Document 525
PRE-IMPLEMENTATION REPORT

CHAPTER: Greater Austin
COUNTRY: Panama
COMMUNITY: Sieykin
PROJECT: Water Project
TRAVEL DATES: June 26-Aug 19

PREPARED BY

April 18, 2010
ENGINEERS WITHOUT BORDERS-USA
www.ewb-usa.org

Document 525 - Pre-Implementation Report
Greater Austin
Sieykin, Panama
Water Project

Table of Contents

Pre-Implementation Report Part 1 – Administrative Information

1.0 Contact Information

	Name	Email	Phone	Chapter
Current Project Lead #1				Greater Austin
Current Project Lead #2				Greater Austin
Previous Project Lead				Greater Austin
President				Greater Austin
Mentor #1 (Assessment Trip I)				Greater Austin
Mentor #2 (Assessment Trip II)				N/A
Mentor #3 (Assessment Trip II)				N/A
Mentor #4 (in Austin)				Greater Austin
Mentor #5 (in Austin)				N/A
Mentor #6 (in Austin)				Greater Austin
Mentor #7 (in Austin)				Greater Austin
Mentor #8 (Implementation I)				Greater Austin
Mentor #9 (Implementation I)				Greater Austin
Mentor #10 (Implementation I)				Greater Austin
Health and Safety Officer				Greater Austin
Asst Health and Safety Officer				Greater Austin
NGO/Community Contact				N/A
Education Lead				Greater Austin

2.0 Travel History

Dates of Travel	Assessment or Implementation	Description of Trip
January 5 – 17, 2009	Assessment I	This was the first assessment/exploration trip to verify that the entire community wanted to partner with EWB Greater Austin, and to define the scope of the project with the community.
August 1 – 23, 2009	Assessment II	This was the second assessment trip to collect further data/information for implementation, discuss designs with the community, and to initiate a community-wide health education and hand washing campaign.

3.0 Travel Team

Name	E-mail	Phone	Chapter	Student or Professional
			AUS	Professional
			AUS	Student
			AUS	Student
			AUS	Student
			AUS	Student
			AUS	Student
			AUS	Student
			AUS	Professional
			AUS	Student
			AUS	Student
			AUS	Student
			AUS	Student
			AUS	Student
			AUS	Professional

4.0 Safety

4.1 Travel Safety

4.1.1 State Department and International SOS Travel Warning

There are currently no US State Department travel warnings for Panama.

4.1.2 Point to point travel detail

July/August 2010 Assessment II Itinerary

Date	Activity/Location	Notes
June 26	Rachel/Natalie travel San Antonio to Changinola	Arrive in the evening in Changuinola
June 27	Changuinola	Stay in Changuinola; stay at hotel Semiramis
June 28	Changuinola to Sieykin	Leave in morning for Sieykin (bus to Puerto Silencio, boat to Sieykin)
June 29-July 2	Sieykin	Rachel/Natalie will be between Changuinola/Sieykin for materials procurement
July 1	Corrie/Group 1 San Antonio to Changuinola	Arrive in the afternoon in PTY; Overnight bus to Changuinola (arrive July 2)
July 2	Everyone in Changuinola	Group stays in Changuinola; stay at Hotel Semiramis
July 3	Changuinola to Sieykin	Leave in morning for Sieykin (bus to Puerto Silencio, boat to Sieykin)
July 4-20	Sieykin	Implementation
July 9	Rachel travels Sieykin to Changuinola; Changuinola to Panama City	Leave Sieykin in morning (8 am), arrive in Changuinola 11 am; Take flight to Panama City from Changuinola
July 10	Rachel travels Panama City to Austin	Flight arrives in San Antonio at 4:13pm
July 21	Group 1/Corrie/Natalie: Sieykin to Changuinola; Group 1: Changuinola to Panama City Corrie/Natalie: Changuinola to Bocas	Leave Sieykin in morning (8 am), arrive in Changuinola 11 am; Take flight to Panama City from Changuinola Take bus from Changuinola to Bocas
July 22	Group 1: PTY to Austin	Flight leaves Panama at 10:05am
July 22-27	Corrie/Natalie stay in Panama	Stay in Bocas
July 28	Corrie/Natalie: Bocas to Boquete	Bus from Bocas to David, David to Boquete
July 29	Group 2 travel San Antonio to Panama City Corrie/Natalie in Boquete	Arrive late afternoon in PTY; Overnight bus to Changuinola (arrive July 30) Meet with Boquete Rotary
July 30	Corrie/Natalie meet group in Changuinola	Corrie/Natalie take bus Boquete to David, David to Changuinola Group stays in Changuinola; stay at Hotel Semiramis
July 31	Changuinola to Sieykin	Leave in morning for Sieykin (bus to Puerto Silencio, boat to Sieykin)
August 1-17	Sieykin	Implementation
August 10	Chris travels Sieykin to Changuinola; Changuinola to Panama City	Leave Sieykin in morning (8 am), arrive in Changuinola 11 am; Take flight to Panama City from Changuinola
August 11	Chris travels Panama City to Austin	Flight arrives in San Antonio at 4:29pm
August 18	Corrie/Natalie/Group 2: Sieykin to Changuinola; Changuinola to Panama City	Leave Sieykin in morning (8 am), arrive in Changuinola 11 am; Take flight to Panama City from Changuinola; Overnight in Panama City
August 19	PTY to Austin	Flight leaves Panama at 10:05am

Daily Travel/Lodging Details

- The EWB group will have a Travel Guide Book for Panama to help (should the need arise) in locating reliable restaurants, hotels, etc.
- All EWB group members will have a Katadyn self-purifying water bottle for all drinking water consumed outside of Panama City.

Day 1: U.S. to Panama – Rachel/Natalie

Travel: San Antonio to Panama City

- Austin to San Antonio: Rachel and Natalie will leave Austin to drive to San Antonio Airport (1.5 hr drive)
- Panama City to Houston: Continental flight to Panama City (via Houston) departure times:
  - Flight CO1675/875: Depart San Antonio 7:00 AM, arrive Panama City 1:04 PM ($625.70 per person w/tax, round trip[1])
- Panama City to Changuinola: Rachel/Natalie will take a registered airport shuttle to Albrook Terminal to catch a bus to Changuinola:
  - Bus departs Albrook Terminal 8:00pm, arrive Changuinola 6:00am ($24 per person w/tax[1])
- Rachel/Natalie will walk or take a taxi to Hotel Semiramis.

Lodging: Overnight on bus

Food/Water:

- Group 1 will purchase airport food for breakfast and lunch, and will eat dinner at Albrook Mall.

Day 2 (June 27) – Rachel/Natalie

Travel: Changuinola to Sieykin

- Changuinola to Puerto Silencio: group walks to bus terminal for Puerto Silencio; buses depart every half hour; 15 min bus ride.
- Puerto Silencio to Sieykin: Edwin/other community members meet Rachel/Natalie at Puerto Silencio and transport group via motor canoes to Sieykin.
- EWB group walks with community members from shore to community (15-20 minute walk).

Lodging: Sieykin.

Food/Water

- Breakfast: Restaurant in Changuinola, nearby hotel.
- Lunch/dinner: Sieykin[2].

Day 3 (June 28) – Rachel/Natalie

Travel: Group remains in Changuinola; Rachel and Natalie will meet/stay with group in Changuinola

Lodging: Changuinola: Hotel Semiramis

Food/Water

- Breakfast/Lunch/Dinner: Restaurant in Changuinola, nearby hotel.

Day 4 – 7 (June 29-July 2) – Rachel/Natalie

Travel: Rachel/Natalie will travel between Changuinola/Sieykin as needed to transport materials with the community.

Lodging: Sieykin

Food/Water: Purified stream water using Katadyn water bottles and cooked food in Sieykin.

---

[1] Prices as of April 10, 2010.

[2] There are several community members who cook all meals for the EWB group throughout the stay in the community.

<u>Day 6 (July 1) - Group 1/Corrie</u>
Travel: San Antonio to Panama City
- Austin to San Antonio: Group 1 will leave Austin to drive to San Antonio Airport (1.5 hr drive)
- Panama City to Houston: Continental flight to Panama City (via Houston) departure times:
  - Flight CO3140/875: Depart San Antonio 7:25 AM, arrive Panama City 1:05 PM ($625.70 per person w/tax, round trip[3])
- Panama City to Changuinola: Group 1 will take a registered airport shuttle to Albrook Terminal to catch a bus to Changuinola:
  - Bus departs Albrook Terminal 8:00pm, arrive Changuinola 6:00am ($24 per person w/tax[1])
- Group 1 will walk or take a taxi to Hotel Semiramis.

Lodging: Overnight on bus
Food/Water:
- Group 1 will purchase airport food for breakfast and lunch, and will eat dinner at Albrook Mall.

<u>Day 7 (July 2) – Group 1/Corrie/Rachel/Natalie</u>
Travel: Group remains in Changuinola; Rachel and Natalie will meet/stay with group in Changuinola
Lodging: Changuinola: Hotel Semiramis
Food/Water
- Breakfast/Lunch/Dinner: Restaurant in Changuinola, nearby hotel.

<u>Day 8 (July 3) – Group 1/Corrie/Rachel/Natalie</u>
Travel: Changuinola to Sieykin
- Changuinola to Puerto Silencio: group walks to bus terminal for Puerto Silencio; buses depart every half hour; 15 min bus ride.
- Puerto Silencio to Sieykin: Edwin/other community members meet Group 1 at Puerto Silencio and transport group via motor canoes to Sieykin.
- EWB group walks with community members from shore to community (15-20 minute walk).

Lodging: Sieykin.
Food/Water
- Breakfast: Restaurant in Changuinola, nearby hotel.
- Lunch/dinner: Sieykin[4].

<u>Day 9 – 25 (July 4-20) – Corrie/Group 1</u>
Travel: Group remains in Sieykin
Lodging: Sieykin
Food/Water: Purified stream water using Katadyn water bottles and cooked food in Sieykin.

---
[3] Prices as of April 10, 2010.
[4] There are several community members who cook all meals for the EWB group throughout the stay in the community.

<u>Day 14 (July 9) – Rachel only</u>
Travel: Sieykin to Panama City

- Rachel will leave Sieykin and arrive in Changuinola late morning
  - Water taxi (motor boat) down the river to Puerto Silencio
  - Take bus from Puerto Silencio to Changuinola (buses come approximately every 15 min, 10 min ride to downtown Changuinola)
- Rachel will walk or take cab to Changuinola Airport from downtown; Aeroperlas flight departs Changuinola at 4:00 pm, arriving in Panama at 5:30 pm.

Lodging: Zuly's Backpacker's or Aly Dagang, Panama City
Food/Water

- Breakfast/Lunch: Changuinola restaurant/bakery
- Dinner: Panama City restaurant

<u>Day 15 (July 10) – Rachel only</u>
Travel: Panama City to Houston/San Antonio

- Rachel will take cab from hostel/Aly's to international airport in Panama City
- Continental Flight from Panama City to Houston/San Antonio (CO 873/1079):
  - Depart Panama City: 10:05 AM, arrive in Houston 2:10 PM, arrive in San Antonio: 4:13 PM

Lodging: Rachel returns home
Food/Water:

- Breakfast: hostel or restaurant in Panama City
- Lunch: Houston Airport
- Dinner: Home

<u>Day 26 (July 21) – Group 1/Corrie/Natalie</u>
Travel: Sieykin to Panama City

- Group 1/Corrie/Natalie will leave Sieykin in the morning (8 AM) and will arrive in Changuinola around 10:30 AM
  - Motor boat down the river to Puerto Silencio
  - Take bus from Puerto Silencio to Changuinola (buses come approximately every 15 min, 10 min ride to downtown Changuinola)
- Group 1 will walk or take cab to Changuinola Airport from downtown; Aeroperlas flight departs Changuinola at 4:00 pm, arriving in Panama City at 5:30 pm.
- Corrie/Natalie will take a bus from Chaguinola to Almirante (buses come every 20 minutes, 45 minute ride, $1.20)

Lodging: Group 1: Zuly's Backpacker's, Panama City
Corrie/Natalie: Hostel in Almirante
Food/Water

- Breakfast/Lunch: Changuinola restaurant/bakery
- Dinner: Group1: Panama City restaurant
  Corrie/Natalie: Almirante restaurant

Day 27 (July 22) – Group 1
Travel: Panama City to Houston/San Antonio
- Group 1 will take cab(s) from hostel to international airport in Panama City
- Continental Flight from Panama City to Houston/San Antonio (CO 873/6):
  - Depart Panama City: 10:05 AM, arrive Houston 3:30 PM, arrive San Antonio: 4:29 PM

Lodging: Group 1 returns home
Food/Water:
- Breakfast: hostel or restaurant in Panama City
- Lunch: Houston Airport
- Dinner: Home

Day 27 – 32 (July 22-27): Corrie/Natalie
Time off in Bocas

Day 33 (July 28): Corrie/Natalie
Travel: Bus from Almirante to David (bus ride takes 4.5 hours, $7)
Lodging: Boquete Rotary
Food/Water: Corrie/Natalie will purchase food in Boquete

Day 34 (July 29) – Group 2
Travel: Group 2: San Antonio to Panama City
- Austin to San Antonio: Group 2 will leave Austin to drive to San Antonio Airport (1.5 hr drive)
- Panama City to Houston: Continental flight to Panama City (via Houston) departure times:
  - Flight CO3140/875: Depart San Antonio 7:25 AM, arrive Panama City 1:05 PM ($625.70 per person w/tax, round trip[5])
- Panama City to Changuinola: Group 2 will take a registered airport shuttle to Albrook Terminal to catch a bus to Changuinola:
  - Bus departs Albrook Terminal 8:00pm, arrive Changuinola 6:00am ($24 per person w/tax[1])
- Group 2 will walk or take a taxi to Hotel Semiramis.

Lodging: Group 2: Overnight on bus
Corrie/Natalie: Boquete Rotary
Food/Water:
- Group 2 will purchase airport food for breakfast and lunch, and will eat dinner at Albrook Mall.
- Corrie/Natalie will purchase food in Boquete

Day 35 (July 30) – Group 2
Travel: Group remains in Changuinola; Corrie and Natalie will meet/stay with group in Changuinola (Bus from David to Changuinola depart every 30 minutes, 4.5 hours, $8/person)
Lodging: Changuinola: Hotel Semiramis
Food/Water
- Breakfast/Lunch/Dinner: Restaurant in Changuinola, nearby hotel.

[5] Prices as of April 10, 2010.

Day 36 (July 31) – Group 2/Corrie/Natalie

Travel: Changuinola to Sieykin

- Changuinola to Puerto Silencio: group walks to bus terminal for Puerto Silencio; buses depart every half hour; 15 min bus ride.
- Puerto Silencio to Sieykin: Edwin/other community members meet Group 2 at Puerto Silencio and transport group via motor canoes to Sieykin.
- EWB group walks with community members from shore to community (15-20 minute walk).

Lodging: Sieykin.

Food/Water

- Breakfast: Restaurant in Changuinola, nearby hotel.
- Lunch/dinner: Sieykin[6].

Day 37 – 53 (August 1-17) – Group 2/Corrie/Natalie

Travel: Group remains in Sieykin

Lodging: Sieykin

Food/Water: Purified stream water using Katadyn water bottles and cooked food in Sieykin.

Day 46 (August 10): Chris only

Travel: Sieykin to Panama City

- Chris will leave Sieykin and arrive in Changuinola late morning
  - Water taxi (motor boat) down the river to Puerto Silencio
  - Take bus from Puerto Silencio to Changuinola (buses come approximately every 15 min, 10 min ride to downtown Changuinola)
- Chris will walk or take cab to Changuinola Airport from downtown; Aeroperlas flight departs Changuinola at 4:00 pm, arriving in Panama at 5:30 pm.

Lodging: Zuly's Backpacker's

Food/Water

- Breakfast/Lunch: Changuinola restaurant/bakery
- Dinner: Panama City restaurant

Day 47 (August 11) – Chris only

Travel: Panama City to Houston/San Antonio

- Chris will take cab from hostel to international airport in Panama City
- Continental Flight from Panama City to Houston/San Antonio (CO 873/1079):
  - Depart Panama City: 10:05 AM, arrive in Houston 2:10 PM, arrive in San Antonio: 4:29 PM

Lodging: Chris returns home

Food/Water:

- Breakfast: hostel or restaurant in Panama City
- Lunch: Houston Airport
- Dinner: Home

[6] There are several community members who cook all meals for the EWB group throughout the stay in the community.

<u>Day 54 (August 18) – Group 2/Corrie/Natalie</u>
Travel: Sieykin to Panama City

- Group 2 will leave Sieykin and arrive in Changuinola in the morning
    - Motor boat down the river to Puerto Silencio
    - Take bus from Puerto Silencio to Changuinola (buses come approximately every 15 min, 10 min ride to downtown Changuinola)
- Group 2 will walk or take cab to Changuinola Airport from downtown; Aeroperlas flight departs Changuinola at 4:00 pm, arriving in Panama City at 5:30 pm.

Lodging: Zuly's Backpacker's, Panama City
Food/Water

- Breakfast/Lunch: Changuinola restaurant/bakery
- Dinner: Panama City restaurant

<u>Day 55 (August 19) – Group 2/Corrie/Natalie</u>
Travel: Panama City to Houston/San Antonio

- Group 2 will take cab(s) from hostel to international airport in Panama City
- Continental Flight from Panama City to Houston/San Antonio (CO 873/6):
    - Depart Panama City: 10:05 AM, arrive in Houston 3:30 PM, arrive in San Antonio: 4:24 PM

Lodging: Group 2 returns home
Food/Water:

- Breakfast: hostel or restaurant in Panama City
- Lunch: Houston Airport

4.1.3 On-the-ground phone number and email for travel team

4.2 Site Safety – Health and Safety Plan

Health and Safety Plan attached.

5.0 Budget

5.1 Cost

Expense	Total Cost
Airfare	$11,555.50
On Ground	$3,692.50
Materials	$9,679.00
Other	$2,300.00
Total	$27,227.00

5.2 Hours

Names	# of Weeks	Hours/Week	Trip Hours	Total Hours
Project Leads				
	34	10	1200	1540
	34	10	1320	1660
Mentors				
	10	3	528	558
	34	1.5	0	51
	34	1.5	0	51
	34	1.5	0	51
	10	1.5	528	543
	10	1.5	0	15
	6	1.5	528	537
Other Team Members				
Travelers (10)	34	3	5280	6300
Other Members (20)	34	1.5	0	1020

5.3 Donors and Funding

Donor Name	Type (company, foundation, private, in-kind)	Account Kept at EWB-USA?	Amount
Total Amt Raised			$ 23,609.70

6.0 Project Location

Longitude: 82°40'50.92"W
Latitude: 9°23'58.85"N

7.0 Project Impact

Number of persons directly affected: 200
Number of persons indirectly affected: 400

8.0 Mentor Resume

Please refer to Appendix F for the resumes of Tim Ager, Chris Mansuri, and Eric Thurman.

Pre-Implementation Report Part 2 – Technical Information

1.0 INTRODUCTION

The purpose of this document is to identify the chosen design option and provide the design of the proposed water treatment and distribution system the EWB-Greater Austin Chapter plans to build for the central sector of the community in Sieykin, Panama. For a thorough analysis demonstrating how the project team came to this final design, please refer to Appendix E for our Alternative Analysis Report.

The design consists of two components, a potable and non-potable water system. The potable system will provide the community with a reliable source of clean water for drinking, cooking, and dishwashing by utilizing source protection, while the non-potable system will consist of upgrading their current system to provide the quantity of water the community requires for the purposes of bathing and laundry. This report addresses how the water will be collected and protected from the source for the potable system, and how the water will be collected and filtered for the non-potable system. It also addresses the distribution and storage of the water from each system.

This report includes the design for one component of a larger project. The community of Sieykin consists of five different sectors, each with their own unique needs with respect to water collection and distribution. This implementation trip is the first of many to improve health conditions and quality of life by providing all community members with potable drinking water, a reliable water distribution/storage system, and eventually safe sanitation infrastructure.

2.0 PROGRAM BACKGROUND

Introduction/Background

The Panama Project was launched in spring 2008. The project began immediately following an EWB member's return from a semester abroad in Panama with the SIT Panama program. After traveling throughout the country and making contacts through SIT, the EWB member worked with a partner NGO (La Alianza para la Conservación y el Desarrollo, or the Alliance for Conservation and Development, ACD) and SIT to identify a community where an EWB project would be feasible. This decision was based on safety in the community, familiarity of SIT and ACD with the community, the community's need for a project, and the predicted involvement of community members. SIT provided the contact information of the community members that coordinate SIT's program in the Naso community of Sieyic, which is across the river from the EWB Greater Austin project community of Sieykin. Communication was immediately initiated with Sieykin via the main contact, Edwin Sanchez. The EWB Greater Austin group remained in contact with the community via Edwin for approximately one year prior to the first EWB trip to the community. During this year, Edwin arranged various community-wide meetings to discuss the community's desire to partner with EWB, as well as gathered preliminary information for the EWB group to complete the EWB-USA 501 project submission application. The EWB Greater Austin group traveled to Sieykin in January 2009 for the first needs assessment trip.

The project is located in northwestern Panama in Sieykin, a community consisting of 400 people which belongs to the indigenous group of the Naso. Among the smallest and most impoverished indigenous groups in Panama, the Naso people number only 3,300 people. Houses are made from locally harvested wood. There are no roads or vehicles in Naso communities; all transportation is carried out on foot, in motorized canoes, by bamboo raft, and by horse. The Naso people retain the last monarchy governance system in the Americas.

Community Need

The community, and most of the Naso people, lack access to many basic services, including water treatment, a reliable water distribution system, sanitation infrastructure, comprehensive health services, and electricity. This lack of access to basic services in Sieykin has resulted in numerous health and community development issues. The people of Sieykin consistently suffer from diarrhea, vomiting, fever, and other water-related illnesses due to contaminated drinking water. There are also other health issues identified in the community, the most common involving skin problems and respiratory illnesses.

Water testing from both assessment trips ascertained that community water contains the presence of E. Coli and/or coliforms, indicating that fecal contamination and harmful pathogen presence in the community's water is highly likely. Many community members do not have a water distribution system that comes to their home. For the areas that do have water distribution, the system is old and unreliable, often requiring community members to drink water from surface water streams, open to contamination from humans and animals. The existing water system is gravity fed from the source, which is a network of mountain springs. Most community members utilize some version of an open-pit latrine for sanitation services; however, these latrines are not always strategically located or kept clean.

EWB Greater Austin Assessment Trip I and II

The first assessment trip to the community was undertaken in January 2009 by five EWB Greater Austin members, one professional mentor, and 2 UT graduate nursing students. The principal goal of the first assessment trip was to become familiar with the community of Sieykin in northwestern Panama to determine if residents would like to partner with EWB Greater Austin in a project, as well to assess the needs of the community. Tasks completed on the trip included performing numerous community meetings, water testing, land surveying, community in-home interviews, a materials survey, a community health assessment, and a meeting with a local non-governmental organization (NGO) to discuss future collaboration and partnership. During this trip, the community decided that it would like to partner with EWB in a project, and identified its first project priority to be improvement of community water quality and water distribution. The EWB group gathered valuable information to begin forming preliminary design concepts to present to the community in the second assessment trip.

During spring semester 2009, the project group researched and begun developing preliminary design options for the community project. The group also developed plans to initiate a health campaign in the community in order to educate community members, as it pertains to clean water, sanitation, and hygiene.

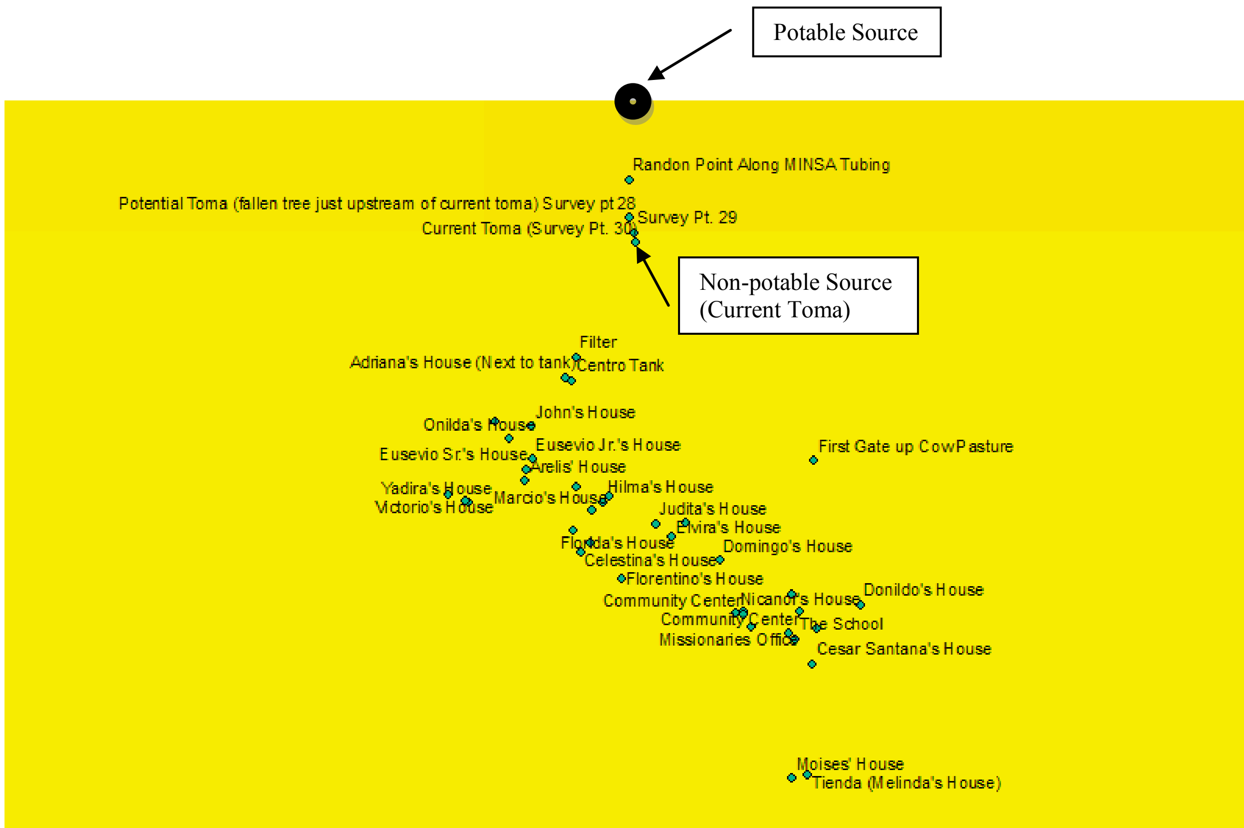
During the second assessment trip in August 2009, six EWB members and two professional mentors travelled to Panama to further assess the feasibility of this project and to collect detailed, additional information necessary for project implementation. One of the group's goals was to discuss project plans, management, and organization in detail with the community to ensure that the project is exactly what the community desires. This was done through individual household interviews and community-wide meetings. A second goal was to collect detailed additional information necessary for actual project implementation. This included identifying potential spring sources and collecting flow rate and water testing data at those sources to assess the feasibility of a closed spring system. Also, thorough survey data was collected of the potential pipe path and of every house in the sector of the community where initial implementation is planned. A third goal was to meet with governmental and non-governmental agencies in-country to gain support and assistance with the project. The final goal for this assessment trip was to launch a health and hygiene campaign in the community to teach them about waterborne illness, person to person disease transmission, and the importance of hand washing.

Document 525 - Pre-Implementation Report
Greater Austin
Sieykin, Panama
Water Project

3.0 FACILITY DESIGN

3.1 Description of the Proposed Facilities

3.1.1 Map of area with construction locations indicated.



Map 1: Relative Locations of Houses in Community and Key Surveying Points

Please see AppendixC for Map 2: Piping Network

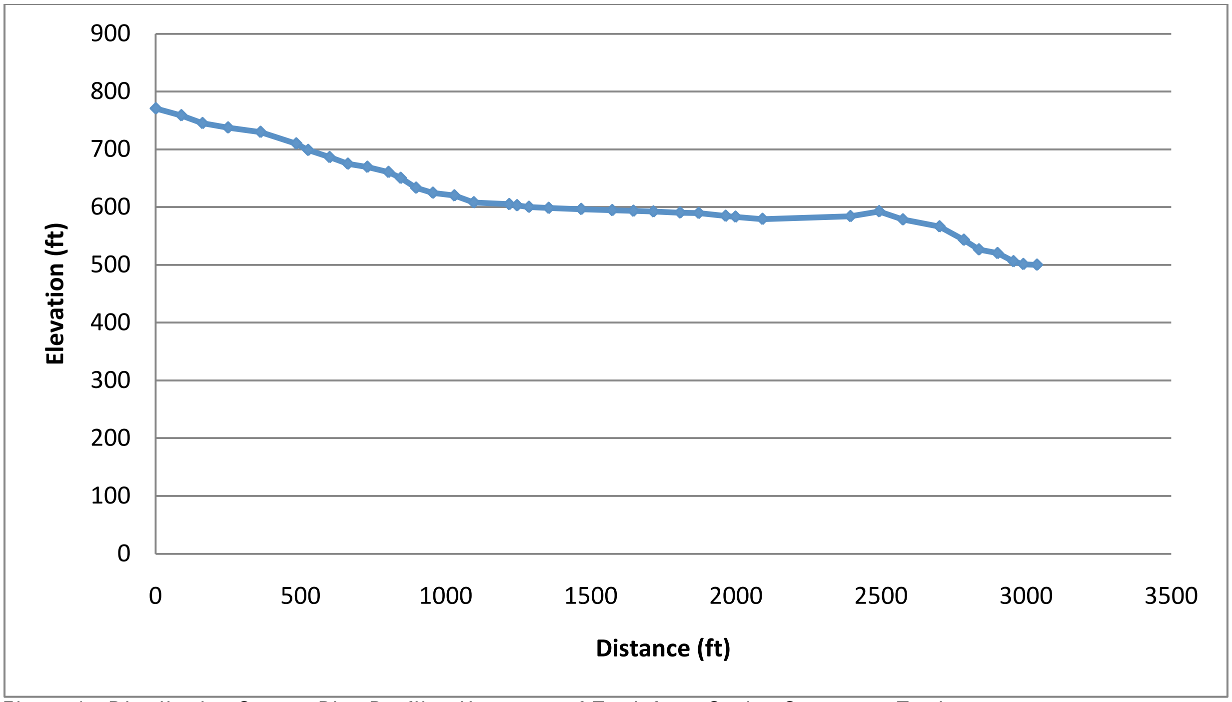


Figure 1 : Distribution System Pipe Profile - Upstream of Tank from Spring Sources to Tank

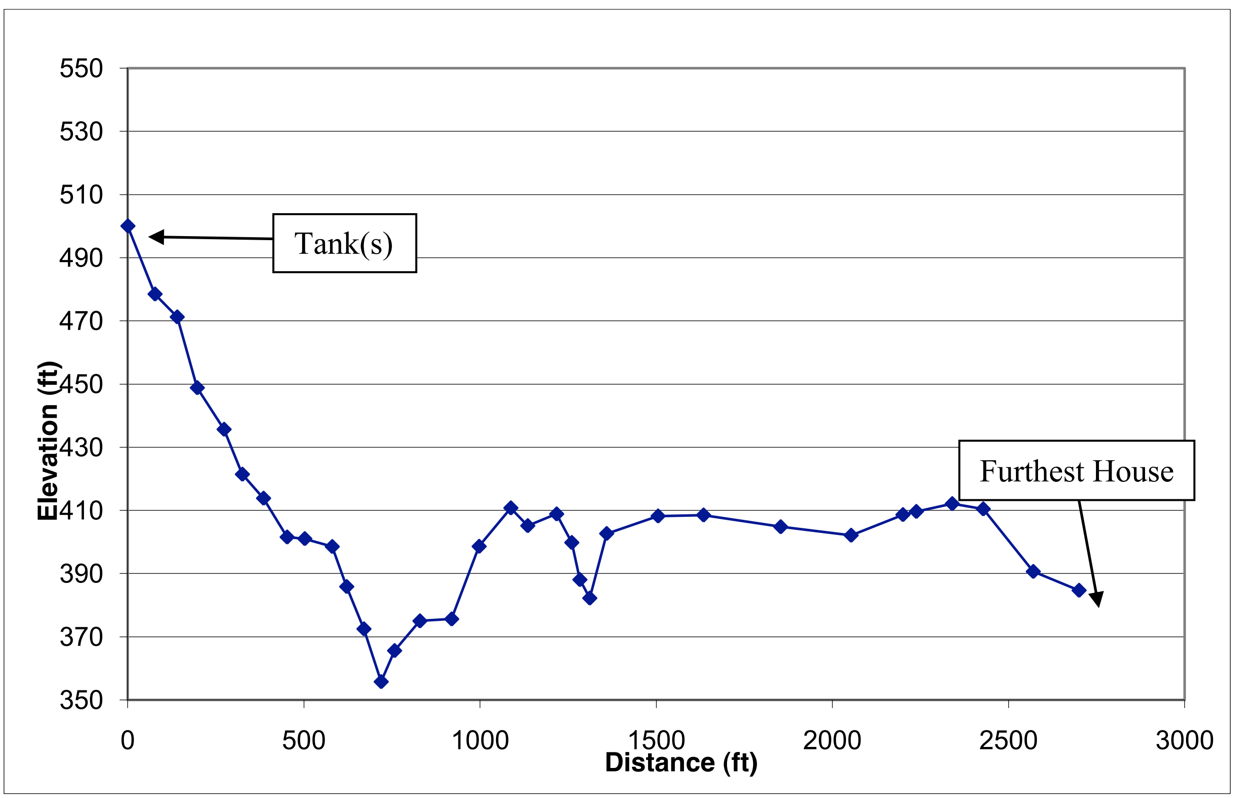


Figure 2: Distribution System Pipe Profile – Tank to Furthest House

3.1.2 Demand

The estimated daily required water supply volume is based on the population of the Centro sector. According to the interviews conducted on the second assessment trip and the average number of people in each home, there are approximately 150 people in the Centro sector. Using an annual growth rate of 2% (According to the CIA (Central Intelligence Agency)[1] ,Panama's national average growth rate is about 1.5%, but given larger family size in indigenous tribes, we added 0.5%to this rate to be conservative) and a basic population growth equation,

$$p_{fa} = p_0\left(1 + \frac{k * n}{100}\right)$$

where p_o is the current population, n is the design life of fifteen years, and k is the population growth rate, the population is estimated to grow to 195 people fifteen years from now. To simplify calculations, this is rounded to 200 people.

The supply and distribution system design are based on this conservative estimate to provide a system that can sustain the community for at least the next fifteen years. The World Health Organization (WHO)[2] suggests a minimum of 50 liters/person/day of potable water for proper health and hygiene. Panama's Ministry of Health (MINSA)[3] recommends a minimum of 114 liters/person/day and the United Nations[4] suggests a minimum of 15-20 liters/person/day. Due to the water usage habits of the community and the recommendations of Peace Corps volunteers[5], combined non-potable and potable demand of 200 liters/person/day will be used for this project. Though the system will not need to provide water for agriculture or animals, large quantities of water are used for washing clothes. Currently, the community is not very concerned with water conservation, and taps are usually left running. Though we intend to encourage change, we understand that the old habits will result in higher daily water use. It is possible that if the system does not meet expectations and does not supply enough water, the community might decide to bypass the new system and will be less inclined to maintain the system. The 200 liters/person/day will meet the community's needs.

It was decided that one fourth of this total water demand will be potable water. This means that 50 liters/person/day will be potable and 150 liters/person/day will be non-potable. This gives each person as much potable water as the WHO[2] recommends for total water and will provide enough water for drinking and cooking and other potable needs.

3.1.3 Supply

Please see Appendix D for Water Testing Data

The flow rates for three springs were measured during Assessment Trip II and can be seen in Table 1. These flow rates are then translated into daily totals in Table 2 (the total volume of water that each spring gives in a day).

Spring A	Spring C	Spring D
19.85 L/min	27.22 L/min	13.68 L/min
9.75 L/min		

Table 1- Flow Rates for Three Springs in the Central Sector

Note: Spring B was removed from this document as its flow was deemed insufficient

Spring A	Spring C	Spring D
28577 L/day	39191 L/day	19704 L/day
14043 L/day		

Table 2- Daily Totals of Water for the three springs

Members of the water committee have collected some data during our absence from the community for two of the springs. Wet season data can be found in Table 3, and dry season data, taken in March 2010, is given in Table 4. One of the springs has completely dried up during the dry season, but spring #2 is still giving sufficient water to supply the potable needs of the community. Because the dry season generally does not last longer than a few weeks, it is reasonably safe to say that Spring C will continue to produce sufficient water to meet the community's needs.

Spring A	Spring C
11.22 L/min	15.01 L/min
13.27 L/min	14.89 L/min
	15.19 L/min

Table 2- Additional flow rates measured by the Sieykin Water Committee

Spring A	Spring C
0 L/min	6.5 L/min
	6.5 L/min
	6.96 L/min

Table 3- Dry season flow rates measured by the Sieykin Water Committee

3.1.4 Source Protection

Water testing showed that the springs identified above provide potable water without treatment, and are in watersheds that appear to be safe from significant contamination sources such as agriculture or development. This clean spring water will be supplied to the Centro sector of the community. A spring box will be used to protect the emerging spring water from contamination from non-potable surface runoff and contamination from bugs and animals.

In order to capture the maximum amount of clean spring water, the area around the spring will be excavated until the spring is isolated to a single location, known as the eye of the spring. This excavation also includes digging downward to the confining subsurface layer to ensure that no water can escape beneath the spring box. Once the eye of the spring is found and isolated, the excavated area will be backfilled with cleaned rocks. Depending on the conditions of the confining layer beneath the spring, a concrete bed reinforced with a rebar grid may be poured to direct the water beneath the rock backfill. This will only be necessary if the confining layer is too permeable. A concrete top reinforced with a rebar grid will be poured to cover the rock backfill, protecting the clean water from surface runoff.

The spring box itself is a small poured and formed concrete structure reinforced with rebar. The back side of the box into which the clean water will enter will have a cut-out area approximately half the height of the box. This area will have a grate made of vertical rebar inserted through PVC pipe. This grate will prevent the rock backfill from entering the spring box. The front of the box will include three PVC outlet pipes. The clean-out pipe will enter at an angle through the floor of the spring box and will allow periodic flushing of sediment during maintenance. When not performing maintenance, the clean-out pipe should be capped. The outflow pipe will be connected to the pipeline to the potable water storage tank. The overflow pipe, located near the top of the box, will allow excess water to drain. The overflow pipe should include a mesh screen to prevent insects or animals from entering the spring box. The overflow pipe should drain onto a concrete pad to prevent erosion around the spring box.

The box will have a heavy, tight lid (also made of concrete) to keep out contamination while still providing a means of accessing the box to periodically remove accumulated sediment. This lid will be slightly mounded to shed water during periods of rainfall. Additionally, the lid will have four rebar handles to facilitate lifting by two people for maintenance.

The spring box will be anchored to the confining hard layer by a concrete footing at the bottom side of the front of the spring box. This footing should be poured into a dug-out area of the hard layer if possible. The footing will also prevent water from flowing beneath the spring box and eroding the soil beneath it.

A local mason will be hired to perform the concrete work involved in constructing the spring box. Actual sizing of the spring box and excavated area will be determined by local conditions, though an effort has been made to be conservative with the proposed design. Sand and gravel are locally available near the community but will have to be sifted to obtain proper grain sizes. A diversion ditch behind the excavated area will be dug during construction to minimize surface runoff over the spring box site.

3.1.5 Non-potable water source

The non-potable collection system will be in the same location as the current water collection system is located. A new collection system will be implemented that will use metal pipe for above-ground exposed piping which will then be connected to buried PVC pipe. Also, the new collection system will have an enhanced method of preventing debris from entering the pipe. The pipe inlet will have a large aggregate filter to prevent debris from getting in the pipe and will be constructed by placing 1inch to 4 inch diameter rocks inside of a chicken wire type meshing.

This filter will prevent clogs and damage inside the pipe, a problem with the current system. A drawing can be found in 3.3.5 Non-potable Water Collection.

3.1.6 Potable and Non-Potable Water Distribution System

A gravity fed potable water distribution system will be installed to supply village residents with an average daily demand of 2640 gallons per day (gpd). Schedule 40, 1-inch NPS potable main, sold in twenty foot sections, will be installed and connected to a 1320 gallon (5000 L) potable water storage tank. This 1 inch main will connect to Schedule 40, 0.5-inch NPS to provide potable water to 30 end users throughout the village.

A gravity fed non-potable water distribution system will be installed, pending available time and monetary resources, to provide residents with an average daily demand of 7920 gpd. Schedule 40, 2-inch NPS potable main, sold in twenty foot sections, will be installed and connected to an existing non-potable storage tank. Schedule 40, 0.5-inch NPS services will branch from this two inch main to provide non-potable water to 30 end users throughout the village. The non-potable water system is designed such that the villagers can maintain a similar lifestyle regarding previous water consumption while encouraging conservation of protected potable water sources. As such, more liberal flow capacity constraints are designed into the non-potable system.

The potable and non-potable water system has been designed with dissimilar piping diameters to 1) encourage the use of non-potable water for all non-consumption and non-hygienic needs and 2) discourage scavenging of spare or replacement parts from the potable system to the non-potable system and vice-versa. In the case of potable and non-potable piping in a common trench with similar diameters, it will be necessary to distinguish piping (e.g. with paint or duct tape markings in 5 foot spacing). Hydraulic models of the non-potable and potable systems have been designed in commercially available modeling software (PipeFlow Expert, Daxesoft Inc.). References to the model and output presented refer to work performed in this program.

Valves

A one-inch gate valve will be installed downstream of the supply tank on the potable supply main. This valve will allow total system shutoff in the event of a major system failure or contamination issue. Furthermore, the addition of this valve will allow the community to facilitate the encouragement of use of non-potable water by further restricting the availability of potable water. This flow restriction redundancy (in addition to the reduction of pipe diameter) was deemed preferable due to high uncertainty in daily users demand patterns as a result of a small pool of possible end users. A similar two-inch gate valve will be installed downstream of the non-potable supply tank for shut-off purposes.

Ball valves will be installed at two high points within the potable water main to 1) aid in bleeding entrained air from the main during the initial fill and 2) allow for a degree of system separation such that portions of the system can be shut down and isolated.

1.27 cm (0.5 in) potable water faucets (globe valves) will be installed at all 30 end users' taps located throughout the distribution system. Potable and non-potable faucets will be painted different colors to aid in distinguishing potable water from non-potable water.

Drain Valves/Cleanouts

At low points in the pipes, it is possible that some impurities may settle down and cause obstruction to the flow of the water. To avoid this, a draining gate valve may be placed at such points. When the gate valve is opened, the water rushes out, thus removing all the silt, clay etc. from the main line. Therefore, two (2) cleanouts will be located in each distribution system at the two (2) lowest points to allow for total drainage and cleaning of the system when necessary. Additional cleanout points may be added, if necessary, during construction. The basic design/placement of a drain valve is pictured below:

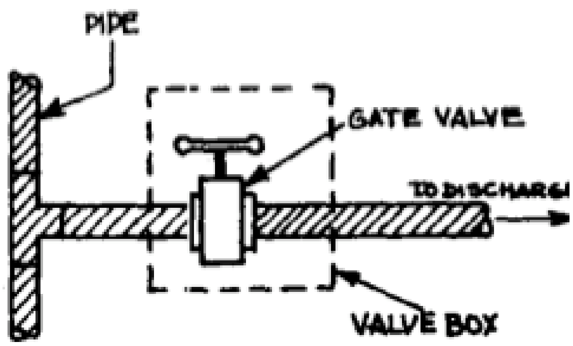


Figure 3: Drain Valve[1]

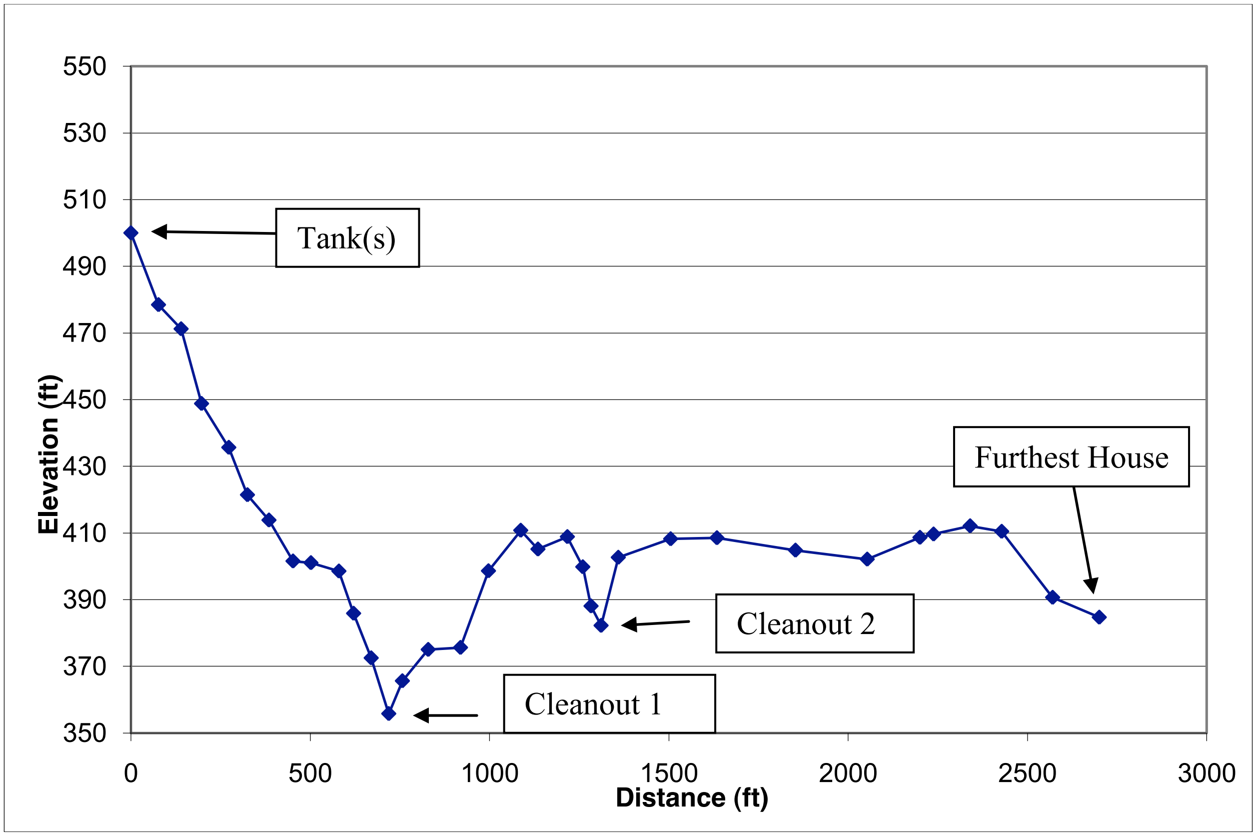


Figure 4: Distribution System Pipe Profile – Tank to Furthest House (w/ cleanouts labeled)

Valve Boxes

Valve boxes will be constructed using wood and nails. Four sides of the box will be nailed together to appropriated protect valves from the sides. Then a final piece of wood will be placed on top. A drawing can be seen in Section 3.3.6 Potable and Non-potable Water Distribution System.

3.1.7 Suspended Pipes

The purpose of this section is to describe the best method for determining where support of the pipe is needed and to provide designs for the ravine/stream crossings and changes of elevation which prevent the pipe from being buried. This section also discusses how to protect the pipe from UV degradation. The general layout of the pipeline was decided during the last assessment trip, however this route will vary as environmental obstacles are encountered. The following descriptions and solutions specifically address construction options for various situations which will be encountered.

It is not recommended that PVC pipe be suspended above ground or left unsupported. The deflection of the PVC pipe, or its sag, will increase as the unsupported length increases, possibly preventing the ideal flow conditions. According to Mumtaz Baig[7], a professional engineer in water engineering, the maximum distance a PVC pipe can span without support is 3.05 m (10 ft), however he recommends leaving PVC unsupported for only half this distance. With the relatively small diameters of 3.81 cm (1.5 in) to 5.08 cm (2.0 in) PVC pipe being considered, the unsupported length of the PVC pipe will be 1.22 m (4 ft), in order to reduce the potential for deflection. To account for this in system designs, unburied PVC pipe supports will be located approximately every 1.22 m (4 ft), along the main. This is a conservative distance. However, we are aware that the quality of pipe available may or may not meet the US standards that the calculations are based on. It should be noted that if the pipe-in-pipe method of protecting the PVC pipe discussed below is used, the unsupported length effectively doubles to 2.44 m (8 ft).

If galvanized iron pipe (GI) is used, the maximum unsupported length is 3.96 m (13 ft) according to A Handbook of Gravity-Flow Water Systems[8]. Note that GI pipe would only be used for the sections above ground, so metal to PVC pipe connections would be necessary to connect buried sections to unburied sections.

For stream crossings a variety of options, most notably the cable-stayed bridge and the suspension bridge methods, will be considered depending on the conditions of the stream. For both, two support towers will be installed on either side of the crossing. The exact location of the towers will be determined on site. They must be placed a substantial distance from the edge of the ravine and secured within the ground. A tower will consist of a 2x4" board, with a notch cut into the top, driven into the ground at least 0.91 m (3 ft). This is in accordance with the Engineers Without Borders – USA website[9] which requires that the footing described below be placed 1m (3.28 ft) below ground level. Due to the loads applied, the sustainability and integrity of the wood will be of concern. If the wood is not treated, a wood sealant will be needed in order to protect from water and insect degradation. Another alternative is to use galvanized fence posts or GI pipe for the towers to which the cable can be attached. If a pipe is used for the tower, notching or drilling may be difficult, therefore something similar to a C clamp or a PVC cap the same size as the pipe that could be notched will have to be secured on top of the pipe. In most cases the towers will need to be anchored by poured concrete. The purpose of the poured concrete will be to stabilize the tower in the ground and to prevent the tower from sinking due to the load of the cable. In the event that poured concrete is not an efficient method, the tower may be set on top of a buried CMU to prevent the board from sinking. The tower will still need to be buried 3 ft. and packed with soil to ensure stability. The poured concrete method is preferable. According to the Water Resources Guidelines on the Engineers Without Borders – USA website[10], the towers should have a span to height ratio of 5. Behind the towers, the cables will be anchored into the ground by concrete masonry units (CMU). The cables will be fed through either a hole or a notch drilled or cut into the tower and connected at approximately a 45-degree angle to the anchor system (see drawings in section 3.3.7). The wires will be wrapped though one of the voids in the CMU and secured with wire clamps. The CMU should be buried at least 3/4 of its height to ensure stability and to leave the top hole accessible. In the event cable clamps are not available, the cable may be wrapped around the CMU and covered with concrete. Similarly, the cable can be wrapped around a short length of PCV pipe that is set in the middle of a poured concrete block. Cables are preferably galvanized in order to resist corrosion and maximize sustainability. Barbed wire is an alternative to the cable due to its relative strength, availability and low cost.

For the cable stay method, a single cable will be strung from one tower, looped around the pipe, and strung to the other tower, forming a saddle in the middle for the pipe to sit in. This method will eliminate the need for tying directly to the pipe and allow for thermal expansion and contraction. A concern with a stream crossing method is the difficulty of construction due to the distance from the creek-bed to the support height. The cable stayed bridge method offers an advantage in that the wire can be looped around the pipe on the ground and then raised from either tower to support the pipe. A disadvantage of this method is that it can only offer one location of support. Therefore, this method would be preferable for crossings under 3.05 m (10 ft).

A similar alternative for longer distances is a suspension-type bridge where a cable is run directly between the towers instead of forming a saddle beneath the pipe. Smaller stays are then tied from the main cable to the pipe at 1.22 m (4 ft) intervals. This option allows many locations of support along the pipe and can be considered for wider ravines. This method would follow the same tower construction and anchor systems as described above. Due to the longer spans of pipe considered for this method, the towers may need to be constructed from 4x4's or GI pipe to ensure long term sustainability. Cable clamps would be necessary to secure the cables around the pipe and to the anchor system. This method may be more difficult to construct than the cable-stayed bridge method above due to the need to access that pipe at several different points along the length. However, it is possible to secure the cable to the pipe before extending the pipe over the ravine.

In both cases mentioned above, there is concern that the pipe may be susceptible to lateral wind loads. In high-risk areas, the pipe may need to be supported along its length. Using 45-degree elbows, the pipe can be raised from its ground level to the wire level and back down. The wire can be wrapped around the pipe continuously along its length similar to how it is wrapped for the saddle bridge. Alternatively, separate cables can tie the pipe to the main cable, every1.22 m (4 ft), similar to the suspension bridge cable stays. With this method, it is important to note that the change in elevation of the pipe may affect the flow of water.

Another method would be a pier-support bridge consisting of piers driven into the streambed. The footings would consist of buried CMU's and would be constructed similarly to the towers for the cable stayed bridge. The pier would be a galvanized pipe resting on top of the CMU unit. To prevent compromise of the support system due to flowing water, the piers would need to be buried at least 0.91 m (3 ft) below the surface, measured from the surface to the top of the CMU. The piers may also consist of a galvanized pipe buried to the aforementioned depth and filled with concrete. The water pipe will rest on top of the GI pipe on either an attached bracket or a notched PVC cap. Because GI pipe or double sleeved PVC pipes will be used in order to protect from UV damage above ground, the pier spacing can be a maximum of 2.44 m (8 ft). A larger PCV pipe may be considered as the pier support for the ease of making notches as pipe support. Due to the difficulty in driving a pier every 2.44 m (8 ft), this method should be considered for shorter spans, less than twenty feet 6.10 m (20 ft). A limitation of this design is the height of the pier as it can only be as tall as the longest pole or plank available. Therefore, this method should be used for crossing where the pipe is not very high above the ground. Construction of the foundation should be done under relatively dry conditions, without flowing water. If this condition is hard to obtain, then an alternative design should be used.

For elevation changes, number of simple solutions applicable to many situations were developed for ease of implementation. Due to the availability of wood the most efficient option would be a pole drive method, similar to the pier-support bridge. A notch would be made at the top for the PVC to sit in. The pipe may need to be secured in the notch with a strap across the top and two screws into the top of the plank. Again an alternative to a wooden plank is a metal pole to which the pipe can be secured. The PVC pipe must be placed so that any weather conditions or animal movement would not move the pipe. Because the pipes will more than likely be on a slope, the 2x4's should be sunk into the slope at least 0.9144 m (3 ft) deep. In steep sections, these supports should be secured in the same manner as the towers of the bridges. Alternatively, concrete masonry units (CMU) can be used instead of boards in order to support the pipe by feeding the pipe through the holes in the block. The CMU foundations should be cut into the slope so that the block rests on a flat surface. The purpose of the CMU will be to support the pipe a relatively small distance above the ground. This is recommended for sections where the pipe might need to run alongside a creek. Elevating the pipe will keep it out of the stream. All necessary measures should be taken and assessed on site, to ensure the stability of the foundation under a load and the possibility of soil inundation. If the soil conditions are unsuitable for a foundation type support, wire or rope can be used as supports. Galvanized or barbed wire is preferable for sustainability reasons. Making use of local materials and support structures is an option to consider if they appear more feasible than any of the proposed methods.

Unburied PVC pipe must be protected from UV degradation that would weaken the pipe structurally. PVC becomes very brittle when exposed to long term UV radiation, but there are options for covering the pipe to block these rays. One guaranteed method for UV protection is to run the pipe through another pipe. This requires PVC pipe with an inner diameter greater than the outer diameter of the system's pipe. This can add significantly to the cost of the system. It is important to note that if the pipe-in-pipe method is used, the length of unsupported pipe can be approximately doubled in the above implementation methods. Alternative options require that an opaque material must be used in order to block the UV rays from the pipe. A number of other materials could be used if more available, including any type of wrap available, such as duct tape. The pipe-in-pipe or wrap method is recommended. The important factor is that there is always a layer of protection blocking the UV rays from the PVC pipe.

Alternatively, it can be much more cost-effective to leave the unburied PVC pipe unprotected. Much of the path is shaded by thick jungle and trees and the pipe will not suffer from intense direct UV damage. In these conditions the pipe should not fail for many years. Rather than buying expensive GI pipe or large PVC pipe, it would cost less to simply provide replacement pipe for when the existing pipe breaks.

3.1.8 Potable Tank

A new storage tank will be built for the potable water system. Current measurements of the flow rate of possible spring sources indicate that the flow rate is greater than the average demand but that a storage tank will be needed to meet demand during peak water usage periods of the day. The Sequent Peak Method for sizing reservoirs was used to do a rough calculation of the size of storage tank that will be needed, 5,000 L (see section 3.2.3).

The potable tank will be placed at a higher elevation than all points of demand, and the water distribution system will be gravity-fed.

The potable tank will be constructed from cast concrete to store five cubic meters or 176.6 cubic feet of water. The height of the tank will be 1.52 m (5 ft), while the interior square side will be 1.81 m (5.95 ft). The tank will be constructed with a sidewall thickness of 0.152 m (0.5 ft) and a roof thickness of 0.152 m (0.5 ft). Moment rebar will be spaced every 0.152 meters (0.5 ft) across the roof. See calculations and sketch in Appendix A for construction details and rebar placement.

The foundation will initially be cast into wooden formwork and allowed to cure for seven days. Perforated PVC pipes will be included in the foundation system to allow for water drainage from underneath the tank. Next, wooden formwork will be placed for construction of the tank sidewalls. The sidewall formwork can be constructed during the foundation-curing period.

Finally, after wall construction and seven days of curing, the sidewall formwork from the interior of the tank will be removed and roof formwork construction will begin. A hatch will be incorporated in the roof design to allow for maintenance access. In addition, the tank will contain in and out flow pipes, as well as an overflow pipe. The overflow pipe will be connected via PVC pipe to the nearest stream or drainage ditch. Bricks or blocks of concrete will be placed inside the tank to mitigate the effects of turbulence from water's entrance into the tank.

During potable tank construction, an adequately secured tarp will cover the entire tank to protect rainwater from changing the water to cement ratio and therefore weakening the strength of the concrete. Additionally, sand filled rice bags (burlap sack) or a wooden enclosure will be formed around the tank to protect the concrete from runoff water during construction.

Materials required for the construction of the tank will be plywood, metal brackets for the formwork, cement, fine aggregate, coarse aggregate, mixing shovels and buckets to transport the concrete into the formwork, a tarp and anchoring materials for the tarp, PVC pipe, a hand powered drill or similar piercing tool, metal brackets, nails, a hammer, tools for digging into the ground, a metal hatch, a trowel, a level, steel rebar and rice bags (burlap sack).

3.1.9 Non-potable tank

The community currently has a 5,000 gallon poured concrete storage tank that will be used for the non-potable system. It has leaks, but otherwise it is functional and structurally sound. Because no new construction is required for the non-potable tank, it is not included in the calculations and drawing sections of the design.

Mortar mix ("fly ash" or Sika) will be purchased from the Changuinola hardware store in order to patch the leaks in the existing non-potable tank. Alternatively, mortar mixture can manually be made in Sieykin from Portland cement and fine aggregate. After the creation of mortar, the non-potable tank will be drained so that it can be accessed from the inside. The holes will then be patched by a spackling knife with mortar. Curing time shall be allowed; however, curing time should not be prolonged as the non-potable tank is currently the only existing water storage device in the village.

3.1.11 Faucets

Standard ball valve faucets are proposed to be used. These faucets are consistent with what the community currently utilizes and is already familiar with. The two faucets for each system (i.e. 1 for potable water, 1 for non-potable) and the pipe leading up to the faucet will be painted with different color paints to differentiate one from another.

As the piping approaches the houses, the pipe will exit the ground travelling vertically towards people's houses. Piping will be attached to houses by using barbed-wire or other durable tie-wire. The wire will securely attach the pipe to the houses, as to prevent pipe movement and buckling. This method is preferred over building a concrete or concrete filled steel tube housing for the pipe because such a structure would be rigid, not ductile, and lack an ability to be changed in the future. In addition, such a structure would be heavy and, as every house is of a different design and height, no standard for end user tap designs can be established. However, a typical Naso house and potential tap design can be seen in the figure in section 3.3.11 Faucets.

In addition, rocks and gravel will be placed in areas that will experience significant runoff from discarded water after use. This will prevent erosion and help to promote spaces that are free of mud and standing water.

3.2 Description of Design and Design Calculations

3.2.2 Demand

Demand calculations were made using the following numbers and equations. The following numbers are from the sources cited in the description section (3.1.2). The first equation uses the current population and the growth rate to find the population in fifteen years. The variables of the equation are defined in the chart.

1. $$p_{fa} = p_0\left(1 + \frac{k * n}{100}\right)$$

Sieykin Centro Sector Water Demand Calculations	
Annual population growth rate (k)	2%
Present population (p_0)	150
Design life (n)	15 years
Future population (p_{fa})	195

The future population is then multiplied by the individual daily demand in equation two to find the total daily water demand.

2. $$gpd = P_{fa} * y$$

Individual demand (y)	53 gallons/person/day	200 L/p/d
Total Daily Demand (gdp)	10335 gallons/day	39000 L/d

The final equation finds the demand per minute by dividing daily demand by minutes per day. The number gives an average demand volume that can aid in sizing the pipe above the tank.

3. $$q = \frac{p_{fa} * y}{1440}$$

Total Daily Demand	10335 gallons/day	39000 L/d
Demand per minute (q)	7.18 gallons/minute	27.08 L/min

Finally the demand is broken down into the potable portion of the system. One fourth of the total demand is the demand for the potable system.

Split System: Amount of Potable Water		
Individual Potable Demand	13.2 gallons/person/day	50 liters/person/day
Total Daily Potable Demand	2575.7 gallons/day	9750 liters/day

3.2.3 Supply

Current measurements of the flow rate of possible spring sources indicate that the flow rate is greater than the average demand, but a storage tank would be needed to ensure that demand will be met even if it is not constant throughout the day. The Sequent Peak Method for sizing reservoirs was used to do a rough calculation of the size of storage tank that will be needed.

The sequent peak method for tank sizing determines the minimum tank storage required based on historical or assumed inflows and demands. For example (in The cumulative deficit, K_t, at each time step is calculated according to the following equation:

$$K_t = \begin{cases} demand_t - inflow_t + K_{t-1} & If\, demand_t - inflow_t + K_{t-1} \geq 0 \\ 0 & If\, demand_t - inflow_t + K_{t-1} < 0 \end{cases}$$

The maximum value of all cumulative deficits K_t is the required storage to ensure that the demand is met at all times.

For the sequent peak calculations, several assumptions have been made. A constant flow rate of 1.5 gal/min (= 5.67 L/min → 340.2 L/h) was assumed. This is lower than the measured flow rates, so the storage tank should be oversized, ensuring that it is large enough to meet the community's needs even if the demand increases over the lifetime of the system. To simulate varied demand throughout the day, demand between the hours of 10:00 PM and 5:00 AM is assumed to be zero because very little water is used at night, and a constant demand of 625 L/h is assumed for the other hours of the day (to total 10,000 L/day). The calculations are shown in

Table 5. As can be seen from these calculations and the resulting graph, the storage size required for the potable water tank is 4,557 L.

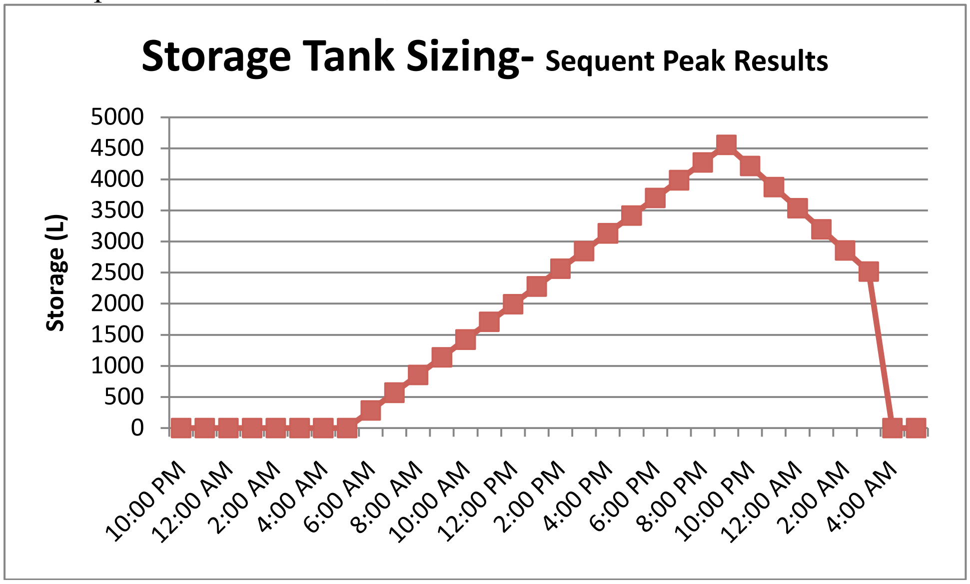


Figure 5: Sequent Peak Results to determine potable water tank size

Storage (i.e. Cumulative Demand) = the amount that you need to have stored up to that point in order to meet your demand, the size tank able to hold this amount of water in order to meet your demand

Time	Demand (L)	Inflow	K_{t-1}	K_t
10:00 PM	0	340.2	0	0
11:00 PM	0	340.2	0	0
12:00 AM	0	340.2	0	0
1:00 AM	0	340.2	0	0
2:00 AM	0	340.2	0	0
3:00 AM	0	340.2	0	0
4:00 AM	0	340.2	0	0
5:00 AM	0	340.2	0	0
6:00 AM	625	340.2	0	284.8
7:00 AM	625	340.2	284.8	569.6
8:00 AM	625	340.2	569.6	854.4
9:00 AM	625	340.2	854.4	1139.2
10:00 AM	625	340.2	1139.2	1424
11:00 AM	625	340.2	1424	1708.8
12:00 PM	625	340.2	1708.8	1993.6
1:00 PM	625	340.2	1993.6	2278.4
2:00 PM	625	340.2	2278.4	2563.2
3:00 PM	625	340.2	2563.2	2848
4:00 PM	625	340.2	2848	3132.8
5:00 PM	625	340.2	3132.8	3417.6

6:00 PM	625	340.2	3417.6	3702.4
7:00 PM	625	340.2	3702.4	3987.2
8:00 PM	625	340.2	3987.2	4272
9:00 PM	625	340.2	4272	**4556.8**
10:00 PM	0	340.2	4556.8	4216.6
11:00 PM	0	340.2	4216.6	3876.4
12:00 AM	0	340.2	3876.4	3536.2
1:00 AM	0	340.2	3536.2	3196
2:00 AM	0	340.2	3196	2855.8
3:00 AM	0	340.2	2855.8	2515.6
4:00 AM	0	340.2	2515.6	0
5:00 AM	0	340.2	0	0

Table 4- Calculations for the Sequent Peak Method used to size the storage tank for potable water

3.2.4 Source Protection

Refer to section 3.1.4 for a description of the spring box design and 3.3.4 for applicable diagrams.

3.2.5 Non-potable Source ie. filter dam

The design criteria for the non-potable water collection system were to prevent debris from entering the pipe and also provide for good conveyance of water away from the non-potable source to the underground PVC piping. This has been accomplished by use of the large aggregate filter and positioning the non-potable water collection source in an appropriate area so water can quickly be moved away from the source and underground. A drawing of the large aggregate filter can be seen in 3.3.5 Non-potable Water Collection.

3.2.6 Potable and Non-Potable Water Distribution System

Potable Water System

Spring to Tank

To convey water from the spring to the potable water tank, approximately 914.4 m (3000 ft) of 3/4-inch Schedule 40 PVC pipe will be installed. Hydraulic modeling indicates that the available head between the spring and potable tank will result in a flow rate of approximately 7 gpm. This flow rate will ensure that tank drawdown under maximum flow demand conditions does not empty the tank. A butterfly valve placed on this line could be used to limit this flow rate if necessary.

Average Potable Water Demand

To determine the average daily demand, community surveys and WHO recommendations were utilized to determine a total potable water demand to the system of 10,000 L day^{-1}. Recall that 30 total end users (taps) are distributed throughout the village.

$$\left(10000\frac{L}{day}\right)\left(\frac{1}{30\ taps}\right) = 333.3\frac{L}{day - tap}$$

Convert to gallons (pipeflow expert units)

$$\left(333\frac{L}{day-tap}\right)\left(\frac{.264gal}{L}\right) = 88\frac{gal}{day-tap}$$

Time varying water demands generally follow a system-wide diurnal curve[1] and previous experience with the Sieykin community found that users demand, on average, one-third of the total days potable water volume over a three hour period.

$$\left(88\frac{gal}{day - tap}\right)\left(\frac{1}{3}\right)\left(\frac{1}{180\ min}\right)(1\ day) = 0.16\ \frac{gal}{min} \approx 0.2\ \frac{gal}{min}$$

A node at each end user location in the model was assigned a water demand of 0.2 gallons per minute. Model simulation pressures, flow rates, and hydraulic grade line values for the 30 user taps appear below in Table 6.

Model results for the average potable water demand scenario indicate that the system, as designed, can adequately deliver the average daily demand of 0.2 gpm to all taps simultaneously. System pressures range from 28 psi.g to 67 psi.g. Guidelines[2] dictate that gravity fed systems produce a minimum of 20 psi.g for all system end users, mainly to ensure adequate fire protection. These considerations would imply an acceptable level of system pressure for this community. Model simulations predict pipe velocities which range from 0.21 ft sec^{-1} to 2.45 ft sec^{-1}, falling within a suggested maximum velocity of 8 ft sec^{-1}. [2]

One limitation of a gravity-fed distribution system is limited control over system pressures and flow rates throughout the system. By replacing a particular end user's static demand input with a constant level reservoir, model simulations predicting the actual end user flow rates realized can be calculated. This was performed to ensure reasonable tap flow rates to end users. In the region of nodes N127-N129, a region of short distance and high elevation change from the tank, the model predicts a fully open flow-rate of 6.4 gpm. While high, this flow rate can be attenuated to an appropriate level utilizing the installed globe valve at the user's discretion. Efforts should be made to encourage this behavior, as it will ensure adequate system pressure to enable flow to neighboring users. In the region of nodes N108-N110, a region of long distance and low elevation change from the tank, the model predicts a fully open flow rate of 4.2 gpm. Again, this flow rate will likely result in end users not fully opening their taps, a behavioral inevitability. Alternatively, if these high flow-rates result in over-use of potable water, the community will have the option to throttle the available potable water via the system main butterfly valve installed immediately downstream of the potable water tank.

Table 6: Model simulation results under average demand conditions at 30 end user taps.

Node	Elevation ft	Press. at Node psi.g	HGL at Node ft.hd Fluid	Demand Out US gpm
N126	191.72	48.02	302.71	0.2
N123	197.75	45.28	302.41	0.2
N125	197.33	45.47	302.43	0.2
N124	182.88	51.70	302.38	0.2
N130	212.87	38.99	302.99	0.2
N127	153.44	63.72	300.72	0.2
N129	151.55	64.57	300.79	0.2
N128	146.53	66.71	300.72	0.2
N121	190.76	46.78	298.87	0.2
N118	177.74	51.83	297.54	0.2
N119	179.13	51.22	297.52	0.2
N120	177.84	51.78	297.51	0.2
N122	238.38	28.14	303.41	0.2
N101	172.62	53.29	295.78	0.2
N102	175.01	51.85	294.85	0.2
N103	170.17	53.94	294.83	0.2
N104	174.3	52.08	294.66	0.2
N105	210.77	35.63	293.11	0.2
N106	209.77	35.46	291.73	0.2
N107	208.02	35.85	290.89	0.2
N108	214.73	32.56	289.97	0.2
N109	203.68	37.47	290.28	0.2
N110	210.07	34.68	290.22	0.2
N111	207.14	35.46	289.1	0.2
N112	207.14	35.46	289.1	0.2
N113	207.14	35.46	289.1	0.2
N114	208.05	35.23	289.47	0.2
N115	206.32	35.99	289.51	0.2
N116	184.69	45.30	289.39	0.2
N117	191.47	42.38	289.41	0.2

Maximum Potable Water Demand

Maximum potable water demand to the system is given by equation :

$$PHD = \frac{MDD}{1440}[C * N + F] + 18$$

Where PHD is the system peak hourly demand (gpm), C and F are an empirical coefficient associated with ranges of end users (dimensionless), N is the number of end users (dimensionless). Utilizing N = 30, a MDD of 88 gpd and coefficients C and F given as 3 and 0, respectively, yields a PHD of 0.8 gpm to each end user. As it is unlikely that 30 users will simultaneously demand a peak flow, a design condition of 15 randomly distributed end users requiring PHD was simulated as a worst-case condition. Model simulation pressure, flow rate, and hydraulic grade line appear below in Table 7.

Table 7. Model simulation results under maximum demand conditions at 30 end user taps.

Node	Elevation	Press. at Node	HGL at Node	Demand Out
	ft	psi.g	ft.hd Fluid	US gpm
N126	191.72	48.02	302.71	0.2
N123	197.75	45.28	302.41	0.2
N125	197.33	45.47	302.43	0.2
N124	182.88	51.70	302.38	0.2
N130	212.87	38.99	302.99	0.2
N127	153.44	63.72	300.72	0.2
N129	151.55	64.57	300.79	0.2
N128	146.53	66.71	300.72	0.2
N121	190.76	46.78	298.87	0.2
N118	177.74	51.83	297.54	0.2
N119	179.13	51.22	297.52	0.2
N120	177.84	51.78	297.51	0.2
N122	238.38	28.14	303.41	0.2
N101	172.62	53.29	295.78	0.2
N102	175.01	51.85	294.85	0.2
N103	170.17	53.94	294.83	0.2
N104	174.3	52.08	294.66	0.2
N105	210.77	35.63	293.11	0.2
N106	209.77	35.46	291.73	0.2
N107	208.02	35.85	290.89	0.2
N108	214.73	32.56	289.97	0.2
N109	203.68	37.47	290.28	0.2
N110	210.07	34.68	290.22	0.2
N111	207.14	35.46	289.1	0.2
N112	207.14	35.46	289.1	0.2
N113	207.14	35.46	289.1	0.2
N114	208.05	35.23	289.47	0.2
N115	206.32	35.99	289.51	0.2
N116	184.69	45.30	289.39	0.2
N117	191.47	42.38	289.41	0.2

Node	Elevation ft	Press. at Node psi.g	HGL at Node ft.hd Fluid	Demand Out US gpm
N123	197.75	38.48	286.68	0.8
N124	182.88	44.77	286.35	0.8
N127	153.44	53.47	277.02	0.8
N128	146.53	56.45	277.01	0.8
N121	190.76	34.64	270.82	0.8
N119	179.13	37.95	266.85	0.8
N122	238.38	23.23	292.06	0.8
N102	175.01	33.01	251.32	0.8
N104	174.3	32.50	249.42	0.8
N108	214.73	4.38	224.85	0.8
N110	210.07	7.46	227.31	0.8
N111	207.14	6.33	221.77	0.8
N112	207.14	6.33	221.76	0.8
N114	208.05	6.42	222.88	0.8
N115	206.32	7.36	223.34	0.8
N126	191.72	42.09	289	0.2
N125	197.33	38.89	287.21	0.2
N130	212.87	33.77	290.92	0.2
N129	151.55	54.65	277.86	0.2
N118	177.74	38.71	267.22	0.2
N120	177.84	38.66	267.19	0.2
N101	172.62	36.30	256.52	0.2
N103	170.17	35.43	252.06	0.2
N105	210.77	14.34	243.92	0.2
N106	209.77	11.85	237.16	0.2
N107	208.02	10.78	232.94	0.2
N109	203.68	10.84	228.73	0.2
N113	207.14	6.38	221.89	0.2
N116	184.69	17.25	224.56	0.2
N117	191.47	14.33	224.59	0.2

Table 8: Model simulation results under maximum demand conditions at 30 end user taps.

Model results for the maximum potable water demand scenario indicate that the system, as designed, can adequately deliver the maximum daily demand of 0.8 gpm to 15 randomly distributed taps while delivering 0.2 gpm to the remaining 15 taps, simultaneously. System pressures range from 15.5 psi.g to 55 psi.g. Under PHD conditions, guidelines[2] dictate that gravity fed systems produce a minimum of 20 psi.g for system end users. Considering the location and extent of improvement of this system over the distribution system currently servicing villagers, it is taken that the aforementioned system pressures are acceptable. Model simulations predict pipe velocities in the system which range from 0.12 ft sec^{-1} to 5.6 ft sec^{-1}, again falling within a suggested maximum velocity of 8 ft sec^{-1}.[2]

Potable Water Alternative

To further encourage discourage the use of potable water for non-potable needs, a potable water system design alternative was investigated. A design alternative consisting of Schedule 40 1-inch NPS water main connected to Schedule 40, 0.375 inch NPS branches was investigated. This scenario will maintain unique pipe sizes between potable and non-potable systems.

Model results for the average potable water demand scenario indicate that this system, as designed, can adequately deliver the average daily demand of 0.2 gpm to all taps simultaneously (see Table 9). System pressures range from 28 psi.g to 65 psi.g, within guidelines[2.] Model simulations predict pipe velocities which range from 0.34 ft sec^{-1} to 2.2 ft sec^{-1}, within suggested maximum values[2].

Repeating the previously mentioned analysis to model flow at an open tap results in flow rates in the region of N127-129 of 3.5 gpm. This flow rate to an open tap is more appropriate than the 9 gpm previously calculated, considering a design constraint of reducing potable water use and encouraging non-potable use where possible. This will require less user input in attenuating personal instantaneous consumption which would otherwise be necessary to maintain system pressure to neighboring users. In the region of N108-N110, this results in an open tap flow rate of 3.25 gpm, again more favorable than the previously realized 6.6 gpm. These fully open flow scenarios do not result in the loss of system pressure to neighboring users, i.e., the 0.2 gpm average daily flow to the neighbors is not impeded by the presence of a neighboring fully open tap.

Table 9: Model simulation results under average demand conditions at end user taps

Node	Elevation	Press. at Node	HGL at Node	Demand Out
	ft	psi.g	ft.hd Fluid	US gpm
N126	191.72	48.28	303.32	0.2
N123	197.75	45.34	302.55	0.2
N125	197.33	45.55	302.6	0.2
N124	182.88	51.74	302.47	0.2
N130	212.87	39.17	303.4	0.2
N127	153.44	62.65	298.24	0.2
N129	151.55	63.54	298.42	0.2
N128	146.53	65.64	298.23	0.2
N121	190.76	47.38	300.28	0.2
N118	177.74	51.55	296.88	0.2
N119	179.13	50.92	296.83	0.2
N120	177.84	51.47	296.8	0.2
N122	238.38	28.30	303.8	0.2
N101	172.62	54.17	297.82	0.2
N102	175.01	52.77	296.97	0.2
N103	170.17	54.85	296.93	0.2
N104	174.3	52.87	296.5	0.2
N105	210.77	36.68	295.56	0.2
N106	209.77	36.62	294.4	0.2
N107	208.02	37.03	293.6	0.2
N108	214.73	33.61	292.42	0.2
N109	203.68	38.73	293.19	0.2
N110	210.07	35.89	293.03	0.2
N111	207.14	36.42	291.32	0.2
N112	207.14	36.42	291.32	0.2
N113	207.14	36.42	291.33	0.2
N114	208.05	36.50	292.4	0.2
N115	206.32	37.29	292.52	0.2
N116	184.69	46.61	292.41	0.2
N117	191.47	43.71	292.49	0.2

Maximum Potable Water Demand

A potable water simulation utilizing the alternative scenario was repeated for the maximum design flow condition of 0.8 gpm, assigned randomly to half of the users. Results of this simulation is summarized in Table 10.

Table 10: Model simulation results under maximum demand conditions at 30 end user taps

Node	Elevation	Press. at Node	HGL at Node	Demand Out
	ft	psi.g	ft.hd Fluid	US gpm
N126	191.72	42.90	290.86	0.8
N125	197.33	39.48	288.58	0.8
N130	212.87	33.40	290.07	0.8
N127	153.44	44.36	255.97	0.8
N128	146.53	47.32	255.9	0.8
N120	177.84	37.98	265.61	0.8
N101	172.62	39.71	264.4	0.8
N102	175.01	36.37	259.07	0.8
N105	210.77	18.01	252.41	0.8
N106	209.77	15.74	246.14	0.8
N108	214.73	6.78	230.4	0.8
N109	203.68	15.51	239.54	0.8
N112	207.14	11.97	234.8	0.8
N114	208.05	12.24	236.35	0.8
N116	184.69	22.02	235.58	0.8
N123	197.75	39.67	289.45	0.2
N124	182.88	46.07	289.36	0.2
N129	151.55	46.25	258.44	0.2
N121	190.76	37.84	278.22	0.2
N118	177.74	38.62	267.01	0.2
N119	179.13	38.00	266.96	0.2
N122	238.38	24.67	295.41	0.2
N103	170.17	39.41	261.26	0.2
N104	174.3	37.43	260.82	0.2
N107	208.02	15.87	244.7	0.2
N110	210.07	13.71	241.76	0.2
N111	207.14	12.12	235.15	0.2
N113	207.14	12.12	235.16	0.2
N115	206.32	13.79	238.19	0.2
N117	191.47	20.59	239.05	0.2

Model results for the maximum potable water demand scenario indicate that the system can deliver the maximum daily demand of 0.8 gpm to 15 randomly distributed taps while delivering 0.2 gpm to the remaining 15 taps. System pressures range from 7 psi.g to 47 psi.g. Note that the low system pressure occurs at the most remote and lowest elevation differential node (N108). If this node does not require 0.8 gpm (i.e. peak demand is swapped with another random location), the pressure at this node increases to approximately 15 psi. Under PHD conditions, this system does not meet domestic U.S. guidelines[2], however, in light of aforementioned potable water constraints, this may be desirable. Model simulations predict pipe velocities in the system which range from 0.371 ft sec^{-1} to 6.1 ft sec^{-1}, below suggested maximums[2].

Non-Potable Water System

Creek to Tank

To convey water from the creek to the potable water tank, approximately 1000 feet of 1-inch Schedule 40 PVC pipe will be installed. Hydraulic modeling indicates that the available head between the creek and potable tank will result in a flow rate of approximately 11 gpm. A butterfly valve placed on this line could be used to limit this flow rate if necessary.

Average Non-Potable Water Demand

To determine the average daily non-potable demand, community surveys and the previously mentioned WHO recommendations were utilized to determine a total non-potable fraction of water demand to the system of 30,000 L day^{-1}

$$\left(30000\,\frac{L}{day}\right)\left(\frac{1}{30\ taps}\right) = 1000\,\frac{L}{day-tap}$$

Convert to gallons (pipeflow expert units)

$$\left(1000\,\frac{L}{day-tap}\right)\left(\frac{.264gal}{L}\right) = 264\,\frac{gal}{day-tap}$$

Following the previously outlined method of accounting for time varying water demands results in the following demand to each tap:

$$\left(264\,\frac{gal}{day-tap}\right)\left(\frac{1}{3}\right)\left(\frac{1}{180\ min}\right)(1\ day) = 0.48\,\frac{gal}{min} \approx 0.5\,\frac{gal}{min}$$

A node at each end user location in the non-potable model was assigned a water demand of 0.5 gallons per minute. Model simulation pressure, flow rate, and hydraulic grade line appear below in Table 11.

Model results for the average potable water demand scenario indicate that the system, as designed, can adequately deliver the average daily demand of 0.5 gpm to all taps simultaneously. System pressures range from 29 psi.g to 65 psi.g., within previously defined guidelines. Model simulations predict pipe velocities which range from 0.5 ft sec^{-1} to 1.5 ft sec^{-1}, again falling within suggested guidelines.

Repeating the analysis outlined in the potable water distribution section results in fully open flow rates in the N127-N129 region of 7.6 gpm. While high, this flow rate could be attenuated to an appropriate level utilizing the globe valve at this end user's tap. In the region of nodes N108-N110, the model predicts a fully open flow rate of 6.5 gpm. Again, this flow rate will likely result in end users not fully opening their taps. As with the potable design case, if the non-potable system design is implemented the community could choose to throttle the available non-potable water via the system main butterfly valve.

Table 11: Model simulation results under average demand conditions at end user taps

Node	Elevation ft	Press. at Node psi.g	HGL at Node ft.hd Fluid	Demand Out US gpm
N126	191.7	49.2	305.3	0.5
N123	197.8	46.0	304.0	0.5
N125	197.3	46.2	304.1	0.5
N124	182.9	52.4	303.9	0.5
N130	212.9	39.9	305.1	0.5
N127	153.4	62.1	297.1	0.5
N129	151.6	63.1	297.3	0.5
N128	146.5	65.1	297.1	0.5
N121	190.8	49.3	304.8	0.5
N118	177.7	52.6	299.3	0.5
N119	179.1	52.0	299.3	0.5
N120	177.8	52.5	299.2	0.5
N122	238.4	29.0	305.3	0.5
N101	172.6	57.0	304.3	0.5
N102	175.0	55.8	304.0	0.5
N103	170.2	57.9	303.9	0.5
N104	174.3	55.8	303.3	0.5
N105	210.8	40.3	303.9	0.5
N106	209.8	40.6	303.6	0.5
N107	208.0	41.2	303.2	0.5
N108	214.7	37.8	302.2	0.5
N109	203.7	43.1	303.2	0.5
N110	210.1	40.2	303.0	0.5
N111	207.1	40.5	300.8	0.5
N112	207.1	40.5	300.8	0.5
N113	207.1	40.5	300.8	0.5
N114	208.1	40.9	302.6	0.5

N115	206.3	41.7	302.8	0.5
N116	184.7	51.2	303.0	0.5
N117	191.5	48.3	303.1	0.5

Maximum Non-Potable Water Demand

Following the previously determined methodology for determining maximum non-potable water demand results in a peak non-potable demand of 1.15 gpm to each end user. As it is unlikely that 30 users will simultaneously demand a peak flow, a design condition of 20 randomly distributed end users requiring PHD was simulated as a worst-case condition. Model simulation pressure, flow rate, and hydraulic grade line appear below in Table 12.

Table 12: Model simulation results under maximum demand conditions at 30 end user taps

Node	Elevation	Press. at Node	HGL at Node	Demand Out
	ft	psi.g	ft.hd Fluid	US gpm
N126	191.7	48.3	303.5	1.2
N123	197.8	43.8	298.9	1.2
N124	182.9	49.9	298.3	1.2
N130	212.9	38.6	302.0	1.2
N128	146.5	60.7	286.7	1.2
N121	190.8	48.2	302.1	1.2
N119	179.1	48.4	290.9	1.2
N122	238.4	27.9	302.9	1.2
N101	172.6	55.2	300.2	1.2
N103	170.2	55.4	298.3	1.2
N104	174.3	52.1	294.7	1.2
N106	209.8	37.9	297.4	1.2
N107	208.0	37.8	295.4	1.2
N108	214.7	32.5	289.9	1.2
N109	203.7	39.9	296.0	1.2
N111	207.1	33.6	284.9	1.2
N112	207.1	33.6	284.8	1.2
N113	207.1	33.6	284.8	1.2
N115	206.3	38.7	295.7	1.2
N116	184.7	47.7	294.9	1.2
N125	197.3	44.4	300.0	0.5
N127	153.4	58.3	288.2	0.5
N129	151.6	59.2	288.4	0.5
N118	177.7	49.3	291.6	0.5
N120	177.8	49.2	291.5	0.5
N102	175.0	54.1	300.0	0.5
N105	210.8	38.3	299.2	0.5
N110	210.1	37.7	297.3	0.5
N114	208.1	38.0	295.8	0.5
N117	191.5	45.7	297.1	0.5

Model results for the maximum potable water demand scenario indicate that system, as designed, can adequately deliver the maximum daily demand of 1.15 gpm to 20 randomly distributed taps and .5 gpm to the remaining 10 taps, simultaneously. System pressures range from 28 psi.g to 61 psi.g. This design meets the aforementioned design standards for PHD conditions. Model simulations predict pipe velocities in the system which range from 0.6 ft sec^{-1} to 2.7 ft sec^{-1}, falling within a previously described suggested maximum.

$$\left(10000\,\frac{L}{day}\right)\left(\frac{1}{30\ taps}\right) = 333.3\,\frac{L}{day-tap}\left(333\,\frac{L}{day-tap}\right)\left(\frac{.264gal}{L}\right)$$
$$= 88\,\frac{gal}{day-tap}\left(88\,\frac{gal}{day-tap}\right)\left(\frac{1}{3}\right)\left(\frac{1}{180\ min}\right)(1\ day) = 0.16\ \frac{gal}{min}$$
$$\approx 0.2\ \frac{gal}{min} PHD = \frac{MDD}{1440}[C*N+F] + 18\left(30000\,\frac{L}{day}\right)\left(\frac{1}{30\ taps}\right)$$
$$= 1000\,\frac{L}{day-tap}\left(1000\,\frac{L}{day-tap}\right)\left(\frac{.264gal}{L}\right)$$
$$= 264\,\frac{gal}{day-tap}\left(264\,\frac{gal}{day-tap}\right)\left(\frac{1}{3}\right)\left(\frac{1}{180\ min}\right)(1\ day) = 0.48\ \frac{gal}{min}$$
$$\approx 0.5\ \frac{gal}{min}$$

3.2.8 Potable Tank

Please see Appendix A.

3.2.11 Faucets

Criteria for faucet and end user designs were based on the need for there to be easy variability in planning for construction, during construction and post construction. The faucet and end user design allows for easy construction, use and maintenance of the system while providing appropriate sustainability. A drawing of a typical Naso house and faucet design can be seen in 3.3.11 Faucets.

3.3 Drawings:

3.3.4 Source Protection

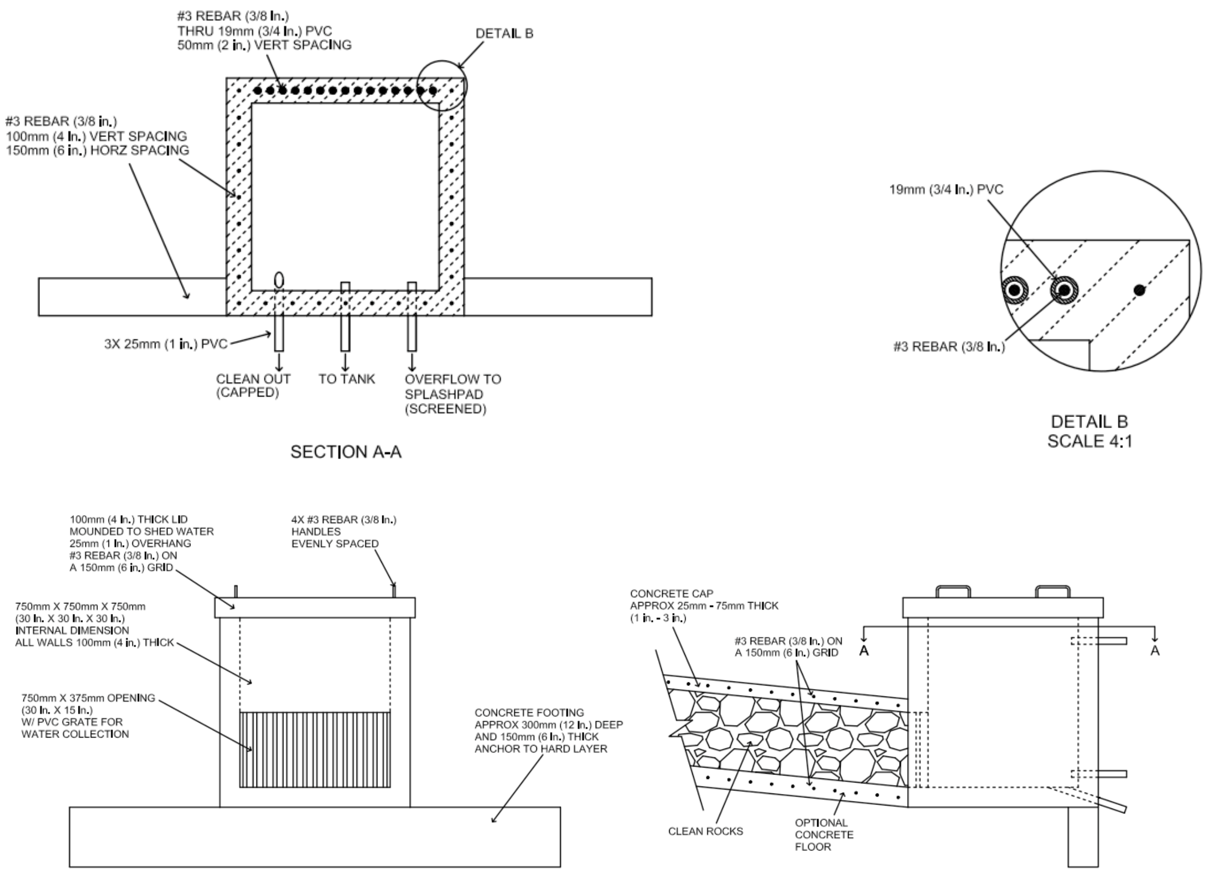


Figure 5: Spring Box

3.3.5 Non-potable Source

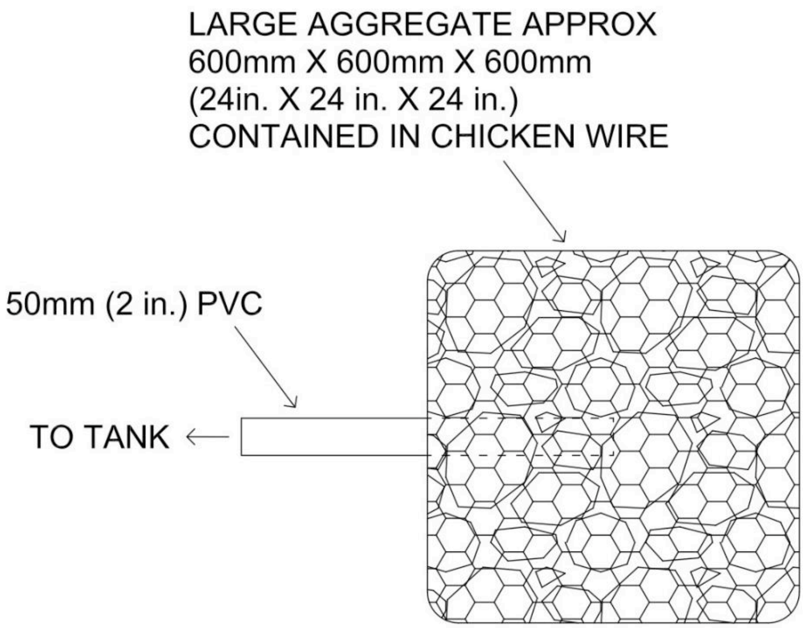


Figure 6: Large Aggregate Filter

3.3.6 Piping

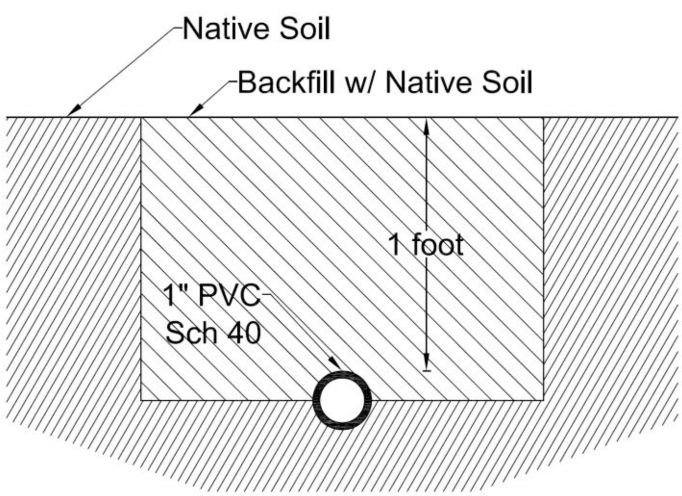


Figure 7: Burying Piping

Note: Though the diagram indicates a depth of '1 foot,' 0.3048 m (1 ft) will serve as the minimum depth for use in areas with particularly difficult digging conditions; in all other areas (especially in crossing high-traffic areas such as walking paths) an optimal depth of 04572.m (18 in) will be used. This is based on suggestions for a former Peace Corps volunteer who has worked on a water system in Panama[1].

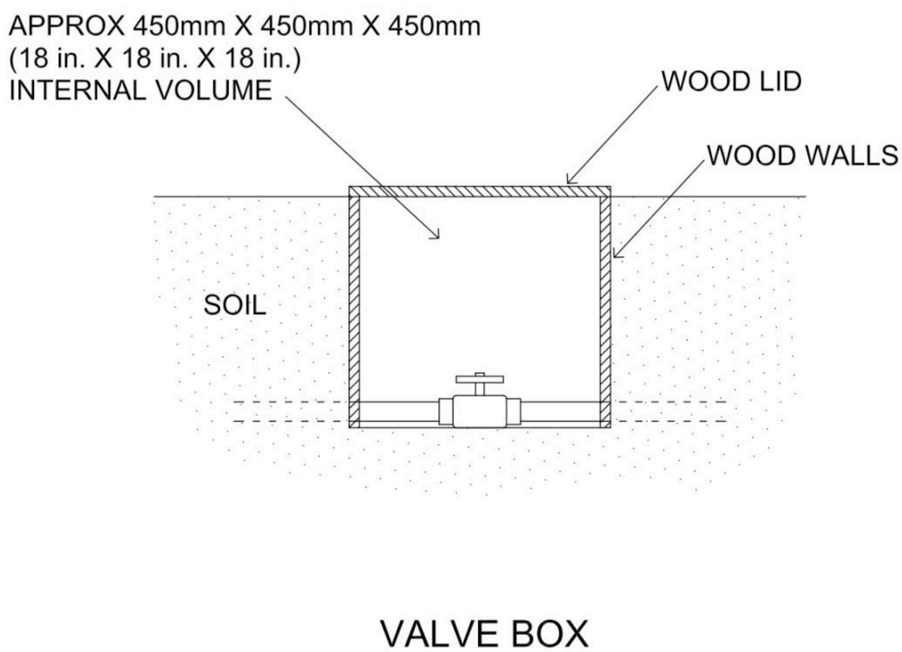


Figure 8: Valve Box (accessible protection for valves)

3.3.7 Piping bridge systems-ie suspending over ravines or streams

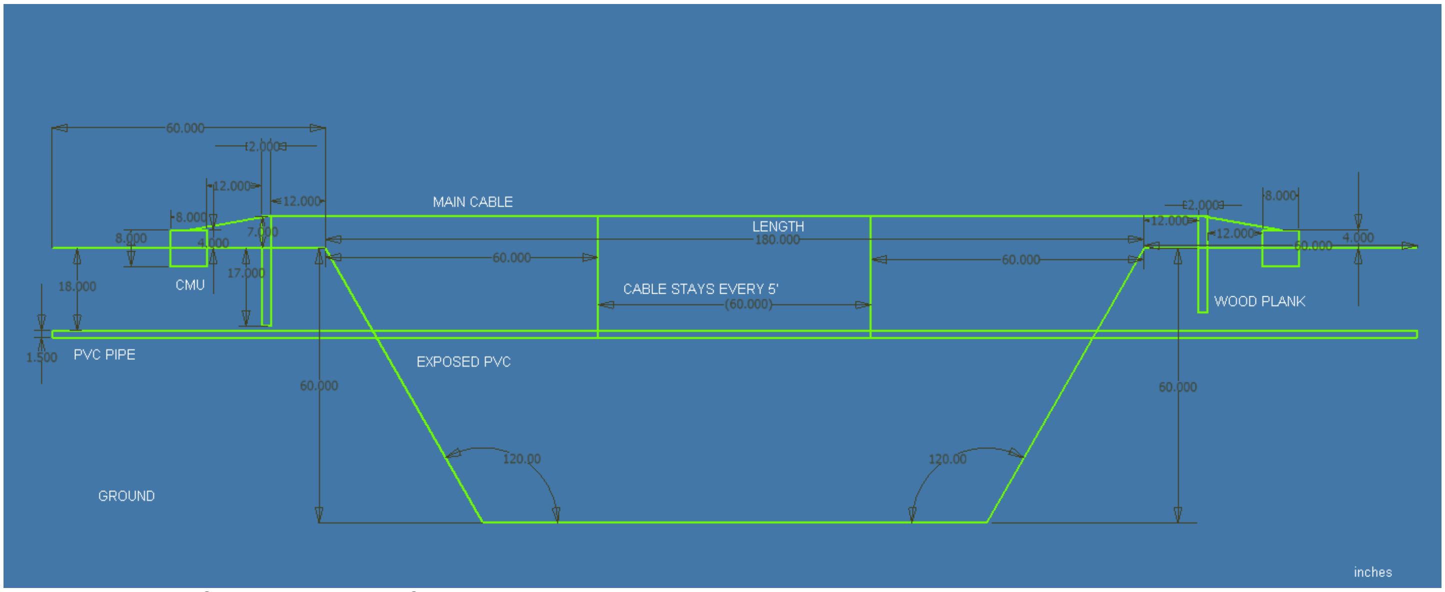


Figure 9: Aerial Suspension Bridge (Option 1)

As illustrated the pipe comes out of the ground and spans a distance then reenters the ground. Cable stays off of the main cable support the pipe every four to five feet. The main cable is supported by the wooden plank towers and then secured to CMU block in the ground.
(Diagram in inches)

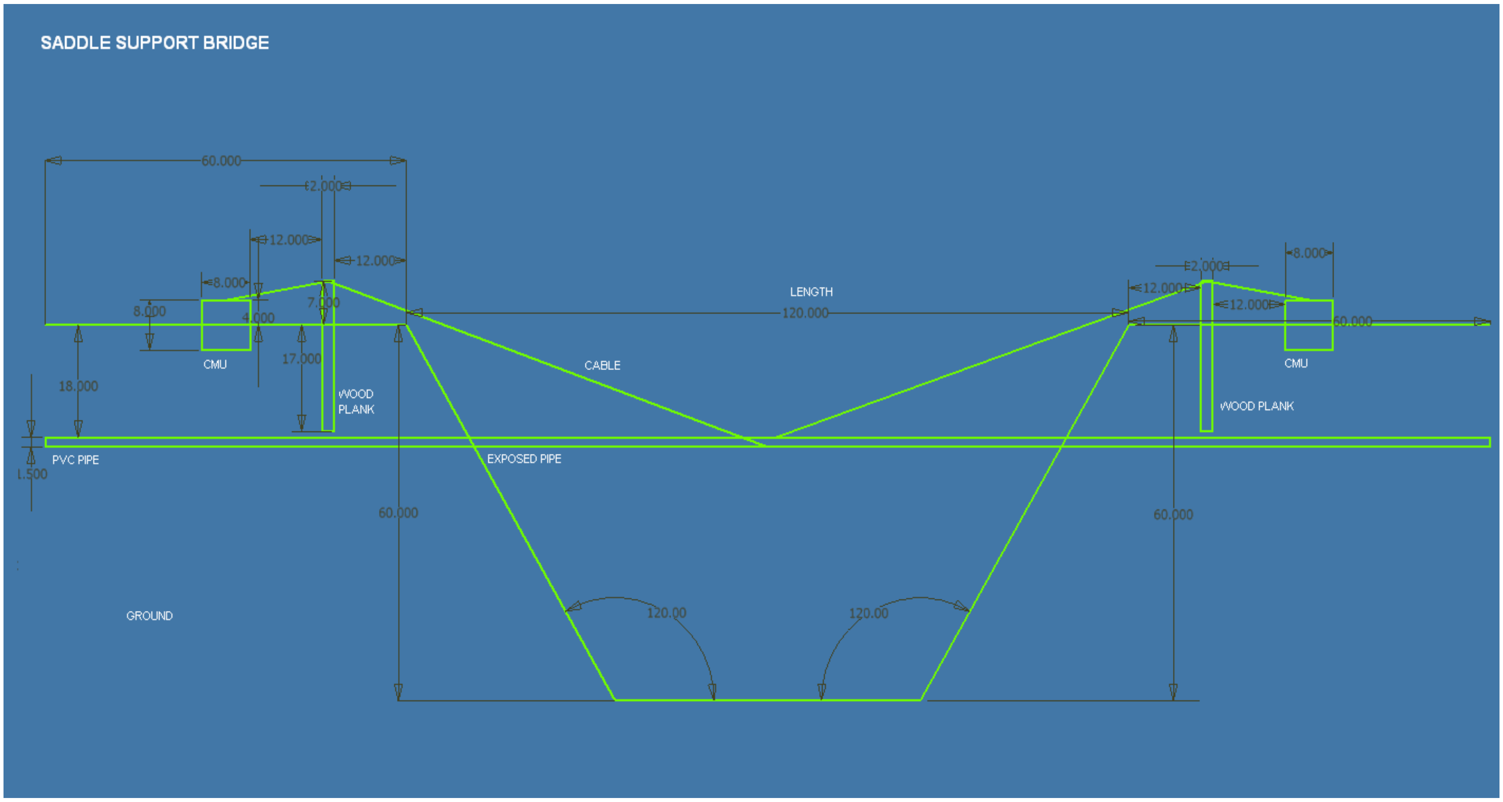


Figure 10: Aerial Suspension Bridge (Option 2)

The single cable loops around the pipe to create a saddle. *(Diagram in inches)*

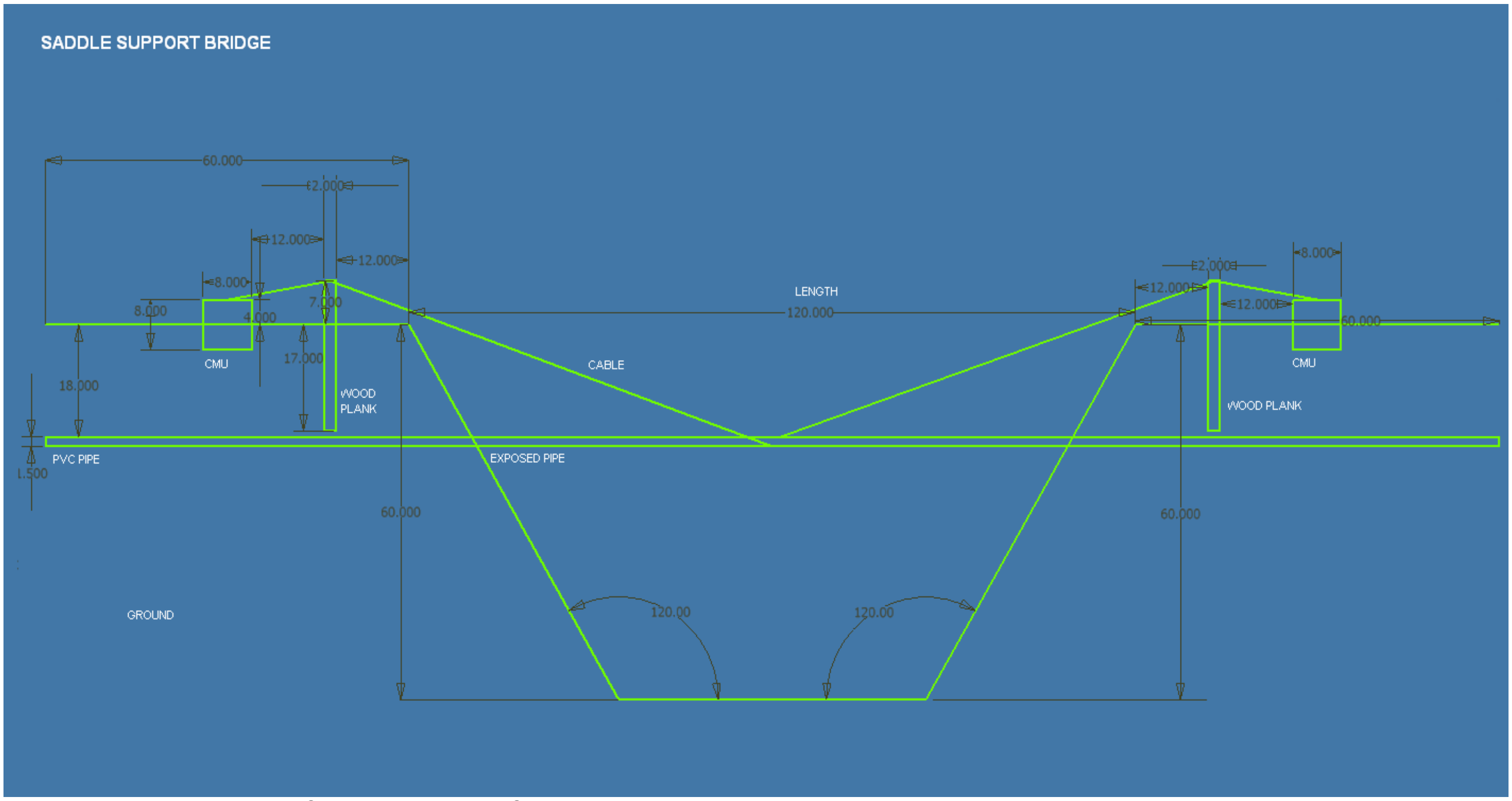


Figure 11: Aerial Suspension Bridge (Option 3)

Wooden planks or poles driven into the ground and stabilized on CMUs with poured concrete support the pipe. *(Diagram in inches)*

3.3.8 Potable Tank

Please see Appendix A (pgs 19, 21, 23, 30-40) for applicable tank diagrams.

3.3.11 Faucets

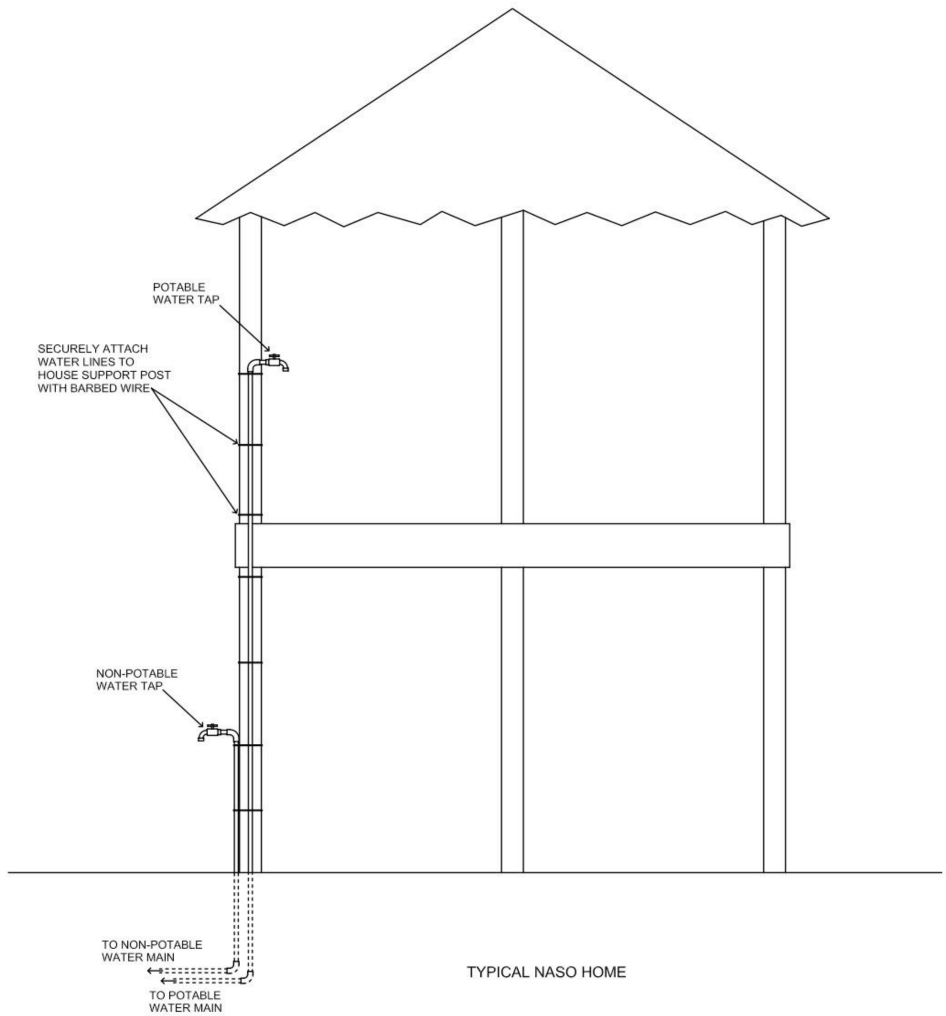


Figure 12: Household Non-Potable and Potable Faucet Setup

4.0 PROJECT OWNERSHIP

Due to the distance and physical barriers between the 5 sectors of the community, 5 separate water systems will need to be installed (incl. the system for the central sector described above). The constructed facilities will be owned by families who contribute to their sector's water system both financially and with labor (i.e. building the spring boxes and tanks, trenching, laying pipe, installing faucets, etc.) All community members will be recruited to aid in the construction of each sector's system, but only those families who will benefit from the new water system will be expected to pay monthly water fees.

5.0 CONSTRUCTION

5.1 Construction Plan

Rachel Chisolm and Natalie Craik will be traveling to the community five days ahead of the first travel group to begin the process of procuring the materials. The team met with the hardware store owner in Changuinola during the first assessment trip and has been in contact with him via email. Once the chapter has approval to move forward with implementation, the project team will contact the owner with a list of the required materials to ensure he has the quantity of items in stock upon our arrival in country.

The role of the Sieykin Water Committee will be to organize the community's boat drivers and community members to load the materials, transport them upriver, and then carry the materials to the appropriate work site. Rachel and Natalie's role will be to provide oversight of this process. The list of materials will be approved by the professional mentor when the order is placed based on the approved design. Communication with the hardware store owner prior to travel should raise any issues with materials availability before Rachel and Natalie arrive in country. If a particular item becomes unavailable and an engineering decision is required, the situation would be rectified upon the professional mentor's arrival in Changuinola who would then identify the appropriate alternative materials.

During implementation, the project team's role will be to provide oversight and direct the different aspects of the project (i.e. building the potable tank, digging the ditch to bury the pipe, laying/connecting the pipe, building a spring box, etc). Project members will work alongside community members. As decided in the last assessment trip, community members will be responsible for the labor required for construction. The Water Committee will organize this community labor. They will be able to assign tasks based on individuals' skill sets as well as participate in building the system.

Section 7.0: SUSTAINABILITY contains the Memorandum of Understanding developed with the community during the second assessment trip. A local mason has been identified with previous tank and spring box construction experience and will be hired to direct construction of both the potable water tank and the spring box.

Please refer to Table 5.1 for the construction schedule for Trip 1 and Table 5.2 for the construction schedule for Trip 2. Contingency days have been built into the schedule to allow for delays. We have also allowed for project members to have “time off” to rest and socialize with the community. This scheduled time off is interchangeable with days of delay. Also, if delays are not due to weather, the time will be utilized to investigate spring sources in the other sectors and gather assessment data for these other sectors.

Table 5.1: Construction Schedule Trip 1

	Day Number	1		2		3		4		5		6		7		8		9		10		11		12		13		14		15		16	
Piping	Stake & Clear Path	2	2	2	2																												
Piping	Excavation					1	1	1	1	1	1	1	1			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
Piping	Assembly																									1	1	1	1	1	1		
Piping	Pressure Test																													X	X		
Piping	Backfill																									1	1	1	1	1	1		
Piping	Post Pressure Test Repairs																							0.5	1								
Piping	Disinfect Pipes																																
Piping	Non-Potable Inlet (Old System)																																
Bridge	Clear Rocks and Vegetation																																
Bridge	Construct River Crossing Hangers															2	2	1	1	2	2	1	1										
Bridge	Assemble Pipes																	1	1			1	1										
Bridge	Hang Pipe																	X	X			X	X										
Source	Clear Site			1																													
Source	Probe Subsurface			1																													
Source	Excavate				2	2	2	2	2																								
Source	Gather & wash Stones/Gravel																																
Source	Transport Cement & Aggregate																																
Source	Construct Forms																																
Source	Mix/Pour/Cure Concrete Box																																
Source	Assemble Pipes & Vents																																
Source	Place rock in drainage field																																
Source	Mix/Pour/Cure Concrete Cap																																
Tank	Clear Site	1	1	1	1																												
Tank	Cut Wood			1	1																												
Tank	Gather & Wash Stones/Gravel							1	1	1	1	1	1			1	1	1	1	1	1	1	1	1	1								
Tank	Excavate	1	1																														
Tank	Construct Frame			1	1	2	2									2	2	2	2														
Tank	Transport Cement & Aggregate	1	1	1	1	1	1													1	1												
Tank	Mix/Pour/Cure Cement					1	1													1	1	2	2	2	2	2	2	2	2				
Tank	Restore/Disinfect Old Tank																									1	1	1	1	1	1		
	Total EWB People	5	5	8	8	7	7	4	4	2	2	2	2	0	0	6	6	6	6	6	6	6	6	4.5	5	6	6	6	6	4	4	0	0
	Total Community Members	28	28	26	28	33	33	14	14	10	10	9	9	0	0	9	9	11	11	17	17	16	16	14	13	16	16	16	16	11	11	0	0

Table 5.2: Construction Schedule Trip 2

	Day Number	1		2		3		4		5		6		7		8		9		10		11		12		13		14		15		16	
Pipinng	Stake & Clear Path																																
	Excavation	2	2	2	2	2	2	2	2	2	2	2	2	2	2			1	1	1	2	1	2	2	2								
	Assembly	1	1	1	1	1	1	1	1	1	1	1	1	1	1			1	1	1	1	1	1	1	1								
	Pressure Test							X	X													2	2										
	Backfill							1	1	1	1	1	1					1	1							2	2	2	2	2	2		
	Post Pressure Test Repairs																									2	2						
	Disinfect Pipes																											1	1				
	Non-Potable Inlet (Old System)																	2	2	2	2	2	2										
Bridge	Clear Rocks and Vegetation																																
	Construct River Crossing Hangers																	2	2	1	1		2	2	1	1							
	Assemble Pipes																			1	1				1	1							
	Hang Pipe																			X	X				X	X							
Source	Clear Site																																
	Probe Subsurface																																
	Excavate	2	2	2	2	2	2																										
	Gather & wash Stones/Gravel	1	1	1	1	1	1																										
	Transport Cement & Aggregate			1	1																												
	Construct Forms						2	2	2	2																							
	Mix/Pour/Cure Concrete Box							2	2	2	2	2																					
	Assemble Pipes & Vents											1																					
	Place rock in drainage field												1																				
	Mix/Pour/Cure Concrete Cap													2	2																		
Tank	Clear Site																																
	Cut Wood																																
	Gather & Wash Stones/Gravel																																
	Excavate																																
	Construct Frame																																
	Transport Cement & Aggregate																																
	Mix/Pour/Cure Cement																																
	Restore/Disinfect Old Tank																																
	Total EWB People	6	6	7	7	6	8	8	8	8	6	7	5	5	5	0	0	7	7	6	7	6	9	5	5	6	4	3	3	2	2	0	0
	Total Community Members	18	18	18	18	18	19	15	15	15	14	14	9	11	11	0	0	13	13	16	16	12	14	12	14	9	5	4	4	4	4	0	0

5.2 Construction Safety Plan

Health and Safety Plan attached.

6.0 OPERATION AND MAINTENANCE PLAN

ADMINISTRATIVE STRUCTURE

The community recently elected a water committee to help facilitate communication between the EWB group and the community and to supervise the construction and maintenance of the new facilities. As this group is composed of many younger community members, a few more experienced community members are currently serving as mentors for the committee.

The members of the water committee include:

Yadira Sanchez B.- President
Eusebio Barnat*- Secretary
Aracely Santana- Treasurer
Elvira Villagra- Fiscal
Teodoro Bonilla- Vocal
Lionel Barnat- Vocal

*- Eusebio Barnat has been the primary committee contact with EWB and has corresponded with the group (approximately twice a month, more frequently when necessary) through email.

FINANCIAL

Engineers Without Borders – Greater Austin will pay for all construction materials that the community is not able to provide. Any repairs following implementation will be paid for by community members.

Water committee members or sector representatives chosen by this committee will be responsible for collecting and recording monthly water fees from families served by the water system. Payments will be recorded and the funds will be given to the Water Committee Treasurer (currently Aracely Santana) to pay for future repairs.

If a family is not able or willing to pay the necessary fees, the water committee will convene and discuss the proper course of action (i.e. determining some other method of payment, temporarily shutting off their water, etc).

TECHNICAL EXPERTISE/EDUCATION

Fortunately, due to their simplicity of design, spring boxes require little maintenance and technical expertise post-implementation. Water committee members and sector representatives will receive hands-on instruction regarding all system components so that they will be able to diagnose any system malfunction and arrange the necessary repairs (incl. purchasing parts and organizing labor).

Instruction will be accomplished through in-the-field demonstrations and workshops. The EWB group found this method of instruction to be very effective in spreading technical information and also garnering community support for the project, especially when respected members of the community were involved. Manuals (in Spanish) will also be provided for committee members and sector representatives to explain the proper course of action in the event of system malfunction.

7.0 SUSTAINABILITY

The overall simplicity of the design and its components, combined with the community's previous use and knowledge of similar systems, will ensure the sustainability of this project. The system is low tech, utilizing a gravity fed distribution system supplied from existing spring sources. This type of system is already in use in Sieykin. Additional explanation of the spring box or artesian well, how it works and how it will need to be maintained, will be provided to the community. The community members will participate in building the system, and learn by doing. On-site training sessions and workshops regarding how to maintain the system over time will also be provided. This will include both regular maintenance and how to identify potential problems. As new houses are added in the community, they will have gained the knowledge and confidence from this experience to be able to expand the system as needed. The materials used in the design are all available from within the community and local hardware stores. The individual components of the design are inexpensive. The cost of replacing a broken pipe or a broken faucet will be reasonably cheap. To prepare for such incidents and regular maintenance costs, each family utilizing the water system will pay a monthly fee, to be determined and paid to the water committee, for this purpose.

The following Memorandum of Understanding was drawn up during the August 2009 assessment trip, and establishes the responsibilities of each organization in order to facilitate social sustainability:

MEMORANDUM OF UNDERSTANDING

Water Committee Responsibilities

- Organize the required labor and the participation of each family
- Organize the transportation of materials between Puerto Silencio and the construction site
- Collect monthly fee for the maintenance of the system
- Organize the maintenance of the system for each family, each sector, and the whole community
    - Complete bi-monthly "check-ups" on the system to ensure that there is no visible damage to the system and that all piping is properly buried.
- Train community members on the function and maintenance of the water system
- Make necessary arrangements for the EWB group (incl. food and shelter) prior to their stay

Community Member Responsibilities (each family…)

- Participate in the construction of the water system in each sector

- Manage their water use
- Pay a small fee each month for the maintenance of the water system
- Provide local materials and loan construction tools for use in building the water system
- Provide volunteer guides for the EWB group
- Transport materials between Puerto Silencio and the construction site

EWB Responsibilities

- Design an appropriate and durable water system
- Hold workshops for the water committee (and other interested individuals) on the function and maintenance of the water system
- Pay for construction materials which the community is not able to provide
- Pay for the gasoline for the transportation of the materials
- Collaborate with the community and any other organizations that are able to support the project
- Participate in the construction of the water system

8.0 EDUCATION

EWB members will continue the education campaign which was initiated on the second assessment trip. This campaign is split into two parts: 1) health education and 2) system operation and maintenance. The main purpose of the health education portion of this campaign is to build a strong relationship with the community members, explain the process of disease transmission, and demonstrate the connection between the community's water quality and health problem. We will be using visuals to illustrate the primary health issues in Sieykin and explain how improved water quality and hand-washing will help to address these issues. The health education program will be split into two parts, a school-based program with the children and household interviews with the adult community members. The system operation and maintenance portion of the education campaign will focus on educating and training community members on simple construction and maintenance tasks. Community members will be provided with booklets describing the system design and the proper steps to take in case of system failure.

8.1 Health Education Campaign

We are planning on continuing health education activities with students in the local school. The basic theory behind our education campaign is one of student-discovery rather than lecture-style teaching. Our hands-on approach will be the most successful way for students to practice these techniques and internalize their importance. Our health education program is being designed with extensive graphic, auditory, and oral components that appeal directly to a child's natural learning process. This method of teaching will leave the children with a lasting, memorable experience that will directly impact their health and well-being.

We will address 3 main themes in the campaign, including:

- Hygiene and healthy practices
- Germs: What they are and how they are spread
- Water Conservation

We will conduct several educational activities for the schoolchildren, including:

- Activity book – We are designing an activity book for the children containing various activities in addition to coloring pages to reinforce the ideas presented under the themes of hygienic practices, water conservation, storage, etc. A few pages from the activity book can be found in Appendix G.
- The Transmission Routes activity – This activity will be used to train the children on the fecal-oral transmission routes. This will allow them to discover how diarrheal disease can be spread through the environment. This activity can be found in Appendix G.
- The Sorting activity – This is an interactive activity that will allow the children to exchange information and discuss common water, hygiene and sanitation practices according to their good and bad impacts on health. The aim is not to test their knowledge

or to correct personal habits, but rather to provide a starting point for a discussion of local beliefs and practices. This activity can be found in Appendix G.

- Tippy-tap -The Tippy-tap is a simple water dispenser which enables people to wash their hands without wasting water. The Tippy-tap primarily consists of a container, which releases a small amount of water, just enough for a clean hand wash, each time it is tipped. And when the 'tap' is released, it swings back to its earlier upright position. We will hold a workshop where the children will make their own Tippy-taps and at the end of the session, take it home with them.
- Handwashing song – We will encourage the children to sing this song while washing their hands. The following words will be sung to the tune of Happy Birthday:

Lavate las manos
Con agua y jabon
Lavate las manitas
Para la buena salud

- Microscope - We acquired a powerful light microscope as a donation from the School of Biological Sciences of The University of Texas at Austin. It will be used to show the Naso community members what a microorganism looks like. We want to give them an opportunity to see for themselves the bacteria they are ingesting. This way they can better understand the logic of hygiene and sanitation. If we are able to show them what their bodies are fighting against, instead of just teaching them about an "invisible" enemy, they will be more willing and prepared to defend themselves from disease.
- Water Conservation - The Holy Hose - This will be used to teach them that if they use a lot of water, then their neighbors down the line will not. It will be a hose with various holes in it. When water is pumped through, the water that spews from the last hole will not have as great of height. If the first hole is plugged, though, then the height should increase. Thus, their water use affects their community.
- Skits – We are planning to perform interactive skits to show how pathogens enter the body, emphasizing the importance of hand-washing. The group will also use glow-in-the-dark gel and black lights in an active hand-washing activity with each child to show the benefit of washing with soap.
- Certificate - After we complete our program at the school we will give out certificates to the kids.

8.2 Household Interviews

Adult education will be one of the focuses of the household interviews. The primary purpose of the household interviews for our third trip to Sieykin will be to strengthen the relations we built within the community on the last two trips and ensure that every member of the community understands the project and is willing to participate. We have found that visiting as many of the individual households as possible is much more effective in relaying information than community meetings, and the household interviews gave community members the chance to ask members of the EWB group questions and to express any ideas or concerns that they had. We found out on the last trip that a few of the community members in outlying areas did not know anything about the project before EWB members visited them in their homes, which underlies the importance of this grassroots effort at community organizing. On this trip, as on the last two trips, we plan on having volunteer guides from the community accompany us for the household interviews. This proved valuable on the last assessment trips because it aided in the acceptance of the members of the EWB group, and the guides were able repeat what was said in Naso to ensure that the community members understood everything completely. The household interviews also allow the EWB group to learn more about the Naso culture and life in the community and to build a trust with the community members. This understanding of the Naso culture has been useful in determining what will and will not be effective and what the best way to communicate important information is.

In addition to the primary public relations focus of the interviews, we will also talk about our plan for implementation and get input from the community members on how to improve the system. We will present the community members with a handout showing the overall layout of the system, information on water storage, conservation and how to perform simple maintenance task and how to pay the monthly water tax, the amount of which will be decided in meetings with the water committee. We also plan on gathering further data on the number of people in each household and illnesses for children under the age of five. This information will help us determine metrics for the success of the project. This will serve as a baseline in determining if the new water system will help reduce the amount of water-borne diseases.

The following is a list of posters and handouts that will be used by the EWB group in the health education program with the adults.

- Water Contamination – This handout explains the concept behind water contamination. We will distribute this at household interviews and will show the results from the water tests done during the second assessment trip. This handout can be found in Appendix G.
- Water Storage – These handouts show proper water storage and chlorination practices. We will encourage the community members to chlorinate their water when they are planning on storing it for long durations in the dry season. These handouts will be passed out during the household interviews. These are attached in Appendix G.
- System layout – This will be a diagram of the system showing the spring-box, tank and the potable/non-potable pipes leading to the houses. It will be distributed as handouts during the household interviews and will also be put in the community center as a poster

8.3 Water System Administration

The following topics will be discussed with the water committee.

- Payment Agreement - It will also contain the water tax information. The amount of the water tax and ways to pay it will be decided in meetings with the water committee. We will use this document as a draft and will finalize it with the water committee. The agreement is called "Acuerdo del Pago para los Servicios del Acueducto" and is attached in Appendix G.
- Basic Administration of Aqueduct System – This document presents some ideas on what the tasks of the water committee should be and will be finalized at a community meeting at the beginning of the trip. This document is called "Administración Básico del Acueducto" and is attached in Appendix G.
- Water system surveys – These are surveys designed for community members to see what needs to be fixed/improved on. We will ask the water committee to survey the community once every 4 months. These surveys can be found in Appendix G.

8.4 Community Meetings and Training Sessions

To ensure that the project is sustainable and that the community takes ownership of the system, we will work closely with the community members on the implementation and conduct community meetings and training sessions. During the last assessment trip, the water committee was trained on how to measure the flow rate of the springs. Since then they have sent us flow rate data during the dry season. During the implementation trip we will conduct training sessions for the water committee and the whole community to ensure that they understand how the system works and how to maintain it. The following topics will be discussed with the water committee and will then be presented to the whole community.

- System Maintenance – We will conduct hands-on training sessions with the community members to show specific maintenance tasks that needs to the performed by all households. Maintenance tasks will be listed in a handout and along with the Community Member Responsibilities section of the Memorandum of Understanding (Section 7.0) will be passed out at the training session.
- Concrete Mixing – We will conduct a training session for the community members to show how to mix concrete. We will use the document in Appendix G called "Como Hacer Concreto y Mezcla".
- Community-wide Meetings – We will discuss project plans, management, and organization in detail with the community to ensure that the project is exactly what the community desires. This will be done through community-wide meetings.

- Focus Group Meetings – We will meet with individual focus groups (women, teachers, etc.) to discuss the water system and the health education campaign. This will ensure that everyone's input is taken into account while implementing the system and that the entire community takes ownership of the system.

9.0 COST ESTIMATE

Implementation Trip I : Logistics Budget

Item	Description	Unit cost	#	Duration/Quantity	Total
Airfare	International: San Antonio to Panama City	$ 625.00	15	tickets	$ 9,375.00
	Domestic	$ 104.50	17	tickets	$ 1,776.50
	Oversize Baggage (International)	$ 100.00	2	bags	$ 200.00
	Extra Baggage (Domestic)	$ 12.00	17	bags	$ 204.00
Bus fare	Panama City to Changuinola	$24	12	tickets	$ 288.00
	Changuinola to David, David to Boquete (2 people, Round Trip)	$7.50	4		$ 30.00
Taxi fare	In Panama City, Boquete and Changuinola				$ 200.00
Boat fare	Boat from Porto Silencio to Sieykin	$50	8	trips	$ 200.00
Community Food & Lodging	Food & lodging in community for 15 people (See breakdown below)	$ 8.00		night	$ 2,304.00
Hotels	Panama City (Zuli's Backpackers) : 15 people, 1 night	$ 8.50	15	night	$ 127.50
	Changuinola (Hotel Semiramis) : 12 people, 1 night; 2 people, 2 nights,	$ 10.80	19	night	$ 205.20
	Boquete (Hectar Sanchez' Lodge): 2 people, 2 nights	$ 13.20	4		$ 52.80
Food (in Panama City & Changuinola	per day while in Panama City and Changuinola : 12 people, 3 days; 2 p	$ 15.00	19	day	$ 285.00
Satellite Phone & Phone cards		$400			$ 400.00
Health Insurance	To be paid for by traveler				$ -
Travel Insurance	To be paid for by traveler				$ -
First Aid Kit & Medical Supplies		$ 100.00			$ 100.00
Gifts	Gifts for children, host families and workers in the community	$ 100.00			$ 100.00
Miscellaneous	Unexpected/Unaccountded for expences	$ 300.00			$ 300.00
					$ 16,148.00

Community Food & Lodging	Days	Per day	# people	Total
Natalie	40	8	2	$640.00
Corrie	36			
Rachel	10	8	1	$80.00
1st trip travelers	18	8	6	$864.00
2nd trip travelers	18	8	5	$720.00
Total	122		14	$2,304.00

Document 525 - Pre-Implementation Report
Greater Austin
Sieykin, Panama
Water Project

Cost Estimate for Potable Tank			**$ 912.08**				
*doesn't include construction tools							
TRANSPORTATION							
Weight of Cement				2628			
	Rebar Size		lb/ft				
Weight of Rebar	3/8"		0.376	110	*Souce: http://www.allmetalssupply.com/rebar_sizes.htm		
			Total weight	2738.543856			
			Boat loads	2.738543856			
			Rounded boat loads	**3**			
Cost per boat load	$100		**total cost**	**$300**			
Potable Water Tank							
Assumed size of filter tank (m3):	Height (m)	1.7	**Volume of concrete for tank (m3)**				
5	Inner Side Length (m)	1.8	3.82				
	Wall Thickness (m)	0.15					
	Base Thickness (m)	0.15	**Volume of concrete for tank (yd3)**				
	Cap Thickness (m)	0.15	4.996371292				
Concrete mix design							
used http://concrete.union.edu/AVUSNon.htm#EIGHT to develop basic estimate mix design							
	lb/yd^3	lbs needed	kg needed	cost per 50kg bag	**Cost cement $**		4000psi
cement	526	2628	1194.586954	9.5	**$226.97**		slump 2in
coarse aggregate*	1993	9958	4526.258175	0			max agg size 1in
fine aggregate*	1504	7515	3415.701101	0			water cement ratio .57
*Aggregates will be acquired in community							1.5% air content
							unit weight coarse aggregate 100pcf
Steel rebar							
assume rebar will run at 1ft by 1 ft spacing		Spacing (m)	0.3				
	how many needed?	how long?	total length (m)	total length (ft)	cost per ft for3/8 in	**Total rebar cost**	
Columns	26	1.7	44.2	144.976			
Rows	25.2	1.8	45.36	148.7808			
total LF of rebar			89.56	293.7568	$4.30	**$385.11**	

Cost Estimate for River-crossings in Sieykin, Panama Engineers Without Borders - Greater Austin								
Material	**Description**	**Unit**	**Units Needed (Designed)**	**Safety Factor**	**Total Needed**	**Length**	**Unit Price**	**Total Price**
50 kilo sack of cement	Securing Bridge Towers and Supports		10	1	10		9.3	$93.00
6" Concrete Blocks	Pipe Supports, towers supports		60	1	60		0.55	$33.00
Wood Screws	Securing straps on pipes		250	1	250		0.03	$7.50
2" 45 Elbow Joint	Elevating Pipe to wire height		6	1	6		0.75	$4.50
1" 45 Elbow Joint	Elevating Pipe to wire height		6	1	6		0.17	$1.02
Barbed Wire	Supporting the Pipe		1	1	1	500	10	$10.00
Wire Clamps	Secure Wire		25	1	25		0.5	$12.50
Total Cost								**$161.52**

Cost Estimate for Spring Box in Sieykin, Panama

Engineers Without Borders Greater Austin Chapter

Minimum

Cover Slab for Intake Rock Filter		
Length	0.50	m
Width	0.20	m
Thickness	0.10	m
Rebar Spacing	0.20	m
Cement Ratio	0.17	
Sand Ratio	0.33	
Gravel Ratio	0.50	

Floor Slab in Collection Box		
Length	0.50	m
Width	0.50	m
Thickness	0.10	m
Rebar Spacing	0.20	m
Cement Ratio	0.17	
Sand Ratio	0.33	
Gravel Ratio	0.50	

Walls of the Collection Box		
Height	0.50	m
Width	0.50	m
Thickness	0.10	m
Rebar Spacing in	0.20	m
# of Concrete Wa	3.50	
Rebar Spacing in	0.05	
# of Screened Wa	1.00	
Cement Ratio	0.17	
Sand Ratio	0.33	
Gravel Ratio	0.50	

Achoring Lip for Collection Box		
Width	0.50	m
Length	0.30	m
Thickness	0.10	m
Rebar Spacing	0.20	m
Cement Ratio	0.17	
Sand Ratio	0.33	
Gravel Ratio	0.50	

Rebar Calculations

Cover Slab		
Rebar Needed	1.70	m
Rebar (30 feet)	0.19	Pieces
Floor Slab in Collection Box		
Rebar Needed	3.50	m
Rebar (30 feet)	0.38	Pieces
Walls of the Collection Box		
Rebar Needed	17.50	m
Rebar (30 feet)	1.91	Pieces
Door Lid		
Rebar Needed	2.30	m
Rebar (30 feet)	0.25	Pieces
Total Rebar		
Rebar Needed	2.73	Pieces
Waste %	10.00	%
Total to Purchase (3/8")	**3.01**	**Pieces**

Volume Calculations

Cover Slab		
Cement Volume	0.00	m^3
Sand Volume	0.01	m^3
Gravel Volume	0.01	m^3
Concrete Volume	**0.01**	**m^3**
Floor Slab in Collection Box		
Cement Volume	0.01	m^3
Sand Volume	0.01	m^3
Gravel Volume	0.02	m^3
Concrete Volume	**0.03**	**m^3**
Walls of the Collection Box		
Cement Volume	0.02	m^3
Sand Volume	0.04	m^3
Gravel Volume	0.07	m^3
Fill Concrete Volume	**0.09**	**m^3**
Lip		
Cement Volume	0.00	m^3
Sand Volume	0.01	m^3
Gravel Volume	0.01	m^3
Concrete Volume	**0.02**	**m^3**
Cement Needed		
Cement Needed	0.03	m^3
Waste %	10.00	%
Cement Required (50 kg	**1.14**	**Bags**
Sand Needed		
Sand Needed	0.07	m^3
Waste %	10.00	%
Sand Required	**0.08**	**m^3**
Gravel Needed		
Gravel Needed	0.10	m^3
Waste %	10.00	%
Gravel Required	**0.11**	**m^3**

Cost	$	36.20

Maximum

Cover Slab for Intake Rock Filter		
Length	0.95	m
Width	0.95	m
Thickness	0.10	m
Rebar Spacing	0.10	m
Cement Ratio	0.17	
Sand Ratio	0.33	
Gravel Ratio	0.50	

Floor Slab in Collection Box		
Length	0.95	m
Width	0.95	m
Thickness	0.10	m
Rebar Spacing	0.10	m
Cement Ratio	0.17	
Sand Ratio	0.33	
Gravel Ratio	0.50	

Walls of the Collection Box		
Height	0.95	m
Width	0.95	m
Thickness	0.10	m
Rebar Spacing in Wall	0.10	m
# of Concrete Walls	3.50	
Rebar Spacing in Screen	0.05	
# of Screened Walls	1.00	
Cement Ratio	0.17	
Sand Ratio	0.33	
Gravel Ratio	0.50	

Achoring Lip for Collection Box		
Width	2.40	m
Length	0.30	m
Thickness	0.15	m
Rebar Spacing	0.20	m
Cement Ratio	0.17	
Sand Ratio	0.33	
Gravel Ratio	0.50	

Rebar Calculations

Cover Slab		
Rebar Needed	19.95	m
Rebar (30 feet)	2.18	Pieces
Floor Slab in Collection Box		
Rebar Needed	19.95	m
Rebar (30 feet)	2.18	Pieces
Walls of the Collection Box		
Rebar Needed	81.70	m
Rebar (30 feet)	8.94	Pieces
Door Lid		
Rebar Needed	9.98	m
Rebar (30 feet)	1.09	Pieces
Total Rebar		
Rebar Needed	14.39	Pieces
Waste %	10.00	%
Total to Purchase (3/8")	**15.83**	**Pieces**

Volume Calculations

Cover Slab		
Cement Volume	0.02	m^3
Sand Volume	0.05	m^3
Gravel Volume	0.07	m^3
Concrete Volume	**0.09**	**m^3**
Floor Slab in Collection Box		
Cement Volume	0.02	m^3
Sand Volume	0.05	m^3
Gravel Volume	0.07	m^3
Concrete Volume	**0.09**	**m^3**
Walls of the Collection Box		
Cement Volume	0.08	m^3
Sand Volume	0.16	m^3
Gravel Volume	0.24	m^3
Fill Concrete Volume	**0.32**	**m^3**
Lip		
Cement Volume	0.03	m^3
Sand Volume	0.05	m^3
Gravel Volume	0.08	m^3
Concrete Volume	**0.11**	**m^3**
Cement Needed		
Cement Needed	0.15	m^3
Waste %	10.00	%
Cement Required (50kg)	**5.02**	**Bags**
Sand Needed		
Sand Needed	0.30	m^3
Waste %	10.00	%
Sand Required	**0.33**	m^3
Gravel Needed		
Gravel Needed	0.45	m^3
Waste %	10.00	%
Gravel Required	**0.50**	m^3

Cost	$	125.80

Summary

	Min	**Max**
Cement and rebar	36.20	125.80
PVC Pipe (1/2")	1.60	5.77
Shovels (3)	19.23	19.23
Wire screen for seive	4.00	10.00
Chlorine	?	?
Transporting materials	100.00	100.00
Total Cost	161.03	260.80

Total weight (lb)	265.21	840.44

Materials to gather on site

- Gravel
- Sand
- Wood for frame

Cost Estimation for Pipeline

NON-POTABLE MATERIALS LIST								
Material	**Description**	**Unit**	**Units Needed**	**Safety Factor**	**Total Needed**	**Length**	**Unit Price**	**Total Price**
2" PVC (ANSI) SDR 41	Non-potable water main	20' Sections	157	1	157	3140	15	$2,355.00
2" PVC Butterfly Valve	Shut-off/Throttling Valve	-	1	1	1		26.48	$26.48
2" PVC Ball Valve	Function as air release valves during initial fill and sectional shut-off/build clean-outs	-	10	1	10		26.48	$264.80
2" PVC Tee	Tee for splitting 2" pipe	-	13	1	13		1.5	$19.50
2" PVC 90-deg Elbow	2" 90-deg direction change		20	1	20		0.5	$10.00
2" PVC 45-deg bend	2" 45-deg direction change		20	1	20		0.5	$10.00
2" PVC Coupling	Make joints between 2" pipes	-	150	1	150		1	$150.00
2"-0.5" PVC Reducer	Reduce pipe from 2" to 0.5"	-	20	1	20		1	$20.00
0.5" PVC (ANSI) Sch. 40	Non-potable water service pipe	20' Sections	146	1	146	2920	4.05	$591.30
0.5" PVC Tee	Tee for splitting 0.5" pipe	-	14	1	14		0.5	$7.00
0.5" PVC 90-deg Elbow	0.5" 90-deg direction change		20	1	20		0.17	$3.40
0.5" PVC 45-deg bend	0.5" 45-deg direction change		20	1	20		0.17	$3.40
0.5" PVC Faucet/Globe Valv	End user valve	-	30	1	30		4.99	$149.70
0.5" PVC Coupling	Make joints between 0.5" pipes	-	92	1	92		0.12	$11.04
Joint Compound	Connect main		20	1	20		5.1	$102.00
						NON-POTABLE TOTAL		$3,723.62

NON POTABLE MATERIALS LIST - Creek to Tank								
1" PVC (ANSI) Sch. 40	Potable water main	20' Sections	50	1	50	1000	9	$450.00
1" PVC Coupling	Make joints between 1" pipes	-	50	1	50		0.35	$17.50
1" PVC 90-deg Elbow	1" 90-deg direction change		5	1	5		0.5	$2.50
1" PVC 45-deg bend	1" 45-deg direction change		5	1	5		0.5	$2.50
1" PVC Butterfly Valve	Shut-off/Throttling Valve	-	1	1	1		26.48	$26.48
					Spring to Tank POTABLE SUBTOTAL			$498.98

POTABLE MATERIALS LIST - Option 1

Material	Description	Unit	Units Needed	Safety Factor	Total Needed	Length	Unit Price	Total Price
Spring to Tank								
3/4" PVC (ANSI) Sch. 40	Potable water main	20' Sections	155	1	155	3100	4.55	$705.25
3/4" PVC Coupling	Make joints between 1" pipes	-	154	1	154		0.35	$53.90
3/4" PVC 90-deg Elbow	1" 90-deg direction change		5	1	5		0.5	$2.50
3/4" PVC 45-deg bend	1" 45-deg direction change		5	1	5		0.5	$2.50
3/4" PVC Butterfly Valve	Shut-off/Throttling Valve	-	1	1	1		26.48	$26.48
					Spring to Tank POTABLE SUBTOTAL			$790.63
Tank to Users								
1" PVC (ANSI) Sch. 40	Potable water main	20' Sections	157	1	157	3140	9	$1,413.00
1" PVC Butterfly Valve	Shut-off/Throttling Valve	-	1	1	1		26.48	$26.48
1" PVCBall Valve	Function as air release valves during initial fill and sectional shut-off/build clean-outs	-	10	1	10		26.48	$264.80
1" PVC Tee	Tee for splitting 1" pipe	-	8	1	8		1	$8.00
1" PVC 90-deg Elbow	1" 90-deg direction change		5	1	5		0.5	$2.50
1" PVC 45-deg bend	1" 45-deg direction change		5	1	5		0.5	$2.50
1" PVC Coupling	Make joints between 1" pipes	-	87	1	87		0.35	$30.45
1"-0.5" PVC Reducer	Reduce pipe from 1" to 0.5"		10	1	10		1	$10.00
0.5" PVC (ANSI) Sch. 40	Non-potable water service pipe	20' Sections	146	1	146	2920	4.55	$664.30
0.5" PVC Tee	Tee for splitting 0.5" pipe	-	14	1	14		0.5	$7.00
0.5" PVC 90-deg Elbow	0.5" 90-deg direction change	-	20	1	20		0.17	$3.40
0.5" PVC 45-deg bend	0.5" 45-deg direction change	-	20	1	20		0.17	$3.40
0.5" PVC Faucet/Globe V	End user valve	-	215	1	215		0.35	$75.25
0.5" PVC Coupling	Make joints between 0.5" pipes	-	30	1	30		1	$30.00
0.5" Faucet/Globe Valve	End user valve	-	30	1	30		4.99	$149.70
Joint Compound			20	1	20		5.1	$102.00
					Tank to Users POTABLE SUBTOTAL			$2,792.78

POTABLE MATERIALS LIST - Option 2

Material	Description	Unit	Units Needed	Safety Factor	Total Needed	Length	Unit Price	Total Price
Spring to Tank								
3/4" PVC (ANSI) Sch. 40	Potable water main	20' Sections	155	1	155	3100	4.55	$705.25
3/4" PVC Coupling	Make joints between 1" pipes	-	154	1	154		0.35	$53.90
3/4" PVC 90-deg Elbow	1" 90-deg direction change		5	1	5		0.5	$2.50
3/4" PVC 45-deg bend	1" 45-deg direction change		5	1	5		0.5	$2.50
3/4" PVC Butterfly Valve	Shut-off/Throttling Valve	-	1	1	1		26.48	$26.48
					Spring to Tank POTABLE SUBTOTAL			$790.63
Tank to Users								
1" PVC (ANSI) Sch. 40	Potable water main	20' Sections	157	1	157	3140	9	$1,413.00
1" PVC Butterfly Valve	Shut-off/Throttling Valve	-	1	1	1		26.48	$26.48
1" PVC Ball Valve	Function as air release valves during initial fill and sectional shut-off	-	2	1	2		3	$6.00
1" PVC Tee	Tee for splitting 1" pipe	-	13	1	13		1	$13.00
1" PVC 90-deg Elbow	1" 90-deg direction change		20	1	20		0.5	$10.00
1" PVC 45-deg bend	1" 45-deg direction change		20	1	20		0.5	$10.00
1" PVC Coupling	Make joints between 1" pipes	-	150	1	150		0.35	$52.50
1"-0.375" PVC Reducer	Reduce pipe from 1" to 0.375"	-	20	1	20		1	$20.00
0.375" PVC (ANSI) Sch. 40	Potable water service pipe	20' Sections	146	1	146	2920	3.5	$511.00
0.375" PVC Tee	Tee for splitting 0.5" pipe	-	14	1	14		0.75	$10.50
0.375" PVC 90-deg Elbow	0.5" 90-deg direction change		20	1	20		0.17	$3.40
0.375" PVC 45-deg bend	0.5" 45-deg direction change		20	1	20		0.17	$3.40
0.375" PVC Faucet/Globe V	End user valve	-	30	1	30		4.99	$149.70
0.375" PVC Coupling	Make joints between 0.375" pi	-	92	1	92		0.12	$11.04
Joint Compound	Connect main			1	0		5.1	$0.00
					Tank to Users POTABLE SUBTOTAL			$2,240.02

Weight Calculations				
Section	**Material**	**Unit weight (20 ft sections)**	**Units needed**	**Total Weight(lb)**
Non-Potable	2" PVC (ANSI) SDR 41	13.6	157	2135.2
	1" PVC (ANSI) Sch. 40	6.4	50	320
	0.5" PVC (ANSI) Sch. 40	3.2	146	467.2
Potable (Spring to Tank)	3/4" PVC (ANSI) Sch. 40	4.2	155	651
Potable (Tank to Users opt 1)	1" PVC (ANSI) Sch. 40	6.4	157	1004.8
	0.5" PVC (ANSI) Sch. 40	3.2	146	467.2
Potable (Tank to Users opt 2)	1" PVC (ANSI) Sch. 40	6.4	157	1004.8
	0.375" PVC (ANSI) Sch. 40	2.18	146	318.28

Tank to Users POTABLE SUBTOTAL		2240.02	
	POTABLE TOTAL OPT 1	3583.41	
	POTABLE TOTAL OPT 2	3030.65	
Transportation Cost			
Totals (Potable + Non)	**w/ Potable opt 1**	$700	Max weight per boat trip = 1000 lb
	w/ Potable opt 2	$700	Cost per boat load = $100
			Valves, Elbows and Coupling takes 2 boat trips
Grand Totals (Potable + Non)	**w/ Potable opt 1**	$8,506	
	w/ Potable opt 2	$7,953	

Total Implementation Materials Cost	
Pipeline	$8,506
Springbox	$261
Water Tank	$912
River-crossings	$162
Total	$9,679

10.0 MENTOR ASSESSMENT

The Panama Project Team prepared this 525 Final (95%) Design document through continual communication and cooperation, both within the team, as well as with other members of EWB Greater Austin (both student and professional). Besides making themselves readily available for general technical guidance, professionals Chris Lombardo and Charlotte Gilpin provided timely advice on EWB processes and procedures obtained through participating in several previous EWB projects. Joe Goessling was often called upon to share his experiences in the Peace Corps working on a water project in Panama. His professional guidance coupled with practical knowledge of local materials and practices were extremely helpful. Other EWB Greater Austin professionals providing technical information include Chris Mansuri, Eric Thurman, and Adil Mohammed. Additionally, the team sought advice from non-EWB members within the professional and the academic arena.

Weekly meetings of about twenty students were held and chaired by the project co-leads Natalie Craik and Corrie Thompson to work on the design, planning, and education for the project in Seiykin, Panama. The first five to ten minutes were used to update everyone on the project's progress and announce any important information regarding the project, EWB Greater Austin, or other items of mutual interest. Following this the team would break up into subgroups to brainstorm, discuss the logistics of the project, and consider potential solutions and problems. Any new members or individuals interested in joining EWB were briefed on the project and then directed to the subgroup that matched their interests and skill sets.

Breaking into subgroups greatly increased the efficiency of the meeting discussions. Each subgroup was directed by a subgroup lead, including Kenny O'Neill - construction (which was further divided into piping/mapping, bridge, source protection, and tank construction), Andrea Tee - health education, Travis Hampton - fund raising and grant writing, Patrick Dunlap - health and safety, Hannah Romaine - supply and demand, and Adrienne O'Neill - water treatment. All subgroups played an integral part in putting together this comprehensive document; it was truly a collaborative effort.

After careful consideration of the water supply and demand data based on information collected from the two previous assessment trips, it was decided that two parallel water systems (potable and non-potable) would be implemented. The existing non-potable water system will be upgraded to repair damaged piping and valves, seal the leaking storage tank, and include a large aggregate filter at the stream source to reduce debris and prevent clogs. A new potable water system will consist of a spring box, storage tank (sized using the Sequent Peak Method), and piping distribution system. The pipes for both systems will run underground where possible and incorporate bridging techniques elsewhere. Because the spring source cannot provide enough potable water to meet all the needs of the community, each house will have a non-potable water tap on the lower level for bathing and laundry and a potable water tap on the upper level for drinking, cooking, and dishwashing.

Realizing that providing clean water is only part of the solution, the team has also worked hard on developing health education materials. Both children and adults in the community will be taught hygiene and healthy practices, how germs are spread, and water conservation. The health education materials have been created to be fun and interactive so as to be more effective, including skits, songs, take-home activity books, and hands-on demonstrations.

I have attended the weekly project meetings since early February and have been impressed with the organization of this team and with how they have conducted themselves individually. Team members take very seriously the dual responsibilities of designing an appropriate community water system and health education. They are willing to work hard on tasks and communicate with each other easily. Information is readily shared between subgroups in an open environment with the absence of ego, politics, or cliques. New members are warmly greeted, made to feel welcome immediately, and quickly become contributing members of the team. This positive atmosphere has enabled a large project to be smoothly developed while allowing all team members to learn and grow from the experience.

Tim Ager, Professional Mentor

APPENDIX A

STRUCTURAL CALCULATIONS AND DRAWINGS

for

POTABLE WATER TANK
WATER PROJECT
SIEYKIN, PANAMA

EWB Greater Austin

LOADING
&
DESIGN CRITERIA

for

POTABLE WATER TANK
WATER PROJECT
SIEYKIN, PANAMA

EWB Greater Austin

Water Project
Sieykin, Panama

LOADING & DESIGN CRITERIA

TABLE OF CONTENTS

Water Project
Sieykin, Panama

Codes and Standards

- 2009 International Building Code (IBC) in conjunction with Panama Building Code Addendums (REP-2003) – See Appendix B
- ASCE 7-05 Minimum Design Loads for Buildings and Other Structures
- ACI 318-08

Material Specifications and Strengths

Concrete

Normal Weight Concrete

Slab on Grade	f'c	=	2.0 ksi
Foundation Grade Beams	f'c	=	2.0 ksi
Cast-in-place Walls	f'c	=	2.0 ksi
Cast in place roof	f'c	=	2.0 ksi

Reinforcing Steel

ASTM A615 - GR 40 (GR 60 for Walls)	Deformed bars
ASTM A185	Welded Wire Fabric

Live Loads

Tank Roof

40 psf – Non-reducible

Tank Foundation

62.4 pcf – Water Weight (Water weight considered as Live Load – conservative)

Dead Loads

Tank Roof

15 psf – Miscellaneous

Tank Walls

62.4 pcf – Lateral Water Pressure

Water Project
Sieykin, Panama

Wind Loads

The following design parameters are used to calculate design wind pressures to be used for the Tank wall design on the above referenced project in accordance with ASCE 7-05 and 2003 Panama Building Code (REP -2003) recommendations. Design loads are based on the following parameters:

I_w = 1.15 (Occupancy III Structure)

V = 140 km/hr (90 mph basic wind speed) per REP-2003

Exposure = C (Open Terrain)

Seismic Loads

The following design parameters are used to calculate design seismic loads to be used for the Tank wall design on the above referenced project in accordance with ASCE 7-05 and 2003 Panama Building Code (REP -2003) recommendations. Design loads are based on the following parameters:

Ip = 1.50 (Occupancy III Structure)

Aa = 0.24
Av = 0.28 (Values prescribed by REP-2003 for Changuinola zone)

Soil Classification – D (Stiff soil – conservative)

Seismic Performance Category – D (REP – 2003)

Fa = 1.3
Fv = 1.9 (REP -2003)

Ca = Fa * Aa = 1.3*0.24 = 0.312

Seismic Force for non-structural elements:
Fp = 4.0*Ca*Ip*Wp
= 4.0*0.312*1.5*Wp = 1.87*Wp (very conservative)

Geotechnical Report

Foundation Loads

Geotechnical report is not available for this project. Conservative estimate of the soil bearing pressure is considered as follows

Foundation System:

Bearing Press = 1500 psf	Grade Beam to be embedded at least 1'-0" below lowest adjacent grade.

TITLE SHEET OF

POTABLE WATER TANK DESIGN

TANK DIMENSIONS

REQUIRED VOLUME = 5000 Liters (1320 GAL)

$= 5000 \times 0.001 = 5\ m^3$

$= 5\ m^3 \times 35.315 \approx 177\ ft^3$

INTERIOR TANK DIMENSIONS

$6\ ft\ (L) \times 6\ ft\ (W) \times 5\ ft\ (H) = 180\ ft^3$

$1.83\ m\ (L) \times 1.83\ m\ (W) \times 1.52\ m\ (H) = 5.09\ m^3$

ASSUME 6" THICK WALLS (0.15 m) AND 6" THICK ROOF (0.15 m)

OVERALL TANK DIMENSIONS

$7\ ft\ (L) \times 7\ ft\ (W) \times 5.5\ ft\ (H)$

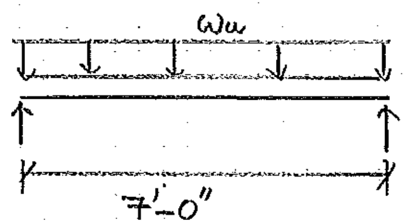
$2.13\ m\ (L) \times 2.13\ m\ (W) \times 1.68\ m\ (H)$

TANK DESIGN

ROOF DESIGN

LOADS.

CONSIDER 1'-6" DESIGN STRIP



SELF WEIGHT – 150pcf × 6"/12 × 1'-6" = 112.5 plf

DL – 15 psf × 1'-6" = 23 plf

w_D = 112.5 + 22.5 = 135 plf

LL – 40 psf × 1'-6" = 60 plf.

TWO CASES CONSIDERED.

FOR POSITIVE MOMENT & REINF. DESIGN – PINNED SUPPORT

FOR NEGATIVE MOMENT & REINF DESIGN – FIXED SUPPORT.

$\boxed{\text{6" THICK SLAB w/ \#3 @ 9" O.C – O.K}}$

SEE ATTACHED 'ENERCALC' DESIGN RESULTS.

Title :
Dsgnr:
Description :

Scope :

Job #
Date: 7:40AM, 18 APR 10

Rev: 580010
User: KW-0604564, Ver 5.8.0, 1-Dec-2003
(c)1983-2003 ENERCALC Engineering Software

Concrete Rectangular & Tee Beam Design

Page 1
watertank.ecw:Calculations

Description Tank Roof Design - Positive Moment

General Information

Code Ref: ACI 318-02, 1997 UBC, 2003 IBC, 2003 NFPA 5000

Span	7.00 ft	f'c	2,000 psi
Depth	6.000 in	Fy	40,000 psi
Width	18.000 in	Concrete Wt.	145.0 pcf
		Seismic Zone	4
		End Fixity	Pinned-Pinned
Beam Weight Added Internally		Live Load acts with Short Term	

Reinforcing

Rebar @ Center of Beam...	Count	Size	'd' from Top	Rebar @ Left End of Beam...	Count	Size	'd' from Top	Rebar @ Right End of Beam...	Count	Size	'd' from Top
#1	2	3	3.00in	#1	2	3	3.00 in	#1	2	3	3.00 in

Load Factoring

Note: Load factoring supports 2003 IBC and 2003 NFPA 5000 by virtue of their references to ACI 318-02 for concrete design.
Factoring of entered loads to ultimate loads within this program is according to ACI 318-02 C.2

Uniform Loads

	Dead Load	Live Load	Short Term	Start	End
#1	0.023 k	0.060 k	k	0.000 ft	7.000 ft

Summary

Beam Design OK

Span = 7.00ft, Width= 18.00in Depth = 6.00in

Maximum Moment : Mu	1.75 k-ft	Maximum Deflection	-0.0125 in
Allowable Moment : Mn*phi	1.87 k-ft		
Maximum Shear : Vu	0.94 k	Max Reaction @ Left	0.67 k
Allowable Shear : Vn*phi	4.11 k	Max Reaction @ Right	0.67 k

Shear Stirrups...

Stirrup Area @ Section 0.440 in2

Region	0.000	1.167	2.333	3.500	4.667	5.833	7.000 ft
Max. Spacing	Not Req'd	Not Req'd	Not Req'd	Not Req'd	Not Req'd	Not Req'd	Not Req'd in
Max Vu	0.938	0.674	0.337	0.329	0.329	0.666	0.930 k

Bending & Shear Force Summary

Bending...	Mn*Phi	Mu, Eq. C-1	Mu, Eq. C-2	Mu, Eq. C-3
@ Center	1.87 k-ft	1.75 k-ft	1.64 k-ft	0.73 k-ft
@ Left End	1.87 k-ft	0.00 k-ft	0.00 k-ft	0.00 k-ft
@ Right End	1.87 k-ft	0.00 k-ft	0.00 k-ft	0.00 k-ft
Shear...	**Vn*Phi**	**Vu, Eq. C-1**	**Vu, Eq. C-2**	**Vu, Eq. C-3**
@ Left End	4.11 k	0.94 k	0.88 k	0.39 k
@ Right End	4.11 k	0.93 k	0.87 k	0.39 k

Deflection

Deflections...	Upward			Downward		
DL + [Bm Wt]	0.0000 in	at	7.0000 ft	-0.0086 in	at	3.5000 ft
DL + LL + [Bm Wt]	0.0000 in	at	7.0000 ft	-0.0125 in	at	3.5000 ft
DL + LL + ST + [Bm Wt]	0.0000 in	at	7.0000 ft	-0.0125 in	at	3.5000 ft

Reactions...	@ Left	@ Right
DL + [Bm Wt]]	0.461 k	0.461 k
DL + LL + [Bm Wt]	0.671 k	0.671 k
DL + LL + ST + [Bm Wt]	0.671 k	0.671 k

Concrete Rectangular & Tee Beam Design

Description Tank Roof Design - Positive Moment

Section Analysis

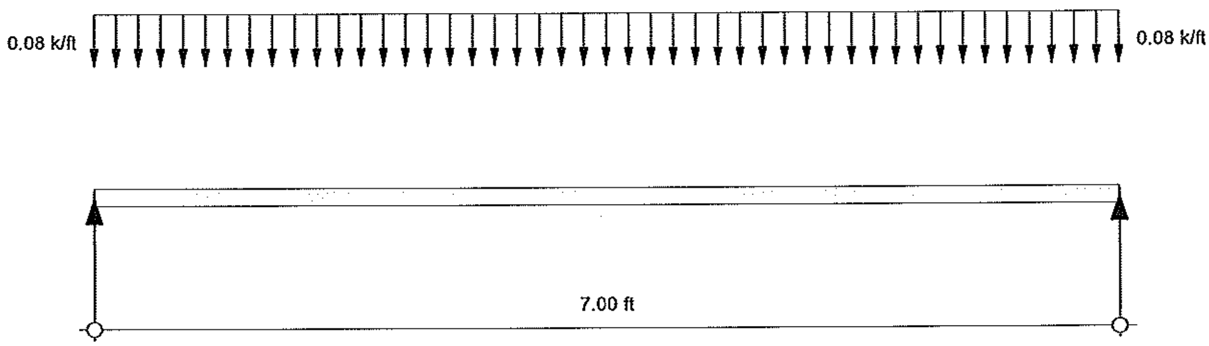
Evaluate Moment Capacity...	Center	Left End	Right End
X : Neutral Axis	0.335 in	0.335 in	0.335 in
a = beta * Xneutral	0.285 in	0.285 in	0.285 in
Compression in Concrete	8.713 k	8.713 k	8.713 k
Sum [Steel comp. forces]	0.000 k	0.000 k	0.000 k
Tension in Reinforcing	-8.800 k	-8.800 k	-8.800 k
Find Max As for Ductile Failure...			
X-Balanced	2.055 in	2.055 in	2.0551 in
Xmax = Xbal * 0.75	1.541 in	1.541 in	1.541 in
a-max = beta * Xbal	1.747 in	1.747 in	1.747 in
Compression in Concrete	40.090 k	40.090 k	40.090 k
Sum [Steel Comp Forces]	0.000 k	0.000 k	0.000 k
Total Compressive Force	40.090 k	40.090 k	40.090 k
AS Max = Tot Force / Fy	1.002 in2	1.002 in2	1.002 in2
Actual Tension As	0.220 OK	0.000 OK	0.000 OK

Additional Deflection Calcs

Neutral Axis	0.785 in	Mcr	3.02 k-ft
Igross	324.00 in4	Ms:Max DL + LL	1.17 k-ft
Icracked	15.18 in4	R1 = (Ms:DL+LL)/Mcr	2.570
Elastic Modulus	2,549.1 ksi	Ms:Max DL+LL+ST	1.17 k-ft
Fr = 7.5 * f'c^.5	335.410 psi	R2 = (Ms:DL+LL+ST)/Mcr	2.570
Z:Cracking	0.000 k/in	I:eff... Ms(DL+LL)	324.000 in4
Z:cracking > 175 : No Good!		I:eff... Ms(DL+LL+ST)	324.000 in4
Eff. Flange Width	18.00 in		

ACI Factors (per ACI 318-02, applied internally to entered loads)

ACI C-1 & C-2 DL	1.400	ACI C-2 Group Factor	0.750	Add"l "1.4" Factor for Seismic	1.400
ACI C-1 & C-2 LL	1.700	ACI C-3 Dead Load Factor	0.900	Add"l "0.9" Factor for Seismic	0.900
ACI C-1 & C-2 ST	1.700	ACI C-3 Short Term Factor	1.300		
....seismic = ST * :	1.100				



Mu:Max = 1.75 k-ft

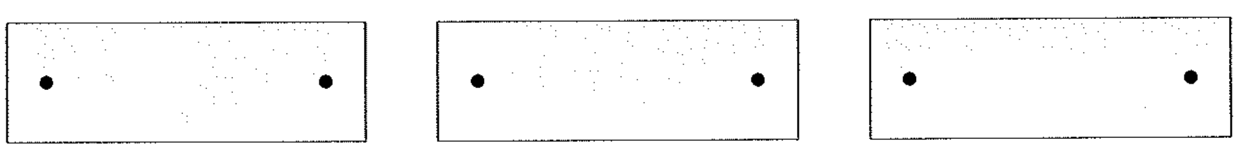
Dmax = 0.0125 in

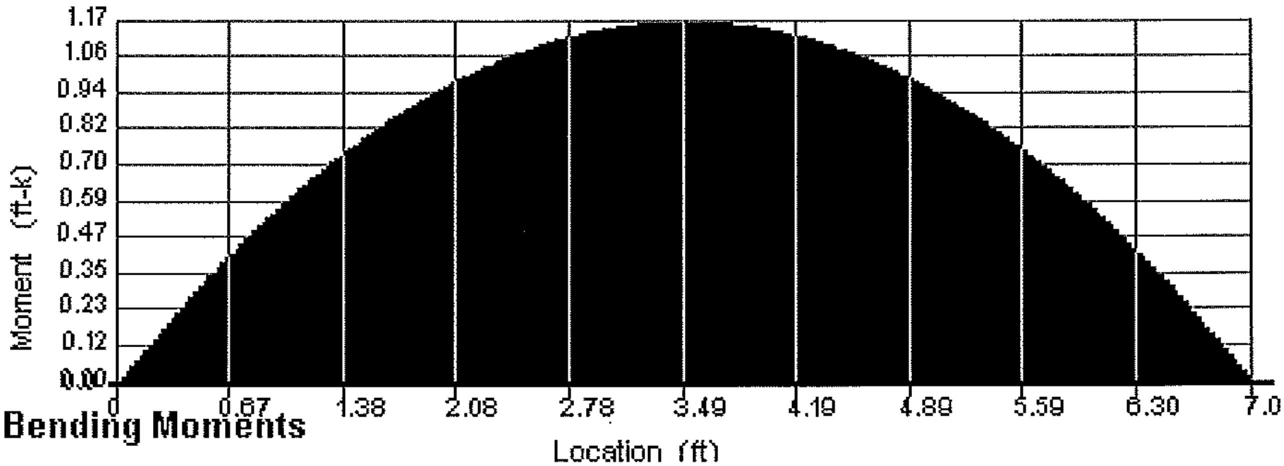
Rmax = 0.671 k

Vu-Max = 0.938 k

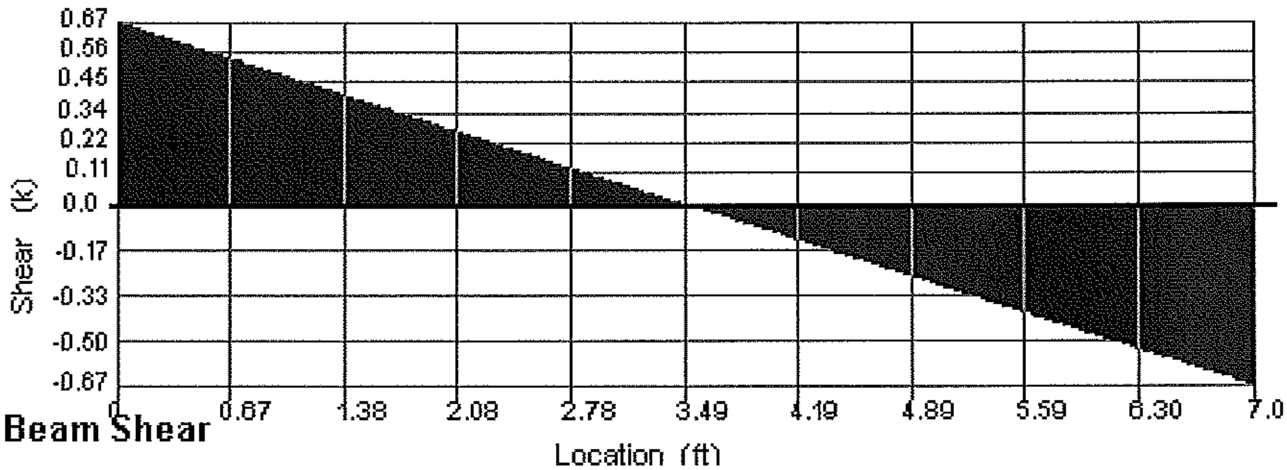
Rmax = 0.671 k

Vu Max = 0.930 k

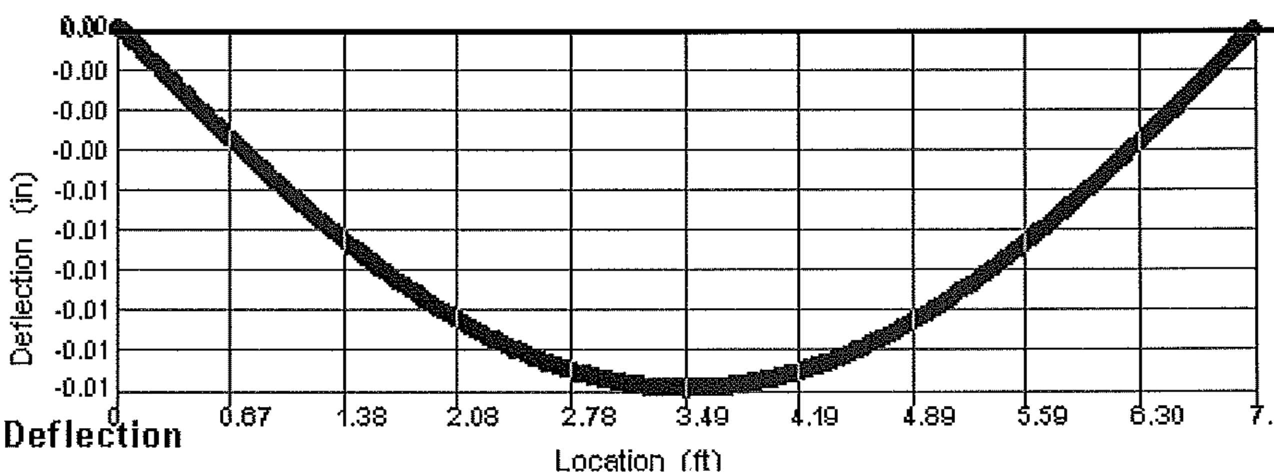




Bending Moments



Beam Shear



Deflection

Concrete Rectangular & Tee Beam Design

Description Tank Roof Design - Negative Moment

General Information

Code Ref: ACI 318-02, 1997 UBC, 2003 IBC, 2003 NFPA 5000

Span	7.00 ft	f'c	2,000 psi
Depth	6.000 in	Fy	40,000 psi
Width	18.000 in	Concrete Wt.	145.0 pcf
		Seismic Zone	4
		End Fixity	Fixed-Fixed
Beam Weight Added Internally		Live Load acts with Short Term	

Reinforcing

	Rebar @ Center of Beam...			Rebar @ Left End of Beam...			Rebar @ Right End of Beam...		
	Count	Size	'd' from Top	Count	Size	'd' from Top	Count	Size	'd' from Top
#1	2	3	3.00in	2	3	3.00 in	2	3	3.00 in

Load Factoring

Note: Load factoring supports 2003 IBC and 2003 NFPA 5000 by virtue of their references to ACI 318-02 for concrete design. Factoring of entered loads to ultimate loads within this program is according to ACI 318-02 C.2

Uniform Loads

	Dead Load	Live Load	Short Term	Start	End
#1	0.023 k	0.060 k	k	0.000 ft	7.000 ft

Summary

Beam Design OK

Span = 7.00ft, Width= 18.00in Depth = 6.00in

Maximum Moment : Mu	-1.17 k-ft	Maximum Deflection	-0.0025 in
Allowable Moment : Mn*phi	1.87 k-ft		
Maximum Shear : Vu	0.94 k	Max Reaction @ Left	0.67 k
Allowable Shear : Vn*phi	4.11 k	Max Reaction @ Right	0.67 k

Shear Stirrups...

Stirrup Area @ Section 0.000 in2

Region	0.000	1.167	2.333	3.500	4.667	5.833	7.000 ft
Max. Spacing	0.000	0.000	0.000	0.000	0.000	0.000	0.000 in
Max Vu	4.105	4.105	4.105	4.105	4.105	4.105	4.105 k

Bending & Shear Force Summary

Bending...	Mn*Phi	Mu, Eq. C-1	Mu, Eq. C-2	Mu, Eq. C-3
@ Center	1.87 k-ft	0.58 k-ft	0.55 k-ft	0.24 k-ft
@ Left End	1.87 k-ft	-1.17 k-ft	-1.10 k-ft	-0.48 k-ft
@ Right End	1.87 k-ft	-1.17 k-ft	-1.10 k-ft	-0.48 k-ft
Shear...	**Vn*Phi**	**Vu, Eq. C-1**	**Vu, Eq. C-2**	**Vu, Eq. C-3**
@ Left End	4.11 k	0.94 k	0.88 k	0.39 k
@ Right End	4.11 k	0.93 k	0.87 k	0.39 k

Deflection

Deflections...	Upward			Downward		
DL + [Bm Wt]	0.0000 in	at	0.0000 ft	-0.0017 in	at	3.5000 ft
DL + LL + [Bm Wt]	0.0000 in	at	0.0000 ft	-0.0025 in	at	3.5000 ft
DL + LL + ST + [Bm Wt]	0.0000 in	at	0.0000 ft	-0.0025 in	at	3.5000 ft

Reactions...	@ Left	@ Right
DL + [Bm Wt]]	0.461 k	0.461 k
DL + LL + [Bm Wt]	0.671 k	0.671 k
DL + LL + ST + [Bm Wt]	0.671 k	0.671 k

Concrete Rectangular & Tee Beam Design

Description Tank Roof Design - Negative Moment

Section Analysis

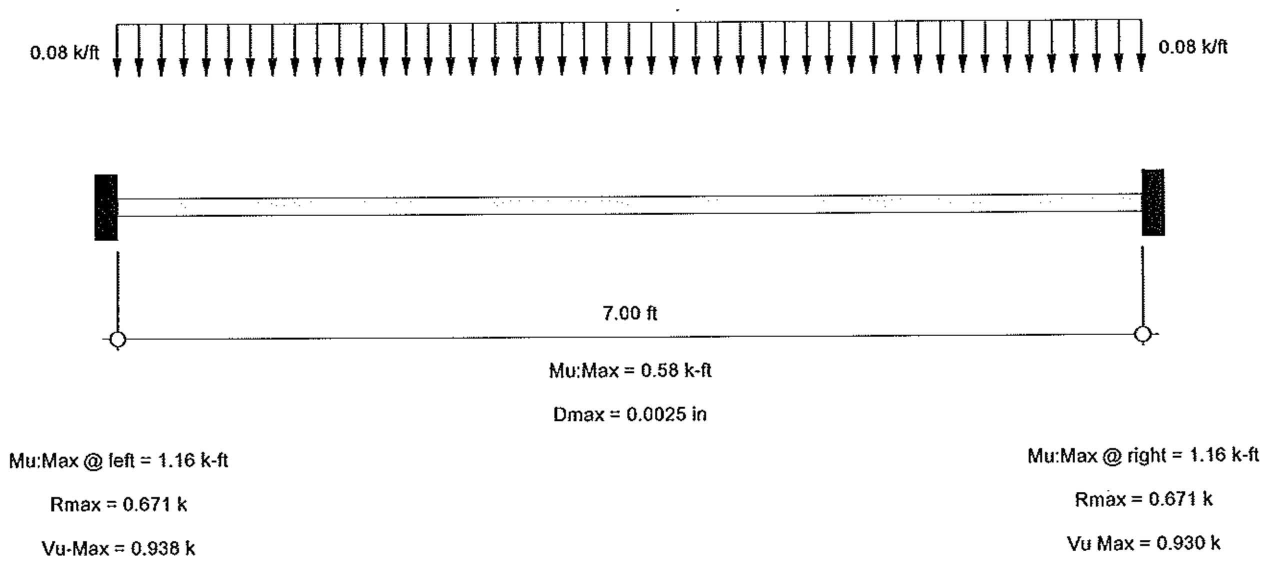
Evaluate Moment Capacity...	Center	Left End	Right End
X : Neutral Axis	0.335 in	0.335 in	0.335 in
a = beta * Xneutral	0.285 in	0.285 in	0.285 in
Compression in Concrete	8.713 k	8.713 k	8.713 k
Sum [Steel comp. forces]	0.000 k	0.000 k	0.000 k
Tension in Reinforcing	-8.800 k	-8.800 k	-8.800 k
Find Max As for Ductile Failure...			
X-Balanced	2.055 in	2.055 in	2.0551 in
Xmax = Xbal * 0.75	1.541 in	1.541 in	1.541 in
a-max = beta * Xbal	1.747 in	1.747 in	1.747 in
Compression in Concrete	40.090 k	40.090 k	40.090 k
Sum [Steel Comp Forces]	0.000 k	0.000 k	0.000 k
Total Compressive Force	40.090 k	40.090 k	40.090 k
AS Max = Tot Force / Fy	1.002 in2	1.002 in2	1.002 in2
Actual Tension As	0.220 OK	0.220 OK	0.220 OK

Additional Deflection Calcs

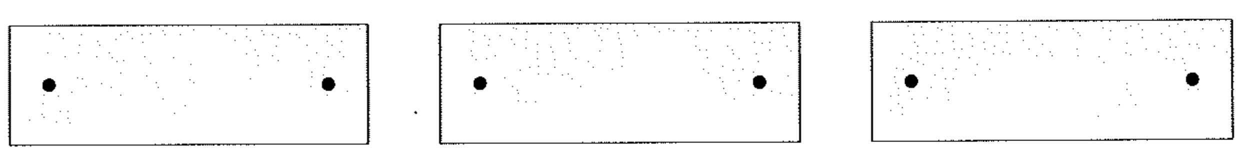
Neutral Axis	0.785 in	Mcr	3.02 k-ft
Igross	324.00 in4	Ms:Max DL + LL	0.78 k-ft
Icracked	15.18 in4	R1 = (Ms:DL+LL)/Mcr	3.855
Elastic Modulus	2,549.1 ksi	Ms:Max DL+LL+ST	0.78 k-ft
Fr = 7.5 * f'c^.5	335.410 psi	R2 = (Ms:DL+LL+ST)/Mcr	3.855
Z:Cracking	0.000 k/in	I:eff... Ms(DL+LL)	324.000 in4
Z:cracking > 175 : No Good!		I:eff... Ms(DL+LL+ST)	324.000 in4
Eff. Flange Width	18.00 in		

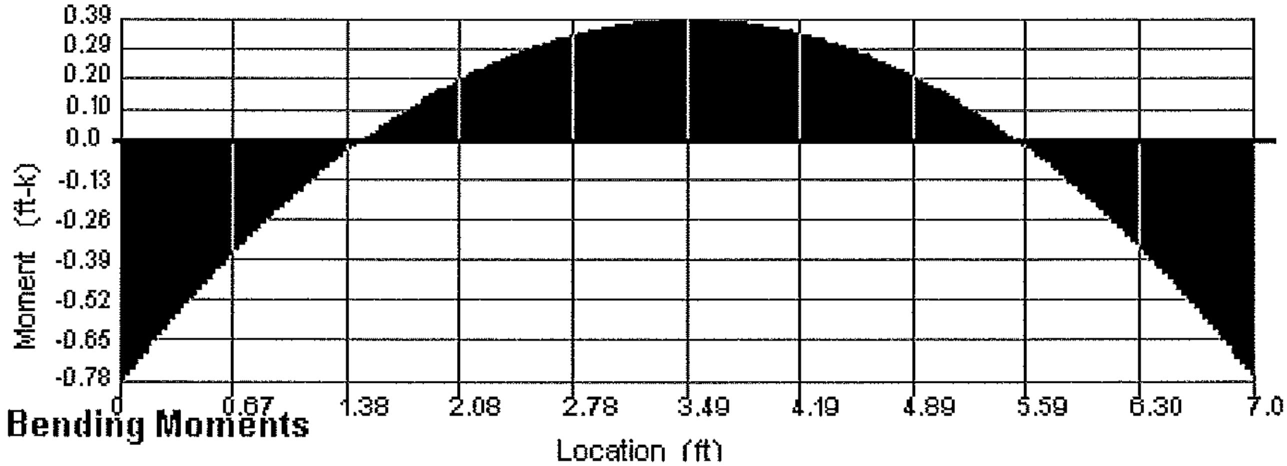
ACI Factors (per ACI 318-02, applied internally to entered loads)

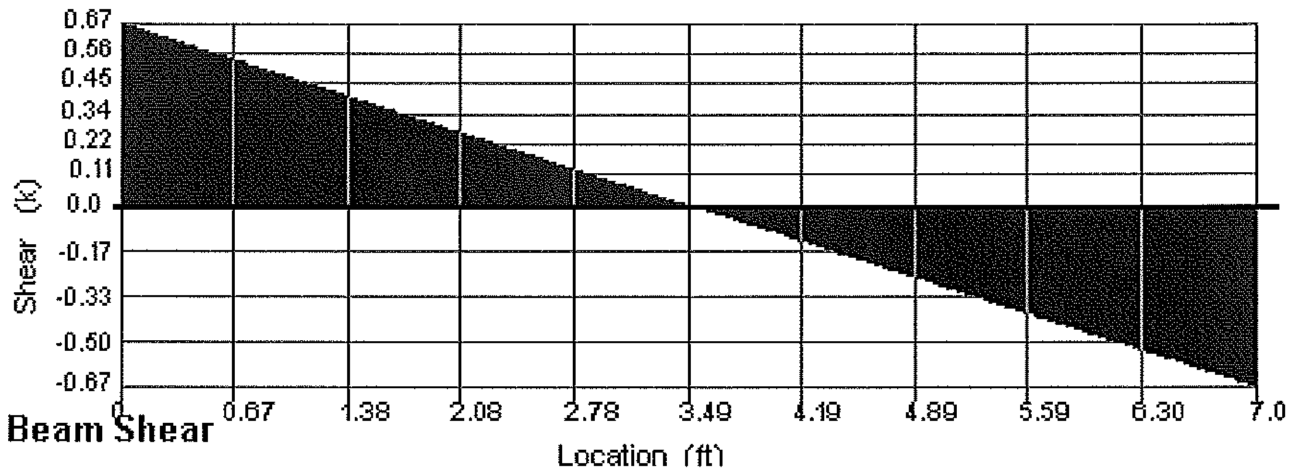
ACI C-1 & C-2 DL	1.400	ACI C-2 Group Factor	0.750	Add"l "1.4" Factor for Seismic	1.400
ACI C-1 & C-2 LL	1.700	ACI C-3 Dead Load Factor	0.900	Add"l "0.9" Factor for Seismic	0.900
ACI C-1 & C-2 ST	1.700	ACI C-3 Short Term Factor	1.300		
....seismic = ST * :	1.100				

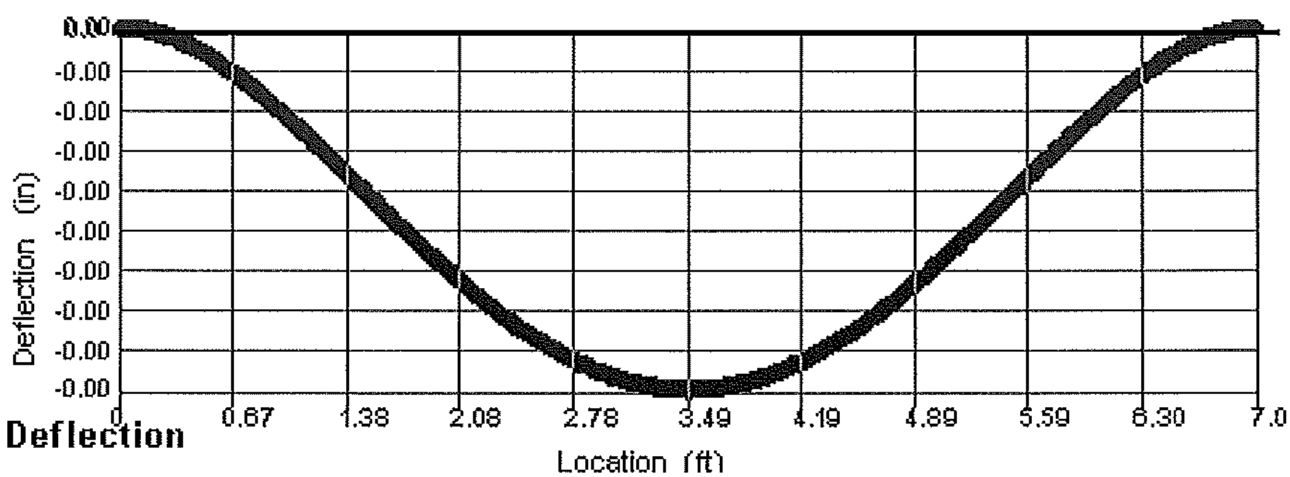


0.08 k/ft
0.08 k/ft
7.00 ft
Mu:Max = 0.58 k-ft
Dmax = 0.0025 in
Mu:Max @ left = 1.16 k-ft
Rmax = 0.671 k
Vu-Max = 0.938 k
Mu:Max @ right = 1.16 k-ft
Rmax = 0.671 k
Vu Max = 0.930 k




0.39
0.29
0.20
0.10
0.0
-0.13
-0.26
-0.39
-0.52
-0.65
-0.78
Moment (ft-k)
0
0.67
1.38
2.08
2.78
3.49
4.19
4.89
5.59
6.30
7.0
Bending Moments
Location (ft)


0.67
0.56
0.45
0.34
0.22
0.11
0.0
-0.17
-0.33
-0.50
-0.67
Shear (k)
0
0.67
1.38
2.08
2.78
3.49
4.19
4.89
5.59
6.30
7.0
Beam Shear
Location (ft)


0.00
-0.00
-0.00
-0.00
-0.00
-0.00
-0.00
-0.00
-0.00
-0.00
Deflection (in)
0
0.67
1.38
2.08
2.78
3.49
4.19
4.89
5.59
6.30
7.0
Deflection
Location (ft)

WIND LOAD CALCULATION (PER ASCE 7-05)

BASIC WIND SPEED, $V = 90$ mph

$I_\omega = 1.15$

EXPOSURE - C

$f = q_z G C_f$ (Eq 6-28)

$q_z = 0.00256 K_z K_{zt} K_d V^2 I$

$K_z = 0.85$ (Ht < 15'-0")

$K_d = 0.9$ (SQUARE TANKS - TABLE 6-4)

$K_{zt} = (1 + K_1 K_2 K_3)^2$

ALTERNATIVELY, USE $K_{zt} = 1.0$

$q_z = 0.00256 \times 0.85 \times 1.0 \times 0.9 \times 90^2 \times 1.15 = 18.24$ psf

$G = 0.85$ (SECTION 6.5.8.1)

$C_f = 1.3$ ($h/D < 1.0$, FIGURE 6-21)

$$\boxed{f = 18.24 \text{ psf} \times 0.85 \times 1.3 = 20.2 \text{ psf}}$$

TANK WALL DESIGN

LOADS

CONSIDER 1'-0" DESIGN STRIP.

SELF WEIGHT - 150 pcf × 6"/12 × 5.5'

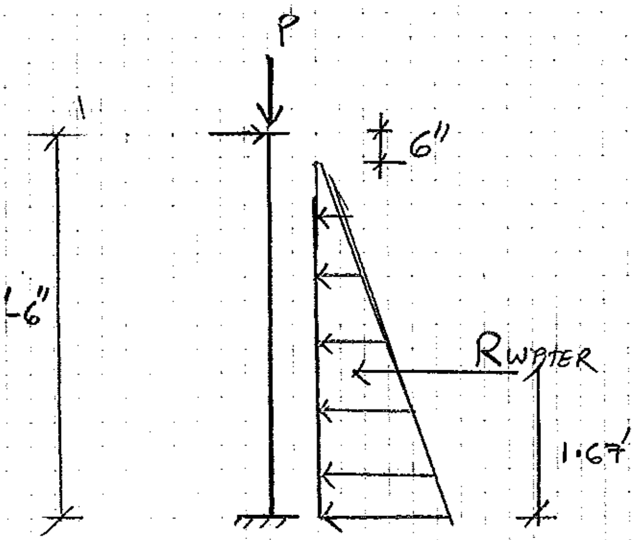
= 412.5 plf

ROOF CONC. WEIGHT

- 150 pcf × 6"/12 × 7'/2 = 262.5 plf

ROOF DL - 15 psf × 7'/2 = 52.5 plf

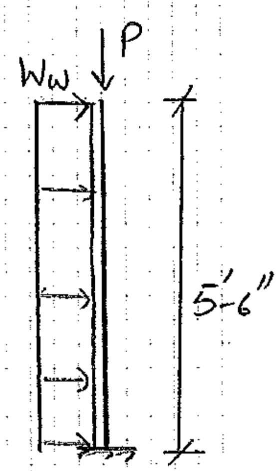
ROOF LL - 40 psf × 7'/2 = 140 plf.



CASE 1: HYDROSTATIC + ROOF LOADS

$$P_{DL} = 412.5 + 262.5 + 52.5 = 0.73^{k/ft}$$

$$P_{LL} = 0.14^{k/ft}$$



CASE 2: WIND + ROOF LOADS

HYDROSTATIC LOADS.

$$R_{WATER} = \{(62.4\ pcf) \times 5'\} \times 0.5 \times 5' = 780^{\#/ft}$$

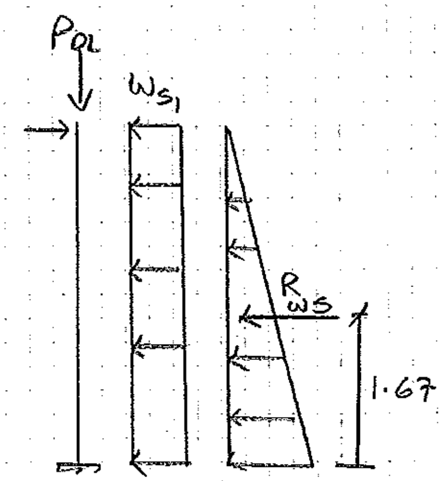
WIND LOADS.

$$W_W = 20.2\ psf \times 1'\text{-}0" = 20.2\ plf$$

WIND ALWAYS ACTS AGAINST HYDROSTATIC PRESSURE. GOVERNING CASE IS WHEN TANK IS EMPTY

SEISMIC LOADS.

$P_{DL} = 0.73^{K/ft}$
$R_w = 0.78^{K/ft}$
} SEE PREV. CALCS



CASE 3: SEISMIC + ROOF LOADS

W_{S_1} = SEISMIC LOAD DUE TO WALL SELF WEIGHT

$W_{S_1} = 412.5 \text{ plf} \times 1.87 = 0.77^{K/ft}$

R_{WS} = SEISMIC LOAD OF WATER

$R_w = R_w \times 1.87 = 0.78^{K/ft} \times 1.87 = 1.46^{K/ft}$

6" THICK WALL WITH #3 @ 9" O.C VERTICAL AND #3 @ 12" O.C HORIZONTAL REINFORCEMENT O.K.

SEE ATTACHED 'ENERCALC' RESULTS

Printed: 18 APR 2010

Concrete Slender Wall

File: c:\users\adil\desktop\wall.ec6
ENERCALC, INC. 1983-2008, Ver: 6.0.18, N:75855

Lic. # : KW-06004564 License Owner : ENCOTECH ENGINEERING INC

Description : Tank Wall Design - Case 1: Roof Loads + Hydrostatic Loads

General Information

Code Ref: ACI 318-05, Sec. 14.8

f'c : Concrete 28 day strength	=	2.0 ksi	Wall Thickness	6.0 in	Temp Diff across thickness	=	deg F
Fy : Rebar Yield	=	60.0 ksi	Rebar at wall center		Min Allow Out-of-plane Defl Ratio	=	150
Ec : Concrete Elastic Modulus	=	2,549.12 ksi	Rebar "d" distance	3.0 in	Minimum Vertical Steel %	=	.0020
Fr : Rupture Modulus	=	223.607 psi	Lower Level Rebar . . .				
Max % of ρ balanced	=	0.60	Bar Size #	3			
Max Pu/Ag = f'c *	=	0.060	Bar Spacing	9.0 in			
Concrete Density	=	150.0 pcf					

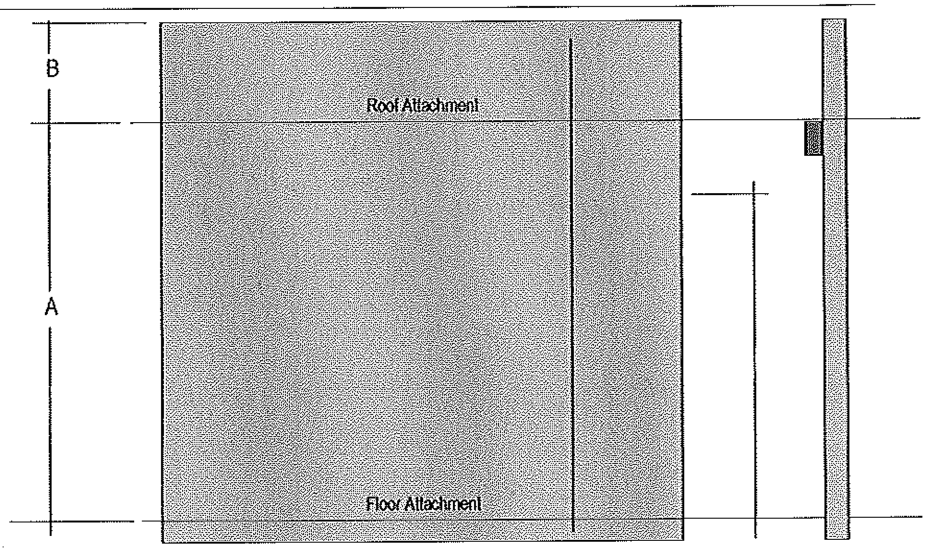
One-Story Wall Dimensions

A Clear Height = 5.50 ft
B Parapet height = ft

Wall Support Condition Top Pinned, Bottom F

Initial Lateral Disp. @ Top Support in

Width "strip width" for analysis 12.0 in



Vertical Loads

Vertical Uniform Loads . . . *(Applied per foot of Strip Width)*		DL : Dead Load	Lr : Roof Live Load	Lf : Floor Live Load	S : Snow Load	
Ledger Load	Eccentricity in					k/ft
Concentric Load		0.730	0.140			k/ft

Lateral Loads

Full area WIND load psf

Fp 1.0 = 0.0 psf

Wall Weight Seismic Load Input Method : Direct entry of Lateral Wall Weight

Seismic Wall Lateral Load psf

Concentrated Lateral Loads . . . *(Applied to full "STRIP Width")*

	Load #1	Load #2
DL : Dead Load	k	k
Lr : Roof Live Load	k	k
Lf : Floor Live Load	0.780 k	k
E : Seismic Load	k	k
W : Wind Load	k	k
Height above base	1.670 ft	ft

Distributed Lateral Loads . . . *(Applied to full "STRIP Width")*

	Load #1	Load #2
DL : Dead Load	k/ft	k/ft
Lr : Roof Live Load	k/ft	k/ft
Lf : Floor Live Load	k/ft	k/ft
E : Seismic Load	k/ft	k/ft
W : Wind Load	k/ft	k/ft
Location of start & end of load above base . . .		
Dist. to TOP	ft	ft
Dist. to BOTTOM	ft	ft

Concrete Slender Wall

Lic. # : KW-06004564 License Owner : ENCOTECH ENGINEERING INC

Description : Tank Wall Design - Case 1: Roof Loads + Hydrostatic Loads

DESIGN SUMMARY

		Governing Load Combination . . .	Actual Values . . .		Allowable Values . . .	
PASS	Moment Capacity Check	+1.20D+0.50Lr+1.60L	Max Mu	0.66221 k-ft	Phi * Mn	2.2602 k-ft
PASS	Service Deflection Check	D + L + Lf	Min. Defl. Ratio	25,953.7	Deflection Ratio	150
			Max. Deflection	.0025430 in	Clear Ht. / Ratio	0.440 in
PASS	Axial Load Check	+1.40D	Max Pu / Ag	21.9479 psi	0.06 * f'c	120.0 psi
PASS	Reinforcing Limit Check	+1.40D	Max As/bd	.0040740	As/bd = 0.5 * ρbal	.0085520
PASS	Minimum Moment Check	+1.40D	Mcracking	1.3416 k-ft	Minimum Phi Mn	1.8377 k-ft

Maximum Reactions . . . *for Load Combination....*

Top Horizontal	D + Lf + S	117.909 lbs
Base Horizontal	D + Lr + Lf	662.096 lbs
Vertical Reaction	D + Lr + Lf	1.2825 k

Design Maximum Combinations - Moments

Load Combination	Axial Load Pu k	Axial Load 0.06*f'c*b*t k	Mcr k-ft	Mu k-ft	Phi	Phi Mn k-ft	As in^2	As Eff in^2	As Ratio	0.6 * Rho:bal
+1.40D at 3.30 to 3.48	1.253	8.640	1.34	0.00	0.88	2.25	0.147	0.168	0.0041	0.0086
+1.20D+0.50Lr+1.60L at 1.83 to 2.02	1.276	8.640	1.34	0.66	0.88	2.26	0.147	0.168	0.0041	0.0086
+1.20D+0.50L+0.50S at 1.83 to 2.02	1.206	8.640	1.34	0.21	0.88	2.24	0.147	0.167	0.0041	0.0086
+1.20D+1.60Lr+0.50L at 1.83 to 2.02	1.430	8.640	1.34	0.21	0.88	2.31	0.147	0.170	0.0041	0.0086
+1.20D+1.60Lr+0.50L+0.80W at 1.83 to 2.02	1.430	8.640	1.34	0.21	0.88	2.31	0.147	0.170	0.0041	0.0086
+1.20D+0.50L+1.60S at 1.83 to 2.02	1.206	8.640	1.34	0.21	0.88	2.24	0.147	0.167	0.0041	0.0086
+1.20D+0.50L+1.60S+0.80W at 1.83 to 2.02	1.206	8.640	1.34	0.21	0.88	2.24	0.147	0.167	0.0041	0.0086
+1.20D+0.50Lr+0.50L+1.60W at 1.83 to 2.02	1.276	8.640	1.34	0.21	0.88	2.26	0.147	0.168	0.0041	0.0086
+1.20D+0.50L+0.50S+1.60W at 1.83 to 2.02	1.206	8.640	1.34	0.21	0.88	2.24	0.147	0.167	0.0041	0.0086
+1.20D+0.50L+0.20S+E at 1.83 to 2.02	1.206	8.640	1.34	0.21	0.88	2.24	0.147	0.167	0.0041	0.0086
+0.90D+1.60W at 3.30 to 3.48	0.806	8.640	1.34	0.00	0.89	2.11	0.147	0.160	0.0041	0.0086
+0.90D+E at 3.30 to 3.48	0.806	8.640	1.34	0.00	0.89	2.11	0.147	0.160	0.0041	0.0086

Design Maximum Combinations - Deflections

Load Combination	Axial Load Pu k	Moment Values Mcr k-ft	Moment Values Mactual k-ft	Stiffness I gross in^4	Stiffness I cracked in^4	Stiffness I effective in^4	Deflections Deflection in	Deflections Defl. Ratio
D + L + Lf at 2.75 to 2.93	1.076	1.34	0.31	216.00	12.03	216.000	0.003	25,953.7
D + L + W at 2.75 to 2.93	0.936	1.34	0.31	216.00	11.89	216.000	0.003	25,955.0
D + L + W + S/2 at 2.75 to 2.93	0.936	1.34	0.31	216.00	11.89	216.000	0.003	25,955.0
D + L + S + W/2 at 2.75 to 2.93	0.936	1.34	0.31	216.00	11.89	216.000	0.003	25,955.0
D + L + S + E/1.4 at 2.75 to 2.93	0.936	1.34	0.31	216.00	11.89	216.000	0.003	25,955.0

Reactions - Vertical & Horizontal

Load Combination	Base Horizontal	Top Horizontal	Vertical @ Wall Base
D Only	0.0 lbs	0.00 lbs	1.143 k
S Only	0.0 lbs	0.00 lbs	0.000 k
W Only	0.0 lbs	0.00 lbs	0.000 k
E Only	0.0 lbs	0.00 lbs	0.000 k
D + Lr + Lf	662.1 lbs	117.90 lbs	1.282 k
D + Lf + S	662.1 lbs	117.91 lbs	1.143 k
D + Lf + W + S/2	662.1 lbs	117.91 lbs	1.143 k
D + Lf + S + W/2	662.1 lbs	117.91 lbs	1.143 k
D + Lf + S + E/1.4	662.1 lbs	117.91 lbs	1.143 k

Concrete Slender Wall

Description : Tank Wall Design - Case 2: Roof Loads + Wind Load

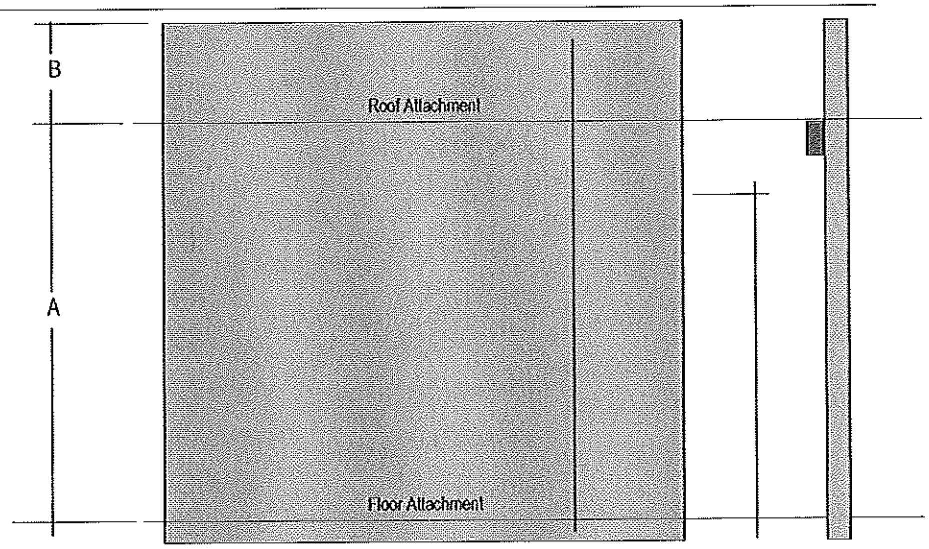
General Information

Code Ref: ACI 318-05, Sec. 14.8

f'c : Concrete 28 day strength	=	2.0 ksi	Wall Thickness	6.0 in	Temp Diff across thickness	=	deg F
Fy : Rebar Yield	=	60.0 ksi	Rebar at wall center		Min Allow Out-of-plane Defl Ratio	=	150
Ec : Concrete Elastic Modulus	=	2,549.12 ksi	Rebar "d" distance	3.0 in	Minimum Vertical Steel %	=	.0020
Fr : Rupture Modulus	=	223.607 psi	Lower Level Rebar . . .				
Max % of ρ balanced	=	0.60	Bar Size #	3			
Max Pu/Ag = f'c *	=	0.060	Bar Spacing	9.0 in			
Concrete Density	=	150.0 pcf					

One-Story Wall Dimensions

A Clear Height	=	5.50	ft
B Parapet height	=		ft
Wall Support Condition	Top Pinned, Bottom F		
Initial Lateral Disp. @ Top Support			in
Width "strip width" for analysis		12.0	in



Vertical Loads

Vertical Uniform Loads . . . (Applied per foot of Strip Width)		DL : Dead Load	Lr : Roof Live Load	Lf : Floor Live Load	S : Snow Load	
Ledger Load	Eccentricity in					k/ft
Concentric Load		0.730	0.140			k/ft

Lateral Loads

Full area WIND load 20.20 psf

Fp = Wall Wt. * 0.0 = 0.0 psf

Wall Weight Seismic Load Input Method : ASCE seismic factors enteres

Enter SDS Value per ASCE 12.14.7.6

S_{DS} =

DESIGN SUMMARY

		Governing Load Combination . . .	Actual Values . . .			Allowable Values . . .
PASS	Moment Capacity Check	+0.90D+1.60W	Max Mu	0.068570 k-ft	Phi * Mn	2.1099 k-ft
PASS	Service Deflection Check	D + L + W + S/2	Min. Defl. Ratio	210,337	Deflection Ratio	150
			Max. Deflection	.0003140 in	Clear Ht. / Ratio	0.440 in
PASS	Axial Load Check	+1.40D	Max Pu / Ag	21.9479 psi	0.06 * f'c	120.0 psi
PASS	Reinforcing Limit Check	+1.40D	Max As/bd	.0040740	As/bd = 0.5 * ρbal	.0085520
PASS	Minimum Moment Check	+1.40D	Mcracking	1.3416 k-ft	Minimum Phi Mn	1.8377 k-ft

Maximum Reactions . . .	*for Load Combination....*	
Top Horizontal	W Only	41.6548 lbs
Base Horizontal	D + Lf + W + S/2	69.4474 lbs
Vertical Reaction	D + Lr + Lf	1.2825 k

Concrete Slender Wall

Description : Tank Wall Design - Case 2: Roof Loads + Wind Load

Design Maximum Combinations - Moments

Load Combination	Axial Load Pu (k)	0.06*f'c*b*t (k)	Mcr (k-ft)	Mu (k-ft)	Phi	Phi Mn (k-ft)	As (in^2)	As Eff (in^2)	As Ratio	0.6 * Rho:bal
+1.40D at 3.30 to 3.48	1.253	8.640	1.34	0.00	0.88	2.25	0.147	0.168	0.0041	0.0086
+1.20D+0.50Lr+1.60L at 3.30 to 3.48	1.144	8.640	1.34	0.00	0.88	2.22	0.147	0.166	0.0041	0.0086
+1.20D+0.50L+0.50S at 3.30 to 3.48	1.074	8.640	1.34	0.00	0.88	2.20	0.147	0.165	0.0041	0.0086
+1.20D+1.60Lr+0.50L at 3.30 to 3.48	1.298	8.640	1.34	0.00	0.88	2.27	0.147	0.168	0.0041	0.0086
+1.20D+1.60Lr+0.50L+0.80W at 3.30 to 3.48	1.298	8.640	1.34	0.03	0.88	2.27	0.147	0.168	0.0041	0.0086
+1.20D+0.50L+1.60S at 3.30 to 3.48	1.074	8.640	1.34	0.00	0.88	2.20	0.147	0.165	0.0041	0.0086
+1.20D+0.50L+1.60S+0.80W at 3.30 to 3.48	1.074	8.640	1.34	0.03	0.88	2.20	0.147	0.165	0.0041	0.0086
+1.20D+0.50Lr+0.50L+1.60W at 3.30 to 3.48	1.144	8.640	1.34	0.07	0.88	2.22	0.147	0.166	0.0041	0.0086
+1.20D+0.50L+0.50S+1.60W at 3.30 to 3.48	1.074	8.640	1.34	0.07	0.88	2.20	0.147	0.165	0.0041	0.0086
+1.20D+0.50L+0.20S+E at 3.30 to 3.48	1.074	8.640	1.34	0.00	0.88	2.20	0.147	0.165	0.0041	0.0086
+0.90D+1.60W at 3.30 to 3.48	0.806	8.640	1.34	0.07	0.89	2.11	0.147	0.160	0.0041	0.0086
+0.90D+E at 3.30 to 3.48	0.806	8.640	1.34	0.00	0.89	2.11	0.147	0.160	0.0041	0.0086

Design Maximum Combinations - Deflections

Load Combination	Axial Load Pu (k)	Moment Values Mcr (k-ft)	Mactual (k-ft)	Stiffness I gross (in^4)	I cracked (in^4)	I effective (in^4)	Deflections Deflection (in)	Defl. Ratio
D + L + Lf at 3.12 to 3.30	1.049	1.34	0.00	216.00	12.00	216.000	0.000	0.0
D + L + W at 3.12 to 3.30	0.909	1.34	0.00	216.00	11.86	216.000	0.000	0.0
D + L + W + S/2 at 3.12 to 3.30	0.909	1.34	0.04	216.00	11.86	216.000	0.000	210337.1
D + L + S + W/2 at 3.12 to 3.30	0.909	1.34	0.02	216.00	11.86	216.000	0.000	420674.1
D + L + S + E/1.4 at 3.12 to 3.30	0.909	1.34	0.00	216.00	11.86	216.000	0.000	0.0

Reactions - Vertical & Horizontal

Load Combination	Base Horizontal	Top Horizontal	Vertical @ Wall Base
D Only	0.0 lbs	0.00 lbs	1.143 k
S Only	0.0 lbs	0.00 lbs	0.000 k
W Only	69.4 lbs	41.65 lbs	0.000 k
E Only	0.0 lbs	0.00 lbs	0.000 k
D + Lr + Lf	0.0 lbs	0.00 lbs	1.283 k
D + Lf + S	0.0 lbs	0.00 lbs	1.143 k
D + Lf + W + S/2	69.4 lbs	41.65 lbs	1.142 k
D + Lf + S + W/2	34.7 lbs	20.83 lbs	1.142 k
D + Lf + S + E/1.4	0.0 lbs	0.00 lbs	1.143 k

Concrete Slender Wall

Description : Tank Wall Design - Case 3: Roof Loads + Siesmic Load

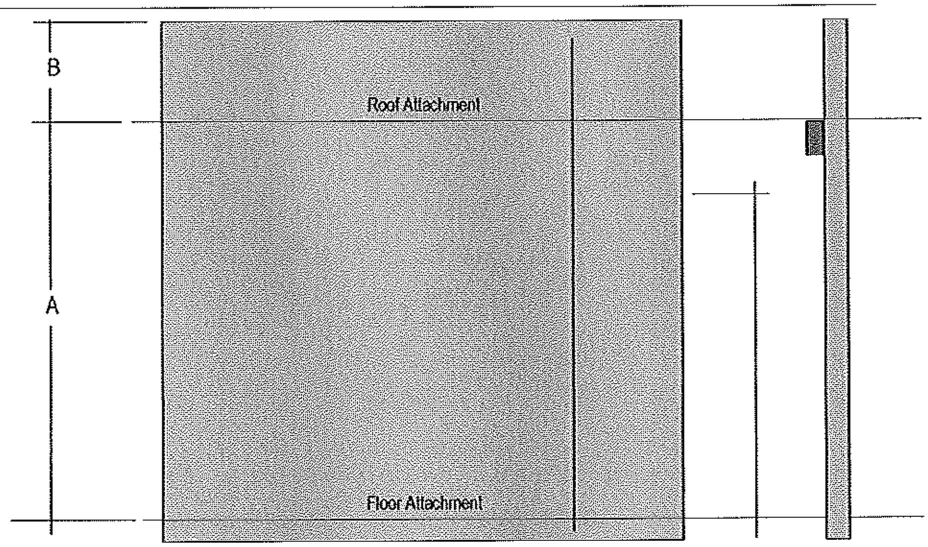
General Information

Code Ref: ACI 318-05, Sec. 14.8

f'c : Concrete 28 day strength	=	2.0 ksi	Wall Thickness	6.0 in	Temp Diff across thickness	=	deg F
Fy : Rebar Yield	=	60.0 ksi	Rebar at wall center		Min Allow Out-of-plane Defl Ratio	=	150
Ec : Concrete Elastic Modulus	=	2,549.12 ksi	Rebar "d" distance	3.0 in	Minimum Vertical Steel %	=	.0020
Fr : Rupture Modulus	=	223.607 psi	Lower Level Rebar . . .				
Max % of ρ balanced	=	0.60	Bar Size #	3			
Max Pu/Ag = f'c *	=	0.060	Bar Spacing	9.0 in			
Concrete Density	=	150.0 pcf					

One-Story Wall Dimensions

A Clear Height	=	5.50 ft
B Parapet height	=	ft
Wall Support Condition		Top Pinned, Bottom F
Initial Lateral Disp. @ Top Support		in
Width "strip width" for analysis		12.0 in



Vertical Loads

Vertical Uniform Loads . . . (Applied per foot of Strip Width)		DL : Dead Load	Lr : Roof Live Load	Lf : Floor Live Load	S : Snow Load	
Ledger Load	Eccentricity in					k/ft
Concentric Load		0.730	0.0			k/ft

Lateral Loads

Full area WIND load		0.0 psf	Wall Weight Seismic Load Input Method :	Direct entry of Lateral Wall Weight
Fp	1.0 =	0.0 psf	Seismic Wall Lateral Load	psf

Concentrated Lateral Loads . . . *(Applied to full "STRIP Width")*

	Load #1	Load #2
DL : Dead Load	k	k
Lr : Roof Live Load	k	k
Lf : Floor Live Load	0.0 k	k
E : Seismic Load	1.460 k	k
W : Wind Load	k	k
Height above base	1.670 ft	ft

Distributed Lateral Loads . . . *(Applied to full "STRIP Width")*

	Load #1	Load #2
DL : Dead Load	k/ft	k/ft
Lr : Roof Live Load	k/ft	k/ft
Lf : Floor Live Load	k/ft	k/ft
E : Seismic Load	0.770 k/ft	k/ft
W : Wind Load	k/ft	k/ft
Location of start & end of load above base . . .		
Dist. to TOP	5.50 ft	ft
Dist. to BOTTOM	0.0 ft	ft

Concrete Slender Wall

Description : Tank Wall Design - Case 3: Roof Loads + Siesmic Load

DESIGN SUMMARY

		Governing Load Combination . . .	Actual Values . . .		Allowable Values . . .	
PASS	Moment Capacity Check	+0.90D+E	Max Mu	2.0773 k-ft	Phi * Mn	2.1139 k-ft
PASS	Service Deflection Check	D + L + S + E/1.4	Min. Defl. Ratio	1,391.0	Deflection Ratio	150
			Max. Deflection	0.047448 in	Clear Ht. / Ratio	0.440 in
PASS	Axial Load Check	+1.40D	Max Pu / Ag	21.9479 psi	0.06 * f'c	120.0 psi
PASS	Reinforcing Limit Check	+1.40D	Max As/bd	.0040740	As/bd = 0.5 * ρbal	.0085520
PASS	Minimum Moment Check	+1.40D	Mcracking	1.3416 k-ft	Minimum Phi Mn	1.8377 k-ft

Maximum Reactions . . .	*for Load Combination....*	
Top Horizontal	E Only	1,645.14 lbs
Base Horizontal	E Only	3,908.69 lbs
Vertical Reaction	D Only	1.1425 k

Design Maximum Combinations - Moments

Load Combination	Axial Load Pu k	Axial Load 0.06*f'c*b*t k	Mcr k-ft	Moment Values Mu k-ft	Phi	Phi Mn k-ft	As in^2	As Eff in^2	As Ratio	0.6 * Rho:bal
+1.40D at 3.30 to 3.48	1.253	8.640	1.34	0.00	0.88	2.25	0.147	0.168	0.0041	0.0086
+1.20D+0.50Lr+1.60L at 3.30 to 3.48	1.074	8.640	1.34	0.00	0.88	2.20	0.147	0.165	0.0041	0.0086
+1.20D+0.50L+0.50S at 3.30 to 3.48	1.074	8.640	1.34	0.00	0.88	2.20	0.147	0.165	0.0041	0.0086
+1.20D+1.60Lr+0.50L at 3.30 to 3.48	1.074	8.640	1.34	0.00	0.88	2.20	0.147	0.165	0.0041	0.0086
+1.20D+1.60Lr+0.50L+0.80W at 3.30 to 3.48	1.074	8.640	1.34	0.00	0.88	2.20	0.147	0.165	0.0041	0.0086
+1.20D+0.50L+1.60S at 3.30 to 3.48	1.074	8.640	1.34	0.00	0.88	2.20	0.147	0.165	0.0041	0.0086
+1.20D+0.50L+1.60S+0.80W at 3.30 to 3.48	1.074	8.640	1.34	0.00	0.88	2.20	0.147	0.165	0.0041	0.0086
+1.20D+0.50Lr+0.50L+1.60W at 3.30 to 3.48	1.074	8.640	1.34	0.00	0.88	2.20	0.147	0.165	0.0041	0.0086
+1.20D+0.50L+0.50S+1.60W at 3.30 to 3.48	1.074	8.640	1.34	0.00	0.88	2.20	0.147	0.165	0.0041	0.0086
+1.20D+0.50L+0.20S+E at 3.12 to 3.30	1.091	8.640	1.34	2.08	0.88	2.20	0.147	0.165	0.0041	0.0086
+0.90D+1.60W at 3.30 to 3.48	0.806	8.640	1.34	0.00	0.89	2.11	0.147	0.160	0.0041	0.0086
+0.90D+E at 3.12 to 3.30	0.818	8.640	1.34	2.08	0.89	2.11	0.147	0.160	0.0041	0.0086

Design Maximum Combinations - Deflections

Load Combination	Axial Load Pu k	Moment Values Mcr k-ft	Moment Values Mactual k-ft	Stiffness I gross in^4	Stiffness I cracked in^4	Stiffness I effective in^4	Deflections Deflection in	Deflections Defl. Ratio
D + L + Lf at 3.12 to 3.30	0.909	1.34	0.00	216.00	11.86	216.000	0.000	0.0
D + L + W at 3.12 to 3.30	0.909	1.34	0.00	216.00	11.86	216.000	0.000	0.0
D + L + W + S/2 at 3.12 to 3.30	0.909	1.34	0.00	216.00	11.86	216.000	0.000	0.0
D + L + S + W/2 at 3.12 to 3.30	0.909	1.34	0.00	216.00	11.86	216.000	0.000	0.0
D + L + S + E/1.4 at 3.30 to 3.48	0.895	1.34	0.77	216.00	11.84	16.281	0.047	1,391.0

Reactions - Vertical & Horizontal

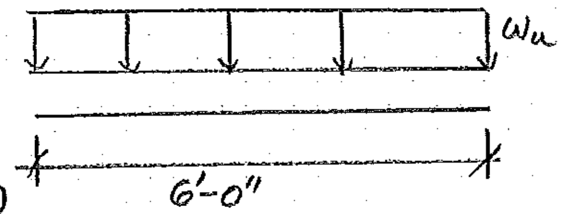
Load Combination	Base Horizontal	Top Horizontal	Vertical @ Wall Base
D Only	0.0 lbs	0.00 lbs	1.143 k
S Only	0.0 lbs	0.00 lbs	0.000 k
W Only	0.0 lbs	0.00 lbs	0.000 k
E Only	3,908.7 lbs	1,645.14 lbs	0.000 k
D + Lr + Lf	0.0 lbs	0.00 lbs	1.143 k
D + Lf + S	0.0 lbs	0.00 lbs	1.143 k
D + Lf + W + S/2	0.0 lbs	0.00 lbs	1.143 k
D + Lf + S + W/2	0.0 lbs	0.00 lbs	1.143 k
D + Lf + S + E/1.4	3,116.9 lbs	850.14 lbs	1.143 k

TANK FLOOR SLAB ON GRADE DESIGN

LOADS

CONSIDER 1'-0" DESIGN STRIP

SELF WEIGHT - 150 pcf × 8"/12 × 1'-0" = 100 plf



LIVE LOAD (WATER WEIGHT)

w_L = 62.4 pcf × 5'-0" (WATER HEIGHT) × 1'-0" = 312 plf .

SEE ATTACHED 'ENERCALC' RESULTS

$\boxed{\text{8" THICK SLAB ON GRADE w/ \#4 @ 12" O.C - O.K}}$

Title :
Dsgnr:
Description :

Scope :

Job #
Date: 7:58AM, 18 APR 10

Concrete Rectangular & Tee Beam Design

Description Tank Floor Design

General Information

Code Ref: ACI 318-02, 1997 UBC, 2003 IBC, 2003 NFPA 5000

Span	6.00 ft	f'c	2,000 psi
Depth	8.000 in	Fy	40,000 psi
Width	12.000 in	Concrete Wt.	145.0 pcf
		Seismic Zone	4
		End Fixity	Fixed-Fixed
Beam Weight Added Internally		Live Load acts with Short Term	

Reinforcing

	Rebar @ Center of Beam... Count	Size	'd' from Top		Rebar @ Left End of Beam... Count	Size	'd' from Top		Rebar @ Right End of Beam... Count	Size	'd' from Top
#1	1	4	4.00in	#1	1	4	4.00 in	#1	1	4	4.00 in

Load Factoring

Note: Load factoring supports 2003 IBC and 2003 NFPA 5000 by virtue of their references to ACI 318-02 for concrete design.
Factoring of entered loads to ultimate loads within this program is according to ACI 318-02 C.2

Uniform Loads

	Dead Load	Live Load	Short Term	Start	End
#1	k	0.312 k	k	0.000 ft	6.000 ft

Summary

Beam Design OK

Span = 6.00ft, Width= 12.00in Depth = 8.00in

Maximum Moment : Mu	-2.00 k-ft	Maximum Deflection	-0.0018 in
Allowable Moment : Mn*phi	2.28 k-ft		
Maximum Shear : Vu	1.79 k	Max Reaction @ Left	1.23 k
Allowable Shear : Vn*phi	3.65 k	Max Reaction @ Right	1.23 k

Shear Stirrups...

Stirrup Area @ Section 0.000 in2

Region	0.000	1.000	2.000	3.000	4.000	5.000	6.000 ft
Max. Spacing	0.000	0.000	0.000	0.000	0.000	0.000	0.000 in
Max Vu	3.649	3.649	3.649	3.649	3.649	3.649	3.649 k

Bending & Shear Force Summary

Bending...	Mn*Phi	Mu, Eq. C-1	Mu, Eq. C-2	Mu, Eq. C-3
@ Center	2.28 k-ft	1.00 k-ft	0.86 k-ft	0.13 k-ft
@ Left End	2.28 k-ft	-2.00 k-ft	-1.72 k-ft	-0.26 k-ft
@ Right End	2.28 k-ft	-2.00 k-ft	-1.72 k-ft	-0.26 k-ft
Shear...	**Vn*Phi**	**Vu, Eq. C-1**	**Vu, Eq. C-2**	**Vu, Eq. C-3**
@ Left End	3.65 k	1.79 k	1.54 k	0.23 k
@ Right End	3.65 k	1.77 k	1.52 k	0.23 k

Deflection

Deflections...	Upward	at		Downward	at	
DL + [Bm Wt]	0.0000 in	at	0.0000 ft	-0.0004 in	at	3.0000ft
DL + LL + [Bm Wt]	0.0000 in	at	0.0000 ft	-0.0018 in	at	3.0000ft
DL + LL + ST + [Bm Wt]	0.0000 in	at	0.0000 ft	-0.0018 in	at	3.0000ft

Reactions...	@ Left	@ Right
DL + [Bm Wt]]	0.290 k	0.290 k
DL + LL + [Bm Wt]	1.226 k	1.226 k
DL + LL + ST + [Bm Wt]	1.226 k	1.226 k

Concrete Rectangular & Tee Beam Design

Description Tank Floor Design

Section Analysis

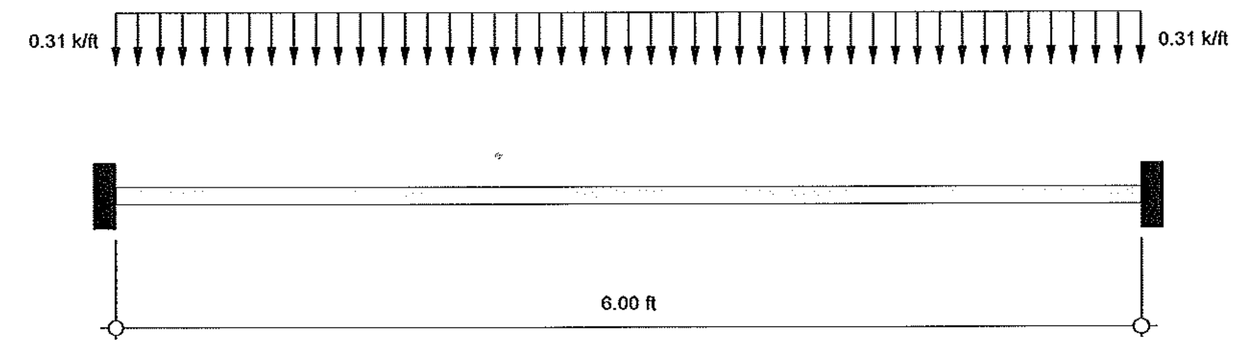
	Center	Left End	Right End
Evaluate Moment Capacity...			
X : Neutral Axis	0.460 in	0.460 in	0.460 in
a = beta * Xneutral	0.391 in	0.391 in	0.391 in
Compression in Concrete	7.976 k	7.976 k	7.976 k
Sum [Steel comp. forces]	0.000 k	0.000 k	0.000 k
Tension in Reinforcing	-8.000 k	-8.000 k	-8.000 k
Find Max As for Ductile Failure...			
X-Balanced	2.740 in	2.740 in	2.7402 in
Xmax = Xbal * 0.75	2.055 in	2.055 in	2.055 in
a-max = beta * Xbal	2.329 in	2.329 in	2.329 in
Compression in Concrete	35.636 k	35.636 k	35.636 k
Sum [Steel Comp Forces]	0.000 k	0.000 k	0.000 k
Total Compressive Force	35.636 k	35.636 k	35.636 k
AS Max = Tot Force / Fy	0.891 in2	0.891 in2	0.891 in2
Actual Tension As	0.200 **OK**	0.200 **OK**	0.200 **OK**

Additional Deflection Calcs

Neutral Axis	1.060 in	Mcr	3.58 k-ft
Igross	512.00 in4	Ms:Max DL + LL	1.23 k-ft
Icracked	24.43 in4	R1 = (Ms:DL+LL)/Mcr	2.918
Elastic Modulus	2,549.1 ksi	Ms:Max DL+LL+ST	1.23 k-ft
Fr = 7.5 * f'c^.5	335.410 psi	R2 = (Ms:DL+LL+ST)/Mcr	2.918
Z:Cracking	0.000 k/in	I:eff... Ms(DL+LL)	512.000 in4
Z:cracking > 175 : No Good!		I:eff... Ms(DL+LL+ST)	512.000 in4
Eff. Flange Width	12.00 in		

ACI Factors (per ACI 318-02, applied internally to entered loads)

ACI C-1 & C-2 DL	1.400	ACI C-2 Group Factor	0.750	Add"l "1.4" Factor for Seismic	1.400
ACI C-1 & C-2 LL	1.700	ACI C-3 Dead Load Factor	0.900	Add"l "0.9" Factor for Seismic	0.900
ACI C-1 & C-2 ST	1.700	ACI C-3 Short Term Factor	1.300		
....seismic = ST * :	1.100				



Mu:Max = 0.99 k-ft

Dmax = 0.0018 in

Mu:Max @ left = 1.99 k-ft

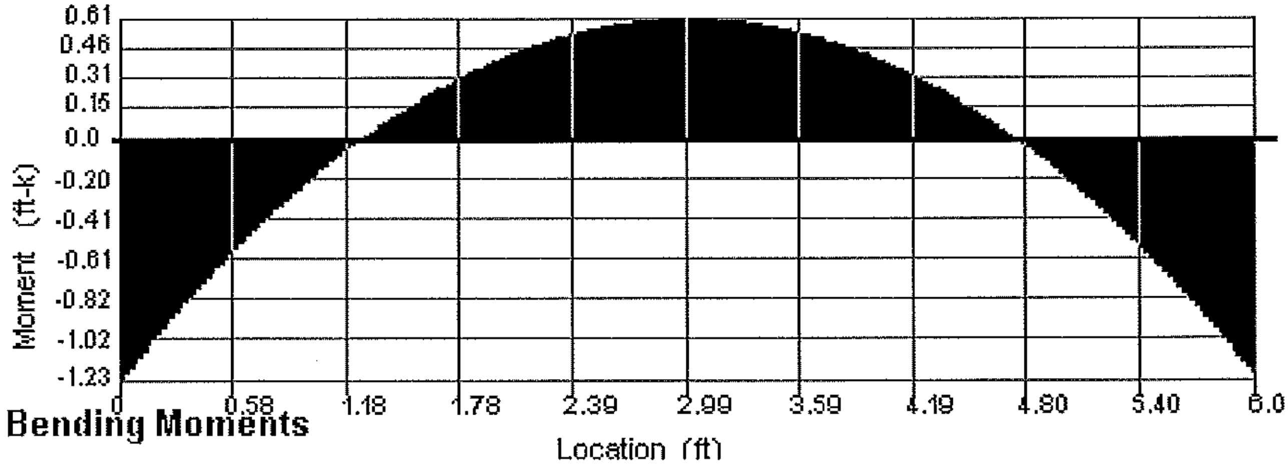
Rmax = 1.225 k

Vu-Max = 1.789 k

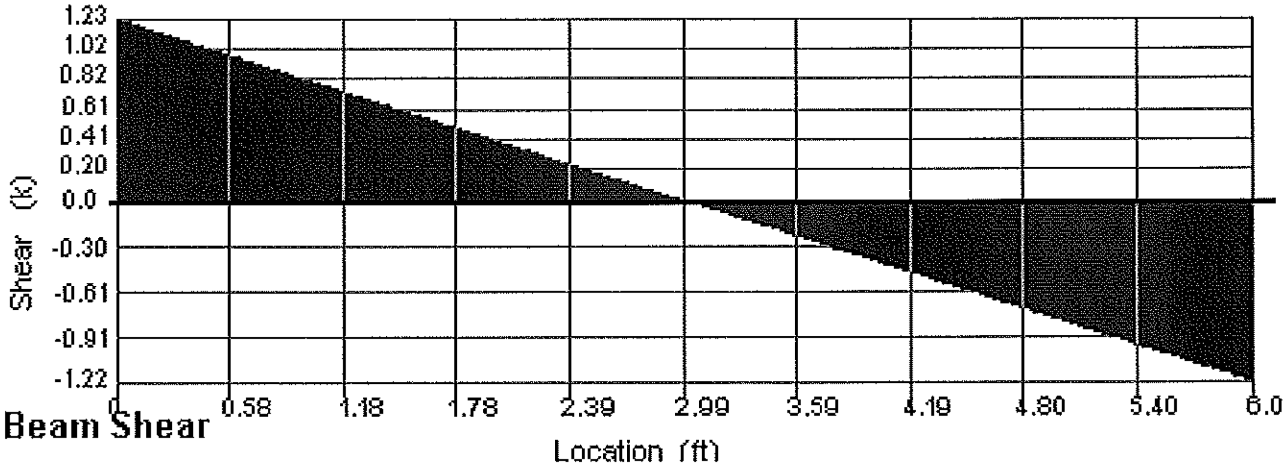
Mu:Max @ right = 1.99 k-ft

Rmax = 1.225 k

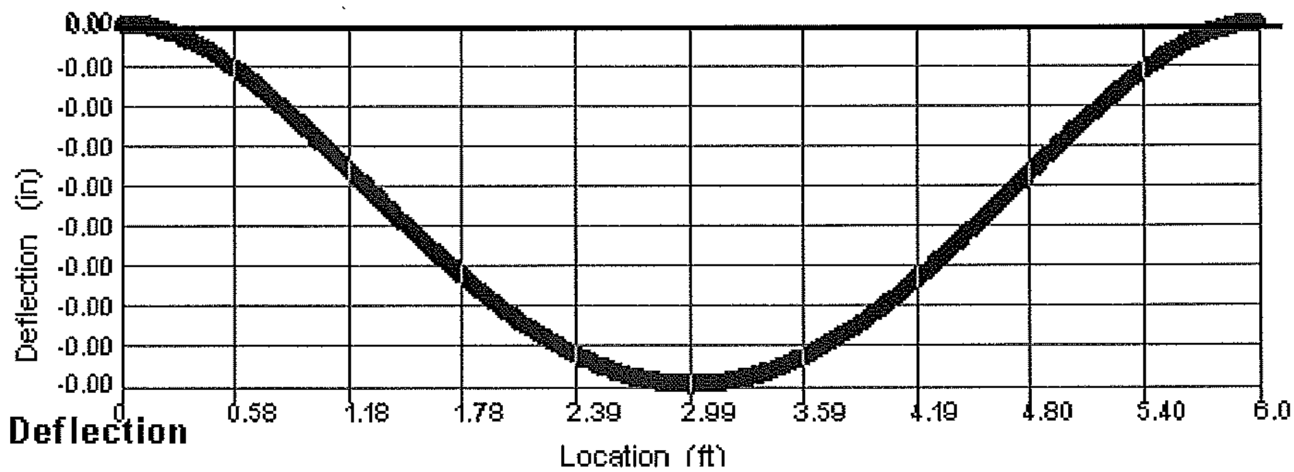
Vu Max = 1.773 k



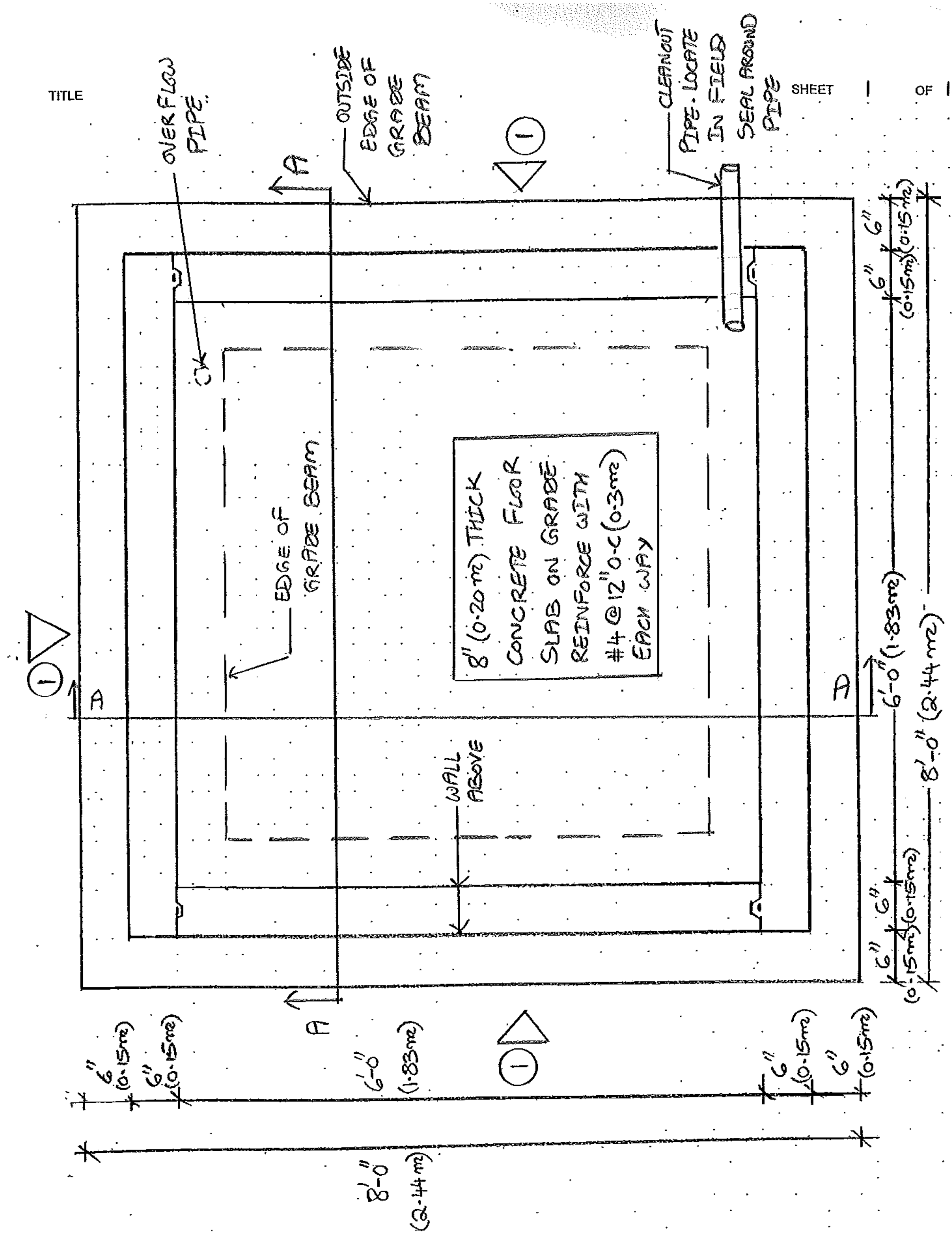
Bending Moments



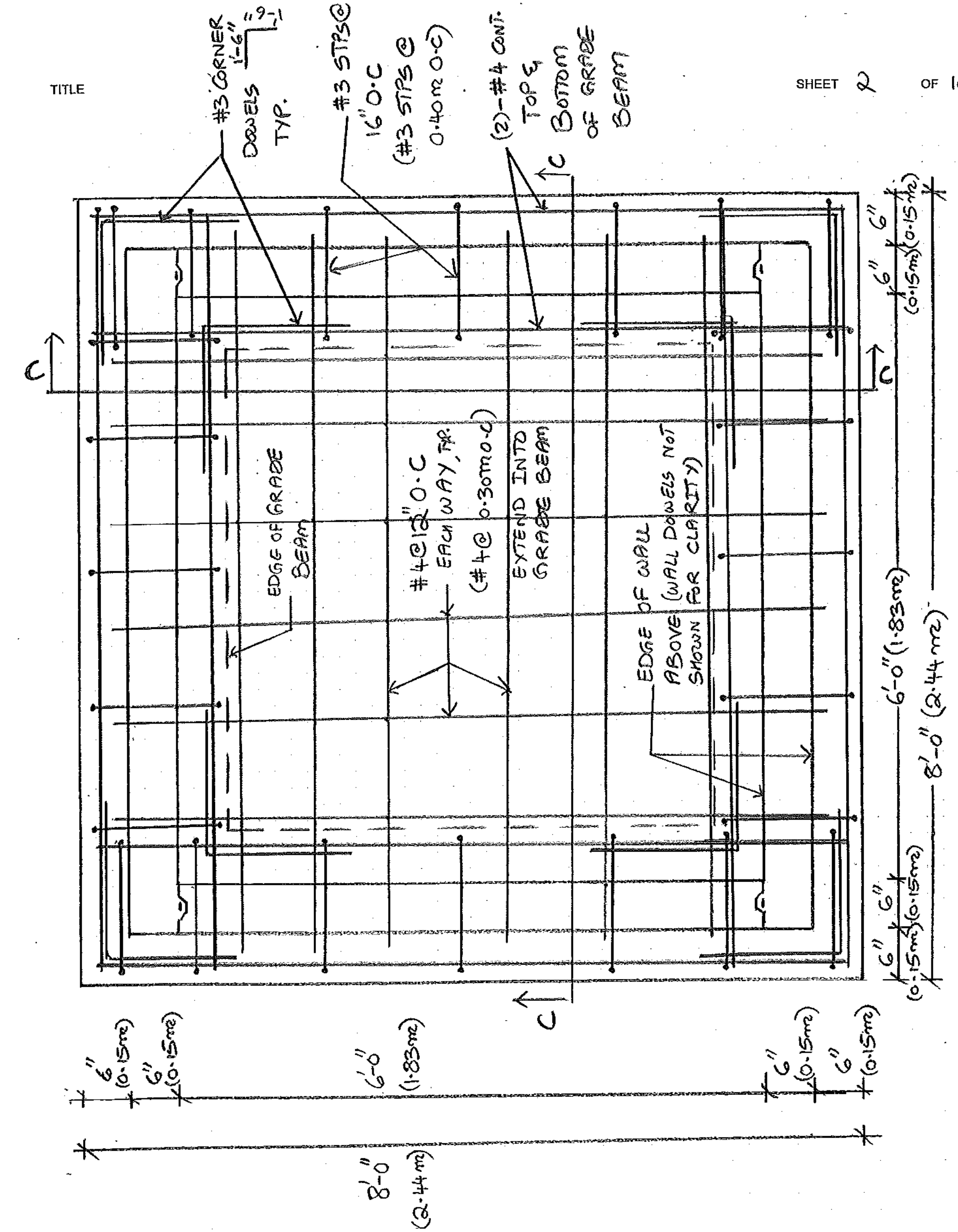
Beam Shear



Deflection



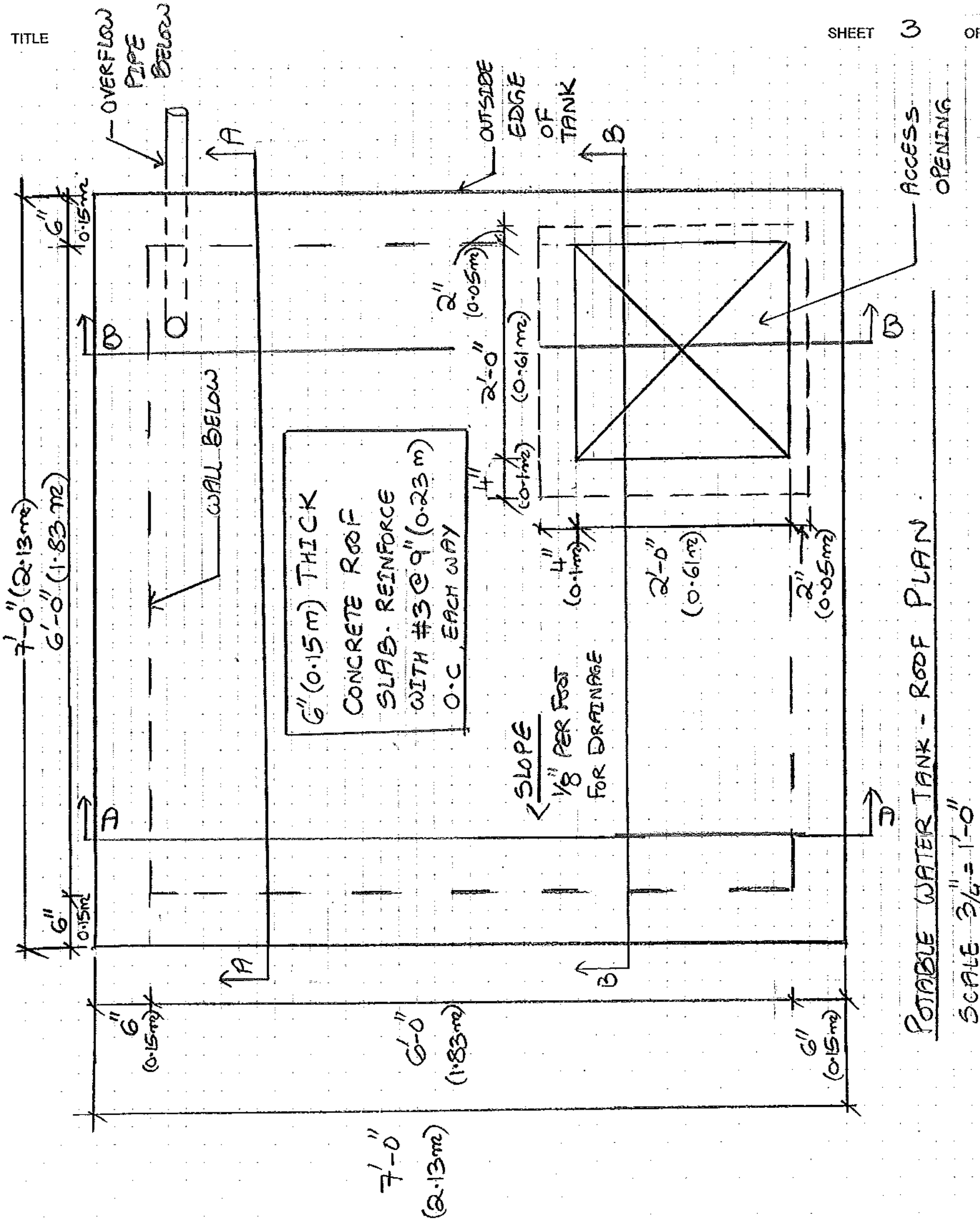
POTABLE WATER TANK - FOUNDATION PLAN
SCALE 3/4" = 1'-0"

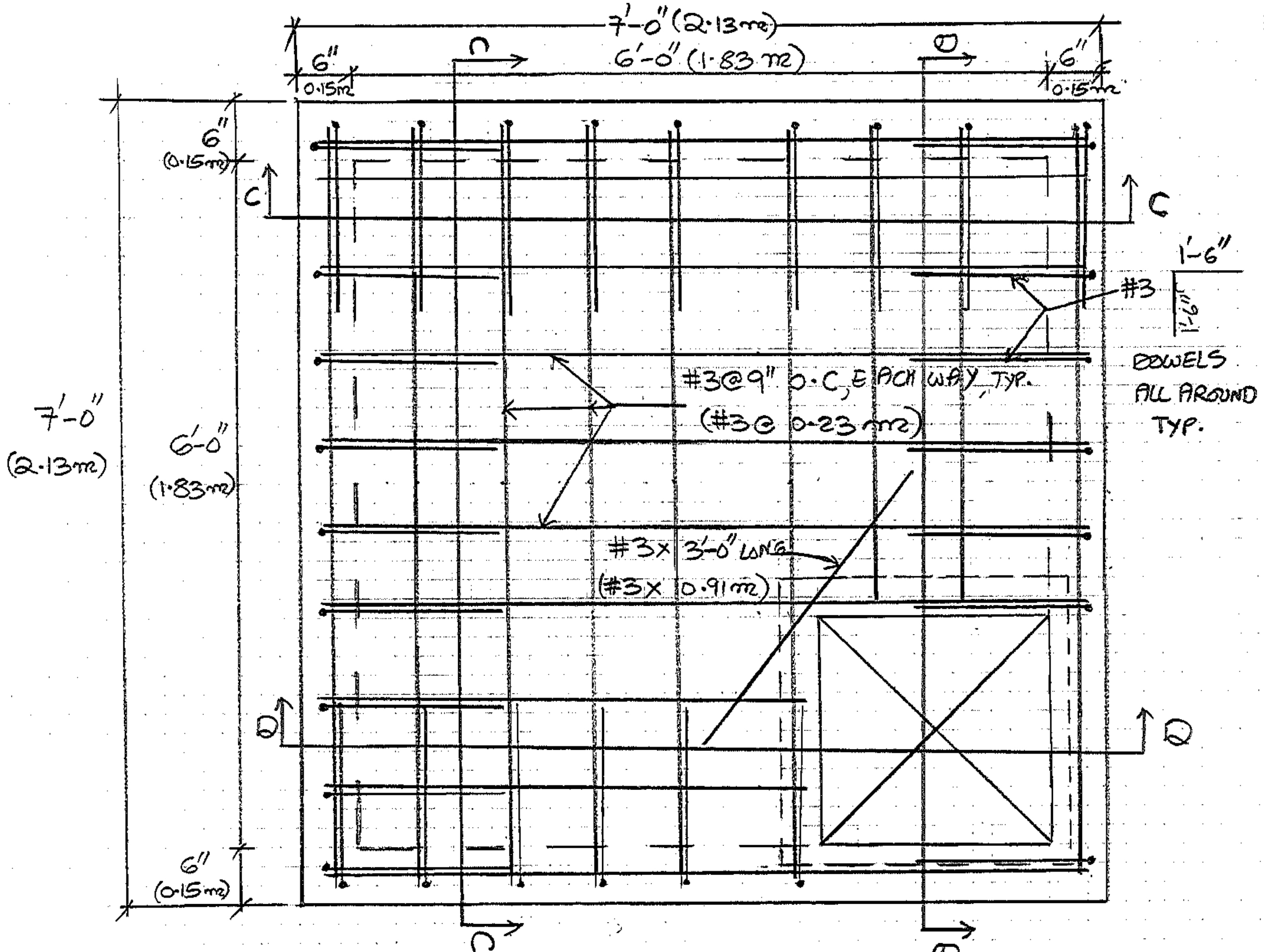


POTABLE WATER TANK - FOUNDATION REINFORCEMENT

SCALE 3/4" = 1'-0"

TITLE

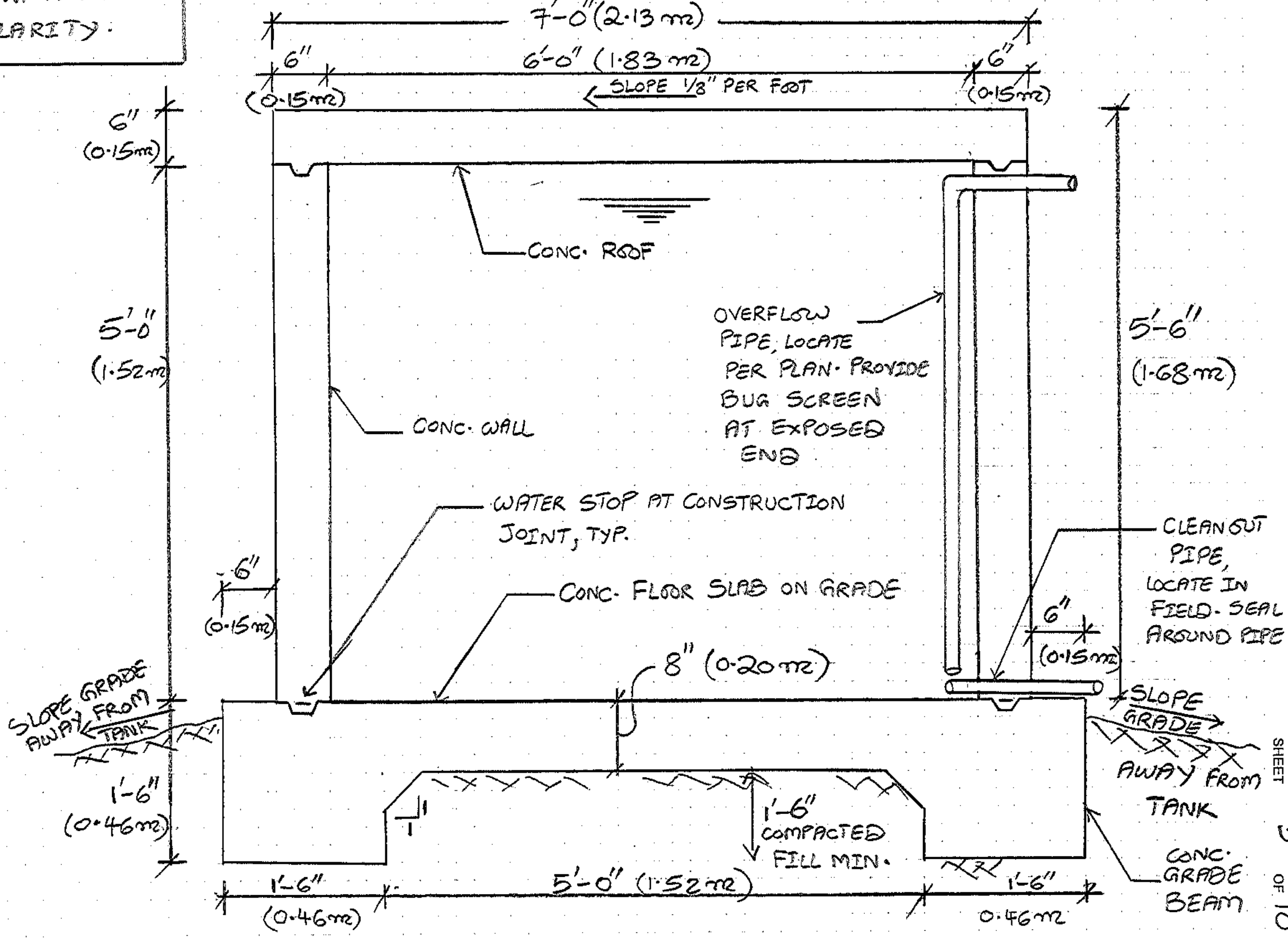

OVERFLOW PIPE BELOW
OUTSIDE EDGE OF TANK
ACCESS OPENING
A
B
WALL BELOW
6"(0.15m) THICK CONCRETE ROOF SLAB. REINFORCE WITH #3@9"(0.23 m) O.C. EACH WAY
SLOPE 1/8" PER FOOT FOR DRAINAGE
7'-0"(2.13m)
6'-0"(1.83m)
6" (0.15m)
2" (0.05m)
2'-0" (0.61m)
4" (0.1m)
POTABLE WATER TANK - ROOF PLAN
SCALE 3/4" = 1'-0"



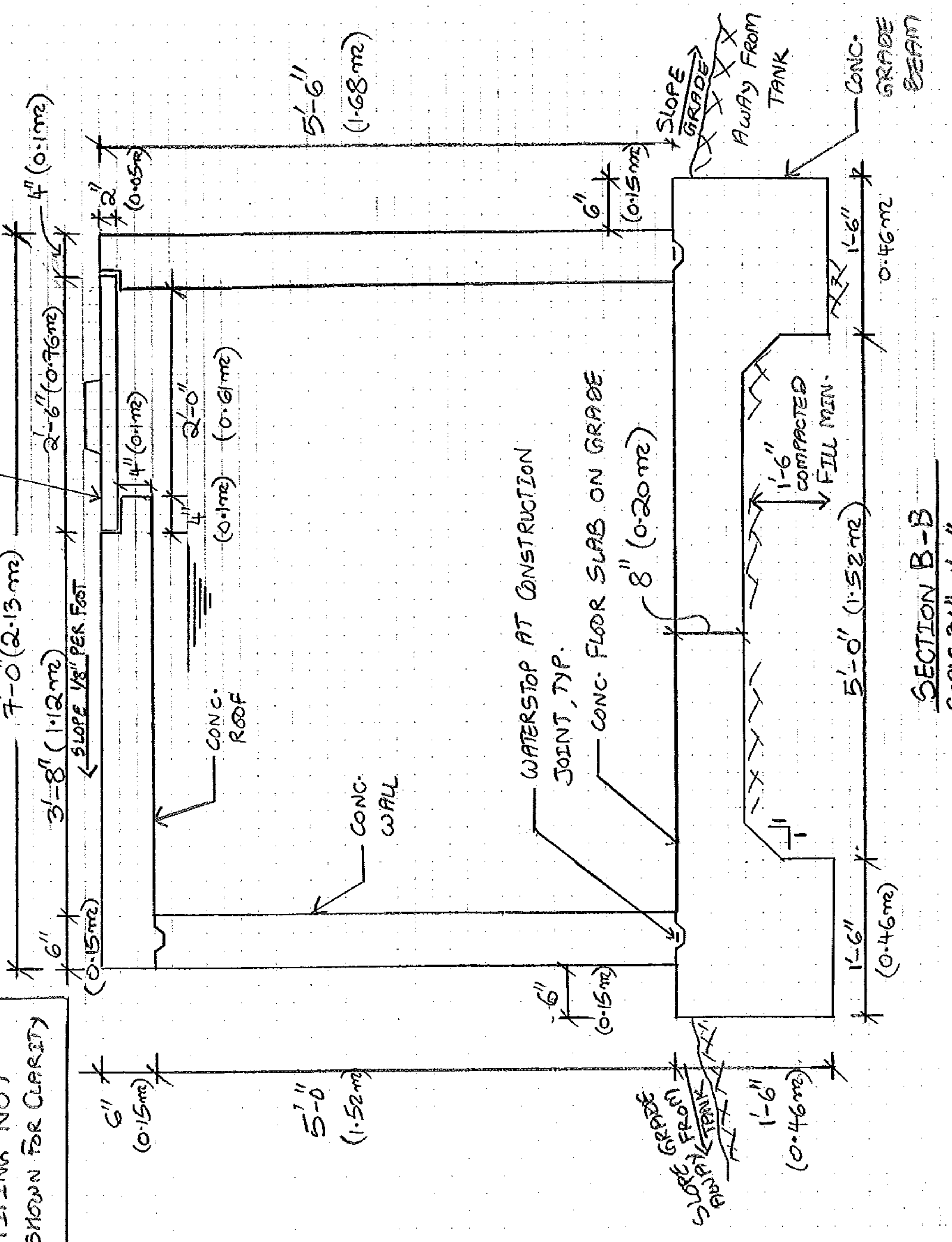
POTABLE WATER TANK - ROOF REINFORCEMENT

SCALE 3/4" = 1'-0"

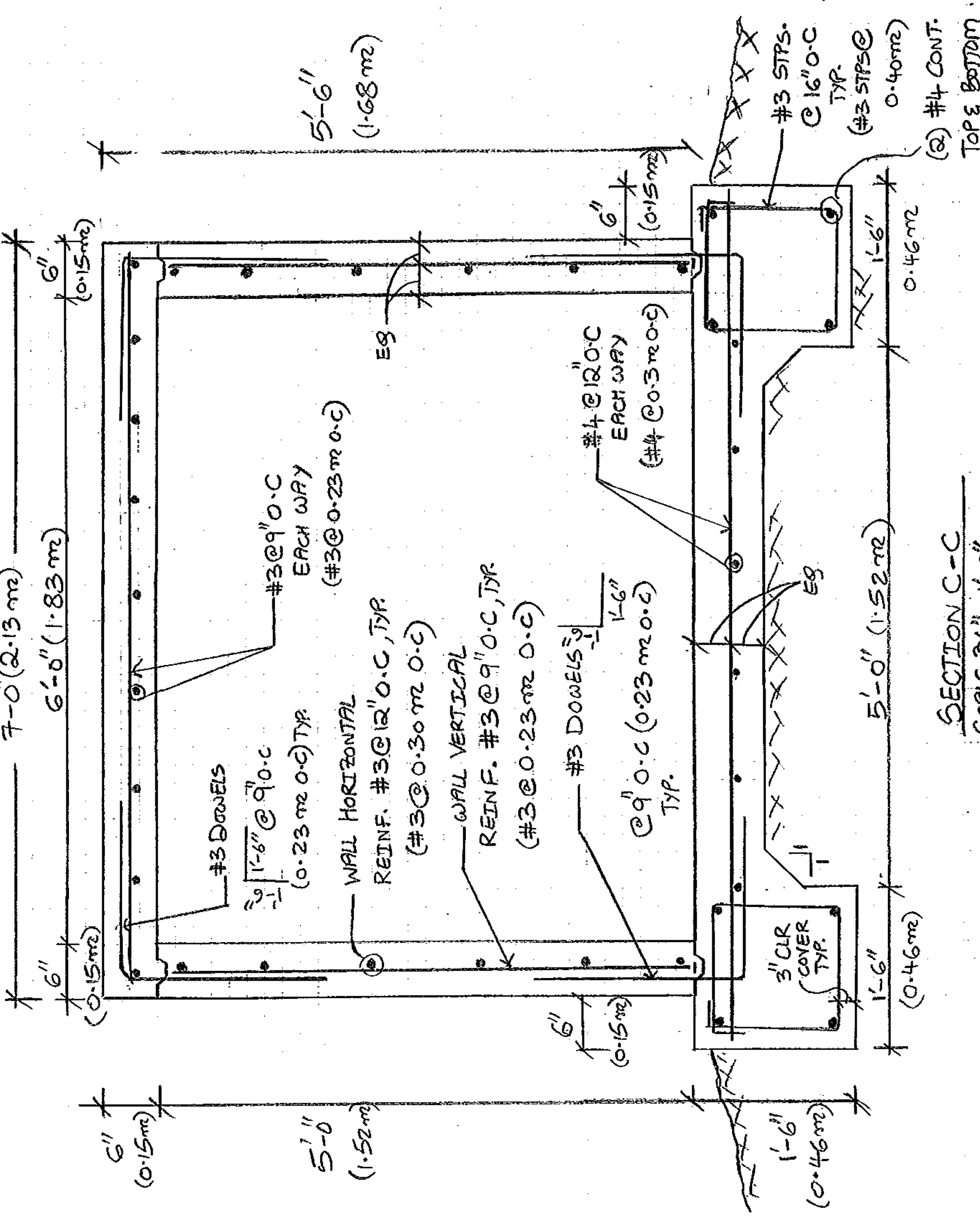
NOTE: INLET/OUTLET PIPING NOT SHOWN FOR CLARITY.



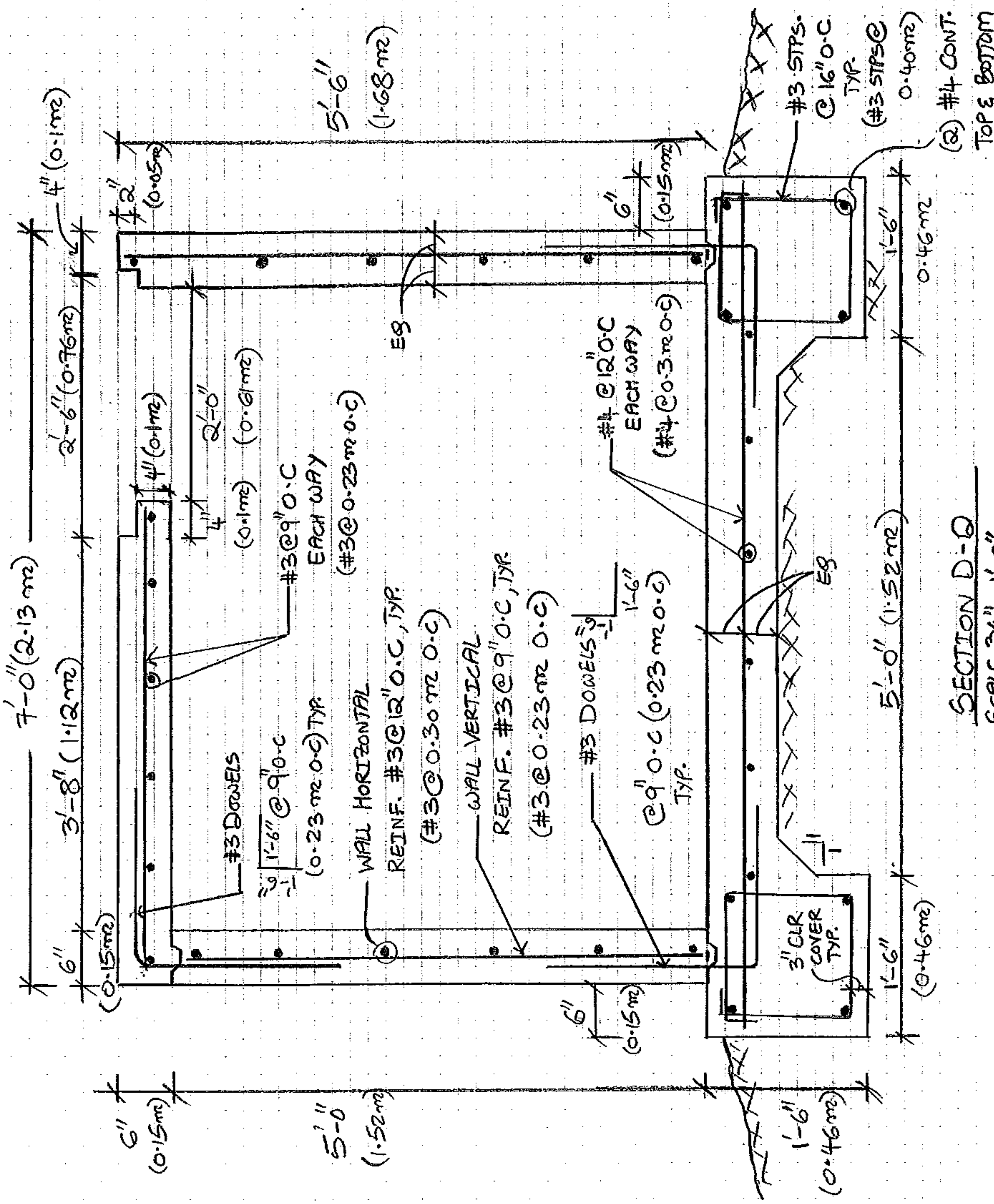
SECTION A-A
SCALE 3/4" = 1'-0"

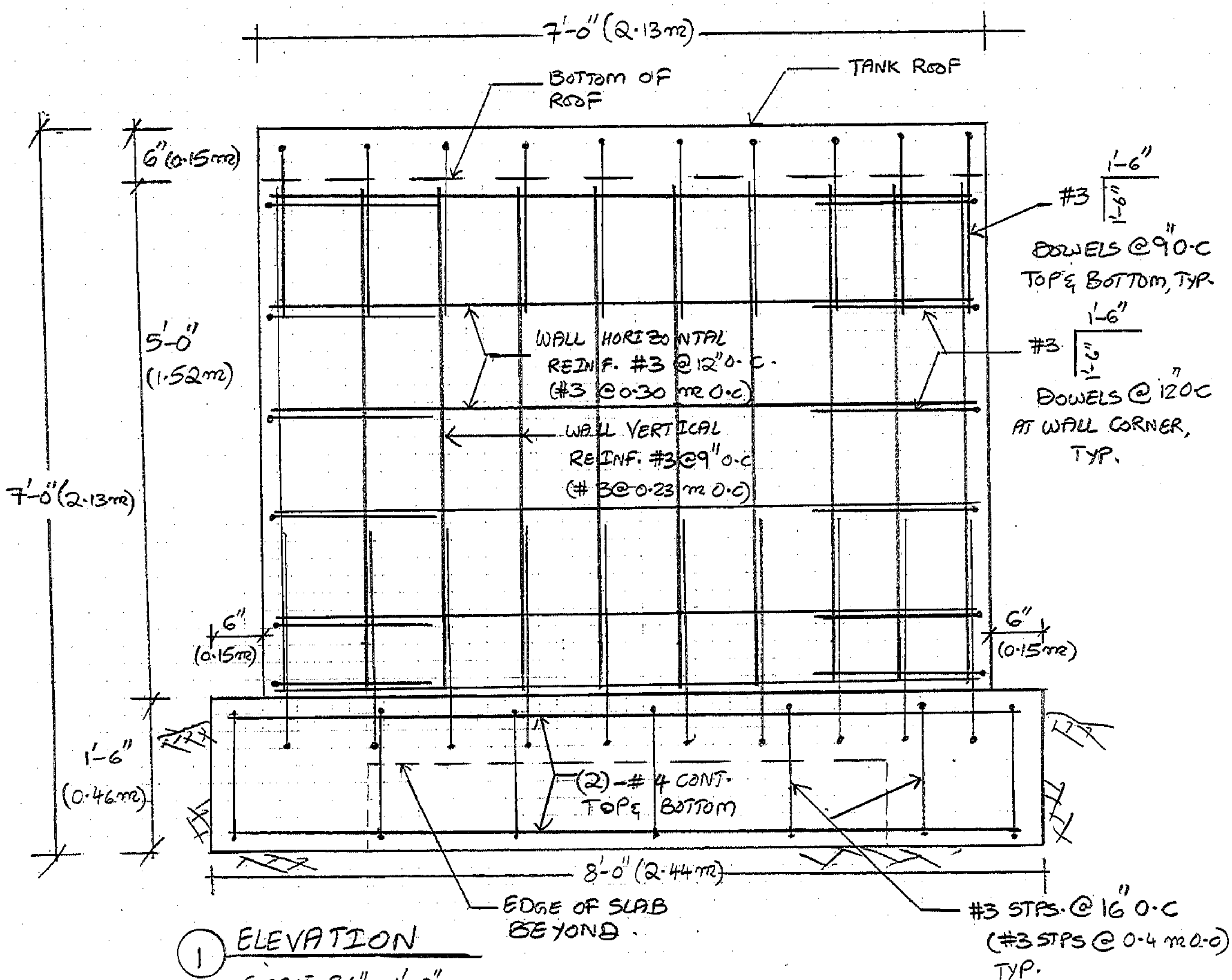


NOTE: INLET/OUTLET PIPING NOT SHOWN FOR CLARITY


SECTION C-C
SCALE 3/4" = 1'-0"
7'-0" (2.13 m)
6'-0" (1.83 m)
5'-6" (1.68 m)
5'-0" (1.52 m)
6" (0.15 m)
1'-6" (0.46 m)
#3 STPS. @ 16" O.C TYP. (#3 STPS @ 0.40 m)
(2) #4 CONT. TOP & BOTTOM
#4 @ 12" O.C EACH WAY (#4 @ 0.3 m O.C)
#3 @ 9" O.C EACH WAY (#3 @ 0.23 m O.C)
#3 DOWELS 1'-6" @ 9" O.C (0.23 m O.C) TYP
WALL HORIZONTAL REINF. #3 @ 12" O.C, TYP (#3 @ 0.30 m O.C)
WALL VERTICAL REINF. #3 @ 9" O.C, TYP (#3 @ 0.23 m O.C)
#3 DOWELS 1'-6" @ 9" O.C (0.23 m O.C) TYP.
EQ
3" CLR COVER TYP.

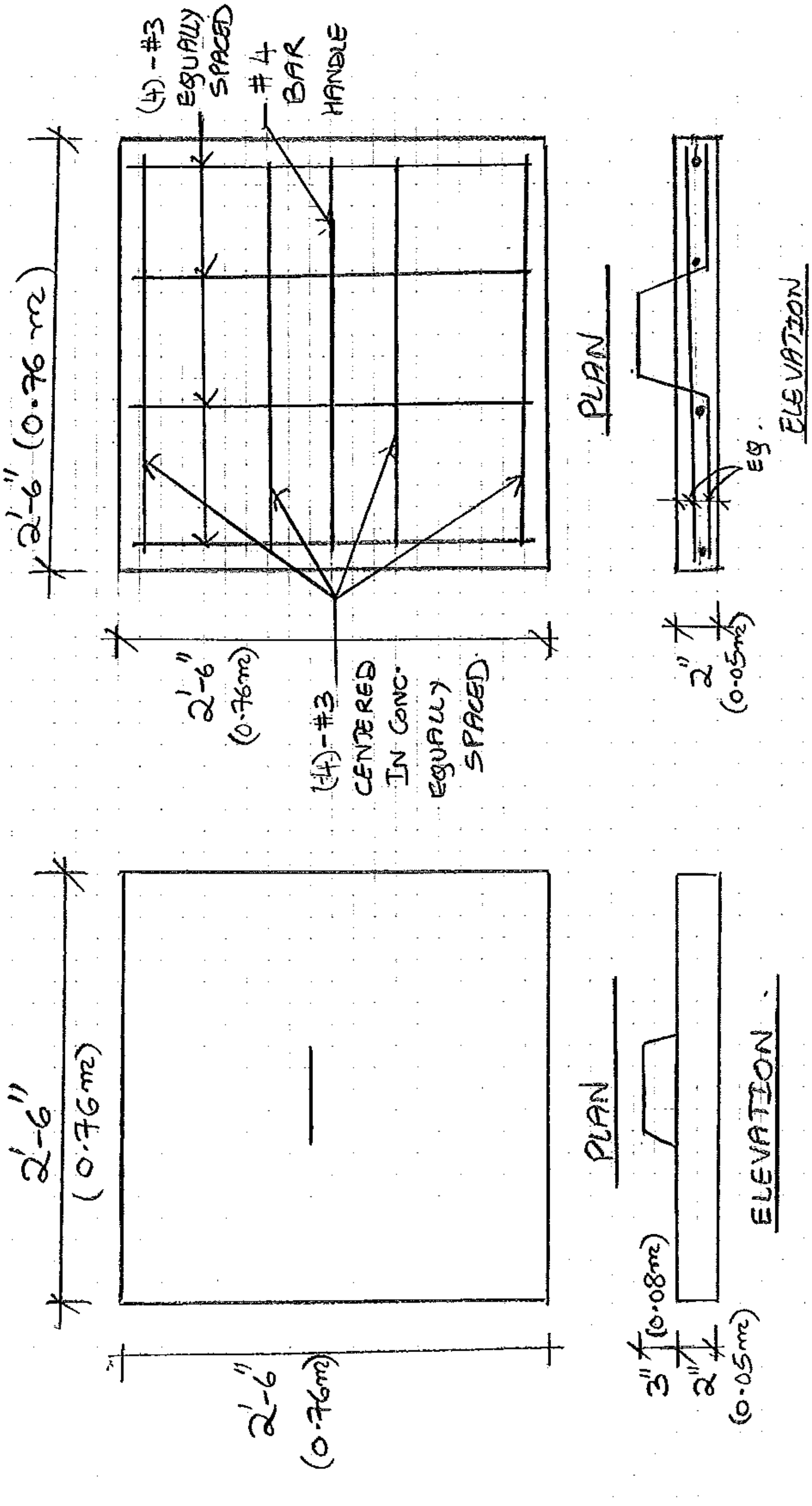
TITLE


SECTION D-D
SCALE 3/4" = 1'-0"
7'-0" (2.13 m)
3'-8" (1.12 m)
2'-6" (0.76 m)
4" (0.1 m)
2" (0.05 m)
6" (0.15 m)
5'-6" (1.68 m)
2'-0" (0.61 m)
4" (0.1 m)
#3 @ 9" O.C EACH WAY
(#3 @ 0.23 m O.C)
#3 DOWELS 1'-6" @ 9" O.C (0.23 m O.C) TYP.
WALL HORIZONTAL REINF. #3 @ 12" O.C, TYP.
(#3 @ 0.30 m O.C)
WALL VERTICAL REINF. #3 @ 9" O.C, TYP.
(#3 @ 0.23 m O.C)
#3 DOWELS 1'-6" @ 9" O.C (0.23 m O.C) TYP.
#4 @ 12" O.C EACH WAY
(#4 @ 0.3 m O.C)
EQ
EQ
#3 STPS. @ 16" O.C TYP.
(#3 STPS @ 0.40 m)
(2) #4 CONT. TOP & BOTTOM
1'-6" (0.46 m)
5'-0" (1.52 m)
1'-6" (0.46 m)
3" CLR COVER TYP.
6" (0.15 m)
6" (0.15 m)
5'-0" (1.52 m)
1'-6" (0.46 m)



1 ELEVATION
SCALE 3/4" = 1'-0"

TITLE



ACCESS HATCH COVER

SCALE 1"=1'-0"

APPENDIX B

PANAMA BUILDING CODE ADDENDUM (REP – 2003) FOR REFERENCE

WIND CODE EVALUATION

PANAMA

Evaluation conducted by Jorge Gutiérrez

NAME OF DOCUMENT: "Reglamento de Diseño Estructural para la República de Panamá" REP-2003 ("Structural Design Code for the Republic of Panama"). Chapter 3- Wind Loads.

YEAR: 2003 (expected year of approval)

GENERAL REMARKS: The first Panamanian Structural Provisions (REP-84) were approved in 1984 and the current version dates from 1994 (REP-94). A new version (REP-2003) has been drafted and it is in the process of final approval by the "Junta Técnica de Ingeniería y Arquitectura" (JTIA) (Technical Board of Engineering and Architecture). Implementation is expected sometime this year (source: Ernesto Ng, Panamanian structural engineer, personal e-mail communication). Under the Title of "Wind Loads", Chapter 3 of this new version contains specific regulations for Wind load definition, analysis and design. This is the document that has been evaluated.

SPECIFIC ITEMS:

NOTE: Bracketed numbers refer to Code specific chapters or articles: [3.2].
There are also bracketed references to the corresponding Chapters of ASCE-7-98, Minimum Design Loads for Buildings and Other Structures, which is the main reference for wind in REP-2003.
Parenthesis numbers refer to Items of this document: (see 1.1).

1. SCOPE

1.1 Explicit Concepts and Limitations. [3.1.1; 3.1.5]

The Code applies to buildings, including their primary structural system as well as components and claddings. It also applies to commercial signs.

A minimum wind pressure of 0.48 kN/m^2 must always be considered.

No reduction on wind pressure is allowed due to protection of the building by near by structures or by terrain conditions.

1.2 Performance Objectives.

Not explicitly defined.

2. WIND HAZARD

2.1 Basic Wind Speed. [3.2; 3.4.2]

The Basic Wind Speed is defined as the 3 second gust speed at 10m above the ground in Exposure Category C (see 2.4), corresponding to a Return Period of 50 years. Design values for Basic Wind Speed are 115 km/h for the Pacific and 140 km/h for the Caribbean [Table 3-2].

2.2 Topography. [3.3.7]

Wind effects due to sudden topography changes produced by escarpments, hills or ridges should be considered in the design. This effect is quantified by the Topography Factor K_{zt} given by the following equation:

$$K_{zt} = (1 + K_1 K_2 K_3)^2$$

Values for K_1, K_2, K_3 are given in a figure [Fig.3-1, identical to Fig. 6.2 of ASCE 7-98]

2.3 Height above Ground (Case Specific). [3.3.6.2]

This effect is defined by the Velocity Pressure Exposure Coefficient K_z (or K_h) which is a function of the Exposure Category (see 2.4) as defined by the following Table [identical to Table 6.5 of ASCE 7-98]:

Velocity Pressure Coefficients K_z ans K_h [Table 3.5]

Height above ground level, z		**Exposure Categories** (see 2.4)					
		A		**B**		**C**	**D**
m	(ft)	Case 1	Case 2	Case 1	Case 2	Cases 1 y 2	Cases 1 y 2
0 – 4.6	(0 – 15)	0.68	0.32	0.70	0.57	0.85	1.03
6.1	(20)	0.68	0.36	0.70	0.62	0.90	1.08
7.6	(25)	0.68	0.39	0.70	0.66	0.94	1.12
9.1	(30)	0.68	0.42	0.70	0.70	0.98	1.16
12.2	(40)	0.68	0.47	0.76	0.76	1.04	1.22
15.2	(50)	0.68	0.52	0.81	0.81	1.09	1.27
18.0	(60)	0.68	0.55	0.85	0.85	1.13	1.31

Height above ground level, z		Exposure Categories (see 2.4)					
		A		B		C	D
m	(ft)	Case 1	Case 2	Case 1	Case 2	Cases 1 y 2	Cases 1 y 2
21.3	(70)	0.68	0.59	0.89	0.89	1.17	1.34
24.4	(80)	0.68	0.62	0.93	0.93	1.21	1.38
27.4	(90)	0.68	0.65	0.96	0.96	1.24	1.40
30.5	(100)	0.68	0.68	0.99	0.99	1.26	1.43
36.6	(120)	0.73	0.73	1.04	1.04	1.31	1.48
42.7	(140)	0.78	0.78	1.09	1.09	1.36	1.52
48.8	(160)	0.82	0.82	1.13	1.13	1.39	1.55
54.9	(180)	0.86	0.86	1.17	1.17	1.43	1.58
61.0	(200)	0.90	0.90	1.20	1.20	1.46	1.61
76.2	(250)	0.98	0.98	1.28	1.28	1.53	1.68
91.4	(300)	1.05	1.05	1.35	1.35	1.59	1.73
106.7	(350)	1.12	1.12	1.41	1.41	1.64	1.78
121.9	(400)	1.18	1.18	1.47	1.47	1.69	1.82
137.2	(450)	1.24	1.24	1.52	1.52	1.73	1.86
152.4	(500)	1.29	1.29	1.56	1.56	1.77	1.89

Notes:

1. **Case 1:** All components and cladding.
   Case 2: All primary systems for buildings and other structures.
2. Linear interpolation for intermediate z values is allowed .

The K_z values of the Table above can be calculated with the following equations:

$$K_z = 2.01\ (4.6 / z_g)^{2/\alpha} \qquad \text{for } z < 4.6 \text{ m}$$
$$K_z = 2.01\ (z / z_g)^{2/\alpha} \qquad \text{for } 4.6 \text{ m} < z < z_g$$

With α and z_g defined by the following Table [Table 3.6]
:

Exposure	**α**	**z_g** (m)
A	5.0	457
B	7.0	366
C	9.5	274
D	11.5	213

2.4 Ground Roughness (Number of Exposure Categories). [3.3.6.1; 3.4.2]

Four Exposure Categories (A, B, C and D) are defined [the same of ASCE-7-98, article 6.5.6.1].

Exposure A. Large city centers with at least 50% of buildings with heights over 21m (Code states that this category does not apply in Panama).

Exposure B. Urban and suburban areas, wooded areas, other terrain with numerous closely spaced obstructions having the size of single family dwellings or larger.

Exposure C. Open terrain with scattered obstructions having heights less than 9m.

Exposure D. Flat unobstructed areas exposed to wind flowing from open ocean from 1.6 km. It extends 460m inland.

3. WIND DESIGN ACTIONS

3.1 Importance Factors. [3.1.2]

According to their importance and use, buildings are classified in four categories (I, II, III and IV) as follows:

Category I: Buildings and related structures whose failure implies low risk for human life including but not limited to rural, storage or temporary facilities.

Category II: Normal occupancy public or private buildings (not included in categories I, III or IV.

Category III: Hazardous facilities or high occupancy public or private buildings.

Category IV: Essential facilities.

An importance Factor I is assigned to each category as follows [Table 3.4]:

Use Category	Importance Factor I
I	0.87
II	1.00
III	1.15
IV	1.15

3.2 Scale Effects.

Not considered.

3.3 Pressure (Internal and External). [3.1.5; 3.3.9; 3.3.10, 3.3.11]

Minimum net wind pressure will be 0.48 kN/m^2. Net pressure is the algebraic sum of pressures acting on opposite sides of the building.

In order to estimate the internal pressure coefficients, buildings are classified as Enclosed, Partially Enclosed or Open [3.3.9; identical to 6.2 of ASCE-7-98].

Wind velocity pressure q_z (in kN/m^2) at height z (in m) is given by the following equation:

$$q_z = 0.0473\, K_z\, K_{zt}\, K_d\, V^2\, I$$

Where:
K_z = Velocity pressure exposure coefficient (see 2.3)
K_{zt} = Topography Factor (see 2.2)
K_d = Directionality Factor (see 3.5)
V = Basic Wind Speed in km/h (see 2.1)
I = Importance Factor (see 3.1)

For roofs, the corresponding wind velocity pressure q_h is q_z for z = h, the medium roof height.

The Internal Pressure Coefficient GC_{pi} is a function of the enclosure conditions according to the following Table:

Enclosure Type	**GC_{pi}**
Open	0.00
Partially enclosed	±0.55
Enclosed	±0.18

The External Pressure Coefficient C_p for primary systems (i.e. the structural elements and components of the lateral force resisting structural system) is presented in a Figure [Fig. 3-2, identical to Fig. 6.3 of ASCE-7-98]. Components and cladding External Pressure Coefficients GC_p are commented elsewhere (see 6.2).

For non building structures the corresponding Force Coefficients C_f are given in Tables [Tables 3.8 to 3.11, identical to Tables 6.9 to 6.12 of ASCE-7-98]

3.4 Dynamic and Aeroelastic Effects (Gust Effects). [3.3.8]

For regular buildings the design forces include gust magnification effects on flexible structures (see 1.1).

For rigid structures (natural period $T \leq 1$s) the Gust Effect Factor G will be 0.85 unless it is calculated following a specific procedure [equations 3-2 to 3-5, equivalent to equations 6-2 to 6-5 of ASCE-7-98 with dimensions in meters instead of feet]. For flexible structures (natural period T > 1 s), or for wind sensitive structures, the Gust Effect Factor G_f is also calculated following a specific procedure [equations 3-6 to 3-12, equivalent to equations 6-6 to 6-12 of ASCE-7-98 modified to use dimensions in meters instead of feet].

In lieu of the previous procedures, determination of Gust Effect Factors by any rational analysis defined in the recognized literature is permitted.

3.5 Directionality Effects. [3.3.4]

Wind should be considered as coming from any direction. The Wind Directionality Factor K_d (see 3.3) varies from 0.85 to 0.95 and shall be determined from a Table [Table 3-3, identical to Table 6-6 of ASCE-7-98]. This factor should only be applied when used in conjunction with load combinations given by ASCE-7-98 [Sections 2.3 and 2.4 of ASCE-7-98]; otherwise K_d = 1.

4. METHODS OF ANALYSIS

4.1 Simplified Procedure. [3.4]

The Simplified Procedure in REP-2003 is like a code within the Code. It contains its own definitions, structural type classification, wind pressures, drift limitations, etc. It departs from the Simplified Procedure of ASCE-7-98 [6.4 of ASCE-7-98] and it does not define when can be applied as a simpler alternative to the Analytical Procedure (see 4.2).

Three Structural Types are defined for this procedure:

Type 1. One and two story single family dwellings; any enclosed structure with less than 18 m in height.
Type 2. All buildings whose structure is not dynamically sensitive to wind.
Type 3. All buildings whose structure is dynamically sensitive to wind.

Wind Pressures for each Structural Type are tabulated according to height and Category of Exposure [Table 3-12 for Structural Type 1, Tables 3-13 to 3-16 for Structural Types 2 and 3]. For Structural Type 3 these are minimum pressure values and a detailed analysis following ASCE-7-98 is required.

Drift limits are defined in the following Table:

Structural Material	Drift Limit (Δ/Δh)
Steel	0.00200 (1/500)
Reinforced concrete	0.00278 (1/360)

For parapets, commercial signs, cladding and non-structural components the methods defined in the Analytical Procedure (see 4.2) are used (see 6.2).

4.2 Analytical Procedure. [3.3]

This method applies to regular buildings (i.e. those without unusual geometry) as well as other type of regular structures.

The method does not apply to buildings whose characteristics may induce complex effects (vortex effects, instability) that do require special analyses.

For regular buildings the design forces include gust magnification effects on flexible structures. For unusual structures these effects must be considered by means of refined theories or wind tests (see 4.3).

The Design Procedure follows 10 steps [3.3.3 and 6.5.3 of ASCE-7-98]:

- The Basic Wind Speed V (see 2.1) and Wind Directionality Factor K_d shall be determined (see 3.5).
- The Importance Factor I shall be determined (see 3.1).
- An Exposure Category and Velocity Pressure Exposure Coefficient K_z or K_h shall be determined for each wind direction (see 2.3 and 2.4).
- A Topographic Factor K_{zt} shall be determined (see 2.2).
- A Gust Effect Factor G or G_f shall be determined (see 3.4).
- An Enclosure Classification shall be determined (see 3.3).
- Internal Pressure Coefficients GC_{pi} shall be determined (see 3.3).
- External Pressure Coefficients C_p or GC_{pf} shall be determined (see 3.3).
- Velocity Pressure q_z or q_h shall be determined (see 3.3).
- Design Wind Load P or F shall be determined (see 3.3).

For parapets, commercial signs, cladding and non-structural components the method defined is the same as for the Simplified Procedure (see 6.2).

4.3 Experimental Procedure. [3.3.2]

A brief paragraph states that for unusual and flexible structures gust magnification effects must be considered either via refined theories or wind tests (see 4.2).

5. INDUCED EFFECTS

5.1 Impact of Flying Objects.

Not considered.

5.2 Wind Driven Rain.

Not considered.

6. SAFETY VERIFICATIONS

6.1 Structure.

The Code contains no specific requirements for safety verifications. However, it is evident that Wind loads W are considered ultimate loads and must be combined with Dead D and Live L loads to determine the Ultimate Load. All structural elements must be dimensioned and detailed according to strength design theory. Drift limits are defined for the Simplified Procedure only (see 4.1) but they should be applied to all analytical procedures.

6.2 Claddings and Non-Structural Elements. [3.3.11.2.2; 3.3.12.4]

For both the Simplified and Analytical Procedures (see 4.1 and 4.2) wind pressure p for claddings and non-structural elements are calculated with the following equations:

Buildings with $h \leq 18m$: $p = q_h [(GC_p) - (GC_{pi})]$
Buildings with $h > 18m$: $p = q (GC_p) - q_i (GC_{pi})$

Where:

q_h = Velocity pressure evaluated at mean roof height h.
$q = q_z$ for upwind walls calculated at height z above the ground.
$q = q_h$ for downwind walls, side walls and roofs, evaluated at height h.
$q_i = q_h$ for upwind walls, lateral walls, downwind walls and roofs.
G = Gust Factor (see 3.4).
C_p = External Pressure Coefficient.
(GC_{pi}) = Internal Pressure Coefficient (see 3.3)

Combined gust effect factor G and external pressure coefficients C_p (see 3.3) for components and cladding (GC_p) are given in specific figures [Fig. 3-3 to 3-5 for $h \leq 18m$ or Fig. 3-6 for $h > 18m$; same as Figs. 6-5 through 6-7 and 6-8 respectively of ASCE-7-98]. Pressure coefficient values and gust effect factor shall not be separated.

7. SMALL RESIDENTIAL BUILDINGS. [3.4]

No specific requirements are given for Small Residential Buildings. However, the Simplified Procedure can be applied to one and two story single family units classified as Type 1 Structures (see 4.1).

RECOMMENDATIONS FOR CODE IMPROVEMENT

Chapter 3 of the REP-2003 Code, Wind Loads, is a state of the art Wind Code that follows very closely the Wind Load requirements of ASCE-7-98.

However, a Simplified Procedure is presented (see 4.1) that does not derive from ASCE-7-98 and in practice becomes a code within the Code, with independent definitions and concepts and sometimes misleading requirements, in addition to the fact that it is not clear when it can be applied as an alternative to the more advanced Analytical Procedure. It is therefore recommended that the scope and design requirements of the Simplified Procedure should be modified along the lines of ASCE-7-98 or its updated version ASCE-7-02.

SEISMIC CODE EVALUATION

PANAMA

Evaluation conducted by Jorge Gutiérrez

NAME OF DOCUMENT: **"**Reglamento de Diseño Estructural para la República de Panamá" REP-2003 ("Structural Design Code for the Republic of Panama"). Chapter 4- Seismic Loads.

YEAR: 2003 (expected year of approval)

GENERAL REMARKS: The first Panamanian Code was approved in 1984 and the current version dates from 1994 (REP-94). A new Code (REP-2003) has been drafted and it is in the process of final approval by the "Junta Técnica de Ingeniería y Arquitectura" (Engineering and Architecture Technical Board). Implementation is expected sometime this year (source: Ernesto Ng, Panamanian structural engineer, personal e-mail communication). Under the Title of "Seismic Loads", Chapter 4 of this new version contains specific regulations for Earthquake Resistant analysis and design. This is the document that has been evaluated.

SPECIFIC ITEMS:

NOTE: Bracketed numbers refer to Code specific chapters or articles: [ ]
Parentheses numbers refer to Items of this document: (see 2.2)

1. SCOPE

1.1 Explicit concepts. [4.1]

The Code is intended for buildings and related structures.

It states that earthquake loads on the structure are reduced by the effects of their inelastic behavior under strong earthquakes. Therefore, structural detailing should provide adequate element and structural ductility, even if seismic loads do not control the design.

1.2 Performance Objectives. [4.1.4.3; 4.1.4.4]

Four Building Use categories are defined (see 3.1). Category IV buildings (essential facilities) must have protected access and must remain operational after a severe earthquake.

Based on Building Use classification and earthquake intensity, defined in terms of effective peak accelerations related to velocity A_v (see 2.6), five Seismic Performance categories (A, B, C, D and E) are defined for buildings, according to the following Table:

Seismic Performance Classification			
	Use Category		
Values of A_v	I ó II	III	IV
$A_v < 0.05$	A	A	A
$0.05 \le A_v < 0.10$	B	B	C
$0.10 \le A_v < 0.15$	C	C	D
$0.15 \le A_v < 0.20$	C	D	D
$0.20 \le A_v$	D	D	E

2. SEISMIC ZONING AND SITE CHARACTERIZATION

2.1 Seismic Zoning (Quality of Data). [4.1.4.1]

No seismic zone map of the country is available in the document at hand. However, specific values of effective peak accelerations A_a and effective peak accelerations related to velocity A_v are defined for major cities. They can be interpolated for any other place in the country:

Effective Peak Acceleration Coefficients A_a and A_v					
City	A_a	A_v	City	A_a	A_v
Aguadulce	0.14	0.14	David	0.21	0.27
Aligandí	0.19	0.19	El Real	0.22	0.27
Almirante	0.21	0.22	El Valle	0.12	0.14
Bocas del Toro	0.21	0.21	Jaqué	0.22	0.28
Boquete	0.18	0.20	La Palma	0.21	0.27
Changuinola	0.24	0.28	Las Tablas	0.17	0.20
Chepo	0.20	0.28	Panamá	0.15	0.20
Chiriquí Grande	0.18	0.20	Penonomé	0.11	0.14
Chitré	0.15	0.15	Portobelo	0.17	0.19
Chorrera	0.13	0.15	Puerto Armuelles	0.25	0.34
Colón	0.15	0.20	Puerto Obaldía	0.21	0.22
Concepción	0.22	0.28	Santiago	0.15	0.18
Coronado	0.12	0.15	Soná	0.17	0.19

2.2 Levels of Seismic Intensity.

Only one level of seismic intensity is assigned to each particular city, although Effective Peak Ground Accelerations will vary according to Soil Profile Types (see 2.6).

2.3 Near Fault considerations. [4.2.6.3.3.1]

Near fault effects are considered for Base Isolated Buildings only (see 6.6). In these cases, a factor N_s related to distance to near faults and earthquake magnitude, and ranging from 1.0 to 1.5, is used for the calculation of the building base displacement.

2.4 Site Requirements. [4.1.4.5]

Buildings with the highest Seismic Performance category (E, see 1.2) can not be placed on sites where active faults are present.

2.5 Site Classification. [4.1.4.2]

Six soil profiles are defined according to several parameters as indicated in the following Table:

Soil Profile Classification			
Type of Soil Profile	**Shear wave velocity $\bar{v}_s$**	**$\overline{\text{SPT}}$ $\bar{N}$ ó $\bar{N}_{ch}$**	**Undrained shear strength $\bar{s}_u$**
A. Hard Rock	>1500 m/s	N.A.	N.A.
B. Rock	760 a 1500 m/s	N.A.	N.A.
C. Very dense soil and soft rock	370 a 760 m/s	>50	>100 kPa
D. Stiff Soil Profile	180 a 370 m/s	15 a 50	50 a 100 kPa
E. Soft Soil Profile	<180 m/s	<15	<50 kPa
F. Soil profiles requiring specific site evaluation	1. Vulnerable or collapsible soils		
	2. Highly organic clays		
	3. High plasticity clays		
	4. Very deep soft or intermediate clays		

Note: N.A. = Not applicable.

2.6 Peak Ground Accelerations (Horizontal and Vertical). [4.1.4.2.4; 4.2.2.6]

Effective horizontal peak ground accelerations A_a for Rock (Soil Profile B, see 2.5), also called ground intensities, are defined for major cities (see 2.1). Their values vary from 0.12 to 0.25 of g. For other types of soil profile these values are scaled by a factor F_a.

Similarly, for the effective peak acceleration related to velocity A_v (see 2.1), there are corresponding scaling factors F_v. The F_a and F_v values are given in the following Tables:

F_a as function of Soil Profile Type and rock peak ground acceleration					
Type of Soil Profile	Ground Intensity, A_a				
	≤0.1g	0.2g	0.3g	0.4g	≥0.5g[b]
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	[a]
F	[a]	[a]	[a]	[a]	[a]

F_v as function of Soil Profile Type and rock peak ground acceleration					
Type of Soil Profile	Ground Intensity, A_a				
	≤0.1g	0.2g	0.3g	0.4g	≥0.5g[b]
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.7	1.6	1.5	1.4	1.3
D	2.4	2.0	1.8	1.6	1.5
E	3.5	3.2	2.8	2.4	[a]
F	[a]	[a]	[a]	[a]	[a]

Notes: Use interpolation for intermediate values of A_a
[a] Specific geotechnical studies and analysis of dynamic amplification effects are required.
[b] Specific studies may lead to higher values of A_a.

Vertical ground accelerations are not explicitly defined but their effect is considered in the calculation of the earthquake load E (see 5.1).

3. PARAMETERS FOR STRUCTURAL CLASSIFICATION

3.1 Occupancy and Importance. [1.3; Table 1.1]

Buildings are classified in four categories (I, II, III and IV) according to their importance and use as follows:

Category I: Buildings and related structures whose failure implies low risk for human life including but not limited to rural, storage or temporary facilities.
Category II: Normal occupancy public or private buildings (not included in categories I, III or IV.
Category III: Hazardous facilities or densely occupied public or private buildings.
Category IV: Essential facilities.

3.2 Structural Type. [4.2.2.2]

Six Structural Types are considered:

- **Bearing Wall Systems.**

- **Building Frame Systems**
- **Moment-resisting Frame Systems**
- **Dual Systems with Special Moment Frames able to resist 25% of prescribed seismic forces.**
- **Dual Systems with Intermediate Moment Frames able to resist 25% of prescribed seismic forces.**
- **Inverted Pendulum Systems.**

Each Structural Type contains several subtypes depending on their structural materials and configuration. For each subtype, values for the Reduction Factor R, varying from 1¼ to 8, (see 4.2) and for the Displacement Factor C_d, varying from 1¼ to $6^1/_2$, (see 5.7) are defined. Additionally, there are some height and structural system limitations for specific Seismic Performance Categories (see 1.2) [Table 4.2.2.2].

3.3 Structural Regularity: Plan and Vertical. [4.2.2.3]

Buildings are classified as regular or irregular according to the following criteria:

Plan Irregularity: Torsional irregularity, Re-entrant corners, Diaphragm discontinuity, Out-of-plane offsets, Nonparallel systems.

Vertical Irregularity: Stiffness irregularity-soft story, Mass irregularity, Vertical geometric irregularity, In-plane discontinuity in vertical lateral-force-resisting elements, Discontinuity in capacity-weak story.

Specific requirements are defined for irregular buildings according to their Seismic Performance categories (see 2.1).

3.4 Structural Redundancy. [4.2.2.5.2.5]

There are no quantitative considerations related to structural redundancy (or the lack of it). However, a brief statement says that, for buildings of Seismic Performance categories B, C, D or E (see 2.1), it becomes necessary to consider the potentially adverse effect that the failure of a particular element, component or joint may have on the complete structure.

3.5 Ductility of elements and components. [Table 4.2.2.2]

The ductility of elements and components, and its effect in the overall ductility of the whole structure, is considered in the values assigned to the Reduction Factor R and the Displacement Factor C_d, according to the specific structural materials and configurations of the Structural Types and subtypes (see 3.2).

4. SEISMIC ACTIONS

4.1 Elastic Response Spectra (Horizontal and Vertical). [4.2.4.5]

No explicit Elastic Response Spectrum is defined. However, it is possible to define it from the Design Spectrum (see 4.2) as such:

$$S_a/g = 1.2\ C_v\ /\ T^{2/3} \leq 2.5\ C_a$$

Where:

$C_a = F_a\ A_a$ Zone and site dependant effective peak acceleration (see 2.1 for A_a and 2.6 for F_a).

$C_v = F_v\ A_v$ Zone and site dependent effective peak acceleration related to velocity (see 2.1 for A_v and 2.6 for F_v).

$T =$ Natural period.

For Base Isolated Buildings (see 6.6) the Code contains a detailed procedure to define an elastic response spectrum [Table 4.2.6.4.4.1]. In this case, the descending branch decays as $1/T$ instead of $1/T^{2/3}$.

4.2 Design Spectra. [4.2.4.5]

The Design Spectra corresponds to the Seismic coefficient C_s and is given by:

$$C_s = 1.2\ C_v\ /\ (R\ T^{2/3}) \leq 2.5\ C_a\ /\ R$$

Where

C_a, C_v and T were previously defined (see 4.1) and

R = Reduction Factor, varying from 1¼ to 8 according to structural types and subtypes (see 3.2).

4.3 Representation of acceleration time histories. [4.2.6.4.4.2]

Acceleration time histories are considered as an option for Base Isolated Buildings only (see 6.6). For these cases the Code specifies the need of 3 independent time histories in each direction, whose average (SRSS) elastic spectra for 5% damping should not be less than 1.3 times the elastic design spectra on more than 10% of the interval of natural periods.

4.4 Design Ground Displacement.

Not considered.

5. DESIGN FORCES, METHODS OF ANALYSIS AND DRIFT LIMITATIONS

5.1 Load Combinations including Orthogonal Seismic Load Effects. [4.2.2.6; 9.6.1.1]

The article related to load combinations [4.2.2.6] refers to specific chapters for each structural material. However, these chapters are very short and refer to particular US Codes like ACI or AISC for concrete and steel. However, the CD version of the Panamanian Code consulted by the evaluator indicates, in a somehow misplaced article [9.6.1.1], that for concrete structures the ACI-318-02 combination of dead D, live L and earthquake E loads should be substituted by the following:

$$(1.1)(1.2D + 0.5L + 1.0E) \quad \text{and}$$
$$(1.1)(0.9D + 1.0E)$$

Earthquake load E [4.2.2.6] is defined as:

$$E = \pm Q_E \pm 0.5\, C_a\, D$$

Where:
Q_E = The effect of horizontal seismic forces on each particular element.
C_a = Zone and site dependant effective peak acceleration (see 4.1).
D = Dead load effect.

The term (0.5 C_a D) can be interpreted as the contribution of earthquake vertical ground accelerations on the structure (see 2.6).

5.2 Simplified Analysis and Design Procedures.

Not considered, except for the case of small residential units (see 7)

5.3 Static Method Procedures. [4.2.3]

The total base shear force V is given by:

$$V = C_s\, W$$

Where:
C_s = Seismic Coefficient (see 4.2).
W = Total structural weight for earthquake purposes (Dead plus a fraction of Live loads)

Structural Period T for calculation of C_s is empirically estimated as:

$$T = C_T\, (3.28\, h_n)^{0.75}$$

Where
C_T = An empirical coefficient varying from 0.020 to 0.035.
h_n = Total building height from base (in m).

Vertical distribution of the total base shear V is as follows:

$F_x = C_{vx} V$ with $C_{vx} = W_x h_x^k / \Sigma_i W_i h_i^k$

k = 1 for buildings with $T \leq 0.5$
k = 2 for buildings with $T \geq 2.0$
k is linearly interpolated for T on the interval: $0.5 \leq T \leq 2.0$.

Torsional effects must be considered (see 5.6). The overturning moment is reduced by a factor τ that varies from 1.0 for the top 10 stories to 0.8 for the lower 20 (if the building has more than 30 stories, linear interpolation is applied to the intermediate ones).

5.4 Mode Superposition Methods. [4.2.4]

Required whenever Static Method Procedures (see 5.3) are not allowed. The Design Spectrum is given by the Seismic Coefficient C_s (see 4.2) with the following exceptions:

- The limit value of 2.5 C_a / R does not apply to buildings with Seismic Performance categories D or E (see 1.2) with a period $T \geq 0.7s$ on Soil Profiles type E or F (see 2.5).
- For buildings on Soil Profiles type D, E or F (see 2.5) with period $T \leq 0.3s$, $C_s = C_a (1.0 + 5.0T) / R$.
- For buildings having modes with natural periods $T \geq 4.0s$, $C_s = 3C_v/RT^{4/3}$ for those periods.

Combination of modes will be according to SRSS or CQC.
Overturning moments at the foundation level can be reduced up to 10%.

5.5 Non-Linear Methods. [4.2.6.2.5.3.2]

Not considered, except for base isolated structures (see 6.6).

5.6 Torsional considerations. [4.2.3.5.2]

For Static Method Procedures (see 5.3) the analysis must include a story Torsional Moment M_t equal to the story shear times the calculated eccentricity plus an accidental value of 5% of the building dimension. For buildings with Torsional Irregularity (see 3.3) the accidental torsion is increased by a factor $A_x = (\delta_{max} / 1.2\ \delta_{av})^2$, being δ_{max} and δ_{av} the maximum and average displacements at the story.

5.7 Drift Limitations. [4.2.2.7; 4.2.3.7.1]

Inelastic displacements δ_x are calculated from the elastic displacements δ_{xe} as:

$$\delta_x = C_d \, \delta_{xe}$$

with the Displacement Factor C_d depending on the Structural Type and subtype (see 3.2).

The relative interstory drifts limits are given in the following Table:

Drift Limits, Δ_a			
Type of Building	**Seismic Performance Classification** (see 1.2)		
	I y II	III	IV
All buildings with non structural and architectonic elements designed to accommodate the structure story drifts, except those having masonry structural walls.	0.025	0.020	0.015
All other buildings	0.020	0.015	0.010

5.8 Soil-Structure Interaction Considerations. [4.2.5]

This subject has a very thorough coverage along the lines of USA codes. Both Static Method Procedures and Mode Superposition Methods can be applied.

6. SAFETY VERIFICATIONS

6.1 Building Separation. [4.2.2.7]

No specific regulations are defined for building separations other than to indicate that all building parts should be designed and built as an integrated structure unless they have been separated to avoid pounding damage among each other during their total inelastic displacements (see 5.7).

6.2 Requirements for Horizontal Diaphragms. [4.2.2.5.2.7;]

Diaphragms must be designed to resist a minimum horizontal force equal to 50% of the seismic coefficient C_s (see 4.2) times the diaphragm's own weight plus that part of the total seismic story shear that must be carried through the diaphragm due to changes in the stiffness distribution of the resisting system along the height of the structure. Both shear and in plane bending moments on the diaphragm must be resisted, as well as the forces in their mechanical or welded connections.

6.3 Requirements for Foundations. [4.4]

Specific foundation requirements according to the building seismic performance categories A, B, C, D and E (see 1.2), are presented.

6.4 P-Δ Considerations. [4.2.3.7.2]

No *P-Δ* considerations are necessary for buildings satisfying:

$$\theta = P_x \, \Delta \, / \, V_x \, h_{sx} \, C_d \leq 0.10$$

Where:
P_x = Total vertical load over level x.
V_x = Seismic shear force at level x.
Δ = Interstory drift at level x corresponding to V_x.
h_{sx} = Interstory height below level x.
C_d = Displacement Factor (see 3.2)

In any case $\theta \leq \theta_{max} = 0.5 / \beta \, C_d \leq 0.25$

Where β is the ratio of seismic shear demand to shear capacity at level x.

For $0.1 < \theta < \theta_{max}$ the *P-Δ* effects on the structural response must be evaluated. Calculated interstory drifts (see 5.7) must be increased by a factor $1.0 / (1.0 - \theta)$. For $\theta > \theta_{max}$ the structure is considered as unstable and must be redesigned.

6.5 Non-Structural Components. [4.3]

An extensive article (24 pages) defines minimum design requirements for non-structural, architectonic, mechanical and electric systems and components. In general they must be designed to resist seismic forces F_p given by:

$$F_p = 4.0 \, C_a \, I_p \, W_p \quad \text{or} \quad F_p = a_p \, A_p \, I_p \, W_p \, / \, R_p$$

Where:
C_a = Seismic Coefficient (see 4.1).
W_p = Component's Weight.
I_p = Component's Importance Factor (varying from 1.0 to 1.5).
A_p = Component's acceleration coefficient (as a fraction of g).
a_p = Component's Amplification Factor, tabulated (varying from 1.0 to 2.5)
R_p = Response modification Factor, tabulated (varying from 1.5 to 6.0).

6.6 Provisions for Base Isolation. [4.2.6]

An extensive article (21 pages) provides detailed procedures for the analysis and design of base isolated buildings. Static, Mode Superposition and Time History procedures are contemplated. Near fault effects are considered (see 2.3)

7. SMALL RESIDENTIAL BUILDINGS [6]

In general, small residential buildings can be designed with the general procedures contemplated in the Code for their specific structural materials. However, Chapter 6 - Single Family Dwellings, contains prescriptive type regulations for one story typical buildings. These regulations can be extended to alternative types of buildings evaluated and approved according to defined procedures.

8. PROVISIONS FOR EXISTING BUILDINGS [13]

There are no specific procedures for existing buildings. A general chapter (Chapter 13 - Remodeling of Structures and other Facilities) refers specifically to building remodeling. It is a short (half page) chapter specifying that all remodeled buildings must satisfy the Code requirements or else they must undergo a structural upgrading process approved by a professional engineer.

RECOMMENDATIONS FOR CODE IMPROVEMENT

The proposed Code REP-2003 is a modern Code along the lines of the IBC-2000 Code, without being a mere transcription of it. The regulations for non structural systems and components are quite comprehensive. There are two extensive chapters on soil-structure interaction and base isolated structures that provide excessive details for these subjects even though their applicability in the country seems quite limited.

Some minor improvements may be recommended, as the use of Rayleigh's Method for the calculation of the natural period instead of the very unreliable empirical equations provided (see 5.3).

From a formal perspective, the numbering methodology for identification of articles is quite cumbersome, sometimes carrying up to six figures (i.e. 4.2.2.5.2.5)

N1, 300.0ft
0.0psi.g@ 6.0ft
P1 ,L=68.5ft
N2,280.9ft
P7 ,L=121.0ft
P2 ,L=308.0ft
P15 ,L=129.0ft
N16,256.5ft
P36 ,L=78.0ft
0.20 US gpm
N122,238.4ft
P24 ,L=120.0ft
N17,234.2ft
N130,212.9ft
0.20 US gpm
P16 ,L=144.0ft
N18,197.3ft
P20 ,L=37.0ft
N22,196.4ft
P21 ,L=51.0ft
N123,197.8ft
0.20 US gpm
P19 ,L=25.0ft
N126,191.7ft
0.20 US gpm
P22 ,L=25.0ft
N125,197.3ft
0.20 US gpm
P23 ,L=88.0ft
N124,182.9ft
0.20 US gpm
P17 ,L=151.0ft
N19,160.7ft
P18 ,L=157.0ft
P25 ,L=83.0ft
N20,151.6ft
N127,153.4ft
0.20 US gpm
P27 ,L=86.0ft
N128,146.5ft
0.20 US gpm
P26 ,L=1.0ft
N129,151.6ft
0.20 US gpm
N3,213.8ft
P3 ,L=236.0ft
N4,185.9ft
P4 ,L=49.0ft
P29 ,L=116.0ft
N30,190.8ft
P30 ,L=1.0ft
N121,190.8ft
0.20 US gpm
P31 ,L=135.0ft
N32,171.2ft
P32 ,L=80.0ft
P35 ,L=42.0ft
N120,177.8ft
0.20 US gpm
N33,178.0ft
P33 ,L=8.0ft
N118,177.7ft
0.20 US gpm
P34 ,L=31.0ft
0.20 US gpm
N119,179.1ft
N5,172.5ft
P37 ,L=1.0ft
N101,172.6ft
0.20 US gpm
P5 ,L=87.0ft
N6,165.6ft
P38 ,L=72.0ft
N102,175.0ft
0.20 US gpm
P6 ,L=168.0ft
N7,198.6ft
P39 ,L=88.0ft
N103,170.2ft
0.20 US gpm
P40 ,L=129.0ft
N41,166.9ft
P41 ,L=164.0ft
0.20 US gpm
P28 ,L=90.0ft
N8,210.8ft
P42 ,L=5.0ft
N105,210.8ft
0.20 US gpm
P8 ,L=148.0ft
N9,188.1ft
P9 ,L=76.0ft
N10,202.7ft
P43 ,L=40.0ft
N106,209.8ft
0.20 US gpm
P10 ,L=146.0ft
N11,208.2ft
P11 ,L=129.0ft
P44 ,L=132.0ft
N107,208.0ft
0.20 US gpm
N12,208.5ft
P45 ,L=219.0ft
N46,204.8ft
P46 ,L=56.0ft
N47,203.8ft
P47 ,L=434.0ft
N108,214.7ft
0.20 US gpm
P54 ,L=78.0ft
N109,203.7ft
0.20 US gpm
P55 ,L=150.0ft
N110,210.1ft
0.20 US gpm
P12 ,L=309.0ft
N13,202.1ft
P50 ,L=87.7ft
N51,207.1ft
P51 ,L=1.0ft
N111,207.1ft
0.20 US gpm
P52 ,L=1.0ft
N112,207.1ft
0.20 US gpm
P53 ,L=1.0ft
N113,207.1ft
0.20 US gpm
P13 ,L=157.0ft
N14,208.6ft
P49 ,L=30.0ft
N55,206.3ft
P48 ,L=60.0ft
N114,208.1ft
0.20 US gpm
P56 ,L=5.0ft
N115,206.3ft
0.20 US gpm
P14 ,L=370.0ft
N15,190.7ft
P57 ,L=130.0ft
N116,184.7ft
0.20 US gpm
P58 ,L=96.0ft
N117,191.5ft
0.20 US gpm

Appendix D: Water Testing Data (from Assessment II – Aug 09)

On Assessment II, EWB members performed water testing on 12 different water sources in the community. All of the current and potential water sources were tested for E coli, total coliform, nitrate, nitrite, iron, arsenic, total and free chlorine, ammonia, phosphate, alkalinity, total dissolved solids, conductivity, pH, hardness, and temperature. These tests revealed the presence of coliform and E. coli in all "tomas" (concrete collection boxes used to collect and pipe drinking water to a given sector). All other test results were normal, including arsenic. The concerning levels of arsenic found on the last trip were attributed to the landslides that had occurred 2 months prior to the January travel date. The "ojos" (true spring sources) currently providing water the central sector were located and tested as well. And while EWB members found these to be negative for E. coli, the flow rates of these sources (about 1/4 the flow rate of the current system for the central sector) were deemed to be insufficient to justify building a source water tapping system. Further, the high variability in the flow rate of these "ojos" (dependant on when the last rain occurred) indicates that these sources may not be true spring sources and a potential for contamination exists.

	EPA/WHO Standards	**Centro Ojo A**	**Centro Ojo B**	**Centro Ojo C**	**Centro Ojo D**
Description	-	Ojo for Centro Sector, farthest upstream; located beside large fallen tree and muddy slope; soil is orange and clay-like, vegetation is young; land owned by Simon Berche	Ojo for Centro Sector; walking upstream, to the left of 'Centro Ojo A' source deemed too small to tap, no tests taken	Ojo for Centro Sector, downstream from 'Centro Ojo A'; composed of 2 small sources –"right" (R) and "left" (L) (these potentially connect underground to form 1 true ojo)	Ojo For Centro Sector; called "Srökso"; located at beginning of a ravine, in watershed of Laboria; dries up a bit during the summer; " land owned by Benamin Bonilla
Date (Time)	-	8/10/2009 ; 12:25:00	8/11/2009 ; 10:30:00	8/11/2009 ; 12:30:00	08/13/2009; 10:30:00
Guide	-	Eusebio Barnat Sr.	Eusebio Barnat Jr.	Eusebio Barnat Jr.	Marcio Bonilla
Conditions	-	Drizzling, Cloudy; rained last night	Cloudy; hasn't rained for 1day	Skies clear; hasn't rained for 1day	Sunny with clear skies; hasn't rained in 3 days
Hardness (mg/L or ppm as CaCO3)	N/A *(usually 100-200)*	60, 60, 45	--	50, 60, 60	25, 25
Alkalinity (mg/L or ppm as CaCO3)	N/A *(usually 100-200)*	45, 45, 60	--	40, 30, 40	40, 40
pH (w/ strip test)	**6.5 – 8.5** *(dependent on acidity of soil)*	6.0, 6.0, 6.2	--	6.0, 6.0, 6.0	6.2, 6.2
pH (w/ pH probe)	**6.5 - 8.5** *(dependent on acidity of soil)*	5.7, 5.6, 5.8	--	5.7 (R), 5.8 (L)	6.3, 6.2
Total Chlorine (mg/L or ppm)	N/A	0, 0	--	0, 0	0, 0
Free Chlorine (mg/L or ppm)	**4**	0, 0	--	0, 0	0, 0

Phosphate (mg/L or ppm)	N/A	3, 2	--	7,4 (R), 13, 10 (L)	7, 4
Nitrite (mg/L or ppm)	**1**	0, 0	--	0, 0	0, 0
Nitrate (mg/L or ppm)	**10**	0, 0	--	0, 0	0, 0
Ammonia (mg/L or ppm)	N/A (*Usually* < 2 mg/L)	0, 0	--	0, 0	0, 0
Iron	**0.3**	0, 0	--	0.05 (R), 0.15 (L), 0.05 (L)	0.10, 0.15
Conductivity (µS/cm)	N/A *(Usually 2X Hardness)*	32, 35	--	46 (R), 47 (L)	37
Arsenic (ppb)	**.01 ppm or 10 ppb****	0, 0	--	0, 0	0, 0
Temperature	**-**	75 °F (78 °F outside), 73 °F (80 °F outside),	--	72 °F (R), 73 °F (L)	75 °F, 80 °F
Coliform Count (1 mL sample)	**0**	3, 2, 2 (non-sterile procedure) // 1, 1, 0, 0	--	10, 25, 19, 16, 1, 3	29, 40, 30, 21
E-Coli Count (1 mL sample)	**0**	**0, 0 (non-sterile procedure) // 0, 0**	--	**0, 0, 0, 0**	**0, 0**
Flow Rate		5.25 gal/min on 08/10* 2.58 gal/min on 08/11*	--	7.20 gal/min	3.62 gal/min

* - the variability of these results based on rainfall (i.e. a higher flow rate following a night of rain) indicates that this source is not a true ojo

	EPA/WHO Standards	Centro Toma	Centro Tanque	Piterson Ojos	Piterson Toma
Description	-	Current Toma for the Centro Sector, downstream from toma installed by MINSA; water very turbid; surrounded by large flat rocks	Current Large Tank which serves 20-25 households; is chlorinated 1x per year, before school begins.	Convergence of 2 small ojos upstream of current Piterson toma; deemed too small to tap	Current Toma for Piterson Sector; 9 families use this aqueduct (perhaps 1 family has their own); large amount of tree cover; surrounded by many rocks
Date (Time)	-	08/13/2009; 15:40:00	08/17/2009; 15:30:00	08/15/2009; 10:00:00	08/15/2009; 12:30:00
Guide	-	Fanor Santana	Community Water Testing Session	Eusebio Barnat Jr.	Eusebio Barnat Jr.
Conditions	-	Cloudy, no rain for 3 days	Cloudy, began raining after tests finished	Cloudy, no rain	Cloudy, no rain
Hardness (mg/L or ppm as CaCO3)	N/A *(usually 100-200)*	50, 35	50, 60, 60	--	50, 50, 50
Alkalinity (mg/L or ppm as CaCO3)	N/A *(usually 100-200)*	30, 35	30, 40, 40	--	65, 90, 85
pH (w/ strip test)	**6.5 – 8.5** *(dependent on acidity of soil)*	6.8, 6.5	7.2, 7.2, 7.2	--	7.2, 7.0, 7.0
pH (w/ pH probe)	**6.5 - 8.5** *(dependent on acidity of soil)*	7.2	7.1	--	7.4, 7.3
Total Chlorine (mg/L or ppm)	N/A	0, 0	0, 0	--	0, 0
Free Chlorine (mg/L or ppm)	**4**	0, 0	0, 0	--	0, 0
Phosphate (mg/L or ppm)	N/A	3, 2	20, 20	--	10, 10
Nitrite (mg/L or ppm)	**1**	0, 0	0, 0	--	0, 0
Nitrate (mg/L or ppm)	**10**	0, 0	0, 0	--	0, 0
Ammonia (mg/L or ppm)	N/A *(usually < 2 mg/L)*	0, 0	0, 0	--	0, 0
Iron	**0.3**	0.15, 0.20	0, 0	--	.05, .05
Conductivity (μS/cm)	N/A *(usually 2X Hardness)*	72, 73	74	--	86
Arsenic (ppb)	**.01 ppm or 10 ppb****	0, 0	--	--	--
Temperature	-	75 °F (78 °F outside)	80 °F	--	72 °F
Coliform Count (1 mL sample)	**0**	43, 43	15, 10, 18, 25	--	42, 45, 50, 44
E-Coli Count (1 mL sample)	**0**	**7, 6**	**6, 8**	--	**0, 1**

Flow Rate	**--**	--	24.15 gal/min (1.21 gal/min for pipe out of tank serving single family)	6.97 gal/min	25.99 gal/min

	EPA/WHO Standards	**Salinas Quebrada**	**Salinas Toma**	**Villagra Toma**	**Shlöbing Toma**
Description	**-**	Small Quebrada flowing from where previous toma stood; flow rate decreased significantly after source covered by landslides in November 2008; toma hasn't been used in 6 yrs	Current toma for Salinas area; 10 min walk from soccer field; (2) 3" pipes at toma; piping very fragile	Current toma for Barriada Villagra/Dunsi; Has cloth over entrance to keep out "stuff"	Current toma for Shlöbing
Date (Time)	**-**	08/16/2009; 13:07:00	08/17/2009; 10:15:00	08/17/2009; 08:00:00	08/17/2009; 09:00:00
Guide	**-**	Sonia Salina	Fanor Santana	Inocencio Villagra	Hector Torres Varga and Antonio Sanchez
Conditions	**-**	Clear, rained last night	Sunny and clear, hasn't rained in last day	Sunny and clear, hasn't rained in last day	Sunny and clear, hasn't rained in last day
Hardness (mg/L or ppm as CaCO3)	N/A *(usually 100-200)*	50, 50, 50	30, 40, 30	--	--
Alkalinity (mg/L or ppm as CaCO3)	N/A *(usually 100-200)*	40, 40, 40	20, 30, 30	--	--
pH (w/ strip test)	**6.5 – 8.5** *(dependent on acidity of soil)*	6.8, 6.8, 7.0	6.5, 6.4, 6.5	--	--
pH (w/ pH probe)	**6.5 - 8.5** *(dependent on acidity of soil)*	--	--	6.8	--
Total Chlorine (mg/L or ppm)	N/A	0, 0, 0	0, 0	--	--
Free Chlorine (mg/L or ppm)	**4**	0, 0, 0	0, 0	--	--
Phosphate (mg/L or ppm)	N/A	7, 5	3, 3	--	--
Nitrite (mg/L or ppm)	**1**	0, 0	0, 0	--	--
Nitrate (mg/L or ppm)	**10**	0, 0	0, 0	--	--
Ammonia (mg/L or ppm)	N/A (*usually* < 2 mg/L)	0, 0	0, 0	--	--
Iron	**0.3**	--	--	--	--
Conductivity (μS/cm)	N/A *(usually 2x Hardness)*	--	--	66	--
Arsenic (ppb)	**.01 ppm or 10 ppb****	--	--	--	--

Temperature	--	--	--	--	--
Coliform Count (1 mL sample)	--	40, > 50, > 50, > 50	29, 25	24, 29	25, 25, 22, 25
E-Coli Count (1 mL sample)	--	**3, 3**	**6, 5**	**0, 1**	**3, 1**
Flow Rate	--	22.64 gal/min	22.47 gal/min	--	--

Appendix E: Alternative Analysis

(Excerpts from the 523 – Alternative Analysis Report)

1.0 INTRODUCTION

The purpose of this document is to present a formal analysis of all the alternatives which have been considered for the EWB- Greater Austin water and sanitation project in Sieykin, Panama. The objective of Phase I of the project in Sieykin is to provide clean drinking water to the central sector of the community. All of the information used in this report about the community and what resources are available was gathered in the first two assessment trips: January 2009 and August 2009. According to information gathered from household interviews, the population of the central sector was determined to be approximately 150 people. If a 1.503% growth rate is assumed (the national average for Panama), the population would be about 188 in 15 years. For ease of calculation this is rounded to 200, which should assure that design would account for population growth for at least the next 15 years. The total demand was assumed to be 200 L/person/day or a total of 40,000 L/day. Demand for potable water (including cooking and washing dishes) was assumed to be 50 L/person/day or a total of 10,000 L/day.

Because of the size and layout of the community, design and implementation will be done by sector. The community, along with members of the EWB-Greater Austin team, has decided the central sector will be the first to receive potable water. The reasons for this decision are as follows: 1) The school and health post, which cater to the some of the most vulnerable members of the community, are located in the central sector, 2) The central sector has the most residents, and 3) The water quality and bacteria levels of the water tested in central sector were the worst in all of the community.

Provision of clean drinking water for the other sectors of the community will be targeted in subsequent phases of the project, and the alternatives analysis presented here applies only to the central sector. Alternatives that could be implemented at the household level (point-of-use) were considered along with community-wide alternatives. The alternatives that were considered are given below in Table 1, and whether the alternative would be implemented at the household level or community scale is indicated.

Table 1- Alternatives to be Analyzed

	Community-wide Alternative	Point-of-Use Alternative
Source Protection- Spring Box	X	
Slow Sand Filter	X	
BioSand Filters		X
Solar Disinfection		X
Ceramic Filters		X
Chlorination	X	X
Rainwater Harvesting		X
Hand Dug Well	X	

2.0 Demand Analysis

During the second EWB assessment trip, a total of 38 households were interviewed. Of those households, 17 were in the central district where the first phase of implementation will be. According to the interviews, the average number of people per household for the entire community was 6.2, and for the central district the average was 5.8 people per household. Extrapolating this to the total number of households in the central district (26) gives a total of 150 people. This is most likely a conservative estimate since some of the households included in this estimate are the buildings that do not have heavy water demand, such as the health post and an office building. EWB standards require that a project be designed so that it is still functioning at full capacity 15 years from the time of implementation. If a 1.503% population growth is used (US CIA, 2009), the national growth rate for Panama, the design population for the central district would be 188 people:

$$N = N_o e^{rt}$$

$$150\left(e^{0.0154\times 15}\right) = 188$$

The WHO states that the necessary quantity of water for proper health and hygiene is 50 L/person/day (Howard & Bartram, 2003), but observation in the community of Sieykin is that more water would be needed to satisfy community members given their current water usage habits. Although there is no water need for agricultural purposes (it rains regularly enough to make irrigation unnecessary), community members use large quantities of water in daily activities such as washing clothes. After talking to Peace Corps volunteers and engineers who have development experience in the region, it has been decided that 150-200 L/person/day is a reasonably generous estimate. This means that the community would require between 28,350 and 37,800 L/day (or between 7490 and 9987 gal/day):

$$189\,people\left(150L/person/day\right) = 28,200L/day$$

$$189\,people\left(200L/person/day\right) = 37,600L/day$$

$$28,350L/day/\left(3.785L/gal\right) = 7450gal/day$$

$$37,800L/day/\left(3.785L/gal\right) = 9933gal/day$$

This translates to an average supply of at least 5.2-6.9 gal/min:

$$\frac{7450gal/day}{1440\min/day} = 5.2gal/\min \qquad \frac{9933gal/day}{1440\min/day} = 6.9gal/\min$$

To simplify calculations and provide some latitude in design, the estimated demand is rounded to 40,000 L/day for the Central district of the community.

One alternative to be considered is to treat only the amount of potable water required. The WHO says that 50 L/person/day is sufficient to meet all needs for proper hygiene and food preparation (Howard & Bartram, 2003). If a minimum 50 L/person/day of potable water is supplied, the resulting demand for potable water is 10,000 L/day, one fourth the original demand.

3.0 DESCRIPTION OF COMPARISON METHODOLOGY

A variety of water treatment methods were researched and analyzed in order to address their overall effectiveness and their ability to fulfill this specific water need. The structure of the alternative analysis is broken into three levels, the general feasibility, risk identification, and a cost and time estimate of each project. The alternatives are treated water in a parallel system, central system, or point-of-use treatment. Alternatives within point-of-use and parallel systems only treat 50 L/person/day of potable water, while the central system treats 200 L/person/day. All proposed alternatives will undergo the initial step of general feasibility analysis, but several alternatives will be eliminated before they reach more in depth analysis.

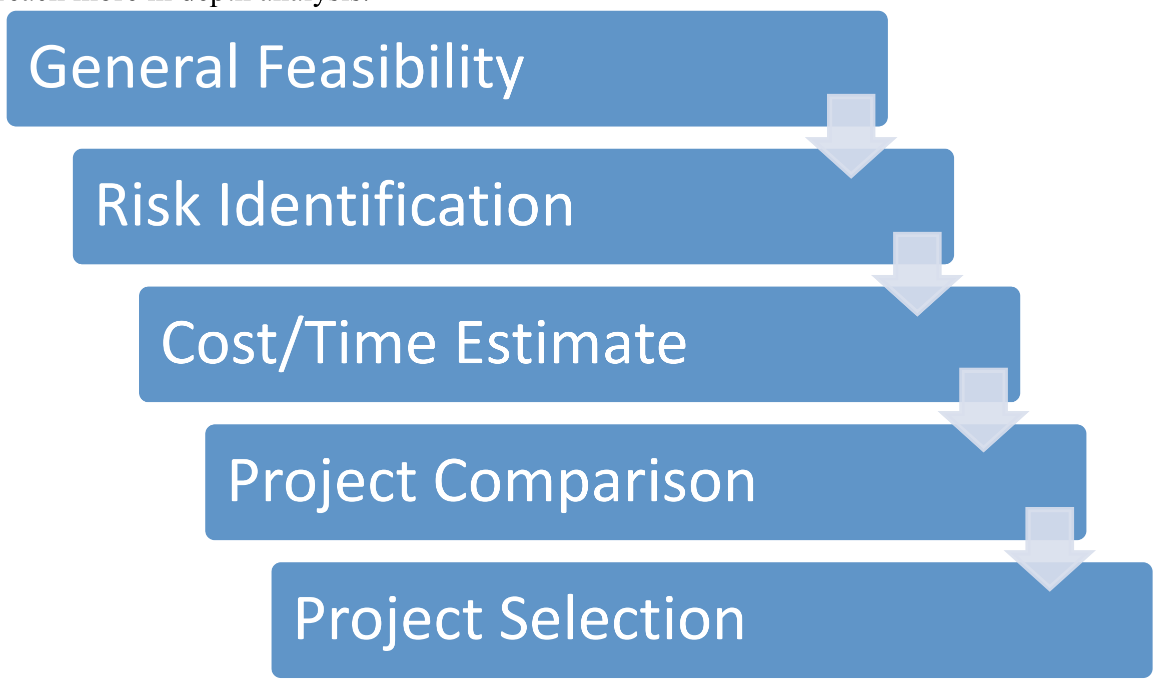


Figure 1 - Methodology Flow Chart

The general feasibility of an alternative concentrates on the possibility of implementing each treatment method within the physical and cultural constraints of the community. This level of analysis presents a broad view of the overall project, and provides an introductory look at each alternative. This is the first and most significant step in the alternative analysis, because if a design is not capable of being implemented, no further analysis is needed. The community of Sieykin is a rural community without electricity, and it is located two hours upriver from the nearest city. These two conditions make many possible solutions unrealistic, but other issues such as availability of materials must also be taken into consideration. The feasibility analysis will eliminate several alternatives and also narrow the scope of the next levels of analysis.

After analyzing the possibility of each project, it is necessary to acknowledge and address the risks that accompany them. The risk identification step goes beyond the surface level look at feasibility, and it discusses the unknowns that come with each alternative. There is little information on the several aspects of the community and the area where it resides including the geology, the location of the water table, and the reliability of the alternatives. The risks need to be considered, because even realistic projects could fail after a short period of time or upon implementation. These unknowns are much more difficult to determine since the community is so remote, but they are critical to the selection and success of a treatment alternative.

The final level of each alternative analysis is the cost and time estimate. This step provides the quantitative details that lead to the final project selection. The previous two levels of analysis have taken broader qualitative perspectives of the scenario, but the estimates provide a numerical comparison from project to project. The cost estimates are broken down into categories of project materials, project tools, and transportation costs. The individual costs of materials and tools have been defined by the initial trips to Sieykin. The teams took a survey of different costs at the hardware store in Changuinola and determined the cost of transportation by boat from the city. The time estimate is also important, because the EWB teams are limited in size, and the final project will need to be implemented in a reasonable amount of time. The time to project completion will be directly related to the size of the teams working. In most cases, the actual costs will vary slightly from the estimates, but this process provides a final level of analysis for project selection.

Table 2- Decision Factors

General Feasibility	Availability of materials, Availability of required technology, Correlation of alternative with ecosystem factors: Amount of sunshine, Amount of rain, Groundwater quality, Level of water table, etc.
Community Feasibility	Likelihood of acceptance of alternative by community
Effectiveness	Ability of alternative to provide safe drinking water over the lifespan of the project
Risks	Potential problems and circumstances that could prevent the alternative from serving its purpose
Cost	Dollar amount associated with the alternative
Time	Time required to implement alternative

4.0 DESCRIPTION OF ALTERNATIVES

4.1 Source Protection- Spring Box

There are several springs that give between 2 and 5 gal/min of clean water in the land above the community. This alternative would involve building a spring box to protect the source and a gravity-fed piping system to carry the water to the community.

4.2 Slow Sand Filter

This alternative would consist of a large community-scale sand filter that would provide drinking water to the community. Sand is available in the community, but it would need to be cleaned and sieved.

4.3 BioSand Filters

This is essentially the same as the slow sand filter but on the household level.

4.4 Solar Disinfection

This is an inexpensive way to disinfect drinking water that would need to be implemented at the individual household level. It basically involves leaving water in a transparent container exposed to direct sunlight for a minimum of 6 hours (or longer if sunlight is not direct).

4.5 Ceramic Filters

This a method for filtering drinking water that uses filters made of clay mixed with fine particles that burn up in the firing process, leaving a porous ceramic filter.

4.6 Chlorination

A drip chlorinator using liquid chlorine (this is the only form of chlorine that is readily available in the area) would be installed at the storage tank for the community. Point of use chlorination is being promoted as an intermediate solution to the drinking water problem until a permanent drinking water system is implemented.

4.7 Rainwater Harvesting

Roof runoff would be collected and stored in tanks at the individual household level. The analysis of this alternative does not involve treatment of the water.

4.8 Hand Dug Well

Because of the difficulty of transporting heavy equipment to the community, any well would need to be hand dug. A hand pump could be installed or a solar panel could be used to power an electric pump (because of the history of solar panels being stolen in the community, this is probably not a viable option).

5.0 ANALYSIS OF ALTERNATIVES

5.1 Source Protection- Spring Box

Background

Source protection is a water treatment method based on the construction of a spring box to utilize the natural flow of a spring. A spring is a natural flow of groundwater that creates a source of surface water. Spring water uses the ground, soil, and gravel for filtration, often producing clean and potable water. There are two main springs near Sieykin that could provide safe water to the community at

reasonable flow rates. Each spring is a 20 to 30 minute walk uphill from the community, so a large distance of pipe will be needed, but there will be enough pressure to bring the water to the tank site.
Spring boxes are a form of source protection to reduce the possibility of surface contamination once clean groundwater surfaces. A spring box is usually built by digging out a section of soil around the source of a spring, and then installing a brick or concrete structure around the spring to increase storage capacity. Trenched piping runs from the box downhill to the community to carry protected water to a storage tank in town from which it will be distributed. A diagram of a typical spring box is provided in Figure 2.

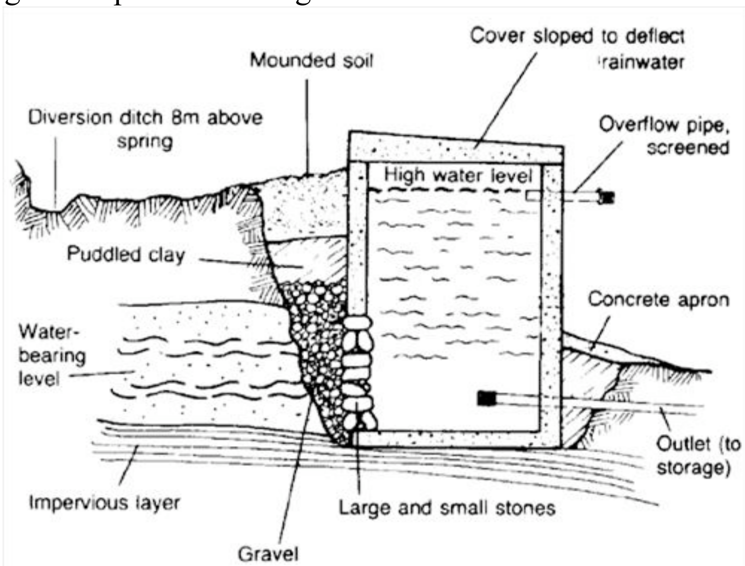


Figure 2 - Spring Box Diagram (Lifewater International)

Advantages

- Quality of water
- Consistent water source
- Cost
- Ease of construction

Disadvantages

- Possible construction problems
- Possible problems in pipe trenching

Analysis

General Feasibility

Overall, a spring box would be a strong clean water alternative for the Sieykin community. The building materials are readily available in the nearby city, and the springs will naturally filter the water. Based on the demand analysis in the introduction, the spring box would provide an adequate amount of water for the potable needs of the community. The community would be satisfied with spring water, because the taste of the water would not be affected by addition of chemicals. The construction of the box itself would not be a difficult task, but the transportation of materials uphill may be strenuous. Laying the piping is the biggest concern because the springs are located far from the community up mountainous, jungled terrain. The spring would be reliable, and the system would be relatively easy to maintain. This project would be physically and culturally feasible, and it presents a strong case to be a solution to the community's water treatment problem. Past EWB project teams have also successfully completed spring box implementations so there are sources of experience within the organization.

The main issue with building a spring box is that the springs that have been found in the area do not produce enough water to provide for all the needs of the community. The measured flow rates for three springs and the corresponding quantity of water produced daily are given in Table 3 and Table 4. Additional measurements have been made by members of the water committee and are given in Table 5. It can be seen from this data that no one spring is sufficient to provide all of the water that the community requires, but any is sufficient to provide the 10,000 L/day of potable water. The two measurements from Spring A given in Table 3 were taken on different days, and the flow rates appear to be greatly affected by the amount of rain. Measurements will be taken by the water committee during the dry season in March to determine the minimum flow of each of these springs.

Table 3- Flow Rates of Three Springs Measured in Assessment Trip II

Spring A	Spring C	Spring D
5.25 gal/min	7.20 gal/min	3.62 gal/min
2.58 gal/min		

Table 4- Daily Totals of Water for the Three Springs

Spring A	Spring C	Spring D
28577 L/day	39191 L/day	19704 L/day
14043 L/day		

Table 5- Additional Flow Rates as Measured by the Sieykin Water Committee

Spring #1	Spring #2
2.97 gal/min	3.97 gal/min
3.51 gal/min	3.94 gal/min
	4.02 gal/min

Risks

The spring box presents a relatively low number and level of risks. The potential issues that could arise with a spring box are difficulty laying piping, pipe failures that could affect the whole community, and contamination issues from soil movement. The first issue could come about during the construction of the project. The pipe is going to have to travel a long distance from the spring to the community, and there is a possibility the team will encounter and have to dig out rock while making the trenches. In addition, the terrain through which the pipe will travel is quite rugged and heavily covered with jungle vegetation. This could slow the construction time and make the pipe more difficult to lay. Pipe failures will hopefully be rare, but the risk is that a single pipe failure would affect a large amount of people. The solutions would most likely be simple and materials would be available for community members to mend the pipe, but rather than just affecting a single household, a large portion of the community could be cut off from clean water. Lastly, the contamination issue is also a rare event that would probably not be significant over time. There is the chance that storms could force dirt and contaminants into the spring box, or that wildlife could penetrate the cover. This would temporarily contaminate the source, but repairs could easily be made to correct the problems.

Cost & Time

The majority of the cost for the spring box is based on the piping from the springs to the tank and the tank to the homes. Other significant costs include transportation costs and rebar. The springs will provide a constant flow and will naturally filter the water, so there is not variable cost for increasing capacity. The project is relatively inexpensive, and maintenance will not add large costs. Construction time will be dependent on the time to lay pipe. Building the spring boxes will not take more than around seven days, but the pipe could take over ten days. If the team were to encounter rock or other harsh conditions, the construction time could be extended. Detailed calculations for the cost and time required for each the source protection alternative is provided in Appendix A. The resulting cost and time for this alternative are:
Cost: $3,700
Time: 33-42 days

Decision

Spring box source protection presents a strong argument for being the best solution to Sieykin's water problems. This alternative is simple, reliable, and relatively low risk. Source protection is a feasible means of providing water to Sieykin, and it should be compared among the top alternatives for the top project selection.

5.2 Slow Sand Filter

Background

Slow sand filtration has a history of more than 150 years of being used effectively to treat water for the removal of bacteria and to prevent the spread of gastrointestinal disease (Logsdon, Kohne, Abel, & LaBonde, 2002). Use of slow sand filtration in the developed world has waned since the early 20th century, with pressurized rapid filtration becoming the more popular method. There has been a recent renewed interest in slow sand filtration, particularly for use in developing countries (Logsdon, Kohne, Abel, & LaBonde, 2002). Slow sand filtration is suitable for small-scale water systems in the developing rural and semi-rural communities due to the availability of construction materials and methods in-community, relatively simple construction, and high efficiency in removing bacterial contamination (Huisman & Wood, 1974).

The principles behind slow sand filtration are relatively straightforward. The filter tank holds a layer of fine grain sand supported by a bed of coarse gravel. On top of the sand bed is a bio-layer composed of algae, bacteria, plankton and other microorganisms collectively known as *schmutzdecke* (German: "dirt cover"). Raw influent water from a surface water source enters through the top of the filter tank. The raw water slowly (at a rate of approximately 0.1 m/h) passes through the schmutzdecke and sand bed. The schmutzdecke mechanically strains suspended materials along with consuming nutrients and harmful microorganisms. Water and suspended material that passes through the schmutzdecke then travels through the sand layer where the suspended material is adsorbed onto or otherwise captured by the filter media. Cleaned water flows out through the coarse gravel support layer into collection pipes and is then stored in a clear well reservoir. Figure 3 shows a typical slow sand filtration system.

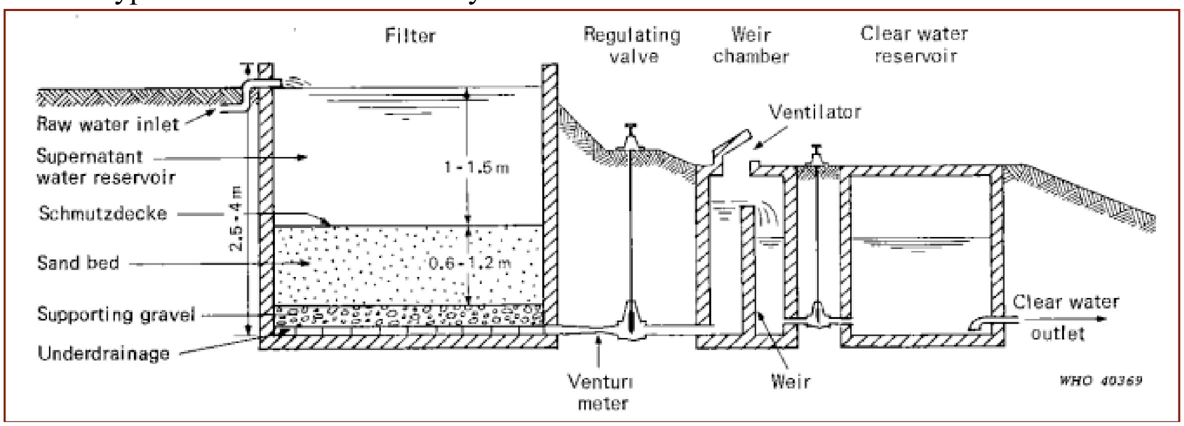


Figure 3 - Slow Sand Filter Layout (Huisman & Wood, 1974, p. 18)

Slow sand filters perform quite well at microorganism removal, including coliform bacteria, giardia, and cryptosporidium, as shown in Table 6. Bacteria removal is especially important in the Sieykin community, as mentioned in the introduction to this project.

Table 6 - Microorganism Removal by Slow Sand Filtration (Logsdon, Kohne, Abel, & LaBonde, 2002)

Reference	Organism	Filtration rate (m/h)	Temperature (°C)	Removal percentage
Poynter and Slade (1977)	Poliovirus	0.2	16 to 18	99.997 average
Poynter and Slade (1977)	Poliovirus	0.4	16 to 18	99.865 average
Poynter and Slade (1977)	Poliovirus	0.2	5 to 8	99.68 average
Poynter and Slade (1977)	Poliovirus	0.5	5 to 8	98.25 average
Bellamy et al. (1985*b*)	Total coliform bacteria	0.12	17	97 average
Bellamy et al. (1985*b*)	Total coliform bacteria	0.12	5	87 average
Bellamy et al. (1985*a*)	*Giardia*	0.12	5 to 15	99.994 average
Bellamy et al. (1985*a*)	*Giardia*	0.4	5 to 15	99.981 average
Bellamy et al. (1985*b*)	*Giardia*	0.12	17	>99.93 to >99.99
Bellamy et al. (1985*b*)	*Giardia*	0.12	5	>99.92 to >99.99
Pyper (1985)	*Giardia*	0.08	0.5	93.7
Pyper (1985)	*Giardia*	0.08	0.5 to 0.75	99.36 to 99.91
Pyper (1985)	*Giardia*	0.08	7.5 to 21	99.98 to 99.99
Ghosh et al. (1989)	*Giardia*	0.3	4.5 to 16.5	>99.99
Ghosh et al. (1989)	*Giardia*	0.4	4.5 to 16.5	99.83 to 99.99
Ghosh et al. (1989)	*Cryptosporidium* oocysts	0.15 to 0.40	4.5 to 16.5	>99.99
Hall et al. (1994)	*Cryptosporidium* oocysts	0.2	Not stated	99.8 to 99.99
EES and TWU (1996[a])	*Cryptosporidium* oocysts	0.29	12 to 14	>99.99

Advantages

- Quality of water
- Filter bed and some construction materials available on-site

Disadvantages

- Requires large amount of land
- Requires large amount of sand of a particular size and uniformity
- EWB requires experienced concrete engineer/builder
- Maintenance

Analysis

For the analysis of building and installing a slow sand filtration system in the central district of Sieykin, we explored two possibilities: filtering enough water to supply the full water needs (drinking, cooking, cleaning, laundry, etc.) of the community, and filtering water for only drinking and cooking needs. The full water need was estimated at 200 L/p/d, and the drinking water need was estimated at 50 L/p/d. Preliminary designs were made based on guidelines from the ASCE Task Committee on Slow Sand Filtration report, *Slow Sand Filtration*.[1] A summary of these calculations is provided in Appendix B and Appendix D. Time estimates include time for land clearing, construction, and concrete curing. Due to the remoteness of the Sieykin community and the lack of data available for determining construction times, the time estimates are largely based on best-guess approximations.

[1] With additional help from Patrick Dunlap and Kenny O'Neill

General Feasibility

Construction of a slow sand filtration system is possible in Sieykin. Materials such as cement, rebar, and pipes for the concrete filter tank are available at the hardware store in Changuinola Most of the other necessary materials, such as sand and coarse aggregate for the filter tank and wood for the forms to make the tank, are available in and around the village. Sand was collected during the August 2009 trip to the community and analyzed this semester at the University of Texas. It was determined that the supply available met the criteria for slow sand filtration media. There is concern, however, that the amount of sand required for both the concrete mix and filter media would be extremely difficult to gather and sieve to the required sizes and transport from its source along the riverbanks to the proposed filter site uphill.

Slow sand systems need a large amount of land due to the amount of surface area required for the filter. There is space available in the Sieykin village, though clearing and leveling of the site would likely be quite labor intensive and time consuming.

Culturally and socially, the Sieykin community appears willing to accept responsibility for a system such as a slow sand filter. The community Water Committee would be accountable for ensuring that maintenance of the filter media is performed. However, very high-quality training and specific instructions would need to be provided to direct the maintenance efforts. In the case of the central system, there would not be any reduction in current water use required, so acceptance should not be an issue.

Risks

There are several risks to the successful implementation of a slow sand filtration system in Sieykin. The national EWB organization requires that an engineer who has experience building a slow sand filter be present to lead the construction effort. The EWB team believes it will be difficult to find a qualified experienced engineer to devote several weeks abroad for this project.

Once the slow sand filtration system is implemented and operational, proper maintenance (both scheduled and unscheduled) is required. The schmutzdecke layer of the filter slowly grows with time, which leads to increased head loss and thus reductions in effluent flowrate. Once this loss becomes too great to sufficiently provide water, the schmutzdecke must be carefully scraped from the filter media. It must then be allowed to reestablish for a period of a few days to 2 weeks in order for the filter to function optimally. This process must be done approximately once every 30 days to 6 months, depending on the schmutzdecke growth rate (Logsdon, 1991). This scraping also removes some of the sand media along with the biofilm, so after several maintenance cycles, new sand would need to be harvested, sieved, and deposited into the filter tank.

Most concerning is that it is difficult to tell if a slow sand filter would definitely work for treating the source water of Sieykin. Logsden, et al. (2002) state that “there is a lack of a way to predict a priori the treatability of a source water.” If a slow sand filter is constructed and fails to function properly, time and money would have been wasted and the community would be left with a failed clean water supply project.

Cost & Time

Due to the serious consideration given to this alternative, extensive estimates of cost and time were performed. Detailed calculations for the cost and time required for each of the slow sand filter alternatives are provided in Appendix C and Appendix E. A summary of these results is presented in this section.

Central System (200 L/p/d)

The hydraulic loading rate of a slow sand filter should be approximately 0.1 m/h (Logsdon, 1991). For the central system requirements described earlier, the total water to be delivered daily would be 40 m^3/d. This results in a total required filter area of

$$Area = \left(\frac{40\frac{m^3}{d}}{0.1\frac{m}{\square}}\right)\left(\frac{1\ d}{24\ \square}\right) = 16.7\ m^2$$

To ensure that during maintenance and cleaning at least some clean water can still be produced, the filter will be divided into two equal sections, resulting in each section requiring an area of 16.67/2 = 8.35 m^2. Since each side of the tank will be square, the resulting length of each side of the two square sections is $(8.25\ m^2)^{0.5}$ = 2.9 m.

Based on these area requirements and side length calculations, along with the design parameters outlined in Appendix B. The total volumes of concrete and sand required are 10.44 m^3 and 13.45 m^3, respectively.

Cost estimates based primarily on prices from the hardware store in Changuinola and time estimates based on roughly assumed work rates are provided in Appendix C. In summary, the total cost and time for the slow sand filter central (200 L/p/d) system are:

Cost: $5,060

Time: 36 days

Parallel System (50 L/p/d)

Design calculations and cost & time estimates for a parallel system with a slow sand filter follow those presented above and are presented in Appendix D and Appendix E. In summary, the total cost and time for this system are:

Cost: $3,320

Time: 28 days

Decision

Due to the relatively high risk associated with building and maintaining a slow sand filter for the clean water project in Sieykin it is not a viable option. Compared with other options, the estimated cost and time required for slow sand filtration are also relatively high, especially for the central system 200 L/p/d case.

5.3 BioSand Filters

Background

BioSand filters have been in use in the developing world since their inception the early 1990s by Dr. Manz at the University of Calgary (CAWST, 2009). Dr. Manz helped start the Centre for Affordable Water and Sanitation Technology, which publishes information on the design of and aids in implementation of BioSand filters in rural communities worldwide (CAWST, 2009).

The mechanism behind producing clean water from BioSand filters is quite similar to that of slow sand filters as discussed in the previous section. A diagram of a typical BioSand filter is provided in Figure 4. The main difference between the community-scale slow sand filter and BioSand filters is that BioSand filters are generally considered point-of-use sources of clean water, meaning each family would own a private filter. Each family then is responsible for proper use and maintenance of their filter, though some guidance and aid from knowledgeable community members would be expected.

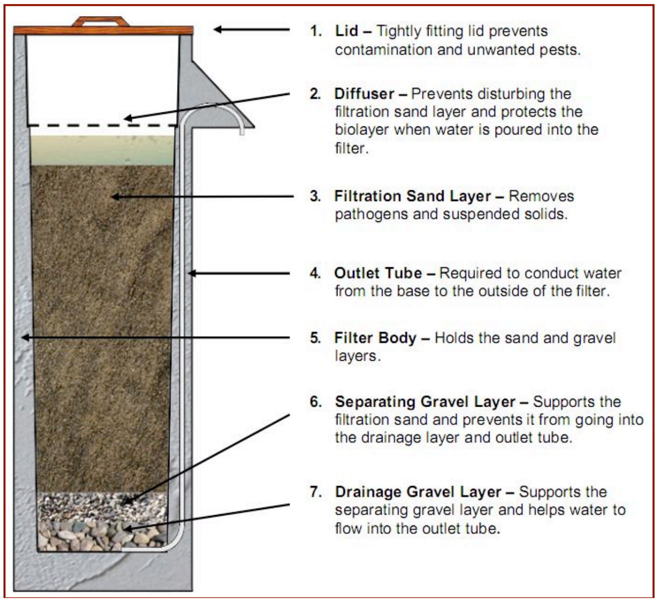


Figure 4 - BioSand Filter Diagram (CAWST, 2009)

Advantages

- Water quality
- Well documented design
- Wealth of expertise in implementing
- Cost

Disadvantages

- Quantity of water produced
- Maintenance

Analysis

Because BioSand filters are a point-of-use alternative, an assumption has been made that the volume of water put through the filters would be lower than the parallel system design parameter of 50 L/p/d. This is due in part to the fact that users would think more about what water to filter, and thus would likely only treat their drinking and some cooking water.

General Feasibility

Just as for the slow sand filter, materials for the construction of BioSand filters are available in Changuinola as well as in the local community. The materials and very detailed construction steps are explained fully in the CAWST BioSand filter manual, noted in the bibliography of this report (CAWST, 2009).
There is one major issue with the feasibility of BioSand filters in Sieykin. The houses in Sieykin are wooden and built on wooden stilts. It was noted on the last EWB assessment trip that the houses are not very sturdy and therefore might not be able to support the additional weight of a large concrete filter inside, so filters would have to be placed outside on the ground. Carrying the clean water from the filters outside instead of from indoor faucets would require a substantial change in behavior by the community. There is a big concern that this change would lead to disuse of the filters.

Risks

The biggest risk with the point-of-use BioSand filters is that even after providing each family in Sieykin with a filter and education on using it, many would simply not go through the trouble of using it properly or frequently. In addition, maintenance of the BioSand filters could be an issue just as discussed in the community slow sand filtration system. It would be difficult to train the community on the upkeep of the filters.

Cost & Time

Detailed calculations for the number of BioSand filters required for Sieykin are provided in Appendix F. Appendix G contains detailed cost and time estimates for building the BioSand filters. A summary of these results is presented in this section.
BioSand filters can produce between 60 – 80 L of potable water per day (McCarroll, 2008). However the filters would likely be distributed on a per-family basis. Assuming a future population of 65 families, 65 BioSand filters would be required. Given the average production of potable water from each filter, this would amount to approximately 20 L/p/d, averaged across the number of people in the community.
Based on this number of filters and the design guidelines in the CAWST manual, cost and time estimates have been produced. The details of these estimates are in Appendix G.
In summary, the total cost and time for implementing point-of-use BioSand filters are:
Cost: $1,400
Time: 15 days

Decision

The cost and time to build BioSand filters, along with a wealth of documented experience in using them in the developing world makes them an attractive option. However, due mostly to the fact that BioSand filters would have to be placed inconveniently outside of the households, this alternative is rejected as an acceptable clean water option for Sieykin.

5.4 Solar Disinfection

Background

Solar disinfection is a good source of disinfection for inhabitants of developing regions where access to resources for water treatment are limited. The combination of heat and ultraviolet radiation kill most bacterial pathogens present in a water supply when left in a transparent container under direct sunlight. When a temperature of 45°C is reached and the container is exposed to at least seven hours of direct sunlight, bacterial pathogens are inactivated, making the water safe to drink (McGuigan, Joyce, Conroy, Gillespie, & Elmore-Meegan, 1998). Turbidity present in the water makes solar disinfection less effective because the UV rays cannot penetrate the water. It has been shown that if a temperature of 55°C is reached bacteria will be inactivated even in water with high turbidity (McGuigan, Joyce, Conroy, Gillespie, & Elmore-Meegan, 1998).

Analysis

The problem with using solar disinfection in Sieykin is that a majority of the days have overcast conditions for all or part of the day. This makes it difficult to achieve the temperatures and UV exposure needed to effectively treat the water. On cloudy days it generally takes two days for the water to be properly treated (McGuigan, Joyce, Conroy, Gillespie, & Elmore-Meegan, 1998). Solar disinfection is only feasible as a point-of-use treatment method, and the effort required to treat the water makes it unlikely to be used properly by the community. During the household interviews for EWB's second assessment trip one of the community members stated that he was using solar disinfection, but he was using an opaque container that does not allow UV penetration. This goes to show that the entire community is unlikely to use this method of treatment properly. Another similar alternative is ultraviolet disinfection, but this would not be a feasible alternative in Sieykin because the community lacks the electricity supply to power a UV lamp.

In areas where water is scarce and direct sunlight is plentiful, solar disinfection would be a good treatment alternative because the only thing needed is a clear plastic bottle (such as a soda bottle) and there are no operation and maintenance costs.

5.5 Ceramic Filters

Background

Ceramic filters are a point-of-use option for filtration that can readily be used in many rural or emergency situations (Kayaga, 2007). Ideally, the filters are made locally with local materials to encourage sustainability and stimulate the local economy. The filters are created by mixing local clays with organic material and then firing them in a kiln. After firing, the filters are often coated with some form of silver to function as a disinfectant.

The filters work by trapping particles while allowing water to trickle though the small pores in the ceramic. Filters with no silver coating remove some bacteria, but in order achieve nearly 100% efficiency the silver coating is required. To maintain high filter volume outputs the ceramic must be scrubbed approximately once a month to remove the build-up of solids that are trapped during the filtration process (Lantagne, 2002).

Depending on the materials used to construct the filters, the rate of flow is approximately 0.5 to 3.5 L of water per hour (Lantagne, 2002). In communities that are accustomed to using water sparingly this is more than enough filtration and disinfection. However, the community of Sieykin has always had ample access to water and individuals consume far more water than the point-of-use ceramic filters could provide.

Analysis

Not all soils and organic materials can be used to create ceramic filters (Lantagne, 2002). The local materials have not been evaluated for their ability to be used in filter manufacturing. Without this information, it is impossible to determine if ceramic filters could even be constructed locally. Also, the community currently does not have a kiln for ceramic firing. The remoteness of the community (it is only accessible by boat and an up-hill hike) would hinder the expansion of a ceramic filter business if it were to be created.

There is the option of manufacturing or purchasing the filters in another country or area of Panama and shipping them to the village. This option is not sustainable due to the dependence on renewing and replenishing old or broken filters through continued purchases from non-local sources. Though the costs of individual filters can be cheap, from $5 to $25 each; they cannot meet the high volume demands of the community.

Decision

Ceramic filters are not a viable alternative in the community due to their limited volume output and the fact that they cannot currently be manufactured locally.

5.6 Chlorination

Background

Chlorine is a popular method of drinking water disinfection in developed countries (Gordon, Cooper, Rice, & Pacey, 1987). Disinfection by chlorine occurs when the chemical is introduced to the system as either a gas, solid or liquid form and is converted to hypochlorous acid, HOCL. Hypochlorous acid is a strong disinfectant and destroys disease-causing microorganisms by interacting with enzymes within the cell that are critical to the metabolic processes of the microorganism. When water is chlorinated to the appropriate dose, a chlorine-residual is generated. This protects the system from contamination by maintaining disinfection properties throughout the entire distribution system (Droste, 1997).

Advantages

- Provides chlorine-residual and continued protection against contamination throughout the water system
- Requires very few changes to the existing distribution system (negating the piping that would be replaced regardless of alternative selected)
- If chlorine is available it is a relatively cheap disinfectant

Disadvantages

- The community has expressed dislike of the taste of chlorinated water
- There is currently not a reliable source of chlorine near the community

Analysis

The chlorine disinfection system evaluated in this alternatives evaluation is a community scale system. The chlorine would be added prior to the water being distributed to individual households. There are multiple methods of introducing chlorine into a water system but they are all dependant on the phase and quality of chlorine available.

General Feasibility

A critical aspect in the selection of chlorine as a disinfection method is the availability of supplies. Chlorine for disinfection purposes can be transported as a gas, liquid or solid. Each of these different phases of chlorine requires a different method of introduction to the drinking water. Because of the remoteness of the location under consideration, gaseous chlorine is immediately a non-viable selection due to its requirements of being stored and transported under-pressure and the advanced technological requirements for the successful introduction of the gas into the liquid.

According to information gathered on the initial surveying trip liquid chlorine (in the form of bleach) is available in Changuinola but solid forms of chlorine are currently only manufactured in different region of the country. The long term dependence on the success of a supply chain is a risk to the chlorine disinfection alternative. Proper volumes of chlorine need to be stored within the community to prepare for the potential disruption of the supply chain.

The volume of liquid bleach, at 4-6% available chlorine, required to disinfect 10,000 L of water per day is approximately five gallons per day (EPA, 2006). However, it was determined during the initial EWB visit to the region that the chlorine content of bleach in the local area was not reliable. This could lead to the potential under or over dosing of the water supply.

Risks

Introducing disinfection via chlorination to a community is not void of challenges. The community members may not enjoy the taste of chlorinated water. There is evidence collected during the in-home interviews conducted by the EWB group that residents expressed their dislike of drinking chlorinated water. If the community members chose not to drink chlorinated water due to the taste and smell the system will not be able to serve its purpose.

Chlorine disinfection has the potential to create disinfection by-products. These by-products include chloroform and bromoform, among others (Richardson, 2002). Chloroform is identified by the EPA as a carcinogen and adverse health effects have been attributed to the consumption of bromoform (EPA, 2000). The consequence of introducing these components to the drinking water needs to be weighed against the benefits of chlorine disinfection.

Cost

The overall cost for a chlorine disinfection system is not prohibitive. Detailed calculations can be found in Appendix H. The time and construction required to introduce chlorine to the water system are also relatively modest. However, the costs do include a yearly cost for chlorine which may be difficult to maintain by the community after the EWB team concludes their project.

Decision

The lack of readily available materials and potential that the community will completely reject the water due to its different taste results in disinfection by chlorine not being a viable alternative.

5.7 Rainwater Harvesting

Background

Rainwater Harvesting has traditionally been considered an ideal source of clean water for areas in developing countries that receive adequate regular rainfall and where surface or groundwater is scarce. The region of Bocas del Toro seems to have plenty of rainfall, and there is little variation throughout the year (see Figure 5 which shows average monthly rainfall in the area). There have, however, been studies that show that the water quality collected from roof runoff is not sufficient for potable uses (Lye, 2002). There is also the risk of further contamination in storage tanks where the water is kept (Crabtree, Ruskin, Shaw, & Rose, 1996). All of the houses in Sieykin have thatch roofs, a material that can harbor bacteria growth that would negatively affect the quality of roof runoff. In order for rainwater harvesting to be a viable option in the community, all of the roofs would need to be replaced, and gutters would need to be installed in all of the households. Because additional treatment would be necessary to achieve water quality that would meet WHO or US EPA standards, rainwater harvesting does not seem like an ideal alternative for the community. Nevertheless, some rough calculations have been done to assess whether this would be a feasible alternative.

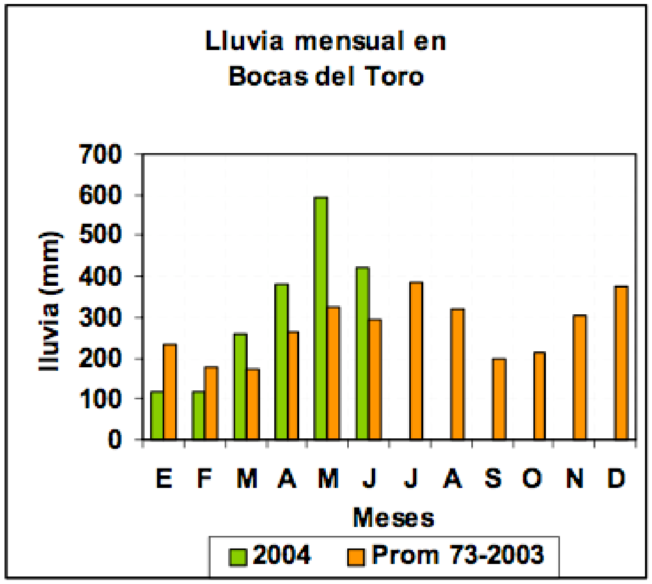


Figure 5 - Monthly rainfall in Bocas del Toro (ETESA, 2005)

Orange bars represent the monthly average (in mm), and green bars represent measurements taken in the first part of the year 2004.

Analysis

To estimate the quantity of water that could be collected from a roof, an average household size is assumed to be 20 ft. by 15 ft., which would be an average area of 300 ft^2 per household. With a total of 26 households in the central sector, this results in a total area of 7800 ft^2 or 725 m^2. This is then converted into an average daily supply based on the average daily rainfall for each month, shown in Table 7.

Table 7 - Average daily supply of rainwater available for consumption based on rough estimates

	Average Monthly Rainfall (mm)	Daily Average (mm)	Supply (m^3/day)
January	230	7.42	5.38
February	180	6.43	4.66
March	170	5.48	3.98
April	260	8.67	6.28
May	310	10.00	7.25
June	290	9.67	7.01
July	380	12.26	8.89
August	310	10.00	7.25
September	200	6.67	4.83
October	220	7.10	5.15
November	320	10.67	7.73
December	380	12.26	8.89

The demand, as calculated in the introduction, is estimated to be 10,000 L/day (10 m^3/day) for potable uses and a total of 40,000 L/day (40 m^3/day) for all uses. Figure 6 shows that even the demand for potable water cannot be met by rainwater harvesting given the estimated size of the houses.

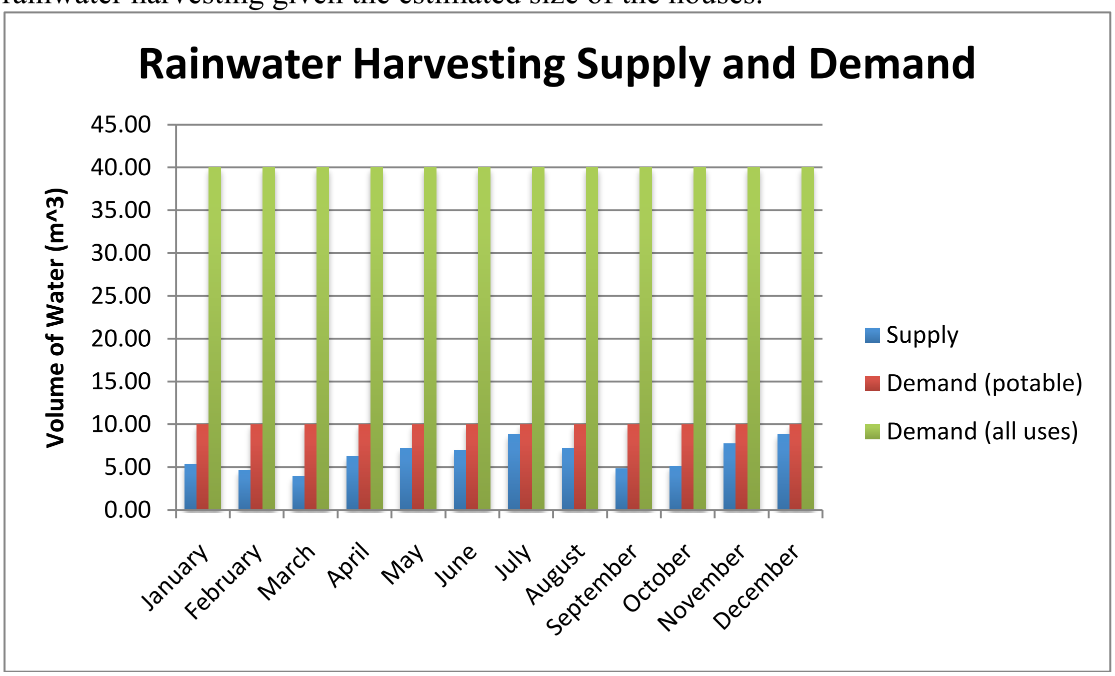


Figure 6 - Available supply from rainwater collection for each month as compared to estimated demand

When the cumulative supply and demand are considered, it can be seen that the shortfall in supply will only increase throughout the year (see Figure 7).

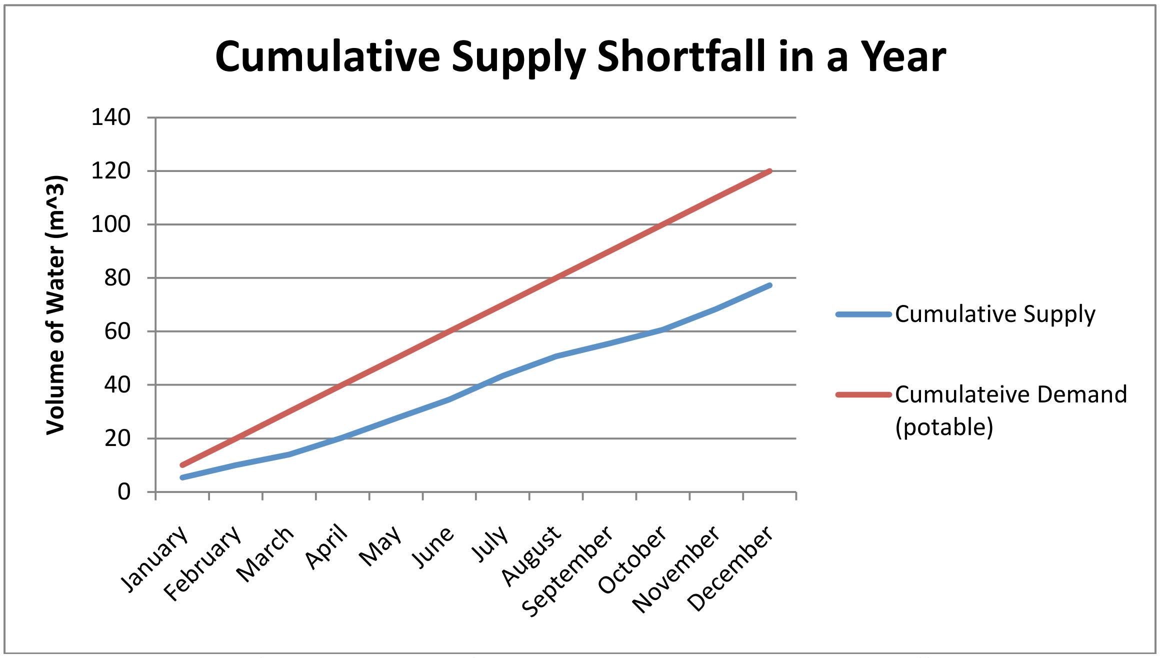


Figure 7 - The shortfall in supply will be further compounded when the cumulative effect is considered

General Feasibility

Although rainwater harvesting is shown to be an unviable alternative in Sieykin, both from the supply/demand and the cost/benefit analyses, it could be useful in other applications in the developing world. In a community-wide water system there are economies of scale for many systems that are negated for rainwater harvesting because each household must be fitted with the infrastructure (i.e. gutters and storage tanks) needed. It would be a viable alternative for a household that is responsible for its own water supply, as it would be easy to implement on a household level. However, the issue of additional treatment needed is something that should not be overlooked.

Cost

An analysis of the cost of replacing the roof materials and installing gutters in all the houses of the central district is shown in Table 8. Even this rough estimate is more expensive than the cost estimates of more feasible alternatives such as spring water tapping and slow sand filtration. This cost analysis does not include the cost of storage tanks, which would most likely be needed for each household. The cost of storage tanks of any variety is not insignificant, and this would further increase the cost, making it an even less viable alternative given the potential benefit.

Table 8 - Rainwater collection implementation costs

Roofing Materials

area/house (ft^2)	Total # houses	total area (ft^2)	cost/sq ft ($)	Cost ($)
300	26	7800	0.8	6240

Gutter Materials

perimeter/house (ft)	Total # houses	total perimeter (ft)	cost/ft ($)	Cost ($)
70	26	1820	0.5	910
			Total Cost ($)	7,150

5.8 Hand Dug Well

Background

A well is a structure used to extract water from the ground by tapping groundwater from an aquifer (Watt & Wood, 1977). The goal of the well is to provide a constant flow of clean water free from the contamination that affects surface water. In order to place a well in the community of Sieykin, the well must be dug and built by hand since there is no electricity and transporting heavy machinery would not be possible. The well is estimated to be approximately ten meters deep to reach the water table, avoid surface contamination, and remain within a practical sinking level (Watt & Wood, 1977). The structure would be a cylindrical concrete construction with layers of gravel and sand providing a natural filter between the soil and the well. Rebar and mortar will be used to reinforce the structure. Water will enter the well through the base, which has been sunk into the water table. A plug, a cement block covering gravel and sand, provides the last means of filtration for the entering water. A hand pump or electric pump would be used to extract water from the well, and a piping network will distribute the water to homes. Electric pumping could be achieved through the use of a solar powered pump at the surface of the well. The well will have to be constructed a significant distance away from any pit latrines and the wellhead will be covered to avoid contamination. Figure 8 shows the general construction of a hand dug well (Watt & Wood, 1977).

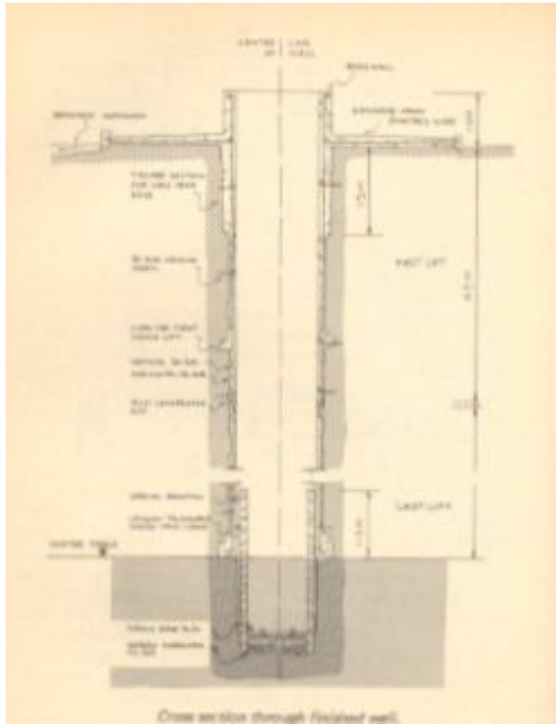


Figure 8 - Hand Dug Well Diagram (Watt & Wood, 1977)

Advantages

- Quantity of water
- Can be constructed in the community

Disadvantages

- Lack of effective distribution
- Pumping
- Difficult to construct
- Difficult to maintain

Analysis

General Feasibility

In general, the well could feasibly be built and provide access to clean, reliable water. The biggest feasibility issue with the well is the means of distributing well water throughout the community. The tools, materials, and manpower are available for the well, but the lack of electricity would mean approximately 10,000 L of potable water would have to be hand pumped from the well daily. A solar pump could be used for pumping, but the inconsistent amount of sunlight and cloud cover would not provide a reliable amount of pumped water to the community.

Risks
The building and maintenance of a well have a high level of risk. The geology of the region is unknown, so there is the possibility that there are thick rock layers underneath the soil surface. Rock would make the digging process much more difficult and in some cases, even impossible. This could occur at any depth of the well, so the problem may not be encountered until one of the last days of construction. Another risk presents itself with the use of a solar powered pump. In the past, solar panels have been stolen from the community, and there is no guarantee any new panels would remain untouched.

Cost & Time
Even though a hand dug well is deemed impractical after the risk identification, a cost estimate will provide an idea of costs and time. With a team of six to eight people, the well would take approximately ten days of preparatory work and two days for each meter of depth. Assuming a depth of thirty feet, the well would take around four to five weeks to construct. The cost of the well would be between $4,000 and $5000, depending on the distribution method. An electric pump with a solar panel would be more expensive than a hand pump, but it would allow for water to be delivered to the community from the well. Detailed calculations for the cost and time required for each of the slow sand filter alternatives are provided in Appendix I.
Cost: $4,000
Time: 28-35 days

Decision
Building a well to tap clean groundwater is a strong alternative in several ways, but unreliable distribution and possible construction issues are major causes for concern in Sieykin.

5.9 Analysis of Point-of-use, Community-wide, and Parallel Systems

A point of use system would be implemented at the household level and includes options such as ceramic filters, household BioSand filters, rainwater harvesting and solar disinfection. It was determined that anything implemented at the household level requires each individual to be knowledgeable of the system and to be responsible for using and maintaining it properly. This increases the risk factor for each of the alternatives. This, in addition to the fact that more materials are generally required, makes any point-of-use alternative a less than ideal decision.

A community-wide system would involve supplying the entire quantity of 40,000 L/day as potable water. When analyzing all of the alternatives, it was determined that this is not a very feasible decision, as it does not involve the most efficient use of resources. The two community-wide alternatives that were most seriously being considered were slow sand filtration and spring water tapping. A community-wide slow sand filter would require a prohibitive amount of materials, so it was decided that only the potable water need should be treated. When considering the spring water tapping alternative, none of the springs gave a high enough flow rate to supply the entire community's needs, so if this alternative were to be implemented, it would need to be in parallel with a non-potable system. There are many disadvantages of implementing two parallel systems, including the risk that they will not be used properly. If one system breaks it is likely that repairs will not be done and only one system will be used. The best way to mitigate this risk is to install a tap with potable water in each of the houses and a tap of non-potable water below each house where most of the activities that do not require potable water, such as bathing and washing clothes, are done. This gives a physical separation between potable and non-potable water that would make the education task of the EWB group much easier. Other ways to differentiate between the two systems, such as using different pipe sizes and color-coding the taps, are being investigated.

6.0 DESCRIPTION OF PREFFERED ALTERNATIVE

Our chosen alternative is a spring box and a gravity-fed piping system to provide potable water along with a gravity-fed piping system using surface water from a stream above the community to provide water for all the non-potable uses of the community. The springs that are present above the central sector of the community do not provide enough water to meet all of the needs of the community, but one spring should provide enough for the potable water needs. When all of the alternatives for treating the water were considered, it was determined that the additional time and cost to treat all of the water could not be justified. Because it made sense to only treat the water that is required for potable use, we returned to considering the source protection alternative (using a spring box). The spring box is by far the preferable alternative for several reasons. The cost, materials, and time required to construct is less than for any of the other alternatives considered. The simplicity of the design means that is can more easily be constructed, and quality control will be easier. The water from the springs tested meets WHO and EPA standards, so no treatment would be required. This contributes to the sustainability of the project because operation costs are almost non-existent. The only costs are for maintenance to the system that will be funded through a monthly fee that community members will be required to pay. The water committee will be responsible for the collection of the monthly fee and oversight of the maintenance of the system.

In order to provide water for all the community's needs, a parallel system of non-potable water will be required. Plans are to use the existing system, which is a gravity-fed piping system that uses surface water taken from a stream above the community. It was with great hesitation that we have made the decision to have two different systems for potable and non-potable water. The concerns with this plan are that the community will not use it properly, and if one system breaks, they will either take parts from one system to fix the other (which could lead to contamination issues for the potable system) or simply not repair the broken system. We believe that through strategic design and proper education we can mitigate these risks. Because the houses are raised up, we can put a tap that provides potable water in each of the houses and a non-potable tap on the ground below each house. This fits with the current habits of the community. Most of the uses for potable water such as cooking and washing dishes happen in the house, and most of the need for non-potable water such as washing clothes typically happens outside the house. The physical separation between the potable and non-potable water will make the education task much easier. In addition, the taps can be color-coded so that community members will easily know what water is potable. To prevent the possibility of exchange of materials for the two systems, we plan to use different pipe sizes for the potable system and the non-potable system.

While the ideal would be to have just one system, we found that it is not feasible to provide 40,000 L/day of potable water. We hope to be able to use as much of the existing system as possible to provide the non-potable water, and we will construct an entirely new system (including a spring box, tank, and piping) for the potable water.

References

Brown, J., & Sobsey, M. (2007). *Use of Ceramic Water Filters in Cambodia: Improving Household Drinking Water Quality.* University of North Carolina: UNICEF.

CAWST. (2009, September). *BioSand Filter Manual.* Retrieved November 8, 2009, from CAWST Training Manuals web site: http://www.cawst.org/index.php?id=383

Crabtree, K. D., Ruskin, R. H., Shaw, S. B., & Rose, J. B. (1996). The Detection of Cryptosporidium Oocysts and Giardia Cysts in Cistern Water in the U.S. Virgin Islands. *Water Research , 30* (1), 208-216.

Droste, R. (1997). *Theory and Practice of Water and Wastewater Treatment.* Hoboken: John Wiley & Sons, Inc.

EPA. (2000, January). *Bromoform.* Retrieved December 12, 2009, from Technology Transfer Network Air Toxics Web Site: http://www.epa.gov/ttn/atw/hlthef/bromofor.html

EPA. (2000, January). *Chloroform.* Retrieved December 12, 2009, from Technology Transfer Network Air Toxics Web Site: http://www.epa.gov/ttn/atw/hlthef/chlorofo.html

EPA. (2006, November 26). *Emergency Disinfection of Drinking Water.* Retrieved December 13, 2009, from Ground Water & Drinking Water: http://www.epa.gov/ogwdw000/faq/emerg.html

ETESA. (2005, January 5). *Hidrometeorología Republica de Panama: Comportamiento de la Lluvia 2004.* Retrieved December 12, 2009, from http://www.hidromet.com.pa/sp/Documentos/lluvia_2004.pdf

Gordon, G., Cooper, W. J., Rice, R. G., & Pacey, G. E. (1987). *Disinfectant residual measurement.* American Water Works Association.

Howard, G., & Bartram, J. (2003). *Domestic Water Quantity, Surface Level and Health: Executive Summary.* Retrieved December 12, 2009, from World Health Organization web site: http://www.who.int/water_sanitation_health/diseases/wsh0302/en/

Huisman, L., & Wood, W. (1974). *Slow Sand Filtration.* Geneva: World Health Organization.

Kayaga, S. M. (2007). *Technical Notes for Emergencies - Technical Note No. 5.* Leicestershire: World Health Organization.

Lantagne, D. (2002). *Investigation of the Potters for Peace Colloidal Silver-Impregnated Ceramic Filter: Intrinsic Effectiveness and Field Performance in Rural Nicaragua.* Allston: Alethia Environmental.

Lawler, D. F., & Benjamin, M. M. (2009). *Physical / Chemical Treatment Processes for Water and Wastewater.* Unpublished.

Lifewater International. (n.d.). *Methods of Developing Sources of Surface Water.* Retrieved December 6, 2009, from Rural Water Supply Technical Library: http://www.lifewater.org/rural-ws.aspx#RWS

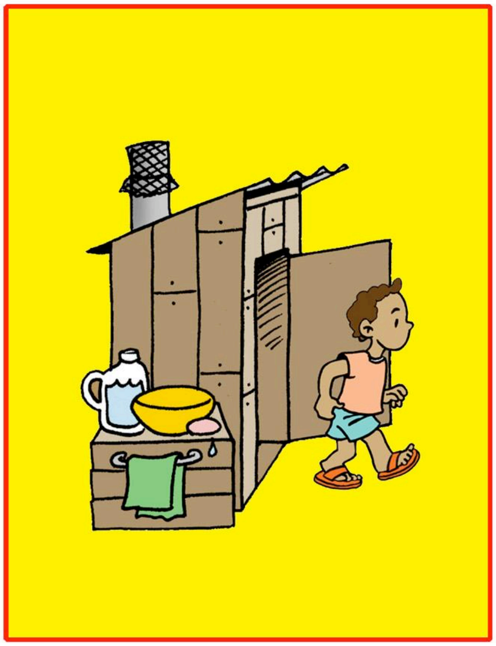
Logsdon, G. S. (Ed.). (1991). *Slow sand filtration: a report prepared by the Task Committee on Slow Sand Filtration.* New York: ASCE.

Logsdon, G. S., Kohne, R., Abel, S., & LaBonde, S. (2002). Slow sand filtration for small water systems. *J. Environ. Eng. Sci.*, *1*, 339-348.
Lye, D. J. (2002). Health Risks Associated with Consumption of Untreated Water from Household Roof Catchment Systems. *Journal of the American Water Resources Association*, *38* (5), 1301-1306.
McCarroll, R. (2008). *The All Natural Biosand Filter Manual.* Friends Who Care Canada.
McGuigan, K., Joyce, T. M., Conroy, R. M., Gillespie, J. B., & Elmore-Meegan, M. (1998). Solar Disinfection of Drinking Water Contained in Transparent Plastic Bottles: Characterizing the Bacterial Inactivation Process. *Journal of Applied Microbiology*, *84*, 1138-1148.
Richardson, S. D. (2002). The role of GC-MS and LC-MS in the discovery of drinking water disinfection by-products. *Journal of Environmental Monitoring*, *4* (1), 1-9.
US CIA. (2009, November 25). *The World Fact Book: Panama*. Retrieved December 13, 2009, from https://www.cia.gov/library/publications/the-world-factbook/geos/pm.html
Watt, S. B., & Wood, W. E. (1977). *Hand dug wells and their construction.* London: Intermediate Technology Publications.

Appendix F: Mentor Resumes

Pages from the Activity Book

A page from the Transmission Routes Activity



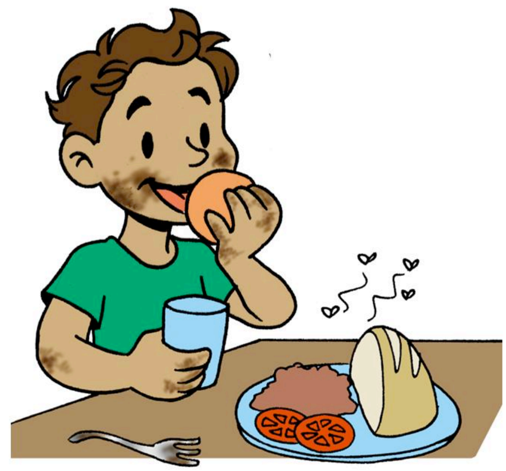
TR GAME 9

TR GAME 10

TR GAME 11

TR GAME 12

A page from the Sorting Activity

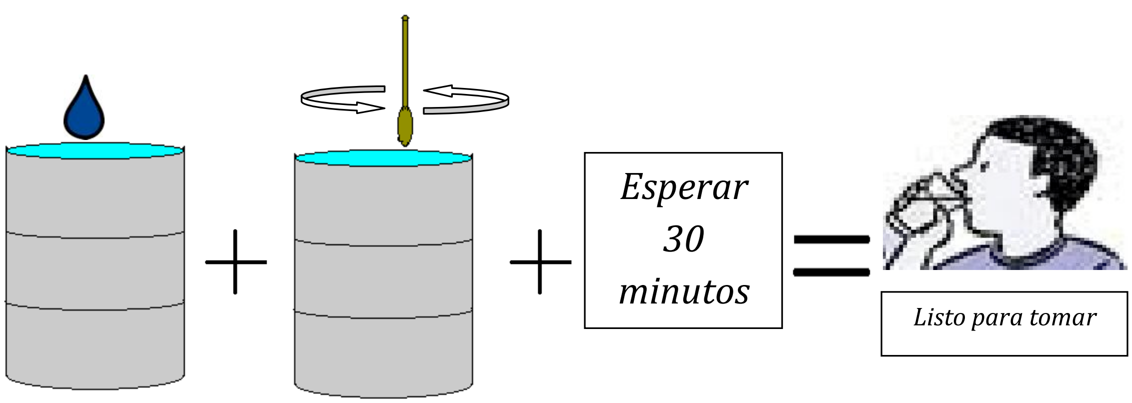


Tratamiento de Agua con

1 galón……………………………………………………………8 gotas

Un cubo (de 5 galones)……………………………1 cucharadita

Un tanque grande (de 54 galones)………..11 cucharaditas



Acuerdo del Pago para los Servicios del Acueducto

Yo, _______________, de la comunidad de Sieykin estoy de acuerdo de lo siguiente:

1. Pagaré $______ mensuales para los servicios del acueducto.
2. El comité del acueducto tiene el derecho a cortar la línea de agua a mi casa si el pago esta atrasado por 3 meses.
3. Para reinstalar la línea de agua a mi casa, tengo que pagar la deuda de los últimos 3 meses y $_______para el pago de reinstalación.

Firma y Fecha:

Tesorero del comité del acueducto	Dueño de la casa	Presidente del comité del acueducto

Administración Básico del Acueducto

El comité de agua tiene la obligación de manejar el sistema de acueducto. Es necesario mantener el sistema para proteger a la comunidad de enfermedades relacionadas con la contaminación de agua. También, el comité tiene que asegurar la calidad y regular la cantidad de agua que llega a la comunidad. Abajo hay una lista de obligaciones del comité de agua para ayudarle a ser exitoso en su función.

Asunto	Obligaciones
La Fuente / La Cuenca	▪ Proteger los árboles en la cuenca del acueducto. ▪ Proveer cantidad de agua suficiente para la comunidad. ▪ Limpiar la fuente de residuos como ramas, hojas, piedras, etc.
Mantenimiento del Sistema	▪ Arreglar daños del acueducto. ▪ Cuidar el acueducto limpiando la toma de agua y el tanque. ▪ Enterrar toda la tubería. ▪ Conectar nuevas casas al sistema. ▪ Asesorar apoyo técnico de agencias como Ingenieros Sin Fronteras y MINSA .
Educación	▪ Proveer charlas, seminarios, y talleres sobre la salud y temas del acueducto a la comunidad. ▪ Informar la gente de la comunidad sobre reuniones y las actividades del comité.
Cobro de Agua y Fondos	▪ Recaudar el pago del agua y servicios. ▪ Proveer recibos del pago. ▪ Fijar el pago mensual para recaudar suficiente fondos para mantener el acueducto y aumentar los ahorros en la caja. ▪ Llevar cuenta de los pagos, compras, y mejoramientos del acueducto.

Análisis de las Fortalezas y Debilidades Del Sistema de Agua

Fortalezas

¿Cuáles son los aspectos positivos en su comunidad con respecto a su acueducto y su comité de agua?

Debilidades

¿Cuáles son los aspectos negativos en su comunidad con respecto a su acueducto y su comité de agua?

Debilidades	Causas	Soluciones	Plan de Acción
1.			
2.			
3.			
4.			

¿Qué es más importante para nuestro acueducto?

Nombre:

Sección:

	Poco importante				Muy importante
Estructura para llevar agua de las quebradas (o toma de agua)	1	2	3	4	5
Conservación de cuenca	1	2	3	4	5
Almacenaje y desinfección de agua en la casa	1	2	3	4	5
Problemas con aire y sedimento en los tubos	1	2	3	4	5
Desinfección con cloro del agua del acueducto	1	2	3	4	5
Solicitar apoyo económico para proyectos	1	2	3	4	5
Buscar y evaluar fuentes de agua	1	2	3	4	5
Retiro de sedimento / Filtración	1	2	3	4	5
Puentes para la tubería del acueducto	1	2	3	4	5
Problemas con la presión de agua	1	2	3	4	5
Falta de agua / Problemas con la cantidad	1	2	3	4	5
Administración del comité del acueducto	1	2	3	4	5
Problemas con el almacenamiento de agua	1	2	3	4	5
Problemas con la salud atribuido al agua	1	2	3	4	5
Conocimiento del manejo del acueducto	1	2	3	4	5

¿QUÉ ES AGUA CONTAMINADA?

Hay dos tipos principales de agua contaminada. Ambos, usualmente, ocurren al mismo tiempo. Sin embargo, es posible que uno esté presente sin el otro. El primero tipo es **sedimento y contaminación química**. Este tipo ocurre cuando materia orgánica o inorgánica está presente. Ejemplos de contaminación orgánica o inorgánica muy comunes son: abono químico, insecticida, tierra, y desechos de vegetación. Estos tipos de contaminación pueden ocurrir naturalmente en la cuenca o pueden resultar por actividades de los seres humanos, como métodos agrícolas en la cuenca que queda cerca de o a más altura de la toma de agua. Algunos de estos tipos de contaminación son muy nocivos para los seres humanos, como los abonos químicos e insecticida, los cuales pueden causar cáncer. Las muestras comunes que indican la presencia de sedimento o contaminación química son las siguientes:

- El agua tiene sabor raro. (Sedimento o Contaminación química)
- El agua tiene un olor raro. (Contaminación química)
- El agua tiene color; usualmente tendrá un tinte café, amarillo, o rojo. (Sedimento)
- El agua tiene partículas que se asientan después de un periodo. (Sedimento)

El segundo tipo de contaminación del agua es **Contaminación Biológica**. Este tipo ocurre cuando microbios están presentes en el agua. Un microbio es una forma de vida pequeñita que los seres humanos no pueden ver con sus propios ojos. Algunos ejemplos de microbios son bacteria, virus, protozoos, y gusanos. Aunque la mayoría de los microbios no son nocivos para su salud, muchos con origen fecal (en este sentido, los que se encuentran en el excremento de cualquier animal o ser humano) te pueden causar enfermedades.

Microbios fecales están presentes en el suelo del monte dejado por animales que viven en y pasan por el área de la cuenca del acueducto. Cuando llueve, estos microbios y también sedimento y contaminación química son arrastrados por la lluvia y llevados por canales de drenaje a la cuenca. Los canales de drenaje incluyen ríos, quebradas, y charcos. La cuenca es utilizada para el acueducto. Niveles altos de contaminación se mesclan con el agua del acueducto durante los primeros meses de la época de lluvia debido a la acumulación de contaminación en la cuenca durante la época seca. Como resultado, estos niveles altos de contaminación en el agua del acueducto causan muchas enfermedades. Una grande porción de gente que usa este acueducto sufre enfermedades, incluyendo diarreas, irritaciones e infecciones en la piel. Mientras que algunos casos puedan ser apacibles, otros pueden ser muy severos y causar la muerte. Estas enfermedades suceden más frecuentemente, en niños y ancianos, debido su más débil sistema inmunológico. Cuando ninguno de los dos tipos de contaminación está presente en el agua del acueducto, entonces el agua se considera **agua potable**.

Como Hacer Concreto y Mezcla

Cuando uno trabaja con cemento es importante que se use las composiciones de los materiales correctamente para garantizar que el concreto o la mezcla tienen la fuerza necesaria. Esta página contiene información de cómo uno puede hacer concreto y mezcla correctamente para el uso en tomas y tanques de agua.

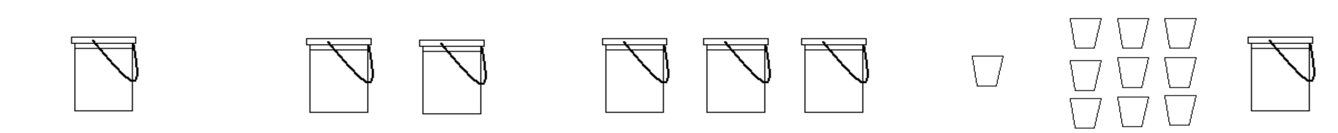
La Cantidad de Cada Material Para Hacer Concreto o una Mezcla Apropiada Para una Obra Específica

Material	Toma de Agua		Tanque de Agua									
	Todo del Concreto	Todo del Mezcla (Repello)	Fundación	Plancha	Losa	Para Llenar el Bloque	Tapa	Mezcla Para Pegar Los Bloques	Repello Exterior	Sobre Piso (Repello)	Repello Interior (Primero Capa)	Repello Interior (Segundo Capa)
Cemento	1	1	1	1	1	1	1	1	1	1	1	1
Arena	2	2	2	2	2	2	2	3	3	2	3	2
Gravilla	3		3	3	3	4	3					
Sika - 1	1 : 9	1 : 8								1 : 8	1 : 9	1 : 8

** Los números en cada cuadro indica cuanto partes del material debe ser añadido para hacer el concreto o la mezcla correctamente. Una parta es lo mismo de una pala, un cubo, o carretilla.

** Para los cuadros de Sika - 1 hay dos números (ejemplo: 1 : 9). El primero numero indica la cantidad de Sika - 1 que debe añadir con agua (indicada por el segundo numero). Puede usar un vaso de cualquiera tamaño y debe mezclarlos en una cubo.

Por Ejemplo: Para hacer concreto para toma de agua necesita añadir 1 parte de cemento, 2 partes de arena, 3 partes de gravilla, y Sika -1 (1 : 9), deben ser añadido así:



1 Cubo de Cemento **2 Cubos de Arena** **3 Cubos de Gravilla** **1 Vaso de Sika-1 con 9 Vasos de Agua Mezclados en un Cubo**

**** Todos de los materiales deben ser limpios antes que se los usa.** Si, la gravilla y arena no son limpias, el concreto y la mezcla no durarán mas que 5 años. Pero, si ellos son limpios el concreto y la mezcla durarán mas que 15 años. Para limpiar los materiales puede llavarlas con agua repetidamente hasta el agua que sale es clarita.

Appendix H: Panama City Back-up Hotel Information

Riande Airport Hotel

Via Tocumen | PO Box 6-999, El Dorado, Panama City, Panama

NEW RESERVATIONS:

- Please call (866) 568-7029
- Outside the US please call 1-210-507-5997
- Give code 3668 when calling

Lodging offering guest rooms, a 24-hour front desk and a variety of services and amenities.

Contemporary Low-rise Hotel located 2 minutes from int'l airport (free transfer) & 20 minutes from Panama City.

The unique Riande Airport offers visitors an oasis of comfort and relax in a great location near the International airport and with a convenient proximity to the city. It is the only hotel in Panama near the international airport and at the same time it's very close to the city, if you came for shopping you should stay only 10 minutes from the largest shopping center in Central America. The hotel features 192 warm and inviting accommodations that promise to offer the perfect atmosphere for pleasant moments and a variety of services that meet the needs of all travelers. Among our facilities we include the greatest swimming pool surrounded by picnic areas and the largest green yard, pool tables, tennis, volleyball and basketball courts, children playground, Jacuzzi, jogging area, mini zoo, souvenir/gift shop, on site parking spaces and round trip airport shuttle at no charge, a renovated Business Center with high speed Internet. Two restaurants that serve international meals complemented by spectacular pool views and it surroundings, daily Happy Hours and disco music at the Bogey's Lobby Bar in an inviting atmosphere. Well-equipped cconference facilities with capacity up to 400 persons. With a convenient location and so many exiting things to do, the Riande Airport hotel & Resort is guaranteed to be a pleasurable stay. Please note that reservations made through Internet or GDS may not be cancelled or changed by contacting the hotel. Cancellations and modifications must be made through the booking source.

Appendix I: Previously Visited Restaurants in Panama

Panama City

Visited:

1. Crepes and Waffles
2. Habibi's
3. Various Restaurants in Clayton/Ciudad del Saber

Changuinola

1. Chiquita Banana
2. Café Buen Sabor (alongside Hotel Semiramis)
3. Senor Beitia's Bakery
4. Pizzeria
5. Grocery store across the street from Hotel Semiramis

Appendix J: Panama Country Contacts

Panama Country Contacts

Name	Title	Role	E-mail	Phone

Graciela Castillo de Quezada	Emily's Host Mom in Panama City	Emergency Contact	graciecq@hotmail.com	Res: 236-3494 Cell: 66-63048	Betania, La Gloria Ave. 17C. Norte Casa N 8-1. El Dorado

Appendix K: Packing List

Supplies Packing List:

To buy or borrow, if not already available

Water Testing:
- Water testing equipment
- Plenty of gloves & safety glasses
- Make sure to get squirt bottle!!
- Small plastic tarp
- Medium waste bottle for arsenic waste
- Several Thick plastic bags for test waste
- Tightly sealed/protected bottle of DI water
- Container for water testing stuff

Other:
- Suitcase/duffle to hold supplies
- Mosquito Nets (2 ppl fit comfortably per net) & string
- Katadyn Water Bottles (and maybe larger purifier for washing dishes, etc.?)
- LED lantern (for communal table)
- Rubber bands/safety pins
- Sharpies
- Pencils/water resistant or proof notebook for writing in rain
- Trash Bags/Ziplock
- Batteries
- Radios
- Duct tape
- Flagging tape
- 3 Notebooks
- Battery for charging surveying equipment

Tools:
- Container for Tools
- Rope
- Compass
- Knife?
- Bungee Cords

Medicine:
- First Aid Kit
- Snake Bite First Aid Kit
- Itch - Bactine, Neosporin
- Sleep - Benadryl, Melatonin
- Foot/Blister protection - Bandaids, Athletic tape
- Parasites - Flagyl (can be purchased in Changuinola)
- Other - Probiotics ("yogurt pills")

Hygiene:
- Toilet Paper (purchase in Changuinola)
- Group Pump Hand Sanitizer (for communal table)
- DEET Insect Repellant & Sunscreen

Snacks/Food (Cliff Bars, Odwalla bars, nuts, beef jerky, dried fruit)
Gifts for all in Panama who have helped us:

- Edwin
- Community members/families (around 7 gifts?)
- Headlamps for cooks?

Appendix L: Community Photos

Figure 1: Houses in Sieykin

Figure 2: Houses in Sieykin

Figure 3: Typical Naso Home & Faucet Setup

Figure 4: Current Tank (future Non-Potable Tank)

Figure 5: Future Piping Route (densely forested, along stream bed)

Figure 6: Stream Water Source for Central Sector (future site of large aggregate filter)

Figure 7: Typical Water Collection Box in Sieykin

Figure 8: Typical Water Collection Box in Sieykin

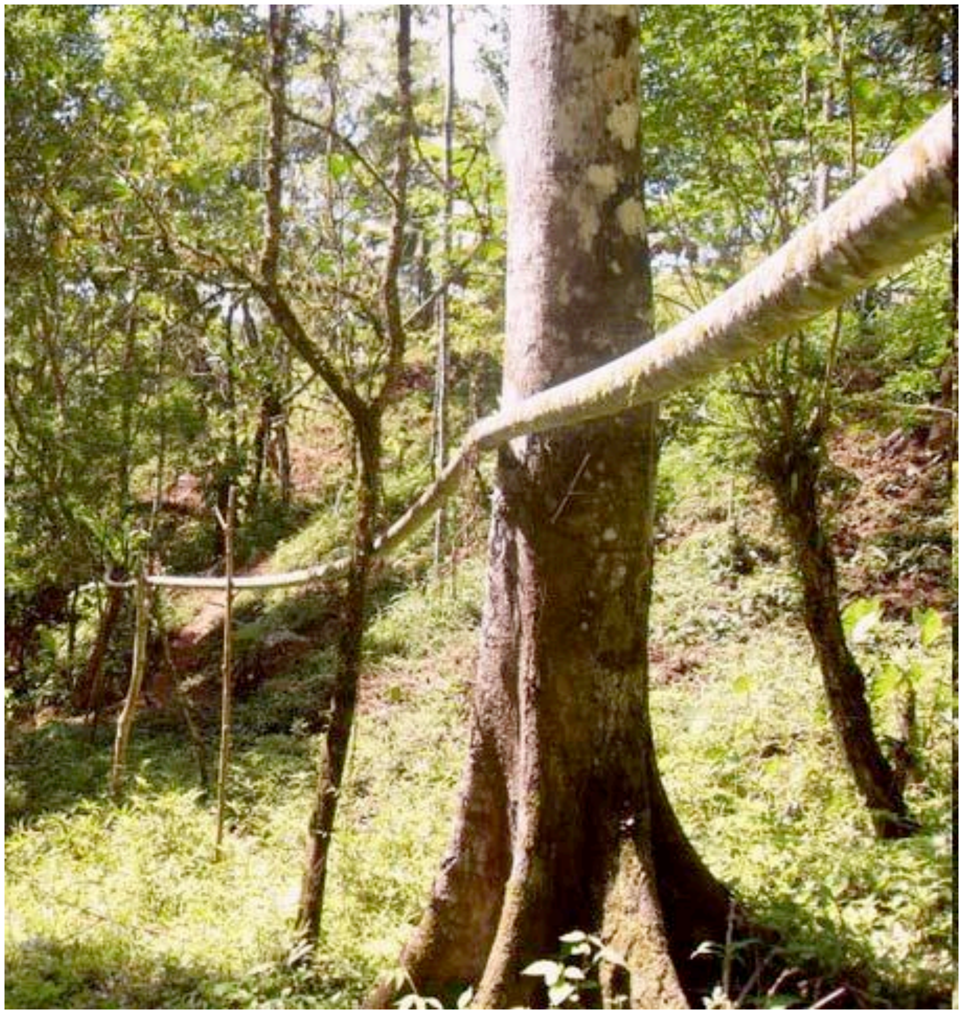


Figure 9: Current Piping (precariously mounted above ground and exposed to UV radiation)

Figure 10: Current Piping (fragile and easily separated)

Figure 11: Spring Source (future site of spring box)

Figure 12: Eusebio (Sieykin Water Committee Secretary)
taking Flow Rate Data at Spring Source

Figure 13: Spring Source (future site of spring box)

Figure 14: Spring Source (future site of spring box)