Document 524
Draft Final Design Report

Chapter: Rensselaer Polytechnic Institute
Country: Panama
Community: Isla Popa II (Sandubidi)
Project: Development of Clean Water Source

Prepared By:

20 September 2015

ENGINEERS WITHOUT BORDERS USA
www.ewb-usa.org

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Draft Final Design Report Part 1 – Administrative Information

1.0 Contact Information *(correspondence regarding report reviews will be sent to the listed President, Project Leads, Mentors and Faculty Advisors)*

Project Title	Name	Email	Phone	Chapter Name or Organization Name
Project Leads				
President				
Responsible Engineer in Charge				
Additional Mentor				
Additional Mentor				
Faculty Advisor (if applicable)				
Health and Safety Officer				
Assistant Health and Safety Officer				
Education Lead				
Planning, Monitoring, Evaluation and Learning (PMEL) Lead				
In-country Community Contact				
In-country NGO Contact				

2.0 Travel History

Dates of Travel	Assessment or Implementation	Description of Trip
January 2012	Assessment	Initial Assessment trip: Established contact with community; preliminary water testing
August 2012	Assessment	Secondary Assessment: Collected data on existing infrastructure, rainfall, water quality, and land
August 2013	Assessment	Tertiary Assessment: Revisited water quality data; gathered structure measurements on pavilion
January 2015	Implementation	Constructed large-scale rainwater catchment system and installed biosand filters in school kitchen for water treatment.

3.0 Planning, Monitoring, Evaluation and Learning

3.1 The travel team has reviewed the 901B – Program Impact Monitoring Report template and has assigned travel team members to complete this report during the upcoming trip. We acknowledge that the completed 901B is required with the eventual submittal of the 526 – Post-Implementation Trip Report. _X__Yes ___No

3.2 Is the draft 903 – Implementation Agreement included as an appendix to this report? _X_Yes ___No

4.0 Budget

EWB-USA TRIP BUDGET	
EWB-USA Chapter Name ::	RPI
Project Name ::	
Type of Trip ::	
Trip Type: A= Assessment; I= Implementation; M= Monitoring + Evaluation	
NOTE: The fees associated with each trip type will auto-populate the EWB-USA HQ section.	I
Lines with an asterisk are automatically calculated.	**BUDGET *(PRE-TRIP)***
DIRECT COSTS	
Travel + Logistics	
Airfare	$6,675
Food + Lodging	$500
Other Travel Expenses (ex: Rental Vehicle, Taxis/Drivers, Exit Fees/Visas, Innoculations/Medical Exams, Insurance)	$1,000
Sub-Total*	**$8,175**
Labor	
In-Country Logistical Support	$500
Local Skilled labor	$75
Sub-Total*	**$575**
EWB-USA HQ (this section is auto-calculated based on trip type)	
Program Quality Assurance/Quality Control + Infrastructure*	$4,900
Less EWB-USA HQ Subsidy*	$3,690
Owed by Chapter Sub-Total*	**$1,210**
Project Materials + Equipment (itemized, as appropriate)	
Hardware store purchases (detailed in materials list)	$350
Wood purchased	$250
Sub-Total*	**$600**
Misc. (details required)	
Bug repellent devices	$5
Phone Card	$15
Skype Credit	$10
Sub-Total*	**$30**
TOTAL DIRECT COST*	**$10,590**

IN-KIND CONTRIBUTIONS Community In-Kind Contributions to Project Costs	
Labor	$0
Materials	$0
Logistics	$0
Sub-Total*	**$0**
TOTAL IN-KIND CONTRIBUTIONS*	**$0**
FUNDS RAISED **Funds Raised for Project + Grants Received**	
Cash from community (EWB-USA requires a minimum 5% contribution)	**$60**
Total $ in Project Fund at EWB-USA HQ	$11,448
Total $ in Project Fund at University	$0
Total*	**$11,448**
Funds Raised for Chapter	
Total $ in Chapter General Fund at EWB-USA HQ	$5,569
Total $ in Chapter General Fund at University	$0
Total*	**$5,569**

5.0 Project Discipline(s): Check the specific project discipline(s) addressed in this report. Check all that apply.

Water Supply
____ Source Development
__X_ Water Storage
__X_ Water Distribution
__X_ Water Treatment
____ Water Pump

Sanitation
____ Latrine
____ Gray Water System
____ Black Water System

Structures
____ Bridge
____ Building

Civil Works
____ Roads
____ Drainage
____ Dams

Energy
____ Fuel
____ Electricity

Agriculture
____ Irrigation Pump
____ Irrigation Line
____ Water Storage
____ Soil Improvement
____ Fish Farm
____ Crop Processing Equipment

Information Systems
____ Computer Service

6.0 Project Location

Latitude: -82.11667
Longitude: 8.183333

7.0 Number of People

Number of persons directly affected: 350
Number of persons indirectly affected: 350+

8.0 Professional Mentor Resume(s) - Please see document ***405 - Mentor Qualifications*** for the requirements of the Responsible Engineer in Charge (REIC) and the overall Professional Mentor Team. This can be found in the Sourcebook Downloads on the Member Pages of the website.

See Appendix D: Professional Mentor Resumes

Draft Final Design Report Part 2 – Technical Information

1.0 Executive Summary

This document outlines the proposed implementation plan for the Development of Clean Water Source Project by the Rensselaer Polytechnic Institute Chapter in Isla Popa II, Panama, project number 8801. The implementation trip this document refers to is scheduled to take place in early January of 2016. The objective of the implementation is to construct a chlorine treatment system that is compatible with the community of Isa Popa II by building off of the chapter's previously implemented rainwater catchment system.

EWB-RPI plans to travel to Isla Popa II in order to implement a chlorine treatment system to address the lack of community adoption of the previously implemented biosand filters. Following the January 2015 implementation trip, community members expressed their dislike of the biosand filters, and reported that they did not adequately meet their requirements for a water treatment system. Therefore, the chapter is requesting approval for a return implementation trip to address the community's issues with water quality by building a chlorine treatment system integrated into the chapter's previously constructed rainwater catchment system.

The goal of this project is to provide on-demand access to treated water that is safe for immediate consumption. This will be accomplished through a minor addition to the previously implemented rainwater catchment system. A secondary, much smaller, intermediate water storage tank will be added. This intermediate tank will be filled with water from the main rainwater storage tank manually. As water is added to the intermediate tank, the proper amount of chlorine can also be added. In this way, the intermediate storage tank will store a small supply of treated water that can be drawn from and replenished as needed. Once completed, students and staff at the local school will be able to access treated water any time, addressing the community request for a system that provides on demand access to treated water. It is estimated that this project will affect approximately 350 community members.

The community of Isla Popa II is a rural community on the island of Isla Popa. The community has a relatively dispersed layout, but is centered around the school and dock. The population is around 350 people, consisting mostly of families with young children. The community is governed through democratically elected leaders responsible for various aspects of community life, such as the school, church, and community structures. A draft of the Implementation Agreement has been created, and is attached to this document. The chapter plans to negotiate and approve the agreement with the community prior to traveling.

The program with Isla Popa II started in the fall of 2010. It was quickly determined that the community's needs mandated a water project. The chapter took three assessment trips before implementing the rainwater collection system in January of 2015. The first assessment trip took place in January of 2012, the second during August of 2012, and the third assessment trip took place in August of 2013. During the first implementation trip in January of 2015, the chapter built a rainwater catchment system on a communal structure near the school and installed biosand filters in the school kitchen to treat the collected water. While some issues have arisen since the chapter's return home, the system is able to successfully harvest large volumes of rainwater for community use. This is the only project that EWB-RPI is currently working on, with about twenty members actively involved.

For the current project, calculations were performed to determine the appropriate amount of chlorine to be added per gallon of water. This will ensure that the community is dosing the collected rainwater with an adequate amount of chlorine while minimizing the effect on taste. This will allow for effective treatment of water without discouraging use due to an unpleasant taste. Structural integrity analysis was again required for design of the chlorine treatment tank stand. These calculations can be found in Appendix A.

Project drawings are attached that describe the proposed design and how it will interact with the previous implementation. This includes accurate dimensions for the tank stand and necessary piping. These are included in Appendix A.

The team plans on staying in the community of Isla Popa II for seven days, with two extra days for travel to and from region. The first day will be spent gathering and transporting materials on Isla Colon and transporting them via water taxi to Isla Popa. The following three days will be spent constructing the tank stand. The next day will be spent attaching the required piping to the system, while the last day of planned construction will focus on community training and education. An extra day was built into the plan to accommodate any unexpected challenges. The role of the traveling chapter members is as technical contractors. Members will provide construction oversight and assist with the construction of more technical aspects of the design, such as the piping. However, community members will be doing most of the physical construction, with a team of three to four people per day assisting in construction.

The sustainability of this project is verified through low maintenance cost, availability of replacement parts, and the community-driven nature of the project. The community has demonstrated that it has the technical and financial capacity to maintain the project, given the initial proper training. The materials needed to operate and repair the proposed system can be purchased on another island in the region, Isla Colon. Once the materials are obtained, the system is easy to preserve, simply requiring cleaning four times a year. The community also has several individuals who are invested in the system and the clean water it provides who will be responsible for operations and maintenance.

This small implementation will adequately meet the needs of Isla Popa II in a sustainable manner. It provides an on demand source of clean water with low maintenance and operating costs. The community has demonstrated that is has the technical and financial capacity to maintain the project given proper training. Most importantly, the relationship between the community and EWB-RPI has steadily improved over the years, resulting in open dialogue which allows the project to more flow more smoothly and more accurately meet the needs of the community.

2.0 Program Background

When the project was started, the community of Isla Popa II does not have reliable access to clean water. Primarily, the community relies on rainwater collection. Often, the rainwater is stored in unsanitary conditions and is not treated prior to consumption. To address these issue, the chapter traveled to Isla Popa II multiple times on a series of assessment trips and an implementation trip to provide the community with a dependable source of water and a method of water treatment. The constructed system harvested the rainfall that fell on the community pavilion and stored it in two 600 gallon tanks placed adjacent to the pavilion. Point-of-use biosand filters were constructed to treat the collected water, and community members were taught the necessary procedures for constructing and maintaining these filters.

Several weeks after returning from this implementation trip, the community communicated their dissatisfaction with biosand filtration. They believed that the biosand filters were complicated and took too much time to treat water before drinking. They also informed us around this time that one of the biosand filters constructed for community use had been accidentally broken. This led the chapter to believe that biosand filters may not be the best option for water treatment within Isla Popa II. As a result, the chapter completed an alternatives analysis of possible water treatment options for the community of Isa Popa II. Through this analysis, the chapter concluded chlorine treatment to be the best option for this community. Chlorine treatment effectively purifies water and was the option preferred by the community. The chapter is currently planning to return to the community of Isla Popa II in January of 2016 to address the need for a water treatment method that is compatible with community needs.

3.0 Facility Design

3.1 Description of the Proposed Facilities

The proposed design adds a new water treatment method to the rainwater catchment system implemented on the chapter's previous implementation trip. A 55 gallon drum will be placed horizontally on a separate stand to be built in front of each of 600 gallon rainwater storage tanks. Water will flow from the large tank into the 55 gallon drum, which serves as an intermediate storage tank. Chlorine can then be added to the intermediate tank in appropriate amounts. Once treated, water can be accessed at any time throughout the day from the intermediate tank. This treatment method is designed to make the process of chlorination as simple as possible for community members and to allow for the on-demand access of treated water.

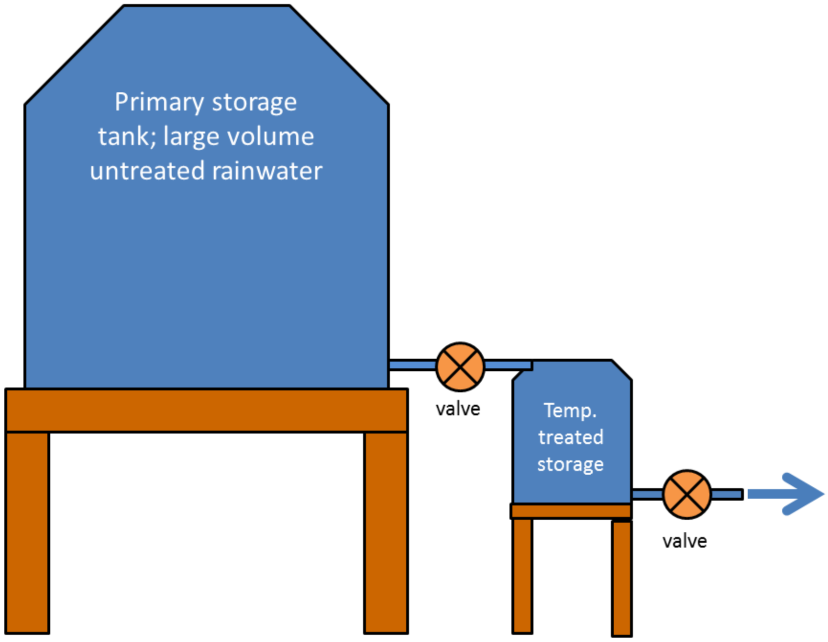

Figure 5.1.1 – Simplified graphic of proposed sytem

The system functions through the use of a valve to control the flow of water from the large rainwater storage tank to the smaller 55 gallon drum. Once filled, the appropriate amount of chlorine can be added to the now full 55 gallon drum. This task will be performed by community members trained by traveling chapter members in the proper chlorine dosing techniques. Once the water stored in the 55 gallon drum has been treated, community members can draw water from this source as needed through the use of a secondary valve. The intermediate storage tank, in the form of the 55 gallon drum, is necessary to control the inflow of water to allow for accurate levels of chlorination and store treated water for community access.

3.2 Description of Design and Design Calculations

The proposed system uses a 55 gallon drum as an intermediate storage tank between the outlet spigot and the 600 gallon rainwater storage tank implemented on the chapter's last trip to Isla Popa II. This modification to the previously constructed system will allow the community to have access to treated water without having to wait for the completion of a long treatment procedure. The two tanks are to be connected via PVC piping and flow between the two tanks will be controlled by a manually operated valve. The 55 gallon intermediate storage tank will be placed horizontally on its side, rather than standing vertically, in order to keep the outlet spigot as high above the ground as possible. This will allow easier community access and limit exposure of the outlet spigot to contamination by local wildlife.

The intermediate storage tank is necessary to meet the community's request for treated water that can be accessed on-demand without having to wait for a treatment process. The intermediate storage tank was chosen to be a plastic 55 gallon drum due to the wide availability, compact size, and adequate volume. The availability of 55 gallon drums for purchase at local hardware stores will be confirmed prior to travelling. On previous trips to Isla Popa II, communities were observed to be using plastic 55 gallon drums for rainwater catchment, providing a strong indication that a plastic 55 gallon drum is an available commodity. Additionally, the relatively small diameter of a 55 gallon drum allows the access spigot to be kept as far from the ground as possible. The volume of water stored in a 55 gallon drum is also adequate to meet the daily needs of the community. When designing the previously constructed rainwater catchment system, it was estimated that the school students would be the primary users of the system. Prior calculations estimated that approximately 250 liters of water would be required to meet the daily needs of the school[1]. This equates to approximately 66 gallons of water per day. The two 55 gallon drums, one coupled to each 600 gallon rainwater tank, will be sufficient to meet the needs of the community, providing just under 110 gallons of treated water per day. This volume is sufficient to supply the school with treated water for the entire day, and a water treatment procedure needs to only be performed once at the start of each day. Once treated at the beginning of the day, the 55 gallon drum intermediate storage tanks will provide treated water for the duration of the day.

The tank stand designed to support the intermediate tank will be built from local nispero lumber, purchased directly in Isla Popa II. The tank stand will be mounted in concrete footings to improve stability and durability. Strength calculations were conducted to ensure the structural integrity of the tank stand (Appendix A). Tests were conducted by the chapter in previous years to determine the material properties of nispero wood. The stand also must straddle a four foot by four foot square concrete splash pad constructed on the previous implementation trip. As a result, the longitudinal length of the tank stand is much longer than the length of the 55 gallon drum.

Water will be piped from the 600 gallon rainwater storage tank to the intermediate tank through schedule 40 PVC piping. The outflow piping on the 600 gallon tank will have to be removed and replaced with piping that is compatible with the current design. The previous design utilized metal piping for its durability. However, due to the imprecise nature of construction in remote areas, the flexibility in length sizing of PVC piping is preferred to the durability of metal piping. Pipes will be joined using standard PVC pipe fittings and PVC cement. Silicone sealant will be used to ensure a water tight seal. As a precautionary measure, the valve controlling the outflow of the 600 gallon tank will be placed as near as possible to the 600 gallon tank while still remaining in an accessible location. Therefore, if the piping were to develop a leak, water flow can be shut off to allow the leak to be fixed.

The 55 gallon drum has two access holes for piping. These holes are located on the flat face of the drum near the outer diameter. The holes are arranged 180 degrees apart. See design drawings in Appendix A for further details. The 55 gallon drum will be oriented so that they line up vertically, with the top hole serving as an inlet, while the bottom hole serves as an outlet. Since there are only two holes present, in order to add chlorine to the drum a chlorine access pipe has

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[1] EWB-RPI. “525 Pre-Implementation Report”. *Appendix B: Rainwater Data Simulation Sample.* 15 June 2014.

been built into the inlet piping connecting the 55 gallon drum to the 600 gallon tank. Chlorine can be added to the drum through this vertical pipe without further modification of the drum.

In the event the tank is not completely empty, but the community would like to replenish treated water reserves, water can still be added to the 55 gallon drum. As long as the community is able to determine how much untreated water has been added to the intermediate tank, the appropriate amount of chlorine can be added to the tank to treat the newly added water. In order to ensure accurate chlorine addition, it is necessary to know the volume of water that was added to the 55 gallon drum. However, the water level in the tank is not easily observable simply by looking at the tank. In order to display to community members the amount of water present in the 55 gallon drum, a water meter will be constructed into the outlet piping of the 55 gallon drum. The water meter consists of a clear plastic PVC tube that is connected to the outlet piping and extends vertically above the diameter of the 55 gallon drum. By placing the water meter in the outlet piping but before the outlet spigot, pressure in the 55 gallon drum will force water in the water meter up to a level that is equal to the water level in the storage drum. This tube will be demarcated by traveling chapter members on site to accurately measure the water level of the 55 gallon drum. This will be done by adding known volumes of water to the tank, allowing the water to settle, and then marking the water meter with the corresponding volume present. Alternatively, calculations could be done knowing the tank dimensions to determine the volume of water present based on the water level indicated.

The community will be able to access treated water in the storage tank through an outlet valve. This outlet valve is located about two feet above the ground. This outlet valve is positioned in a similar way to the previous implementation, and the two feet of vertical space will be sufficient to allow community members to easily fill water receptacles.

When chlorinating drinking water, the International World Health Organization recommends that the residual chlorine level be at 0.5 mg/L. In order to achieve this level, it is recommended that water be dosed with 2.5 mg of chlorine per liter of water[2]. Using this information, the chapter performed calculations to determine the amount of bleach that should be added to each gallon of water. These calculations are outlined in Appendix B.

Bleach is available to the community in the form of non-concentrated liquid bleach. The specific concentration of this bleach is unknown, but will be verified prior to travel. Dialogue with the community indicates that the bleach available is standard household bleach. Household bleach typically has a concentration of 5.25% to 8.25% sodium hypochlorite, the active ingredient in bleach, and the chapter has prepared dosing information for both of these concentrations. For 5.25%, 0.17 mL of bleach should be added per gallon of water. For 8.25%, 0.11 mL of bleach should be added per gallon of water. Several graduated cylinders will be purchased for the community water board to accurately measure the volume of bleach to be added.

The presence of certain solutes and organic matter in water can cause residual chlorine levels to fluctuate. To ensure proper levels of chlorine are being maintained, dpd (diethyl paraphenylene

[2] Bob Reed. "Measuring Chlorine Levels in Water Supplies". *World Health Organization*. 2011.

diamine) indicator tests will be conducted. The dpd tests, similar to pH test strips, change color with different concentrations of free chlorine. When first using the system, the chlorine residual will be tested with these strips to ensure proper levels of free chlorine are present, and that the amount of chlorine added to the intermediate tank results in the recommended residual of 0.5 mg/L. This will ensure that chlorine levels are not too low, leading to ineffective treatment, or too high, leading to an unpleasant taste. Should the previously calculated chlorine levels be outside recommend limits, the dosing plan will be adjusted accordingly on-site and any manuals left with the community will be updated. Additionally, community members will periodically use these test strips to ensure proper chlorine levels are being maintained.

When dosing with chlorine, the World Health Organization WHO recommends that the turbidity of the water should be less than 5 NTU, and the pH level of the water should be between 6.8 and 7.2[2]. The first flush system present on the rainwater catchment system will separate the majority of particulate contaminates, and turbidity is not expected to be an issue. Tests conducted in August 2012 show that the pH level of direct rainfall in the community is 5. Various tanks within the community had pH levels ranging from 5 to 7. The Safe Drinking Water Foundation states that below a pH of 4.5, chlorine can react to form dangerous compounds which are harmful to human health[3]. Adding bleach, a highly alkaline solution, should increase the pH to within acceptable levels. Due to the relatively pure nature of the available water, which is collected from rain, this is not expected to be a problem. However, the chapter will conduct pH tests on litmus paper to ensure that the pH of collected rainwater is not approaching unsafe levels.

3.3 Drawings

See Appendix A: Drawings and Calculations.

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[2] Bob Reed. "Measuring Chlorine Levels in Water Supplies". *World Health Organization*. 2011.
[3] "What is Chlorination?" *Safe Drinking Water Foundation.*

3.4 Names and Qualifications of Designers

Name	Student or Professional	Qualifications	Work Done

4.0 Project Ownership

The team has designed a simple chlorination system to be added to the rainwater catchment system that was constructed in January 2015. The constructed chlorination system will be built adjacent to the existing rainwater collection tank stands, and will have a footprint much smaller than that of the rainwater collection tank stands. The additional infrastructure built for retrofitting the existing catchment system with a chlorination system will be constructed on the same plot of land in the community that was used for the January 2015 implementation. This centralized community land is publically owned. As the entire system, including catchment and chlorination treatment, is purposed to serve the needs of the community's school children, the school president, Daniel Viagra, will have partial ownership of the project. Additionally, construction lead and president of public structures [redacted] will have partial ownership of the constructed systems. Water Board members designated on the first Assessment trip by EWB-RPI will also be key co-owners of the project.

[redacted] and [redacted], acting as primary owners of the project, will be charged with maintaining the system. Maintenance includes, but is not limited to, quarter-yearly rainwater catchment tank cleaning with chlorine and the replacement of any broken system components. [redacted], a community elder and Water Board member, has been identified as an appropriate aid for technical maintenance tasks that must be done to the system. Ramon has accumulated years of experience replacing plumbing fixtures in the community and expressed great interest in the technical aspects of the team's January 2015 rainwater catchment system construction.

Operation of the chlorine water treatment system will be the responsibility of [redacted]. Each morning, at the start of the school day, [redacted] must dose the proper amount of chlorine for disinfection of the intermediate tank water. Additionally, he will periodically test for residual chlorine in the water after dosing. The team will provide training to [redacted] for the performance of these tasks. For contingency purposes, [redacted] and [redacted] will also be trained in the event that [redacted] is unable to chlorinate water at the start of a given school day.

5.0 Construction Plan

The chapter plans to construct the proposed implementation over the course of six days. However, chapter members will remain in the community for seven days, to accommodate any unforeseen challenges. The largest logistical challenge the team will face is acquiring all required supplies on the first day in country. If certain supplies are overlooked or unavailable, a team member may be forced to return to Isla Colon during the additional "contingency day" to acquire the missing component.

Phase Number	Tasks	Est. Days to Complete
Phase I	- Acquire materials at hardware store - Transport materials to Isla Popa II	1
Phase 2	- 55 gallon drum stand construction	3
Phase 3	- Assemble piping	1
Phase 4	- Training and testing	1

Phase 1

This phase consists of acquiring the required construction materials prescribed by the implementation plan and transporting them to Isla Popa II. Materials will be purchased on Isla Colon, where members will be arriving from Panama City. The team will spend the morning and early afternoon on this commercialized island, ensuring that all the necessary materials have been acquired. Materials will then be transported to Isla Popa II via water taxis which are available for hire around Isla Colon. By reserving three water taxis in advance, the chapter will be able to transport themselves and the necessary materials to Isla Popa II.

Phase 2

In this phase, chapter members will work closely with three laborers from the community to collaboratively construct the stand that will support the 55 gallon drum intermediate tank. This will be a hands-on construction task. Footings for the foundation will need to be dug, the stand assembled, and concrete poured into the footings to securely mount the stand. Key project leaders in the community are familiar with this process, as it is very similar to the construction completed on the previous implementation trip. Additionally, operation of the existing rain catchment system will be evaluated in this stage to determine if the first flush system is operating properly. Traveling chapter members will be trained in the proper use of hand tools and simple powered tools that will be used during construction prior to travel. Additionally, the chapter will practice using PVC cement and silicon sealant to ensure an adequate seal is made on the actual project prior to travelling. Community residents who participated in construction during the last implementation trip will be recruited to assist in construction. These laborers are familiar with woodworking, concrete mixing, and other basic construction tasks. Combined with their knowledge of the local environment and experience building locally, they are incredibly valuable assets to the construction team.

Phase 3

During phase 3, chapter members will work with community members to assemble the piping that connects the 600 gallon rainwater storage tank to the intermediate 55 gallon drum. This work is more technical, and while the workload is smaller, it needs to be done carefully in order to avoid jeopardizing the integrity of system, as a failure in the piping could cause hundreds of gallons of water to go to waste. Fewer many community laborers will be needed for this construction task, but key stakeholders in the community should assist in construction to understand the purpose of each component and proper assembly techniques.

Phase 4

By this phase, all construction should be completed. Chapter members will shift focus and will engage in training community members in the proper operation, cleaning, and testing of the constructed system.

Primarily, the chapter will serve as a technical contractor for the community. Chapter members are expected to serve in a managerial role, ensuring construction is proceeding as planned and that community members are well trained in the use of the system. As they learn best-practice in tank stand construction, community members will provide most of the direct labor. Community members are capable handymen and can handle almost any construction task, such as assembling wooden structures or mixing and pouring concrete. A labor force of approximately three to four workers a day during heavy construction days during Phase 2 will be necessary to allow construction to flow smoothly.

During the trip, each traveling member will have a specific role to ensure efficient use of time and that each objective is completed. These roles are outlined below.

Construction Lead (Student)

This role will be filled by a student who is very familiar with the proposed design. Responsibilities of this role include managing efficient use of community labor to complete the construction of the proposed system and ensuring construction accuracy to proposed designs. The construction lead will ensure that the design is built properly and is built to last.

Assistant Construction Lead (Student)

The primary responsibility of this role is to assist the construction manager throughout the construction process. The construction site will likely have many activities going on at once, and an assistant construction mentor should take charge as a technical advisor for these activities when the construction manager is busy with other tasks.

Assistant Construction Lead (Mentor)

The mentor serving in this role should advise the construction manager throughout the construction process. With more experience comes better foresight; this mentor should be constantly observing all the activities going on at the construction site to ensure decisions are not made that may seem like an appropriate solution at the time, but could result in a failure of the system. This mentor will also be able to provide technical advice should unexpected problems arise during construction.

PMEL Lead (Student)
The role of the PMEL lead is measure the impact of the project on the local community. The PMEL lead will conduct interviews with families in the community about current water usage and treatment practices to establish an updated baseline of health in the community. This baseline will be critical in benchmarking the impact of the clean-water system the team has implemented. Efforts to strengthen community involvement with the Water Board will be made. Additionally, the PMEL lead is responsible for conducting monitoring tasks related to the previous implementation. This includes inspecting previously implemented systems, documenting the state of the systems, and making small repairs if needed.

Community Education Lead (Student)
The education lead is responsible for ensuring the community is aware of water quality issues. The education lead will serve in a missionary role, teaching community members of the importance of water quality. They will also be responsible for teaching community members how to properly use the newly implemented system and properly dose chlorine for water disinfection.

Quality Assurance Lead (Mentor)
The mentor in this role is responsible for general oversight of the project. The mentor should attempt to identify project sustainability issues and work to resolve these issues prior to trip completion in order to ensure a successful implementation. This role is not strictly purposed for construction, as this team member should also advise the PMEL and Education leads on issues regarding community relations.

Student Translator (Student)
The student in this role will facilitate communication between the team and community members. While many students traveling will have a limited grasp of Spanish, the common language in Panama, the student translator will be fluent in Spanish. This will ensure that critical design aspects, operation procedures, and other important information are properly communicated to the community. Although providing conditional support on the construction site, this translator position is purposed to work closely with the PMEL and Community Education Leads, as these functions are less tangible and require a more in-depth understanding of the language.

6.0 Materials List And Cost Estimate

6.1 Hardware Store Purchases

The majority of constructions supplies can be purchased at Madera's Richard, a hardware store on Isla Colon. Previously Sertebocas, this hardware store is where the chapter purchased supplies for the last implementation trip. The store can also be contacted directly by the chapter via phone, allowing for confirmation of material availability. Prior to travel, the chapter will call the hardware to confirm parts availability and part prices.

Item Name	Price	Qty	Extended Price
55 gallon plastic drum	$ 69.99	2	$ 139.98
3/4 in. x 10 ft. PVC schedule 40	$ 2.93	2	$ 5.86
3/4 in. x 5 ft. Clear PVC Sch. 40	$ 10.56	2	$ 21.12
3/4 in. PVC Sch. 40 Elbow	$ 0.48	6	$ 2.88
3/4 in. PVC Sch. 40 Tee	$ 0.48	2	$ 0.96
3/4 in. PVC Sch. 40 3-way elbow	$ 14.82	2	$ 29.64
3/4 in. PVC Coupling	$ 0.35	6	$ 2.10
3/4 in. PVC ball valve	$ 1.95	2	$ 3.90
2.8 oz silicone sealant	$ 3.95	1	$ 3.95
3 in. stainless steel screws	$ 0.10	100	$ 10.00
3.5 in. Galvanized nails (per pound)	$ 1.28	1	$ 1.28
12 cubic ft concrete	$ 45.00	1	$ 45.00
PVC purple primer	$ 5.96	1	$ 5.96
PVC Cement	$ 4.94	1	$ 4.94
1/4 in. steel mesh 2 ft. x 5 ft.	$ 8.77	1	$ 8.77
1 gallon of wood impregnating oil	$ 36.50	1	$ 36.50
		TOTAL	**$ 322.84**

6.2 Wood Count

Wood is ordered directly from a supplier on the island of Isla Popa, and is cut to specifications. Therefore, an order of 2x4's will have cross sectional dimensions of 2 inches by 4 inches, unlike the United States standard of 1.5 inches by 3.5 inches. A quote for the price of wood will be requested from the supplier prior to travel.

Quantity	Cross Section (inches)	Length (inches)
8	3 x 3	29
8	2 x 4	58
8	2 x 4	28
8	2 x 4	16
8	2 x 4	16
6	2 x 4	6
2	2 x 4	60

7.0 Operation and Maintenance

7.1 Operations

The proposed system is operated by simply filling the intermediate tank with water, adding the appropriate amount of chlorine, and then drawing water from the intermediate tank. Flow of water through the system is controlled with two valves. One of these valves controls inflow to the 55 gallon drum from the 600 gallon rainwater storage tank and the other controls outflow from the 55 gallon drum. The outflow valve will be operated by residents who wish to access water from the system. When the intermediate tank needs to be refilled, the inflow valve will be opened until the tank has reached the desired capacity. Prior to drawing water from the intermediate tank, chlorine will be added to the intermediate tank. The exact volume of chlorine to be added per unit of water is specified in the facility design. The chlorine is added to the 55 gallon drum through a secondary inlet valve on the piping connecting the 600 gallon tank to the 55 gallon tank. This chlorine inlet valve will be capped when not in use to prevent contamination of the intermediate water tank.

Prior to filling the intermediate water tank, the current water level needs to be recorded. Chlorine only needs to be added to treat the newly added water. For example, if the tank was one quarter full of treated water and then completely refilled with untreated rainwater, only three quarters of the total tank volume is untreated water, so the user would only add three quarters of the chlorine necessary to treat a full tank of water. The system will include a water meter which clearly tells the user the current water levels in the tank. The water meter will be labeled in both the ascending and descending directions. For example, if the 55 gallon drum is ten gallons short of full, the water meter will read both 45 gallons and 10 gallons. This will ensure that the user is easily able to identify how much water needs to be treated.

In order to ensure complete and proper dosing of the intermediate tank with chlorine, the inlet pipe will need to be flushed with water to carry any residual bleach from the interior of the pipe into the intermediate tank. This can be accomplished in several ways. One method involves mixing the appropriate amount of bleach for the entire 55 gallon drum in a smaller vessel with a small volume of water. This high concentration bleach and water mixture can then be added to the intermediate tank through the inlet valve. Using this method, a lower percentage of the liquid bleach will remain in the inlet pipe. Another possible method is simply adding the chlorine through the inlet valve, then pouring a small volume of water through the same inlet pipe, washing any residual bleach droplets into the 55 gallon drum. Alternatively, water can be allowed to flow from the main rainwater storage tank to the intermediate tank to wash remaining drops of chlorine into the main tank. It is recommended that a combination of these methods be used to ensure all of the added chlorine makes its way completely to the intermediate tank.

The estimated operational costs for this project only include the cost of chlorine used to treat collected rainwater. It is estimated that the community will draw approximately sixty-six gallons of water per day from the rainwater storage tanks. Following the recommended dosing plan, this equates to approximately twelve milliliters of bleach per day required to treat collected rainwater. Over the course of thirty days, the community will need 360 millimeters of bleach. Annually, this is just over one gallon of bleach. While bleach prices can vary widely. In the United States, bleach is available for as little as three dollars for 121 fluid ounces at grocery stores. However, assuming bleach costs ten dollars per gallon in the Bocas del Toro region of Panama, this is still well within the financial capabilities of Isla Popa II. The cost of bleach will be verified prior to traveling to ensure the community is able to meet daily operating expenses.

7.2 Maintenance

To promote the longevity of the proposed system, some routine maintenance is required. The two main aspects of maintenance include cleaning the 55 gallon drums and inspecting the piping for leaks.

It is expected that minor damage may occur to the piping of the system. In order to repair a leak in the piping, silicon sealant or other adhesive materials can be used. In order to properly seal the leak, most pipe repair systems require the piping to be dry. Flow through the pipe should be shut off prior to attempting repairs if possible to assure a high quality patch. In the event that a component of the piping is broken beyond the capabilities of silicon sealant and adhesive materials, a replacement part can be purchased at the local hardware store.

The intermediate storage tanks should be thoroughly cleaned and disinfected four times per year, or if a tank has obviously become contaminated. Sources of obvious contamination include noticeable reduction in water quality, such as increased turbidity. Following the guidelines outlined by the World Health Organization, the tank should be cleaned using the following procedure[4]:

1. The cleaner should wash their hands and put on appropriate protective gear, including a facemask and gloves.
2. Empty the tank until it is at ¼ of its full volume.
3. Use a brush and 2 liters of concentrated chlorine solution to scrub the interior surfaces of the tank.
4. Allow the concentrated chlorine solution to remain standing in the tank for 24 hours.
5. Empty the tank onto the gravel surrounding the first flush system to limit damage to the environment.
6. Rinse the tank thoroughly prior to continuing use. If possible, check the chlorine residual of the first volume of water added to the tank to ensure chlorine levels are within recommended limits.

The system is expected to require little maintenance. It is estimated that routine maintenance on the system should amount to only ten hours of labor per year. The expected cost of this routine maintenance is estimated to be sixty-five dollars per year, primarily spent on sealant for leaks, replacement parts, and bleach for tank cleaning.

8.0 Sustainability

8.1 Background

The main target of the team's sustainability initiatives are regular maintenance and preservation of the water catchment and chlorine treatment systems. Working with community for several

[4] WHO (World Health Organization). (1997). *Guidelines for Drinking-Water Quality (Second Edition)*

years, the team is confident the water board is capable of navigating various issues the system may face over time.

With a chlorination system, a steady supply of chlorine is required. Chlorine is readily available at another island in the region, Isla Colon. Community members travel to Isla Colon about twice a month. With proper planning, enough bleach can be bought during these regular trips to meet their demand for many weeks. As a result, community members are able to obtain supplies necessary for proper system operation without serious deviation from their current daily routines.

Structural maintenance of the constructed infrastructure is another key area for sustainable initiatives .The wood used to construct the tank stands is local nispero wood. Moving forward, the same type of locally-harvested wood will be used as the primary lumber for any required structural repairs. Since the wood is both affordable for the community and has been used by the team in the primary water tank stand construction, it would be the best option for structural maintenance. Furthermore, this local wood species is naturally resistant to rotting which prolongs its service life.

Another primary system sustainability initiative is the prescribed cleaning of the tank system. Since initial construction, the tank system has been emptied and disinfected with chlorine by quarter-yearly according to reports form the community. Tank cleaning was accomplished using a scrubbing brush and a high concentration bleach and water solution. While cleaning, any defects found in the piping and structure can be repaired or fixed. All maintenance tasks have been successfully delegated to [redacted] and [redacted], with [redacted] assisting in technical repairs. In order to ensure smooth operations, those currently responsible will need to be trained in how the new chlorination system works.

To promote healthy communication between the team and the community members and to ensure system longevity, the team plans to expand the community water board during the January 2016 Implementation trip. There are currently no women on the water board; women community-wide have taken less of an interest in the project than men and children. Maintaining a dialogue supporting the involvement of a larger portion of the community, especially women, would help ensure long-term longevity of the filtration/chlorination system.

With the implementation of a new chlorine treatment system, routine system maintenance must be expanded to include the valve that controls water flow into the chlorination tank. This component may wear and break with continued use by young children. With proper training from the team, members of the water board would be able to replace a potentially faulty or worn valve. A replacement valve could be obtained from the nearby Isla Colon.

8.2 Organizational Capacity of The Community

On the island, a water board has been established which is made up of three key members: [redacted], [redacted] and [redacted]. In total there are about four to five members. The current number of members is transitory due to the long duration of the project. During the trip in January 2016, the team will strengthen the water board to include a variety of members, especially more women. The board is in charge of fundraising on behalf of the project and maintaining the current structures. In the future, designated board members will be in charge of dosing the tanks with chlorine, maintaining all tanks, and general operations. Meeting times are closely tied to the church, which meets every Thursday night. Fundraising also occurs at church; the board raised money for implementations in January 2015 at church bingo events. The committee has been heavily involved in the design process, providing feedback after the previous implementation trip and commenting on proposed designs. After the trip in January 2015, the community expressed dislike towards the biosand filters. They felt the biosand filters were slow, not durable, and water was not readily available when they wanted it. Additionally, how the biosand filter was able to treat water was confusing to the community. As chlorine treatment is more commonplace in the community and the community members have more of an interest in this method of water disinfection, the team is eager to demonstrate proper chlorine usage to community members. During the implementation trip, the community was also heavily involved in building the tank stand and the biosand filters, demonstrating their interest in the project.

8.3 Financial Capacity of The Community

Chlorine is available at a low cost to the community in the form of liquid bleach that can be purchased on Isla Colon. Besides the chlorine, the valve connecting the collection tank and treatment tank, as well as maintenance of the tanks themselves, is able to be sustained by individuals in the community who regularly commute to Isla Colon and are available to acquire parts as the need arises. Wood is readily available on Isla Popa II and can be supplied by the community members themselves.

In order to ensure the costs associated with system maintenance and repair are available when needed, mandatory community collections are in place in conjunction with Church functions. Money gathered in these collections is used towards maintaining and operating the rainwater catchment and treatment system. These collections are specifically targeted towards the parents of the community's children, as the school children are the primary benefactors of this system. Since the majority of community members congregate at church, it is the ideal location and time for collection of funds.

8.4 Technical Capacity of The Community

Chlorine treatment has been chosen as the preferred treatment method since the community already has experience with chlorine treatment. It does not require much technical knowledge or experience to operate or to build. The major concern in operation is dosing with the correct quantity of chlorine. This will be explained through a manual which will be laid out in simple directions and displayed with the tank to ensure proper operation.

The members of the community have ample experience in construction, which was demonstrated to the team during the January 2015 implementation process. Multiple copies of the plans for the tank stands will remain at the community with the water board so that any repairs can be easily performed by its members. Cleaning of the tank is a simple task as well, which can easily be performed by a member of the water board. Again, detailed instructions for tank cleaning procedures will be laid out in a manual left with the community. Since the community also has experience with chlorine treatment, they will be performing a familiar process that needs little instruction. Guidelines will be provided to them that explain the ratio of chlorine solution to water volume, and other specific operation points.

8.5 Education

One of the underlying problems in the community is a lack of understanding of the importance of clean water. In order to impress on the community of the importance of treating collected rainwater, traveling members of the chapter will conduct rapid bacterial tests on water sources throughout the community. These bacterial tests will be compared to a control test of treated water to show community members that the water they are drinking is not as clean as it appears. The goal of these bacterial tests is to show community members that chlorine treatment is necessary in order to improve their water quality, hopefully leading to more community members adopting chlorine treatment.

Ensuring community members understand the proper operation of the proposed system is another important education objective. In order for chlorine treatment to be effective, the proper amount of chlorine needs to be added to the system. Adding too little chlorine makes the treatment ineffective. Adding too much and the water will develop a strong taste that most people find unpleasant, discouraging chlorine use. It is important the community doses their water supply properly to ensure chlorine treatment is effective and accepted within the community. In order to achieve this objective, charts dictating the amount of chlorine to be added to the tank based on the water added will be attached to the system in an obvious location. The operator will then be able to reference this chart when dosing the intermediate tank with chlorine to ensure the proper amount is added.

To promote the operational lifespan of the system, water board members will be educated in the proper maintenance of the system. This will be achieved through participation in the construction of the system and through training once the system is complete. The water board will also be given a manual that describes routine maintenance procedures, such as tank cleaning, and how to go about repairing aspects of the system that may break, such as piping connections.

Another major effort that must be undertaken is the expansion of the water board. There have been problems with the water board being ineffective. Some members often stop participating or move away without finding a replacement. Whether a result of this or through direct action, responsibility for the system has fallen to those that are most invested in the system, including [redacted], [redacted], and [redacted]. The small size of the water board limits their capabilities and influence in the community as a group dedicated to improving water quality and supply.

Another issue with water board is a lack of comprehensive involvement of the whole community. Currently, the water board is primarily male due to a tendency among the community to separate by gender. A goal of this implementation trip is to improve the stability of the water board by recruiting a more gender diversity among members of the board. This will be a priority during the trip, as a more stable, comprehensive water board will make the project more sustainable.

9.0 Site Assessment Activities

No site assessment activities are planned for this trip.

10.0 Professional Mentor Assessment

10.1.1 Professional Mentor Name and Role

Responsible Engineer In Charge.

10.1.2 Professional Mentor Assessment

With this report, the chapter builds upon its previous efforts to increase the supply of safe water to the community. The chapter has refocused on treatment and disinfection, which is a critical step in developing a safe water supply.

The chapter has presented appropriate treatment alternatives to the community, and worked with the community to select chlorine as a suitable disinfection method. The chapter has continued to develop its understanding of chlorine disinfection, to understand its limitations, and practices for best use. The chapter has developed a plan to dose chlorine to the collected rainwater.

Chlorine disinfection is a logical next step for the community. The community is more comfortable with chlorine than they are with the current biosand filters. Even so, education on the uses of chlorine will play an important role in the implementation.

10.1.3 Professional Mentor Affirmation

I, [redacted], acknowledge that this project is being performed using good engineering judgment, and I accept responsibility for the course that the project is taking.

10.2.1 Professional Mentor Name and Role

Professional Mentor who has travelled

10.2.2 Professional Mentor Assessment

The 524 report has come together quickly given the change in direction based on EWB national has provided with the assumption that water is readily available and that water quality needs improvement. There seems to be a disconnect between policy (any water collection system needs to be treated) and community needs (would like water at school kitchen). The attempt at balancing these two may end up with a finished product (chlorine dosing tank) that may only be partially used by the community. Since the community members do not appear to be suffering from water borne disease, the goal of education will be the critical component of this implementation trip to demonstrate the need to water treatment.

10.2.3 Professional Mentor Affirmation

I, [redacted], as a professional mentor acknowledge I was actively involved in the implementation phase and accept responsibility for the path this project is currently taking.

10.3.1 Professional Mentor Name and Role

Travelling Professional Mentor

10.3.2 Professional Mentor Assessment

As one of the professional mentors present during the implementation phase of this project I was aware of the community's resistance to the biosand filters. I was not affiliated with the project at the time of the assessment phase, thus, I do not know if this sentiment could have been detected sooner or have been effectively remedied through better education. Being fluent in Spanish and having communicated extensively with community lead Ambrosio Bekar over the past 9 months I do believe there is an unrealistic expectation that we will provide a system which will provide safe potable water with little or no maintenance responsibility on their part. Rectification of this will require intensive education to raise the community's understanding of the role of contaminated water in disease (which is currently lacking) and the importance of developing and maintaining a safe water supply system going forward.

I believe the group's current plans to retrofit the existing tanks with secondary chlorination tanks, coupled with a detailed and structured educational program, is an excellent method of maximizing benefit of the pre-existing facility. While the shift from sand filtration to chlorination may seem a "midstream change of horses" I believe this represents an excellent opportunity to demonstrate the flexibility and adaptability that is crucial to successful engineering.

10.3.3 Professional Mentor Affirmation

I, [redacted], have been involved throughout the design phase of this project as a professional mentor. I am satisfied with the progress made and the path by which the project goals are to be met.

APPENDICES

Appendix A: Design Drawings and Calculations

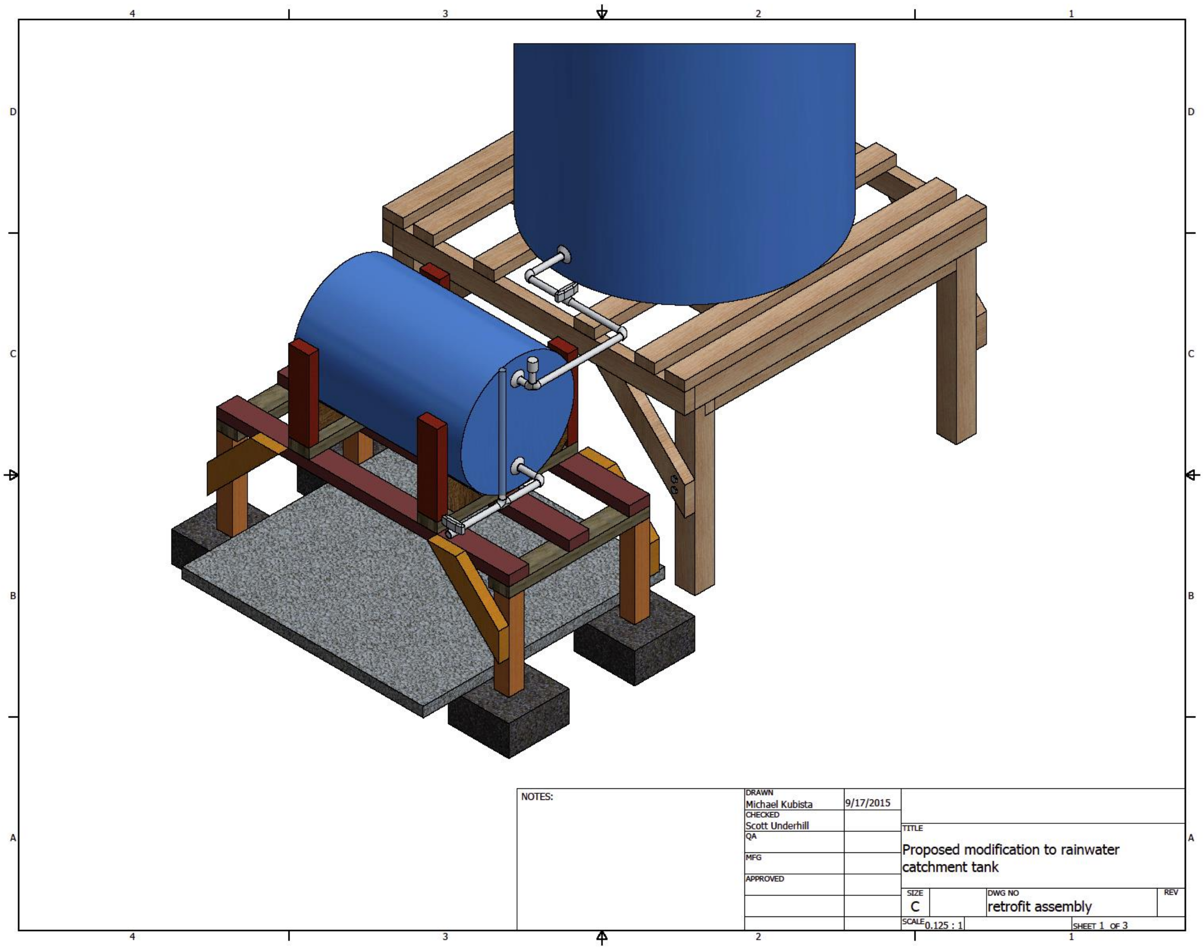
Appendix B: Chlorine Dosing Calculations

Appendix C: Draft of 903 Implementation Agreement

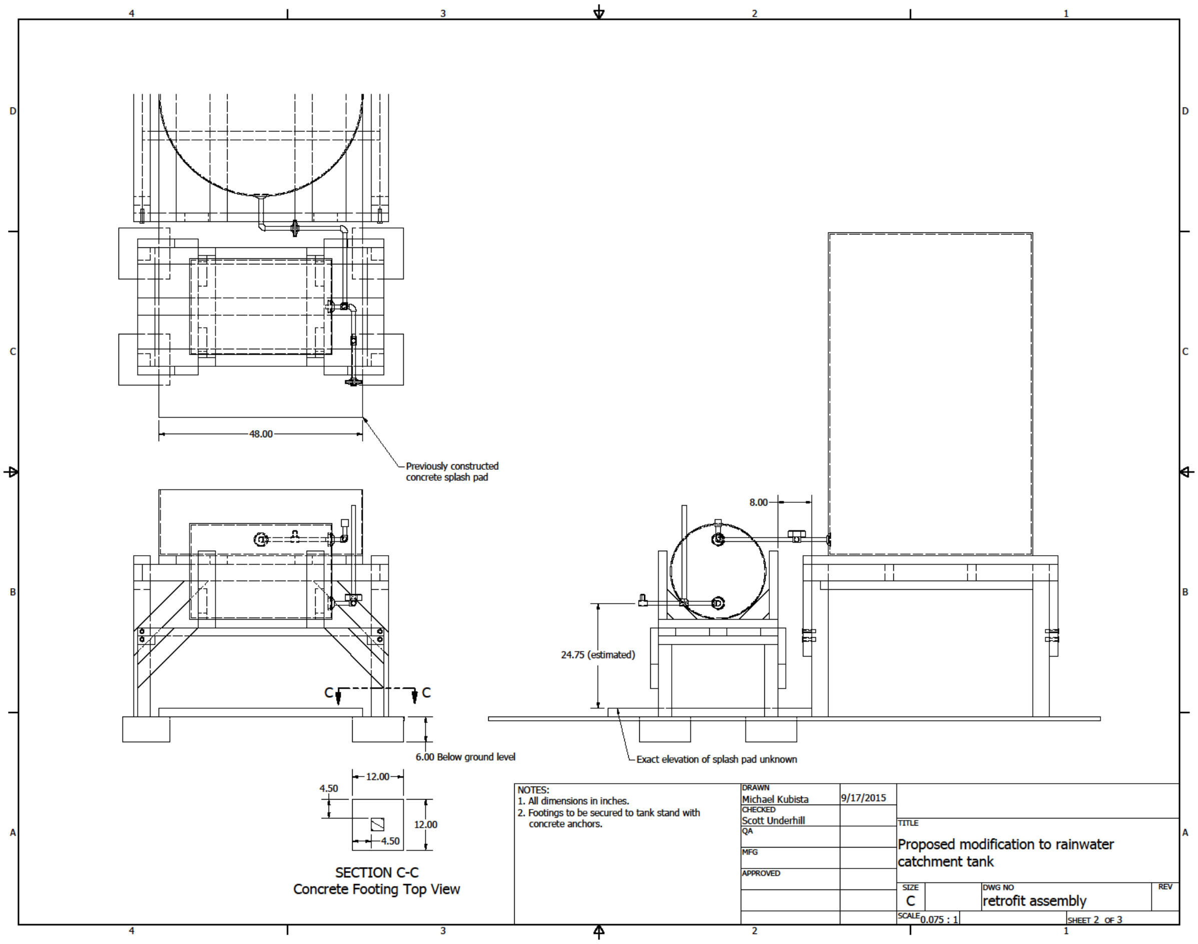
Appendix D: Professional Mentor Resumes

NOTE: All design drawings attached as separate appendix for clarity

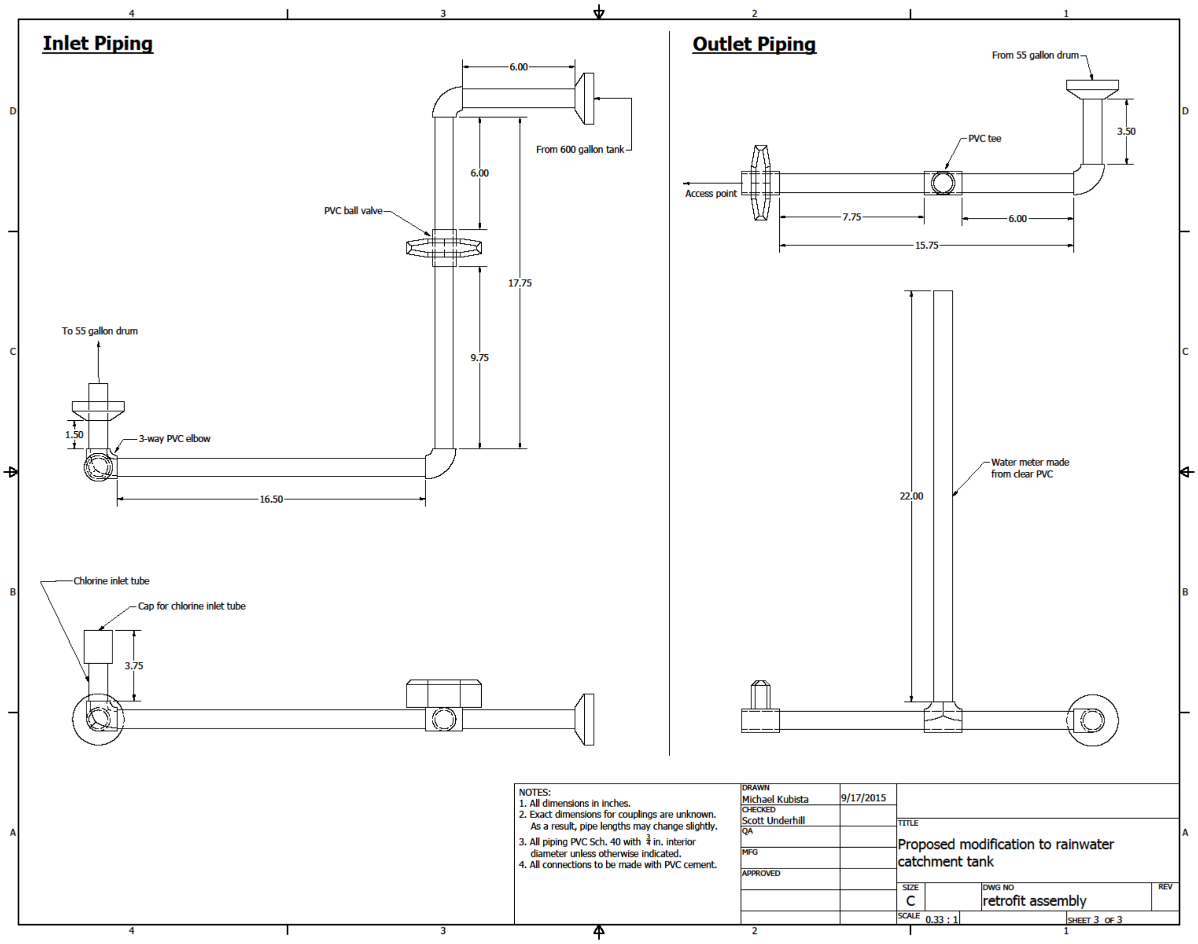
A.1 Proposed system design rendering



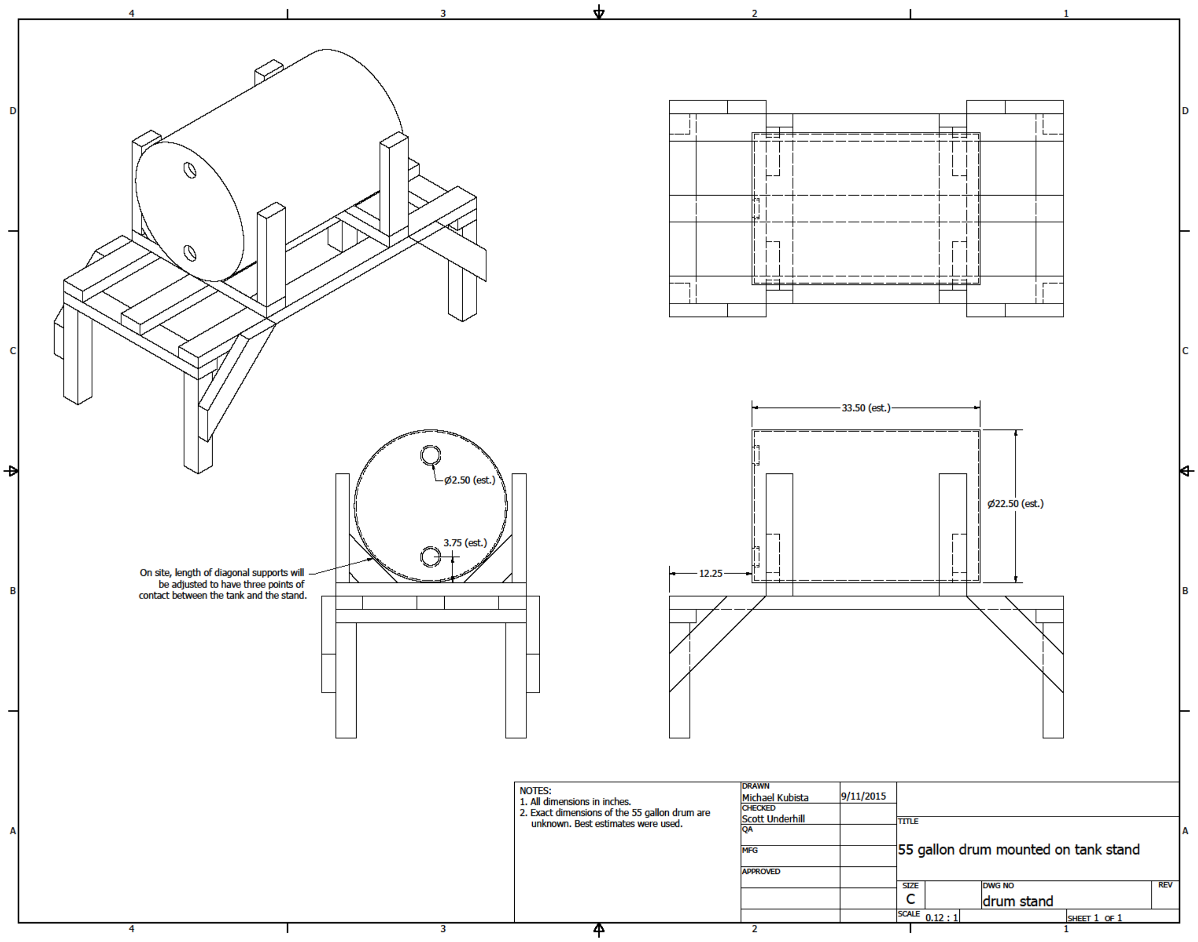
A2. Proposed system design



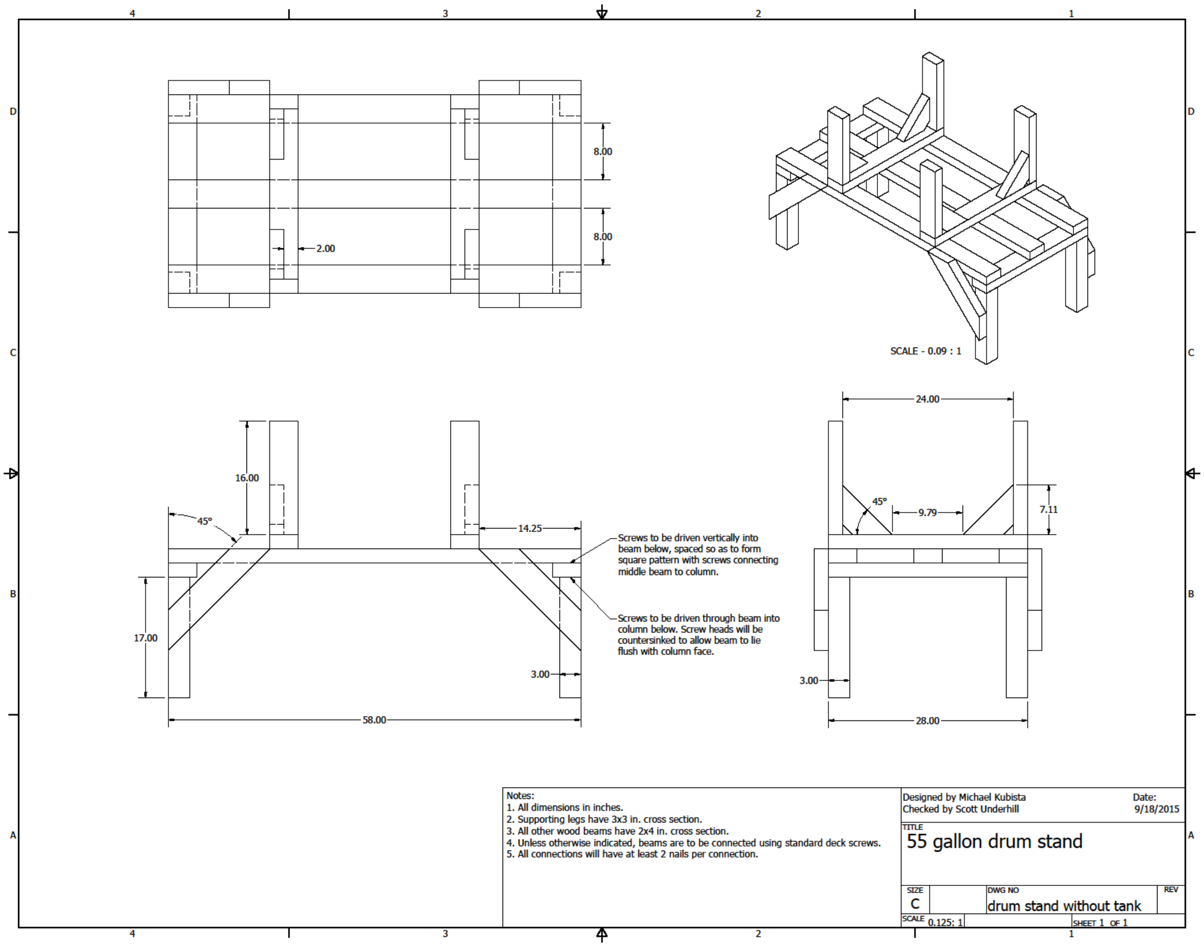
A.3 Proposed piping assembly



A.4 Proposed 55 gallon drum stand assembly



A.5 Proposed 55 gallon drum stand dimensions



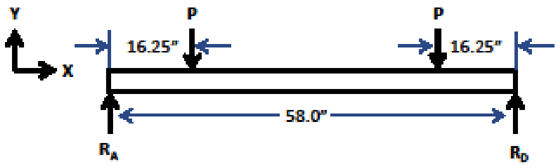
A.6 Material Properties of Wood

Property	Condition	Number of samples tested	Metric (Mpa)
Tensile Modulus	dry	2	11856.34
	wet	1	11894.09
Ultimate Tensile Stress	dry	2	43.04
	wet	1	2.61
Flexural Modulus	dry	1	3.10
	wet	1	1.30
Ultimate Flexure Stress	dry	1	4.17
	wet	1	6.17
Compressive Modulus	dry	1	4082.28
	wet	1	1555.22

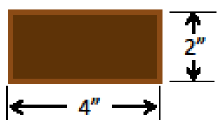
A.7 Stuctural Integrity Calculations

Deflection of Supporting Decking

Free body diagram of longitudinal beam



Beam cross section:



The maximum deflection of the longitudinal supporting decking is calculated using singularity functions and the equation of the elastic curve.

Panamanian building code for light wood framing structures:

$$Maximum\ allowable\ deflection = \frac{L}{240}$$

$$E = 1.7 \times 10^6\ psi$$

$$L = 58\ in$$

$$I = \frac{1}{12}bh^3$$

$$Equation\ of\ the\ elastic\ curve: \frac{d^2y}{dx^2} = \frac{M(x)}{EI}$$

From free body diagram, the following moment singularity function is derived:

$$M(x) = (100lbs)x\ - (100lbs) < x - 16.25" >^1\ - (100lbs) < x - 41.75" >^1$$

By solving the above differential equation for deflection in terms of displacement [$y(x)$], the maximum deflection of the beam can be calculated.

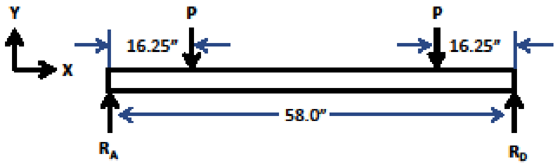
$$Max.\ displacement\ occurs\ at\ midpoint\ of\ beam: x = 29\ in$$

$$\boxed{y(29\ in.) = 0.135\ in} \qquad y_{allowable} = 0.242\ in$$

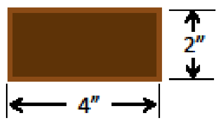
Maximum deflection of the decking is less than the maximum allowable deflection.

Loading of Supporting Decking

Free body diagram of longitudinal beam



Beam cross section:



$\sigma_M = bending\ stress$
$M = maximum\ bending\ moment$
$c = distance\ from\ neutral\ axis$
$I = second\ moment\ of\ inertia$
$P_{total} = total\ load$

$$\sigma_M = \frac{Mc}{I} \qquad I = \frac{1}{12}bh^3$$

$$P_{total} = 460\ lbs\ of\ water$$

$$P = \frac{P_{total} \cdot 1.3\ (factor\ of\ safety)}{(3\ long.beams) \cdot (2\ trans.beams)}$$

Total load is 55 gallons of water, supported by two transverse beams. The two transverse beams are supported by three longitudinal beams. See design drawings for further detail.

$$P \cong 100\ lbs$$

$$M = 1625\ lb \cdot in \qquad \sigma_M = \frac{12Mc}{bh^3} \qquad \boxed{\sigma_M = 609.4\ psi} \qquad \sigma_{ultimate} \approx 3121\ psi$$

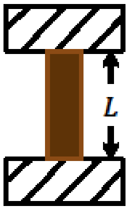
$$c = 1\ in$$

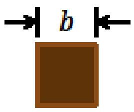
The ultimate stress for Nispero wood is estimated to be 3121 psi. Prior test results show the ultimate tensile strength of Nispero wood to be 6242 psi when dry and 378.5 psi when saturated with water. This exponential drop in strength is most likely a result of error, as only one sample was tested while saturated.

Column Buckling:

Euler Buckling Formula: $P = \frac{\pi^2 EI}{(L_e)^2}$

P = load on column
E = elastic modulus
I = second moment of inertia
L_e = effective length
L = length of column
b = side length of square column cross section





assume ends of column are fixed,
therefore: $L_e = 0.5\,L$

Total load: $55\ gal.water \cong 460\ lbs$ (*assuming denisty of* $8.36\ lbs$ *per gallon*)

$4500\ in^3$ *of structural wood* $\cong 222\ lbs$ (*assuming density of* $84.5^*\ lbs/ft^3$)[1]

$$I = \frac{b^4}{12} \qquad b = \left(\frac{3PL^2}{\pi^2 E}\right)^{1/4}$$

$$\boxed{b = 0.0115\ in}$$

$E = 1.7 \times 10^6\ psi$

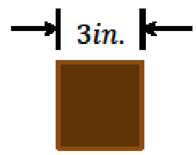
$L = 17\ in$

$$P = \frac{(222\ lbs + 460\ lbs)\cdot 1.3\ (factor\ of\ safety)}{4\ (number\ of\ legs)}$$

$P = 221.75\ lbs$

*Density of Black Ironwood lumber used as approximation, density of Nispero lumber unknown.

The proposed design calls for supporting columns with a 3in. x 3in. cross section. This is significantly larger than the minimum allowable dimension of 0.0115 in. calculated above.



(1) Meier, Eric. *Top Ten Heaviest Woods*. The Wood Database. 2015. Retrieved 13 Sept. 2015.

Appendix B: Chlorine Dosing Calculations

1) Objective

Calculate the amount of chlorine required from household bleach required to provide a residual chlorine level of 0.5 mg/L

2) References

The World Health Organization recommends the residual chlorine should be around 0.5mg/l. The organization states that adding 2.5 mg/l of free chlorine will give this residual chlorine level[5]. The following calculations and materials properties are referenced from "OxyChem Sodium Hypochlorite Handbook" by OxyChem[6].

3) Formulas

Start – Normal household bleach has sodium hypochlorite concentrations typically ranging from 5.25% or 8.25%. Sodium hypochlorite is the active ingredient of bleach.
Goal – Determine the appropriate volume of bleach to add to a 55 gallon tank to treat the water to make it safe for drinking.

Contents of Household Bleach:

- Household bleach's main ingredient is sodium hypochlorite (5.25% or 8.25% by weight), which is molar equivalent to free chlorine, as both free chlorine and sodium hypochlorite have the same oxidizing power[6]. Therefore, every mole of NaOCl present is equal to one mole of Cl_2.
- 0.4 to 4.0 grams per liter of NaOH is added for stability[6].

a. Starting with a weight concentration of 5.25 g NaOCl per 100 g of household bleach.
b. Levels of sodium hypochlorite are molar equivalent to the levels of free chlorine (Cl_2) in a solution. The molar mass ratio between NaOCl and free chlorine (Cl_2) is 1.05, calculated by dividing the molar mass of sodium hypochlorite by the molar mass of free chlorine.
c. The weight concentration of free chlorine can be calculated by dividing the weight concentration of sodium hypochlorite by the molar mass ratio. This gives a weight concentration of free chlorine (Cl_2) of 5.00 g per 100 g of household bleach.
d. The mass of equivalent fee chlorine per liter of household bleach can then be determined by multiplying the weight concentration of free chlorine with the density of household bleach. For a 5.25% concentration bleach, the specific gravity is approximately 1.082[6]. This results in 53.8 g of free chlorine per liter of household bleach.
e. Convert this to mg/L by multiplying by 1000mg/g and get 53,800 mg/L

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[5] Bob Reed. "Measuring Chlorine Levels in Water Supplies". *World Health Organization*. 2011.
[6] "Sodium Hypochlorite Handbook". *Occidental Chemical Corporation.* December 2014.

f. Starting with a 55 gallon tank convert to liters with the value of 3.7684 L/G.
g. Multiply this number by 2.5 mg/L to obtain the desired amount of chlorine for the tank, which is 520.5 mg.
h. Divide this by the concentration of free chlorine in a L of household bleach, to get the appropriate volume of bleach.
i. Multiply by 1000 to convert to ml.

4) Calculations

a. Start with a weight concentration of 5.25 g NaOCl per 100 g of bleach.
b. Levels of sodium hypochlorite are molar equivalent to the levels of free chlorine (Cl_2) in a solution. Calculate the molar mass ratio.

$$molar\ mass ratio = \frac{molar\ mass\ NaOCl}{molar\ mass\ Cl_2} = \frac{74.5\ g/mol}{71.0\ g/mol} = 1.05\ \frac{g\ NaOCl}{g\ Cl_2}$$

c. Calculate the weight concentration of free chlorine from the weight concentration of NaOCl using the molar mass ratio.

$$\frac{5.25\ wt\%\ NaOCl}{1.05\ \left(\frac{g\ NaOCl}{g\ Cl_2}\right)} = 5.00\ wt\%\ Cl_2$$

d. Determine the mass of free chlorine per liter of bleach. For 5.25% concentration bleach, the specific gravity is approximately 1.082. Density of water is 8.34 lb/gal.

$$density\ of\ bleach \cong density\ of\ water = \frac{453.6\ \ g/lb * 8.34\ lb/gallon}{3.7854\ L/gal * 100\%} = 10g/L$$

$$available\ Cl_2\ =\ 5.00\ wt\%\ Cl_2 * (10g/L * 1.082) = 54.1\ g/L$$

e. Convert this number to mg/L.

$$\frac{54.1g}{1L} * \frac{1{,}000mg}{1g} = \frac{54{,}100\ mg}{1L}$$

f. Using the volume of a 55 gallon tank, convert this number to L with value of 3.7684 L/Gal.

$$55G * \frac{3.7684L}{1Gal} = 208.2\ L$$

g. Obtain desired amount of chlorine for 208.2 L using recommended value of 2.5mg/L.

$$208.2L * \frac{2.5mg}{L} = 520.5mg$$

h. Divide the above by the concentration of chlorine in a liter of bleach to obtain the desired amount of L of bleach.

$$\frac{520.5mg}{\left(\frac{54{,}100\ mg}{1L}\right)} = 520.5mg * \frac{1L}{54{,}100mg} = 0.00962L$$

i. Convert this to milliliters.

$$0.00962L * \frac{1000ml}{1L} = 9.62ml$$

5) Results

For a 55 Gallon tank, 9.67ml of household bleach with a 5.25% Sodium Hypochlorite solution should be added to the 55 gallons of stored water to achieve a residual free chlorine level of 0.5g/L. The charts below outline the recommended dosage procedures for adding bleach to water for successful treatment.

Recommended Addition of 5.25% Bleach (mL) to Water (Gallons)										
Gallons	ml		Gallons	ml		Gallons	ml		Gallons	ml
1	0.18		16	2.81		31	5.45		46	8.09
2	0.35		17	2.99		32	5.63		47	8.26
3	0.53		18	3.16		33	5.80		48	8.44
4	0.70		19	3.34		34	5.98		49	8.62
5	0.88		20	3.52		35	6.15		50	8.79
6	1.05		21	3.69		36	6.33		51	8.97
7	1.23		22	3.87		37	6.51		52	9.14
8	1.41		23	4.04		38	6.68		53	9.32
9	1.58		24	4.22		39	6.86		54	9.49
10	1.76		25	4.40		40	7.03		55	9.67
11	1.93		26	4.57		41	7.21			
12	2.11		27	4.75		42	7.38			
13	2.29		28	4.92		43	7.56			
14	2.46		29	5.10		44	7.74			
15	2.64		30	5.27		45	7.91			

Recommended Addition of 5.25% Bleach (mL) to Water (Liters)							
Liters	ml		Liters	ml		Liters	ml
5	0.23		80	3.72		155	7.20
10	0.46		85	3.95		160	7.43
15	0.70		90	4.18		165	7.67
20	0.93		95	4.41		170	7.90
25	1.16		100	4.65		175	8.13
30	1.39		105	4.88		180	8.36
35	1.63		110	5.11		185	8.60
40	1.86		115	5.34		190	8.83
45	2.09		120	5.58		195	9.06
50	2.32		125	5.81		200	9.29
55	2.56		130	6.04		205	9.53
60	2.79		135	6.27		208.1	9.67
65	3.02		140	6.51			
70	3.25		145	6.74			
75	3.49		150	6.97			

The above calculations can be repeated for 8.25% concentration sodium hypochlorite bleach, another common variety of bleach. Bleach with this concentration has a specific gravity of approximately 1.12[7]. Following the same procedure, the below charts highlight the recommended dosage amounts for 8.25% bleach.

[7] "Sodium Hypochlorite Handbook". *Occidental Chemical Corporation.* December 2014.

Recommended Addition of 8.25% Bleach (mL) to Water (Gallons)										
Gallons	ml		Gallons	ml		Gallons	ml		Gallons	ml
1	0.11		16	1.72		31	3.33		46	4.95
2	0.22		17	1.83		32	3.44		47	5.05
3	0.32		18	1.94		33	3.55		48	5.16
4	0.43		19	2.04		34	3.66		49	5.27
5	0.54		20	2.15		35	3.76		50	5.38
6	0.65		21	2.26		36	3.87		51	5.48
7	0.75		22	2.37		37	3.98		52	5.59
8	0.86		23	2.47		38	4.09		53	5.70
9	0.97		24	2.58		39	4.19		54	5.81
10	1.08		25	2.69		40	4.30		55	5.91
11	1.18		26	2.80		41	4.41			
12	1.29		27	2.90		42	4.52			
13	1.40		28	3.01		43	4.62			
14	1.51		29	3.12		44	4.73			
15	1.61		30	3.23		45	4.84			

Recommended Addition of 8.25% Bleach (mL) to Water (Gallons)							
Liters	ml		Liters	ml		Liters	ml
5	0.14		80	2.27		155	4.40
10	0.28		85	2.41		160	4.54
15	0.43		90	2.56		165	4.69
20	0.57		95	2.70		170	4.83
25	0.71		100	2.84		175	4.97
30	0.85		105	2.98		180	5.11
35	0.99		110	3.12		185	5.25
40	1.14		115	3.27		190	5.40
45	1.28		120	3.41		195	5.54
50	1.42		125	3.55		200	5.68
55	1.56		130	3.69		205	5.82
60	1.70		135	3.83		208.1	5.91
65	1.85		140	3.98			
70	1.99		145	4.12			
75	2.13		150	4.26			

Appendix C: Draft of 903 Implementation Agreement

EWB-USA projects are most successful when there is a three-way partnership between each of the entities listed below. Each partner has specific skills and expertise, which together, contribute to a more sustainable project over the long-term.

- **Community** - Community Water Board
    - Headed by [redacted], President of the Community
- **EWB-USA Chapter:** Rensselaer Polytechnic Institute Student Chapter

This contract is between Rensselaer Polytechnic Institute chapter of Engineers Without Borders, USA, and Isla Popa II for the purpose of setting guidelines for Development of Clean Water Source in Isla Popa II, Panama. **The specific conditions listed below must be included in the standard EWB-USA Implementation Agreement.** Additional roles and responsibilities identified by any party to the agreement may be added at the discretion of all parties to the agreement. This document must be signed by all parties in order to begin construction of Development of Clean Water Source in Isla Popa II, Panama. The roles and responsibilities agreed to in the previously-signed Project Agreement remain in effect in addition to the commitments outlined below.

<u>PRE-CONSTRUCTION PHASE</u>

Isla Popa II responsibilities:

- Provide 5 % of the capital construction cost in cash before construction begins.
- Provide written confirmation that the land required for the project implementation is owned by the community before construction begins. Alternatively, in lieu of ownership, the community can provide written confirmation that it has a permanent easement to use the property.
- Provide written confirmation that it has the legal right to use the water supply that is being developed in this project ***(all water supply projects only – other project types omit this bullet).***
- Commit 3 workers for 8 hours per day for 5 days to the construction site.
- Provide the name of the community representative responsible for organizing the in-kind labor
    - Provide the following list of equipment and tools for construction:
    - List equipment and tools and quantities of each
        - Ladder
        - Food and residence for RPI chapter of EWB

- Provide the following materials for construction:

Lumber

Number of Pieces	**Measurements(inches)**	**Length(inches)**
8	3x3	29
8	2x4	58
8	2x4	28
8	2x4	16
8	2x4	16
6	2x4	6
2	2x4	60

Rensselaer Polytechnic Institute chapter of EWB-USA responsibilities:

- Provide 95 % of the capital construction cost in cash before construction begins.
- Provide qualified representatives of the design team during construction for observation or oversight.
- Communicate the requirements of site preparation prior to the chapter arriving for construction. This will be communicated to the community and the local partner two months prior to construction, or earlier as determined by the project needs.
- Provide the following list of equipment and tools required for construction:

Item name	**Qty**
tin snips	1
drill with appropriate bits	2
reciprocating saw	1
clamps	4
hand saw	2
vice grips	2
pliers	2

screwdriver	4
hammer	1
chisel	1

- Provide the following materials for construction:

Item Name	**Qty**
55 gallon plastic drum	2
3/4 in. x 10 ft. PVC schedule 40	2
3/4 in. x 5 ft. Clear PVC Sch. 40	2
3/4 in. PVC Sch. 40 Elbow	6
3/4 in. PVC Sch. 40 Tee	2
3/4 in. PVC Sch. 40 3-way elbow	2
3/4 in. PVC Coupling	6
3/4 in. PVC ball valve	2
2.8 oz silicone sealant	1
3 in. stainless steel screws	100
3.5 in. Galvanized nails (per pound)	1
12 cubic ft concrete	1
PVC purple primer	1
PVC Cement	1
1/4 in. steel mesh 2 ft. x 5 ft.	1
1 gallon of wood impregnating oil	1

POST-CONSTRUCTION/OPERATIONS AND MAINTENANCE PHASE

Isla Popa II responsibilities:

- Pay for 100% of the costs to operate and maintain the project, Development of Clean Water Source in Sandubidi Panama. This cost is estimated to be $65 per year, local currency.

- Monetary resources will be collected from the community for operations and repairs monthly and through fundraising events such as bingo nights or through monthly collections. The amount collected per the schedule above will be: $5/month
- The position/committee responsible for identifying maintenance needs is: The Water Board
- This position/committee will be appointed by the president of the community:
- This position/committee will serve in this role for 2 years.
- The position/committee responsible for performing maintenance is: The Water Board
- This position/committee will be appointed by the president of the community.
- This position/committee will serve in this role for 2 years.

Rensselaer Polytechnic Institute chapter of EWB-USA responsibilities:

- Develop a detailed operation and maintenance manual for the community (including applicable photos and local language, as appropriate). The manual will include a maintenance schedule and anticipated costs.
- Provide monitoring and evaluation of the project, Development of Clean Water Source in Sandubidi Panama, for a period of not less than one year post-construction and as long as the program is active.
- Perform repairs to the project that are the result of errors in the design until they are corrected.

In addition to the responsibilities listed above, indicate the responsible party for each of the following:

- Coordination of transportation for travel team members of Rensselaer Polytechnic Institute chapter of EWB-USA will be provided by EWB-Panama.
- Coordination of translation services for travel team members of Rensselaer Polytechnic Institute chapter of EWB-USA will be provided by Ambar Mena and Paul Pagnozzi
- Scheduling of community-provided labor will be provided by Ambrosio Bekar. This includes 3 community workers for 8 hours per day at the construction site.
- Procurement of construction materials before Rensselaer Polytechnic Institute chapter of EWB-USA arrives for construction will be provided by Maderas Richards.
- Transportation of materials will be funded by EWB-USA.

On behalf of, and acting with the authority of the residents of Isla Popa II and Rensselaer Polytechnic Institute chapter of EWB-USA, the under-signed agree to abide by the above conditions.

[redacted]
Project Lead EWB-RPI

[redacted]
President of Isla Popa II

Appendix D: Professional Mentor Resumes