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GIS and 2016 Water Quality Assessment: Summer Internship with the Massachusetts Department of Environmental Protection

Xiaoyan Hu 3736156
Clark University, xiahu@clarku.edu

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Xiaoyan Hu

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Accepted on the recommendation of

Jie Tian, Ph.D., Project Advisor

ABSTRACT

GIS and Water Quality Assessment:

Summer Internship with the Massachusetts Department of Environmental Protection

Xiaoyan Hu

My 2015 summer internship at Massachusetts Department of Environmental Protection lasted for 12 weeks from June 1 to August 12. I was supervised by Juliet Swigor. As a GIS Specialist intern, I assisted staff from Division of Watershed Management, working on 2016 National Water Quality Assessment project. My responsibilities were diverse, including watershed delineation, database management, customized ArcGIS add-in tool development and mapping. I extracted sub-basins and generated land use statistic summary for all of them across the entire Massachusetts using python scripts. Also a map covers detailed distribution of watersheds was created. This paper reports information of organization description, areas of expertise, the summer internship, and it also provides examples of my works and review of the summer internship.

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Jie Tian, Ph.D.

Chief Instructor

Academic History

Name: Xiaoyan Hu

Place of Birth: Fuzhou, Fujian **Date:** Oct 17, 1991

Baccalaureate School: Minjiang University **Date:** May, 2014

Baccalaureate Subject: B.S. in Natural Resource Management and Urban Planning

Dedication

I would like to dedicate this internship paper to my parents, brother, and boyfriend, who have always been there for me and offered their continue support throughout my studies. I would also like to thank the people with whom I have become closely acquainted from the Clark University, GISDE communities for their support within the academic and friendship realms.

ACKNOWLEDGEMENTS

I would like to thank Jiabin Heng, who drove me to the work place every day during the 12 weeks. I would also like to thank Jie Tian, Yelena Ogneva-Himmelberger, Ron Eastman, and Florencia Sangermano. I would like to especially thank the Massachusetts Department of Environmental Protection (MassDEP) for making this internship possible. Finally, I would like to thank Juliet Swigor for giving me the opportunity, and helping me throughout the process.

Table of Contents

CHAPTER 1. INTRODUCTION

While pursuing my bachelor's degree, I have developed a great deal of interests in GIS, especially the GIS application of environmental protection. The Geographic Information Science for Development and Environment (GISDE) Master's program at Clark University has been a great launching board for my career in GIS for environmental protection. As a joint program between the Geography and International Development, Community & Environment Departments, I am able to study with some of the best faculty and students from different academic backgrounds.

As a requirement of the GISDE program, I chose the internship track to apply the GIS techniques and skills learned in class to the real world. My internship at the Massachusetts Department of Environmental Protection (MassDEP) working as a GIS Specialist Intern for 2016 Water Quality Assessment in Massachusetts was a great experience for my future career path, since it fits nicely with my career goal of utilizing GIS techniques in environmental resource protection and management. I learned about this internship opportunity through MassDEP website and noticed that they have a Volunteer Internship Program. My coursework experience with vector GIS as well as python scripting at Clark laid a solid foundation for meeting the requirement of the internship and came in handy during work. Through my time at MassDEP, I learnt a lot about Hydrology and land use management, as well as programming in this field. I am thankful to have the impressive summer at MassDEP.

Overall, what I learnt at Clark and MassDEP are both beneficial for my personal life and career path. This report covers the organization mission and expertise, my internship responsibilities, as well as my in-depth assessment of my internship.

CHAPTER 2. DESCRIPTION OF ORGANIZATION

2.1 Organization's Mission

The Massachusetts Department of Environmental Protection (MassDEP) is an environmental regulatory agency within the Executive Office of Energy and Environmental Affairs (EEA). The agency is responsible for toxics and hazards management, solid and hazardous wastes recycling, hazardous waste sites and spills cleanup, wetland and coastal resources preservation, so as to protect human health and environmental sustainability. MassDEP is one of the agencies in the Executive Office of Energy and Environmental Affairs and its role under Article 97 of the Massachusetts Constitution is to guarantee the people's right to "clean air and water", as well as "the natural scenic, historic and aesthetic qualities of the environment" [1].

2.2 Location

MassDEP consists of six offices across the entire state: Northeast Region-Wilmington, Southeast Region-Lakeville & Barnstable, Western Region-Springfield, Central Region-Worcester, and Wall Experiment Station-Lawrence. I spent 12 weeks interning at the MassDEP Worcester office. It is located in a residential neighborhood, occupying the entire first floor of a converted factory, near the Route 12 West Boylston street entrance. Its

service area spans from the Connecticut border to the New Hampshire line, and it encompasses all of Worcester County and includes some municipalities in Western Middlesex and Norfolk counties, together with 77 towns and cities with a combined population of nearly 900,000. The major river basins (Blackstone, Nashua, Concord, Merrimack, Chicopee, French and Quinebaug, and Millers) as well as the Wachusett Reservoir and its watershed are among the chief natural features of the Central region[2].

2.3 Areas of Expertise

MassDEP covers different areas of expertise based on its main features: Climate & Clean Energy, Air Quality, Water Resources, Waste & Recycling, Toxic & Hazards, Cleanup of sites & spills.

Climate & Clean Energy: MassDEP is working to reduce greenhouse gas emissions and clean up carbon pollution to reduce the present and future impacts of climate instability in Massachusetts. MassDEP also focuses on promoting the development of renewable energy and energy efficiency projects to protect the environment and support a clean-energy economy.

Air Quality: Breathing polluted air can irritate the throat and make breathing difficult. MassDEP makes every effort to reduce the risks posed by air pollution and climate change. For example, in 1983, Massachusetts became one of the first states in the country to start testing vehicle emission through the Massachusetts Vehicle Check program[3].

Water Resources: The division of watershed management is further split into four programs: Drinking Water, Wetlands, Wastewater Management, and Watershed

Planning. As the EPA'S primary agent for the federal Safe Drinking Water Act in Massachusetts, the Program regulates water quality monitoring, new source approvals, water supply treatment, distribution protection, and reports of water quality data[4]. The Wetlands Program not only ensures the protection of inland and coastal wetlands, but also contributes to prevention of pollution, storm damage and flood control. The Wastewater program regulates the waste water discharge and ensures the safety of septic systems. The Watershed Planning is responsible for the health of state's watersheds and provides environmental monitoring data for water quality control and land use change analysis.

Waste & Recycling: MassDEP does not only lays emphasis on maximizing waste reduction, recycling and compost but also makes efforts for reuse and disposal of solid and hazardous wastes. The website of Recycling in My Community[5] detailed information on donation procedure, reduction of wastes as well as reuse and recycling of unwanted items.

Toxics & Hazards: MassDEP regulates and provides management guidance for many toxic and hazardous materials through regulations, policies, permits and online reporting, and the Toxics Use Reduction Act (TURA). It also provides information on how to properly manage hazardous household products[6].

Cleanup of Sites & Spills: The Bureau of Waste Site Cleanup is responsible for making immediate and effective response to environmental emergencies, such as oil spills. The Site Cleanup Information Roadmap website[7] is established for viewers who need to report any spill of oil or hazardous material as well as enabling these viewers to obtain immediate information that they need.

2.4 Structures

MassDEP is an equal-opportunity organization. Employees come from diverse backgrounds and have knowledge and interest in the environmental field. The MassDEP Volunteer Internship Program provides interns with education, training, hands-on experience, supervision, and networking opportunities, utilizing modern technology and information systems. The MassDEP bureaus in Boston include: Bureau of Water Resources, Bureau of Air & Waste, Bureau of Policy & Planning, Bureau of Waste Site Cleanup, Bureau of Administrative Services (including Office of Diversity), Office of Research & Standards, and Office of General Counsel. Moreover, there are five MassDEP Regional Offices: Northeast Region-Wilmington, Southeast Region-Lakeville & Barnstable, Western Region-Springfield, Central Region-Worcester, and Wall Experiment Station-Lawrence$_2$.

2.5 GIS Section

The main GIS services group is located in Boston, MA, in the MassDEP headquarters. This small team works with various bureaus and programs, and is responsible for managing geographic datasets, department's use of Geographic Information System and data visualization. The GIS program complies and manages spatial datasets that are published through MassGIS, including: Public Water Supply Sources and Protection Areas, Wetlands, Eelgrass Beds, Tier Classified 21e Sites, BWP Facilities, Ground Water Discharge Permits, Non-Potential Drinking Water Source Areas, and Areas Affected by Title V$_8$. In addition, they also provide training sections and technical support for Department of Environment Protection (DEP) staff using GIS.

CHAPTER 3. INTERNSHIP DESCRIPTION

I worked as a GIS specialist intern at MassDEP, under the guidance of Mrs Juliet Swigor, who is the regional coordinator for MassDEP Central Regional Office. During my summer internship, I interacted with the MassDEP Division of Watershed Management (DWM) staff and interns involved with the Water Management Program for questions, data processing, and feedback.

On the first day, Juliet Swigor gave me a detailed introduction about on-going projects that I would mainly work on. The internship laid much emphasis on vector data processing, land cover change analysis for watershed assessment, planning, and management. I was involved in one main project: 2016 Watershed Planning program. My primary responsibilities at MassDEP included: 1) Data collection, data processing, database management, and mapping; 2) Generation of pie charts in order to display land-use statistics summaries for further web map use; 3) Provision of technical assistance and training for interns who had limited experience with GIS.

3.1 Program Introduction

Watershed planning forms part of the mission of MassDEP, as it contributes to the public health and safety, as well as environment sustainability. This Water Quality Assessment report uses the Massachusetts Surface Water Quality Standards (SWQS) as guidance to assess the Aquatic Life, Fish Consumption, Shellfish Harvesting, Primary and Secondary Contact Recreation and Aesthetics uses. The Water Quality Assessment program is aimed at reporting for the requirements of Sections 305(b) and 303(d) of the Federal Clean Water

Act, and monitoring the chemical, physical, and biological integrity of waterbodies in the state. Section 305(b) of the CWA codifies the process whereby waters are evaluated with respect to their capacity to support designated uses as defined in the Massachusetts Surface Water Quality Standards. These uses include aquatic life, fish consumption, drinking water, shellfish harvesting, primary (e.g., swimming) and secondary (e.g., boating) contact-recreation, and aesthetics. The 305(b) process entails assessing each of these uses, where applicable, for rivers, lakes and coastal waters in the state and identifies, wherever possible, causes and sources of use impairment[9]. Land-use change statistics will be summarized, and other information will be added for developing a template reporting on water quality conditions. After finishing my portion of the project, other employees working on web maps will upload the databases and spatial georeferenced river, lake, and estuary segment shapefiles. Afterwards they will publish a web map titled "the Massachusetts 2016 Integrated List of Waters (305(b)/303(d))" for public review. It ensures that the environmental data are known and documented. This water quality reporting process is the principal means by which the EPA, Congress, and the public evaluate existing water quality, assess progress made in maintaining and restoring water quality, and determine the extent of remaining problems[10]. This program began with Mary Cox, An alumni of the GISDE program in Clark who completed in 2015, who also worked with Juliet Swigor to set up the framework for the program and begun the actual watershed delineation for some basins.

3.2 Data Collection

The Dataset I used in the processing can also be downloaded from MassDEP official website. It included: two georeferenced ArcMap shapefiles, and three data layers containing the geospatial documentation document delineating waterbody segments: Hydrologic Unit Code (HUC) convention data layer, Watershed Planning Program (WPP) data layer, and MassDEP 2012 Integrated List of Waters (305(b)/303(d)) [11]. The MassGIS 1:25,000 hydrography based on USGS topographic maps is used for geo-referencing, USGS topographic quadrangles and MassGIS color orthophotos are used as a base map for all river segments.

3.3 Data Process

The data processing was carried out under three main categories. The first part was data preparation. The second part involved the running of python scripts in order to speed up processing, since there were thousands of sub-basins that needed to be processed under this section. The last part was generating land-use statistics summaries and conducting quality control review for final results.

Data Preparation:

The first step was to update original basins' databases, 2012 Integrated List of Waters (305(b)/303(d)) database, by cleaning up no longer existing segments, and added newly updated streams based on field work feedbacks. Interpretation of hydrologic flow direction was also required for updating pour points dataset. ArcHydro software and USGS Streams Stats online tool were used to create watersheds for waterbodies. On-screen editing was

also required for editing these watersheds and ArcMap was used as needed, since there were some errors with auto-create watersheds. Individual segments derived from the MassGIS 1:25,000 hydrography based on USGS topographic maps also needed to be added in order to update basin databases.

Extract Basin-specific Data:

"Watershed Tools" Toolbox in ArcMap is a set of scripts mainly created by Molly Cox last year, I only made slightly changes to them, in order to make sure it runs properly and results in corrected outputs corresponding to different basins. The toolbox covers different functions for different purposes of data extraction processing: 1) Creation of individual sub-basin feature classes. It splits a shapefile or feature class into individual shapefiles by stream segment, and then dissolves each individual shapefile. 2) Creation of proximal sub-basin feature classes. It creates proximal sub-basins within 5 kilometers radius of pour points. 3) Creation of stream buffer feature classes. It creates 100 meter stream buffers around the previously created 25k polygon hydrography shapefile and clips a master buffer file using individual sub-basins feature classes as clip features. 4) Creation of proximal stream buffer feature classes. It clips proximal stream buffers using the 5km buffer of pour points generated before. Figure 1 in the figure section is an example of the Quinsigamond River (MA51-09) in the Blackstone basin, presenting the four shapefiles on the top right corner created by the functions mentioned above.

Land-use Statistics:

Land-use statistics summaries were developed based on those extracted basin-specific data. Python scripts were also used to create spreadsheets for the four shapefiles created before containing information on the breakdown of the land-use data, including: Agriculture, Developed, Nature, and Wetland. The amount of impervious surface within the watershed was also evaluated. Output in jpeg format with one pie chart and one table as indicated in Figure 2, which indicating the following: area summaries, percentage of areas of different land-use types, as well as the percentage of impervious surface area within the sub-basin. Impervious surface areas include all the hard top manmade surfaces within the watershed, which do not allow precipitation to infiltrate the ground, but instead cause rain or snowmelt to runoff[12]. Quality control review was conducted after running all scripts, in order to find out errors generated by incorrected commands. Different methods will be used to double check the statistics summary spreadsheets, included: checking the watershed areas using query button in ArcMap and/or attribute tables, using draw tool to draw a polygon along sub-basin boundary and thus to calculate its area.

Detailed Sub-basins Map:

Since most sub-basins information were stored in separate data layers: Hydrologic Unit Code (HUC) convention data layer, Watershed Planning Program (WPP) data layer, and MassDEP 2012 Integrated List of Waters (305(b)/303(d)) 3 data layer, most of them were out of date. My responsibility was to create detailed basin maps, which integrated all sub-basins boundaries and attributes in one shapefile. The main rule was using the linework from WPP sub-basin layer; if there was no WPP covered but HUC, use the boundaries of

sub-basins from HUC layer; if there was no existing line in the edit file, the newly updated databases with latest versions of sub-basins boundaries would be used. The methodology of combining watersheds was simple but tedious. At first, Query Builder in Layer Properties dialog box was used, to make a definition query in order to find out the individual sub-basin currently being working on. And if the sub-basin had already been covered by WPP data layer or HUC data layer, simply copy it, if there was no existing linework, copy, trace, and cut polygon tool would be applied. Figure 3 is the detailed basins map I created. It has finished yet, some small basins were assigned to other interns to practice with.

Further Steps:

It is still an on-going project, in which MassDEP attaches much importance. All of those final results, including shapefile, database, pie chart and spreadsheet will be upload online to replace the existing 2012 Integrated List of Waters (305(b)/303(d)) web map (Figure 4). DWM staff will work on use assessment decisions based on the Massachusetts Surface Water Quality Standards (SWQS), which prescribe minimum water quality criteria to sustain the existing and designated uses[10].

CHAPTER 4. INTERNSHIP ASSESSMENT

My summer internship at Massachusetts Department of Environment Protection (MassDEP) as GIS specialist intern was a great experience for my academic and career development. During the 12 weeks of my internship, I successfully assisted staff from the Department of Water Management and finished my part of GIS related work for the “2016 Water Quality Assessment in Massachusetts” project. It was an amazing experience that I was able to

produce useful outputs and contributed my quota to the Commonwealth. My previous experience of cartography and the skills learned from class at Clark University have been widely applied. I will definitely recommend the internship for other GISDE students, since the supervisor Juliet Swigor is kind and knowledgeable, as well as her great experience in the use of GIS and python scripts are concerned.

4.1 What I learned?

One of the greatest benefits for me this summer was working with professional hydrologists. I was able to learn a great deal from them about the concepts of water quality standards and use assessments. This enables me to finish tasks with full understanding, since in the Water Quality Assessment program, a good understanding of how to interpret direction of hydrologic flow on a topographic map is required. I also learned a lot about problem solving, self-study ability, as well as technical skills.

In the process of data preparation, I learned how to apply Arc Hydro and USGS Streams Stats web application. Arc Hydro is part of ArcGIS, it was a great opportunity for me to learn and apply my experience to real life applications. Arc Hydro was applied to batch watershed delineation using pour points. USGS Stream Stats web application is an integrated GIS application that is based on Arc Hydro Tool but provided map-based user interface. After figuring out the concepts of the basic logic behind those two tools, I was able to get an insight on how watersheds were created based on segments. I also could identify mistakes earlier, and troubleshoot these problems.

In the process of running python scripts for extracting basin-specific data and land-use statistics, I got the opportunity to look at how python scripts were used in the real-world project and the disparities in the relation to the one I wrote for my Python Programming final project at Clark University. The major difference was the detailed processing message displayed on the screen, which provided users a clear information why the process crashed. Overwriting output and clearing memory with every iteration were also important steps. Since some of the steps needed to be redone several times based on the field feedback, the overwrite settings saved much processing time.

In creating the detailed sub-basins map, I learned how to trace, copy, paste features in the ArcMap. It was tedious, but was a fast approach as compared to simple digitizing. In this case, I was able to contribute to similar tasks in an effective way.

Aside obtaining technical experiences, I also gained a great experience of cooperating and working together with colleagues in real project, which is also important for my future career development. In MassDEP, everyone was in charge of a specific procedure of a project, meeting and feedbacks were essential for improvement. I am confident that this teamwork experience will benefit me a great deal.

In the end though, another thing I learned from the internship is how to explain GIS data processing steps to non-GIS users. I obtained this knowledge from Juliet Swigor as I assisted in training interns.

4.2 What helped me?

In approaching the internship, my academic background at Clark made me well-prepared for technical services at Mass Department of Environment Protection (MassDEP). The Introduction to GIS course, which I took at Clark University during the first semester, was highly related to my internship tasks and made it easier for me to tackle most problems including data processing and map production. Introduction to Remote Sensing course was also helpful during the internship. Since the ability of remote sensing imagery interpretation was also required for watershed delineation. The satellite imagery interpretation skill I learned was extremely useful to me as I was able to draw a watershed by hand. Another course I want to mention is Computer Programming for GIS, which I believed is a requirement for GIS specialist, since the python script can increase the geoprocessing efficiency. In the Water Quality Assessment in Massachusetts, there were thousands of sub-basins that required same processing steps. This is time-consuming and tedious when these are being accomplished by hand. Based on the knowledge I learned from Computer Programming in GIS, I was able to easily customize scripts for specific basins and also understood the toolbox that Molly Cox created without any difficulty.

CHAPTER 5. CONCLUSION

I really appreciate the opportunity to work at MassDEP with talented professionals this past summer. I felt lucky to have a great experience with Juliet Swigor, who was not only my supervisor but also considered as a friend. I learnt a great deal about Hydrology, and how to integrate GIS techniques into a water quality assessment program. My works focused on

watershed updating, database management, land use statistics, as well as map production. Almost all the problems I encountered were fixed by technical skills I gained at Clark and my prior background in GIS. Also working with a supervisor enabled me to easily communicate with a GIS professional, which was also a great valuable experience for me. I would highly recommend this internship opportunities at to other IDCE students.

List of Figures:

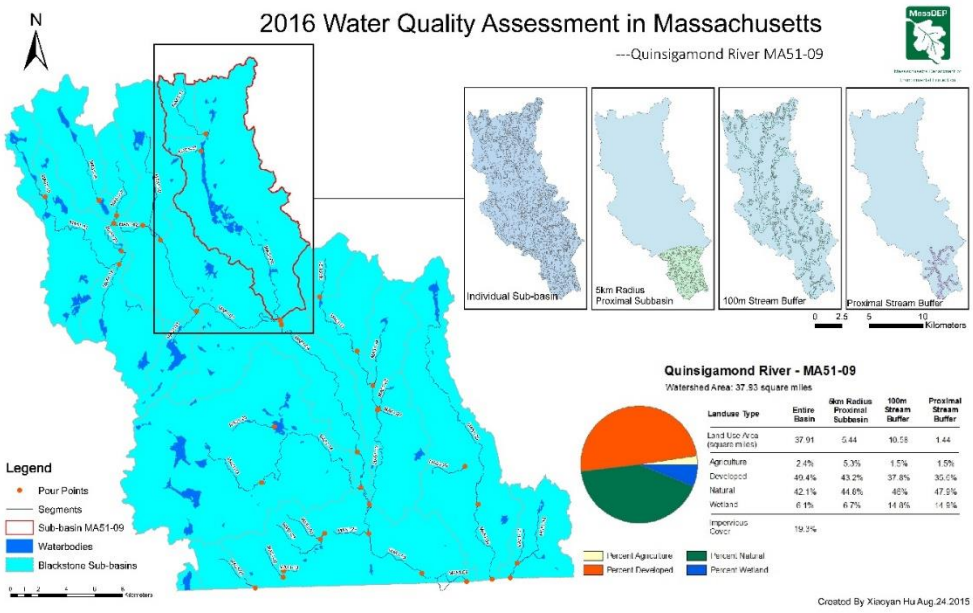
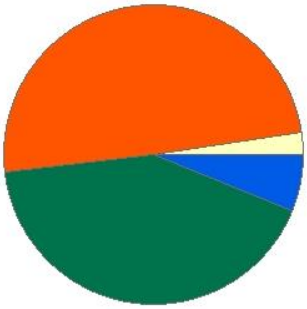


Figure 1. Example map of Quinsigamond River (MA51-09)

Quinsigamond River - MA51-09

Watershed Area: 37.93 square miles



Landuse Type	Entire Basin	5km Radius Proximal Subbasin	100m Stream Buffer	Proximal Stream Buffer
Land Use Area (square miles)	37.91	5.44	10.58	1.44
Agriculture	2.4%	5.3%	1.5%	1.5%
Developed	49.4%	43.2%	37.8%	35.6%
Natural	42.1%	44.8%	46%	47.9%
Wetland	6.1%	6.7%	14.8%	14.9%
Impervious Cover	19.3%			

Percent Agriculture
Percent Developed
Percent Natural
Percent Wetland

Figure 2. Land-use Statistics Summaries for Quinsigamond River (MA51-09)

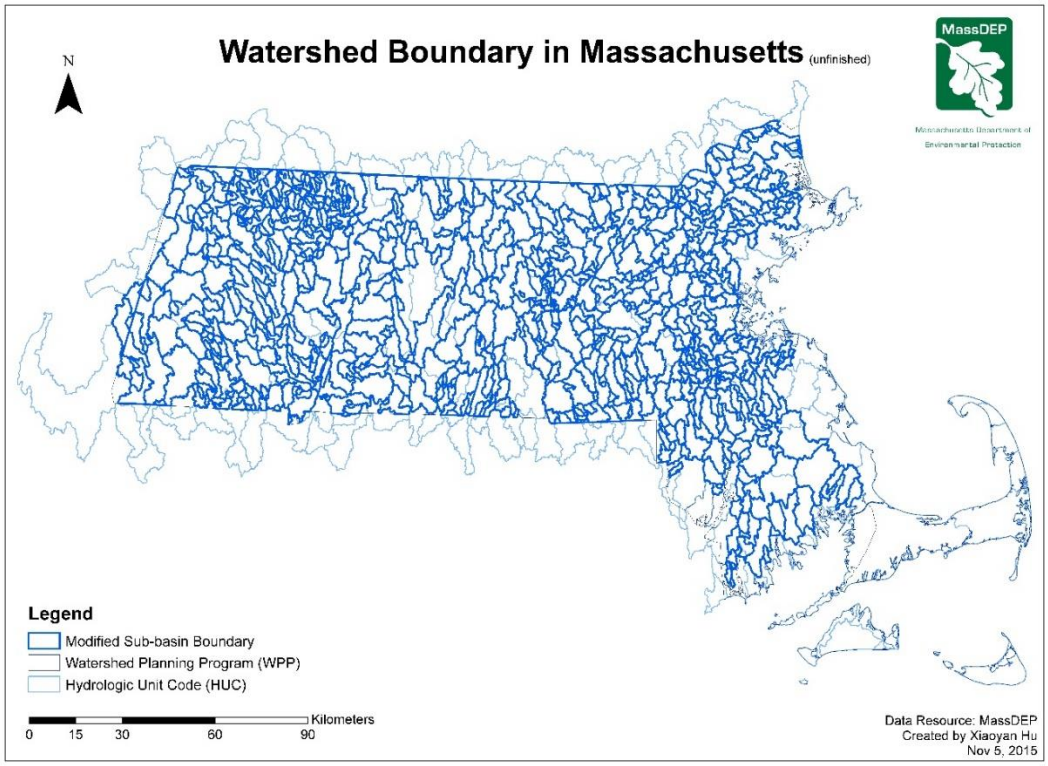


Figure 3. Basin map (unfinished)

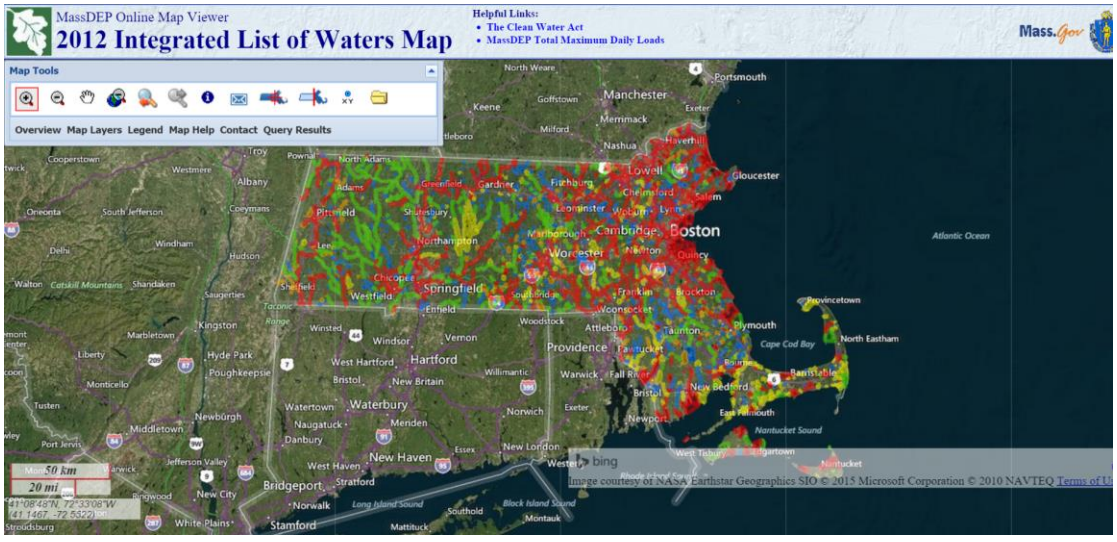


Figure 4. 2012 Integrated List of Waters Web Map[3]

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