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Massachusetts Water Resource Outreach Center

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Stormwater Runoff Education & Environmental Stewardship

Project Team in Front of Salisbury Pond in Worcester, MA;
Sean Burke, Tom Kouttron, Cielo Sharkus, and Mike Cooke (left to right)

Abstract

In collaboration with the Fitchburg Department of Public Works and Fitchburg Public Schools, our team developed a fifth grade Stormwater Education Program consisting of a Student Workbook and Educator Resource Guide. Through interviews, analysis of stormwater materials, collaboration with municipal officials, and pilots of our materials, we aimed to help the City of Fitchburg comply with the U.S. Environmental Protection Agency's Public Education and Outreach minimum control measure. The Student Workbook and Educator Resource Guide combine interdisciplinary learning with hands-on, outdoor activities to instill environmental stewardship among younger generations. We hope that our program will promote growth of Science, Technology, Engineering and Math programs within the diverse cities.

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Stormwater & Environmental Education

The Fresh Water Crisis

Approximately one-tenth of one percent of the world's water is categorized as fresh water, a critical component to a biodiverse and healthy ecosystem. However due to the modern Anthropocene fresh water has become heavily polluted. Large amounts of organic, solid, and chemical pollutants accumulate in fresh water each day due to stormwater runoff. The Pacific Institute is a global think tank whose focus is fresh water research, and its researchers estimate that 2 million tons of sewage, industrial and agricultural waste are dumped into waterways each day, reducing water quality and posing a significant threat to ecosystems and public health (Pacific Institute, 2010).

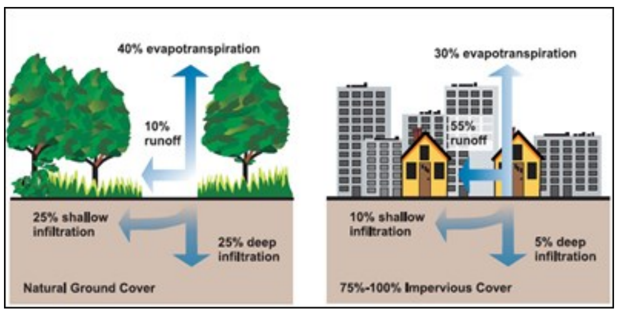

Figure 1: *Effects of Impervious Surfaces on Stormwater Runoff (U.S. EPA, 2003)*

Common Pollutants

Heavy precipitation brings large volumes of water to residential and commercial areas, where impervious surfaces prevent water from infiltrating the ground (U.S. EPA, 2017). This water, known as stormwater runoff, flows along roofs, parking lots, and streets until it reaches a body of water. As shown in **Figure 1**, 55% of precipitation that falls in urban areas becomes runoff. As this runoff flows across impervious surfaces it picks up a hazardous mix of chemicals and pollutants, which are described in **Table 1.** These pollutants are then introduced into rivers, reservoirs, and lakes through this runoff (U.S. EPA, 2017).

Stormwater runoff carrying fertilizers and sediment contaminates aquatic ecosystems by introducing nitrogen and phosphorus into waterways. These chemicals accelerate algae production and deplete dissolved oxygen, causing native species to die and water quality to decrease (NOAA, 2004). Additionally, stormwater runoff contaminated with animal waste introduces *E. coli* bacteria into waterways, which can cause diarrhea, nausea, and vomiting for people and animals who come in contact with the contaminated water (Mayo Clinic, 2014). Moreover, rock salt which is a deicing agent for roads introduces high concentrations of chlorine into water bodies. During thaw events, snowmelt floods waterways with high concentrations of chlorine in a short-period of time. The chlorides introduced during these thaw events remains concentrated in water for 4-6 weeks, posing a threat to surrounding ecosystems (NRC, 2008). Lastly, hydrocarbons such as

Table 1: *Overview of Stormwater Runoff Pollutants (Adapted from NSW Government, 2013)*

Contaminant	Sources for Contamination
Bacteria and Viruses	Animal waste, lawns, leaking sewer pipes, roads, septic systems, sewer cross-connections
Metals	Atmospheric deposition, automobiles, rust from bridge piers and pilings, combustion processes, corroding metals, industrial areas, soil erosion
Nitrogen and Phosphorus	Animal waste, atmospheric deposition, automobile exhaust, detergents, lawn fertilizers, soil erosion
Oil and Grease/Hydrocarbons	Driveways, gas stations, illicit dumping, parking lots, roads, vehicle maintenance areas
Organic Materials	Animal waste, commercial landscaping, human waste, residential lawns and gardens
Pesticides and Herbicides	Commercial and industrial landscaping, residential lawns and gardens, roadside, soil-runoff, utilities
Sediments and Floatables	Atmospheric deposition, construction activities, drainage, channel erosions, driveways, lawns, roads streets

petroleum and gasoline found on streets and parking lots present significant risks to waterways due to their carcinogenic effects on wildlife (Nemeth et al., 2010). Due to these risks, the Municipal Separate Storm Sewer System (MS4) Permit was implemented in 1994 to protect biodiversity and human health. The development of the MS4 Permit has led to stormwater management and water quality improvements throughout the United States.

The MS4 Permit

Prior to the passing of the MS4 Permit, state legislation moved to improve stormwater quality during the 1970s and 1980s by implementing Municipal Separate Storm and Sewer Systems (MS4s). These systems consisted of interconnected ditches, drains, underground pipes, and outlets that transported and discharged stormwater without treatment into nearby water bodies (U.S. EPA, 2017). Although these systems significantly reduced urban flooding, they discharged untreated stormwater directly into waterways as shown in **Figure 2**. Due to resulting decreases in water quality, the United States Environmental Protection Agency (U.S. EPA) began to regulate stormwater discharges through the issuance of permitting programs and regulations beginning in 1987 (Copeland, 2015).

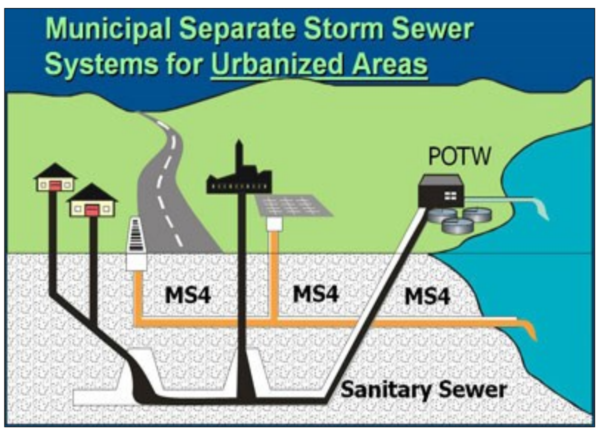

Figure 2: *The Flow of Stormwater through an MS4 (U.S. EPA, n.d.)*

The most recent U.S. EPA regulation is an updated MS4 Permit issued in 2016 and goes into effect on July 1, 2018. This permit establishes six control measures to reduce municipal stormwater pollution. The first control measure, Public Education and Outreach, is the most relevant to this stormwater education project. This control measure mandates the implementation of educational programming that increases stormwater knowledge and facilitates behavior change amongst the public (U.S. EPA, 2016). The educational programming must target four audiences, including residents, commercial businesses, developers, and industrial facilities, and convey a least two educational messages per audience within five years. The permit also mandates that municipalities evaluate the effectiveness of the educational programs (U.S. EPA, 2016). Despite establishing these aforementioned requirements, the MS4 Permit does not identify educational methods that are effective at facilitating environmental behavior change.

The Guide to Effective Education

The Public Education and Outreach control measure seeks to promote pro-environmental behavior through stormwater education. Pro-environmental behavior, which refers to deliberate actions that aim to minimize environmental impacts of the Anthropocene, may not be easily incited through traditional education according to Anja Kollmuss and Julian Agyeman (Kollmuss and Agyeman, 2002). At the time of their publication, Kollmuss and Agyeman were Environmental Policy professors at Tufts University whose work compiled and analyzed over 30 years of environmental psychology. Based on their work, any educational program that uses traditional behavioral models may not be effective for facilitating pro-environmental behavior.

According to traditional models, environmental knowledge is the main influencer of behavioral change as shown in **Figure 3**. However, this line-

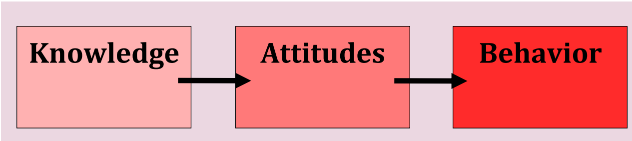

Figure 3: *Traditional Behavior Model (adapted from Kollmuss & Agyeman, 2002a)*

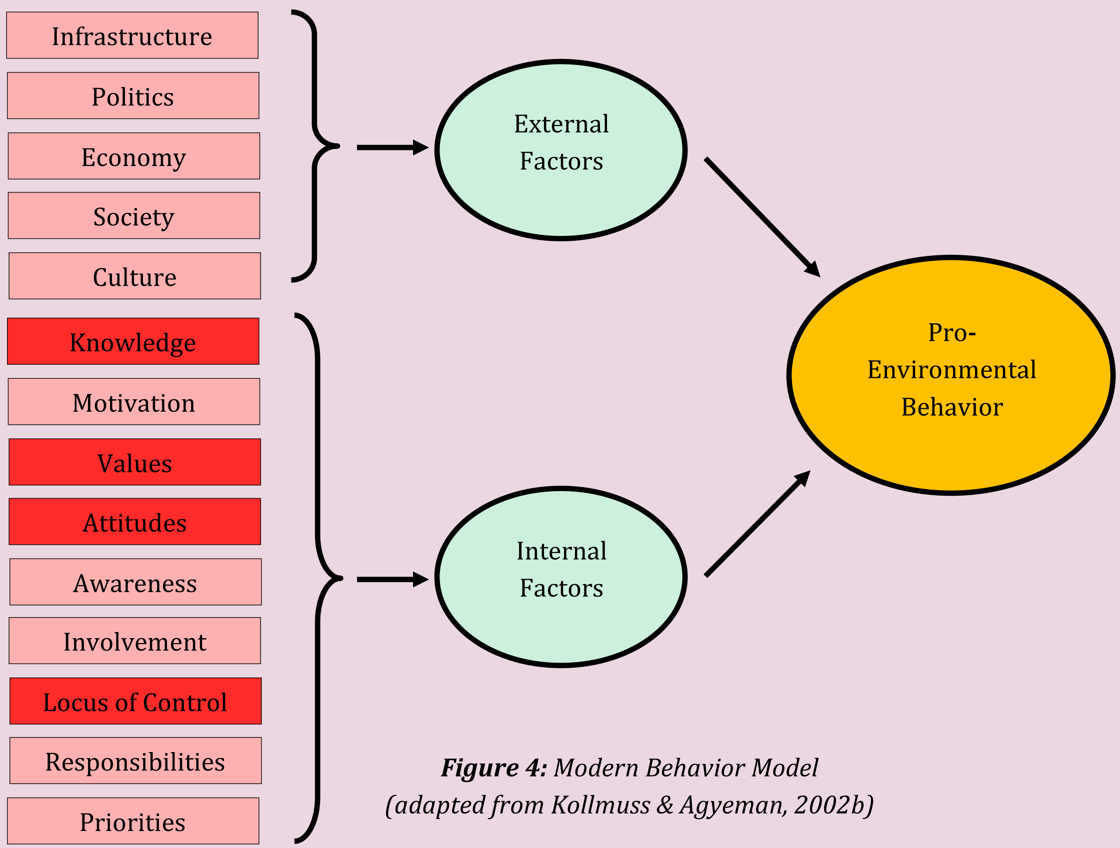

***Figure 4:** Modern Behavior Model (adapted from Kollmuss & Agyeman, 2002b)*

ar model was disproved when Kollmuss and Agyeman found that increases in knowledge did not directly increase pro-environmental behavior (Kollmuss & Agyeman, 2002). The discovery of this disconnect between environmental knowledge and behavior led to the development of more complex behavior models presented in **Figure 4**.

This model establishes a variety of external and internal factors that influence pro-environmental behavior. However, a synthesis of two additional environmental psychology studies* revealed four prerequisites for pro-environmental behavior: knowledge about the environment, possession of a locus of control, integration of values, and positive attitudes. Since an individual cannot act on an issue they are unaware of, *knowledge* is the first prerequisite for behavioral change (Hungerford & Volk, 1990). Secondly, a *locus of control* is the belief that an individual's actions may have a meaningful impact on a situation (Kollmuss & Agyeman, 2002).). Third, personal *values* are tied to intrinsic motivation, therefore any cause that aligns with an audience's values has the capability to motivate the audience into action (Hungerford & Volk, 1990). Lastly, positive *attitudes* influence individuals to be overall more willing to participate (Hungerford & Volk, 1990). Any educational program that seeks to facilitate pro-environmental behavior will need to incorporate these four prerequisites.

Current stormwater education programs consist of handbooks and outreach programs. In **Table 2,** we compare the ability of educational handbooks and outreach programs to satisfy the four prerequisites for effective environmental education. While stormwater handbooks are effective at spreading stormwater knowledge, our team determined they do not satisfy the other three prerequisites that lead to behavioral change. On the other hand, outdoor outreach programs were determined to be effective in satisfying these three remaining prerequisites. Furthermore, the overall effectiveness of outdoor outreach programs was proven by Louise Chawla, an professor of Environmental Design at the University of

**Two additional studies included Hungerford & Volk, 1990 and Chawla, 1999.*

Colorado Boulder, in 1999 when she concluded that outdoor experiences are the primary motivation behind pursuing environmentalism as a career. Based on the results in **Table 2**, an educational approach that pairs a stormwater handbook with an outdoor education program would satisfy the four core factors that influence behavioral change: knowledge, locus of control, values, and attitudes.

The added benefit of moving away from traditional educational methods is the ability to cater to a wider audience. The traditional approach of spreading knowledge and awareness does not resonate with audiences who speak English as their second language (ESL) or require special education. In order to be compatible with ESL and special education audiences, educational approaches must draw upon three tenants: literacy, culture, and motivation (CAPELL, 2011). The incorporation of these three tenets into the handbook and outdoor program will connect with the values and inspirations of a wider audience than traditional knowledge-based education.

Fitchburg, Massachusetts

Fitchburg is a medium sized city of 40,414 residents located 46 miles northwest of Boston (U.S. Census Bureau, 2016). The main waterbody in Fitchburg is the North Nashua River, which gave rise to early milling industry in the 19th century. The city is characterized by a diverse population of residents resulting from migration events during the industrial revolution. Immigrants came from countries such as Ireland, Italy, Finland, Germany, England, and Canada and settled into ethnic neighborhoods that remain prevalent today (City of Fitchburg Master Plan, 2017). Over the past decade Fitchburg has been further diversified by Hispanic, African American, and South East Asian residents. Based on the 2010 Census minority groups account for almost 22% of Fitchburg's population (Fitchburg, Massachusetts Population, n.d.). In addition to a diverse community Fitchburg is characterized by a relatively low income per capita when compared with regional and State averages. As stated by the Fitchburg 2020 committee, many ethnicities have a lower income per capita than the surrounding Fitchburg-Leominster area and state averages (City of Fitchburg Master Plan, 2017).

Figure 5: *Fitchburg, Massachusetts (Mass.gov)*

Table 2: *Analysis of Stormwater Handbooks and Outreach Programs*

Approach	Knowledge	Locus	Values	Attitudes
*Handbooks**	Yes	Somewhat	No	No
*Outreach Programs***	Somewhat	Yes	Yes	Yes

**Handbooks for analysis included Burton & Pitt, 2002; Mays, 2001; and Erickson et al, 2013.*
***Outreach Programs for analysis included Nashua River Watershed Association Programs, City of Fitchburg DPW "Rain Garden Workshop", and Boston Water & Sewer Commission Stormwater Curriculum*

Fitchburg Public Schools (FPS) has a unique population of students, as reported in **Table 3**. Approximately two out of three students come from low income families, a third of students reported English as a second language, and more than one in five students require special education services (Mass. Dept. of Elementary & Secondary Education, 2011). Additionally FPS face a high turnover rate of new students, where an average of 300 transient and homeless students leave the district by the end of every academic year (Mass. Dept. of Elementary & Secondary Education, 2011). Therefore Fitchburg students may require more specialized academic programming than students within other Massachusetts municipalities.

The proximity of Fitchburg to the North Nashua River allowed industry to thrive in the 19th century, but also led to the impairment of the river. Despite significant water quality improvements made during the 20th century, water quality within the North Nashua River still remains an issue for the City of Fitchburg. In 2012, Fitchburg was issued a federal consent decree from the U.S. EPA that mandated the water quality be improved in the river. In 2016, Fitchburg experienced increased stormwater volumes that overwhelmed the city's wastewater treatment plant, resulting in the discharge of 8.5 million gallons of sewage into the North Nashua River. As a result, Fitchburg has been fined multiple times by the U.S. EPA for violations against national stormwater policies (Erickson, 2016). In 2017, the Massachusetts Department of Environmental Protection conducted a study showing that the river is still impaired by E. coli and excess phosphorus (Erickson & Edwards, 2018). Due to the consent decree and the level of impairment of the river, the Fitchburg Department of Public Works (DPW) is seeking to reduce runoff volume and improve stormwater quality to save the North Nashua River from further U.S. EPA violations.

Table 3: *Demographics of Fitchburg Public Schools*
(Mass. Dept. of Elementary & Secondary Education, 2011)

Selected Populations	Number	District %	State %	Enrollment by Race/Ethnicity	Number	District %	State %
Total enrollment	**4,881**	**100.0**	--	African-American/ Black	330	6.8	8.2
First Language not English	1,544	31.6	16.3	Asian	279	5.7	5.5
Limited English Proficient*	606	12.4	7.1	Hispanic/Latino	2,062	42.2	15.4
Special Education**	1,067	21.4	17.0	White	1,985	40.7	68.0
Low-income	3,316	67.9	34.2	Native American	4	0.1	0.2
Free Lunch	2,792	57.2	29.1	Native Hawaiian/ Pacific Islander	2	0.0	0.1
Reduced-price lunch	524	10.7	5.1	Multi-Race, Non-Hispanic	219	4.5	2.4

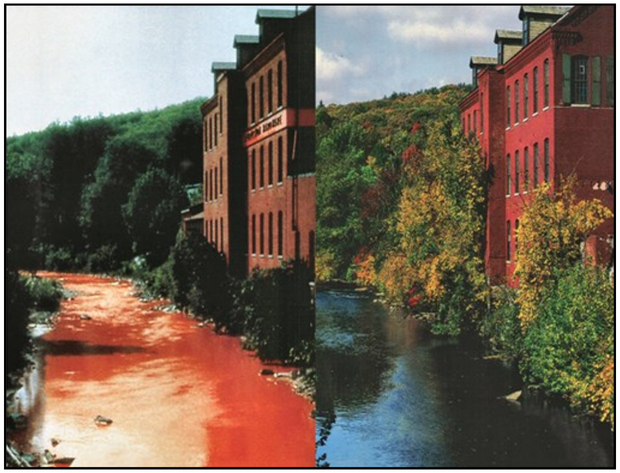

Figure 6: *North Nashua River during 1960s (left) vs 1980s (right)*
(Nashua River Watershed Assoc.. Archives, 2012a)

Project Goal

This project sought to assist the Fitchburg DPW and FPS in compliance with the MS4 Permit's Public Education and Outreach minimum control measure. The project goal was to develop a Stormwater Education Program that satisfied the requirements of the MS4 Permit's first control measure while also having high student and teacher usability. The program serves to empower, motivate, and spread awareness among students to create a generation of "community scientists" who are stakeholders in the future of their environment.

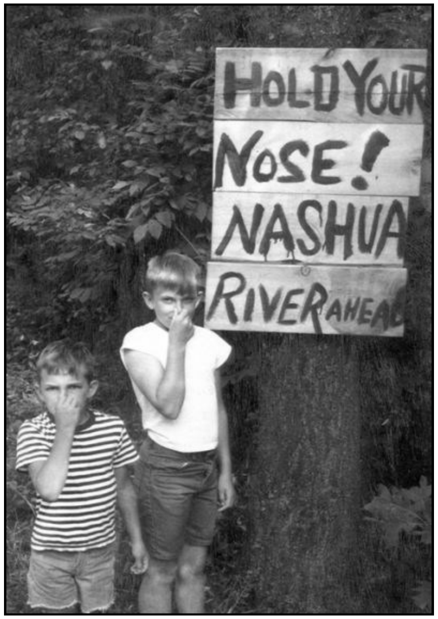

Figure 7: *Kids Near North Nashua River (Nashua River Watershed Assoc.. Archives, 2012b)*

Methods

The goal of this project was to assist the Fitchburg DPW and FPS comply with the Public Education and Outreach control measure identified in the 2016 MS4 Permit. In order to tackle this goal, we broke our approach into three phases indicated by **Figure 8**: Preliminary Research, Development, and Revision & Implementation. Each of the phases consisted of two objectives as shown by **Figure 9**. We discuss each objective below.

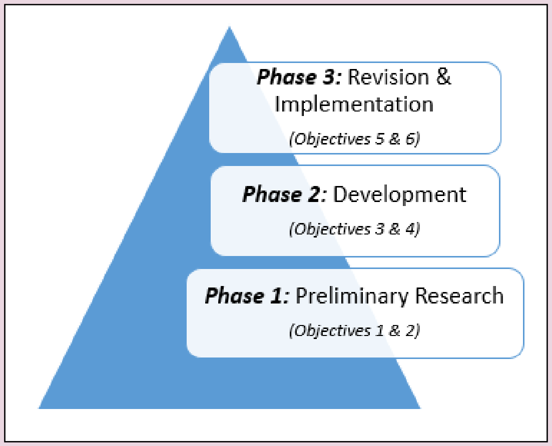

Figure 8: *The Three Phases*

Phase I: Preliminary Research

The first step to creating the Stormwater Program was understanding curriculum requirements and the MS4 Permit. To create an educational program that aligned with FPS curriculum, the team began analyzing the 2016 Massachusetts Science Technology and Engineering (STE) Framework. Our team performed independent research of the STE Frameworks for Grades 5, 6,

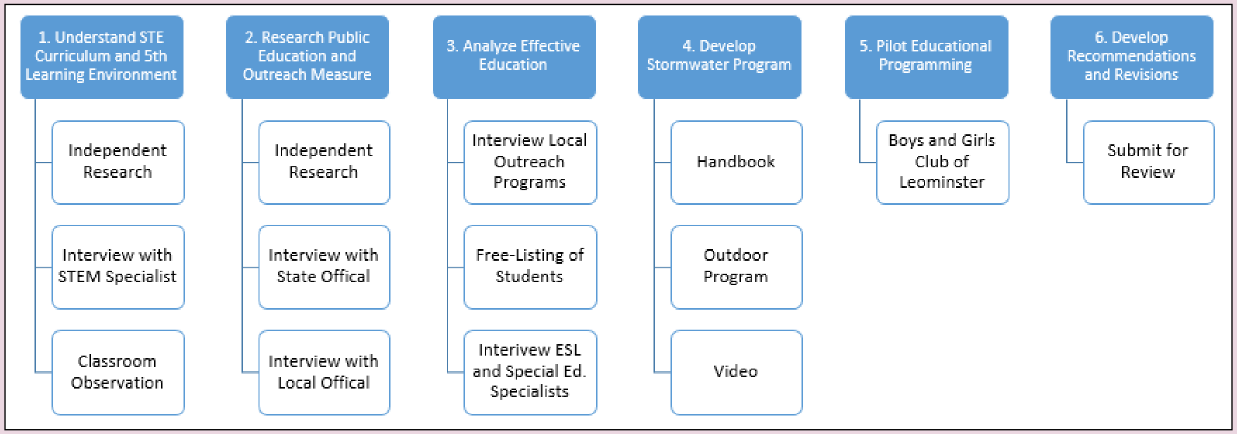

Figure 9: *The Six Objectives*

Figure 10: *STEM Logo*
(Fitchburg Public Schools, 2018a)

and 7. We conducted additional research of the STE Frameworks through a semi-structured interview with Ms. Jessica Stodulski, the STEM Specialist for FPS. After compiling the results of the interview and independent research, the team determined that the fifth grade was the optimal age for the Stormwater Education Program.

Next, we analyzed the STE classroom environment through direct observation. Direct observation is commonly used within schools to evaluate classroom environments and teacher-student interactions, and therefore was effective for our needs (Stuhlman et. al, n.d.). We observed one Advanced Academic Learning Initiative (AALI) class at McKay Elementary School for 60 minutes without any interactions with the teachers or students. This specialized class was strictly STE-focused and consisted of 15 fifth and sixth grade students. Team members recorded observations of teaching and learning styles in an observation matrix and supplementary field notes.

Our team then conducted research on the 2016 MS4 Permit, focusing on the Public Education and Outreach control measure. In addition to analyzing the permit, we team conducted semi-structured interviews with Mr. Fred Civian, Stormwater Coordinator for the Massachusetts Department of Environmental Protection (MassDEP) and Nick Erickson, a Civil Engineer for the Fitchburg DPW to gain statewide and local perspectives on the permit.

Upon completing the two objectives in Phase I, we compiled all of the data produced by direct observations, content analysis and interviews. We then converted the data into individual line items, and proceeded to group similar line items into categories (Berg & Lune, 2012). We lastly extracted themes based on similarities between the categories. Through this analysis we began to understand the relationship between the 2016 STE Frameworks and classroom teaching methods, as well as the specific educational messages required by the MS4 Permit.

Phase II: Development of Effective Stormwater Program

The focus of the second phase was to develop an effective Stormwater Education Program for FPS. Prior to development, the team interviewed seven environmental outreach organizations in order to understand how to effectively conduct an educational program. We selected the outreach organizations through an online search of environmental groups around Worcester County. We interviewed seven directors and educational specialists from the seven organizations listed in **Table 4**. The team conducted semi-structured interviews with each organization to identify social, environmental, and local indicators of the program's success such as changed behavior in students, cost-effectiveness, and changes in the local environment (U.S. EPA, 2010).

Table 4: *Outreach Organizations Interviewed For Phase II*

Outreach Organizations
Boston Water and Sewer Commission
Massachusetts Audubon
Massachusetts Department of Environmental Protection
Massachusetts Watershed Coalition
Montachusett Opportunity Council
Nashua River Watershed Association
Town of Franklin Department of Public Works

The team additionally interviewed the English Language Learner (ELL) Director and a Special Education Specialist within FPS. Semi-structured interviews with Bonnie Baer-Simahk and Kristin Gallo, respectively, informed the team of the best methods for teaching to the student demographics of FPS. Using the same analysis method described in Phase I, our team was able to identify environmental teaching methods proven to cater to ELL and Special Education students.

We used the collective findings from Phase I and II to design a Stormwater Education Program for fifth graders within FPS. This program consists of three components: 1) a Student Workbook; 2) an Educator Resource Guide; and 3) an educational video. We designed each of the three deliverables to satisfy requirements of 2016 STE Frameworks as well as the 2016 MS4 Permit explored in Phase I, and to incorporate the effective education elements identified in Phase II.

Phase III: Implementation & Revision of Stormwater Program

Once our team created the Student Workbook, Educator Resource Guide, and educational video, the focus shifted to implementation. The team piloted an informal education lesson as well as several hands-on activities at the Fifth Annual Central Massachusetts Science Festival held at the Boys and Girls Club of Fitchburg and Leominster. In addition, the team unveiled the resources to a focus group of fifth grade teachers. Based on the written and verbal feedback received from the pilot and focus group, the team went through multiple iterations of the Student Workbook, Educator Resource Guide, and educational video until the project sponsors were content with the deliverables. Finally, the team presented the materials to the Fitchburg DPW and FPS. These presentations highlighted that the materials met the requirements of the Public Education and Outreach control measure as well as the STE Frameworks. Once we received collective support from the Fitchburg DPW and FPS, we shared the finalized deliverables with the project sponsors.

Figure 11: *Pilot at Boys and Girls Club Science Festival*

Findings & Deliverables

Throughout this project we worked to create a Stormwater Education Program that empowers and educates fifth grade students within large, diverse, and urban school districts. The common thread within our deliverables was to develop material that helps students from urban areas become "community scientists" and stakeholders in the future of the environment.

Throughout this project, we learned that schools in low-income cities, such as Fitchburg face many challenges when implementing new science programs. An interview with Jessica Stodulski, the Fitchburg District STEM Specialist, revealed that teacher and student turnover rates as well as strict time constraints due to standardized test preparation make it difficult to implement new programming (Personal Communication, March 12, 2018). Additionally, fifth grade teachers spend valuable time backtracking to address gaps in student background knowledge (J. Stodulski, Personal Communication, March 12, 2018). Finally, Bonnie Baer-Simahk, the Director of ELL for FPS, stated that many of the 700 ELL students within Fitchburg struggle with academic subjects, including math and science, due to language barriers (Personal Communication, March 30, 2018).

Due to the challenges facing teachers and students, our team focused on supporting both the

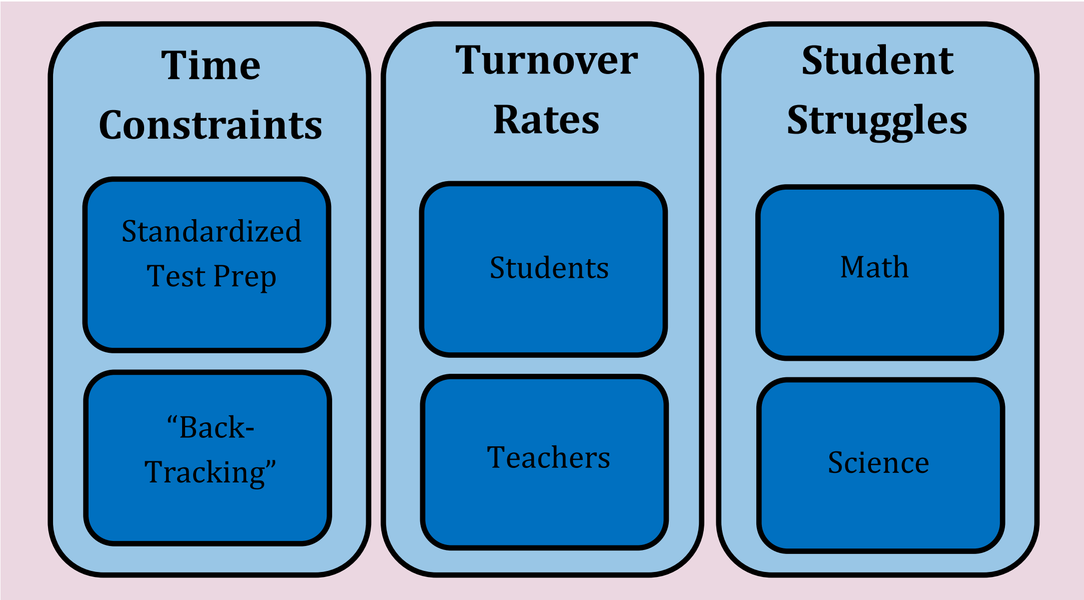

Figure 12: *Main Obstacles Facing Diverse, Urban Schools*

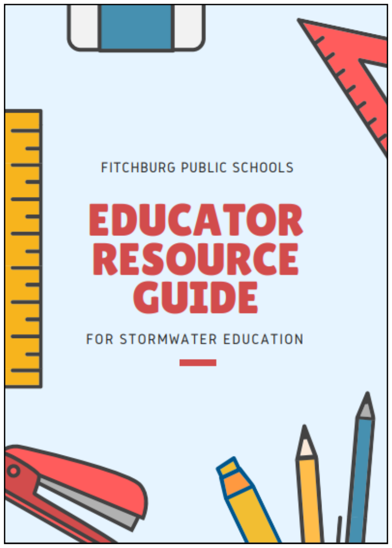

Figure 13: *Educator Resource Guide Cover Page*

diverse students of FPS, as well as the hardworking educators. Our team developed an **Educator Resource Guide** to support teachers and a separate but parallel **Wild About Water Student Workbook** to support students. In the following sections we describe the components of each deliverable and how each support their intended audience.

Educator Resource Guide

Prior to the development of the Educator Resource Guide, the team found there was a high need for educator support within FPS. In an interview with Jessica Stodulski, we found that science educators are responsible for developing their own lessons and units (Personal Communication, March 12, 2018). Although many educators share lessons with one another or find premade units online, our research found that this responsibility, in combination with tight time constraints and frequent reviewing of material, creates stress for teachers. In order to alleviate some of these stressors, we developed the guide to include five components: 1) Curriculum Guide, 2) Community Resources Index, 3) Educational Support Index, 4) Lesson Development Index, and 5) Outdoor Activities Index.

Curriculum Guide

The development of the Curriculum Guide was centered on the aforementioned finding that **educators face a heavy time constraint due to standardized test preparation and frequent material review** (J. Stodulski, Personal Communication, March 12, 2018). As a result, educators need to be able to maximize their time by identifying which units and activities satisfy specific STE Frameworks, as well as Science and Engineering Practices. We therefore created a Curriculum Guide that is to be used in parallel with the Student Workbook and the educators' individualized lesson plans. This Curriculum Guide allows educators to maximize their time by concentrating lesson plans around specific Science and Engineering Practices and state STE Frameworks. Furthermore, the Curriculum Guide allows educators to identify what components of the student workbook are most relevant to their specific classroom needs.

Community Resources Index

When designing the second component of the Educator Resource Guide, the Community Resources Index, we focused on identifying local programs that could benefit students in classrooms. Through interviews with seven outreach organizations, we found that these organizations offer programs for students about environmental science and water education. For example, the Nashua River Watershed Association (NRWA) offers a program called "Scientists in Residence". As part of this program, an educational specialist from the NRWA leads a series of hands-on, science workshops with students in outdoor and indoor settings (Martha Morgan, Personal Communication, March 21, 2018). However, we were told that the **FPS have a "spotty connection" with local outreach organizations** (J. Stodulski, Personal Communication, March 12, 2018). The primary reason why outreach programs have not spread to all schools in Fitchburg is because teachers are not aware of the organizations or the programs offered (J. Stodulski, Personal Communication, April 25, 2018). In order to foster a stronger connection between FPS and local outreach programs like the NRWA, we provided an index of local outreach organizations that offer opportunities for students to learn about local ecosystems, green infrastructure, and other topics relating to stormwater runoff. With this index, educators will be more aware of local outreach organizations and hopefully will contact these organizations for field trips and guest lectures, or encourage students to take advantage of these opportunities during their free time.

The NRWA is a local non-profit organization in Fitchburg that works to protect the natural ecosystem of the Nashua River and preserve clean water for human and wildlife communities. The Nashua River Watershed Association was founded in 1969 on the belief that every individual has the power to make a difference. That belief led to the clean-up of one of the nation's most polluted rivers, an internationally recognized success story.

The NRWA provides many different programs and educational opportunities for the students of Fitchburg such as:

- Scientists-in-Residence
- The River Classroom
- Wild World of Water

NASHUA RIVER WATERSHED ASSOCIATION

Many of these programs are ESL accessible. For more information contact:

Stacey Billings Chilcoat
NRWA Education & River Classroom Director
Nashua River Watershed Association
592 Main Street, Groton, MA 01450
Phone: 978-448-0299
Email: StaceyC@nashuariverwatershed.org

Figure 14: *Community Resources Index*
Image: NRWA Logo
(Nashua River Watershed Assoc. Archives, 2012c)

Educational Support Index

The third component of the Educator Resource Guide consists of a network of environmental and educational specialists. We found that it would be beneficial for educators if they were **provided an index of contacts for local environmental experts and educational specialists to help guide their individualized curriculum development**. We therefore designed this Educational Support Index to assist educators directly in their professional development, and included professionals such as Frederick Civian, Stormwater Coordinator for Massachusetts, Jessica Stodulski, STEM Education Specialist for FPS, and Bonnie Baer-Simahk, ELL Director for FPS. This resource will help FPS educators develop a network of educational specialists, environmental professionals, and leaders in environmental education that may help them develop or implement the Stormwater Education Program.

Table 5: *Educational Support Index*

Jessica Stodulski *STEM Specialist*	**Bonnie Baer-Simahk** *ELL Director*
Kristin Gallo *Special Ed. Educator*	**Fred Civian** *Stormwater Coordinator*

Lesson Development Index

The last component of the Educator Resource Guide, the Lesson Development Index, was developed to provide teachers with classroom activities and lessons. Based on an interview with Jessica Stodulski, our group found that FPS is currently in the process of developing lesson material that adheres to the 2016 STE Frameworks. Until the district is able to fully develop these materials, **educators within FPS rely on open-source websites to develop curriculum** (Personal Communication, March 18, 2018). To assist educators in the creation of effective stormwater education, we developed an index including a variety of stormwater education resources described in **Figure 15**.

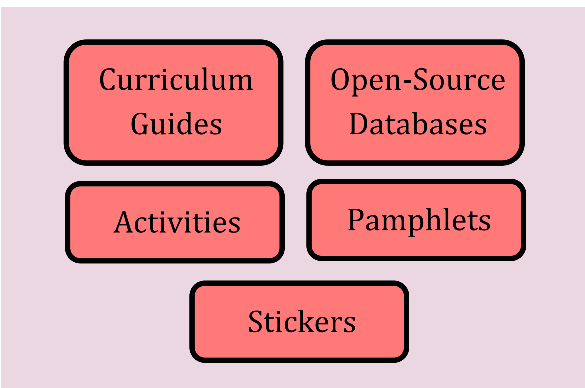

Figure 15: *Lesson Development Index*

Outdoor Activities Index

The final component to the Educator Resource Guide was an Outdoor Activities Index. This index is a list of hands-on outdoor activities that teachers can use to extend stormwater learning beyond the classroom and into the outside environment. Throughout our research, we found that **experiential outdoor activities are effective with satisfying the first Science and Engineering Practice**. This practice, as put forth by the 2016 STE Frameworks, requires students to develop questions about nature, and in interviews with Lisa Carlin of Mass Audubon and Martha Morgan of the River Watershed Association revealed that outdoor education stimulates investigation of natural phenomenon (Personal Communication, March 16 and 21 respectively, 2018).

Secondly, we found that **hands-on, outdoor activities cater to ELL students**. Kristin Steinmetz, an Education Coordinator for Mass Audubon, explained that ELL students benefit from her outdoor programs because "hands-on learning...is universal" and there are no language barriers associated with this type of learning (Personal Communication, March 22, 2018). The benefits of outdoor learning also extend beyond ELL students. Ms. Steinmetz reflected that all students, even those with behavioral issues, become "happy" and react positively to outdoor activities within the sanctuary (Personal Communication, March 22, 2018).

Finally, we found that **students have increased interest in science when provided with hands-on activities**. Our team's observations of the AALI class at McKay Arts Academy revealed the students' strong interest for hands-on learning. During this class, 15 students worked in teams to build and program robots. Observers rated student involvement on a scale from one to five, with one representing "minimal involvement" and five representing "exceptional involvement". The AALI class received a mean score of 4.5 for student involvement, and this score was directly attributed to the hands-on building and programming of the robot. Based on our observations, hands-on activities have the potential to keep students fully engaged in experimentation and learning with minimal teacher instruction or supervision.

For the above reasons, we found it mutually beneficial for the students and educators to incorporate hands-on, outdoor activities within the Educator Resource Guide. Not only does hands-on outdoor learning help satisfy the statewide curriculum, but it caters to non-native English speakers and stimulates the interest of all students.

Student Workbook

Prior to the development of the "Wild About Water" Student Handbook, our team found that **fifth grade was the most optimal grade for the implementation of a stormwater program**. Preliminary research of the STE Frameworks and initial meetings with Jessica Stodulski revealed that fifth grade was the most optimal grade for a stormwater program (Personal Communication, March 12, 2018). The fifth grade STE Framework requires students to model the water cycle as well as gather information about ways communities can reduce human impact on the environment (Mass. Dept. of Elementary and Secondary Education, 2016). These fifth grade science standards are natural parallels with stormwater runoff education. Furthermore, survey responses from 70 Fitchburg fifth grade students revealed that 79% of fifth graders have not heard of the term "stormwater", as shown in **Figure 16**. The overlap between the STE Frameworks and the students' unawareness of stormwater created the "perfect storm" for the implementation of a stormwater program within fifth grade (Paula Giaquinto, Personal Communication, February 12, 2018).

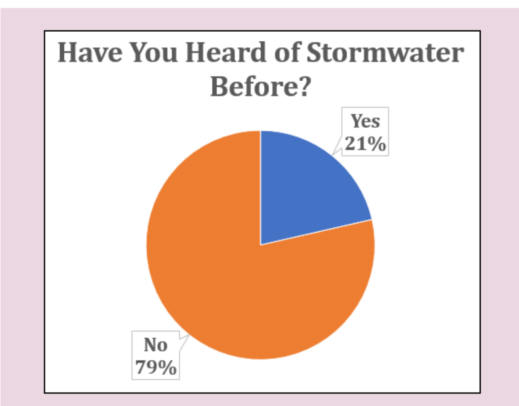

Figure 16: *Student Unawareness of Stormwater*

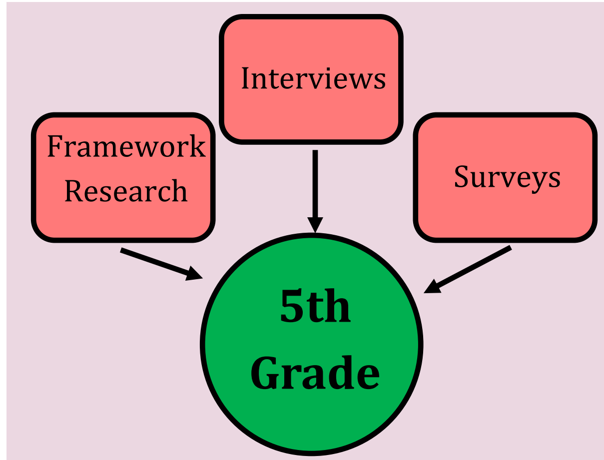

Figure 17: *Determination of Most Optimal Grade*

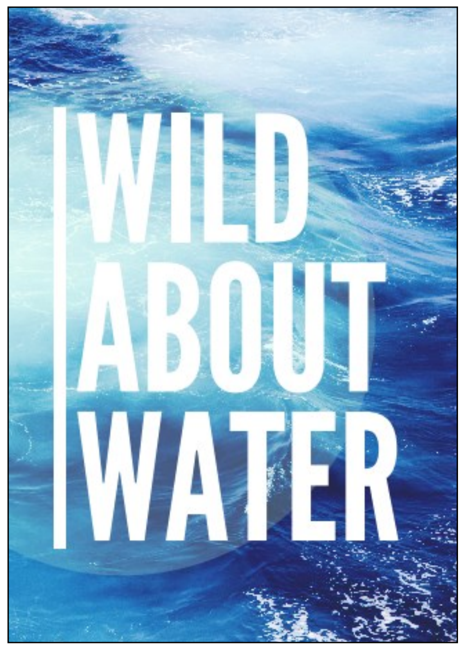

Figure 18: *Student Workbook Cover Page*

We created the Student Workbook in a manner that made it accessible to all demographics. We also developed the Student Workbook so it satisfies a variety of educational and environmental standards. In order to achieve these objectives, we developed the Student Workbook to have three components: 1) Accessible Vocabulary, 2) Interdisciplinary Chapter Content, and 3) Critical Thinking Activities.

Accessible Vocabulary

In order to create an educational program that caters to the maximum number of students, the team designed the Student Workbook with Accessible Vocabulary. Stefanie Covino, Coordinator of Mass Audubon's Shaping the Future of Your Community Program, reflected to our group that the complicated, technical terminology used by stormwater professionals often inhibits public understanding. The simplification of terms like Best Management Practices and Low-Impact Development to "Stormwater Solutions" or "Nature-Based Solutions" would facilitate much easier public understanding of stormwater basics (Personal Communication, March 16, 2018). Furthermore, Bonnie Baer-Simahk stated that "the complex vocabulary and sentence structures found in technical writing is new for most students, and is particularly challenging for English Language Learners" (Personal Communication, April 25, 2018). Therefore, this simplified terminology will better facilitate overall student comprehension of Student Workbook, especially for the large ELL student population in Fitchburg. Simplified terminology can be found within the vocabulary glossary located at the end of each chapter. If students are able to understand complex topics, then they will be able to share their stormwater knowledge with other residents and community members.

Best Management Practice (BMP): reduce the amount of pollution from s

stormwater solutions: An approach protects, restores, or mimics the natu

infiltration: The process of a liquid b

rain gardens: A modified landscape

Figure 19: *Sample Vocabulary Glossary*

Interdisciplinary Chapter Content

When creating chapter content, we focused on aligning the content with the eight Science and Engineering Practices and the 2016 Massachusetts STE Frameworks. Our group learned that the success of any educational program within FPS is dependent on its adherence to these state standards (Jessica Stodulski, Personal Communication, March 12, 2018). Consequently, we developed chapter content that followed Massachusetts State STE Frameworks and the Science and Engineering Practices. However, it was essential that the chapter content was also interdisciplinary, combining math, science, and creativity. Lisa Carlin, an Assistant Sanctuary and Camp Director for Mass Audubon, conveyed that **teachers are more inclined to use interdisciplinary lessons** because these lessons help them satisfy their curriculum standards faster (Personal Communication, March 16, 2018). In order to help teachers satisfy the greatest number of standards within the shortest time, we developed the Student Workbook content to be interdisciplinary: combining mathematical models, the scientific process, and creative ingenuity.

Critical Thinking Activities

The last component of the student workbook is a collection of hands-on, cooperative, and visual activities that engage the critical thinking abilities of students. During an observation of Kim Heymann's AALI class at McKay Arts Academy, we became aware of the benefits of critical thinking activities. **When given the opportunity to critically explore and experiment independently, students within her class became fully immersed in their work,** and retained the most knowledge. Furthermore, a later interview with Kim Heymann revealed that **students within FPS struggle with critical-thinking**. Kim stated that "getting students to experiment and inquire in a group setting is a great way to improve [the students'] critical thinking abilities" (Personal Communication, March 28, 2018). For these reasons, we included group-focused problem-solving activities at the end of each chapter of the workbook to strengthen students' critical thinking and increase student involvement.

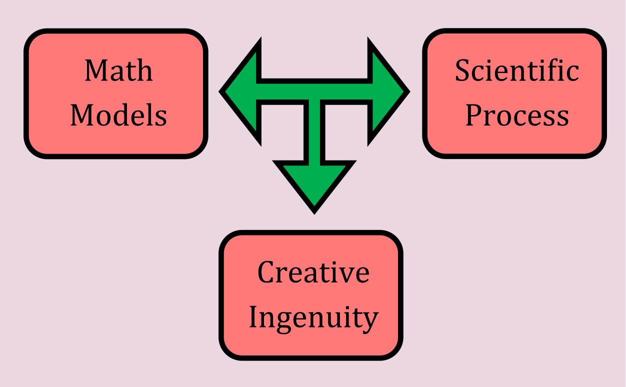

Figure 20: *Interdisciplinary Chapter Content*

Educational Video

The third and final resource we developed for FPS is a short educational video. This video is intended to provide basic stormwater knowledge as well as inspire students to become stewards of environmental responsibility within their community. Prior to the development of the video, Jessica Stodulski reflected to our group that **Fitchburg students often have limited access to diverse and relatable role models within the STEM field** (Personal Communication, March 27,2018). Consequently, the team's focus became developing a video that would provide the students with local stormwater role models. The video is centered around a character named "Runoff Randy". Randy is "The Original Rain Wrangler" and educates the students about runoff in an entertaining, Bill Nye-fashion. Within the video, Randy interviews three members of Fitchburg High School's "Envirothon" team about environmentalism. The inclusion of these high school students provides the fifth graders with young, local role models that the fifth graders can aspire to be. The "Envirothon" team is active within the local Fitchburg community, and the younger students would benefit largely from future collaboration with the team.

Recommendations & Conclusions

If the Fitchburg Public Schools and Department of Public Works continue to pursue this program, we offer the four following recommendations .

1. *We recommend that FPS implement this program in fifth grade science classrooms district wide.* The program is consistent with the Massachusetts STE Frameworks, is engaging for students, and provides extensive supporting resources for educators. As a result, the program is well-suited for district-wide and future statewide implementation.

Figure 21: *Fitchburg Public Schools Logo (Fitchburg Public Schools, 2018b)*

2. *We recommend that the Fitchburg DPW develop on-site Green Infrastructure features for McKay Arts Academy, Longsjo Middle School, and Memorial Middle School.* These features would serve as "outdoor learning laboratories" promoting hands-on, outdoor environmental learning opportunities. As shown in the Findings section, tactile learning in an outdoor environment holds a number of benefits for students and educators alike.

3. *We recommend that science educators within FPS cultivate a closer relationship with local environmental outreach organizations.* Organizations like the Nashua River Watershed Association and Mass Audubon offer stormwater programs tailored for both ELL and native English speaking fifth grade students.

4. *We recommend that the ELL Department within FPS translates the Student Workbook and Educator Resource Guide into other languages.* Multilingual translations of the materials will increase accessibility to the significant ELL population within FPS.

During this seven week project, our team set out to develop a Stormwater Educational Program for immediate use within Fitchburg, a large, diverse, and low-income city in Massachusetts. We hope that the Stormwater Education Program will help the Fitchburg DPW satisfy the first minimum control measure of the 2016 MS4 Permit. This permit outlines a rigorous set of regulations and requirements that municipalities must meet before Summer 2018. Not only are municipalities facing financial obstacles, but many aren't equipped with sufficient personnel to take on such a demanding permit. As a result, we hope that the resources developed during this project will satisfy the MS4 Permit's first control measure and improve the City of Fitchburg's compliance with the permit.

Figure 22: *City of Fitchburg Logo (City of Fitchburg, 2018)*

In addition to benefiting the Fitchburg DPW, we hope that the Stormwater Education Program increases the ease with which urban schools can teach science to their diverse student population. It is our hope that these resources will spread awareness of stormwater runoff to the fifth grade students of FPS. Moreover, we hope these resources help FPS teachers to empower a generation of "community scientists" who are leaders of environmental responsibility and stewardship within their local community.

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