United States Environmental Protection Agency

Region 7

Total Maximum Daily Load

Wyaconda Lake (MO_7009)

Clark County, Missouri

for Karen A. Flournoy
William A. Spratlin
Director
Water, Wetlands and Pesticides Division

12/21/10
Date

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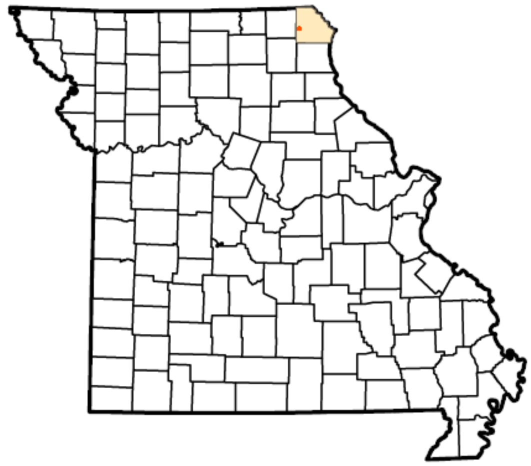
Total Maximum Daily Loads
for Wyaconda Lake, MO
Pollutant: Atrazine



Name: Wyaconda Lake (Wyaconda New Lake)[1]

Location: Clark County, MO

Hydrologic Unit Code (HUC): 071100010804

Water Body Identification (WBID): 7009

Missouri Lake Classification: Lake or reservoir used primarily as a public drinking water supply (L1)

Designated Beneficial Uses:
- Livestock and Wildlife Watering
- Protection of Warm Water Aquatic Life
- Protection of Human Health (Fish Consumption)
- Drinking Water Supply
- Whole Body Contact Recreation—Category B
- Secondary Contact Recreation

Impaired Beneficial Use: Drinking Water Supply

Size of Impaired Segment: 9 acres

Location of Impaired Segment: Section 33, Township 65N, Range 09W

Latitude (y)	**Longitude** (x)	**Northing** (y)	**Easting** (x)
40.3990	-91.9083	4472615	592643

Pollutant: Atrazine

Identified Source on 303(d) List: Rural nonpoint sources

TMDL Priority Ranking: High[2]

[1] Clark County has two lakes named Wyaconda Lake, with the older one being small and unclassified. MDNR refers to the larger, classified lake as Wyaconda New Lake. Wyaconda New Lake is not the correct name for the lake; therefore, the name will be corrected in subsequent 303(d) lists. In this document the lake will be referred to by its correct name, Wyaconda Lake.
[2] According to the 1998 Missouri 303(d) List.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

LIST OF ACRONYMS

µg/L	Micrograms per Liter
ASL	Above Sea Level
Avg.	Average
BFI	Base Flow Index
BMP	Best Management Practice
CAFO	Concentrated Animal Feeding Operation
CFR	Code of Federal Regulations
cm/s	Centimeters per Second
CSR	Code of State Regulation
CSTR	Continuously Stirred Tank Reactor
CWA	Clean Water Act
DAR	Drainage Area Ratio
deg.	Degrees
DO	Dissolved Oxygen
EDU	Ecological Drainage Unit
EPA	U.S. Environmental Protection Agency
GIS	Geographic Information System
GWLF	Generalized Watershed Loading Functions
ha	Hectare
HUC	Hydrologic Unit Code
IEM	Iowa Environmental Mesonet
kg	Kilograms
kg/yr	Kilograms per Year
LA	Load Allocation
lb	Pounds
lb/yr	Pounds per Year
LC	Loading Capacity
m	Meters
m^3	Cubic Meters
MCL	Maximum Contaminant Level
MDC	Missouri Department of Conservation
MDL	Maximum Daily Limit
MDNR	Missouri Department of Natural Resources
mg/L	Milligrams per Liter
mg/m^3	Milligrams per Cubic Meter
mi^2	Square Mile
MoRAP	Missouri Resource Assessment Partnership
MOS	Margin of Safety
MS4	Municipal Separate Storm Sewer System

MSDIS	Missouri Spatial Data Information Service
MSOP	Missouri State Operating Permit
NCDC	National Climate Data Center
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRCS	National Resources Conservation Service
PCS	Permit Compliance System
SLM	Simple Lake Model
TMDL	Total Maximum Daily Load
TSD	Technical Support Document
USACE	U.S. Army Corp of Engineers
USGS	U.S. Geological Survey
WBID	Water Body Identification
WLA	Wasteload Allocation
WQS	Water Quality Standards
WTP	Water Treatment Plant
WWTP	Wastewater Treatment Plant

1. INTRODUCTION

The Wyaconda Lake Total Maximum Daily Load (TMDL) is being established in accordance with Section 303(d) of the Clean Water Act (CWA). The water quality limited segment of Wyaconda Lake is included on the U.S. Environmental Protection Agency (EPA)–approved 2008 Missouri 303(d) List. EPA is establishing this TMDL to meet the milestones of the 2001 Consent Decree, *American Canoe Association, et al. v. EPA*, No. 98-1195-CV-W in consolidation with No. 98-4282-CV-W, February 27, 2001.

Section 303(d) of the CWA and Federal Chapter 40 of the Code of Federal Regulations (CFR) Part 130 requires states to develop TMDLs for waters not meeting designated beneficial uses. The TMDL process quantitatively assesses the impairment factors so that states can establish water-quality-based controls to reduce pollution and restore and protect the quality of their water resources. The purpose of a TMDL is to determine the maximum amount of a pollutant (the load) that a water body can assimilate without exceeding the water quality standards (WQS) for that pollutant. WQS are benchmarks used to assess the quality of rivers and lakes. The TMDL also establishes the pollutant loading capacity (LC) necessary to meet the Missouri WQS established for each water body based on the relationship between pollutant sources and water quality conditions. The TMDL consists of a wasteload allocation (WLA), a load allocation (LA) and a margin of safety (MOS). The WLA is the portion of the allowable load that is allocated to point sources. The LA is the portion of the allowable load that is allocated to nonpoint sources. The MOS accounts for the uncertainty associated with linking pollutant loads to the receiving water body's response. This uncertainty is often associated with assumptions and data limitations of the analysis methods used to assess the water body.

In addition to establishing a TMDL for Wyaconda Lake in Missouri, this report provides a summary of information, results and recommendations related to the impairment based on a broad analysis of watershed information, analysis of water quality data and computer modeling to support TMDL development. The sections of this report are organized as follows:

- Section 2 provides background information on the Wyaconda Lake watershed.
- Section 3 describes the potential sources of concern.
- Section 4 presents the applicable WQS and TMDL target.
- Section 5 describes the technical approach used to develop a TMDL.
- Sections 6 to 10 present the required TMDL elements (LC, WLA, LA, MOS, seasonal variation).
- Sections 11 to 13 summarize the monitoring plan, reasonable assurances and public participation.
- Section 14 presents a summary of the administrative record.

2. BACKGROUND

This section of the report provides background information on Wyaconda Lake and its watershed. Included in this section is a description of the watershed location, geology, soils, population, land use and land cover. In addition, water quality problems present in the watershed are described.

2.1 The Setting

Wyaconda Lake is located in the Central Plains/Cuivre/Salt Ecological Drainage Unit (EDU) (Sarver et al., 2002). Wyaconda Lake is 9 acres, and the Wyaconda Lake watershed is approximately 208 acres. The topographic relief of the watershed draining to the impaired lake has an approximate maximum elevation of 700 feet above sea level (ASL) and gradually slopes down approximately 20 feet, to 680 feet ASL. The watershed was defined using the 12-digit watershed HUC (071100010804) and was further delineated using elevation contours based on U.S. Geological Survey (USGS) topographic maps and national hydrography streams data. Clark County has two lakes named Wyaconda Lake, with the older one being small and unclassified. Although the Missouri Department of Natural Resources (MDNR) has data on both lakes, to differentiate between them, it refers to the larger, classified lake as Wyaconda New Lake. This is not the correct name for the lake; therefore, the name will be corrected in subsequent 303(d) lists. In this document the lake will be referred to as Wyaconda Lake.

Wyaconda Lake is a reservoir previously used by the city of Wyaconda for public drinking water purposes. The lake is created by the Wyaconda City Dam, which is situated on an unnamed tributary of the South Wyaconda River. The lake has two main outlet options, an overflow spillway and a 4-inch outlet pipe. The outlet pipe leads to a pump station that divides the outlet pipe, with one branch leading to the city of Wyaconda's water treatment plant (WTP), and the other draining to the watercourse below the dam (USACE, 1978).

Wyaconda Lake was listed on the 1998 Missouri 303(d) List due to high atrazine concentrations impairing the Drinking Water Supply designated beneficial use. The basis of this listing was supported by data from MDNR and pesticide manufacturers, including Novartis (Syngenta) and Monsanto, which collected data on Wyaconda Lake from 1994 - 2008. Data from these sampling events indicated that atrazine concentrations were routinely above the Missouri WQS numeric criterion of 3 micrograms per liter (µg/L) for the Drinking Water Supply. This number is based on the health risk associated with a 70-year exposure period and is interpreted as an instantaneous limit. In the 1998 Missouri 303(d) List, corn and sorghum production was listed as a pollutant source contributing to the elevated atrazine levels in Wyaconda Lake.

Wyaconda Lake is no longer used as a public water supply due to the increased costs associated with treatment. Wyaconda Lake exceeded Missouri Safe Drinking Water Act Regulations 10 CSR 60-4.050, 10 CSR 60-4.090, 10 CSR 60-7.010, 10 CSR 60-8.010, and 10 CSR 60-14.010.[3]

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[3] MDNR report entitled, MDNR Public Drinking Water Branch Statement of Facts and Compliance Schedule for Wyaconda, Missouri, Permit Number MO2010875, dated February 9, 2009.

The major water quality problem is high atrazine levels due to pesticides contained in runoff or drainage from agricultural land dominating the watershed.

Atrazine is a widely used herbicide for control of broadleaf weeds. In Missouri, atrazine is the most heavily used herbicide applied to corn and sorghum. Based on the review of available scientific studies, EPA determined in 2000 that atrazine is not likely to cause cancer in humans. In an abundance of caution, EPA is sponsoring epidemiological studies through the National Cancer Institute to evaluate the potential for any association between atrazine exposure to people and cancer, even though rigorously conducted animal studies show that this result is unlikely. However, as discussed on EPA's web page and as indicated in the *2003 Atrazine Reregistration Eligibility Decision*, EPA plans to convene a Scientific Advisory Panel meeting concerning atrazine and its possible association with carcinogenic effects in 2011.[4]

One set of water quality data collected by the pesticide manufacturer Novartis (Syngenta) and the MDNR between 1998 and 2006 included 229 measurements of raw water collected from the lake. These data have shown that the long-term average for atrazine exceeds the criterion of 3 µg/L.

2.2 Physiographic Location, Geology and Soils

The Wyaconda Lake watershed, only a small portion of the larger Wyaconda River watershed, lies within the eastern section of the Glaciated Plains Natural Division physiographic region (Thom and Wilson, 1980), which is also known as the Dissected Till Plains (Fenneman, 1938; MDC, 2010). These plains were formed by glaciers that deposited glacial till consisting of mostly clay and some rock. Over time, wind-blown soil (loess) was deposited on top of these soils left by the receding glaciers. Across most of the basin, this loess ranges from zero to eight feet deep, on top of 100 to 200 feet of glacial till. Pennsylvanian aged rock lies beneath the soils of the upper basin, and shifts to Mississippian aged rock in the lower basin (MDNR, 1984). This stratification of layers limits the amount of water that infiltrates into groundwater. Additionally, the large amount of clay and numerous shale and coal deposits also limit the vertical movement of water within the basin (MDNR, 1984). Consequently, most of the stream flow within the basin is only supported by surface runoff, and there are no significant springs within the basin, causing poor baseflow during extended dry periods (MDC, 2010).

Because of the glacial till, the soils in the upper basin dramatically differ from the lower basin. The upper basin is characterized as deep loess and drift general soil association (Allgood and Persinger, 1979). The topography is classified as rolling to hilly, with some wide, nearly level ridge tops and bottom land adjacent to streams. The soils were formed under mostly tall grass prairie vegetation and are of the Edina, Kilwinning, Lamoni or Armster soil associations (MDC, 2010). These soils range in slope from 0 to 20 percent, with clayey subsoils, and are all highly susceptible to erosion (SCS, 1975). The lower basin soils are characterized as the Central Mississippi Valley Wooded Slopes (Allgood and Persinger, 1979). The uplands in this area have soils from the Winfield, Lindley, and Keswick soil associations, which are deep, well-drained, and gently sloping to steep (SCS, 1992). However, these upland soils are also highly susceptible

[4] http://www.epa.gov/pesticides/reregistration/atrazine/atrazine_update.htm

to erosion. Soils in the floodplains are from the Arbela, Fatima and Blackoar soil associations and are deep, nearly level and poorly to moderately drained (MDC, 2010).

A soil's Hydrologic Soil Group relates to the rate at which water enters the soil profile, which in turn affects the amount of water that enters the stream as direct runoff. Table 1 provides a summary of soil types (i.e., Hydrologic Soil Groups) in the impaired Wyaconda Lake watershed. The dominant soil type, Group C, covers approximately 73.8 percent of the watershed. Group C includes sandy and silty loam soils that have a moderately fine to fine structure. These soils have low infiltration rates when thoroughly wetted and consist primarily of soils with a layer that impedes the downward movement of water. Approximately 20.8 percent of soils in the impaired watershed are categorized as Group D, which include silty loams and complexes that have the highest runoff potential. These soils have very low infiltration rates when thoroughly wetted and consist primarily of clay soils, soils with a permanent high-water table, soils with a claypan or clay layer at or near the surface and shallow soils over nearly impervious material (Purdue Research Foundation, 2009). The remaining area (5.4 percent) of the watershed is covered by water.

Table 1. Wyaconda Lake Watershed Soils Summary (NRCS, 2010)

Soil Name	Hydrologic Soil Group	Watershed Area		Percent (%)
		Acre	Square Miles	
Armstrong loam	C	144.50	0.226	69.4
Gara loam	C	9.15	0.014	4.4
Subtotal		**153.65**	**0.240**	**73.8**
Adco silt loam	D	37.99	0.059	18.2
Belinda silt loam	D	5.42	0.008	2.6
Subtotal		**43.41**	**0.067**	**20.8**
Water		11.28	0.018	5.4
Total		**208.34**	**0.325**	**100.0**

2.3 Rainfall and Climate

Two weather stations are located near the Wyaconda Lake watershed (Figure 1): Station 134389 (Keosauqua, Iowa) and Station 235130 (Luray, Missouri). The Keosauqua station was used for the precipitation data, and the Luray station was used for the majority of the temperature data, with some supplementation of data from the Keosauqua station. Figure 2 provides a summary of rainfall and climate data for both stations based on 14-year totals (1994 – 2008) (NOAA, 2010). The annual average precipitation at these stations was 37.66 inches, and the average daily temperature was 52.32 degrees Fahrenheit over the 14-year period. These nearby weather stations will provide useful information for simulations and modeling associated with the watershed and TMDL development.

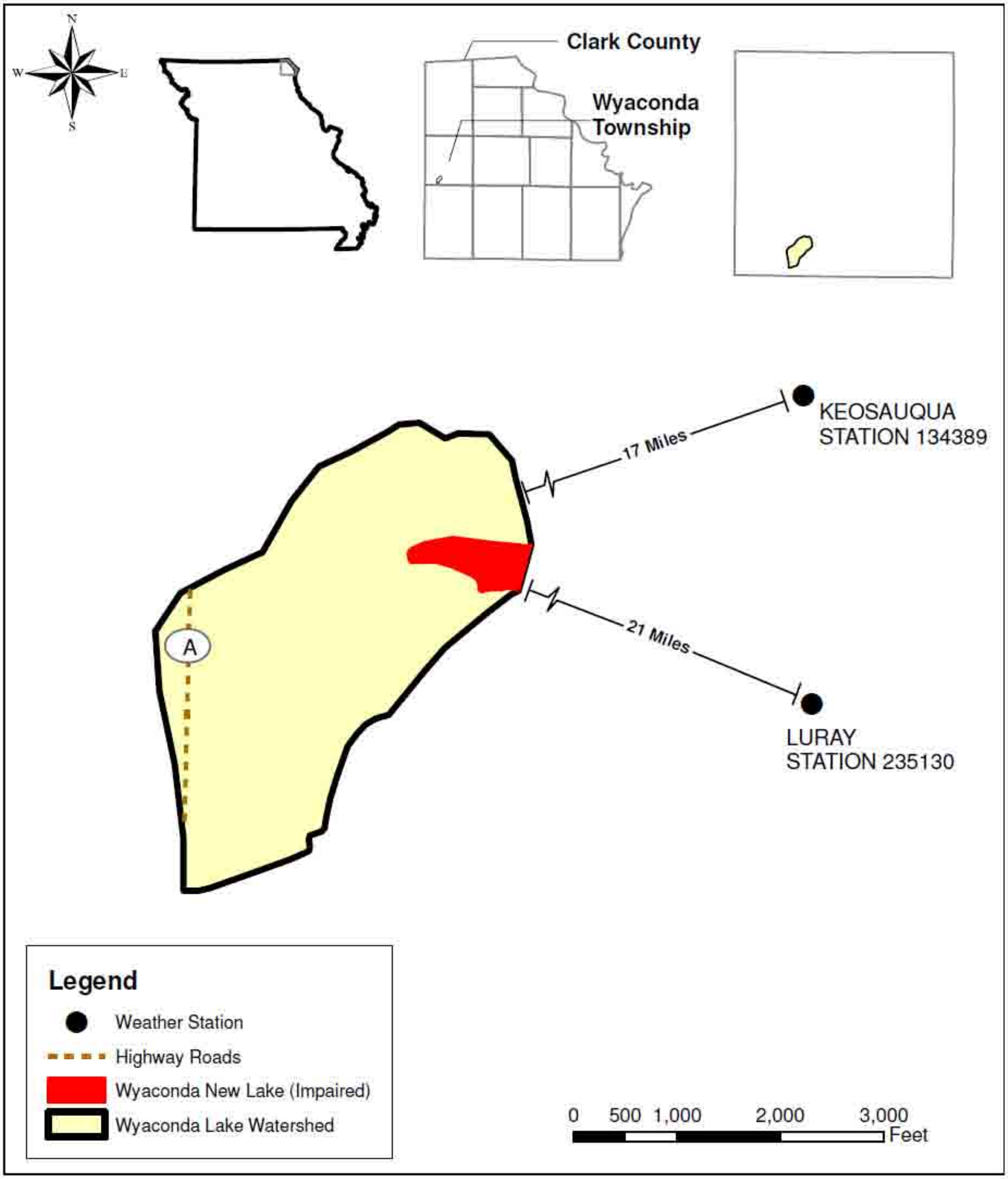

Figure 1. The Location of the Wyaconda Lake Watershed and the Weather Stations.

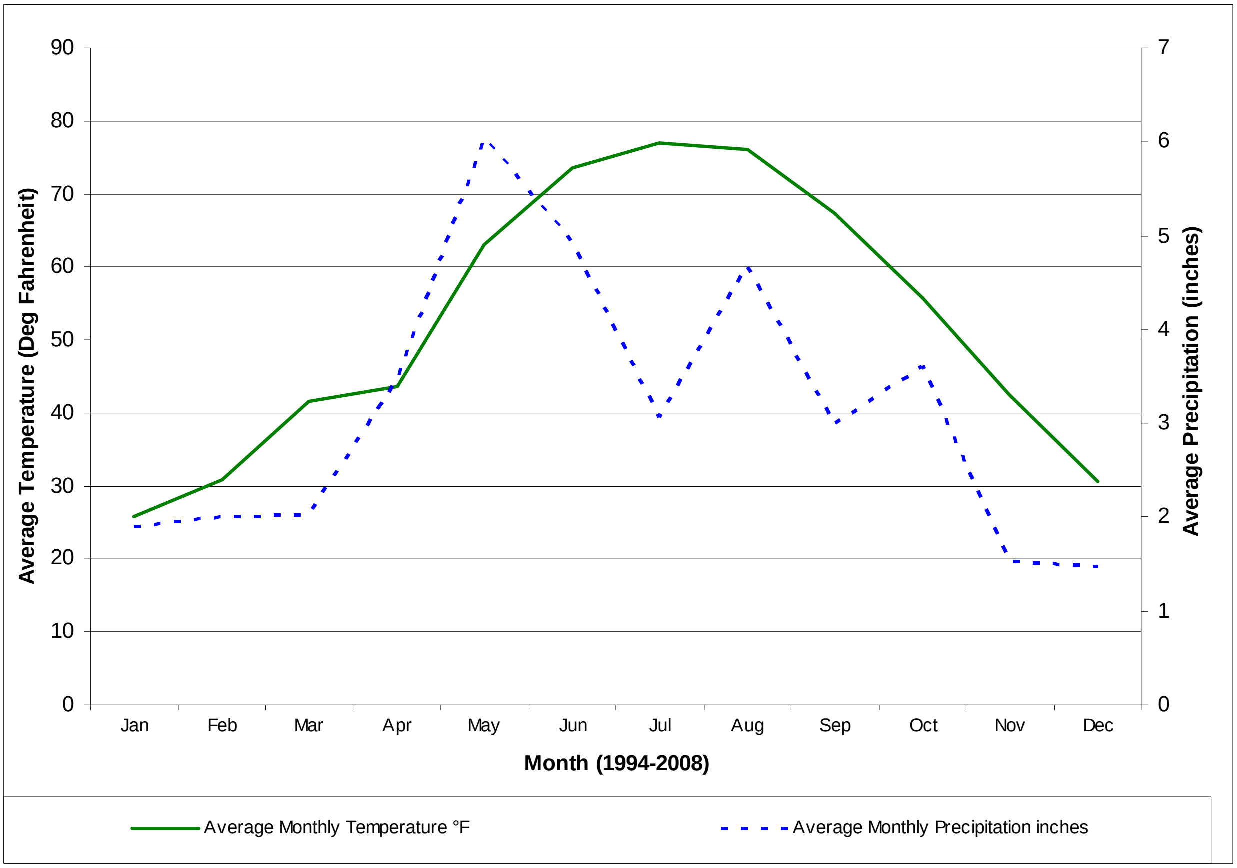

Figure 2. Fourteen-year Monthly Temperature and Precipitation Averages (NOAA, 2010).

2.4 Population

The population data for the Wyaconda Lake watershed is not directly available. However, the U.S. Census Bureau reports that the 2000 population for Clark County was 7,416 (U.S. Census Bureau, 2000). The Wyaconda Lake watershed population was estimated to be two people. This estimation was calculated using a geographic information system (GIS) and selecting the census block points within the watershed area (0.325 square miles [mi^2]).

2.5 Land Use and Land Cover

The land use and land cover of the Wyaconda Lake watershed is shown in Figure 3 and is summarized in Table 2 (MoRAP, 2005). The primary land uses and land covers are cropland (54.4 percent) and grassland (30.5 percent). Impervious[1], low-intensity urban, forest and open water occupy the remaining 15.1 percent of the watershed area. Comprising over half of the watershed, cropland is by far the dominant land use. This large percentage of cropland in the Wyaconda Lake watershed is most likely the main source of the elevated atrazine levels due to agricultural runoff and overspraying.

Table 2. Land Use and Land Cover in the Wyaconda Lake Watershed (MoRAP, 2005)

Land Use/Land Cover	Watershed Area		Percent (%)
	Acres	Square Miles	
Impervious[1]	8.91	0.014	4.3
Low-Intensity Urban	0.37	0.001	0.2
Cropland	113.36	0.177	54.4
Grassland	63.64	0.099	30.5
Forest	9.67	0.015	4.6
Open Water	1.11	0.002	0.5
Wyaconda Lake [2]	11.28	0.018	5.4
Total	**208.34**	**0.326**	**100**

[1] Impervious land uses includes non-vegetated, impervious surfaces, such as areas dominated by streets, parking lots, and buildings (MoRAP, 2005).

[2] Wyaconda Lake area not included in Generalized Watershed Loading Functions (GWLF) stream flow model. Due to the increased accuracy of Geographic Information System (GIS) data layers for analysis over previous methods of lake area measurements, the lake area used in the TMDL analysis may not correspond with other documents.

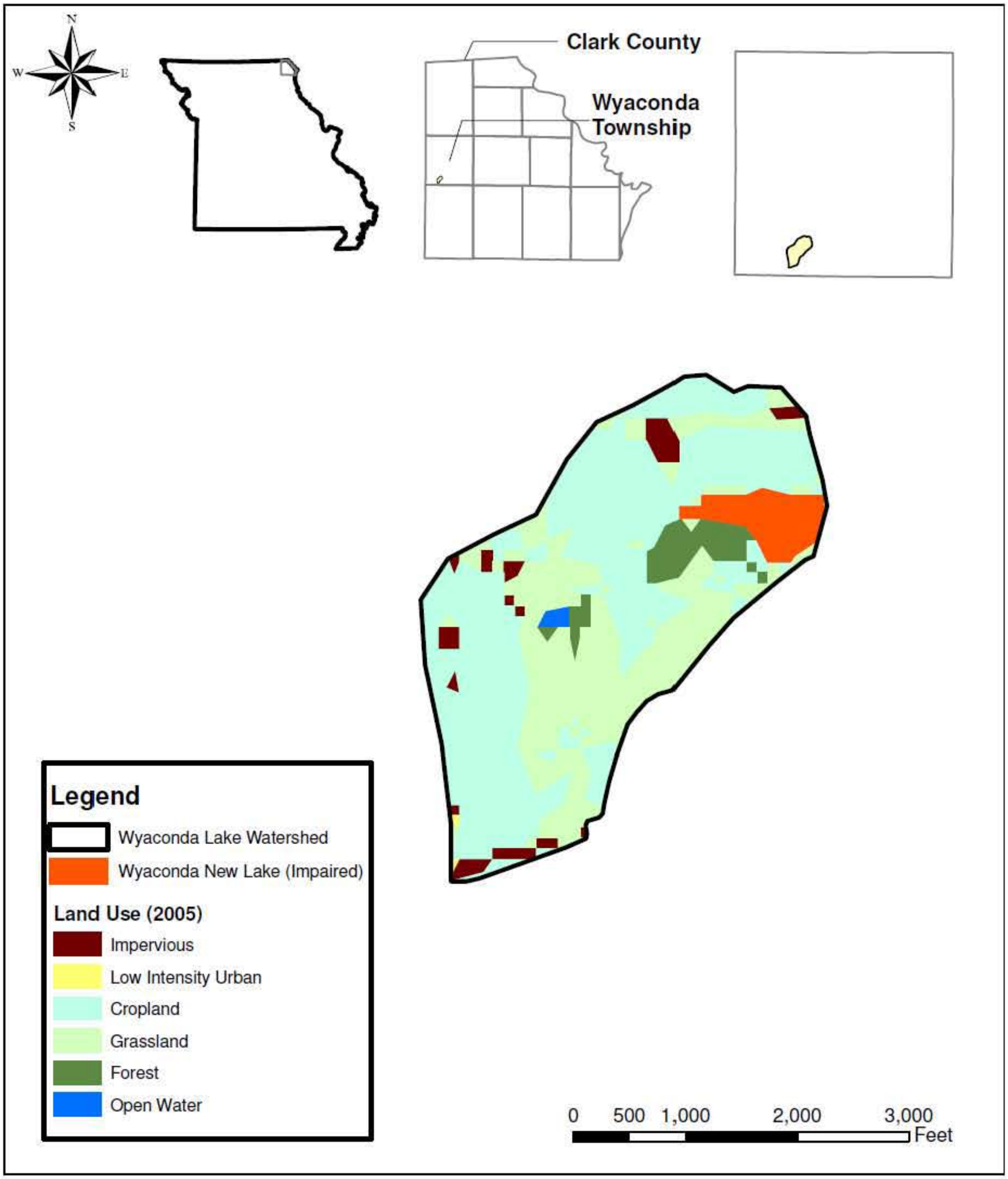

Figure 3. Land Use and Land Cover in the Wyaconda Lake Watershed (MoRAP, 2005).

2.6 Defining the Problem

Wyaconda Lake is impaired due to exceedances of Missouri's WQS for Drinking Water Supply (10 CSR 20-7.031). Water quality data were collected by pesticide manufacturers Novartis (Syngenta) and Monsanto and were supplemented with data from MDNR to produce a data set from 1994 - 2008 of raw water data (directly from Wyaconda Lake) and finished water data (after going through the city of Wyaconda's WTP) (MDNR, 2008). Water quality data were analyzed according to criteria set forth by MDNR, which uses instantaneous violations of the maximum contaminant level (MCL) to determine compliance with WQS. For atrazine, the MCL is 3 µg/L. The raw water data used for analysis consisted of 339 atrazine measurements collected between one and five times per month from 1996 – 2008. The descriptive statistics for all the atrazine concentration data are summarized in Table 3. Approximately 95 samples (28.02 percent) exceeded the MCL for atrazine. Sixty-two of the MCL exceedances occurred during one time period from April 2005 to August 2006. Other stretches of exceedances included 17 from July 1996 to October 1998 and 14 exceedances from May 2001 to November 2002. Figure 4 shows the atrazine concentrations over time. Pesticide application on agricultural fields is performed during the active growing season, mainly during the summer months. Table 4 and Figure 5 summarize the seasonal trends and criteria violations. However, elevated atrazine concentrations do not occur every year. This may be the result of atrazine volumes applied, weather conditions and/or the type of crop grown. The data used in this TMDL is provided in Appendix A.

Table 3. Summary Statistics for Atrazine Concentration Data from 1996 – 2008 at Wyaconda Lake (MDNR, 2008)

Sampling Events	Mean	Median	Minimum	Maximum	Lower Quartile	Upper Quartile	Criteria (µg/L)	Percent of samples > 3.0 µg/L
339	3.03	1.20	0.00	23.01	0.55	3.28	3	28.02

Table 4. Monthly Criteria Exceedance Data for Wyaconda Lake (MDNR, 2008)

Month	Samples	Exceedances[1]	Percentage (%)
January	24	6	25.0
February	22	5	22.7
March	27	3	11.1
April	28	5	17.9
May	32	9	28.1
June	34	13	38.2
July	31	10	32.3
August	28	14	50.0
September	29	10	34.5
October	28	9	32.1
November	27	7	25.9
December	29	4	13.8

[1] The MCL for atrazine is 3 µg/L.

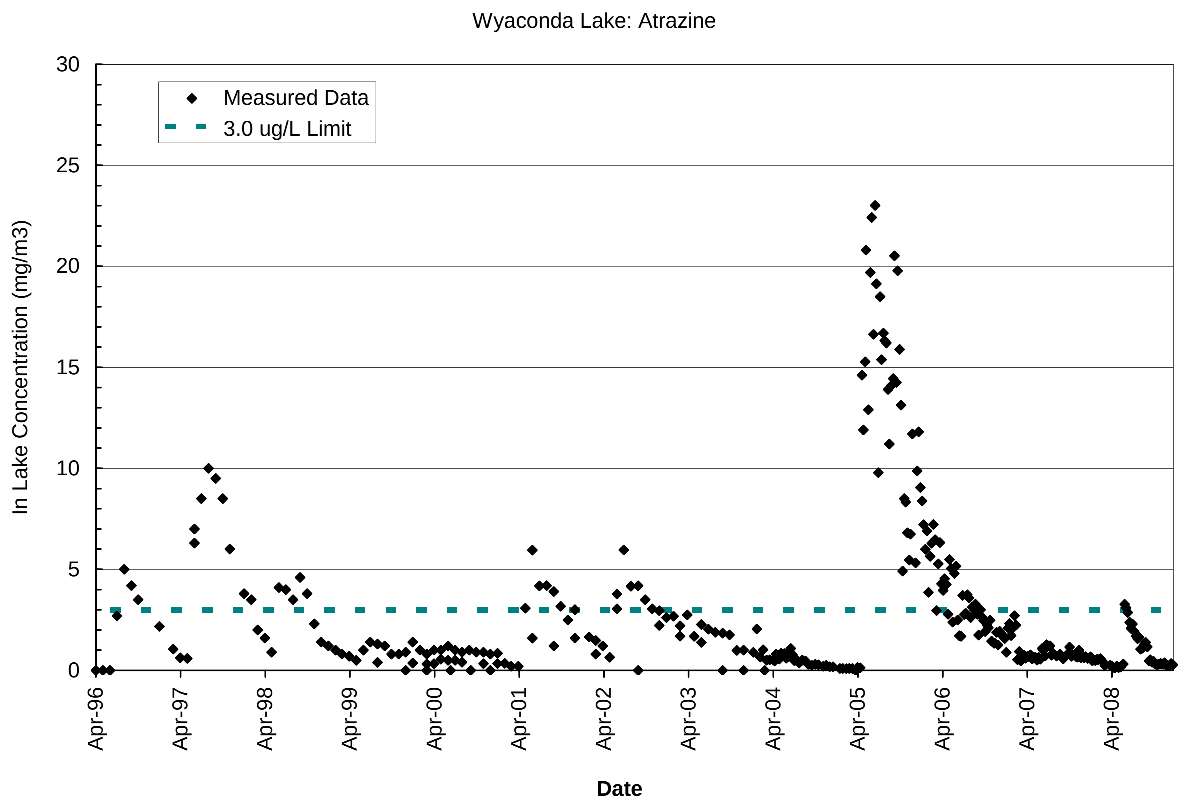

Figure 4. Atrazine Concentrations from 1996 – 2008 (MDNR, 2008)

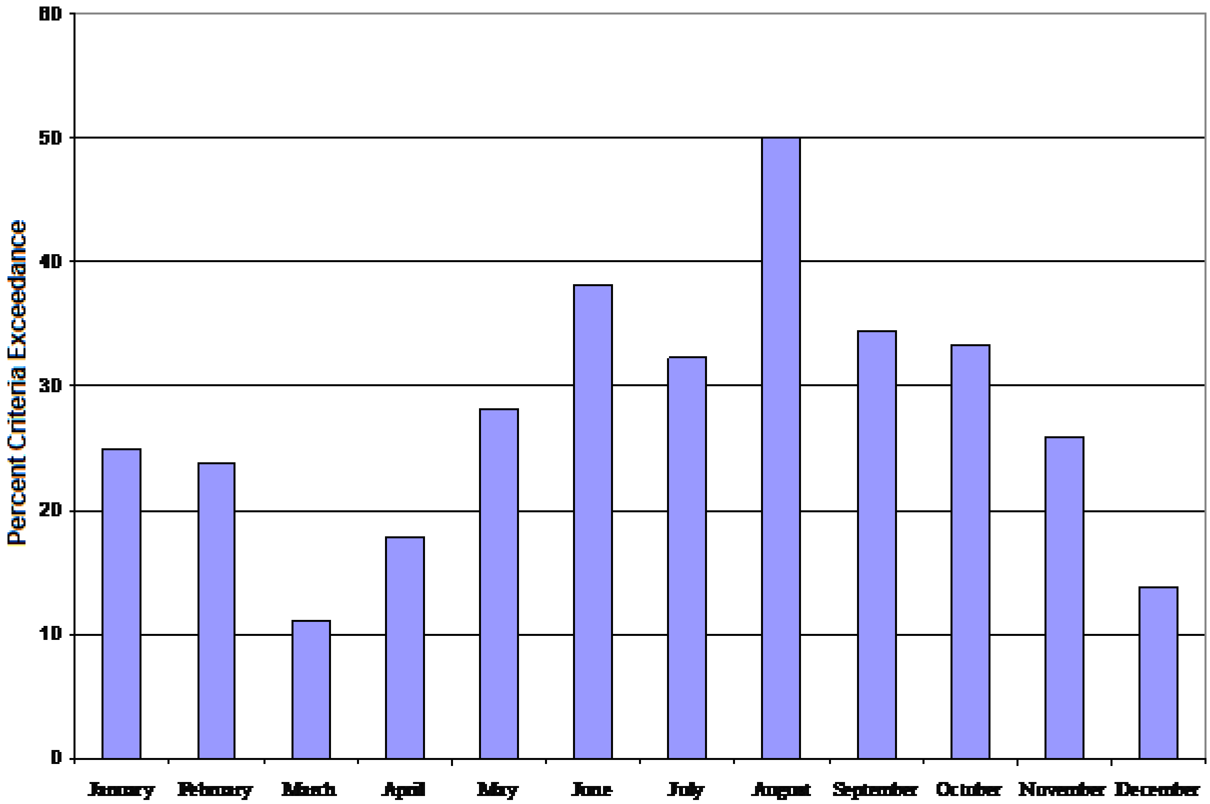

Figure 5. Monthly Criteria Exceedance Data for Wyaconda Lake (MDNR, 2008)

3. SOURCE INVENTORY

A source assessment is used to identify and characterize the known and suspected sources contributing to the impairment in Wyaconda Lake. For the purpose of this report, sources have been divided into two broad categories: point sources and nonpoint sources. Point sources can be defined as sources-either constant or time transient-which occur at a fixed location in a watershed. Nonpoint sources are generally accepted to be diffuse sources not entering a water body at a specific location. Atrazine from rural nonpoint sources are considered to be the primary contributors to impairment in Wyaconda Lake.

3.1 Point Sources

The term “point source” refers to any discernible, confined and discrete conveyance, such as a pipe, ditch, channel, tunnel or conduit that transports pollutants to a water body. For the purposes of TMDL development, point sources are defined as sources regulated through the National Pollutant Discharge Elimination System (NPDES) program. Missouri has its own program for administering the NPDES program, referred to as the Missouri State Operating Permit (MSOP) system. The NPDES and MSOP programs are the same and for the purposes of this document the term “NPDES” will be used. The following regulated entities are included in this source category:

- Municipal and industrial wastewater treatment plants (WWTPs),
- Concentrated Animal Feeding Operations (CAFOs),
- Storm water runoff from Municipal Separate Storm Sewer Systems (MS4s) and
- General permitted facilities (e.g., including storm water runoff from construction and industrial sites).

General permits (as opposed to site specific permits) are issued for activities that are similar enough to be covered by a single set of requirements. Storm water permits are issued for activities that discharge only in response to precipitation events. Point sources in the Wyaconda Lake watershed were identified by consulting EPA's Permit Compliance System (PCS) website[5] and MDNR's GIS inventory[6] of NPDES–permitted facilities covered under storm water or general permits. This inventory can be found at the Missouri Spatial Data Information Service (MSDIS) website[7]. These databases identified no regulated sources or NPDES permits associated with Wyaconda Lake.

3.2 Nonpoint Sources

Nonpoint sources include all other categories not classified as point sources and are generally accepted to be diffuse sources not entering a water body at a specific location. Atrazine from rural nonpoint sources is considered to be the primary contributor to impairment in Wyaconda Lake. Potential nonpoint sources contributing high atrazine levels in the Wyaconda Lake watershed include runoff from agricultural areas, runoff from urban areas, runoff from on-site wastewater treatment systems and various sources associated with riparian habitat conditions. Each of these potential nonpoint sources is discussed further in the following sections.

In the absence of an NPDES permit, the discharges associated with sources were applied to the LA, as opposed to the WLA for purposes of this TMDL. The decision to allocate these sources to the LA does not reflect any determination by EPA as to whether these discharges are, in fact, unpermitted point source discharges within this watershed. In addition, by establishing these TMDLs with some sources treated as LAs, EPA is not determining that these discharges are exempt from NPDES permitting requirements. If sources of the allocated pollutant in this TMDL are found to be, or become, NPDES-regulated discharges, their loads must be considered as part of the calculated sum of the WLAs in this TMDL. WLA in addition to that allocated here is not available.

3.2.1 Runoff from Agricultural Areas

The 2005 land-use/land-cover data (MoRAP, 2005) indicate there are approximately 113 cropland acres in the Wyaconda Lake watershed. This acreage comprises 54.4 percent of the entire watershed and approximately 37.0 percent of the riparian[8] buffer (Table 5). Runoff and drainage from agricultural lands can be a large source of chemicals, nutrients and oxygen-

[5] www.epa.gov/enviro/html/pcs/index.html (EPA, 2010)
[6] The GIS layers were updated in May and June 2009 (MSDIS, 2010).
[7] http://msdis.missouri.edu/datasearch/ThemeList.jsp
[8] A riparian corridor (or zone or area) is the linear strip of land running adjacent to a stream bank or water body.

consuming substances. No point source loads of atrazine were identified in the Wyaconda Lake watershed. Therefore, the only loads addressed in this TMDL are nonpoint sources of atrazine.

Atrazine is a systemic herbicide typically applied to row crops during spring to provide broadleaf control and grass suppression. Atrazine is one of the lowest-cost herbicides on a cost-per-acre basis (Devlin et al., 2000), which adds to its widespread use in row crops. In the state of Missouri, atrazine is applied to 80 percent of corn at an application rate of 1.363 pounds per acre (USDA, 2006). Atrazine's runoff potential is high due to its weak adsorption to soil particles, and it persists in the soil for a long time, with a half life of 6 months. Approximately 90 percent of atrazine loss occurs in the water portion of runoff, and only 10 percent with the eroding soil particles (Devlin et al., 2000). Potential transport mechanisms of atrazine include overland runoff, drainage tile discharge containing atrazine from infiltration, groundwater flow, and direct rainfall to the lake containing low levels of contaminated dust. Atrazine can be applied in a variety of ways to decrease the amount available for runoff, and best management practices (BMPs) can be employed based on site specific conditions to minimize atrazine runoff. Using atrazine BMPs in the Wyaconda Lake watershed will help reduce the nonpoint source load from row crops and contribute to decreasing atrazine concentrations in the lake.

3.2.2 Runoff from Urban Areas

Storm water runoff from urban areas can also be a significant source of chemicals and pollutants. Pesticide application can lead to chemical runoff. Because approximately 4.3 percent of the watershed is classified as impervious or low-intensity urban, with no high-intensity urban land use, and atrazine is not typically applied to these land uses, urban runoff is unlikely to be a major contributor of atrazine to Wyaconda Lake.

3.2.3 Runoff from Onsite Wastewater Treatment Systems

Although if they fail, onsite wastewater treatment systems may provide nutrients and bacteria to water bodies, they are not a source of atrazine.

3.2.4 Riparian Habitat Conditions

Riparian (streamside) conditions can have a strong influence on instream water quality. Well-vegetated riparian corridors are a vital functional component of stream ecosystems and are instrumental in the detention, removal and assimilation of nutrients and chemicals in the water column (i.e., they act as buffers). Therefore, a well-vegetated riparian corridor is better able to moderate the impacts of high nutrient loads and chemical runoff on a stream than is a poorly vegetated corridor. Wooded riparian buffers can also provide shading, which reduces stream temperatures and increases the DO saturation capacity of the stream. In addition, tree roots better stabilize streambanks and resist erosion more effectively than do grasses, row crops or shrubbery.

As indicated in Table 5, the land in the Wyaconda Lake 30-meter riparian corridor is classified as grassland (44.4 percent), cropland (37.0 percent), and forest (18.6 percent) (MoRAP, 2005). Compared to wooded areas, grassland and cropland have the potential to provide much less shading and higher chemical and nutrient loads due to pesticide application, fertilization and livestock activity. More than two-thirds of the riparian corridor is comprised of grassland and cropland. Because these land types are associated with high chemical and nutrient loads, their presence near Wyaconda Lake indicates that transport of pollutants from these areas is more likely to occur compared to other land uses further from the receiving water. The large percentage of cropland in the riparian areas of Wyaconda Lake is most likely the main source of the elevated atrazine levels due to agricultural runoff, drainage and potential overspraying.

Table 5. Percentage Land Use and Land Cover Within 30 Meter Riparian Buffer (MoRAP, 2005)

Land Use/Land Cover	Acres	Square Miles	Percentage (%)
Grassland	1.57	0.002	44.4
Cropland	1.31	0.002	37.0
Forest	0.66	0.001	18.6
Total	**3.53**	**0.005**	**100.0**

4. APPLICABLE WATER QUALITY STANDARDS AND NUMERIC WATER QUALITY TARGETS

The purpose of developing a TMDL is to identify the maximum amount of a pollutant (the load) a water body can receive and still achieve WQS. WQS are therefore central to the TMDL development process. The TMDL process quantitatively assesses the impairment factors so states can establish water quality-based controls to reduce pollution from both point and nonpoint sources and to restore and protect the quality of their water resources. The water quality-based approach allows the pollutants entering the water body to be set at a level protective of its designated (or beneficial) uses. Technology-based controls set allowable pollutant loads entering a water body based on performance of pollution-control technologies without regard to the condition of the receiving water body.

Under the CWA, every state must adopt WQS to protect, maintain and improve the quality of the nation's surface waters (U.S. Code Title 33, Chapter 26, Subchapter III). These standards represent a level of water quality that will support the CWA's goal of "fishable/swimmable" waters. Missouri's WQS (10 Code of State Regulation [CSR, 2009] 20-7.031) consist of three components: designated uses, criteria (general and numeric), and an antidegradation policy.

Beneficial or designated uses for Missouri streams are found in the WQS at 10 CSR 20-7.031(1)(C), (1)(F) and Table H (CSR, 2009). Criteria for designated uses are found in 10 CSR 20-7.031, Tables A and B (CSR, 2009). Missouri's antidegradation policy is outlined in 10 CSR 20-7.031(2) (CSR, 2009).

4.1 Designated Beneficial Uses

The impaired Wyaconda Lake (WBID 7009) is 9 acres and is classified as a lake or reservoir used primarily as a public drinking water supply (L1). Designated beneficial uses include:

- Drinking Water Supply,
- Livestock and Wildlife Watering,
- Protection of Warm Water Aquatic Life,
- Protection of Human Health (Fish Consumption),
- Whole Body Contact Recreation (Category B) and
- Secondary Contact Recreation.

Drinking Water Supply is the impaired designated beneficial use.

4.2 Criteria

Wyaconda Lake is listed as impaired on the EPA-approved 2008 Missouri 303(d) List because water quality monitoring revealed elevated atrazine concentrations due to rural nonpoint sources. Atrazine concentrations were routinely above the numeric criterion for Drinking Water Supply. The specific numeric criterion is 3 µg/L.

Atrazine loadings are flow dependent and seasonal, with the highest observed concentrations typically occurring in the spring and early summer. Approximately 95 of 339 samples (28.02 percent) exceeded the MCL for atrazine. Sixty-two of the MCL exceedances occurred during one time period from April 2005 to August 2006. Other stretches of exceedances included 17 from July 1996 to October 1998 and 14 exceedances from May 2001 to November 2002. Figure 4 reports the atrazine concentrations in Wyaconda Lake over time. The high concentrations in Wyaconda Lake during these months coincide with herbicide and pesticide application. Thus, while exceedances of 3 µg/L may occur throughout the year, they are related to herbicide application during the growing season.

4.3 Antidegradation Policy

Missouri's WQS include EPA's "three-tiered" approach to antidegradation, which may be found at 10 CSR 20-7.031(2) (CSR, 2009):

- Tier 1 - Protects existing instream uses and a level of water quality necessary to maintain and protect those uses. Tier 1 provides the absolute floor of water quality for all waters of the United States. Existing instream water uses are those uses that were attained on or after November 28, 1975, which is the date of EPA's first WQS Regulation.

- Tier 2 - Protects and maintains the existing level of water quality where it is better than applicable water quality criteria. Before water quality in Tier 2 waters can be lowered, there must be an antidegradation review consisting of: 1) a finding that it is necessary to accommodate important economic and social development in the area where the waters are located; 2) full satisfaction of all intergovernmental coordination and public participation provisions; and 3) assurance that the highest statutory and regulatory requirements for point sources and BMPs for nonpoint sources are achieved. Furthermore, water quality may not be lowered to less than the level necessary to fully protect the "fishable/swimmable" uses and other existing uses.

- Tier 3 - Protects the quality of outstanding national and state resource waters, such as waters of national and state parks, wildlife refuges and waters of exceptional recreational or ecological significance. There may be no new or increased discharges to these waters and no new or increased discharges to tributaries of these waters that would result in lower water quality.

5. MODELING APPROACH

Atrazine loading to Wyaconda Lake was estimated using a linked lake and watershed modeling approach. A Simple Lake Model (henceforth referred to as the Wyaconda Simple Lake Model) was used to represent in-lake atrazine concentrations for Wyaconda Lake. BasinSim 1.0 (Ting et al., 1999) was the model used to simulate water flows from the Wyaconda Lake watershed. Atrazine measurements from Wyaconda Lake between 1996 and 2008 were reviewed to assess the impact on Wyaconda Lake's Drinking Water Supply designated use. These data were used to calibrate the Wyaconda Simple Lake Model, and inverse modeling was used to predict atrazine loads from the watershed.

The Wyaconda Lake BasinSim 1.0 application incorporates Generalized Watershed Loading Functions (GWLF) Version 2.0 (Haith et al., 1992), which is a model capable of simulating watershed hydrology and developing cumulative monthly water inflows to the lake. The GWLF model was used to estimate monthly average volumes (cubic meters [m^3]) entering the lake from the watershed during 1994–2008. Model inputs for temperature and precipitation were obtained from Luray (235130) and Keosauqua (134389) weather stations through the Iowa Environmental Mesonet's (IEM's) website[9]. Transport parameters (i.e., land-use area, runoff curve number, ground water recession and seepage coefficients) for this application were based on soil type, land use and watershed topography. A description of the GWLF modeling, including inputs used to simulate watershed conditions for the TMDL are included in Appendix B. GWLF flow outputs (i.e., summary, annual averages and monthly averages) are included in Appendix C.

Atrazine concentrations in Wyaconda Lake were estimated using a well-mixed lake spreadsheet model with monthly variable inflows, volume, and outflows. This simple model uses a Runge-Kutta fourth-order numerical integration method to solve the differential equations required to simulate a completely mixed lake under variable loading conditions for a user-defined time step. Within the simple model framework, pollutants may undergo a first-order

[9] http://mesonet.agron.iastate.edu/

reaction rate to represent decay, hydrolysis or other losses. The first-order reaction rate is commonly used to represent these types of losses. Model initial conditions are presented in Table 6.

Average monthly stream flows (cubic meters [m^3] per month), developed using GWLF, were used to estimate flows and atrazine loading in the Wyaconda Simple Lake Model. Outflows from the lake were calculated using reservoir routing. The stage discharge relationship was taken from previous dam inspection reports developed by the U.S. Army Corp of Engineers (USACE, 1978), and the stage volume relationship was developed from information included in the dam safety inspection. Details of this calculation are provided in Appendix D. To estimate inflow atrazine concentrations, inflow values were initially set equal to the corresponding observed in-lake measurements and were adjusted when necessary to fit the modeled in-lake concentrations to in-lake measurements.

Table 6. Wyaconda Simple Lake Model Initial Conditions

Parameter	Value	Units
Initial Volume	54406.9	m^3
Initial Water Elevation	209.49	meters
Reaction Rate	0.0833333	/month
Settling Velocity	0	meters (m)/month
Initial Concentration	2.41	milligrams per liter (mg/L)
Calculation Step	0.2	month
Print Step	0.2	month
Initial Time	1	month
Final Time	168	month

The Wyaconda Simple Lake Model results for existing conditions are presented in Figure 6, Figure 7 and Figure 8. A detailed description of the Wyaconda Simple Lake Model is provided in Appendix E. Figure 6 presents the entire period of predicted and measured lake concentrations. Figure 7 presents measured and predicted monthly averages, and Figure 8 shows the regression of monthly average atrazine values. In general, the model performs well; minimum and maximum values are matched in the model and monthly and seasonal trends are captured. A least-squares regression fit between predicted and observed monthly average atrazine in-lake concentration (Figure 8) shows a good relationship between the two variables (coefficient of determination [R^2] = 0.9786) and a slope near 1.0. Figure 9 shows a comparison between monthly simulated and measured atrazine concentrations, and Figure 10 shows a histogram of monthly percent error from the model. These figures show that the predicted monthly concentrations are similar to the measured atrazine data, as the majority of the data (98 of 136) compared has less than 25 percent error. Table 7 includes a statistical summary of the entire period simulated. This comparison shows that overall error associated with the comparison of predicted and measured data is low.

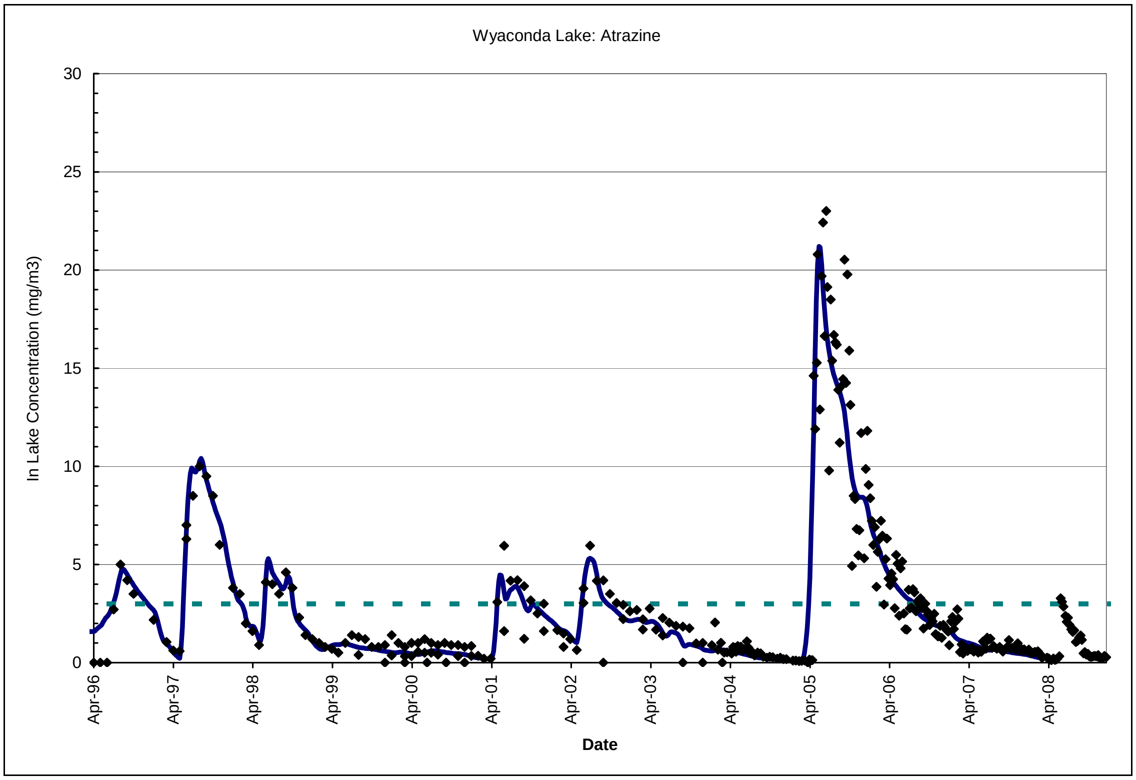

Figure 6. Wyaconda Simple Lake Model Results for Existing Conditions (1996–2008)

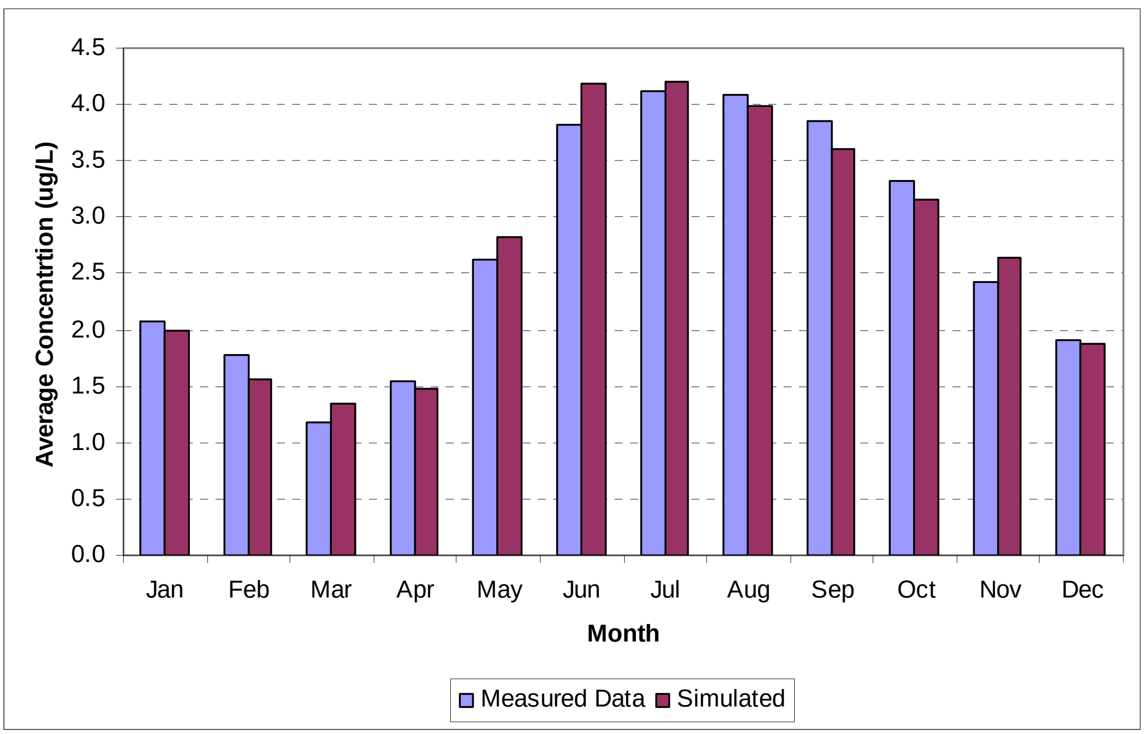

Figure 7. Observed and Predicted Average Atrazine Concentration in Wyaconda Lake (1996–2008)

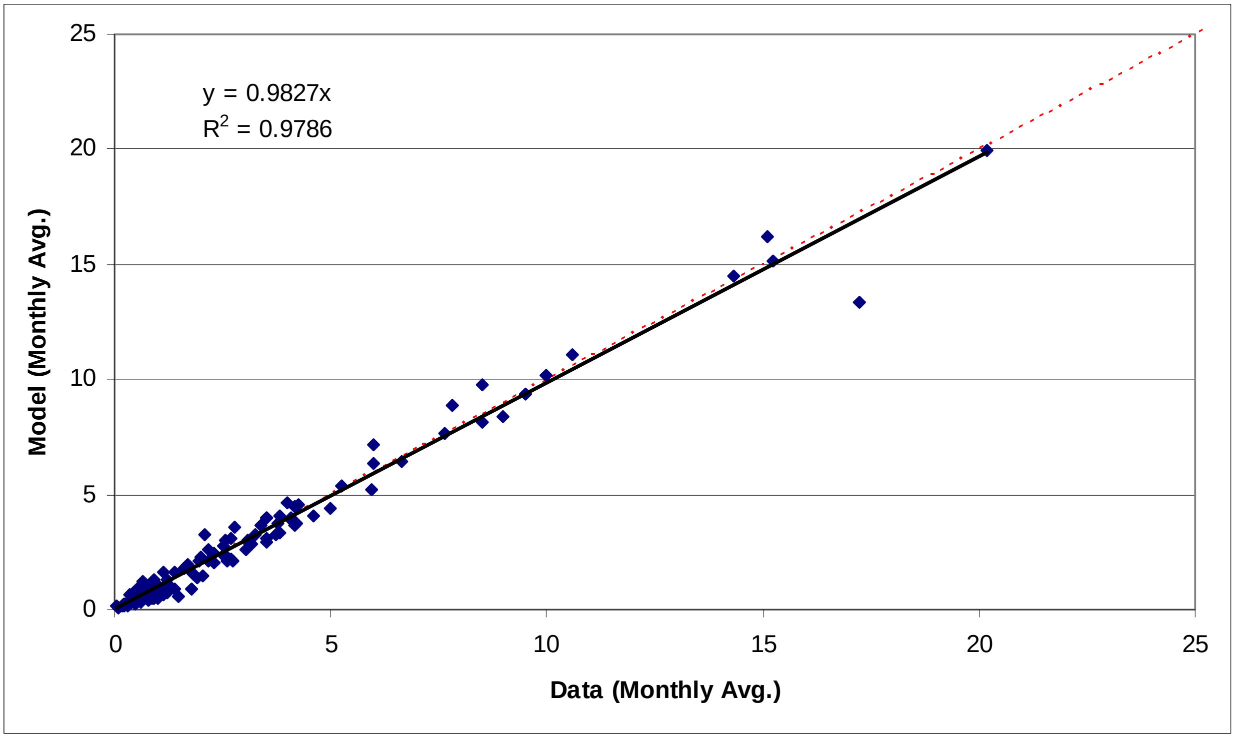

Figure 8. Linear Regression Between Average Monthly Observed and Predicted In-Lake Concentrations

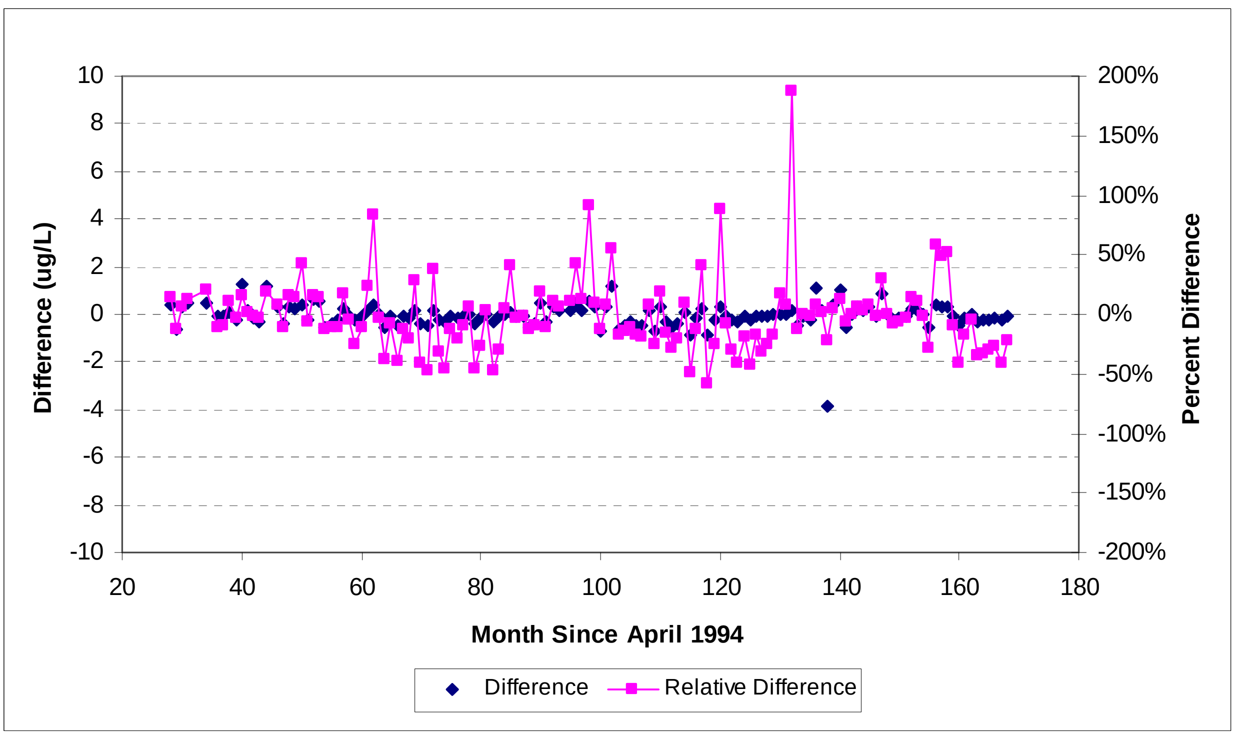

Figure 9. Monthly Difference Between Simulated and Measured Atrazine

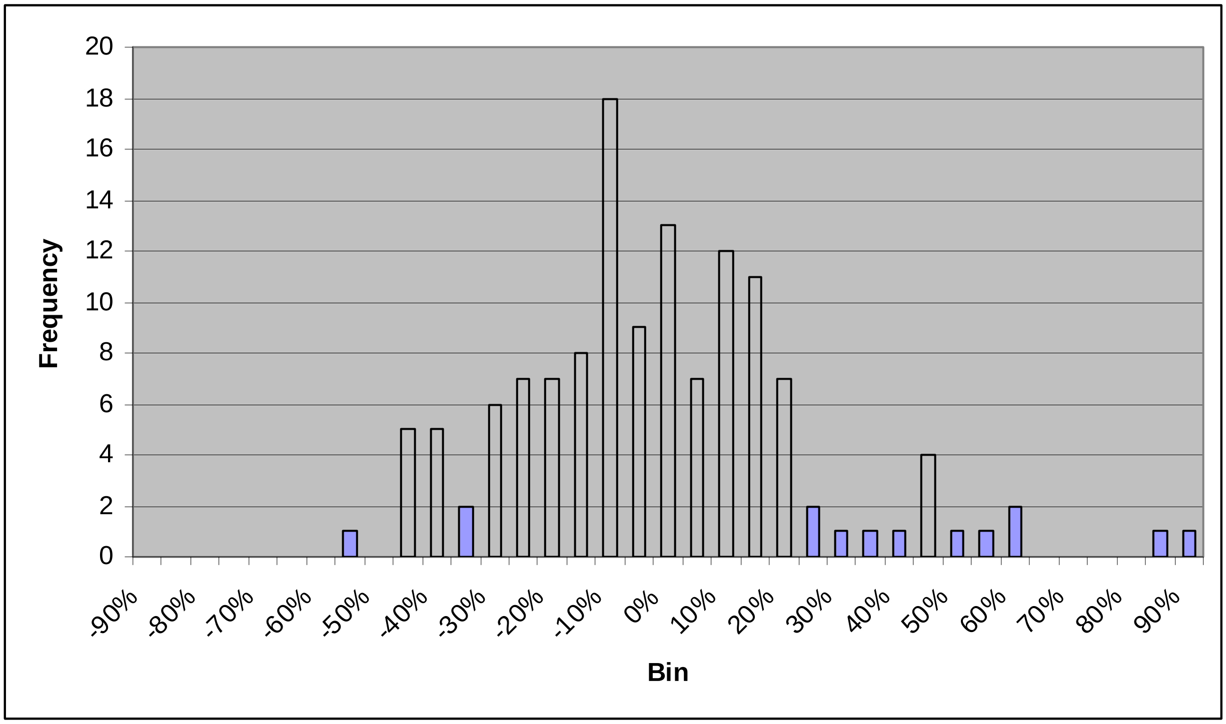

Figure 10. Distribution of Monthly Percent Error From the Lake Model

Table 7. Summary of Statistical Comparison Between Simulated and Measured Atrazine Data

Model Comparison Statistic	Result
Average Difference	-0.05
Absolute Average Difference	0.33
Percent Average Relative Difference	-1.48%
Percent Average Absolute Relative Difference	21.39%
Coefficient of Determination	0.978
Root Mean Squared Error	0.515
Percent Bias	-1.69%

6. CALCULATION OF LOADING CAPACITY

Row crops cover approximately 54 percent of the Wyaconda Lake watershed. Atrazine can be applied in a variety of ways to decrease the amount available for runoff, and BMPs can be employed based on site specific conditions to minimize atrazine runoff. Using atrazine BMPs in the Wyaconda Lake watershed will help reduce the nonpoint source load from row crops and contribute to decreasing atrazine concentrations in the lake. Based on current conditions in Wyaconda Lake, loads delivered to the lake from nonpoint sources will need to be reduced to 0.45 kilograms per year (kg/year) (0.99 pounds per year [lb/year]). This is equivalent to an estimated average annual reduction of 21 percent. Given that most, if not all, of the reductions will occur during the spring application period, the TMDL can be met through a 53 percent reduction in load delivered during the spring and summer months (May through August). This percent reduction is equivalent to an average reduction of 0.21 kg (0.47 lb) during the spring and summer.

The pollutant allocations described in this section apply throughout the entire year; however, based on typical atrazine use, most, if not all, of the reductions in land application and/or implementation of BMPs will need to occur during the spring application period in order to meet the TMDL.

6.1 Atrazine TMDL Summary

The equation for the TMDL shows the Wyaconda Lake atrazine LC:

TMDL = LC (0.45 kg/year [0.99 lb/year]) = WLA (0 kg/year [0 lb/year]) + LA (0.45 kg/year [0.99 lb/year]) + MOS (implicit)

Table 8 summarizes the TMDL calculated for atrazine using the simple lake model and GWLF. Annual and seasonal loads are provided because likely control mechanisms will need to focus on controlling runoff during peak application periods (i.e., spring and summer).

Table 8. Wyaconda Lake Atrazine Annual and Daily TMDL Summary[1]

	Annual Atrazine Load		**Atrazine Load Delivered During Spring and Summer (May–August)**	
Average Existing Condition	0.57 kg/yr 0.00156 kg/day	1.25 lb/yr 0.00342 lb/day	0.41 kg 0.0034 kg/day	0.89 lb 0.0073 lb/day
TMDL Condition	0.45 kg/yr 0.004 kg/day	0.99 lb/yr 0.009 lb/day	0.19 kg 0.005 kg/day	0.42 lb 0.011 lb/day
Required Reduction (load)	0.12 kg/yr 0.00033 kg/day	0.26 lb/yr 0.00071 lb/day	0.21 kg 0.0017 kg/day	0.47 lb 0.0039 lb/day
Required Reduction (percent)	21		53	

[1] Average existing condition, TMDL condition, and daily limit are based on model simulations during the 1996–2008 period.

[2] An average of 1996–2008 simulated monthly loads for May were used as the basis for calculating average daily load delivered using the TSD methodology (see section 8 below).

7. WASTE LOAD ALLOCATION (POINT SOURCE LOADS)

A WLA of zero (µg/L) atrazine is set for this TMDL. No load reductions are required to achieve this allocation because no existing point sources were identified as contributing to the impairment.

8. LOAD ALLOCATION (NONPOINT SOURCE LOADS)

The long-term average annual LA for this TMDL is 0.45 kg/yr (0.99 lb/yr). This is equivalent to a 21 percent reduction in the estimated existing annual nonpoint source loading. Given that most, if not all, of the reductions will occur during the spring application period, the TMDL can be met through a 53 percent reduction in load delivered during the months of May, June, July and August. This percent reduction is equivalent to an average reduction of 0.21 kg (0.47 lb) (from 0.41 kg [0.89 lb] to 0.19 kg [0.42 lb]) during the spring and summer months. The approach used to convert these loads to maximum daily values is based upon the maximum daily permit calculations provided in the *Technical Support Document (TSD) for Water Quality-based Toxics Control* (EPA, 1991). The monthly average for the spring and summer period was converted to an maximum daily limit (MDL) using guidance provided in Table 5-2 of the TSD. Using a coefficient of variation of 1.5 (calculated with 1996–2008 measured data) and a 95th percentile probability, a multiplication factor of 3.31 was calculated. Daily maximum loads for the spring and summer months are 0.005 kg/day (0.011 lb/day). The daily maximum is included to meet the decision of the U.S. Court of Appeals for the D.C. Circuit in *Friends of the Earth, Inc. v. EPA* et al., No. 05-5015 (April 25, 2006) and is not meant to occur every day. Using the 95th percentile value, this daily load should only be seen 5 percent of the days in the averaging period.

9. MARGIN OF SAFETY

A MOS is required in the TMDL calculation to account for uncertainties in scientific and technical understanding of water quality in natural systems. The MOS is intended to account for such uncertainties in a conservative manner. Based on EPA guidance, the MOS can be achieved through one of two approaches:

1) Explicit - Reserve a numeric portion of the LC as a separate term in the TMDL.
2) Implicit - Incorporate the MOS as part of the critical conditions for the WLA and LA calculations by making conservative assumptions in the analysis.

The MOS is incorporated implicitly in the selection and application of models used to develop the TMDL. In applying the Wyaconda Simple Lake Model, TMDL calculations were based on a long simulation period that takes into account critical conditions which are the portion of the year with the highest measured and modeled atrazine concentrations (spring and summer). By using a long record and focusing on the critical periods (high application rates and observed lake concentrations), the analysis is based on the most conservative periods available in the data record. Thus, the load reductions are conservative and have been developed to be protective for the most critical period of the year.

10. SEASONAL VARIATION

Atrazine is applied in the watershed in the spring and summer months when rainfall occurs frequently. During these months, monitoring data collected soon after a rainfall event indicate that atrazine concentrations in Wyaconda Lake increase sharply. Atrazine concentrations in the lake increase throughout the spring and summer and then slowly decrease by dilution, degradation and outflow until the next application season. A three- or four-inch rain during any time outside the application season can produce an observable decline in the lake atrazine concentration. The high concentration water is displaced by water containing small amounts of the chemical, changing the overall concentration. Setting loads protective of the application season (which is the critical condition) will result in protection of water quality in Wyaconda Lake year round.

11. MONITORING PLAN

No future monitoring has been scheduled for Wyaconda Lake at this time. In general, future monitoring is scheduled and conducted by MDNR approximately three years after the approval of the TMDL or in a reasonable time frame following the completion of permit compliance schedules and/or the application of new effluent limits. Any volunteer or permittee water quality monitoring that occurs in Wyaconda Lake will be used for evaluating the present lake condition to see if the state's WQS established by the TMDL are being met.

12. REASONABLE ASSURANCES

MDNR has the authority to issue and enforce state operating permits. Inclusion of effluent limits into a state operating permit and requiring that effluent and instream monitoring be reported to MDNR should provide reasonable assurance that instream WQS will be met. Section 301(b)(1)(C) requires that point source permits have effluent limits as stringent as necessary to meet WQS. However, for WLAs to serve that purpose, they must themselves be stringent enough so that (in conjunction with the water body's other loadings) they meet WQS. This generally occurs when the TMDL's combined nonpoint source LAs and point source WLAs do not exceed the WQS-based LC and there is reasonable assurance that the TMDL's allocations can be achieved. Discussion of reduction efforts relating to nonpoint sources can be found in the implementation section of the TMDL.

13. PUBLIC PARTICIPATION

EPA regulations require that TMDLs be subject to public review (40 CFR 130.7). EPA is providing public notice of this draft TMDL for Wyaconda Lake on the EPA, Region 7, TMDL website: http://www.epa.gov/region07/water/tmdl_public_notice.htm. The response to comments and final TMDL will be available at: http://www.epa.gov/region07/water/apprtmdl.htm#Missouri.

Wyaconda Lake in Clark County, Missouri, is included on the EPA-approved 2008 Missouri 303(d) List. This TMDL is being established by EPA to meet the requirements of the 2001 Consent Decree, *American Canoe Association, et al. v. EPA*, No. 98-1195-CV-W in consolidation with No. 98-4282-CV-W, February 27, 2001. EPA is developing this TMDL in cooperation with the state of Missouri and EPA is establishing this TMDL at this time to meet the *American Canoe* consent decree milestones. Missouri may submit and EPA may approve a revised or modified TMDL for this water at any time.

Before finalizing EPA established TMDLs (such as this TMDL), the public is notified that a comment period is open on the EPA Region 7 website for at least 30 days. EPA's public notices to comment on draft TMDLs are also distributed via mail and electronic mail to major stakeholders in the watershed or other potentially impacted parties. After the comment period closes, EPA reviews all comments, edits the TMDL as is appropriate, writes a Summary of Response to Comments and establishes the TMDL. For Missouri TMDLs, groups receiving the public notice announcement include a distribution list provided by MDNR, the Missouri Clean Water Commission, the Missouri Water Quality Coordinating Committee, stream team volunteers, state legislators, County Commissioners, the County Soil and Water Conservation District and potentially impacted cities, towns and facilities. EPA followed this public notice process for this TMDL. Links to active public notices for draft TMDLs, final (approved and established) TMDLs and Summary of Response to Comments are posted on the EPA website: http://www.epa.gov/region07/water/tmdl.htm.

14. ADMINISTRATIVE RECORD AND SUPPORTING DOCUMENTS

An administrative record on the Wyaconda Lake TMDL has been assembled and is being kept on file with EPA.

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Appendix A

Water Quality Data Used in the Development of the Wyaconda Lake Atrazine TMDL

Org	WBID	WATER BODY	SUPPLY	RF	YR	MO	DY	ATRAZINE (μg/L)
Novartis	7009	WYACONDA RES.	WYACONDA	R	1996	7		2.7
Novartis	7009	WYACONDA RES.	WYACONDA	R	1996	8		5
Novartis	7009	WYACONDA RES.	WYACONDA	R	1996	9		4.2
Novartis	7009	WYACONDA RES.	WYACONDA	R	1996	10		3.5
Monsanto	7009	WYACONDA RES.	WYACONDA	R	1997	1		2.18
Monsanto	7009	WYACONDA RES.	WYACONDA	R	1997	3		1.05
Monsanto	7009	WYACONDA RES.	WYACONDA	R	1997	4		0.62
Monsanto	7009	WYACONDA RES.	WYACONDA	R	1997	5		0.59
Monsanto	7009	WYACONDA RES.	WYACONDA	R	1997	6		6.3
Novartis	7009	WYACONDA RES.	WYACONDA	R	1997	6		7
Novartis	7009	WYACONDA RES.	WYACONDA	R	1997	7		8.5
Novartis	7009	WYACONDA RES.	WYACONDA	R	1997	8		10
Novartis	7009	WYACONDA RES.	WYACONDA	R	1997	9		9.5
Novartis	7009	WYACONDA RES.	WYACONDA	R	1997	10		8.5
Novartis	7009	WYACONDA RES.	WYACONDA	R	1997	11		6
Novartis	7009	WYACONDA RES.	WYACONDA	R	1998	1		3.8
Novartis	7009	WYACONDA RES.	WYACONDA	R	1998	2		3.5
Novartis	7009	WYACONDA RES.	WYACONDA	R	1998	3		2
Novartis	7009	WYACONDA RES.	WYACONDA	R	1998	4		1.6
Novartis	7009	WYACONDA RES.	WYACONDA	R	1998	5		0.9
Novartis	7009	WYACONDA RES.	WYACONDA	R	1998	6		4.1
Novartis	7009	WYACONDA RES.	WYACONDA	R	1998	7		4
Novartis	7009	WYACONDA RES.	WYACONDA	R	1998	8		3.5
Novartis	7009	WYACONDA RES.	WYACONDA	R	1998	9		4.6
Novartis	7009	WYACONDA RES.	WYACONDA	R	1998	10		3.8
Novartis	7009	WYACONDA RES.	WYACONDA	R	1998	11		2.3
Novartis	7009	WYACONDA RES.	WYACONDA	R	1998	12		1.4
Novartis	7009	WYACONDA RES.	WYACONDA	R	1999	1		1.2
Novartis	7009	WYACONDA RES.	WYACONDA	R	1999	2		1
Novartis	7009	WYACONDA RES.	WYACONDA	R	1999	3		0.8
Novartis	7009	WYACONDA RES.	WYACONDA	R	1999	4		0.7
Novartis	7009	WYACONDA RES.	WYACONDA	R	1999	5		0.5
Novartis	7009	WYACONDA RES.	WYACONDA	R	1999	6		1
Novartis	7009	WYACONDA RES.	WYACONDA	R	1999	7		1.4
MDNR	7009	WYACONDA RES.	WYACONDA	R	1999	8		0.39
Novartis	7009	WYACONDA RES.	WYACONDA	R	1999	8		1.3
Novartis	7009	WYACONDA RES.	WYACONDA	R	1999	9		1.2
Novartis	7009	WYACONDA RES.	WYACONDA	R	1999	10		0.8
Novartis	7009	WYACONDA RES.	WYACONDA	R	1999	11		0.8
MDNR	7009	WYACONDA RES.	WYACONDA	R	1999	12		0
Novartis	7009	WYACONDA RES.	WYACONDA	R	1999	12		0.9
Monsanto	7009	WYACONDA RES.	WYACONDA	R	2000	1		0.36
Novartis	7009	WYACONDA RES.	WYACONDA	R	2000	1		1.4
Novartis	7009	WYACONDA RES.	WYACONDA	R	2000	2		1

Org	WBID	WATER BODY	SUPPLY	RF	YR	MO	DY	ATRAZINE (μg/L)
MDNR	7009	WYACONDA RES.	WYACONDA	R	2000	3		0
Monsanto	7009	WYACONDA RES.	WYACONDA	R	2000	3		0.32
Novartis	7009	WYACONDA RES.	WYACONDA	R	2000	3		0.8
Monsanto	7009	WYACONDA RES.	WYACONDA	R	2000	4		0.33
Novartis	7009	WYACONDA RES.	WYACONDA	R	2000	4		1
Monsanto	7009	WYACONDA RES.	WYACONDA	R	2000	5		0.55
Novartis	7009	WYACONDA RES.	WYACONDA	R	2000	5		1
MDNR	7009	WYACONDA RES.	WYACONDA	R	2000	6	12	0
Monsanto	7009	WYACONDA RES.	WYACONDA	R	2000	6		0.5
Novartis	7009	WYACONDA RES.	WYACONDA	R	2000	6		1.2
Monsanto	7009	WYACONDA RES.	WYACONDA	R	2000	7		0.5
Novartis	7009	WYACONDA RES.	WYACONDA	R	2000	7		1
Monsanto	7009	WYACONDA RES.	WYACONDA	R	2000	8		0.4
Novartis	7009	WYACONDA RES.	WYACONDA	R	2000	8		0.9
MDNR	7009	WYACONDA RES.	WYACONDA	R	2000	9	7	0
Novartis	7009	WYACONDA RES.	WYACONDA	R	2000	9		1
Novartis	7009	WYACONDA RES.	WYACONDA	R	2000	10		0.9
Monsanto	7009	WYACONDA RES.	WYACONDA	R	2000	11		0.33
Novartis	7009	WYACONDA RES.	WYACONDA	R	2000	11		0.9
MDNR	7009	WYACONDA RES.	WYACONDA	R	2000	12		0
Novartis	7009	WYACONDA RES.	WYACONDA	R	2000	12		0.8
Monsanto	7009	WYACONDA RES.	WYACONDA	R	2001	1		0.34
Novartis	7009	WYACONDA RES.	WYACONDA	R	2001	1		0.85
Novartis	7009	WYACONDA RES.	WYACONDA	R	2001	2		0.35
Novartis	7009	WYACONDA RES.	WYACONDA	R	2001	3		0.2
Novartis	7009	WYACONDA RES.	WYACONDA	R	2001	4		0.2
Novartis	7009	WYACONDA RES.	WYACONDA	R	2001	5		3.08
MDNR	7009	WYACONDA RES.	WYACONDA	R	2001	6		1.6
Novartis	7009	WYACONDA RES.	WYACONDA	R	2001	6		5.95
Novartis	7009	WYACONDA RES.	WYACONDA	R	2001	7		4.18
Novartis	7009	WYACONDA RES.	WYACONDA	R	2001	8		4.2
MDNR	7009	WYACONDA RES.	WYACONDA	R	2001	9		1.21
Novartis	7009	WYACONDA RES.	WYACONDA	R	2001	9		3.9
Novartis	7009	WYACONDA RES.	WYACONDA	R	2001	10		3.17
Novartis	7009	WYACONDA RES.	WYACONDA	R	2001	11		2.5
MDNR	7009	WYACONDA RES.	WYACONDA	R	2001	12		1.6
Novartis	7009	WYACONDA RES.	WYACONDA	R	2001	12		3
Novartis	7009	WYACONDA RES.	WYACONDA	R	2002	2		1.65
MDNR	7009	WYACONDA RES.	WYACONDA	R	2002	3		0.8
Novartis	7009	WYACONDA RES.	WYACONDA	R	2002	3		1.48
Novartis	7009	WYACONDA RES.	WYACONDA	R	2002	4		1.2
Novartis	7009	WYACONDA RES.	WYACONDA	R	2002	5		0.65
MDNR	7009	WYACONDA RES.	WYACONDA	R	2002	6		3.77
Novartis	7009	WYACONDA RES.	WYACONDA	R	2002	6		3.04
Novartis	7009	WYACONDA RES.	WYACONDA	R	2002	7		5.96
Novartis	7009	WYACONDA RES.	WYACONDA	R	2002	8		4.17
MDNR	7009	WYACONDA RES.	WYACONDA	R	2002	9		0
Novartis	7009	WYACONDA RES.	WYACONDA	R	2002	9		4.19
Novartis	7009	WYACONDA RES.	WYACONDA	R	2002	10		3.5
Novartis	7009	WYACONDA RES.	WYACONDA	R	2002	11		3.04

Org	WBID	WATER BODY	SUPPLY	RF	YR	MO	DY	ATRAZINE (μg/L)
MDNR	7009	WYACONDA RES.	WYACONDA	R	2002	12		2.22
Novartis	7009	WYACONDA RES.	WYACONDA	R	2002	12		2.95
Novartis	7009	WYACONDA RES.	WYACONDA	R	2003	1		2.61
Novartis	7009	WYACONDA RES.	WYACONDA	R	2003	2		2.68
Novartis	7009	WYACONDA RES.	WYACONDA	R	2003	3		2.21
MDNR	7009	WYACONDA RES.	WYACONDA	R	2003	3		1.69
Novartis	7009	WYACONDA RES.	WYACONDA	R	2003	4		2.75
Novartis	7009	WYACONDA RES.	WYACONDA	R	2003	5		1.68
Novartis	7009	WYACONDA RES.	WYACONDA	R	2003	6		2.27
MDNR	7009	WYACONDA RES.	WYACONDA	R	2003	6		1.38
Novartis	7009	WYACONDA RES.	WYACONDA	R	2003	7		2.04
Novartis	7009	WYACONDA RES.	WYACONDA	R	2003	8		1.88
MDNR	7009	WYACONDA RES.	WYACONDA	R	2003	9		0
Novartis	7009	WYACONDA RES.	WYACONDA	R	2003	9		1.84
Novartis	7009	WYACONDA RES.	WYACONDA	R	2003	10		1.76
Novartis	7009	WYACONDA RES.	WYACONDA	R	2003	11		0.98
Novartis	7009	WYACONDA RES.	WYACONDA	R	2003	12		1
MDNR	7009	WYACONDA RES.	WYACONDA	R	2003	12		0
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2004	1	12	0.89
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2004	1	27	2.05
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2004	2	10	0.66
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2004	2	23	1.01
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2004	3	9	0.51
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2004	3	23	0.52
MDNR	7009	WYACONDA RES.	WYACONDA	R	2004	3		0
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2004	4	6	0.53
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2004	4	13	0.46
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2004	4	19	0.8
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2004	4	27	0.76
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2004	5	3	0.56
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2004	5	11	0.85
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2004	5	18	0.72
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2004	5	25	0.82
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2004	6	1	0.6
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2004	6	8	0.67
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2004	6	15	0.71
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2004	6	22	1.08
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2004	6	29	0.77
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2004	7	6	0.49
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2004	7	13	0.51
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2004	7	20	0.49
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2004	7	27	0.36
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2004	8	10	0.51
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2004	8	24	0.47
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2004	9	5	0.3
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2004	9	21	0.25
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2004	10	5	0.3
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2004	10	19	0.27
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2004	11	9	0.2
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2004	11	22	0.25

Org	WBID	WATER BODY	SUPPLY	RF	YR	MO	DY	ATRAZINE (μg/L)
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2004	12	7	0.18
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2004	12	21	0.18
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2005	1	20	0.1
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2005	2	2	0.1
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2005	2	16	0.08
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2005	3	1	0.09
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2005	3	15	0.1
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2005	3	29	0
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2005	4	6	0.15
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2005	4	11	0.11
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2005	4	18	0.13
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2005	4	25	14.61
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2005	5	2	11.9
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2005	5	9	15.28
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2005	5	13	20.8
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2005	5	23	12.9
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2005	5	31	19.69
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2005	6	7	22.42
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2005	6	14	16.64
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2005	6	21	23.01
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2005	6	27	19.13
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2005	7	5	9.79
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2005	7	12	18.5
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2005	7	19	15.38
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2005	7	27	16.69
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2005	8	2	16.32
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2005	8	9	16.2
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2005	8	16	13.9
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2005	8	22	11.2
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2005	8	30	14.09
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2005	9	7	14.44
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2005	9	13	20.52
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2005	9	21	14.25
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2005	9	27	19.78
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2005	10	5	15.89
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2005	10	11	13.13
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2005	10	18	4.92
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2005	10	25	8.5
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2005	11	1	8.33
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2005	11	8	6.81
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2005	11	16	5.46
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2005	11	21	6.74
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2005	11	29	11.7
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2005	12	13	5.32
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2005	12	20	9.87
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2005	12	27	11.81
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	1	3	9.05
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	1	10	8.38
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	1	17	7.21
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	1	24	5.99

Org	WBID	WATER BODY	SUPPLY	RF	YR	MO	DY	ATRAZINE (μg/L)
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	1	31	6.9
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	2	7	3.86
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	2	14	5.64
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	2	21	6.29
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	2	28	7.22
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	3	7	6.47
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	3	14	2.96
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	3	21	5.27
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	3	28	6.32
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	4	4	4.28
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	4	11	3.95
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	4	18	4.54
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	4	25	4.25
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	5	2	2.78
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	5	9	5.49
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	5	16	5.04
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	5	23	2.39
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	5	30	4.8
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	6	6	5.16
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	6	13	2.5
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	6	20	1.71
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	6	27	1.68
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	7	5	3.71
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	7	11	2.76
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	7	18	2.82
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	7	25	3.74
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	8	1	3.58
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	8	8	2.61
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	8	15	3.13
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	8	22	3.01
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	8	29	3.28
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	9	5	2.78
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	9	12	1.74
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	9	20	3
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	9	26	2.63
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	10	3	2.46
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	10	10	1.92
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	10	17	2.25
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	10	24	2.1
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	10	31	2.48
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	11	7	1.45
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	11	17	1.34
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	11	20	1.34
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	11	28	1.88
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	12	5	1.26
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	12	12	1.93
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	12	19	1.82
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2006	12	27	1.67
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	1	3	1.58
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	1	9	0.89

Org	WBID	WATER BODY	SUPPLY	RF	YR	MO	DY	ATRAZINE (μg/L)
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	1	17	2.1
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	1	23	2.32
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	1	30	1.72
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	2	6	2.09
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	2	14	2.71
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	2	20	2.24
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	2	27	0.53
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	3	6	0.93
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	3	13	0.46
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	3	20	0.71
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	3	27	0.74
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	4	3	0.6
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	4	10	0.69
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	4	17	0.68
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	4	24	0.76
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	5	1	0.57
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	5	8	0.65
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	5	15	0.63
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	5	22	0.51
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	5	29	0.64
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	6	5	0.55
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	6	13	1.08
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	6	19	0.99
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	6	26	0.71
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	7	2	1.27
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	7	11	1.2
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	7	17	1.22
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	7	24	0.75
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	7	31	0.85
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	8	15	0.71
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	8	29	0.8
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	9	12	0.57
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	9	25	0.73
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	10	2	0.81
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	10	10	1.15
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	10	17	0.7
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	10	24	0.75
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	10	31	0.76
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	11	7	0.68
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	11	14	0.66
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	11	20	0.99
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	11	27	0.62
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	12	4	0.73
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	12	11	0.61
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	12	19	0.68
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2007	12	27	0.59
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	1	9	0.67
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	1	16	0.48
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	1	29	0.49
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	2	5	0.54

Org	WBID	WATER BODY	SUPPLY	RF	YR	MO	DY	ATRAZINE (μg/L)
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	2	12	0.53
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	2	20	0.58
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	2	27	0.46
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	3	4	0.4
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	3	10	0.24
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	4	2	0.25
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	4	9	0.22
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	4	16	0.15
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	4	23	0.13
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	5	1	0.21
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	5	8	0.14
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	5	14	0.16
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	5	19	0.19
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	5	29	0.32
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	6	4	3.28
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	6	10	3.1
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	6	17	2.86
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	6	26	2.38
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	7	1	2.08
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	7	8	2.29
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	7	15	1.93
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	7	22	1.7
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	7	30	1.56
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	8	5	1.64
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	8	12	1.05
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	8	20	1.1
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	8	27	1.28
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	9	3	1.38
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	9	10	1.16
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	9	17	0.47
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	9	22	0.53
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	9	30	0.4
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	10	7	0.44
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	10	14	0.31
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	10	22	0.29
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	10	29	0.31
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	11	5	0.34
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	11	12	0.33
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	11	19	0.31
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	11	24	0.38
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	12	3	0.22
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	12	10	0.22
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	12	17	0.25
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	12	22	0.34
Syngenta	7009	WYACONDA RES.	WYACONDA	R	2008	12	30	0.27

Appendix B

GWLF Model Documentation

B.1 Overview of GWLF

Generalized Watershed Loading Functions (GWLF) Version 2.0 (Haith et al., 1992) was selected for simulating watershed hydrology for the Wyaconda Lake Atrazine TMDL. GWLF is a model capable of simulating watershed hydrology and estimating monthly average volumes (m^3) entering Wyaconda Lake from surface runoff, groundwater flow and stream flow. Within GWLF, stream flow consists of surface runoff and groundwater discharge. Surface runoff is computed using the Soil Conservation Service Curve Number Equation, while groundwater discharge is obtained from a lumped parameter watershed daily water balance. GWLF was used to simulate monthly average volumes from the watershed during 1994–2008. For the water quality modeling, the volumes from 1998–2006 were used.

B.2 GWLF Model Setup

This section of the appendix describes the process that was used to setup the GWLF model for the Wyaconda Lake watershed.

B.2.1 Watershed delineation, transport parameters and weather data

The Wyaconda Lake watershed was delineated using the USGS 7.5 minute quadrangle, Wyaconda 1991. The downstream boundary of the watershed corresponds to the Wyaconda City Dam. Transport parameters (e.g., land use area, runoff curve number, groundwater recession and seepage coefficients) for this application were calculated using land cover, soils, and watershed slope. The Wyaconda Lake watershed was divided into 13 rural land uses and 2 urban land uses using a combination of Natural Resources Conservation Service (NRCS) soil data and MSDIS 2005 land cover classes (NRCS, 2010). Transport parameters for each land use are shown in Table B-1.

Table B-1. Transport Parameters Associated with Each Land Use in Wyaconda Lake Watershed

Land Use	Soil Type	Curve Number	Acres	Hectares
Cropland 1	Gara loam, 20 to 30 percent slopes, eroded	90	2.24	0.90835
Cropland 2	Adco silt loam, 1 to 5 percent slopes	93	29.04	11.7529
Cropland 3	Belinda silt loam, 0 to 2 percent slopes	93	3.47	1.40252
Cropland 4	Armstrong loam, 5 to 12 percent slopes, eroded	90	42.54	17.2133
Cropland 5	Armstrong loam, 12 to 18 percent slopes, eroded	90	36.08	14.5992
Deciduous Forest 1	Gara loam, 20 to 30 percent slopes, eroded	77	5.46	2.20977
Deciduous Forest 2	Armstrong loam, 12 to 18 percent slopes, eroded	77	3.77	1.5249
Deciduous Woody/Herbaceous	Armstrong loam, 12 to 18 percent slopes, eroded	77	0.44	0.18
Grassland 1	Gara loam, 20 to 30 percent slopes, eroded	79	1.44	0.58343
Grassland 2	Adco silt loam, 1 to 5 percent slopes	84	6.95	2.81068
Grassland 3	Belinda silt loam, 0 to 2 percent slopes	84	0.03	0.01028
Grassland 4	Armstrong loam, 5 to 12 percent slopes, eroded	79	26.61	10.7694
Grassland 5	Armstrong loam, 12 to 18 percent slopes, eroded	79	28.61	11.5785
Impervious		98	8.91	3.6054
Low-Intensity Urban		82	0.37	0.14801
Open Water		100	1.11	0.4492
Total [1]	**NA**	**NA**	**197.06**	**79.7458**

[1] Total area excludes the area of Wyaconda Lake.

USGS Gage 05495000 Fox River at Wayland, Missouri, was used to calculate the groundwater recession parameter through standard hydrograph separation techniques (Chow, 1964). The recession coefficient was calculated using methods specified in the GWLF manual (Haith et al., 1992) and presented below.

$$r = \frac{\ln[F(t_1)/F(t_2)]}{t_2 - t_1}$$ Equation 1

Where,

r = recession constant
$F(t_1)$ = Flow at time t_1 (m3/s)
$F(t_2)$ = Flow at time t_2 (m3/s)
t_1 = time step 1
t_2 = time step 2

Seepage and initial conditions were set to default parameters suggested by GWLF model documentation (Haith et al., 1992). GWLF inputs, including Wyaconda Lake weather data and the transport file used to simulate watershed conditions for the Wyaconda Lake Atrazine TMDL, are included in this appendix. GWLF flow outputs (i.e., summary, annual averages and monthly averages) are included in Appendix C. Daily weather data for average air temperature and daily precipitation were retrieved from the National Climatic Data Center (NCDC). Precipitation data from the Luray 2 N weather station (COOP ID 235130) were used because this was the closest NCDC station with the appropriate period of record (1998–2006). Daily Maximum and Daily Minimum temperature data were obtained from the Keosaqua weather station (CO OP ID 13489) to match the period of record obtained from Luray 2 N.

B.2.2 Point Sources

No point sources were simulated within the Wyaconda Lake watershed.

B.2.3 Critical Conditions

The GWLF model was run for the period 1994 through 2008. This included the period of record available for the atrazine data, including several exceedances of the water quality criterion.

B.3 Model Calibration

No hydrology data available in the Wyaconda Lake watershed; therefore, GWLF was not calibrated to observed data. The results of the GWLF model were compared with the base flow index (BFI) of USGS gages in the region. The GWLF BFI was calculated as a mean annual ratio of subsurface flow to total annual runoff as there is no inflowing stream. The resulting BFI of 0.23 is comparable to 0.21, which is the upper 95 percent confidence interval of the average BFI of the gages at the Fox River and Wyaconda River. Additionally, the GWLF monthly modeled runoff compares to the monthly lake discharge calculated from the lake water surface elevation (Figure B1).

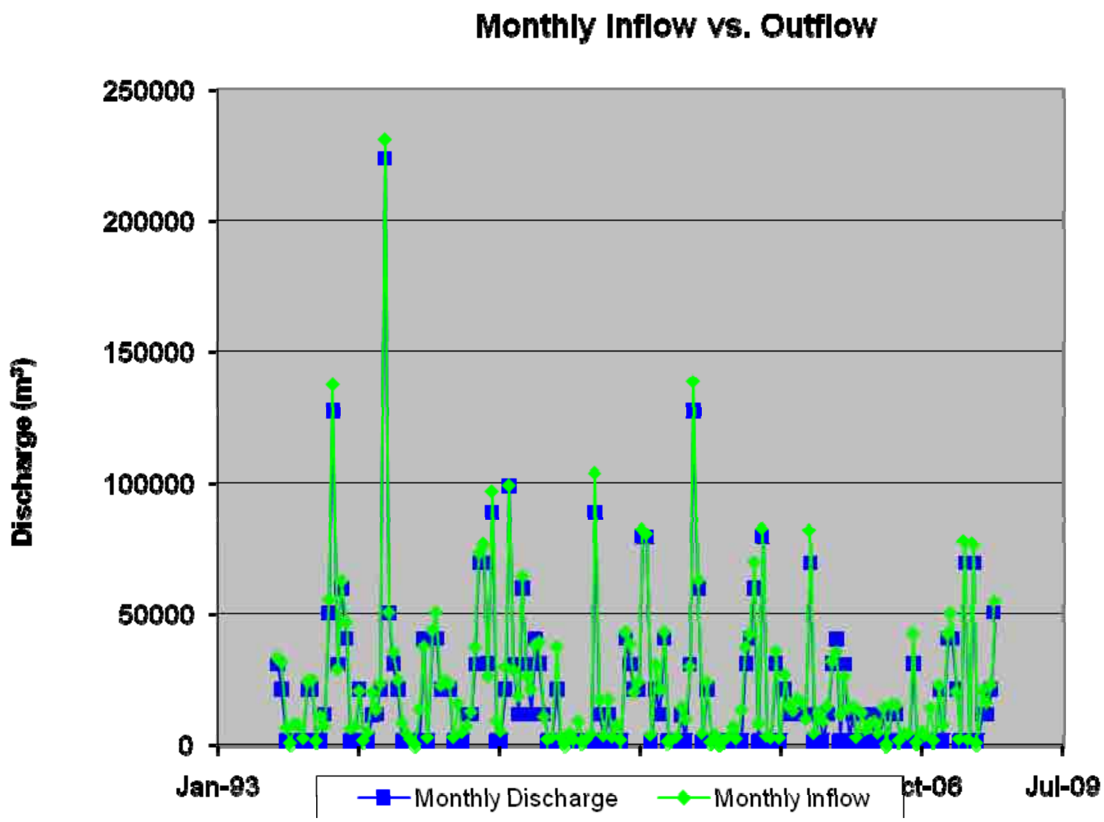

Figure B 1. Comparison of modeled monthly inflow v. lake outflow.

Weather Data File for GWLF (see model manual for explanation)

30,Apr-	18.89,0	23.06,0	21.94,0	10.00,0	12.22,0
94	17.78,0	22.78,0	.025	.25	.25
11.94,0	16.94,0	31,Jul-	23.06,0	13.61,0	8.89,2.
13.89,0	17.78,0	94	26.94,0	12.78,0	175
4.44,0	16.94,0	25.28,0	.25	13.33,1	8.33,0.
11.94,0	15.28,0	23.89,0	19.17,0	.125	75
10.83,0	17.78,0	20.00,0	17.22,0	14.17,0	10.28,0
3.06,0	19.17,0	24.72,0	20.56,0	14.44,0	13.06,0
3.06,0	20.56,0	29.17,0	24.44,0	15.28,0	10.00,0
12.78,0	23.06,0	28.06,0	27.22,0	22.22,0	.425
12.50,0	21.67,0	.15	26.67,0	31,Oct-	4.72,0
11.39,1	.675	26.67,0	24.17,0	94	6.39,0
.3	21.67,0	23.06,0	18.89,0	23.33,0	8.61,0
11.11,0	15.28,0	22.22,0	19.72,0	17.50,0	11.94,0
.85	13.89,0	20.83,0	23.33,0	16.67,0	10.28,1
7.78,0	18.06,0	25.56,0	27.22,0	15.83,0	.2
11.39,0	21.39,0	27.50,0	27.22,0	.15	5.56,0
16.39,0	22.50,0	25.28,0	26.39,0	16.11,0	3.06,0
16.94,0	25.00,0	22.78,0	.5	20.83,0	6.67,0
.25	30,Jun-	22.50,0	28.06,0	22.50,0	7.50,0
13.06,0	94	22.22,0	24.72,0	15.28,0	1.11,0
13.89,0	21.11,0	23.61,0	.1	.7	6.67,0
22.22,0	14.44,3	.5	19.17,0	10.28,0	6.94,2.
19.44,0	.1	23.61,0	.375	8.33,0	725
13.06,0	17.78,0	27.78,0	21.94,0	8.89,0	0.56,0
11.11,5	17.78,0	26.11,0	.775	10.56,0	3.61,0
.75	21.67,0	24.44,0	20.56,1	12.78,0	6.11,0
9.72,0	25.83,0	22.50,0	.55	11.39,0	2.22,0
12.22,0	25.00,0	23.33,0	30,Sep-	16.94,0	2.78,0
21.94,0	21.67,0	24.17,0	94	16.94,0	11.39,2
23.06,0	18.61,0	.5	16.11,0	21.11,0	.675
23.89,0	21.39,0	21.39,0	16.67,0	20.56,0	2.78,0
15.56,0	.425	21.39,0	20.28,0	15.56,0	-0.28,0
8.33,0	20.83,0	20.00,0	18.61,0	13.61,0	1.94,0
7.50,0	21.39,0	20.00,0	19.72,2	13.61,0	31,Dec-
5.28,1.	27.50,0	.075	.3	16.11,0	94
9	28.33,0	20.56,0	18.89,0	10.56,0	8.89,0
31,May-	28.33,0	22.50,0	18.33,0	10.28,0	10.00,0
94	27.50,0	23.33,0	21.39,0	.175	12.22,0
7.22,0	27.22,0	31,Aug-	22.78,0	5.00,0	10.83,0
8.61,0	28.06,0	94	23.33,0	4.44,0	5.56,0
12.22,0	27.50,0	26.11,0	22.22,0	10.00,0	-1.39,0
12.78,0	.175	25.28,0	23.33,0	13.33,0	-
15.28,0	27.78,0	26.11,0	25.00,0	10.83,0	1.39,4.
16.11,2	.5	.4	27.78,0	5.83,0	825
.775	25.56,0	24.44,3	26.94,0	7.22,2.	-0.56,0
11.67,1	25.00,0	.35	23.06,0	05	-1.94,0
.775	25.28,0	17.78,0	18.06,0	30,Nov-	-4.72,0
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17.22,0	21.39,0	22.50,0	20.00,0	5.83,1.	10.83,0
16.11,0	23.33,0	26.39,0	21.11,0	6	-3.89,0
21.11,0	23.06,0	22.22,0	21.94,0	13.06,0	-5.56,0
16.67,0	22.22,0	22.78,0	18.33,2	17.50,0	-5.56,0
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21.94,0	18.61,0	3.06,0	0.83,0.	29,Feb-	6.11,0
23.61,0	19.17,0	6.11,0	175	96	8.61,0
22.50,0	14.44,0	5.56,0	31,Jan-	-	11.67,0
25.83,0	14.72,0	10.28,0	96	18.33,0	9.44,0
25.56,0	11.94,0	6.67,0	0.56,0	-	6.11,0
24.44,0	.125	3.61,0	-1.67,0	24.72,0	4.72,0
26.67,0	10.28,0	1.94,0	-7.78,0	-	6.94,0
27.50,0	.05	1.11,0	-	27.50,0	3.61,0
27.78,0	11.39,0	-3.61,0	5.83,0.	-	-0.83,0
27.78,0	13.61,0	5.83,0	325	20.00,0	0.83,0
28.06,0	14.44,0	9.72,0	-9.17,0	-8.06,0	0.00,0
27.50,0	17.78,0	5.00,0	-	-7.50,0	1.67,0
30,Sep-	19.72,0	-8.06,0	14.72,0	5.83,0	2.22,0
95	20.00,0	-5.28,0	-	6.39,0	13.06,0
21.67,0	10.56,0	6.11,0	14.17,0	5.83,0	3.89,1.
19.44,0	9.44,0	31,Dec-	-	9.17,0	3
22.22,0	10.28,0	95	10.00,0	2.22,0	-4.44,0
23.61,0	19.72,0	8.89,0	-0.83,0	-2.22,0	-1.67,0
24.72,0	15.00,0	7.78,0	0.28,0	2.22,0	3.89,0
25.00,1	14.44,0	8.61,0	0.00,0.	1.11,0	8.89,0.
.275	8.06,0.	0.56,0	375	-3.61,0	5
17.22,0	275	3.33,0	3.06,0	-	8.61,0
.325	7.22,0	-3.33,0	6.11,0	7.78,0.	5.56,1.
15.28,0	9.17,0	-	3.61,0	45	5
13.89,0	15.28,0	3.61,0.	-2.22,0	-2.78,0	30,Apr-
14.72,0	9.44,0	25	4.17,0	-6.94,0	96
16.67,0	11.39,0	-	6.94,0	1.94,0	4.72,0
18.61,0	11.11,0	7.78,0.	-	10.00,0	14.72,0
.2	10.00,1	15	1.11,0.	4.17,0	15.56,0
21.39,0	.65	-	45	4.17,0	11.67,0
.575	9.17,0	16.39,0	-	7.78,0.	.1
20.83,0	7.50,0	-	16.94,1	075	4.17,0
19.17,0	5.28,0.	13.33,0	.525	8.89,0	3.06,0
21.39,0	025	.175	-	12.22,0	3.06,0
17.50,0	4.17,2.	-9.44,0	10.00,0	15.83,0	4.17,0
16.11,0	85	-9.44,0	-3.06,0	5.28,1.	4.17,0
15.83,0	30,Nov-	-3.06,0	1.67,0	4	8.61,0
12.50,1	95	3.06,0	-5.00,0	-7.78,0	18.89,0
.275	10.56,1	-0.56,0	-	-8.89,0	20.28,0
9.72,0.	.8	0.00,0	10.83,0	31,Mar-	6.67,0
175	7.50,2.	0.56,0	.25	96	6.11,0
5.56,0.	375	-	-5.83,0	-2.22,0	5.83,2.
7	-1.67,0	0.28,0.	-	-3.06,0	8
7.50,0	-3.61,0	275	3.61,0.	-7.50,0	7.50,0.
9.44,0	1.39,0	0.00,0.	325	-0.56,0	15
13.06,0	4.17,0	075	-	3.61,1.	15.83,0
15.28,0	3.33,0	-5.56,0	11.39,1	925	20.00,0
18.33,0	-2.78,0	-5.56,0	.25	-	17.78,0
17.78,0	7.78,0	-5.00,0	-8.06,0	3.61,0.	15.83,0
19.72,0	7.78,0	-4.17,0	-	2	12.50,0
21.67,2	-	-1.67,0	8.61,1.	-	14.44,0
.85	5.00,0.	-1.94,0	3	12.78,0	.525
31,Oct-	725	0.56,0	-	.175	9.44,0
95	-2.50,0	-1.94,0	16.94,0	-	16.11,0
	-1.39,0	-6.67,0		13.33,0	18.61,0

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025	0.56,0	11.94,0	20.56,0	29.17,0	21.11,0
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0.83,4.	5.00,1.	.125	19.17,0	28.61,0	99
55	35	16.67,0	18.33,0	26.67,0	24.17,0
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28,Feb-	3.89,0	.55	26.67,0	31.39,0	17.78,0
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25	1	6.94,0	8.33,0.	16.94,0	28.61,0
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31,Dec-	3.06,0	-1.67,0	14.44,0	10.00,0	26.67,0
01	-1.39,0	31,Mar-	18.61,0	9.44,0	27.22,0
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25	-1.11,0	11.94,0	24.72,0	.825	22.50,1
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175	825	5.28,0	8.06,0.	26.67,0	30.00,0
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B.4 Transport File (see model manual for explanation)

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Appendix C

GWLF Output

This is the raw monthly output from GWLF. Refer to the GWLF Users Manual for additional details and definitions.

Abbreviations:

Precip – Precipitation
ET – Evapotranspiration
cm – centimeters
ha – hectares
t/h – tons per hectare
Dis. N – Dissolved Nitrogen
Tot. N – Total Nitrogen
Dis. P – Dissolved Phosphorus
Tot. P – Total Phosphorus
t – tons

New Project				Tot area (h)=	79.75	Rows/ Yr=	40
	YEAR	2-14 Mean					
	Precip (cm)	**ET (cm)**	**Groundwater (cm)**	**Runoff (cm)**	**Stream (cm)**		
Apr	8.81	5.48	2.43	1.02	3.45		
May	15.34	9.03	3.15	4.12	7.26		
Jun	12.49	12.22	1.54	3.18	4.72		
Jul	7.76	13.69	0.11	1.89	2		
Aug	11.87	9.76	0	3.08	3.09		
Sep	7.56	5.4	0	1.73	1.73		
Oct	9.15	3.81	0	2.27	2.27		
Nov	3.88	0.86	0	0.67	0.67		
Dec	3.76	0.35	0.2	0.84	1.04		
Jan	4.81	0.27	0.43	1.38	1.82		
Feb	5.08	0.46	0.68	1.95	2.64		
Mar	5.15	1.26	0.98	1.17	2.15		
YEAR	95.66	62.59	9.53	23.31	32.84		
SOURCE	**Area (ha)**	**Runoff (cm)**					
Cropland 1	0.9	25.05					
Cropland 2	11.8	33.39					
Cropland 3	1.4	33.39					
Cropland 4	17.2	25.05					
Cropland 5	14.6	25.05					
Deciduos Forest 1	2.2	9.36					
Deciduos Forest 2	1.5	9.36					
Deciduos Woody/Herbaceous	0.2	9.36					

Grassland 1	0.6	10.75					
Grassland 2	2.8	15.41					
Grassland 3	0	15.41					
Grassland 4	10.8	10.75					
Grassland 5	11.6	10.75					
Impervious	3.6	63.41					
Low Intensity Urban	0.1	13.3					
Open Water	0.4	95.66					
Groundwater							
Point Source							
TOTAL	79.75						
New Project							
	YEAR	1					
	Precip (cm)	**ET (cm)**	**Groundwater (cm)**	**Runoff (cm)**	**Stream (cm)**		
Apr	10.05	5.63	2	1.69	3.69		
May	5.23	8.66	3.18	0.54	3.72		
Jun	5.15	13.03	0.14	0.42	0.55		
Jul	1.23	6.35	0	0.01	0.01		
Aug	7.33	5.02	0	0.65	0.65		
Sep	6.3	5.27	0	0.62	0.62		
Oct	3.08	3.16	0	0.14	0.14		
Nov	11.8	0.97	0	2.43	2.43		
Dec	6.08	0.46	0	2.84	2.84		
Jan	1.95	0.09	0	0.08	0.08		
Feb	3.5	0.41	0	1.21	1.21		
Mar	2.68	1.38	0	0.79	0.79		
YEAR	64.35	50.42	5.32	11.44	16.76		
SOURCE	**Area (ha)**	**Runoff (cm)**					
Cropland 1	0.9	12.06					
Cropland 2	11.8	18.08					
Cropland 3	1.4	18.08					
Cropland 4	17.2	12.06					
Cropland 5	14.6	12.06					
Deciduos Forest 1	2.2	2.71					
Deciduos Forest 2	1.5	2.71					
Deciduos Woody/Herbaceous	0.2	2.71					
Grassland 1	0.6	3.34					
Grassland 2	2.8	5.77					
Grassland 3	0	5.77					
Grassland 4	10.8	3.34					
Grassland 5	11.6	3.34					
Impervious	3.6	40.59					
Low Intensity Urban	0.1	4.6					
Open Water	0.4	64.35					
Groundwater							
Point Source							

TOTAL	79.75						
New Project							
	YEAR	2					
	Precip (cm)	**ET (cm)**	**Groundwater (cm)**	**Runoff (cm)**	**Stream (cm)**		
Apr	14.83	4.86	4.07	2.17	6.24		
May	25.03	7.81	9.32	6.78	16.1		
Jun	7.63	12.07	2.81	0.44	3.25		
Jul	18.2	14.1	0.07	6.9	6.97		
Aug	16.53	13.32	0	5.05	5.05		
Sep	7.38	6.23	0	0.41	0.41		
Oct	5.78	3.81	0	0.6	0.6		
Nov	4.9	0.59	0	2.36	2.36		
Dec	1.1	0.21	0	0.14	0.14		
Jan	5.8	0.19	0	0.29	0.29		
Feb	1.93	0.58	0	2.45	2.45		
Mar	5.6	0.82	1.12	0.28	1.4		
YEAR	114.68	64.59	17.39	27.86	45.25		
SOURCE	**Area (ha)**	**Runoff (cm)**					
Cropland 1	0.9	30.29					
Cropland 2	11.8	41.24					
Cropland 3	1.4	41.24					
Cropland 4	17.2	30.29					
Cropland 5	14.6	30.29					
Deciduos Forest 1	2.2	9.63					
Deciduos Forest 2	1.5	9.63					
Deciduos Woody/Herbaceous	0.2	9.63					
Grassland 1	0.6	11.45					
Grassland 2	2.8	17.57					
Grassland 3	0	17.57					
Grassland 4	10.8	11.45					
Grassland 5	11.6	11.45					
Impervious	3.6	79.07					
Low Intensity Urban	0.1	14.79					
Open Water	0.4	114.68					
Groundwater							
Point Source							
TOTAL	79.75						
New Project							
	YEAR	3					
	Precip (cm)	**ET (cm)**	**Groundwater (cm)**	**Runoff (cm)**	**Stream (cm)**		
Apr	5.75	5.06	2.29	0.38	2.67		
May	38.1	8.46	8.55	18.75	27.31		
Jun	8.47	12.17	4.8	1.15	5.95		
Jul	11.4	12.97	0.16	3.73	3.89		

Aug	12.73	11.2	0	2.45	2.46		
Sep	6.75	6.39	0	0.73	0.73		
Oct	4.45	4.02	0	0.32	0.32		
Nov	3.4	0.5	0	0.07	0.07		
Dec	0.28	0.28	0	0	0		
Jan	4.58	0.23	0	1.49	1.49		
Feb	9.2	0.35	0	4.27	4.27		
Mar	4.03	1.38	0	0.13	0.13		
YEAR	109.13	63.01	15.81	33.49	49.3		
SOURCE	**Area (ha)**	**Runoff (cm)**					
Cropland 1	0.9	36.29					
Cropland 2	11.8	45.97					
Cropland 3	1.4	45.97					
Cropland 4	17.2	36.29					
Cropland 5	14.6	36.29					
Deciduos Forest 1	2.2	16.13					
Deciduos Forest 2	1.5	16.13					
Deciduos Woody/Herbaceous	0.2	16.13					
Grassland 1	0.6	18.06					
Grassland 2	2.8	24.26					
Grassland 3	0	24.26					
Grassland 4	10.8	18.06					
Grassland 5	11.6	18.06					
Impervious	3.6	77.81					
Low Intensity Urban	0.1	21.5					
Open Water	0.4	109.13					
Groundwater							
Point Source							
TOTAL	79.75						
New Project							
	YEAR	4					
	Precip (cm)	**ET (cm)**	**Groundwater (cm)**	**Runoff (cm)**	**Stream (cm)**		
Apr	8.8	4.43	2.57	2.52	5.08		
May	15.45	7.47	2.98	2.6	5.57		
Jun	9.95	12.06	1.25	1.1	2.35		
Jul	10.08	13.88	0.03	2.53	2.57		
Aug	10.48	10.88	0	2.39	2.39		
Sep	4.15	7.24	0	0.13	0.13		
Oct	9.25	4.2	0	1.48	1.48		
Nov	4.95	0.69	0	0.34	0.34		
Dec	3.83	0.26	0	0.7	0.7		
Jan	4.95	0.29	0	1.34	1.34		
Feb	10.18	0.78	2.07	2.11	4.18		
Mar	10.3	1.21	5.7	3.01	8.72		
YEAR	102.35	63.38	14.6	20.25	34.85		
SOURCE	**Area**	**Runoff**					

	(ha)	(cm)					
Cropland 1	0.9	21.77					
Cropland 2	11.8	31.21					
Cropland 3	1.4	31.21					
Cropland 4	17.2	21.77					
Cropland 5	14.6	21.77					
Deciduos Forest 1	2.2	5.45					
Deciduos Forest 2	1.5	5.45					
Deciduos Woody/Herbaceous	0.2	5.45					
Grassland 1	0.6	6.69					
Grassland 2	2.8	11.29					
Grassland 3	0	11.29					
Grassland 4	10.8	6.69					
Grassland 5	11.6	6.69					
Impervious	3.6	65.94					
Low Intensity Urban	0.1	9.14					
Open Water	0.4	102.35					
Groundwater							
Point Source							
TOTAL	79.75						
New Project							
	YEAR	5					
	Precip (cm)	**ET (cm)**	**Groundwater (cm)**	**Runoff (cm)**	**Stream (cm)**		
Apr	10.78	5.11	7.96	1.16	9.12		
May	12.03	10.28	1.67	1	2.67		
Jun	24.93	11.93	2.64	8.22	10.86		
Jul	3.5	14.03	0.69	0.26	0.95		
Aug	5.78	12.17	0.02	0.32	0.34		
Sep	11.45	8.18	0	3.15	3.15		
Oct	24.95	4.02	0	11.15	11.15		
Nov	10.78	1	0	3.02	3.02		
Dec	3.45	0.55	0.97	1.23	2.2		
Jan	9.28	0.19	3.11	4.56	7.67		
Feb	3.03	0.65	2.87	0.3	3.16		
Mar	3.1	1.06	1.68	0.84	2.52		
YEAR	123.03	69.18	21.6	35.22	56.81		
SOURCE	**Area (ha)**	**Runoff (cm)**					
Cropland 1	0.9	38.43					
Cropland 2	11.8	49.98					
Cropland 3	1.4	49.98					
Cropland 4	17.2	38.43					
Cropland 5	14.6	38.43					
Deciduos Forest 1	2.2	14.96					
Deciduos Forest 2	1.5	14.96					
Deciduos Woody/Herbaceous	0.2	14.96					
Grassland 1	0.6	17.13					

Grassland 2	2.8	24.26					
Grassland 3	0	24.26					
Grassland 4	10.8	17.13					
Grassland 5	11.6	17.13					
Impervious	3.6	87.38					
Low Intensity Urban	0.1	21.05					
Open Water	0.4	123.03					
Groundwater							
Point Source							
TOTAL	79.75						
New Project							
	YEAR	6					
	Precip (cm)	**ET (cm)**	**Groundwater (cm)**	**Runoff (cm)**	**Stream (cm)**		
Apr	11.2	5.64	3.11	1.11	4.22		
May	8.58	9.14	3.83	0.66	4.5		
Jun	9.65	12.37	0.15	0.69	0.84		
Jul	3.3	15.92	0	0.08	0.08		
Aug	4.58	4.46	0	0.11	0.11		
Sep	11.58	1.77	0	4.12	4.12		
Oct	2.93	4.08	0	0.22	0.22		
Nov	0.53	1.14	0	0.01	0.01		
Dec	4.03	0.4	0	0.35	0.35		
Jan	2.85	0.25	0	0.09	0.09		
Feb	3.03	0.69	0	0.99	0.99		
Mar	2.05	1.66	0	0.04	0.04		
YEAR	64.28	57.52	7.1	8.48	15.57		
SOURCE	**Area (ha)**	**Runoff (cm)**					
Cropland 1	0.9	8.51					
Cropland 2	11.8	13.19					
Cropland 3	1.4	13.19					
Cropland 4	17.2	8.51					
Cropland 5	14.6	8.51					
Deciduos Forest 1	2.2	1.75					
Deciduos Forest 2	1.5	1.75					
Deciduos Woody/Herbaceous	0.2	1.75					
Grassland 1	0.6	2.18					
Grassland 2	2.8	3.95					
Grassland 3	0	3.95					
Grassland 4	10.8	2.18					
Grassland 5	11.6	2.18					
Impervious	3.6	35.13					
Low Intensity Urban	0.1	3.09					
Open Water	0.4	64.28					
Groundwater							
Point Source							
TOTAL	79.75						

New Project							
	YEAR	7					
	Precip (cm)	**ET (cm)**	**Groundwater (cm)**	**Runoff (cm)**	**Stream (cm)**		
Apr	3.23	5.38	0	0.07	0.07		
May	5.48	10.14	0	0.21	0.21		
Jun	23.1	11.56	0	11.87	11.87		
Jul	9.83	11.91	0	1.65	1.65		
Aug	4.4	4.21	0	0.19	0.19		
Sep	9.73	3.98	0	1.68	1.68		
Oct	4.25	4.42	0	0.14	0.14		
Nov	4.2	0.63	0	0.75	0.75		
Dec	3.48	0.06	0	0.03	0.03		
Jan	6.7	0.19	0	5.09	5.09		
Feb	9.88	0.27	0	4.35	4.35		
Mar	6.33	0.81	0.56	1.65	2.21		
YEAR	90.57	53.56	0.56	27.68	28.24		
SOURCE	**Area (ha)**	**Runoff (cm)**					
Cropland 1	0.9	29.73					
Cropland 2	11.8	37.15					
Cropland 3	1.4	37.15					
Cropland 4	17.2	29.73					
Cropland 5	14.6	29.73					
Deciduos Forest 1	2.2	14.22					
Deciduos Forest 2	1.5	14.22					
Deciduos Woody/Herbaceous	0.2	14.22					
Grassland 1	0.6	15.79					
Grassland 2	2.8	20.66					
Grassland 3	0	20.66					
Grassland 4	10.8	15.79					
Grassland 5	11.6	15.79					
Impervious	3.6	62.83					
Low Intensity Urban	0.1	18.53					
Open Water	0.4	90.58					
Groundwater							
Point Source							
TOTAL	79.75						
New Project							
	YEAR	8					
	Precip (cm)	**ET (cm)**	**Groundwater (cm)**	**Runoff (cm)**	**Stream (cm)**		
Apr	7.9	6.61	2.27	0.33	2.61		
May	22.33	9.17	4.36	4.83	9.19		
Jun	15.15	11.74	5.92	3.43	9.36		
Jul	2.33	14.89	0.32	0.03	0.35		
Aug	13.48	10.82	0.01	3.12	3.12		

Sep	9.75	6.58	0	2.14	2.14		
Oct	16.28	3.74	0	4.56	4.56		
Nov	2.25	1.28	0	0.03	0.03		
Dec	3.2	0.59	0	0.07	0.07		
Jan	5.45	0.46	0	0.07	0.07		
Feb	1.55	0.55	0.08	1.69	1.76		
Mar	2.23	1.09	0.81	0.33	1.14		
YEAR	101.88	67.53	13.77	20.64	34.41		
SOURCE	**Area (ha)**	**Runoff (cm)**					
Cropland 1	0.9	22.39					
Cropland 2	11.8	31.75					
Cropland 3	1.4	31.75					
Cropland 4	17.2	22.39					
Cropland 5	14.6	22.39					
Deciduos Forest 1	2.2	5.44					
Deciduos Forest 2	1.5	5.44					
Deciduos Woody/Herbaceous	0.2	5.44					
Grassland 1	0.6	6.83					
Grassland 2	2.8	11.76					
Grassland 3	0	11.76					
Grassland 4	10.8	6.83					
Grassland 5	11.6	6.83					
Impervious	3.6	65.81					
Low Intensity Urban	0.1	9.5					
Open Water	0.4	101.88					
Groundwater							
Point Source							
TOTAL	79.75						
New Project							
	YEAR	9					
	Precip (cm)	**ET (cm)**	**Groundwater (cm)**	**Runoff (cm)**	**Stream (cm)**		
Apr	10.25	5.51	2.49	0.74	3.23		
May	22.35	8.19	6.25	10.1	16.36		
Jun	13.85	13.34	1.93	5.29	7.22		
Jul	4.83	15.31	0.11	0.18	0.29		
Aug	10.13	8.19	0	2.5	2.5		
Sep	1.9	3.02	0	0.02	0.02		
Oct	6.1	2.77	0	0.14	0.14		
Nov	0.7	0.72	0	0.01	0.01		
Dec	1.9	0.36	0	0.07	0.07		
Jan	1.05	0.14	0	0.34	0.34		
Feb	2.68	0.27	0	0.76	0.76		
Mar	2.15	1.19	0	0.17	0.17		
YEAR	77.88	59	10.79	20.34	31.12		
SOURCE	**Area (ha)**	**Runoff (cm)**					

Cropland 1	0.9	21.82					
Cropland 2	11.8	28.18					
Cropland 3	1.4	28.18					
Cropland 4	17.2	21.82					
Cropland 5	14.6	21.82					
Deciduos Forest 1	2.2	9.28					
Deciduos Forest 2	1.5	9.28					
Deciduos Woody/Herbaceous	0.2	9.28					
Grassland 1	0.6	10.44					
Grassland 2	2.8	14.27					
Grassland 3	0	14.27					
Grassland 4	10.8	10.44					
Grassland 5	11.6	10.44					
Impervious	3.6	51.03					
Low Intensity Urban	0.1	12.55					
Open Water	0.4	77.88					
Groundwater							
Point Source							
TOTAL	79.75						
New Project							
	YEAR	10					
	Precip (cm)	**ET (cm)**	**Groundwater (cm)**	**Runoff (cm)**	**Stream (cm)**		
Apr	9.9	5.68	0	1.14	1.14		
May	15.28	8.51	0	3.89	3.89		
Jun	16.03	11.34	0	4.47	4.47		
Jul	17.08	14.17	0	7.9	7.9		
Aug	5.7	11.59	0	0.71	0.71		
Sep	19.95	6.43	0	9.36	9.36		
Oct	3.53	4.03	0	0.23	0.23		
Nov	3.88	0.87	0	0.12	0.12		
Dec	9.33	0.45	0	4.01	4.01		
Jan	5.5	0.19	0	0.02	0.02		
Feb	1.58	0.37	0	3.32	3.32		
Mar	7.15	1.53	0.74	0.79	1.53		
YEAR	114.88	65.17	0.74	35.97	36.71		
SOURCE	**Area (ha)**	**Runoff (cm)**					
Cropland 1	0.9	39.34					
Cropland 2	11.8	49.79					
Cropland 3	1.4	49.79					
Cropland 4	17.2	39.34					
Cropland 5	14.6	39.34					
Deciduos Forest 1	2.2	16.67					
Deciduos Forest 2	1.5	16.67					
Deciduos Woody/Herbaceous	0.2	16.67					
Grassland 1	0.6	18.9					
Grassland 2	2.8	26.02					

Grassland 3	0	26.02					
Grassland 4	10.8	18.9					
Grassland 5	11.6	18.9					
Impervious	3.6	83.03					
Low Intensity Urban	0.1	22.86					
Open Water	0.4	114.88					
Groundwater							
Point Source							
TOTAL	79.75						
New Project							
	YEAR	11					
	Precip (cm)	**ET (cm)**	**Groundwater (cm)**	**Runoff (cm)**	**Stream (cm)**		
Apr	4.63	5.73	0.66	0.75	1.41		
May	13.75	9.96	0.02	1.46	1.48		
Jun	9.15	11.57	0.43	1.14	1.57		
Jul	7.93	12.87	0.01	0.82	0.83		
Aug	24.28	10.04	0	9.02	9.02		
Sep	3.28	7.28	0	0.37	0.37		
Oct	10.23	3.9	0	0.99	0.99		
Nov	4.3	1.01	0	0.93	0.93		
Dec	2.88	0.44	1.58	0.16	1.74		
Jan	5.13	0.19	2.52	1.25	3.77		
Feb	4.25	0.66	3.88	0.38	4.26		
Mar	2.4	1.17	1.26	0.09	1.35		
YEAR	92.18	64.82	10.35	17.38	27.74		
SOURCE	**Area (ha)**	**Runoff (cm)**					
Cropland 1	0.9	18.09					
Cropland 2	11.8	25.82					
Cropland 3	1.4	25.82					
Cropland 4	17.2	18.09					
Cropland 5	14.6	18.09					
Deciduos Forest 1	2.2	5.89					
Deciduos Forest 2	1.5	5.89					
Deciduos Woody/Herbaceous	0.2	5.89					
Grassland 1	0.6	6.81					
Grassland 2	2.8	10.16					
Grassland 3	0	10.16					
Grassland 4	10.8	6.81					
Grassland 5	11.6	6.81					
Impervious	3.6	56.65					
Low Intensity Urban	0.1	8.59					
Open Water	0.4	92.18					
Groundwater							
Point Source							
TOTAL	79.75						

New Project							
	YEAR	12					
	Precip (cm)	**ET (cm)**	**Groundwater (cm)**	**Runoff (cm)**	**Stream (cm)**		
Apr	8.78	6.05	1.9	0.93	2.83		
May	5.63	8.66	0.88	0.58	1.46		
Jun	8.88	13.48	0.03	1.34	1.38		
Jul	3.4	12.89	0	0.17	0.17		
Aug	8.5	7.11	0	1.11	1.11		
Sep	7.48	4.98	0	0.31	0.31		
Oct	6.8	4.1	0	0.69	0.69		
Nov	3.7	0.92	0	0.95	0.95		
Dec	1.95	0.26	0	0.47	0.47		
Jan	7.15	0.63	0	1.41	1.41		
Feb	0.28	0.39	0	0.01	0.01		
Mar	9.72	1.38	0	1.42	1.42		
YEAR	72.25	60.83	2.82	9.39	12.21		
SOURCE	**Area (ha)**	**Runoff (cm)**					
Cropland 1	0.9	9.47					
Cropland 2	11.8	15.5					
Cropland 3	1.4	15.5					
Cropland 4	17.2	9.47					
Cropland 5	14.6	9.47					
Deciduos Forest 1	2.2	1.21					
Deciduos Forest 2	1.5	1.21					
Deciduos Woody/Herbaceous	0.2	1.21					
Grassland 1	0.6	1.71					
Grassland 2	2.8	3.77					
Grassland 3	0	3.77					
Grassland 4	10.8	1.71					
Grassland 5	11.6	1.71					
Impervious	3.6	40.95					
Low Intensity Urban	0.1	2.78					
Open Water	0.4	72.25					
Groundwater							
Point Source							
TOTAL	79.75						
New Project							
	YEAR	13					
	Precip (cm)	**ET (cm)**	**Groundwater (cm)**	**Runoff (cm)**	**Stream (cm)**		
Apr	7.95	6.23	0.79	0.7	1.5		
May	1.98	9.18	0.03	0.06	0.09		
Jun	6.5	12.57	0	0.18	0.19		
Jul	5.43	11.32	0	0.23	0.23		
Aug	15.68	10.14	0	4.51	4.51		
Sep	1.7	2.7	0	0.02	0.02		

Oct	5.55	1.83	0	0.34	0.34		
Nov	5.78	0.99	0	0.13	0.13		
Dec	4.35	0.56	0	1.55	1.55		
Jan	2.15	0.29	0	0.08	0.08		
Feb	6.1	0.25	0	2.56	2.56		
Mar	6.8	1.82	0	0.6	0.6		
YEAR	69.95	57.89	0.82	10.96	11.79		
SOURCE	**Area (ha)**	**Runoff (cm)**					
Cropland 1	0.9	11.2					
Cropland 2	11.8	16.1					
Cropland 3	1.4	16.1					
Cropland 4	17.2	11.2					
Cropland 5	14.6	11.2					
Deciduos Forest 1	2.2	3.48					
Deciduos Forest 2	1.5	3.48					
Deciduos Woody/Herbaceous	0.2	3.48					
Grassland 1	0.6	4.12					
Grassland 2	2.8	6.3					
Grassland 3	0	6.3					
Grassland 4	10.8	4.12					
Grassland 5	11.6	4.12					
Impervious	3.6	38.26					
Low Intensity Urban	0.1	5.31					
Open Water	0.4	69.95					
Groundwater							
Point Source							
TOTAL	79.75						
New Project							
	YEAR	14					
	Precip (cm)	**ET (cm)**	**Groundwater (cm)**	**Runoff (cm)**	**Stream (cm)**		
Apr	10.55	4.96	3.54	1.26	4.79		
May	13.48	10.43	3.01	2.6	5.61		
Jun	9.13	12.71	0.12	1.94	2.06		
Jul	3.58	13.75	0	0.08	0.08		
Aug	22.1	12.75	0	8.6	8.6		
Sep	3.15	5.39	0	0.09	0.09		
Oct	18.9	4.65	0	8.67	8.67		
Nov	1.03	0.82	0	0.02	0.02		
Dec	9.18	0.11	0	2.12	2.12		
Jan	1.95	0.3	0	1.95	1.95		
Feb	12.45	0.13	0	2.22	2.22		
Mar	5.05	1.23	0.85	5.83	6.68		
YEAR	110.53	67.24	7.51	35.37	42.89		
SOURCE	**Area (ha)**	**Runoff (cm)**					
Cropland 1	0.9	38.27					

Cropland 2	11.8	48.16						
Cropland 3	1.4	48.16						
Cropland 4	17.2	38.27						
Cropland 5	14.6	38.27						
Deciduos Forest 1	2.2	17.58						
Deciduos Forest 2	1.5	17.58						
Deciduos Woody/Herbaceous	0.2	17.58						
Grassland 1	0.6	19.6						
Grassland 2	2.8	26.01						
Grassland 3	0	26.01						
Grassland 4	10.8	19.6						
Grassland 5	11.6	19.6						
Impervious	3.6	80.47						
Low Intensity Urban	0.1	23.16						
Open Water	0.4	110.53						
Groundwater								
Point Source								
TOTAL	79.75							

Appendix D

Reservoir Routing for Wyaconda Lake

Hydrologic routing was performed for Wyaconda Lake to determine the lake level and volume during the 14-year period simulated using the linked watershed and water quality modeling. To determine the inflow into the lake from the watershed, GWLF was utilized to generate total monthly flows to the watershed. Included in GWLF output are stream and groundwater contributions to Wyaconda Lake. Daily precipitation and temperature data from two weather stations were used to calculate monthly evaporation and precipitation to Wyaconda Lake. Thus, between the measured precipitation, estimated evaporation, simulated watershed flow, and estimated outflow a water balance for Wyaconda Lake was generated.

D.1 Precipitation

Precipitation from Luray 2 N weather station (COOP ID 235130) was used to calculate monthly precipitation to Wyaconda Lake. Monthly total precipitation in centimeters was multiplied by the surface area of the lake to calculate the total inflow volume attributed to rainfall.

D.2 Evaporation

Using temperature data from Keosaqua weather station (COOP ID 13489) and the Hargreaves evaporation equation, evaporation was estimated for Wyaconda Lake. The Hargreaves equation has been found to be a reliable approximation for pan evaporation. To confirm that this equation provided reasonable evaporation estimates, results were compared to the Mean Class A Pan Evaporation for this area of Missouri (McCuen, 1998). Values from the Hargreaves equation were found to be similar to Pan Evaporation (49.7 inches/year); therefore, it was multiplied by a pan factor of 0.7 to estimate evaporation expected from a reservoir. Evaporation estimated in millimeters was multiplied by the surface area of the lake to calculate the total volume of water lost via evaporation.

Hargreaves Equation:
$E = 0.0023\ S_0\ d_T\ (T + 17.8)$ = Evaporation (millimeters)
d_T = difference between mean monthly max. and mean monthly min. temperatures
S_0 = water equivalent of extraterrestrial radiation
$= 15.392\ d_r\ (w_s \sin F \sin d + \cos F \cos d \sin w_s)$
$d_r = 1 + 0.033 \cos (2p\ J / 365)$
$w_s = \arccos(-\tan F \tan d)$
$d = 0.4093 \sin (2p\ J / 365 - 1.405)$
J = Julian day number
F = Latitude

D.3 Stream and Ground Water Flow

GWLF was used to estimate stream and groundwater flows to the lake. See Appendix B of this document for a description of GWLF results.

D.4 Lake Bottom Seepage

Seepage losses from the lake were assumed to be negligible. This assumption is supported by an estimate of vertical groundwater flow from the lake using Darcy's equation:

$$Q = KIA$$

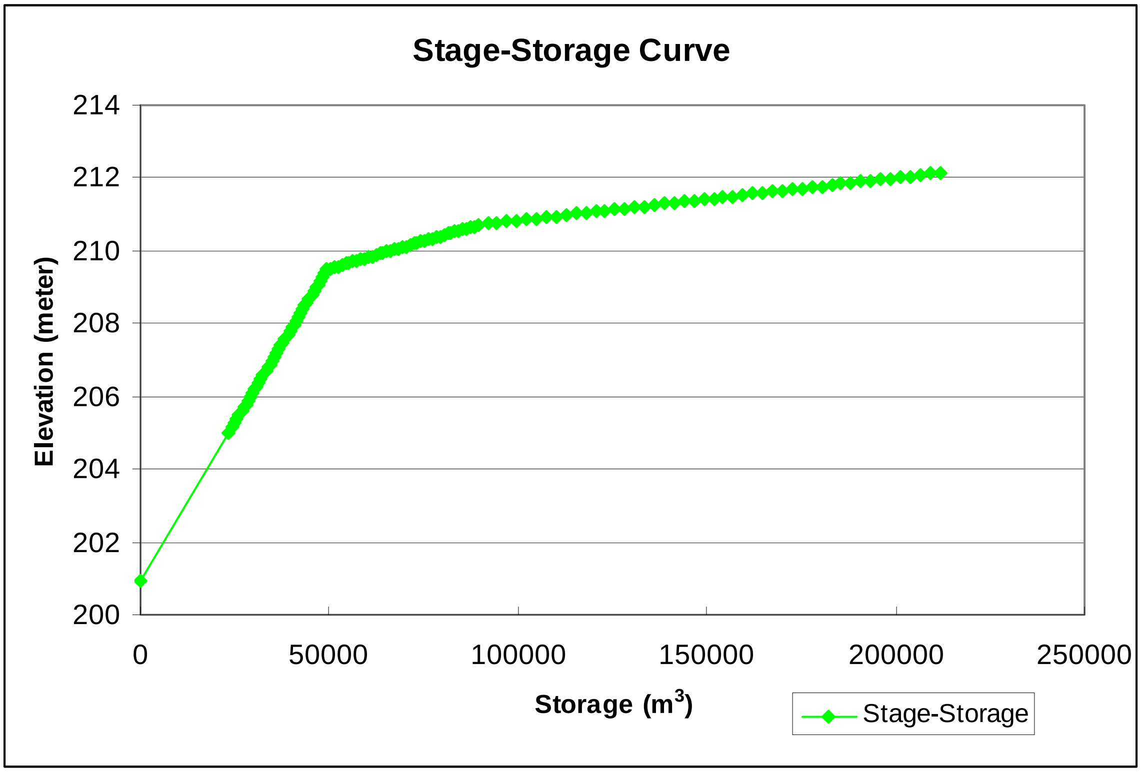
Where;

Q = flow
K = hydraulic conductivity
I = Hydraulic gradient
A = area of flow

No data directly related to these parameters was available for Wyaconda Lake; however, based on the surrounding soil types and a general understanding of reservoir dynamics the following assumptions were made. A literature value for horizontal hydraulic conductivity based on the soil types in the watershed was used. This value was reduced by two orders of magnitude to convert it to vertical conductivity based on the assumption that the soils are anisotropic (Maidment, 1992). This value was further reduced by two orders of magnitude to account for accumulation of fine particles in the lake bed sediment. This resulted in an estimated hydraulic conductivity of 10^{-12} centimeters per second (cm/s). Horizontal hydraulic conductivity of 10^{-8} cm/s for clay soils (Fetter, 1994) plus the additional factors related to vertical conductivity and lake bottom fines. The lake has a surface area of nine acres. Assuming that groundwater is far below the lake bottom, flow out of the lake can be estimated by multiplying the hydraulic conductivity by the area. This results in a loss of 0.006 m^3/yr from the lake. This is a conservative estimate as groundwater levels likely reduce the hydraulic gradient to below 1.0 and the seepage area of the lake is likely less than the surface area of the lake. The resulting estimate of seepage from the lake is small compared to other gains and losses; therefore, it was not included in the water balance.

D.5 Outflows

The monthly net inflows were disaggregated into daily net inflows for the hydraulic routing of the lake. The Modified Puls routing method was used with a time step of 1 day. Based on the findings of the USACE's Dam Safety Inspection (1978), stage-storage and stage-discharge curves (Figure D.1) were created for the lake. The resulting precipitation, evaporation, watershed inflow, net inflow, lake volume, stage and outflow are provided in Table D.1. Figure D.2 presents average monthly lake elevation levels for Wyaconda Lake.



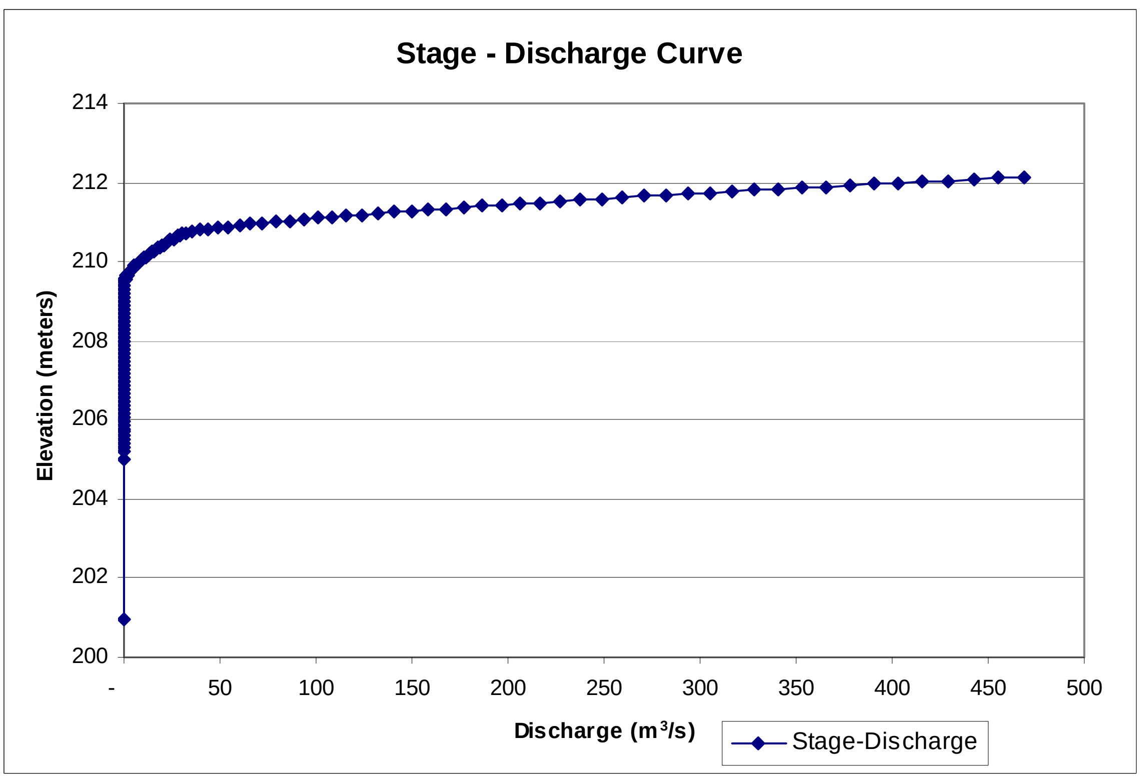


Figure D.1. Stage Storage and Stage Discharge Curves for Wyaconda Lake

Table D.1. Total Inflow, Lake Volume, Lake Stage and Outflow from the Modified Puls Routing for Wyaconda Lake

Calendar Month	Model Month	Precip. (m^3)	Evap. (m^3)	Watershed Flow (m^3)	Total Lake Inflow (m^3)	Monthly Discharge (m^3)	Average Lake Level (m)	Average Lake Volume (m^3)
Apr-94	1	4327	3249	29040	33368	31099	209.412	48995.850
May-94	2	2252	3827	29276	31528	21540	209.401	48900.108
Jun-94	3	2218	4447	4329	6546	2202	209.486	49339.190
Jul-94	4	530	4584	79	608	2275	209.428	49003.507
Aug-94	5	3156	4454	5116	8272	2275	209.286	48182.947
Sep-94	6	2713	3987	4879	7592	2202	209.479	49300.649
Oct-94	7	1326	3435	1102	2428	2275	209.331	48444.034
Nov-94	8	5081	2635	19124	24205	21466	209.375	48750.577
Dec-94	9	2618	2119	22351	24969	21540	209.378	48769.564
Jan-95	10	840	1331	630	1469	2275	209.154	47418.335
Feb-95	11	1507	1661	9523	11030	2055	209.379	48719.774
Mar-95	12	1154	2520	6217	7371	11908	209.135	47338.662
Apr-95	13	6386	3044	49109	55494	50363	209.428	49139.524
May-95	14	10778	3697	126707	137485	127494	209.499	49758.068
Jun-95	15	3285	4258	25578	28863	31099	209.379	48803.143
Jul-95	16	7837	4726	54854	62691	60069	209.463	49364.677
Aug-95	17	7118	4887	39744	46861	40804	209.413	49020.498
Sep-95	18	3178	3645	3227	6404	2202	209.213	47758.992
Oct-95	19	2489	3342	4722	7211	2275	209.389	48779.718
Nov-95	20	2110	2168	18573	20683	21466	209.398	48885.472
Dec-95	21	474	1594	1102	1575	2275	208.825	45516.129
Jan-96	22	2497	1280	2282	4780	2275	208.721	44919.359
Feb-96	23	831	1748	19282	20113	11761	209.342	48536.354
Mar-96	24	2411	2116	11018	13429	11908	209.335	48494.905
Apr-96	25	2476	3052	21013	23489	21466	209.365	48692.765
May-96	26	16405	3802	214930	231335	223817	209.509	50080.282
Jun-96	27	3647	4281	46827	50474	50363	209.421	49100.982
Jul-96	28	4909	4531	30614	35523	31172	209.392	48876.382
Aug-96	29	5481	4521	19360	24842	21540	209.369	48713.617
Sep-96	30	2906	3828	5745	8652	2202	209.476	49281.378
Oct-96	31	1916	3473	2518	4435	2275	209.486	49339.190
Nov-96	32	1464	2049	551	2015	2202	209.393	48799.610
Dec-96	33	121	1612	0	121	2275	208.880	45833.164
Jan-97	34	1972	1235	11726	13698	2275	209.241	47921.860
Feb-97	35	3961	1778	33605	37566	40584	209.380	48841.822
Mar-97	36	1735	2637	1023	2758	2275	209.338	48481.332
Apr-97	37	3789	2876	39980	43769	40731	209.420	49067.687
May-97	38	6653	3576	43836	50488	40804	209.419	49057.796
Jun-97	39	4284	4235	18495	22779	21466	209.348	48596.411
Jul-97	40	4487	4632	20226	24713	21540	209.352	48620.372
Aug-97	41	4665	4462	18809	23474	21540	209.385	48806.862
Sep-97	42	1847	3719	1023	2870	2202	208.753	45099.633
Oct-97	43	4118	3334	11648	15765	2275	209.199	47679.422
Nov-97	44	2203	2295	2676	4879	2202	209.486	49339.190
Dec-97	45	1705	1817	5509	7214	11908	209.113	47208.119
Jan-98	46	2203	1777	10546	12749	11908	209.387	48793.290
Feb-98	47	4532	2179	32897	37428	30952	209.407	48971.326
Mar-98	48	4585	2406	68626	73211	69701	209.461	49378.249

Calendar Month	Model Month	Precip. (m^3)	Evap. (m^3)	Watershed Flow (m^3)	Total Lake Inflow (m^3)	Monthly Discharge (m^3)	Average Lake Level (m)	Average Lake Volume (m^3)
Apr-98	49	4799	3141	71774	76573	69628	209.443	49283.197
May-98	50	5355	4141	21013	26368	31172	209.379	48801.786
Jun-98	51	11098	4254	85468	96566	88892	209.485	49581.037
Jul-98	52	1558	4750	7477	9035	2275	209.486	49339.190
Aug-98	53	2573	4751	2676	5249	2275	209.486	49339.190
Sep-98	54	5097	4254	24791	29887	21466	209.401	48904.742
Oct-98	55	11106	3496	87751	98857	98598	209.480	49568.159
Nov-98	56	4799	2692	23767	28566	31099	209.406	48957.309
Dec-98	57	1536	2071	17314	18850	11908	209.355	48606.799
Jan-99	58	4131	1411	60363	64494	60069	209.453	49308.729
Feb-99	59	1349	2101	24869	26218	30952	209.371	48764.854
Mar-99	60	1380	2444	19832	21212	11908	209.403	48886.535
Apr-99	61	4986	3291	33211	38197	40731	209.387	48874.980
May-99	62	3819	3949	35415	39234	31172	209.408	48969.627
Jun-99	63	4296	4235	6611	10906	11834	209.267	48100.618
Jul-99	64	1469	4610	630	2099	2275	208.744	45049.902
Aug-99	65	2039	3847	866	2904	2275	208.041	40984.404
Sep-99	66	5155	3813	32424	37579	21466	209.175	47594.334
Oct-99	67	1304	3492	1731	3036	2275	209.483	49320.541
Nov-99	68	236	2760	79	315	2202	208.996	46506.395
Dec-99	69	1794	1790	2755	4548	2275	208.628	44378.536
Jan-00	70	1269	1515	708	1977	2275	208.515	43725.818
Feb-00	71	1349	2091	7791	9140	2129	208.827	45531.563
Mar-00	72	913	2702	315	1227	2275	208.905	45982.356
Apr-00	73	1438	2797	551	1989	2202	208.329	42652.253
May-00	74	2439	3409	1653	4092	2275	207.931	40350.335
Jun-00	75	10283	4230	93417	103700	88892	209.408	49137.810
Jul-00	76	4376	4612	12986	17361	11908	209.368	48681.396
Aug-00	77	1959	4763	1495	3454	2275	209.399	48835.665
Sep-00	78	4331	4136	13222	17553	11834	209.367	48678.740
Oct-00	79	1892	3497	1102	2994	2275	209.186	47604.826
Nov-00	80	1870	2140	5903	7772	2202	209.219	47797.533
Dec-00	81	1549	933	236	1785	2275	209.376	48705.121
Jan-01	82	2983	1599	40058	43041	40804	209.416	49039.147
Feb-01	83	4398	1482	34235	38633	30952	209.421	49053.914
Mar-01	84	2818	2204	17393	20210	21540	209.356	48639.021
Apr-01	85	3517	3521	20541	24057	21466	209.358	48654.223
May-01	86	9940	3957	72325	82265	79333	209.471	49466.418
Jun-01	87	6744	4241	73663	80407	79260	209.487	49567.012
Jul-01	88	1037	4429	2755	3792	2275	208.738	45012.604
Aug-01	89	6001	4618	24554	30555	21540	209.288	48247.390
Sep-01	90	4340	3837	16842	21182	11834	209.404	48890.718
Oct-01	91	7247	3316	35887	43134	40804	209.413	49020.498
Nov-01	92	1002	3107	236	1238	2202	209.463	49204.295
Dec-01	93	1424	2091	551	1975	2275	209.083	47008.055
Jan-02	94	2426	1923	551	2977	2275	208.809	45422.884
Feb-02	95	690	1894	13851	14541	11687	209.323	48425.093
Mar-02	96	993	2330	8972	9964	2275	209.283	48164.298
Apr-02	97	4563	3192	25420	29983	31099	209.382	48822.414
May-02	98	9949	3755	128753	138702	127494	209.496	49739.419
Jun-02	99	6165	4479	56821	62987	59995	209.449	49288.443

Calendar Month	Model Month	Precip. (m^3)	Evap. (m^3)	Watershed Flow (m^3)	Total Lake Inflow (m^3)	Monthly Discharge (m^3)	Average Lake Level (m)	Average Lake Volume (m^3)
Jul-02	100	2150	4915	2282	4432	2275	209.486	49339.190
Aug-02	101	4509	4637	19675	24184	21540	209.362	48676.319
Sep-02	102	846	3863	157	1003	2202	208.799	45369.423
Oct-02	103	2715	2718	1102	3817	2275	208.247	42177.945
Nov-02	104	312	1885	79	390	2202	207.843	39838.729
Dec-02	105	846	1519	551	1397	2275	207.328	36862.958
Jan-03	106	467	1060	2676	3143	2275	207.086	35464.277
Feb-03	107	1193	1101	5981	7174	2055	207.432	37467.055
Mar-03	108	957	1947	1338	2295	2275	207.638	38653.269
Apr-03	109	4407	2798	8972	13379	2202	208.183	41804.342
May-03	110	6802	3812	30614	37416	31172	209.382	48820.435
Jun-03	111	7136	4140	35179	42315	40731	209.400	48952.063
Jul-03	112	7603	4728	62173	69776	60069	209.424	49140.888
Aug-03	113	2537	4809	5588	8125	2275	209.486	49339.190
Sep-03	114	8881	3830	73663	82544	79260	209.481	49528.471
Oct-03	115	1571	3483	1810	3381	2275	209.480	49301.892
Nov-03	116	1727	2429	944	2672	2202	209.236	47893.887
Dec-03	117	4153	2079	31559	35712	31172	209.392	48876.382
Jan-04	118	2448	1431	157	2606	2275	209.380	48723.770
Feb-04	119	703	1644	26128	26832	21393	209.398	48889.761
Mar-04	120	3183	2791	12041	15224	11908	209.361	48644.097
Apr-04	121	2061	3246	11097	13158	11834	209.314	48370.408
May-04	122	6121	4066	11648	17768	11908	209.381	48755.992
Jun-04	123	4073	4158	12356	16429	11834	209.360	48640.198
Jul-04	124	3530	4470	6532	10062	11908	209.281	48177.871
Aug-04	125	10808	4324	70987	81796	69701	209.435	49229.056
Sep-04	126	1460	4085	2912	4372	2202	209.486	49339.190
Oct-04	127	4554	3366	7791	12345	11908	209.297	48271.116
Nov-04	128	1914	2715	7319	9233	2202	209.486	49339.190
Dec-04	129	1282	1958	13694	14976	11908	209.371	48700.045
Jan-05	130	2284	1570	29670	31954	31172	209.399	48913.680
Feb-05	131	1892	1991	33526	35418	40584	209.405	48986.352
Mar-05	132	1068	2485	10625	11693	2275	209.421	48966.208
Apr-05	133	3908	3375	22272	26181	31099	209.379	48803.143
May-05	134	2506	3796	11490	13996	2275	209.347	48537.280
Jun-05	135	3953	4438	10861	14814	11834	209.324	48428.221
Jul-05	136	1514	4830	1338	2851	2275	209.444	49096.752
Aug-05	137	3784	4722	8736	12519	2275	209.457	49171.348
Sep-05	138	3330	4298	2440	5769	2202	209.486	49339.190
Oct-05	139	3027	3432	5430	8457	11908	209.403	48886.535
Nov-05	140	1647	2558	7477	9124	2202	209.219	47797.533
Dec-05	141	868	1647	3699	4567	2275	209.486	49339.190
Jan-06	142	3183	2283	11097	14280	11908	209.361	48644.097
Feb-06	143	125	1661	79	203	2055	209.390	48781.716
Mar-06	144	4327	2573	11175	15502	11908	209.355	48606.799
Apr-06	145	3539	3452	11805	15344	11834	209.360	48640.198
May-06	146	881	3689	708	1590	2275	208.970	46355.338
Jun-06	147	2893	3852	1495	4389	2202	208.436	43268.916
Jul-06	148	2417	4141	1810	4227	2275	208.102	41338.736
Aug-06	149	6980	4591	35494	42474	31172	209.244	48018.524
Sep-06	150	757	3514	157	914	2202	208.646	44482.971

Calendar Month	Model Month	Precip. (m^3)	Evap. (m^3)	Watershed Flow (m^3)	Total Lake Inflow (m^3)	Monthly Discharge (m^3)	Average Lake Level (m)	Average Lake Volume (m^3)
Oct-06	151	2471	2735	2676	5146	2275	208.221	42028.752
Nov-06	152	2573	2260	1023	3596	2202	208.193	41862.154
Dec-06	153	1936	2147	12199	14135	2275	208.941	46187.496
Jan-07	154	957	1739	630	1587	2275	209.467	49227.296
Feb-07	155	2715	1211	20147	22863	21320	209.377	48770.474
Mar-07	156	3027	3065	4722	7749	2275	209.486	49339.190
Apr-07	157	4696	3033	37697	42394	40731	209.410	49009.875
May-07	158	6001	4205	44151	50151	40804	209.422	49076.445
Jun-07	159	4064	4333	16212	20276	21466	209.335	48519.328
Jul-07	160	1594	4521	630	2223	2275	209.147	47381.037
Aug-07	161	9838	4973	67682	77520	69701	209.457	49359.600
Sep-07	162	1402	3886	708	2111	2202	208.899	45947.545
Oct-07	163	8413	3719	68233	76646	69701	209.448	49303.653
Nov-07	164	459	2322	157	616	2202	208.766	45176.716
Dec-07	165	4086	1623	16684	20771	11908	209.239	47935.433
Jan-08	166	868	1578	15347	16215	11908	209.384	48774.641
Feb-08	167	5542	1367	17471	23014	21393	209.381	48790.085
Mar-08	168	2248	2521	52572	54820	50437	209.455	49295.157

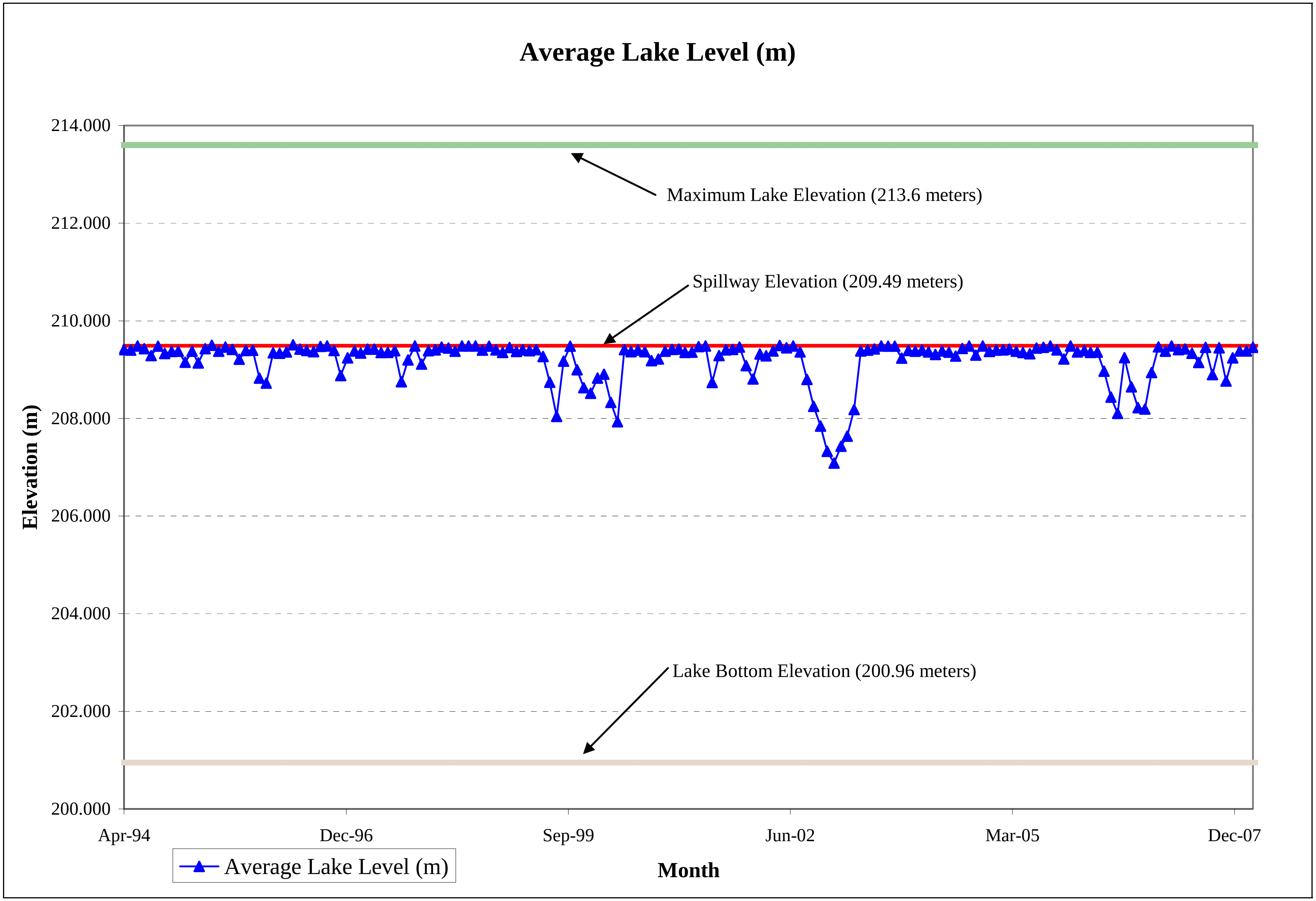


Figure D.2. Average Monthly Lake Elevation Levels for Wyaconda Lake

Appendix E

Simple Lake Model Description

The Simple Lake Model (SLM) is a mass balance model that can be applied at any equal time-step interval (e.g., day or month). The model simulates the lake concentration of a pollutant of interest given a series of inflow loadings (the product of inflow and pollutant concentration in the inflow). The original SLM maintained a constant lake volume throughout the period of analysis where outflow is set equal to inflow. For this analysis, the model was altered to accept varying lake volumes and outflows by the specified time-step. The same mass balance equation (Equation 1) as the original model remains in effect except that inflow and outflow are considered separately.

$$\frac{dc}{dt} = Q_{in}c_{in} - Q_{out}c - k_d Vc - v_v Ac \qquad \text{(EQ E.Equation1)}$$

Where

Q_{in} = inflow (m^3/time)
Q_{out} = outflow (m^3/time)
c_{in} = concentration in inflow (mg/m^3)
c = in-lake concentration (mg/m^3)
k_d = decay rate ($time^{-1}$)
V = volume (m^3)
v_v = volatilization velocity (m/time)
A = surface area (m^2).

The mass balance for this model simulates the lake as a continuously stirred tank reactor (CSTR) (Figure E.1) meaning there are no concentration differentials simulated within the lake.

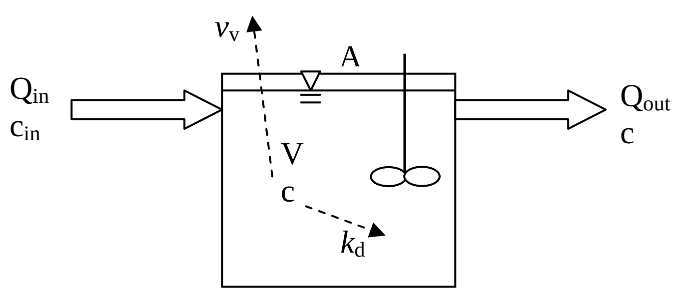


Figure E.1. Conceptual Diagram of the Simple Lake Model

Dotted arrows indicate losses from the system.

Inputs to the model include time series of inflow, inflow concentration, lake volume, lake surface area, and outflow. Rate constants required by the model include pollutant decay rate and volatilization velocity. Finally, an initial in-lake concentration of the pollutant is required for the model. The model output consists of the in-lake concentration of the pollutant.

Calculation of the mass balance is accomplished using the fourth-order Runge-Kutta method. This numerical method is an iterative approach to solving the ordinary differential equation. To employ this method, the user must supply a calculation time step (i.e. 0.1 month) over which the Runge-Kutta method will be iterated to arrive at an estimate of in-lake concentration at each reporting time step as is also specified by the user (i.e., 1 month).

Because the model simulates the lake as a CSTR, there are several limitations:

- In-lake concentration differentials (e.g., stratification due to temperature) are not taken into account.
- Temperature and pH effects are not explicitly modeled, although the specification of volatilization velocity and decay rate allows the user some control over these effects.

For this analysis, the model is applied at a monthly time-step. Application of the model at a larger time-step (1 month as opposed to 1 day) eliminates the need to represent some of the more detailed lake processes that are not included in this model.

E.1 Wyaconda Lake Model

The Wyaconda Lake model was run for the period April 1994 through March 2008 (168 months). In-lake atrazine concentrations are available beginning in 1996 and simulated watershed flows are available for the entire period. The calculation time step is 0.2 months, and results are reported as average monthly concentrations. Hydrologic inputs (inflow, lake volume and outflow) are detailed in Appendix C of this document.

The Wyaconda Lake model was used to conduct inverse modeling for atrazine loads from the watershed into the lake. Monthly atrazine loads were estimated and added to the model. The CSTR mass balance equation utilized a decay rate of 0.083 per month. This can be interpreted as 8.3% of the atrazine in the lake is lost each month. This is a slow loss rate that is consistent with the research on atrazine and model calibration showed that this rate provided a good fit to the observed data. Research has shown that atrazine has a typical half life of 60 days in the topsoil and much longer in groundwater because it is stable and only slightly soluble in water (Devlin et. al. 2000; Christensen, 1998). A first order decay rate of 0.083 is equivalent to a half life of approximately nine months. Predicted in-lake concentrations using these loads were compared to measured monthly atrazine data. Once the model results matched the measured atrazine data well, the loads were considered representative of historical conditions. Table E.1 includes the estimated inflow concentration and predicted in-lake concentration for the historical simulation performed.

Table E.1. Estimated Monthly Atrazine Inflow Concentrations and Predicted In-Lake Concentrations

Month	Inflow Conc. (µg/L)	In-lake Conc. (µg/L)	Month	Inflow Conc. (µg/L)	In-lake Conc. (µg/L)	Month	Inflow Conc. (µg/L)	In-lake Conc. (µg/L)
1	2.0	2.3	45	0.0	1.8	89	3.0	2.4
2	2.0	2.2	46	0.0	1.3	90	0.0	1.8
3	2.0	2.2	47	3.0	3.9	91	5.0	1.6
4	2.0	2.0	48	1.5	4.7	92	2.0	1.3
5	2.0	1.9	49	2.0	4.0	93	1.1	1.2
6	2.0	1.8	50	0.0	4.0	94	1.2	3.7
7	2.0	1.7	51	9.0	3.4	95	0.7	5.2
8	2.0	1.6	52	0.0	2.0	96	1.0	4.5
9	2.0	1.6	53	0.0	1.6	97	1.0	3.3
10	2.0	1.6	54	7.0	1.1	98	1.0	2.9
11	2.0	1.6	55	2.0	0.7	99	7.0	2.6
12	2.0	1.5	56	2.0	0.7	100	10.0	2.3
13	2.0	1.6	57	0.8	0.9	101	0.0	2.1
14	2.0	1.8	58	0.7	0.9	102	0.0	2.2
15	2.0	1.8	59	0.5	1.0	103	8.0	2.1
16	2.0	1.7	60	1.0	0.9	104	4.0	2.1
17	2.0	1.7	61	1.4	0.8	105	3.0	2.0
18	2.0	1.7	62	0.8	0.7	106	4.0	1.5
19	2.0	1.6	63	2.0	0.7	107	2.5	1.5
20	2.0	1.6	64	0.8	0.6	108	2.0	1.5
21	2.0	1.5	65	0.8	0.6	109	2.0	1.0
22	2.0	1.4	66	0.5	0.5	110	1.9	0.9
23	2.0	1.5	67	0.9	0.5	111	1.0	0.9
24	2.0	1.6	68	1.0	0.5	112	2.0	0.7
25	2.0	1.6	69	0.4	0.5	113	1.0	0.6
26	2.0	1.9	70	0.7	0.4	114	0.5	0.6
27	3.0	2.3	71	0.8	0.5	115	2.0	0.6
28	5.0	3.1	72	0.6	0.6	116	0.8	0.6
29	10.0	4.4	73	0.8	0.6	117	0.3	0.5
30	0.0	4.5	74	0.7	0.5	118	1.0	0.5
31	0.0	4.0	75	0.5	0.5	119	0.7	0.4
32	0.0	2.6	76	0.9	0.5	120	0.8	0.3
33	0.0	0.9	77	0.6	0.4	121	0.5	0.2
34	0.0	0.6	78	0.4	0.3	122	0.5	0.2
35	0.0	0.7	79	0.6	0.2	123	0.3	0.2
36	0.0	6.4	80	0.4	0.2	124	0.3	0.1
37	0.0	9.8	81	0.2	0.3	125	0.2	0.1
38	0.0	10.1	82	0.2	3.0	126	0.2	0.1
39	30.0	9.4	83	0.2	3.7	127	0.1	0.2
40	10.0	8.2	84	0.2	3.7	128	0.1	3.3
41	18.0	7.2	85	0.2	3.8	129	0.1	15.2
42	0.0	4.1	86	8.0	3.0	130	0.1	19.9
43	0.0	3.1	87	2.0	2.8	131	0.1	16.2
44	0.0	2.3	88	8.0	2.8	132	0.1	14.5

Month	Inflow Conc. (µg/L)	In-lake Conc. (µg/L)
133	17.0	13.4
134	80.0	11.0
135	0.0	8.8
136	0.0	8.4
137	5.0	7.6
138	10.0	6.3
139	0.0	5.4
140	0.0	4.6
141	15.0	4.0
142	2.0	3.6
143	2.0	3.3
144	4.0	2.9

Month	Inflow Conc. (µg/L)	In-lake Conc. (µg/L)
145	3.0	2.4
146	4.0	2.1
147	2.5	1.9
148	4.0	1.8
149	1.7	1.7
150	1.7	1.4
151	1.7	1.1
152	1.9	1.0
153	0.7	0.9
154	0.7	0.8
155	0.6	0.7
156	0.8	0.7

Month	Inflow Conc. (µg/L)	In-lake Conc. (µg/L)
157	1.1	0.6
158	0.8	0.6
159	0.7	0.5
160	0.9	0.5
161	0.7	0.4
162	0.7	0.3
163	0.5	0.2
164	0.5	2.3
165	0.3	2.2
166	0.2	2.2
167	0.2	2.0
168	0.2	1.9

Appendix F

Supplemental Implementation Plan

States are not required under Section 303(d) of the CWA to develop TMDL implementation plans and EPA does not approve or disapprove them. However, MDNR included an implementation plan in this TMDL to provide information regarding how point and nonpoint sources can or should be controlled to ensure implementation efforts achieve the loading reductions identified in this TMDL. EPA recognizes that technical guidance and support are critical to determining the feasibility of and achieving the goals outlined in this TMDL. Therefore, this informational plan is included to be used by local professionals, watershed managers and citizens for decision-making support and planning purposes. It should not be considered to be a part of the established Wyaconda Lake TMDL.

Point Sources

Implementation of the point source portion of a TMDL is typically performed via permit action. Effluent limits and monitoring requirements for existing permits are reevaluated to reflect the water quality targets set by the TMDL as the permits approach renewal. In the case of the Wyaconda Lake watershed, there are no point source contributors to the impairment. Therefore, implementation associated with point sources is not necessary at this time. Any future discharge permits in the watershed will be evaluated against TMDL targets prior to issuance.

Nonpoint Sources

Nonpoint sources of atrazine are not regulated in Missouri. However, with cropland comprising a significant portion of the land area in the Wyaconda Lake watershed, agricultural runoff is likely a major contributor of atrazine to the impaired water body. BMPs to reduce atrazine from entering water bodies are associated with various pesticide application practices as well as various cultural practices pertaining to runoff reduction.

According to the University of Missouri Extension, various practices associated with the application of atrazine can be implemented to reduce the likelihood of water body contamination. Such practices include maintaining an application buffer of at least 66 feet from the edge of a stream and 200 feet from the edge of a lake or reservoir, as well as maintaining a 50-foot buffer from any water body when mixing and loading atrazine. To reduce the likelihood of atrazine runoff, the University of Missouri Extension also recommends not applying atrazine when rain is in the immediate forecast or fields are saturated. Applications of atrazine should be made using only the needed amount and with care taken to reduce drift. Alternative herbicides can also be used alone or mixed with atrazine to reduce the overall amount of atrazine used. This also aids in preventing weeds from developing pesticide resistance. The use of split applications is a common BMP associated with reducing atrazine contamination, but due to the number of runoff events in Missouri, split applications may provide two periods of atrazine losses and are currently not recommended by the University of Missouri Extension pending further study (Smith, *et al*., 1999).

In addition to application procedures, the University of Missouri Extension also recommends various cultural practices that can be implemented to reduce the likelihood of water body contamination by atrazine. These practices include the use of vegetative filter strips, terraces, contour farming and grass hedges in order to slow down runoff and reduce pesticide movement from the field. Additional strategies recommended to reduce runoff of atrazine include the use of cover crops or leaving crop residue in the field (Smith, *et al.*, 1999).

In an effort to most effectively implement these voluntary BMPs, MDNR may work with the Natural Resources Conservation Service, local university extension offices and the local Soil and Water Conservation District to encourage local agricultural producers to implement these practices. An additional approach may be to work with these agencies to form a watershed group comprised of local stakeholders to promote the use of pesticide management and erosion control practices.

References

Smith, M., P. Blanchard, W. Johnson, and G. Smith, 1999. Atrazine Management and Water Quality: A Missouri Guide. Accessed 03 Nov. 2010. [Online WWW] Available URL: http://extension.missouri.edu/publications/DisplayPub.aspx?P=M167