Document 525
PRE-IMPLEMENTATION REPORT

CHAPTER: Worcester Polytechnic Institute
COUNTRY: Guatemala
COMMUNITY: Guachthu'uq
PROJECT: Rainwater Catchment
TRAVEL DATES: December 27, 2012 – January 9, 2013

PREPARED BY

Kali Manning	Christopher Sontag
Jennifer Moutinho	Thomas Moutinho
Jon Dorich	Taoning Wang
Prateek Sahay	

August 16, 2012

ENGINEERS WITHOUT BORDERS-USA
www.ewb-usa.org

Table of Contents

Part 1: Administrative Information

1.0 Contact Information

Project Title	Name	Email	Phone	Chapter Name or Organization Name
Project Lead	Chris Sontag	cdsontag@wpi.edu	978-870-2060	EWB-WPI
President	Lexa Vresilovic	avresilovic@wpi.edu	518-265-8234	EWB-WPI
Mentor	Matthew Gamache	GamacheM@cdm.com	857-389-2170	Boston Professionals
Mentor	Patricia Austin	Pat.austin@state.ma.us	508-792-7423 x204	Boston Professionals
Faculty Advisor (if applicable)	Creighton Peet	cpeet@wpi.edu	508-315-9395	EWB-WPI
Health and Safety Officer	Laura Pumphrey	lmpumphrey@wpi.edu	806-817-5275	EWB-WPI
Assistant Health and Safety Officer	Tom Moutinho	tjmoutinho@wpi.edu	207-831-7011	EWB-WPI
Education Lead	Creighton Peet	cpeet@wpi.edu	508-315-9395	EWB-WPI
NGO/Community Contact	Michelle Banks	paatitzat@gmail.com	502-4556-5763	

2.0 Travel History

Dates of Travel	Assessment or Implementation	Description of Trip
7/20/2010-8/03/2010	Assessment	First trip for health surveys, water sampling and meetings with community members and town officials
7/23/2011-08/07/2011	Assessment	Collected more data on water consumption, existing rainwater harvesting practices, and developed a memorandum of understanding with the community

3.0 Travel Team

#	Name	E-mail	Phone	Chapter	Student or Professional
1	Lexa Vresilovic	avresilovic@wpi.edu	518-265-8234	EWB-WPI	Student
2	Tom Moutinho	tjmoutinho@wpi.edu	207-831-7011	EWB-WPI	Student
3	Jennifer Moutinho	jmoutinho@wpi.edu	207-831-2964	EWB-WPI	Student
4	Laura Pumphrey	lmpumphrey@wpi.edu	860-817-5275	EWB-WPI	Student
5	Chris Sontag	cdsontag@wpi.edu	978-870-2060	EWB-WPI	Student
6	Laureen Elgert	lelgert@wpi.edu	508-450-3313	EWB-WPI	Professional
7	Patricia Austin	Pat.austin@state.ma.us	508-284-4356	Boston Professionals	Professional

4.0 Health and Safety

The travel team will follow the site-specific HASP that has been prepared for this specific trip and has been submitted as a standalone document along with this pre-trip report.

5.0 Budget

5.1 Project Budget

	Project City/Region and Country =>	Guachthu'uq, Guatemala
	EWB-USA Chapter =>	EWB-WPI
Year =>	**2012**	
Trips Planned	**1**	
Planned Month for Trip	**August**	
Type of Trip (1)	**I**	
Trip type: A= Assessment; **I**= Implementation; **M**= Monitoring & Evaluation		
Direct Costs	**Project Budget**	**Total Budget**
Travel		
Airfare		$4200
Gas		$0
Rental Vehicle		$0

Taxis/Drivers		$1500
Misc.		$0
Sub-Total	$0	$5700
Travel Logistics		
Exit Fees/ Visas		$235
Inoculations		$0
Insurance		$0
Licenses & Fees		$0
Medical Exams		$0
Passport Issuance		$0
Misc.		$0
Sub-Total	$0	$235
Food & Lodging		
Lodging		$930
Food & Beverage (Non-alcoholic)		Included in Lodging
Misc.		$0
Sub-Total	$0	$930
Labor		
In-Country logistical support		$1000
Local Skilled labor		$0
Misc. (Price fluctuations of materials)		$500
Sub-Total	$0	$1500
EWB-USA		
Program QA/QC**(1)**	$0	$0
Sub-Total	$0	$0
Project Materials & Equipment *(details needed)*		
House L (gutters)		$13
House A (gutters, roofing, tank)		$540
Misc. building supplies (tools)		$212
Concrete and its Transport		$260
First Flush System		$140
Sub-Total	$0	$1165
Misc. *(details needed)*		
Report Preparation		$0
Advertising & Marketing		$0
Postage & Delivery		$0
Misc.		$0
Sub-Total	$0	$0
TOTAL	$0	$0
EWB-USA National office use:		
Indirect Costs		
EWB-USA		
Program Infrastructure**(1)**	$0	$0

Sub-Total	$0	$0
TOTAL	$0	$0
Note (1): These rows are calculated automatically based on type of trip.		
Non-Budget Items:		
Additional Contributions to Project Costs		
Community		
Labor		$0
Materials		$0
Logistics		$0
Cash		$0
Other		$0
Sub-Total	$0	$0
EWB-USA Professional Service In-Kind		
Professional Service Hours		---
*Hours converted to $$***(1)**	$0	$0
Sub-Total	$0	$0
GRAND TOTAL (Project cost)	$0	$9530
Funds Raised for Project by Source	**Actual Raised to Date**	
Source and Amount *(Expand as Needed)*		
Engineering Societies		$0
Corporations		$0
University		$0
Rotary		$800
Grants - Government		$0
Grants - Foundation/Trusts		$0
Grants - EWB-USA program		$8500
Other Nonprofits		$0
Individuals		$0
Special Events		$600
Misc.		$0
		$0
Total	$0	$9900

5.2 Donors and Funding

Donor Name	**Type (**company, foundation, private, in-kind**)**	**Account Kept at EWB-USA?**	**Amount**
Pratt & Whitney	Company	Yes	$8,500
Total Amount Raised:			

6.0 Project Discipline

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

7.0 Project Location

Guachthu'uq is on the outskirts of the municipality of San Cristóbal which is in the state of Alta Verapaz.
Longitude: 90º 29' 24.37" W *(Degrees, Minutes, Seconds)*
Latitude: 15º 22' 13.04" N *(Degrees, Minutes, Seconds)*

8.0 Project Impact

Number of persons directly affected: 36 families
Number of persons indirectly affected: 80 families (neighboring community of Rexquix and Pamoc)

9.0 Professional Mentor/Technical Lead Resume

Patricia E. Austin, P.E.

11 Dell Avenue
Worcester, Mass. 01604
508 752 6732

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 25+ 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 10 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

- 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

- Grew up on a working dairy farm. Experience with basic components of animal husbandry and crop management. Continue to assist family with sales at farmers markets in locations throughout the state.
- Created urban basketball program for Worcester neighborhood serving many underprivileged children. Program just completed 6th year and has grown from 65 to 175 participants.
- Amateur musician (piano, fiddle); piano teacher
- Participate in numerous community organizations serving environmental and social justice issues in Central Massachusetts.

Education

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

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

License P.E., Sanitary Engineering, Massachusetts Number 35422

Part 2: Technical Information

1.0 Introduction

The Engineers Without Borders chapter at Worcester Polytechnic Institute has been working with the community of Guachthu'uq. Through previous assessment trips in 2010 and 2011, EWB-WPI has determined with the collaboration of the community that the lack of a sufficient supply of sanitary drinking water is the community's greatest challenge to overcome. The chapter aims to provide the community of Guachthu'uq, Guatemala with a sufficient water supply for the entire year. We plan on accomplishing our goal by implementing individual rainwater catchment systems. An important consideration was that each house is located on vastly different terrain and varying plot sizes. The condition of each home differs greatly including their current ability to collect rain water. The plans EWB-WPI have created take into consideration the different present rain water catchment systems; the team designed how to either incorporate and improve upon the existing systems or create entirely new rain water catchment systems. To ensure that these systems are successful and meet the needs of the community members, EWB-WPI will implement two pilot rainwater catchment systems and monitor their progress over the course of the next year. The pilot homes were chosen on the last implementation trip by the community members.

This report presents the current condition of the two pilot homes and the complete designs for the improvements to each individual rain water catchment system. The designs include only local materials creating a system that the community members will be able to maintain in the future. EWB-WPI has also created designs that allow for local labor, requiring only basic tools. With the existence of systems already in the community, EWB-WPI has observed the success of these designs. The rainwater catchment tanks require no energy, being gravity feed, thus they are a cost effective design for a community largely independent of electricity.

Education of both the maintenance of the systems as well as the conservation of potable water from the catchment tanks will be an important aspect associated with the success of this project. This education will not only be presented to the families of the two pilot homes, but also to the community as a whole. EWB-WPI hopes that the community members will learn to be more sparing with sanitary water usage by having a complete understanding of what rainwater should be used for. Ultimately the education of the community will be the greatest challenge with language and cultural barriers; however it is also the most important aspect of this implementation trip, to ensure that all members of the community understand that the rainwater harvesting systems already present can be used more efficiently.

2.0 Program Background

The community of Guachthu'uq is located in central Guatemala and is home to 280 people in 41 homes. Their lack of access to clean water year round is one of the greatest concerns. Michelle Banks, a volunteer for the Pacayas Project, voiced the community's needs to EWB-USA in early 2008. The EWB-USA student chapter at Worcester Polytechnic Institute accepted this project in 2009 and successfully completed their first assessment trip in the summer of 2010, and their second assessment trip in the summer of 2011. In this section, we will review each of the previous forms, summarize what we have accomplished on previous assessment trips, and outline our actions up to this point. We will also cover the important aspects related to the water project and how it influenced us to continue the project with individual rainwater catchment systems.

During the dry season (February to May), the community relies solely on a spring water diversion box located approximately one-kilometer downhill from the center of the community. This water source is located on a private estate, which the locals call the "Finca." The community has had some problems in regard to accessing the Finca source. In 2006, the land owner and the families who live in the communities that access the spring (Guachthu'uq, Las Arrugas, and La Reforma) agreed to restrict access to the actual source and to construct a spring diversion box about 100 meters downstream where families can collect drinking water and wash clothing. This has helped community relations, but the distance between the spring and the community of Guachthu'uq continues to be a problem since families have to make multiple trips each day. There is also concern about the quality of the spring water. The source does not receive any water treatment, and many people in the community, especially children, suffer from dysentery and parasitic worms.

During the rainy season (June to January), the community gathers water in rainwater collection tanks that were donated by the municipal government in 2009. They have not proved as helpful as the community members wish. The dry season in the region has reportedly become longer and the rainy season is beset by rising temperatures and decreased rainfall. Though these collection tanks have eased some of the community's water problems, not all of the families in the community own a collection tank and many of the collection systems are used inefficiently.

Previous Trips

As is the case with most EWB groups, the majority of data collection occurred during the Assessment Trips. The objectives of the first Assessment trip completed in July/August 2010 were as follows:

- Assess the feasibility of each of the possible water solutions
- Test the quality of the available water
- Make connections within the community, and the surrounding area

The following data was collected during this trip:

- Met with a geologist at the University of San Carlos in Cobán, to learn about the geology of the land in the community and obtain rainwater data. The following information was conveyed during these visits to the University:
    - Karst formations cause water to seep down into the ground very quickly due to the porous material of the earth. Consequently resulting in a lack of water filtration and lack of stability for a structurally sound well. The crevasses and the porous material cause the water quality to be very poor.
    - A deep well may be required to reach the water table.
    - A 300 page report of rainwater data was provided to the group. This report consisted of rainfall data from San Cristobal ranging from 1981-2001. This information was vital to the assessment for rainwater collection. See Appendix A for a summary of this report.
- Water quality sampling
    - The team was able to test the water quality of the local spring (Finca) and rainwater from three water catchment tanks. These water quality tests included iron, hardness, turbidity, nitrates, conductivity, alkalinity, total suspended solids, and pH. Refer to Appendix B for the results of each test.
- Layout of the community
    - A large portion of the trip was spent in the community identifying the plausibility of a water distribution system. Refer for Appendix C for the community layout.
    - Consistent electricity does not exist throughout the community.

Once home, this data was analyzed and the following steps were taken:

- Analytical Analysis
    - The rainwater data was used to calculate monthly rainfall averages to provide a basic understanding on how much rain falls in the community.
    - All of the rainwater data was entered into a dynamic excel model. For an example of this model, see Appendix D.
- Chemical Analysis
    - See Appendix B for the results of the water quality tests
- Physical Analysis
    - Due to the lack of electricity in the community, a distribution system was ruled out.
    - A well was not plausible because the geology of the land in the community is not viable.

Based on the data analyses conducted over the course of the 2010/2011 academic school year, a 2nd assessment trip was deemed necessary. The group felt that they were not yet ready to complete an alternatives assessment at that point in time because of the following data/information gaps:

- Needed detailed information on each of the houses in the community in order to have a better understanding of their specific needs.
- Needed to know if there was land available for the community tank.

- Needed a more comprehensive materials assessment.
- Needed more rainfall data because of its primary focus in the project.
- Needed to conduct additional water quality tests.

With all this in mind, the following objectives and corresponding activities were laid out for the 2nd assessment trip:

- Individual home assessments
    - Refer to Home Assessments for detailed information.
- Determine if there is land available for a community tank
    - Took a tour of the community and viewed land plots large enough to house a community tank. However, these land plots were either already owned or for sale.
    - Met with a lawyer specializing in land transactions to determine the necessary steps to acquire land to build a community tank on.
        - The community would have to purchase the land as a whole.
- Conduct a materials assessment
    - The group visited five different construction stores and recorded prices and relative quantities of materials necessary for the construction of rainwater catchment systems. See Appendix E for a complete list of the materials assessed.
- Collect more rainwater data
    - Rainfall data was obtained from an anonymous source ranging from 1979 – 2010 (Appendix A).
    - Because rainwater was the primary focus of the project, the group invested in a rain gauge. This rain gauge was purchased through the University of San Carlos, and is set up close to the community. The gauge records rainfall daily and the group receives this information via email from the sponsoring NGO.
- Water quality tests
    - The team was able to further test the water quality of the local spring (Finca) and rainwater from three water catchment tanks. E-Coli and Fecal coliform tests were conducted. Refer to Appendix B for results of these tests.

Home Assessments

The home assessments were conducted to obtain a comprehensive understanding of each of the homes in the community. With the information from these assessments, the group intended to add to the existing model, understand the specific needs of each house, develop blue prints of each house, have general information about each house, know how much water each house uses daily, and have the overall condition of the house. In order to accomplish this, the following data was collected:

- Interviews with the family members
    - Family name
    - Size of family
    - How many months they go without water
    - How much water is used daily and for what purposes

- Measurements of the inside and outside of the homes including roofs, gutters, and existing water tanks.
- Took pictures and drew rough outlines of each house.
- Completed in-depth drawings of the current roof system including:
    - Roof quality
    - Slope of roof
    - Tree coverage
    - Quality of current gutter system

This data was gathered from 36 of the 41 homes, because 5 homes chose not to participate in the home assessments.

Descriptions of Alternatives

Four potential alternative designs were considered and summarized below. A detailed presentation of these alternatives has been made in the 523 report for this project, submitted in April 2012. See Appendix F for a more thorough discussion.

Groundwater

Well

Construction of a well was one of the alternatives considered. The ideal location would be in the center of the community; but in reality would be located wherever water could be found. Water would be collected by means of a bucket and brought to the home for use. However after meeting with the geologist at the University of San Carlos in Cobán, EWB-WPI learned that the geology of the land in the community consists of karst formations which cause the water to seep into the ground quickly due to the porous nature of the karst material. The karst formations cause a lack of proper water filtration resulting in poor water quality as well as creating a lack of stability for a structurally sound well.

Surface Water

Distribution System

A spring box currently exists in the community; however, the community members have to walk to the spring box multiple times per day to fetch water. A distribution system would function to transport the water from the source to the homes of the community members. However this is not feasible due to the low elevation of the spring box compared to all the homes. An energy source would be required to pump the water up hill to the homes. The community currently has no source of electricity and an alternative energy such as solar or biomass was determined to be inappropriate for the situation at hand.

Atmospheric Water

Individual Rainwater Catchment Tanks

The high volume of rainfall the community receives during the wet season makes individual rainwater catchment tanks a feasible option. Each home would receive its own tank(s), depending on how many people live in the home. The rainwater would be collected on the roof and then funneled into the catchment tanks using a gutter system.

Communal Rainwater Catchment Tank

Communal rainwater catchment tank(s) has been considered as being a feasible option as well. A communal tank could be constructed at a high elevation in the community. This option would allow for gravity distribution if there were resources to construct a distribution system. Alternatively, multiple communal tanks could be implemented in clusters to serve groups of families. After community meetings and assessment of land ownership in the community, EWB-WPI was unable to find any usable land for purchase. For a shared tank the community would need to buy the land as a community; a strong resistance to implement this plan has been expressed by the community.

The decision between individual and communal tanks has many factors that are considered in an orderly fashion in Table 1.

Table 1: Individual Tanks vs. Communal Tanks

	Individual Rainwater Catchment	**Communal Rainwater Catchment**
Pros	Proximity to Homes	Less expensive to implement
	More individual responsibility / less potential neglect	Potential to bring community together
	Less potential disputes over water	Less man-hours spent on maintenance
	Easier maintenance	Large water capacity
	Better water conservation	
	Ability to adapt to population	
	Not subject to exploitation	
Cons	More expensive to implement	Subject to exploitation / disputes
	More design and planning needed	Less individual responsibility / more potential neglect
	More education needed for maintenance	Water communal board required
	More man-hours spent on maintenance	No back-up sources available
		Difficulty in maintenance
		Further away from homes
		Less sustainable water conservation
		Land ownership complications
		Lack of ability to adapt to population

Current Situation

Three houses were selected for implementation during the second assessment trip by the community members. A large amount of data was collected for most of the homes in the village. The team chose three houses with different structural conditions and water demands for design and implementation on the next trip. As part of the data collection process, each house in the community was labeled with a letter of the alphabet. The houses that were originally selected for the pilot projects were House A, House L, and House W. The locations of these houses and the community layout are shown in Appendix C. As we worked on the design process this past academic year and communicated with the community, it became apparent that some of the families, including the family living in House W, do not own their property. It was not possible to work out an agreement with the actual property owner of House W, so this house will not be included in the construction on the upcoming trip. Therefore, this report will describe the design process for House A and house L.

House A and House L will serve as models for the development of individual rainwater catchment systems for the rest of the community. The houses have very different characteristics and will provide adequate data for post-implementation analysis. House A has a total of four roofs; three of them are part of the main living structure and the fourth is isolated covering a tank. House L has seven roofs on four different structures, one of which is separate and is built over two rainwater storage tanks. During the data collection process, Houses A and L were categorized by the team as average condition. With these variations in structure and size, the team will be able to effectively test the plausibility of their designs. After construction, the yearlong monitoring period (Fall 2012 through Summer 2013),will provide the team with information to modify the design as needed to best fit the community, and implement individual rainwater catchment systems throughout the entire community.

Rainfall data

The EWB-WPI team acquired rainfall data for the town of San Cristobal from the University of Coban and other local researchers. The data spans 1979 thorough 2001, from which monthly averages were calculated (see Appendix A). To add to this data, we receive updates from the rain gauge we installed in San Cristobal on our second Assessment Trip. These data have been added into the monthly calculated averages as they are received.

There are years that received abnormal amounts of rain, for example in 1994, when 1073 mm of rain fell (lower than average), and in 1984 when 2198.9 mm of rain fell (higher than average). Clearly, there is a large variance in rainfall, however usually it is not this drastic. In the design calculations, we will pay close attention to how the system will work in drier and rainier years. This will be accomplished by using the monthly rainfall averages shown in Table 2. With monthly averages, the fluctuations in annual rainfall will be accounted for when designing the rainwater catchment systems.

Table 2: Monthly Rainfall Averages

Month	**Average Rainfall (mm)**
January	46.45
February	36.46
March	46.76
April	70.07
May	142.5
June	291.0
July	266.3
August	262.8
September	285.7
October	181.5
November	106.5
December	56.68

3.0 Facility Design

3.1 Description of the Proposed Facilities

Rainwater Harvesting Systems

The pilot system is made up of the following components:
1. Roof and gutter system that collects rainwater
2. PVC piping to transport water from gutter to storage tanks
3. First flush system, to get rid of debris from roofs
4. Rotoplast Plastic Storage Tanks – 2500 Liters each
5. Concrete base for tank

The two pilot homes, House A and House L, both have rainwater harvesting systems however neither system meets the needs of each family.

House A	Has an average system which needs that addition of a new 2500 L tank and a gutter system that will utilize the three roofs of the home that are currently not being used.
House L	Has one of the better working systems and simply needs the addition of gutters to connect unused roof area to an existing tank that typically does not fill.

Educational Materials

EWB-WPI aims to educate the members of the community in order to promote proper rainwater consumption and maintenance to the systems. These goals will be achieved through providing each family with a pictorial poster and verbal communication.

3.2 Description of Design and Design Calculations

For both pilot houses we will explain the specific design we chose and provide reasons why EWB-WPI felt the design was appropriate for both families.

Dynamic Excel Model

This model allowed for the calculation of how much storage is required to provide an annual water supply. It uses average monthly rainfall data to determine, with the calculated consumption rate for each family size, the average flux of water on a daily basis into the overall system. This model has enabled EWB-WPI to test our proposed designs with a degree of confidence that the system will meet the annual demand. View Appendix D for an example of the Excel Sheet.

Information Research and Design Calculations

Consumption Rates

One of the most integral measurements for the success of the rainwater catchment systems is the family consumption rates. In order to approximate this value as accurately as possible, the team employed three different methods. The home owners were asked how much water they consume per day, and how many months of the year they go without water during the second assessment trip home surveys. This data was used to determine an average consumption rate per person. By multiplying this consumption rate by the number of people in the household, an average household consumption rate was calculated. Table 3 shows these different calculation options.

Table 3: Water Consumption Comparison

House	Daily Consumption Rate (Survey) (L)	Number of Household Members	Consumption per Person (L)	Daily Family Consumption Rate (Based on Average Consumption per Person)
A	123.0	6	20.5	102.6
B	124.9	11	11.4	188.1
C	105.6	4	26.4	68.4
D	113.6	3	37.9	51.3
E	153.9	8	19.2	136.8
F	189.3	10	18.9	171
G	28.4	5	5.7	85.5
H	94.6	6	15.8	102.6
I	94.6	7	13.5	119.7
J	47.3	8	5.9	136.8
K	18.9	8	2.4	136.8
L	75.4	10	7.5	171

M	75.4	10	7.5	171
N	37.9	12	3.2	205.2
O	47.3	6	7.9	102.6
Q	88.2	8	11.0	136.8
S	94.6	8	11.8	136.8
T	94.6	7	13.5	119.7
U	45.4	4	11.4	68.4
V	45.4	4	11.4	68.4
W	37.8	3	12.6	51.3
Y	94.6	5	18.9	85.5
Z	94.6	4	23.7	68.4
BB	28.4	5	5.7	85.5
CC	378.5	8	47.3	136.8
DD	37.9	5	7.6	85.5
GG	189.3	5	37.9	85.5
HH	378.5	6	63.1	102.6
Average:	104.9	7	17.1	

Rain Flux

Rain flux is a measurement tool to determine the amount of water that a surface collects on a day to day basis. Efficiency rate for collection of rainwater, surface area of the roof, and rainfall per month are all needed to determine the rain flux for a roof during any month. The equation used to calculate rain flux is below. Note that the factor of 1000 is to convert cubic meters to liters. This equation produces a unit of Liters/day:

Rain Flux = 1000*Efficiency Rate*Surface Area*Month Rainfall Average*Number of days in the Month

Below is a sample calculation for Roof 2 on House L for the month of August (8^{th} month).

<u>Sample Rain Flux Calculation for House L – Roof 2 in August</u>
Rainfall = 0.262761 m
Efficiency Rate = 70% = 0.70
Surface Area of Roof 2 = 26.00253 m^2
Number of days in month = 31 days

Rain Flux= 1000*0.70*26.00253 m^2*0.262761 m*31 days

Rain Flux= 4782.716 m^3/31 days = 154.28 m^3/day
Rain Flux=154.28 L/day

As shown above, the rain flux for Roof 2 on House L in August is 154.28 L/day. This same equation can be applied to any roof and combined to calculate the total rain flux for any house.

Screens

Installing screens on the gutter and downspout system is an integral part of creating a safe source of drinking water. Gutter screens and other forms of debris prevention are commonly used in the United States to prevent clogging. While the addition of screens to a gutter helps with debris build up, depending on the size of the screen small seeds or buds can still get in the gutter, and in our case the water catchment tank. The Rain Trade Corporation recommends cleaning gutters out twice a year at the very least-- more if there is a lot of foliage or a wet climate.
The material available for gutter screens is rolls of metal screening. The procedure for installation of screens will vary depending on house and roof. What all tanks will share in common is a very fine metal screen on the downspout leading into the tanks. This screen will act as a last resort for blocking debris from entering the tanks, and will need to be checked for clogs preferably before each rainfall.

On Roof 1 of House A, the rust is minimal and therefore the roof need not be replaced. The gutter system already there will just need to be cleaned out thoroughly prior to the screen installations. In Figure 12, Roof 1 is shown surrounded by trees and with leaves and debris on the roof. Because of this high debris collecting area installing screen across the entire gutter is the best and safest option. There is only one section of gutter on Roof 1, so installing screen across top of the entire gutter is reasonable. The metal screen would have the same, or larger holes, as the screen used on the water tank pipe. It would be cut to length, attached between the gutter and roof, and then bent over the outside edge of the gutter. If six inches of screen were left to hang over the edge of the gutter, unsecured, this would allow for regular and easy maintenance of the gutter while also protecting it from debris flowing off the roof. We could also do this for Roof 1 on House L, but as shown in the pictures, there is little to no debris on the roofs, so an entire screen system may not be necessary.

Roof and Gutter System

The gutter needs to meet a minimum slope in order to drain the rain water efficiently. However, we do not want to set up the gutter too steep, causing the end of the gutter to be lower than the inflow pipe of the water storage tank, which would create a stoppage in water. The slope has to be at least 0.5% for the first 2/3 of the gutter and 1% for the last 1/3 of the gutter. This setup allows all of the water input to flow without any congestion (Thomas & Martinson 99).

As recommended by EWB, we will use the steel trapezoidal gutter. This type of gutter is available locally through the hardware stores of San Cristobal. Also, because the collecting roof area is not too big on either house, we can use the typical gutter size of 5 to 6 inches. The gutters we can buy from local hardware stores in Guatemala are 8 feet in length. If the length of a gutter is n ft, the total length we need for a 25.15ft roof side is:

L= ((25/n)-1)0.5+25.15, use integer with 25/n, where n is the length of the gutter.

For each overlap part, we will put a gutter clip, which is screwed into the wall.

Since the gutters are only 8 feet long, we will have to connect all the 8 feet gutters together to make a longer one. For House A, the longest gutter we will need is around 30 feet. 6 inches of overlap is recommended by EWB for the connection of each gutter, and it should be screwed in the overlapping part. 6 inches overlap is designed for structural support and to prevent leaking. During the raining season, there might be a lot of water running in the gutter, and 6 inches overlap is necessary to keep the gutter from fracturing.

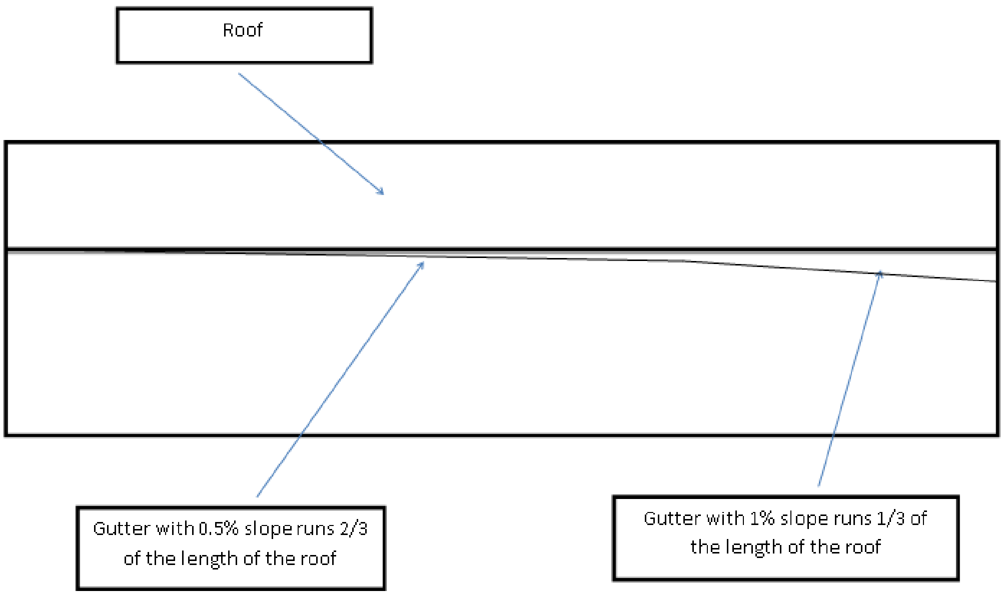


Figure 1: Side View of House with Gutter

The gutters will be attached to the walls of the outside of each home using gutter clips. Gutter clips can either support the gutter underneath by holding it up and being screwed into the wall, or be placed inside the gutter and a screw placed through the gutter into the wall. We will most likely use a gutter clip like that shown below:

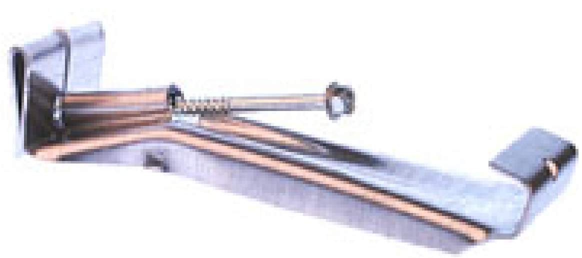


Figure 2: Example of Gutter Clip

Figure 3: Example of Gutter Clip and Gutter

This type of gutter clip is placed inside the gutter. They are available in different sizes according to the gutter size bought. We will have about 33 meters of added gutters that we will be installing, this is equivalent to about 108 feet of gutters. It is suggested to use top hanging gutters at every 0.8 meters of gutter. Based on this calculation, we will need about 42 gutter clips. When the gutter is taken around corners, the clips and brackets needs to be placed within 0.3 meters of the edge corner. There are only a couple of times when we will be transferring piping around a corner. We will need to do this approximately one time for House L, and 3-4 times for House A.

Figure 4: PVC/Downspout Holding Bracket

The gutter brackets shown above will be used for to secure the sections of PVC to the wall to prevent movement and to ensure stability. They will be used on all PVC piping along the sides of the houses. It is suggested that they be placed at about 2 meters apart for each bracket. The brackets should not be as tight as possible and allow a slight gap to allow for the gutter to expand when needed.

Downspout

For the downspout of the gutter system we will use a locally available downspout that will be able to connect to the gutters purchased. To account for the large bursts of rainfall that are common in Guatemala, we will buy the largest (by area) downspout that is available and that will still fit the common 6 inch gutter. This will allow all of the water collected to be transported to the storage tank.

First Flush Design Description

The first flush is put in place in order to discard the initial rainwater that falls on the roof. This initial rainfall cleans the surface of the roof of debris and contaminant that should not be harvested in the tank. As stated in The Texas Manual on Rainwater Harvesting the minimum volume of water that should be discarded with the first flush is 10 gallons for every 1000 feet squared of roof area. Based on the standard from the manual we decided to discard 12.5 gallons of water for every 1000 square feet of roof area. The calculations below determine the size requirements of each first flush system in order to collect the correct amount of water in each first flush system. The conversion 1 gallon = 231 in^3 was assumed to calculate the following values.

PVC volume:
3" PVC: 0.384 gals/ft
4" PVC: 0.66 gals/ft
6" PVC: 1.456 gals/ft
8" PVC: 2.58 gals/ft
10" PVC: 4.03 gals/ft
12" PVC: 5.8 gals/ft

First Flush systems for each pilot home

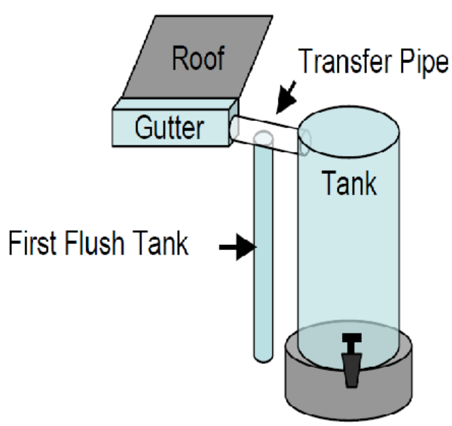


Figure 5: Example of First Flush Placement

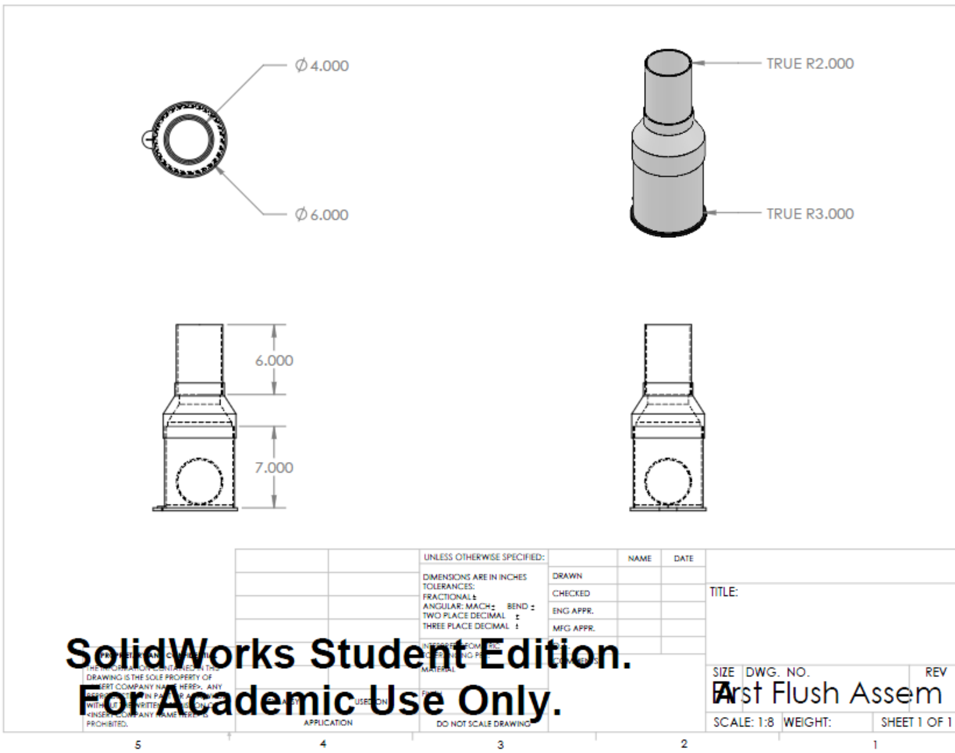


Figure 6: First Flush Design

It is very important to note that each first flush dimensions will be different based on the roof area that the first flush is responsible for. This will be more discussed in the calculations section as well. The basic design is shown above, but the length of the bigger diameter PVC piping will be a different length dependent on the roof area it is servicing. Also, at the end of the pipe, there will be a removable cap to clear the dirty water out.

Concrete Base

With the addition of the rain water harvesting tank being added to House A, an additional concrete base will be essential. The concrete base is necessary to raise the tank off the ground and supply a stable flat surface for it to reside on. The water spout is located at the bottom of the tank and thus must be moved away from the ground to allow for better sanitation and easy access. Since concrete takes time to cure properly, efforts are being made to have skilled labor in the community make the concrete base before we arrive in the August. Contact has been made with the local NGO, Michelle Banks, as well as the community leader; both parties agreed that it may be possible for the community to achieve this goal before we arrive. Although this plan of action is ideal, it is not necessary. Plans have been made that allow for plenty of time in our construction plan that will allow us to oversee the construction of the base while in Guatemala. The concrete base will need roughly a week to cure enough to support the weight of an empty tank and it will continue to cure after the tank it place on top. With that said, if plans are delayed due to rain and the base is not poured until the second week our team has the confidence that the family members of House A will be able to move the tank onto the base after the correct amount of time has passed for the concrete to cure.

Shape and Constructability

The size of the concrete base has been decided based on the size of the tank weight of the tank. When pouring concrete it is important for the ground under the base to be able to support the concrete and weight of the tank. The tank that will be place on the concrete base is 5 feet in diameter and has a volume of 2500 Liters. The tank itself weighs about 300 pounds plus the weight of the water which can be estimated as 2500 kilograms when full. 2500 kg is equivalent to 5500 lbs. When the tank is full, it will have a total weight of almost 6000 pounds. With this as the weight capacity the concrete base must be able to support a tank full of water as well as raise the water spout away from the ground enough to allow for sanitary access. Currently the concrete bases in place in the community homes that already have systems are a foot high. In order to be consistent with a working model we have designed the bases to have the dimensions of 5' x 5' x 1' this will allow the entire tank to rest of the base and it will raise the tank of the ground enough for the spout to be accessible. However this size base will cost a large sum of money and with some research we have found that with rebar a six inch slab of concrete would be sufficient to hold the 6000 lbs. that we need. In order to raise the tank off the ground by a foot as well as reduce total cost of the system the use of gravel has been incorporated into the design. This design calls for a 4 inch packed layer of gravel to be placed set into the ground and create a solid incompressible base under the concrete. The actual concrete base will have a 4 foot by 4 foot 6 inch high section of packed gravel in middle of the base. The concrete will then be laid on and around the gravel thus creating a 6 inch layer of concrete surrounding the packed gravel. The complete base will be the total foot high however almost half of it will be just gravel within. In the six inches of concrete in the top layer, rebar will be placed 3 inches from the surface to add strength to the base if an earthquake were ever to create stress fractures in the base. The use of gravel as a space holder within the slab will allow us to create a concrete base that has the correct form and function yet at a less expensive price.

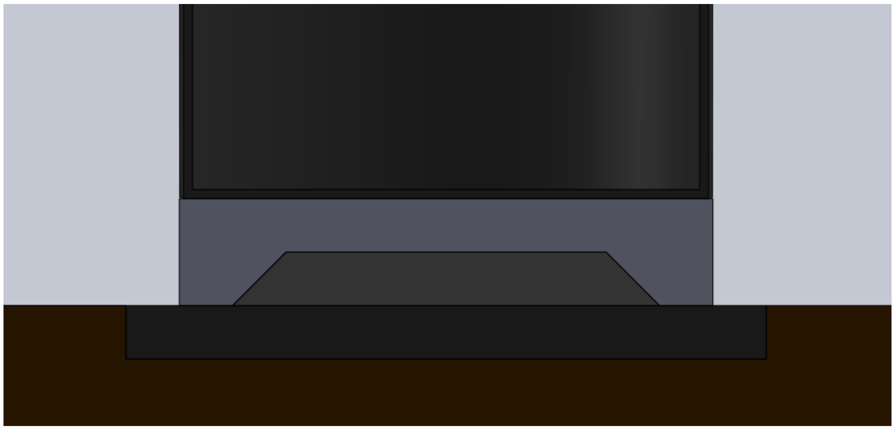


Figure 7: Side View of Concrete Base with Tank

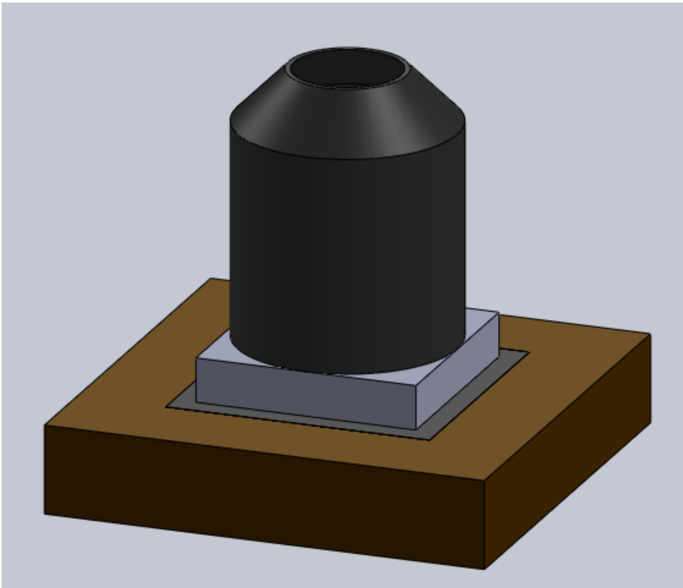
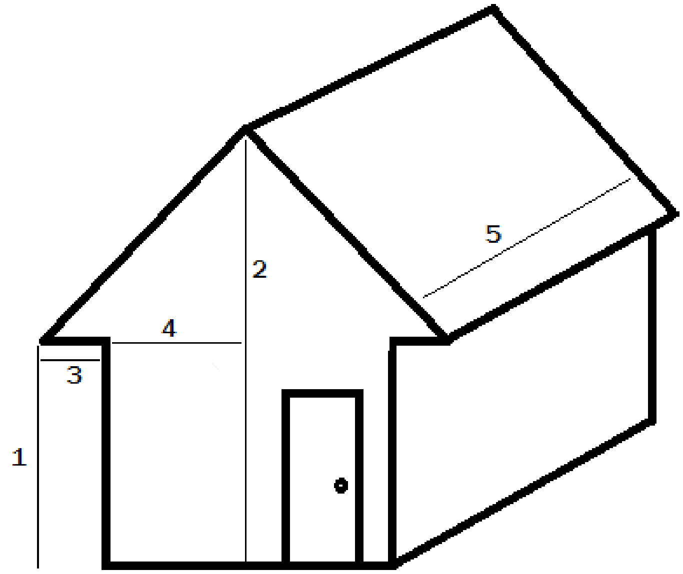


Figure 8: Full View of Concrete Base with Tank

General House Information

As can be seen in Table 3, there is a wide range of water consumption rates. This variation is clearly seen with the homes of 8 people, which corresponds to a consumption rate range of 18.9 L to 378.5 L. Clearly neither of these extremes is accurate. This can be attributed to the inconsistency with survey answers and the inability of the community members to accurately tell how much water they consume per day. Therefore, the overall average per person must be used instead. When comparing the average consumption rate per household to the average rate per person multiplied by the number of people in each household, the range of rates is more reasonable (104.9 L to 119.7 L/Day). Based on this analysis, the team has decided to assume an average of 120 L/Day per household. This average was then used to calibrate the excel model based on the number of months the family members said they went without water.

The measurements of each house will be included in the description of the usable land. The image below describes all the important measurements taken for each house.



Legend	
1	Ground to Base of roof
2	Ground to peak of roof
3	Edge of roof to outside wall
4	Base of roof: wall to point below peak
5	Length of roof

Figure 9: House Measurements

Figure 10: Example of Rainwater Harvesting tank and Concrete Base

The rainwater harvesting tank (manufactured by Rotoplast)

Volume: 2500 Liters
Height: 1.60 meters
Diameter: 1.55 meters

Concrete base for tank:

The surface area of the base is determined by the number of tanks resting on it.
A typical size for two tanks is:
Length: 3.0 meters
Width: 1.5 meters

Typically a single tank base is a square with side length of 1.5 meters.
The typical height of the existing bases is 40 centimeters or roughly a foot and 4 inches.

A generic rainwater catchment system is relatively simple in design. The rain will fall onto the roof and flow into the gutters which direct the water via gravity to the collection tank. As the water flows toward the tank it will pass through a screen filter that will stop large debris such as leaves and branches from continuing. After the screen filter, the water will flow through a first flush system which disposes the initial rain that runs through the system in hopes that this water will wash away the majority of the contaminants that were present on the roof. With the first flush only the water that runs through the pre-cleaned system is collected. As members of the family need water they will take it out using the spigot at the bottom of the tank. Our goal is to ensure that the tank is filled with water at the beginning of the dry season. Having easy access to water year round will allow the family to have no need to walk several kilometers a day to collect water at the only local water source. This saves them between one and a half to three hours per day, depending on their house location.

Current Situation and Proposed Designs

In the following sections we outline the current houses and situations that we will be working with throughout our first implementation. We will discuss the current conditions of the two house structures with existing rainwater systems. Detailed measurements were taken for all important aspects of each pilot house during the second assessment trip. We will present images of the two homes from multiple angles and report the data about the effectiveness of the current system in supplying water year round. After establishing the current conditions of the two pilot homes, the designs for the improvements will be discussed in detail.

House A Current Situation

House A currently is a mid-sized home that is composed of two separate structures. Roof 1 is separate from the entire house and was installed and built by the local government during a campaign season. Roof 1 is supported by four columns with no walls; its only purpose is to collect rainwater. The structure has its own gutter system that feeds into a 2500 L tank located underneath. The condition of the Roof 1 system is average, though it is beginning to rust.

The second structure is the home in which the family lives. It consists of Roofs 2, 3, and 4. Currently on Roof 3 there are two separate gutter systems beginning on each side of the roof. The gutters do not attach in the middle and the water falls into two makeshift containers, which is the only means for catching and storing water off any of the three roofs on the main house. Because the house has a significant amount of roof area, it could be utilized to generate enough water for the family year round. Roofs 2, 3, and 4 have large amounts of rust and will need to be replaced.

This house is located at N 15 22.397, W 90 29.723

The pictures (Figure 11 through Figure 16) below show the layout and the key aspects of House A.

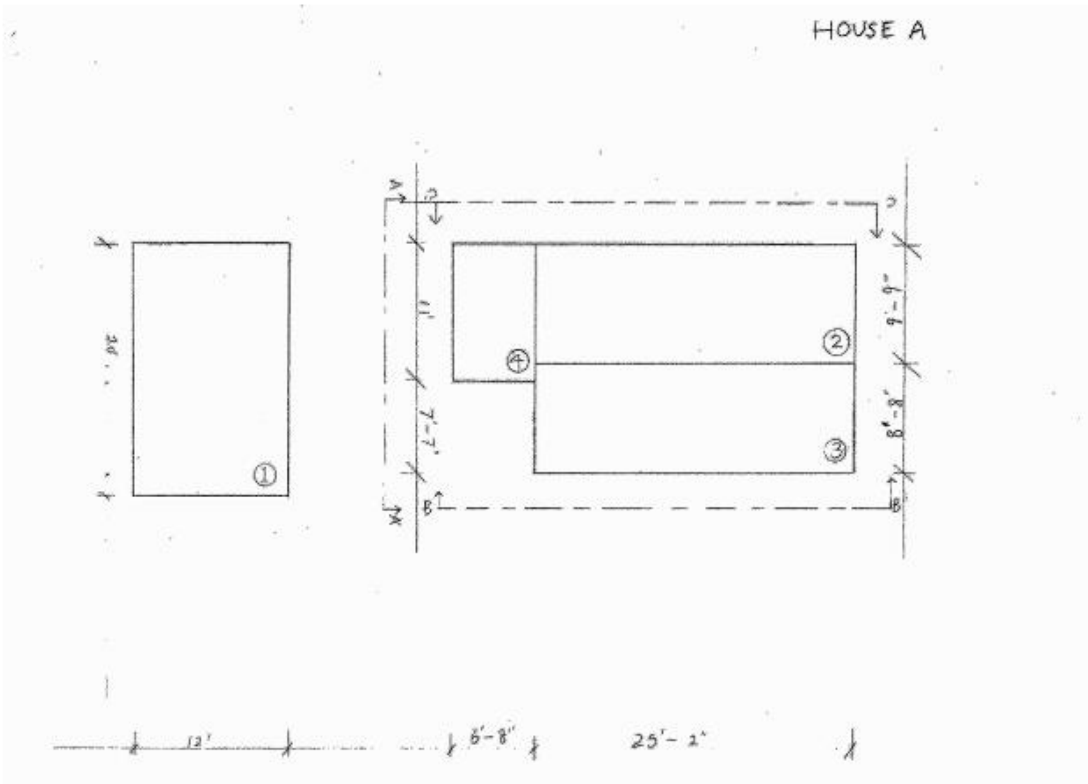


Figure 11: House A Current Layout

Figure 12: House A, Roof 1 and Structure

Figure 13: House A, Roof 2 (Roof 3 opposite peak of Roof 2)

Figure 14: House A, Roof 4

Figure 15: House A, Roof 2 (back left), Roof 3 (back right), and Roof 4 (front center)

Figure 16: House A: Half Gutter on Roof 3 (water drops into small container from gutter)

The questionnaire taken for House A (Appendix G) is shown below with all of the measurements taken during the home assessment. After House A was chosen as a pilot house, detailed measurements were made and are shown in Table 4. Despite having a rainwater catchment system, House A, does not have any water in their tank during 4 months out of the year. The existing measurements for the features of House A are displayed in Table 5 below. Only Roof 1 is connected to the 2500 L tank.

Table 4: Roof Measurements for House A

	Roof 1	Roof 2	Roof 3	Roof 4
Height 1 (edge)	249 cm	210 cm	180 cm	195 cm
Height 2 (Peak)	343 cm	340 cm	340 cm	226 cm
Slope of Roof	10°	22°	17°	0°
Edge of Roof to outside wall	See other governmental tanks	23 cm	39 cm & 13 cm	---
Base of Roof	610 cm	300 cm	270 cm	333 cm
Length	370 cm	768 cm	768 cm	204 cm

Table 5: Current Rain Water Catchment System for House A

Length of roof 1	3.7	m
Width of roof 1	6.10	m
Length of roof 3	7.68	m
Width of roof 3	2.70	m
Total Surface Area	45.61	m^2
Volume of Tank 1	2500	L
Volume of Tank 2	187	L
Volume of Tank 3	46.75	L
Volume of Tank 4	0	L
Total Storage Volume	2733.75	L
Consumption Rate	120	L/Day
Efficiency Rate	70%	

Based on a consumption rate of 120 L/day from calibrating the model based on the average consumption rate per person calculated and the months without water provided by the family (Appendix G), the average monthly rainfall data (Table 6), and roof area (Table 4), we were able to calculate the current daily influx of water. Based on these calculations, we were able to graph the dynamic storage of water during a typical year (average conditions) in the one tank that they currently have. During the interview with the family, it was stated that their tank was empty for 4 months of the year. Using the household consumption rate, and all of the data presented above, it was calculated that for the household to be without water for 4 months during a typical year, approximately 70% of the rainfall that would have landed on the roof would have been conveyed to the entrance of the tank/containers (note that if the tank is full, the water conveyed to the entrance of the tank would not contribute to storage). This 70% value was used to 'calibrate' the model to the data and was applied as an efficiency rate (Table 5). Each house would (in theory) have its own efficiency rate. In essence the calculations need to be calibrated in this manner to assess future alternatives.

The graph of water stored per day in the tanks/containers at House A during a typical year is shown in Figure 17, with the actual time series data included in Appendix D. As shown, the model has been calibrated to produce 4 months per typical year of no stored water. It can also be inferred from Figure 17 that during many days in the wet season, water conveyed to the tanks does not make it into storage because the system is already at capacity.

Table 6: Average Daily Rainfall Data (Current System)

Month	Rainfall		Flux	
1	0.046455	m	47.84	L/Day
2	0.036463	m	41.58	L/Day
3	0.046761	m	48.16	L/Day
4	0.070069	m	74.57	L/Day
5	0.142479	m	146.74	L/Day
6	0.290993	m	309.68	L/Day
7	0.266277	m	274.24	L/Day
8	0.262761	m	270.62	L/Day
9	0.28565	m	304.00	L/Day
10	0.181464	m	186.89	L/Day
11	0.106539	m	113.38	L/Day
12	0.056684	m	58.38	L/Day

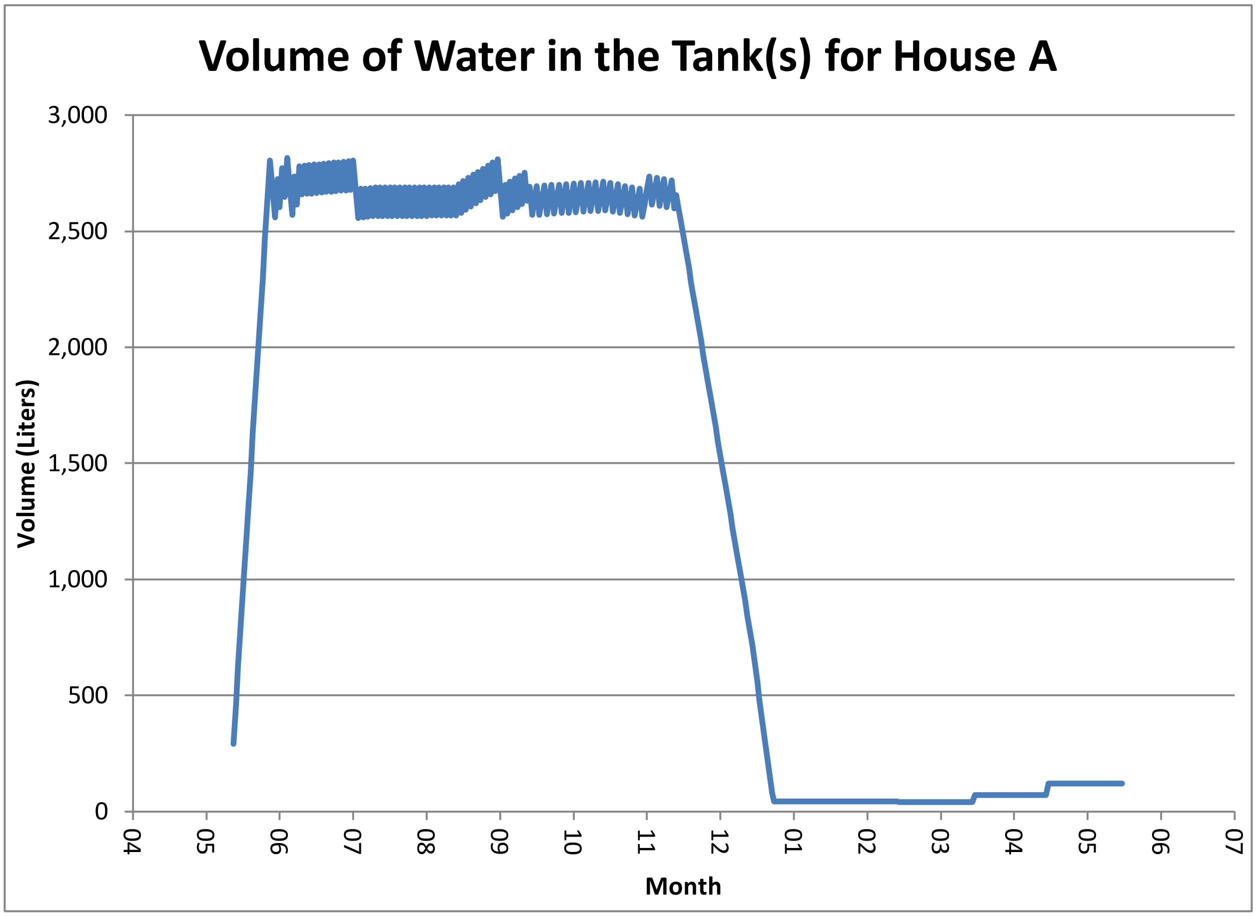


Figure 17: Dynamic Representation of Volume of Water Stored in the Tanks for House A During a Typical Year

House A Proposed Design

For House A, we are planning to add one, new, 2500 L tank and a gutter system to three roofs of the home. The house already contains a 2500 L tank, however the water collected yearlong is not enough for the family (Figure 17). The water consumption rate for House A was found to be around 120 liters per day (Table 3) which is based on a family size of 6 people. With only the existing water tank under Roof 1, the family does not get adequate water for four months out of the year. For this reason, EWB-WPI proposes that new gutters are added to Roof 2, 3, and 4, all of which currently lack gutters. These three roof and gutter systems will direct water into a new 2500 L tank. Incorporating the three additional roofs and the second storage tank enables the family to have sufficiently high water level for the entire year (Figure 18).

Table 8 was populated using our excel model and shows the monthly flux of water into the system of the proposed design system. In the flux columns, its shows:

- The total flux of the entire system, incorporating all four roofs.
- The flux of water from Roof 1, the current system at the house.
- The flux of water from just Roof 2, 3, and 4, part of the proposed design.

Table 7: Proposed Water Catchment System Input - House A

length of roof 1	**3.7**	m
width of roof 1	**6.1**	m
length of roof 2	**7.68**	m
width of roof 2	**2.7**	m
length of roof 3	**7.68**	m
width of roof 3	**3**	m
length of roof 4	**3.33**	m
width of roof 4	**2.04**	m
Total Surface Area	**73.1392**	m2
Surface Area of Roof 1	**22.57**	
Surface Area of Roofs 2, 3, and 4	**50.5692**	
Volume of Tank 1	**2500**	L
Volume of Tank 2	**2500**	L
Volume of Tank 3		L
Volume of Tank 4		L
Total Storage Volume	**5000**	L

Consumption Rate	**120**	L/Day
% Consumed from Tank 1	**31%**	
% Consumed form Tank 2	**69%**	
Efficiency Rate	**70%**	

Table 8: Increased Water Flux with all Roofs Connected for House A (Proposed Design)

Month	Rainfall		Flux (Total, Roof 1, Roofs 2-4)			
1	0.046455	m	76.72	23.68	53.05	L/Day
2	0.036463	m	66.67	18.58	41.64	L/Day
3	0.046761	m	77.23	23.83	53.40	L/Day
4	0.070069	m	119.58	35.71	80.01	L/Day
5	0.142479	m	235.31	72.61	162.70	L/Day
6	0.290993	m	496.60	148.30	332.28	L/Day
7	0.266277	m	439.76	135.71	304.06	L/Day
8	0.262761	m	433.96	133.92	300.04	L/Day
9	0.28565	m	487.48	145.58	326.18	L/Day
10	0.181464	m	299.69	92.48	207.21	L/Day
11	0.106539	m	181.82	54.30	121.66	L/Day
12	0.056684	m	93.62	28.89	64.73	L/Day

Our proposed design for House A is based on the fact that currently they have enough roof area to support a rainwater system. At this time the problem with this house is that they are only utilizing about one full roof, Roof 1, and one half of a roof, Roof 3, to collect water. Also, the makeshift containers for water collection that are currently below Roof 3 on their main house are inadequate and lack the necessary collection volume.

For House A, we are not going to alter anything on the separate structure, Roof 1. Our proposed solution is to add another 2500L storage tank and to incorporate Roof 2, 3, and 4 into the system. We will need to replace each of these currently rusty roofs with new corrugated iron and install gutter systems along the bottom of each roof. Each of the gutter systems would run into the new 2500L tank. Based on our data and calculations displayed in the graph below (Figure 18), installing the proposed design would provide House A with water volume throughout the year.

Note, the percentage consumed from each tank is based off the percentage of roof area connected to the tank relative to the entire roof area of the system. The tanks connected to more roof area, will fill up faster and should be used first.

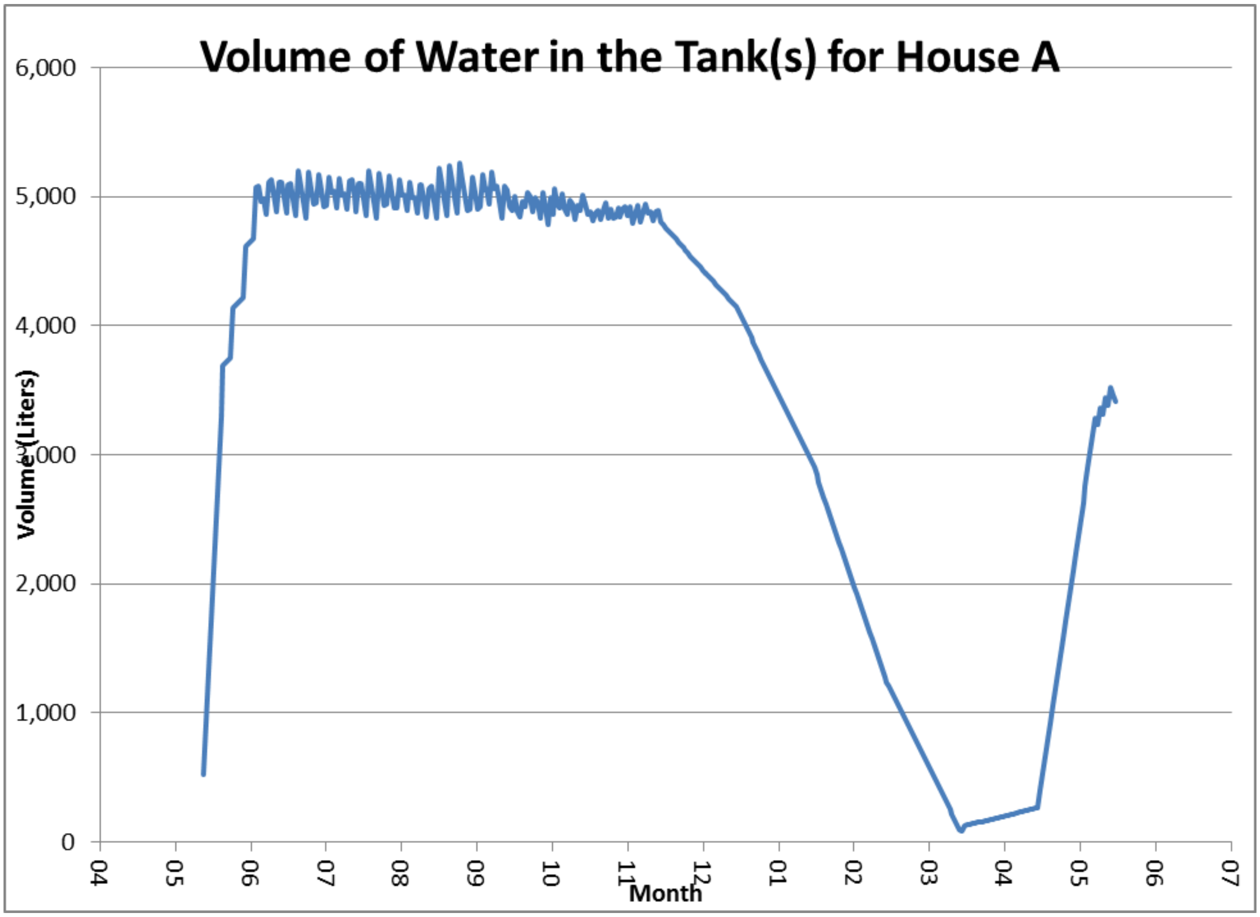


Figure 18: Rainwater Volume Levels with Proposed Design for House A

First Flush Proposed Design

House A has two separate gutter systems; each system requires a first flush system.

The first gutter system from roof 1 feeds into one tank. Roof 1 has an area of 232 ft^2 for this roof; 3 gallons must be collected in the first flush. In order to collect this volume of water we need 4.55 ft of 4" PVC, 2.06 ft of 6" PVC or 1.16 ft of 8" PVC. (The other diameters of PVC are not included due to the ineffective length of piping required.)

The second gutter system connects roofs 2, 3, and 4. Together these roofs have a total area of 618 ft^2 thus requiring the collection of 7.7 gallons to be discarded. For PVC sizing, we will need 12 ft of 4" PVC, 5.3 ft of 6" PVC or 3.0 ft of 8" PVC.

Sensitivity Analysis

In this section we will look at different factors that could alter the expected results. Some different factors that we will be altering to view the effect will include efficiency, consumption rates, and rainfall data. The rainfall data will be based on the drier months and the rainier months from the data we have since 1979. Shown below are the graphs of the volume in the tank for House A over the year labeled with the change that was made from the original assumptions. A short discussion will follow each graph discussing how this affects our design.

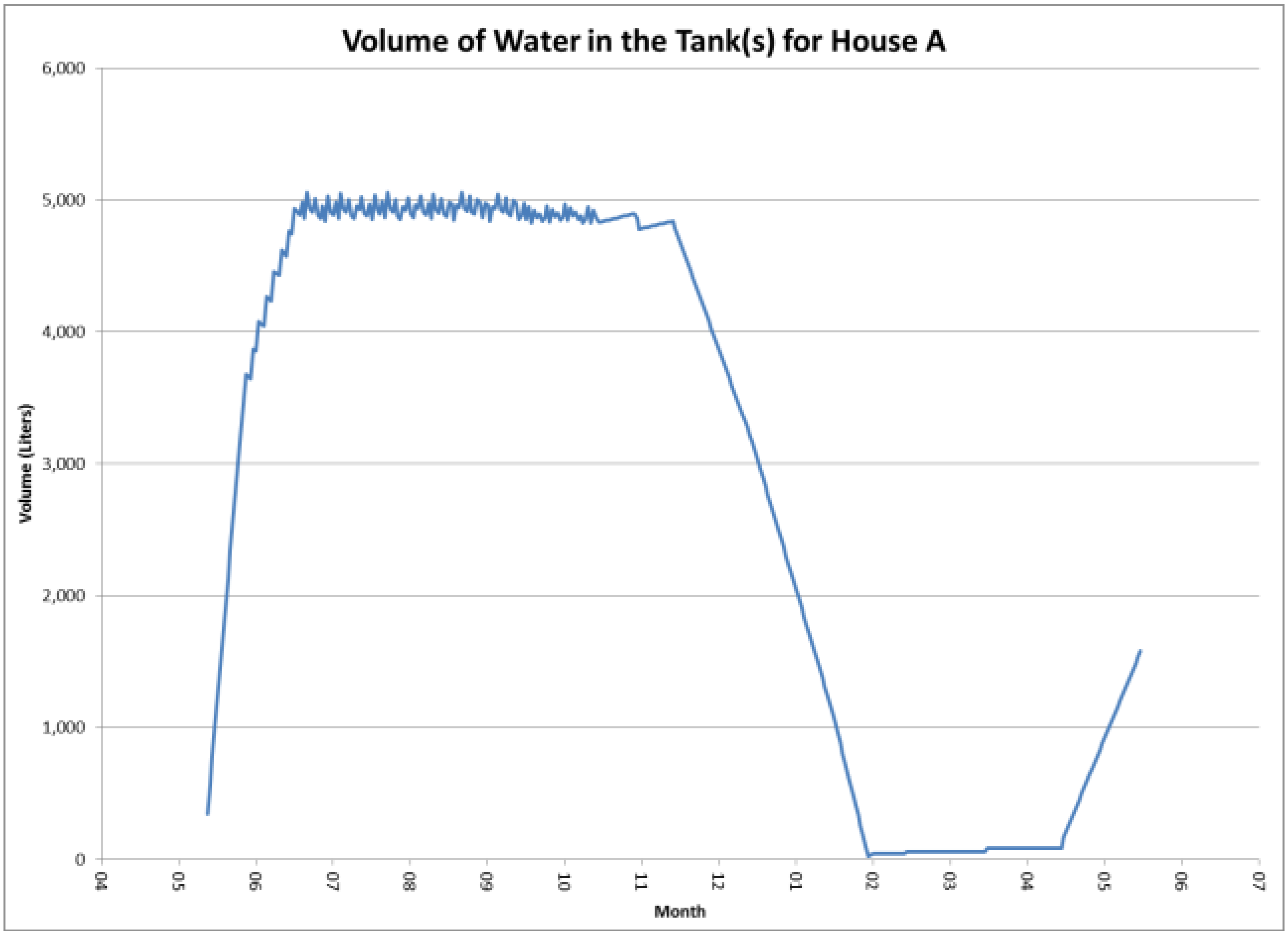


Figure 19: Volume in tanks over year -House A with 50% efficiency

Above is the volume in the tanks of House A with an efficiency of only 50%. This system will not function at its full potential, but this efficiency is about 35% below what is generally accepted as the amount of water that gets into the tank. With this efficiency, the family is only without water for about two months. An equivalence of this happening would be a very important part breaking and it not being fixed for the entire year. This shows a crippled system, and is highly unlikely to occur. At about 70% efficiency, the family can expect to see water for the entire year in their tanks.

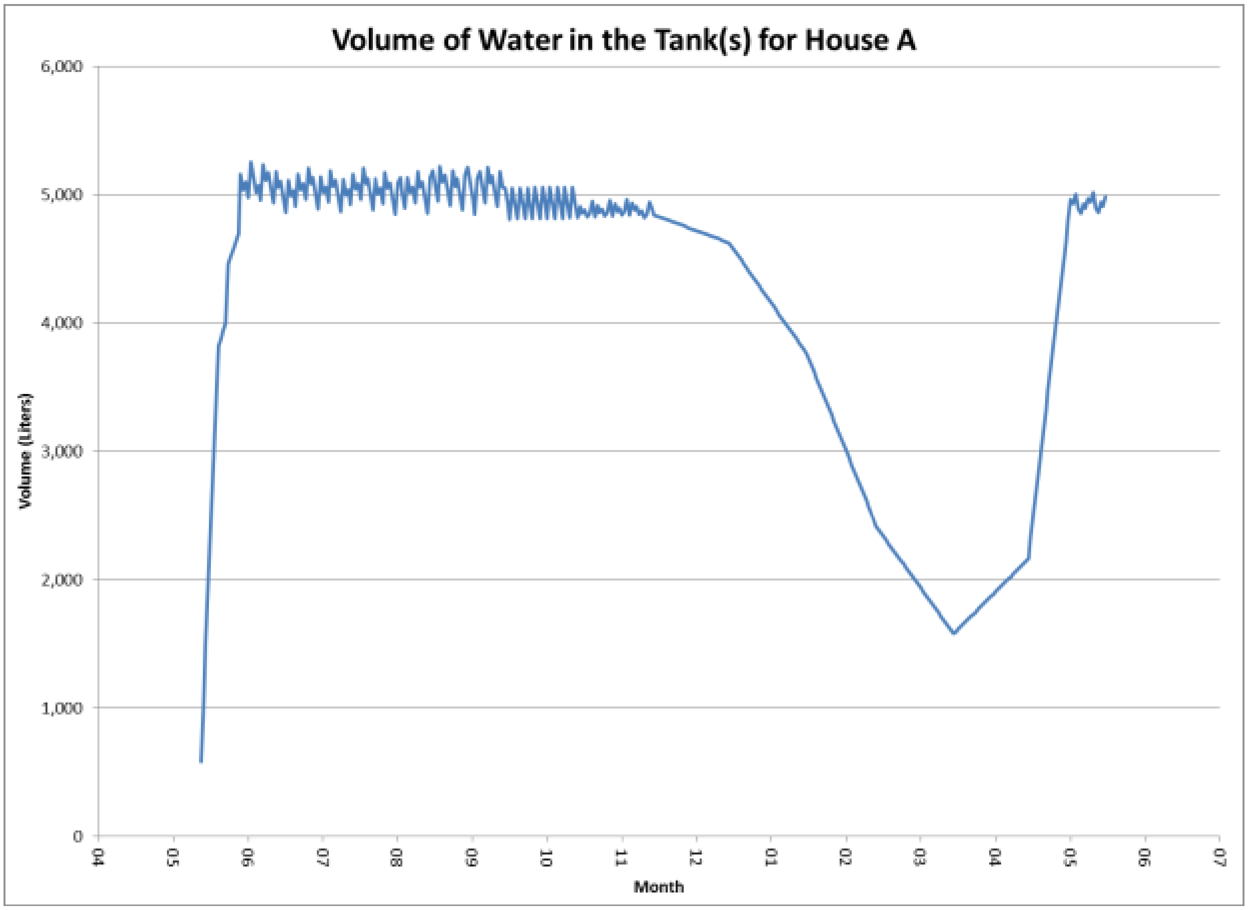


Figure 20: Volume in tanks over year -House A with 85% efficiency

From our sources, the generally accepted value for percentage of water that reaches the tanks from the roof is 85%. Clearly, with this amount of water reaching the tanks, the system does not come anywhere close to empty, in fact the lowest point it should reach is about 2000 L of water in the tank; enough to last the family for about 16 days.

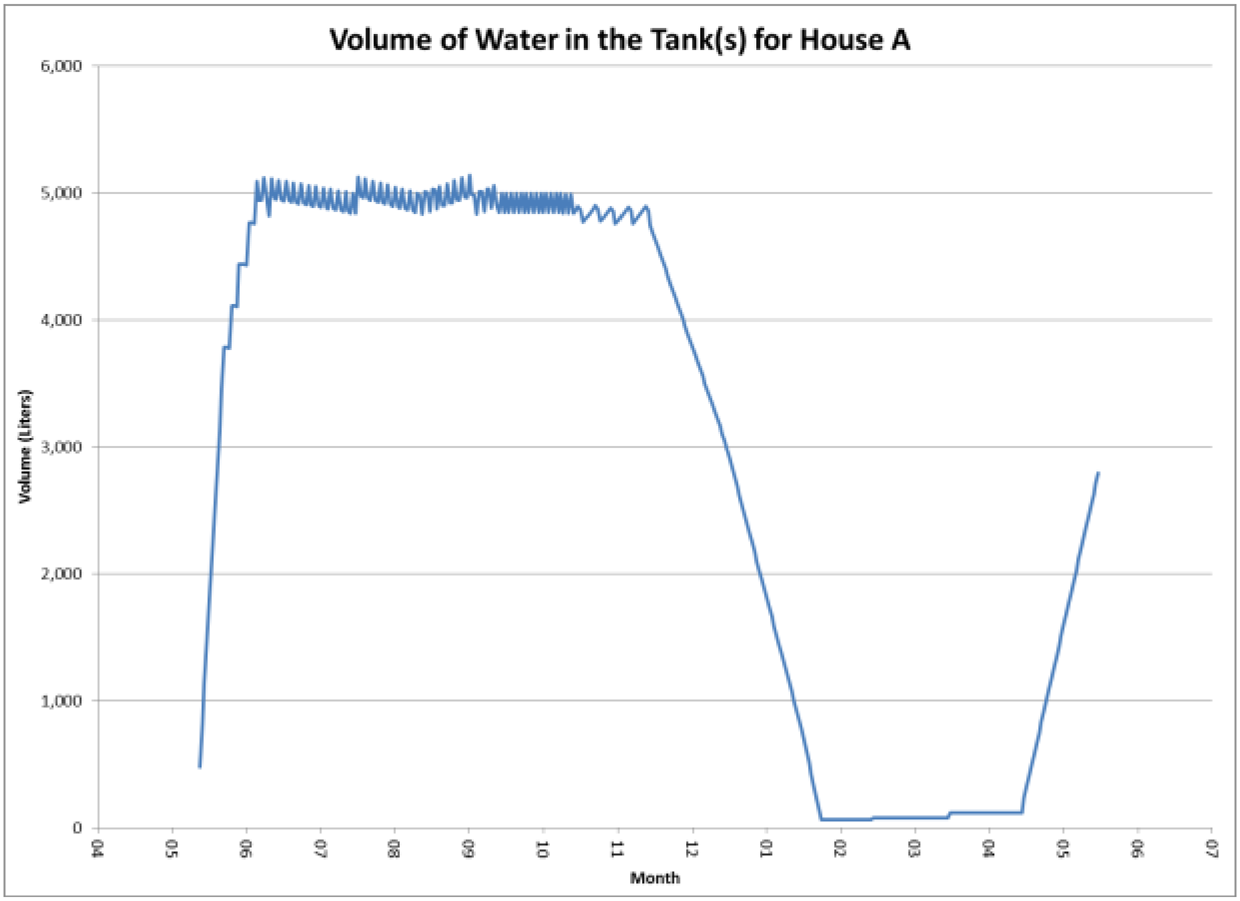


Figure 21: Volume in tanks over year -House A with 150 L/day consumption rate

This chart shows the volume in the tanks if House A were to use 150 L/day. This may in fact happen when the family members see all of the extra amounts of water. We are hoping to minimize this effect through education and over time the family will learn that this water is strictly for drinking and cooking and will conserve it for those purposes to avoid walking to the water source every day.

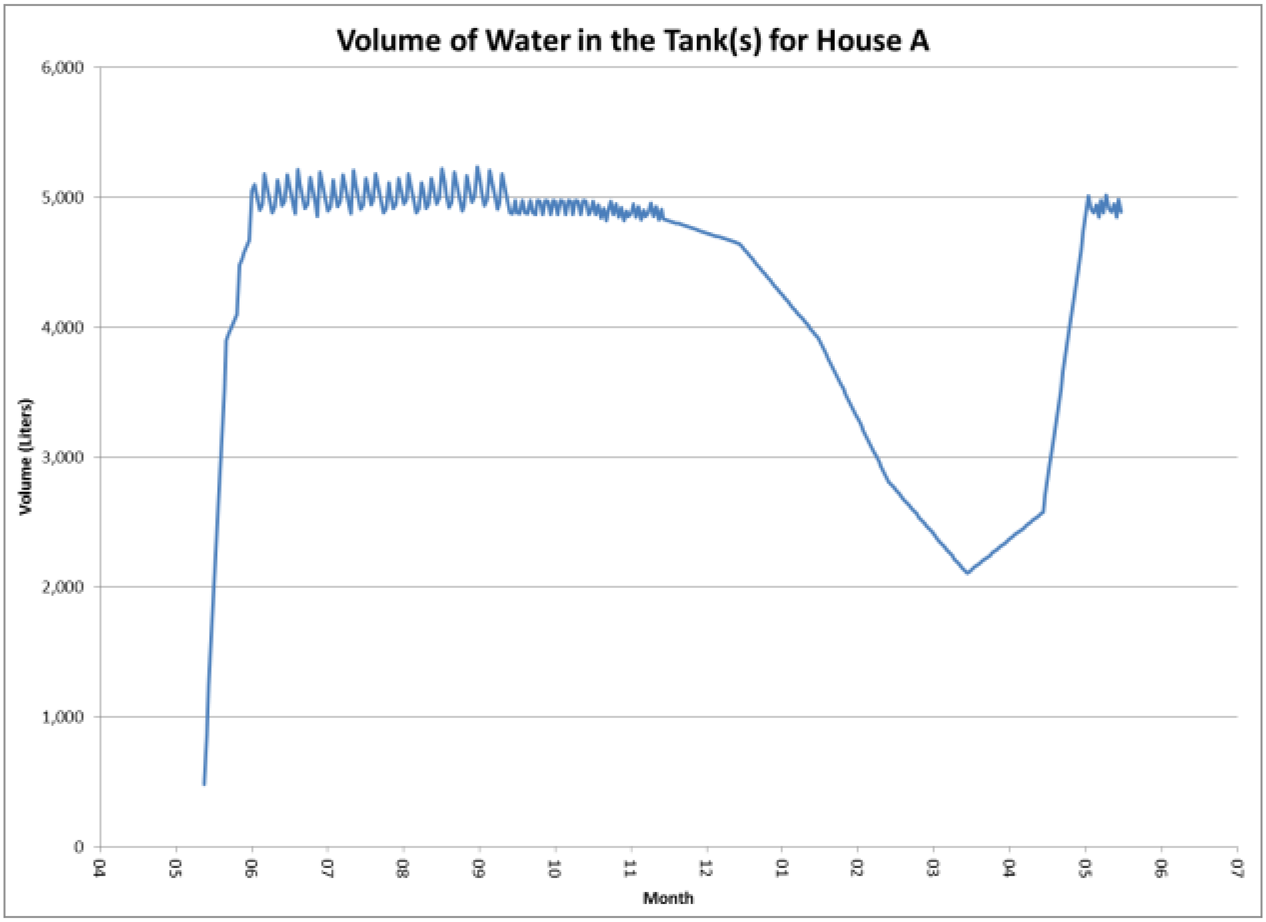


Figure 22: Volume in tanks over year -House A with 100 L/day consumption rate

This graph is shown if the family was to use less water than expected. If the family only uses water for drinking and cooking, then this is a very realistic consumption rate for the community. This shows that they will have plenty of water for these necessities and possibly even some extra for other things, even though they will be encouraged to conserve.

The next analysis will look at the driest year since 1979. Again, this took place in 1994 with an annual rainfall of only 1073 mm. The monthly rainfall is shown in the chart below, and these numbers are used to generate the graph.

Table 9: 1994 Monthly Rainfall

Month	Rainfall	
January	0.085	m
February	0.029	m
March	0.0877	m
April	0.0688	m

May	0.0841	m
June	0.1861	m
July	0.0883	m
August	0.1966	m
September	0.1582	m
October	0.0968	m
November	0.0451	m
December	0.0323	m

Notice how these amounts of rainfall do not follow the general pattern of the rainy and dry seasons and the numbers are abnormal for the region.

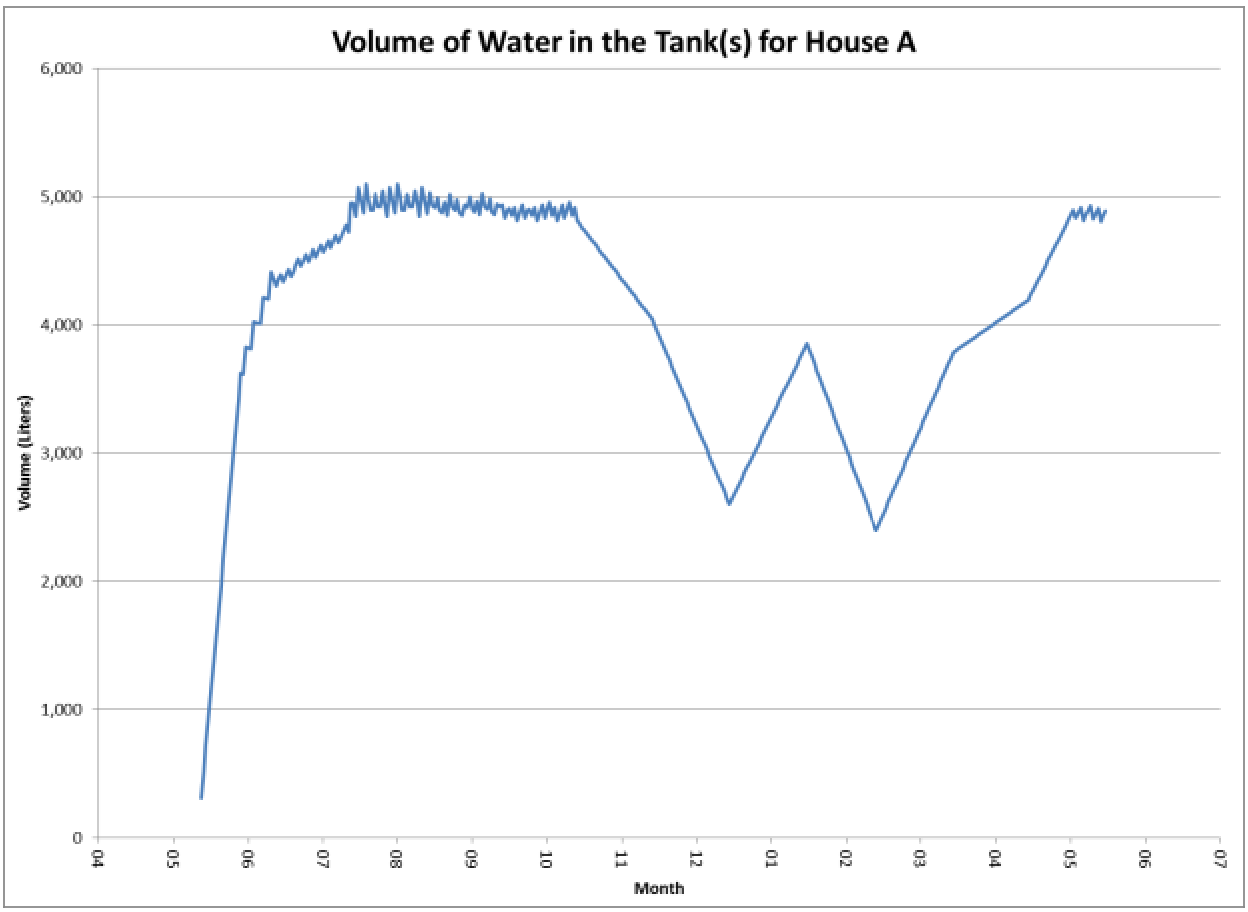


Figure 23: Volume in tanks over year -House A during driest year, 1994.

This graph shows that this type of rainfall may actually be better for the community. Although they received much lower rainfall volumes over the year, the pattern of the rainfall was actually improved when it came to storage. Because the rainfall did not happen all at once, the amount of rain they could expect daily would refill the tank every day because of the near constant rainfall throughout the year.

Lastly, we will show the system based on the rainiest year, which occurred in 1984. These data below shows the monthly rainfall for 1984.

Table 10: 1984 Monthly Rainfall

Month	Rainfall	
1	0.0534	m
2	0.0342	m
3	0.0825	m
4	0.0409	m
5	0.1944	m
6	0.3605	m
7	0.3603	m
8	0.374	m
9	0.3686	m
10	0.201	m
11	0.1154	m
12	0.0671	m

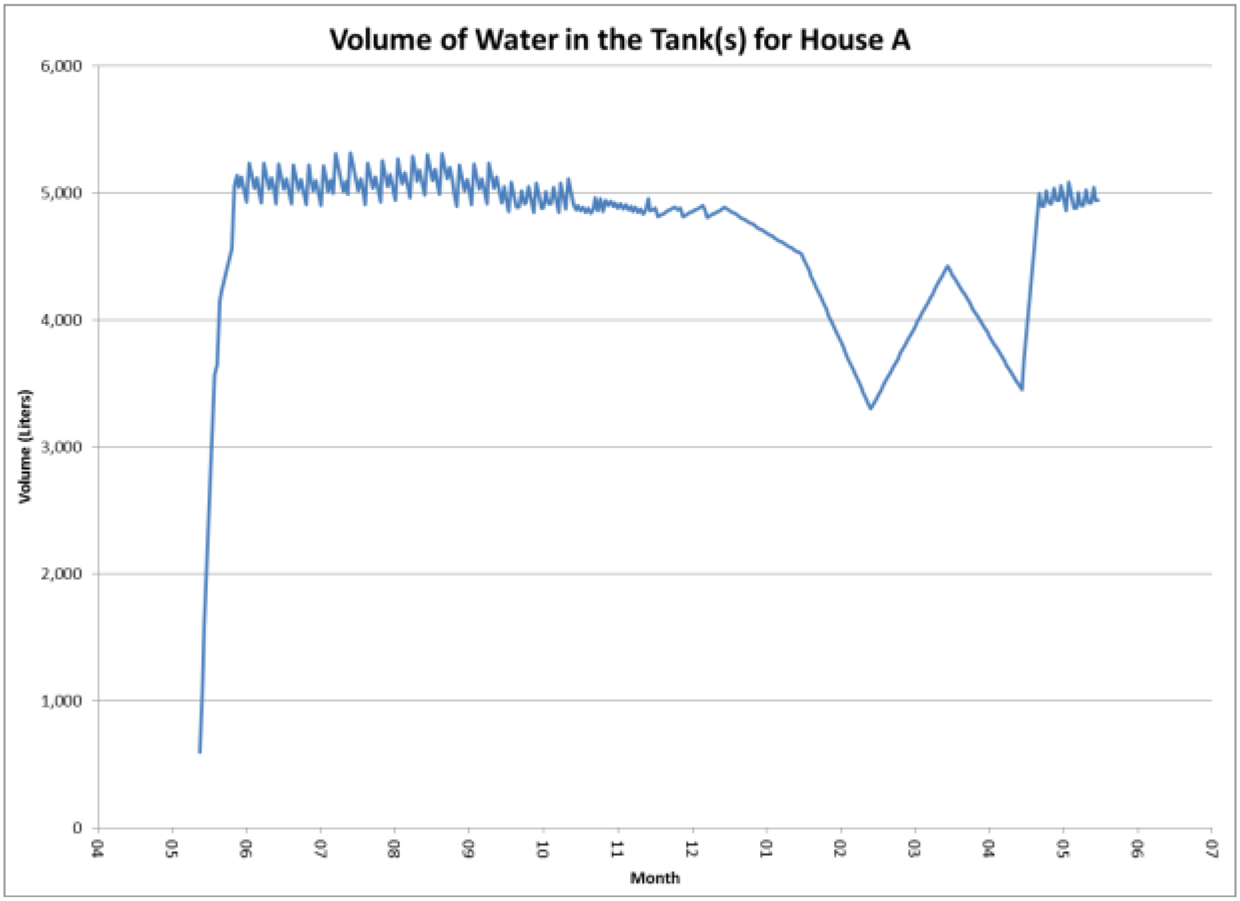


Figure 24: Volume in tanks over year -House A during rainiest year, 1984.

As expected, the system performs better than during the average year. The family will not come anywhere close to using all of their water based on their current habits.

Lastly, we will look at the driest dry season. This is arguably the biggest testing factor that will prove our system. In almost all occasions, the amount of rain during the rainy season is not important. The rainwater catchment tanks by the time the rainy season is over, and much before that, always reaches its maximum storage capacity. It is at the transition to the dry season where the water levels start to decline quite rapidly. We will look at the lowest rainfall amounts from February to May, which is the typical dry season in our community. Based on all of our rainfall data, the driest dry season occurred in 2000, with only a combined 121.10 mm from February to May. That year's rainfall data is shown below.

Table 11: 2000 Rainfall Data - Driest Dry Season

Month	Rainfall	
1	0.0554	m
2	0.0256	m

3	0.0018	m
4	0.0202	m
5	0.0735	m
6	0.3084	m
7	0.244	m
8	0.3087	m
9	0.3667	m
10	0.2107	m
11	0.2196	m
12	0.0405	m

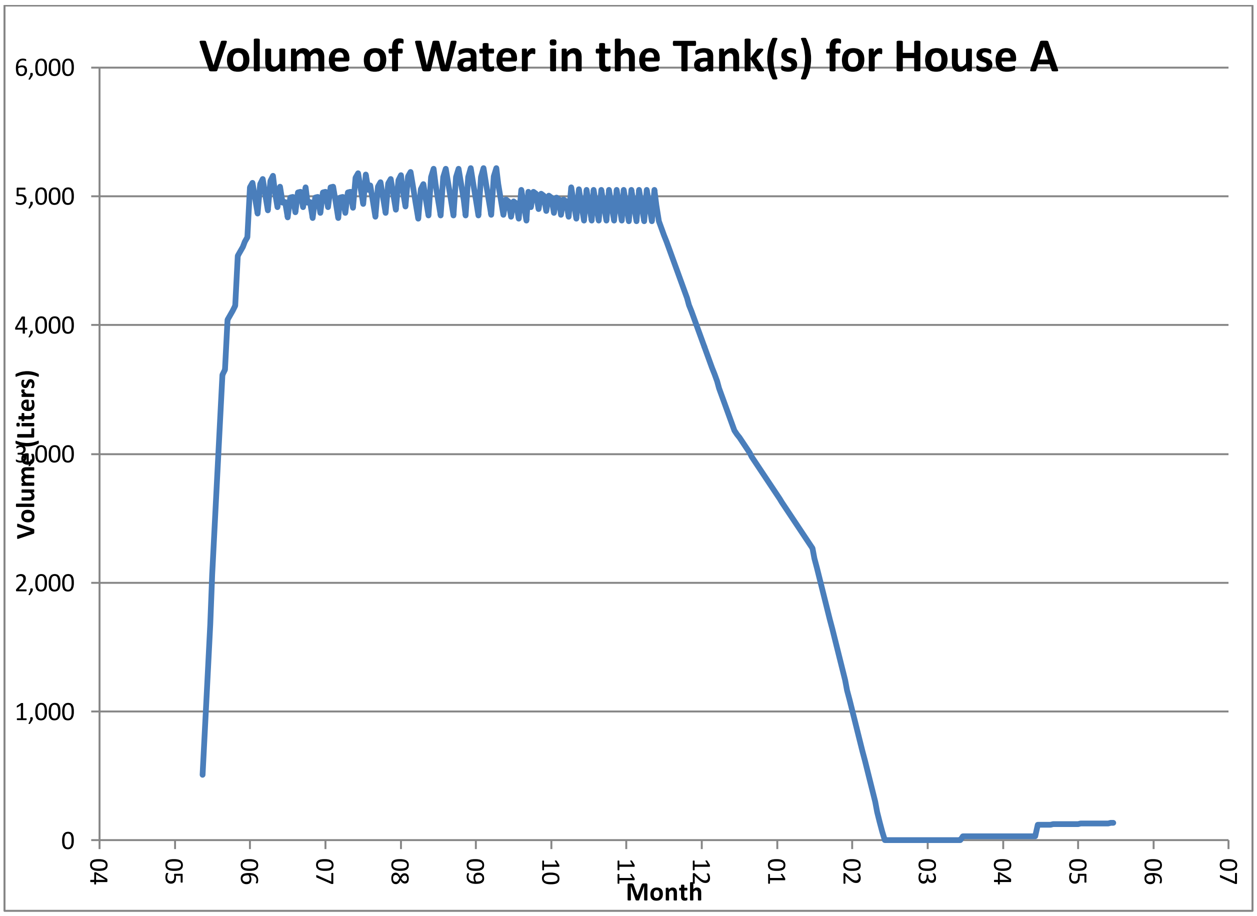


Figure 25: House A - Driest Dry Season

As a result of using the driest dry season data, it obviously takes a significant toll on our design. The insignificant amounts of rain from February to May make it impossible for the system to regain any useful amounts of water to sustain the system from what is taken out of it each day. However, it would not be economically feasible for the community to prepare for this type of rainfall. The designs to prepare for this would have to include entirely new structures for added roof space and/or purchase more storage tanks. Both of these alternatives would require an estimated double the cost. If these events are duplicated, the family will have to resort to their previous means of water gathering during the couple of months when the tanks are mostly empty.

As shown with the different models, and altering the assumed values, our system for House A is designed to provide for uncertainties and will continue to work in the most abnormal conditions.

House L Current Situation

The owners of House L have more resources (land, tanks, buildings) than the average village household. They also were very easy to work with and provided some of what we perceived to be the more accurate answers to our survey questions. There are 10 individuals that live in House L and the adjacent House M, built on the abutting lot. The three generations living on this shared land also share harvested water. House L has seven separate roof structures, many of which are being under-utilized. Similar to House A, this pilot home has a separate structure devoted to rainwater catchment, Roof 1, which supplies a 2500 L tank located under it. The other two 2500L plastic tanks are under and supplied by Roof 2. Roof 2 is very similar to Roof 1, as it is a separate structure from the house and is only used for rainwater catchment. Below are pictures and drawings of the key aspects of House L (Figure 26 through Figure 32).

The house is located at N 15 22.747, W 90 29.884.

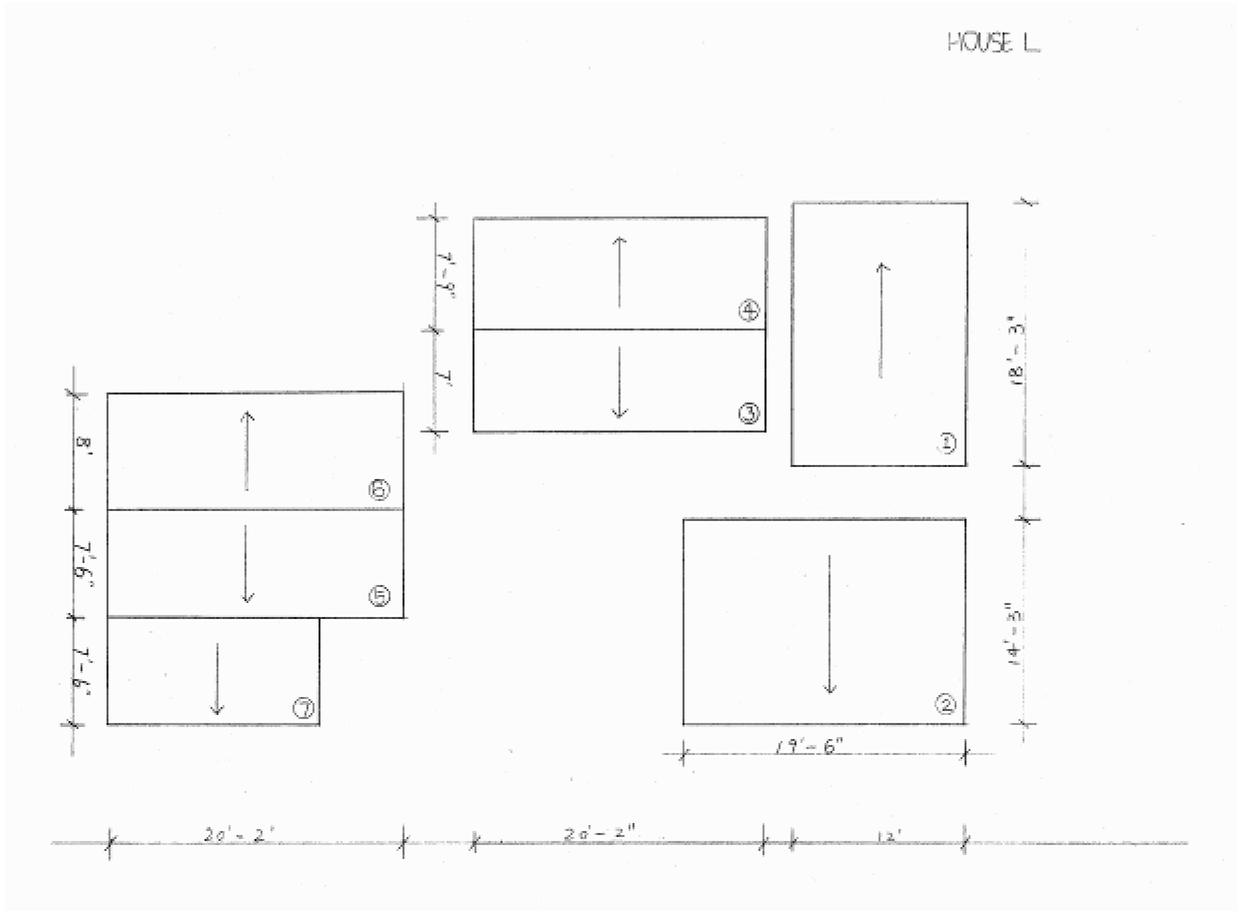


Figure 26: House L Layout

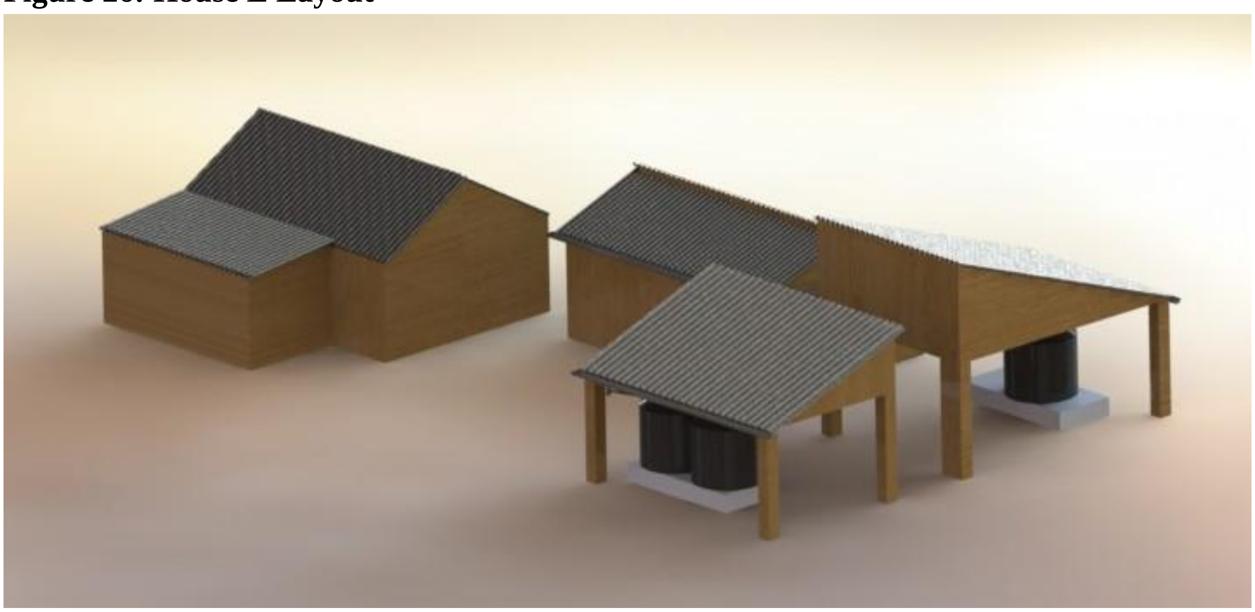


Figure 27: House L Current Layout

Figure 28: House L, Roof 1 (connected to one 2500 L tank underneath)

Figure 29: House L, Roof 4 (Roof 3 on opposite side)

Figure 30: House L, taken under Roof 1, Roof 3 (right), and Roof 6 (far left back)

Figure 31: House L, Roof 2 (with two 2500 L storage tanks)

Figure 32: House L, Roof 6 (left), Roof 5 (right), and Roof 7 (back right)

The questionnaire taken for House L (Appendix G) is shown below with all of the measurements taken during the home assessment. After House L was chosen as a pilot house, the following measurements were made (Table 12). Currently House L has no water in their storage tanks for 2 months each year. The excel sheet below (Table 13) shows the dimensions of the roofs used currently and calculates the amount of water that is collected with those surface areas. Only the roofs that are currently incorporated in the rainwater catchment system are included. Roof 1 is connected to one 2500 L tank and Roof 2 is connected to two 2500 L tanks.

Table 12: Roof Measurements for House L

	Roof 1	Roof 2	Roof 3	Roof 4	Roof 5	Roof 6	Roof 7
Height 1 (base to edge)	255cm	236	229cm	185	219cm	210cm	245cm
Height 2 (base to peak)	215cm	380cm	302cm	302cm	295cm	295cm	219cm
Slope of Roof	10°	10°	10°	25°	20°	20°	18°
Edge of roof to outside wall	25cm	20cm					
Base of roof	431cm	560cm	210cm	234cm	226cm	243cm	230cm
Length of roof	594cm	366cm	614cm	614cm	615cm	615cm	450cm

Table 13: Current Rain Water Catchment System for House L

Length of roof 1	**4.31**	m
Width of roof 1	**5.94**	m
Length of roof 2	**5.60**	m

Width of roof 2	**3.66**	m
Total Surface Area	**46.094**	m^2
Volume of Tank 1	**2500**	L
Volume of Tank 2	**2500**	L
Volume of Tank 3	**2500**	L
Volume of Tank 4	**0**	L
Total Storage Volume	**7500**	L
Consumption Rate	**125**	L/Day
Efficiency Rate	**70%**	

Based on a consumption rate of 125 L/day from our field survey and calibrating the model (Table 3), the average monthly rainfall data (Table 14), and roof area (Table 13), we were able to calculate the current average influx of water the house was able to collect daily. Based on these calculations, we are able to graph the entire yearlong volume of water in the current tanks. We can check that this graph is accurate by comparing it to the family's response of the tank being empty for 2 months a year based on our interview (Appendix G). The graph of water consumption and volume of water available for House L is shown as Figure 33. Shown in Appendix C, a time series estimates the amount of water in the tank daily and it can clearly be seen that from mid-February to mid-April the water levels in the tank are roughly zero.

We determined the efficiency of the systems to be 70% because it is a generally conservative value. In most cases when calculating the amount of water that will make it from the roof to the tank, it is based off the "run-off coefficient". This takes into account evaporation and any losses between the roof and the storage tank. This runoff is only dealing with the total amount of water that lands on the roof, and the actual percentage that makes it into the storage tank, passing through a gutter system and piping. Usually, a runoff coefficient of 0.85 or 85% is used for a hard roof in the humid tropics (Thomas & Martinson 24). Our community matches both of those criteria, so we could have assumed that 85% of the rainwater would be collected in the tank. However, to give us some leeway with the design, we chose an efficiency of only 70%. With this chosen efficiency we will ensure a design that will work even in the drier years.

Table 14: Average Daily Rainfall Data (Current System)

Month	Rainfall		Flux	
1	0.046455	m	48.36	L/Day
2	0.036463	m	42.02	L/Day

3	0.046761	m	48.67	L/Day
4	0.070069	m	75.37	L/Day
5	0.142479	m	148.31	L/Day
6	0.290993	m	312.99	L/Day
7	0.266277	m	277.17	L/Day
8	0.262761	m	273.51	L/Day
9	0.28565	m	307.25	L/Day
10	0.181464	m	188.89	L/Day
11	0.106539	m	114.59	L/Day
12	0.056684	m	59.00	L/Day

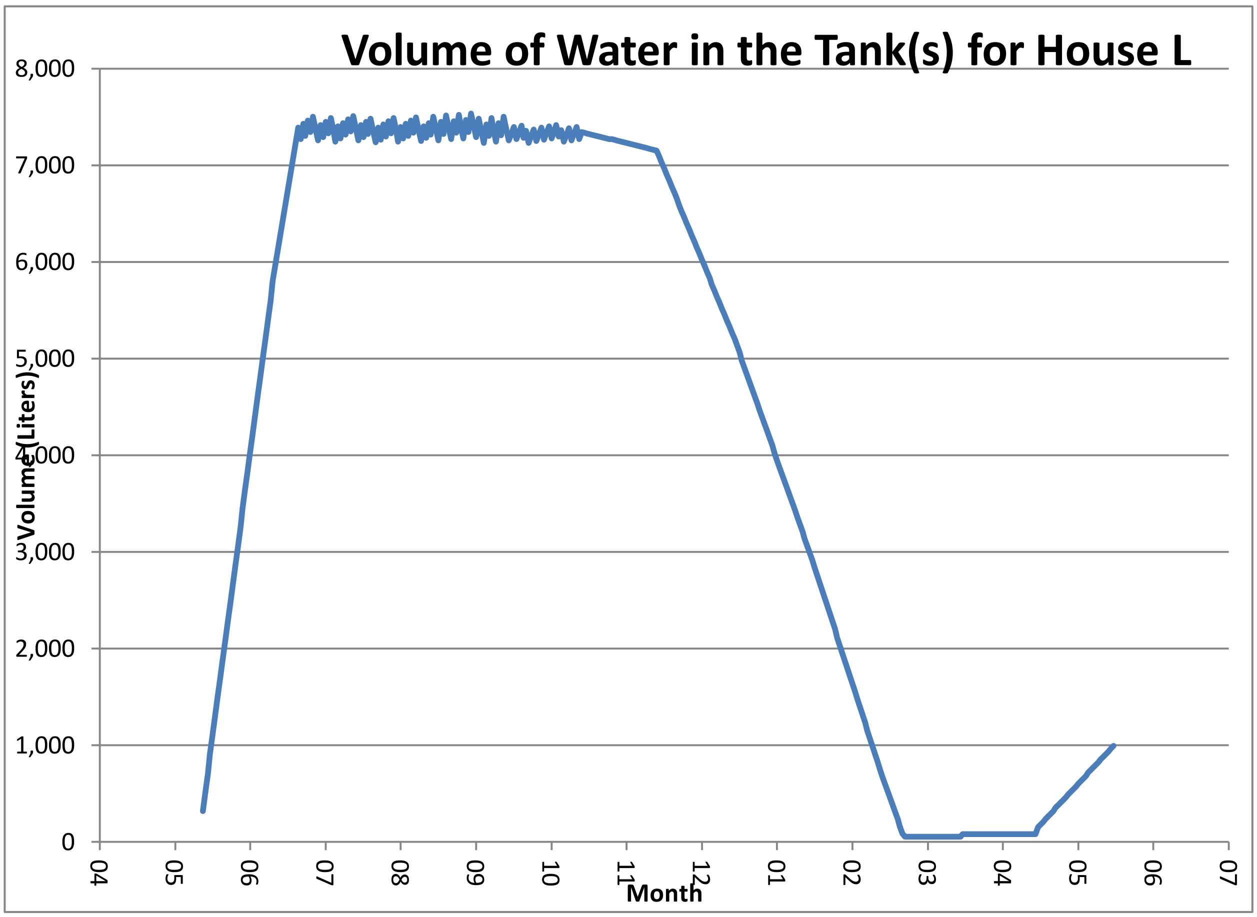


Figure 33: Volume of Water in the Tanks for House L

House L Proposed Design

House L currently does not have enough roof area to support the three tanks that they already have on their property. The tanks fill up to their potential during the rainy season, but during the dry season they cannot collect enough water with the current two roofs to support their water consumption. Our proposed solution is only to alter the Roof 1 system. Since Roof 1 is adjacent to Roof 3 and 4, our plan is to add a gutter system to each of these two roofs (Roof 3 and 4). The gutter system would then connect to the 2500 L tank located under Roof 1. With this increased water collection combined with Roof 2, this design would give them the amount of roof area needed to ensure that each tank has a constant amount of water flow in to either exceed or equal the amount of water taken out by the family.

Using rainfall data, we are able to estimate the amount of water that our proposed system would supply to the family in House L. Table 16 was populated using our excel model and shows the monthly flux into the system using the proposed design. In the flux columns, its shows:

The total flux of the entire system, incorporating all four roofs.
The flux of water from Roof 2, the current system at the house.
The flux of water from just Roof 1, 3, and 4, part of the proposed design.

Table 15: Proposed Design Input – House L

User Input Data		
length of roof 2	**5.6**	m
width of roof 2	**3.66**	m
length of roof 1	**4.31**	m
width of roof 1	**5.94**	m
length of roof 3	**6.14**	m
width of roof 3	**2.1**	m
length of roof 4	**6.14**	m
width of roof 4	**2.34**	m
Total Surface Area	**73.359**	m2
Surface Area of Roof 2	**25.6014**	
Surface Area of Roofs 1,3,4	**47.7576**	
Volume of Tank 1	**5000**	L
Volume of Tank 2	**2500**	L

Total Storage Volume	**7500**	L
Consumption Rate	**125**	L/Day
% Consumed from Tank 1	**35%**	
% Consumed form Tank 2	**65%**	
Efficiency Rate	**70%**	

Note, the percentage consumed from each tank is based off the percentage of roof area connected to the tank relative to the entire roof area of the system. The tanks connected to more roof area, will fill up faster and should be used first.

Table 16: Increased Water Fluxes with Proposed Design

Month	Rainfall		Flux (Total, Roof 2, Roofs 1, 3, 4)			
1	0.0465	m	76.95	26.86	50.10	L/Day
2	0.0365	m	66.87	21.08	39.32	L/Day
3	0.0468	m	77.46	27.03	50.43	L/Day
4	0.0701	m	119.9	40.51	75.56	L/Day
5	0.1425	m	236.0	82.37	153.7	L/Day
6	0.2910	m	498.1	168.2	313.8	L/Day
7	0.2663	m	441.1	153.9	287.2	L/Day
8	0.2628	m	435.3	151.9	283.4	L/Day
9	0.2857	m	489.0	165.1	308.0	L/Day
10	0.1815	m	300.6	104.9	195.7	L/Day
11	0.1065	m	182.4	61.59	114.9	L/Day
12	0.0567	m	93.90	32.77	61.13	L/Day

As you can see in the graph below (Figure 34), with the added roof area of Roof 3 and 4 to the system, House L now has enough roof area to utilize the full potential of its water storage volume maintaining enough water all year. Also, this house will have a reserve if it does not rain for several weeks. The average year will only allow the water levels to reach about 2000L before it starts to refill again with the rainy season.

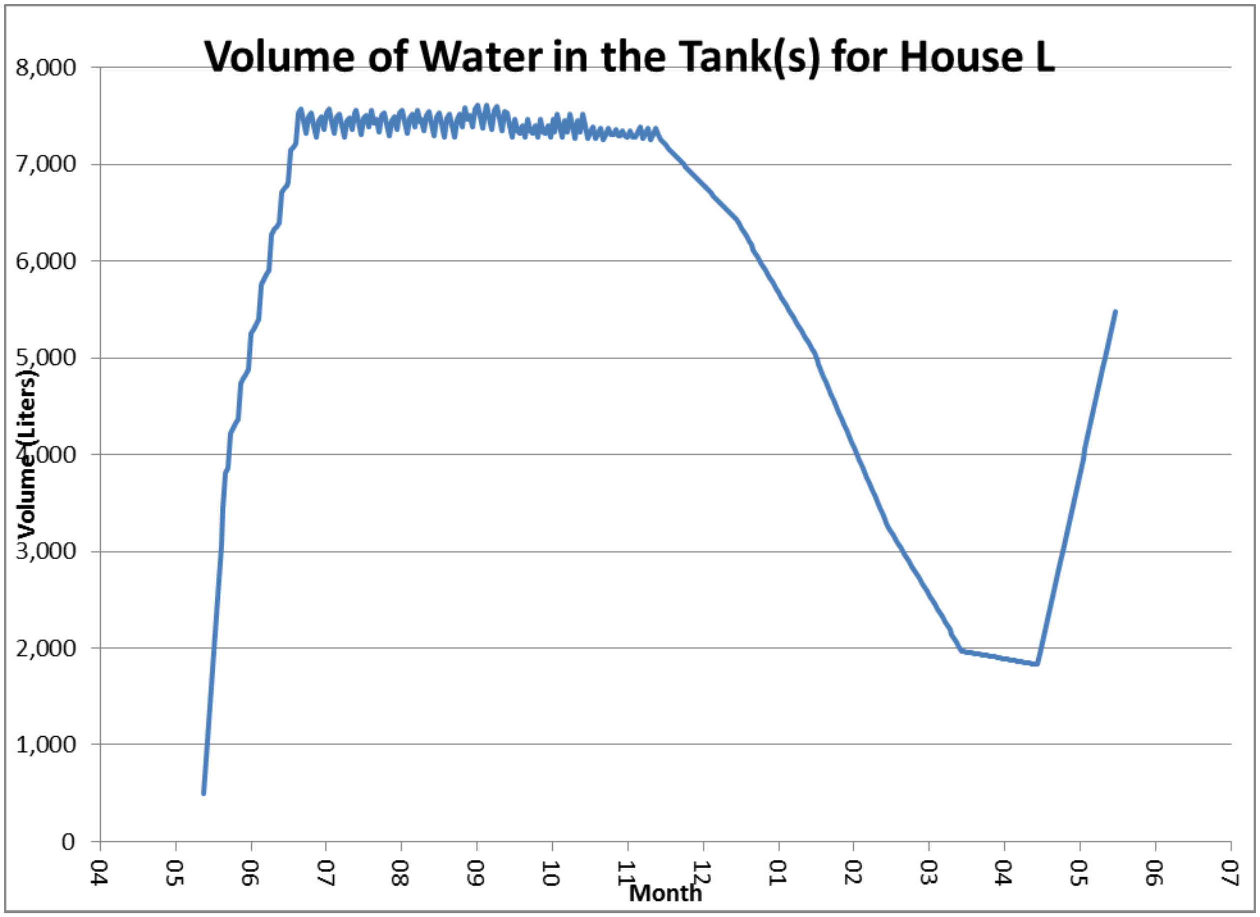


Figure 34: Graph of Volume in Tank for Proposed Design of House L

First Flush Proposed Design

The first gutter system for House L consists of roof 2 with an area of 280 ft^2 thus requiring 3.5 gallons. In order to collect this volume of water we need 5.3 ft of 4" PVC, 2.4 ft of 6" PVC or 1.36 ft of 8" PVC.

The second gutter system connects roofs 1, 3, and 4. This system has a total area of 523 ft^2 thus a collection of 6.55 gallons. In order to collect this volume of water we need 9.9 ft of 4" PVC, 4.5 ft of 6" PVC or 2.53 ft of 8" PVC.

Sensitivity Analysis

In this section we will look at different factors that could alter the expected results. Some different factors that we will be altered to view the effect will include efficiency, consumption rates, and rainfall data. The rainfall data will be based on the drier months and the rainier months from the data we have since 1979. Below are the graphs of the volume in the tank for House L over the year labeled with the change that was made from the original assumptions. A short discussion will follow each graph discussing how this affects our design.

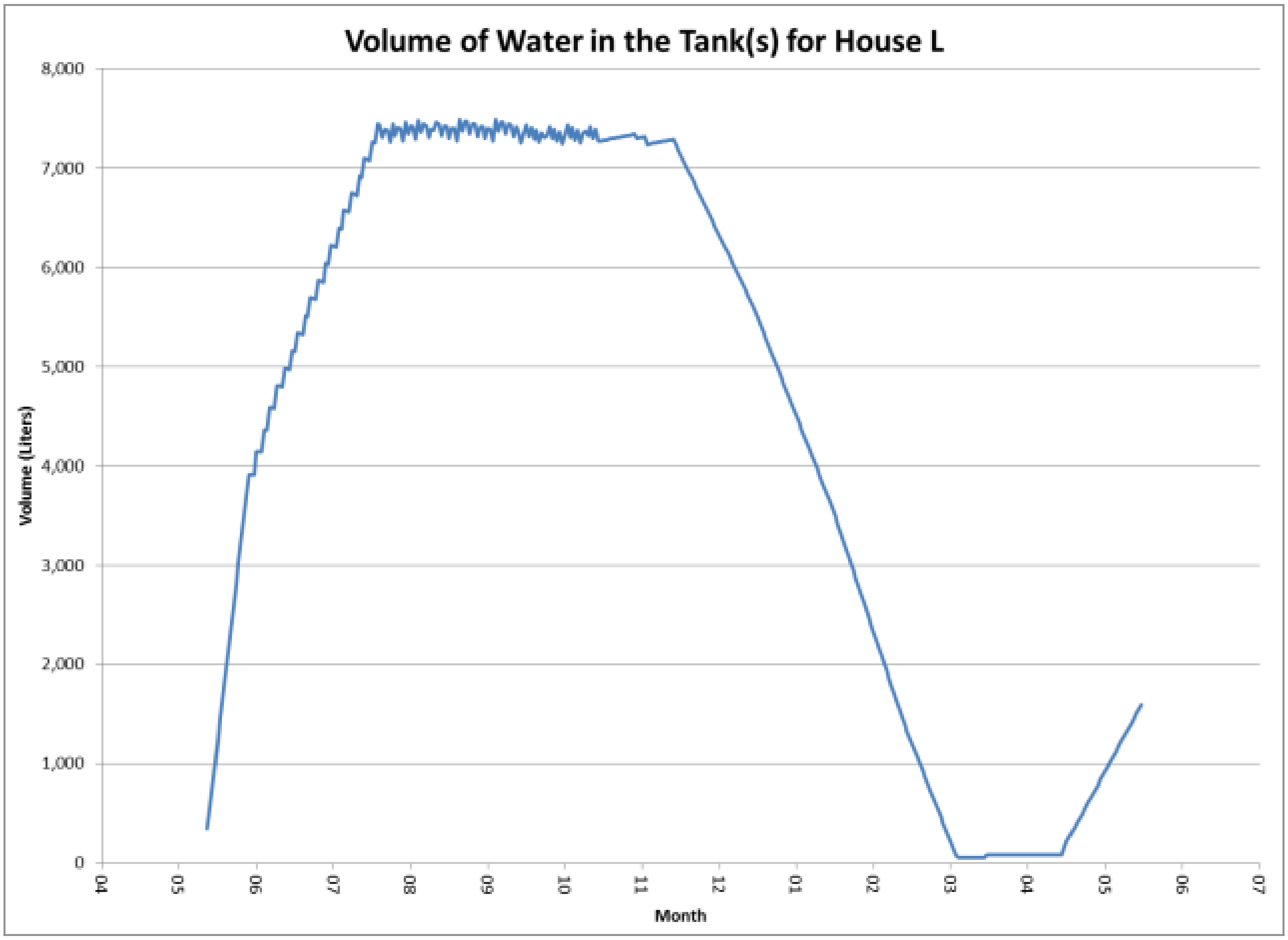


Figure 35: Volume in tanks over year -House L with 50% efficiency

Above is the volume in the tanks of House L with an efficiency of only 50%. This system will not function at its full potential, but this efficiency is about 35% below what is generally accepted as the amount of water that gets into the tank. With this efficiency, the family is only without water for a month. An equivalence of this happening would be a very important part breaking and it not being fixed for the entire year. This shows a crippled system, and is highly unlikely to occur. At about 60% efficiency, the family can expect to see water for the entire year in their tanks.

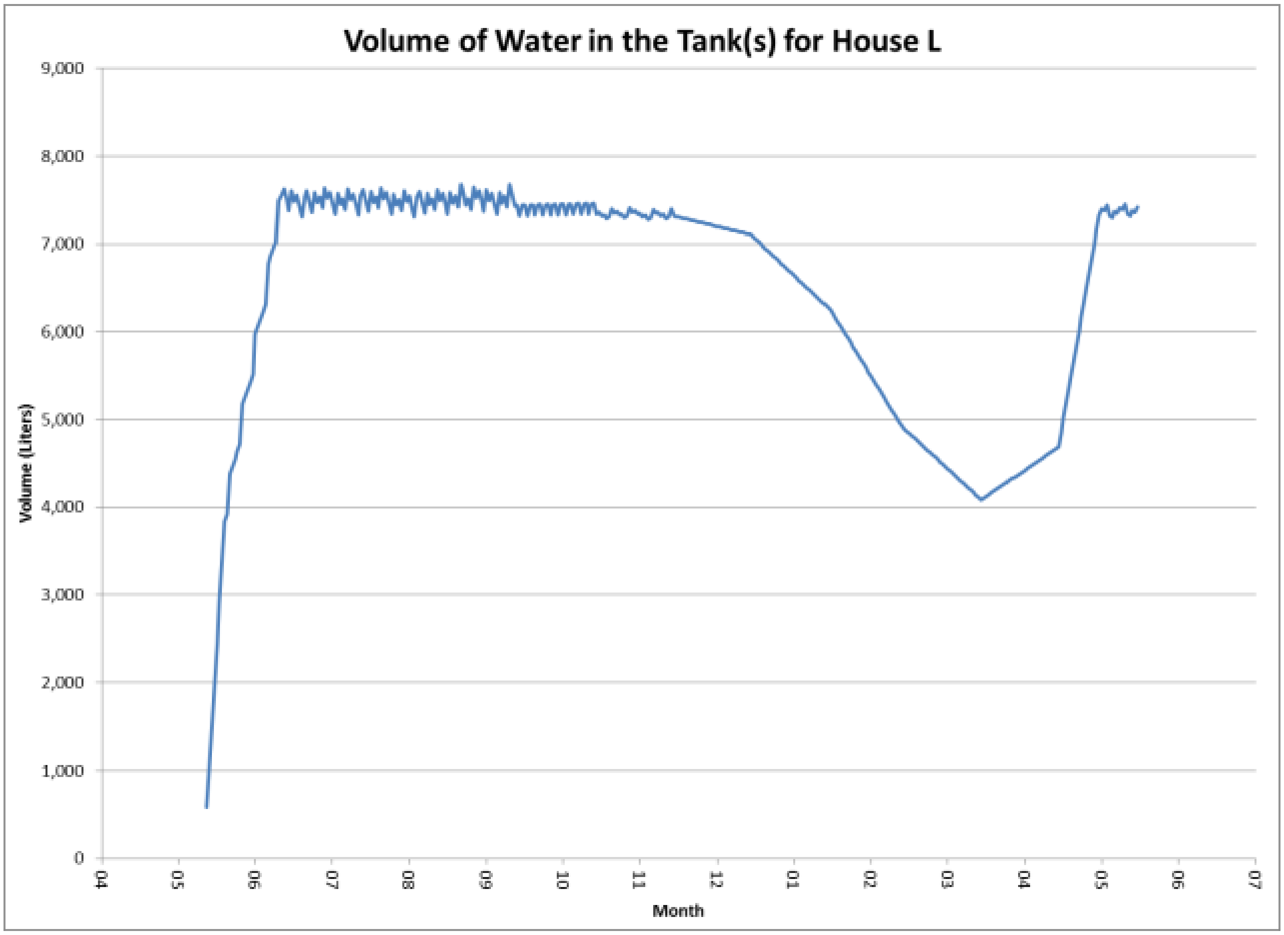


Figure 36: Volume in tanks over year -House L with 85% efficiency

From our sources, the generally accepted values for percentage of water that reaches the tanks from the roof is 85%. Clearly, with this amount of water reaching the tanks, the system does not come anywhere close to empty, in fact the lowest point it should reach is about 4000 L of water in the tank; enough to last the family for about 33 days.

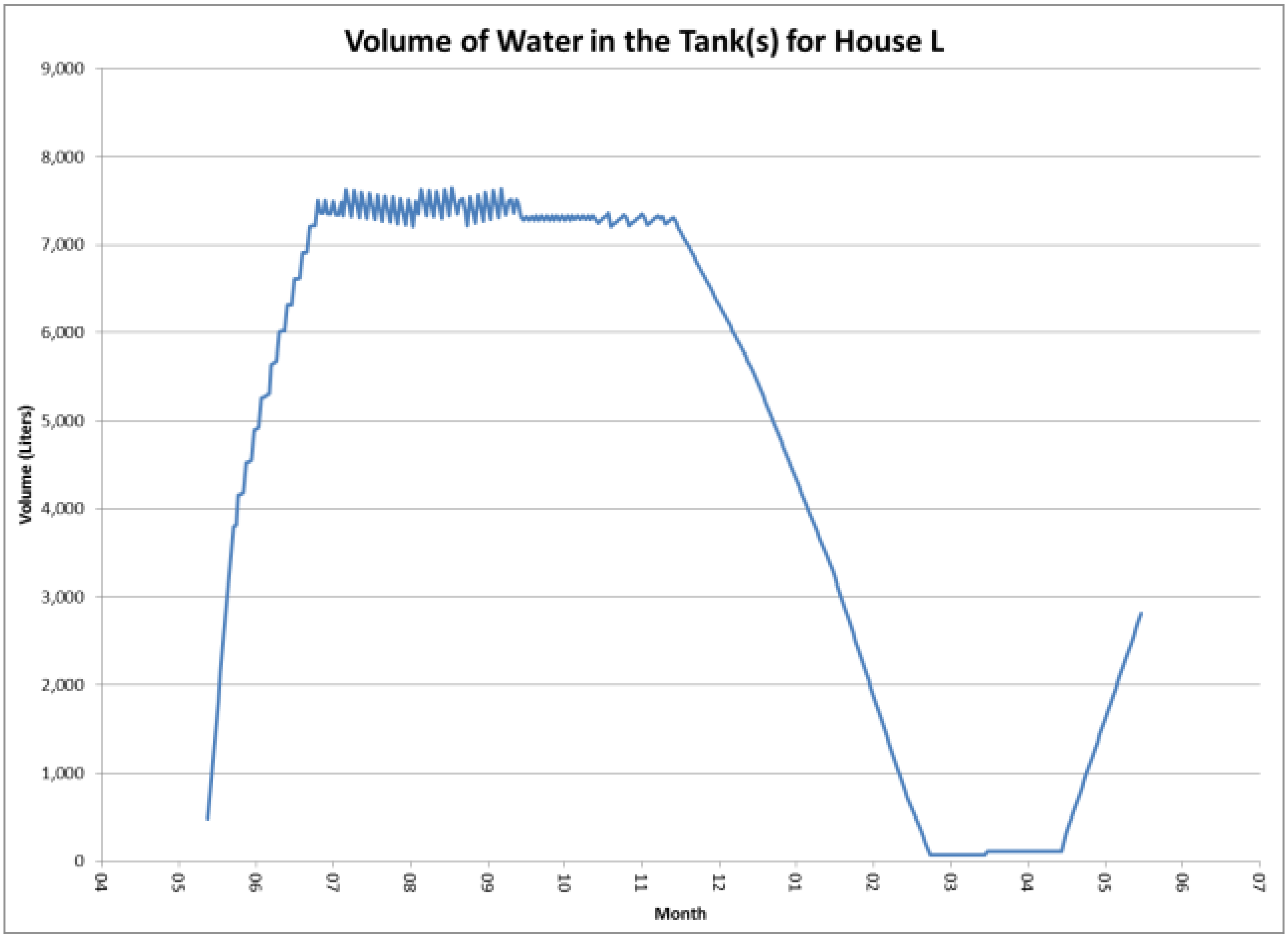


Figure 37: Volume in tanks over year -House L with 150L/day consumption rate

This chart shows the volume in the tanks if House L were to use 150 L/day. This may in fact happen when the family members see all of the extra amounts of water. We are hoping to minimize this effect through education and over time the family will learn that this water is strictly for drinking and cooking and will conserve it for those purposes to avoid walking to the water source every day.

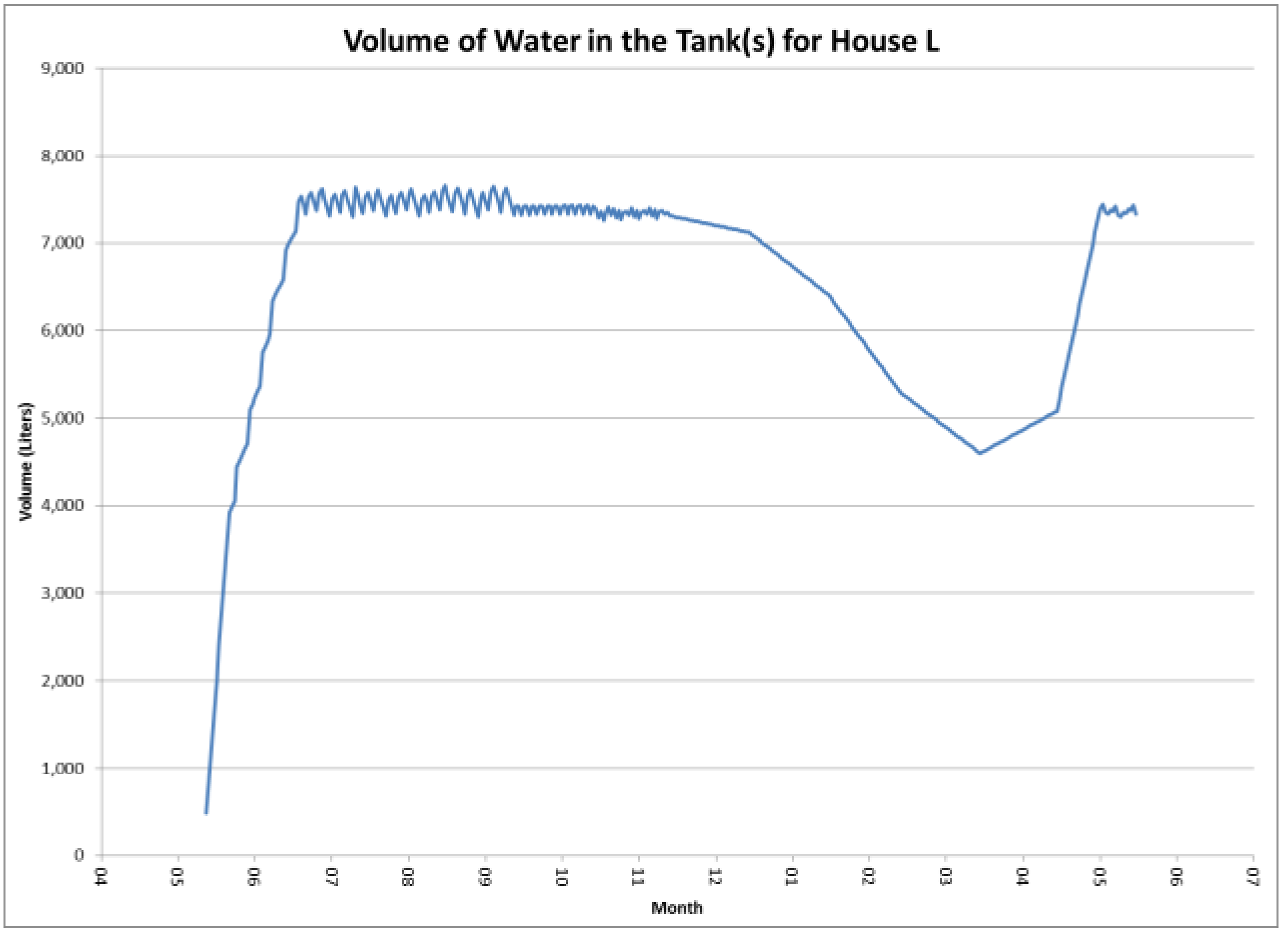


Figure 38: Volume in tanks over year -House L with 100L/day consumption rate

This graph shows the effects of the family using less water than expected. If the family only uses water for drinking and cooking, then this is a very realistic consumption rate for the community. This shows that they will have plenty of water for these necessities and possibly even some extra for other things, even though they will be encouraged to conserve.

The next analysis will look at the driest year since 1979. Again, this took place in 1994 with an annual rainfall of only 1073 mm. The monthly rainfall is shown in the chart below, and these numbers are used to generate the graph.

Table 17: 1994 Monthly Rainfall

Month	Rainfall	
January	0.0850	m
February	0.0290	m
March	0.0877	m
April	0.0688	m

May	0.0841	m
June	0.1861	m
July	0.0883	m
August	0.1966	m
September	0.1582	m
October	0.0968	m
November	0.0451	m
December	0.0323	m

Notice how these amounts of rainfall do not follow the general pattern of the rainy and dry seasons and the numbers are abnormal for the region.

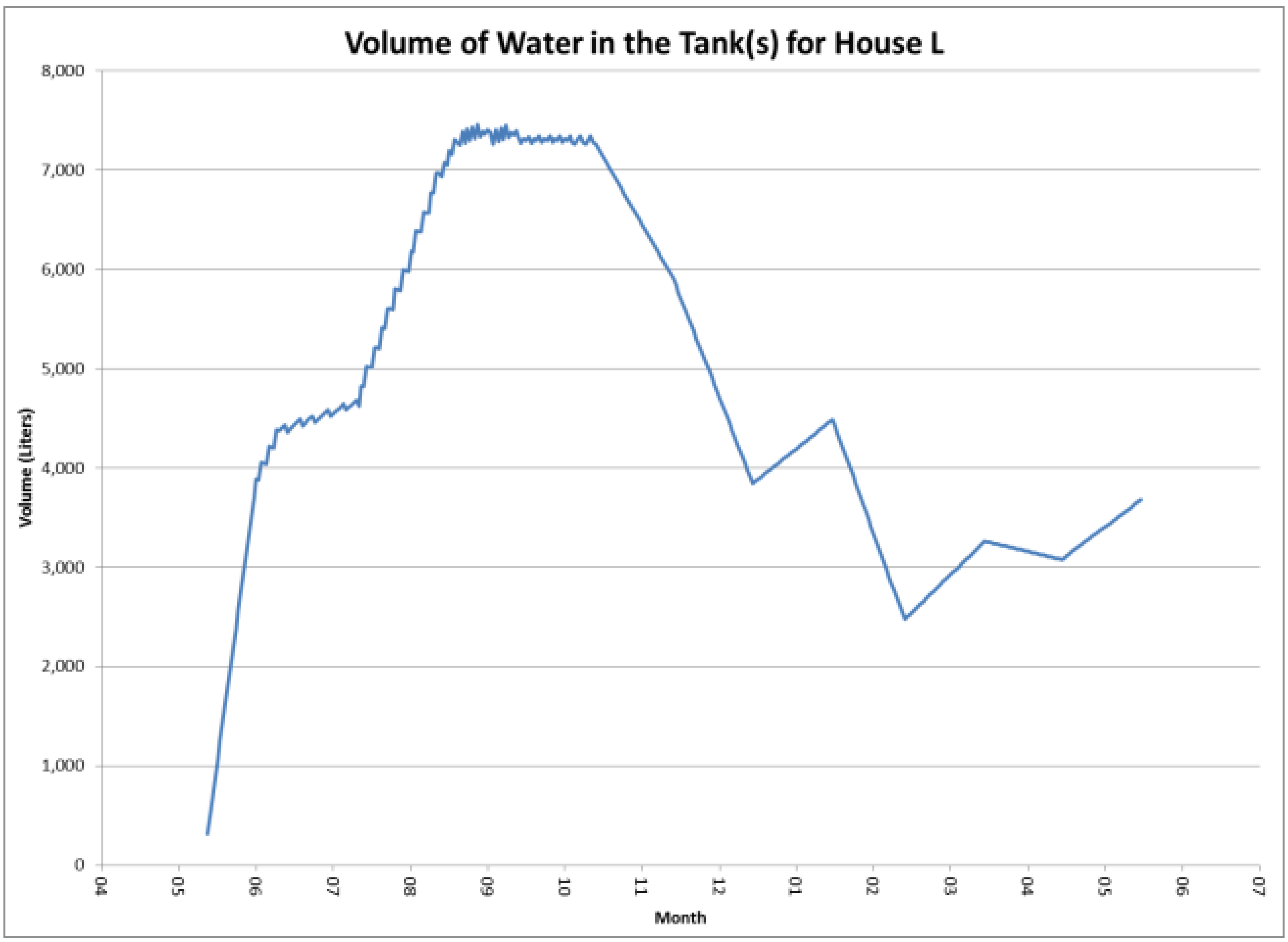


Figure 39: Volume in tanks over year –House L system in driest year, 1994.

This graph shows that this type of rainfall may actually be better for the community. Although they received much lower rainfall volumes over the year, the pattern of the rainfall was actually improved when it came to storage. Because the rainfall did not happen all at once, the amount of rain they could expect daily would refill the tank every day because of the near constant rainfall all year long in 1994.

Lastly, we will show the system based on the rainiest year, which occurred in 1984. The data below shows the monthly rainfall for 1984.

Table 18: 1984 Monthly Rainfall

Month	Rainfall	
1	0.0534	m
2	0.0342	m
3	0.0825	m
4	0.0409	m
5	0.1944	m
6	0.3605	m
7	0.3603	m
8	0.374	m
9	0.3686	m
10	0.201	m
11	0.1154	m
12	0.0671	m

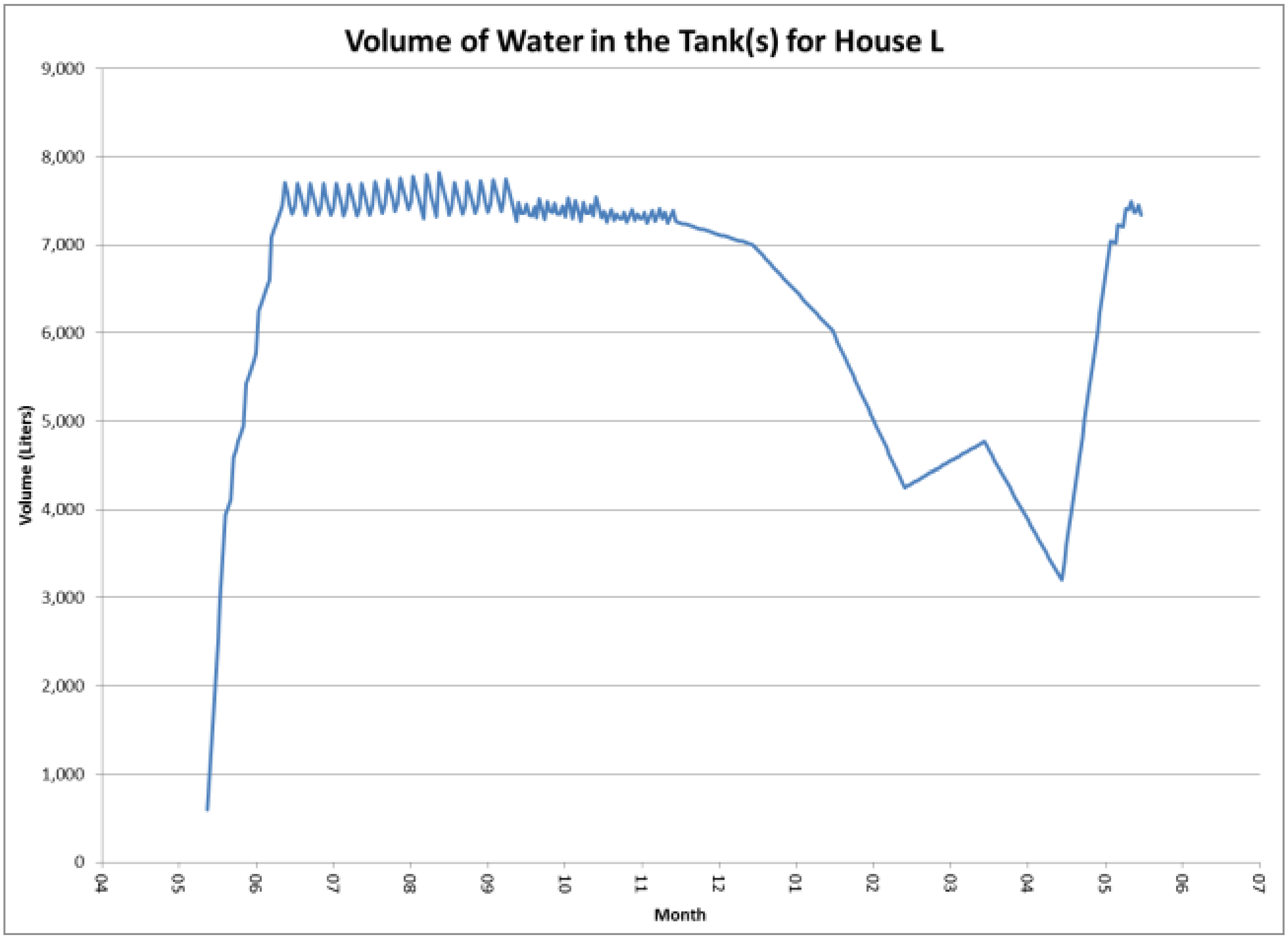


Figure 40: Volume in tanks over year –House L system in rainiest year, 1984.

As expected, the system performs better than during the average year. The family will not come anywhere close to using all of their water based on their current habits.

Lastly, we will look at the driest dry season. This is arguably the biggest testing factor that will prove our system. In almost all occasions, the amount of rain during the rainy season is not important. The rainwater catchment tanks by the time the rainy season is over, and much before that, always reaches its maximum storage capacity. It is at the transition to the dry season where the water levels start to decline quite rapidly. We will look at the lowest rainfall amounts from February to May which is the typical dry season in our community. Based on all of our rainfall data, the driest dry season occurred in 2000, with only a combined 121.10 mm from February to May. That year's rainfall data is shown below.

Table 19: 2000 Rainfall Data - Driest Dry Season

Month	Rainfall	
1	0.0554	m

2	0.0256	m
3	0.0018	m
4	0.0202	m
5	0.0735	m
6	0.3084	m
7	0.244	m
8	0.3087	m
9	0.3667	m
10	0.2107	m
11	0.2196	m
12	0.0405	m

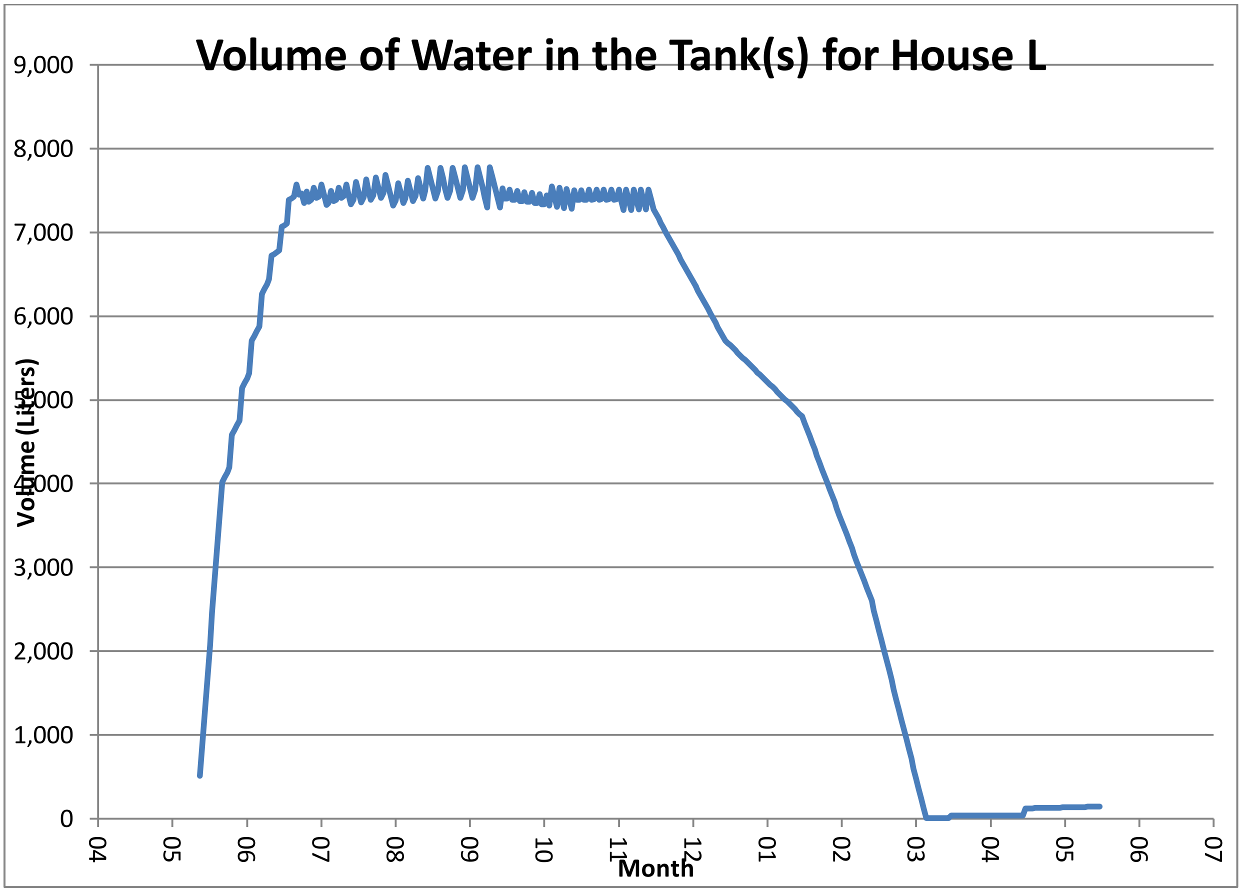


Figure 41: House L - Driest Dry Season

As a result of using the driest dry season data, it obviously takes a significant toll on our design. The insignificant amounts of rain from February to May make it impossible for the system to regain any useful amounts of water to sustain the system from what is taken out of it each day. However, it would not be economically feasible for the community to prepare for this type of rainfall. The designs to prepare for this would have to include entirely new structures for added roof space and/or purchase more storage tanks. Both of these alternatives would require an estimated double the cost. If these events are duplicated the family will have to resort to their previous means of water gathering during the couple of months when the tanks are mostly empty.

As shown with the different models, and altering the assumed values, our system for House L is designed to provide for uncertainties and will continue to work in the most abnormal conditions. The following information will apply to both houses but in different proportions.

3.3 Drawings

This section includes drawings of each of the proposed new parts of the rainwater catchment systems. We have shown pictures for each pilot house of the roofs with gutter systems, piping to tanks, and placement of water tanks and bases. We have also designed the systems in a 3D modeling program allowing for a better understanding of the 2D drawings. Drawings are in English units unless otherwise noted.

House A

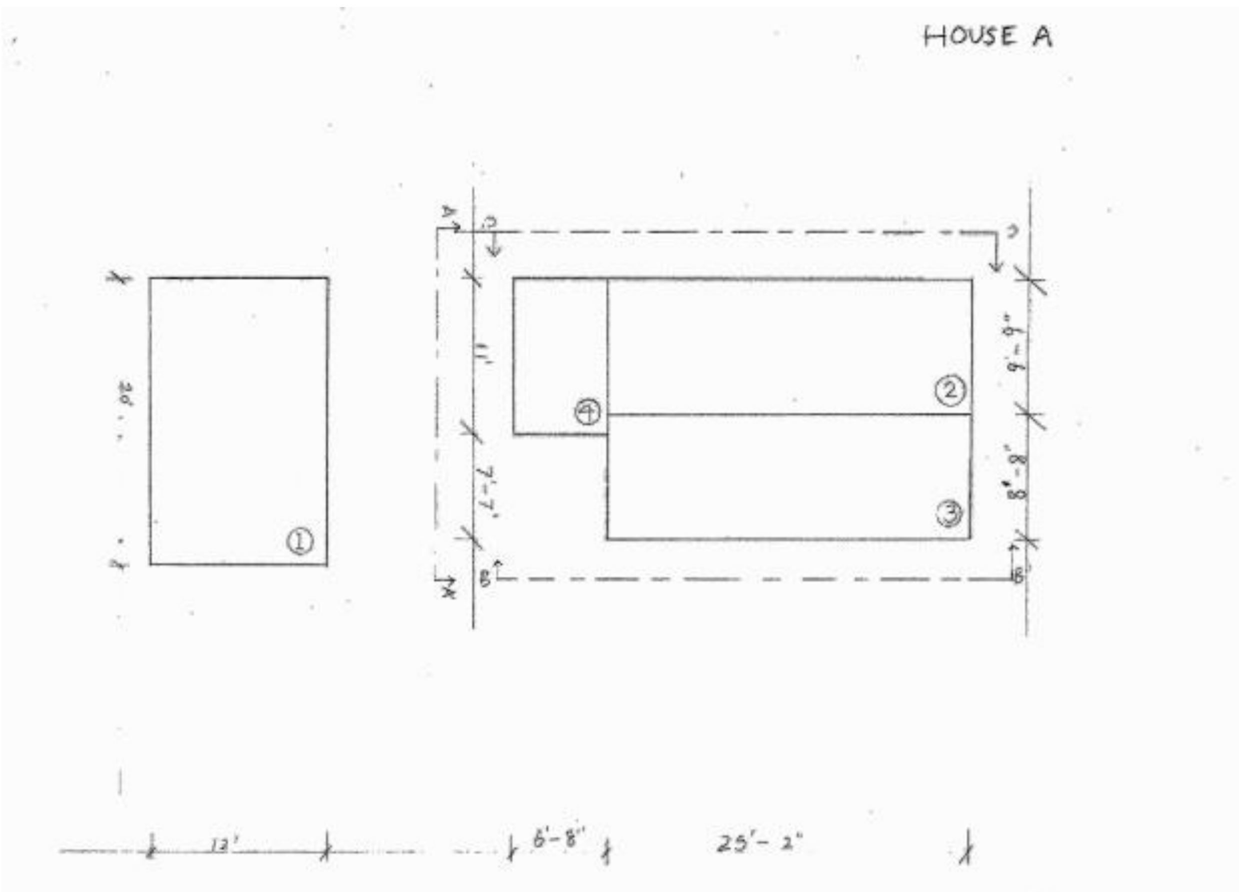


Figure 42: House A Layout

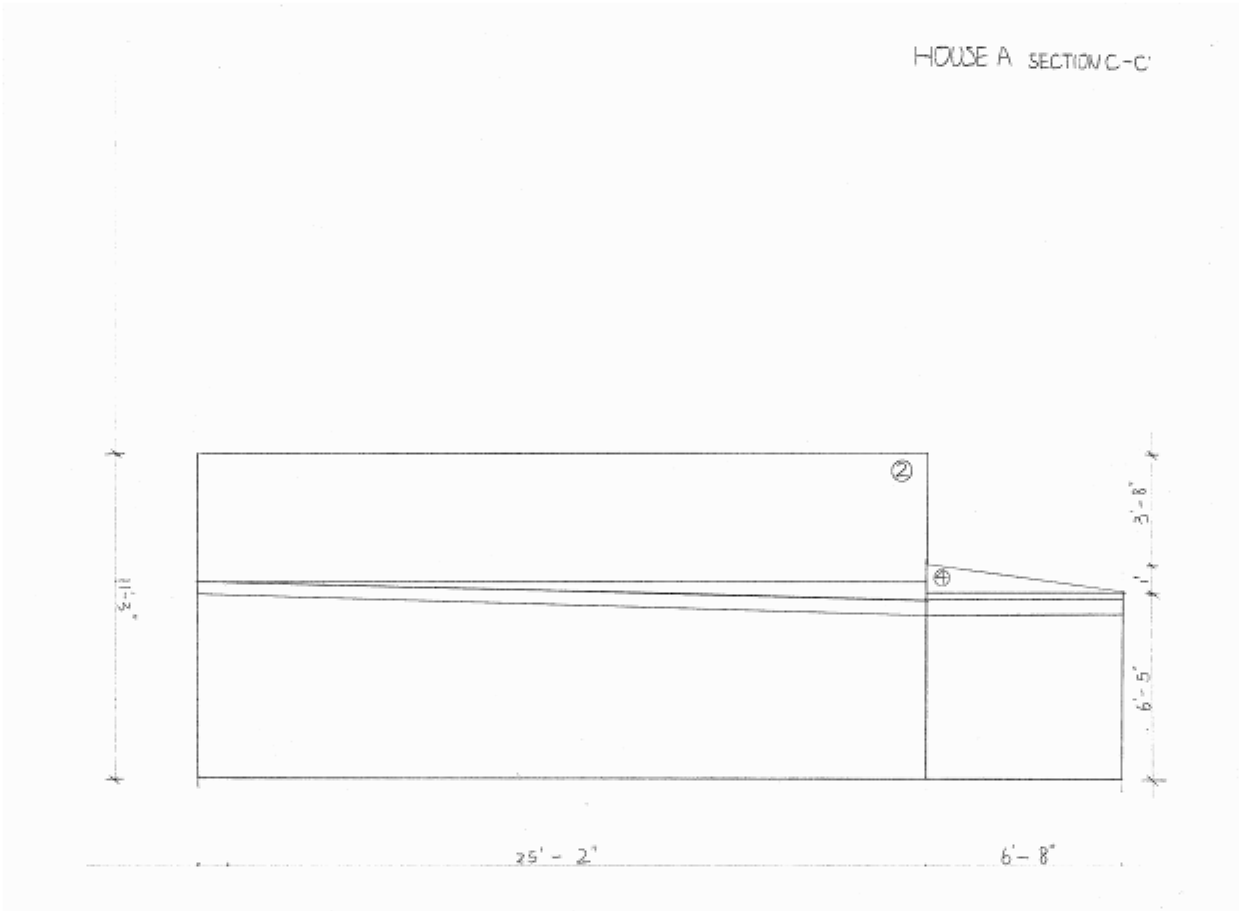


Figure 43: House A, Back View (with Proposed Gutter Systems)

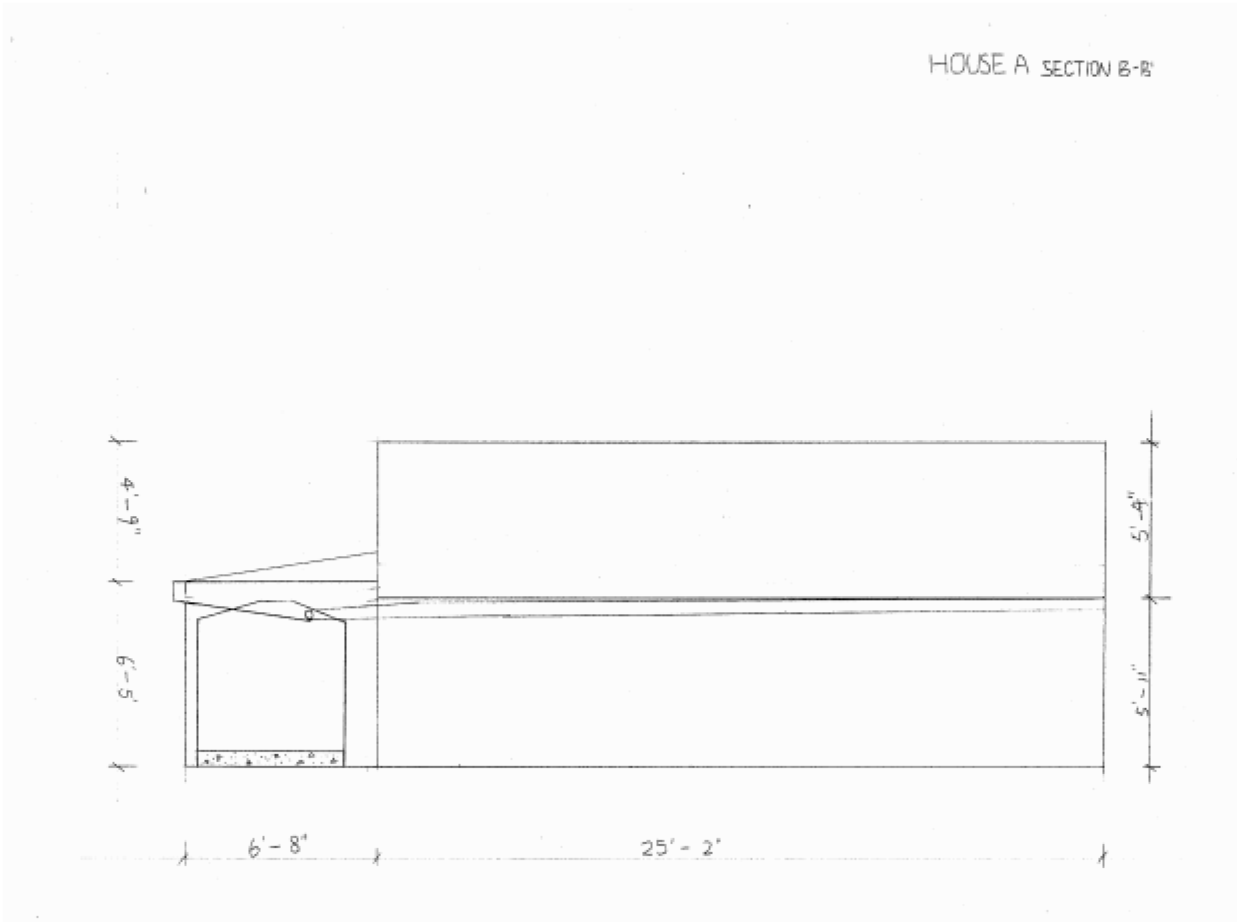


Figure 44: House A, Front View (proposed Design)

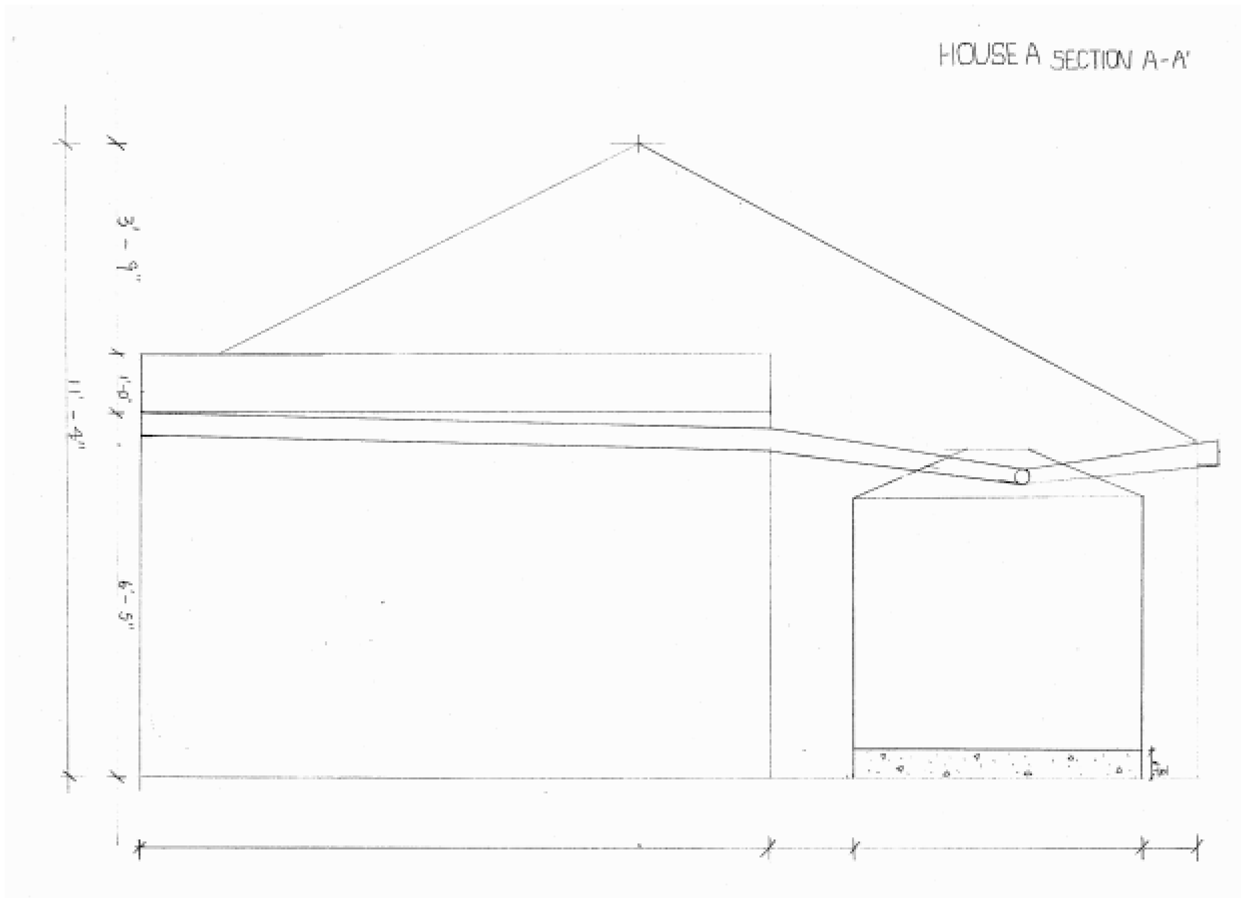


Figure 45: House A, Left Side of House

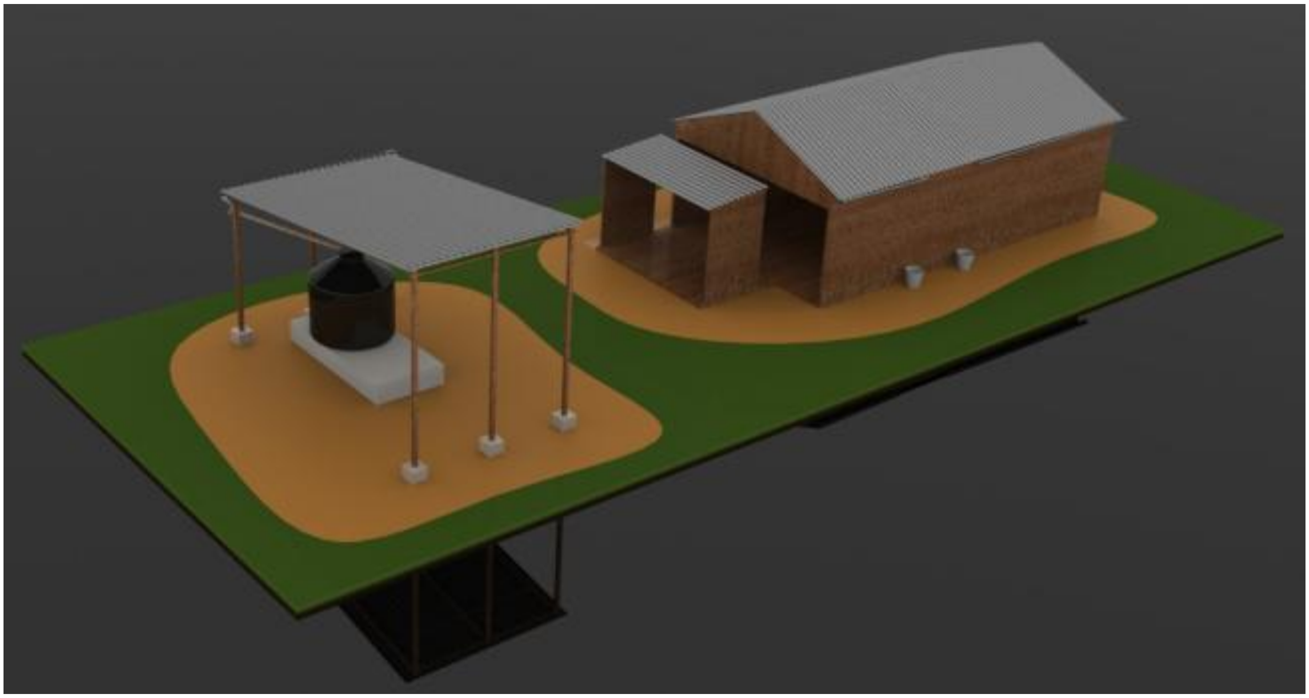


Figure 46: House A, current layout

Figure 47: House A, Front View (proposed Design)

Figure 48: House A, (Roof 2 (back left), Roof 3 (back right), and Roof 4 (front center)) (Proposed Design)

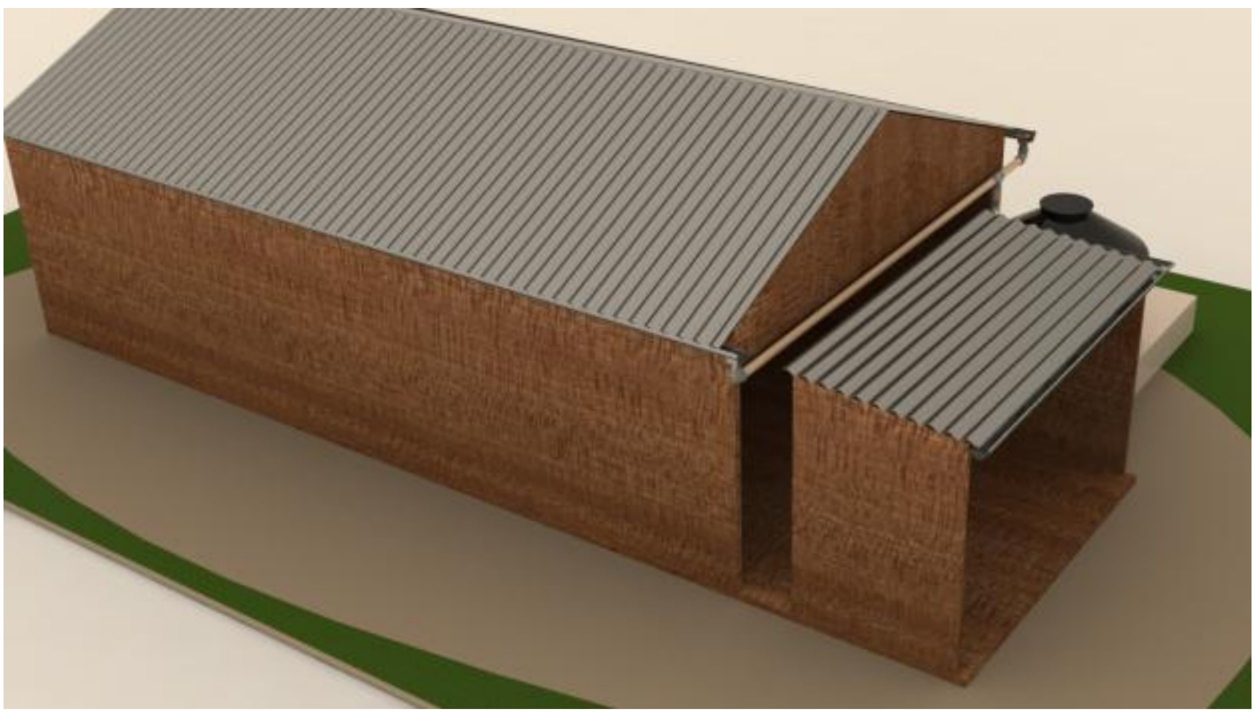


Figure 49: House A, rear (Proposed Design)

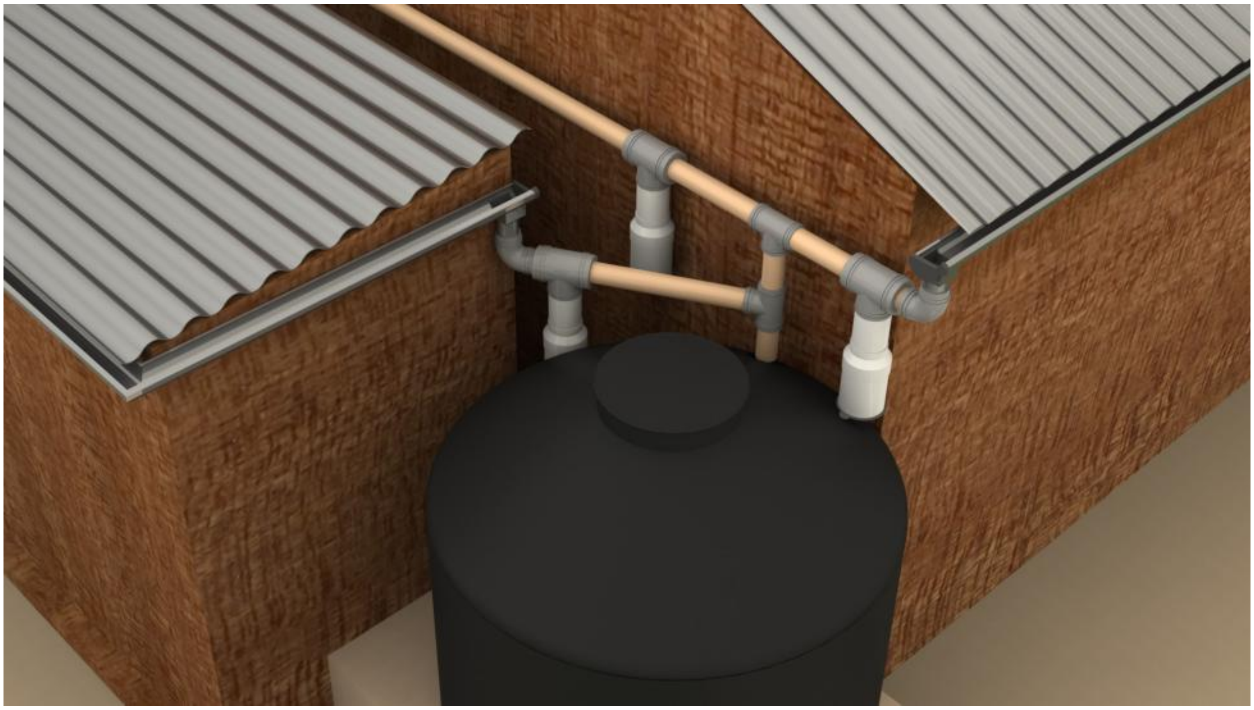


Figure 50: House A, proposed first flush

Figure 51: House A, complete proposed design

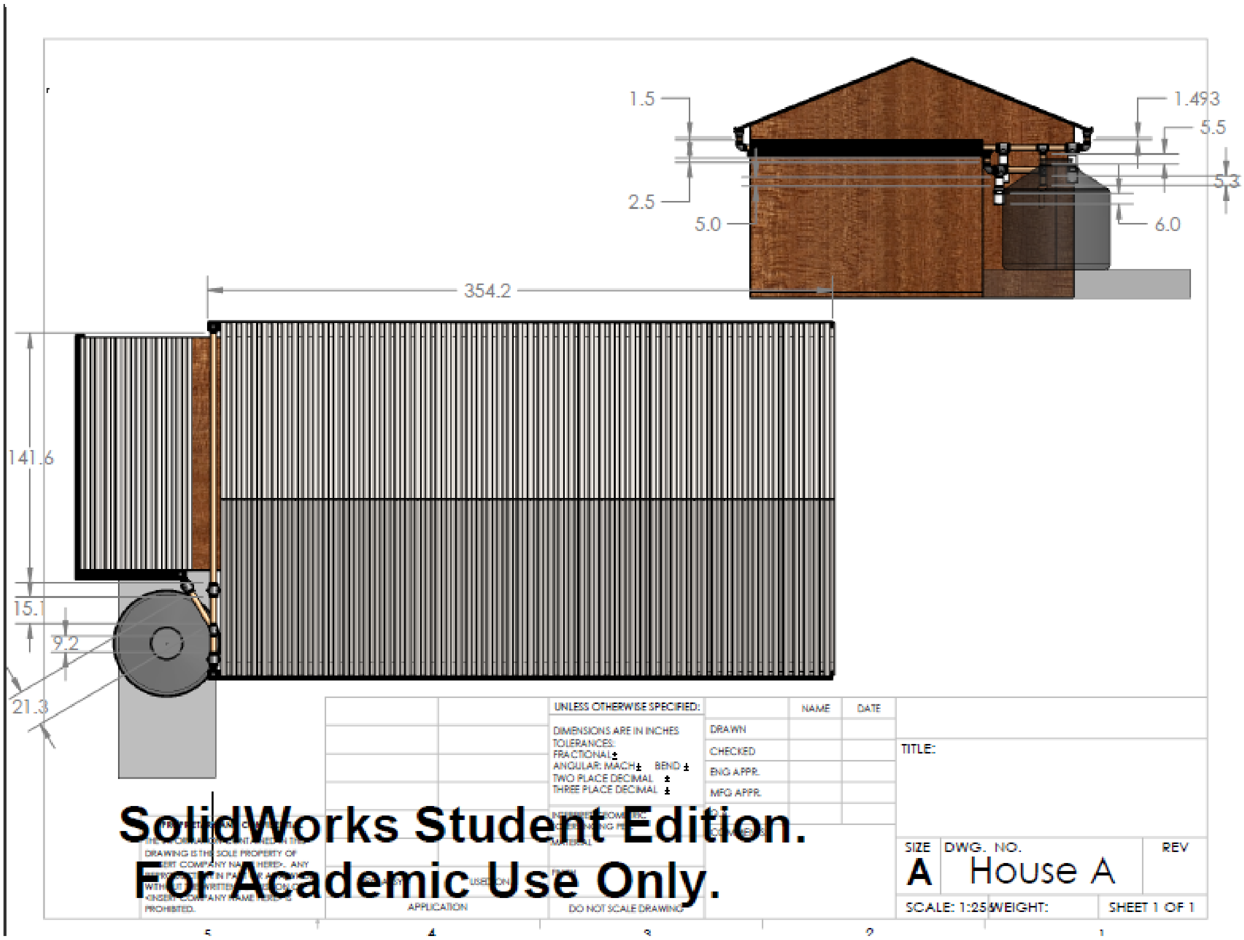


Figure 52: House A, dimensional drawing

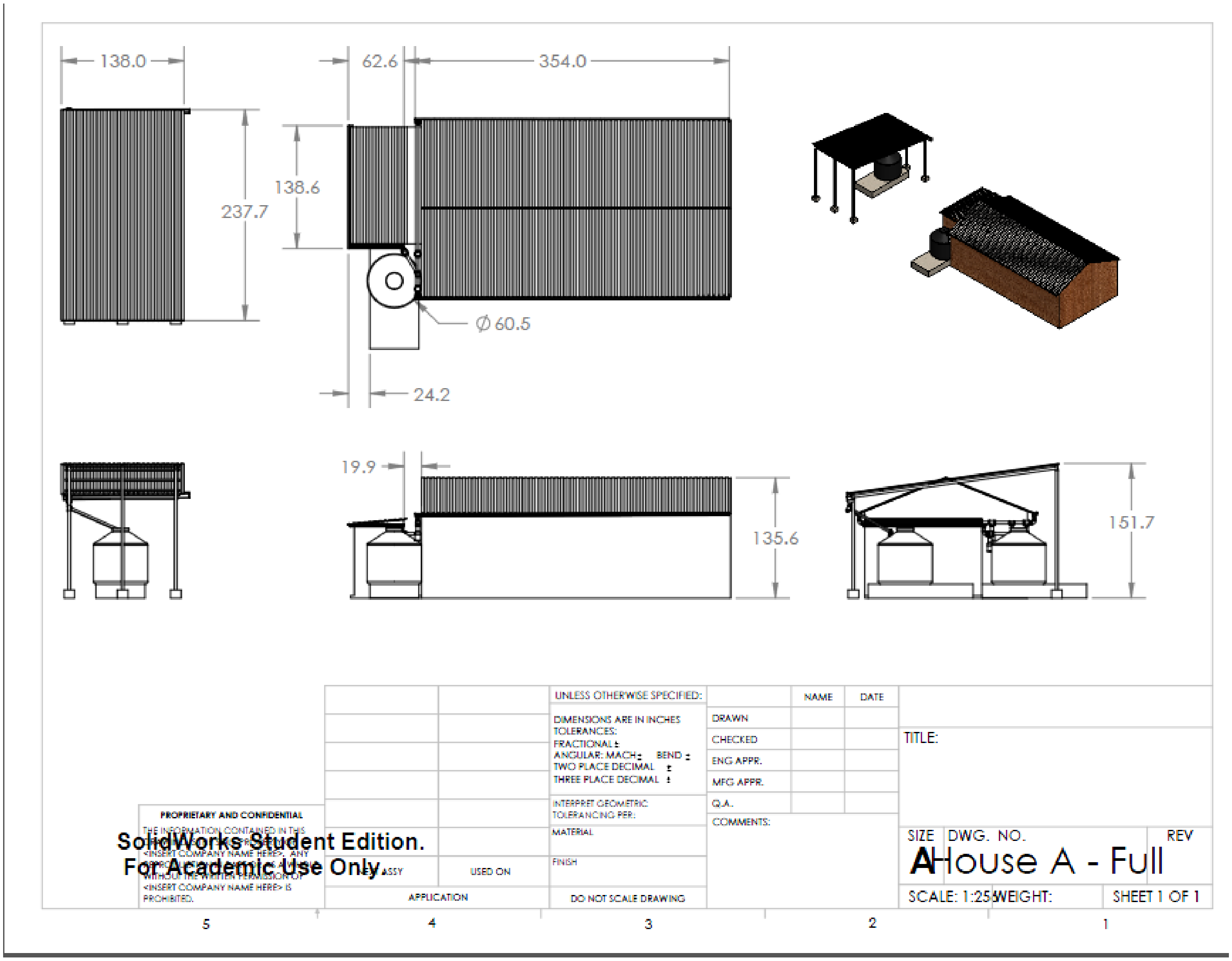


Figure 53: House A - Proposed Design

House L

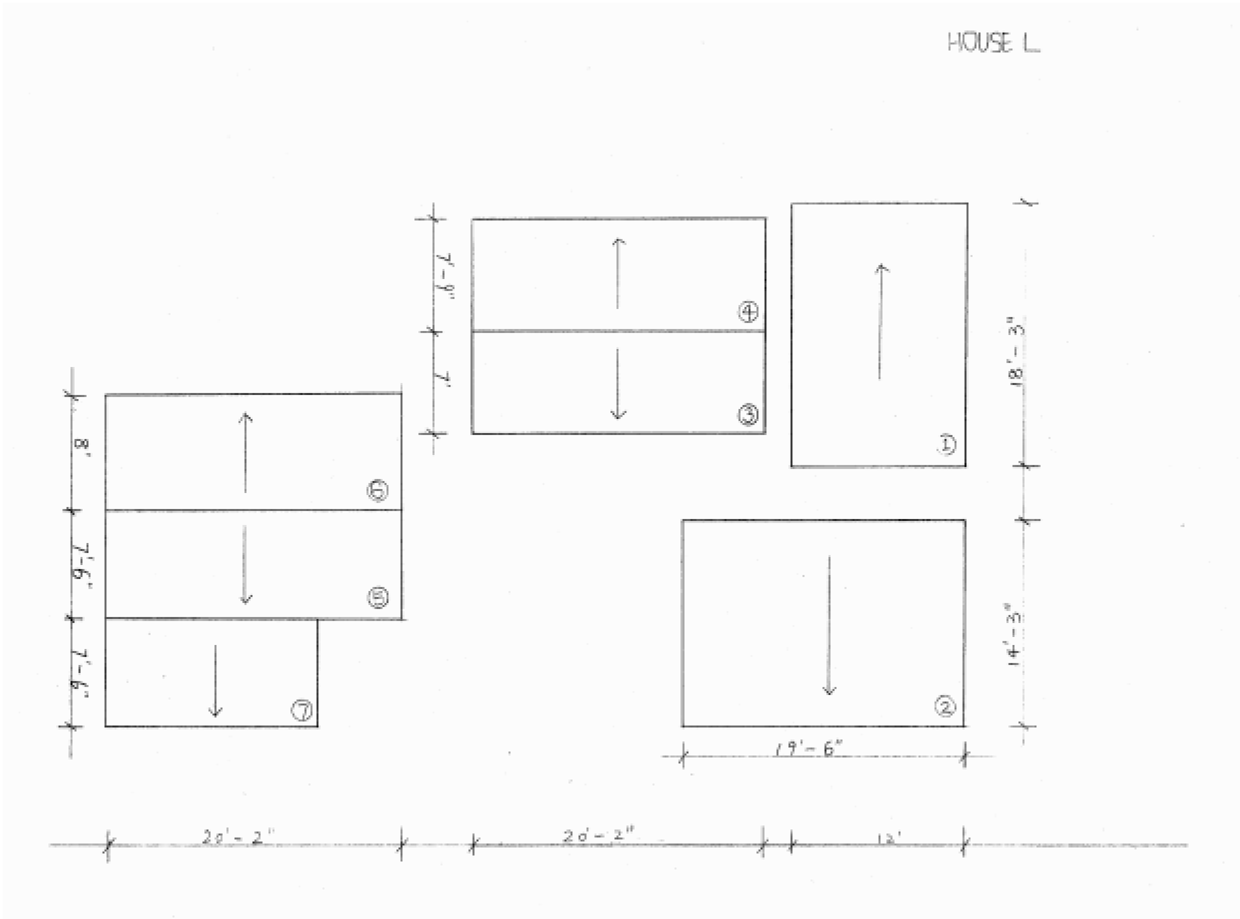


Figure 54: House L Layout

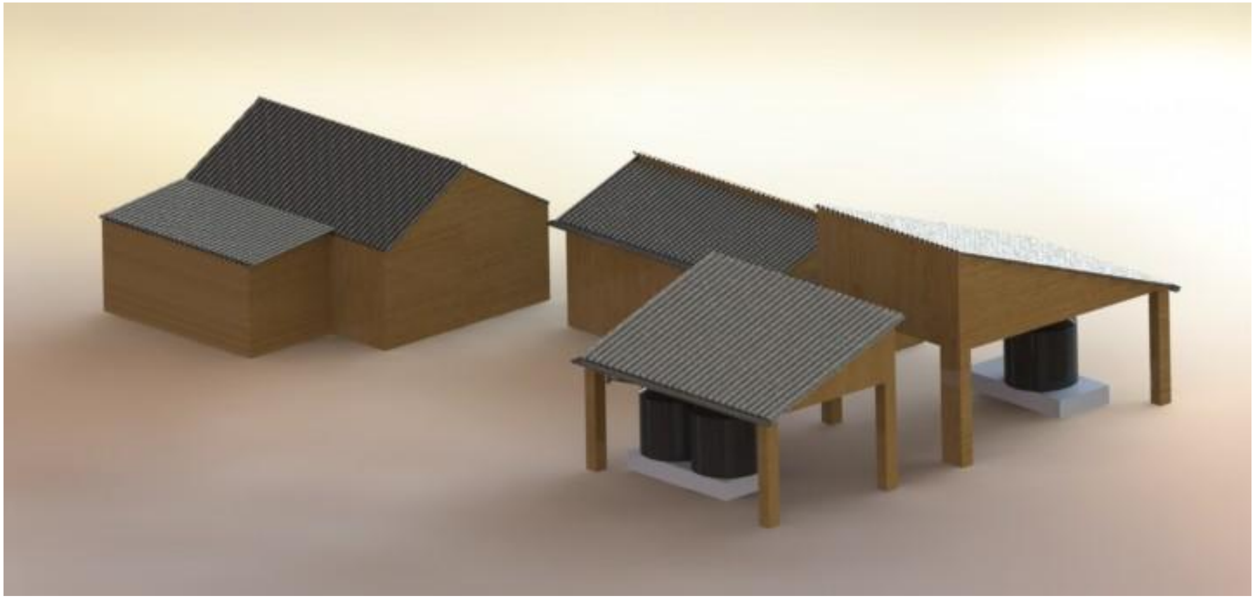


Figure 55: House L Layout

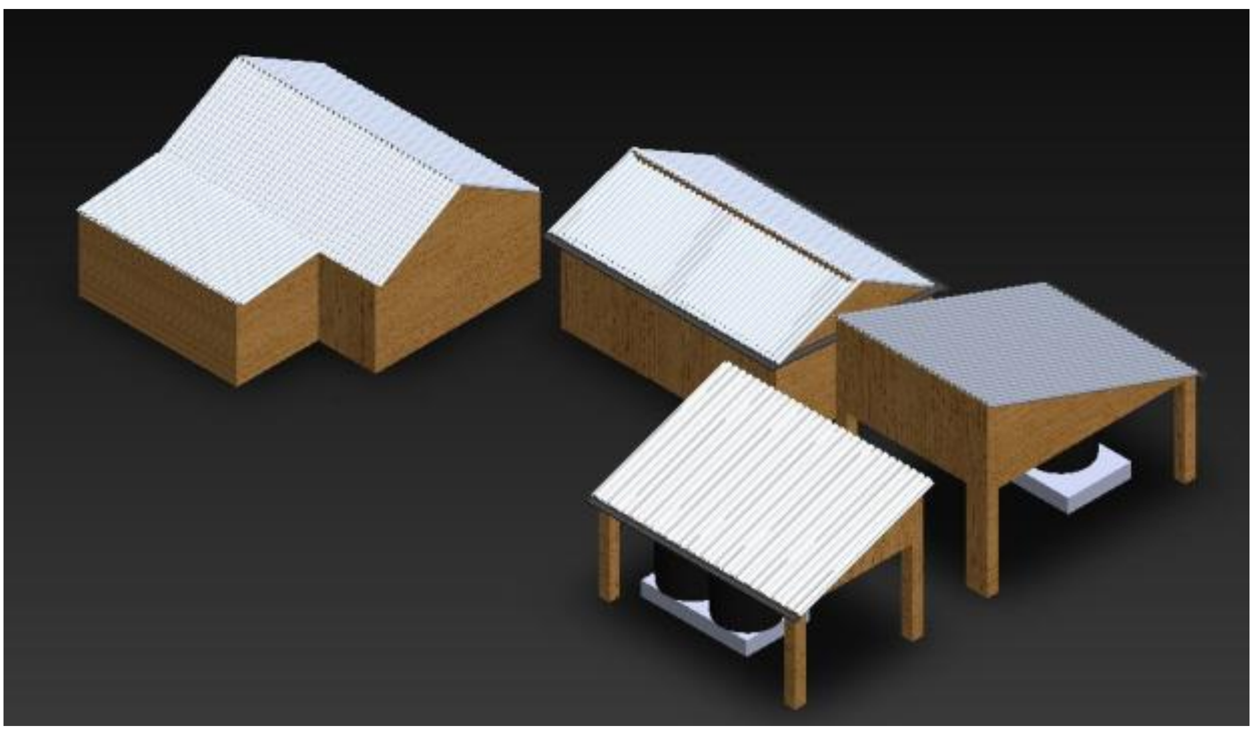


Figure 56: House L, current

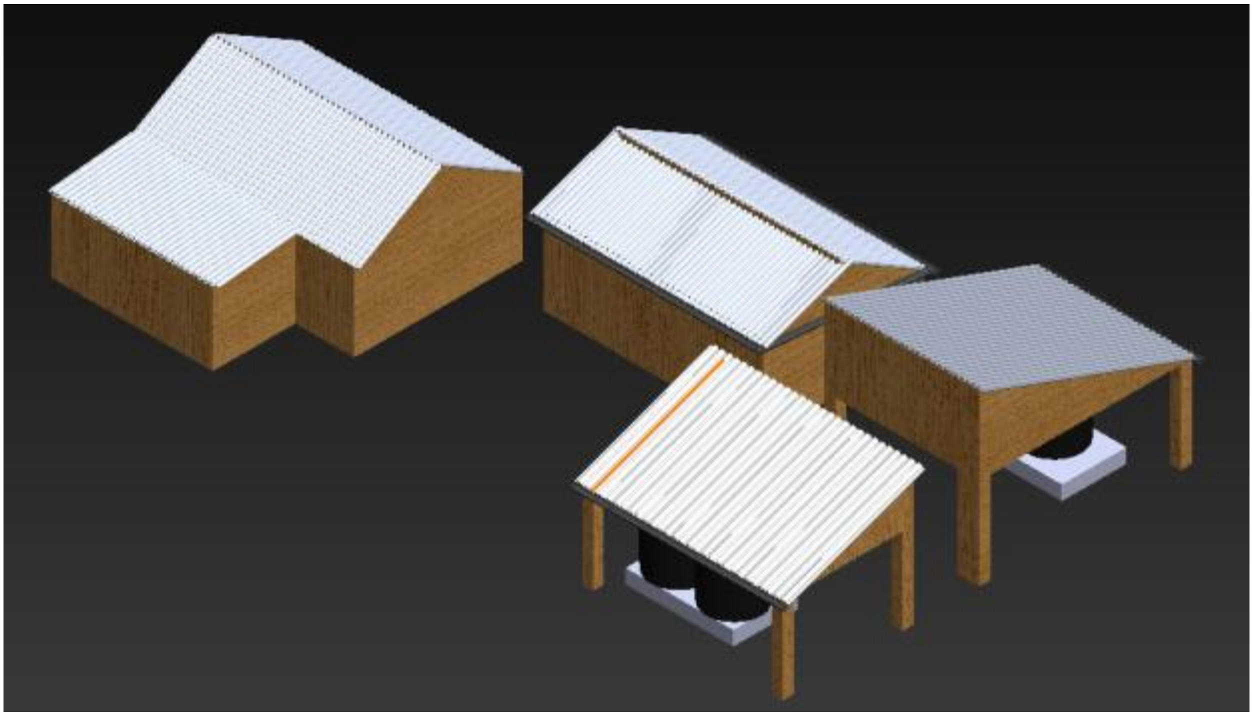


Figure 57: House L, proposed design

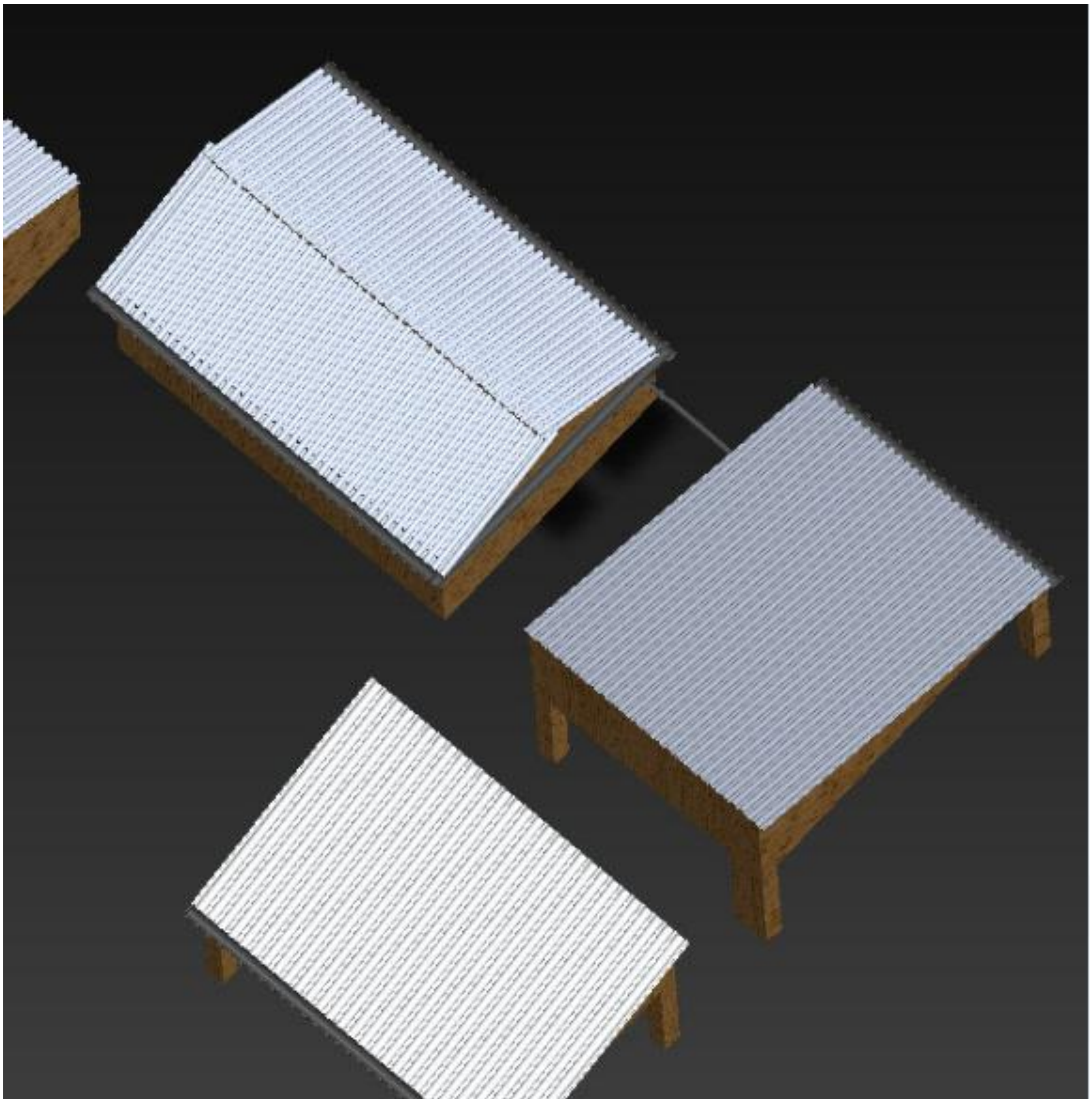


Figure 58: House L, proposed gutter system from Roof 3 and 4

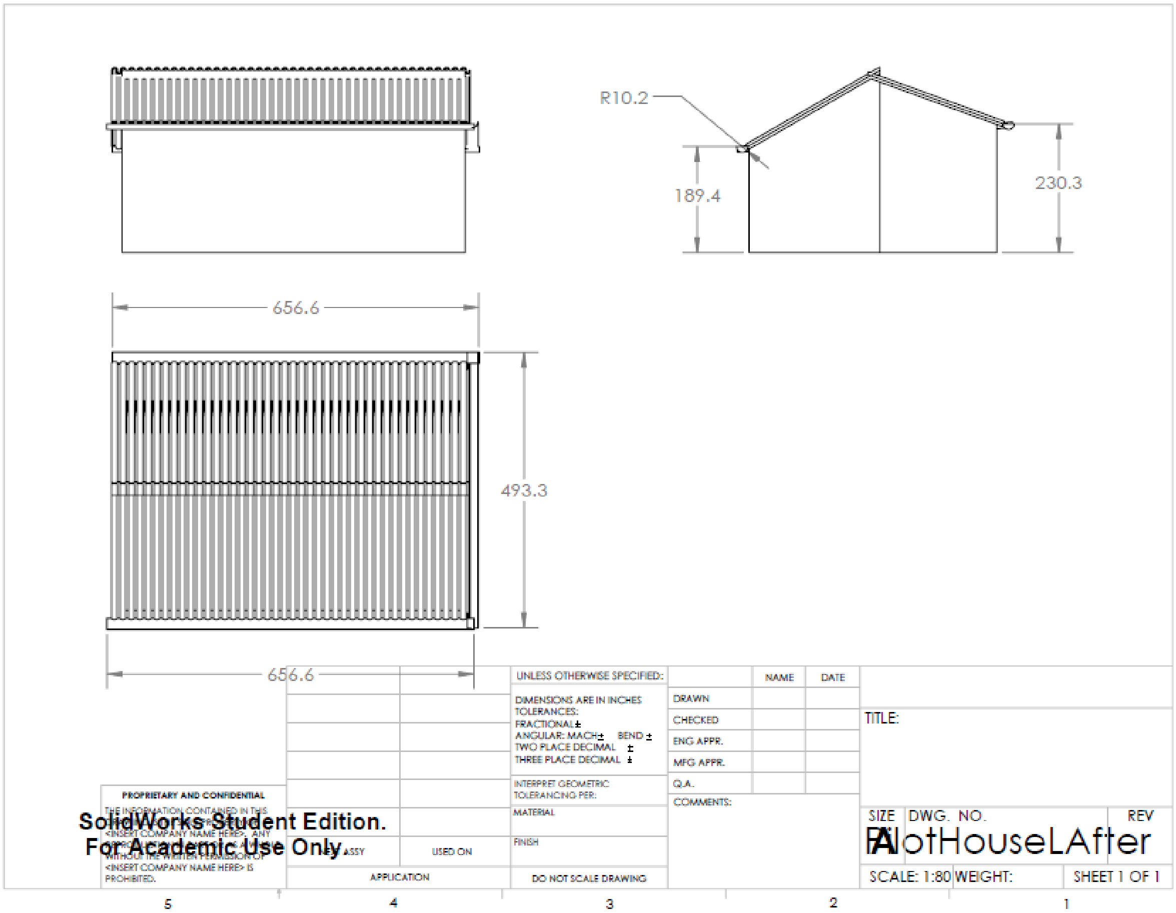


Figure 59: House L Proposed Design Measurements - Roof 3 and 4

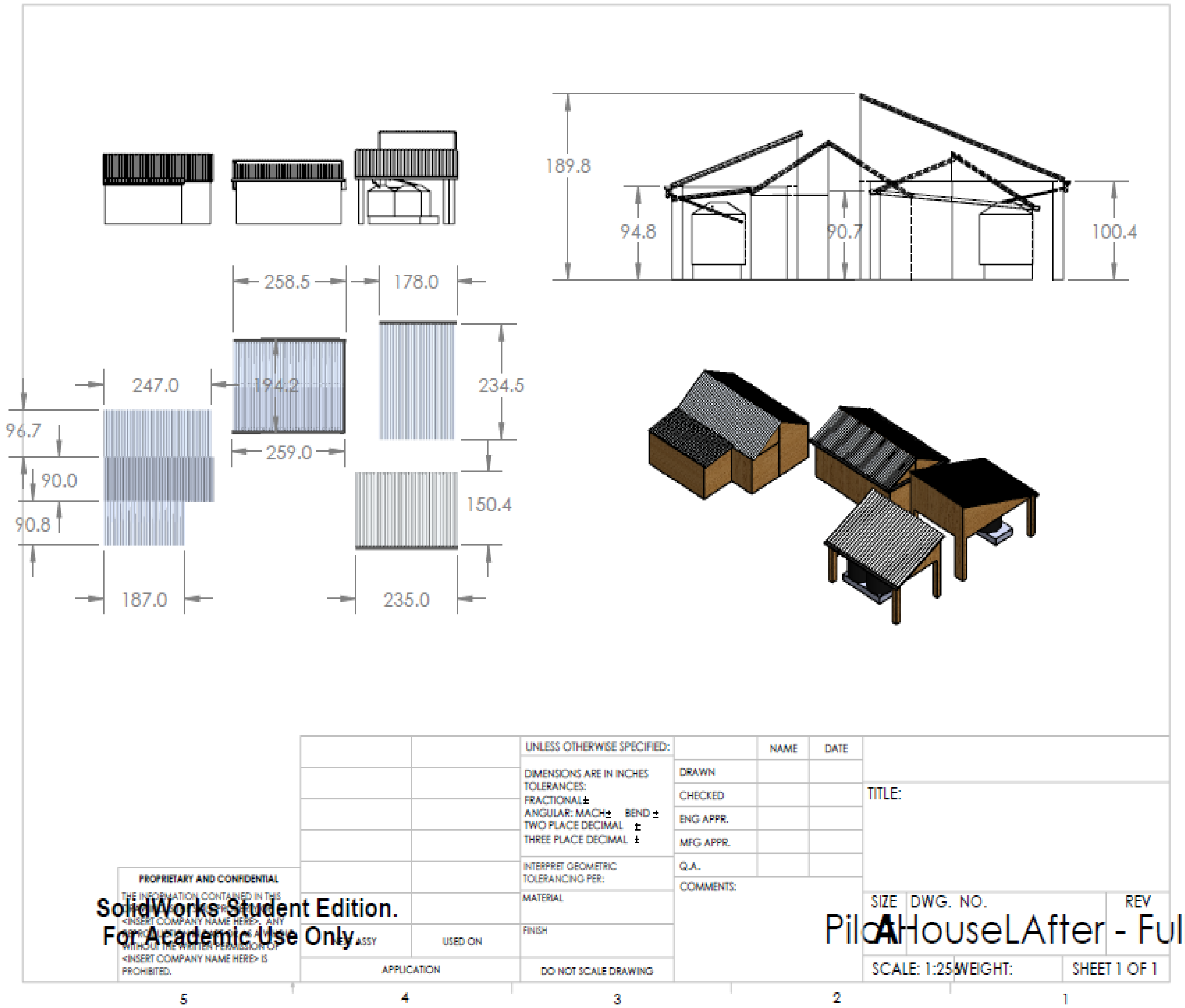


Figure 60: House L Proposed Design

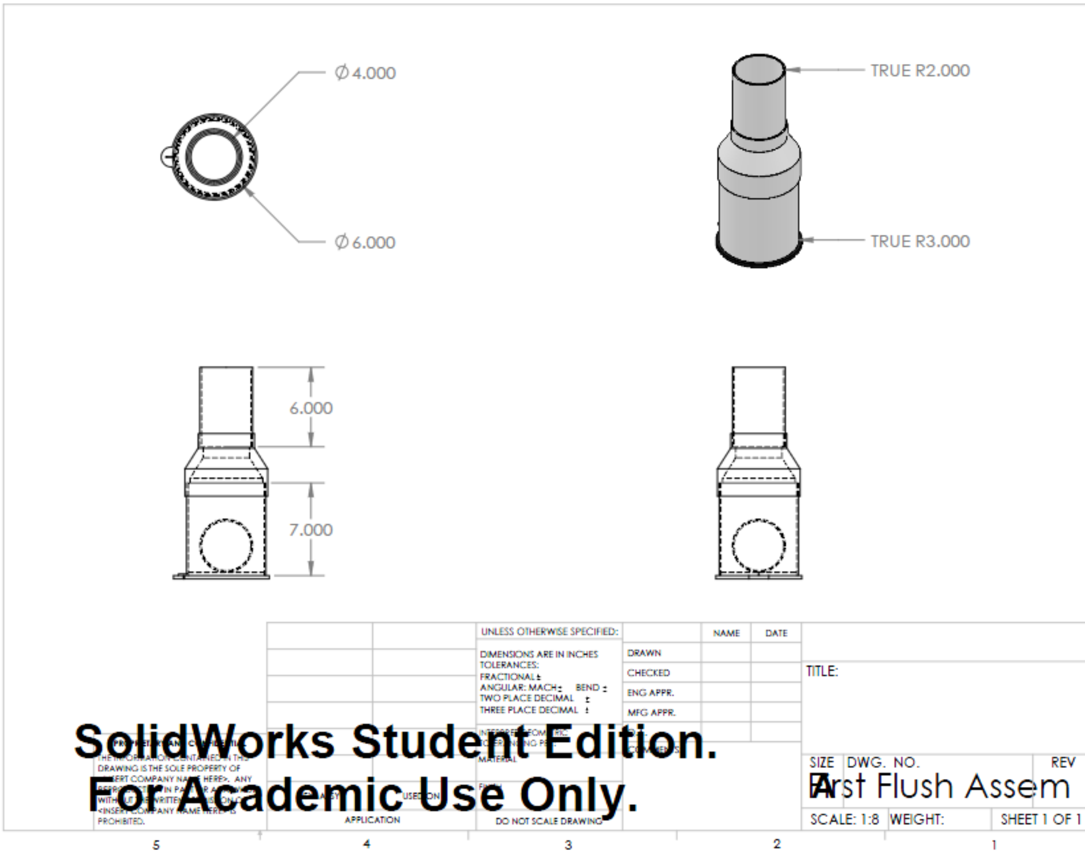


Figure 61: First Flush Design

The community does not have an official map, only two which were both drawn by the community leader, Don Domingo. These hand drawn maps are what we have been using on our assessment trips and research. These maps are shown in Appendix C.

4.0 Project Ownership

As previously stated, each home in the community will be receiving a rainwater catchment system on their private property. The team is working with the community to develop a purchasing scheme that will be within the means of the individual families and foster ownership of the system. In addition, each family will be directly responsible for the maintenance and repair of their system. This responsibility will foster a feeling of ownership among the community members. They will have to rely on themselves to maintain the systems and collect enough water for a year round supply.

Since the individual families will be responsible for their own systems, EWB-WPI will work with each family individually to educate them in proper maintenance practices to assist in the ownership process. The first step in this education implementation will be to have the family members present and assist during construction of the system. While the system is being built or fixed, the process will be fully explained to ensure they understand how the systems were assembled. This will help give a general understanding to the families on how they will need to maintain and fix the systems if a part is broken.

5.0 Construction Plan

Constructability

The pilot homes that our community picked for us to help them engineer and construct water systems for are currently designed with material limitations in mind. In our previous assessment trip, we documented important materials (as seen in Appendix E) easily accessible to our community. The local hardware stores have all of the materials that we need to buy to build the rainwater catchment systems. The skills that are necessary for the proper construction of our project are basic carpentry skills and cement structure construction. As seen on our assessment trip our community members have the skills needed to help us on our implementation trip. Foreseeable constraints that may hinder our construction process include the slow curing time of cement, and the difficulty of getting supplies to our pilot homes because although the materials are locally available, transporting all of the raw material will be difficult due to the large hill and dirt road.

Itinerary

December 27 to January 10

<u>Overview</u>
Week 1:

- Travel to construction store to purchase materials and have them shipped to the community
- Discuss the rainwater catchment plans with the community, and the pilot families in detail.

- Meet with the community members that will be helping us build
- Meet with the families that are receiving the rainwater catchment systems and discuss the building process and how they can assist.
- Build the two rainwater catchment systems

Week 2:

- Finish construction of the rainwater catchment systems
- Work with community members to:
    - Establish data collection plan
    - Discuss future fundraising ideas and the importance of fundraising
    - Reinforce the communication plan established last year
    - Identify households that will receive rainwater catchment systems on our next trip
- Meet with other area-organizations including NGOs, non-profit organizations, and the Geology department at the University of Cobán
    - Establish a data collection plan with the University and local collaborators in San Cristobal
    - Establish communication plan with the University
- Work with the pilot families to:
    - Discuss how to use and repair the rainwater catchment system
    - Discuss how they will help us collect data over the next year and why it is important

Details

Day 1
Travel from Boston to Miami/Texas to Guatemala City to San Cristóbal.

Day 2
Morning: Becoming acquainted with the area, and home-stays
Meet with community and discuss plans for future.
Have community identify who can help build the rainwater catchment systems, identify what tools the community has and what we need to buy
Check up with fundraising/Discuss future fundraising ideas and the importance of fundraising
Reinforce the communication plan established last year

Afternoon: Meet with families receiving rainwater catchment systems to describe what we will be doing and ask that they be present for the construction process

Day 3
Morning: Trip to Coban to buy materials for construction and arrange transportation [Group 1]
Meet with Sergio at University with grad students [Group 1]
Establish communication plan with the University [Group 1]
Continue meeting with the families [Group 2]
Travel to San Cristobal to buy materials [Group 2]

Day 4 (Sunday/down day)

Spend day with families in the community, doing chores with family. Trust building.

Day 5
Mark out locations of concrete base
Prepare forms for concrete base
Dig trench for concrete base location
In depth analysis of pilot homes, looking at more precise measurements

Day 6
Meetings with NGOs/non-profits and government groups
Meeting with Grad students to set up monitoring system
Meet again with Sergio to finalize data collection/Establish data collection plan with the community
Meet with other organizations in the area
Fix rain gauge

Day 7
Make form for concrete base of House A
Mix concrete
Build concrete base for the tank of House A

Day 8-9
Replace roof of House A
Attach gutters to House A and House L
Connect gutters to tanks on House L

Day 10
Education day, work on educating community.
Invite Sergio to be present during this process
Spend time with a family, bonding and learning more about their daily activities.
Pick next pilot houses with community.
Monitor pilot homes water use to compare with stats back home.

Day 11 (Sunday/down day): Fieldtrip day for travelers

Day 12
Continue to explore the idea of a community tank
Take in-depth measurements of the next houses that will be receiving rainwater catchment systems.
Questionnaire for new pilot homes on water use

Day 13
Connect gutters to new tank for House A

Complete unfinished work from previous days
Collaboration and future planning

Day 14: Depart from San Cristobal to Antigua

Day 15: Travel from Antigua to Guatemala City Airport and leave Guatemala

If anything should interfere with the time table presented above, the team will progress to the next section's goals and return to the previous ones when possible. The largest problem based on the above events would be the curing of concrete. EWB-WPI believes that even if the cement has not finished curing prior to our departure, the community members will be able to complete this process and connect the tank to the system without our presence. The systems we are presenting are additions to what the community members currently have, so their completion of the design is plausible.

EWB-WPI will arrive in-country and participate directly in placement of the tanks; gutter attachment, replacement of roofs; EWB-WPI will be overseeing this work as well. All unskilled labor will be provided by the community of Guatchthu'uq with the exception of that done by EWB-WPI while onsite.

All materials have been located in a minimal of at least one hardware store in the five that were assessed. In addition, these stores will be able to transport the materials to the community after ordering. See the list of materials in Appendix E. Note it is separated by each different hardware store.

6.0 Sustainability

6.1 Background

EWB-WPI has analyzed numerous options to provide the community of Guachthu'uq with water for the entire year. Our decisions were made based upon the necessity for the systems to be easily repaired by the community members without having the knowledge of designing the systems, financial status of the community members, environmental disruption, and cultural integration. We selected the most effective option that will utilize the locally available raw materials that are easily accessible to the members of our community (Appendix E). To help ensure the longevity of the systems we will need to educate the members as we build the systems alongside them. The tanks are estimated to last 35 to 45 years without any abnormal wear and tear as stated by Rotoplast. The roofs and gutters will be made out of rust resistance steal however they will rust over the estimated time of 15 years. Replacing a roof is feasible for the community members to do with very little education and their prior knowledge. Under ideal conditions the life span of our systems is 15 years without any major repairs; however the systems will be able to last longer if necessary.

In addition to the ability of rainwater catchment systems to be built using readily available materials and last for an extended period of time, the materials can be purchased by community members when repair is necessary. The community of Guachthu'uq is incredibly poor, however, EWB-WPI selected materials that are already present in the community, ensuring their ability to be replaced. Their pre-existing presence in the community also decreases the environmental and cultural disruption that will be caused. The rainwater catchment systems that will be implemented are additions to the current systems that the majority of the families already have. However, the ones in use do not have enough roof area, efficiency or storage capacity to provide water for the entire year. With the additions proposed, the community members will have a similar system that they know and understand how to use, that will provide water year round. Cultural sustainability ensures that once the systems are built for the community members they will be kept and maintained.

6.2 Operation and Maintenance

Each family will be responsible for the operation and maintenance of their individual rainwater catchment tank, including financial obligations for repairs. During construction, there will be volunteers throughout the community to assist and lend their expertise. However, when the systems are being constructed, members of the house will need to be present to ensure that they understand the process and can assist with construction. If the house members assist in construction, they will learn what all of the parts are and what needs to be done to fix the system if it breaks. Since all of the parts will be purchased locally, the community members will know what to purchase for replacements. In addition, the EWB-WPI team will be able to explain to the family which tank to use water from first. This will be determined based on the excel model.

First Flush Operation

The first flush system will ensure that any remnants left in the system after the dry season and the annual cleaning are removed. This first flush system is a new component to the existing rainwater harvesting systems. In order to ensure that the family members in the pilot homes get cleaner rainwater collection we are going to recommend that they empty the first flush system whenever there is a stretch of time that it does not rain for more than two weeks. During the rainy season we are going to recommend that the first flush is only emptied every few storms because rain is so frequent that the roof will remain relatively clean throughout the rainy season.

Gutters and PVC

The gutters and PVC piping will need to be checked several times a year to ensure it is working as planned. The families will need to look for any leaks or breaks in the PVC piping or gutters, and will replace the broken portion when found. As part of our education material, we will give a list of materials used for each system and where the materials were purchased. The families will be able to easily identify the store where the piping and gutters were purchased to buy replacements. The PVC piping and gutters will be sealed with PVC primer or glues that will seal the cracks in the piping and gutters. If gutter clips become disconnected from the roof, the family will need to either reattach it or buy a new one, using the information above to locate the stores. When larger holes are found that are not easily fixed, the family may have to replace the entire section of gutter or piping. Since family members built their own home, they have the skills needed to perform this maintenance. In the event of a blockage, or buildup of material, the family will have to manually remove the debris, most likely using available community ladders. Once a month the family should check the piping and gutters to remove any debris to prevent this from happening, this will be addressed through education. However, this should not be much of a problem because many trees are not directly over the houses and are not very tall. Gutters can simply be swept out by using a broom or brush. It is suggested to clean the gutters before the rainy season starts, and periodically throughout the rainy season.

Storage tanks

The lifetime of the tanks are expected to be 35-45 years as advertised by Rotoplast, the tank manufacturer. The family members will not have to worry about replacing the tank for a significant amount of time. With our implemented screens and first flush system, very little debris should be able to make it into the tank. According to sources, these are the least important object that needs to be cleaned. At no time, should anyone enter the tank, because it introduces new levels of bacteria that were not previously in the tank. Also, the walls of the tank should not be scrubbed because it can destroy the layer of beneficial bacteria that lives in the tank. When the water tastes bad or smells, bleach can be used to sanitize the tank. Also, if blockages occur or debris builds up in the tank, which should be quite uncommon, the water will need to be drained and the debris scooped out.

6.3 Education

An important part in helping the community collect rain water is ensuring that each member understands how the system operates, how to maintain it, and how to use it more efficiently ensuring water throughout the year. With the community providing the labor, a large amount of the education will take place while the system is being built (learning by doing). The family members will observe the parts that will be purchased and gain an understanding on how we recommend they are used. EWB-WPI also intends to leave information pertaining to the systems components and where they have been purchased while in-country.

In order to have an efficient implementation of the rain water catchment system in the community, it is necessary to discuss with the community members what the system entails and how to maintain it. As part of our goal during the assessment trip EWB-WPI would like to conduct two different types of community meetings. The first type of community meeting would be with all the community members in which our main task will be to inform them about the rain water catchment system and how it would help them. As part of this presentation, EWB-WPI wants to address different conservation techniques and distribute a pictorial poster to each family. This pictorial poster depicts the type of activities that can be done with the water from the tanks such as for drinking and cooking and which activities are not recommended such as bathing and washing clothes. At the end of this presentation EWB-WPI would like all the families to have an understanding the importance of conserving their water supply and how to use their water efficiently.

In the second type of meeting EWB-WPI would like to focus on educating the family members of the two families who are receiving the improvements to their rain water catchment system during the assessment trip. During these meetings with the individual families, EWB-WPI will address in detail the first flush system and how they have to maintain their roofs and catchment systems. As part of this meeting, visual representations of the first flush system through pictorials and a small hands-on activity with the family will be used. This will allow the family members to practice the proper maintenance techniques and ask questions in case they don't understand the presentation that we will provide them with. This meeting with the individual families is important so that they can receive a more detailed explanation of the project using the system as an example since the first meeting will be focused as a more general discussion on water conservation and proper maintenance techniques.

As part of the interaction that EWB-WPI will have with all the community members, it will be important to maintain a strong presence and awareness of our presentation after we leave the community. Therefore the community leader Angel will receive additional information in more detail about the different resources in the community and in the town about water conservation and also in case there is an emergency who he can contact. As the community leader he will be able to follow up with the community about the different conservation techniques and discuss with them if any issues arise. In Appendix H, EWB-WPI has created a list of the main topics that will be important for the travelers to touch upon within the meetings. These different communication techniques will allows us to maintain the trust of the community and identify what other concerns the residents have in regards to the implementation of the water catchment system.

Through these conversations EWB-WPI will aim to explain and teach the importance of maintaining and cleaning each system; however the team plans to also leave pictorial posters in the community to help remind the family members throughout the year as well. The posters rely mainly on visual aid due to the difficulties associated with translation of English to the native language Poqomchi as well as the degree of literacy of the members of the community being unknown. The visual was kept as realistic as possible to portray realistic environment and people. Realism was preferred over cartoons due to advice from other EWB project members that reported the local tendency of not being able to relate to cartoons. The posters will be laminated in order to increase their lifetime since they will be used around water. A copy of the poster is shown in Appendix H. In this way, we hope that the community will feel more a part of this long-term project, promoting conversation throughout the year rather than a recipient of our systems yearly during our travels.

It will also be important to reinforce why rainwater was a better alternative over well water. EWB-WPI will remind the community members that drilling a well would have been expensive as well as result in dirty water compared to the potable water that will be collected from the rain water. Through conversation during previous trips EWB-WPI has determined that the community members understand that it is the Finca water that is making them sick and that boiling the water will make it safer to drink. For this reason, EWB-WPI will focus on educating the families on water conservation and system maintenance so that the water collected can last throughout the dry season. It will be important while installing the rain water catchment systems, to ask the family members what they would like to learn more about and how it would be more effectively taught.

In order to store potable water in the tanks, our designs include a first flush device. EWB-WPI will educate through explaining to the community that the use and maintenance of the first flush is important in reducing sickness. We will reassure each family that while some water is disposed of through the first flush, this is a very important process for cleaning the roof after the dry season. While EWB-WPI will suggest this cleaning using the first flush should take place annually, it may vary between houses based on the amount of debris build-up that occurs.

Due to the fluctuation of rainwater throughout the year, it was determined that the optimum use of water would consist of different level of consumption for separate tanks. This determination was made through calculation of the total surface area of the roofs that a tank is getting water from. Since larger surface area directly translates to more water for the tank, optimum water use percentage was derived through these measures. Table 20 show the percentage of water collected per tank in relation to the total predicted amount of water collected each month for both House A and L.

Table 20: Roof Area Proportions

House A Tank Use		
	Tank 1 (Roof 1)	Tank 2 (Roof 2, 3, 4)
Surface Area	21.57 m^2	50.53 m^2
Recommended Percentage of Water Usage	30 %	70 %

House L Tank Use			
	Tank 1 (Roof 1, 3, 4)	Tank 2 (Under roof 2)	Tank 3 (Under roof 2)
Surface Area Used	47.75 m^2	25.6 m^2	25.6 m^2
Recommended Percentage of Water Usage	65%	17.5%	17.5%

According to the data, water in Tank 2 will collect more than twice the amount of water that Tank 1 of House A collects. Similarly, Tank 1 of House L will collect more than twice the amount of water collected by Tank 2 and 3 combined. Therefore, frequent use of Tank 2 (House A) and Tank 1 (House L) is recommended for the water to last through the dry seasons. This will simply serve as a basis for when we educate the community about which tank to take from. The tanks with more roof area will fill up much faster, so they should be drunk from first.

This method of education and up keep will be successful for several reasons. Firstly, there is already a ladder and brooms in the community that can be used for cleaning the roofs and gutters. Secondly, the picture instructions will be laminated and given to each family, ensuring everyone has instructions that cannot be damaged by water. Thirdly, the majority of the community members already have basic construction skills. If a portion of the system needs repair, they will know how to successfully repair it. Finally, a list of all of the materials used for the system and the store each material was purchased at will be left with the community. Therefore, if a part of the system needs to be replaced, the community members will know what the part is and where to buy a replacement.

7.0 Monitoring

7.1 Monitoring plan for current project

The primary goal of the pilot projects is to prove that our designs will provide water for the families year round, and that our model matches up with the rainfall data provided. The primary metric that will be used to establish the rainwater catchment systems success will be the comparison of rainfall data from the rain gauge in the community, to the number of days that the families did not have water in their tank. In conjunction with this metric, we will record the number of repairs the family had to make during the one year time period, evaluate the condition of the systems on our next trip, and compile information based on a repetitive set of qualitative questions and observations.

EWB-WPI has partnered with the geology department at the University of Coban to execute the data collection plan. Graduate students in the department will be versed in the plans during the team's implementation trip. The plan will include the following:

- Five household will be chosen to participate in the data collection plan, including Houses A and L.
- For each day without rain, the family will drop a chip in a jar.
- At the beginning of each month, a graduate student from the university will visit the five households and count and record the number of chips in the jar (and remove them from the jar). They will also talk about the previous month with the family. The students will have a standard set of questions to ask, such as:
    - Did the rain collection system work properly last month?
    - Did you need to perform any maintenance last month? If so, what repairs were made and how much did it cost?
    - Did you go without water from the tanks last month?
    - Did you have to collect water from the Finca at all? If so, how much did you collect and what was that water used for?
    - Did anyone get sick last month?
    - How many times was the first flush system emptied?
    - Did you use that water to: drink, cook, wash dishes, bathe, or wash clothes?
    - Did you have to collect

The survey sheets will be scanned and emailed to the EWB-WPI team, along with the downloaded rainfall data from the rain gauge each month. Not only with EWB-WPI have contact with the university, but an email address has also been established with a leader in the community, allowing direct contact with the community. EWB-WPI plans to introduce Sergio's monitoring team during one of the community meetings we will have. We want to make sure that the community members and the pilot families are comfortable with this monitoring plan.

In addition to the vital information this process will provide, it will also incorporate the University with our project, and incorporate the community members fully. This process will engage the family members in the project throughout the year helping to reinforce how each system is a collaborative project between EWB-WPI and the community. The information collected will also be important in creating and modifying our current model as we design individual rainwater harvesting systems for other families within the community.

7.2 Monitoring of past-implemented projects

The group will not be monitoring any past-implemented projects, because this is our first implementation trip.

8.0 Community Agreement/Contract

During the second assessment trip, the travelling team discussed and signed a Memorandum of Understanding (MOU) with the community of Guachthu'uq, and the COCODE. The topics discussed included project ownership, monetary commitments, information transfer between the community members and EWB-WPI, and labor commitments. The community is aware and agreed to take complete ownership of the rainwater catchment systems, and cover approximately 25% of the cost. The rainwater catchment systems will be owned individually, however, the funding will be done as an entire community. In addition, they have agreed to maintain a transfer of information throughout the year long pilot project. This is necessary for successfully understanding the efficacy of the designs. The community members also agreed to provide the manual labor to build the rainwater catchment systems. For the individual MOU's in full, see Appendix D.

All of the information within the MOU's were discussed in full with the community before being written and signed. This ensured that all parties had an adequate say in the mutual commitments between EWB-WPI and the community members of Guachthu'uq. The community members were enthusiastic about signing this agreement because they understood it as a sign of EWB-WPI's commitment to them, and appreciated all of our efforts to assist them. In addition, EWEB-WPI discussed fundraising ideas with the community members including a raffle and approaching the municipality for funding.

On this implementation trip EWB-WPI plans to discuss and approve another agreement with the community members and the pilot families. The topics will include operation and maintenance costs, data collection, fundraising, and construction assistance. EWB-WPI wants to reinforce the community's understanding of their role both financially and physically. We also want to have a separate understanding with the pilot families regarding their participation in data collection since it is vital to the understanding of our models and their applicability to the rest of community.

9.0 Cost Estimate

On the second assessment trip, we performed a materials assessment of the available materials near the community. We looked at five different construction stores and took inventory of the materials that may be used in our construction of the pilot projects. See Appendix E for an exhaustive list of materials and prices. The major material components of construction are as follows:

Table 21: Materials Assessment

System Component	Material	Price (Q)
Roof	Corrugated Iron Sheets	85 Q per 2.6 ft by 12 ft
Gutters	Gutters	25 Q for 8 ft
	Gutter Elbows	50 Q
	Gutter Clips	13 Q

	Pipes	120 Q for 4m
Water Tanks	Plastic 2500 L Tank	2300 Q
	Cement Base for Tank	72 Q per bag

Note that a Q represents the Guatemalan Quetzal. As of Saturday, September 15, 2012 the exchange rate is 7.98Q – 1 USD.

For both pilot homes, we have created a cost estimate based on measurements from each home assessment and the list of materials and prices for the stores in Guatemala. Each cost estimate will be shown with a brief explanation of how we got that price.

House A

For House A, we are focusing on replacing three roofs, adding a gutter system, and another 2500 L tank to ensure the family has water year round. We will not be altering Roof 1 because it is in above average condition and already has a gutter and tank system, which is why the cost is zero for all components pertaining to Roof 1. Based on our home assessment, we found that Roof 2, 3, and 4 were in good condition, but were severely rusted which would affect the quality and safety of the rain water collected. For this reason, we feel each of the roofs must be replaced which is shown in the cost assessment. Next, the gutter system must be installed on Roof 2, 3 and 4, all of which currently lack an adequate gutter system. The price reflected above shows the estimated amount of gutter length that we will need based on the lengths of the roof. Lastly, we will be planning on adding another 2500 L tank to the house, connected to Roof 2, 3 and 4, shown below in Table 22. The costs for additional materials such as nails, gutter clips and concrete are listed after the costs for each house.

Table 22: Cost Estimate for House A

	Length (m)	Width (m)	Surface Area (m^2)	Units	Cost per Unit (Q)	Total Cost (Q)
Roof 1	3.5	6.2	21.6	7.4	85.00	0.00
Roof 2	8.8	3.0	26.2	9.0	85.00	765.00
Roof 3	8.8	3.0	26.2	9.0	85.00	765.00
Roof 4	3.4	1.5	5.10	2.0	85.00	170.00
Gutter 1	3.5			1.2	25.00	0.00
Gutter 2	8.8			3.0	25.00	75.00
Gutter 3	8.8			3.0	25.00	75.00
Gutter 4	3.4			1.0	25.00	25.00
	Volume					
Tank 1	2500			1.0	2300.00	0.00

Tank 2	2500			1.0	2300.00	2300.00
TOTAL COST	4175.00	Q				
	539.00	USD				

House L

House L has one of the most sophisticated water catchment system already implemented. They only lack water for 2 months out of the year. They have two roof systems with three tanks, but currently they lack the necessary amount of roof area connected to the tanks to ensure water for the whole year. Our plan is to add a gutter system to Roof 3 and 4, which are in fair condition and have not begun to rust, feeding into the 2500 L tank which is under Roof 1 currently. This addition will help the family keep their tanks full for the 2 months in which they are without water now.

The total cost is simply for the gutter system which is calculated by the length of each roof from the home assessment, and also gutter clips to install the gutters to the side of the house. This total estimated cost is less than $20 (Table 23). Since House L currently has the most expensive parts of the rainwater catchment system, the storage tanks, the cost for House L is low. With the community's plan to fundraise as a whole, this house will help reduce the funds needed to compensate for the more expensive houses.

Table 23: Cost Estimate for House L

	Length (m)	Width (m)	Surface Area (m^2)	Units	Cost per Unit (Q)	Total Cost (Q)
Roof 2	5.8	4.5	26.0	8.9	85.00	0.00
Roof 1	3.6	5.6	20.2	6.9	85.00	0.00
Roof 3	6.2	2.4	15.0	5.1	85.00	0.00
Roof 4	6.2	2.2	13.6	4.7	85.00	0.00
Gutter 2	5.8			1.8	25.00	0.00
Gutter 1	3.6			1.1	25.00	0.00
Gutter 3	6.2			2.0	25.00	50.00
Gutter 4	6.2			2.0	25.00	50.00
	Volume					
Tank 1	2500			1.0	2300.00	0.00
Tank 2, 3	5000			2.0	2300.00	0.00

TOTAL COST	100.00	Q				
	13.00	USD				

Listed below is a detailed list of the tools and supplies needed to implement both homes discussed previously.

Table 24: Additional Materials and Tools Cost Estimate

	Unit Cost (Q)	Unit Cost (US)	Number to units	Total Cost (USD)
Transportation of cement	388.00	50.00	1	50.00
Pipe elbows	35.00	4.50	10	45.00
Concrete bags	40.00	5.00	42	210.00
Shovel	55.00	7.00	2	14.00
Tarp	10.00	1.30	2	2.60
Screen	20.00	2.50	33	82.50
Nails	8.00	1.00	2	2.00
Wire	7.00	1.00	1	1.00
Gutter Clips	13.00	2.00	20	40.00
Pipes	200.00	25.00	1	25.00
			Total:	472.00

First Flush Systems

There will be four first flush systems implemented in these homes along with the rainwater catchment systems. Below is a total cost estimate for the first flush systems.

Table 25: First Flush Systems Cost Estimate

	Unit Cost (Q)	Unit cost (USD)	Number of Units	Total cost (USD)
20' of 6" PVC	195.00	25.00	1	25.00
10' of 4" PVC	130.00	15.00	1	15.00
6" to 4" coupling	35.00	5.00	4	20.00
6" end cap	35.00	5.00	4	20.00
3' of 1" PVC	35.00	5.00	1	5.00
Plastic ball	35.00	5.00	4	20.00
			Total:	105.00

10.0 Site Assessment Activities

n/a

11.0 Professional Mentor/Technical Lead Assessment

11.1 Professional Mentor/Technical Lead Name (who provided the assessment)

Patricia E. Austin, P.E.

11.2 Professional Mentor/Technical Lead Assessment

I have worked closely with the entire WPI EWB team, including the students selected to travel this summer, over the past year. The technical subcommittee has done an excellent job developing the design presented in the report using the process outlined by the 523, 524, 525 documents. Tasks have been assigned to team members, and completed in a timely manner. The students have worked independently; and were prompt in contacting Matt Gamache (co-mentor) or myself when they encountered a problem.

An excellent rainfall flux model was developed. The students understand the limitations and have incorporated the uncertainty into their design. In addition, they have developed a plan to work with the community and the local university to get better data over the next school year. The students have communicated with the community during the school year. This has helped immensely in developing the design and trying to anticipate problems that may be encountered during the implementation trip.

11.3 Professional Mentor/Technical Lead Affirmation

I have been closely involved in the project for the past year. I accept responsibility for the course this project is taking. It has been a pleasure working with the students on this team.

Bibliography

Thomas, Terry H., and D. Brett. Martinson. Roofwater Harvesting: A Handbook for Practitioners. Delft, The Netherlands: IRC International Water and Sanitation Centre, 2007. Print.

Appendix

Appendix A: Rain Water Averages in San Cristobal

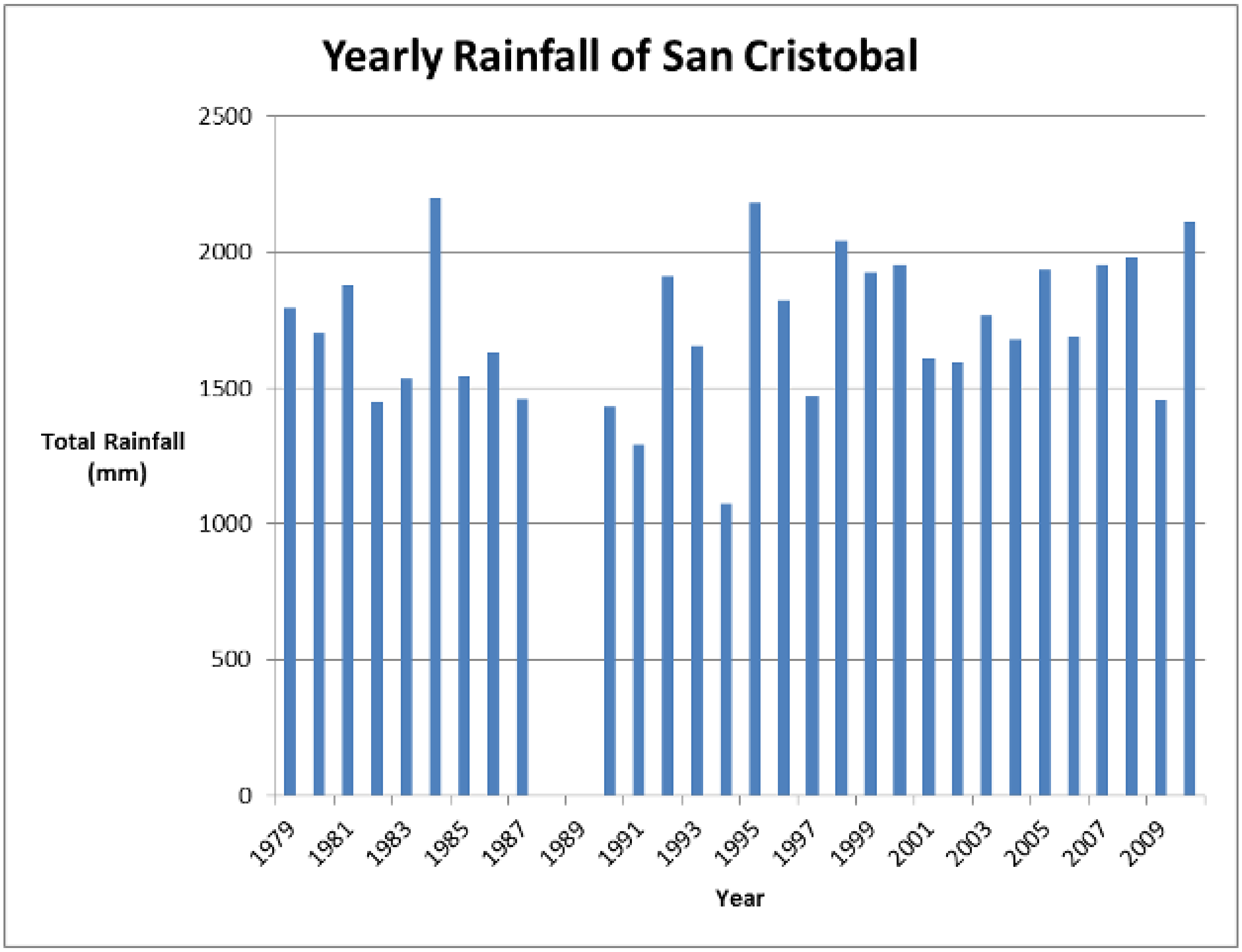
Appendix A.1: Data receive from University of San Carlos in Cobán

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1981	20.1	113.1	24.5	23.1	165.8	327.9	340.7	376.5	210.1	188.2	49.2	58	1877.1
1982	95	14.6	18.5	61.9		348	269.4	194.1	353.3	121.3	34.5	33.4	1449
1983	37.1	55.5	11.1	134.4	88.9	189.1	304.4	253.5	194.8	153.6	75.4	74.9	1535.6
1984	53.4	34.2	82.5	40.9	194.4	360.5	360.3	374	368.6	201	115.4	67.1	2198.9
1985	32.1	84.6	30.4	84.7	44.8	259	301.6	242.6	236.3	134	41	87.1	1546.1
1986	50.7	40	46.8	24.9	217.4	335.9	196.4	216.3	266	154.9	88.8	47.5	1634.9
1987	26.7	15.3	25	31.5	20.5	350.3	422.9	249.9	189.7	77.1	42.3	36.3	1460.8
1988	44.1	46.8								249.2	100.1		
1989				77.5				284.5	422.9	161.2	137.2	47.9	
1990	50.2	48.9	45.5	52.5	103.7	284.9	198.2	218	289.8	176.7	203	60.7	1431.3
1991	46.9	25.3	40.1	66.7	85.2	225.4	177.9	78.8	229.1	184.3	39.4	138.7	1290.9
1992	23.5	12.3	28.6	88.3	130	302.3	281.1	180.9	373.9	143.7	248.5	124.6	1914.2
1993	43.6	16.4	16.9	102.2	98.6	422.5	163.1	316.5	240.7	177.3	49.6	53.8	1657.6
1994	85	29	87.7	68.8	84.1	186.1	88.3	196.6	158.2	96.8	45.1	32.3	1073
1995	34.6	44.1	34.2	186.7	62.7	412.6	278.5	400.2	373.9	264	57	69.9	2183.8
1996	34.5	35.9	35.8	65.9	187	330.5	293.7	176.2	231	236.5	189.6	39.2	1821.3
1997	51.8	50.4	36.5	40.1	97.7	113	239.7	184.9	467.6	129.4		57.1	1468.2
1998	37.7	0.5	41.7	102.6	78.7	343.7	306.5	184.5	301.1	422.2	182.7	42.6	2044.5
1999	58	71.9	56.1	87.9	73.5	308.4	244	308.7	366.7	210.7	113.4	25.5	1924.8
2000	55.4	25.6	1.8	20.2	372.1	304	148.2	338	283.8	275.1	71.1	60.7	1956
2001	25.6	64.2	97.7	50.4	164.7	156.6							
AVG	45.3	41.43	40.07368421	70.56	126.1	292.6684211	256.3833333	251.3	292.5	187.86	99.12105263	60.91052632	1692.666667
STDEV	18.99044081	27.26134916	25.59355045	40.72313968	81.88442357	84.47084344	83.09868867	83.98756522	86.71525561	76.64832473	64.82331181	29.60163086	313.6216717
San Cristobal	15°21'22"	90°28'33"											

Appendix A.2: Data received from Anonymous source

Note this table is rainfall in millimeters over that respective year. The data that we have for 1988-1989 are unavailable because measurements are missing from several of the months of those years. A graphical chart is shown below to easily see the difference in rainfall over the years.

Year	Rainfall (mm)
1979	1794.90
1980	1702.70
1981	1877.1
1982	1449
1983	1535.6
1984	2198.9
1985	1546.1
1986	1634.9
1987	1460.8
1988	
1989	
1990	1431.3
1991	1290.9
1992	1914.2
1993	1657.6
1994	1073
1995	2183.8
1996	1821.3
1997	1468.2
1998	2044.5
1999	1924.8
2000	1956
2001	1608.20
2002	1595.50
2003	1766.10
2004	1677.20
2005	1937.00
2006	1689.20
2007	1954.80
2008	1980.30
2009	1455.00
2010	2110


Yearly Rainfall of San Cristobal
Total Rainfall (mm)
2500
2000
1500
1000
500
0
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
Year

Appendix B: Water Quality Results

Appendix B.1: Finca Spring Box – Chemistry Results for Drinking Water

Engineers Without Borders - Guatemala Survey – 2010 Chemistry Results for Drinking Water Sources				
Parameter	**Acceptable Result**	**Sample 01 – Rain Water Tank**	**Sample 02 – Wood FINCA**	**Sample 03 - FINCA**
Total Iron (mg/l as Fe)	0.3	<0.05	0.22	0.09
Total Hardness (mg/l as $CaCO_3$)	< 500	1.2	230	220
Turbidity (NTU)	< 1.0	0.89	4.0	2.2
Total Alkalinity (mg/l as $CaCO_3$)	< 500	4.9	230	220
Conductivity (μS/cm @ 25°C)	1000	<10	430	420
Total Suspended Solids (mg/l)	<5.0	<5.0	<5.0	-
pH (Standard Units)	6.0 – 9.0	6.1	7.2	7.3
Nitrate (mg/l as N)	5.0	<0.10	0.89	0.84
Pesticides (μg/l)				
Delta BHC	-	-	-	<0.024
Lindane	0.0002	-	-	<0.024
Alpha-BHC	-	-	-	<0.024
Beta-BHC	-	-	-	<0.024
Heptachlor	-	-	-	<0.024
Aldrin	-	-	-	<0.024
Heptachlor epoxide	-	-	-	<0.024
Endrin	0.002	-	-	<0.047
Endrin aldehyde	0.002	-	-	<0.047
Endrin ketone	0.002	-	-	<0.047
Dieldrin	-	-	-	<0.047
4,4'–DDE	-	-	-	<0.047
4,4'-DDD	-	-	-	<0.047
4,4'-DDT	-	-	-	<0.047
Endosulfan I	-	-	-	<0.024
Endosulfan II	-	-	-	<0.047
Endosulfan sulfate	-	-	-	<0.047
Methoxychlor	-	-	-	<0.235
Toxaphene	-	-	-	<0.235
Chlordane	0.002	-	-	<0.235
cis-Chloradane	0.002	-	-	<0.024
trans-Chloradane	0.002	-	-	<0.024

Key:
Yellow – Approaching dangerous levels
Red – Dangerous levels

Engineers Without Borders
Guatemala Survey – 2011
Summary of Chemistry Results for Drinking Water Sources

While a limited number of samples were obtained during the EWB survey in Guatemala July of 2010, the results provide valuable information that can be used to establish a long-term program for providing the people in the village with potable water for drinking and cooking. Samples were collected during the "rainy" season. In other words, all results indicate better water quality than normal because of the influence of rain water. However, the two shallow well sources clearly indicate elevated turbidity values. Turbidity, while a chemical/physical indicator, parallels the total viable bacteria, Total Coliform, and E. coli levels in the water supply. The team performed bacteria tests during the second assessment trip in August of 2011. The wells are not a potential source of potable water without extensive treatment, impossible with the resources available in the village. The total hardness, total alkalinity, conductivity, pH and conductivity data for the shallow well supplies meet acceptable potable water standards. The values are similar to those for ground water supplies in the United States. The nitrate (as nitrogen) and turbidity values for the shallow well samples are relatively high, supporting the year-round non potable nature of this water source. The total iron values, while below acceptable potable water limits, are projected to increase with decrease in rainfall. Iron is a concern since it is a nutrient for pathogenic bacteria. The chemical sample results for the rain water tanks are surprising. The water is chemically pure, with a conductivity value < 10 microsiemens/cm or < 5 mg/l dissolved ionic material. For reference, the conductivity is equivalent to that obtained for product water from most high purity water system reverse osmosis units in North America. Unfortunately, the turbidity value of 0.89 NTU indicates that both periodic water collection tank maintenance and treatment by residual disinfecting agent are required to provide a reliable year-round source of potable water. However, based on review of all data, the rain water collection systems can provide a viable source of potable water with minimal treatment.

Appendix B.2: E-Coli and Fecal Coliform Test Results

Data Collected

	(1A +1B Pink) E.coli/Fecal	(2+3 Purple)	(1A + 1B +2 + 3) Total	Volume sampled (ml)
Aqua Pura	2	13	15	5
Finca 1	2	0	2	1
Finca 2	0	7	7	1
Don Domingo 1	17	79	96	1
Don Domingo 2	6	37	43	1
A1	0	26	26	1
A2	1	10	11	1
X1	0	11	11	1
X2	0	2	2	1

Data Analysis

Location	E.coli/Fecal	Total	Volume sampled (ml)	E.Coli-fecal coliform/100 ml	Total Coliform/100 ml
Aqua Pura	2	15	5	40	300
Finca 1	2	2	1	200	200
Finca 2	0	7	1	0	700
Don Domingo 1	17	96	1	1700	9600
Don Domingo 2	6	43	1	600	4300
A1	0	26	1	0	2600
A2	1	11	1	100	1100
X1	0	11	1	0	1100
X2	0	2	1	0	200

The target range of organisms on the plates is between 20 and 300 organisms for this test. When colony counts are less than 20, the test is considered statistically questionable for accuracy. However, we consulted with the manufacturer of the test and determined that the results should be included as an indication of presence of fecal coliform.

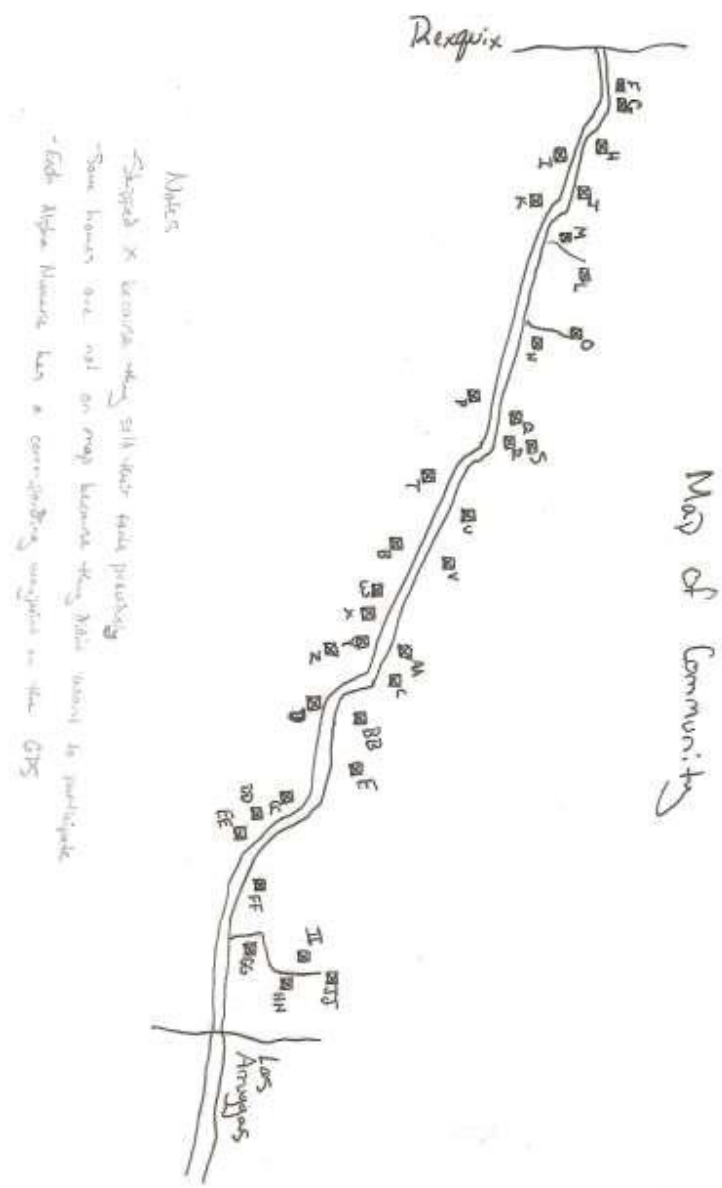
The results were compared with the the Massachusetts Water Quality Standards for coliform in source water which state:

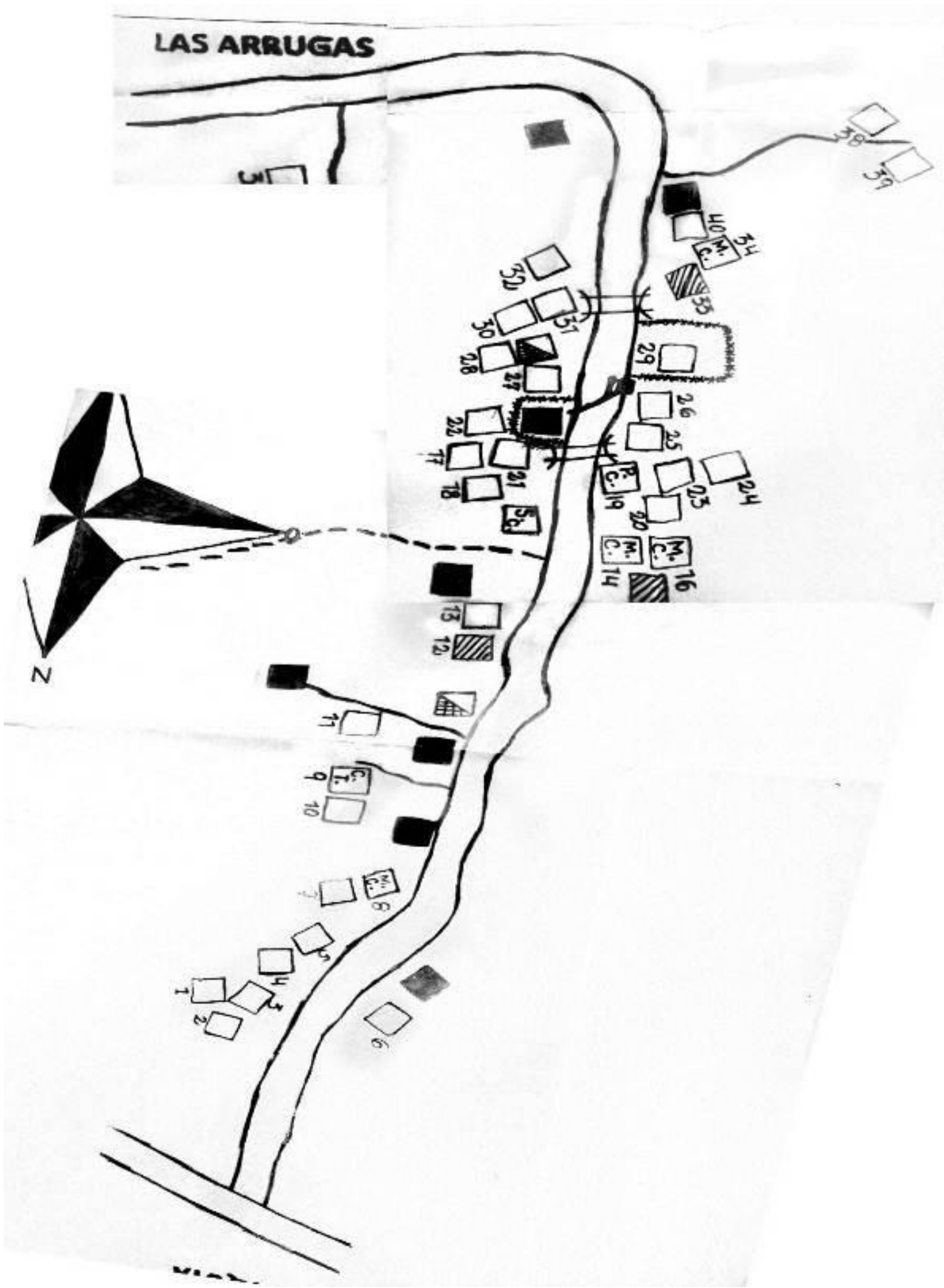
At water supply intakes in unfiltered public supplies, either:

1) Fecal coliform shall not exceed 20 fecal coliform organisms per 100 ml in all samples taken in any six month period.
2) Total coliform shall not exceed 100 organisms per 100 ml in 90% of the samples taken in any six month period.

All the results exceeding this number are in red in the table above. Thus, although the results are not definitive, the testing clearly indicated the presence of significant contamination that could be related to transmission of water borne illness or disease.

Appendix C: Community Layout




LAS ARRUGAS
N

Appendix D: Dynamic Excel Model and Outcomes

Appendix D.1: Example of Rainwater Data in Dynamic Excel Model

Example of measurements and rainwater data, showing influx of water based on month. (House A)

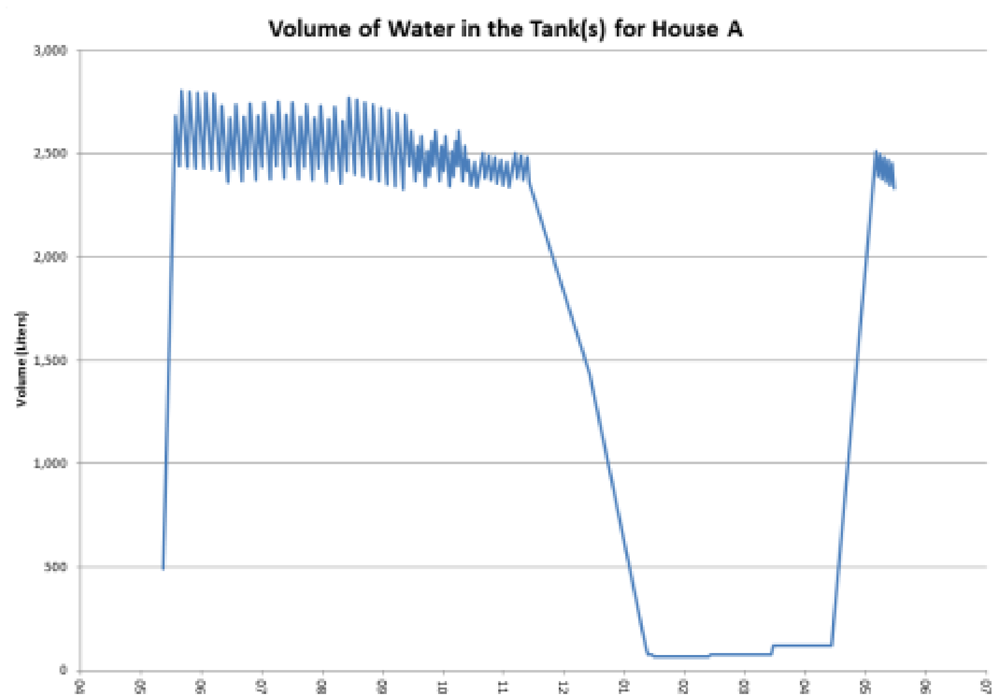
User Input Data

length of roof 1	3.5061	m
width of roof 1	6.15749	m
length of roof 2	8.84146	m
width of roof 2	2.95939	m
length of roof 3	8.84146	m
width of roof 3	2.95939	m
length of roof 4	3.3528	m
width of roof 4	1.524	m
Total Surface Area	79.0292	m2
Surface Area of Roof 1	21.5887	
Surface Area of Roofs 2, 3,	57.4404	
Volume of Tank 1	2500	L
Volume of Tank 2		L
Volume of Tank 3	0	L
Volume of Tank 4		L
Total Storage Volume	2500	L
Consumption Rate	123	L/Day
% Consumed from Tank 1	30%	
% Consumed form Tank 2	70%	
Efficiency Rate	70%	

Rainfall Data

Month	Rainfall		Flux (Total, Roof 1, Roofs 2-4)			
1	0.04645	m	82.90	22.65	60.25	L/Day
2	0.03646	m	72.04	17.78	47.29	L/Day
3	0.04676	m	83.45	22.80	60.65	L/Day
4	0.07007	m	129.21	34.16	90.88	L/Day
5	0.14248	m	254.26	69.46	184.80	L/Day
6	0.29099	m	536.60	141.86	377.43	L/Day
7	0.26628	m	475.18	129.81	345.37	L/Day
8	0.26276	m	468.91	128.09	340.81	L/Day
9	0.28565	m	526.74	139.25	370.50	L/Day
10	0.18146	m	323.83	88.46	235.37	L/Day
11	0.10654	m	196.46	51.94	138.19	L/Day
12	0.05668	m	101.15	27.63	73.52	L/Day

Example of graph based on influx of rain and consumption rate over a year showing that the house would be without rainwater for 3 months out of the year with this system design.



Appendix D.2: House A Time Series of Tank Volume Over the Year with Current System

Month	Date	Flux into Tank	Flux out of Tank	Volume in Tank	Volume of Overflow
		L/Day	L/Day	L	L/Day
6	6/1/2010			0	
6	6/2/2010	299.69	0	299.69	0.00
6	6/3/2010	299.69	121	478.39	0.00
6	6/4/2010	299.69	121	657.08	0.00
6	6/5/2010	299.69	121	835.78	0.00
6	6/6/2010	299.69	121	1014.47	0.00
6	6/7/2010	299.69	121	1193.17	0.00
6	6/8/2010	299.69	121	1371.86	0.00
6	6/9/2010	299.69	121	1550.56	0.00
6	6/10/2010	299.69	121	1729.25	0.00
6	6/11/2010	299.69	121	1907.95	0.00
6	6/12/2010	299.69	121	2086.64	0.00
6	6/13/2010	299.69	121	2265.34	0.00
6	6/14/2010	299.69	121	2444.03	0.00
6	6/15/2010	299.69	121	2622.73	0.00
6	6/16/2010	299.69	121	2801.42	0.00
6	6/17/2010	299.69	121	2980.12	0.00
6	6/18/2010	299.69	121	3158.81	0.00
6	6/19/2010	299.69	121	3337.51	0.00
6	6/20/2010	299.69	121	3516.20	0.00
6	6/21/2010	299.69	121	3694.90	0.00
6	6/22/2010	299.69	121	3873.59	0.00
6	6/23/2010	299.69	121	4052.29	0.00
6	6/24/2010	151.39	121	4082.68	0.00
6	6/25/2010	299.69	121	4261.38	0.00
6	6/26/2010	151.39	121	4291.77	0.00
6	6/27/2010	151.39	121	4322.16	0.00
6	6/28/2010	151.39	121	4352.55	0.00
6	6/29/2010	299.69	121	4531.25	0.00
6	6/30/2010	151.39	121	4561.64	0.00
7	7/1/2010	138.53	121	4579.17	0.00
7	7/2/2010	138.53	121	4596.70	0.00
7	7/3/2010	274.24	121	4749.94	0.00
7	7/4/2010	138.53	121	4767.47	0.00
7	7/5/2010	138.53	121	4785.01	0.00
7	7/6/2010	138.53	121	4802.54	0.00

7	7/7/2010	274.24	121	4955.78	0.00
7	7/8/2010	138.53	121	4973.31	274.24
7	7/9/2010	0.00	121	4852.31	274.24
7	7/10/2010	274.24	121	5005.55	0.00
7	7/11/2010	0.00	121	4884.55	274.24
7	7/12/2010	138.53	121	4902.08	0.00
7	7/13/2010	138.53	121	4919.62	274.24
7	7/14/2010	135.71	121	4934.32	274.24
7	7/15/2010	138.53	121	4951.85	274.24
7	7/16/2010	0.00	121	4830.85	274.24
7	7/17/2010	138.53	121	4848.39	0.00
7	7/18/2010	274.24	121	5001.63	0.00
7	7/19/2010	0.00	121	4880.63	274.24
7	7/20/2010	138.53	121	4898.16	0.00
7	7/21/2010	135.71	121	4912.87	0.00
7	7/22/2010	138.53	121	4930.40	274.24
7	7/23/2010	138.53	121	4947.93	274.24
7	7/24/2010	0.00	121	4826.93	274.24
7	7/25/2010	274.24	121	4980.17	0.00
7	7/26/2010	0.00	121	4859.17	274.24
7	7/27/2010	138.53	121	4876.70	0.00
7	7/28/2010	274.24	121	5029.94	0.00
7	7/29/2010	0.00	121	4908.94	274.24
7	7/30/2010	138.53	121	4926.47	274.24
7	7/31/2010	0.00	121	4805.47	274.24
8	8/1/2010	270.62	121	4955.09	0.00
8	8/2/2010	136.70	121	4970.80	270.62
8	8/3/2010	0.00	121	4849.80	270.62
8	8/4/2010	136.70	121	4865.50	0.00
8	8/5/2010	270.62	121	5015.12	0.00
8	8/6/2010	0.00	121	4894.12	270.62
8	8/7/2010	136.70	121	4909.82	0.00
8	8/8/2010	133.92	121	4922.74	270.62
8	8/9/2010	136.70	121	4938.44	270.62
8	8/10/2010	136.70	121	4954.15	270.62
8	8/11/2010	0.00	121	4833.15	270.62
8	8/12/2010	270.62	121	4982.76	0.00
8	8/13/2010	0.00	121	4861.76	270.62

8	8/14/2010	136.70	121	4877.47	0.00
8	8/15/2010	270.62	121	5027.09	0.00
8	8/16/2010	0.00	121	4906.09	270.62
8	8/17/2010	136.70	121	4921.79	270.62
8	8/18/2010	0.00	121	4800.79	270.62
8	8/19/2010	270.62	121	4950.41	0.00
8	8/20/2010	136.70	121	4966.11	270.62
8	8/21/2010	0.00	121	4845.11	270.62
8	8/22/2010	270.62	121	4994.73	0.00
8	8/23/2010	0.00	121	4873.73	270.62
8	8/24/2010	136.70	121	4889.43	0.00
8	8/25/2010	136.70	121	4905.14	0.00
8	8/26/2010	133.92	121	4918.05	270.62
8	8/27/2010	136.70	121	4933.76	270.62
8	8/28/2010	136.70	121	4949.46	270.62
8	8/29/2010	0.00	121	4828.46	270.62
8	8/30/2010	270.62	121	4978.08	0.00
8	8/31/2010	0.00	121	4857.08	270.62
9	9/1/2010	148.61	121	4884.69	0.00
9	9/2/2010	294.19	121	5057.88	0.00
9	9/3/2010	0.00	121	4936.88	304.00
9	9/4/2010	148.61	121	4964.50	304.00
9	9/5/2010	0.00	121	4843.50	304.00
9	9/6/2010	294.19	121	5016.69	0.00
9	9/7/2010	0.00	121	4895.69	304.00
9	9/8/2010	148.61	121	4923.30	0.00
9	9/9/2010	0.00	121	4802.30	304.00
9	9/10/2010	294.19	121	4975.49	0.00
9	9/11/2010	148.61	121	5003.10	304.00
9	9/12/2010	0.00	121	4882.10	304.00
9	9/13/2010	148.61	121	4909.71	0.00
9	9/14/2010	145.58	121	4934.29	304.00
9	9/15/2010	148.61	121	4961.91	304.00
9	9/16/2010	0.00	121	4840.91	304.00
9	9/17/2010	148.61	121	4868.52	0.00
9	9/18/2010	294.19	121	5041.71	0.00
9	9/19/2010	0.00	121	4920.71	304.00
9	9/20/2010	148.61	121	4948.32	304.00

9	9/21/2010	0.00	121	4827.32	304.00
9	9/22/2010	294.19	121	5000.51	0.00
9	9/23/2010	0.00	121	4879.51	304.00
9	9/24/2010	148.61	121	4907.12	0.00
9	9/25/2010	145.58	121	4931.70	304.00
9	9/26/2010	148.61	121	4959.32	304.00
9	9/27/2010	148.61	121	4986.93	304.00
9	9/28/2010	0.00	121	4865.93	304.00
9	9/29/2010	294.19	121	5039.12	0.00
9	9/30/2010	0.00	121	4918.12	304.00
10	10/1/2010	94.41	121	4891.53	186.89
10	10/2/2010	94.41	121	4864.94	0.00
10	10/3/2010	186.89	121	4930.83	0.00
10	10/4/2010	94.41	121	4904.23	186.89
10	10/5/2010	94.41	121	4877.64	186.89
10	10/6/2010	92.48	121	4849.12	0.00
10	10/7/2010	94.41	121	4822.53	0.00
10	10/8/2010	186.89	121	4888.42	0.00
10	10/9/2010	94.41	121	4861.83	0.00
10	10/10/2010	94.41	121	4835.24	0.00
10	10/11/2010	186.89	121	4901.13	0.00
10	10/12/2010	94.41	121	4874.54	186.89
10	10/13/2010	186.89	121	4940.43	0.00
10	10/14/2010	0.00	121	4819.43	186.89
10	10/15/2010	94.41	121	4792.83	0.00
10	10/16/2010	186.89	121	4858.72	0.00
10	10/17/2010	94.41	121	4832.13	0.00
10	10/18/2010	186.89	121	4898.02	0.00
10	10/19/2010	94.41	121	4871.43	0.00
10	10/20/2010	186.89	121	4937.32	0.00
10	10/21/2010	94.41	121	4910.73	186.89
10	10/22/2010	94.41	121	4884.13	186.89
10	10/23/2010	92.48	121	4855.62	0.00
10	10/24/2010	94.41	121	4829.02	0.00
10	10/25/2010	186.89	121	4894.91	0.00
10	10/26/2010	94.41	121	4868.32	0.00
10	10/27/2010	94.41	121	4841.73	0.00
10	10/28/2010	186.89	121	4907.62	0.00

10	10/29/2010	94.41	121	4881.03	186.89
10	10/30/2010	186.89	121	4946.92	0.00
10	10/31/2010	94.41	121	4920.33	186.89
11	11/1/2010	0.00	121	4799.33	113.38
11	11/2/2010	109.73	121	4788.05	0.00
11	11/3/2010	109.73	121	4776.78	0.00
11	11/4/2010	55.43	121	4711.21	0.00
11	11/5/2010	109.73	121	4699.93	0.00
11	11/6/2010	109.73	121	4688.66	0.00
11	11/7/2010	55.43	121	4623.08	0.00
11	11/8/2010	109.73	121	4611.81	0.00
11	11/9/2010	109.73	121	4600.53	0.00
11	11/10/2010	109.73	121	4589.26	0.00
11	11/11/2010	55.43	121	4523.69	0.00
11	11/12/2010	109.73	121	4512.41	0.00
11	11/13/2010	109.73	121	4501.14	0.00
11	11/14/2010	55.43	121	4435.57	0.00
11	11/15/2010	109.73	121	4424.29	0.00
11	11/16/2010	109.73	121	4413.02	0.00
11	11/17/2010	55.43	121	4347.44	0.00
11	11/18/2010	109.73	121	4336.17	0.00
11	11/19/2010	109.73	121	4324.89	0.00
11	11/20/2010	55.43	121	4259.32	0.00
11	11/21/2010	109.73	121	4248.05	0.00
11	11/22/2010	109.73	121	4236.77	0.00
11	11/23/2010	109.73	121	4225.50	0.00
11	11/24/2010	55.43	121	4159.93	0.00
11	11/25/2010	109.73	121	4148.65	0.00
11	11/26/2010	109.73	121	4137.38	0.00
11	11/27/2010	55.43	121	4071.81	0.00
11	11/28/2010	109.73	121	4060.53	0.00
11	11/29/2010	109.73	121	4049.26	0.00
11	11/30/2010	55.43	121	3983.68	0.00
12	12/1/2010	58.38	121	3921.06	0.00
12	12/2/2010	58.38	121	3858.44	0.00
12	12/3/2010	58.38	121	3795.82	0.00
12	12/4/2010	58.38	121	3733.20	0.00
12	12/5/2010	58.38	121	3670.58	0.00

12	12/6/2010	58.38	121	3607.96	0.00
12	12/7/2010	58.38	121	3545.34	0.00
12	12/8/2010	58.38	121	3482.71	0.00
12	12/9/2010	58.38	121	3420.09	0.00
12	12/10/2010	58.38	121	3357.47	0.00
12	12/11/2010	58.38	121	3294.85	0.00
12	12/12/2010	58.38	121	3232.23	0.00
12	12/13/2010	58.38	121	3169.61	0.00
12	12/14/2010	58.38	121	3106.99	0.00
12	12/15/2010	58.38	121	3044.37	0.00
12	12/16/2010	58.38	121	2981.75	0.00
12	12/17/2010	58.38	121	2919.13	0.00
12	12/18/2010	58.38	121	2856.50	0.00
12	12/19/2010	58.38	121	2793.88	0.00
12	12/20/2010	58.38	121	2731.26	0.00
12	12/21/2010	58.38	121	2668.64	0.00
12	12/22/2010	58.38	121	2606.02	0.00
12	12/23/2010	58.38	121	2543.40	0.00
12	12/24/2010	58.38	121	2480.78	0.00
12	12/25/2010	58.38	121	2418.16	0.00
12	12/26/2010	58.38	121	2355.54	0.00
12	12/27/2010	58.38	121	2292.91	0.00
12	12/28/2010	58.38	121	2230.29	0.00
12	12/29/2010	58.38	121	2167.67	0.00
12	12/30/2010	58.38	121	2105.05	0.00
12	12/31/2010	58.38	121	2042.43	0.00
1	1/1/2011	47.84	121	1969.27	0.00
1	1/2/2011	47.84	121	1896.12	0.00
1	1/3/2011	47.84	121	1822.96	0.00
1	1/4/2011	47.84	121	1749.81	0.00
1	1/5/2011	47.84	121	1676.65	0.00
1	1/6/2011	47.84	121	1603.49	0.00
1	1/7/2011	47.84	121	1530.34	0.00
1	1/8/2011	47.84	121	1457.18	0.00
1	1/9/2011	47.84	121	1384.03	0.00
1	1/10/2011	47.84	121	1310.87	0.00
1	1/11/2011	47.84	121	1237.71	0.00
1	1/12/2011	47.84	121	1164.56	0.00

1	1/13/2011	47.84	121	1091.40	0.00
1	1/14/2011	47.84	121	1018.25	0.00
1	1/15/2011	47.84	121	945.09	0.00
1	1/16/2011	47.84	121	871.93	0.00
1	1/17/2011	47.84	121	798.78	0.00
1	1/18/2011	47.84	121	725.62	0.00
1	1/19/2011	47.84	121	652.47	0.00
1	1/20/2011	47.84	121	579.31	0.00
1	1/21/2011	47.84	121	506.15	0.00
1	1/22/2011	47.84	121	433.00	0.00
1	1/23/2011	47.84	121	359.84	0.00
1	1/24/2011	47.84	121	286.69	0.00
1	1/25/2011	47.84	121	213.53	0.00
1	1/26/2011	47.84	121	140.37	0.00
1	1/27/2011	47.84	121	67.22	0.00
1	1/28/2011	47.84	121	-5.94	0.00
1	1/29/2011	47.84	24.16850447	17.74	0.00
1	1/30/2011	47.84	24.16850447	41.41	0.00
1	1/31/2011	47.84	41.4123006	47.84	0.00
2	2/1/2011	37.55	47.84398824	37.55	0.00
2	2/2/2011	37.55	37.55284637	37.55	0.00
2	2/3/2011	37.55	37.55284637	37.55	0.00
2	2/4/2011	37.55	37.55284637	37.55	0.00
2	2/5/2011	37.55	37.55284637	37.55	0.00
2	2/6/2011	37.55	37.55284637	37.55	0.00
2	2/7/2011	37.55	37.55284637	37.55	0.00
2	2/8/2011	37.55	37.55284637	37.55	0.00
2	2/9/2011	37.55	37.55284637	37.55	0.00
2	2/10/2011	37.55	37.55284637	37.55	0.00
2	2/11/2011	37.55	37.55284637	37.55	0.00
2	2/12/2011	37.55	37.55284637	37.55	0.00
2	2/13/2011	37.55	37.55284637	37.55	0.00
2	2/14/2011	37.55	37.55284637	37.55	0.00
2	2/15/2011	37.55	37.55284637	37.55	0.00
2	2/16/2011	37.55	37.55284637	37.55	0.00
2	2/17/2011	37.55	37.55284637	37.55	0.00
2	2/18/2011	37.55	37.55284637	37.55	0.00
2	2/19/2011	37.55	37.55284637	37.55	0.00

2	2/20/2011	37.55	37.55284637	37.55	0.00
2	2/21/2011	37.55	37.55284637	37.55	0.00
2	2/22/2011	37.55	37.55284637	37.55	0.00
2	2/23/2011	37.55	37.55284637	37.55	0.00
2	2/24/2011	37.55	37.55284637	37.55	0.00
2	2/25/2011	37.55	37.55284637	37.55	0.00
2	2/26/2011	37.55	37.55284637	37.55	0.00
2	2/27/2011	37.55	37.55284637	37.55	0.00
2	2/28/2011	37.55	37.55284637	37.55	0.00
3	3/1/2011	48.16	37.55284637	48.16	0.00
3	3/2/2011	48.16	48.15960375	48.16	0.00
3	3/3/2011	48.16	48.15960375	48.16	0.00
3	3/4/2011	48.16	48.15960375	48.16	0.00
3	3/5/2011	48.16	48.15960375	48.16	0.00
3	3/6/2011	48.16	48.15960375	48.16	0.00
3	3/7/2011	48.16	48.15960375	48.16	0.00
3	3/8/2011	48.16	48.15960375	48.16	0.00
3	3/9/2011	48.16	48.15960375	48.16	0.00
3	3/10/2011	48.16	48.15960375	48.16	0.00
3	3/11/2011	48.16	48.15960375	48.16	0.00
3	3/12/2011	48.16	48.15960375	48.16	0.00
3	3/13/2011	48.16	48.15960375	48.16	0.00
3	3/14/2011	48.16	48.15960375	48.16	0.00
3	3/15/2011	48.16	48.15960375	48.16	0.00
3	3/16/2011	48.16	48.15960375	48.16	0.00
3	3/17/2011	48.16	48.15960375	48.16	0.00
3	3/18/2011	48.16	48.15960375	48.16	0.00
3	3/19/2011	48.16	48.15960375	48.16	0.00
3	3/20/2011	48.16	48.15960375	48.16	0.00
3	3/21/2011	48.16	48.15960375	48.16	0.00
3	3/22/2011	48.16	48.15960375	48.16	0.00
3	3/23/2011	48.16	48.15960375	48.16	0.00
3	3/24/2011	48.16	48.15960375	48.16	0.00
3	3/25/2011	48.16	48.15960375	48.16	0.00
3	3/26/2011	48.16	48.15960375	48.16	0.00
3	3/27/2011	48.16	48.15960375	48.16	0.00
3	3/28/2011	48.16	48.15960375	48.16	0.00
3	3/29/2011	48.16	48.15960375	48.16	0.00

3	3/30/2011	48.16	48.15960375	48.16	0.00
3	3/31/2011	48.16	48.15960375	48.16	0.00
4	4/1/2011	72.16	48.15960375	72.16	0.00
4	4/2/2011	72.16	72.16403165	72.16	0.00
4	4/3/2011	72.16	72.16403165	72.16	0.00
4	4/4/2011	72.16	72.16403165	72.16	0.00
4	4/5/2011	72.16	72.16403165	72.16	0.00
4	4/6/2011	72.16	72.16403165	72.16	0.00
4	4/7/2011	72.16	72.16403165	72.16	0.00
4	4/8/2011	72.16	72.16403165	72.16	0.00
4	4/9/2011	72.16	72.16403165	72.16	0.00
4	4/10/2011	72.16	72.16403165	72.16	0.00
4	4/11/2011	72.16	72.16403165	72.16	0.00
4	4/12/2011	72.16	72.16403165	72.16	0.00
4	4/13/2011	72.16	72.16403165	72.16	0.00
4	4/14/2011	72.16	72.16403165	72.16	0.00
4	4/15/2011	72.16	72.16403165	72.16	0.00
4	4/16/2011	72.16	72.16403165	72.16	0.00
4	4/17/2011	72.16	72.16403165	72.16	0.00
4	4/18/2011	72.16	72.16403165	72.16	0.00
4	4/19/2011	72.16	72.16403165	72.16	0.00
4	4/20/2011	72.16	72.16403165	72.16	0.00
4	4/21/2011	72.16	72.16403165	72.16	0.00
4	4/22/2011	72.16	72.16403165	72.16	0.00
4	4/23/2011	72.16	72.16403165	72.16	0.00
4	4/24/2011	72.16	72.16403165	72.16	0.00
4	4/25/2011	72.16	72.16403165	72.16	0.00
4	4/26/2011	72.16	72.16403165	72.16	0.00
4	4/27/2011	72.16	72.16403165	72.16	0.00
4	4/28/2011	72.16	72.16403165	72.16	0.00
4	4/29/2011	72.16	72.16403165	72.16	0.00
4	4/30/2011	72.16	72.16403165	72.16	0.00
5	5/1/2011	146.74	72.16403165	146.74	0.00
5	5/2/2011	146.74	121	172.48	0.00
5	5/3/2011	146.74	121	198.22	0.00
5	5/4/2011	146.74	121	223.96	0.00
5	5/5/2011	146.74	121	249.70	0.00
5	5/6/2011	146.74	121	275.44	0.00

5	5/7/2011	146.74	121	301.18	0.00
5	5/8/2011	146.74	121	326.92	0.00
5	5/9/2011	146.74	121	352.66	0.00
5	5/10/2011	146.74	121	378.40	0.00
5	5/11/2011	146.74	121	404.14	0.00
5	5/12/2011	146.74	121	429.88	0.00
5	5/13/2011	146.74	121	455.62	0.00
5	5/14/2011	146.74	121	481.36	0.00
5	5/15/2011	146.74	121	507.10	0.00
5	5/16/2011	146.74	121	532.84	0.00
5	5/17/2011	146.74	121	558.58	0.00
5	5/18/2011	146.74	121	584.32	0.00
5	5/19/2011	146.74	121	610.06	0.00
5	5/20/2011	146.74	121	635.80	0.00
5	5/21/2011	146.74	121	661.54	0.00
5	5/22/2011	146.74	121	687.28	0.00
5	5/23/2011	146.74	121	713.02	0.00
5	5/24/2011	146.74	121	738.76	0.00
5	5/25/2011	146.74	121	764.50	0.00
5	5/26/2011	146.74	121	790.24	0.00
5	5/27/2011	146.74	121	815.98	0.00
5	5/28/2011	146.74	121	841.72	0.00
5	5/29/2011	146.74	121	867.46	0.00
5	5/30/2011	146.74	121	893.20	0.00
5	5/31/2011	146.74	121	918.94	0.00

Appendix D.3: House L Time Series of Tank Volume Over the Year with Current System

Month	Date	Flux into Tank	Flux out of Tank	Volume in Tank	Volume of Overflow
		L/Day	L/Day	L	L/Day
6	6/1/2010			0	
6	6/2/2010	318.74	0	318.74	0.00
6	6/3/2010	318.74	123	514.48	0.00
6	6/4/2010	318.74	123	710.22	0.00
6	6/5/2010	318.74	123	905.97	0.00
6	6/6/2010	318.74	123	1101.71	0.00
6	6/7/2010	318.74	123	1297.45	0.00
6	6/8/2010	318.74	123	1493.19	0.00
6	6/9/2010	318.74	123	1688.93	0.00
6	6/10/2010	318.74	123	1884.67	0.00
6	6/11/2010	318.74	123	2080.41	0.00
6	6/12/2010	318.74	123	2276.16	0.00
6	6/13/2010	318.74	123	2471.90	0.00
6	6/14/2010	318.74	123	2667.64	0.00
6	6/15/2010	318.74	123	2863.38	0.00
6	6/16/2010	318.74	123	3059.12	0.00
6	6/17/2010	318.74	123	3254.86	0.00
6	6/18/2010	318.74	123	3450.60	0.00
6	6/19/2010	318.74	123	3646.35	0.00
6	6/20/2010	318.74	123	3842.09	0.00
6	6/21/2010	318.74	123	4037.83	0.00
6	6/22/2010	318.74	123	4233.57	0.00
6	6/23/2010	318.74	123	4429.31	0.00
6	6/24/2010	318.74	123	4625.05	0.00
6	6/25/2010	318.74	123	4820.80	0.00
6	6/26/2010	318.74	123	5016.54	0.00
6	6/27/2010	318.74	123	5212.28	0.00
6	6/28/2010	318.74	123	5408.02	0.00
6	6/29/2010	318.74	123	5603.76	0.00
6	6/30/2010	318.74	123	5799.50	0.00
7	7/1/2010	282.26	123	5958.76	0.00
7	7/2/2010	282.26	123	6118.02	0.00
7	7/3/2010	282.26	123	6277.28	0.00
7	7/4/2010	282.26	123	6436.54	0.00
7	7/5/2010	282.26	123	6595.80	0.00
7	7/6/2010	282.26	123	6755.06	0.00

7	7/7/2010	282.26	123	6914.32	0.00
7	7/8/2010	282.26	123	7073.58	0.00
7	7/9/2010	282.26	123	7232.84	0.00
7	7/10/2010	282.26	123	7392.10	0.00
7	7/11/2010	0.00	123	7269.10	282.26
7	7/12/2010	282.26	123	7428.35	0.00
7	7/13/2010	0.00	123	7305.35	282.26
7	7/14/2010	282.26	123	7464.61	0.00
7	7/15/2010	0.00	123	7341.61	282.26
7	7/16/2010	282.26	123	7500.87	0.00
7	7/17/2010	0.00	123	7377.87	282.26
7	7/18/2010	0.00	123	7254.87	282.26
7	7/19/2010	282.26	123	7414.13	0.00
7	7/20/2010	0.00	123	7291.13	282.26
7	7/21/2010	282.26	123	7450.39	0.00
7	7/22/2010	0.00	123	7327.39	282.26
7	7/23/2010	282.26	123	7486.65	0.00
7	7/24/2010	0.00	123	7363.65	282.26
7	7/25/2010	0.00	123	7240.65	282.26
7	7/26/2010	282.26	123	7399.91	0.00
7	7/27/2010	0.00	123	7276.91	282.26
7	7/28/2010	282.26	123	7436.17	0.00
7	7/29/2010	0.00	123	7313.17	282.26
7	7/30/2010	282.26	123	7472.43	0.00
7	7/31/2010	0.00	123	7349.43	282.26
8	8/1/2010	278.53	123	7504.96	0.00
8	8/2/2010	0.00	123	7381.96	278.53
8	8/3/2010	0.00	123	7258.96	278.53
8	8/4/2010	278.53	123	7414.49	0.00
8	8/5/2010	0.00	123	7291.49	278.53
8	8/6/2010	278.53	123	7447.03	0.00
8	8/7/2010	0.00	123	7324.03	278.53
8	8/8/2010	278.53	123	7479.56	0.00
8	8/9/2010	0.00	123	7356.56	278.53
8	8/10/2010	0.00	123	7233.56	278.53
8	8/11/2010	278.53	123	7389.09	0.00
8	8/12/2010	0.00	123	7266.09	278.53
8	8/13/2010	278.53	123	7421.63	0.00

8	8/14/2010	0.00	123	7298.63	278.53
8	8/15/2010	278.53	123	7454.16	0.00
8	8/16/2010	0.00	123	7331.16	278.53
8	8/17/2010	278.53	123	7486.69	0.00
8	8/18/2010	0.00	123	7363.69	278.53
8	8/19/2010	0.00	123	7240.69	278.53
8	8/20/2010	278.53	123	7396.22	0.00
8	8/21/2010	0.00	123	7273.22	278.53
8	8/22/2010	278.53	123	7428.76	0.00
8	8/23/2010	0.00	123	7305.76	278.53
8	8/24/2010	278.53	123	7461.29	0.00
8	8/25/2010	0.00	123	7338.29	278.53
8	8/26/2010	278.53	123	7493.82	0.00
8	8/27/2010	0.00	123	7370.82	278.53
8	8/28/2010	0.00	123	7247.82	278.53
8	8/29/2010	278.53	123	7403.36	0.00
8	8/30/2010	0.00	123	7280.36	278.53
8	8/31/2010	278.53	123	7435.89	0.00
9	9/1/2010	0.00	123	7312.89	312.89
9	9/2/2010	312.89	123	7502.78	0.00
9	9/3/2010	0.00	123	7379.78	312.89
9	9/4/2010	0.00	123	7256.78	312.89
9	9/5/2010	312.89	123	7446.67	0.00
9	9/6/2010	0.00	123	7323.67	312.89
9	9/7/2010	312.89	123	7513.55	0.00
9	9/8/2010	0.00	123	7390.55	312.89
9	9/9/2010	0.00	123	7267.55	312.89
9	9/10/2010	312.89	123	7457.44	0.00
9	9/11/2010	0.00	123	7334.44	312.89
9	9/12/2010	312.89	123	7524.33	0.00
9	9/13/2010	0.00	123	7401.33	312.89
9	9/14/2010	0.00	123	7278.33	312.89
9	9/15/2010	312.89	123	7468.22	0.00
9	9/16/2010	0.00	123	7345.22	312.89
9	9/17/2010	312.89	123	7535.11	0.00
9	9/18/2010	0.00	123	7412.11	312.89
9	9/19/2010	0.00	123	7289.11	312.89
9	9/20/2010	312.89	123	7479.00	0.00

9	9/21/2010	0.00	123	7356.00	312.89
9	9/22/2010	0.00	123	7233.00	312.89
9	9/23/2010	312.89	123	7422.89	0.00
9	9/24/2010	0.00	123	7299.89	312.89
9	9/25/2010	312.89	123	7489.77	0.00
9	9/26/2010	0.00	123	7366.77	312.89
9	9/27/2010	0.00	123	7243.77	312.89
9	9/28/2010	312.89	123	7433.66	0.00
9	9/29/2010	0.00	123	7310.66	312.89
9	9/30/2010	312.89	123	7500.55	0.00
10	10/1/2010	0.00	123	7377.55	192.36
10	10/2/2010	0.00	123	7254.55	192.36
10	10/3/2010	192.36	123	7323.91	0.00
10	10/4/2010	192.36	123	7393.26	0.00
10	10/5/2010	0.00	123	7270.26	192.36
10	10/6/2010	192.36	123	7339.62	0.00
10	10/7/2010	192.36	123	7408.97	0.00
10	10/8/2010	0.00	123	7285.97	192.36
10	10/9/2010	192.36	123	7355.33	0.00
10	10/10/2010	0.00	123	7232.33	192.36
10	10/11/2010	192.36	123	7301.69	0.00
10	10/12/2010	192.36	123	7371.04	0.00
10	10/13/2010	0.00	123	7248.04	192.36
10	10/14/2010	192.36	123	7317.40	0.00
10	10/15/2010	192.36	123	7386.75	0.00
10	10/16/2010	0.00	123	7263.75	192.36
10	10/17/2010	192.36	123	7333.11	0.00
10	10/18/2010	192.36	123	7402.46	0.00
10	10/19/2010	0.00	123	7279.46	192.36
10	10/20/2010	192.36	123	7348.82	0.00
10	10/21/2010	192.36	123	7418.17	0.00
10	10/22/2010	0.00	123	7295.17	192.36
10	10/23/2010	192.36	123	7364.53	0.00
10	10/24/2010	0.00	123	7241.53	192.36
10	10/25/2010	192.36	123	7310.89	0.00
10	10/26/2010	192.36	123	7380.24	0.00
10	10/27/2010	0.00	123	7257.24	192.36
10	10/28/2010	192.36	123	7326.60	0.00

10	10/29/2010	192.36	123	7395.95	0.00
10	10/30/2010	0.00	123	7272.95	192.36
10	10/31/2010	192.36	123	7342.31	0.00
11	11/1/2010	116.70	123	7336.01	0.00
11	11/2/2010	116.70	123	7329.70	0.00
11	11/3/2010	116.70	123	7323.40	0.00
11	11/4/2010	116.70	123	7317.10	0.00
11	11/5/2010	116.70	123	7310.80	0.00
11	11/6/2010	116.70	123	7304.50	0.00
11	11/7/2010	116.70	123	7298.20	0.00
11	11/8/2010	116.70	123	7291.90	0.00
11	11/9/2010	116.70	123	7285.60	0.00
11	11/10/2010	116.70	123	7279.29	0.00
11	11/11/2010	116.70	123	7272.99	0.00
11	11/12/2010	116.70	123	7266.69	0.00
11	11/13/2010	116.70	123	7260.39	0.00
11	11/14/2010	116.70	123	7254.09	0.00
11	11/15/2010	116.70	123	7247.79	0.00
11	11/16/2010	116.70	123	7241.49	0.00
11	11/17/2010	116.70	123	7235.18	0.00
11	11/18/2010	116.70	123	7228.88	0.00
11	11/19/2010	116.70	123	7222.58	0.00
11	11/20/2010	116.70	123	7216.28	0.00
11	11/21/2010	116.70	123	7209.98	0.00
11	11/22/2010	116.70	123	7203.68	0.00
11	11/23/2010	116.70	123	7197.38	0.00
11	11/24/2010	116.70	123	7191.07	0.00
11	11/25/2010	116.70	123	7184.77	0.00
11	11/26/2010	116.70	123	7178.47	0.00
11	11/27/2010	116.70	123	7172.17	0.00
11	11/28/2010	116.70	123	7165.87	0.00
11	11/29/2010	116.70	123	7159.57	0.00
11	11/30/2010	116.70	123	7153.27	0.00
12	12/1/2010	60.09	123	7090.35	0.00
12	12/2/2010	60.09	123	7027.44	0.00
12	12/3/2010	60.09	123	6964.52	0.00
12	12/4/2010	60.09	123	6901.61	0.00
12	12/5/2010	60.09	123	6838.70	0.00

12	12/6/2010	60.09	123	6775.78	0.00
12	12/7/2010	60.09	123	6712.87	0.00
12	12/8/2010	60.09	123	6649.96	0.00
12	12/9/2010	60.09	123	6587.04	0.00
12	12/10/2010	60.09	123	6524.13	0.00
12	12/11/2010	60.09	123	6461.21	0.00
12	12/12/2010	60.09	123	6398.30	0.00
12	12/13/2010	60.09	123	6335.39	0.00
12	12/14/2010	60.09	123	6272.47	0.00
12	12/15/2010	60.09	123	6209.56	0.00
12	12/16/2010	60.09	123	6146.65	0.00
12	12/17/2010	60.09	123	6083.73	0.00
12	12/18/2010	60.09	123	6020.82	0.00
12	12/19/2010	60.09	123	5957.90	0.00
12	12/20/2010	60.09	123	5894.99	0.00
12	12/21/2010	60.09	123	5832.08	0.00
12	12/22/2010	60.09	123	5769.16	0.00
12	12/23/2010	60.09	123	5706.25	0.00
12	12/24/2010	60.09	123	5643.33	0.00
12	12/25/2010	60.09	123	5580.42	0.00
12	12/26/2010	60.09	123	5517.51	0.00
12	12/27/2010	60.09	123	5454.59	0.00
12	12/28/2010	60.09	123	5391.68	0.00
12	12/29/2010	60.09	123	5328.77	0.00
12	12/30/2010	60.09	123	5265.85	0.00
12	12/31/2010	60.09	123	5202.94	0.00
1	1/1/2011	49.24	123	5129.18	0.00
1	1/2/2011	49.24	123	5055.42	0.00
1	1/3/2011	49.24	123	4981.67	0.00
1	1/4/2011	49.24	123	4907.91	0.00
1	1/5/2011	49.24	123	4834.15	0.00
1	1/6/2011	49.24	123	4760.40	0.00
1	1/7/2011	49.24	123	4686.64	0.00
1	1/8/2011	49.24	123	4612.88	0.00
1	1/9/2011	49.24	123	4539.13	0.00
1	1/10/2011	49.24	123	4465.37	0.00
1	1/11/2011	49.24	123	4391.61	0.00
1	1/12/2011	49.24	123	4317.86	0.00

1	1/13/2011	49.24	123	4244.10	0.00
1	1/14/2011	49.24	123	4170.34	0.00
1	1/15/2011	49.24	123	4096.59	0.00
1	1/16/2011	49.24	123	4022.83	0.00
1	1/17/2011	49.24	123	3949.07	0.00
1	1/18/2011	49.24	123	3875.31	0.00
1	1/19/2011	49.24	123	3801.56	0.00
1	1/20/2011	49.24	123	3727.80	0.00
1	1/21/2011	49.24	123	3654.04	0.00
1	1/22/2011	49.24	123	3580.29	0.00
1	1/23/2011	49.24	123	3506.53	0.00
1	1/24/2011	49.24	123	3432.77	0.00
1	1/25/2011	49.24	123	3359.02	0.00
1	1/26/2011	49.24	123	3285.26	0.00
1	1/27/2011	49.24	123	3211.50	0.00
1	1/28/2011	49.24	123	3137.75	0.00
1	1/29/2011	49.24	123	3063.99	0.00
1	1/30/2011	49.24	123	2990.23	0.00
1	1/31/2011	49.24	123	2916.48	0.00
2	2/1/2011	42.79	123	2836.27	0.00
2	2/2/2011	42.79	123	2756.06	0.00
2	2/3/2011	42.79	123	2675.85	0.00
2	2/4/2011	42.79	123	2595.65	0.00
2	2/5/2011	42.79	123	2515.44	0.00
2	2/6/2011	42.79	123	2435.23	0.00
2	2/7/2011	42.79	123	2355.02	0.00
2	2/8/2011	42.79	123	2274.81	0.00
2	2/9/2011	42.79	123	2194.61	0.00
2	2/10/2011	42.79	123	2114.40	0.00
2	2/11/2011	42.79	123	2034.19	0.00
2	2/12/2011	42.79	123	1953.98	0.00
2	2/13/2011	42.79	123	1873.78	0.00
2	2/14/2011	42.79	123	1793.57	0.00
2	2/15/2011	42.79	123	1713.36	0.00
2	2/16/2011	42.79	123	1633.15	0.00
2	2/17/2011	42.79	123	1552.94	0.00
2	2/18/2011	42.79	123	1472.74	0.00
2	2/19/2011	42.79	123	1392.53	0.00

2	2/20/2011	42.79	123	1312.32	0.00
2	2/21/2011	42.79	123	1232.11	0.00
2	2/22/2011	42.79	123	1151.91	0.00
2	2/23/2011	42.79	123	1071.70	0.00
2	2/24/2011	42.79	123	991.49	0.00
2	2/25/2011	42.79	123	911.28	0.00
2	2/26/2011	42.79	123	831.07	0.00
2	2/27/2011	42.79	123	750.87	0.00
2	2/28/2011	42.79	123	670.66	0.00
3	3/1/2011	49.57	123	597.23	0.00
3	3/2/2011	49.57	123	523.80	0.00
3	3/3/2011	49.57	123	450.36	0.00
3	3/4/2011	49.57	123	376.93	0.00
3	3/5/2011	49.57	123	303.50	0.00
3	3/6/2011	49.57	123	230.07	0.00
3	3/7/2011	49.57	123	156.64	0.00
3	3/8/2011	49.57	123	83.20	0.00
3	3/9/2011	49.57	83.20359886	49.57	0.00
3	3/10/2011	49.57	49.56802039	49.57	0.00
3	3/11/2011	49.57	49.56802039	49.57	0.00
3	3/12/2011	49.57	49.56802039	49.57	0.00
3	3/13/2011	49.57	49.56802039	49.57	0.00
3	3/14/2011	49.57	49.56802039	49.57	0.00
3	3/15/2011	49.57	49.56802039	49.57	0.00
3	3/16/2011	49.57	49.56802039	49.57	0.00
3	3/17/2011	49.57	49.56802039	49.57	0.00
3	3/18/2011	49.57	49.56802039	49.57	0.00
3	3/19/2011	49.57	49.56802039	49.57	0.00
3	3/20/2011	49.57	49.56802039	49.57	0.00
3	3/21/2011	49.57	49.56802039	49.57	0.00
3	3/22/2011	49.57	49.56802039	49.57	0.00
3	3/23/2011	49.57	49.56802039	49.57	0.00
3	3/24/2011	49.57	49.56802039	49.57	0.00
3	3/25/2011	49.57	49.56802039	49.57	0.00
3	3/26/2011	49.57	49.56802039	49.57	0.00
3	3/27/2011	49.57	49.56802039	49.57	0.00
3	3/28/2011	49.57	49.56802039	49.57	0.00
3	3/29/2011	49.57	49.56802039	49.57	0.00

3	3/30/2011	49.57	49.56802039	49.57	0.00
3	3/31/2011	49.57	49.56802039	49.57	0.00
4	4/1/2011	76.75	49.56802039	76.75	0.00
4	4/2/2011	76.75	76.7502674	76.75	0.00
4	4/3/2011	76.75	76.7502674	76.75	0.00
4	4/4/2011	76.75	76.7502674	76.75	0.00
4	4/5/2011	76.75	76.7502674	76.75	0.00
4	4/6/2011	76.75	76.7502674	76.75	0.00
4	4/7/2011	76.75	76.7502674	76.75	0.00
4	4/8/2011	76.75	76.7502674	76.75	0.00
4	4/9/2011	76.75	76.7502674	76.75	0.00
4	4/10/2011	76.75	76.7502674	76.75	0.00
4	4/11/2011	76.75	76.7502674	76.75	0.00
4	4/12/2011	76.75	76.7502674	76.75	0.00
4	4/13/2011	76.75	76.7502674	76.75	0.00
4	4/14/2011	76.75	76.7502674	76.75	0.00
4	4/15/2011	76.75	76.7502674	76.75	0.00
4	4/16/2011	76.75	76.7502674	76.75	0.00
4	4/17/2011	76.75	76.7502674	76.75	0.00
4	4/18/2011	76.75	76.7502674	76.75	0.00
4	4/19/2011	76.75	76.7502674	76.75	0.00
4	4/20/2011	76.75	76.7502674	76.75	0.00
4	4/21/2011	76.75	76.7502674	76.75	0.00
4	4/22/2011	76.75	76.7502674	76.75	0.00
4	4/23/2011	76.75	76.7502674	76.75	0.00
4	4/24/2011	76.75	76.7502674	76.75	0.00
4	4/25/2011	76.75	76.7502674	76.75	0.00
4	4/26/2011	76.75	76.7502674	76.75	0.00
4	4/27/2011	76.75	76.7502674	76.75	0.00
4	4/28/2011	76.75	76.7502674	76.75	0.00
4	4/29/2011	76.75	76.7502674	76.75	0.00
4	4/30/2011	76.75	76.7502674	76.75	0.00
5	5/1/2011	151.03	76.7502674	151.03	0.00
5	5/2/2011	151.03	123	179.06	0.00
5	5/3/2011	151.03	123	207.09	0.00
5	5/4/2011	151.03	123	235.13	0.00
5	5/5/2011	151.03	123	263.16	0.00
5	5/6/2011	151.03	123	291.19	0.00

5	5/7/2011	151.03	123	319.22	0.00
5	5/8/2011	151.03	123	347.25	0.00
5	5/9/2011	151.03	123	375.28	0.00
5	5/10/2011	151.03	123	403.31	0.00
5	5/11/2011	151.03	123	431.34	0.00
5	5/12/2011	151.03	123	459.38	0.00
5	5/13/2011	151.03	123	487.41	0.00
5	5/14/2011	151.03	123	515.44	0.00
5	5/15/2011	151.03	123	543.47	0.00
5	5/16/2011	151.03	123	571.50	0.00
5	5/17/2011	151.03	123	599.53	0.00
5	5/18/2011	151.03	123	627.56	0.00
5	5/19/2011	151.03	123	655.59	0.00
5	5/20/2011	151.03	123	683.63	0.00
5	5/21/2011	151.03	123	711.66	0.00
5	5/22/2011	151.03	123	739.69	0.00
5	5/23/2011	151.03	123	767.72	0.00
5	5/24/2011	151.03	123	795.75	0.00
5	5/25/2011	151.03	123	823.78	0.00
5	5/26/2011	151.03	123	851.81	0.00
5	5/27/2011	151.03	123	879.84	0.00
5	5/28/2011	151.03	123	907.88	0.00
5	5/29/2011	151.03	123	935.91	0.00
5	5/30/2011	151.03	123	963.94	0.00
5	5/31/2011	151.03	123	991.97	0.00

Appendix E: Materials List and Prices

Material	Lentro Ferretero del Norte	Ferreteria Central	El Agro Constructor	Mascam	Ferreteria el Obrero	Additional Information
Cement	71.50 Q/ bag	72.5 Q/ bag	70 Q/ bag	71.4 Q/ bag	71.35 Q	bag= 42.5kg, 7cm x 13.5cm x 27cm
Cinder Blocks			3.5 Q	3 Q- stone, 3.5 Q- pumice/ block	3 Q- stone, 3.8 Q- pumice/ block	
Chimney	100 Q	190 Q- 3m	135 Q	180 Q/ 3m		
Caulking	30 Q	35 Q				
Mortar				90 Q/ bag		
Gutters	25 Q/ 8ft	26.5 Q/ 2.44m	25 Q/ 3m			
Gutter Elbows	50 Q					
Gutter Clips	13 Q	12.5 Q	15 Q			
Pipes	130 Q/ 4m	195 Q/ 6m	125 Q/ 6m			
Corrugated Iron	85 Q/ 80cm x 12ft	90 Q	Q 93/ 12ft		150.60 Q/ 12ft lamina	
2500 L Tanks	1 Q/ L	2300 Q/ 2500 L	950 Q/ 750 L		1994 Q- 2500L, 6150 Q- 5000L, 11600 Q- 10000L, 1540 Q- 1700L, 1005 Q- 1100L	
Wire	7 Q/ 10m	7 Q/ 10m	7 Q/ 10m			
Nails	8 Q/ lb	8 Q/ lb	8 Q/ lb			
Screen	20 Q/ m	23 Q/ yard	10 Q/ yd			
Tarps	10 Q/ yd	13.5 Q/ yd	15 Q/ yd			
Ladder	130 Q				455.60 Q- 3ft, 520 Q- 4ft, 613 Q- 5ft, 1205 Q- 8 ft, 2475 Q- 20 ft	
Trowel	30 Q	30 Q	30 Q			
Shovels	55 Q	55 Q	55 Q			
Rebars	50 Q/ m	27.5 Q/ bar- 6m				
Corrugated Fiberglass	90 Q/ piece				226 Q/ 12ft	
Pipe Elbow	35 Q	35 Q	30 Q			
Carbon Fiber	230 Q/ 80cm x 12ft					
Special Nails	9 Q/ lb	9 Q/ lb	9 Q/ lb			
Self boring- Extra special	0.75 Q/ lb	0.75 Q/ lb	0.75 Q/ lb			

Appendix F: Analysis of Alternatives

Groundwater - Well

Implementing a well would be very difficult due to the complex geology in the area. We discovered through discussion with local geologists during our first assessment that the ground surrounding the community has karst formations. This means that water seeps down into the ground very quickly due to the porous material of the earth. Because of the porous material of the earth, there is a lack of water filtration and lack of stability for a structurally sound well. Our community, being spread out on a mountain slope, might require a deep well to reach the water table, which would be an excessively expensive operation. Also because of the crevasses and the porous material the water quality is very poor.

The community would still have to share the well, requiring the community members to walk to wherever the well was drilled. These trips for water require a large time portion and prevent the community members from participating in other activities such as attending school or finding a job. Conversely, the community members use the Finca as a gathering place, and a well would continue to provide them with the opportunity to bond with other members. However, determining a location for the well would also be a challenge due to community politics.

As compared to other alternatives, this would require less education for the whole community, and would most likely be handled by a small group of members selected by the community. We believe this is not a viable option due to the extreme costs, contamination of the water, and complexity of the geology in the area.

Surface Water - Distribution System

Currently, our community uses a spring box system located on the Finca. Based on the data collected, a distribution system would not be feasible for many reasons. Firstly, the spring dries up during the dry season. Secondly, there is not a consistent source of electricity, and the spring source is downhill from the community. In addition, the water is contaminated. At least some of the contamination comes from the environment, because the water path crosses several properties higher up on the mountain. These water paths flow through fertilizers and other contaminants that flow with the water down to the spring box. Based on the data shown in Appendix B, we concluded that the water was too contaminated to be useful.

Atmospheric Water

Communal Rainwater Catchment Tanks

From a technical standpoint a communal tank is reliable, but when it comes to maintenance, the complexity of the community makes it difficult. The maintenance would have to be run by an elected communal board in such a way that the system is kept in functioning order and water conservation practices are followed. However, with such a large source of water and it being shared, each family may not receive equal amounts of water, leading to some families over consuming while others not receiving enough. The communal board will also deal with the maintenance and sanitation of the tank, requiring less time for education as opposed to teaching the entire community.

Other surrounding communities have a similar water problem and may attempt to exploit the new resource. If something were to happen to the community tank, there will be potentially no back-up sources for the community. It is also more difficult to enforce the maintenance because the individual members of the community do not feel a personal attachment to the source as they would if it were their own catchment system.

Although, the cost for each communal tank is very high, we would need much fewer tanks and systems to support to entire community due to the large volume capacity, resulting in a lower total cost.

Also, there will be less total man hours spent on maintenance for this tank, because there will be fewer tanks and therefore require less individuals to work on them. However, because there is only a very small number of tanks, this makes the maintenance and care of them that much more important. If one of these tanks were to break and is unable to be fixed quickly, the entire community will suffer and not have a water source.

Currently, there is no public location available for construction of a catchment tank. The land would need to be purchased or donated to the community. The process would also require the community, lawyers, and the local municipality to be involved. Lastly, if the community population increases for any reason, it will be harder to find additional land to build another communal tank. Although this is not the most viable option, we believe this is still feasible. This still remains a viable option due to the likely possibility of lower costs.

Individual Rainwater Catchment Tanks

Individual rainwater catchment tanks have many benefits for the community. The tanks are durable and require little maintenance. The responsibility of repairs lies with each individual family and will have minimal effect on the community as a whole. The community has a substantial rainy season which will provide enough water for each family to last through the dry season with multiple tanks as deemed necessary per home. These tanks will provide easy access to water because the tanks will be placed on each family's property using existing infrastructure. Also, this will set-up will be easier for the community to adjust to growth in numbers.

Despite these benefits, implementing individual rainwater catchment tanks is not without flaw. Individual rainwater catchment tanks would require a larger time commitment from EWB-WPI, additional analysis and planning for each house, and community changes. The largest time commitment will come from teaching the community how to purify the rainwater, and teaching each family how to take care of its own water. The team would also be teaching the families about how to maximize the efficiency of their home systems and how to make necessary repairs over the lifetime of the system. Because each family will be responsible for their own water, there will be less potential disputes about overconsumption of water. The water catchment tanks will not be subject to exploitation because they will be located on private property, and not in an open community area. Also, as a result of each family being responsible for their own water, they will be more likely to conserve what they have because it will be their own tank, and their own supply.

Also, EWB-WPI would need to decide on which type of tank to implement. There are two options; one being constructing the tanks from scratch, or buying the tanks from local vendors. Constructing the tanks requires much more of a time commitment but is less costly. Buying the tanks from vendors allows us to spend less time but is a more substantial cost. They are much more expensive to implement because it requires adding the necessary infrastructure to each home, and adding most likely multiple tanks to each home. This adds up to be a higher cost than the communal tanks. Also, because we will deal with each individual house, this will require EWB-WPI to create more designs and additional planning to adapt the system to each house. However, we still believe this is the most viable option due to proximity of the homes to the water systems, ease of maintenance, and a sense of personal ownership with the individual tanks.

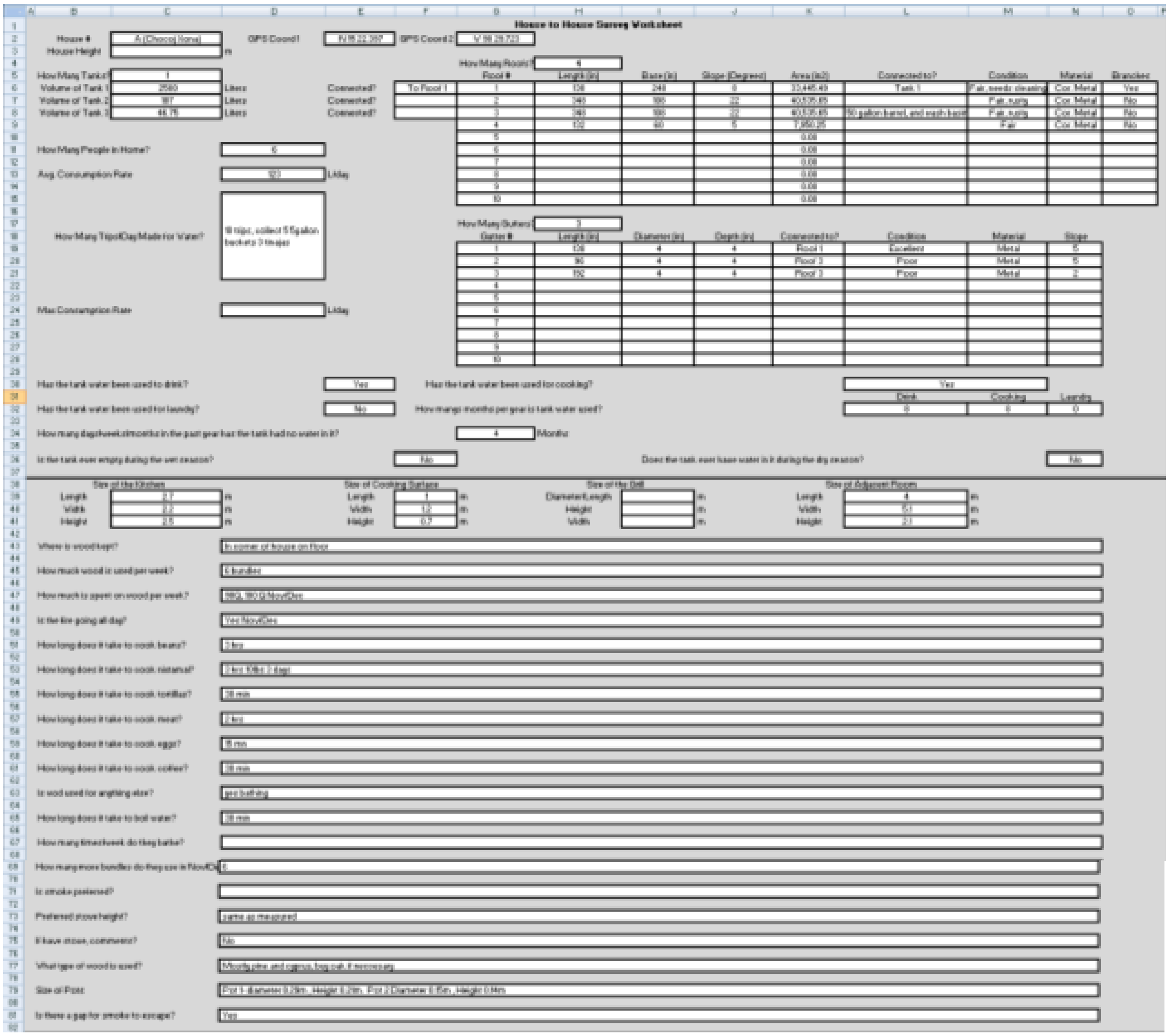
As a result of individual rainwater catchment tank implementation, there could potentially be a large community dynamic change. Currently, the Finca is a community gathering place where members talk and interact with one another. Using individual tanks would remove this social gathering location, unless the community members follow our advice and continue to do laundry at the Finca to conserve water. However, even if the Finca is no longer employed, we believe that this would not be detrimental to community dynamics or relations. See Appendix F below for a chart directly comparing individual and communal rainwater catchment tanks.

Description of Preferred Alternative

Based on these criteria EWB-WPI narrowed down our implementation options to individual rainwater catchment tanks. Using our dynamic model we determined that this was indeed a feasible option and that we would be able to provide drinking water to each home in the community. We decided to pursue individual household rainwater systems because of the readily available and cost-effective materials, individual maintenance, and reliability of rainwater. Also, the long-term reliability, hygienic properties, and practicality of the design make this design most preferable (see section 3, parts a-c). As a result, we intend to implement three rainwater catchment systems in three different homes in the community to serve as pilot systems during the implementation trip. With these pilot homes we hope to collect data and ensure that the individual rainwater catchment systems are working well for the community members. Upon verifying the success of the pilot project, the next trip will involve applying the project to the entire community. However, if the pilot project is unsuccessful, the group will determine the flaws in the design and create a more effective and sustainable solution.

Appendix G: Home Assessment Questionnaire

House A



House to House Survey Worksheet

House #: A (Chocoj Xona) | GPS Coord 1: N 15 22.357 | GPS Coord 2: W 90 29.723
House Height: m

How Many Tanks? 1
Volume of Tank 1: 2500 Liters — Connected? To Roof 1
Volume of Tank 2: 187 Liters — Connected?
Volume of Tank 3: 44.75 Liters — Connected?

How Many Roofs? 4

Roof #	Length (in)	Base (in)	Slope (Degrees)	Area (in2)	Connected to?	Condition	Material	Branches
1	138	248	0	33,445.49	Tank 1	Fair, needs cleaning	Cor. Metal	Yes
2	348	108	22	40,535.85		Fair, rusty	Cor. Metal	No
3	348	108	22	40,535.85	50 gallon barrel, and wash basin	Fair, rusty	Cor. Metal	No
4	132	60	5	7,950.25		Fair	Cor. Metal	No
5				0.00				
6				0.00				
7				0.00				
8				0.00				
9				0.00				
10				0.00				

How Many People in Home? 6
Avg. Consumption Rate: 123 L/day
How Many Trips/Day Made for Water? 18 trips, collect 5 5gallon buckets 3 tinajas
Max Consumption Rate: L/day

How Many Gutters? 3

Gutter #	Length (in)	Diameter (in)	Depth (in)	Connected to?	Condition	Material	Slope
1	138	4	4	Roof 1	Excellent	Metal	5
2	96	4	4	Roof 3	Poor	Metal	5
3	192	4	4	Roof 3	Poor	Metal	2
4							
5							
6							
7							
8							
9							
10							

Has the tank water been used to drink? Yes
Has the tank water been used for cooking? Yes
Has the tank water been used for laundry? No
How many months per year is tank water used? Drink: 8 | Cooking: 8 | Laundry: 0
How many days/weeks/months in the past year has the tank had no water in it? 4 Months
Is the tank ever empty during the wet season? No
Does the tank ever have water in it during the dry season? No

Size of the Kitchen			Size of Cooking Surface			Size of the Drill			Size of Adjacent Room		
Length	2.7	m	Length	1	m	Diameter/Length		m	Length	4	m
Width	2.2	m	Width	1.2	m	Height		m	Width	5.1	m
Height	2.5	m	Height	0.7	m	Width		m	Height	2.1	m

Where is wood kept? In corner of house on floor
How much wood is used per week? 6 bundles
How much is spent on wood per week? 78Q, 180 Q Nov/Dec
Is the fire going all day? Yes Nov/Dec
How long does it take to cook beans? 2 hrs
How long does it take to cook nixtamal? 2 hrs 10lbs 2 days
How long does it take to cook tortillas? 30 min
How long does it take to cook meat? 2 hrs
How long does it take to cook eggs? 15 min
How long does it take to cook coffee? 30 min
Is wood used for anything else? yes bathing
How long does it take to boil water? 30 min
How many times/week do they bathe?
How many more bundles do they use in Nov/Dec? 6
Is smoke preferred?
Preferred stove height? same as measured
If have stove, comments? No
What type of wood is used? Mostly pine and cypress, buy oak if necessary
Size of Pots: Pot 1- diameter 0.29m, Height 0.2m, Pot 2 Diameter 0.15m, Height 0.14m
Is there a gap for smoke to escape? Yes

House L

House to House Survey Worksheet

House #	L (La Hue)	GPS Coord 1	N 15 22.767
House Height	m	GPS Coord 2	W 90 25.094
How Many Tanks?	3		
Volume of Tank 1	2500 Liters	Connected?	To Roof 1
Volume of Tank 2	2500 Liters	Connected?	To Roof 1
Volume of Tank 3	2500 Liters	Connected?	To Roof 2
How Many People in Home?	10 (in L and M) 6 in L		
Avg. Consumption Rate	75.4 L/day		
How Many Trips/Day Made for Water?	6, 2.5 gallons trips per day for L (8, 2.5 gallon trips per day for L and M), with a max of 10, 2.5 gallon trip per day		
Max Consumption Rate	120 L/day		

How Many Roofs? 10

Roof #	Length (in)	Base (in)	Slope (Degrees)	Area (in2)	Connected to?	Condition	Material	Branches
1	143	219	18	31,900.12	Tanks 1 and 2	Excellent	Corr. Metal	None
2	229	179	18	41,925.75	Tank 3	Fair	Corr. Metal	None
3	245	95	35	20,413.53	Not Connected	Fair	Corr. Metal	None
4	245	86	35	25,721.72	Not Connected	Fair	Corr. Metal	None
5	247	92	30	26,239.42	Not Connected	Fair	Corr. Metal	None
6	247	94	30	26,809.04	Not Connected	Fair	Corr. Metal	None
7	181	95	18	17,460.26	Not Connected	Fair	Corr. Metal	None
8 (from House M)	243	94	20	24,307.85	Not Connected	Fair	Corr. Metal	None
9 (From House M)	243	155	18	38,266.04	Not Connected	Fair	Corr. Metal	None
10 (From House M)	98	97	18	9,622.57	Not Connected	Fair	Corr. Metal	None

How Many Gutters? 2

Gutter #	Length (in)	Diameter (in)	Depth (in)	Connected to?	Condition	Material
1	143	4	4	Roof 1	Excellent	Corr. Metal
2	229	4	4	Roof 2	Excellent	Corr. Metal
3	243	4	4	Roof 8	Excellent	Corr. Metal
4	243	4	4	Roof 9	Excellent	Corr. Metal
5						
6						
7						
8						
9						
10						

Has the tank water been used to drink?	Yes
Has the tank water been used for cooking?	Yes
Has the tank water been used for laundry?	Yes
How many months per year is tank water used?	Drink: 10; Cooking: 10; Laundry: 10
How many days/weeks/months in the past year has the tank had no water in it?	2 Months
Is the tank ever empty during the wet season?	No
Does the tank ever have water in it during the dry season?	No

Size of the Kitchen		Size of Cooking Surface		Size of the Grill		Size of Adjacent Room	
Length	5.8 m	Length	1.20 m	Diameter/Length	m	Length	m
Width	3.43 m	Width	0.79 m	Height	m	Width	m
Height	2.19 m	Height	0.61 m	Width	m	Height	m

Where is wood kept?	
How much wood is used per week?	5-6 bundles
How much is spent on wood per week?	75 Q
Is the fire going all day?	No
How long does it take to cook beans?	Good beans: 1 1/2 - 2 hrs, bad: 3 hours
How long does it take to cook nixtamal?	1 1/2 hrs, use a lot of wood, cook 15 lbs, will last 2 days
How long does it take to cook tortillas?	1 hr
How long does it take to cook meat?	1 1/2 - 2 hrs
How long does it take to cook eggs?	15 minutes
How long does it take to cook coffee?	30 min
Is wood used for anything else?	Yes, bathing
How long does it take to boil water?	dry wood: 1 hr to 1 1/2 hr; wet wood: 2 1/2 hrs
How many times/week do they bathe?	3
How many more bundles do they use in Nov/Dec?	1 more
Is smoke preferred?	Yes, for bugs
Preferred stove height?	Same as measured
If have stove, comments?	No
What type of wood is used?	Pine and cyprus is found - if they need to they buy oak

Appendix H: Education Material

Figure 62: Pictorial Poster Explaining Water Conservation

Checklist of Important Points

Community Assessment
1. General Community Meeting
- Reiterate the reasons why rain water harvesting has been chosen over drilling a well
- Presentation about water conservation and proper maintenance techniques
    - distribute the pictorial posters to one member of each family
    - Explain how important it is to use the first flush
- Discuss any concerns that the families may have
- Discuss the importance what the implementation process entails

2. Meeting with individual families
- Discuss with the families the first flush system (Hands-on workshop)
- Present proper maintenance of the roofs such as cleaning the leaves and making sure that water valve is properly closed to avoid water leakage.
- Discuss with the any concerns with the families about the first flush and other topics related to this

The following is a timeline for the future education plans:

- In the interest of starting an education program about water conservation with children from the community, travelers will be looking to build a relationship with local schools as well as the CECEP museum. On future trips the hope will be that EWB-WPI can maintain this connection and begin these education programs.
- A strong effort will be made on future trips to reconnect with previous pilot families that would have already received rainwater catchment systems. Travelers will be evaluating how well the system works for each family, if they are using the water in the ways we suggested, and any other social or health issues related to the tank system.
- In order to continue to build and maintain a working and trusting relationship with the community members, the future travel teams will be allotting time in the itinerary to spend time with the families outside of the implementation of the rainwater catchment systems.
- Further evaluation of the community dynamic will be important on this implementation trip so that in future trips travelers can access the feasibility of relying on past pilot families to help in the construction and education of other community members as they construct their rainwater catchment systems.
- One important concern that EWB-WPI has with the implementation of individual water tanks is that the community's social dynamic will be affected negatively as they will lose the Finca, as a place of social gathering. EWB-WPI plans to continue monitoring this situation and in the more distant future (after the completion of the rainwater catchment project) look into the construction of either a school or community center in Guachthu'uq to improve the community dynamic, as there is currently no community owned land or school.

Appendix I: Memorandum of Understanding

COCODE Agreement

Cocode Agreement Form

We agree, as members of the governing body of Guachthu'uq, to work with the Worcester Polytechnic Institute Student Chapter of Engineers Without Borders (WPI-EWB) to the best of our abilities. This agreement to work with WPI-EWB centers on general organization of the community. We understand that the implementation of any type of water or stove system in the community will need to be monitored. The responsibility of watching the development of the community of Guachthu'uq around the project lies with the Cocode. Assistance with communication between individual households, the general community and WPI-EWB is crucial for the success of the project. We agree to relay information, concerns, questions and suggestions between the Guachthu'uq community and WPI-EWB.

We also understand that labor and monetary support of the project will be contributed to some degree. Funding the project, including the pilots, will require saving and fundraising by the individuals and by the community. As the Cocode, we agree to control and oversee monetary dealings for the community as a whole. We understand that communication with the local municipality of San Cristobal, Alta Verapaz, including application for government funds, will be directed and completed by the members of Guachthu,uq and the Cocode without the direct involvement of WPI-EWB.

We understand that this project pilot is a test and it may not be successful when EWB-WPI first implements it. It will take time and communication from both parties, both the community of Guachthu'uq by the Cocode and EWB-WPI, in order to make adjustments so the designs can be perfected. Support of the pilot project will be demonstrated by the Cocode. If there are changes in attitudes toward the project, by individuals, the Cocode or the entire community, they will be communicated to WPI-EWB.

Documento de compromiso de Cocode

Estamos de acuerdo, como miembros del gobierno deGuachthu'uq, para trabajar con el Worcester PolytechnicInstitute (InsitutoPolitecnico de Worcester)capítulo estudiante de (Ingenieros Sin Fronteras) (WPI ISF) a lo mejor de nuestras habilidades. Este acuerdo para trabajar con WPI ISF se centra en la organización general de la comunidad. Entendemos que la aplicación de cualquier tipo de sistema de agua o estufa en la Comunidad se necesitara ser monitoreada. La responsabilidad de ver el desarrollo de la comunidad de Guachthu'uq alrededor del proyecto recae en el Cocode. Asistencia en la comunicación entre los hogares, la comunidad en general y WPI ISF es crucial para el éxito del proyecto. Estamos de acuerdo transmitir información, inquietudes, preguntas y sugerencias entre la comunidad de Guachthu'uq y WPI ISF.

También entendemos que trabajo y apoyo financiero del proyecto se contribuyera en cierta medida. Financiación del proyecto, incluyendo los pilotos, será necesario conseguir fondos por los individuos y la comunidad. Como el Cocode, estamos de acuerdo controlar y supervisar las relaciones monetarias para la comunidad. Entendemos que la comunicación con la municipalidad local de San Cristóbal, Alta Verapaz, incluida la solicitud de fondos del Gobierno, será dirigida y completada por los miembros de Guachthu'uq y el Cocode sin la participación directa de WPI ISF.

Entendemos que este piloto del proyecto es una prueba y no puede ser exitosa. Tomará tiempo y comunicación de ambas partes, tanto de la comunidad de Guachthu'uq por el Cocode y WPIISF, a fin de hacer ajustes para que los diseños pueden ser perfeccionados. Apoyo del proyecto piloto será demostrado por el Cocode. Si hay cambios en las actitudes hacia el proyecto, por individuos, el Cocode o toda la Comunidad, se comunicará a ISF WPI.

Nombre Firma

Angel caj cū
luis Antonio yuja cal.
Edgar Efraín Xi cal.
Clemencia Ibañez
Angelina Quej moran
José Emiliano sis xuc.

CONSEJO COMUNITARIO DE DESARROLLO
CASERIO GUACHTUQ
COCODE
SAN CRISTOBAL VERAPAZ A.V.

Community Agreement

Community Project Agreement Form

We plan to work with the Worcester Polytechnic Institute Student Chapter of Engineers Without Borders (WPI-EWB) to the best of our ability. We will provide labor and monetary support towards the completion of the projects. We understand that we have to be dedicated to the project by conveying any concerns, questions or suggestions about how to make the project more applicable to our community to EWB-WPI.

We understand that we are to select the three homes for the rain water catchment system pilot program and three homes for the improved stove pilot program. We understand that the families who are not selected are not forgotten. These few pilot homes will be actively working to ensure that the designs meet the community's needs. Once the EWB-WPI group and the community have decided that the designs are satisfactory, we will start working with other families to implement the rain water catchment systems and improved stoves.

We understand that these pilot programs are a test, and they may not be entirely successful when EWB-WPI first implements them. It will take time and full communication from both parties, both the community of Guachthu'uq and EWB-WPI, in order to make adjustments so the designs can be perfected.

We understand that these projects that EWB-WPI has proposed will require a long process over a number of years. This is because EWB-WPI intends to ensure that the designs are effective and will work with each family to train them in how to use the designs properly. This will ensure that if something happens, either if something breaks or requires standard maintenance, we, the families of Guachthu'uq, will be able to fix the systems after all systems have been implemented, and each family understands the proper upkeep and maintenance.

We understand that it is our responsibility to communicate with the municipality or other appropriate government agencies in order to request funding for these projects. We also understand that we might have to fundraise in other ways in order to raise money for these projects.

Formulario de acuerdo de proyecto comunitario

Queremos trabajar con el Worcester Polytechnic Instituto estudiante capítulo de Ingenieros Sin Fronteras (WPI-ISF) a lo mejor de nuestra capacidad. Ofrecemos trabajo y apoyo financiero para la ejecución de los proyectos. Entendemos que tenemos que ser dedicados al proyecto transmitiendo inquietudes, preguntas o sugerencias acerca de cómo hacer el proyecto más aplicable a nuestra comunidad a ISF-WPI.

Entendemos que tenemos que seleccionar las tres casas para el programa piloto del sistema de captación de lluvia y tres casas en el programa piloto de la estufa mejorada. Entendemos que las familias que no fueron seleccionadas no serán olvidadas. Estas pocas casas pilotos trabajaran activamente para asegurar que los diseños satisfagan las necesidades de la comunidad. cuando el grupo de ISF-WPI y la comunidad han decidido que los diseños son satisfactorios, comenzaremos a trabajar con otras familias para aplicar los sistemas de captación de agua de lluvia y estufas mejoradas.

Entendemos que estos programas pilotos son una prueba, y no pueden ser totalmente exitosos cuando WPI ISF los implementa primero. Tomará tiempo y comunicación de ambas partes, tanto de la comunidad de Guachthu'uq y ISF-WPI, para poder hacer ajustes para que los diseños puedan ser perfeccionados.

Entendemos que estos proyectos que ha propuesto la ISF-WPI requerirá un largo proceso durante varios años. Esto es porque ISF-WPI tiene la intención de asegurarse de que los diseños son eficaces y que trabajarán con cada familia para entrenarlos en cómo utilizar correctamente los diseños. Esto asegurará que si pasa algo, ya sea si algo se rompe o requiere mantenimiento, nosotros, los familiares de Guachthu'uq, seríamos capaz de arreglar los sistemas después de que todos los sistemas se han aplicado, y cada familia entiende que es el mantenimiento adecuado.

Entendemos que es nuestra responsabilidad de comunicar con la municipalidad u otras agencias gubernamentales apropiadas para solicitar la financiación de estos proyectos. También entendemos que tenemos que colaborar en otras formas para conseguir financiamiento para estos proyectos.

Nombre Firma

1. Dolores Chun Lem.
2. Marcela Ical Moran
3. Zonia Isabela Laj Jom.
4. Silvia Patricia Choc Chun
5. Isabel Xona Xuc.
6. Julia Yuja.
7. Alejandrina Veronica Yuja.

COMITE COMUNITARIO DE DESARROLLO CASERIO GUACHTHU'UQ COCODE

Josefina Lem Mo
Herlinda Velasquez
Marcia Cal Caj
Zoila esperanza ical cojoc

Cristobal Luj Coj
Secondino Sucu

Celestina Cal Caj

Elvira Choc Lem

Eledia E. Xona Xujà

Isabela Caj Pop.

Ricardo Gualim

Santiago Lem.

Juan Gua Láj

Víctor Caj Cù

Elvira Cal Chon

Rosa Gualim Cal

Josefina Clara Gua Mó

clara Caj Cu

Edgar Efrain yujà cal.

EWB-WPI Agreement

Engineers Without Borders Agreement Form

We agree, as members of the Worcester Polytechnic Student Chapter of Engineers Without Borders, to work with the Community of Guachtu´uq, Alta Verapaz, to the best of our abilities.

We agree to update the community with any changes in the project, whether it is in regards to designs or costs. This may require very frequent communication, which we are prepared to conduct. We will do our best to make the designs fit the needs of the community and take into consideration all of the input the community has given us thus far. This includes keeping the project as low in cost as possible without sacrificing the correct functioning of the designs and their long term maintenance.

EWB-WPI is going to ensure that the designs are effective, and we will work with each family to train them how to use the designs properly. This will ensure that if something happens, either if it breaks or needs simple maintenance, the families of Guachthu'uq, will be able to fix the systems after all systems have been implemented. We will continue to work on the project until all systems have been completed to the community members´ satisfaction.

Ingenieros sin fronteras formade acuerdo

Estamos de acuerdo, como miembros del Worcester Polytechniccapítulo estudiante de Ingenieros Sin Fronteras, para trabajar con la comunidad de Guachtu´uq, Alta Verapaz, a lo mejor de nuestras habilidades.

Estamos de acuerdo en actualizar la comunidad con los cambios en el proyecto, ya sea en cuanto a diseños o los costos. Esto puede requerir comunicación muy frecuente, que estamos dispuestos a realizar. Haremos nuestro mejor esfuerzo para hacer que los diseños satisfagan las necesidades de la comunidad y tener en consideración todas las sugerencias que la comunidad nos ha dado hasta ahora. Esto incluye mantener el proyecto conlos costos más bajos posible sin sacrificar el correcto funcionamiento de los diseños y su mantenimiento.

ISF-WPI va a garantizar que los diseños son eficaces, y vamos a trabajar con cada familia para entrenarlos cómo utilizar correctamente los diseños. Esto asegurará que si pasa algo, ya sea si rompe o necesita mantenimiento simple, las familias de Guachthu'uq, serán capaz de arreglar los sistemas después de la implementación de todos los sistemas. Seguiremos trabajando en el proyecto hasta que se ha completado todos los sistemas a la satisfacción de la comunidad.

Nombre	Firma
Alberto Phillips	
Kali Manning	
Lexa Vresilovic	
Creighton Peet	
Julie Bliss	
Chris Gosteau	
Emily McWilliam	