traditional Methods	85
Conclusions	87
CHAPTER 5 – CHANNEL MORPHOLOGY	90
Introduction.....	90
Research Objective	92
Methodology	92
Channel Measurement	92
Analyzing Changes in Channel Morphology.....	94
Results and Discussion	96
Changes in Bankfull Width Measurements.....	96
Channel Area Enlargement between 2002 and 2004.....	98
Conclusions	101
Implications for Future Management	103
CHAPTER 6 – PRELIMINARY EVALUATION OF A WATERSHED DEVELOPMENT ASSESSMENT TOOL	105
Introduction.....	105
Research Objective	106
Methodology	107
Results and Discussion	109
Conclusions	112
CHAPTER 7– PROJECT SUMMARY	114
Summation of Results.....	115
Land Use Change and Impervious Cover	115
Water Quality	116

The Relationship between Sediment Concentration and Turbidity.....	118
Channel Morphology	119
Preliminary Evaluation of the L-THIA Watershed Development Assessment Tool	121
Implications for Future Land Management	122
Opportunities for Further Research.....	125
REFERENCES	128
APPENDIX A: DETAILED PROCEDURES.....	134
A.1. Procedure for Splitting Samples	134
A.2. Procedure for Suspended Sediment Concentration (SSC)	134
APPENDIX B: WATER SAMPLE RESULTS	136
B.1. Event Samples Collected at the USGS Station Site.....	136
B.2. Low-flow Samples Collected at the USGS Station Site	137
B.3. Event Samples Collected at the North Branch Site.....	137
B.3. Event Samples Collected at the North Branch Site.....	138
B.4. Low-flow Samples Collected at the North Branch Site	139
B.5. Event Samples Collected at the South Branch Site.....	139
B.5. Event Samples Collected at the South Branch Site.....	140
B.6. Low-flow Samples Collected at the South Branch Site	141
APPENDIX C: CHANNEL MORPHOLOGY DATA SHEETS	142

LIST OF TABLES

Table 1.1.	Sources of Nonpoint Pollution from Urban Residential and Commercial Areas	7
Table 1.2.	Average percentage of impervious cover for various land uses	10
Table 2.1.	Assumptions of typical road coverage by land use type	26
Table 2.2.	Percentage of impervious surface by land use category for the Green Bay Region, Village of Howard,	27
Table 2.3.	Percentage of watershed land use for the Baird Creek USGS Station site in 2000, 2003, 2004, 2005, and projected 2022	32
Table 2.4.	Percentage of watershed land use for the North Branch of Baird Creek in 2000, 2003, 2004, 2005, and projected 2022	33
Table 2.5.	Percentage of watershed land use for the South Branch of Baird Creek in 2000, 2003, 2004, 2005, and projected 2022	34
Table 2.6.	Percentage of watershed land use for the main channel of Baird Creek below the confluence of the North and South Branches in 2000, 2003, 2004, 2005, and projected 2022	35
Table 2.7.	Percentage of watershed land use for the Christa McAuliffe Park Ravine in 2000, 2003, 2004, 2005, and projected 2022	36
Table 2.8.	Percentage of watershed land use for the Huron-Sitka Detention Basin Ravine in 2000, 2003, 2004, 2005, and projected 2022	37
Table 2.9.	Percentage of each watershed under active construction, 2000-2005	39
Table 2.10.	Estimated percentage of impervious cover in each subwatershed of Baird Creek	39
Table 3.1.	Summary statistics from the WDNR Baird Creek Watershed Management Study, 2001-2002	45
Table 3.2.	Summary of precipitation events and sites collecting samples over the study period	54

Table 3.3.	Summary of precipitation events, event and low-flow samples, and sample analysis for each Baird Creek sampling site, 2004	56
Table 3.4.	Summary of 2004 monthly precipitation	57
Table 3.5.	Total precipitation depths and intensities observed for sampled runoff events	58
Table 3.6.	Descriptive statistics for event and low-flow sediment and phosphorus samples	63
Table 3.7.	Results from statistical analyses of concentration data	65
Table 3.8.	Mean daily discharge and turbidity-derived suspended sediment and total phosphorus loads for the USGS Station and North Branch sites, 9 – 20 June, 2004	68
Table 3.9.	Fish species collected on Baird Creek as a percentage of total abundance. Sampling conducted by St. Norbert College in 1998 – 1999 and by UW-Milwaukee in 2003 – 2004	73
Table 4.1.	Mean daily discharge and sediment loads predicted by turbidity and USGS GCLAS software for the USGS Station site, 9 – 20 June, 2004	85
Table 5.1.	Bankfull width at channel morphology assessment sites listed by category	98
Table 5.2.	Bankfull channel area at morphology assessment sites listed by category	99
Table 6.1.	Conversion of detailed land use categories from Chapter 2 into land uses recognized by the L-THIA model	109
Table 6.2.	Water Year 2004 observations for runoff, phosphorus, and suspended solids at the USGS Station at Superior Road, SWAT model predictions for 2000 land use, and L-THIA predictions for 2004 and 2022 land use	110
Table C.1.	Bankfull width, bankfull depth, and channel area measurements recorded during the 2002 and 2004 morphology assessments	143

LIST OF FIGURES

Figure 1.1.	Location of Baird Creek in Brown County, Wisconsin	2
Figure 1.2.	Sediment load visible at the confluence of the South and North Branches of Baird Creek, March 2004	5
Figure 1.3.	Generalized flow and water quality hydrograph for urban precipitation events	11
Figure 3.1.	Locations of low-flow and storm event sampling sites on the North Branch, South Branch, and main channel of Baird Creek	47
Figure 3.2.	ISCO Model 1392 Wastewater Sampler and view of the North Branch sampling site showing sampler and staff gage	48
Figure 3.3.	YSI 6200 multi-parameter sonde	48
Figure 3.4.	Automated USGS monitoring station with ISCO 3700R sampler, gas bubbler, and data logger	48
Figure 3.5.	Diagram of the equal width increment (EWI) sampling method	49
Figure 3.6.	Continuous discharge and discrete sample collection points for the USGS Station site, 14 May to 25 June, 2004	58
Figure 3.7.	Continuous discharge and discrete sample collection points for the North Branch site, 8 June to 20 June, 2004	61
Figure 3.8.	Continuous discharge and discrete sample collection points for the South Branch site, 8 June to 20 June, 2004.....	61
Figure 3.9.	Boxplots showing upper limit, 75th quartile, median, 25th quartile, and lower limit values for (a) event TSS concentrations, (b) low-flow TSS concentrations, (c) event total phosphorus concentrations, (d) low-flow total phosphorus concentrations, (e) event dissolved phosphorus fraction, and (f) low-flow dissolved phosphorus fraction	64
Figure 4.1.	Discharge, sediment sample concentrations, and turbidity data for the USGS Station site, 14 May – 25 June, 2004	80
Figure 4.2.	Relationship between sediment concentrations and turbidity at the USGS Station site, April – October 2004	81

Figure 4.3.	Discharge, sediment sample concentrations, and turbidity data for the North Branch site, 8 – 20 June, 2004	82
Figure 4.4.	Relationship between sediment concentrations and turbidity at the North Branch site, June – October 2004	83
Figure 4.5.	Comparison of turbidity-predicted and GCLAS estimated sediment concentrations for the USGS Station Site, 8 – 20 June, 2004: (a) discharge, sediment samples, turbidity-predicted continuous sediment concentrations, and turbidity data, (b) discharge, sediment samples, and GCLAS estimated continuous sediment concentrations, and (c) hourly and cumulative precipitation data	86
Figure 5.1.	Locations of 2002 and 2004 channel morphology sampling sites on Baird Creek and its tributaries	93
Figure 5.2.	Typical measurements located horizontally and vertically in relation to the stringline at each channel morphology assessment site	94
Figure 5.3.	Bankfull width, bankfull depth, and channel area measurements recorded during the 2002 and 2004 morphology assessments	97
Figure 5.4.	Percent change in bankfull width at the morphology assessment sites between 2002 and 2004	100
Figure 5.5.	Percent of channel enlargement at the morphology assessment sites between 2002 and 2004	100
Figure 5.6.	Photo of the wetland complex upstream of Site 2 on the Christa McAuliffe Park Ravine	102

LIST OF PLATES

Plate 2.1.	Comparison of City of Green Bay versus Brown County Planning watershed boundaries for Baird Creek	22
Plate 2.2.	Baird Creek watershed boundary, 2000	23
Plate 2.3.	Baird Creek watershed boundary, 2004	24
Plate 2.4.	Baird Creek watershed land use, 2000	29
Plate 2.5.	Baird Creek watershed land use, May 2004	30
Plate 2.6.	Baird Creek proposed watershed land use, Green Bay Smart Growth 2022 Plan	31
Plate 6.1.	Hydrologic soils groups for the Baird Creek watershed land use	108

LIST OF ACRONYMS

AES – Applied Ecological Services, Inc.
BCPF – Baird Creek Preservation Foundation
BLRPC – Bay Lakes Regional Planning Commission
BMP – Best Management Practice
CAD – Computer-Assisted Drafting
EPA – U.S. Environmental Protection Agency
ESA – Environmentally Sensitive Area
EWI – Equal Width Increment Sampling Method
GCLAS – Graphical Constituent Loading Analysis System Software
GIS – Geographical Information System
GPS – Global Positioning System
IBI – Index of Biological Integrity (Fish)
LFRWMP – Lower Fox River Watershed Monitoring Program
L-THIA – Long-Term Hydrological Impact Assessment Model
NURP – National Urban Runoff Program
SAS – Statistical Analysis Software (SAS Institute Inc. 2003)
SSC – Suspended Sediment Concentration
SWAT – Soil & Water Assessment Tool
TSS – Total Suspended Solids
USGS – U.S. Geological Survey
UWGB – University of Wisconsin – Green Bay
UWM – University of Wisconsin – Milwaukee
WDNR – Wisconsin Department of Natural Resources
WY 2004 – Water Year 2004 (1 October 2003 – 30 September 2004)