EWB EPA January 2014 Trip

The Worcester Polytechnic Institute student chapter of Engineers Without Borders, USA will be traveling to Guachthu'uq, Guatemala from January 2nd to 14th, 2014. The travel team will be comprised of two faculty advisors/mentors, Laureen Elgert and Pat Austin, as well as four students: Thomas Moutinho, Katie Picchione, Thomas Washburn, and Michele Mensing. The goal of this trip is to implement rainwater harvesting systems in two homes, perform extensive water quality tests, and further community education on proper system maintenance and water usage.

Implementation and Monitoring

This report lacks background information about the project; refer to the 522 from May 2013.

Analysis of Data

Below is a bar chart from the data we have collected from Alvaro to date. By comparing the red and purple bars we can see that the consumption rate per person for drinking and cooking varies greatly from home to home.

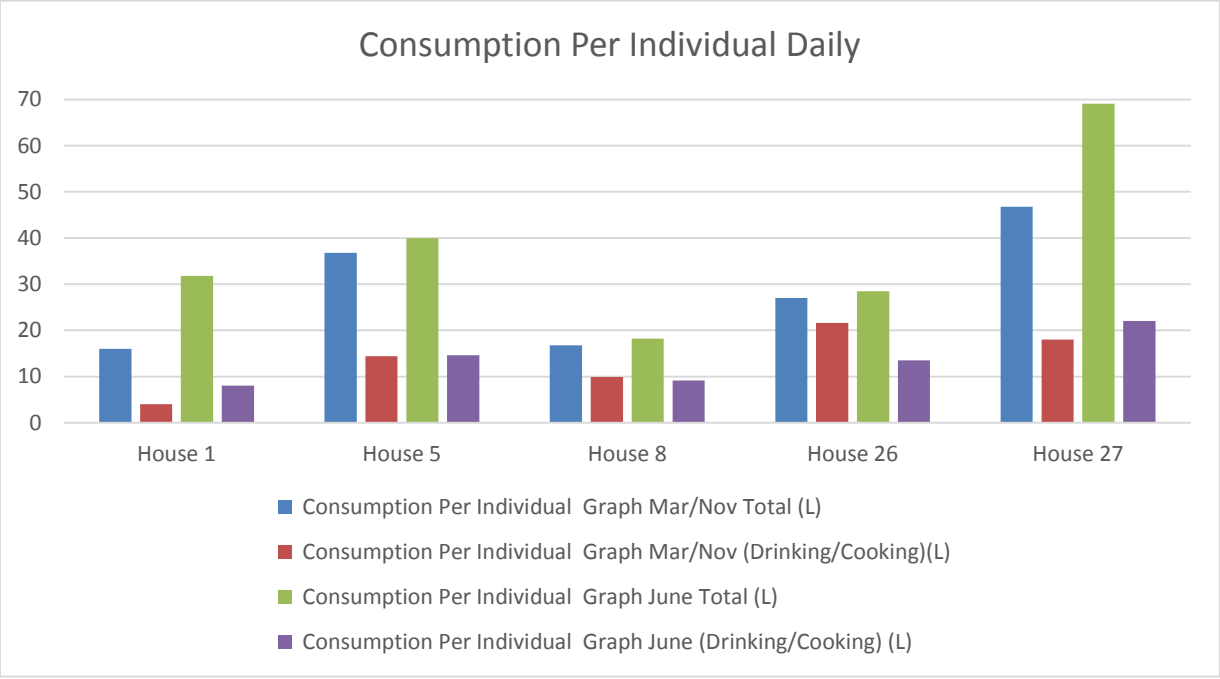


Figure 1: Graph of consumption levels for various households.

The following two graphs represent the importance of education on water usage from the tanks. The weeks in March are data from a month between the pilot implementation trip and the monitoring trip. The weeks from June are data from the month after we travelled. It appears that Roberto's family understands that it is important to use the tank water for drinking and cooking while using the finca water for washing clothes. Some of the change in volume recorded the graphs might be from error in filling out the monitoring forms, as there was some confusion on how to fill in the forms during the first few weeks of monitoring (which occurred in March). This can speak towards the large difference in total

liters of water consumed by Roberto's family. While there is evidence there is an error in the amount of the water used, we do believe the ratio of water taken from the tank versus the finca is accurate. Ideally, all families should be using tank water and finca water in the manner that Roberto's family did in June: allocating tank water for drinking and finca water for washing clothes. This behavior is not consistent across all the families we have been monitoring. This shows the importance of education in the community.

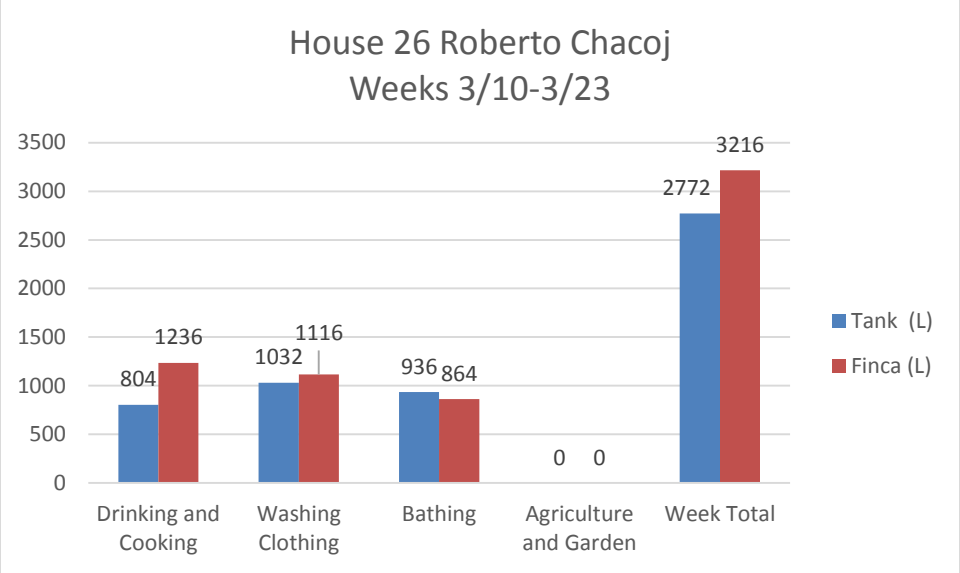


Figure 2: Distribution of water usage at Roberto's house for two weeks in March.

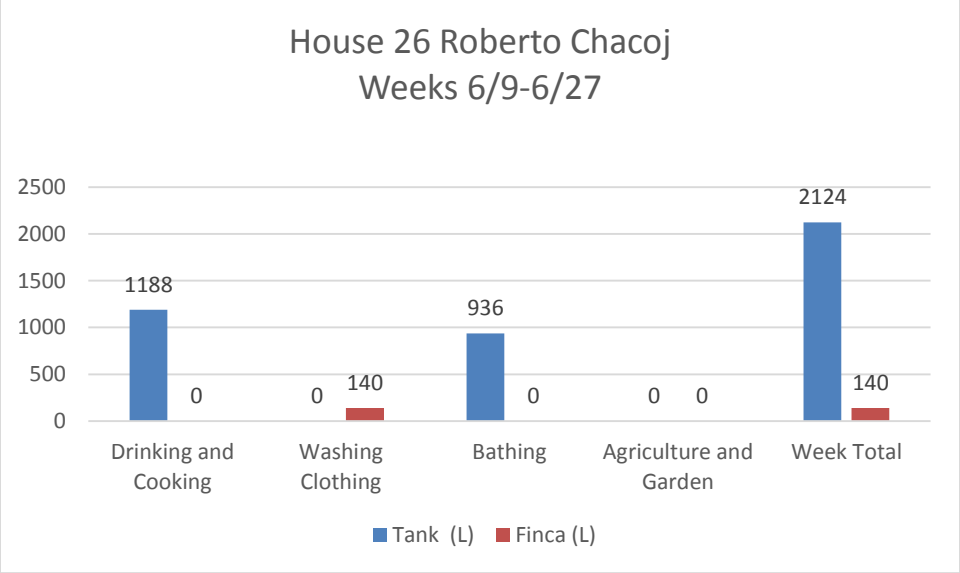


Figure 3: Distribution of water usage at Roberto's house for two weeks in June.

Below is the average consumption and allocation of water used by the mid-wife. The mid-wife is a good example of proper water usage, since she uses more tank water for drinking while more finca water for washing clothes. She serves as a model to help us distribute knowledge about proper water usage between the tanks and the finca.

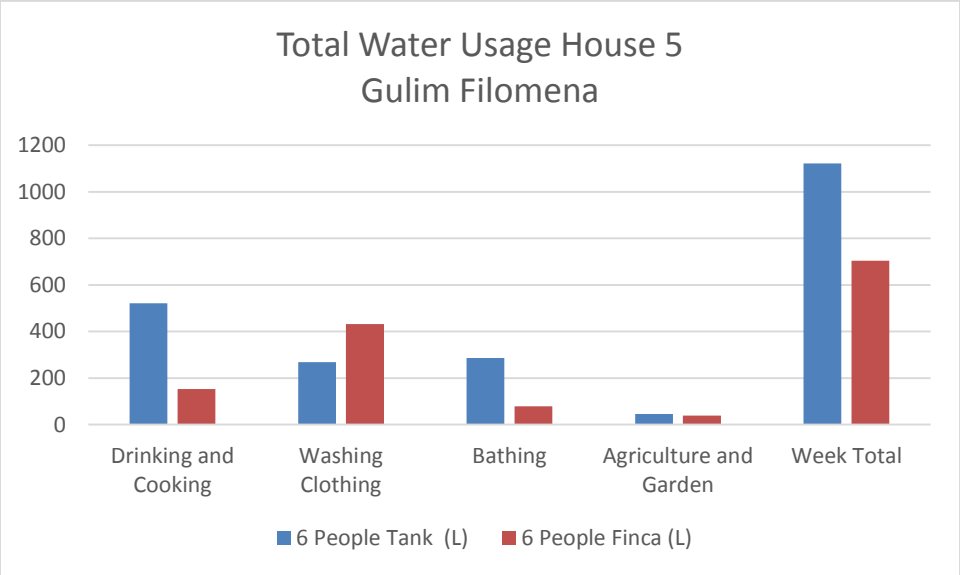


Figure 4: Averaged distribution of water usage at the mid-wife's house.

Education

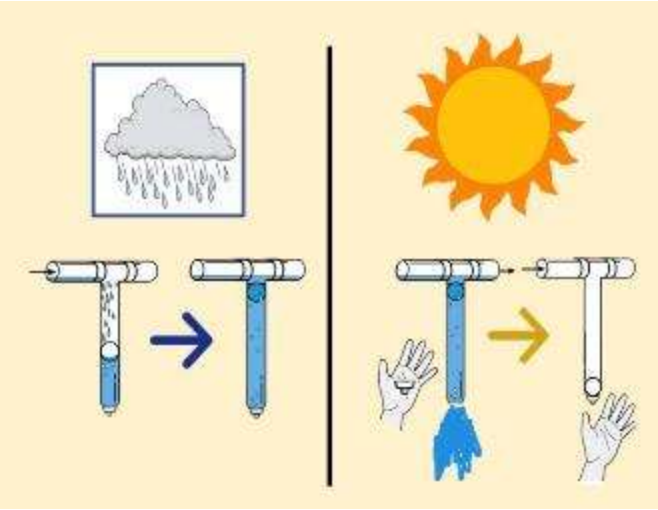
Several posters were designed to convey key ideas about how to properly use and maintain the rainwater harvesting systems. Though currently in Spanish, the words will be translated into Poquomchi for Guachthu'uq.

Poster 1 says "Clean the Roofs and Gutters" and depicts the difference between gutters and roofs littered with leaves and ones free of debris. The words "Dirty, Bad" and "Clean, Good" correspond with the colors outlining the photos of cluttered and clean systems to facilitate understanding.

Poster 2 illustrates proper handling and use of water from different sources. It shows that water bottles should be used to draw water from the tank for cooking and drinking while the tinajas should be used to hold finca water for laundry and bathing. This prevents contamination of clean water from dirty containers.

Poster 3 indicates that even tank water must be boiled for one minute before drinking it. The two pictures of pots attempt to convey the idea that water must be heated up before it boils and then must boil for an additional minute to sterilize.

Poster 4 shows proper use of the first flush system. When it rains, the first flush will fill with water. When the rain stops, the first flush must be manually emptied.



System design

Pre-System In field design

We need to look for a proper material to cover the clear water level tubes from the sun. The tubes that we implemented last time have become a source of algae contamination. In order to stop growth of algae need to find a material to cover the clear tubes and allow the families to view the level of water in the tanks.

System Design Verifications

We have researched and calculated that a 2" PVC pipe is an adequate diameter to transport the peak flow of rainfall (data from our rain gauge) from a roof area at maximum 100 m^2.

Additional calculations that we conducted show that with three inches of head pressure an overflow pipe of 2 inches is adequate to allow the peak amount rainwater flow into the tank from a roof area of 100 M^2 or less. See Appendix A for calculations.

Lastly, we constructed a prototype of a first flush to verify that a water bottle works as a stopper because we have not been able to find an adequate ball for the first flush in Guatemala.

Components

- Base
    - The base has been re-designed to reduce the necessary man hours for construction, while maintaining the structural integrity. We believe this design will adequately support the tanks and reduce the risk of erosion induced damage to the tank. Instead of a 12" thick concrete base, we will be laying 3" of reinforced concrete and laying a grid of cinder blocks on top. The cinder blocks will provide the necessary elevation of the tank for the families to access the spout. Figures 6 and 7 on the following page show this set up.
- First flush
    - The new first flush design supports the weight of the water from the bottom rather than hanging from the downspout. It has a 3" to 1.5" reducer to a 1.5" ball valve that will act as the manual release for the collected water. The first flush will be supported by a pipe that rests on two cinder blocks. At the bottom of this pipe will be an upside down 'Y' connector that will allow the families to collect the dispensed water and use for agricultural needs. A visual is shown on the next page in Figure 5.
- Overflow
    - 2" Pipe from the bottom of the tank to help clean tank
    - Overflow must be at least three inches below the top of the tank
    - A visual is shown in Appendix A.

Figure 5: Model of the first flush with a ball inside as a stopped. Note: the new design uses a water bottle as a stopper, and there will be a supporting piece of PVC at the bottom.

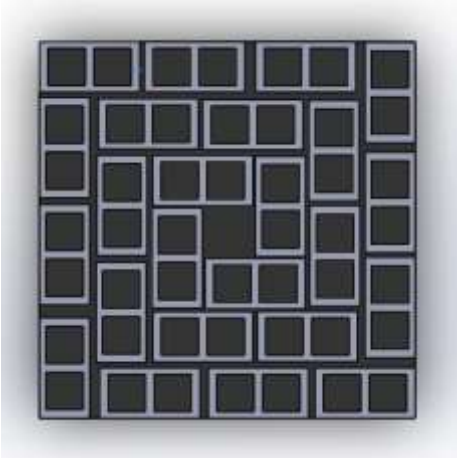


Figure 6: Top view of the cinder block arrangement.

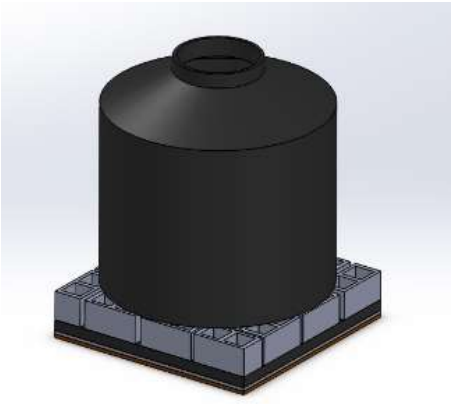
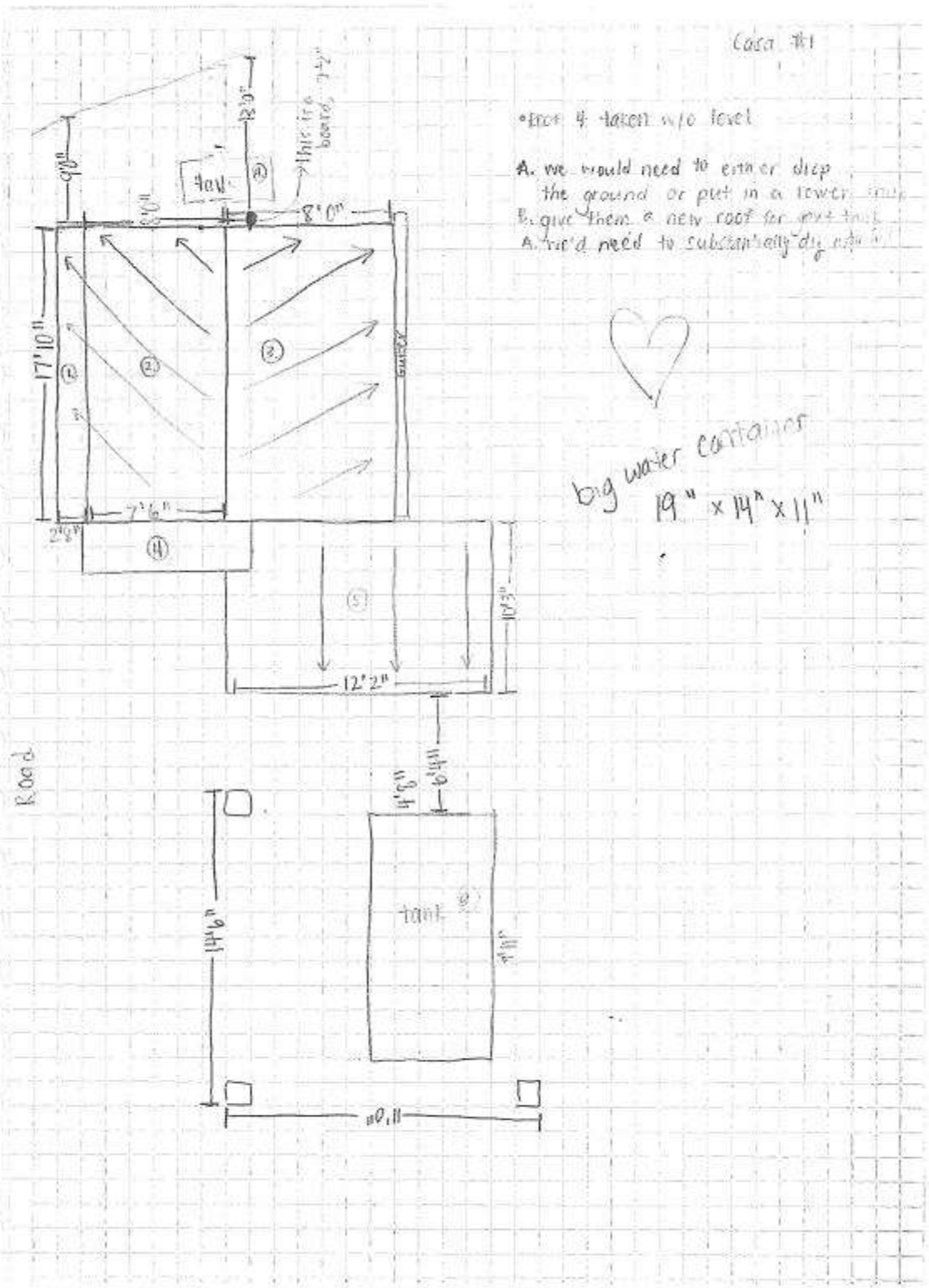


Figure 7: View of the tank sitting atop the concrete and cinder block base.

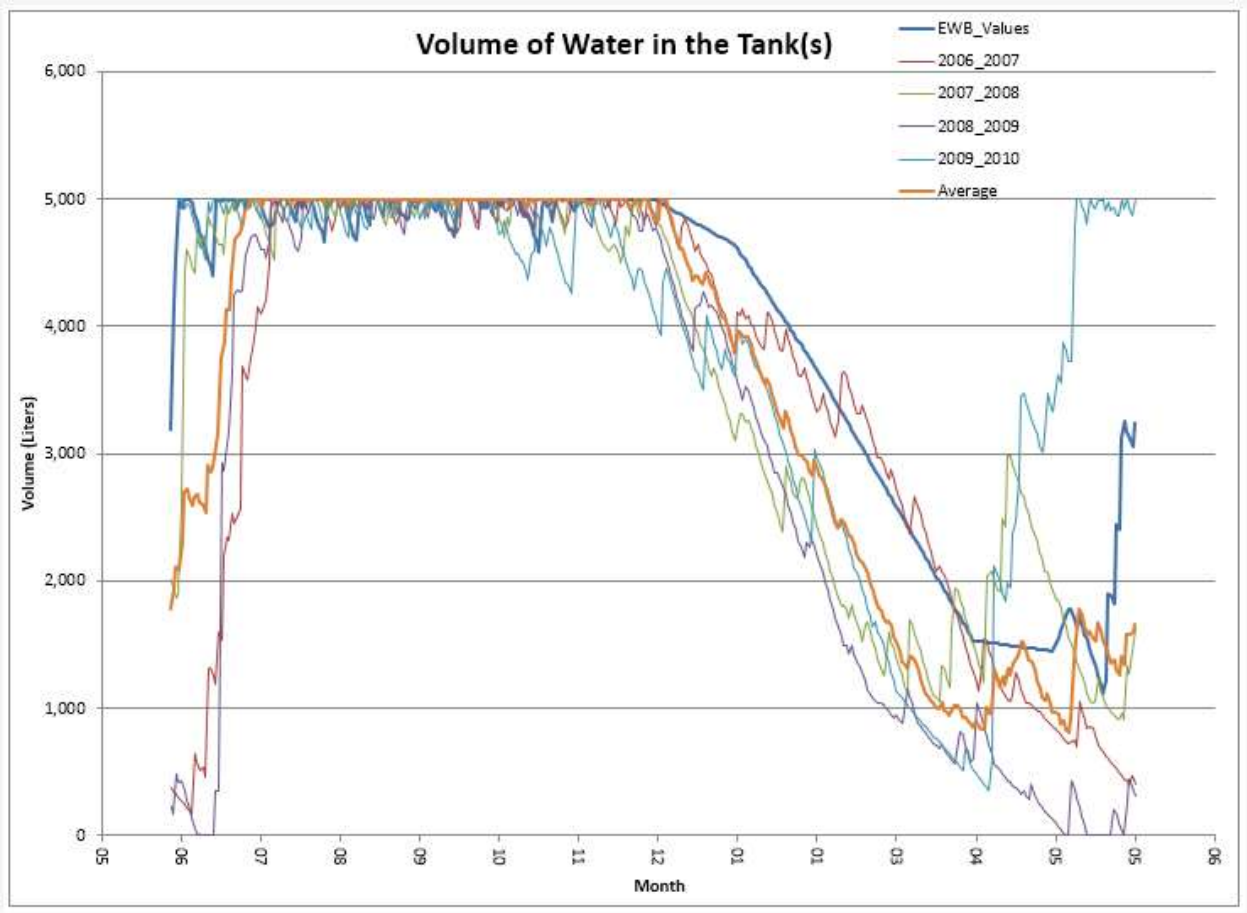
House 1


Casa #1
•roof 4 taken w/o level
A. we would need to enter or dig the ground or put in a tower
B. give them a new roof for next to
A. we'd need to substantially dig
big water containers
19" x 14" x 11"
Thick ire board, 1"
12'0"
9'0"
8'0"
17'10"
7'6"
2'6"
10'3"
12'2"
Road
tank
4'9"
6'9"
14'6"
10'11"

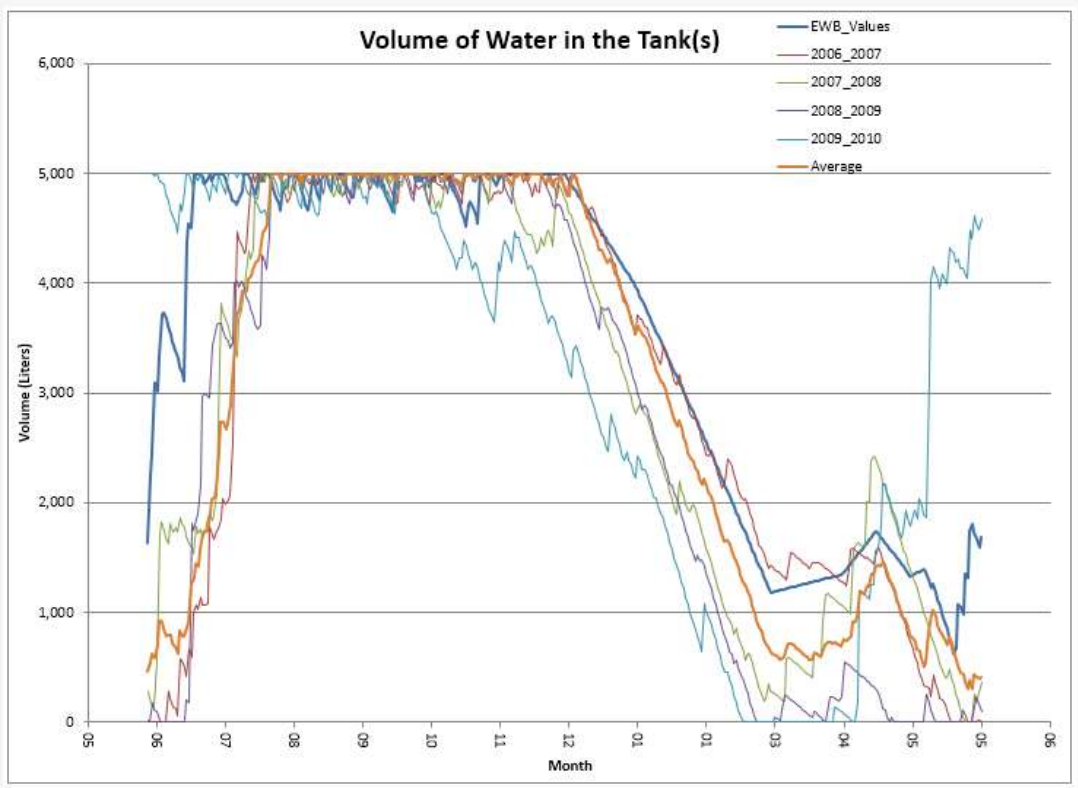
Two options:

1. Add a roof structure that utilizes the old layout of for the removed government system.
2. Tell them they need to ration at 3 Liters per person per day for 1.5 month.

Option 1:



Option 2:



Rough list of Materials:

(2) Tanks

(2 or '1') Bases

- Concrete
- (24) Cinder blocks
- Rebar

(2 or 3) first flush systems

- 1.5" ball valve
- 2: 3" to 1.5"
- 1.17 M of 3" PVC

(2 or 3) 5.5 meter length of gutter

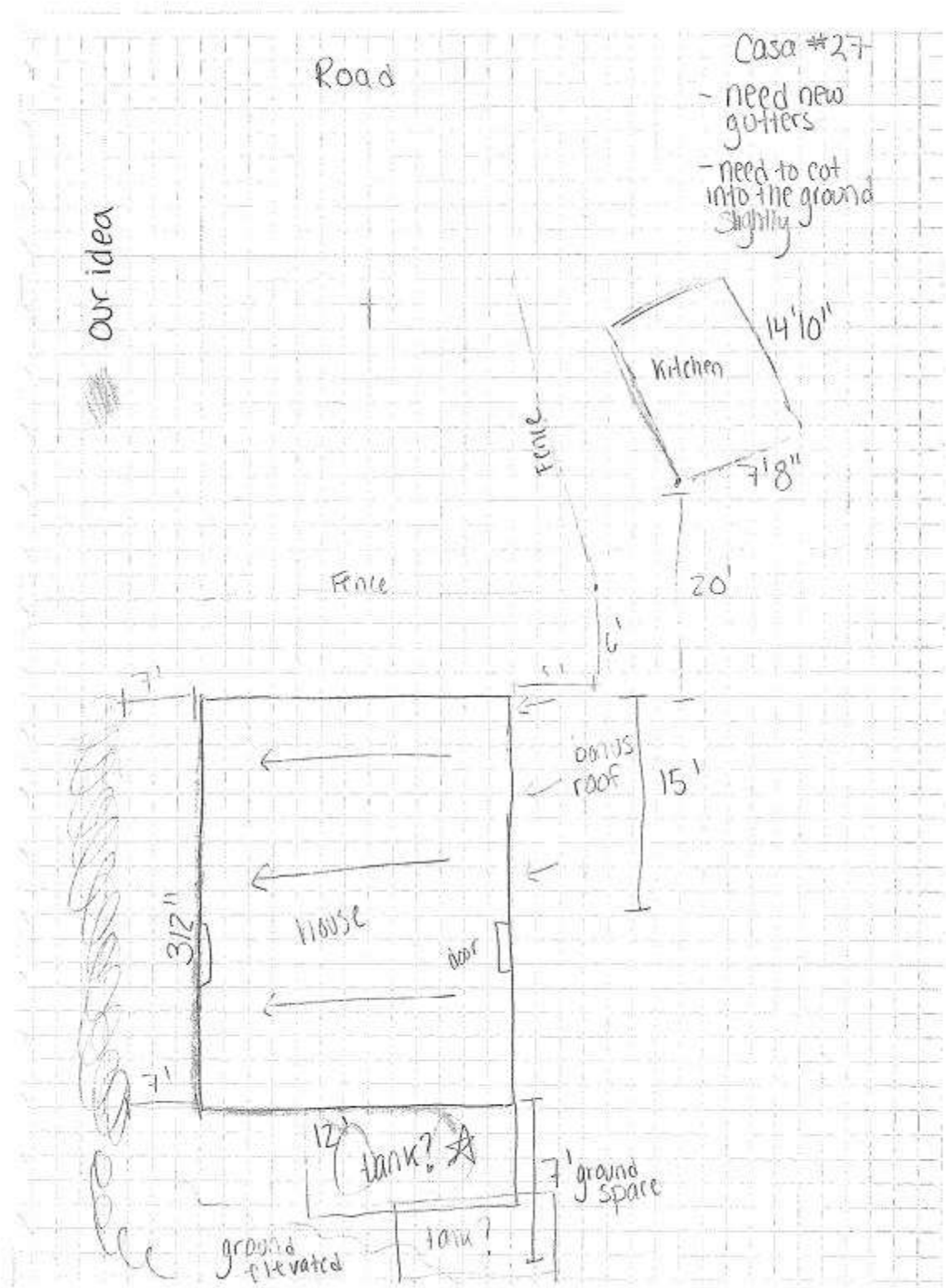
(2 or 3) gutter down spouts

2" PVC (6 meters)

Roof materials

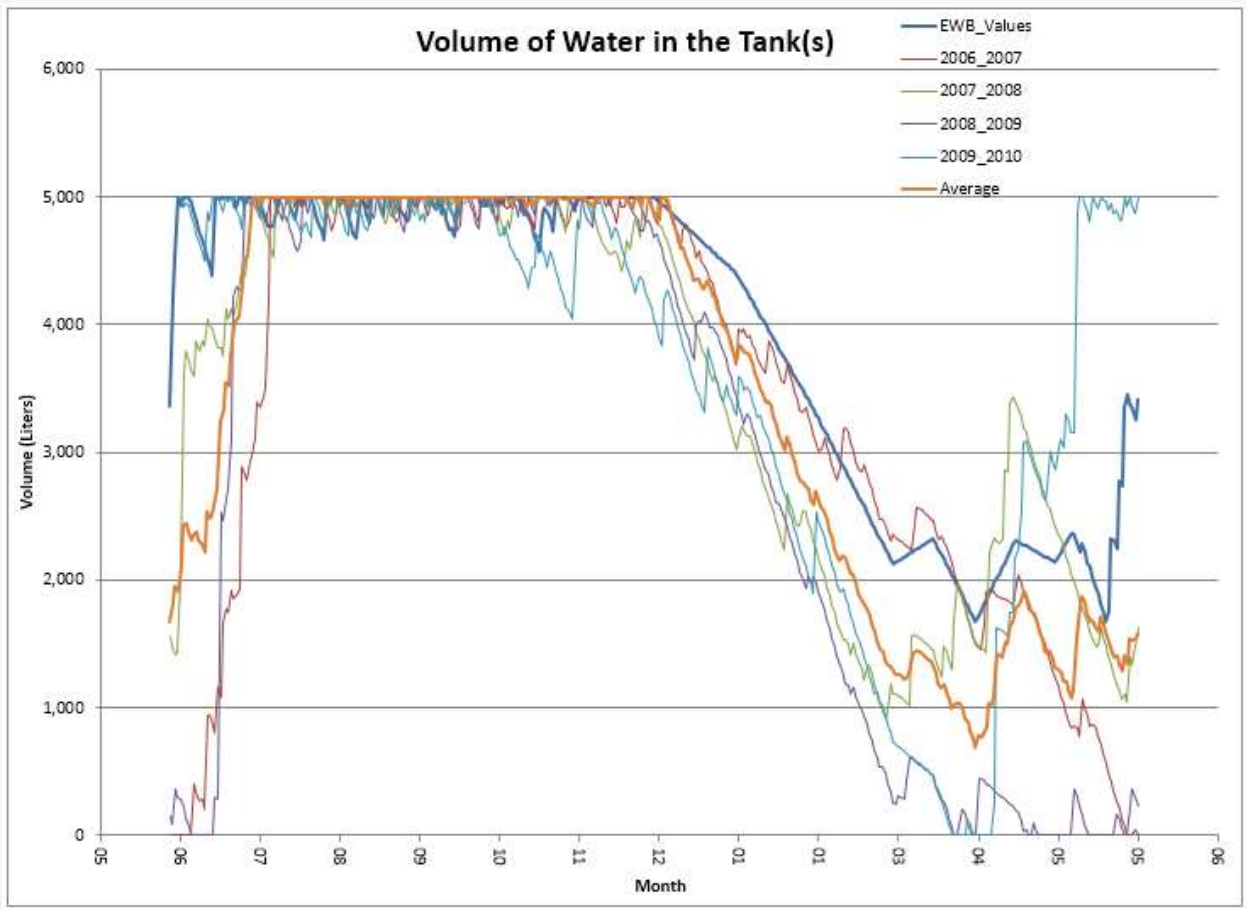
Wood

House 27


Casa #27
- need new gutters
- need to cut into the ground slightly
Road
Our idea
Kitchen
14'10"
7'8"
Fence
Fence
20'
6'
7'
bonus roof
15'
3/12"
House
door
7'
12'
tank?
7' ground space
ground elevated
tank?

Design:

Add 2 meters of roof to the side(s) of their house. Add two tanks and bases. Half-ration for 2 months.



Rough list of materials:

(2) Tanks

(2) Bases

- Concrete
- (24) Cinder blocks
- Rebar

(1) First flush systems

- 1.5” ball valve
- 2: 3” to 1.5”
- 1.17 M of 3” PVC

(1) 11 meter length of gutter

(2 or 3) gutter down spouts

2” PVC (6 meters)

Roof materials

Wood

Water quality

Colilert Protocol (Tube)

1) Collect sample in “whirl-pak”
2) Label tube (cap and body) with marker. Include location, sample number, date, and initials.
3) Gently invert “whirl-pak” to homogenize sample.
4) Open new plastic dropper. Insert dropper into “whirl-pak” of water sample and uptake liquid. Never touch dropper tip!
5) Dispense liquid into tube until level has reached pre-marked level on tube (~10mL)
6) Tightly recap tube and gently invert until chemicals dissolve.
7) Incubate for 24h at body temperature. Samples can be placed in pockets, etc.
8) After incubation period, check color. Yellow means that coliform bacteria is present.
9) In dark, take tube and shine blacklight. Check fluorescence (yes means that e. coli is present). Take pictures!

Petrifilm Protocol

1) Remove from bag (handle with care; do not touch layer between film)
2) Label sample on upper region of the white layer with marker (location, sample number, date, initials)
3) Open new plastic dropper. Insert dropper into “whirl-pak” of water sample and take up roughly 1mL (avoid bubbles). Never touch dropper tip!
4) Lift top white flap of petrifilm, exposing red circular region. Dispense 1mL of sample carefully onto center of red region. Once dispensed, manually remove any bubbles that may have formed using dropper.
5) Gently lay white flap back down. Sample should visually start to spread out and fill the red center region. If needed, use spreader (should not need).
6) Allow petrifilm to sit for 1 minute. This will allow the sample to solidify into a gel.
7) Carefully place petrifilm between two pieces of cardboard (never touch the inside layer of the petrifilm). Tape cardboard together at all four ends (remember that you will have to remove this tape later!).
8) Incubate for 24h at body temperature. Samples can be placed in pockets, etc.
9) Remove petrifilm from cardboard.
10) Count colony formation. Blue colonies with gas bubbles are e. coli. Red colonies are other bacteria. Record both in spreadsheet. Take pictures!

GENERAL TIPS

*Remember to use new dropper between different samples to avoid cross contamination

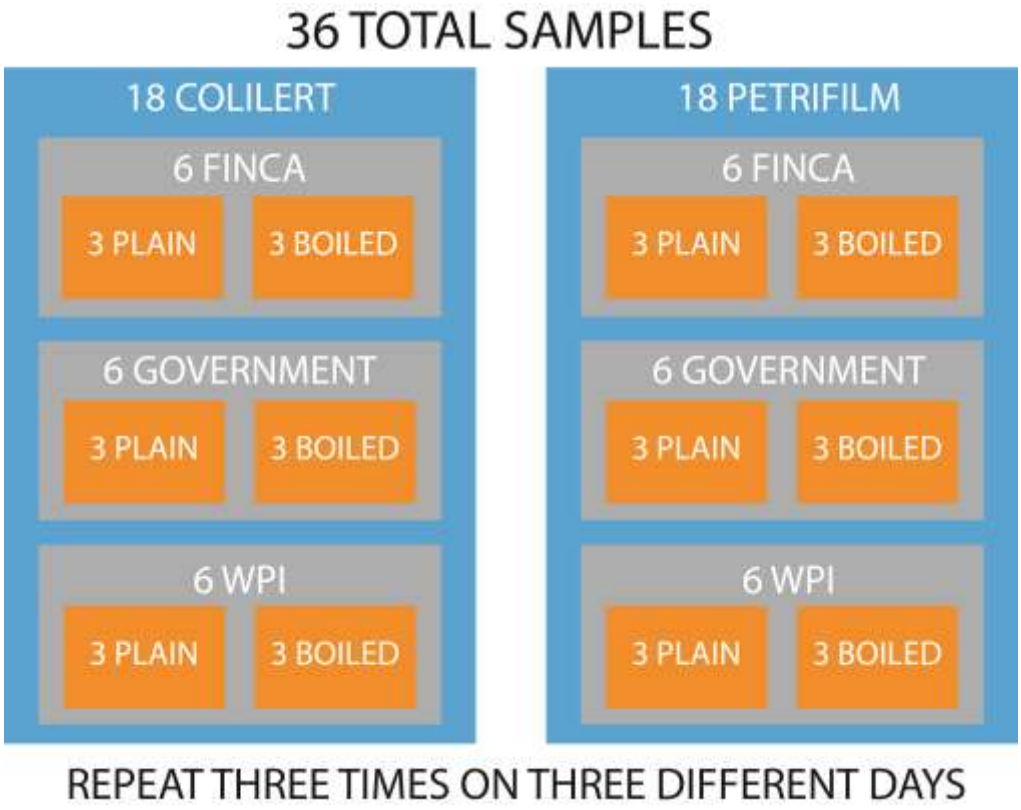
*Wash hands after handling samples

Colony Counting - Interpretation

Risk level	*E. coli*/sample	Colilert fluorescence	Petrifilm # Blue&gas
Low	< 1/10 ml	-	0
Moderate	1-10/10 ml	+	0
High	1-10/ml	+	1-10
Very High	>10/ml	+	>10

pH Protocol

Use pH strips to test three samples from each source (finca, government, WPI) for a total of nine samples. Feel free to perform more tests than this, though it is most likely not required.



Water Quality - Data Sheet

Source:	Collection Date:
Replicate #:	Collection Time:
Incubation Time (hours):	Tester:

Weather Notes:

Tank Notes:

Colilert (Tube)

Yellow (bacteria)? ☐ Yes ☐ No

Fluorescent (e. coli)? ☐ None ☐ Weak ☐ Strong

Petrifilm

Blue colonies (e. coli):

Red colonies (other):

Water pH:

Additional Notes:

Water Quality - Data Sheet

Source:	Collection Date:
Replicate #:	Collection Time:
Incubation Time (hours):	Tester:

Weather Notes:

Tank Notes:

Colilert (Tube)

Yellow (bacteria)? ☐ Yes ☐ No

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Petrifilm

Blue colonies (e. coli):

Red colonies (other):

Water pH:

Additional Notes:

Water Quality Analysis – Useful Information

What not to test for

Turbidity – Not a concern; only in groundwater

Temperature – influences organism function (testing for this already)

Alkalinity – not practical to test for

Dissolved Oxygen – not practical to test for

Nitrites/Nitrates/Ammonia – previous tests came out negative

Phosphates – influences organism function (testing for this already)

Chlorine – we know it's not present

What to test for

E. coli – Plate count and P/A

pH

Color – observation (see table below)

Iron – just ask families about taste

Qualitative Observations

Water Observations	Possible Contaminants
Foamy	Detergents
Black in colour	Manganese, bacteria growth
Brown, yellow or reddish in colour	Iron
Dark brown or yellow in colour	Tannins and pigment from leaves and back
White deposits or scale	Hardness, dissolved metals
Earthy, fishy, muddy, peaty odour	Organic matter, algae, bacteria
Rotten egg odour	Hydrogen sulphide
Chlorine odour	Chlorine residual from water treatment process
Bitter or metallic taste	pH, zinc, copper

Acceptable pH is 6.0 to 8.5

Water Committee Meetings

During the trip, the team plans on having, at a minimum, two official meetings with the Guachthu'uq Water Committee. Ideally we would like to meet with them the first or second day of our arrival to the community to work out and finalize some of the implementation details. Major topics of discussion are outlined below.

- Involve Committee with Water Quality Tests
    - The team would like to have one or two members of the Water Committee perform a few of the water quality tests (outlined in this report) with a member of the travel team.
    - Roberto's wife, Elidia, is the best option for this because of her past involvement with the team, the water committee, and the fact that the tests will be conducted on her family's tanks.
    - The goal of involving members of the Water Committee with the water quality tests is to bring to light the issues with bacteria in the tanks. Hopefully, the visualization of bacteria in the water quality tests and the explanation of how the tests work will help the community understand the importance of maintaining the systems and ensuring the tanks are kept as clean as possible.
- Pick two more homes for May trip (replacements)
    - Even though we are implementing on two homes now during an extra trip, we still want to implement on ten homes in May 2014 as originally planned. We need the Water Committee to determine which additional two homes will be added to the list for May.
    - The travel team will then need to complete a full assessment of the two new homes.
- Discuss amendments to the Memorandum of Understandings
    - We need to revisit the two MOU's created during the May 2013 trip, ensuring that bother are up-to-date and still reasonable as the project progresses.
    - Specifically, we need add to the Beneficiary MOU to cover details about expected monetary contributions, what the system is defined as (gutters, tank, etc.), and the expectations of help from previous beneficiaries during future trips.
    - We also want to talk about the Water Committee MOU to better determine their active role in the community.
- Discuss the Water Committee's Role in Guachthu'uq
    - What have you been doing while we were gone?
    - What plans do you have?
    - How can we work together better to ensure the success of the rainwater harvesting systems?

Community Evaluation

Located in the appendix is a series of questions and talking points to help analyze the sustainability and success of the project. The responses to these interviews and questions will induce discussion of modifications to the system design, EWB-USA WPI's social contact and community impact. For this result to occur the questions and interview topics vary significantly. The first set of questions revolves around the data collection of a family's water consumption. This will assist EWB-USA WPI to understand

how accurate the data is through which the group is drawing conclusions. Now that the community has been collecting this data for about 25, these questions will help assess if this method of data collection is accurate and the best way to collect this information. If not, this data collection and the conversations with Alvaro and the families may have to be redesigned, in order to improve accuracy and the communication and social relationship between EWB and the community.

Questions concerning the rainwater harvesting systems physical design are also asked. These questions fill identify flaws and problem areas in the design and how they can be improved. These interviews will also serve as data collection for the systems in place. Since three different tanks now exist in the community, implemented by three separate groups, it is important to assess them to determine pros, cons, design decisions and system quality. Finally, a series of interviews will be conducted with the water committee. These questions will more clearly establish the role and purpose of this committee in the community. However, these questions will also create goals of the committee, which can be evaluated and monitored as we go into the future.

To see these questions, please refer to the appendix B.

Community Mapping

We aim to improve this map with GPS coordinates and altitudes at various locations along the road.

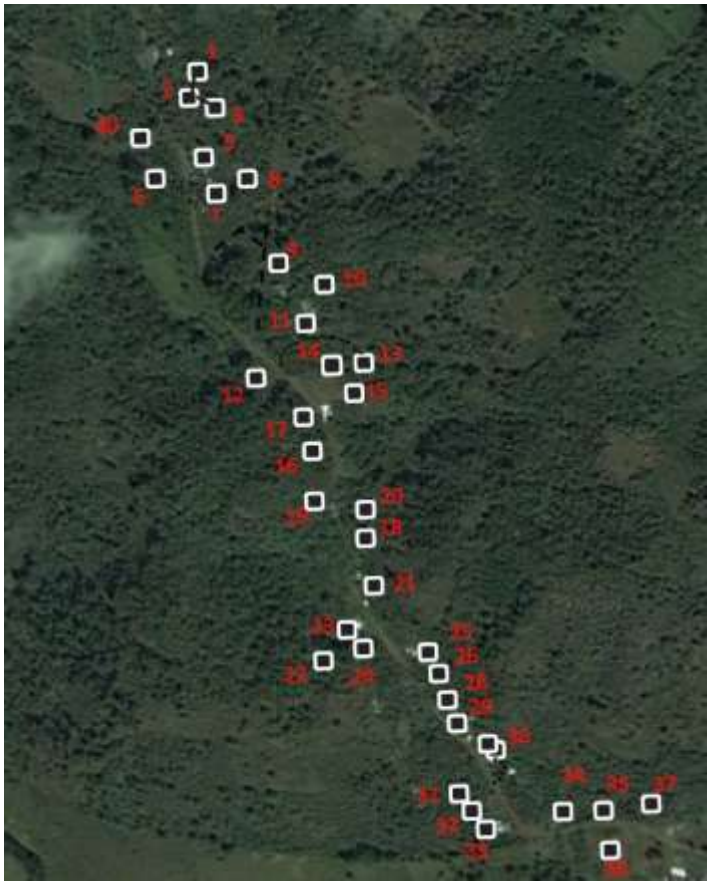

Figure 8: Current map of the community.

Additional Items

- Discuss invoices and accounting with Sucy
    - Take the time to go over the documents surrounding the bank account that Sucy has for this project
    - Discuss better way to transfer money
        - Through Western Union: cheap and fast, but Sucy has to collect at a Western Union
        - Through partnering bank: slow and slightly expensive, but the money goes straight to the account set up
    - Collect copies of receipts of all transactions made in relation to the project
        - Payments to Alvaro for monitoring
        - Purchase of materials in preparation for implementation
- Create a Memorandum of Understanding with Alvaro
    - Need a document outlining both Alvaro's and EWB-USA WPI's expectations of his monitoring role during the year
    - This will also officially outline his reimbursement
- Review the monitoring data and process with Alvaro
    - Gain more feedback on how the monitoring system is working, i.e. are all the families comfortable using it, does Alvaro think it makes sense
    - Ask about specific data that seems off, i.e. one family using the exact same amount of water each week
    - Suggestions for improvement of survey and process
- Create a focus on Planning Monitoring Evaluation and Learning (PMEL)
    - EWB-USA has laid down new ground rules this year for their expectations of project monitoring and evaluation (900 series forms)
    - One person on the travel team will familiarize themselves with EWB-USA's expectations and see where adjustments in our process can or need to be made

Appendix A

Proof of Overflow Sizing

To create an adequate overflow system, the amount of water exiting the tank through the overflow pipe needs to be equal to the amount of water entering the tank from the gutters/downspout. As with the calculations for appropriate sizing of the downspout, we looked at the situation of a 100 m^2 roof coupled with the peak rainfall per minute from our recent rain data to create a maximum flow scenario.

Maximum Average Rainfall in a five minute period: 0.072 inches/minute

Maximum Roof Area: 100 m^2

$$Q_{in} = Roof\ Area * Rainfall$$

$$Q_{in} = 0.003048 \frac{m^3}{s}$$

Desired Size of Outflow Pipe: 2 inch diameter

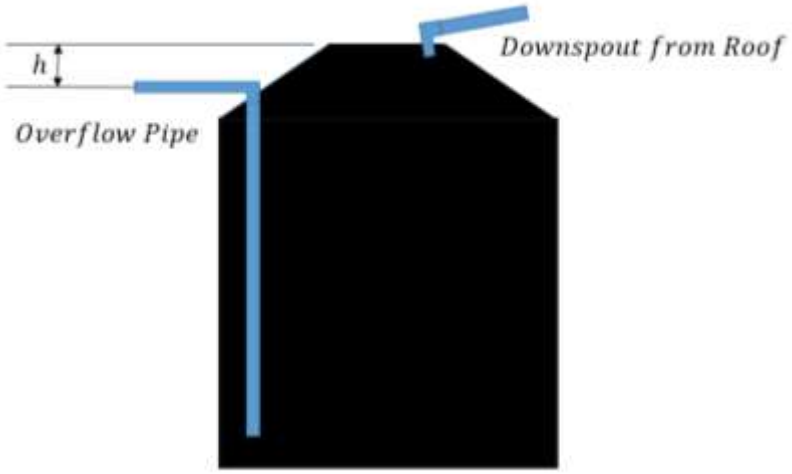

Figure 9: Diagram of typical tank with overflow pulling water from the bottom.

$$Q_{in} = Q_{out}$$

The flow out is dependent on the height of water in the tank. To determine the necessary space (h) between the very top of the tank and the overflow pipe, the following conservation of energy calculations were performed. The left side of the equation is taken inside the tank as the water level is rising, and the right side of the equation is taken at the end of the overflow pipe.

$$\frac{P_1}{\rho} + \frac{{V_1}^2}{2} + gz_1 = \frac{P_2}{\rho} + \frac{{V_2}^2}{2} + gz_2$$

$$P_1 = P_2 = P_{atm}$$

$$z_1 - z_2 = h$$

$$V_1 \approx 0$$

Both points of interest are at atmospheric pressure, the difference in elevation is represented by h, and the velocity of the water rising in the tank is considerably less than the velocity of the water flowing out of the overflow pipe so it is approximated at zero. Rearranging the equation to solve for the velocity through the overflow pipe…

$$V_2 = \sqrt{2gh}$$

$$Q_{out} = A_{pipe} * V_2$$

$$h = \frac{\frac{Q_{out}}{A_{pipe}}^2}{2g}$$

Using a 2 inch diameter overflow pipe, the flow rate 0.003 m^3/s, and gravity as 9.81 m/s^2, this shows the height between the overflow pipe and the top of the tank to be 3.02 inches.

Appendix B

Data Evaluation – The purpose of the following questions are to gauge how families are recording their water consumption in order for EWB-USA WPI to understand their usage. Having an understanding of their usage will help the team to further understand how to improve the systems and the communities understanding on how to use them. For example, the quantity of water a family uses will inform us if more tanks (storage) or a larger roof area (collection) are needed in order to sustain their lifestyle. Knowing how they use the systems will help us to evaluate if the families have understood what we have taught them, for example use the water from the tanks to drink from, and finca for clothes and gardens.

1.) Tell me how your collect your water each day, explain to me your logic in making that estimate?
    a. Do they collect a certain amount each day
    b. Take a photograph if they use a container
2.) If you recorded using tank water and do not have a tank, whose water are you using? Do you have some sort of system worked out with the other family?
3.) Tell me about how you use water in your cooking. Encourage them to show us the amount of water used.
    a. Show me how you use it in food preparation
    b. Show me how you use it to actually cook the food
    c. Show me how you clean dishes or clean up after a meal
4.) Explain to me how you wash your clothes, tell me where and specifically how you rinse the clothing.

a. What containers are used to rinse the clothing (take a photo)

5.) At the end of July (middle of summer) were there any issues obtaining water? Was there a lack of water? Problems with the systems?
6.) Walk me through your interactions with Alvaro when he comes to the community to collect the data? What are your conversations about? Do you ever ask him questions about the data sheets he is collecting?

Evaluation of Existing Solutions: An evaluation of the current solutions will consist of an analysis of all current tanks in the community. Their physical condition will be assessed by the following:

1.) Breaks and leaks on the physical structure
2.) Broken supports for the gutters
3.) Water quality tests (specifically coli)
4.) Description of algy growth within the tank
5.) Noting any contents in the water (bugs to other foreign objects)
6.) Smell of water (If stagnant)
7.) Analysis of the condition of the roof (damage and debris)

Additional notes will be made concerning the cleaning, system repairs and breaks will be noted in charts. The headings for these charts are listed below in this document:

General Information

Government Tank; EWB Tanks; Spanish Embassy Tanks

1.) Who owns the tank and whose land does it sit on?
2.) Approximate age of the tank?
3.) Structural problems with the systems?
4.) Is it cleaned? If so how frequently?
5.) Do the people who use that tank, do they have issues using the water from that tank? Do they prefer another water source?
6.) What is the tank mainly used for (drinking etc.)
7.) What types of structural or functional problems have occurred with the system?

- After discussing all of these ask them which tank do they prefer to use and why? As them to compare and contrast the pros and cons to each of the tanks they have access to?

System Cleanings

- Time Cleaned (Date) MAKE NOTE OF THIS WHEN CONDUCTING THE WATER TESTS
- Parts cleaned (Tank, gutter etc.
- Cleaning products used
- Concerns with cleaning tanks
- Description of what was done

Questions

- Did you wait for the tank to be empty to do the cleaning?

- How would you feel about using some of the water in order to clean the tanks? This water would no longer be potable, but you would have the ability to use it for washing or other activities except consumption?
- Please tell us of any chemicals, chlorine etc. that you may have used to clean the tanks?

System Repairs and Breaks (Apply to all 3 types of tanks)

- Time of Break
- Part or portion broken (take photograph)
- How did the break happen?
- Were you able to find arts to repair the system? If so where did you find them?
- How long did it take to fix and did you have to take time off from work to fix the tank?
- Description of how community member fixed the problem (If applicable)
- Any design suggestions to help improve the design

1.) What concerns do you have with the system after these failures or problems with the system?
2.) What likes and dislikes do you have with the system? This can vary from the location of the system, to cleanliness, to social relations in the community? Tell me about your experience with the tanks.
    a. Hopefully, this question will start some dialog to personal feelings in the community along with impacts on the social relationships in the community. Maybe this will help us to obtain information like that received from Professor Bob Hersh

Questions for the Water Committee

The questions will allow the group to draw conclusions into the social aspects of our project in the community. These questions will open the door to what has been occurring in the community. Since our presence in Guatemala the development of the water committee as well as the decision of a need based selection system demonstrates positive social impact.

1.) Ask about the current members
2.) What types of rolls do you have in the community?
3.) Do the members get together and meet? If so what are the topics of these conversations?
4.) What types of leadership have emerged in the committee? Is one person an expert in one thing while another is in charge of something else?
5.) What types of general concerns have come up in the community concerning the rainwater system implementation?
6.) What are your visions for the water committee?
7.) What do you see as the main role of the committee?
8.) What sort of responsibilities do or should the members of this committee have?
9.) As community members, what do you need more from EWB-USA WPI?
10.) How are the interviews with Alvaro going? Do you have good conversations with him? Are people generally expressing their concerns with him?