DEVELOPMENT OF A WATER QUALITY INTERPRETATION TOOL FOR
CITIZEN MONITORS

by

Christopher M. Riggert

An Abstract
of a thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Arts
Dept. of Biology and Agriculture
University of Central Missouri

May, 2015
ABSTRACT

by

Christopher M. Riggert

Informed and educated citizens can play a crucial role in the collection and analysis of water quality data along with advocating for aquatic resources. This module was developed to allow citizen scientists to export water quality data, summarize their information, and provide a template that allowed generation of reports. These reports include an executive summary, introduction to the watershed, summary of results, analysis and discussion of individual water quality parameters, notations, acknowledgments, references, and links to online data. This module provides another tool for Missouri citizen scientists to become better advocates for water quality of streams at the local level.
DEVELOPMENT OF A WATER QUALITY INTERPRETAION TOOL FOR CITIZEN MONITORS

by

Christopher M. Riggert

A Thesis
presented in partial fulfillment
of the requirements for the degree of
Master of Arts
Dept. of Biology and Agriculture
University of Central Missouri

May, 2015
DEVELOPMENT OF A WATER QUALITY INTERPRETATION TOOL
FOR CITIZEN MONITORS

by

Christopher M. Riggert

May, 2015

APPROVED:

Thesis Chair: Dr. Stefan Cairns

Thesis Committee Member: Dr. Kurt Dean

Thesis Committee Member: Paul Calvert

ACCEPTED:

Chair, Dept. of Biology and Agriculture

UNIVERSITY OF CENTRAL MISSOURI
WARENSBURG, MISSOURI
ACKNOWLEDGMENTS

I would like to thank my Graduate Committee, Dr. Stefan Cairns, Dr. Kurt Dean, and Paul Calvert for their time, expertise, advice, guidance, and support.

I would also like to extend a very special thank you to my wife Brandye. Your words and actions inspired and motivated me to return to school. I could not have done this without your love and support. Words cannot describe how much I have appreciated everything you have done for me.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIST OF FIGURES</td>
<td>xii</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>Background on Water Quality Issues</td>
<td>1</td>
</tr>
<tr>
<td>Volunteering and Citizen Science</td>
<td>3</td>
</tr>
<tr>
<td>Objectives</td>
<td>13</td>
</tr>
<tr>
<td>METHODS</td>
<td>13</td>
</tr>
<tr>
<td>RESULTS/DISCUSSION</td>
<td>14</td>
</tr>
<tr>
<td>CONCLUSION</td>
<td>43</td>
</tr>
<tr>
<td>LITERATURE CITED</td>
<td>45</td>
</tr>
<tr>
<td>APPENDICES</td>
<td></td>
</tr>
<tr>
<td>A. Example of the watershed report</td>
<td>57</td>
</tr>
<tr>
<td>B. Biological monitoring information for water quality report</td>
<td>73</td>
</tr>
<tr>
<td>C. Water temperature information for water quality report</td>
<td>75</td>
</tr>
<tr>
<td>D. Dissolved oxygen information for water quality report</td>
<td>77</td>
</tr>
<tr>
<td>E. DO saturation for water quality report</td>
<td>83</td>
</tr>
<tr>
<td>F. pH information for water quality report</td>
<td>85</td>
</tr>
<tr>
<td>G. Turbidity information for water quality report</td>
<td>87</td>
</tr>
<tr>
<td>H. Conductivity information for water quality report</td>
<td>89</td>
</tr>
<tr>
<td>I. Chloride information for water quality report</td>
<td>91</td>
</tr>
<tr>
<td>J. Nitrogen information for water quality report</td>
<td>93</td>
</tr>
</tbody>
</table>
K. Ammonia information for water quality report..........................97
L. Orthophosphate information for water quality report ......................99
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Stream Team Database Login Screen.</td>
<td>15</td>
</tr>
<tr>
<td>2. Stream Team VWQM Data Query Page.</td>
<td>16</td>
</tr>
<tr>
<td>3. Example Input Query for Site Biological Data.</td>
<td>17</td>
</tr>
<tr>
<td>4. Example Output for Site Biological Data.</td>
<td>18</td>
</tr>
<tr>
<td>5. Example Graph of Site Biological Data.</td>
<td>18</td>
</tr>
<tr>
<td>6. Example Input Query for Site Chemical Data.</td>
<td>19</td>
</tr>
<tr>
<td>7. Example Output for Site Water Chemistry Data.</td>
<td>20</td>
</tr>
<tr>
<td>8. Example Summary Statistics for Site Chemical Data.</td>
<td>20</td>
</tr>
<tr>
<td>9. Example Graph of Site Water Temperature Data.</td>
<td>21</td>
</tr>
<tr>
<td>10. Example Graph of Site Dissolved Oxygen Data.</td>
<td>21</td>
</tr>
<tr>
<td>11. Example Graph of Site Dissolved Oxygen Saturation Data.</td>
<td>22</td>
</tr>
<tr>
<td>12. Example Graph of Site pH Data.</td>
<td>22</td>
</tr>
<tr>
<td>13. Example Graph of Site Conductivity Data.</td>
<td>23</td>
</tr>
<tr>
<td>14. Example Graph of Site Turbidity Data.</td>
<td>23</td>
</tr>
<tr>
<td>15. Example Graph of Site Nitrate as Nitrogen Data.</td>
<td>24</td>
</tr>
<tr>
<td>16. Example Graph of Site Ammonia as Nitrogen Data.</td>
<td>24</td>
</tr>
<tr>
<td>17. Example Graph of Site Orthophosphate Data.</td>
<td>25</td>
</tr>
<tr>
<td>18. Example Graph of Site Chloride Data.</td>
<td>25</td>
</tr>
<tr>
<td>19. Example Input Query for Stream Biological Data.</td>
<td>26</td>
</tr>
<tr>
<td>20. Example Input Query for Stream Water Chemistry Data.</td>
<td>27</td>
</tr>
</tbody>
</table>
21. Example Output for Stream Biological Data ................................................................. 27
22. Example Output for Stream Water Chemistry Data ...................................................... 28
23. Example Summary Statistics for Stream Water Chemistry Data .................................... 29
24. Example Graph of Stream Biological Data ................................................................. 30
25. Example Graph of Site Water Temperature Data .......................................................... 30
26. Example Graph of Site Dissolved Oxygen Data ............................................................ 31
27. Example Graph of Site Dissolved Oxygen Saturation Data ........................................... 31
28. Example Graph of Site pH Data ...................................................................................... 32
29. Example Graph of Site Conductivity Data ...................................................................... 32
30. Example Graph of Site Turbidity Data ......................................................................... 33
31. Example Graph of Site Nitrate as Nitrogen Data ............................................................ 33
32. Example Graph of Site Ammonia as Nitrogen Data ......................................................... 34
33. Example Graph of Site Orthophosphate Data ................................................................. 34
34. Example Graph of Site Chloride Data ............................................................................ 35
35. Example Input Query for Watershed Biological Data ...................................................... 36
36. Example Input Query for Watershed Water Chemistry Data .......................................... 36
37. Example Output for Watershed Biological Data ............................................................. 37
38. Example Output for Watershed Water Chemistry Data .................................................. 38
39. Example Summary Statistics for Watershed Water Chemistry Data .............................. 39
This thesis is written in the style required by the American Fisheries Society’s journal *Fisheries*. 
Introduction

Background on Water Quality Issues

Mankind’s changes in land use have had a substantial impact on our stream resources leading to the passage and revisions to the Clean Water Act which requires States to classify, set numeric criteria and assess waters of their respective States (CWA 2002; MDNR 2014b). Each State must then report on the status of these classified waterways to the United States Environmental Protection Agency (EPA) biannually in a 303(d), 305(b), and 314 Integrated Reporting and Listing Document. The monitoring of our nation’s waters is essential for understanding the conditions of our water resources and provides a foundation for the development of effective environmental policies and promotes wise management and use of these aquatic resources.

The EPA conducted a statistically valid nationwide assessment of the biological condition at 1,392 randomly selected sites in 2004 (EPA 2006). This assessment was designed to provide a national and regional look at stream quality, assist States in developing the capacity for their own monitoring and assessment, and to encourage various jurisdictions collaborate across political boundaries when assessing water quality. The results of this assessment determined 42% of our nation’s streams were in poor biological condition, 25% were in fair biological condition, and 28% were in good biological condition with the main stressors being increased nutrients, excess streambed sediments, and disturbance of the riparian corridors (EPA 2006). The 2004 EPA Wadeable Streams Assessment was repeated in 2008-2009 and also included the large rivers (EPA 2013b). The resulting National Rivers and Streams Assessment 2008-2009
reported 55% of the nation’s streams and rivers were in poor biological condition, 23% were in fair biological condition, and 21% supported healthy biological communities (EPA 2013b).

These declines in our streams’ and rivers’ ability to support healthy biological conditions are reflected in the composite information from individual States. According to the 2004 *Integrated Reporting and Listing Document*, nearly 50% of rivers and streams in the United States do not meet designated use requirements as defined by the Clean Water Act (EPA 2004). The Missouri Department of Natural Resources (MDNR) reported in 2012 that approximately 5,441 stream miles (22.3% of classified streams) did not support at least one specified designated use. Only 324 of these stream miles are impaired due to permitted point source discharges. The remaining impairments are attributed to nonpoint sources such as agriculture as well as urban runoff and construction with major nonpoint source contaminants being bacteria, metals, excess nutrients, chlorides, pH, sediment, temperature, ammonia, and pesticides (MDNR 2012).

Regulating nonpoint sources of pollution is complex because the contaminants are from diffuse areas and can be numerous. However, one potentially effective method for reducing nonpoint source contaminant inputs is by adopting laws that protect streams during development and other land use activities. Examples of possible protection practices include: land use planning, land conservation, aquatic buffers, better site design, erosion and sediment control, stormwater treatment practices, non-stormwater discharges, and watershed stewardship programs (Center for Watershed Protection 2013).
Volunteering and Citizen Science

Passing these environmental regulations is quite challenging, but can be accomplished with the involvement and influence of local stakeholders. Creating this influence is most effective when done at the local level by local citizens (EPA 2002). Overdevest et al. (2004) found that political participation, personal networks, and feelings of community connectedness among volunteers increases with participation in citizen science. There are several documented cases of communities utilizing citizens in community boards (Gurwitt 1992), citizen surveys (Watson et al. 1991), and citizen panels (Kathlene and Martin 1991) to address local issues.

Individuals participating in these political processes are generally unpaid volunteers advocating for a cause in which they believe. Dr. Ivan Scheier defined volunteering as 1) the activity is relatively uncoerced, 2) the activity is intended to help, 3) the activity is done without primary or immediate thought of financial gain, and 4) the activity is work, not play (McCurley and Lynch 1996). Volunteering one’s time is an important aspect for many Americans. According to the United States Bureau of Labor and Statistics (BLS), nearly 63 million Americans, or just over 25% of the population, participated in volunteer activities in 2013 (BLS 2015). The Corporation for National and Community Service (CNCS), over 1.5 million Missouri citizens, or 31.6%, volunteered during that same time period (CNCS 2015).

While a large amount of data exist on number of volunteers, breakdown on who volunteers (gender, age, race, marital status, education, employment, etc.) and activities in which individuals volunteer their time (fundraising, mentoring/teaching/tutoring,
collection of food/clothing, general labor, coaching, refereeing, protective services, environmental), there is a lack of robust data as to what motivates individuals to volunteer. Hauser et al. (2012) outlined three general factors for why individuals volunteer: cognitive, demographic, and social. Cognitive factors include altruistic or egoistic values one may have, the desire to interact with others, wanting something to occupy one’s time, a desire to feel useful, or a societal obligation. Demographic motivations deal with gender, marital status, level of income, education, and employment. The social factor deals with an individual’s ability to develop one’s own self-identity. In general, there appears to be a large social aspect or context to why individuals volunteer. These can include the desire to meet people by connecting with a larger group with similar interests to gain insight on particular topics, to gain insight on a particular group/organization, to give back by using and existing skill set or to learn new skills and talents (Wittich 2000). The individual’s personal perceptions of the benefits of the volunteer activity may also influence their willingness to participate including educational, environmental, recreational, and/or social benefits (Weston et al. 2006; Thomsen 2008; Clayton and Myers 2009).

One volunteer activity growing in popularity is citizen science. Cooper et al. (2007) define citizen science as a method of integrating public outreach and scientific data collection locally, regionally, and across large geographic scales and has the potential to contribute greatly by assisting in the collection and sharing of data (Crall et al. 2010). These activities engage non-professionals (“amateurs”) and professional scientists in scientific investigations (Miller-Rushing et al. 2012) and typically engage
volunteers in the collection of environmental data (Kim et al. 2011). This approach fulfills two broad goals: engaging and educating the public about scientific issues and collecting data that would otherwise be difficult or impossible to obtain and provides substantial benefits to both professional and non-professional participants (Krasny and Bonney 2004; Liarakou et al. 2011; Johnson et al. 2014).

Note that the term “amateur” does not necessarily reflect the non-professional’s level of expertise, indeed, many are recognized as experts in their field and have the ability to collect data and conduct research comparable to professionals (Engel and Voshell 2002; Brandon et al. 2003; Cohn 2008; Miller-Rushing et al. 2012). History provides many examples of “amateurs” that made substantial contributions to science: Chinese citizens have been chronicling the outbreak of locusts for 3500 years (Tian et al. 2011); Japanese court diarists have been recording the dates of the traditional cherry blossom festival for 1200 years (Primack et al. 2009); and French vintners have been documenting the grape harvest days for 650 years (Chuine et al. 2004). In addition to being accomplished scientists and naturalists, many made their living in some other profession including: Charles Darwin (unpaid companion on The Beagle); Benjamin Franklin (printer, diplomat, and politician); Thomas Jefferson (politician and diplomat); as well as Meriwether Lewis and William Clark (soldiers, explorers, and public administrators) (Silvertown 2009; Vetter 2011; Miller-Rushing et al. 2012).

Professional scientists have been utilizing the information collected by amateurs for scientific advancement for hundreds of years. Johan Ernst Gunnerus, an 18th Century Norwegian bishop, created a network of clergymen to submit their observations and
collections of natural objects across Norway to contribute to his research that was consistent with King Frederik V’s policies to lift science and culture to a high European level (Brenna 2011). Many of the specimens and observations Carl Linnaeus utilized to lay the foundation binomial nomenclature, taxonomy, and modern ecology were collected by nonprofessional scientists across the world (Miller-Rushing et al. 2012). However, over the past 150 years the scientific culture has changed resulting in a shift in roles, elevating professional scientists while marginalizing amateurs (Vetter 2011). Interestingly, professional scientists, continued to see the need for using volunteers to collect data from across large geographic areas. The earliest records of amateur naturalists have been providing information to the scientific community in the United States includes the National Weather Service receiving rainfall and temperature data from citizens across large geographic areas and phenological records from farmers and agricultural organizations (Hopkins 1918; Firehock and West 1995). Firehock and West (1995) document other examples including the start of the Audubon Society’s Christmas Bird Count in 1900 and formation of the Izaak Walton League in 1922 (Firehock and West 1995). The past 40 years have slowly brought a shift from the culture of marginalizing amateurs back to the involvement of nonprofessionals in scientific endeavors. State governments began utilizing citizens to collect water quality monitoring data for water chemistry in the late 1960s and biological monitoring using benthic macroinvertebrates in 1976 (Firehock and West 1995).

The utilization of citizen scientists experienced rapid growth after the 1970s with regards to the number of people involved, the number of programs established, and its
relevancy to policy and regulatory decision making (Moore 2006; Lave 2012). Kerr et al. (1994) noted that the involvement in citizen science nearly tripled between 1988 and 1992, with the number of new groups growing to an estimated 500,000 with varying environmental and social contexts (Pretty 2003). Today, citizen scientists participate in projects examining various aspects of environmental quality including climate change, invasive species, conservation biology, ecological restoration, population ecology, and water quality monitoring (“Citizen Science Central” 2014). This substantial increase in participation has been attributed to an increased awareness of human activities and their effects on the declines in ecosystem function and services (Whitelaw et al. 2003; Conrad 2006; Conrad and Daust 2008), as well as the growing concern by nongovernment organizations for cutbacks in funding and personnel within the government agencies responsible for conducting ecological monitoring (Pollock and Whitelaw 2005).

There are also benefits to the government agencies required to collect monitoring data and ultimately benefits to ecosystem function and services. Volunteer water monitoring has a long tradition as a citizen science endeavor and States have been increasingly seeing the utility of citizen scientists (Firehock and West 1995). Data are needed on streams impaired by nonpoint sources of pollution, yet reduced budgets have led to the need for creative coverage for monitoring these areas (Firehock and West 1995). Increased improvement and availability of training has resulted in higher quality data, and recognizing the increased value in working with citizens for gaining support for government programs that include environmental controls (Firehock and West 1995). Data from this type of programming engages laypersons in monitoring local waterways
and has been used to inform communities of impaired waters (Da Silva Pinho 2000; Karney 2000). Volunteer-generated data have also been used to aid in development, modification and enforcement of natural resource policies and regulations (Stepenuck 2013), and to help obtain protected status for waterbodies (Deutsch et al. 2007; MDNR 2014a). Often, volunteers collect data where there has been little or no other monitoring conducted, thus their results have the potential to provide localized and relevant information to communities. Benefits of citizen science include increases in environmental democracy, science literacy, social capital, and inclusion of citizens in local issues (Conrad and Hilchey 2011).

Monitoring by citizen scientists is an important tool for assessing changes in a desired condition, providing measurements of effectiveness of management actions, and detecting disturbances (Legg and Nagy 2006). Conrad and Hilchey (2011) describe two types of monitoring: commodity based and non-commodity based. Commodity based monitoring focuses on issues of economic importance and can include monitoring fisheries (Sultana and Abeyasekera 2008) or forestry activities (Nagendra et al. 2005). While this type of monitoring is important, there has been an increase in the prevalence of non-commodity based monitoring in North America which deals more with measuring aspects of environmental quality (Lawrence 2006) and may not have direct economic importance. These types of projects may include monitoring for things such as water quality (Mullen and Allison 1999) or indicator species such as benthic macroinvertebrates (Jones et al. 2006).
Participation in citizen science enhances public stewardship of our natural resources and creates an atmosphere of cooperation between volunteers and government agencies. These projects are structured in three general ways: contributory/consultative/functional; collaborative; and co-created/transformative (Bonney et al. 2009; Conrad and Hilchey 2011). The contributory or consultative projects can be viewed as “top-down” kind approach where the project design is done by the scientist, citizens are utilized to collect/submit the information, and any data analysis of these observations are done by the scientist. However, there has recently been a shift in the scientific culture from utilizing citizens as simply data collectors to being actively involved in scientific projects (Lakshminarayanan 2007). This has led to collaborative projects where citizens not only contribute data, but also assist with refining the project design, may analyze the data, and help to disseminate the findings. These collaborative projects tend to be based in non-political areas such as watersheds (Conrad and Hilchey 2011). Increasingly, however, co-created/transformative projects are being developed where the citizens are involved in most or all of the steps or the project may be wholly conceived and implemented by the citizens and are often focused on local issues.

Volunteers rarely participate in citizen science for the sake of collecting data (EPA 2013c). Most wish to know their data are being used and that they are making a difference. Specifically, volunteers aim to: produce data with enough credibility to engage with bureaucracy; collect data that is appealing enough to mobilize the community; and collect data with enough interest to maintain personal interest and motivation (Corburn 2005).
For years, the goal of volunteer monitoring programs has been the acceptance and use of data collected by trained citizens for regulatory purposes. Despite studies showing that many of the skills needed to conduct scientific research can be obtained by novices when proper training is available (Mumby et al. 1995, Darwall and Dulvy 1996, Bonney 2001, Bailenson et al. 2002, Barrett et al. 2002, Brandon et al. 2003, Janzen 2004, Cohn 2008), utilization of citizen data has met with substantial resistance due to the stigma of “Volunteer Data.” Despite this stigma, the number of volunteer water quality monitoring programs has more than doubled in the last 15 years (Kerr et al. 1994; EPA 2013a) and allowed water quality data traditionally collected by professional staff to be increasingly augmented by data collected by volunteers (Loperfido et al. 2010).

One example of citizen science is the Missouri Stream Team Program, a state-wide stream stewardship program sponsored by the Conservation Federation of Missouri, and Departments of Conservation and Natural Resources. The Missouri Stream Team Program was established in 1989 with three goals of Education, Stewardship and Advocacy to promote citizen awareness and involvement on stream and watershed issues. The Program offers a variety of activities in which Missouri citizens can participate. These activities include, but are not limited to litter pickups, planting trees, stenciling storm drains, and conducting educational field trips.

The only activity requiring training is Volunteer Water Quality Monitoring (VWQM). This portion of the Program is a state-wide multi-tiered ambient stream monitoring program and was developed to inform Missourians about the condition of Missouri’s stream resources, educate citizen groups interested in improving water quality
and establish a group of trained volunteers to provide baseline water quality monitoring data. The VWQM portion of the Program utilizes citizen science as a means to educate and involve the community in collecting more information on the health of Missouri’s stream resources. The multiple tiers of training offer the flexibility for volunteers to participate, while providing the sponsoring Agencies with increasingly higher quality data. There are currently four levels of training available, each building on the previous.

- **The Introductory Level Workshop** is the entry level of training in which the citizens to choose and identify a monitoring location, map a watershed, calculate stream discharge, utilize the stream benthic macroinvertebrate community to determine stream health, as well as learning about safety and trespass issues.

- **The Level 1 Workshop** covers water chemistry, how to conduct a visual survey of the area immediately surrounding their monitoring location, and a review of benthic macroinvertebrate identification.

- **The Level 2 Workshop** is the first of two Quality Assurance/Quality Control trainings where the volunteer methods and equipment are tested against known standards and must fall within specified acceptability limits.

- **Finally, the Level 3 Audit** is an “on-site” QA/QC audit by Program Staff at the Volunteer’s site.

Over a 20-year period, the quantity of data submitted by the VWQM Program is staggering with over 9,000 trained volunteers providing over 35,000 data submissions (Missouri Stream Team Database 2015). Data collected by individuals that have attended
these trainings are used to establish baseline water quality information, inform and educate people about the condition of Missouri streams, identify long-term trends and document changes over time, and to locate potential and existing water quality problems as well as alert state agencies of areas that may require more extensive monitoring efforts. Level 2 and 3 data are used to supplement Agency collected data and included MDNR’s bi-annual *Integrated Reporting and Listing Document* to EPA.

These data are also used in many ways by local governments, state agencies, drinking water and wastewater operators, grant-seekers, and others. However, this process often does not directly involve the volunteers and does not result in reports or presentations that are accessible to the public. While these data are being utilized, one of the few complaints from Stream Team members involved in this activity is that they collect data but never know if they are being used (personal observation). Staff limitations make it challenging to compile and disseminate such a report on a statewide or even watershed level (personal observation). There are 4.5 full time employees (FTEs) responsible for administering the VWQM portion of the Missouri Stream Team Program (MDC = 1.75 FTEs, DNR = 2.75 FTEs). Additionally, working for a state agency precludes staff from being direct advocates for stream health, providing an opportunity for the citizen scientists.

**Objectives**

My goal is to improve watershed health by reducing stream degradation from nonpoint source pollution through two objectives:
Objective 1) increase participation and retention of trained Stream Team Volunteer Monitors through the development of an online module where citizen scientists can retrieve, summarize, and use the water quality monitoring data they collect.

Objective 2) increase advocacy on stream issues at the local level through the presentation of this water quality report to their city council, county commission, or other decision making authority to demonstrate the effects that landscape disturbances can have on their local stream resources. This module would provide a roadmap for individuals to interpret and present the data they have collected in an effective manner.

I expect this module to provide a tool for Stream Team Volunteer Monitors allowing them to be more effective advocates for the streams they assess. This will also allow these individuals to take an increased ownership of their data, and the streams in which they assess, increasing volunteer retention.

Methods

The module was developed utilizing Microsoft Access, Excel, and Word. Data were extracted from the Missouri Stream Team Online Database and saved as Microsoft Excel spreadsheets. These were then imported into Microsoft Access for further querying and manipulation then exported as Excel spreadsheets. The data within these spreadsheets were then summarized in both tabular and graphical format and saved as Excel, Word, and .PDF formats. Example web pages were created using Microsoft Word to mimic the look and functionality of the existing Missouri Stream Team Database query functions with hyperlinks created to the appropriate files. Input pages were created to demonstrate
the functionality of extracting either biological or chemical data at the site, stream, or watershed levels.

Export files were then created and linked for the raw data resulting from these queries, summary statistics in tabular form, and graphs for each parameter measured. Each of these was saved as Excel, Word, and .PDF formats for maximum flexibility by the citizen monitor to summarize and export these data for insertion into a presentation or water quality report.

Finally, a template water quality report was generated in Microsoft Word. This template contains numerous sections including an executive summary, introduction to the watershed, methods used, summary of the results, analysis and discussion of individual water quality parameters, notations of complications experienced by the volunteer monitors, acknowledgments, references, and links to data available online. Links to appropriate metadata are included, allowing the citizen monitor to interpret and explain their results.

This entire module will provide the template and example for an online Graphic User Interface (GUI) allowing trained citizen monitors to query water quality monitoring data available in the Missouri Stream Team online Water Quality Monitoring Database.

**Results and Discussion**

Throughout the 20+ year history of the Missouri Stream Team’s VWQM Program, much of the emphasis has been on the training and education of this State’s citizens on the condition of Missouri’s stream resources and provides baseline water
quality monitoring data to the sponsoring agencies. While, various review activities have been attempted, substantially less effort has been spent on retention of existing Volunteer Monitors.

To help facilitate decreased citizen apprehension and increased distribution of information and visibility of their volunteer effort, two links were added to the Missouri Stream Team’s VWQM Login page to launch either the Water Quality Report Module or Water Quality Monitoring Data Interpretation Tool (Figure 1).

**Figure 1.** Login screen on the Missouri Stream Team VWQM Website including the Water Quality Report Module and Water Quality Monitoring Data Interpretation Tool links.

![Login screen](image)

Clicking “Data Interpretation Tool” hyperlink takes the user to the page allowing the user to choose the water quality information they desire (Figure 2). This format provides for the querying of VWQM data in various ways, including by Stream Team and Site, County, Watershed, DNR or MDC Region, Data Type (biological or chemical monitoring), Data Level, and/or Date range. For example, if a user were to examine the
biological health of his/her site on Deer Creek at the Litzinger Road Ecology Center in St. Louis County, he/she would input their Stream Team and site number (Figure 3).

This will generate an output page summarizing the information and providing the user several options for exporting these data (Figure 4). The number of records and geographic location of these samples are provided, as well as a table of basic summary statistics is generated. The ability to export these data in multiple formats is also provided. Raw data can be exported as an Excel table for further manipulation or statistical analysis, or as Word or .PDF formats. The summary table can be exported in these same formats as well as a .JPG file. Additionally, the option to graphically summarize these data is available as well as export and insertion into a presentation document.

**Figure 2.** Query page for the VWQM Data Interpretation Tool.
Figure 3. Example input query for VWQM biological data on a specified site from the input query in the VWQM Data Interpretation Tool.

The graphical summary of these data plots the results of the numeric water quality rating generated from each sampling event as well as plotting the mean score (Figure 5). This allows the user to visually track the health of the stream at that location utilizing the benthic macroinvertebrates scores. This graph can then be inserted into a report or presentation to share these results with others.
Figure 4. Example output page of the VWQM Data Interpretation Tool providing number of data records summary statistics, and data export options for site selected.

<table>
<thead>
<tr>
<th># of Records</th>
<th>Stream</th>
<th>UTM E</th>
<th>UTM N</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>Deer Creek</td>
<td>728482</td>
<td>478155</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>WQ Rating</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>13.111</td>
</tr>
<tr>
<td>Standard Error</td>
<td>1.0724</td>
</tr>
<tr>
<td>Median</td>
<td>14</td>
</tr>
<tr>
<td>Mode</td>
<td>8</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>5.0131</td>
</tr>
<tr>
<td>Sample Variance</td>
<td>25.111</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>-1.2725</td>
</tr>
<tr>
<td>Skewness</td>
<td>-0.5057</td>
</tr>
<tr>
<td>Range</td>
<td>34</td>
</tr>
<tr>
<td>Minimum</td>
<td>5</td>
</tr>
<tr>
<td>Maximum</td>
<td>39</td>
</tr>
<tr>
<td>Sum</td>
<td>118</td>
</tr>
<tr>
<td>Count</td>
<td>9</td>
</tr>
</tbody>
</table>

Figure 5. Example graphical summary of biological data generated from the input query in the VWQM Data Interpretation Tool.
This module will also allow the user to query for water chemistry data in a manner similar to querying biological data (Figure 6). As with the Biological data, an output page is generated summarizing the information and providing several options for exporting these data (Figure 7). Each parameter has its own summary statistics table displayed (Figure 8), as well as the function to graph and export the data. In addition to plotting the values for each parameter by date, the graphs also plot the mean score, and the numeric water quality criteria (if applicable) set by MDNR (Figures 9-18). In this example, there are 104 records at this location, and the user has the option to export data in several formats.

**Figure 6.** Example input query for VWQM water chemistry data on a specified site from the input query in the VWQM Data Interpretation Tool.
**Figure 7.** Example water chemistry output page for data on a specified site from the input query in the VWQM Data Interpretation Tool.

**Figure 8.** Example summary statistics for VWQM water chemistry data on a specified site from the input query in the VWQM Data Interpretation Tool.
**Figure 9.** Example graphical summary of water temperature data from a specified site generated from the input query in the VWQM Data Interpretation Tool.

Water Temperature  
Deer Creek, St. Louis County, Missouri  
US Litzinger Rd Br, Litzinger Rd Ecology Ctr

- **Water Temp (°C)**
- **WQ Standard (32°C)**
- **Average (16.0°C)**

**Figure 10.** Example graphical summary of dissolved oxygen data from a specified site generated from the input query in the VWQM Data Interpretation Tool.

Dissolved Oxygen  
Deer Creek, St. Louis County, Missouri  
US Litzinger Rd Br, Litzinger Rd Ecology Ctr

- **DO2 (mg/L)**
- **WQ Standard (5 mg/L)**
- **Average (9.7 mg/L)**
**Figure 11.** Example graphical summary of dissolved oxygen saturation data from a specified site generated from the input query in the VWQM Data Interpretation Tool.

**Figure 12.** Example graphical summary of pH data from a specified site generated from the input query in the VWQM Data Interpretation Tool.
**Figure 13.** Example graphical summary of conductivity data from a specified site generated from the input query in the VWQM Data Interpretation Tool.

![Conductivity Graph](image)

**Figure 14.** Example graphical summary of turbidity data from a specified site generated from the input query in the VWQM Data Interpretation Tool.

![Turbidity Graph](image)
**Figure 15.** Example graphical summary of nitrate data from a specified site generated from the input query in the VWQM Data Interpretation Tool.

![Nitrate as Nitrogen](image1)

**Figure 16.** Example graphical summary of ammonia data from a specified site generated from the input query in the VWQM Data Interpretation Tool.

![Ammonia as Nitrogen](image2)
Figure 17. Example graphical summary of orthophosphate data from a specified site generated from the input query in the VWQM Data Interpretation Tool.

![Orthophosphate Graph](image17.png)

Figure 18. Example graphical summary of chloride data from a specified site generated from the input query in the VWQM Data Interpretation Tool.

![Chlorides Graph](image18.png)
The module also allows the user to query biological and water chemistry data from a specified stream (Figures 19 and 20). As with the Site piece, an output page is generated summarizing the information and providing several options for exporting these data (Figure 21 and 22). Each parameter has its own summary statistics table displayed (Figure 21 and 23), as well as the function to graph and export the data (Figures 24-33).

**Figure 19.** Example input query for VWQM biological data on a specified stream from the input query in the VWQM Data Interpretation Tool.
Figure 20. Example input query for VWQM water chemistry data on a specified stream from the input query in the VWQM Data Interpretation Tool.

Figure 21. Example biological data output page of the VWQM Data Interpretation Tool providing number of data records summary statistics, and data export options for the stream selected.
**Figure 22.** Example chemical data output page of VWQM Data Interpretation Tool providing number of data records summary statistics, and data export options for the stream selected.
**Figure 23.** Example summary statistics for VWQM water chemistry data on a specified stream from the input query in the VWQM Data Interpretation Tool.

<table>
<thead>
<tr>
<th>Water Temp (°C)</th>
<th>DO2 (mg/L)</th>
<th>DO Saturation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>Mean</td>
<td>Mean</td>
</tr>
<tr>
<td>Standard Error</td>
<td>Standard Error</td>
<td>Standard Error</td>
</tr>
<tr>
<td>Median</td>
<td>Median</td>
<td>Median</td>
</tr>
<tr>
<td>Mode</td>
<td>Mode</td>
<td>Mode</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>Standard Deviation</td>
<td>Standard Deviation</td>
</tr>
<tr>
<td>Sample Variance</td>
<td>Sample Variance</td>
<td>Sample Variance</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>Kurtosis</td>
<td>Kurtosis</td>
</tr>
<tr>
<td>Skewness</td>
<td>Skewness</td>
<td>Skewness</td>
</tr>
<tr>
<td>Range</td>
<td>Range</td>
<td>Range</td>
</tr>
<tr>
<td>Minimum</td>
<td>Minimum</td>
<td>Minimum</td>
</tr>
<tr>
<td>Maximum</td>
<td>Maximum</td>
<td>Maximum</td>
</tr>
<tr>
<td>Sum</td>
<td>Sum</td>
<td>Sum</td>
</tr>
<tr>
<td>Count</td>
<td>Count</td>
<td>Count</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>pH</th>
<th>Conductivity (µS/cm)</th>
<th>Turbidity (NTU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>Mean</td>
<td>Mean</td>
</tr>
<tr>
<td>Standard Error</td>
<td>Standard Error</td>
<td>Standard Error</td>
</tr>
<tr>
<td>Median</td>
<td>Median</td>
<td>Median</td>
</tr>
<tr>
<td>Mode</td>
<td>Mode</td>
<td>Mode</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>Standard Deviation</td>
<td>Standard Deviation</td>
</tr>
<tr>
<td>Sample Variance</td>
<td>Sample Variance</td>
<td>Sample Variance</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>Kurtosis</td>
<td>Kurtosis</td>
</tr>
<tr>
<td>Skewness</td>
<td>Skewness</td>
<td>Skewness</td>
</tr>
<tr>
<td>Range</td>
<td>Range</td>
<td>Range</td>
</tr>
<tr>
<td>Minimum</td>
<td>Minimum</td>
<td>Minimum</td>
</tr>
<tr>
<td>Maximum</td>
<td>Maximum</td>
<td>Maximum</td>
</tr>
<tr>
<td>Sum</td>
<td>Sum</td>
<td>Sum</td>
</tr>
<tr>
<td>Count</td>
<td>Count</td>
<td>Count</td>
</tr>
</tbody>
</table>

29
**Figure 24.** Example graphical summary of biological data from a specified stream generated from the input query in the VWQM Data Interpretation Tool.

![Biological Water Quality Rating](image)

**Figure 25.** Example graphical summary of water temperature data from a specified stream generated from the input query in the VWQM Data Interpretation Tool.

![Water Temperature](image)
Figure 26. Example graphical summary of dissolved oxygen data from a specified stream generated from the input query in the VWQM Data Interpretation Tool.

![Dissolved Oxygen Graph](image)

**Dissolved Oxygen**
Deer Creek, St. Louis County, Missouri

- DO2 (mg/L)
- WQ Standard (5 mg/L)
- Average (9.6 mg/L)

Figure 27. Example graphical summary of dissolved oxygen data saturation from a specified stream generated from the input query in the VWQM Data Interpretation Tool.

![Dissolved Oxygen Saturation Graph](image)

**Dissolved Oxygen Saturation**
Deer Creek, St. Louis County, Missouri

- DO Saturation (%)
- Average (94.6%)
**Figure 28.** Example graphical summary of pH data from a specified stream generated from the input query in the VWQM Data Interpretation Tool.

![pH Graph](image)

**Figure 29.** Example graphical summary of conductivity data from a specified stream generated from the input query in the VWQM Data Interpretation Tool.

![Conductivity Graph](image)
Figure 30. Example graphical summary of turbidity data from a specified stream generated from the input query in the VWQM Data Interpretation Tool.

![Turbidity Graph]

Figure 31. Example graphical summary of nitrate as nitrogen data from a specified stream generated from the input query in the VWQM Data Interpretation Tool.

![Nitrate as Nitrogen Graph]
**Figure 32.** Example graphical summary of ammonia as nitrogen data from a specified stream generated from the input query in the VWQM Data Interpretation Tool.

![Ammonia as Nitrogen](image)

**Figure 33.** Example graphical summary of orthophosphate data from a specified stream generated from the input query in the VWQM Data Interpretation Tool.

![Orthophosphate](image)
**Figure 34.** Example graphical summary of chloride data from a specified stream generated from the input query in the VWQM Data Interpretation Tool.

Finally, the Stream Team VWQM Data Interpretation Tool will allow the user to query biological and/or water chemistry data to assess the health of an entire watershed (Figures 35 and 36). Output pages are then generated providing summary descriptive statistics, and options to export the information in various file types. (Figures 37, 38, and 39). Once generated, these graphic summaries can be inserted into a Water Quality Report by clicking the “Insert Graphs into Water Quality Report” link on the export page generated. This report is in a scientific format and includes an Executive Summary, Introduction, Study Site(s), Methods, Results, Figures/Tables, Discussion, Acknowledgments, and Appendices (See Appendix A).
**Figure 35.** Example input query for VWQM biological data on a specified watershed from the input query in the VWQM Data Interpretation Tool.

**Figure 36.** Example input query for VWQM water chemistry data on a specified watershed from the input query in the VWQM Data Interpretation Tool.
Figure 37. Example biological data output page of the VWQM Data Interpretation Tool providing number of data records summary statistics, and data export options for the watershed selected.
Figure 38. Example water chemistry data output page of the VWQM Data Interpretation Tool providing number of data records summary statistics, and data export options for the watershed selected.
Figure 39. Example summary statistics for VWQM water chemistry data on a specified watershed from the input query in the VWQM Data Interpretation Tool.

<table>
<thead>
<tr>
<th>NO3-N (mg/l)</th>
<th>DO2 (mg/l)</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.664817</td>
<td>Mean</td>
</tr>
<tr>
<td>Standard Error</td>
<td>0.088461</td>
<td>Standard Error</td>
</tr>
<tr>
<td>Median</td>
<td>0.3</td>
<td>Median</td>
</tr>
<tr>
<td>Mode</td>
<td>0.1</td>
<td>Mode</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0.876732</td>
<td>Standard Deviation</td>
</tr>
<tr>
<td>Sample Variance</td>
<td>0.768659</td>
<td>Sample Variance</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>3.768971</td>
<td>Kurtosis</td>
</tr>
<tr>
<td>Skewness</td>
<td>2.111869</td>
<td>Skewness</td>
</tr>
<tr>
<td>Range</td>
<td>3.95</td>
<td>Range</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.05</td>
<td>Minimum</td>
</tr>
<tr>
<td>Maximum</td>
<td>4</td>
<td>Maximum</td>
</tr>
<tr>
<td>Count</td>
<td>164</td>
<td>Count</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Water Temp (°C)</th>
<th>DO Saturation (%)</th>
<th>Conductivity (µS/cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>14.78947</td>
<td>Mean</td>
</tr>
<tr>
<td>Standard Error</td>
<td>0.790187</td>
<td>Standard Error</td>
</tr>
<tr>
<td>Median</td>
<td>15</td>
<td>Median</td>
</tr>
<tr>
<td>Mode</td>
<td>8</td>
<td>Mode</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>9.156136</td>
<td>Standard Deviation</td>
</tr>
<tr>
<td>Sample Variance</td>
<td>83.83483</td>
<td>Sample Variance</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>-1.24599</td>
<td>Kurtosis</td>
</tr>
<tr>
<td>Skewness</td>
<td>0.075792</td>
<td>Skewness</td>
</tr>
<tr>
<td>Range</td>
<td>32</td>
<td>Range</td>
</tr>
<tr>
<td>Minimum</td>
<td>0</td>
<td>Minimum</td>
</tr>
<tr>
<td>Maximum</td>
<td>32</td>
<td>Maximum</td>
</tr>
<tr>
<td>Count</td>
<td>171</td>
<td>Count</td>
</tr>
</tbody>
</table>

According to the Volunteering and Civic Life in America Website (2013), the national average for volunteer retention was nearly 62% between 2009 and 2011. The Missouri Stream Team program has a relatively high retention rate for volunteers, equating to approximately 85% (Missouri Stream Team 2013). However, the retention rate for those volunteers trained to collect water quality monitoring data is closer to 5% (Missouri Stream Team Database 2015). Providing additional education and support to volunteers on how to advocate using the data they collect and interpret will cultivate ownership of the data, and should result in a higher retention rate of trained volunteers.
Teams that do take ownership in “their” stream/watershed compare their information and experiences with other Teams to discuss issues, challenges and successes (personal observation). There is also a fierce sense of pride associated with their watershed and it is not unexpected for an undercurrent of competition to develop with stream and watershed quality (personal observation).

Studies have shown an important component of citizen science is that participating individuals distribute and share the information they gain, increasing the visibility of issues being examined (Couvet et al. 2008). Advocacy is one important method citizens can increase this visibility and influence the direction of public policy (Griffin and Newman 2005). Other benefits include realistic policies grounded in public preferences, the public being potentially more sympathetic of the “tough decisions,” and improved public support (Irvin and Stansbury 2004). To be effective advocates, individuals must be able to make informed decisions regarding scientific issues that affect their personal lives and the well-being of their communities (Brossard et al. 2005). Active citizen involvement can result in a more democratic and effective government, including improved government function, decision legitimacy, citizen receptiveness, and public trust (Berman 1997; King et al. 1998; Walters et al. 2000). The level of political engagement at which a citizen becomes involved can be linked to the policy directions their government is pursuing (Hill and Leighley 1992; Verba et al. 1995; Flavin and Griffin 2009).

It is important to remember many individuals that participate in citizen science are involved with activities in which they do not have background or formal education. This
is also true of the Stream Team’s volunteer monitors and can lead to a lack of confidence in one’s data because of perceived deficiencies in one’s own abilities. However, it is has been shown that volunteers can produce high level data with proper training (Cohn 2008; Engel and Voshell 2002). Missouri Stream Team volunteer monitors are instructed to sample benthic macroinvertebrates and conduct a visual survey two times a year (once with the leaves off and once with the leaves on), water chemistry quarterly, and stream discharge every time they monitor. Those individuals that monitor on a regular basis are more confident in how to conduct the procedures (personal observation). It is to be expected that to then take these data a step further to analyze and present may foster additional emotional or social hurdles preventing these individuals from believing they can be effective stream/watershed advocates.

At its core, citizen science empowers individuals to participate in scientific endeavors of interest to them, and some individuals may wish to take part in projects that provide them a degree of decision-making influence (Rowe and Frewer 2000). Volunteer monitoring programs can have positive effects in communities by influencing this political capacity (Overdevest et al. 2004; Couvet et al. 2008; McKenzie et al. 2014). Educated and organized grassroots efforts can significantly influence political whims, and is most effective when working locally. Citizens advocating at the local level increases the likelihood regulations being passed that will protect Missouri streams.

Interest has increased in recent years in making decisions regarding natural resource management and human health (Rowe and Frewer 2000). As such, an emphasis of citizen science programs has been to enable citizens to utilize their data to advocate on
behalf of resources at the local level. Part of this includes the proper presentation of information and data. The ability to summarize and display their data graphically as well as the generation of a report of these data at either the site, stream, or watershed level will provide a tool for individuals to speak on behalf of the aquatic resource.

Conclusion

Citizen science endeavors such as the Missouri Stream Team’s VWQM Program are filled with individuals that are passionate about the topic, eager to learn more, and want to provide high quality data. There are many uses for these data, and with proper training and practice, can be on par with data collected by professional scientists. Use of these data may be used across large geographic or political areas (e.g. states); however, feedback to those involved in the data collection can be slow and tedious and can discourage further participation. The use of these data to educate and advocate in the areas from which they are collected will be most productive and valuable benefit of this information. Water quality problems often have local causes and should be addressed at the community level. The distribution of this information by those that collect it, in areas where they have the most value will have the greatest effect potentially resulting in the passage of regulations requiring BMPs that will help to reduce nonpoint sources of pollution. Ideally, the sharing of this information will help change the mindsets of land users to change how they use these resources voluntarily.

Data management should consider the end user and use, particularly for citizen science projects. Such data stewardship will help citizen science data to reach its
potential. Additionally, it should not be forgotten that those participating in citizen science may not have background in sciences, data analysis, or technical writing. The process of compiling, analyzing, summarizing, synthesizing and presenting the information can present a daunting task.

The goal of developing this Water Quality Tool was to improve watershed health through two objectives. Objective one was to increase participation and retention of trained Stream Team Volunteer Monitors. The development of this Water Quality Report Tool bridges the potential gap in scientific background by providing a template to better understand and interpret their water quality monitoring data, as well as share the results. It will allow for these citizen scientists to compare and in some places fuel the friendly competition between who has the “better” watershed. By doing so, the first objective will be fulfilled as the individual will become more invested in the resource and takes ownership in the project, keeping him/her engaged active and involved in monitoring.

Objective two was to increase advocacy on stream issues at the local level. The use of this Tool by volunteers fulfills the second objective by providing an avenue for individuals to more comfortably advocate for the stream and watershed resource in which they live, work, and play. Advocating for “their” stream and/or “their” watershed will also help fulfill the first objective as the individual will be even more invested. Summary and analysis of data provide a context for a more formal report to be generated providing background information which can be made available and serve as the basis for presentations by volunteers to the appropriate civic leaders, or other community groups who influence decision-making for implementation of regulations (e.g. riparian buffers,
low impact development, and storm water management) that would have beneficial environmental effects by reducing stream degradation from nonpoint source pollution.


Conrad, C. 2006. Towards meaningful community-based ecological monitoring in Nova Scotia: Where we are versus were we would like to be. *Environments* 34:25-36.


MDNR. 2012. Missouri Water Quality Report (Section 305(b) Report). Water Protection Program, P.O. Box 176, Jefferson City, Missouri 65102.

MDNR. 2014a. Levels of Volunteer Water Quality Monitoring Data Use. Missouri Department of Natural Resources, Division of Environmental Quality, Environmental Services Program, Water Quality Monitoring Section, Jefferson City, Missouri.


Stepenuck, K. 2013. Improving understanding of outcomes and credibility of volunteer environmental monitoring programs. Doctoral dissertation, University of Wisconsin, Madison, WI.


APPENDIX A
EXAMPLE OF THE WATERSHED REPORT

A Water Quality Report for

[INSERT NAME OF STREAM AND/OR WATERSHED],

[INSERT LOCATION INFORMATION] County, Missouri
**Table of Contents**

Executive Summary ............................................................................................................. 2
Introduction ......................................................................................................................... 3
Methods ............................................................................................................................... 4
Results ................................................................................................................................. 5
Discussion ............................................................................................................................ 6
Acknowledgements .............................................................................................................. 7
Executive Summary:

In this section, you should summarize your findings based on the information you collected. This may include the location of the data collection, time range of data collection, interpretation of results, and potential recommendations based on these data.
Introduction:

In this section, you should introduce the topic, indicate why it was written, for whom, and for what purpose, you should include pertinent background information, an explanation of the issue, and overall goal for your sampling.


**Study Site(s):**

*This section should include a detailed description of the monitoring location(s). This includes not only a verbal description, but details of the surrounding area that may impact the water quality of the site(s). The information gathered from the Visual Survey could provide useful information in this section. Additionally, maps of the area and the sampling location(s) would help to provide context. Maps and watershed information can be found at [www.cares.missouri.edu](http://www.cares.missouri.edu).*
Methods:

In this section, you should describe how the water quality data were collected. This includes when the samples were taken, what equipment was utilized, and the procedures used. It may be helpful to break things up into sections if you are including both biological and chemical monitoring data.
Results:

In this section, you report the data collected summarized in tables and figures. These data should be referenced and included within this section. It may be helpful to break things into sections if you are including both biological and chemical monitoring data. You want to follow the same order listed in the Methods section.

- Click here to access SITE data stored in the Missouri Stream Team Water Quality Database.
- Click here to access STREAM data stored in the Missouri Stream Team Water Quality Database.
- Click here to access WATERSHED data stored in the Missouri Stream Team Water Quality Database.

It is important to remember that data over a longer period of time provide a more representative picture of what is occurring and allows for a more accurate interpretation of these data. In general, a minimum of five results for each chemical parameter and three results for macroinvertebrate scores over at least a three year time period are needed to observer potential trends.

Also it is important to look at the standard deviation (a measure of how spread out the numbers are) to determine how much importance one should put in the means.
Figures/Tables:

You should insert any maps, photographs, graphs, and/or tables in this section.
**pH**
Deer Creek Watershed
St Louis County, Missouri

![pH Graph](image)

- **pH**
- **WQ Standard (9.0)**
- **WQ Standard (6.5)**
- **Average (8.1)**

**Conductivity**
Deer Creek
St Louis County, Missouri

![Conductivity Graph](image)

- **Conductivity (µS/cm)**
- **Average (917.4 µS/cm)**
Turbidity
Deer Creek Watershed
St Louis County, Missouri

Nitrate Values
Deer Creek Watershed
St Louis County, Missouri
Ammonia
Deer Creek Watershed
St Louis County, Missouri

Orthophosphate
Deer Creek Watershed
St Louis County, Missouri

Average (0.50 mg/L)
Average (0.44 mg/L)
Chlorides
Deer Creek Watershed
St Louis County, Missouri

Average (217.42 mg/L)
Discussion:

In this section you want to explain your results and tie the information together.

You may wish to include background information from the listed below for each parameter analyzed.

- Biological monitoring
- Water temperature
- Dissolved oxygen
- Dissolved oxygen saturation
- pH
- Turbidity
- Conductivity
- Chlorides
- Nitrate
- Ammonia
- Orthophosphate
Acknowledgments:

In this section, you should recognize those individuals that assisted you in the creation of this document. This might include those that assisted in the data collection, provided technical or financial support, etc.
Appendices:

This section might include raw data, or other longer data sets which you may wish to include in this document.
Biological Monitoring

The quality of a stream’s health can be determined in several ways. Physical monitoring gives information about a stream’s watershed and can help identify possible sources of water quality problems. Chemical analysis provides information about selected parameters at one moment in time. In order to get an indication of stream conditions over a longer period of time, we need to look at the biological community that the stream supports. A more complete assessment of water quality can be accomplished by evaluating the physical, chemical, and biological aspects of a stream.

Biological monitoring, also called biomonitoring, involves sampling the biological community to determine the stream’s health. After collection, the biological organisms are identified. The results are scored and the stream is given a water quality rating. In this program, benthic macroinvertebrates are used as biological indicators of stream health. The term benthic refers to the bottom of a stream.

Advantages of Macroinvertebrates as Biological Indicators

- Non-Mobile
- Species with Different Tolerances
- Continuous Monitoring
- Easy to Collect
- Inexpensive Equipment
Aquatic macroinvertebrates are good indicators of water quality because they are permanent residents of the stream and they can move only short distances. This makes them susceptible to any pollutants that may be in the water. Some pollutants “pulse” through the water. This could be due to discharges of pollutants from a source at intermittent times, variations in flow (e.g., after rain events), or other factors. Chemical sampling will not always reveal this type of impact, but the macroinvertebrate community will reflect impairment. Benthic macroinvertebrates fall into three categories of pollution tolerance: pollution sensitive, somewhat pollution tolerant, and pollution tolerant. The various pollution tolerances of the invertebrates make them very good water quality indicators. If water quality is degraded due to pollutants or degraded stream habitat, the invertebrate community will reflect the degradation.

### Analyzing Invertebrate Data

<table>
<thead>
<tr>
<th>Observation</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. High diversity, high density, many sensitive species such as stoneflies, caddisflies, and mayflies</td>
<td>→ No problems; good water quality</td>
</tr>
<tr>
<td>B. High diversity, low density of species present</td>
<td>→ Recent flooding, Possibly due to poor habitat conditions</td>
</tr>
<tr>
<td>C. Low diversity, high density of species present</td>
<td>→ Organic pollution (nutrient enrichment) or sedimentation; excessive algal growth resulting from nutrient enrichment</td>
</tr>
<tr>
<td>D. Low diversity, low density or no macroinvertebrates but the stream <em>appears</em> clean</td>
<td>→ Toxic pollution (e.g., chlorine, chlorides, acids, heavy metals, oil, herbicides, insecticides); unproductive</td>
</tr>
</tbody>
</table>
Water Temperature

Water temperature is important because most of the physical, chemical and biological characteristics of a river are directly affected by temperature. All aquatic organisms have preferred temperature ranges in which they can survive and reproduce optimally. Temperature also has an important influence on water chemistry. Rates of chemical reactions generally increase with increasing temperature. Temperature is a regulator of the solubility of gases and minerals (solids) – or how much of these materials can be dissolved in water. The solubility of important gases, such as oxygen and carbon dioxide increases as temperature decreases. In addition certain pollutants become more toxic at increased temperatures.

Water temperature affects the amount of dissolved gas in the water, the rate of photosynthesis by algae and other aquatic plants, and the rate of plant growth are all affected by temperature. Plant growth increases with warmer temperatures. When plants die, they are decomposed by bacteria, which use up the oxygen. Increased plant growth means more oxygen being removed from the water during the decomposition process.

The aquatic animals are also affected by water temperature. The metabolic rates of organisms increase with higher temperatures. As respiration and digestion rates increase, fish, aquatic insects and aerobic bacteria need more oxygen to survive. The sensitivity of organisms is also affected by temperature. Many organisms require a specific temperature range and changing that range may eliminate some organisms from
the ecosystem. Under temperature extremes, organisms may become stressed, which makes them more vulnerable to toxic wastes, parasites and disease.

Human activities have affected stream water temperatures. Riparian cover removal may have a large impact on water temperature by eliminating shade and thereby increasing water temperature. The removal of streamside vegetation increases the potential for sediment mobilization to the stream. This soil erosion increases the amount of suspended solids carried by the river. Cloudy water absorbs and holds the sun's heat, which warms the water. Industrial discharges and stormwater runoff from heated surfaces can result in thermal pollution. Thermal pollution is water entering the stream that is warmer than the water already present in the river. Stormwater runoff from these surfaces can reach as much as 120° Fahrenheit.

The Missouri state-wide standard for water temperature is dependent on the designated use for that specific stream. For more information, go to the Missouri Secretary of State’s website: http://www.sos.mo.gov/adrules/csr/current/10csr/10c20-7a.pdf.
Dissolved Oxygen

Dissolved oxygen (DO) is essential for the maintenance of healthy waterways. The presence of oxygen is a positive sign and the absence of oxygen is a sign of severe pollution. Waters with consistently high dissolved oxygen are considered healthy and stable aquatic systems capable of supporting many different types of aquatic life.

Oxygen within the water comes from the atmosphere, aeration, and photosynthesis. Most surface waters contain between 5 and 15 ppm dissolved oxygen. The air we breathe contains approximately 21% oxygen, which equates to 210,000 ppm oxygen. This oxygen gets diffused and entrained from the atmosphere through diffusion as well as waves and tumbling action from the stream as it flows downhill. Algae and other aquatic plants deliver oxygen to the water through photosynthesis.

The presence of DO is critical to maintaining healthy and diverse assemblage of stream biota. Most aquatic life needs a certain level of dissolved oxygen for survival. A depletion of DO can cause a major shift in the organisms present in a stream from those sensitive to pollution to those tolerant of pollution.

Water temperature is influenced by natural and anthropogenic sources. Gases like oxygen are more easily dissolved in cool water than warm water. Rivers respond to seasonal changes in the air temperature. Consequently, oxygen levels will be higher in the winter than the summer.
As water temperature increases ↑, its capacity to dissolve $O_2$ decreases ↓

As water temperature decreases ↓, its capacity to dissolve $O_2$ increases ↑

Therefore, warmer water will not hold as much DO as cold water.

Stream discharge is also related to an area's climate. Dry periods result in severely reduced flow and increased water temperatures. This combination acts to reduce the dissolved oxygen levels. Precipitation (rain, snow) or snow melt increase flow and the mixing of atmospheric oxygen into the water.

Oxygen dissolves more readily in water that does not contain a high concentration of salts, minerals, or other solids.

Aquatic plants are also very important. During daylight hours, dissolved oxygen levels rise due to photosynthesis. Photosynthesis stops as the sun sets, but plant and animal respiration continues to consume oxygen. Just before dawn dissolved oxygen levels fall to their lowest level. Large fluctuations in oxygen from late afternoon to early morning are characteristic of waterways with extensive plant growth.

Human influences on dissolved oxygen in a stream are many. Removal of riparian corridor vegetation eliminates shading of the stream. Lack of shade which causes increased water temperature, and lack of protection from erosion which causes increased solids can work together to reduce oxygen levels.

The input of organic wastes from the decomposition of dead plants and animals, as well as from the excrement of animals depletes oxygen. Organic waste can provide nitrogen and phosphorus which act as fertilizer and stimulate aquatic plant growth. As
these plants die, they too become organic wastes. Dissolved oxygen is impacted because aerobic bacteria consume oxygen as they decompose organic matter. Sources of organic waste are from:

- Stormwater/urban runoff
- Septic systems
- Wastewater treatment plants
- Runoff of manure from animal operations (especially feedlots)
- Discharges from food processing industries

Stormwater runoff from urban areas carries salt, sediment and other pollutants from impervious surfaces (streets, roofs and parking lots) into streams. This raises the total solids in the water and reduces the amount of dissolved oxygen it can hold. In addition, runoff of water from heated surfaces in the watershed, such as streets and parking lots, can cause the stream’s water temperature to rise, and warm water cannot hold as much dissolved oxygen as cooler water.

We have also dammed stream channels to create ponds and reservoirs. Some dams are constructed so that water is released from either the top or the bottom of the reservoir. Although the water on the bottom is cooler than the warm water on top, it may be almost devoid of oxygen as organic matter drops to the bottom and is decomposed by bacteria (using oxygen in the process). The opposite situation can occur when water is released from the top of a dam or spillway. This can cause excessive uptake of air from the atmosphere and results in water that is supersaturated with atmospheric gas.
The level of DO within a stream fluctuates throughout the day and is referred to as the diel fluctuation. The term diel refers to a 24-hour period that usually includes a day and adjoining night. The amount of this fluctuation is dependent on the influences previously mentioned. In late summer many streams experience an algal “bloom” – a large production of the microscopic plants, called algae, which float suspended in the water and give it its green color. Photosynthesis from algae and other aquatic plants will inflate the amount of oxygen in the stream at peak light – when the sun is highest in the sky during the day. At night the algae and other aquatic plants are not photosynthesizing, and are therefore not producing oxygen. Plants respire both day and night and use oxygen in the process, but as long as the sun is shining, they produce more oxygen via photosynthesis than they are using through respiration. At the same time, in the summer the water will be warm. Remember that warm water will not hold as much DO as cold water. Therefore, in the summer, streams may have a natural diel fluctuation in DO due to water temperature, algae, and other aquatic plants, and photosynthesis. The result is a representative graph illustrated below.
The solid line in the graph represents a normal diel DO fluctuation in late summer and the dashed line in the graph represents an extreme diel DO fluctuation in summer. Remember that warmer water increases the metabolic rates of organisms. If the stream lacks a healthy riparian corridor, the water may be hot due to the lack of shade. At night plants do not photosynthesize, so the only source of DO at night in the stream is through physical aeration. An excess of nutrients, like nitrogen and phosphorus, can cause excessive algal growth. So when the sun is shining, this excessive amount of algae pumps a large quantity of oxygen into the water via photosynthesis. Therefore, it follows that they use most of the oxygen at night. Bacteria use oxygen day and night as they decompose dead plants and other organic matter, and the bigger the plant population, the more plants there are to die and decompose.

In summary:

- Plants are not photosynthesizing at night,
- The water is warm or hot and will not dissolve as much oxygen as a cool stream
- The metabolic rates of bacteria responsible for decomposing dead organic matter are higher in warm water; and as metabolic rates increase, so does the bacteria’s demand for oxygen.

All of these factors together result in more oxygen being used at night than is physically added to the stream via aeration during the night. If these processes occur to extreme levels, subsequent extreme fluctuations in dissolved oxygen, represented by the
dashed line on the graph, can occur. Note that the DO level at 6:00 A.M. is within lethal limits for aquatic life.
**APPENDIX E**

BACKGROUND INFORMATION ON DISSOLVED OXYGEN SATURATION FOR WATER QUALITY REPORT. INFORMATION FROM MISSOURI STREAM TEAM LEVEL 1 NOTEBOOK (2014).

**Dissolved Oxygen Saturation**

Saturation is the maximum level of dissolved oxygen that would be present in the water at a specific temperature, in the absence of other influences. Percent saturation is a more meaningful water quality indicator than a DO reading alone. Dissolved oxygen saturation is a better indicator of whether a DO measurement alone is good or bad.

Think of percent saturation as the amount of oxygen present in the water sample compared to the maximum amount that could be dissolved at the same temperature. For example, water is said to be 100% saturated if it contains the maximum amount of oxygen that it can hold at that temperature. A water sample that is 50% saturated only has half the amount of oxygen that it could potentially hold at that temperature. Sometimes water can become supersaturated with oxygen because of rapidly tumbling water.

It is possible to have a DO saturation greater than 100%. Dissolved oxygen is directly related to the temperature of the water and the atmospheric pressure. For ST VWQMs, atmospheric pressure is not an issue because most volunteers are working close to sea level. The standard temperature for reading DO is normally between 68°F & 72°F (20°C & 22°C), and it is at this temperature that the maximum amount of DO water can hold is considered 100%. We have discussed how oxygen is introduced into the water through photosynthesis of aquatic plants, waves and tumbling action. We have also discussed the fact that cooler water can hold more dissolved oxygen. So if the aquatic...
plants are producing more $O_2$ at a faster rate than is being used through respiration, it is possible to get more than 100% $O_2$ saturation at a given temperature.

Percent saturation values of 80-120% are considered to be excellent and values less than 60% or over 125% are considered to be poor. For instance, a DO reading of 8.0 mg/L could be an excellent result during the summer when water temperatures are high and the water's ability to hold oxygen is low. That same reading, however, could indicate problems if that result were obtained during the winter months when water temperatures are low and oxygen-holding capacity is high.

NOTE: Remember that you must have taken the stream water temperature at the time of the DO analysis to determine DO percent saturation.

A General Rule for Ozark Streams

- $> 80\%$ DO saturation reflects healthy DO levels
- $< 80\%$ DO saturation reflects water quality impairment

A General Rule for Prairie Streams and Slow Moving Streams

- $> 60\%$ DO saturation reflects healthy DO levels
- $< 60\%$ DO saturation reflects water quality impairment

*Missouri's state-wide standard for DO is a minimum of 5 mg/L for all streams.*
pH or Parts Hydrogen

Water (H$_2$O) contains both H$^+$, Hydrogen ions and OH$^-$, hydroxide ions. “pH” is an abbreviation for the French expression, “Pouvoir Hydrogene,” meaning “the power of Hydrogen.” It measures the H$^+$ ion concentration of substances and gives results on a scale from 0 to 14. Water that contains equal numbers of H$^+$ and OH$^-$ ions is considered neutral (pH 7). If a solution has more H$^+$ than OH$^-$ ions, it is considered acidic and has a pH less than 7. If a solution contains more OH$^-$ ions than H$^+$ ions, it is considered alkaline (basic) with a pH greater than 7.

The pH scale is logarithmic. Thus, it is important to remember that every one-unit change on the pH scale is a ten-fold change of the sample. As you go up and down the scale, the values change in factors of ten. A one-point pH change indicates the strength of the acid or base has increased or decreased tenfold; a 2-point change indicates a 100-fold change in acidity or basicity, and a 3-point change in pH indicates a 1000-fold change. For example, an increase in pH from 7.0 to 8.0 means the water is 10 times more basic, an increase in pH from 7.0 to 9.0 means the water is 100 times more basic, and an increase in pH from 7.0 to 10.0 means the water is 1,000 times more basic.

Most organisms have adapted to life in water of a specific pH and may die if the pH changes even slightly. At extremely high or low pH values (11.0 or 4.5) the water becomes lethal to most organisms. pH is also important because of how it affects other pollutants in the water. Waters that are very acidic can cause metals such as zinc,
aluminum, and copper to be released into the water column. The metals can then be taken up and accumulated in the food chain. Metals in the water such as copper and aluminum can accumulate on the gills of fish or cause deformities in young fish, reducing their chance of survival. Ammonia compounds convert to a toxic form in water that is basic. The more basic the water, the more toxic is the ammonia that is present.

In the United States the pH of rivers is usually between 6.5 and 9.0. Rain water is normally acidic with a pH of around 5.6. Increased amounts of nitrogen oxides (NO\textsubscript{X}) and sulfur dioxide (SO\textsubscript{2}), primarily from automobile and coal-fired power plant emissions, are converted to nitric acid and sulfuric acid in the atmosphere resulting in acid rain or acid snow. In many areas of the United States the local geology strongly influences the acidity of the local water. In the northeastern United States the geology of the substrate is granite, which has very little neutralizing capacity. If limestone or dolomite is present, which is the case in much of Missouri, the alkaline (basic) limestone and dolomite neutralizes the acid rain before it can have a negative impact on the water quality of lakes and streams.

*Missouri’s state-wide standard for pH is a minimum of 6.5 and a maximum of 9.0 for all streams.*
Turbidity measures the clarity of water. Water with low turbidity is clear while water with high turbidity is cloudy or murky. Suspended matter, such as soil particles and plankton such as algae, most often cause cloudy or murky water. Turbidity is measured in NTU’s (Nephelometric Turbidity Units) which quantifies the amount of light scattered by suspended material in the sample.

Impacts from high turbidity levels include:

- Sediment can block out light needed by aquatic vegetation.
- Suspended particles can increase water temperature.
- Sediment can bury fish eggs and benthic invertebrates.
- Sediment can fill in interstitial spaces, eliminating habitat.

By measuring turbidity, you can evaluate whether excessive soil erosion or algal growth is occurring. Previously discussed methods for measuring nutrient (Nitrogen and Phosphorus) loads can determine if a stream is at risk for excessive algal growth. However, some measurement of suspended solid matter is necessary in order to evaluate the level of soil erosion. Areas where turbidity monitoring is particularly valuable include:
• Areas being developed where a great deal of construction and land disturbance is occurring.

• Downstream from quarries and gravel mining operations. These activities can result in fine particles entering a stream and smothering habitat.

• Agricultural areas that have not adopted best management practices to prevent soil erosion.
Conductivity

All liquid solutions conduct electricity to some degree. The measurement of water’s ability to conduct electricity is called *conductivity*, or *specific conductance*, and is measured in a unit of current, or flow of electricity called micro-Siemens per centimeter (µS/cm). It is the opposite of electrical *resistance*, which is measured in ohms. Pure water is not a good conductor of electricity. Conductivity of water is determined by the amount of solids that are dissolved in the water. Rainfall, interacting with the atmosphere, vegetation, rocks and soil, is the major source of dissolved solids in streams. Groundwater entering streams is another source. Water is uncommonly good at dissolving a wide variety of materials. It is the medium that allows the necessary biochemical reactions in organisms to proceed. Water carries needed minerals and nutrients to living organisms and transports wastes away. Seven common substances make up about 99% of the dissolved solids in streams. In their approximate order of abundance in Missouri waters, these include:

- Bicarbonate
- Calcium
- Magnesium
- Sulfate
- Chloride
• Sodium
• Potassium

It is not surprising that the three most abundant dissolved substances come from the dissolution of limestone and dolomite, Missouri's most abundant rocks. The remaining one percent of dissolved substances can vary considerably, but can include nitrates, different metals, ammonia, phosphorus, and manmade compounds such as pesticides and fuels.

Conductivity may vary primarily due to the influence of rainfall or snowmelt. Precipitation is low in dissolved solids and an unimpacted stream, which has recently received rainfall, will have a lower conductivity value. The conductivity values below are typical readings for various waters and geographic regions.

However, a large change in conductivity values or readings greater than 1200 μS/cm may indicate a need for further investigation. Conductivity can tell us the amount of solids dissolved in the water, but does not tell us what kind of dissolved solids are present. Unexplained changes in conductivity can indicate problems in the watershed.

There is no water quality standard for conductivity because it is a general indicator of water quality.
Chloride is one of the major components of road salt, also known as rock salt. The use of road salt has been implicated in the elevation of chloride and sodium levels in surface and groundwater as well as in the surrounding environment. Sources of chloride run off are roads, parking lots, airports, drains, ditches, salt storage piles, garages, truck washing areas, and sites where snow is piled as well as waste water treatment facilities, industrial and natural sources. It is estimated between 10 and 20 million tons of road salt is used nationally each year.

Chloride is soluble and can enter surface and groundwater easily. Although non-toxic at low levels, elevated levels of chloride in waterbodies can have a detrimental effect on freshwater ecosystems. At high levels, chloride is toxic to freshwater organisms. High levels of chloride can also lead to density stratification in lakes and ponds, resulting in oxygen depletion and fish kills. High chloride concentrations can restrict water use for consumption in domestic and public supply wells, and affect the quality necessary for many industrial uses. Use of water with high chloride concentration for irrigation can damage crops directly through burning of tissue or indirectly by changing the soil structure, which can cause fields to be damaged beyond use or repair.
Missouri water quality standards establish the following limits on chloride:

<table>
<thead>
<tr>
<th>Beneficial Use</th>
<th>Chronic</th>
<th>Acute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aquatic life</td>
<td>178 mg/L</td>
<td>288 mg/L</td>
</tr>
<tr>
<td>Drinking Water</td>
<td>250 mg/L</td>
<td></td>
</tr>
</tbody>
</table>
Nitrogen

Nitrogen is an essential plant nutrient required by all living plants and animals for building protein. All organic (living) matter contains nitrogen. In aquatic ecosystems, nitrogen is present in different forms. The usable forms of nitrogen for aquatic plant growth are ammonia (NH₃) and nitrate (NO₃). Excess amounts of nitrogen compounds can result in unusually large populations of aquatic plants and/or organisms that feed on plants. For instance, some algal blooms are a result of excess nitrogen entering the stream. As aquatic plants and animals die, bacteria break down the organic matter. Ammonia (NH₃) is oxidized (combined with oxygen) by bacteria to form nitrites (NO₂) and nitrates (NO₃).

Nitrogen levels in streams is influenced by natural and anthropogenic sources. When trees shed their leaves in the fall and the leaves drop into the stream, nitrate levels naturally become elevated as a result of decomposition of organic matter. Since all living matter is composed of nitrogen, decomposition of organic matter other than leaves may cause elevated nitrate levels.

Manmade influences on nitrate levels are many. Poorly functioning septic systems may leak nitrogenous waste into streams. Wastewater from treatment plants may be high in nitrogen since most treatment plants do not remove nitrates. Storm drains may carry wastes from pets, fertilizer, broken sewer lines and septic systems. Combined Sewer
Overflows (CSOs) are waste water systems designed to combine with the stormwater system during high flows to bypass wastewater treatment plants. These antiquated systems were originally designed this way as an attempt to avoid overwhelming the wastewater treatment plants. It has long been recognized that these systems were a bad idea because they allow too much untreated water to enter streams. These systems were designed in the early 1900s and can still be found in existence in Kansas City, St. Louis, Sedalia, St. Joseph and Moberly. Runoff from animal production in feedlots and runoff from wastes improperly applied to the land may enter a stream. Runoff from lawn fertilizers may enter a stream if fertilizer is improperly applied or if there is an immediate rainfall event after fertilizer application. Septic systems are a common wastewater treatment method in many areas. Instead of centralized wastewater treatment plants, which exist in most urban settings, people with septic systems have individual wastewater treatment. A septic system is comprised of a main pipe from the house to the septic tank, and a number of pipes with holes in them leading from the septic tank. These pipes are arranged in a grid that usually lies over stone and gravel and is called a "drain field." Wastes from the toilet, kitchen sink, bathtub, and washing machine flow through an underground pipe to a septic tank. In the septic tank solid matter settles out and floating grease may be skimmed off. The remaining liquid enters the drain field through the holes in the pipes and trickles through the stone, gravel and soil. In properly functioning systems, soil particles remove nutrients, like nitrates and phosphates, before they reach groundwater or surface water. People who fail to periodically pump out their septic tank may allow their tanks to overfill with solids. This results in wastes going
directly to the drain field instead of settling in the tank. The drain field becomes plugged and the liquid wastes are no longer filtered through the soil. In this condition, household sewage may pool on the ground and enter surface water through runoff.

*There are currently no numeric nutrient standards for streams. DNR has recently developed nutrient standards for Missouri’s lakes and reservoirs, and is in the process of developing similar nutrient standards for Missouri streams.*
Ammonia

Ammonia (NH₃) is the only nutrient that is directly toxic to aquatic life. However, the toxicity of ammonia is dependent on the pH and the temperature of the water. It is important to note that ammonia levels are not usually a problem in most Missouri streams. However, current wisdom is that ammonia may be the cause of Missouri’s native mussel and clam species’ decline in population. Because this may be the case, tighter ammonia restrictions are being placed on wastewater treatment plants as permits are renewed. To determine the toxicity of ammonia, a measurement of water temperature and pH must have been made at the time of the ammonia analysis.

The Water Quality Standards at the Secretary of State’s Website:

Orthophosphate

Phosphorus is also a plant nutrient. Phosphorus is most readily available to plants as orthophosphate, a reactive form of phosphorus commonly referred to as $\text{PO}_4$ (phosphate). In nature it is generally present in very low levels measured in tenths or hundredths of mg/L. In many instances phosphate can be the nutrient that limits plant growth (called “primary productivity”). This occurs when phosphorus is less abundant in surface water than nitrogen. Even small increases in the amount of phosphorus entering a stream can have a large impact. If point source or nonpoint sources of pollution are high in phosphate, they can over-stimulate the growth of all types of aquatic plants.

Phosphorus occurs naturally in rocks and enters the water column through the natural weathering of rock. Phosphorus binds readily with soil particles. Soil must be highly saturated with phosphorus before excess amounts are detectable in shallow groundwater, which will eventually enter streams where it can have negative impacts.

Manmade influences on nitrate levels are similar to nitrogen. Waste from animal production, particularly poultry litter, can contribute to phosphate loading in streams. Wastewater from treatment plants may be high in phosphorus since most treatment plants do not remove phosphates. Waste from poorly functioning septic systems may reach streams. Runoff from fields and lawns can contribute excess phosphorus, particularly if rainfall events follow fertilizer application. Storm drains and Combined Sewer Overflows
may carry lawn fertilizer and pet waste, or runoff from broken wastewater lines and septic systems.

There are currently no numeric nutrient standards for streams. DNR has recently developed nutrient standards for Missouri’s lakes and reservoirs, and is in the process of developing similar nutrient standards for Missouri streams.