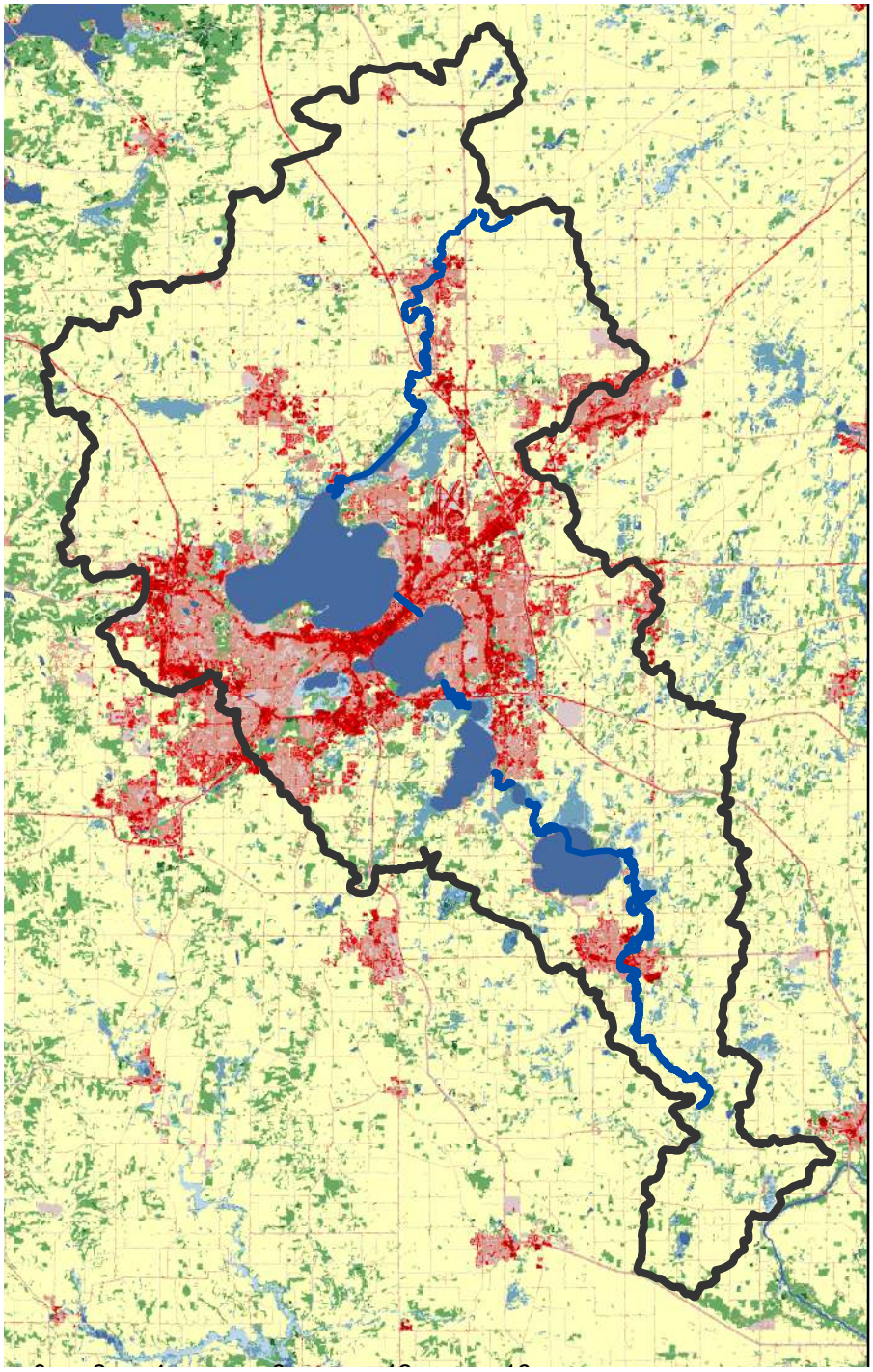
Yahara Canopy Project:
An Urban Watershed Forestry Analysis



Prepared by: The Urban Tree Alliance, 2016

These models were prepared with partial funding from the Wisconsin Department of Natural Resources Urban Forestry Grant Program as authorized under s. 23.097, Wis. Stat.

Table of Contents

I. Introduction

Trees live and grow in watersheds. The trees that we are most interested in here are further distinguished because they grow in cities; they are urban trees living and growing and affecting urban watersheds. Through the Yahara Canopy Project, we've tried to analyze the ways in which the urban tree canopy in the Madison metropolitan region affects water quantity and quality in the Yahara River watershed and, more specifically, in the urbanized subwatersheds. The dynamics are complex and involve the interplay of regional hydrological and aboricultural systems at a variety of scales, one nested into another. The shape, size and quality of the urban tree canopy influences the quality and quantity of water as it moves across the complex assemblages of gutters, roads, pipes, swales, and catchments common. But how can we characterize, demonstrate, and analyze this relationship?

To address this question, we have primarily relied on I-Tree Hydro, a modeling software designed to simulate the effects of changes in urban tree cover and impervious surfaces on the hydrological cycle. But we have also made use of the myriad professional and organizational resources around Madison, WI and within the Yahara River watershed. Madison's identity and geography are tied to a string of lakes running north to south; the Yahara River runs through each. As this project progressed we consulted researchers from the USGS and University of Wisconsin, professional water quality experts in the state, county, and municipal governments, and not-for-profit advocates working toward improved hydrologic conditions. Likewise, we've reached out to their organizational counterparts in the urban forestry profession. In both explicit and implicit ways, these relationships shaped the scope and direction of this work. In this sense, we have embarked on this study by willfully including the ideas of diverse people, in addition to data gleaned from sources like digital elevation models, stream gauge data, and urban forest canopy surveys. What we offer here is a kind of citizen science wrought with reproducible data and tempered with a consideration local knowledge.

In more concrete terms, our purpose for the Yahara Canopy Project is three-fold:

1) It is a case study for applications of I-Tree Hydro. We have run nearly a dozen I-Tree Hydro models in scales that range from the entire Yahara River watershed, major subwatersheds there-in, and an isolated stormwater catchment. We hope this process and the data produced can contribute to the urban forestry profession's understanding of the software itself and it's potential practical applications.

2) It is a process by which we can offer hydrological and forestry data to local governmental and non-governmental agencies working in the Yahara watershed. At the least, this project has produced a portrait of the existing urban forest conditions within the Yahara watershed that can help visualize and interpret environmental values and relationships. Interested citizens or professionals can apply this data portrait for their owns purposes, hopefully in ways that we do not yet foresee.

3) It is an effort by the Urban Tree Alliance, a Madison-based not-for-profit, to extend the tenets of urban forestry, and our organization, to the local watershed community.

There is an ecological interdependence between our trees and water that is not so clearly reflected in our organizations. The Yahara Canopy Project attempts to establish a substantive basis from which an integrated urban watershed forestry approach can be established.

What follows is primarily a presentation and discussion of maps and I-Tree Hydro model outcomes for the Yahara River watershed, the regional Madison metropolitan area (aka the "urbanshed), urbanized subwatersheds, and an isolated stormwater catchment. Explanations of the methodology and data used for models are also included. Most of that we have "discovered" through this work leads to intriguing complications.

Urban Watershed Forestry

For several decades, there has been a concerted effort to merge the work of urban forest and water managers into an interdisciplinary endeavor broadly called urban watershed forestry. In the most general sense this emerging relationship has been formed with the expectation that the presence of tree canopy has beneficial effects on water quantity and quality, i.e. tree canopies reduce water flow and pollutants. One definition describes urban watershed forestry as "the use of forests and the practice of forestry to protect, restore, and sustain water quality, waterflows, and health and function of the watershed." Much of the research and policy within the hybrid field has sought to understand the dynamics of the combined arboricultural and hydrological system. Increasingly, elements within this broad set of relationships have been singled out for increased study. The urban forests' effects on stormwater retention, nutrient recycling, soil erosion, and heath of aquatic systems in terms of phosphorous and sediment loads have all been examined and are still being elaborated.

Rising out of this intersection of fields is I-Tree Hydro, which is one of several free applications developed through I-Tree. I-Tree is a collective of governmental, academic, and private sector researchers that have developed, "tools to quantify ecosystem services and benefit values of community trees and forests at multiple scales." In particular, I-Tree Hydro is, "designed to simulate the effects of changes in urban tree cover and impervious surfaces on the hydrological cycle, including streamflow and water quality, for watershed and non-watershed areas." We've used this tool as the basis of our work. The details and methodologies of its application are included in subsequent discussions.

It is worth noting that even though the relationships between our urban canopy and watershed are under consideration here, trees are only an element in a myriad of factors determining the performance of urban watersheds. Typical and atypical weather patterns, impervious surfaces, stormwater management policies and infrastructure, snow and ice management strategies, leaf management strategies, agricultural production and run-off trends, construction processes, zoning and development policies, and community expectations are all integral to urban hydrological dynamics. It useful and interesting to ask what role out trees play in the matrix, but they are only a single factor that both influences and is influenced by nearly all the forces just mentioned. Furthermore, any one who has spent time trying to measure, or even count, trees will understand that we are

dealing with approximations. Our understanding of trees and water is based on experimentation with single trees. We have a good idea about how water much one tree can intercept and absorb, and an understanding how these rates change and the systems function. Yet, data and empirical processes that can reasonably describe trees collectively, as canopies, is not so easily collected or verified. It is a key finding of this study that even though, we can generalize the roles that trees play, we must also examine local urban factors beyond the canopy in order to better understand local environmental systems.

So, what are we to do? Foremost, we can ask intriguing questions about our trees and keep those questions open as science and practice evolve. This endeavor of urban watershed forestry will likely not lead to a lot of canopy level empirical results. But in way, that frees us to consider our trees in creative ways. Either way, it is too our benefit to err on the side of ambitious urban forestry projects that combine what we know about trees and what we can imagine about them. If urban watershed forestry can leverage interests in water into actions benefitting our urban forests, then we should follow those opportunities.

II. Methods & State, Regional, Municipal Contexts

The Yahara Canopy Project (YCP) began in 2015 on the banks of the Starweather Creek, where the Urban Tree Alliance coordinated planting 24 trees with the help of UTA volunteers and neighborhood residents. Through the project, the relationship between the trees and water was literally apparent. But the experience also made clear opportunities to combine the programmatic activities of groups seeking to affect change in water quality and quantity and healthy urban forests. In terms of both local governmental departments and not-for-profits, water and trees have been largely dealt with on separate tracks. Yet, water and trees are obviously interdependent and both are crucial factors in our urban system. The YCP set out with this mind; it attempted to bridge organizational boundaries and find out more about arboricultural and hydrological dynamics. It started with the question: how do trees affect local watersheds?

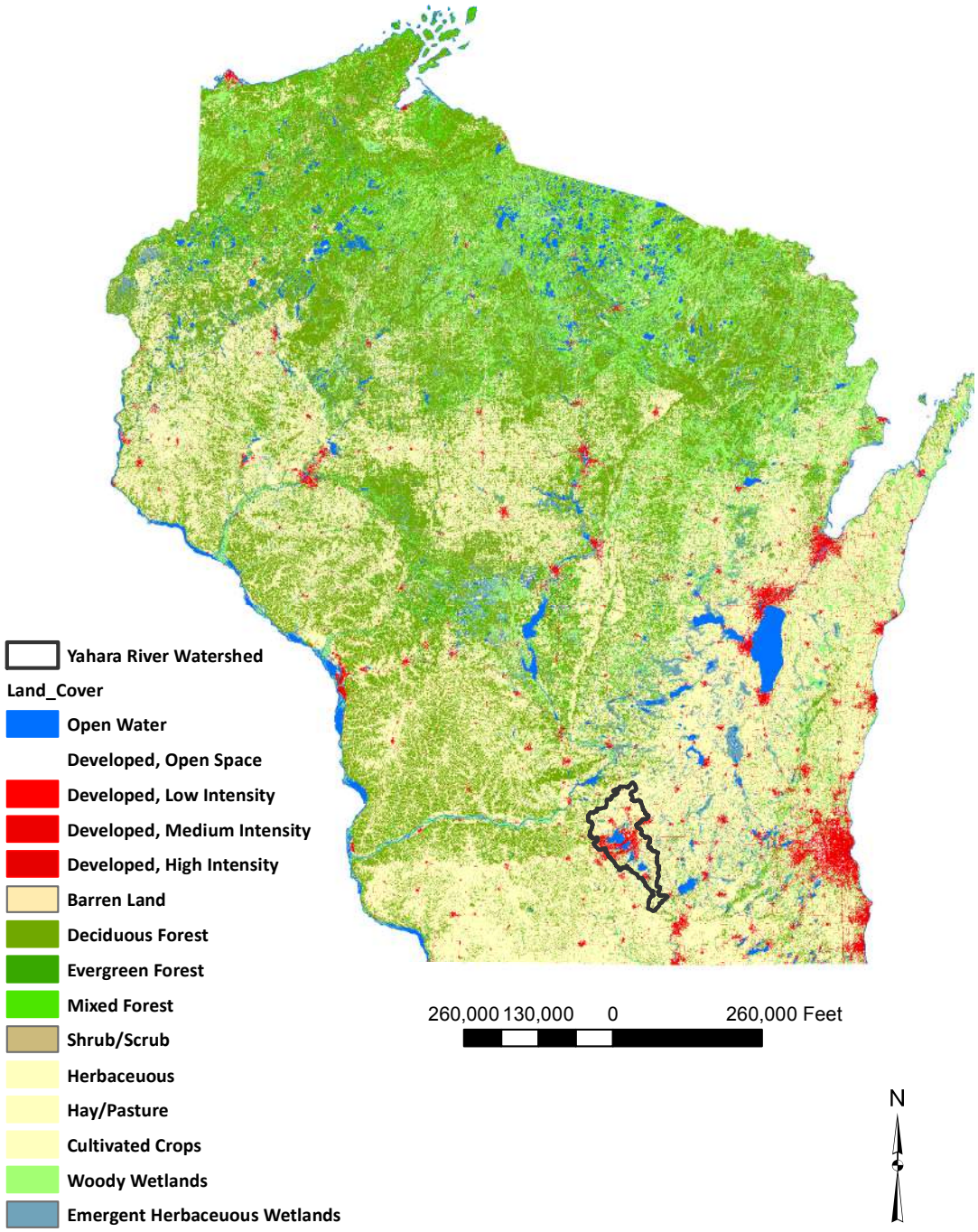
In the fall of 2015, UTA formally partnered with the Clean Lakes Alliance and received a grant though the Wiscosnin Department of Natural Resources Urban Forestry Grant Program undertake the YCP. In total, the YCP included volunteer tree-planting projects in Door Creek Park and Warner Park, outreach to local water-oriented groups, and the urban watershed analysis presented here.

Study Area

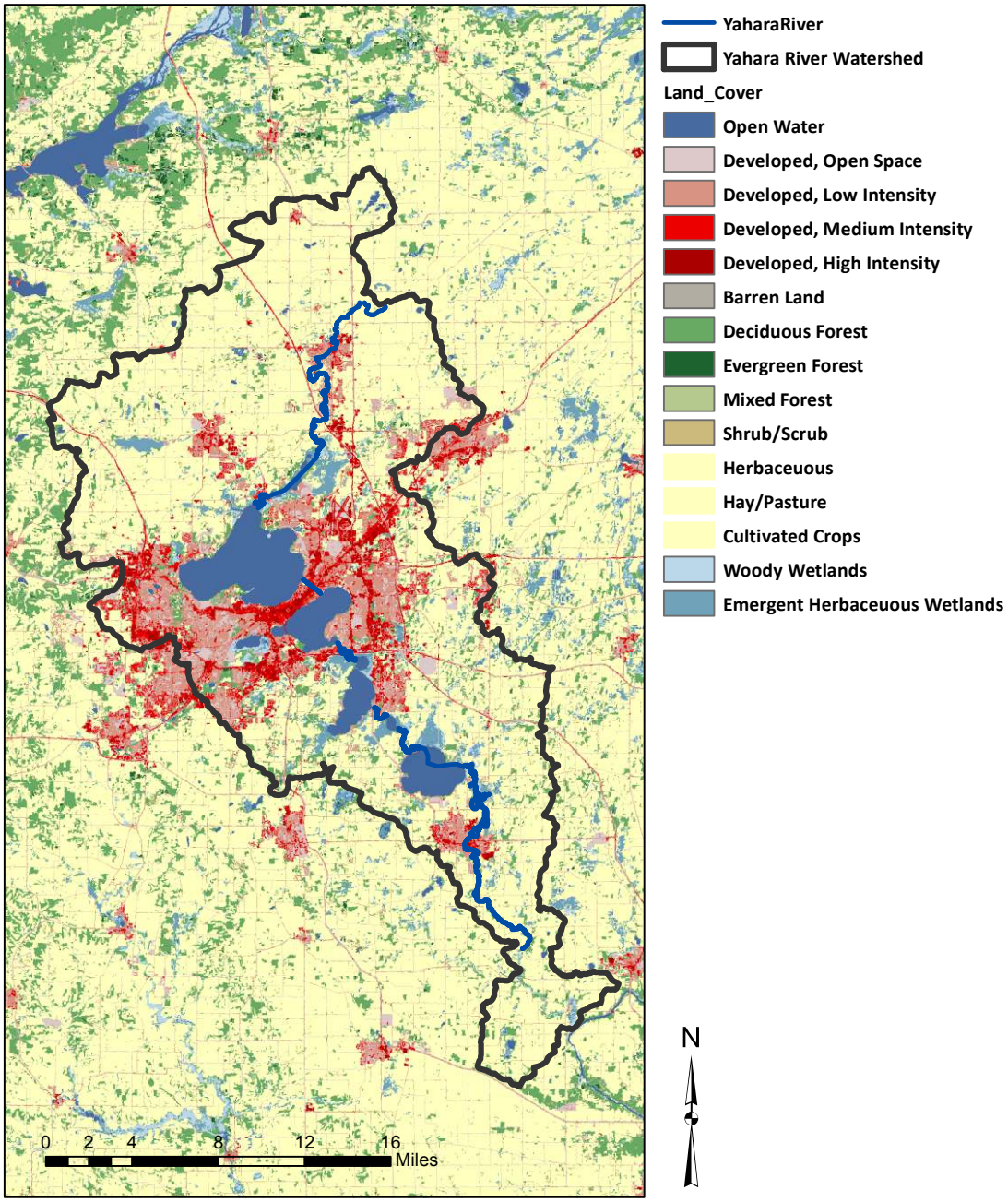
How far should the study boundaries extend? The I-Tree Hydro model was initially run for the entire Yahara watershed. This provided a useful grounding for the study, but the whole watershed includes lands beyond our primary interest in urban areas. The next phase of analysis focused more narrowly on the urbanized metropolitan area comprised of a largely contiguous area of combined city and village jurisdictional boundaries, which is called, here, the "urbanshed". However, the urbanshed is a largely arbitrary, political boundary that reflects development patterns but not necessarily natural features. In response we created an "urban watershed" boundary that combined major subwatersheds that were contained, in some part, within the urbanshed. A perimeter boundary was then delineated for this combined shape. The resulting urban watershed constituted a hydrological boundary that included all subwatersheds directly affecting urbanized areas. Ultimately, I-Tree Canopy and I-Tree Hydro Models were then run at these five scales: the entire Yahara River Watershed, the Yahara urbanshed, and the Yahara urban watershed, urban subwatersheds and storm water catchments.

The following maps illustrate the boundaries used in the analysis and canopy cover data.

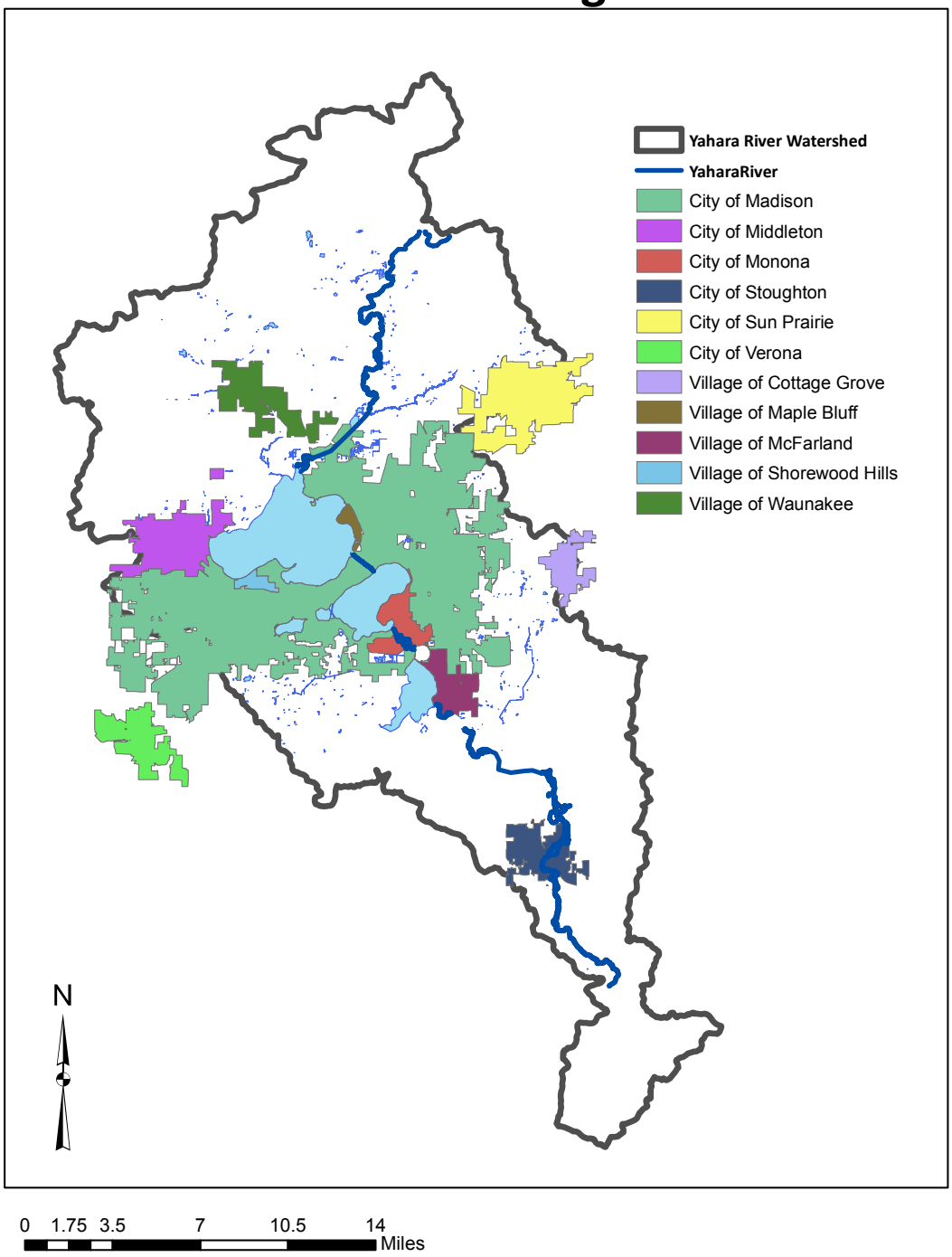
Yahara Canopy Project Area- Land Cover



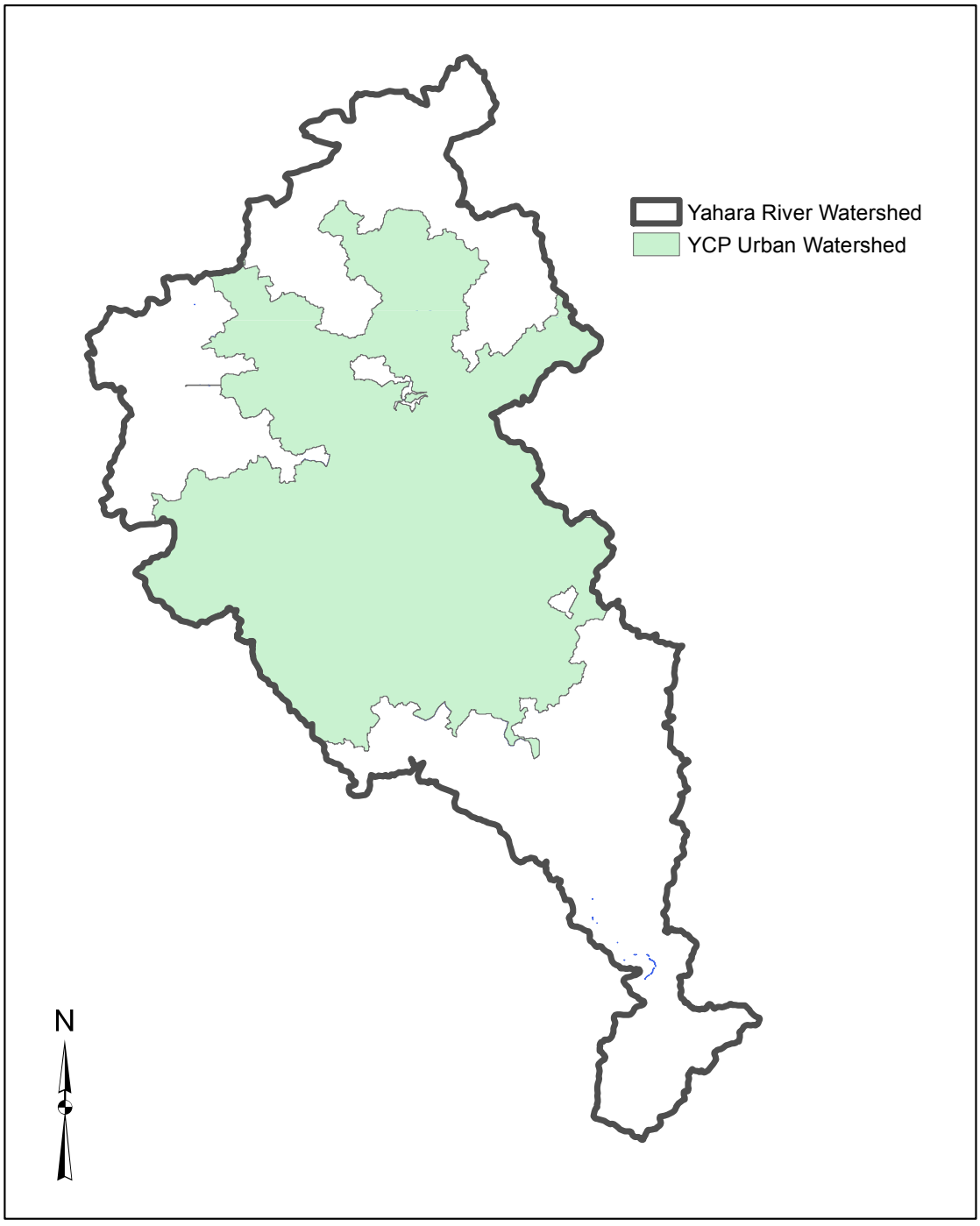
Yahara Canopy Project Area- Landuse



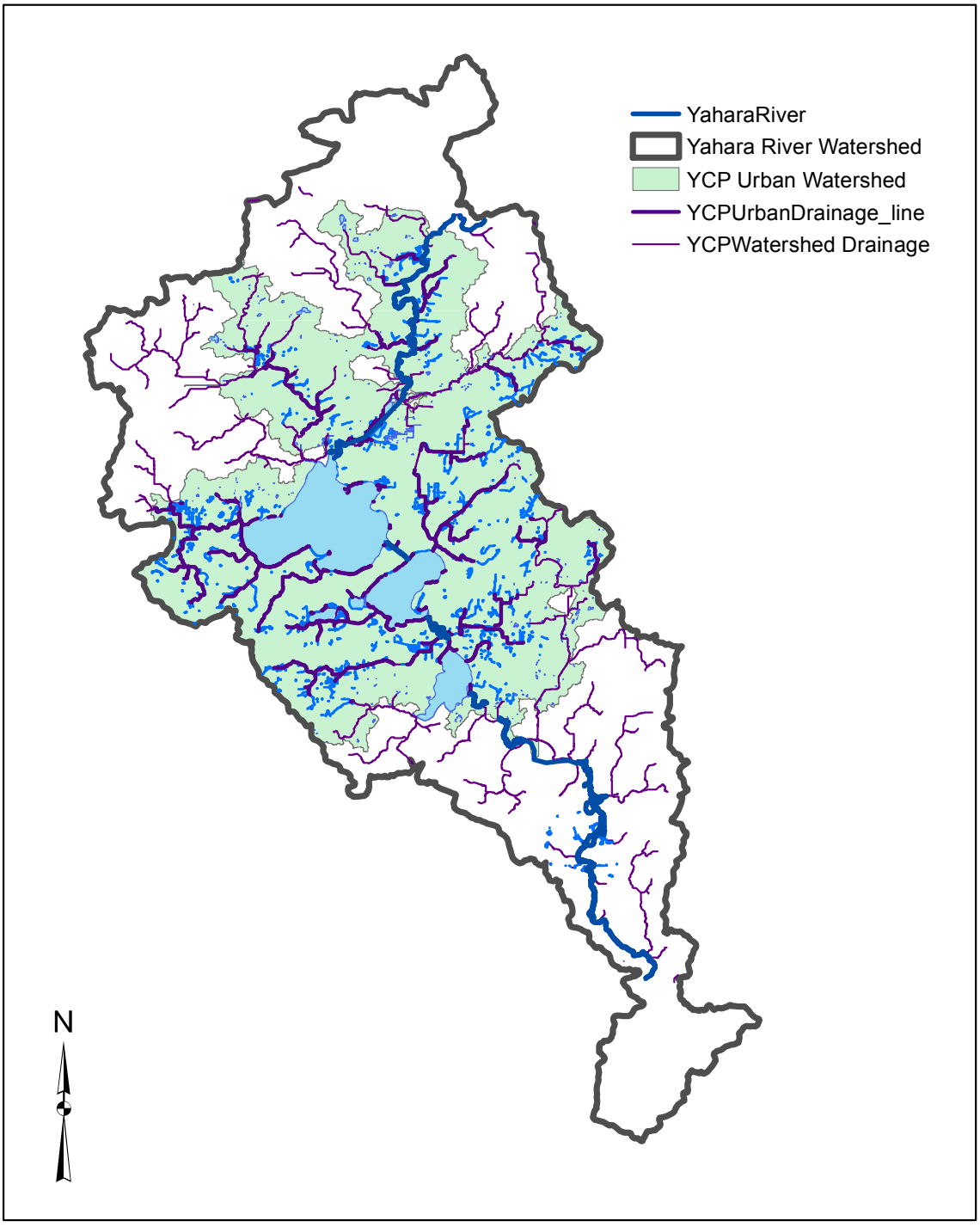
YCP Area - Cities and Villages



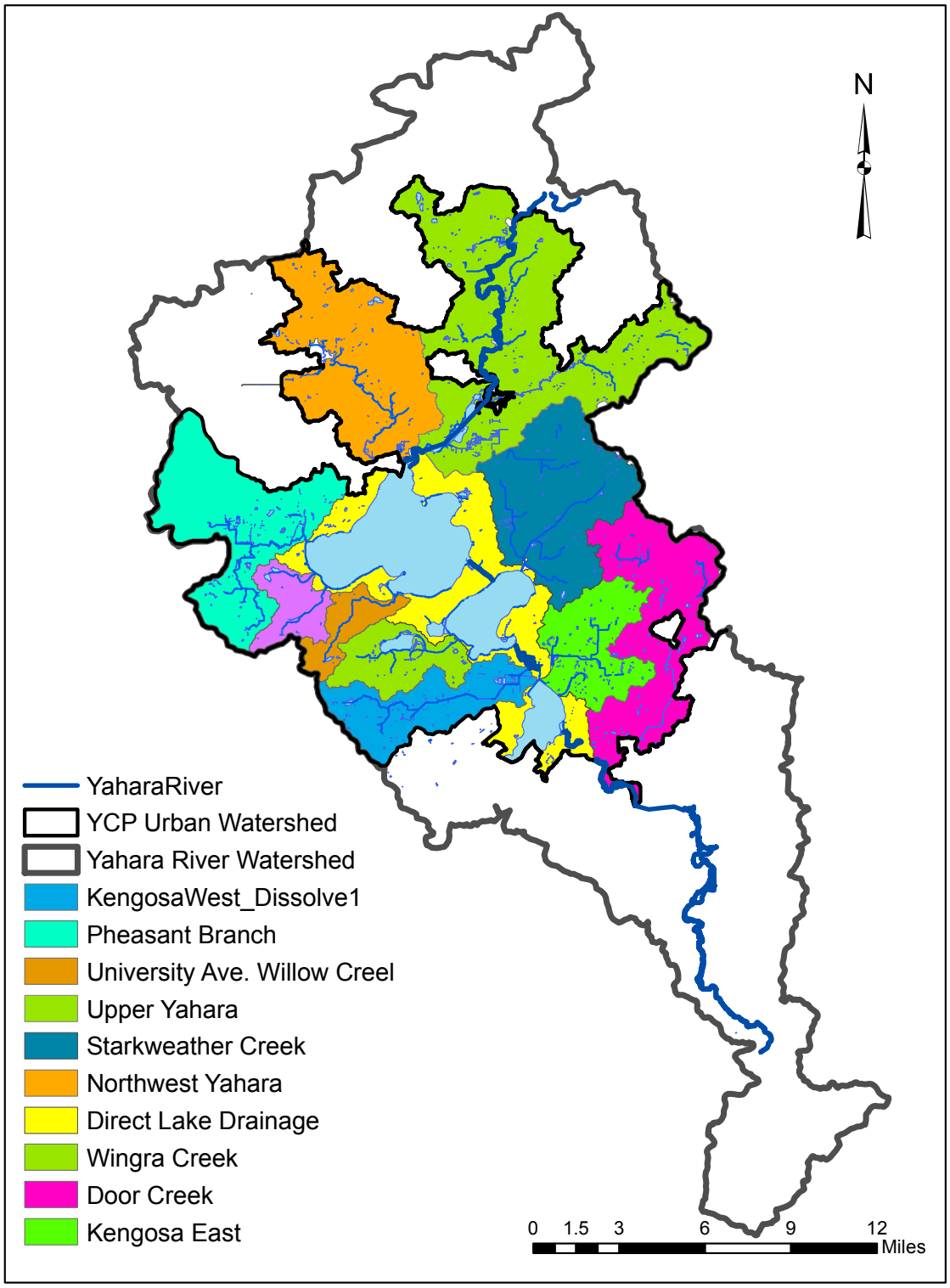
YCP- Urban Watershed



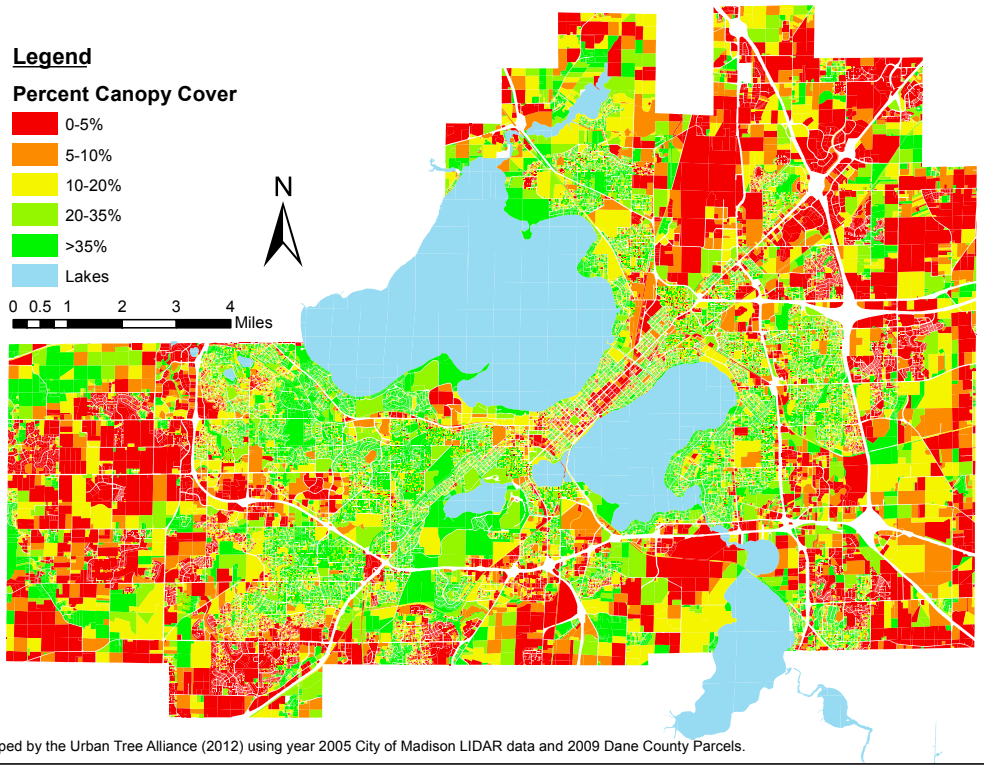
YCP- Urban Watershed & Hydrologic Features



YCP- Subwatersheds



Madison Tree Canopy Cover by Parcel



Developed by the Urban Tree Alliance (2012) using year 2005 City of Madison LIDAR data and 2009 Dane County Parcels.

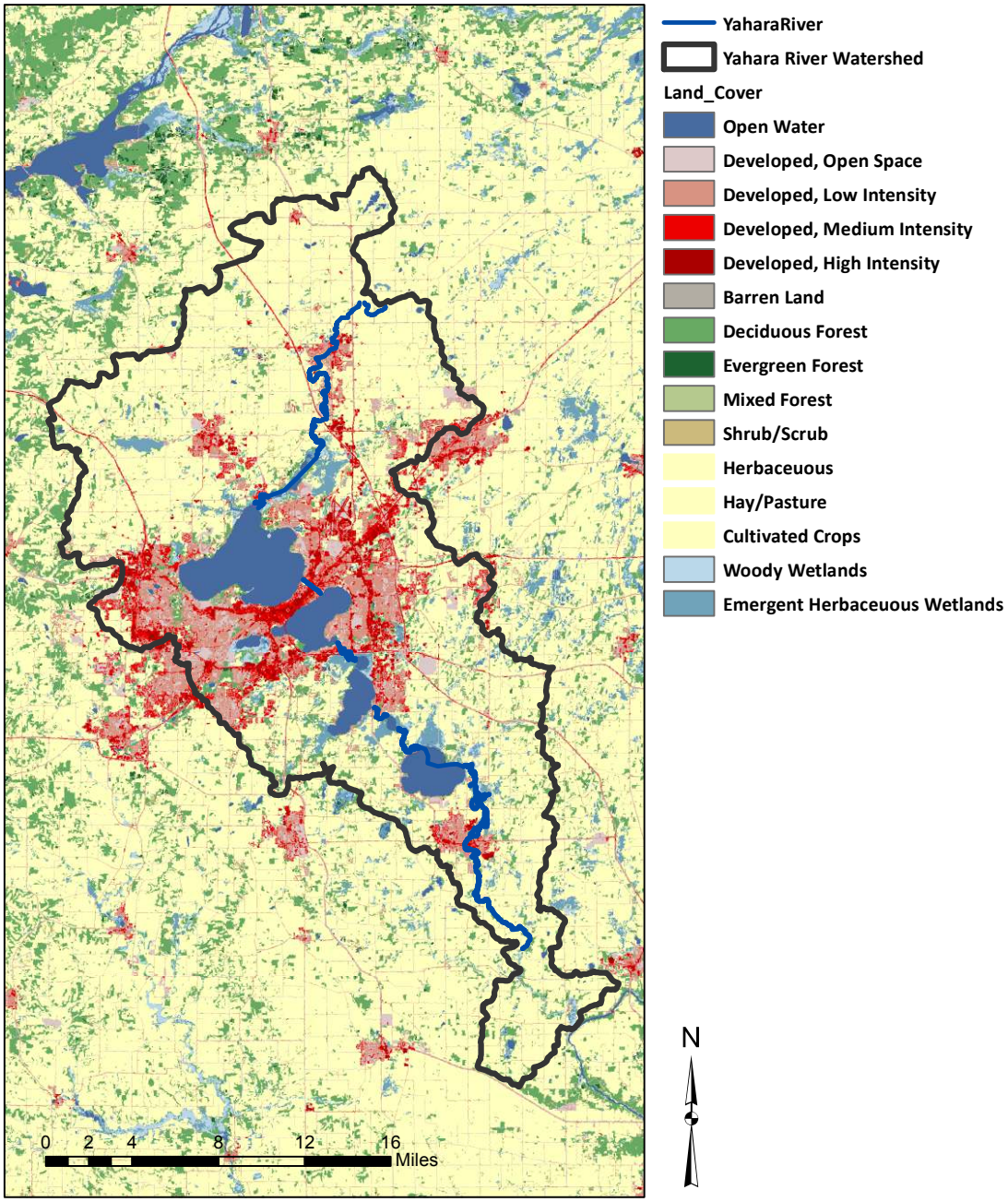
IV. Models-I-Canopy and I-Hydro

The urban watershed analysis utilized traditional GIS processing and two urban forest models provided by I-Tree: I-Tree Canopy and I-tree Hydro. In order develop boundary areas and gather baseline data for canopy cover, land use classifications, hydrological features, and digital elevation models an Arcview geographical information system (GIS) was created. This data, in turn, became critical inputs for the I-tree models. Much can be found on I-tree and it's various programs and capacities on it's website. I-Tree Canopy is a method for estimating cover (or any land use classification) and tree benefits within a defined area. I-Tree Hydro combines the data produced in I-Tree Canopy along with topographical, weather, stream gauge data sets to produce water quantity and quality estimates based on tree cover conditions. Further, I-tree Hydro produces both base and alternative cases for changes in canopy cover; i.e. it estimates the hydrological benefits of existing canopy cover in a given area and then estimates changes in those benefits in a case where canopy cover is either added or removed.

The following section presents the and boundary areas for areas of analysis and results from I-Tree Canopy and I-Tree Hydro models. They appear in the following order:

- Yahara Watershed
- Yahara Urban Watershed- +5%, -%5, +100% canopy changes
- Subwatersheds:
  - Upper Yahara
  - Northwest Mendota
  - Starkweather Creek
  - Pheasant Branch
  - Direct Lake Drainage
  - Southwest Mendota
  - University Ave. / Willow Creek
  - Door Creek
  - Wingra Creek
  - East Waubesa
  - West Waubesa
- Stormwater Catchment
- Comprehensive Results Table

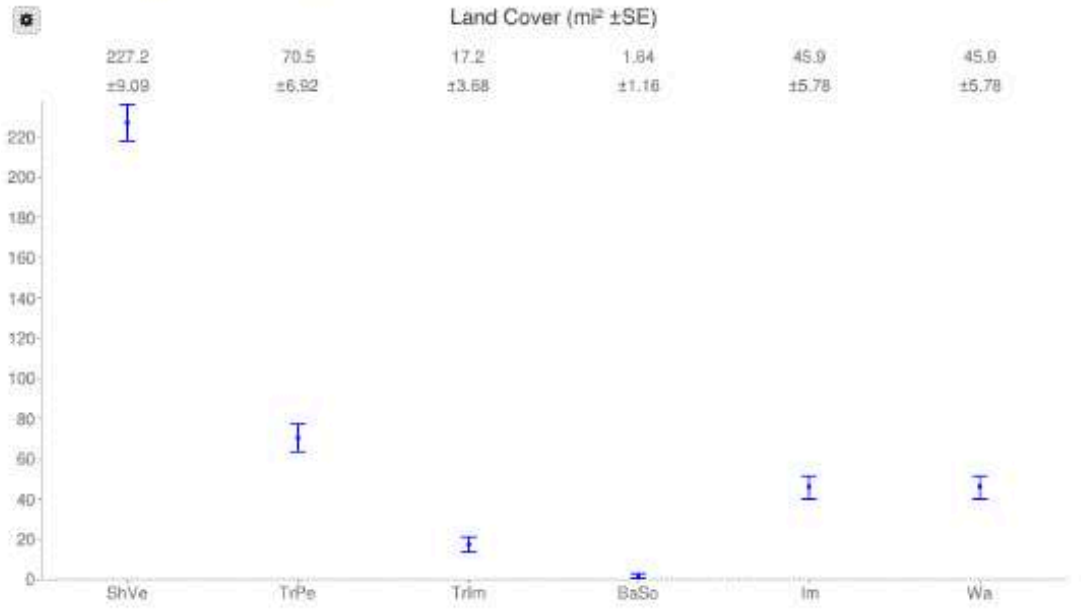
Yahara Canopy Project Area- Landuse



i-Tree Canopy v6.1

Cover Assessment and Tree Benefits Report

Estimated using random sampling statistics on 1/12/17



Cover Class	Description	Abbr.	Points	Land Cover
Short Vegetation	Herbaceous, Ag.	ShVe	277	227.2 ±9.09
Tree, Permeable	Tree, pervious underneath	TrPe	86	70.5 ±6.92
Tree, Impermeable	Tree impermeable underneath	Trlm	21	17.2 ±3.68
Bare Soil	Bare Soil	BaSo	2	1.64 ±1.16
Impermeable	Paving, Roof, Gravel	Im	56	45.9 ±5.78
Water	surface water, wetland	Wa	56	45.9 ±5.78

Tree Benefit Estimates

Abbr.	Benefit Description	Value	±SE	Amount	±SE
CO	Carbon Monoxide removed annually	$2,400.35	±205.62	22.38 T	±1.92
NO2	Nitrogen Dioxide removed annually	$13,015.17	±1,114.89	193.66 T	±16.59
O3	Ozone removed annually	$383,530.80	±32,853.53	988.97 T	±84.72
PM2.5	Particulate Matter less than 2.5 microns removed annually	$941,366.00	±80,638.11	53.42 T	±4.58
SO2	Sulfur Dioxide removed annually	$713.57	±61.12	31.74 T	±2.72
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	$282,340.72	±24,185.51	276.68 T	±23.70
CO2seq	Carbon Dioxide sequestered annually in trees	$7,494,687.10	±642,000.44	207,288.25 T	±17,754.75
CO2stor	Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)	$256,151,754.47	±21,942,148.67	7,083,966.15 T	±606,817.95

i-Tree Hydro Executive Summary

Project Location: Madison, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2005

Model Parameters

Watershed Area	Rainfall	Total Runoff	Stream Gage	Weather Station
square kilometers	*millimeters*	*cubic meters*		
1,307.94	609.35	327,422,323.76	05429700	726410-14837

Land Cover	Base	Alternative		Base	Alternative	LC beneath Tree Cover	Base	Alternative
Tree Cover %	21.5	30.0	Tree LAI	5.0	5.0	Soil Cover %	80.4	80.4
Shrub Cover %	2.6	2.6	Shrub LAI	2.2	2.2	Impervious Cover %	19.6	19.6
Herbaceous Cover %	53.0	48.5	Herbaceous LAI	1.6	1.6			
Water Cover %	11.2	11.2						
Impervious Cover %	11.2	7.2	Directly Connected Impervious Cover (%)	40.0	40.0			
Soil Cover %	0.5	0.5						

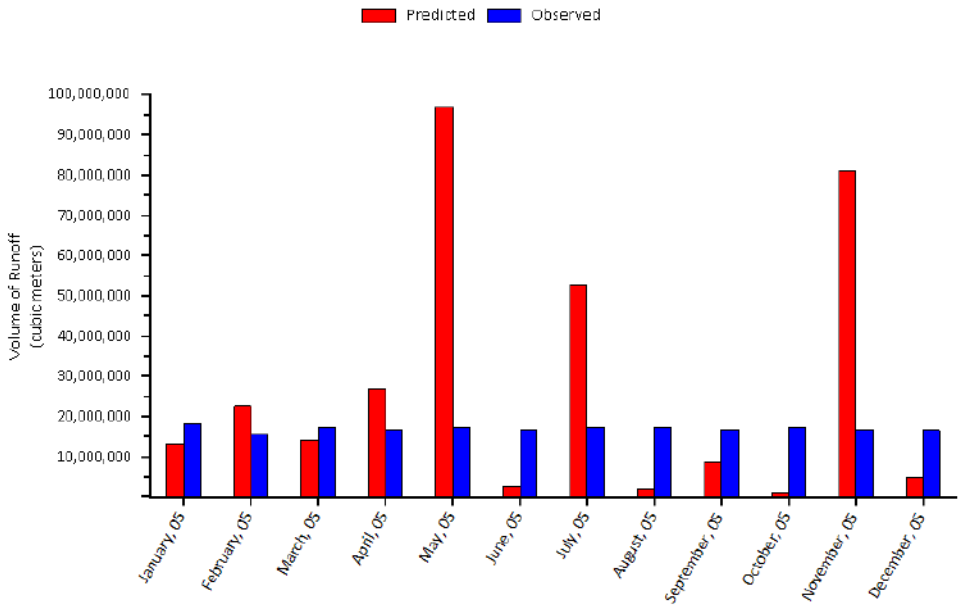
Streamflow Predictions

	Total Runoff		Baseflow		Pervious Flow		Impervious Flow	
	Base	Alternative	Base	Alternative	Base	Alternative	Base	Alternative
Total Flow (cubic meters)	327,422,323.8	317,771,029.7	244,583,279.6	241,893,518.0	21,504,261.1	20,990,284.8	61,334,738.4	54,887,255.4
Highest Flow (cubic meters / hour)	45,972,400.3	46,384,010.3	38,346,040.5	38,955,804.0	5,434,768.9	5,435,985.3	2,191,512.5	1,992,142.6
Lowest Flow (cubic meters / hour)	3.2	3.3	0.1	0.1	0.0	0.0	0.0	0.0
Highest Flow Date	05/19/05	05/19/05	05/19/05	05/19/05	05/19/05	05/19/05	05/19/05	05/19/05
Lowest Flow Date	07/21/05	07/21/05	05/19/05	05/19/05	01/01/05	01/01/05	01/01/05	01/01/05
Median Flow (cubic meters / hour)	182.1	159.3	118.6	100.8	0.0	0.0	0.0	0.0
Number of flow events ABOVE median flow	58.0	59.0	12.0	11.0	5.0	5.0	44.0	45.0
Average length of flow events with flow ABOVE median (hours)	73.3	72.0	380.7	419.0	115.8	115.2	99.3	97.0
High Flow: Number of flow events ABOVE 1 standard deviation	9.0	8.0	7.0	6.0	5.0	5.0	36.0	37.0
Average length of flow events ABOVE 1 standard deviation (hours)	400.9	419.6	493.7	527.0	115.8	115.2	94.4	91.7
Number of flow events BELOW median flow	57.0	58.0	11.0	10.0	0.0	0.0	45.0	46.0
Average length of events BELOW median (hours)	76.6	75.3	397.0	436.7	0.0	0.0	98.1	96.0

i-Tree Hydro Executive Summary

Project Location: Madison, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2005

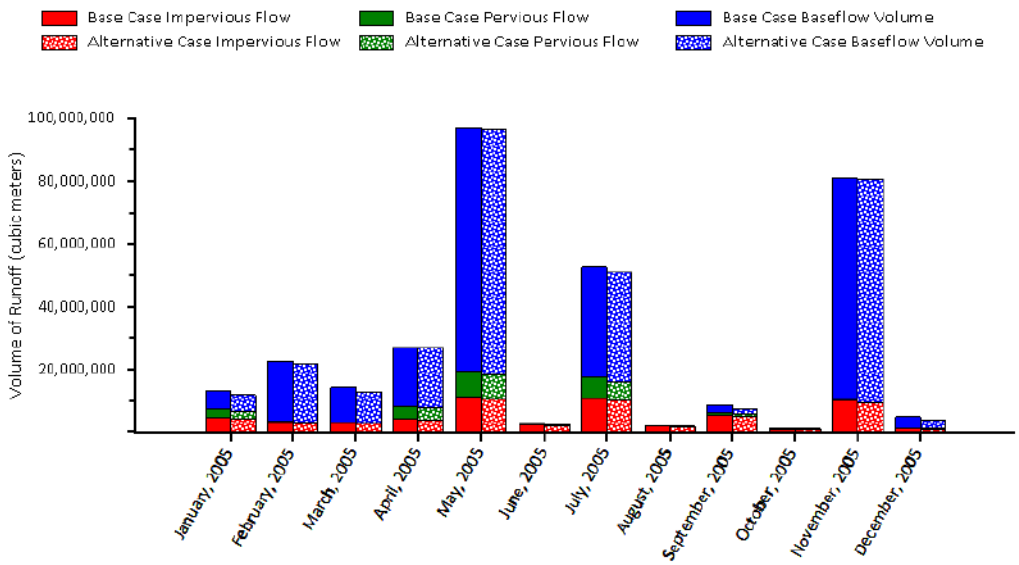
Water Volume: Observed Streamflow vs. Predicted Streamflow
(Predicted is 61% higher than Observed)



i-Tree Hydro Executive Summary

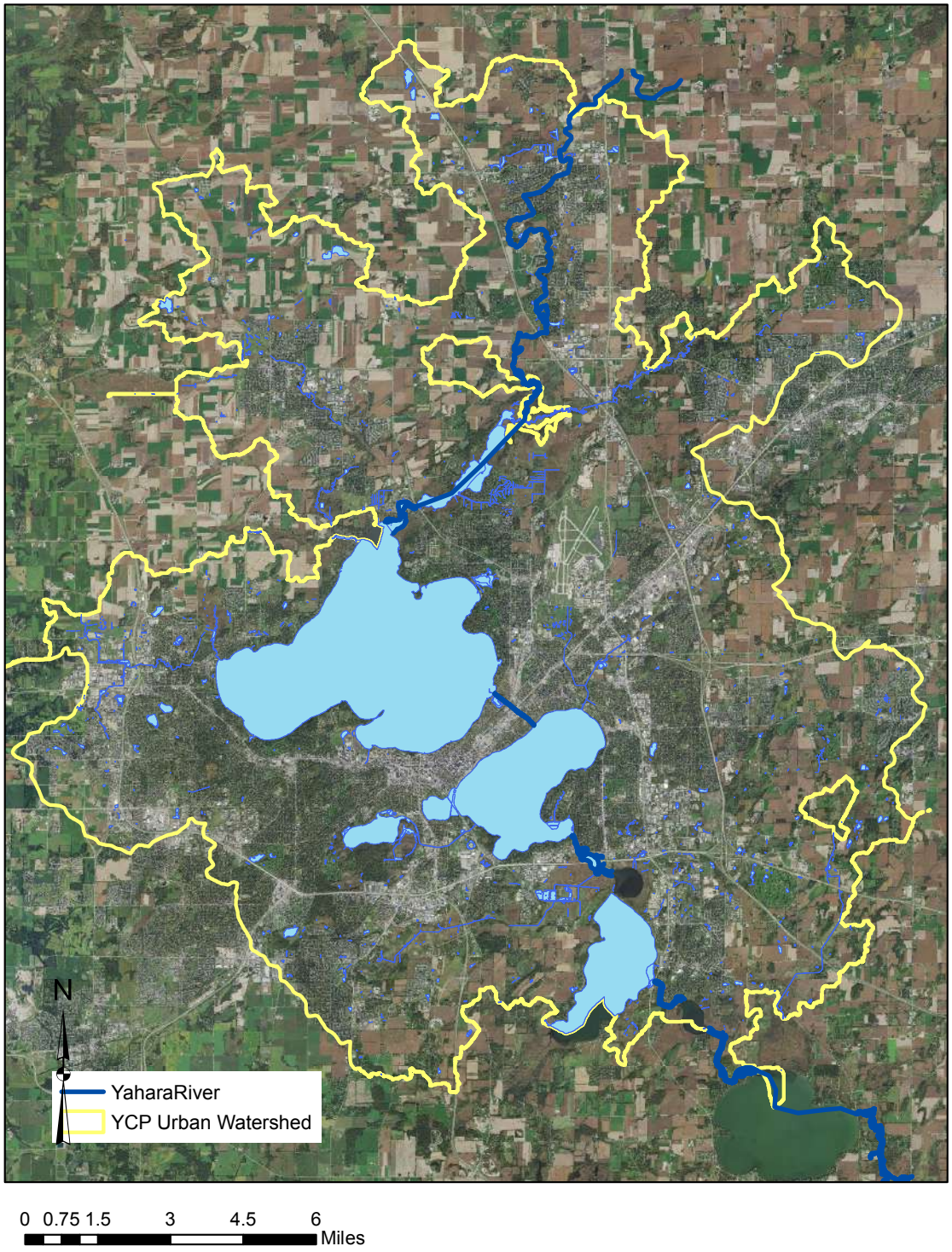
Project Location: Madison, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2005

Base Case vs. Alternative Case Predicted Streamflow Components



Yahara Urban Watershed

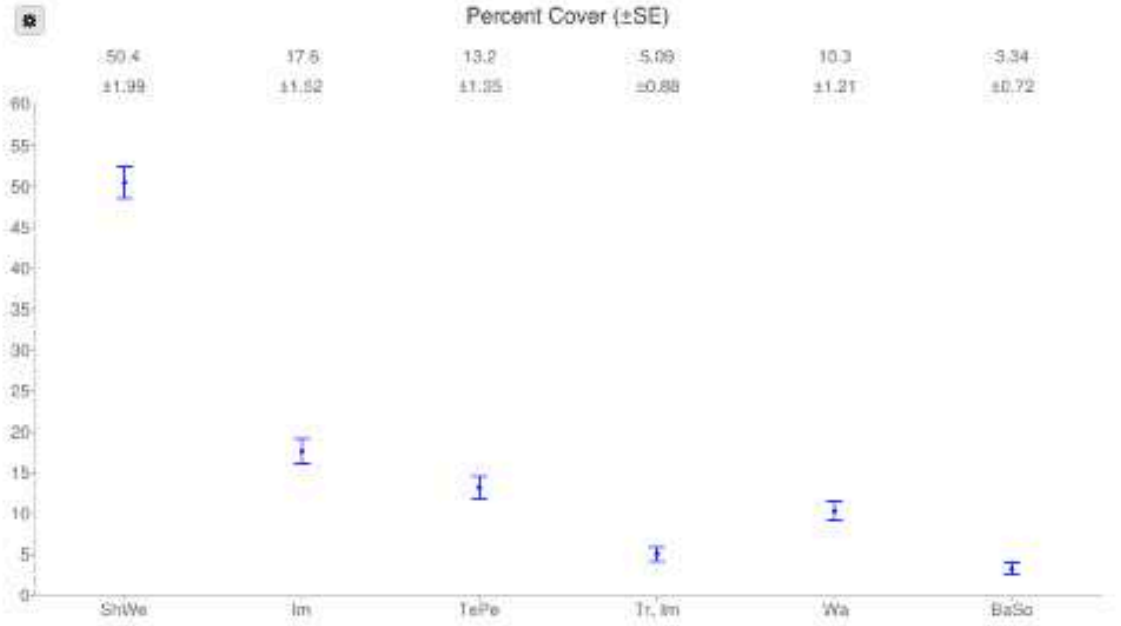
YCP- Urban Watershed & Aerial



i-Tree Canopy v6.1

Cover Assessment and Tree Benefits Report

Estimated using random sampling statistics on 1/12/17



Cover Class	Description	Abbr.	Points	% Cover
Short Vegetation	Ag.,turf, small shrub	ShWe	317	50.4 ±1.99
Impermeable		Im	111	17.6 ±1.52
Tree, Permeable	Canopy over permeable	TePe	83	13.2 ±1.35
Tree, Impermebale	Canopy of impermeable	Tr, Im	32	5.09 ±0.88
Water	Open, wetland	Wa	65	10.3 ±1.21
Bare Soil		BaSo	21	3.34 ±0.72

Tree Benefit Estimates

Abbr.	Benefit Description	Value	±SE	Amount	±SE
CO	Carbon Monoxide removed annually	$1,154.59	±97.33	10.76 T	±0.91
NO2	Nitrogen Dioxide removed annually	$6,260.41	±527.73	93.15 T	±7.85
O3	Ozone removed annually	$184,481.81	±15,551.09	475.70 T	±40.10
PM2.5	Particulate Matter less than 2.5 microns removed annually	$452,805.63	±38,169.73	25.70 T	±2.17
SO2	Sulfur Dioxide removed annually	$343.23	±28.93	15.27 T	±1.29
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	$135,808.46	±11,448.12	133.09 T	±11.22
CO2seq	Carbon Dioxide sequestered annually in trees	$3,605,012.85	±303,888.41	99,697.92 T	±8,404.14
CO2stor	Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)	$123,211,330.26	±10,386,230.65	3,407,453.29 T	±287,234.91

+5 % Canopy Change

i-Tree Hydro Executive Summary

Project Location: Madison, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2012

Model Parameters

Watershed Area	Rainfall	Total Runoff	Stream Gage	Weather Station
square kilometers	*millimeters*	*cubic meters*		
608.65	6,825.74	2,454,455,940.60	0	726410-14837

Land Cover	Base	Alternative		Base	Alternative	LC beneath Tree Cover	Base	Alternative
Tree Cover %	19.3	24.2	Tree LAI	5.0	5.0	Soil Cover %	95.0	95.0
Shrub Cover %	7.9	7.9	Shrub LAI	2.2	2.2	Impervious Cover %	5.0	5.0
Herbaceous Cover %	38.7	36.7	Herbaceous LAI	1.6	1.6			
Water Cover %	13.4	13.4						
Impervious Cover %	19.7	16.7	Directly Connected Impervious Cover (%)	40.0	40.0			
Soil Cover %	1.1	1.1						

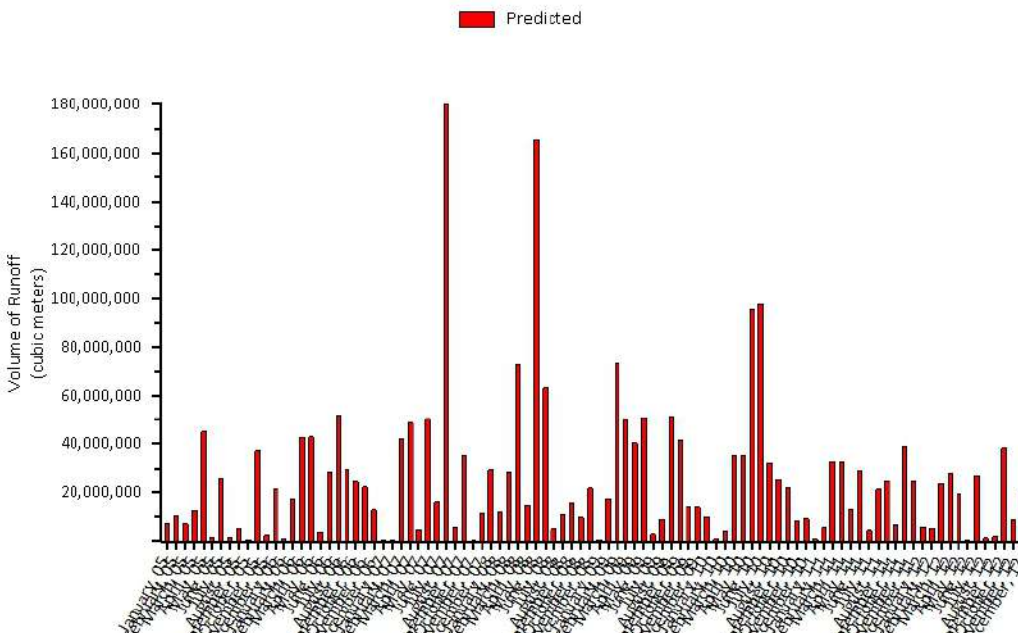
Streamflow Predictions

	Total Runoff		Baseflow		Pervious Flow		Impervious Flow	
	Base	Alternative	Base	Alternative	Base	Alternative	Base	Alternative
Total Flow (cubic meters)	2,454,455,940.6	2,444,577,981.8	1,797,902,458.3	1,825,283,505.4	190,048,249.1	191,173,297.4	466,505,132.7	428,121,589.9
Highest Flow (cubic meters / hour)	33,549,729.6	34,807,255.5	26,411,515.1	27,514,018.7	8,590,142.3	8,768,841.2	2,777,543.3	2,552,891.6
Lowest Flow (cubic meters / hour)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Highest Flow Date	07/22/10	06/19/09	07/22/10	07/22/10	08/22/07	08/22/07	08/22/07	08/22/07
Lowest Flow Date	06/07/09	06/07/09	06/08/09	06/08/09	01/01/05	01/01/05	01/01/05	01/01/05
Median Flow (cubic meters / hour)	111.4	110.0	76.1	75.2	0.0	0.0	0.0	0.0
Number of flow events ABOVE median flow	475.0	484.0	151.0	150.0	55.0	55.0	300.0	299.0
Average length of flow events with flow ABOVE median (hours)	73.8	72.4	232.1	233.7	123.5	123.5	117.0	117.4
High Flow: Number of flow events ABOVE 1 standard deviation	118.0	115.0	135.0	132.0	43.0	43.0	241.0	241.0
Average length of flow events ABOVE 1 standard deviation (hours)	250.9	255.1	234.4	236.8	127.2	127.2	119.7	119.9
Number of flow events BELOW median flow	475.0	484.0	151.0	150.0	0.0	0.0	300.0	299.0
Average length of events BELOW median (hours)	73.9	72.5	233.4	235.0	0.0	0.0	116.8	117.2

i-Tree Hydro Executive Summary

Project Location: Madison, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2012

Water Volume: Predicted Streamflow



i-Tree Hydro Executive Summary

Project Location: Madison, Wisconsin
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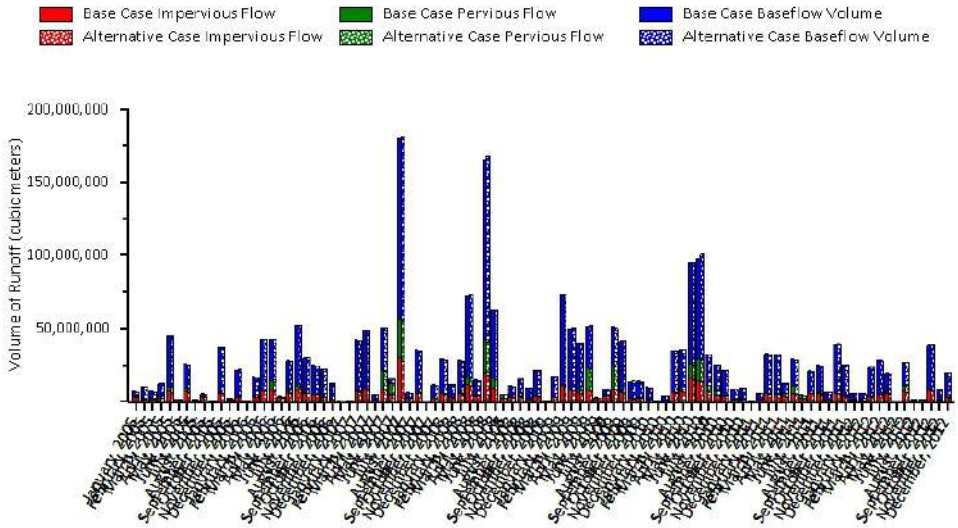
Base Case vs. Alternative Case Predicted Streamflow Components

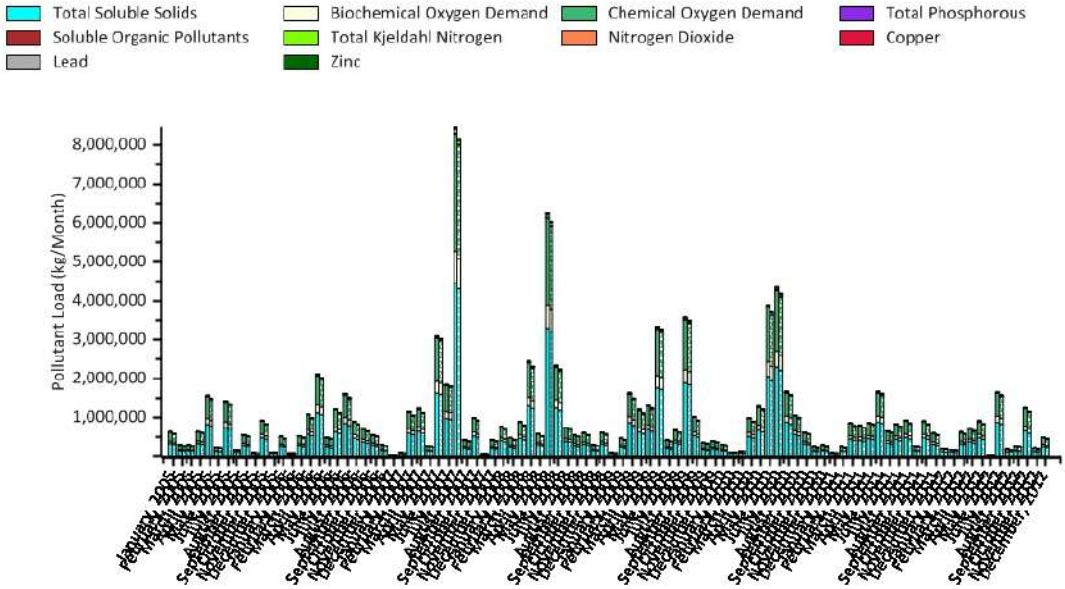


Note: Solid colors represent Base Case values while the hatched pattern indicates Alternative Case values

i-Tree Hydro Executive Summary

Project Location: Madison, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2012

Pollutants: Base Case vs. Alternative Case Event Mean Concentration



Note: Solid colors represent Base Case values while the hatched pattern indicates Alternative Case values

-5% Canopy Change

i-Tree Hydro Executive Summary

Project Location: Madison, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2012

Model Parameters

Watershed Area	Rainfall	Total Runoff	Stream Gage	Weather Station
square kilometers	*millimeters*	*cubic meters*		
608.65	6,825.74	2,454,455,940.60	0	726410-14837

Land Cover	Base	Alternative		Base	Alternative	LC beneath Tree Cover	Base	Alternative
Tree Cover %	19.3	15.2	Tree LAI	5.0	5.0	Soil Cover %	95.0	95.0
Shrub Cover %	7.9	7.9	Shrub LAI	2.2	2.2	Impervious Cover %	5.0	5.0
Herbaceous Cover %	38.7	40.7	Herbaceous LAI	1.6	1.6			
Water Cover %	13.4	13.4	Directly Connected Impervious Cover (%)	40.0	40.0			
Impervious Cover %	19.7	21.7						
Soil Cover %	1.1	1.1						

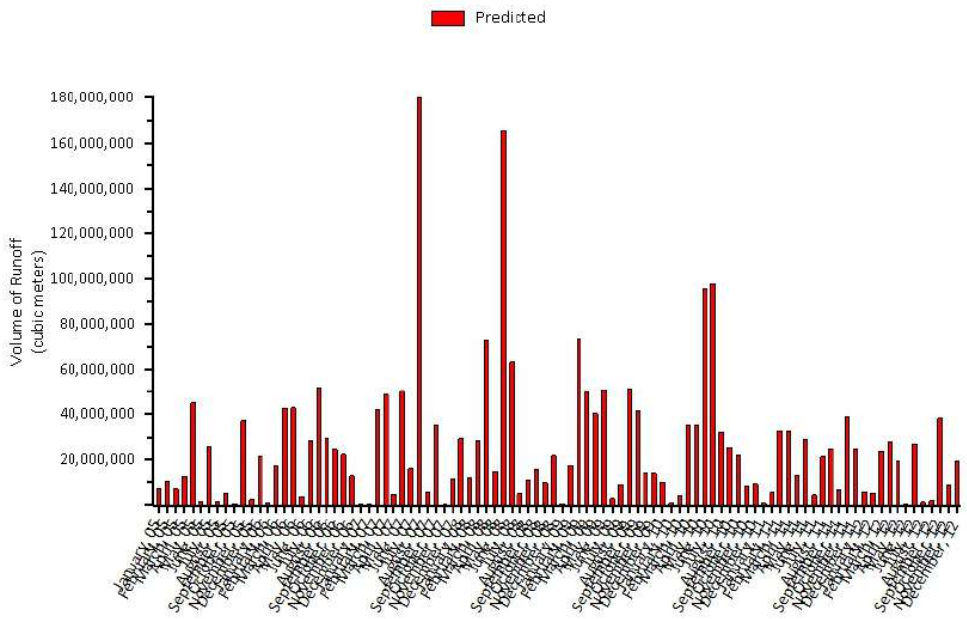
Streamflow Predictions

	Total Runoff		Baseflow		Pervious Flow		Impervious Flow	
	Base	Alternative	Base	Alternative	Base	Alternative	Base	Alternative
Total Flow (cubic meters)	2,454,455,940.6	2,462,138,868.0	1,797,902,458.3	1,781,275,662.1	190,048,249.1	189,207,156.0	466,505,132.7	491,656,172.7
Highest Flow (cubic meters / hour)	33,549,729.6	32,960,680.8	26,411,515.1	25,750,280.8	8,590,142.3	8,466,526.1	2,777,543.3	2,924,275.9
Lowest Flow (cubic meters / hour)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Highest Flow Date	07/22/10	07/22/10	07/22/10	07/22/10	08/22/07	08/22/07	08/22/07	08/22/07
Lowest Flow Date	06/07/09	06/07/09	06/08/09	06/08/09	01/01/05	01/01/05	01/01/05	01/01/05
Median Flow (cubic meters / hour)	111.4	112.3	76.1	77.3	0.0	0.0	0.0	0.0
Number of flow events ABOVE median flow	475.0	470.0	151.0	153.0	55.0	57.0	300.0	300.0
Average length of flow events with flow ABOVE median (hours)	73.8	74.6	232.1	229.1	123.5	124.9	117.0	117.0
High Flow: Number of flow events ABOVE 1 standard deviation	118.0	118.0	135.0	137.0	43.0	43.0	241.0	241.0
Average length of flow events ABOVE 1 standard deviation (hours)	250.9	250.1	234.4	232.1	127.2	129.7	119.7	119.7
Number of flow events BELOW median flow	475.0	470.0	151.0	153.0	0.0	0.0	300.0	300.0
Average length of events BELOW median (hours)	73.9	74.7	233.4	230.3	0.0	0.0	116.8	116.8

i-Tree Hydro Executive Summary

Project Location: Madison, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2012

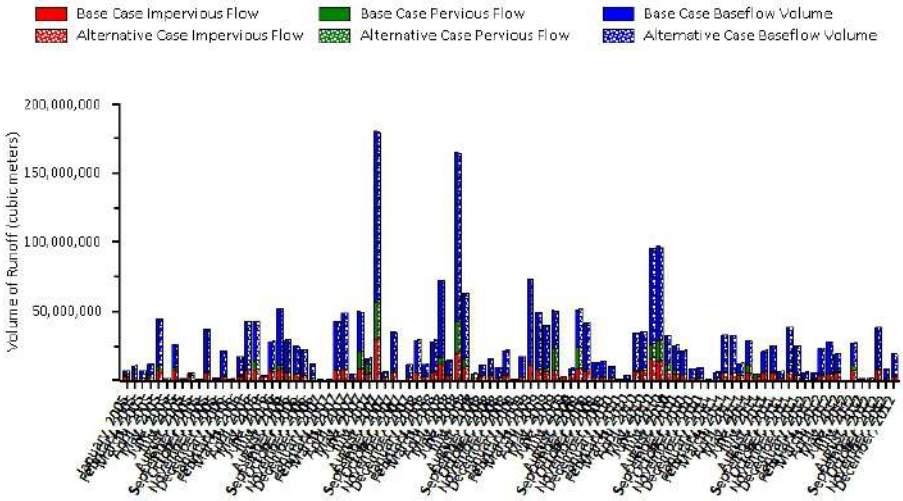
Water Volume: Predicted Streamflow



i-Tree Hydro Executive Summary

Project Location: Madison, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2012

Base Case vs. Alternative Case Predicted Streamflow Components



Note: Solid colors represent Base Case values while the hatched pattern indicates Alternative Case values

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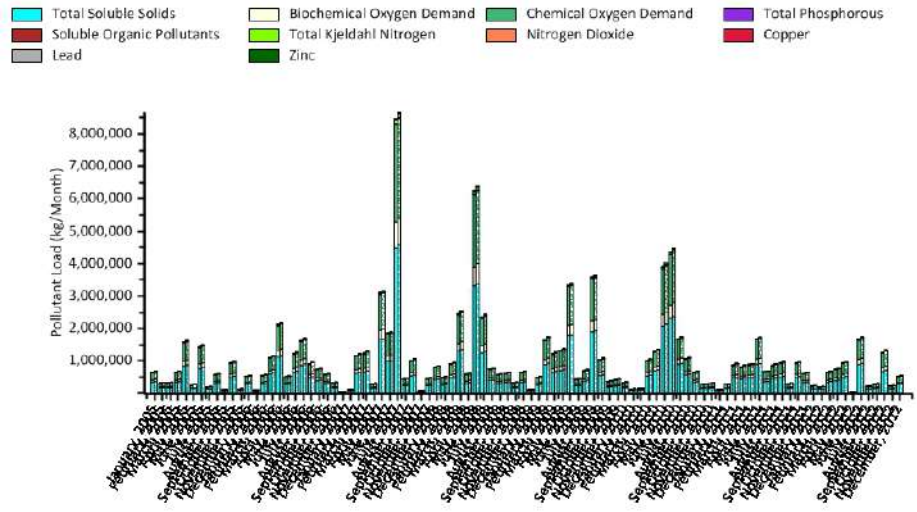
i-Tree Hydro Executive Summary

Project Location: Madison, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2012

Pollutants: Base Case vs. Alternative Case Event Mean Concentration



Note: Solid colors represent Base Case values while the hatched pattern indicates Alternative Case values

+100% Change

i-Tree Hydro Executive Summary

Project Location: Madison, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2012

Model Parameters

Watershed Area	Rainfall	Total Runoff	Stream Gage	Weather Station
square kilometers	*millimeters*	*cubic meters*		
608.65	6,825.74	2,454,455,940.60	0	726410-14837

Land Cover	Base	Alternative		Base	Alternative	LC beneath Tree Cover	Base	Alternative
Tree Cover %	19.3	100.0	Tree LAI	5.0	5.0	Soil Cover %	95.0	95.0
Shrub Cover %	7.9	0.0	Shrub LAI	2.2	2.2	Impervious Cover %	5.0	5.0
Herbaceous Cover %	38.7	0.0	Herbaceous LAI	1.6	1.6			
Water Cover %	13.4	0.0						
Impervious Cover %	19.7	0.0	Directly Connected Impervious Cover (%)	40.0	40.0			
Soil Cover %	1.1	0.0						

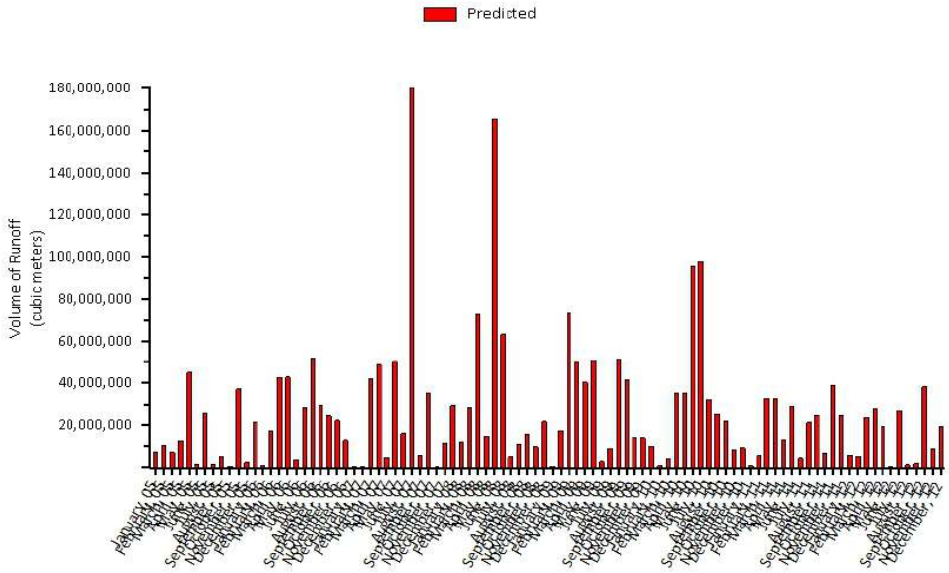
Streamflow Predictions

	Total Runoff		Baseflow		Pervious Flow		Impervious Flow	
	Base	*Alternative*	*Base*	*Alternative*	*Base*	*Alternative*	*Base*	*Alternative*
Total Flow (cubic meters)	2,454,455,940.6	2,102,469,138.6	1,797,902,458.3	1,860,707,471.9	190,048,249.1	183,164,792.0	466,505,132.7	58,596,958.7
Highest Flow (cubic meters / hour)	33,549,729.6	45,373,553.6	26,411,515.1	38,088,168.3	8,590,142.3	10,051,565.1	2,777,543.3	404,650.0
Lowest Flow (cubic meters / hour)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Highest Flow Date	07/22/10	06/19/09	07/22/10	06/19/09	08/22/07	08/22/07	08/22/07	08/22/07
Lowest Flow Date	06/07/09	07/25/12	06/08/09	07/26/12	01/01/05	01/01/05	01/01/05	01/01/05
Median Flow (cubic meters / hour)	111.4	74.3	76.1	64.2	0.0	0.0	0.0	0.0
Number of flow events ABOVE median flow	475.0	245.0	151.0	115.0	55.0	46.0	300.0	204.0
Average length of flow events with flow ABOVE median (hours)	73.8	143.1	232.1	303.0	123.5	124.3	117.0	171.8
High Flow: Number of flow events ABOVE 1 standard deviation	118.0	80.0	135.0	97.0	43.0	37.0	241.0	176.0
Average length of flow events ABOVE 1 standard deviation (hours)	250.9	379.0	234.4	312.1	127.2	127.8	119.7	179.6
Number of flow events BELOW median flow	475.0	245.0	151.0	114.0	0.0	0.0	300.0	205.0
Average length of events BELOW median (hours)	73.9	143.6	233.4	307.5	0.0	0.0	116.8	171.1

i-Tree Hydro Executive Summary

Project Location: Madison, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2012

Water Volume: Predicted Streamflow

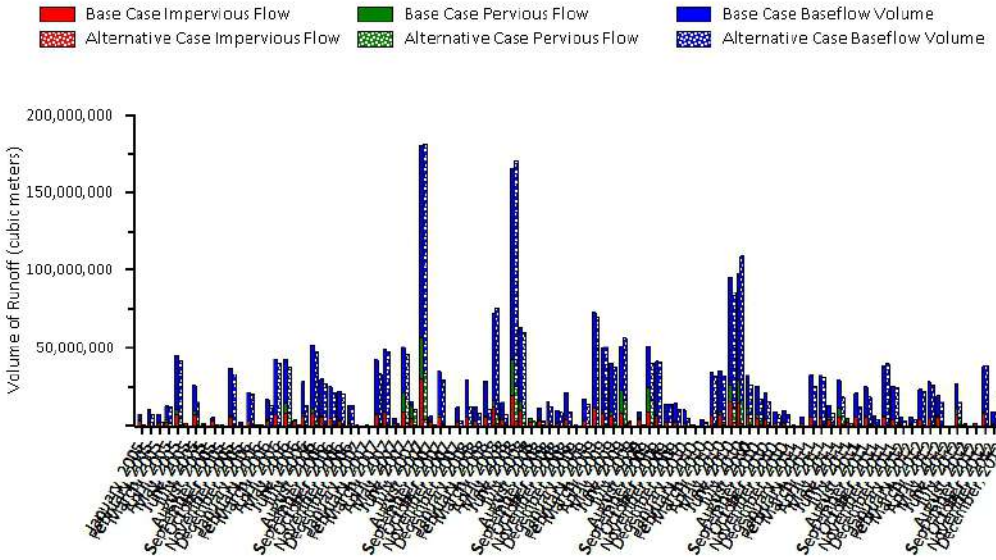


+100% Canopy Change

i-Tree Hydro Executive Summary

Project Location: Madison, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2012

Base Case vs. Alternative Case Predicted Streamflow Components

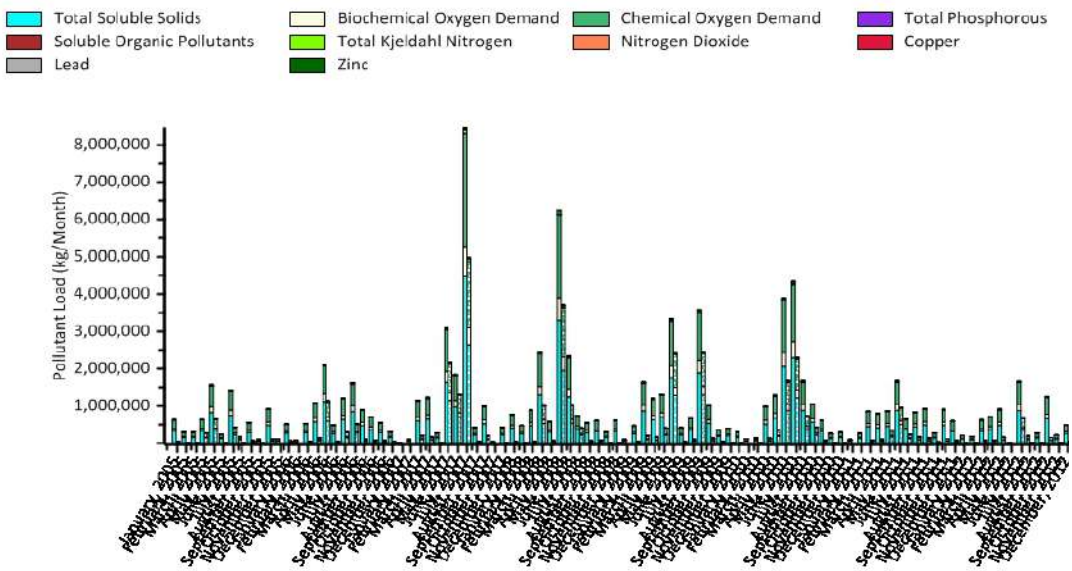


Note: Solid colors represent Base Case values while the hatched pattern indicates Alternative Case values

i-Tree Hydro Executive Summary

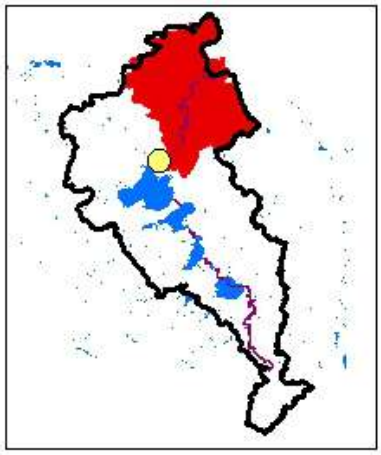
Project Location: Madison, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2012

Pollutants: Base Case vs. Alternative Case Event Mean Concentration



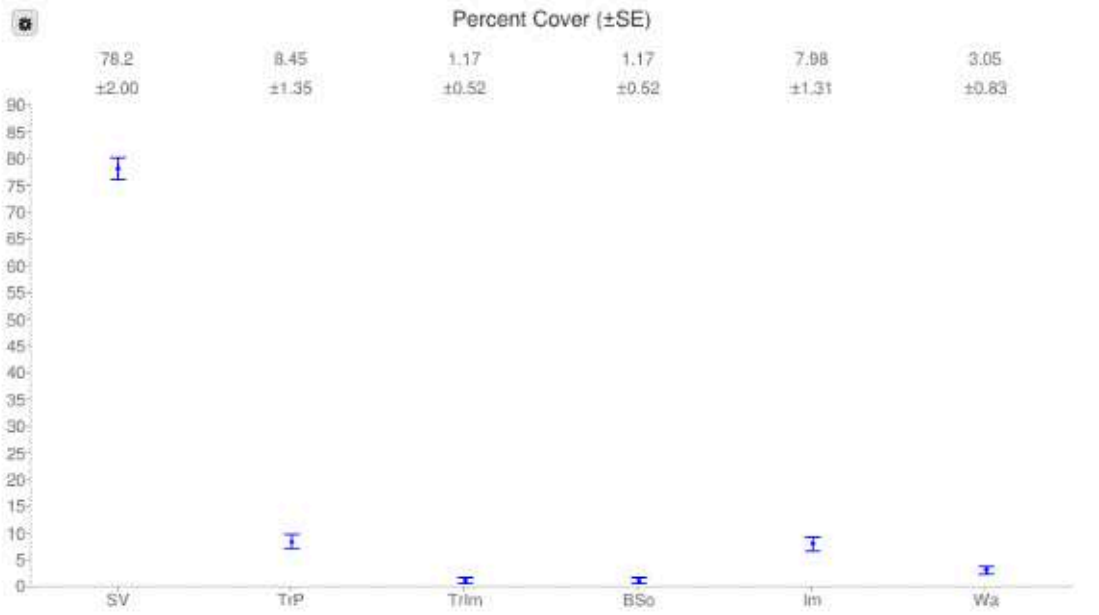
Note: Solid colors represent Base Case values while the hatched pattern indicates Alternative Case values

Northern Yahara



Cover Assessment and Tree Benefits Report

Estimated using random sampling statistics on 12/02/16



Cover Class	Description	Abbr.	Points	% Cover
Short Vegetation	Ag.,turf, small shrub	SV	333	78.2 ±2.00
Tree, Permeable	Tree pervious undneneath canopy	TrP	36	8.45 ±1.35
Tree, Impermeable	Tree, impervious underneath	Trlm	5	1.17 ±0.52
Bare Soil	bare soil	BSo	5	1.17 ±0.52
Impermeable	Paving, gravel, roof, etc	Im	34	7.98 ±1.31
Water	Surface water, wetland	Wa	13	3.05 ±0.83

Tree Benefit Estimates

Abbr.	Benefit Description	Value	±SE	Amount	±SE
CO	Carbon Monoxide removed annually	$304.76	±45.25	2.84 T	±0.42
NO2	Nitrogen Dioxide removed annually	$1,652.47	±245.34	24.59 T	±3.65
O3	Ozone removed annually	$48,694.92	±7,229.65	125.56 T	±18.64
PM2.5	Particulate Matter less than 2.5 microns removed annually	$119,520.37	±17,744.98	6.78 T	±1.01
SO2	Sulfur Dioxide removed annually	$90.60	±13.45	4.03 T	±0.60
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	$35,847.34	±5,322.19	35.13 T	±5.22
CO2seq	Carbon Dioxide sequestered annually in trees	$951,561.66	±141,276.71	26,315.78 T	±3,907.06
CO2stor	Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)	$32,522,263.54	±4,828,524.08	899,414.80 T	±133,534.56

i-Tree Hydro Executive Summary

Project Location: Madison, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2005

Model Parameters

Watershed Area	Rainfall	Total Runoff	Stream Gage	Weather Station
square kilometers	*millimeters*	*cubic meters*		
300.44	609.35	68,842,887.92	05427850	726410-14837

Land Cover	Base	Alternative		Base	Alternative	LC beneath Tree Cover	Base	Alternative
Tree Cover %	9.6	15.0	Tree LAI	5.0	5.0	Soil Cover %	88.0	88.0
Shrub Cover %	78.1	72.7	Shrub LAI	2.2	2.2	Impervious Cover %	12.0	12.0
Herbaceous Cover %	0.0	0.0	Herbaceous LAI	1.6	1.6			
Water Cover %	2.9	2.9	Directly Connected Impervious Cover (%)	40.0	40.0			
Impervious Cover %	7.9	7.9						
Soil Cover %	1.5	1.5						

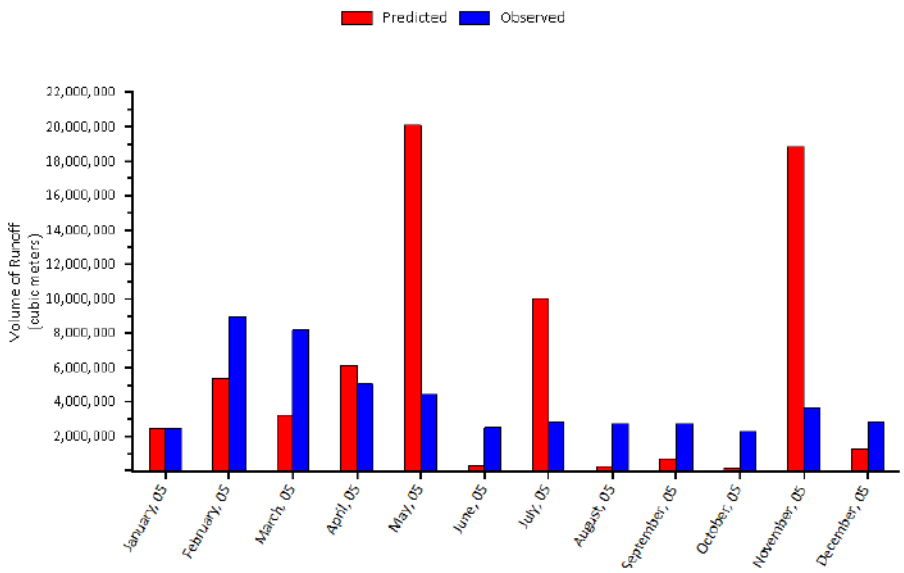
Streamflow Predictions

	Total Runoff		Baseflow		Pervious Flow		Impervious Flow	
	Base	*Alternative*	*Base*	*Alternative*	*Base*	*Alternative*	*Base*	*Alternative*
Total Flow (cubic meters)	68,842,887.9	68,248,215.4	57,682,079.6	56,847,441.9	4,741,673.4	4,704,844.5	6,419,157.7	6,695,927.6
Highest Flow (cubic meters / hour)	9,043,743.3	9,013,489.1	7,553,657.8	7,514,600.8	1,263,389.5	1,260,391.1	226,713.4	238,484.6
Lowest Flow (cubic meters / hour)	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0
Highest Flow Date	05/19/05	05/19/05	05/19/05	05/19/05	05/19/05	05/19/05	05/19/05	05/19/05
Lowest Flow Date	11/05/05	11/05/05	05/19/05	05/19/05	01/01/05	01/01/05	01/01/05	01/01/05
Median Flow (cubic meters / hour)	51.1	50.8	34.3	34.0	0.0	0.0	0.0	0.0
Number of flow events ABOVE median flow	55.0	55.0	9.0	9.0	5.0	5.0	45.0	45.0
Average length of flow events with flow ABOVE median (hours)	77.4	77.4	523.5	523.5	116.2	115.8	97.1	97.1
High Flow: Number of flow events ABOVE 1 standard deviation	8.0	8.0	6.0	6.0	5.0	5.0	37.0	36.0
Average length of flow events ABOVE 1 standard deviation (hours)	460.3	460.3	623.2	623.0	116.2	115.8	97.6	93.3
Number of flow events BELOW median flow	54.0	54.0	8.0	8.0	0.0	0.0	46.0	46.0
Average length of events BELOW median (hours)	80.9	80.9	546.0	546.0	0.0	0.0	95.9	95.9

i-Tree Hydro Executive Summary

Project Location: Madison, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2005

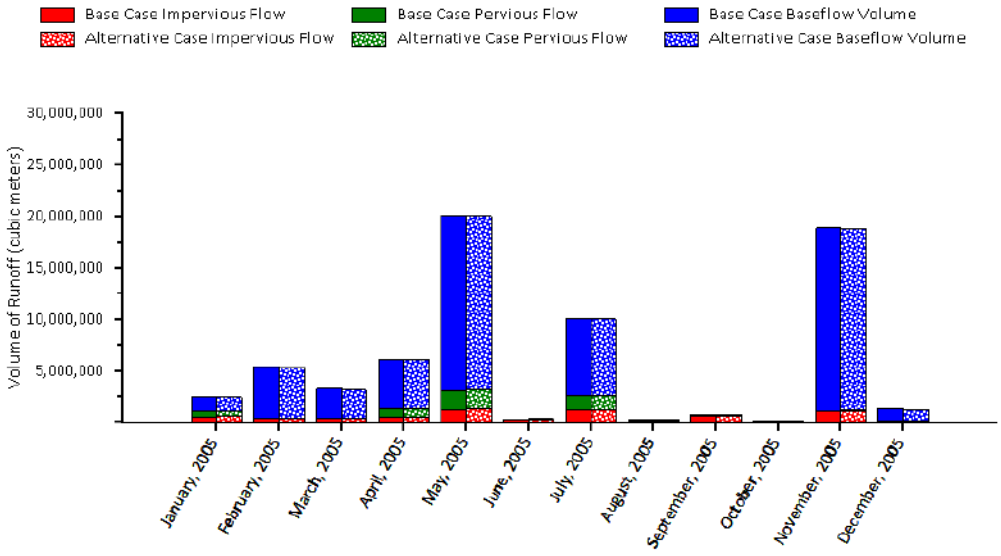
Water Volume: Observed Streamflow vs. Predicted Streamflow
(Predicted is 41% higher than Observed)



i-Tree Hydro Executive Summary

Project Location: Madison, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2005

Base Case vs. Alternative Case Predicted Streamflow Components

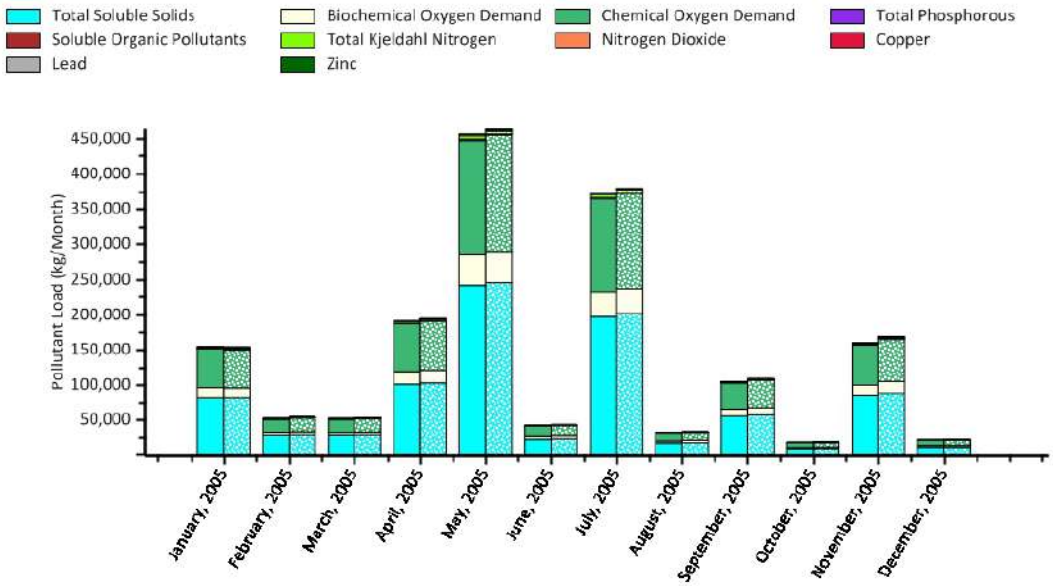


Note: Solid colors represent Base Case values while the hatched pattern indicates Alternative Case values

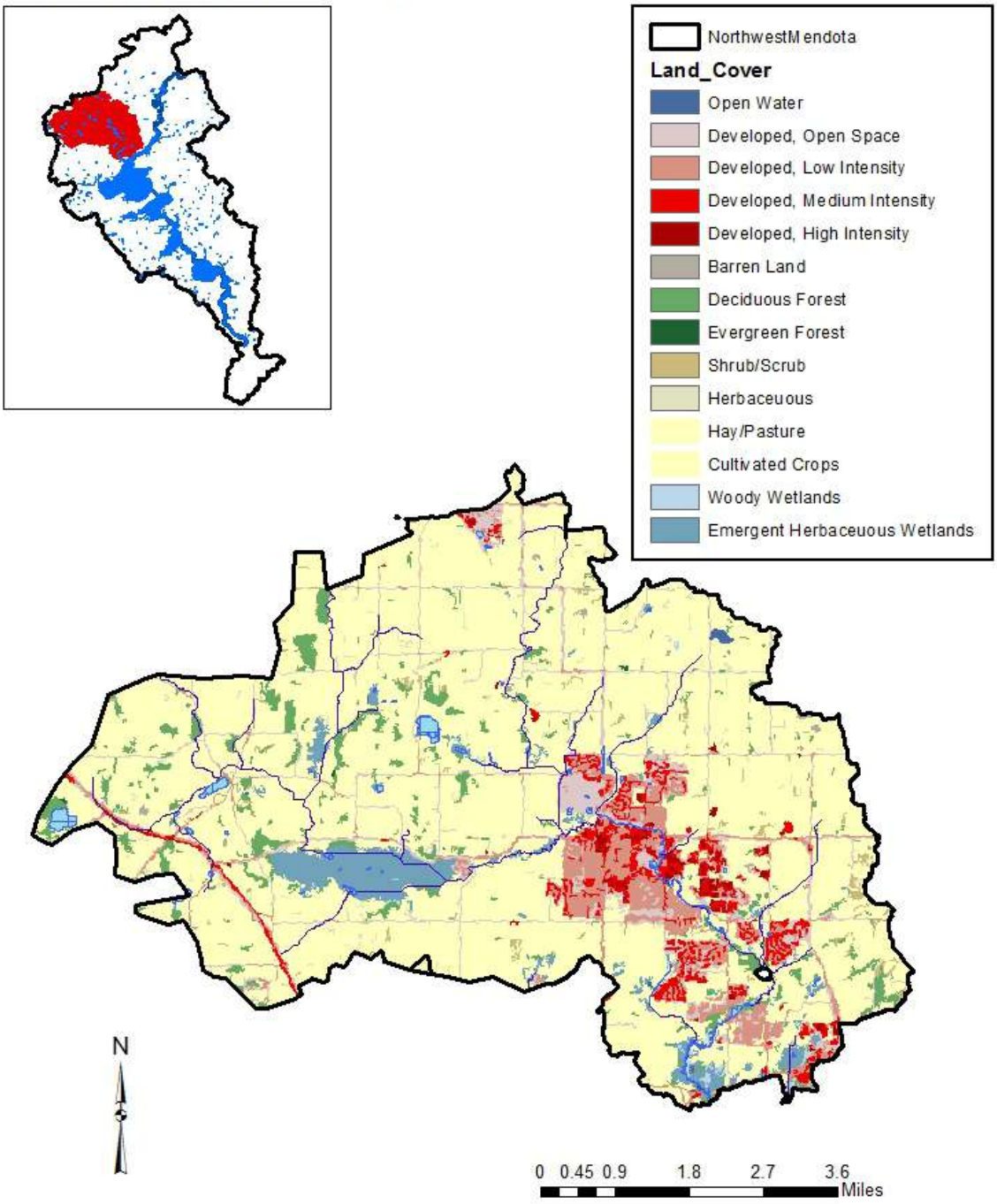
i-Tree Hydro Executive Summary

Project Location: Madison, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2005

Pollutants: Base Case vs. Alternative Case Event Mean Concentration



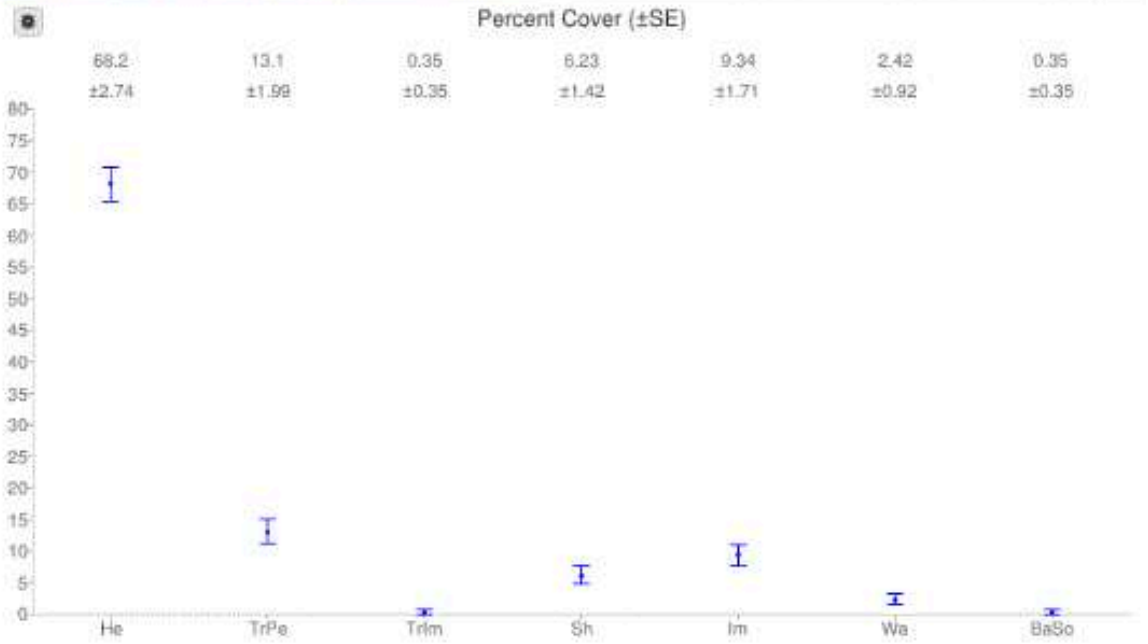
Northwest Mendota



i-Tree Canopy v6.1

Cover Assessment and Tree Benefits Report

Estimated using random sampling statistics on 10/17/16



Cover Class	Description	Abbr.	Points	% Cover
Herbaceous	Ag.,turf	He	197	68.2 ±2.74
Tree, Permeable	Tree, pervious underneath	TrPe	38	13.1 ±1.99
Tree, Impermeable	Tree, Impervious underneath	TrIm	1	0.35 ±0.35
Shrub	low veg	Sh	18	6.23 ±1.42
Impermeable	Paving, roof, gravel	Im	27	9.34 ±1.71
Water	Wetland, Surface	Wa	7	2.42 ±0.92
BareSoil	BareSoil	BaSo	1	0.35 ±0.35

Tree Benefit Estimates

Abbr.	Benefit Description	Value	±SE	Amount	±SE
CO	Carbon Monoxide removed annually	$42.08	±6.27	1.74 T	±0.26
NO2	Nitrogen Dioxide removed annually	$158.78	±23.65	13.66 T	±2.03
O3	Ozone removed annually	$5,726.26	±852.82	69.73 T	±10.38
PM2.5	Particulate Matter less than 2.5 microns removed annually	$10,633.21	±1,583.63	3.59 T	±0.53
SO2	Sulfur Dioxide removed annually	$8.29	±1.23	2.24 T	±0.33
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	$2,225.59	±331.46	19.57 T	±2.91
CO2seq	Carbon Dioxide sequestered annually in trees	$527,020.76	±78,490.39	14,574.95 T	±2,170.68
CO2stor	Carbon Dioxide stored in trees (M… hi… ef… ot… annual rate)	$1…	±2,682,627.24	498,139.31 T	±74,189.01

i-Tree Hydro Executive Summary

Project Location: Waunakee, Wisconsin
Project Time Span: 01/01/2005 - 01/30/2007

Model Parameters

Watershed Area	Rainfall	Total Runoff	Stream Gage	Weather Station
square kilometers	*millimeters*	*cubic meters*		
119.14	1,471.93	81,832,868.95	0	726410-14837

Land Cover	Base	Alternative		Base	Alternative	LC beneath Tree Cover	Base	Alternative
Tree Cover %	13.5	18.5	Tree LAI	5.0	5.0	Soil Cover %	95.0	95.0
Shrub Cover %	6.0	6.0	Shrub LAI	2.2	2.2	Impervious Cover %	5.0	5.0
Herbaceous Cover %	68.0	63.0	Herbaceous LAI	1.6	1.6			
Water Cover %	2.5	2.5	Directly Connected Impervious Cover (%)	40.0	40.0			
Impervious Cover %	9.8	9.8						
Soil Cover %	0.2	0.2						

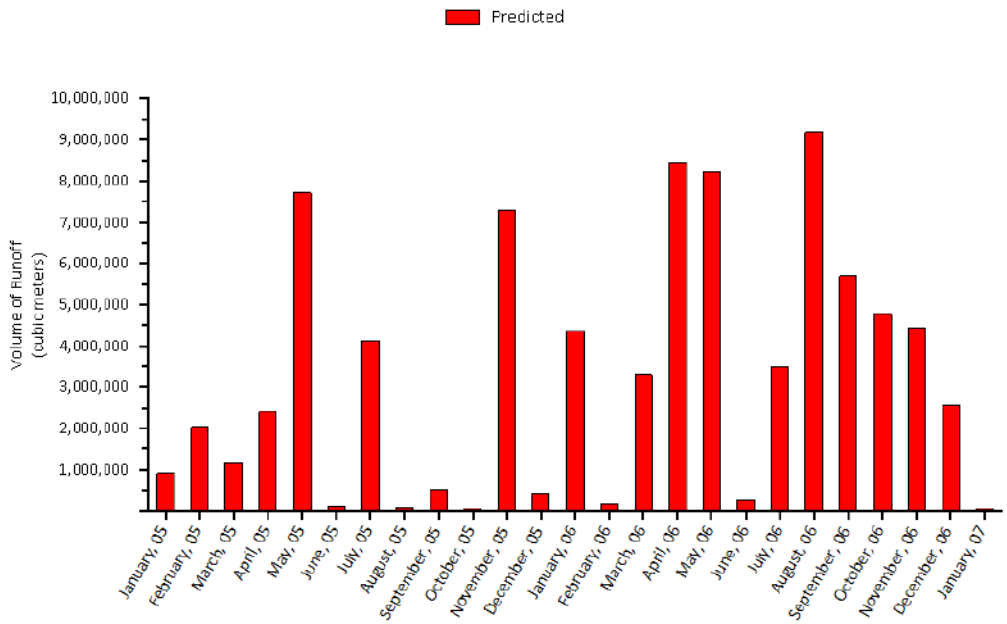
Streamflow Predictions

	Total Runoff		Baseflow		Pervious Flow		Impervious Flow	
	Base	Alternative	Base	Alternative	Base	Alternative	Base	Alternative
Total Flow (cubic meters)	81,832,869.0	81,298,293.2	67,207,959.3	66,599,427.7	7,540,657.6	7,500,852.1	7,084,254.6	7,198,011.0
Highest Flow (cubic meters / hour)	3,245,334.9	3,237,412.1	3,118,308.4	3,109,706.5	1,120,634.0	1,116,768.0	128,642.0	131,001.0
Lowest Flow (cubic meters / hour)	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Highest Flow Date	05/19/05	05/19/05	08/24/06	08/24/06	05/24/06	05/24/06	05/24/06	05/24/06
Lowest Flow Date	11/05/05	11/05/05	08/24/06	08/24/06	01/01/05	01/01/05	01/01/05	01/01/05
Median Flow (cubic meters / hour)	24.5	23.4	17.9	16.7	0.0	0.0	0.0	0.0
Number of flow events ABOVE median flow	123.0	127.0	25.0	25.0	13.0	13.0	85.0	85.0
Average length of flow events with flow ABOVE median (hours)	74.1	71.8	364.8	364.8	132.7	132.9	107.1	107.1
High Flow: Number of flow events ABOVE 1 standard deviation	25.0	25.0	20.0	20.0	12.0	12.0	71.0	71.0
Average length of flow events ABOVE 1 standard deviation (hours)	312.6	316.2	410.1	406.9	134.6	134.8	106.6	107.1
Number of flow events BELOW median flow	123.0	127.0	25.0	25.0	0.0	0.0	85.0	85.0
Average length of events BELOW median (hours)	74.3	72.0	358.7	359.0	0.0	0.0	107.3	107.3

i-Tree Hydro Executive Summary

Project Location: Waunakee, Wisconsin
Project Time Span: 01/01/2005 - 01/30/2007

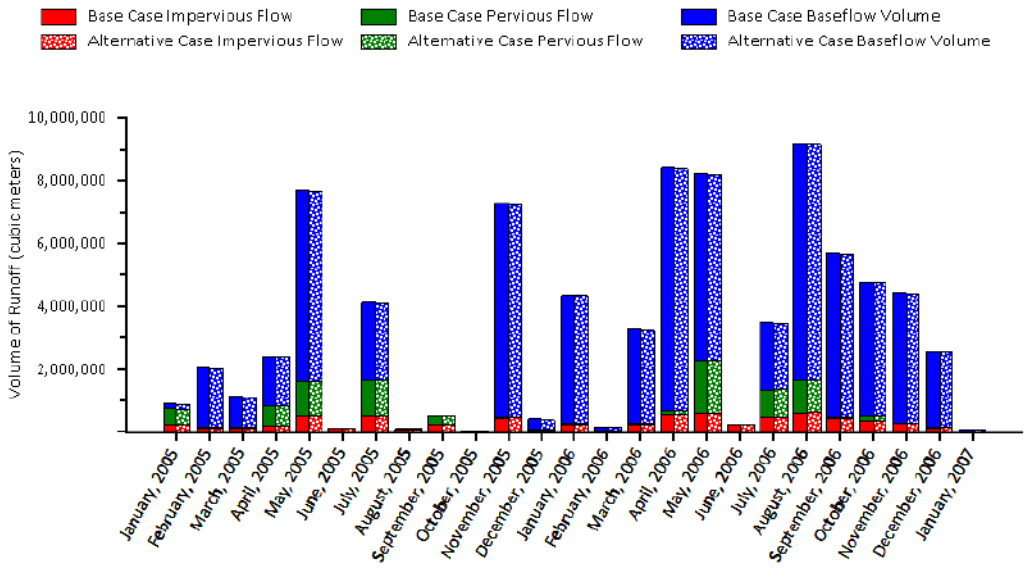
Water Volume: Predicted Streamflow



i-Tree Hydro Executive Summary

Project Location: Waunakee, Wisconsin
Project Time Span: 01/01/2005 - 01/30/2007

Base Case vs. Alternative Case Predicted Streamflow Components

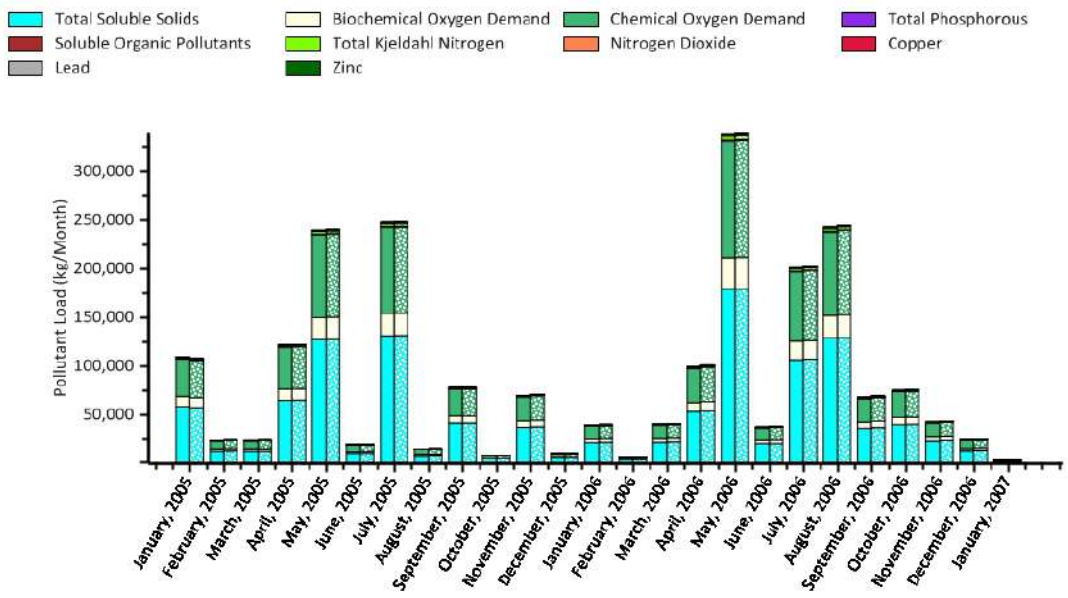


Note: Solid colors represent Base Case values while the hatched pattern indicates Alternative Case values

i-Tree Hydro Executive Summary

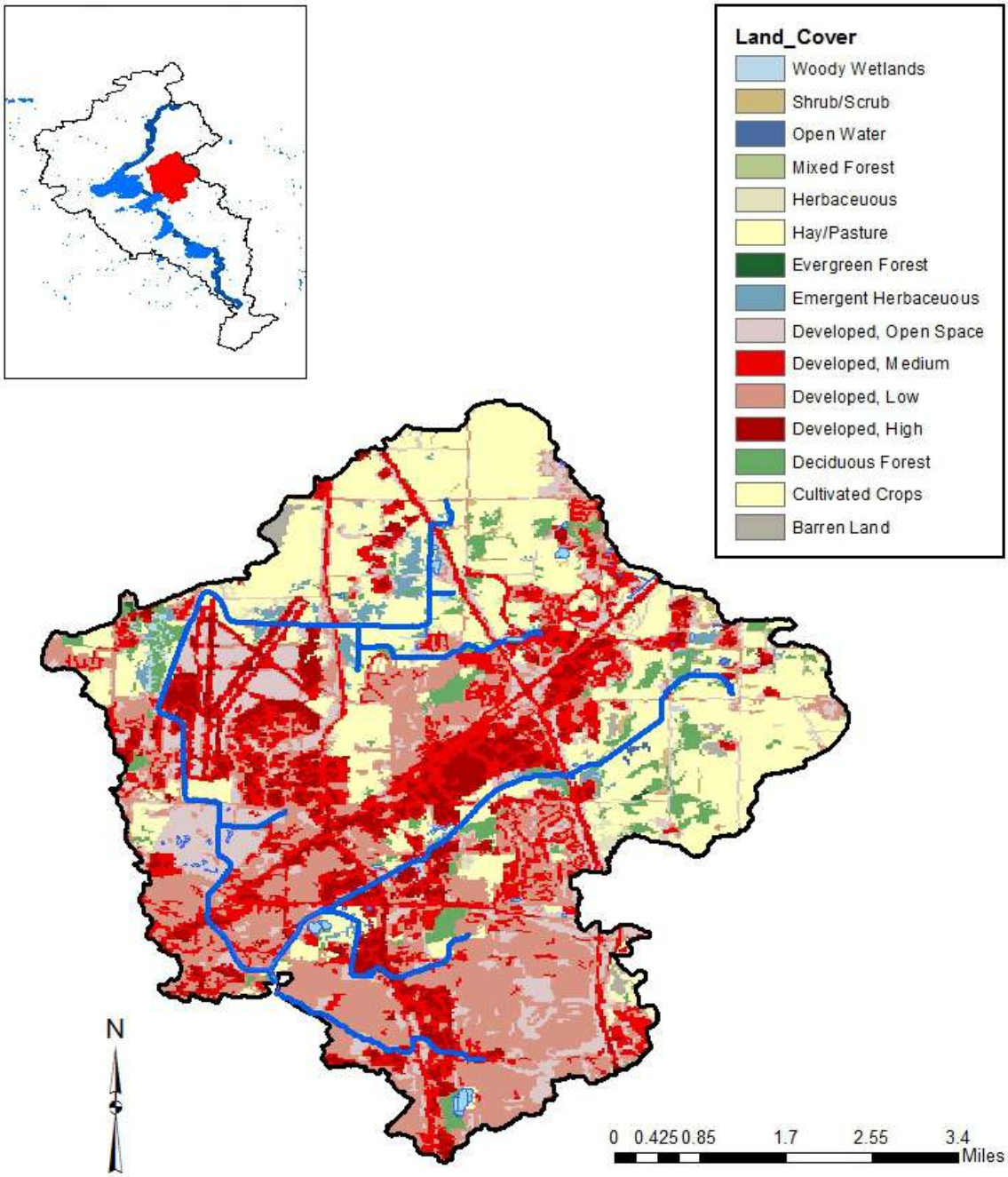
Project Location: Waunakee, Wisconsin
Project Time Span: 01/01/2005 - 01/30/2007

Pollutants: Base Case vs. Alternative Case Event Mean Concentration



Note: Solid colors represent Base Case values while the hatched pattern indicates Alternative Case values

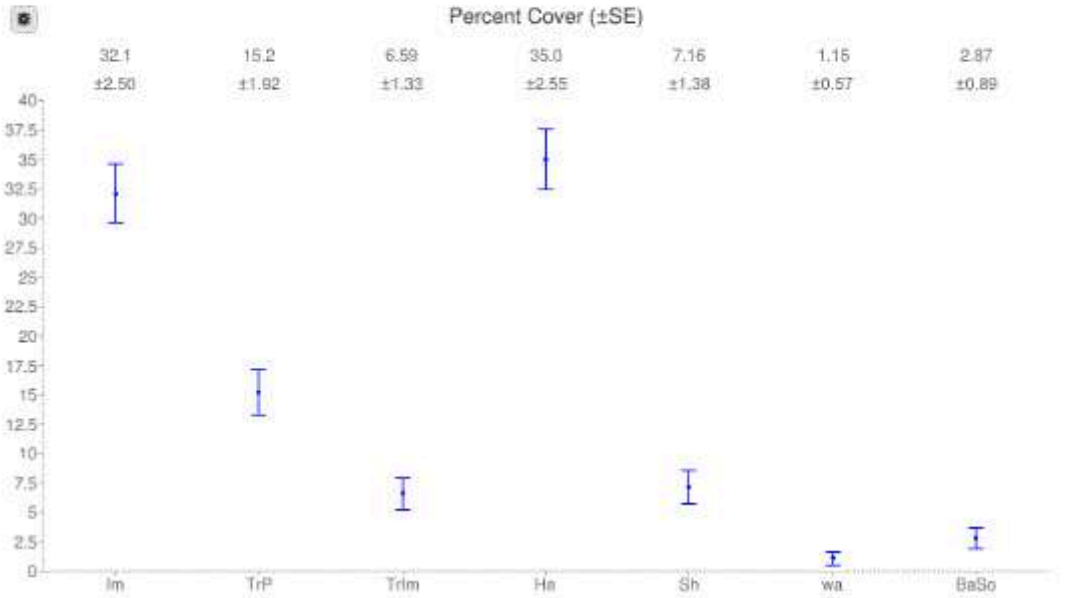
Starkweather Creek



i-Tree Canopy v6.1

Cover Assessment and Tree Benefits Report

Estimated using random sampling statistics on 10/17/16



Cover Class	Description	Abbr.	Points	% Cover
Impermeable	Paving, roof, gravel	Im	112	32.1 ±2.50
Tree, Permeable	Tree, pervious underneath	TrP	53	15.2 ±1.92
Tree Impermeable	Tree, impervious underneath	Trim	23	6.59 ±1.33
Herbaceous	Ag.,turf	He	122	35.0 ±2.55
Shrub	Short Veg	Sh	25	7.16 ±1.38
Water	Surface Water, wetland	wa	4	1.15 ±0.57
BareSoil		BaSo	10	2.87 ±0.89

Tree Benefit Estimates

Abbr.	Benefit Description	Value	±SE	Amount	±SE
CO	Carbon Monoxide removed annually	$724.10	±73.46	1,089.85 lb	±110.57
NO2	Nitrogen Dioxide removed annually	$4,245.93	±430.76	11.11 T	±1.13
O3	Ozone removed annually	$120,292.73	±12,203.97	56.89 T	±5.77
PM2.5	Particulate Matter less than 2.5 microns removed annually	$311,023.86	±31,554.08	3.90 T	±0.40
SO2	Sulfur Dioxide removed annually	$234.70	±23.81	1.83 T	±0.19
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	$97,724.93	±9,914.42	15.65 T	±1.59
CO2seq	Carbon Dioxide sequestered annually in trees	$437,636.59	±44,399.23	12,103.00 T	±1,227.88
CO2stor	Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)	$14,957,446.46	±1,517,467.05	413,653.52 T	±41,966.09

i-Tree Hydro Executive Summary

Project Location: Madison, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2007

Model Parameters

Watershed Area	Rainfall	Total Runoff	Stream Gage	Weather Station
square kilometers	*millimeters*	*cubic meters*		
62.16	2,529.08	85,118,760.90	0	726410-14837

Land Cover	Base	Alternative		Base	Alternative	LC beneath Tree Cover	Base	Alternative
Tree Cover %	21.5	26.5	Tree LAI	5.0	5.0	Soil Cover %	70.0	70.0
Shrub Cover %	7.0	7.0	Shrub LAI	2.2	2.2	Impervious Cover %	30.0	30.0
Herbaceous Cover %	35.0	30.0	Herbaceous LAI	1.6	1.6			
Water Cover %	1.0	1.0						
Impervious Cover %	32.5	32.5	Directly Connected Impervious Cover (%)	40.0	40.0			
Soil Cover %	3.0	3.0						

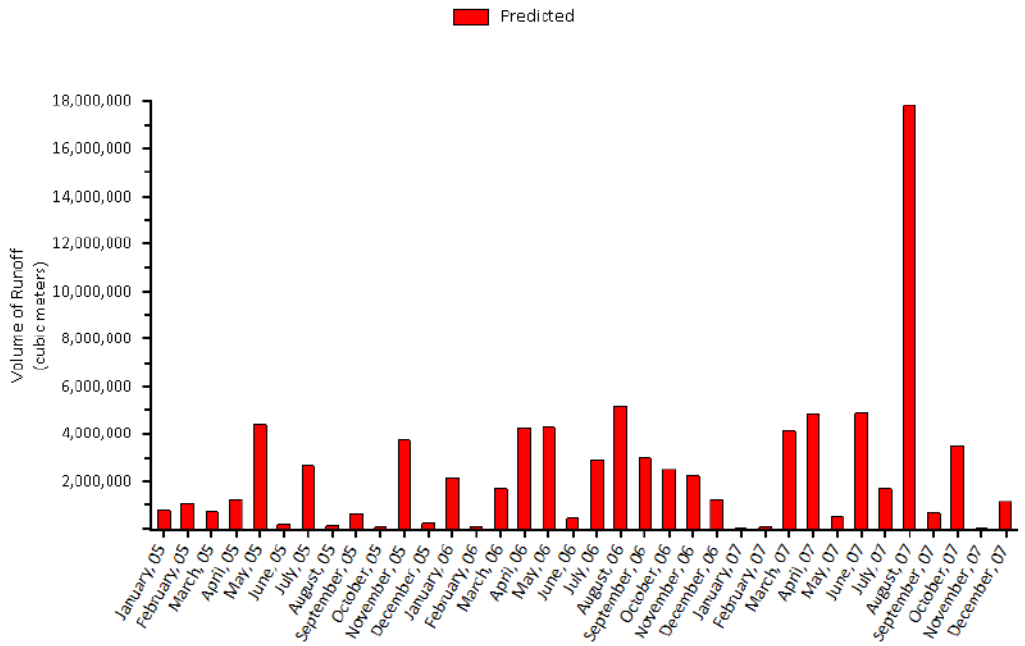
Streamflow Predictions

	Total Runoff		Baseflow		Pervious Flow		Impervious Flow	
	Base	Alternative	Base	Alternative	Base	Alternative	Base	Alternative
Total Flow (cubic meters)	85,118,760.9	84,321,455.6	58,396,463.0	57,041,160.0	6,902,759.0	6,810,871.1	19,819,542.0	20,469,423.7
Highest Flow (cubic meters / hour)	2,499,603.7	2,464,253.5	1,548,168.5	1,518,400.2	833,108.0	820,396.3	332,351.2	344,749.0
Lowest Flow (cubic meters / hour)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Highest Flow Date	06/03/07	06/03/07	05/19/05	05/19/05	08/22/07	08/22/07	08/22/07	08/22/07
Lowest Flow Date	07/27/06	07/27/06	07/27/06	07/27/06	01/01/05	01/01/05	01/01/05	01/01/05
Median Flow (cubic meters / hour)	9.7	8.9	6.7	6.1	0.0	0.0	0.0	0.0
Number of flow events ABOVE median flow	170.0	168.0	48.0	48.0	19.0	19.0	115.0	115.0
Average length of flow events with flow ABOVE median (hours)	76.2	77.1	274.4	274.4	129.6	129.6	112.3	112.3
High Flow: Number of flow events ABOVE 1 standard deviation	43.0	44.0	43.0	43.0	15.0	15.0	90.0	89.0
Average length of flow events ABOVE 1 standard deviation (hours)	256.4	248.5	283.4	282.6	134.7	134.8	116.2	116.8
Number of flow events BELOW median flow	169.0	167.0	47.0	47.0	0.0	0.0	115.0	115.0
Average length of events BELOW median (hours)	77.7	78.6	279.3	279.3	0.0	0.0	114.2	114.2

i-Tree Hydro Executive Summary

Project Location: Madison, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2007

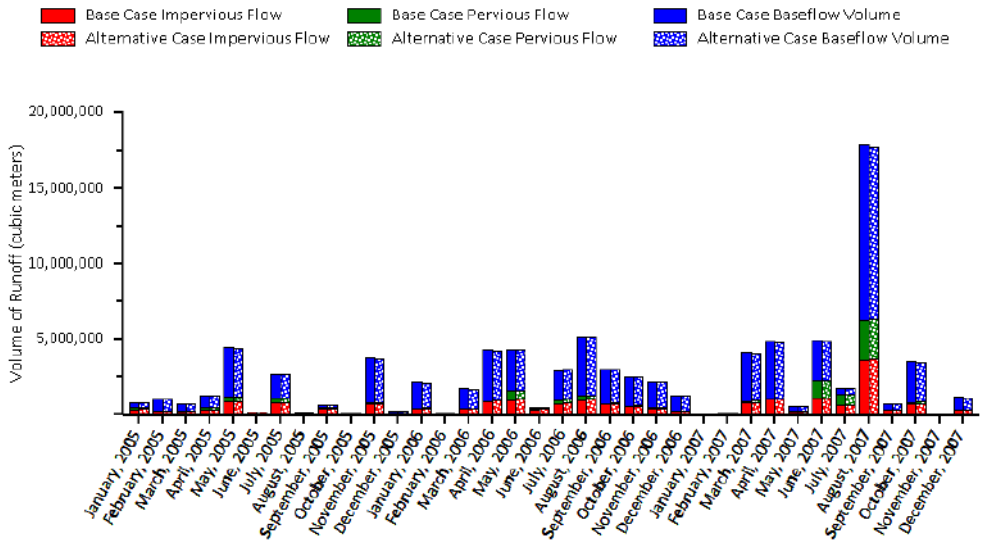
Water Volume: Predicted Streamflow



i-Tree Hydro Executive Summary

Project Location: Madison, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2007

Base Case vs. Alternative Case Predicted Streamflow Components

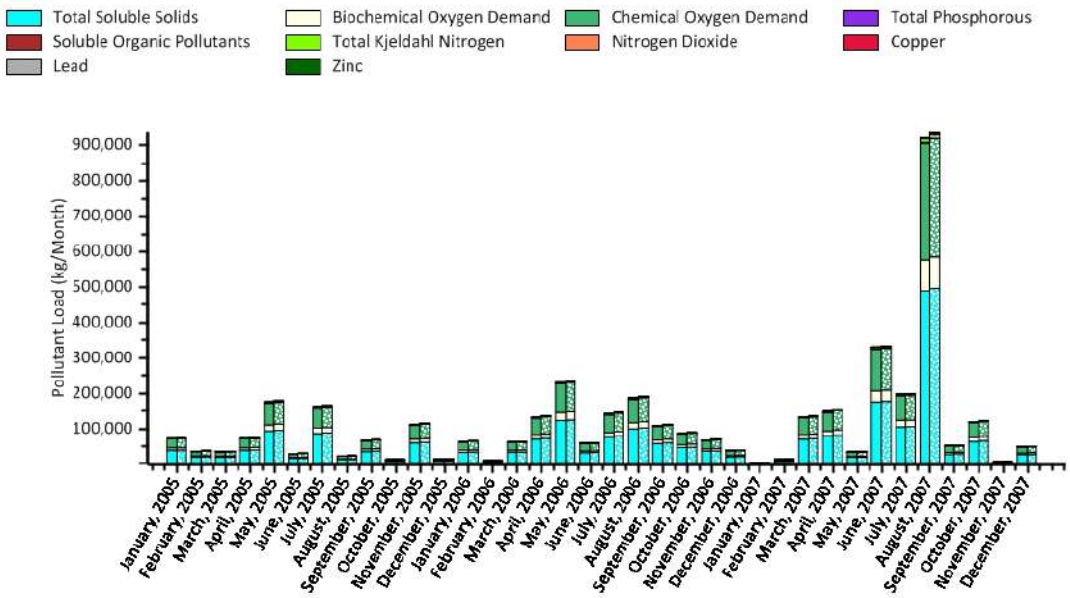


Note: Solid colors represent Base Case values while the hatched pattern indicates Alternative Case values

i-Tree Hydro Executive Summary

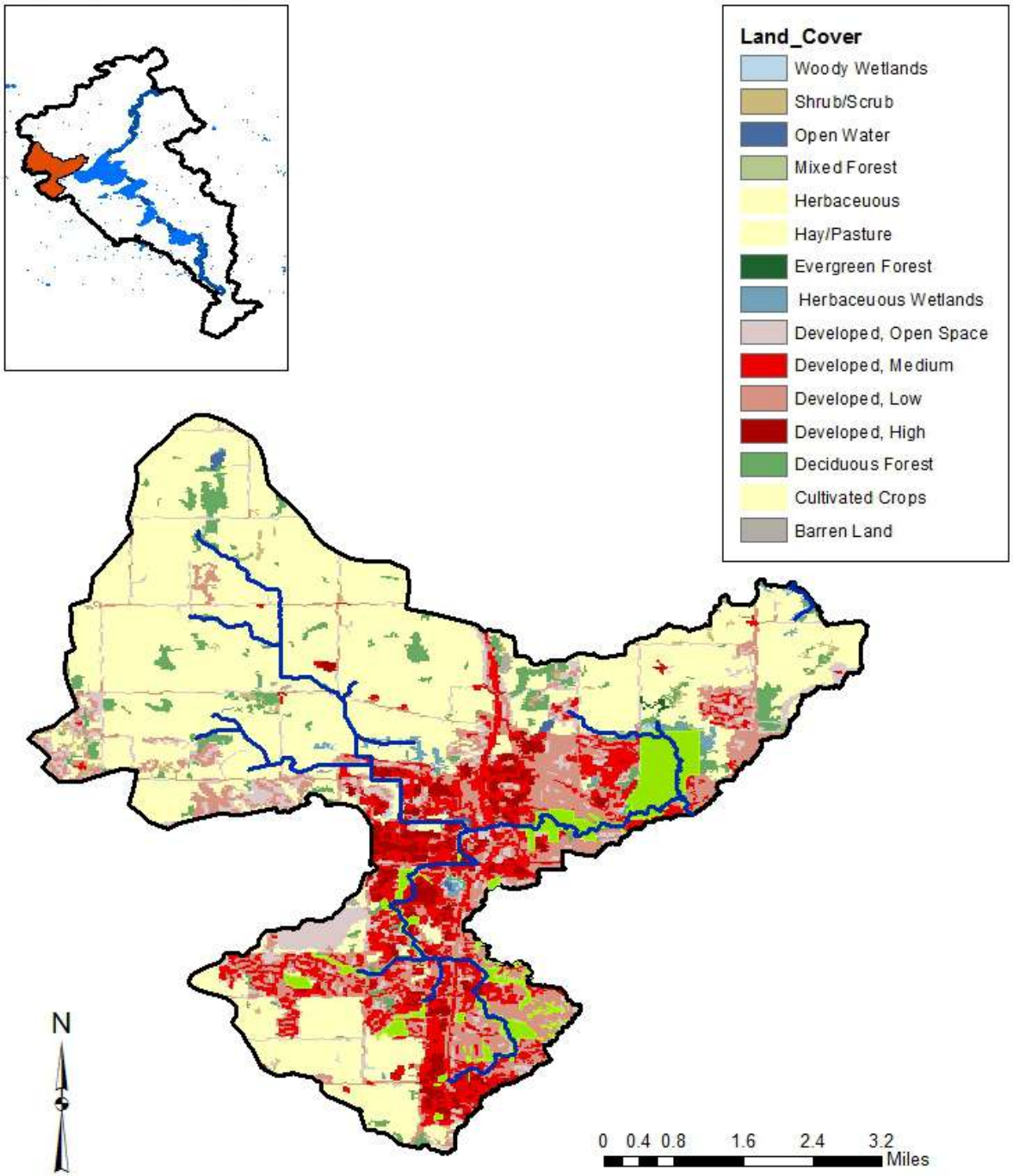
Project Location: Madison, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2007

Pollutants: Base Case vs. Alternative Case Event Mean Concentration



Note: Solid colors represent Base Case values while the hatched pattern indicates Alternative Case values

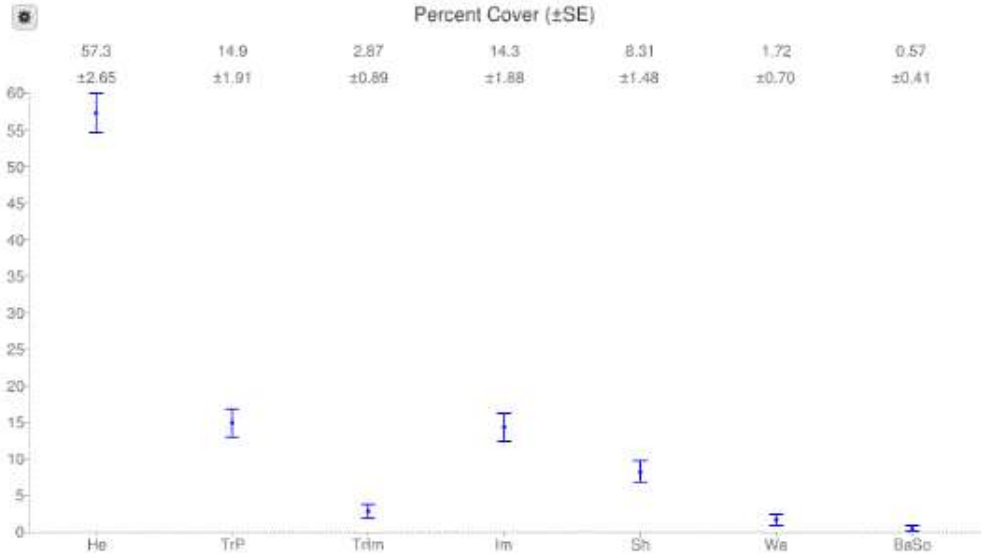
Pheasant Branch



i-Tree Canopy v6.1

Cover Assessment and Tree Benefits Report

Estimated using random sampling statistics on 10/19/16



Cover Class	Description	Abbr.	Points	% Cover
Herbaceous	Ag.,turf	He	200	57.3 ±2.65
Tree,Permeable	Tree, pervious underneath	TrP	52	14.9 ±1.91
Tree, Impermeable	Tree, impervious underneath	Trim	10	2.87 ±0.89
Impermeable	Paving, roof, gravel	Im	50	14.3 ±1.88
Shrub	short veg.	Sh	29	8.31 ±1.48
Water	surface water, wetland	Wa	6	1.72 ±0.70
Bare Soil	Bare Soil	BaSo	2	0.57 ±0.41

Tree Benefit Estimates

Abbr.	Benefit Description	Value	±SE	Amount	±SE
CO	Carbon Monoxide removed annually	$118.82	±13.68	1.11 T	±0.13
NO2	Nitrogen Dioxide removed annually	$644.25	±74.20	9.59 T	±1.10
O3	Ozone removed annually	$18,984.69	±2,186.43	48.95 T	±5.64
PM2.5	Particulate Matter less than 2.5 microns removed annually	$46,597.41	±5,366.54	2.64 T	±0.30
SO2	Sulfur Dioxide removed annually	$35.32	±4.07	1.57 T	±0.18
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	$13,975.80	±1,609.57	13.70 T	±1.58
CO2seq	Carbon Dioxide sequestered annually in trees	$370,985.34	±42,725.70	10,259.73 T	±1,181.59
CO2stor	Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)	$12,679,454.86	±1,460,269.36	350,654.85 T	±40,384.27

i-Tree Hydro Executive Summary

Project Location: Middleton, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2007

Model Parameters

Watershed Area	Rainfall	Total Runoff	Stream Gage	Weather Station
square kilometers	*millimeters*	*cubic meters*		
67.34	2,529.08	91,086,547.10	0	726410-14837

Land Cover	Base	Alternative		Base	Alternative	LC beneath Tree Cover	Base	Alternative
Tree Cover %	18.0	23.0	Tree LAI	5.0	5.0	Soil Cover %	83.0	83.0
Shrub Cover %	8.0	8.0	Shrub LAI	2.2	2.2	Impervious Cover %	17.0	17.0
Herbaceous Cover %	58.0	53.0	Herbaceous LAI	1.6	1.6			
Water Cover %	1.5	1.5						
Impervious Cover %	14.0	14.0	Directly Connected Impervious Cover (%)	40.0	40.0			
Soil Cover %	0.5	0.5						

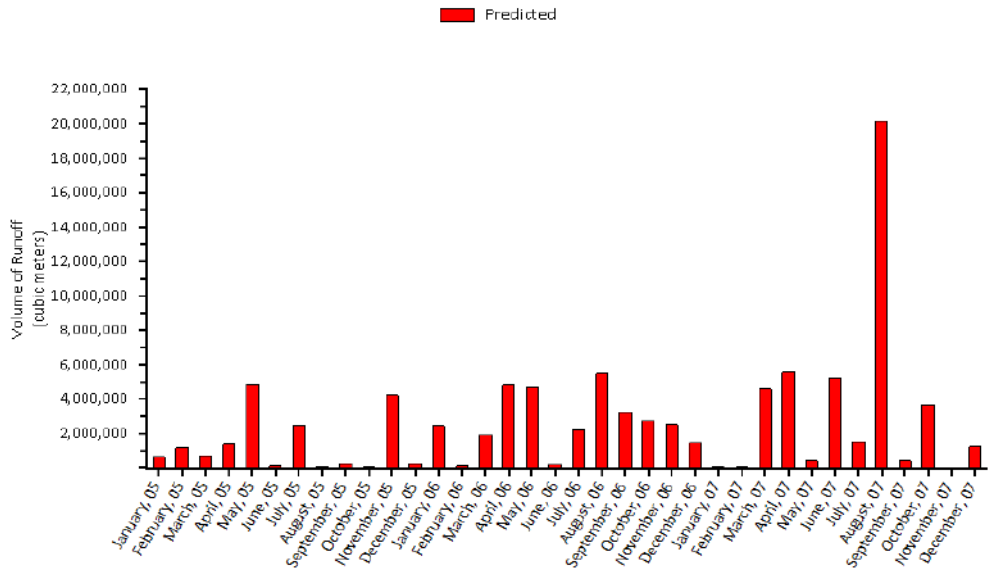
Streamflow Predictions

	Total Runoff		Baseflow		Pervious Flow		Impervious Flow	
	Base	Alternative	Base	Alternative	Base	Alternative	Base	Alternative
Total Flow (cubic meters)	91,086,547.1	90,659,881.6	73,010,070.9	72,211,603.5	8,092,598.9	8,061,722.4	9,983,862.7	10,386,555.4
Highest Flow (cubic meters / hour)	2,877,189.3	2,852,388.1	1,926,595.3	1,912,400.1	1,044,384.7	1,040,216.4	167,267.8	174,878.5
Lowest Flow (cubic meters / hour)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Highest Flow Date	06/03/07	06/03/07	05/19/05	05/19/05	08/22/07	08/22/07	08/22/07	08/22/07
Lowest Flow Date	07/27/06	07/27/06	07/27/06	07/27/06	01/01/05	01/01/05	01/01/05	01/01/05
Median Flow (cubic meters / hour)	14.9	14.4	11.0	10.4	0.0	0.0	0.0	0.0
Number of flow events ABOVE median flow	177.0	177.0	47.0	46.0	18.0	18.0	115.0	115.0
Average length of flow events with flow ABOVE median (hours)	73.2	73.2	280.3	286.6	124.3	124.3	112.3	112.3
High Flow: Number of flow events ABOVE 1 standard deviation	39.0	39.0	41.0	40.0	15.0	15.0	89.0	89.0
Average length of flow events ABOVE 1 standard deviation (hours)	277.9	279.8	294.1	301.0	127.2	127.1	116.8	116.8
Number of flow events BELOW median flow	176.0	176.0	46.0	45.0	0.0	0.0	115.0	115.0
Average length of events BELOW median (hours)	74.6	74.6	285.4	291.7	0.0	0.0	114.2	114.2

i-Tree Hydro Executive Summary

Project Location: Middleton, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2007

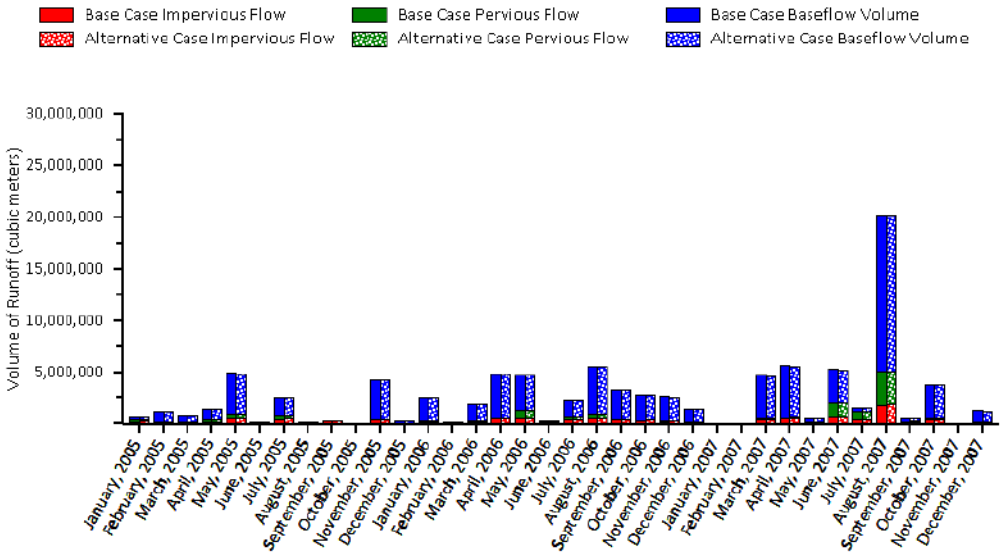
Water Volume: Predicted Streamflow



i-Tree Hydro Executive Summary

Project Location: Middleton, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2007

Base Case vs. Alternative Case Predicted Streamflow Components

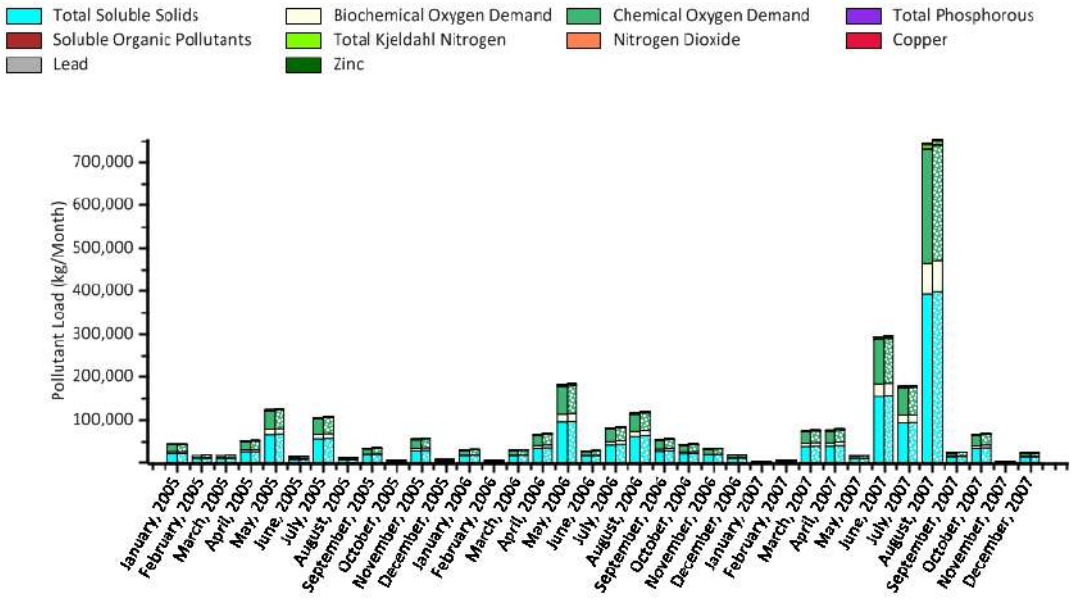


Note: Solid colors represent Base Case values while the hatched pattern indicates Alternative Case values

i-Tree Hydro Executive Summary

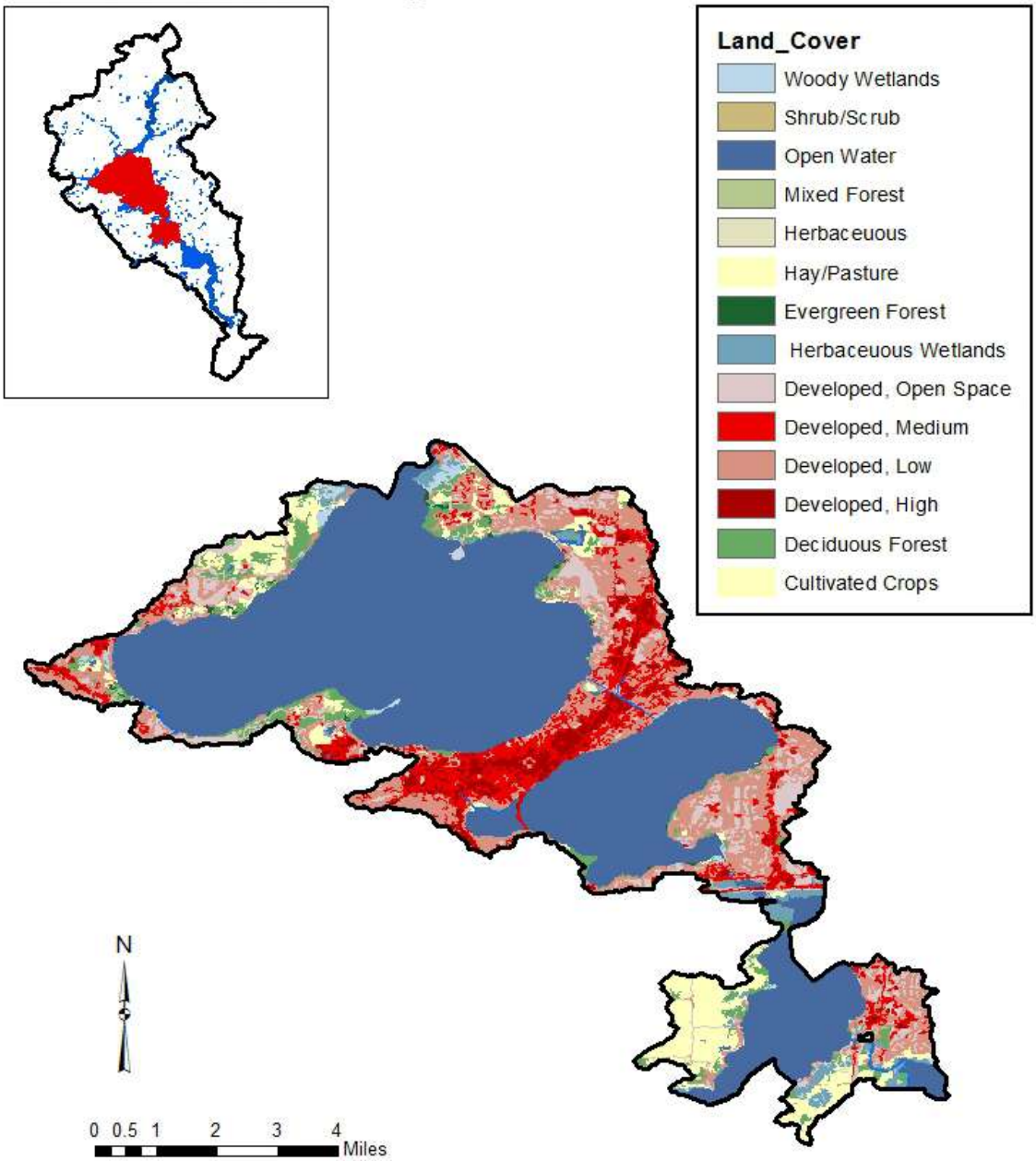
Project Location: Middleton, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2007

Pollutants: Base Case vs. Alternative Case Event Mean Concentration



Note: Solid colors represent Base Case values while the hatched pattern indicates Alternative Case values

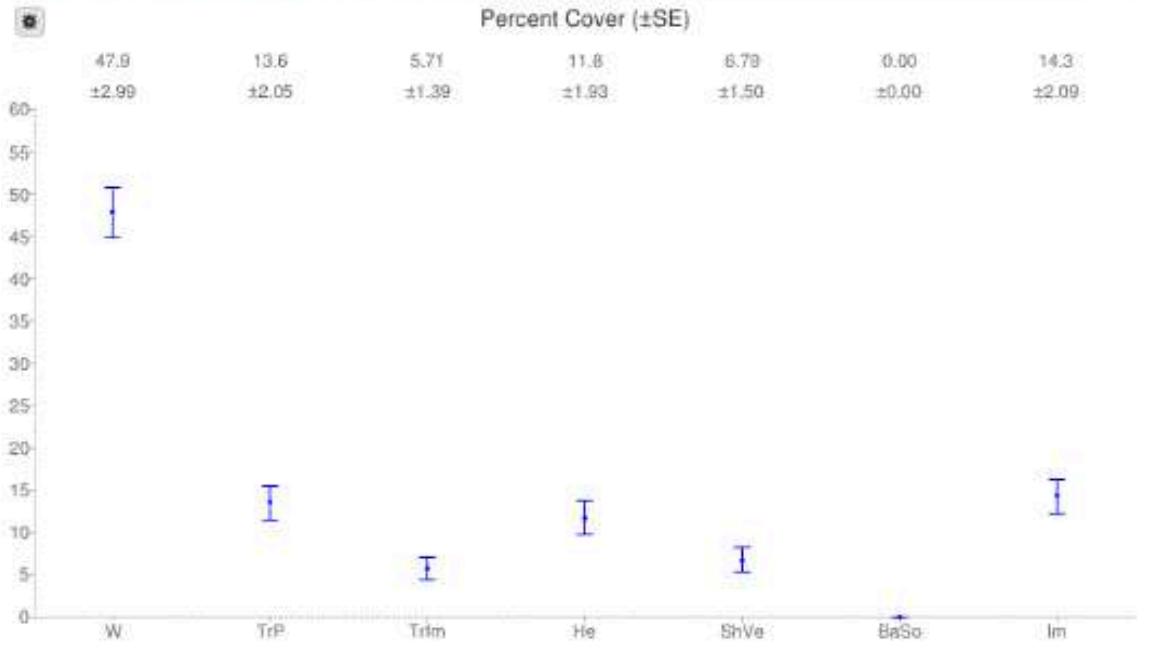
Direct Lake Drainage



i-Tree Canopy v6.1

Cover Assessment and Tree Benefits Report

Estimated using random sampling statistics on 11/02/16



Cover Class	Description	Abbr.	Points	% Cover
Water	surface and wetland	W	134	47.9 ±2.99
Tree, Permeable	Tree, pervious underneath	TrP	38	13.6 ±2.05
Tree, Impermeable	Tree, impervious underneath	Trlm	16	5.71 ±1.39
Herbaceous	Ag.,turf	He	33	11.8 ±1.93
Short Vegetation	shrub, emergent	ShVe	19	6.79 ±1.50
Bare Soil	bare soil	BaSo	0	0.00 ±0.00
Impermeable	Roof, pave, gravel	Im	40	14.3 ±2.09

Tree Benefit Estimates

Abbr.	Benefit Description	Value	±SE	Amount	±SE
CO	Carbon Monoxide removed annually	$238.82	±28.95	2.21 T	±0.27
NO2	Nitrogen Dioxide removed annually	$1,284.09	±156.99	19.11 T	±2.34
O3	Ozone removed annually	$37,839.41	±4,626.18	97.57 T	±11.93
PM2.5	Particulate Matter less than 2.5 microns removed annually	$92,875.82	±11,354.84	5.27 T	±0.64
SO2	Sulfur Dioxide removed annually	$70.40	±8.61	3.13 T	±0.38
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	$27,855.93	±3,405.62	27.30 T	±3.34
CO2seq	Carbon Dioxide sequestered annually in trees	$739,431.02	±90,401.57	20,449.23 T	±2,500.09
CO2stor	Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)	$25,272,109.66	±3,089,724.96	698,909.21 T	±85,447.45

i-Tree Hydro Executive Summary

Project Location: Madison, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2007

Model Parameters

Watershed Area	Rainfall	Total Runoff	Stream Gage	Weather Station
square kilometers	*millimeters*	*cubic meters*		
45.00	2,529.08	56,273,779.42	0	726410-14837

Land Cover	Base	Alternative		Base	Alternative	LC beneath Tree Cover	Base	Alternative
Tree Cover %	20.0	25.0	Tree LAI	5.0	5.0	Soil Cover %	70.0	70.0
Shrub Cover %	6.0	4.0	Shrub LAI	2.2	2.2	Impervious Cover %	30.0	30.0
Herbaceous Cover %	12.0	9.0	Herbaceous LAI	1.6	1.6			
Water Cover %	48.0	48.0						
Impervious Cover %	14.0	14.0	Directly Connected Impervious Cover (%)	40.0	40.0			
Soil Cover %	0.0	0.0						

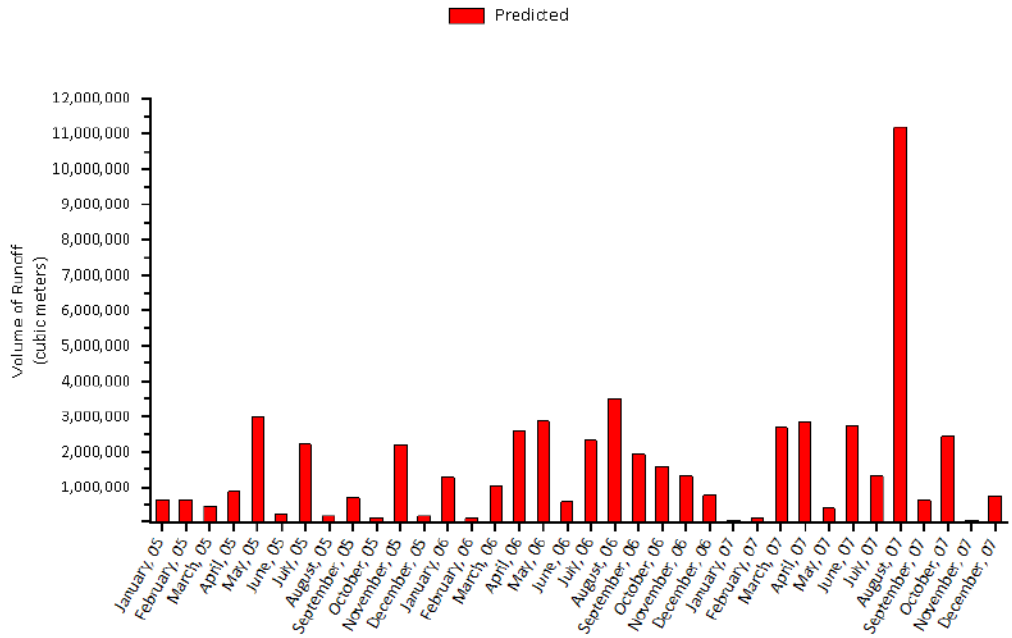
Streamflow Predictions

	Total Runoff		Baseflow		Pervious Flow		Impervious Flow	
	Base	Alternative	Base	Alternative	Base	Alternative	Base	Alternative
Total Flow (cubic meters)	56,273,779.4	55,166,846.0	28,243,704.6	26,802,565.7	3,352,255.5	3,220,911.9	24,677,824.8	25,143,366.6
Highest Flow (cubic meters / hour)	1,243,858.5	1,202,949.0	933,358.5	893,169.0	383,136.8	368,136.0	409,768.7	418,743.9
Lowest Flow (cubic meters / hour)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Highest Flow Date	05/19/05	05/19/05	05/19/05	05/19/05	08/22/07	08/22/07	08/22/07	08/22/07
Lowest Flow Date	08/04/07	08/04/07	08/04/07	08/04/07	01/01/05	01/01/05	01/01/05	01/01/05
Median Flow (cubic meters / hour)	2.1	2.0	1.3	1.2	0.0	0.0	0.0	0.0
Number of flow events ABOVE median flow	160.0	159.0	64.0	63.0	20.0	20.0	117.0	116.0
Average length of flow events with flow ABOVE median (hours)	81.0	81.5	204.7	208.1	132.9	133.0	110.4	111.3
High Flow: Number of flow events ABOVE 1 standard deviation	60.0	60.0	57.0	56.0	18.0	18.0	90.0	90.0
Average length of flow events ABOVE 1 standard deviation (hours)	197.9	197.9	197.0	200.3	132.8	132.9	115.0	115.5
Number of flow events BELOW median flow	159.0	158.0	63.0	62.0	0.0	0.0	117.0	116.0
Average length of events BELOW median (hours)	82.6	83.1	208.4	211.7	0.0	0.0	112.2	113.2

i-Tree Hydro Executive Summary

Project Location: Madison, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2007

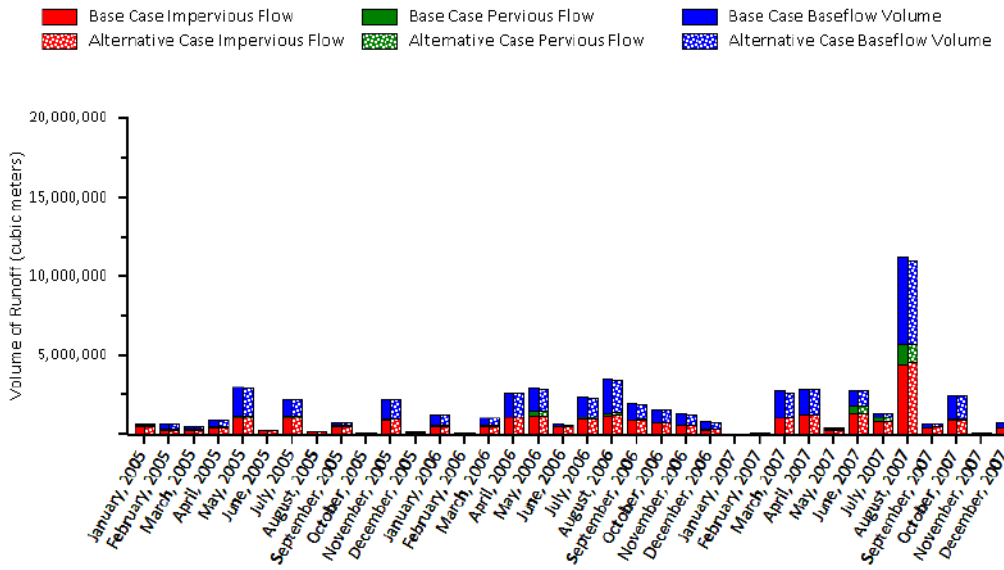
Water Volume: Predicted Streamflow



i-Tree Hydro Executive Summary

Project Location: Madison, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2007

Base Case vs. Alternative Case Predicted Streamflow Components

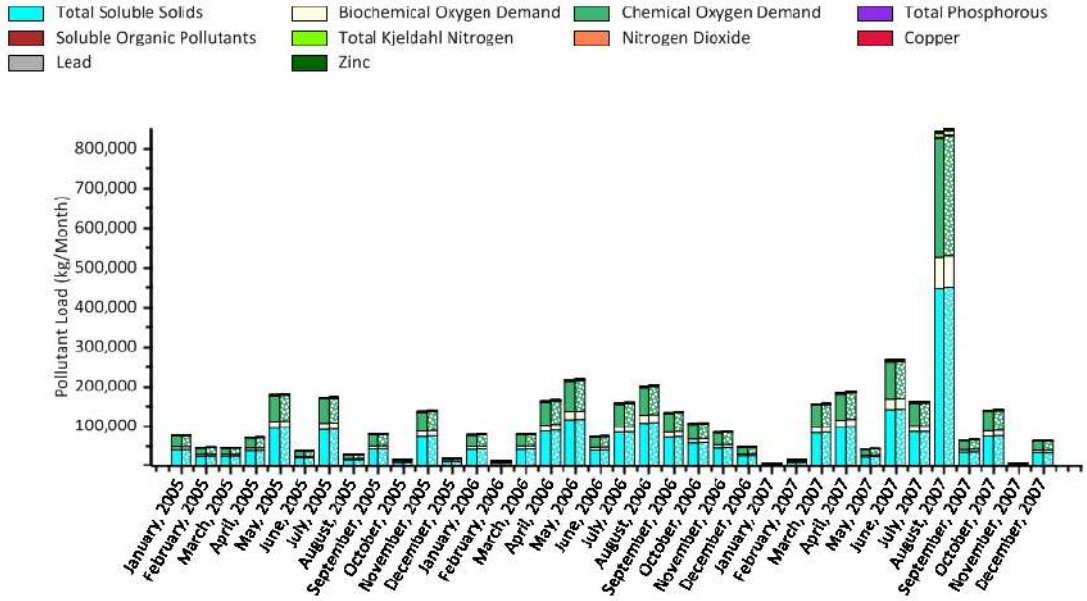


Note: Solid colors represent Base Case values while the hatched pattern indicates Alternative Case values

i-Tree Hydro Executive Summary

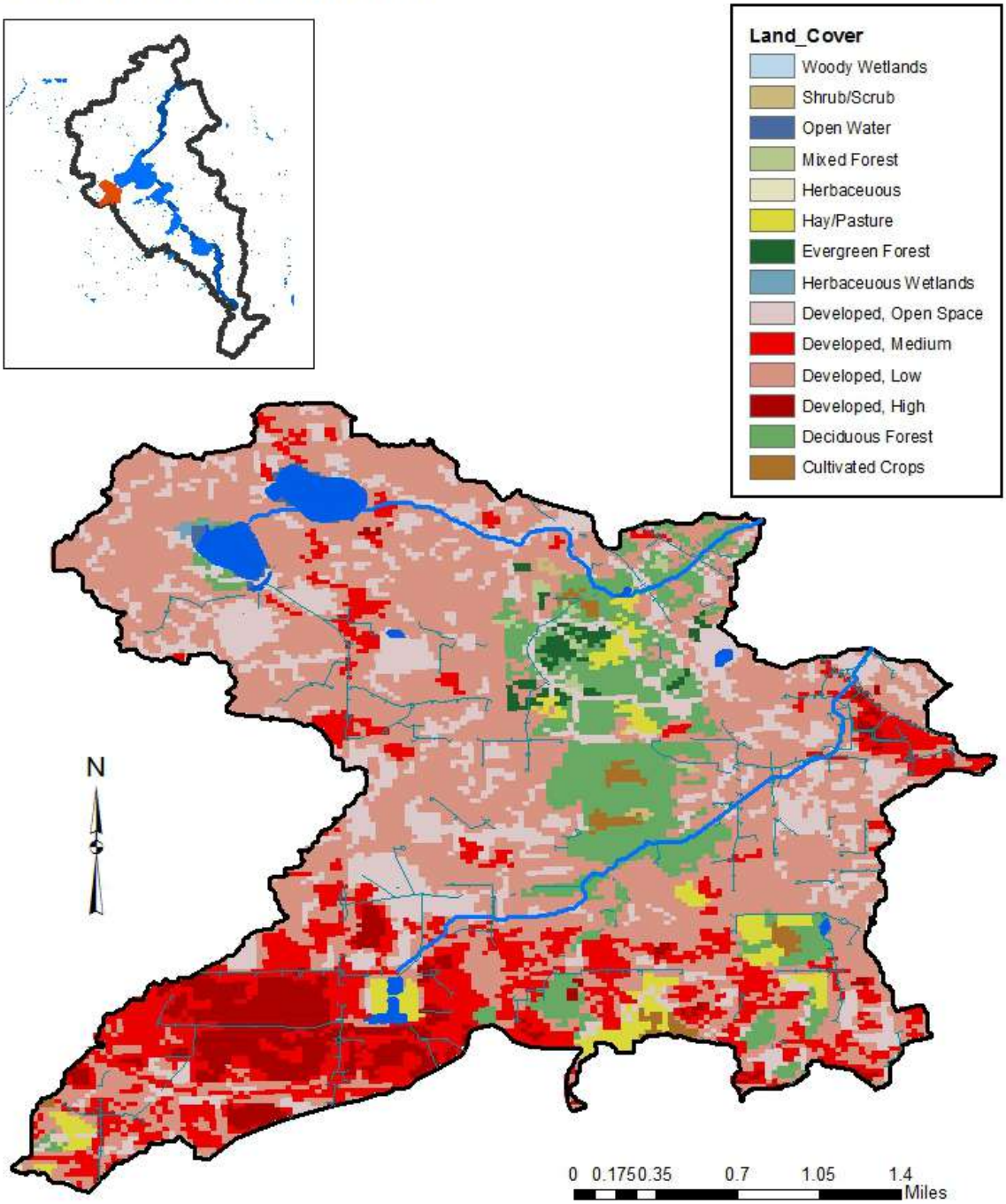
Project Location: Madison, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2007

Pollutants: Base Case vs. Alternative Case Event Mean Concentration



Note: Solid colors represent Base Case values while the hatched pattern indicates Alternative Case values

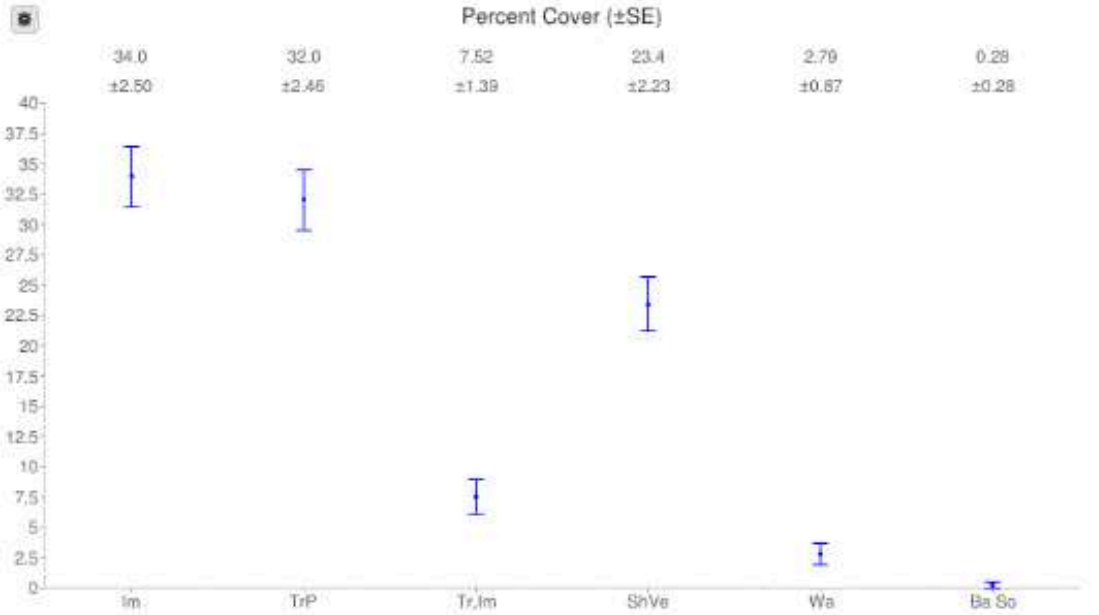
Southwest Mendota



i-Tree Canopy v6.1

Cover Assessment and Tree Benefits Report

Estimated using random sampling statistics on 10/17/16



Cover Class	Description	Abbr.	Points	% Cover
Impermeable	Roof, pave, gravel	Im	122	34.0 ±2.50
Tree, Permeable	Tree, pervious underneath	TrP	115	32.0 ±2.46
Tree, Impermeable	Tree, impermeable underneath	Tr,Im	27	7.52 ±1.39
Short Vegetation	turf,ag	ShVe	84	23.4 ±2.23
Water	surface, wetland	Wa	10	2.79 ±0.87
Bare Soil	Bare Soil	Ba So	1	0.28 ±0.28

Tree Benefit Estimates

Abbr.	Benefit Description	Value	±SE	Amount	±SE
CO	Carbon Monoxide removed annually	$310.44	±20.25	467.25 lb	±30.49
NO2	Nitrogen Dioxide removed annually	$1,820.34	±118.77	4.76 T	±0.31
O3	Ozone removed annually	$51,572.69	±3,364.79	24.39 T	±1.59
PM2.5	Particulate Matter less than 2.5 microns removed annually	$133,344.19	±8,699.87	1.67 T	±0.11
SO2	Sulfur Dioxide removed annually	$100.62	±6.56	1,568.63 lb	±102.34
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	$41,897.27	±2,733.53	6.71 T	±0.44
CO2seq	Carbon Dioxide sequestered annually in trees	$187,626.43	±12,241.44	5,188.88 T	±338.54
CO2stor	Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)	$6,412,654.45	±418,385.20	177,344.25 T	±11,570.59

i-Tree Hydro Executive Summary

Project Location: Madison, Wisconsin
Project Time Span: 01/01/2005 - 01/28/2007

Model Parameters

Watershed Area	Rainfall	Total Runoff	Stream Gage	Weather Station
square kilometers	*millimeters*	*cubic meters*		
15.54	1,468.63	10,628,396.10	0	726410-14837

Land Cover	Base	Alternative		Base	Alternative	LC beneath Tree Cover	Base	Alternative
Tree Cover %	39.5	45.0	Tree LAI	5.0	5.0	Soil Cover %	81.0	81.0
Shrub Cover %	8.0	8.0	Shrub LAI	2.2	2.2	Impervious Cover %	19.0	19.0
Herbaceous Cover %	15.0	9.5	Herbaceous LAI	1.6	1.6			
Water Cover %	2.8	2.8						
Impervious Cover %	34.0	34.0	Directly Connected Impervious Cover (%)	40.0	40.0			
Soil Cover %	0.7	0.7						

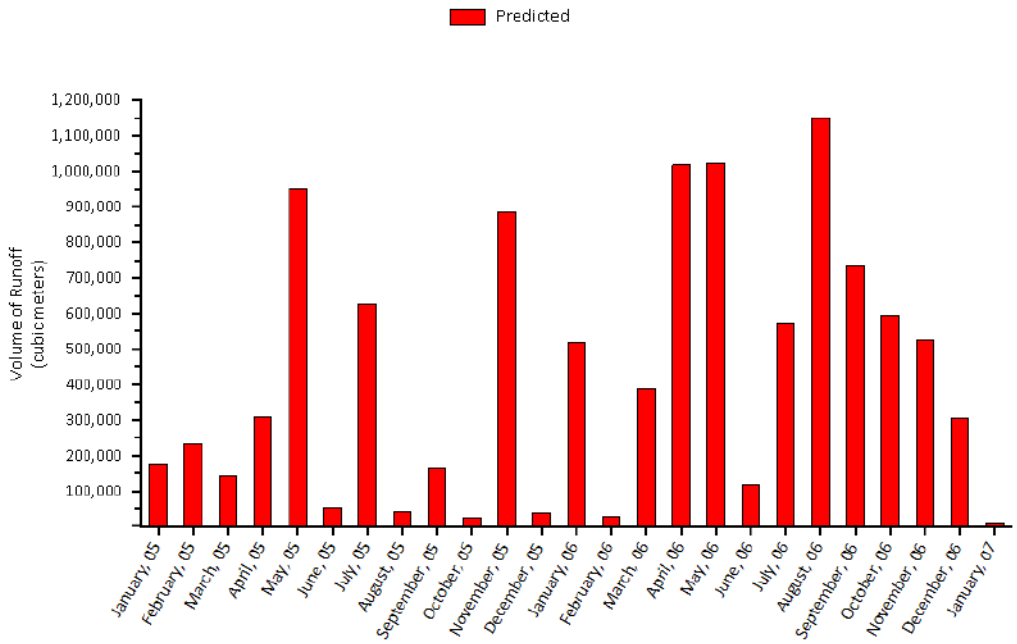
Streamflow Predictions

	Total Runoff		Baseflow		Pervious Flow		Impervious Flow	
	Base	Alternative	Base	Alternative	Base	Alternative	Base	Alternative
Total Flow (cubic meters)	10,628,396.1	10,535,039.4	6,672,946.6	6,543,162.7	868,659.3	843,391.4	3,086,792.5	3,148,486.4
Highest Flow (cubic meters / hour)	352,137.9	348,403.6	295,490.2	290,954.1	113,623.6	111,812.1	56,952.8	58,238.8
Lowest Flow (cubic meters / hour)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Highest Flow Date	05/19/05	05/19/05	08/24/06	08/24/06	05/24/06	05/24/06	05/24/06	05/24/06
Lowest Flow Date	07/21/05	07/21/05	08/24/06	08/24/06	01/01/05	01/01/05	01/01/05	01/01/05
Median Flow (cubic meters / hour)	2.4	2.3	1.7	1.6	0.0	0.0	0.0	0.0
Number of flow events ABOVE median flow	117.0	117.0	26.0	26.0	15.0	16.0	82.0	82.0
Average length of flow events with flow ABOVE median (hours)	77.7	77.7	349.8	349.8	130.0	128.8	111.3	111.3
High Flow: Number of flow events ABOVE 1 standard deviation	34.0	34.0	23.0	22.0	13.0	13.0	67.0	65.0
Average length of flow events ABOVE 1 standard deviation (hours)	228.8	229.4	371.1	378.2	133.1	133.2	111.5	112.9
Number of flow events BELOW median flow	117.0	117.0	26.0	26.0	0.0	0.0	82.0	82.0
Average length of events BELOW median (hours)	78.4	78.4	345.0	345.0	0.0	0.0	110.9	110.9

i-Tree Hydro Executive Summary

Project Location: Madison, Wisconsin
Project Time Span: 01/01/2005 - 01/28/2007

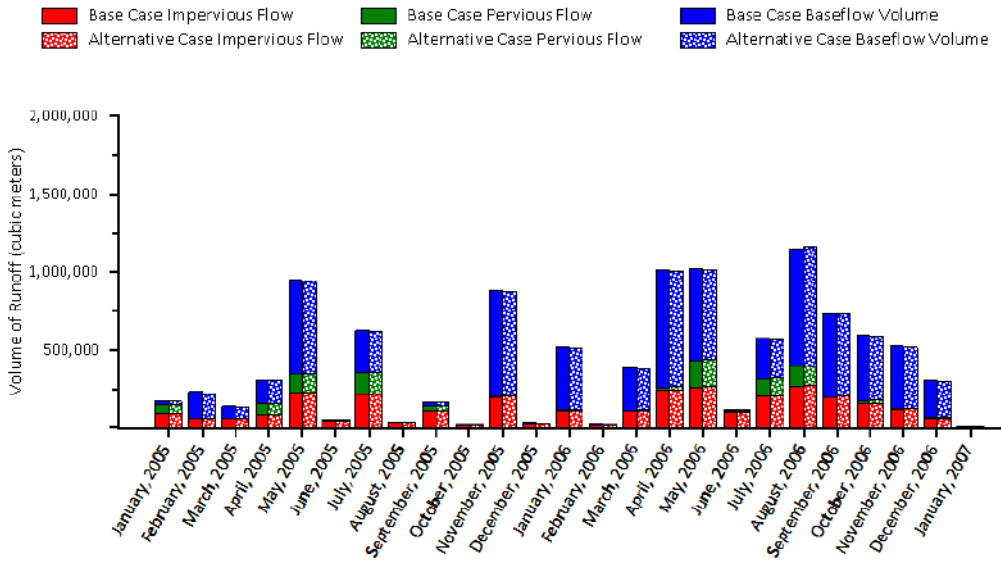
Water Volume: Predicted Streamflow



i-Tree Hydro Executive Summary

Project Location: Madison, Wisconsin
Project Time Span: 01/01/2005 - 01/28/2007

Base Case vs. Alternative Case Predicted Streamflow Components

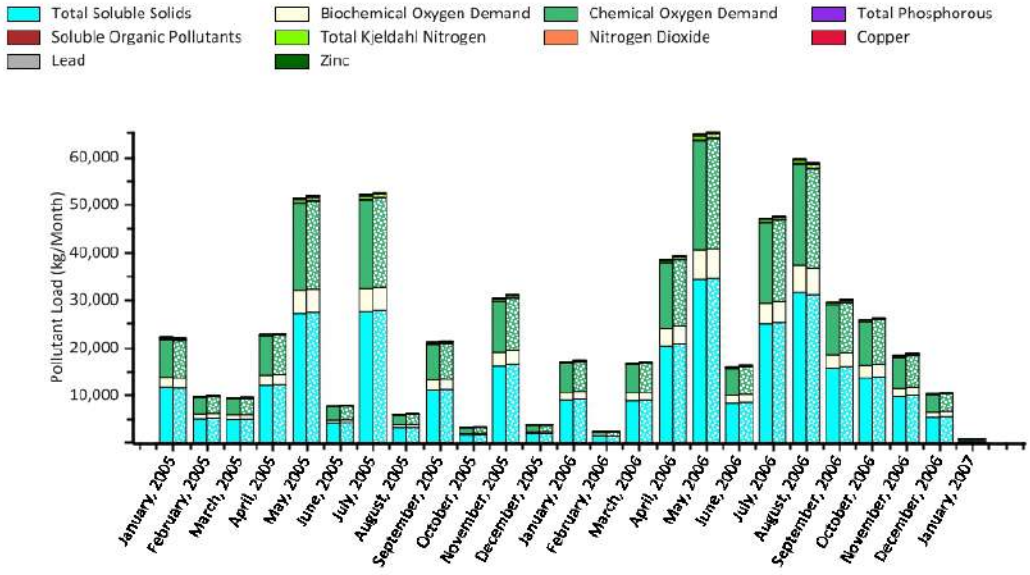


Note: Solid colors represent Base Case values while the hatched pattern indicates Alternative Case values

i-Tree Hydro Executive Summary

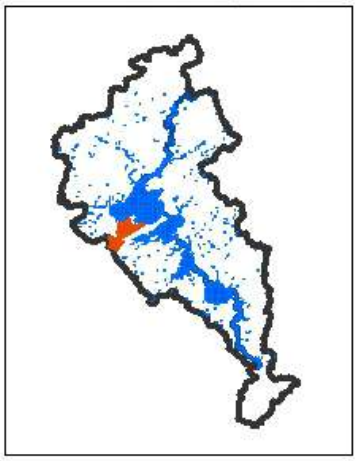
Project Location: Madison, Wisconsin
Project Time Span: 01/01/2005 - 01/28/2007

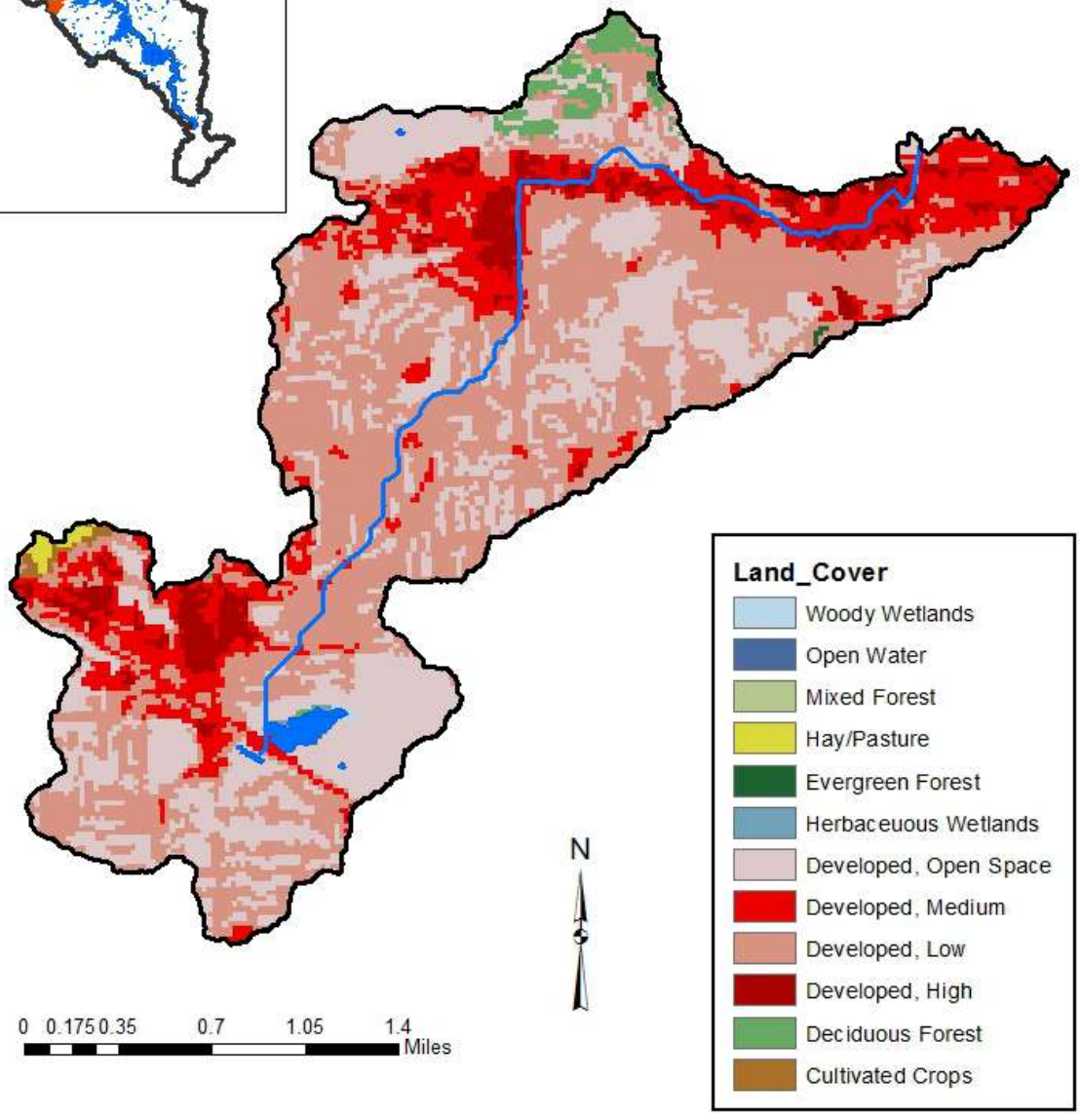
Pollutants: Base Case vs. Alternative Case Event Mean Concentration



Note: Solid colors represent Base Case values while the hatched pattern indicates Alternative Case values

University Ave. Willow Creek

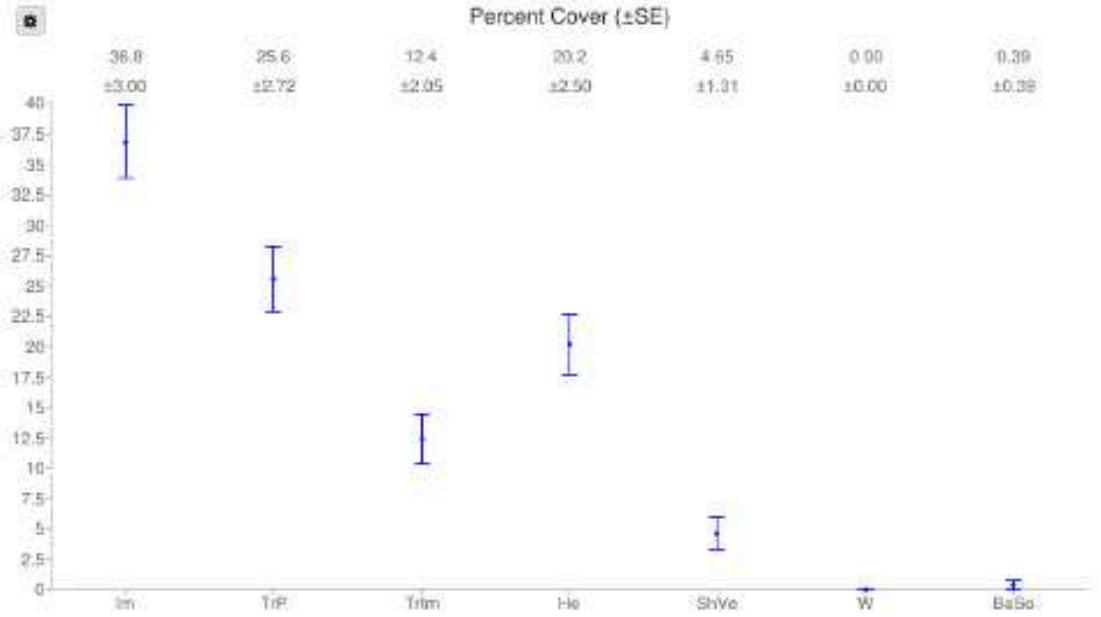




i-Tree Canopy v6.1

Cover Assessment and Tree Benefits Report

Estimated using random sampling statistics on 11/02/16



Cover Class	Description	Abbr.	Points	% Cover
Impermeable	Roof, pave, gravel	Im	95	36.8 ±3.00
Tree, Permeable	Tree, pervious underneath	TrP	66	25.6 ±2.72
Tree, Impermeable	Tree, impervious underneath	Trim	32	12.4 ±2.05
Herbaceous	Ag.,turf	He	52	20.2 ±2.50
Short Vegetation	shrub, emergent	ShVe	12	4.65 ±1.31
Water	surface and wetland	W	0	0.00 ±0.00
Bare Soil	Bare Soil	BaSo	1	0.39 ±0.39

Tree Benefit Estimates

Abbr.	Benefit Description	Value	±SE	Amount	±SE
CO	Carbon Monoxide removed annually	$259.42	±20.64	390.46 lb	±31.06
NO2	Nitrogen Dioxide removed annually	$1,521.20	±121.01	3.98 T	±0.32
O3	Ozone removed annually	$43,097.57	±3,428.39	20.38 T	±1.62
PM2.5	Particulate Matter less than 2.5 microns removed annually	$111,431.27	±8,864.29	1.40 T	±0.11
SO2	Sulfur Dioxide removed annually	$84.09	±6.69	1,310.86 lb	±104.26
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	$35,012.15	±2,785.20	5.61 T	±0.45
CO2seq	Carbon Dioxide sequestered annually in trees	$156,793.12	±12,472.80	4,336.17 T	±344.94
CO2stor	Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)	$5,356,840.61	±426,292.74	148,200.65 T	±11,789.28

i-Tree Hydro Executive Summary

Project Location: Madison, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2008

Model Parameters

Watershed Area	Rainfall	Total Runoff	Stream Gage	Weather Station
square kilometers	*millimeters*	*cubic meters*		
5.00	3,590.29	9,683,525.70	0	726410-14837

Land Cover	Base	Alternative		Base	Alternative	LC beneath Tree Cover	Base	Alternative
Tree Cover %	38.0	43.0	Tree LAI	5.0	5.0	Soil Cover %	70.0	70.0
Shrub Cover %	5.0	5.0	Shrub LAI	2.2	2.2	Impervious Cover %	30.0	30.0
Herbaceous Cover %	20.0	15.0	Herbaceous LAI	1.6	1.6			
Water Cover %	0.0	0.0						
Impervious Cover %	37.0	37.0	Directly Connected Impervious Cover (%)	40.0	40.0			
Soil Cover %	0.0	0.0						

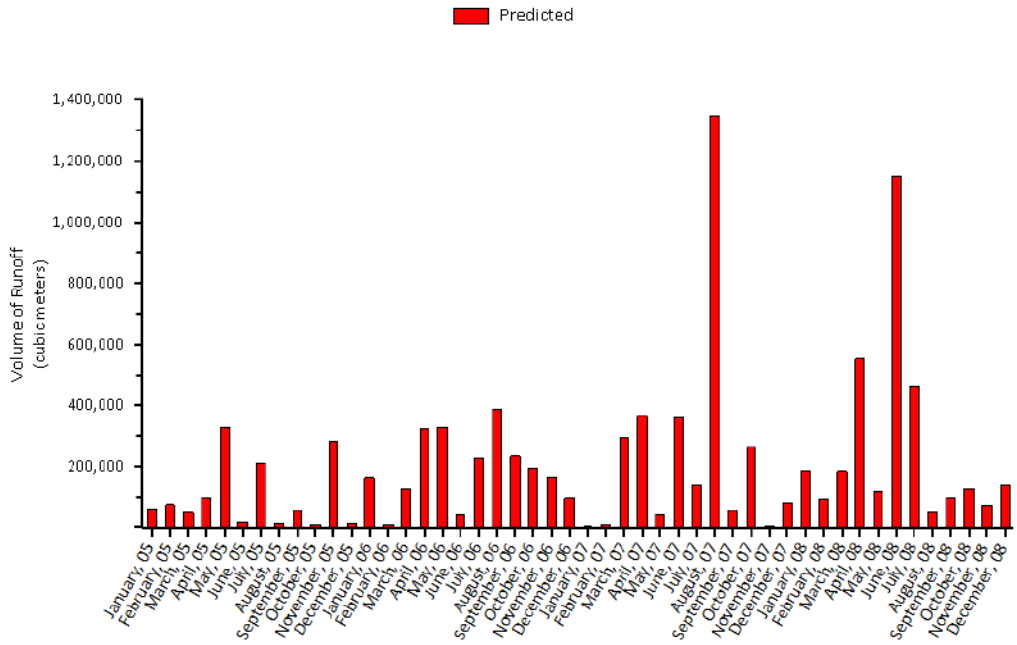
Streamflow Predictions

	Total Runoff		Baseflow		Pervious Flow		Impervious Flow	
	Base	Alternative	Base	Alternative	Base	Alternative	Base	Alternative
Total Flow (cubic meters)	9,683,525.7	9,550,107.0	6,137,689.4	5,943,756.4	787,482.0	774,019.5	2,758,354.3	2,832,331.3
Highest Flow (cubic meters / hour)	172,342.0	169,587.0	133,940.5	131,037.0	60,886.0	59,668.5	32,369.6	33,366.9
Lowest Flow (cubic meters / hour)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Highest Flow Date	06/07/08	06/07/08	06/07/08	06/07/08	08/22/07	08/22/07	08/22/07	08/22/07
Lowest Flow Date	07/27/06	07/27/06	07/27/06	07/27/06	01/01/05	01/01/05	01/01/05	01/01/05
Median Flow (cubic meters / hour)	0.9	0.9	0.6	0.6	0.0	0.0	0.0	0.0
Number of flow events ABOVE median flow	233.0	231.0	79.0	79.0	30.0	30.0	160.0	158.0
Average length of flow events with flow ABOVE median (hours)	75.0	75.7	223.3	223.3	131.4	131.4	108.2	109.6
High Flow: Number of flow events ABOVE 1 standard deviation	68.0	69.0	68.0	67.0	21.0	21.0	122.0	121.0
Average length of flow events ABOVE 1 standard deviation (hours)	221.4	219.7	228.6	228.6	140.5	140.5	114.1	115.3
Number of flow events BELOW median flow	232.0	230.0	78.0	78.0	0.0	0.0	160.0	158.0
Average length of events BELOW median (hours)	75.5	76.2	224.6	224.6	0.0	0.0	109.5	110.9

i-Tree Hydro Executive Summary

Project Location: Madison, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2008

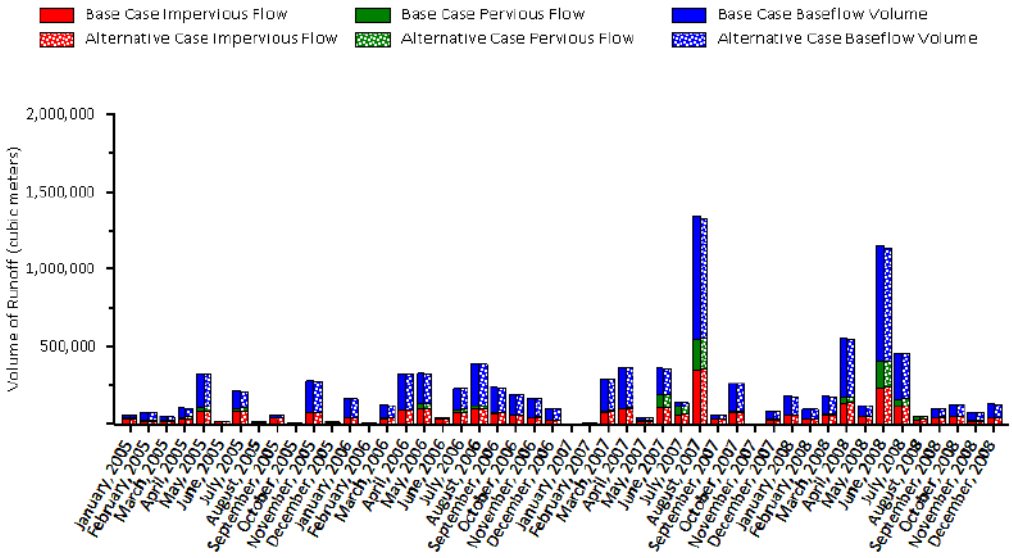
Water Volume: Predicted Streamflow



i-Tree Hydro Executive Summary

Project Location: Madison, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2008

Base Case vs. Alternative Case Predicted Streamflow Components

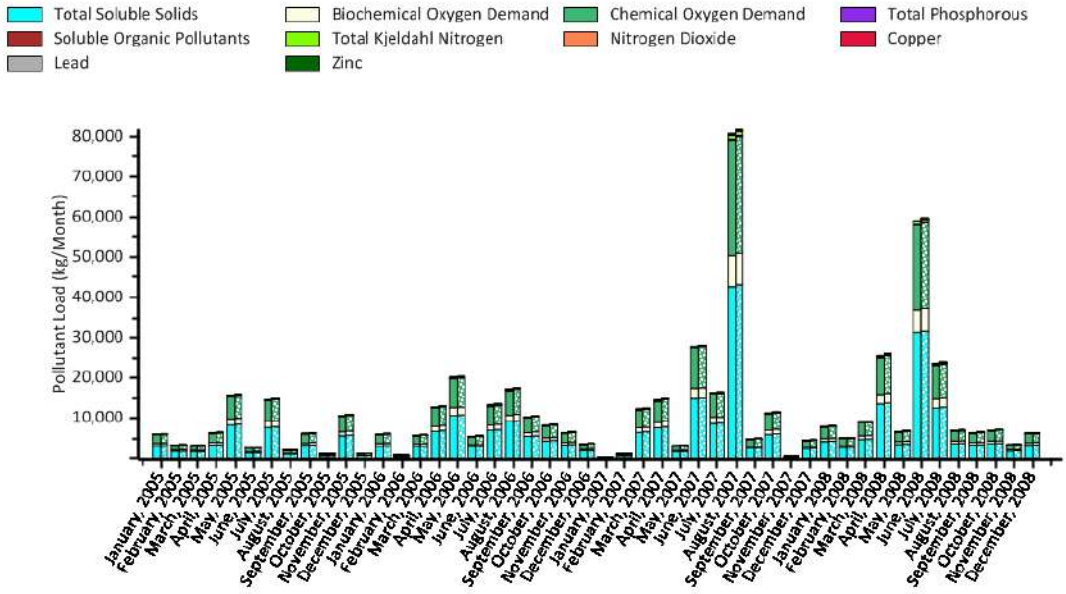


Note: Solid colors represent Base Case values while the hatched pattern indicates Alternative Case values

i-Tree Hydro Executive Summary

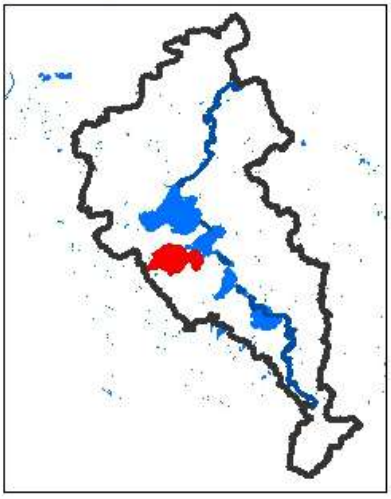
Project Location: Madison, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2008

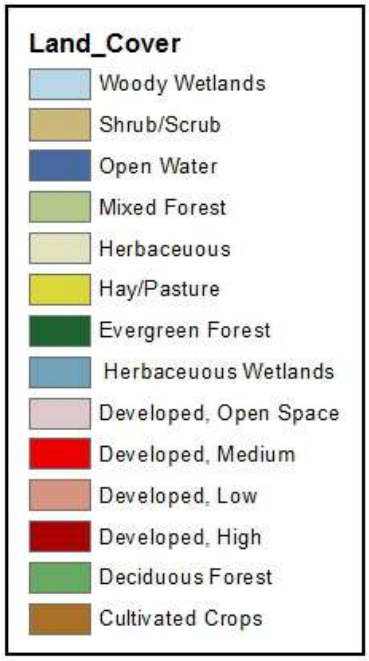
Pollutants: Base Case vs. Alternative Case Event Mean Concentration

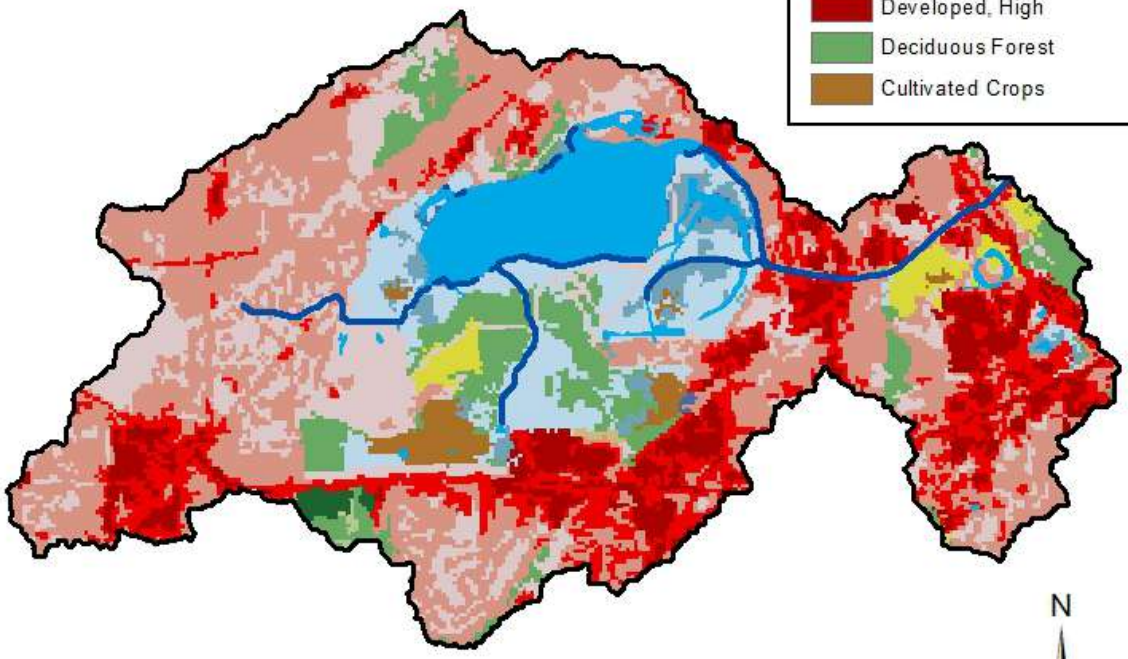


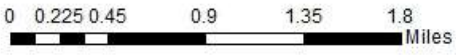
Note: Solid colors represent Base Case values while the hatched pattern indicates Alternative Case values

Wingra Creek



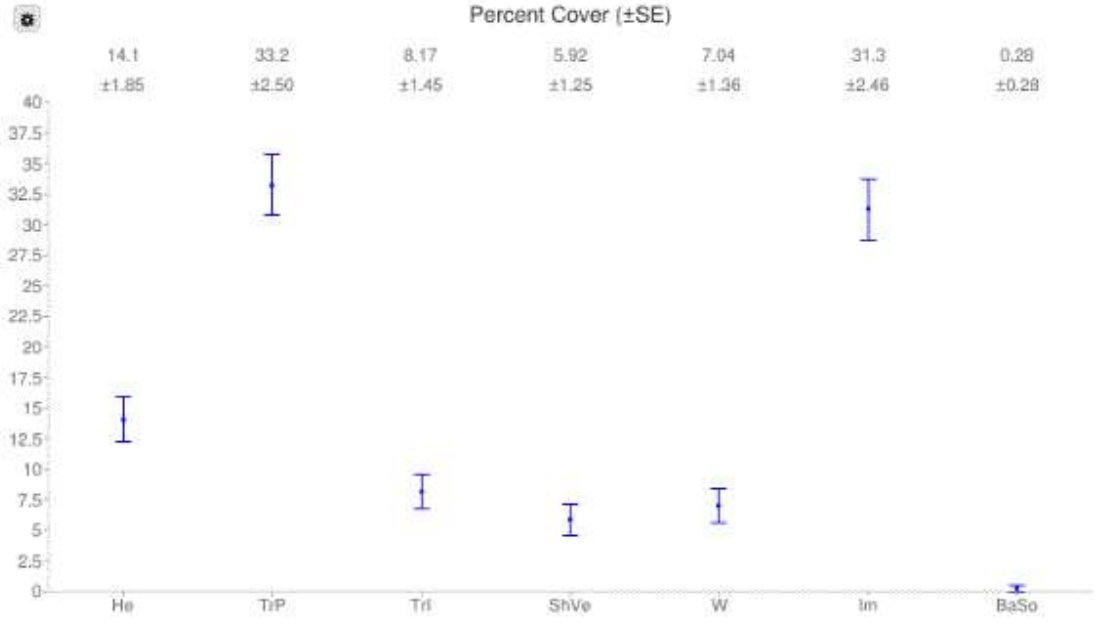






Cover Assessment and Tree Benefits Report

Estimated using random sampling statistics on 12/02/16



Cover Class	Description	Abbr.	Points	% Cover
Herbaceous	Ag.,turf, small shrub	He	50	14.1 ±1.85
Tree, Permeable	Tree, pervious underneath	TrP	118	33.2 ±2.50
Tree, Impermeable	Tree, impervious underneath	Trl	29	8.17 ±1.45
Short Vegetation	Emergent veg.	ShVe	21	5.92 ±1.25
Water	surface and wetland	W	25	7.04 ±1.36
Impermeable	Roof, pave, gravel	Im	111	31.3 ±2.46
Bare Soil	BareSoil	BaSo	1	0.28 ±0.28

Tree Benefit Estimates

Abbr.	Benefit Description	Value	±SE	Amount	±SE
CO	Carbon Monoxide removed annually	$95.46	±8.03	1,780.13 lb	±112.39
NO2	Nitrogen Dioxide removed annually	$517.62	±32.68	7.70 T	±0.49
O3	Ozone removed annually	$15,253.29	±962.99	39.33 T	±2.48
PM2.5	Particulate Matter less than 2.5 microns removed annually	$37,438.79	±2,363.64	2.12 T	±0.13
SO2	Sulfur Dioxide removed annually	$28.38	±1.79	1.26 T	±0.08
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	$11,228.89	±708.92	11.00 T	±0.69
CO2seq	Carbon Dioxide sequestered annually in trees	$298,068.97	±18,818.09	8,243.20 T	±520.42
CO2stor	Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)	$10,187,335.08	±643,160.57	281,734.39 T	±17,786.84

i-Tree Hydro Executive Summary

Project Location: Madison, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2007

Model Parameters

Watershed Area	Rainfall	Total Runoff	Stream Gage	Weather Station
square kilometers	*millimeters*	*cubic meters*		
20.72	2,529.08	27,289,717.58	0	726410-14837

Land Cover	Base	Alternative		Base	Alternative	LC beneath Tree Cover	Base	Alternative
Tree Cover %	41.0	46.0	Tree LAI	5.0	5.0	Soil Cover %	80.5	80.5
Shrub Cover %	6.8	6.8	Shrub LAI	2.2	2.2	Impervious Cover %	19.5	19.5
Herbaceous Cover %	14.0	14.0	Herbaceous LAI	1.6	1.6			
Water Cover %	7.0	7.0						
Impervious Cover %	31.0	26.0	Directly Connected Impervious Cover (%)	40.0	40.0			
Soil Cover %	0.2	0.2						

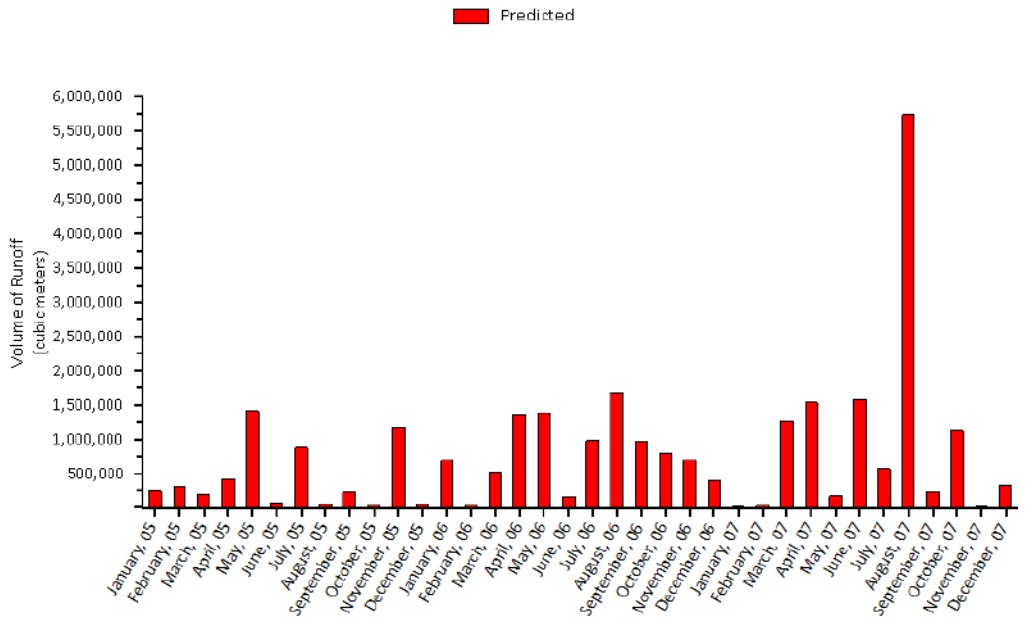
Streamflow Predictions

	Total Runoff		Baseflow		Pervious Flow		Impervious Flow	
	Base	Alternative	Base	Alternative	Base	Alternative	Base	Alternative
Total Flow (cubic meters)	27,289,717.6	27,349,776.7	17,535,300.7	18,238,263.8	2,162,455.5	2,226,179.7	7,591,965.0	6,885,330.9
Highest Flow (cubic meters / hour)	795,064.2	825,827.0	480,094.7	504,585.6	259,663.9	271,495.0	127,534.5	116,338.1
Lowest Flow (cubic meters / hour)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Highest Flow Date	06/03/07	06/03/07	05/19/05	05/19/05	08/22/07	08/22/07	08/22/07	08/22/07
Lowest Flow Date	07/27/06	07/27/06	07/27/06	07/27/06	01/01/05	01/01/05	01/01/05	01/01/05
Median Flow (cubic meters / hour)	2.6	2.7	1.8	1.8	0.0	0.0	0.0	0.0
Number of flow events ABOVE median flow	166.0	165.0	49.0	47.0	19.0	19.0	115.0	115.0
Average length of flow events with flow ABOVE median (hours)	78.0	78.5	268.9	280.7	129.6	129.5	112.3	112.3
High Flow: Number of flow events ABOVE 1 standard deviation	45.0	44.0	43.0	42.0	16.0	15.0	89.0	89.0
Average length of flow events ABOVE 1 standard deviation (hours)	243.2	252.0	279.3	289.1	133.3	134.7	116.8	116.8
Number of flow events BELOW median flow	165.0	164.0	48.0	46.0	0.0	0.0	115.0	115.0
Average length of events BELOW median (hours)	79.6	80.0	273.5	285.4	0.0	0.0	114.2	114.2

i-Tree Hydro Executive Summary

Project Location: Madison, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2007

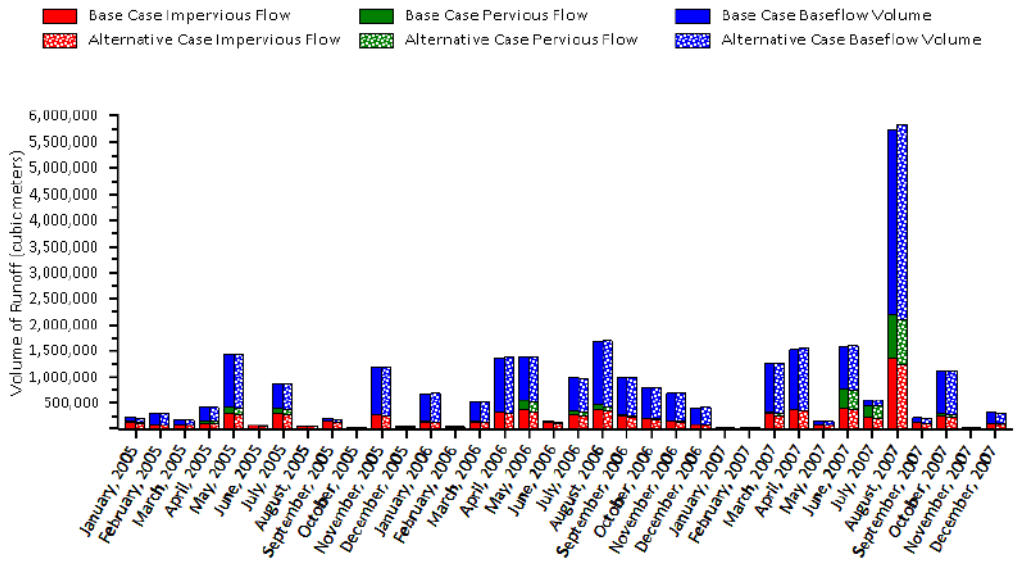
Water Volume: Predicted Streamflow



i-Tree Hydro Executive Summary

Project Location: Madison, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2007

Base Case vs. Alternative Case Predicted Streamflow Components

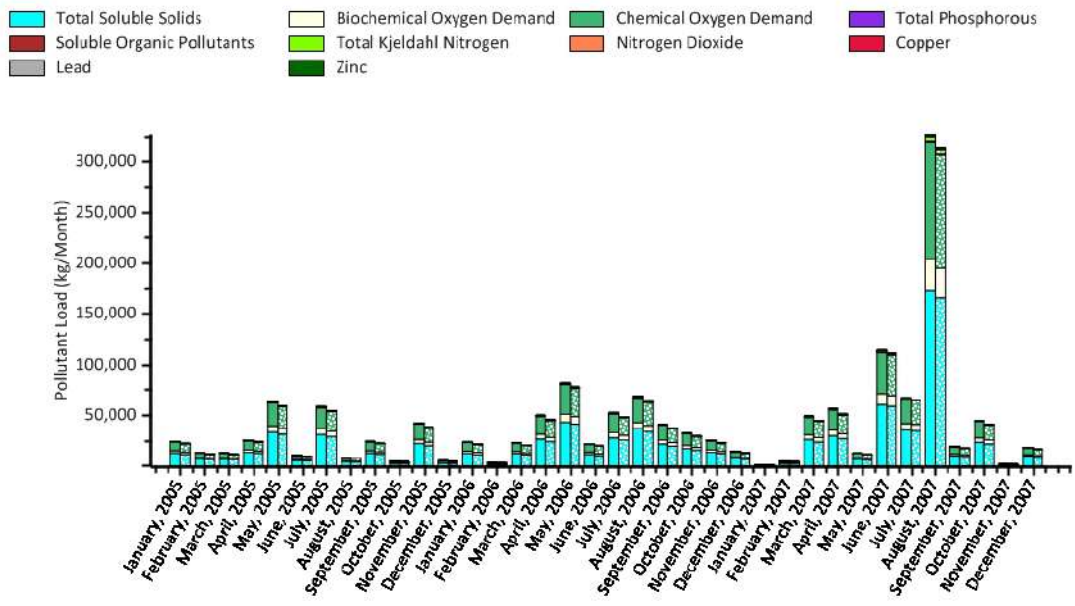


Note: Solid colors represent Base Case values while the hatched pattern indicates Alternative Case values

i-Tree Hydro Executive Summary

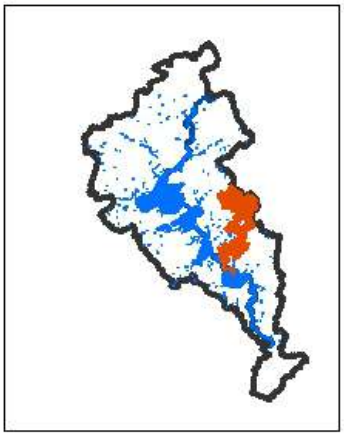
Project Location: Madison, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2007

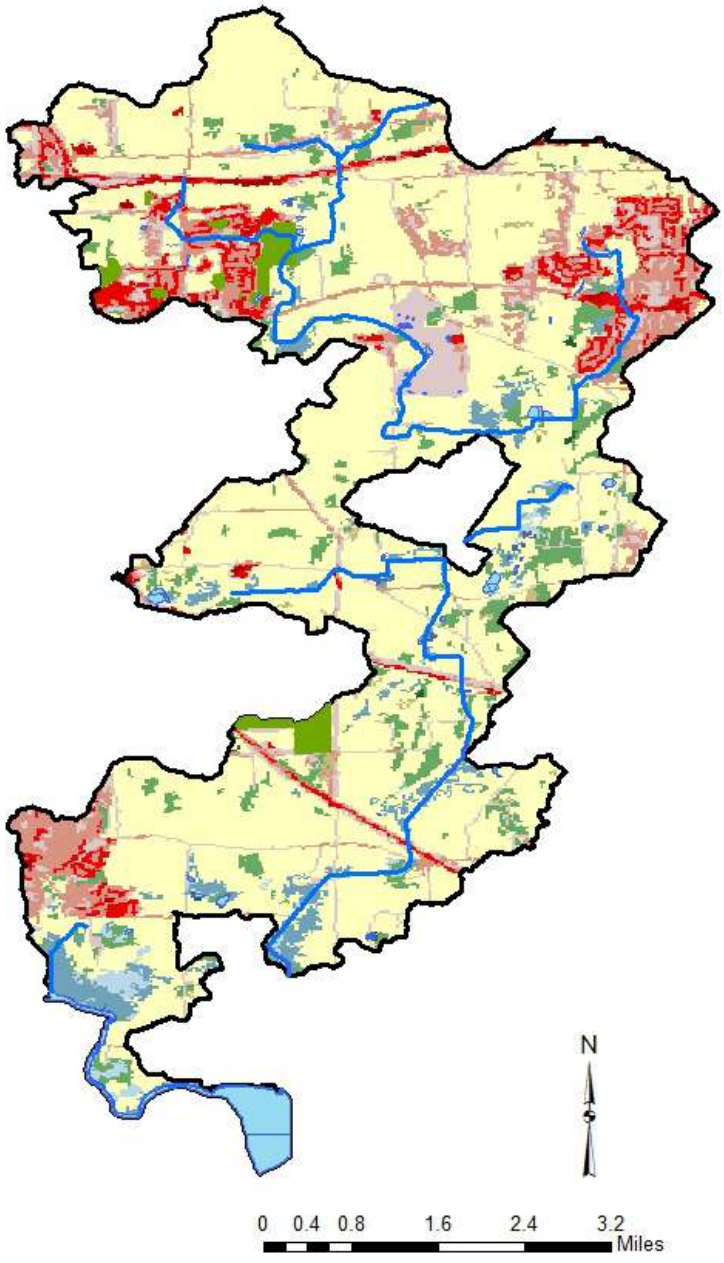
Pollutants: Base Case vs. Alternative Case Event Mean Concentration



Note: Solid colors represent Base Case values while the hatched pattern indicates Alternative Case values

Door Creek





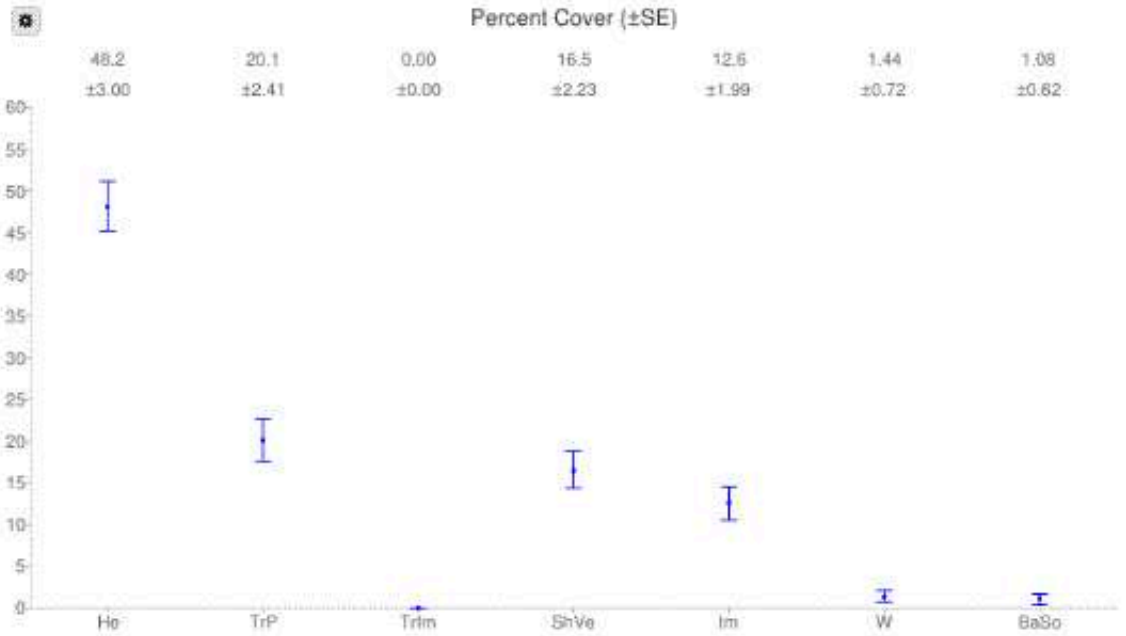
Land_Cover

- Woody Wetlands
- Shrub/Scrub
- Open Water
- Herbaceuous
- Hay/Pasture
- Evergreen Forest
- Herbaceuous Wetlands
- Developed, Open Space
- Developed, Medium
- Developed, Low
- Developed, High
- Deciduous Forest
- Cultivated Crops
- Barren Land

i-Tree Canopy v6.1

Cover Assessment and Tree Benefits Report

Estimated using random sampling statistics on 11/07/16



Cover Class	Description	Abbr.	Points	% Cover
Herbaceous	Ag.,turf, small shrub	He	134	48.2 ±3.00
Tree, Permeable	Tree, pervious underneath	TrP	56	20.1 ±2.41
Tree, Impermeable	Tree, impervious underneath	Trlm	0	0.00 ±0.00
Short Vegetation	shrub emergent	ShVe	46	16.5 ±2.23
Impermeable	Paving, roof, gravel	Im	35	12.6 ±1.99
Water	surface and wetland	W	4	1.44 ±0.72
Bare Soil	Bare Soil	BaSo	3	1.08 ±0.62

Tree Benefit Estimates

Abbr.	Benefit Description	Value	±SE	Amount	±SE
CO	Carbon Monoxide removed annually	$124.81	±14.90	1.16 T	±0.14
NO2	Nitrogen Dioxide removed annually	$876.76	±80.82	10.07 T	±1.20
O3	Ozone removed annually	$19,942.75	±2,381.47	51.42 T	±6.14
PM2.5	Particulate Matter less than 2.5 microns removed annually	$48,948.94	±5,845.25	2.78 T	±0.33
SO2	Sulfur Dioxide removed annually	$37.10	±4.43	1.65 T	±0.20
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	$14,681.09	±1,753.15	14.39 T	±1.72
CO2seq	Carbon Dioxide sequestered annually in trees	$389,707.06	±46,537.00	10,777.49 T	±1,287.00
CO2stor	Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)	$13,319,321.35	±1,590,531.13	368,350.58 T	±43,986.71

i-Tree Hydro Executive Summary

Project Location: McFarland, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2008

Model Parameters

Watershed Area	Rainfall	Total Runoff	Stream Gage	Weather Station
square kilometers	*millimeters*	*cubic meters*		
59.57	3,590.29	122,629,963.30	0	726410-14837

Land Cover	Base	Alternative		Base	Alternative	LC beneath Tree Cover	Base	Alternative
Tree Cover %	20.0	25.0	Tree LAI	5.0	5.0	Soil Cover %	94.0	94.0
Shrub Cover %	17.0	17.0	Shrub LAI	2.2	2.2	Impervious Cover %	6.0	6.0
Herbaceous Cover %	48.0	43.0	Herbaceous LAI	1.6	1.6			
Water Cover %	1.0	1.0						
Impervious Cover %	13.0	13.0	Directly Connected Impervious Cover (%)	40.0	40.0			
Soil Cover %	1.0	1.0						

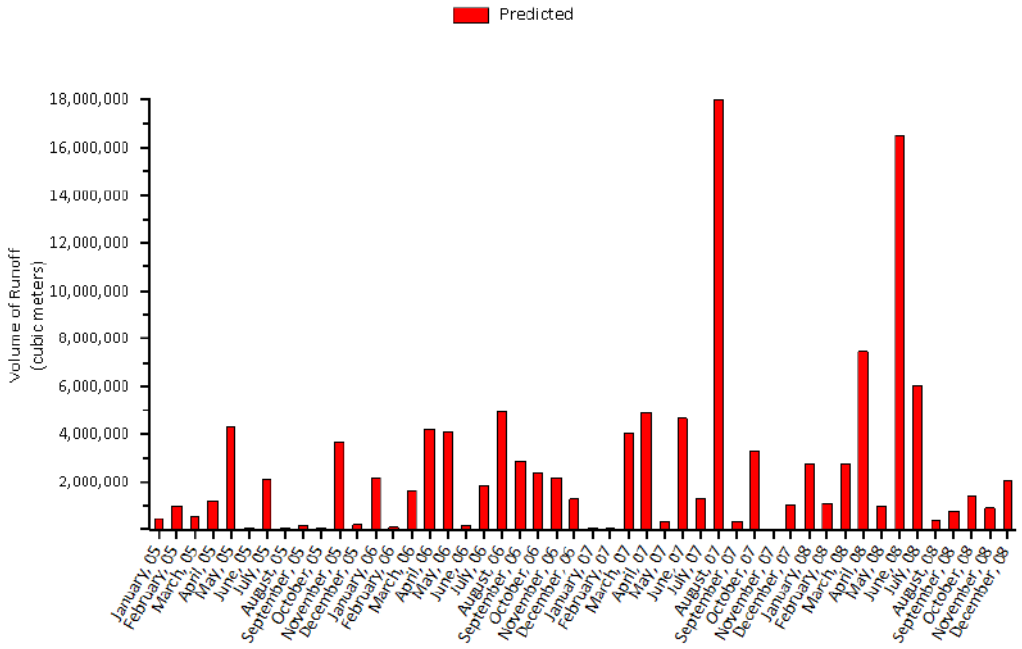
Streamflow Predictions

	Total Runoff		Baseflow		Pervious Flow		Impervious Flow	
	Base	Alternative	Base	Alternative	Base	Alternative	Base	Alternative
Total Flow (cubic meters)	122,629,963.3	121,735,157.3	101,250,839.1	100,199,275.5	10,772,053.1	10,752,712.2	10,607,047.0	10,783,168.4
Highest Flow (cubic meters / hour)	2,758,823.0	2,755,499.0	2,387,411.7	2,382,920.1	935,500.9	934,214.2	121,258.9	123,635.2
Lowest Flow (cubic meters / hour)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Highest Flow Date	06/07/08	06/07/08	06/07/08	06/07/08	08/22/07	08/22/07	08/22/07	08/22/07
Lowest Flow Date	07/27/06	07/27/06	07/27/06	07/27/06	01/01/05	01/01/05	01/01/05	01/01/05
Median Flow (cubic meters / hour)	14.4	13.4	10.3	9.4	0.0	0.0	0.0	0.0
Number of flow events ABOVE median flow	251.0	246.0	76.0	71.0	23.0	23.0	160.0	160.0
Average length of flow events with flow ABOVE median (hours)	69.6	71.1	232.2	248.8	132.6	132.5	108.2	108.2
High Flow: Number of flow events ABOVE 1 standard deviation	55.0	53.0	66.0	65.0	19.0	19.0	125.0	123.0
Average length of flow events ABOVE 1 standard deviation (hours)	271.9	287.5	241.3	254.1	137.3	137.3	112.9	113.8
Number of flow events BELOW median flow	250.0	245.0	75.0	70.0	0.0	0.0	160.0	160.0
Average length of events BELOW median (hours)	70.1	71.5	233.6	250.3	0.0	0.0	109.5	109.5

i-Tree Hydro Executive Summary

Project Location: McFarland, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2008

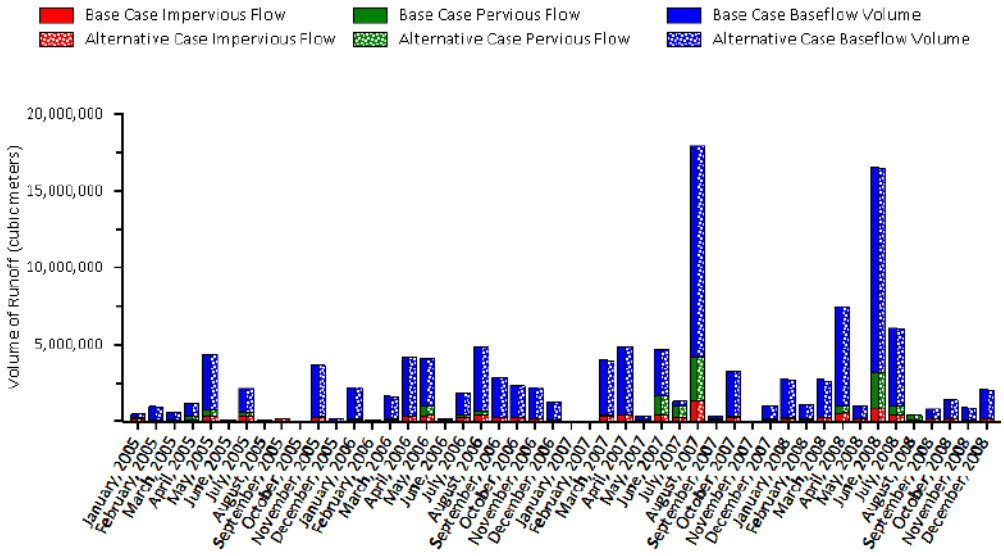
Water Volume: Predicted Streamflow



i-Tree Hydro Executive Summary

Project Location: McFarland, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2008

Base Case vs. Alternative Case Predicted Streamflow Components

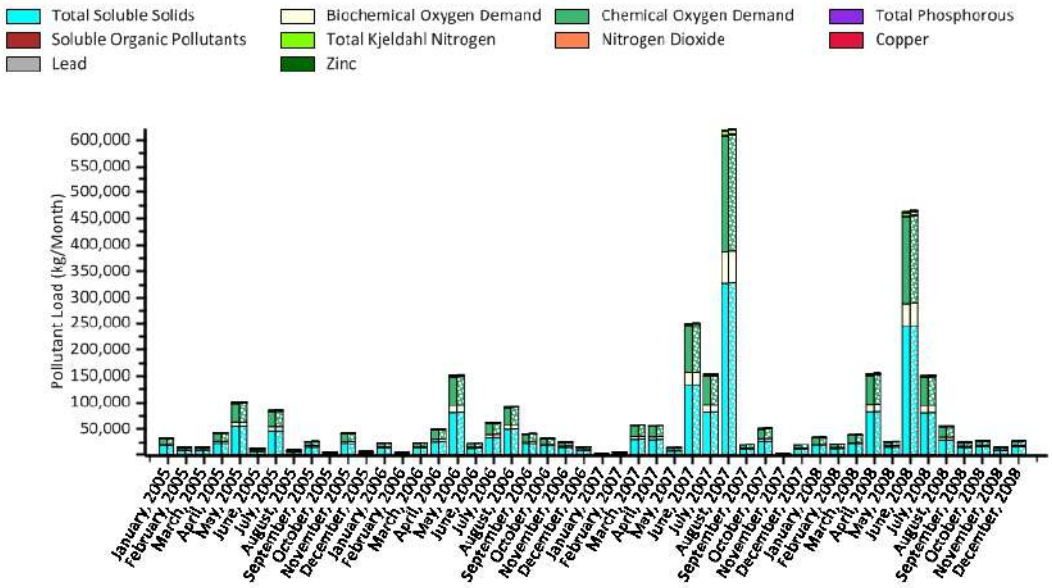


Note: Solid colors represent Base Case values while the hatched pattern indicates Alternative Case values

i-Tree Hydro Executive Summary

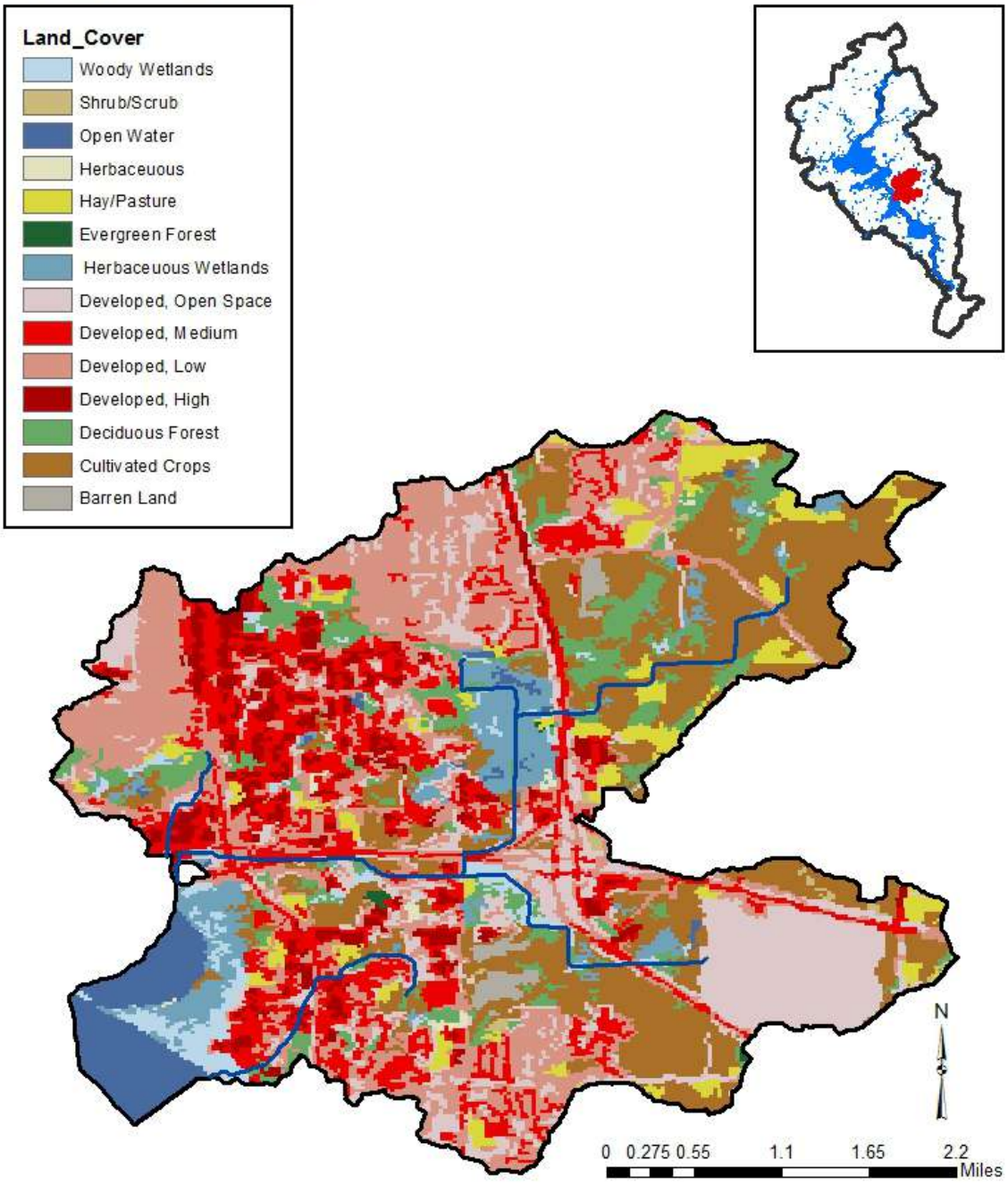
Project Location: McFarland, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2008

Pollutants: Base Case vs. Alternative Case Event Mean Concentration



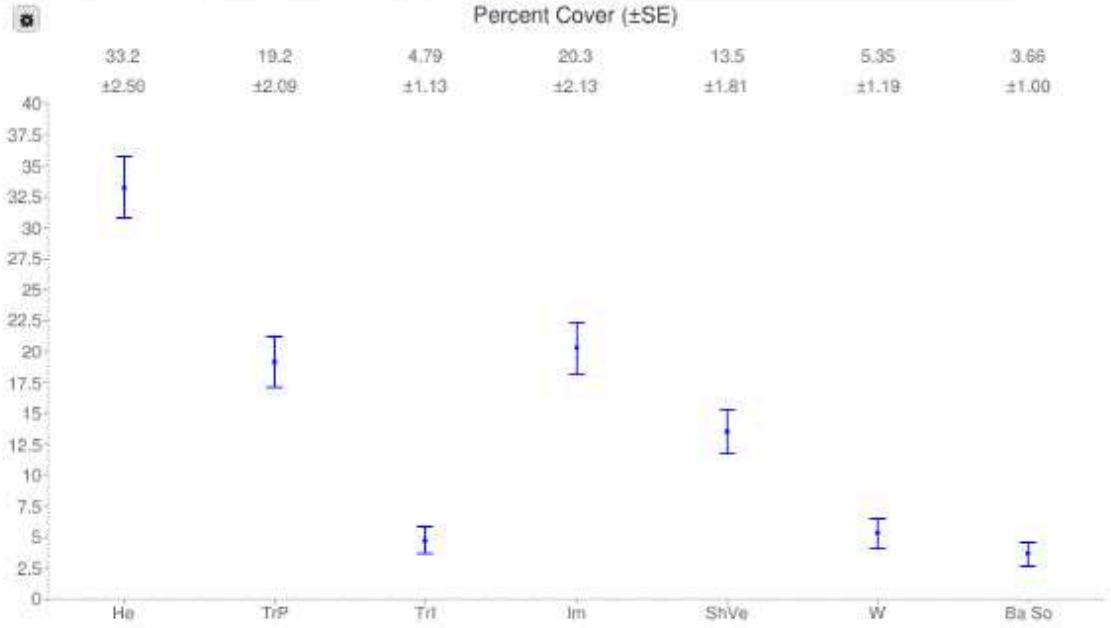
Note: Solid colors represent Base Case values while the hatched pattern indicates Alternative Case values

Waubesa East



Cover Assessment and Tree Benefits Report

Estimated using random sampling statistics on 12/02/16



Cover Class	Description	Abbr.	Points	% Cover
Herbaceous	Ag.,turf, small shrub	He	118	33.2 ±2.50
Tree, Permeable	Tree pervious undnerneath canopy	TrP	68	19.2 ±2.09
Tree, Impermeable	Tree, impermeable underneath	Trl	17	4.79 ±1.13
Impermeable	Roof, pave, gravel	Im	72	20.3 ±2.13
Short Vegetation	emergent woody	ShVe	48	13.5 ±1.81
Water	surface and wetland	W	19	5.35 ±1.19
Bare Soil	Bare Soil	Ba So	13	3.66 ±1.00

Tree Benefit Estimates

Abbr.	Benefit Description	Value	±SE	Amount	±SE
CO	Carbon Monoxide removed annually	$79.59	±7.53	1,484.14 lb	±140.39
NO2	Nitrogen Dioxide removed annually	$431.56	±40.82	6.42 T	±0.61
O3	Ozone removed annually	$12,717.10	±1,202.95	32.79 T	±3.10
PM2.5	Particulate Matter less than 2.5 microns removed annually	$31,213.78	±2,952.60	1.77 T	±0.17
SO2	Sulfur Dioxide removed annually	$23.68	±2.24	1.05 T	±0.10
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	$9,361.84	±885.56	9.17 T	±0.87
CO2seq	Carbon Dioxide sequestered annually in trees	$248,508.57	±23,507.13	6,872.59 T	±650.10
CO2stor	Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)	$8,493,470.75	±803,421.48	234,889.96 T	±22,218.91

i-Tree Hydro Executive Summary

Project Location: McFarland, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2007

Model Parameters

Watershed Area	Rainfall	Total Runoff	Stream Gage	Weather Station
square kilometers	*millimeters*	*cubic meters*		
13.00	2,529.08	17,966,621.70	0	726410-14837

Land Cover	Base	Alternative		Base	Alternative	LC beneath Tree Cover	Base	Alternative
Tree Cover %	24.0	29.0	Tree LAI	5.0	5.0	Soil Cover %	80.0	80.0
Shrub Cover %	13.5	13.5	Shrub LAI	2.2	2.2	Impervious Cover %	20.0	20.0
Herbaceous Cover %	33.0	28.0	Herbaceous LAI	1.6	1.6			
Water Cover %	5.5	5.5						
Impervious Cover %	20.0	20.0	Directly Connected Impervious Cover (%)	40.0	40.0			
Soil Cover %	4.0	4.0						

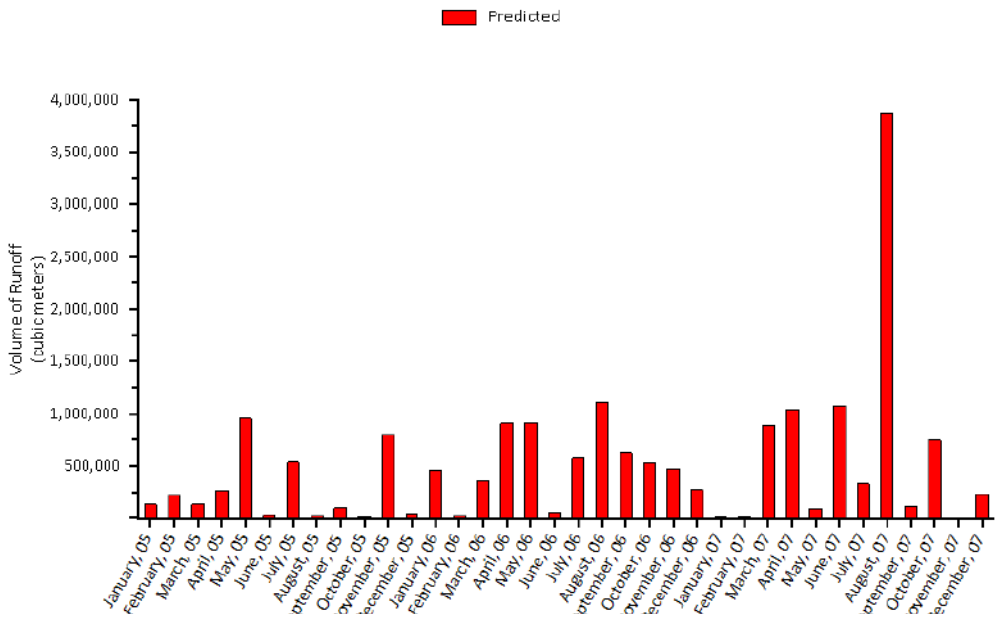
Streamflow Predictions

	Total Runoff		Baseflow		Pervious Flow		Impervious Flow	
	Base	Alternative	Base	Alternative	Base	Alternative	Base	Alternative
Total Flow (cubic meters)	17,966,621.7	17,847,543.0	13,313,806.3	13,114,464.0	1,507,825.1	1,497,488.1	3,144,990.4	3,235,590.1
Highest Flow (cubic meters / hour)	591,030.7	585,336.7	376,623.0	370,503.9	188,679.4	187,278.0	52,718.6	54,447.3
Lowest Flow (cubic meters / hour)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Highest Flow Date	06/03/07	06/03/07	06/03/07	06/03/07	08/22/07	08/22/07	08/22/07	08/22/07
Lowest Flow Date	07/27/06	07/27/06	07/27/06	07/27/06	01/01/05	01/01/05	01/01/05	01/01/05
Median Flow (cubic meters / hour)	2.0	1.9	1.3	1.3	0.0	0.0	0.0	0.0
Number of flow events ABOVE median flow	169.0	169.0	48.0	48.0	18.0	18.0	114.0	114.0
Average length of flow events with flow ABOVE median (hours)	76.6	76.6	274.4	274.4	124.4	124.4	113.3	113.3
High Flow: Number of flow events ABOVE 1 standard deviation	41.0	41.0	44.0	44.0	15.0	15.0	90.0	89.0
Average length of flow events ABOVE 1 standard deviation (hours)	271.0	271.1	280.5	280.5	127.3	127.2	116.9	117.5
Number of flow events BELOW median flow	168.0	168.0	47.0	47.0	0.0	0.0	114.0	114.0
Average length of events BELOW median (hours)	78.1	78.1	279.3	279.3	0.0	0.0	115.2	115.2

i-Tree Hydro Executive Summary

Project Location: McFarland, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2007

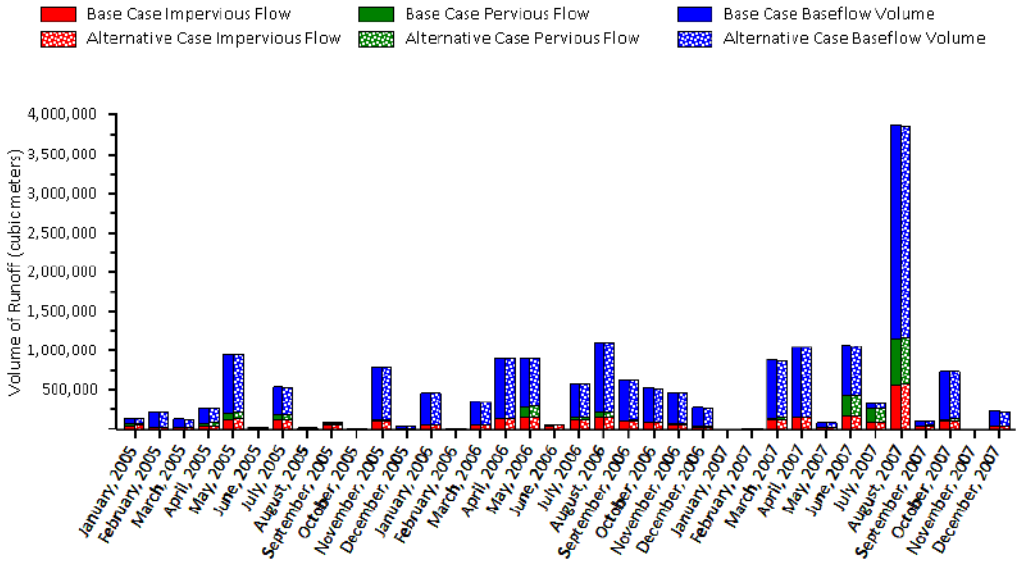
Water Volume: Predicted Streamflow



i-Tree Hydro Executive Summary

Project Location: McFarland, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2007

Base Case vs. Alternative Case Predicted Streamflow Components

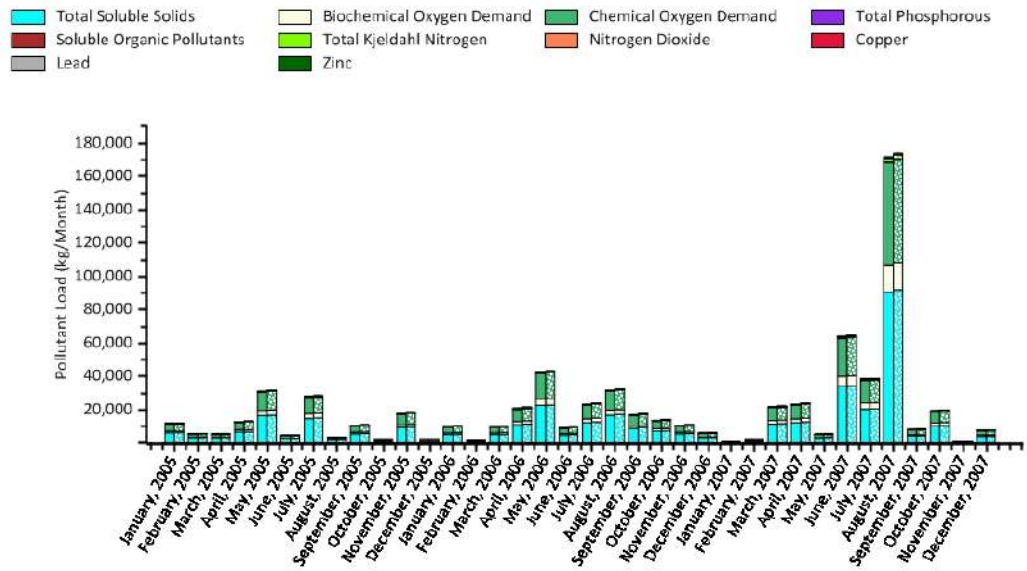


Note: Solid colors represent Base Case values while the hatched pattern indicates Alternative Case values

i-Tree Hydro Executive Summary

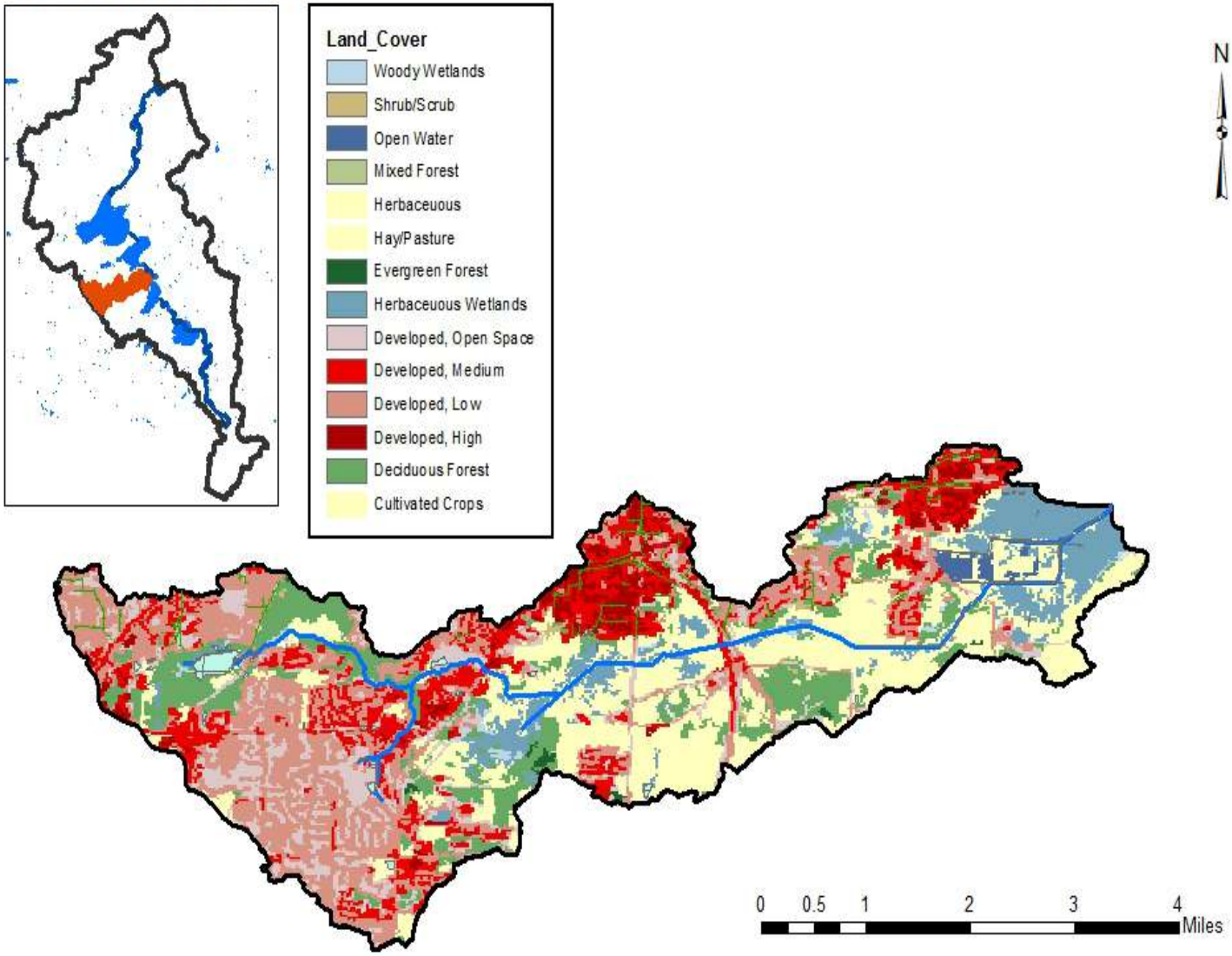
Project Location: McFarland, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2007

Pollutants: Base Case vs. Alternative Case Event Mean Concentration



Note: Solid colors represent Base Case values while the hatched pattern indicates Alternative Case values

West Waubesa



i-Tree Hydro Executive Summary

Project Location: Madison, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2007

Model Parameters

Watershed Area	Rainfall	Total Runoff	Stream Gage	Weather Station
square kilometers	*millimeters*	*cubic meters*		
31.08	2,529.08	42,118,652.44	0	726410-14837

Land Cover	Base	Alternative		Base	Alternative	LC beneath Tree Cover	Base	Alternative
Tree Cover %	31.0	36.0	Tree LAI	5.0	5.0	Soil Cover %	90.0	90.0
Shrub Cover %	19.0	19.0	Shrub LAI	2.2	2.2	Impervious Cover %	10.0	10.0
Herbaceous Cover %	20.0	15.0	Herbaceous LAI	1.6	1.6			
Water Cover %	3.0	3.0						
Impervious Cover %	26.0	26.0	Directly Connected Impervious Cover (%)	40.0	40.0			
Soil Cover %	1.0	1.0						

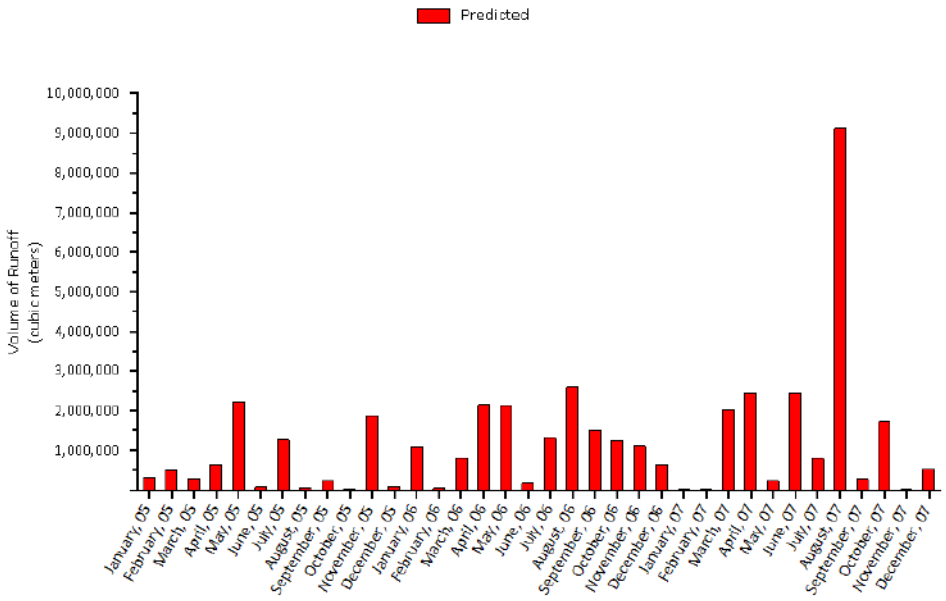
Streamflow Predictions

	Total Runoff		Baseflow		Pervious Flow		Impervious Flow	
	Base	Alternative	Base	Alternative	Base	Alternative	Base	Alternative
Total Flow (cubic meters)	42,118,652.4	41,828,875.1	30,514,456.2	30,135,735.5	3,562,359.5	3,543,064.4	8,041,844.8	8,150,083.5
Highest Flow (cubic meters / hour)	1,309,720.7	1,298,808.6	829,599.1	824,141.5	445,085.3	443,254.7	133,589.9	135,656.1
Lowest Flow (cubic meters / hour)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Highest Flow Date	06/03/07	06/03/07	05/19/05	05/19/05	08/22/07	08/22/07	08/22/07	08/22/07
Lowest Flow Date	07/27/06	07/27/06	07/27/06	07/27/06	01/01/05	01/01/05	01/01/05	01/01/05
Median Flow (cubic meters / hour)	5.0	4.5	3.4	3.1	0.0	0.0	0.0	0.0
Number of flow events ABOVE median flow	170.0	168.0	48.0	48.0	18.0	18.0	117.0	117.0
Average length of flow events with flow ABOVE median (hours)	76.2	77.1	274.5	274.5	124.4	124.5	110.4	110.4
High Flow: Number of flow events ABOVE 1 standard deviation	43.0	43.0	43.0	42.0	15.0	15.0	90.0	90.0
Average length of flow events ABOVE 1 standard deviation (hours)	259.0	266.6	282.5	286.5	127.2	127.3	115.0	115.0
Number of flow events BELOW median flow	169.0	167.0	47.0	47.0	0.0	0.0	117.0	117.0
Average length of events BELOW median (hours)	77.7	78.6	279.3	279.3	0.0	0.0	112.2	112.2

i-Tree Hydro Executive Summary

Project Location: Madison, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2007

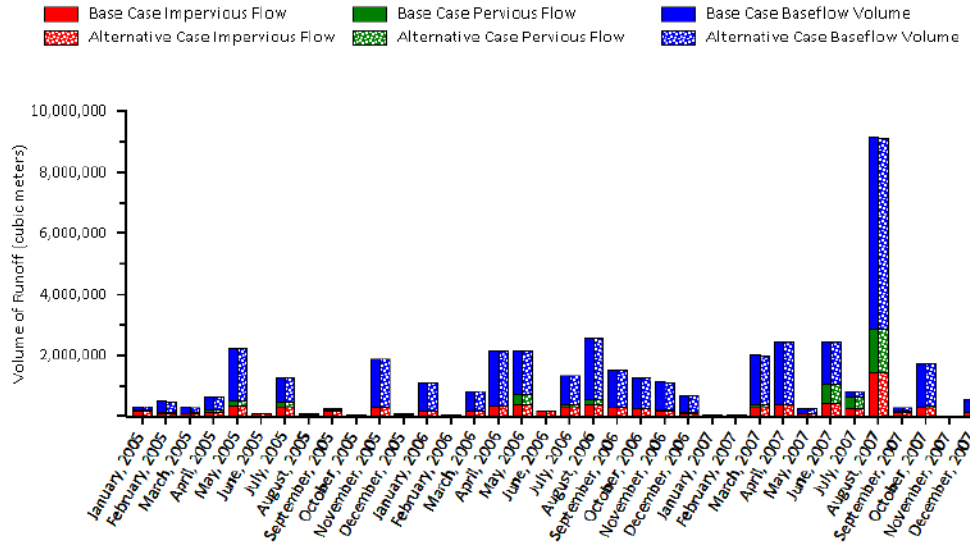
Water Volume: Predicted Streamflow



i-Tree Hydro Executive Summary

Project Location: Madison, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2007

Base Case vs. Alternative Case Predicted Streamflow Components

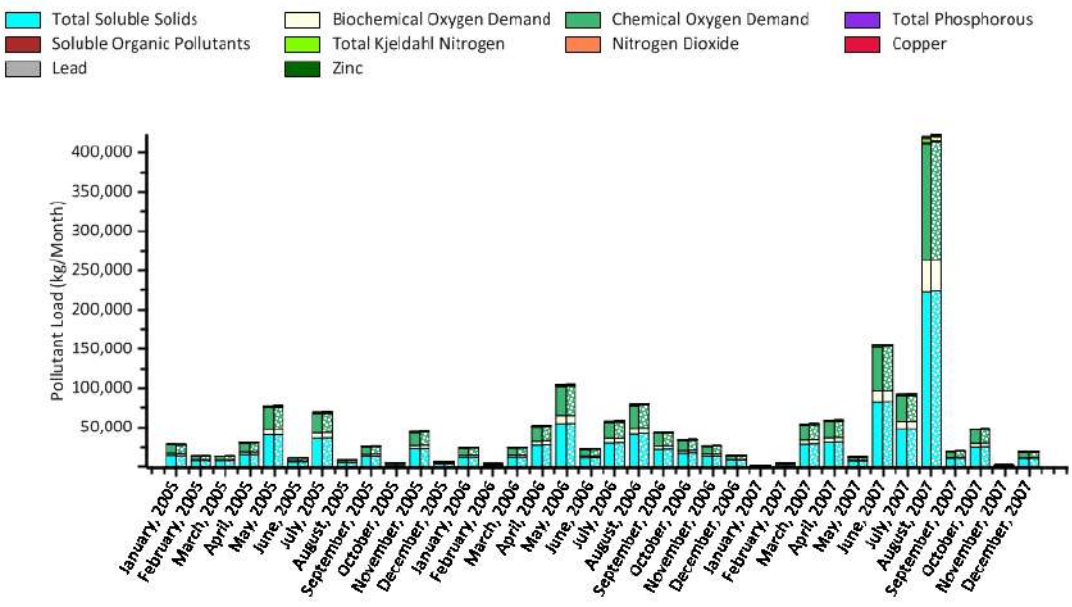


Note: Solid colors represent Base Case values while the hatched pattern indicates Alternative Case values

i-Tree Hydro Executive Summary

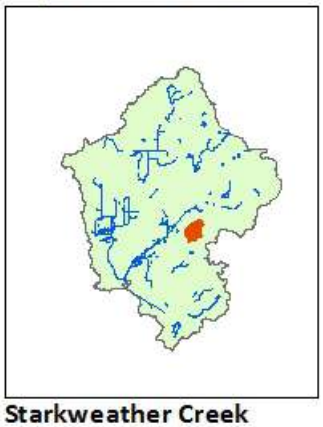
Project Location: Madison, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2007

Pollutants: Base Case vs. Alternative Case Event Mean Concentration

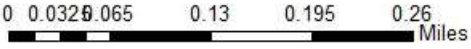


Note: Solid colors represent Base Case values while the hatched pattern indicates Alternative Case values

Sycamore St. Stormwater Catchment

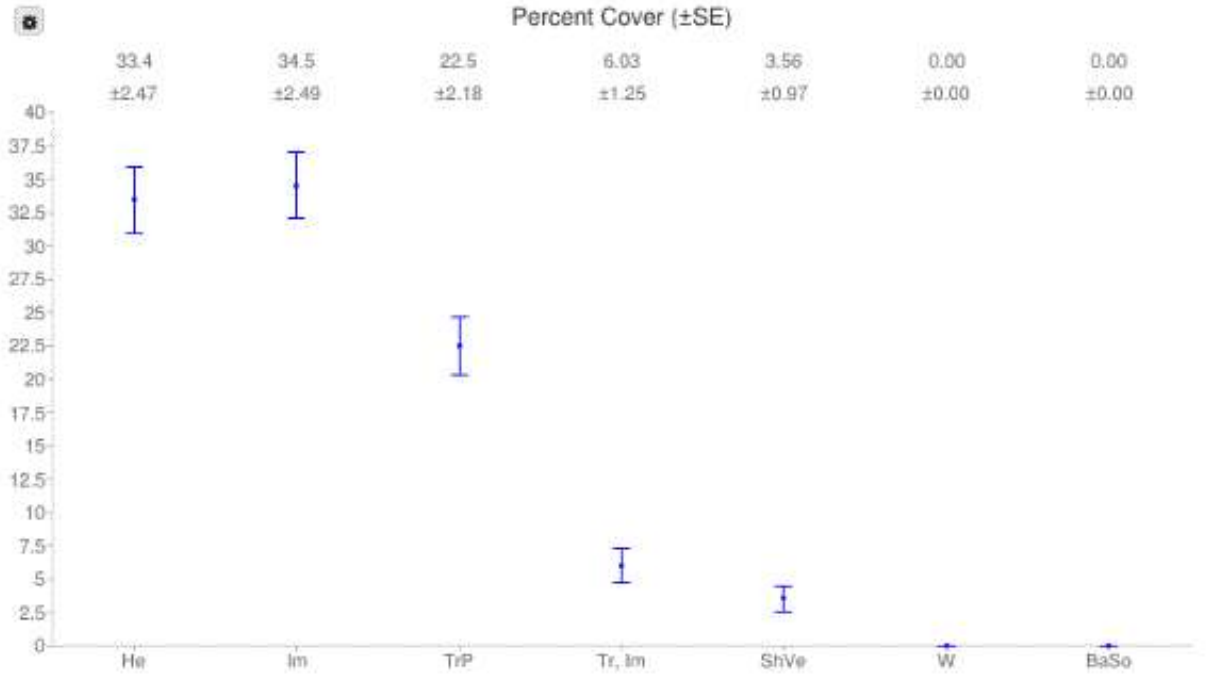


Starkweather Creek
Subwatershed



Cover Assessment and Tree Benefits Report

Estimated using random sampling statistics on 12/07/16



Cover Class	Description	Abbr.	Points	% Cover
Herbaceous	Ag.,turf	He	122	33.4 ±2.47
Impermeable	Roof, pave, gravel	Im	126	34.5 ±2.49
Tree, Permeable	Tree pervious undneneath canopy	TrP	82	22.5 ±2.18
Tree, Impermeable	Tree, impervious underneath	Tr, Im	22	6.03 ±1.25
Short Vegetation	short, woody veg.	ShVe	13	3.56 ±0.97
Water	surface and wetland	W	0	0.00 ±0.00
Bare Soil	Bare Soil	BaSo	0	0.00 ±0.00

Tree Benefit Estimates

Abbr.	Benefit Description	Value	±SE	Amount	±SE
CO	Carbon Monoxide removed annually	$7.77	±0.64	11.69 lb	±0.97
NO2	Nitrogen Dioxide removed annually	$45.54	±3.78	238.23 lb	±19.75
O3	Ozone removed annually	$1,290.27	±106.99	1,220.44 lb	±101.20
PM2.5	Particulate Matter less than 2.5 microns removed annually	$3,336.07	±276.63	83.65 lb	±6.94
SO2	Sulfur Dioxide removed annually	$2.52	±0.21	39.24 lb	±3.25
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	$1,048.21	±86.92	336.62 lb	±27.83
CO2seq	Carbon Dioxide sequestered annually in trees	$4,694.13	±389.24	129.82 T	±10.76
CO2stor	Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)	$160,435.00	±13,303.20	4,436.89 T	±367.90

i-Tree Canopy Annual Tree Benefit Estimates based on these values in lbs/acre/yr and $/T/yr: CO 0.331 @ $1,333.50 | NO2 6.749 @ $383.69 | O3 34.575 @ $2,121.92 |

i-Tree Hydro Executive Summary

Project Location: Madison, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2008

Model Parameters

Watershed Area	Rainfall	Total Runoff	Stream Gage	Weather Station
square kilometers	*millimeters*	*cubic meters*		
0.49	3,590.29	986,558.96	0	726410-14837

Land Cover	Base	Alternative		Base	Alternative	LC beneath Tree Cover	Base	Alternative
Tree Cover %	28.5	33.5	Tree LAI	5.0	5.0	Soil Cover %	79.0	79.0
Shrub Cover %	3.5	3.5	Shrub LAI	2.2	2.2	Impervious Cover %	21.0	21.0
Herbaceous Cover %	33.5	28.5	Herbaceous LAI	1.6	1.6			
Water Cover %	0.0	0.0						
Impervious Cover %	34.5	34.5	Directly Connected Impervious Cover (%)	40.0	40.0			
Soil Cover %	0.0	0.0						

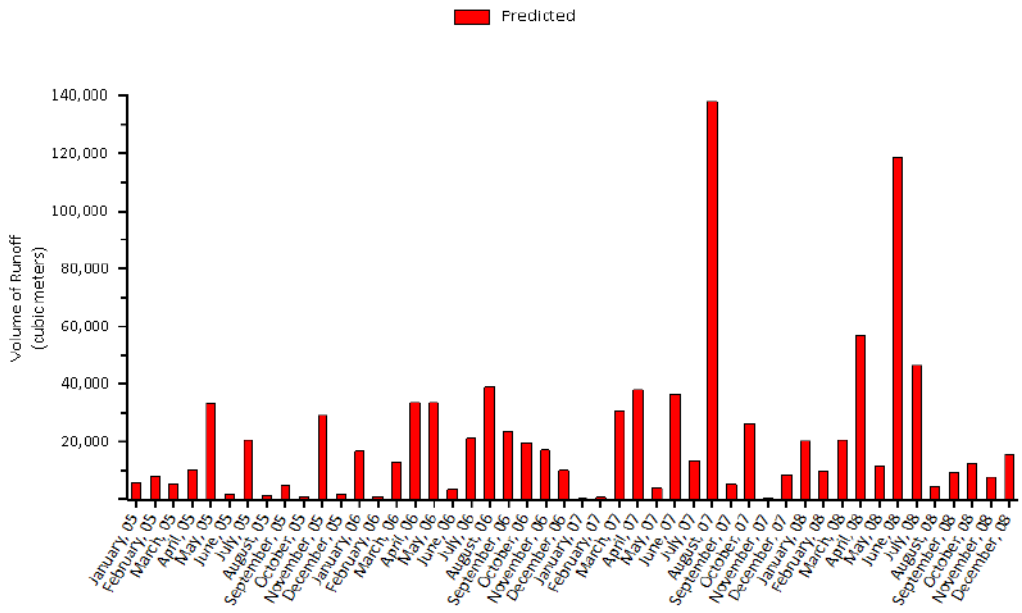
Streamflow Predictions

	Total Runoff		Baseflow		Pervious Flow		Impervious Flow	
	Base	Alternative	Base	Alternative	Base	Alternative	Base	Alternative
Total Flow (cubic meters)	986,559.0	976,329.7	673,134.4	658,572.1	82,812.1	82,058.0	230,612.4	235,699.5
Highest Flow (cubic meters / hour)	18,002.4	17,841.9	14,450.4	14,248.9	6,561.0	6,488.9	2,666.6	2,735.3
Lowest Flow (cubic meters / hour)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Highest Flow Date	06/07/08	06/07/08	06/12/08	06/12/08	08/22/07	08/22/07	08/22/07	08/22/07
Lowest Flow Date	07/27/06	07/27/06	07/27/06	07/27/06	01/01/05	01/01/05	01/01/05	01/01/05
Median Flow (cubic meters / hour)	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0
Number of flow events ABOVE median flow	234.0	234.0	81.0	79.0	27.0	27.0	159.0	159.0
Average length of flow events with flow ABOVE median (hours)	74.7	74.7	217.7	223.3	133.8	133.8	108.9	108.9
High Flow: Number of flow events ABOVE 1 standard deviation	64.0	64.0	68.0	67.0	21.0	21.0	123.0	123.0
Average length of flow events ABOVE 1 standard deviation (hours)	233.4	234.3	224.9	229.8	140.6	140.6	114.1	114.0
Number of flow events BELOW median flow	233.0	233.0	80.0	78.0	0.0	0.0	159.0	159.0
Average length of events BELOW median (hours)	75.2	75.2	219.0	224.6	0.0	0.0	110.2	110.2

i-Tree Hydro Executive Summary

Project Location: Madison, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2008

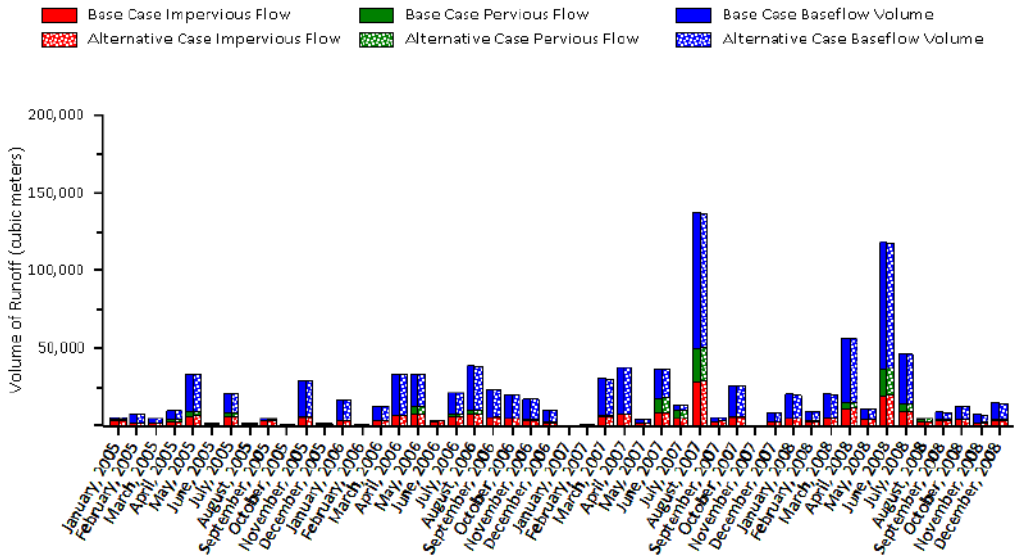
Water Volume: Predicted Streamflow



i-Tree Hydro Executive Summary

Project Location: Madison, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2008

Base Case vs. Alternative Case Predicted Streamflow Components

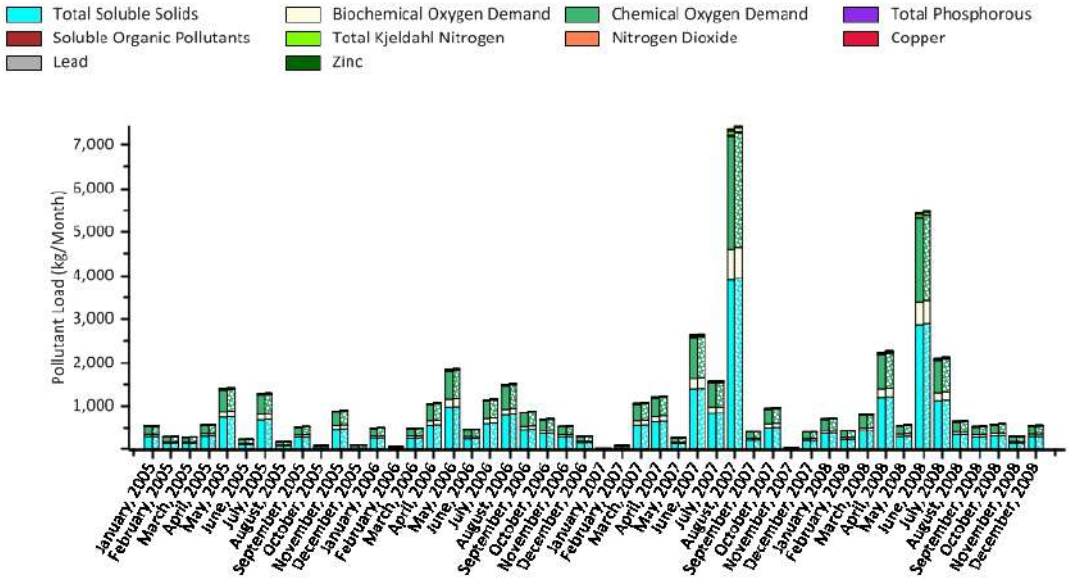


Note: Solid colors represent Base Case values while the hatched pattern indicates Alternative Case values

i-Tree Hydro Executive Summary

Project Location: Madison, Wisconsin
Project Time Span: 01/01/2005 - 12/30/2008

Pollutants: Base Case vs. Alternative Case Event Mean Concentration



Note: Solid colors represent Base Case values while the hatched pattern indicates Alternative Case values

Results Table

	(sq.km.)	Im	He	Tr	TrP	TrI	ShVe	W	BSo	~Tr	Tot Run	~Total Run	dif	%
Watershed														
Yahara River*	1,307.94	11.2	53	21.5	17.2	4.2	2.6	11.2	0.5		327,422,323			
										8.5 add		317,771,029	"-9,651,295"	0.0295
										5 add				
Yahara Urbanshed	608.65	17.6	46	19.3	14.2	5.1	5.4	10.3	3.3		2,454,455,949			
										5 add		2,444,577,981.00	"-987,796"	0.0040
										5 sub		2,462,138,868	"+768,293"	0.0031
										100 add		2,102,469,139	"-35,198,681"	0.1434
Upper Yahara*	300.44	7.9	78.1	9.6	8.5	1.1	0	1	1	5 add	68,842,887	68,248,215	"-594,674"	0.0086
Northwest Mendota	119.14	9.8	68	13.5	13.1	0.4	6	2.5	0.2	5 add	81,832,868	81,298,293	"-534,653"	0.0065
Starkweather Creek	62.16	32.5	35	21.5	15.2	6.3	7	1	3	5 add	85,118,760	84,321,760	"-797,000"	0.0093
Pheasant Branch Creek*	67.34	14	58	18	15.1	2.9	8	1.5	0.5	5 add	91,086,547	90,659,881	"-426,666"	0.0046
Direct Lake Drainage	45	14	12	20	14.2	6.8	6	48	0	5 add	56,273,779	55,166,846	"-1,106,933"	0.0197
Southwest Mendota	15.54	34	15	39.5	32	7.5	8	2.8	0.7	5 add	10,628,396	10,535,039	"-93,357"	0.0087
University / Willow Creek	5	37	20	38	25.6	12.4	5	0	0	5 add	9,683,525	9,550,107	"-133,418"	0.0137
Door Creek	59.57	13	48	20.1	20.1	0	17	1	1	5 add	122,629,963	121,735,157	"-894,806"	0.0072
Wingra Creek	20.72	31	15	40	32.2	8	6.8	7	0.2	5 add	27,289,717	27,349,776	"+60,059	0.0020
East Waubesa	13	20	33	24	19.2	4.8	13.5	5.5	4	5 add	17,966,621	17,847,543	"-119,078"	0.0066
West Waubesa	31.08	26	20	31	28	1	19	3	1	5 add	42,118,652	41,828,875	"-289,777"	0.0069
											613,471,715			
Sycamore Catchment	0.49	34.5	33.5	28.5	22.5	6	3.5	0	0	5 add	986,559	976,329	"-10,230"	0.0104

* gauged stream
Im- Impervious,
He- Herbaceous
TrP-Tree, Permeable Underneath
TrI- Tree ImpermeableUnderneath
ShVe- Short Vegetation
W- Water
Bso- Bare Soil
~Tr- Alternative Case Canopy Change, %pt. change
Tot Run- Total Annual Runoff (cu.meters/yr)
~Tot Run- Alternative Case, Total Annual Runoff (cu.meters/yr)
%Run/$Tr- %runoff decline per %increase in canopy
G- Gauge observed v. predicted

Concluding Thoughts

What do all these tables and graphs tell us about how tree canopy cover affects water quantity and quality in the Yahara watershed?

In our experience the answers tend to be more relative than absolute. Much depends on the local conditions of the study. However, in general, the I-Tree Hydro model seems to suggest relatively small changes in the water quantity and quality as tree canopy increases. This is an unexpected result and seemingly at odds with much of what is commonly understood about the effects trees on the hydrological cycle, particularly in regards to water quantity. Given that stormwater run-off reduction is regularly cited as a primary benefit of urban trees, one would expected to see much higher reduction rates. For instance, in an extreme hypothetical example where the canopy cover Yahara urban watershed is increased from the existing 19.3% canopy cover to 100% canopy cover, the resulting reduction is run-off is about 14%. This is a puzzling finding.

If there is one overriding conclusion from this study, it is that we should be careful in characterizing the canopy cover benefits as they relate to water quantity and quality across an urbanized area. We rely on theoretical models such as I-Tree Hydro to understand these dynamics. And the models seem to present a portrait that is difficult to account for. It is perhaps best to understand the results presented here as a basis of comparison either with other watersheds in entirely different areas or for subwatersheds within the same study area. For instance, the models seem to suggest that trees produce

greater relative benefits in some watersheds compared to others, if even these benefits are also apparently negligible in alternative case scenarios.

In no particular order, here are several more concluding observations:

1) The time required to run an I-Tree Canopy and I-Tree hydro model is relatively small, but the time required to learn and become familiar with the models is relatively long. The learning curve is steep. Much of the difficulty in using these models is in gathering and formatting appropriate data inputs. We'd estimate that once a reasonable facility with the software is established, it takes approximately 10 hours to run a single model beginning to end. However, expect several weeks to become familiar with the process.

2) Local conditions matter. The model presented generic outputs that may not square with observed data or conditions. For example, much of the Yahara River is controlled with a series locks, including on the outlet on Lake Mendota. This is important because if the canopy is perceived as a way of decreasing the extent of downstream or local flooding, then trees may have a relatively small impact given that the hydrological system is otherwise mechanically controlled. Similar consideration should also be paid to whether local stormwater is managed with either a combined or separate sewer system or whether storwater is managed with isolated catchments. Presumably trees would have greater success is reducing storm water related costs in combined stormwater and sewer systems.

3) Phosphorus, in particular, is important. There is good reason to believe that increased tree coverage will increase the amount of phosphorus introduced into a hydrological system. This is important because phosphorus is a critical pollutant for water bodies. In urban areas, trees and fallen leaves play a role transporting phosphorus to storm run-off systems particularly in the fall. However, we found that I-Tree Hydro regularly forecast reductions in phosphorus as canopy coverage increased. This seems at odds with locally observed phosphorus records.

In summary, the demands and opportunities of arboriculture exists within myriad environmental systems. This study raises the possibilities of understanding tree canopy cover as a component of an integrated urban structure. Here, we are concerned primarily the relationships to water. But interests as diverse aspower and gas utilities, avian wildlife habitat, and localized climates all play crucial roles in the lives of trees. If anything, this study tells us is that all of these practices, and many more, have implications for our cities well beyond the collective urban forest canopy.