Rain or shine: Rainwater harvesting systems for dependable, safe drinking water in rural Guatemala

Project Report and Phase II proposal

P3 National Student Design Competition for Sustainability Focusing on People, Prosperity and the Planet

EPA Agreement Number: SU835508

Key contact:

Laureen Elgert, Asst Professor

Environmental and Sustainability Studies

Social Science and Policy Studies

Worcester Polytechnic Institute

Worcester, MA 01609

lelgert@wpi.edu

(508) 450 3313

III. Table of Contents

IV. Executive Summary

Date of Project Report: March 25, 2014

EPA Agreement Number: SU835508

Project Title: Rain or shine: Rainwater harvesting systems for dependable, safe drinking water in rural Guatemala

Faculty Advisor(s), Departments and Institutions:

- Faculty Advisor: Laureen Elgert, Environmental and Sustainability Studies, Worcester Polytechnic Institute
- Professional Advisor: Patricia Austin, P.E., Massachusetts Dept. of Conservation and Recreation Office of Watershed Management, West Boylston, Massachusetts.

Student Team Members, Departments, and Institutions:

- Michele Mensing, Mechanical Engineering & Physics, Worcester Polytechnic Institute
- Tom Moutinho, Biomedical Engineering, Worcester Polytechnic Institute
- Katie Picchione, Mechanical Engineering & Society, Technology, and Policy, Worcester Polytechnic Institute
- Tom Washburn, Civil Engineering, Worcester Polytechnic Institute

Project Period: 8/15/2013 – 8/14/2014

Description and Objective of Research:

The purpose of our project was to design and pilot-test a household rainwater harvesting (RWH) system to improve water security in rural Guatemala. Water security involves three dimensions: sufficient quantity to satisfy basic needs as locally defined; quality that is appropriate for different use (including potable water for drinking and cooking); and access to water by all households. In light of these three dimensions, our project objectives were:

Quantity

1. Sufficient rainwater to satisfy household needs is collected by the catchment system;

Quality

2. The quality of drinking water is improved through design features and shared learning between our team and the community;

Access

3. The catchment system uses appropriate technology, so that it can be affordably and locally repaired and maintained;
4. At least one person per household is trained in maintenance and repair of the catchment system;
5. The catchment systems are based on a flexible design that can be updated and adapted if household water requirements should change or rainfall should fluctuate; and,
6. A catchment system design process that can be implemented in other contexts where a sustainable water source is problematic.

We researched and designed RWH systems in two households in Guach Tuq, focusing on: system efficiency to maximize quantity of water collected; design features that improved water quality; and, local involvement in design and construction to promote homeowners' capacity to maintain the system over the long term, thereby assuring continued access. In addition to implementing RWH systems, we undertook extensive testing to compare the quality of water originating at different sources, and to assess the quality of water from the implemented systems. Finally, we conducted in-depth interviews with twelve households to gain a better understanding of how RWH systems could impact the social, economic and physical factors in household access to water.

Summary of Findings (Outputs/Outcomes):

QUANTITY

- **Average per person water consumption is ~44 liters/day**
- **Water storage capacity was increased to satisfy basic household needs**

Through interviews we established that the average quantity of water required by each person in a household is 44 liters per day. Using a model previously developed by colleagues that incorporates variables such as roof area, system efficiency, average rainfall rates, and number of individuals in the household, the amount of storage necessary to provide the quantity needed was calculated. Through Phase I implementation, storage capacity was increased to meet household requirements at both homes.

Figure 1: Phase I implemented two-tank RWH system.

QUALITY

- **Three design features have improved water quality: netting, first flush and overflow**
- **Portable Microbiology Lab (PML) is a means of water quality testing in challenging environments**
- **Fewer bacteria and no E. coli detected in new tanks, but detected in other samples**

We found three design features to positively impact water quality and to be locally feasible and implementable. Netting secured over system openings filtered out leaves and other debris from entering the storage tank. A first flush system was designed to divert sufficient initial rainwater away from the tank in order to rinse potential contaminants from system surfaces before water collection in the tank. The water from the first flush is not 'wasted' but remains available for uses other than drinking and cooking. An overflow system that takes water from the bottom of the tank (rather than the top) promotes circulation of the tank water and expulsion of old, rather than fresh, water. We established that PML is a feasible way of testing water quality in rural, developing world contexts. The bacteria test can be incubated by 'wearing' it under clothing, and provides a good visual result so that it can be used to increase awareness of water quality in the community. The tests we conducted showed that water from the RWH systems we implemented had lower bacterial counts when compared to both existing RWH tanks and the natural spring source that many people depend upon extensively. One reason for the difference in bacterial counts may be the age of the existing tanks, but proper design is also a factor.

ACCESS

- **Individual RWH systems overcome geographical and social factors that reduce local access to clean water**
- **Local capacity to repair, maintain and adapt systems will promote ongoing access**

- **System cost is a significant barrier to universal access when scaling up RWH implementation regionally**

During interviews, important factors in water security included household location in the community (ranging from ¼-1 mile), competition with other households, and long waits at the natural spring source, particularly in the dry season. Bringing water to individual households addresses these factors by facilitating less time-intensive and more equitable access to water. Working closely with local people in design, re-design, and construction has built local capacity to maintain and adapt RWH systems according to local needs. Many of our original design features have been adapted to use locally available materials, such as replacing plastic gutter clips with wooden supports, and repairing and extending (as opposed to replacing) existing rooftops. The RWH systems have been implemented at a cost of around $900 each, the bulk of which reflects the cost of the water storage tanks. This high cost remains a barrier to access for most households in Guach Tuq and surrounding communities.

Conclusions and Recommendations:

Rainwater harvesting is an appropriate technology which has improved quantity, quality and access dimensions of water security in two households, and has the potential to do so on a wider scale. Benefits to people, prosperity and the planet have been realized in Phase I. **People** have greater access to water at their own homes and save between two and six hours daily by not having to walk to the spring and transport water back to their homes. The RWH systems also provide cleaner water in comparison to the spring, and it is reasonable to expect that this will result in a decline of waterborne diseases over time. RWH systems promote **prosperity** by allowing people to use time saved to pursue income generating activities, or to spend more time in studies and skill development. Once the systems are implemented using local materials, local capacity to maintain them will reduce dependence on outsiders to undertake costly repairs. Local people who have been working on implementation and construction also develop skills that they may apply to income earning opportunities in the future. The **planet** also benefits from these RWH systems by reducing the draw from the local spring (and therefore pollution of the spring that is a byproduct of use) and using considerably less energy than other water delivery mechanisms.

However, in local terms the existing system design remains expensive. The system needs to be constructed more affordably, with local materials, if it is to be more widely accessible. Furthermore, implementation is dependent on the presence of our team. We need to strengthen local capacity for implementation by continuing to work with stakeholders at multiple scales, such as the community-based water committee, local NGOs and the municipal government.

Several strategies have been integral to the success of Phase I and are recognized by our team as vital for ongoing work in scaling up RWH systems in rural Guatemala. First, our work has been characterized by collaboration, mutual learning and adaptive design. We have worked with local people, the end users of the RWH systems, from design to construction. They have learned from us about the principles of RWH and water quality. We have learned from them about construction techniques and local materials. This has led to adapting the original RWH system design to accommodate local contingencies and be more appropriate, usable and sustainable at the local level. Secondly, we have developed strong relationships and close partnerships with local individuals and institutions. We have had strong symbolic and material support in Phase I from CeCEP, a regional NGO; the Mayor of the Municipality of San Cristobal; and the Water Committee of Guach Tuq. Each of these entities has provided indispensable support and resources at various stages of Phase I. Thirdly, our diverse team has approached this project as an interdisciplinary endeavor. This has enabled us to understand the issue of water security broadly, and as a problem that entails social, economic and technical assessments and solutions.

Proposed Phase II Objectives and Strategies:
Phase II focuses on scaling up RWH system implementation to improve water security in Guach Tuq and more broadly in other communities of the San Cristobal Municipality. The proposed **goal of Phase II is to create and facilitate implementation of rainwater harvesting systems that can be built, used, and maintained by the typical Guatemalan family.** We will continue to work with local and regional stakeholders to:

1. **Refine the design of rainwater harvesting systems to optimize for cost**
2. **Expand the implementation to impact a greater portion of the population**

The above objectives will be accomplished over a two year period involving two, three week long trips to Guach Tuq, Guatemala. The success of Phase II depends on contributions from partners involved, including the NGO CeCEP, the San Cristobal Municipality, and the Guach Tuq Water Committee. Outlined below are the methods and tasks needed to accomplish the Phase II goal.

REFINE DESIGN

As identified during Phase I, the design for our current RWH system has not yet been optimized for low-cost, or maximizing incorporation of local materials and resources. For a typical family, the cost of materials and the knowledge needed to build a RWH is out of reach. To alleviate this issue, we will refine the RWH system design so it is financially feasible for families to purchase and build their own systems. Refining the design to optimize RWH systems involves:

- Research into alternative system designs and components used
- Implementation of refined design
- Evaluation of refined design

With affordability in mind, we aim to optimize three aspects of the system: storage tanks, gutters, and the first flush. Preliminary research conducted in Phase I will continue in Phase II to pilot local manufacturing of system components. All new design will be tested and constructed first on the WPI campus in the Civil Engineering labs, and once we are confident with design changes, will be implemented in Guach Tuq on two homes. As learned during Phase I, while the people of Guach Tuq may not have the background to design complete RWH systems, they are very skilled in construction techniques and Guatemalan home improvement with a variety of materials. Our contact at CeCEP will monitor the modified system's usage and report feedback so necessary design alterations can be made. During this implementation trip, meetings with the San Cristobal Municipality and local construction stores will be arranged to make preparations for the second objective: expand implementation.

SCALE UP OF IMPLEMENTATION

With reduced system cost through the refined design and increased local knowledge of system construction, our team's presence may no longer be essential to RWH system implementation. Our methods for scaling-up and expanding implementation are the following:

- Create a pictorial rainwater harvesting "handbook"
- Use San Cristobal Municipality as hub for education on RWH systems
- Demonstrate entrepreneurship opportunities to San Cristobal construction stores

The creation of a RWH "handbook" that is widely distributed will allow families in the area, with minimal background knowledge of RWH, to understand and build their own systems to secure sufficient water. In order to properly distribute knowledge about RWH, we will work with the San Cristobal municipality and their employees to develop an educational program to show local communities how to build RWH systems. This program will include building RWH systems for ten homes in the immediate area as a demonstration to educate others and to continue acquiring water security for local people. Finally, we will approach local San Cristobal construction stores with the idea of creating a RWH inventory section in their shop as a business idea.

Phase II Project Sustainability

The proposed goal of creating and facilitating wide-spread implementation of RWH systems in Guatemala addresses three platforms of sustainability: economic, social, and environmental. Economic sustainability is driven by and addressed in the first objective of refining the RWH design to optimize for cost. By investigating lower cost options, the upfront costs for the RWH system will be significantly lowered, increasing the affordability of the system. Social sustainability is achieved by greater regional equity in water security through the cost reduction, as well. Environmental sustainability is addressed through reduced dependence on ground water sources with RWH that has low energy requirements and uses locally available materials.

Publications/Presentations:

- We have been featured in several campus and alumni publications.
- We have been invited to give a presentation to Congressman Jim McGovern (Massachusetts 2nd District) and at an open house at WPI.
- Moutinho, T., Picchione, K. 2013. Rainwater harvesting in Guach Tuq, Guatemala, presentation at the Engineers Without Borders regional conference, Rutgers University, November 20-23, 2014.
- Austin, P., Elgert, L., Mensing, M. (In progress). *Conducting a Sanitary Survey in Rural Guatemala*, for the Journal of the New England Water Works Association.
- Picchione, K. 2014. *Water Security in Guach Tuq, Guatemala: A Socio-Political and Technical Issue,* presentation at Dimension of Political Ecology (DOPE), University of Kentucky, February 27-March 1, 2014.
- Picchione, K. (in progress). *Technical, social and political determinants of water quality,* for Undercurrents: the Undergraduate Journal of Development Studies.

Supplemental keywords: Water security, Rainwater harvesting; water quality tests; water quantity; water access; system design; evaluation; community ownership

Relevant Websites: http://users.wpi.edu/~ewbwpi/

V. Body of the Report

A. Summary of Phase I Results

1.0 Background and Problem Definition

The community of Guach Tuq, located in the outer reaches of the San Cristobal Municipality, Alta Verapaz, Guatemala, is home to over 200 people in 40 families. While many people in Guach Tuq lack the resources to meet their basic needs, they have unanimously identified inadequate access to sufficient, clean water as their greatest challenge. Our Phase I proposal focused on the problem of water scarcity. Through our work, we learned that water availability (ie: quantity) is one dimension of the larger problem of *water security,* which encompasses **quantity**, **quality** and **access**. While these dimensions are not mutually exclusive, we define them as: the amount of water available for use (quantity); the potability of drinking water (quality); and, the ability of people to claim rights to use of water (access).

People in Guach Tuq generally access water from two main sources, which each present challenges to water quantity, quality and access. During the rainy season (June to January), some families in the community gather water in **individual rainwater collection tanks**. In 2009, around one quarter of the families in Guach Tuq received rainwater harvesting tanks from the municipal government. Though these tanks have eased some of the community's water problems, not all families own a tank, and many of the systems fail to maximize rainwater collection. One of the problems with the government tank project is that consultants were hired to build the systems with minimal community involvement. Thus, local people did not learn the principles and techniques of constructing RWH systems and do not know how to repair or maintain them. Tanks are also difficult to clean and have become dirty over time, compromising water quality.

During the dry season (February to May), when little water collects in the RWH systems, the community relies heavily on the second water source: **a spring water diversion box** located approximately one kilometer downhill from the center of the community. The spring, the source of the water, is located on a private estate, which locals call the *finca*. Although privately owned, there is an unofficial arrangement that allows families to use the water. In 2006, the land owner and the families who live in the communities that access the spring (including Guach Tuq) agreed to construct a large concrete basin with adjacent concrete sinks that acts as a community space to wash clothing.

Access to the water is limited by physical distance from the homes to the spring. For the closest homes, one trip takes ten minutes. For homes at the furthest point of the community, over a mile from the spring and at the top of the hill, a trip to collect water can take an hour or more. Women and children, who undertake the water collection, have to make multiple trips each day.

The spring is located on private land, and access is tenuous for a number of reasons. One key access route to the spring water diversion box cuts directly through the private farm. Constant pedestrian traffic of community members through the property causes conflict, which has resulted in the land owner temporarily denying access. When conflicts have arisen, the landowner has threatened to divert the entire spring away from the reservoir that provides public access to the water source. Access can also be difficult because in the dry season, the flow at the spring is greatly reduced and does not provide enough water to meet community demand.

Women gather in the middle of the night to compete for access to the spring. There is also concern about the quality of the spring water. The spring is not well protected, and community members have reported incidence of water borne disease.

Improved rainwater harvesting (hereafter referred to as RWH) promises a means to overcome water insecurity in Guach Tuq and elsewhere in Guatemala and the developing world. RWH has attracted substantial attention in recent years, as a means of making water systems more available in developing countries. RWH is generally understood to consist of three basic components: the collection surface, the conveyance system, and the storage apparatus (Abdulla and Al-Shareef, 2009). A roof collects rainwater, the water is then channeled through the gutters and into storage tanks. Large RWH systems often provide water for community institutions, such as schools. An assessment of Guach Tuq led us to conclude that, because of physical and social characteristics of the community, a shared (or public) system is impractical and **individual RWH systems** for each home provide a more feasible solution.

2.0 Purpose, Objectives, and Scope

The Phase I goal of this project was to design a sustainable rainwater harvesting system that will enable rural families in remote areas to sustainably collect and store sufficient, potable rainwater during the rainy season, to satisfy household needs year round. Our goal remains unchanged, but after working with the community over the past year, it has evolved to incorporate a more comprehensive approach to water security. We have added an objective that explicitly addresses water quality and have related our original objectives to the three dimensions of water security: **quantity, quality** and **access.**

		PHASE I OBJECTIVES
Quantity	1.	Sufficient water to meet household needs is collected by the RWH system;
Quality	2.	The quality of drinking water is improved through design features and shared learning between our team and the community;
Access	3.	The RWH system uses appropriate technology, so that it can be affordably and locally repaired and maintained;
	4.	At least one person per household is trained in maintenance and repair of the RWH system;
	5.	The RWH systems are based on a flexible design that can be updated and adapted if household water requirements change or rainfall fluctuates; and,
	6.	An RWH system is designed that can be implemented in other contexts where a sustainable water source is problematic.

In close collaboration with homeowners, we designed and implemented two RWH systems, focusing on an efficient system design that maximized quantity of water collected and improved water quality. We addressed project sustainability and ongoing local access to rainwater by stressing collaboration and mutual learning. First, we listened to, and designed around, local ideas about needs and feasibility so that the systems were appropriate for local conditions. Secondly, we actively shared knowledge about design and construction, ensuring that local people have the ability to maintain, improve, and adapt their own systems.

3.0 Data Findings Outputs/Outcome

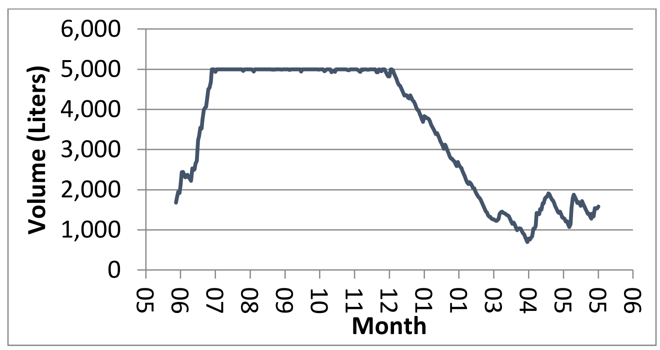
3.1 Quantity

- **Average water consumption per capita is ~44 litres/day**
- **Water storage capacity was increased to satisfy basic household needs**

Household water requirements and storage capacity needs cannot be standardized, as they are influenced by both regional and household variables (Campisano and Modica, 2012). We took several steps to ensure the RWH systems will provide adequate quantities of water for the two families in Guach Tuq who received RWH systems. We used a computational model developed by colleagues at WPI to calculate the storage volume and roof area necessary to supply each home with sufficient drinking water for year round access. This model uses several variables to predict the volume of water in the RWH tank(s) throughout the year. Variables include: 1) local rainfall data from the past 30 years, 2) household roof area, 3) storage volume, 4) number of family members, 5) efficiency of the system, 6) consumption rate. Figure 1 is a graph generated by the model that shows the volume of water available in the new tanks at House 27 throughout the year.

To design systems for the two homes that we implemented on during our trip, we used the model and data collected by WPI colleagues during a previous assessment of homes in the community. We acquired local rainfall data recorded at a nearby university. The efficiency of RWH systems is assumed to be 80%, a value suggested in Thomas & Martinson's Guide to RWH.

Figure 1: Average Predicted Volume of Water in House 27 Tanks



To estimate a water consumption rate, we used data collected during interviews with families on this trip and previous EWB trips. Calculated results can be seen in Table 1. In our model, we use a consumption rate of 12 [L/person/day]. The average cooking and drinking value, 6.8 [L/person/day], was roughly doubled to account for annual rainfall variation and increased usage due to increased availability. (Aladenola and Adeboye, 2010, Mwenge Kahinda and Boroto, 2007).

Activity	Liters/person/day
Drinking	3.23
Cooking	3.08
Average total	**6.81**
Bathing	11.3
Washing	25.2
Average	**37.0**
Average Total	**43.8**

We asked the familiess for input about the design of their system and constructed the systems alongside the community members. During contruction we both learned and shared knowledge about how the systems work.

The two families now have the capacity to store adequate quantity of water to meet their drinking and cooking needs year round. Each family's RWH system can hold up to 5,000L of water. Our model predicts that for a typical year, the families should not run out of water. With increased on-site storage capacity, they no longer need to travel to the *finca* as frequently, freeing up time for the women and children. With greater quantity of water available, water security has been improved for these families.

3.2 Quality

- **Three design features have improved water quality: netting, first flush and overflow**
- **Portable Microbiology Lab (PML) is a means of water quality testing in challenging environments**
- **Fewer bacteria and no E. coli detected in new tanks, but detected in other samples**

Rainwater harvesting provides cleaner water than surface runoff, which can be contaminated by land-use activities. Three design features further enhance the quality of water in the RWH systems: netting that covers all openings in the system to prevent mosquitos, a first flush, and an overflow that pulls from the bottom of the tank. As water flows from the gutters to the tank, it passes through a screen filter that catches large debris such as leaves and branches. Then, a first flush system diverts an initial amount of rain that carries contaminants from the roof and gutters, preventing dirty water from collecting in the tanks. Thus, only the water that runs through the pre-cleaned system is collected in the tanks. The overflow is designed to take older water from the bottom (as opposed to the top) of the tank, promoting refreshment and circulation.

A water quality testing program was developed and implemented on our trip. To yield valid results, most water quality tests require materials and laboratory space not typically available in developing countries. Working with our volunteer advisor, we first, unsuccessfully, reached out to local universities to use their laboratory space. We then contacted manufacturers of microbiological tests commonly used in the water industry and were referred to Dr. Robert Metcalf, (Cal State Sacrmento). Dr. Metcalf has developed a Portable Microbiology Lab (PML) used in many rural and developing areas. The PML provides material to collect and process water samples for two tests, Colilert® by IDEXX and Petrifilm™ by 3M. The two tests are specific for E. coli, which is an

accepted indicator for the presence of fecal contamination. The test can be run without an incubator by "wearing" the test for 18-24 hours to provide the necessary incubation. We tested the PML at WPI and compared duplicates that were incubated in a standard incubator to those worn at body temperture. We also ran duplicate samples and sent them to a Massachusetts state certified laboratory. In both cases there was excellent correlation, which gave us confidence in the test.

We collected, processed, incubated and read 75 samples, that were collected on 3 different days during our trip. We sampled:

- Rotoplas tanks installed by WPI colleagues in January 2013
- Government tanks (both Rotoplas and concrete; installed 5-7 years previous)
- Water from the *finca*
- Raw water and boiled water
- Public Water Supply samples from our homestays in San Cristobal.

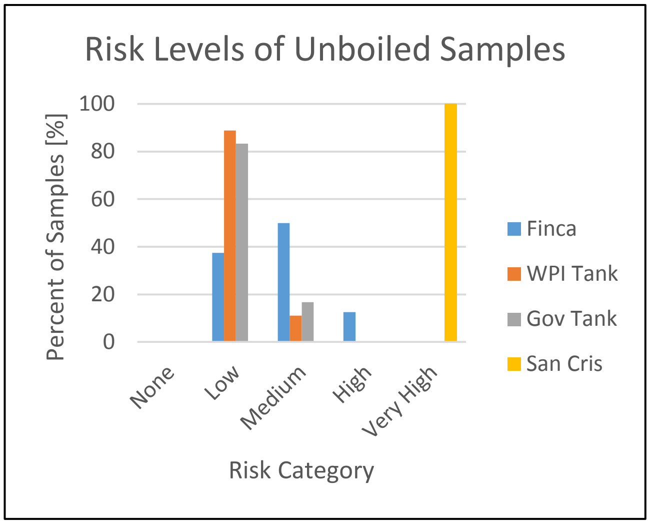
The test results provide a disease risk assessment of water sources as outlined by the World Health Organization's Guidelines for Drinking Water Quality (2004):

Table 2: Description of Criteria for Each Risk Level:

Risk Level	***E. coli* in sample**	**Colilert MUG+**	**# *E. coli* Colonies on Petrifilm**
Conformity with drinking water standard	0	-	0
Low	<1/10 ml	-	0
Moderate	1 -10/10 ml	+	0
High	1 – 10/10 ml	+	1-10
Very High	>10/10 ml	+	>10

All boiled samples, independent of source, had no presence of bacteria. To obtain boiled samples, we asked community members to boil the water in the same way they normally would to drink, which indicates that their method of boiling is effective in eliminating potentially harmful bacteria. All raw (not boiled) samples had traces of bacteria, with the *finca* samples typically posing a higher risk than samples collected from the EWB-USA WPI tank or government tank. The distribution of risk levels of all samples collected is shown in Figure 4.

Figure 4: Risk level of unboiled samples.



Sampling results were fairly consistent. Water quality of the WPI tanks was slightly better than that of the government tanks. The WPI tanks were installed more recently, and so had less time to accumulate debris and other material. In addition, the WPI RWH system was in much better condition than the government system. Many government tanks had openings that allowed leaf litter and other sources of coliform to enter the tank. We observed that most government tanks installed had various design issues, such as improper overflows or large unsealed openings that could be easily fixed to improve stored water quality. We plan to make these modifications in Phase II.

Finca samples were collected at the spring outlet. Low to medium levels of contamination were observed in the samples collected from the spring box. If long-term access to this source is assured, the team will investigate making improvements to the springbox and take source protection measures. Our partners at CeCEP and our home-stay families asked us to sample their water taps, which draw public water supplied by the Municipality of San Cristobal. This water was significantly higher risk than the water from any of the samples collected in Guach Tuq.

3.3 Access

- **Individual RWH systems overcome geographical and social factors that reduce local access to clean water**
- **Local ability to repair, maintain, and adapt RWH systems will promote ongoing access**
- **System cost is a significant barrier to universal access when scaling up RWH implementation regionally**

Phase I implementation improved access to water for the two families who received systems by reducing the distance they need to walk each day to collect water. Since the *finca*, is located at a lower altitude than the community, a family's location influences their access to water. Families located lower on the mountain have a shorter distance to travel and spend less time collecting water. On average, families spend about three man-hours each day collecting water for drinking and cooking alone (30-60 minutes per trip, 2-6 times each day). Women often bring their laundry to the *finca* since it is much easier to carry baskets of clothes than buckets of water. RWH systems mitigate the burden of traveling to the *finca*. The systems built at House 1 and House 27, which provide sufficient water for drinking and cooking, will save each family over 1000 man-hours annually.

On our trip, a great deal of time was spent interacting with the community to better understand the issues that affect access to water. In-depth interviews ranging from one to three hours were conducted with individual families. Two community meetings were held. Team members met with the Guach Tuq water committee. In addition to providing valuable information, time spent with the community members helped to build and strengthen relationships with the community.

Interviews revealed troubling events that have recently occurred at the *finca*. People from other communities, some of whom have access to the municipal water supply, have been using the *finca* more frequently, which raises concerns about water rights within Guach Tuq. Additionally, community members witnessed garbage and animal carcasses strewn around the *finca*. As previously mentioned, the *finca* is an insecure source of water that is often unreliable during the dry season, leading to competition and lines that form at the water basin in the middle of the night where fights and arguments break out. The *finca* is not a public supply and access to it could be cut off completely at any time. RWH systems greatly increase stability and security of access to water by providing resources onsite.

Phase I interviews served to improve access for families through knowledge sharing. Since interviews were semi-structured, we had the opportunity to explain best practices for water management. We explained the importance of using tank water only for drinking and cooking since eight of the twelve families interviewed said that a cause of unequal access is knowledge of how to conserve water. Water quality tests were used to explain the importance of boiling water. We learned methods for cleaning tanks from some families and spread word about those practices. Knowledge diffusion led to an all-around deeper knowledge of how to improve quantity and quality of water available to families.

4.0 Discussion, Conclusion, Recommendations

Our project was a success in several ways, but continues to face challenges that we will further address in Phase II. This section discusses the results of our work and benefits to People, Prosperity, and the Planet. It presents and discusses the main strategic reasons for our success. The Phase I report concludes with overall impressions and recommendations for Phase II.

4.1 P3 Benefits: People, Prosperity, and Planet

People: The community directly benefits from this work. Water will be more plentiful, clean, and accessible at shorter distances. With easy access to water year round, families will have no need to walk several kilometers a day to collect water from the *finca*. RWH systems free up two to six hours each day for women, time that may be used for recreation, education, artistic and entrepreneurial pursuits, and family. People feel they have more control over the quality of water in tanks because they can take care of it. Better quality water in clean, well-maintained systems will reduce the risk of illness. Netting that prevents mosquitos from breeding in the stagnant water of tanks may reduce the frequency of mosquito-borne diseases.

Prosperity: The project offers people in remote areas, with sufficient rainfall, an efficient way to access clean water at low cost. Maintenance costs are minimized in two ways. First, all building materials are sourced from local vendors so that when a piece of the system must be replaced, it will be available. Second, during implementation, local people will learn construction and maintenance techniques. In the future, no construction contracts with outside laborers will be necessary. This project also presents entrepreneurial opportunities related to commercializing the RWH system design and implementing it in other areas with NGO, state, or community support. As mentioned above, hours no longer spent carrying water are likely to be used in endeavors such as education and employment. Motivated community members with whom we have worked to implement systems, could utilize new skills to build RWH systems for families in neighboring communities. Phase II examines ways of generating employment opportunity by scaling up the project.

Planet: The environmental impacts of our project are widespread. Increased abundance of water means less stress on, and pollution of, the *finca* and other natural water sources. Local RWH also reduces the need for costly, extensive municipal infrastructure. When water is locally sourced for local use, less energy and resources, such as petrol and plastic bottles, need be expended on water imports and transportation. While there are manufacturing costs for RWH system materials, the systems consume no energy and have no operational emissions that pumps and other water systems do. Additionally, when system design and regular maintenance yield high quality tank water that requires no further treatment, less firewood will be needed for boiling, potentially reducing deforestation. Less wood burned means less carbon emissions and less smoke in homes, improving living conditions and environmental air quality.

4.2 Strategies for Success

The project elements most important for success were:

1. Collaboration, mutual learning and adaptive design;
2. Relationship building and partnerships; and,
3. Interdisciplinarity

We learned that previous water initiatives in Guach Tuq and attempts to provide community members with RWH systems were not successful. Interviews and interactions with the community divulged that during these projects, community members were not involved in system design and construction. In contrast, our systems are the result of **collaboration, mutual learning, and innovation** among and between our team and the community. In our project, community involvement is fundamental to system design, maintenance, and water quality testing. During construction, the design of the system is explained; once community members understand the basic concepts, they often suggest modifications and improvements. When the owner of a system understands how it works, the family is more likely to maintain it after our team leaves. As a result, local people have ownership, understanding, and control over their RWH systems. In turn, our team learned to think in new ways about engineering, construction, materials, maintenance, and cost in Guatemala. Mutual learning resulted in adaptive innovations such as: 1) community-designed wooden gutter clips that performed better than store-bought plastic clips; 2) roof repairs and additions beneficiaries employed to improve the quantity and quality of harvested rainwater; 3) one beneficiary improved his system's overflow, improving water quality in his tank; 4) one beneficiary adapted gutter and tank positioning to accommodate household changes; 5) using tree branches to support first flushes and overflows, a simple, free solution to an issue previously unsolved by the team that will be used in future systems.

We have also promoted 'citizen science' by raising awareness of the importance of water quality and local capacity to test and improve quality through locally feasible and appropriate means (i.e.: cleaning tanks, boiling water, using potable water for drinking and non-potable water for washing and bathing). One of the water quality tests used provides a chromatic, visual result, which we used as a teaching tool when we discussed water quality with community members. Explaining water quality tests results increased awareness and encouraged shared learning. We reinforced the importance of maintaining clean systems and boiling water by asking community members to participate in testing and to hold and observe water quality tests in their own homes.

Relationship building and partnerships were vital to the success of our project. We built relationships in the community by building the RWH systems alongside community members and working together. We also pursued relationships with other important actors in and around Guach Tuq that contributed, and will continue to contribute, to the success of our project. 1) Water Committee, Guach Tuq: the community has chosen representatives for a Water Committee that has provided leadership and support for project implementation and general water security issues. The Water Committee has coordinated work parties for RWH system construction, assumed a leadership role in community meetings, and has effectively liaised between our team and community members. 2) CeCEP: we work closely with CeCEP (Centro Comunitario Educativo Pokomchi), an NGO working on indigenous issues, based in San

Cristobal. CeCEP has provided office support, translators, advance materials purchasing, and general coordination. 3) Municipality of San Cristobal: we personally met with the mayor of San Cristobal to explain our project and ask for his advice and backing. His enthusiastic support materialized in donations of vehicles and staff to transport construction materials for the RWH system to Guach Tuq. Furthermore, the mayor expressed interest in continuing to work with our team and local people to implement our RWH designs in other regional communities.

Table 3: Summary of Partnerships

Partner	Type of contribution	Approximate Value
Water Committee	Labor, local coordination	Priceless
CeCEP	Coordination, office, liaison, etc.	Priceless
Municipality of San Cristobal	Transportation, labor	$200
EWB-USA WPI	Construction materials	$1331
WPI - Student Assoc	Cash	$600
WPI – Env Studies	Cash	$300
WPI – Social Science	Cash	$500
Patricia E. Austin, P.E.	Water Resources Engineering Consulting	$8,000

Interdisciplinarity was a key strength of our project. Our backgrounds span professional Social Science and Development Studies and Water Quality Engineering, and undergraduate Mechanical, Biomedical, and Civil Engineering, Physics, and Society-Technology Policy. While we divided into teams with different emphases, there was fluidity in our work, which enabled team members to engage in all of the project goals and not create 'silos' of knowledge. Team members identified their interests and self-divided to focus on design and construction, water quality, and broader socio-economic issues of water rights and access. Each team member spent time participating in the fieldwork of the other teams. As needed, we worked together on demanding tasks, such as construction. At the end of each day, we held a debrief meeting to share what we had learned and done. Each team member developed an integrated, trans-disciplinary understanding of how our project was affecting water security and what major challenges that remained.

This project directly addresses the four goals of the EPA's P3 program. First, it supports the engagement and education of the student engineering team in principles of sustainability, understood broadly. The design is technically sound and is appropriate for the resources and abilities of the community. Second, the project sparks innovation in sustainable technologies by evaluating a pilot study in a community context where local needs, environmental conditions, social realities, and economic limitations, determine design constraints. Third, this project supports the demonstration of sustainable technologies around the world by creating an adaptable system design that will enable remote, impoverished people to utilize rainwater, a readily available, though underused resource. The system is expected to satisfy people's basic water needs, a huge benefit, while having few, if any, negative environmental impacts. Appropriate terms of cost and maintenance will also ensure its sustainability. Fourth, the project fosters the development of small sustainably minded businesses as the students examine the potential for adapting and disseminating the technology to other communities within and beyond Guatemala.

5.0 Assurance of Proper Research Conduct
Our team has conducted all the work described herein completely on our own. All information is included as observed and recorded. Materials borrowed from the Worcester Polytechnic Institute Engineers Without Borders Chapter are used with permission and duly noted. Other sources are appropriately cited as well.

B. Proposal for Phase II

1.0 P3 Phase II Project Description
Phase I successfully demonstrated that RWH systems viably provide water security to families in Guach Tuq. Until now, this project has been a small-scale operation. Now, the next step is to expand the project to other communities in the San Cristobal area. The **goal of Phase II is to create and facilitate implementation of rainwater harvesting systems that can be built, used, and maintained by the typical Guatemalan family.** During Phase I implementation, we realized that, while RWH provides efficient access to water, widespread implementation is limited by system cost and support for the current process. We are requesting funding to investigate and develop a method to expand the area of influence, lower the cost of individual systems, and increase the role of the local municipality in distributing knowledge about the construction, use, and maintenance of RWH systems. Over two years, the team will take two trips to Guach Tuq. Extensive monitoring will occur in our absence. The proposed objectives to complete this Phase include:

- **Refine the design of rainwater harvesting systems to optimize for cost**
- **Expand the implementation to impact a greater portion of the population**

1.1 Project Description, Novelty, and Evaluation
The following sections describe the methods in which the above objectives will be accomplished.

1.1.1 Refine Design
The design for our current RWH system has not yet been optimized for low cost, widespread implementation using local materials and resources. While families can financially maintain existing systems, they need aid to establish them. High-density polyethylene (HDPE) storage tanks present a financial barrier, costing roughly 70% of the total system. Most families rely on charitable funding. In Phase I, we funded 95% of the cost of materials. Families contributed in kind labor and the remaining 5%. Families who lack access to potable water and are unable to purchase a system are at a concerning disadvantage. We aim to alleviate this social ill by changing the way people in the San Cristobal area obtain a RWH system. The first step is to refine the RWH system design so it is financially feasible for families to purchase and build their own systems. Refining the design to optimize RWH systems involves:

- Research into alternative system designs and components used
- Implementation of refined design
- Evaluation of refined design

Research of Optimal Rainwater Harvesting Designs
With affordability in mind, we aim to optimize three aspects of the system: storage tanks, gutters, and the first flush. Preliminary research conducted in Phase I will continue in Phase II to pilot

local manufacturing of system components. With Guach Tuq, we have already reduced the cost of the system by 22% by redesigning concrete bases and gutter clips. Our working relationship with the people and their knowledge is key to refining and optimizing future design.

Since storage tanks are the largest financial barrier, new methods of storing water can significantly reduce the cost of a RWH system. We have begun research into hand-constructing reinforced concrete storage tanks.

The current gutters and first flush are also costly. Gutters used in Phase I are plastic, lightweight, and long lasting. Many families in Guach Tuq have metal gutters, which cost less than half the plastic ones, but corrode. Alternate gutter materials, such as wood, bamboo, or tarps, would reduce the cost of the gutters yet maintain water quality and system lifespan. The first flush, made of PVC, will also be redesigned to use cheaper materials and design.

All new design will be tested and constructed first on the WPI campus in the Civil Engineering labs. Once we are confident with design changes, they will be implemented in Guach Tuq.

As learned during Phase I, while the people of Guach Tuq may not have the background to design complete RWH systems, they are very skilled in construction techniques and Guatemalan home improvement with a variety of materials. Their indigenous knowledge will be instrumental in refining and optimizing designs for widespread local implementation.

Implementation of Refined Design in Guach Tuq

With both the refined design and scaling-up objectives in mind, we will spend three weeks in Guach Tuq to accomplish the following tasks:

- Implement two low-cost, refined systems in Guach Tuq
- Meet with San Cristobal Municipality
- Meet with various San Cristobal construction store owners

Implementing the refined system will allow us to review the construction process, share new design ideas with the people of Guach Tuq, and give two additional families access to water. Necessary ties must be made with the San Cristobal municipality and hardware store owners to ensure feasible, sustainable widespread implementation of RWH systems during Phase II.

Evaluation of Refined Design

To confirm that the refined design is culturally appropriate and technically sound, the two families that received refined RWH systems will participate in year-long monitoring. Similar to the monitoring in Phase I, we will employ a CeCEP volunteer to meet with the family twice a month to gather data on system functionality, water usage, and other issues or comments the family has. This information will allow us to identify areas of improvement and make design improvements for future implementation.

With the reduced cost of the refined system, it is possible that others in the community will build systems without our assistance. Members of Guach Tuq and the Water Committee will have the knowledge to facilitate family-initiated implementations. Our contact at CeCEP will monitor their progress, and it will also serve to indicate the social appropriateness of the technology.

1.1.2 Scale-Up of Implementation

With reduced system cost through the refined design and increased local knowledge of system construction, our team's presence may no longer be essential to RWH system implementation. There are a number of players who, we believe, can facilitate wide-scale implementation. The community members of Guach Tuq have demonstrated they can construct the systems. The San Cristobal municipality is cooperative and very willing to provide valuable support to the continuation of this project. CeCEP has a well-established working relationship with the community. And there are San Cristobal businesses that can provide local materials. Our methods for scaling-up and expanding implementation are the following:

- Create a pictorial rainwater harvesting "handbook"
- Use San Cristobal Municipality as hub for education on RWH systems
- Demonstrate entrepreneurship opportunities to San Cristobal construction stores

Our team will create a rainwater harvesting "handbook", which CeCEP, our partner NGO, can readily distribute to families in the area. This "handbook" will be comprised of only pictures, and will depict the construction process and final design of a rainwater harvesting system. The "handbook" will serve as a source of knowledge so families can build systems on their own. In addition, we will work with the San Cristobal Municipality to educate their employees on constructing refined systems. Thus, the Municipality will be able to pursue further initiatives to aid local families. We will also work with the municipality to develop an educational program to teach local communities how to build these systems. This program will include building RWH systems for ten homes in the area as a demonstration to educate others. The final step of the scaling-up process is involving local hardware stores. Currently, to acquire all necessary RWH materials, orders must be made with two to three different stores. Our team will discuss opportunities for local construction stores to create a RWH inventory "section" based on our design. This not only builds local business, but gives the people of San Cristobal easy access to a place with all materials necessary to build a rainwater harvesting system.

1.2 Overall Sustainability of Proposed Project

Our Phase II proposal directly addresses economic, social and environmental sustainability, and promotes sustainable development in Guach Tuq and other communities in the municipality of San Cristobal. First, **economic sustainability** is promoted by making RWH a less expensive alternative to water procurement than it is currently. We will do this by adapting the current design to incorporate a locally constructed tank to replace the current Rotoplas tank (the greatest system expense), and investigating lower cost options that could replace other system features. These adaptations will make the RWH system more accessible in the context of rural Guatemala. Secondly, our Phase II proposal promotes **social sustainability** by creating greater regional equity in water security through a less inhibitive price-tag of RWH systems, thereby extending benefits of access to water with less time investment and greater quality assurance to a greater diversity of households. Furthermore, as in Phase I, the systems will be designed and constructed collaboratively with the community to ensure the development of local ownership and capacity to maintain and adapt the RWH systems. Finally, social sustainability is also promoted by building capacity in the municipality to scale up RWH beyond Guach Tuq, to other communities under its jurisdiction. Thirdly, **environmental sustainability** is promoted by Phase II, by geographically expanding a reduced dependence on existing ground water sources (such as the spring at the *finca*, and others regionally), with a system that has low energy requirements and that uses locally available materials.

Phase II creates significant potential for **broader impacts**, by reducing the cost of RWH and increasing local capacity for implementation and maintenance. We expect that Phase II will involve the scaling up of implementation of RWH systems from two households to the entire community (40 households) in the first instance, by working with Guach Tuq's water committee. Over the longer term, we expect that working with the municipality of San Cristobal, implementation will be scaled up to other communities in the region.

1.3 Educational and Teamwork Aspects of the Proposal

We learned in Phase I that by working closely with the community, we not only create educational opportunities for them, but also for ourselves. This is why we will continue to pursue a focus on 'mutual learning' in Phase II. Through research, pilot implementation and evaluation, our team members have become experts in areas such as modeling water demand, planning strategic consumption under conditions of scarcity, RWH system design, water quality testing and analysis, and conducting and analyzing interview data. We will work with community members to explain these concepts in a meaningful and useful way. We have also learned a lot from the people of Guach Tuq who have participated in our work through design collaborations, implementation and construction, and by permitting us into their homes to have extensive conversations about water security. Once individuals understand the basic RWH concepts they become adept at figuring out ways to modify implementation and monitoring to better meet their needs. They then teach us about local construction techniques, replacing store-bought materials with locally available materials and ways in which water security must be considered within a technical, social and economic context.

In Phase II we will develop and test prototypes for the adapted low-cost RWH systems in WPI laboratories. We will then take the design alternatives to Guatemala and work with local communities and the municipality to assess and further adapt these prototypes in the rural Guatemalan context. We also plan to continue monitoring water quality, and to train local people to undertake their own water quality testing, using the cheaply available PML tests, discovered and used in Phase I.

Mutual learning also describes our work as a team, which will continue to be fundamentally interdisciplinary involving science (water quality), engineering (system design) and social science (community participation and wider factors affecting water security). Our team is diverse, representing professional engineering, social science and development studies, and mechanical, civil and biomedical engineering undergraduates. We will continue to work in a way that integrates team members, rather than separating them, by regularly debriefing together about individual work and tasks, and by alternating in and out of different groups of tasks, such as construction and water quality monitoring. In anticipation of Phase II, we have also begun further outreach to new sources of knowledge and expertise. For example, Prof. Aaron Sakulich, a materials engineer at WPI, will be hosting summer research students to work on affordable tank designs.

2.0 Quality Assurance Statement

All work will be conducted by WPI students, under supervision of Professor Elgert and Ms. Austin. Design work will continue to be based on the demand model currently used. In Phase II the model will be modified for use in the field. We will continue to collect and analyze water quality samples using the method described here. Samples are collected and stored until processing using Standard Methods.

3.0 Project Schedule

The Gantt chart on the following page displays major project milestones for the two year duration of Phase II. The significant milestones, discussed previously, are organized by objective. The green fill indicates objective completion duration, and the blue fill indicates duration of method. Proposed actions for Phase II have sufficient time to be completed within a two-year period. All work done through Phase I (not shown on Gantt chart) provides the necessary knowledge to accomplish the first task of Researching and Building Pilot refined design on campus. The same evaluation criteria, or objectives, of Phase I will remain for determining the success of the modified RWH design.

To ensure the awarded grant funds are spent within the appropriate time period of the Phase II project, specific team members/organizations will be identified as the responsible party.

Table 4: List of tasks with persons responsible and indicators of success.

Task	**Responsible Party**	**Method for Monitoring/Measuring Success**
Research and Pilot Build	Student EWB team with guidance from Dr. Elgert	Has a more cost-effective RWH design been developed and successfully built on campus?
Trip 1- Implementation	P3 team, The Guach Tuq Water Committee, CeCEP	Were two newly design RWH systems installed with help from the community?
Evaluate Design	P3 team and CeCEP	CeCEP volunteer will gather community feedback and relay to P3 team
Modify Design	Student EWB team with guidance from Dr. Elgert and Ms. Austin	Is there a new RWH design that accounts for issues encountered during trip build and community feedback?
Create RWH "handbook"	P3 team and CeCEP	Are people unfamiliar with RWH able to understand basic concepts through book?
Trip 2- Spread RWH	P3 Team, CeCEP, San Cristobal Municipality	Does the municipality continue to host educative RWH sessions in our absence?
Monitor Water and System Usage	P3 Team and CeCEP	Are new systems effective and culturally acceptable? Feedback gathered by CeCEP volunteer and relayed to P3 team.

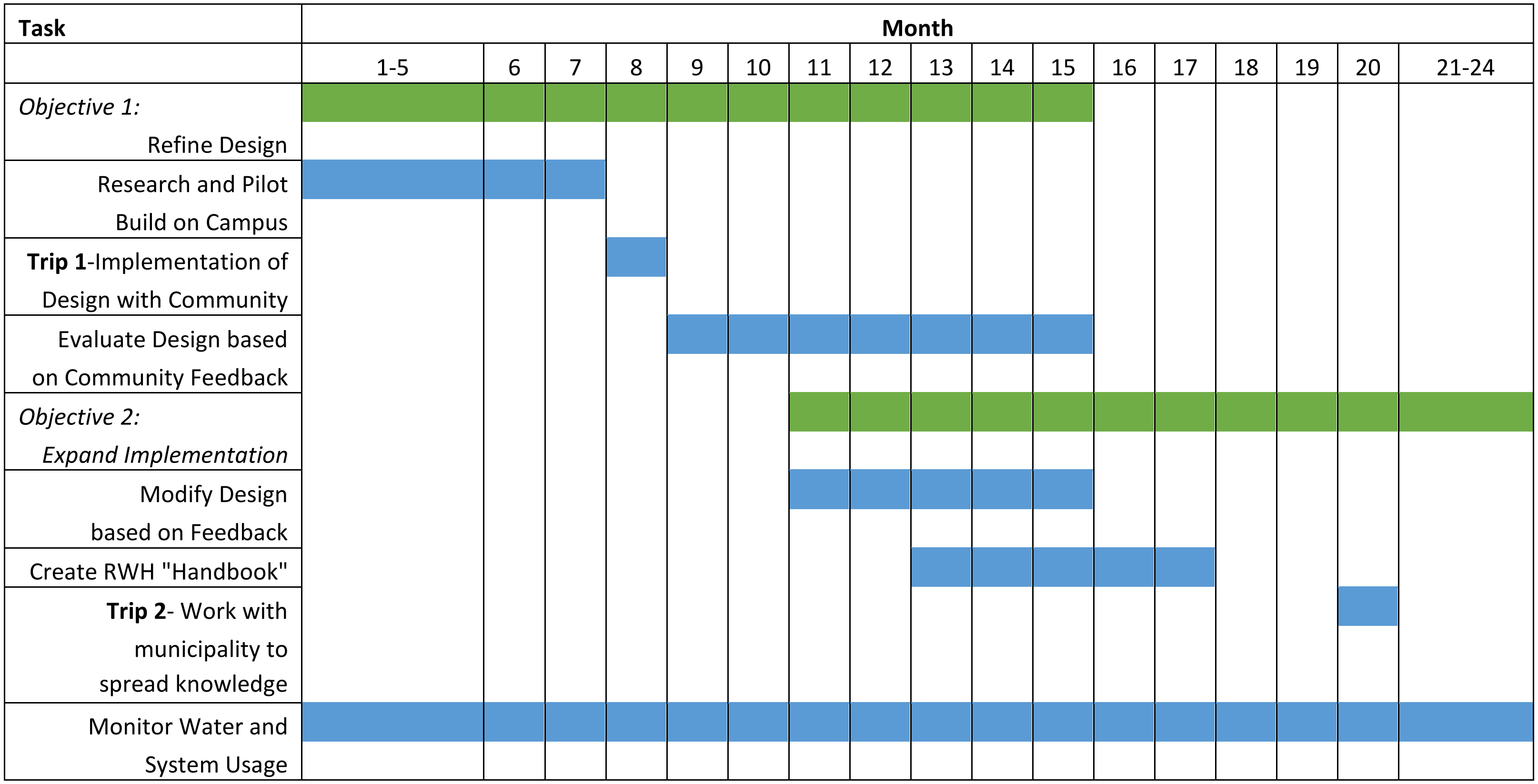


Figure 5: Gantt Chart for project timeline of Phase II work.

4.0 Partnerships

EWB-USA WPI has teamed up with various organizations in Massachusetts and Guatemala. Without support from local and in-country organizations, the rainwater harvesting project for Guach Tuq would not be feasible. In-country partners include the Guach Tuq Water Committee, the Centro Educativo Comunitario Pokomchi (CeCEP), and the local San Cristobal Municipality. Partners in the states include Worcester Polytechnic Institute and Engineers Without Borders USA. Each of the organizations, described in further detail in the following paragraphs, plays a specific role and has made measureable contributions to the success of the RWH project.

Centro Educativo Comunitario Pokomchi (CeCEP)

CeCEP is the in-country, non-governmental organization involved with the project. CeCEP's main role is to serve as the liaison between EWB-USA WPI and the community of Guach Tuq for project planning purposes. They take care of most of the in-country project logistics that are necessary for a smooth implementation and trip. This includes acquiring necessary materials prior to implementation, ensuring community availability for meetings during implementation, and providing translators during the trip. We employ a CeCEP volunteer to help run a monitoring program throughout the year. The monitoring program aids in the collection of data on community water usage, health, and issues with the implemented rainwater harvesting systems. Besides gathering necessary data and employing local people, the monitoring program provides a year-round presence, which solidifies trust with the community that the project will continue as planned, even in our absence.

Arguably more important, CeCEP also acts as a check and balance for project decisions that heavily reflect social implications. The organization understands the people of Guach Tuq to a much higher degree than our team does, and can provide critical insight on how certain project decisions will fare on a social level within the community.

With Phase II, CeCEP will continue to serve as an integral team member. In addition to their current contributions, CeCEP volunteers will help in creating the educative series with the municipality and identify surrounding communities that might benefit from RWH.

Guach Tuq Water Committee

The Guach Tuq Water Committee is a self-initiated entity formed to handle community relations between Guach Tuq, CeCEP, and EWB-USA WPI. The Water Committee is comprised of members of Guach Tuq on a volunteer basis. The members are usually people who have recently benefited from the RWH project, or are on the list to benefit in the near future. They have specific responsibilities related to the project throughout the year and during implementation. The Water Committee has previously and will continue to serve as a facilitator for future beneficiaries to ensure the community has made necessary preparations for upcoming implementation trips. This is critical in enabling a smooth and successful implementation. They also reside over community meetings relating to the RWH project, serve as the main contact for CeCEP, and help educate community members on proper system installation, maintenance, and water conservation.

Prior to the formation of the Water Committee, all project related tasks were handled by the COCODE. The COCODE is the governing body in Guach Tuq, but it is known for enabling corrupt behavior. The Water Committee has enabled the rainwater harvesting project to remain out of the hands of the COCODE, and therefore transparent and fair in the eyes of community members, a key facet in the continued success of the project.

Moving forward, the Water Committee will play the main role in Guach Tuq's longevity of water security. By working with EWB-USA WPI during implementations, the members of the community, and specifically the Water Committee, have gained an extremely specific set of skills related to installation of efficient rainwater harvesting systems. Even after EWB-USA WPI discontinues involvement with Guach Tuq, the Water Committee will be able to sustain the existing infrastructure. They will be able to provide support in terms of system maintenance, help with system expansion, and facilitate a better understanding of the importance of water conservation. Specifically in terms of Phase II goals and objectives, the Water Committee will help in RWH knowledge demonstration and transfer by assisting with builds in the area.

San Cristobal Municipality

The newest project partner is the local San Cristobal Municipality. During the Phase I implementation, the municipality provided on two separate occasions two trucks with municipality employees to transport all of the necessary materials. This helped overcome a major obstacle in the logistic planning of the project, which is transportation of large quantities of materials during multi-home system implementations. After this generous gesture, the team met with the Mayor of San Cristobal to discuss the municipality's involvement in future implementations.

The Mayor of San Cristobal has agreed to support the Guach Tuq rainwater harvesting project through the donation of material storage and transportation. In addition to being a large help to the feasibility of the project with larger scale implementations, this in-kind donation displays the municipality's dedication to providing assistance to their residents.

In regards to the Phase II objective of scaling-up implementation, the municipality will serve as the key team member in this accomplishment. Our team will work with the municipality and CeCEP to develop the educative RWH build series and set municipality workers up with the necessary skills and tools to continue RWH implementations in the area.

Worcester Polytechnic Institute

Worcester Polytechnic Institute (WPI) serves as a multi-faceted partner. WPI supports the infrastructure for the EWB-USA WPI chapter to exist and operate on campus, and has brought our team together through a common workplace. The university provides financial support for our organization to attend conferences and workshops. WPI's International Global Studies Division (IGSD) has travel resources and preparations guides that are available to our team at time of international travel. While WPI's role is mainly logistic and in the background, their on-going support has been and will continue to be necessary for the success of this project.

Engineers Without Borders USA

Engineers Without Borders-USA (EWB-USA) provides necessary infrastructure for the project to continue with technical assurance. EWB-USA serves as a quality assurance and quality control manager for most technical aspects of our rainwater harvesting project. Through regional conferences with other EWB chapters, EWB-USA serves as an information sharing hub so we can gain knowledge from similar projects. They also provide a venue to gain corporate sponsored grants to continue our work.

C. References

Abdulla, F. A.andA. W. Al-Shareef. 2009. 'Roof rainwater harvesting systems for household water supply in Jordan' Desalination 243: 195-207.

Aladenola, O.andO. B. Adeboye. 2010. 'Assessing the potential of rainwater harvesting' Water resource management 24: 2129-2137.

Campisano, A.andC. Modica. 2012. 'Optimal sizing of storage tanks for domestic rainwater harvesting in Sicily' Resources, conservation and recycling 63: 9-16.

Mihelcic, James R. et al. 2009. Field Guide to Environmental Engineering for Development Workers. Reston: American Society of Civil Engineers.

Mwenge Kahinda, J.-m. T., Akpofure E.andJ. R. Boroto. 2007. 'Domestic rainwater harvesting to improve water supply in rural South Africa' Physics and chemistry of the earth 32: 1050-1057.

---. 2010. 'Domestic rainwater harvestin as an adaptation measure to climate change in South Africa' Physics and chemistry of the earth 35: 742-751.

Thomas, T. H.andD. B. Martinson. 1999. Roofwater harvesting: A handbook for practitioners. Delft, The Netherlands: IRC International Water and Sanitation Centre.

Ward, S., F. A. MemonandD. Butler. 2010. 'Rainwater harvesting: model-based design evaluation' Water science & technology 61: 85-96.

World Health Organization. 2004. Guidelines for Drinking-water Quality: Recommendations, Volume 1. Geneva: World Health Organization.

VI. Supporting Letters

The following three pages display letters of support from three of our project partners: CeCEP, the San Cristobal Municipality, and the Guach Tuq Water Committee. CeCEP, a partner we have been working with since 2009, supports the social and developmental work we have been doing in the community. The letter of support, from our primary contact Sucely Ical Lem, states that they will continue to aid with implementation of our project to help the local people. Likewise, the Mayor (Alcalde) of San Cristobal has agreed to provide logistical support for the rainwater harvesting work we are doing in the community. The Municipalidad de San Cristobal offers aid in transporting materials from the city up to the community. The Water Committee of Guach Tuq also supports our project and looks forward to working with our team in the coming years.

Museo Katinamit
San Cristóbal Verapaz
Tel. (502) 7950-4896
cecep@intelnet.net.gt

La Asociación Centro Comunitario Educativo Pokomchi CECEP, con sede en municipio de San Cristóbal Verapaz, Alta Verapaz Guatemala ha venido trabajando con las comunidades de nuestro municipio, desde el año de 1995. En base a la misión de contribuir con el desarrollo social y económico de la población pokomchi, desarrollamos alianzas con organizaciones y grupos que tengan la misión de apoyar estos objetivos. De esta forma desde año 2,009 venimos apoyando al grupo de estudiantes Ingenieros sin fronteras de la universidad WPI de los Estados Unidos. Ellos vienen trabajando en la comunidad de Guachtuhq del municipio de San Cristóbal Verapaz, en la implementación del proyecto de captación de agua pluvial, dicho proyecto beneficiara a 38 familias de la comunidad. Por lo anteriormente expuesto CECEP, representado por mi persona, titular del documento personal de identificación 2615 1277731603, manifiesto mi compromiso en continuar apoyando el desarrollo de este proyecto que benéfica a nuestra población pokomchi.

Y PARA LOS USOS LEGALES QUE A LOS INTERESADOS CONVENGAN EXTIENDO FIRMO Y SELLO LA PRESENTE EN LA VILLA DE SAN CRISTOBAL VERAPAZ, ALTA VERAPAZ GUATEMALA A LOS DIECINUEVE DIAS DEL MES DE MARZO DEL AÑO DOS MIL CATORCE.

Sucely Ical Lem
Coordinadora.
CECEP

Centro Comunitario Educativo Pokomchi
CECEP
ADMINISTRACION
SAN CRISTOBAL, A. V.

Municipalidad de la Villa de San Cristóbal Verapaz
Departamento de Alta Verapaz
Guatemala C.A.

EL INFRASCRITO ALCALDE MUNICIPAL DE LA VILLA DE SAN CRISTOBAL VERAPAZ, DEL DEPARTAMENTO DE ALTA VERAPAZ, POR MEDIO DE LA PRESENTE HACE CONSTAR: Que, este despacho AVALA y apoya la labor que realiza un grupo de estudiantes denominado INGENIEROS SIN FRONTERAS DE LA UNIVERSIDAD WPI DE LOS ESTADOS UNIDOS, ya que ellos han venido trabajando en la comunidad de Guachtuq de este municipio, beneficiando a las familias con la dotación e instalación de sistemas de depósitos para captar agua pluvial, elogiando también dicha labor, porque contribuye al desarrollo integral del municipio y mejora la calidad de vida de los vecinos de la comunidad de Guachtuq.------------------

Y, para los usos legales que convengan al interesado, extiendo, sello y firmo la presente, en San Cristóbal Verapaz, a dieciocho de marzo del año dos mil catorce.--

JULIO ROMEO SURAM CHUN
ALCALDE MUNICIPAL

JULIO ROMEO SURAM CHUN · ALCALDE MUNICIPAL · DE LA VILLA DE SAN CRISTOBAL · ALTA VERAPAZ, GUATEMALA C.A.

COMITE PROSISTEMA DE AGUA GUACHTUHQ, SAN CRISTOBAL VERAPAZ, ALTA VERAPAZ.

En representación de las familias de la Comunidad de Guachtuhq de San Cristóbal Alta Verapaz, Guatemala, C.A. Hacemos de su conocimiento que desde hace varios años los estudiantes de: Worcester Polytechnic Institute, Ingenieros Sin Fronteras de Estados Unidos. Han venido desarrollando un proyecto de Captación de agua Pluvial en nuestra comunidad, el cual su implementación está estimada a largo plazo. Por tal razón nosotros como miembros del Comité de Agua de esta comunidad, nos comprometemos a apoyar a los estudiantes Ingenieros Sin Fronteras, en la implementación del proyecto en los siguientes años hasta su finalización.

Y PARA LOS USOS LEGALES QUE AL INTERESADO CONVENGAN FIRMAMOS Y SELLAMOS LA PRESENTE EN LA COMUNIDAD DE GUACHTUHQ, SAN CRISTOBAL ALTA VERAPAZ. A LOS DIECISIETE DIAS DEL MES DE MARZO DEL AÑO DOS MIL CATORCE.

COMITE PRO SISTEMA DE AGUA
"GUACH - TUQ"
...L APOYO DE
...ROS SIN FRONTERAS

Cristóbal Laj Cojoc
DPI No2200 90777 1603
Presidente Comité de Agua.

Roberto Chacoj
DPI No. 1716 47041 1608
Vicepresidente Comité de Agua.

VIII. Budget Justification

The following sections detail the reasoning behind each budget item. Items in the budget are allocated between the two objectives of Phase II: refining the design and scaling-up implementation. There are two trips associated with Phase II, one to accomplish each objective.

A. Personnel

The EWB-USA group at Worcester Polytechnic Institute, who our team works under, is comprised of student, staff, and professional engineer volunteers. As a volunteer organization, no one is typically compensated for their time. However, in order to accomplish the Phase II objectives, longer trips must be taken which interfere with many student summer employment opportunities. Therefore, while remaining a volunteer based organization, the students attending each trip will be compensated at a weekly rate comparable to undergraduate summer job salaries.

Six students will be compensated $200 per week for a period of three weeks. This amounts to $3,600 per trip. There are two trips, one per year, needed to accomplish Phase II. Therefore the total for personnel is $7,200.

C. Travel

The travel needed to accomplish Phase II will consist of two trips, each three weeks long and occurring in May of 2015 and 2016. Eight team members will attend each trip: six students and two mentors. The breakdown of travel costs for each trip is shown below.

Purpose of Travel	Location & Date	Item	Computation	Cost
Objective 1: Refine the Design	*San Cristobal, Guatemala May 2015*	Airfare	8 people x $690 roundtrip	$5520
		Ground Transport	$350 roundtrip van service to Boston Airport + $1100 roundtrip airport van service in Guatemala	$1450
		Lodging	8 people x 20 nights x $15 per night for homestay + three rooms for one night in hotel ($450)	$2850
		Per diem	8 people x $25 per week x 3 weeks	$600
Trip 1 Total				***$10,420***
Objective 2: Scale-Up Implementation	*San Cristobal, Guatemala May 2016*	Trip 1 Total	Identical Costs	$10,420
Total Travel				**$20,840**

E. Supplies

The supplies to accomplish Phase II are detailed below.

Trip	Supply Items	Cost
Year One: May 2015	Construction Tools (wheelbarrows, shovels, levels, tape measures, etc.)	$272
	Water Quality Tests (4 sets at $75 each plus shipping)	$313
	Materials to research and develop “refined design” at WPI	$500
	Materials to build two pilot “refined design” systems in Guach Tuq (cement, gutters, PVC, wood, etc.)	$2,000
Trip One Total		***$3,085***
Year Two: May 2016	Printing, binding, and distribution of RWH handbook	$500
	Materials to build ten refined rainwater harvesting systems to facilitate scaling-up of implementation (cement, gutters, PVC, wood, etc.)	$12,000
Trip Two Total		***$12,500***
Total Supplies		**$15,585**

F. Contractual

The only contractual costs incurred by this project are the employment of CeCEP volunteers as translators during travel and as monitoring liaisons between trips. A daily rate was settled on by comparing the fair minimum wage in Guatemala and the USA, and then scaling that minimum up to a comparable USA translator wage. The contractual costs for year one and two are identical.

Service	Computation	Cost
Translating	2 translators x $40 per day x 25 days	$2,000
Monitoring	1 employee x $40 per community visit x 50 visits	$2,000
Total (One Year)		*$4,000*
Total Contractual		**$8,000**

H. Other Costs

There are no additional costs associated with the first year of Phase II. The “other” costs associated with the second year, specifically on the May 2016 trip to Guatemala, are to support public education of rainwater harvesting systems through programs with the San Cristobal Municipality. We estimated **$4,500** to educate the municipality workers, coordinate with municipality administration to host an educative event, and hold the public event to spread knowledge through a demonstration rainwater harvesting build.

I. Indirect Costs

As employees and students of Worcester Polytechnic Institute, the team must abide by the indirect cost rate of the university. The indirect costs are 57% of the total direct costs. The total direct costs are $56,125, making the total indirect costs $31,991. Total project costs are then $88,116.

IX. Relevance and Past Performance

A. Relevance to the EPA

Rain or shine: Rainwater harvesting systems for dependable, safe drinking water in rural Guatemala is firmly in line with the EPA's research priorities and supported by EPA's authorizing statutes. The project aims to create greater water security, with a focus on improved quality of water for cooking and drinking, in rural areas that fall within the municipality of San Cristobal, Guatemala, but that are not served by the municipal water supply. Our project goal is to design and implement an accessible RWH system in households that are currently dependent on groundwater sources, to both improve the quality of their drinking water and to reduce the pollution of groundwater. This technical solution incorporates design features that improve the quantity and quality of harvested water, and will be implemented in a way that recognizes, and overcomes, current social and financial barriers to sustainable access to dependable, safe drinking water on very small and remote scales. This project incorporates a system for monitoring water quality for bacterial and E. coli content, to ensure that high standards are maintained over the longer term, and to enable our team to address quality issues that might arise. The project specifically pertains to the following EPA research priority, under the category of **water**:

> *Drinking Water*
>
> *A multitude of drinking water challenges may be addressed by technology solutions. Priority considerations for new technologies include cost, ease of use, and environmental impacts including resource and energy use. Areas of interest include but* ***are not limited to*** *research on:*
>
> a. *Drinking water delivery systems or treatment technologies, especially for small, very small or remote systems. Systems or technologies should address health risks posed by contaminants and pathogens and should be easy to operate and maintain and have minimal energy use. Systems could be community-level or point-of-use/point-of-entry (POU/POE) treatment technologies.*

This research falls under Section 1442 of the Safe Drinking Water Act, and is particularly relevant to the following excerpts of this Act:

Section 1442 of the Safe Drinking Water Act authorizes the EPA to make grants for research, training, studies, and demonstrations relating to … the provision of a dependably safe supply of drinking water, including … (C) new methods of treating raw water to prepare it for drinking, so as to improve the efficiency of water treatment and to remove contaminants from water; (D) improved methods for providing a dependably safe supply of drinking water, including improvements in water purification and distribution, and methods of assessing the health related hazards of drinking water…

B. Past Performance of the Principal Investigator

The principal investigator, Dr. Laureen Elgert, has successfully managed and completed a P3 Phase 1 grant. During the one-year granting period (August 15, 2013 – August 14, 2014), all proposed activities were undertaken according to the proposed project timeline (or sooner), and results were reported by March 25, 2014 according to program requirements. The grant was awarded over one year, thus, no progress report was required, but the final results, outcomes and outputs, are documented and submitted to the EPA in conjunction with the P3 Phase 2 proposal. The P3 Phase 1 grant is the only federal funding that Laureen has received, or been responsible for, to date.

X. Resumes

Laureen Elgert, PhD (PI)

Worcester Polytechnic Institute
Worcester, Mass. 01609
508 450 3313 lelgert@wpi.edu

Current Position
Assistant Professor
Environmental and Sustainability Studies
Social Science and Policy Studies
Worcester Polytechnic Institute
http://www.wpi.edu/academics/Majors/ENV/faculty.html

Education

- PhD London School of Economics, 2011, Development/Environmental Politics, Dissertation: *The Politics of evidence: Towards critical deliberative governance in sustainable development*
- MSc University of Alberta, 2003, Thesis: *Developing Microenterprises in Southern Ecuador*
- BA Trent University, 1999, International Development and Anthropology

Qualifications Summary
I am a social scientist interested in new spheres of 'democratization' and citizen participation in implementing and analyzing environmental policy. My Phd research (in the department of International Development) examined the social and political dynamics and implications of technical interventions in environmental planning. My work examines and experiments with alternative policy frameworks to increase the ways that specialist and popular perspectives can be used side by side. This helps redefine what we mean by 'local' and 'global' perspectives; 'expert' and 'lay' knowledge; and 'political' and 'evidence-based' information. My language facility includes English (Native), Spanish (Fluent), and French (Intermediate). I have taught at undergraduate and graduate levels for 7 years, including such courses as: Introduction to Environmental Studies; Environmental Problems in the Developing World; and, Global Environmental Politics. I have received a number of research awards, including Land Deal Politics Initiative small grant (ISS, Erasmus University, Rotterdam) $3000 (2011), and the Social Science and Humanities Research Council (SSHRC) Doctoral Scholarship $80,000 (2004-2008).

Selected publications

Forthcoming. Elgert, L. Governing portable conservation and development landscapes: Reconsidering evidence in the context of the Mbaracayú Biosphere Reserve. Evidence and Policy.

2013. Elgert, L. Hard facts and software: The coproduction of indicators in a land use planning model, Environmental values, 22(1).

2012 Elgert, L. Can 'responsible' soy production justify the concentration of land in Paraguay? A critical analysis of the claims about environmental, economic and social sustainability, Land Deal Politics Initiative working paper: http://www.cornell-landproject.org/download/landgrab2012papers/elgert.pdf.

2012 Elgert, L. & Krueger, R. Modernizing sustainable development? Standardization, evidence and experts in local indicator development, Local Environment, 17(5): 561-571.

2011 Elgert, L. Certified discourse? The politics of developing soy certification standards. Geoforum, doi: 10.1016/j.geoforum.2011.08.008.

2010 Elgert, L. Certified community development? Local participation in developing environmental certification standards, in Deliberations in Community development: Balancing on the edge, Rothe, P & Carroll, L & Ozegovic, D (Eds.). Hauppage, New York: Nova Science Publishers.

2009 Elgert, L. Politicizing sustainable development: the co-production of globalized evidence-based policy, in Critical Policy Studies, 3(3-4): 375-390.

Selected Project Experience

Nov, 2003-Sept, 2008

The Alberta Research Council (Implementing Agency for CIDA, in Paraguay), Research Scientist

- Community based and ecological indicators of sustainability
- Land use planning software and community participation
- Multi-level governance and collaboration
- Multidisciplinary research and inter-sectoral planning
- Monitoring and Evaluation

Jan, 2001-Oct, 2003

The Alberta Centre for Injury Control and Research, University of Alberta, Research Associate

Social and political determinants of road safety, Policy analysis

Qualitative research and interdisciplinary collaboration

Personal, Community and Volunteer Activities

- American Association of Geographers (AAG)
- Canadian Association for the Study of International Development (CASID)
- Conference of Latin Americanist Geographers (CLAG)

Patricia Austin, P.E.

11 Dell Avenue
Worcester, Massachusetts 01604
(508) 284 4356 Pat.austin@state.ma.us

Current Position
Environmental Engineer
Massachusetts Department of Conservation and Recreation, Division of Watershed Management
180 Beaman Street
West Boylston, Massachusetts 01583
508 752 6732, x 204 pat.austin@state.ma.us

Qualifications Summary
Ms. Austin is a licensed professional sanitary engineer with 30+ years experience working within the Massachusetts Executive Office of Energy and Environmental Affairs on water supply, wastewater, and water quality issues. She currently works at the Massachusetts Department of Conservation and Recreation in the in the water supply protection program for the Metropolitan Boston water system. She is the Environmental Quality Section supervisor, supervising a staff of 11 engineers, environmental scientists, biologists, and planners. Her expertise includes watershed protection and management, surface water quality modeling, water quality sampling design, water quality data interpretation, environmental regulations and permitting, and hydrology.

Selected Project Experience

- Planned, developed and executed multi-year projects to develop and implement long-range watershed protection programs, stormwater drainage improvements, and combined sewer system remediation.
- Direct Water Resource Research Program with University of Massachusetts, Amherst, Department of Civil and Environmental Engineering to develop and maintain 2-dimensional and 3-dimensional reservoir water quality models, watershed runoff models, and develop microbial source tracking methods.
- Partner with Worcester Polytechnic Institute on undergraduate and graduate research projects.
- Supervisor, DCR Wachusett Reservoir Environmental Quality Section. Provide day-to-day supervision of ten person section of engineers, planners, and scientists. Staff conduct and interpret water quality analysis of streams and Wachusett Reservoir, supervise administration of environmental protection regulations, and review projects in the watershed to prevent adverse impact on water resources.
- Project manager for project to develop Watershed Protection Plans for Surface Water Supply of 400 square miles (1990) and three subsequent updates (1998, 2003, 2008). The Watershed Protection Plans used to guide watershed management activities and direct staff activities to provide clean water in adequate quantity to serve the 2 million resident that rely on the system.

- Managed several large consultant engineering projects including water quality modeling, water quality assessments, road drainage improvements (design) and sewage system improvements.
- Developed cooperative research projects with University of Massachusetts Department of Civil and Environmental Engineering working with faculty and graduate students. Topics include use of 2 dimensional and 3 dimensional water quality models to predict reservoir response to pollutant inputs, characterization of watershed runoff, and development of alternative microbial indicators to track sources of pollution.

Personal, Community and Volunteer Activities

- Mentor, WPI EWB group. Participated in 2 trips to Guatemala.
- Created urban basketball program for Worcester Neighborhood serving many underprivileged children. Ran program for 6 years. Participation grew from 60 to 175 participants.
- Participated in numerous community organizations including the Regional Environmental Council, Pernet Family Health Services and the Pleasant Street Neighborhood Network Center.
- Board Member, Worcester Interfaith, Worcester Massachusetts 1999 to 2007
- Director, Massachusetts Association of Conservation Commissions (1994-1996)
- Member, Citizens Advisory Committee for the Extension of Commuter Rail to Worcester
- Member, Citizens Advisory Committee for the Renovation of Union Station
- Member of Worcester Conservation Commission (four years); chairman of Worcester Conservation Commission (two years)
- Amateur musician (piano, fiddle); Member of the Salisbury Singers of Worcester (100 member community chorus). Piano Teacher

Education

M.S., Environmental Engineering
University of Massachusetts at Amherst, 1982

A.B., Biology
College of the Holy Cross, Worcester, Massachusetts, 1977

Awards and Honors

- 1973 Betty Crocker “Future Homemaker of America” Award; Belchertown High School.

Michele Mensing
3 Fawn Drive
Matawan, NJ 07747
(732) 977 3875 mlmensing@wpi.edu

Current Position
Undergraduate Student
Worcester Polytechnic Institute, Worcester, MA
Bachelor of Science in Mechanical Engineering, May 2014
Bachelor of Science in Physics, May 2014
GPA 3.95

Qualifications Summary

- Three years of experience with the EWB-USA WPI Student Chapter and the Water Supply project in Guach Tuq, Guatemala.
- Competency in proper engineering design and scientific research methods and techniques.
- Ability to work effectively in a team setting spanning cultural and international boundaries.
- Leadership experience through various group projects and executive board positions within EWB-USA WPI.

Selected Project Experience
Major Qualifying Project—WPI (Sept 2013-present)
Head and Neck Injury Prevention in Sports

- Design of rotational shock absorber to be worn by football players to limit head acceleration during impacts.
- Development of testing methods and apparatuses which closely simulate typical concussive hits in football.

Interactive Qualify Project—WPI (Oct 2012-Mar 2013)
Community Building Through Student Radio in Wellington, New Zealand

- As an interdisciplinary team of four, consulted a student-run radio station on how to create a meaningful relationship with their target audience.
- Interviewed local venue owners and surveyed students to understand their community engagement, and based on their responses, developed strategies for the radio station to strengthen their own engagement.

Engineers Without Borders-USA WPI Chapter (Oct 2011-present)
Water Supply in Guach Tuq, Guatemala

- Collaborated with a team of students and community in Guatemala to develop rain water harvesting systems that provide a year round, sustainable source of clean drinking water.

Microbiology Research at Rutgers State University, New Brunswick, NJ (June-Aug 2009)

Effects of Different Precultivation Techniques on the Responses of *Pinus rigida* to Mercury

- Worked with a team of graduate and undergraduate students in the Department of Biochemistry and Microbiology to produce and present research findings on mercury and its effects on plant with in the presence of fungi.

Selected Work Experience

ExxonMobil Research and Engineering, Fairfax, VA (May-Aug 2013)

Intern in Offsites & Utilities, Project Development Division

- Analyzed deaerator optimization proposals for technical and operational feasibility.
- Evaluated surge analysis software for use within company.
- Developed Excel tool to assist with Partial Power Failure Analysis in refineries.

Central Metal Fabricators, Inc., Farmingdale, NJ (1NZU4) (May-Aug, 2010-2012)

Intern in Engineering, Design, and Manufacturing

- Reverse-engineered and prototyped mechanical parts for final production, typically for government contracts (experience with ANSI and ASTM standards).
- Communicated and collaborated on projects with customers to meet production quality and deadlines.
- Gained experience with various machinery and manufacturing processes

Personal, Community and Volunteer Activities

- EWB-USA WPI President (2013-2014)
- EWB-USA WPI Fundraising Chair (2012-2013)
- Member of Tau Beta Pi WPI Chapter (Oct 2012-present)
- Member of the American Society of Mechanical Engineers
- Activities Leader Volunteer at the Liberty Science Center, Jersey City, NJ (May-Aug 2012)

Education

High Technology High School, Lincroft, NJ

Class of 2010

Awards and Honors

- Worcester Polytechnic Institute Dean's List (2010-2013)
- Worcester Polytechnic Global Scholar (2010)
- Rochester Institute of Technology Computing Award (2009)
- Panasonic Creative Design Challenge Best Documentation Award (2009)

Thomas James Moutinho Jr.
21 Beatrice Dr.
Gorham, ME 04038
207-831-7011 tjmoutinho@wpi.edu

Current Position
Undergraduate Student
Worcester Polytechnic Institute, Worcester MA
Bachelor of Science in Biomedical Engineering, May 2015
GPA 4.0
Related Coursework: Ordinary differential equations, Calculus, Linear Algebra, Cell Biology, Anatomy, General Biomedical Engineering, Writing, Organic Chemistry.

Qualifications Summary
Three years of experience working with an EWB rainwater harvesting project in Guach Tuq,Guatemala. Technical experience implementing rainwater harvesting systems. Personal interactions working alongside community members.

Selected Publications

Clement AL, Moutinho TJ Jr, Pins GD. Micropatterned dermal-epidermal regeneration matrices create functional niches that enhance epidermal morphogenesis. Acta Biomatar (2013). http://dx.doi.org/10.1016/j.actbio.2013.08.017

Jensen PA, Dougherty BV, Moutinho TJ, Papin JA. Low-cost device for high-throughput growth phenotyping. *in preparation*.

Selected Project Experience
Engineers Without Borders, Worcester Polytechnic Institute, 2011- Present

- Design and implementation of an individual home based rainwater harvesting project in Guach Tuq, Guatemala
- Experience with project management, system design, community education, water quality testing, increased knowledge of social dynamic surrounding water security, increased knowledge about engineering with an integrated social aspect, pouring concrete, building wood support structures, working with PVC, and logistical coordination for implementation

Lab Assistant, Gateway Laboratories, Worcester Polytechnic Institute, 2011 – Present

- Research and development of a skin graft substitute that has keratinocytes growing on collagen gel with a topographic surface with the aim to mimic the micro-geography of natural skin
- Experience in a lab setting, cell culture, chemical preparation, micro-pipetting, conducting experiments, slide preparation, microscopy, imaging techniques, and the design process for unique devices used in the lab.

- Third author on the article, "Micropatterned dermal-epidermal regeneration matrices create functional niches that enhance epidermal morphogenesis" published in Acta Biomaterialia

Selected Work Experience

Research Design Engineer, Papin Lab, University of Virginia, 2012 – 2013

- Research, design, development and testing of a continuous bacterial culture high-throughput bioreactor and another high-throughput spectrophotometer
- Increased understanding of SolidWorks, developed skill in experimental design, furthered development in laboratory techniques, gained experience in electrical Biomedical engineering, and programming in C for Arduino micro-controllers

Tech Assistant, DeLorme Mapping Company, Yarmouth, ME, 2011

- Engineered and designed the proof of concept for a sensor that detects and identifies passing vehicles, and sends information through satellite communication.
- Gained experience in the electrical and computer engineering, and working in an engineering group.

Lab Assistant, Wise Laboratories, University of Southern Maine, Portland, ME 2010

- Researched the effects of micro-gravity on the genotoxicity of Sodium Chromate in human lung cells
- Gained experience using autoclaves, micro-pipettes, cell culture, chromosome damage analysis and proper safety techniques when working with toxic chemicals

Personal, Community and Volunteer Activities

- Project Lead for Engineers Without Borders (2013 – Present)
- Treasurer of Engineers Without Borders (2011 – 2013)
- Member if Alpha Eta Mu Beta, BME Honors Society (2013 – Present)
- Member of Tau Beta Pi Honors Society (2013 – Present)
- Tech Chair of Engineering World Health (2012 – 2013)
- Excellence in Mathematics, Science, and Engineering Program (EMSEP) (2011-present)
- Biomedical Engineering Society (2011-present)
- Captain of the FIRST Robotics Team 172 (2010-2011)

Education

Gorham High School, Gorham ME

Class of 2011

Graduated 3/200

GPA 97.4/100

Awards and Honors

- Worcester Polytechnic Institute Dean's List (2011-2013)
- Charles O. Thompson Scholar (2012, 2013)

Rain or shine: Rainwater harvesting systems for dependable, safe drinking water in rural Guatemala

EPA Agreement Number: SU835508

Katie Picchione
23 Tryon Ct.
Albany, NY 12203
(518) 727 8024 krpicchione@wpi.edu

Current Position
Undergraduate Student
Worcester Polytechnic Institute, Worcester, MA
Bachelor of Science in Mechanical Engineering, May 2016
Bachelor of Science in Society, Technology, and Policy, May 2015
GPA 3.95

Qualifications Summary

- Two years working with the EWB-USA WPI Chapter on the Water Supply project in Guach Tuq, Guatemala.
- Ongoing education in proper engineering design, scientific research methods, and manufacturing techniques.
- Ongoing education in social studies principle and methods related to appropriate technology and political ecology.
- Leadership experience through various group projects and student activities on campus.

Selected Project Experience
Concepts and Case in Water Security (August 2013-Present)

Independent study for Engineers Without Borders to build rainwater-harvesting systems with the community of Guach Tuq Guatemala. After a year of my involvement in EWB, our team spent over three months planning for a two week pilot trip to implement rainwater harvesting systems. Upon return, I wrote a paper about water security that I presented at the Dimensions of Political Ecology Conference at the University of Kentucky in February, 2014.

Great Problems Seminar: Evaluating Biogas as a way to Heat an Urban Greenhouse (Jan-May 2013)

Team researched biogas energy and applied data to assess whether biogas would be a practical way to heat a greenhouse located in Worcester. Team worked with a client and made recommendations as to what type of system would best suit the need. Project won first place in the spring GPS project presentation competition.

Production of Backyard Biogas in an Anaerobic Digester/Microbial Fuel Cell (2009-2012

Three-year research project on biogas energy (methane from anaerobic digestion). Project culminated in designing and building two backyard biogas systems, a simple compressor, a gas purification unit, and an integrated microbial fuel cell component to simultaneously generate electricity.

Selected Work Experience

MicrOrganic Technology Internship (May-August 2013)

Developed microbial fuel cell (MFC) wastewater treatment/alternative energy technology. Gained first-hand experience with a startup company and wastewater treatment quality analysis.

Personal, Community and Volunteer Activities

- Math And Science Help (MASH) Leader, Calculus II—WPI (Aug. 2013-Present)
- Writing Center Peer Tutor—WPI (Nov. 2013-Present)
- Engineering Ambassadors—WPI, National Grid (May 2013-Present)
- Student Delegate at the AAAS Science and Human Rights Coalition (July 2013-Present)
- ME 1800 CNC Lab Peer Learning Assistant—WPI (Jan. 2013-Present)
- Engineers Without Borders: Treasurer (2013-14)—WPI (Aug. 2012-Present)
- Newman Club, Music Ministry (Guitar)—WPI (Aug. 2012-Present)
- Great Problems Seminar: The World's Water, Peer Learning Assistant—WPI (Aug. 2013-Dec. 2013)
- Reaching High (engineering design program for high school girls), Mentor—WPI (Aug. 2012-May 2013)

Education

Academy of the Holy Names High School, Albany, NY
Class of 2012
GPA 4.0

Awards and Honors

- WPI Dean's List 2012-2014
- Ellen Knott Outstanding Women Student Award 2014
- WPI Foisie Scholarship (Endowed Full Tuition)
- WPI Global Scholar
- Davidson Fellows Scholar Honorable Mention
- 2012 RPI High School Business Plan Competition, 3rd Place
- Intel International Science and Engineering Fair 2011 Finalist and 2012 Finalist, 4th Place
- Intel Student Talent Search 2012, Semifinalist

Thomas Washburn
4793 Fawn Hill
Syracuse, NY 13215
(315) 263 2363 tmwashburn@wpi.edu

Current Position
Undergraduate Student
Worcester Polytechnic Institute (WPI), Worcester, MA
Masters Degree in Fire Protection Engineering, May 2017
Bachelor of Science in Civil Engineering, GPA 3.4, May 2016
Concentration: Structural Engineering

Qualifications Summary
- Proficient in the Spanish language
- Hard worker, quick learner, and ability to assume responsibility
- Good facilitator and manager of project work
- Skilled at working with people with diverse backgrounds

Selected Project Experience
Great Problems Seminar: The Worlds Water, WPI, August 2012-December 2013
- Worked in a team of four to explore and research alternative road deicers that could be used in the Northeast to prevent negative effects of sodium pollution
- Functioned as team supervisor
- Improved team presentation skills by presenting our findings during research process

Engineering Design and Development: Westhill High School, September 2011- June 2012
- Worked in a team of four and engineer to develop an alternative commercial and residential design for an abandoned industrial building in Syracuse, NY
- Researched building codes, restrictions, zonings for with alternative designs
- Learned to evaluate multiple solutions as a team to determine the most effective
- Presented proposed design and obstacles to a panel of engineers

Civil Engineering and Architecture: Westhill High School, September 2009 – June 2010
- Worked with a team of four under guidance from Engineer from C&S Companies to develop with alternative commercial design for an industrial harbor
- Designed with the team three structures to go onto the site
- Coordinated communication with Engineer and with other professionals
- Presented design to a panel of professional engineers and school administration

Selected Work Experience
Peer Learning Assistant, Great Problems Seminar, WPI, August 2013-Present
- Assisted professors in teaching the course and mentored students through a research project and their group work
- Reviewed and graded student assignments

Food Server, Arctic Island/Broadway Café, Syracuse NY, March 2011- Present

- Supervised and managed staff during the shift and during closing
- Financial and management responsibilities
- Worked with a team of two to six others

Personal, Community, and Volunteer Activities

Engineers Without Borders, Student Chapter, WPI, August 2012-Present

- Member of Implementation group traveling to Guatemala January 2014
- Analyzed water consumption data and design of rainwater harvesting systems

Crimson Key Tour Guide, WPI, February 2013 – Present

Tutor, Elm Park Community School, Worcester MA, August 2012-Present

- Tutor elementary Math and English to students who need additional assistance

Education

Westhill High School, Syracuse NY
Advanced Regents Diploma with Honors, Rank 12/150, GPA 96.3/100, June 2012

XI. Current and Pending Support

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: Laureen Elgert	Other agencies (including NSF) to which this proposal has been/will be submitted. None.

Support: X Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: Rain or Shine: Rainwater harvesting systems for dependable, safe drinking water in rural Guatemala

Source of Support: EPA P3 Phase 1
Total Award Amount: $14965 Total Award Period Covered: 08/15/2013 – 08/14/2014
Location of Project: Guach Tuq, Guatemala
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending X Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: Rain or Shine: Rainwater harvesting systems for dependable, safe drinking water in rural Guatemala

Source of Support: EPA P3 Phase 2
Total Award Amount: $88790 Total Award Period Covered: 05/15/2014-05/14/2016
Location of Project: Guach Tuq and San Cristobal, Verapaz, Guatemala
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

NSF Form 1239 (10/99) USE ADDITIONAL SHEETS AS NECESSARY

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: Patricia Austin

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: X Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: Rain or Shine: Rainwater harvesting systems for dependable, safe drinking water in rural Guatemala

Source of Support: EPA P3 Phase 1
Total Award Amount: $ 14965 Total Award Period Covered: 08/15/2013 – 08/14/2014
Location of Project: Guach Tuq, Guatemala
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending X Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: Rain or Shine: Rainwater harvesting systems for dependable, safe drinking water in rural Guatemala

Source of Support: EPA P3 Phase 2
Total Award Amount: $88790 Total Award Period Covered: 05/15/2014-05/14/2016
Location of Project: Guach Tuq and San Cristobal, Verapaz, Guatemala
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

NSF Form 1239 (10/99) USE ADDITIONAL SHEETS AS NECESSARY

XII. Confidentiality

We understand that by submitting an application in response to this solicitation, we grant EPA permission to make limited disclosures of the application to technical reviewers both within and outside the Agency for the express purpose of assisting the Agency with evaluating the application. We also understand that information from a pending or unsuccessful application will be kept confidential to the fullest extent allowed under law; information from a successful application may be publicly disclosed to the extent permitted by law.