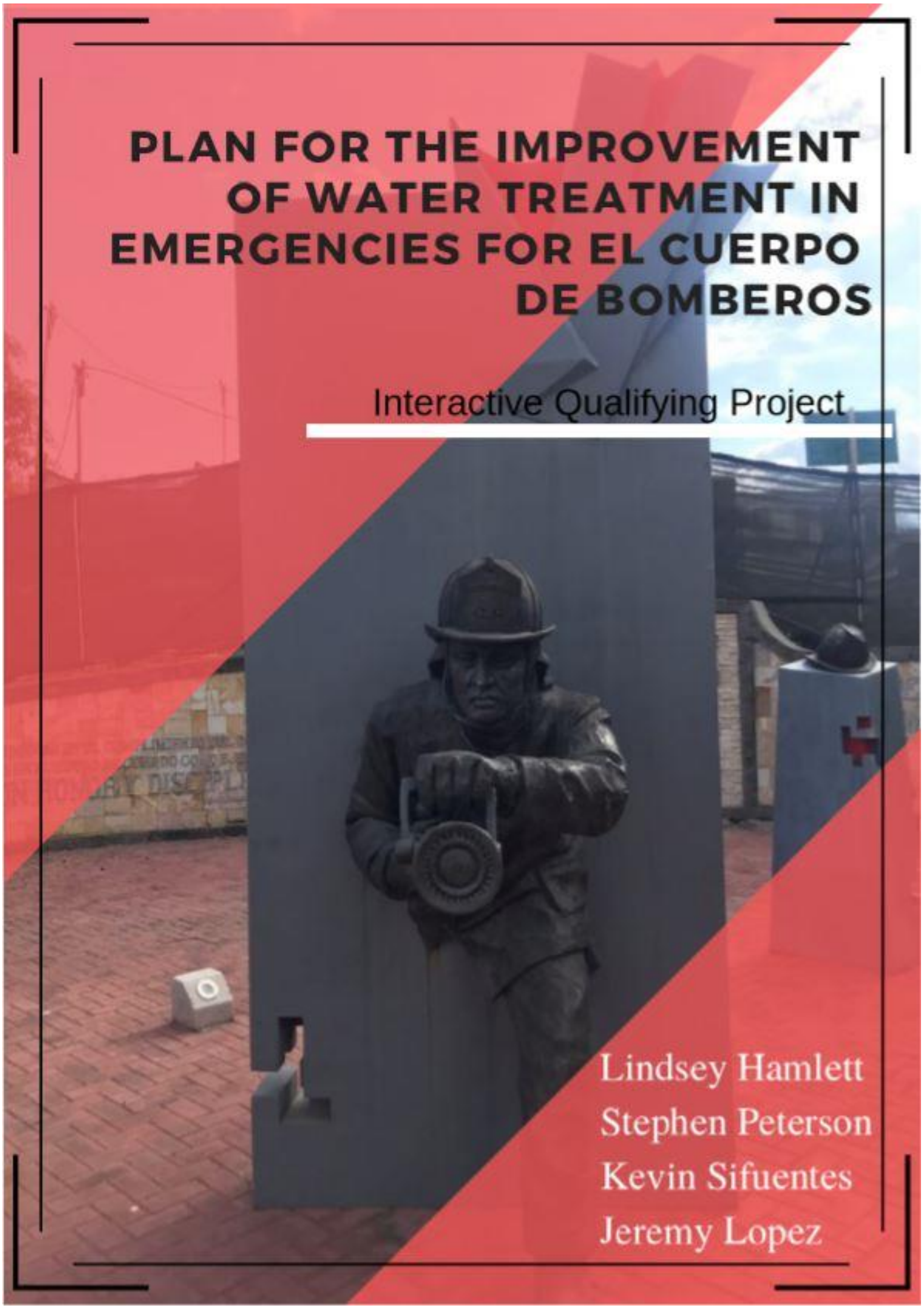


PLAN FOR THE IMPROVEMENT OF WATER TREATMENT IN EMERGENCIES FOR EL CUERPO DE BOMBEROS

Interactive Qualifying Project

Lindsey Hamlett
Stephen Peterson
Kevin Sifuentes
Jeremy Lopez

Plan for the Improvement of Water Treatment in Emergencies for El Cuerpo de Bomberos

An Interactive Qualifying Project Submitted to the
Faculty of *Worcester Polytechnic Institute* in partial
fulfillment of the requirements for the
Bachelor of Science degree.

Submitted By:

Lindsey Hamlett

Stephen Peterson

Kevin Sifuentes

Jeremy Lopez

Date:

March 1, 2019

Alex Sphar, Co-Advisor
James Chiarelli, Co-Advisor
Worcester Polytechnic Institute

Norman Chang Díaz, Sponsor
El Cuerpo de Bomberos de Costa Rica

Abstract

In this research project, the focus was to provide the Bomberos of Costa Rica with methods to improve the overall quality of their disaster relief camps, through enhancing water treatment, disposal processes and hygiene practices. We utilized interviews with key stakeholders to understand the main concerns, which were simplicity, portability and cost. When completed, we achieved innovation in the areas of water treatment, waste water disposal, water harvesting and hygiene practices, all in compliance with Costa Rican laws and regulations.

Acknowledgements

Without the help and guidance of the Cuerpo de Bomberos, Costa Rica, our success in this project would not have been possible. Continuous guidance and clear direction helped us efficiently find solutions to problems in emergency encampments that will be implemented in the future. National Fire Academy Director, Norman Chang Diaz played an enormous role in our project with assistance in ideas, feasibility, and clearly communicating his expectations for our project. Mariam Monge Mora was also an integral part to the completion of our proposals. She assisted us with contacting companies for proposals, research for product ideas, setting up interviews, as well as communicating with companies over the phone for information we were struggling to find. Mariam was always willing to help and was available even after work hours. Her dedication and intelligence were attributes that we are very thankful for. We would also like to thank Rubén Sáenz Vargas for his input and ideas in our weekly sponsor meetings. His knowledge of the functionality of these emergency camps helped in determining the feasibility of our proposed ideas. Linneth Ramírez Barquero, Allan Rodríguez Zamora, and Daniel Garita Madrigal played a pivotal role in the technical aspects of our paper. The Bomberos were a great and helpful sponsor who really made this experience exceptional.

We also would like to thank Doña Marcela Music and Don Jim Music for their efforts in making these projects possible. Mr. and Mrs. Music are the reason behind several years on continued support behind El Cuerpo de Bomberos as well as every sponsor involved in the project work. Without their generosity and constant effort, we would not have this opportunity to study abroad.

To Dr. Darner Mora Alvarado from el Instituto Costarricense de Acueductos y Alcantarillados as well as Professor Reupert Clemens from la Universidad Nacional de Costa Rica, for taking the time to share their knowledge with us. They took time out of their busy schedules to provide us with information on water purification techniques and wastewater disposal laws.

Professors Alex Sphar and James Chiarelli were the driving force behind the completion of this project. We would like to thank them for the amount of time and effort they put into providing constant feedback on our work. They spent long hours reviewing our writing and proposals in order to help us reach our end goal.

Finally, we would like to thank Worcester Polytechnic Institute for this opportunity to broaden our understanding of the world using the engineering skills they have assisted us in developing.

Executive Summary

Natural Disasters are an uncontrollable, damaging factor to the world, which leads to a phase of relief efforts and reconstruction. The Support Unit for Continuity of Operations (USCO) division of the Costa Rican Fire Department (El Cuerpo de Bomberos) is in charge of deploying encampments for rescuers involved in relief efforts. They maintain the staff's well-being and ensure continuity of rescue, providing all essential services. Setting up these camps requires a swift process so rescuers can get into the field and begin recovery.

Our project goal was to work with the Cuerpo de Bomberos to research and design a water treatment and wastewater disposal system that safely and effectively satisfies the needs of a camp comprised of an average of 150 workers, while remaining in compliance with local and international laws. Understanding the concerns of the Bomberos throughout the process proved to be key in developing our final proposal. As members of the Blue Flag Sustainability Program, the Bomberos wanted to ensure they were complying with the health and environmental standards for water quality, greywater, and excreta disposal to mitigate environmental impact. Designing a system that is simple, portable and cost effective will improve the overall efficiency of the camp and allow the rescuers to focus on the emergency.

Project Objectives

1. Determine areas or possible improvement within the Bomberos emergency relief camps, so that the appropriate actions may be taken to upgrade the current situation.
2. Analyze and gauge water demands, water usage and wastewater production throughout camps.
3. Produce portable methods to treat and test water at campsites that comply with Costa Rican and Central American laws.
4. Develop methods for the disposal of effluent wastewater produced by the camp, which are nondestructive to the environment, and add minimal strain on the USCO members erecting the camps.

To better understand the quality of life at these camps, we conducted interviews with USCO workers who have lived in the conditions previously. Understanding the functionality of these camps was vital to the estimation of water demands per activity. In order to recommend the

best wastewater treatment products for the Bomberos to implement, we considered key factors including the ease of use, liters per hour, cost and maintenance, and environmental impacts. We also conducted in-depth research into international and national law regarding excreta disposal, grey water disposal, potable and non-potable treated water.

The final deliverables of this project targeted the different water needs in the camp. Our main categories include a rainwater harvesting system, a filtration water treatment system, a water treatment product and excreta disposal. Multiple proposals were created so that the Bomberos can decide what will work best for them based on our research. We presented a cost analysis for each of the products including the initial cost, cost of maintenance, and how often maintenance should occur. With this information, we then predicted the cost using a 20 year analysis, including the cost per liter to treat after this 20-year period. To ensure feasibility of our system, we discussed possible solutions with the Bomberos once a week to guarantee we were on the right track for what they needed. In order to receive estimates, we requested product proposals from multiple businesses. This assured us that the product could be delivered to Costa Rica and allowed us to have more detailed specifications that are not available online.

Findings for Wastewater Disposal Systems

Stakeholder Perspectives

The Bomberos stressed the importance of simplicity and time efficiency in every action taken during emergency scenarios. Maintaining a healthy rescue staff is vital for the continuity and success of a mission. The Bomberos expressed their desire to implement new technology and practices that will improve water conditions and provide an adequate wastewater treatment system at the encampments while staying in compliance with local and international laws. Our project aimed to present a proposal that satisfies the necessary demands regarding wastewater management and water quality while maintaining simplicity and optimal use of time in order to support the success of a rescue.

Implementation of Infiltration Trenches

Through consulting members of the Bomberos, it was evident that an infiltration trench would be optimal for the disposal of wastewater. The infiltration trench is an extremely straightforward and cost efficient method for the short duration of the camps. Our system design works by inputting the population of the camp and the infiltration rate of the soil to produce the necessary size dimensions of the trench. The infiltration rate can be determined based off the type of soil either found at the location of the trench, or can be tested using the Turf-Tec infiltration meter, which allows for precise measurements in under an hour. The chart effectively summarizes all of the necessary calculations in unambiguous manor, allowing the trench design to be done without any other supplementary information or additional calculations.

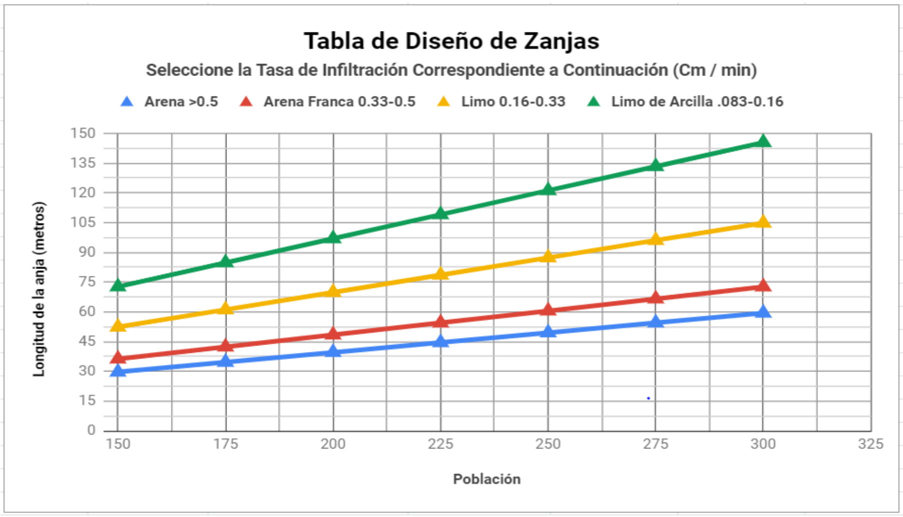


Figure ES.1 Chart used to determine necessary dimensions of a trench

Latrines

Currently the Bomberos implement a style of trench like latrines for emergency camps, but their design was not supported by any form of standards or governing laws. Our group was able to successfully set criteria that allows for sanitary construction and use. These criteria govern the location of the trench with respect to buildings within the relief camp, and with respect to sources of water, which prevents contamination from occurring. Additionally, we provided means of preventing flies from breeding and spreading harmful contaminants. The guidelines we have provided detail every aspect of designing the latrines, in a manner that is readily accessible and compliant with all Costa Rican law. It is easily implementable due the little amount of added energy and materials required, making it a highly feasible solution for excreta disposal.

<u>Findings for Potable Water Systems</u>

P&G Packets

We proposed a number of products for the Bomberos to potentially use for filtering water at the camps. In the end, we presented P&G Purification of water packets as the top product we recommended due to its portability and simple yet effective process. The packets contain powder that can be poured into the contaminated water, which causes the dirty sediments to separate from the clean water after five minutes of stirring. This product calls for a simple screen filter for the water to flow through in order to filter out the contaminants. This product would most likely work best in combination with another water purifier in order to ensure the demand for water is being met. If implemented, it would allow for people at the camp to filter their own water whenever they need to or provide purified water for the kitchen if needed promptly.

LifeSaver Jerrycan

The Jerrycan is an 18-Liter jug that uses ultrafiltration technology to filter out viruses, bacteria, cysts and parasites from contaminated water sources such as ponds, rivers and streams. It is not capable of filtering salt from salt water. The Jerrycan utilizes carbon filters that are capable of processing 500 Liters before needing a replacement. A device is included that indicates when it is necessary to replace the filter.

Desalinator

The ability to utilize salt water gives advantages to the Bomberos considering that Costa Rica has 800 miles of coast. Surrounded by both the Pacific and Atlantic Ocean, this is one of the few portable systems available with the ability to treat salt water. The Bomberos expressed their interest in research on a potential system to treat salt water due to the oceans abundance of water. If the camp is set up near the coast, this product has the ability to produce potable water and can be run every day, all day. With the response time for these emergencies lasting a range from one to 4 weeks on average, this machine should not require any maintenance during the time at the encampment.

Four step filtration system

The four-step filtration system is a lower cost system that treats surface or hydrant water. It is 10 cm in height and simply attaches onto the sink fixture. From the input, the water is first filtered through a 1-micron sediment filter, and is then processed through a granular activated carbon filter paired with a KDF55 attachment that automatically sets the pH (potential hydrogen). The final two stages rid the water of any remaining solids and then kill any viruses or bacteria in the water. The UV disinfection light is closest to the point of use, and produces potable drinking water at the end of its filtration. This system also has an auto shut off if any of the filters malfunction.

Rainwater Harvesting

The Bomberos currently use a gutter system that utilizes material attached between two adjacent tents to form a canal for the rainwater to flow through. However, they had no way of collecting the rainwater. The team conducted research and tests to ultimately design a water collection system. If implemented, it would limit the need to gather water from other sources outside of the camp itself. The two designs are shown in figures ES.3 and ES.4.

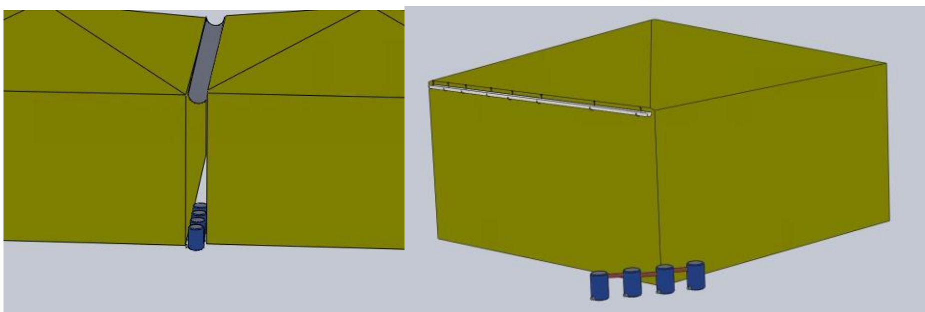


Figure ES.3 and ES.4 Rainwater harvesting systems

The figure on the left shows the design for a collection system that utilizes the current gutters in place. We set a series of barrels underneath the gutter that are linked through connector pipes which fill up each bin one after the other. On the right is an additional option for a collection method. This plan utilizes a gutter hook part that was designed to attach to the edge of the tents and hold a PVC gutter in place. During a typical rainy day in San Jose, roughly 1145L of water can be collected from a 6x12m surface.

Cost Analysis

We included a cost for each product after a 20-year span so the Bomberos can easily see the cost after having learned more about the functionality of each product.

	Desalinator	**Four Step Filtration System**	**JerryCan**	**P&G Packets**
Colones	7.600.000	2.000.000	6.400.000	32.800.000

Dollars	12,500.00	3,000	10,000	54,000

Figure ES.6 Estimated costs for top products

No specific budget was declared by the Bomberos which is why we decided to provide them a variety of options to choose from.

Recommendations

Measure Water Usage and Demands

In order to maximize the efficiency of water treatment, it is necessary to gather specific information on water demands per activity throughout the camp. Certain demands such as drinkable water and cooking water require of potable water quality, while other activities such as showering and washing clothes do not. Understanding the different treatment levels depending on the water usage and quantity results in monetary savings. The Bomberos could also use the data collected in order to understand the exact demands throughout the camp and avoid any additional trips to collect or buy water.

Correlate needs with disaster type

Providing information or reports on special needs that different types of disasters require would prove to be profitable. Through an interview with the Instituto Costarricense de Acueductos y Alcantarillados (AyA), the principal drinking water and wastewater systems operator in the nation, the team understood that a natural disaster such as a hurricane could flood and contaminate water from fire hydrants. Understanding specific conditions per disaster would allow the Bomberos to understand the additional materials or specific solutions that apply to the emergency at task.

Authorship Page

Abstract: Jeremy Lopez, Stephen Peterson

Executive Summary: all

Chapter 1: Introduction: Kevin Sifuentes

Chapter 2: Background:

Inside Look at a Typical Camp: Kevin Sifuentes

Stakeholder Perspective: Lindsey Hamlett

` **Weather Trends in Costa Rica:** Jeremy Lopez & Lindsey Hamlett

Health Standards: Stephen Peterson

Grey & Black Water: Lindsey Hamlett

International Law: Kevin Sifuentes & Stephen Peterson

Water Contamination: Lindsey Hamlett

Groundwater Contamination: Stephen Peterson

Costa Rican Water Access: Kevin Sifuentes

Disaster Relief Organizations: Jeremy Lopez & Lindsey Hamlett

Chapter 3: Methodology:

Interviews: Kevin Sifuentes

Gauge Water Demands: Kevin Sifuentes

Determine Baseline Sanitary Levels: Lindsey Hamlett & Stephen Peterson

Quality Control Kits: Stephen Peterson

Hygiene Practices: Stephen Peterson

Wastewater Treatment Plan: Jeremy Lopez & Lindsey Hamlett

Cost Analysis: Jeremy Lopez & Stephen Peterson

Chapter 4: Findings/Analysis:

Wastewater Norms/Laws: Kevin Sifuentes

Water Treatment: Lindsey Hamlett

Proposed Water Treatment Systems: Jeremy Lopez & Lindsey Hamlett

Rain Water Harvesting: Jeremy Lopez & Kevin Sifuentes & Lindsey Hamlett

Infiltration Trenches: Stephen Peterson

Hygiene Practices: Stephen Peterson

Potential Pollutants: Stephen Peterson

Water Quality Tests: Kevin Sifuentes

Chapter 5: Deliverables/Proposed Items: All

Chapter 6: Future Recommendations: Lindsey Hamlett

Conclusion: Jeremy Lopez

All sections edited by entire team

Table of Contents

List of Figures

List of Tables

Glossary

Biological Oxygen Demand: The quantity of oxygen used in the biochemical oxidation of organic matter in a specified time, at a specified temperature, and under specified conditions.

Black Water: Wastewater from toilets, garbage disposal, and industrial processes.

Chemical Oxygen Demand: The amount of oxygen required for the chemical oxidation of organics in a liquid. Suspended solids are solids that either float on the surface of, or are in suspension in, water, wastewater, or other liquids, and which are largely removable by laboratory filtering.

Escherichia-coli: Bacterium commonly found in the intestines of humans and other animals, some strains of which can cause severe food poisoning.

Fecal Coliform: Bacteria are generally used as indicators of potential water contamination, as these bacteria are found in human and animal feces. Though not harmful to themselves, fecal coliform bacteria indicate the possible presence of other pathogenic bacteria, viruses, and protozoans that line in animal and human digestive systems.

Grey Water: Household waste water that can be reused for some purposes without purification, e.g. bath water, which can be used to water plants.

Methylene Blue Active Substances: Substances that can be found in water samples. This may include substances that can cause industrial and health damage, such as: sulfonates, phosphates, sulfates, carboxylates, detergents.

Microorganisms: Any organism too small to be viewed by the unaided eye, as bacteria, protozoa, and some fungi and algae.

Potential of Hydrogen: The negative logarithm of the hydrogen ion concentration (-log10[H+]) where H+ is the hydrogen-ion concentration in moles per liter. Neutral water has a pH value of 7.

Settleable Solids: Particles of debris and fine matter heavy enough to settle out of wastewater.

Suspended Solids: Solids that either float on the surface of, or are in suspension in, water, wastewater, or other liquids, and which are largely removable by laboratory filtering.

Topography: The detailed mapping or charting of the features of a relatively small area, district, or locality.

Turbidity: Condition in water or wastewater caused by the presence of suspended matter, resulting in the scattering and absorption of light rays.

Residual Chlorine: Chlorine remaining in water or wastewater at the end of specified contact period as combined or free chlorine.

Conductivity: Ability of a material to carry current or heat.

Table of Acronyms

AERSEP: Regulatory Authority for Public Services

ANA: National Water Authority

ASADAS: Administrative Associations of the Aqueducts and Community Sewerage Systems

AyA: Costa Rican Institute of Aqueducts and Sewers

BOD: Biological Oxygen Demand

CAPRE: Regional Coordinating Committee of Drinking Water Institutions and Sanitation of Central America

CCE: Community Emergency Committees

CME: The Municipal Emergency Committees

CNE: The National Commission for the Prevention of Risks and Emergency Care

CNRH: National Water Resource Council

COD: Chemical Oxygen Demand

COE: Emergency Operations Center

CRE: The Regional Emergency Committees

EPA: Environmental Protection Agency

GAC: Granular Activated Carbon

IRFC: The International Federation of Red Cross and Red Crescent Societies

MARENA: Ministry of Environment and Natural Resources

MAGFOR: Ministry of Agriculture and Forestry

MINAE: Environment and Energy Ministry

MINSALUD: Health Minister of Costa Rica

MIFIC: Ministry of Development, Industry and Trade

NSF: National Sanitation Foundation

OXFAM:Oxford Committee for Famine Relief

PAHO: Pan-American Health Organization

pH: Potential of Hydrogen

UN: United Nations

UNA: Universidad Nacional Costa Rica ‘

UNHCR: United Nations High Commissioner for Refugees

USAID: The U.S. Foreign Disaster Assistance

USCO: Support Unit for the Continuity of Operations

UV: Ultraviolet

WHO: World Health Organization

1.0 Introduction

On October 6, 2017, Tropical Storm Nate passed through Central America, specifically in Costa Rica, Nicaragua and Honduras leaving at least 22 dead. Thousands of others in Costa Rica were left without running water or a home, forcing them to sleep in shelters. Heavy rains, landslides and flooding caused serious damage to the region's roads and bridges (Storm Nate, n.d).

The Cuerpo de Bomberos de Costa Rica assists citizens in harm's way, such as the situation mentioned following storm Nate. They are essentially a combination of a fire brigade and a disaster relief unit. Their mission is to "provide a prevention service to protect life, property and the environment" (Bomberos, n.d). Annually, the Bomberos respond to roughly sixty thousand emergencies throughout the region, such as Hurricane Nate. Examples of the services performed by the Bomberos include responding to: fires on public and private properties, situations involving hazardous materials, pest infestations, and natural disasters (Bomberos, n.d).

The Bomberos understand that having a safe place to stay when natural disaster strikes is a critical step for safety and resilience. Since their initial efforts in 2012, the organization has been responsible for the maintenance of relief camps. These camps harbor on average 150 emergency workers and provide services including medical attention, housing, cooking, and sanitation; with running water and electricity.

The average daily water needs in emergency scenarios consists of 20 liters per person (Reed, B. n.d.). In areas where inhabitants are prone to disease and infection, the need potentially grows. In addition to having sufficient water, it must be safe and sanitary for the rescuers. The water must be free from microorganisms, chemical substances and radiological hazards that pose health threats. In order to maintain a healthy population while responding to emergencies, it is crucial that an efficient sustainable water treatment plan is allocated.

Teaming up with the Bomberos, our goal was to conduct studies with reference to both national and international laws applicable to water quality and the disposal of wastewater for the improvement of living conditions throughout the camp. A design of a treatment system that sufficiently addresses the estimated volume of wastewater produced at the camp was developed. Furthermore, an estimated budget of the wastewater treatment system for the Support Unit for Continuity of Operations (USCO) in an emergency camp was developed. The USCO's objective is to provide all primary services such as the appropriate equipment, tools, accessories, temporary housing and food to support emergency rescue teams that are composed of firefighters and other organization rescue teams. They work to maintain the well-being of the camp's population. The parameters for our project includes 150 rescuers staying in a camp. Of the 150, 12-15 are USCO members. The USCO staff receives training and capacitation in logistical issues in order to acquire knowledge for the optimal support of emergency activities and the camp. This project will provide a proposal to improve water and hygiene quality for the USCO staff and rescuers.

2.0 Background

This chapter provides a brief overview of the Bomberos of Costa Rica, weather trends in San Jose, international and local laws pertaining to water filtration, along with practices used for hygiene as well as a brief examination of organizations that have already implemented such techniques in some areas.

2.1 Inside Look at a Typical Camp

Figure 1: Aerial view of typical relief camp (N. Chang Diaz, 2018)

In the process of assembling a relief camp, the Bomberos truck in all supplies and materials necessary for survival. A typical campsite ideally has a $50\square^2$ area; this changes depending on the location. Camps can be located in areas close to the mountains, tropical jungles, and in close proximity to the Pacific or Atlantic Ocean which can alter the area and terrain of the territory. Relief camps are composed of dormitories, a dining room, kitchen, showers, areas for washing clothes and dishes, trench style latrines, and a medical tent to treat any illness that might arise during the rescuers' residency. When emergencies such as hurricanes cause floods and do not allow latrines to be put in place, the Bomberos use portable toilets. Power and electricity is provided at the camp through portable generators that are installed in every room of the camp. Generators and voltage transformers are tactically placed throughout the camp to ensure the best service is provided.

Hygiene practices are a crucial part of maintaining health at the camp. The Bomberos provide education programs to ensure the adequate hygiene manners and actions are practiced at the camp and ultimately reduce illness. Providing sufficient water and being able to transport the necessary amount is a crucial part of survival at these camps; to do so, the Bomberos utilize a series of containers that are capable of holding up to 3000L together, which must be refilled on a daily basis, this is the average water demand per day. Communication is also necessary throughout the process. Each camp has a command center with telephone services and Wi-Fi in order to maintain communications and exchange intelligence from other locations.

The image below shows the outline of a typical emergency camp. This includes the outer dimensions of the different types of tents, generators, and voltage transformers being used. Knowing the purpose and activity taking place in each tent, an estimated water demand can be calculated and factored into the total water consumption.

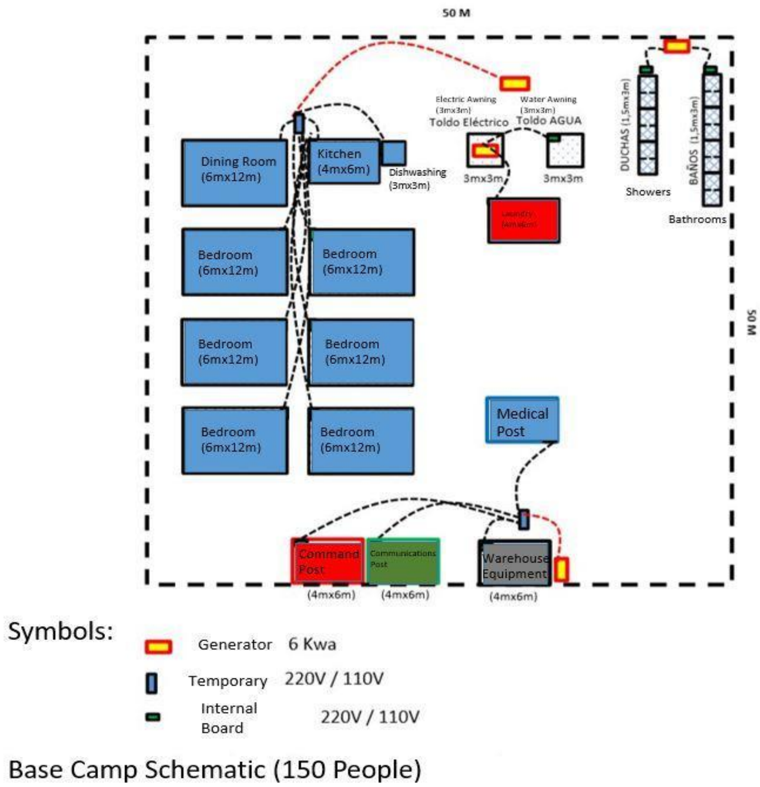


Figure 2: Schematic of a Typical Camp (N. Chang Diaz, 2018)

2.2 Stakeholder Perspective

The firefighters of Costa Rica have the responsibility of training both new members, as well as civilians. Annually they train approximately 1500 civilians and 1500 firefighters. In 2017, they offered 29 courses for firefighters and support staff, and 9 to the public. Working with the public involves training businesses how to defend their property against fires. However, their goal is to eventually transition into a university. The first step toward their goal is to be recognized as a pre-college, and then receive the full certification. Eight new classrooms have been added to help achieve this goal. The Bomberos are responsible for teaching a wide variety of tasks to the public, ranging from dealing with pest problems, to putting out house fires.

While doing this, they also convey the message of promoting environmentally friendly and sustainable practices at these companies. The Academy participates in the Blue Flag (Bandera Azul) sustainability program, which was "founded with the purpose of improving education and information regarding the environment. Since then [Bandera Azul] has been helping to promote the protection of the natural surroundings and increasing public knowledge in this regard" (Delfina Travel Group Inc, 2018).

When it comes to water use, they believe its inexpensive cost and prevalence causes water to be undervalued and poorly rationed. It is the commitment of El Cuerpo de Bomberos de Costa Rica to protect the environment directly through fire prevention and the implementation of water conservation practices. Being leaders in sustainability and considering public opinion, the Bomberos teamed up with WPI to help develop a system to treat water used by rescuers resulting from emergency situations.

2.2.1 Funding El Cuerpo de Bomberos de Costa Rica

According to the law, 4 percent of the first payment of every insurance policy that is written in the country goes towards funding the Fire Department of Costa Rica. Fines levied on citizens and foreigners accumulated from accidents in Costa Rica also fund the Bomberos. Private companies both national and international also play a role in donating funds (Volunteer BaseCamp, n.d.). From this, we were able to get an idea of the budget that the Bomberos are working around and make our buying recommendations based on the information provided as well as general feedback given to us from the Bomberos themselves.

2.3 Weather Trends in Costa Rica

Costa Rica is known for its tropical climate throughout the region. In fact, in the past six years, the capital has experienced steady rainfall patterns with September and October being the wettest months averaging 240mm of rain (holiday-weather, n.d).

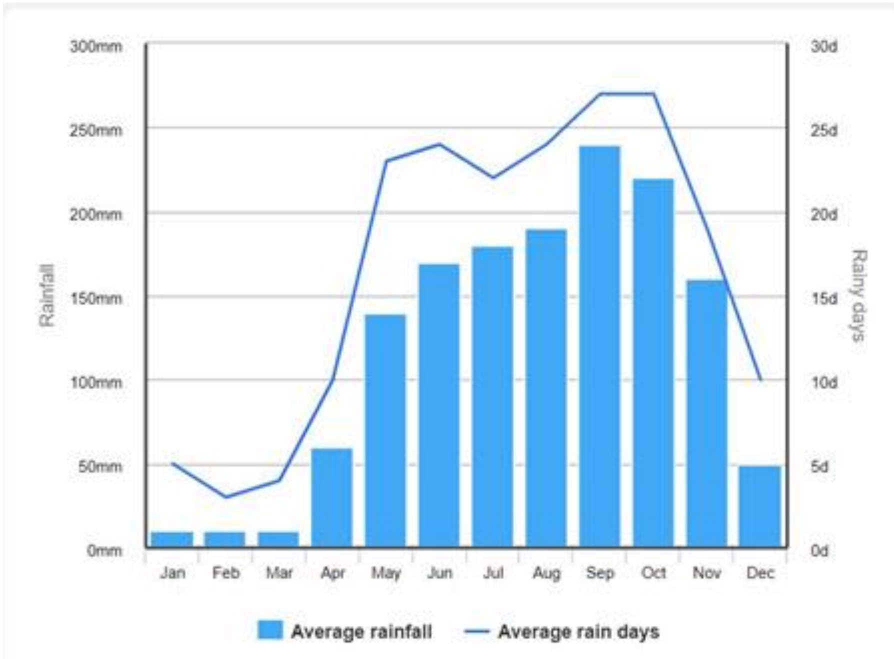


Figure 3: Average annual rainfall in San Jose (San Jose, Costa Rica: Annual Weather Averages. (n.d.))

A wet day in San Jose is one with at least 0.04" of precipitation. However, even though the wetter season lasts roughly 7 months out of the year from May 3 to November 30, the probability of a wet day peaks at 51% on October 7. Following these months is what is termed as the "drier season" lasting from November 30th to May 3 with only a slight 7% chance of a wet day in early March (weatherspark, n.d).

The Bomberos currently do not have a system for collecting rainwater. In the past, they have only set up camp in a location where water can be accessed whether it is from a nearby fire hydrant or a river. Given the dimensions of the different tents in the previous chart, it is evident that there is a lot of surface area to work with for rainwater collection. After speaking with more local residents as well as Bombero staff about the wet season in Costa Rica, during rain season, it rains heavily and for a long duration. The Bomberos can take full advantage of the heavy rainfall to collect and filter the water. These techniques will be discussed later on in the paper.

2.3.1 El Niño & La Niña

El Niño is a weather pattern that is associated with severe climate change, creating oscillation in the temperatures between the atmosphere and the ocean. In Costa Rica specifically, the effects are causing either extreme drought or heavy rainfall, depending on which ocean side one is on: Atlantic or Pacific. El Niño can trigger side effects including droughts and heatwaves. (Sarouhan, T.). The El Niño weather pattern appears approximately every 7 years. La Niña typically has the opposite effect in Costa Rica increasing rainfall slightly on the Pacific side and sometimes drying out the Caribbean.

When a drought occurs, it is important for the residents of that area to be aware of the situation. In time of drought, residents would need to conserve water and ration electricity. El Niño could cause rainfall to fall below 2 percent of monthly averages. What seems like a small percentage could have great impact on the crops and cattle. As crops begin to dry up and are not harvestable, cattle begin to die. Any agricultural shift can cause food shortages, and can impact the economy with a rise in production costs because more resources are needed to sustain livestock and crops. This could greatly affect the camps, as the amount of life's essentials will be at a shortage.

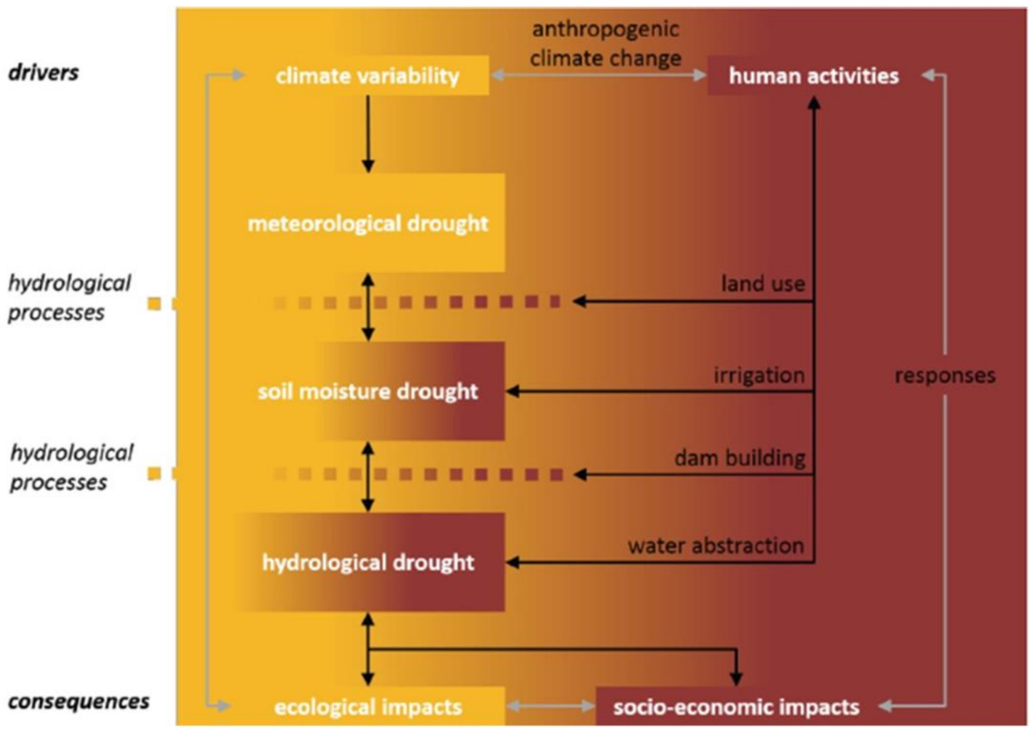


Figure 4: Different society-nature interaction along different types of droughts; (Hund S.V., Allen D.M.)

An additional concern when a drought hits is the increased potential for forest fires. As the lands become drier and plants are dying, the temperatures rise. This becomes a huge risk if a fire started, and would allow it to spread very quickly. Although, large land fires are generally not a normal part of life in Costa Rica, it is still a concern.

In addition to this threat, the wet season contrarily can cause extreme periods of rain resulting in harmful flooding engulfing a region. In the past, heavy rain has lasted up to two weeks straight followed by severe flooding and landslides that can affect an estimated 50,000 to 65,000 people in Costa Rica as well as destroy its communities. Contaminated floodwater has the potential to affect ground wells, which greatly affects the distribution of drinking water as a whole ("Caribbean Hurricane Season Ends," 2002). For these reasons, it is important to be aware of these possible weather patterns and the effects they have on communities when going about our project.

2.3.2 The Microclimates of Costa Rica

Along with vast biodiversity, Costa Rica offers 12 distinct climate zones. Influence from both the Pacific and Atlantic Ocean play a major role in the varying weather patterns. Factors that can dictate the climate are varied terrains, elevation with substantial gains and losses, volcanoes, and rain. On the Pacific Coast, it stays hot even in the rainy season. The extremely dry climate causes rainstorms to be extremely heavy when they do occur, which is very rare. On the coast, rain usually occurs in the afternoon and at night. Depending on the location of the camp, it is strategic to set up at a time when heavy rain is not occurring so that when it does rain, the tents can be installed and prepared to collect water.

Depending on the topography and elevation, mountains could potentially have a few flakes of snow. The higher the elevation, the cooler it gets. Most settlements in Costa Rica will be found in the mid-mountain range. The weather in this range is often between 70 and 85 degrees year round. However, at sea level temperatures average in the 90s during the day and drop to a comfortable upper 70s at night. Guanacaste's temperatures are always hot and dry. In locations of high elevation such as the Monteverde Cloud Forest, you can expect cooler temperatures due to the rainy conditions (Weather and Geography). When depicting the best treatment based on location, it is important to account for the climate and potential contaminants. This makes it possible to control the necessary health standards to help protect the people and environment that the camp is composed of.

2.4 Health standards

Access to clean water is essential for all life, it is necessary for everything from drinking to agriculture to power generation. Depending on water's role in a particular task, it has to adhere to standards that make it safe for human consumption and usage. Water contains polar molecules that make it soluble, and therefore it has the ability to dissolve substances and can contain suspended solid matter and living organisms. All of which are essential qualities for good water. What determines the quality of water is very much dependent on the intended usage. Different limits are set dependent on the characteristic of the water. Constraints typically measured include: pH, total dissolved solids, conductivity, suspended sediment and microorganism levels (United Nations, 2011). Knowing these limits are essential for developing wastewater recycling systems, to ensure that the newly redistributed water is sanitary and safe.

In these emergency camp settings, it is even more vital to provide a sanitary source of water. Illness and disease is quite prevalent in areas following a natural disaster, primarily due to contaminated water sources. Contaminated water can cause many types of diarrheal diseases, including Cholera, and other serious illnesses such as Guinea worm disease, Typhoid, and Dysentery. Contaminated water related diseases cause 3.4 million deaths each year (Segura-Bonilla 2002). The role of clean water will be to prevent the spread of disease and ensure rescuers are healthy enough to perform their task; additionally a healthy population would not place an added strain on the medical support staff. The water needs to be treated properly based on the contaminants inside.

2.5 Grey Water & Black Water

There are different categories of wastewater. Water from sources like sinks, dishwashers, and laundry machines are called grey water. Toilet water is called black water, and must be treated separately from greywater. Harvesting greywater for recycling allows homeowners and business owners a chance to convert waste into a valuable resource. High-toxicity black water has more solid waste and is harder to treat. Most wastewater treatment plans try to mimic the process that normally occurs in nature on an accelerated rate. A common practice is to separate the greywater and blackwater with selective treatment dependent on the water contents.

The greywater utilizes a series of natural settling and filtration systems that reduce scum and solids. Greywater carries soap scum, and if it is retained for too long it will begin to putrefy. The sooner the water is released into the environment, the less amount of time anaerobic bacteria have to grow. In the emergency camps, black water is treated with a latrine trench method, or with portable bathrooms that do not require piping. The treatment is with chemicals and infiltration rates, which can be found in the analysis section of this paper. For the greywater solution, we recommended a multitude of options for the Bomberos to consider. Our solutions are based on the demand, quickness, and effectiveness needed for the specific emergency at hand.

2.6 International Law

When international aid is required by neighboring countries in Central America, the Bomberos could potentially go to the country in emergency crisis and provide help to the ones in need. It is crucial for the Bomberos to understand the applicable laws outside of Costa Rica in order to provide the best help while complying with the local laws of the country in need.

2.6.1 Nicaraguan Law

Nicaragua has created laws governing every aspect of their water supply and distribution systems ranging from groundwater to antidegradation policy. Their laws are broken down into three primary objectives. Firstly, maintain an integrated management system throughout the entire country. Secondly, establish all facilities rights to the usage of water and additional individual's rights to water and their role in maintaining its quality. Lastly, grant all rights to use and exploit water resources. Aside from their three primary objectives, another focus under Nicaraguan law is promoting the philosophy of water being a resource equally shared by every citizen.

Under the National Water Law, the National Water Authority (ANA) was created as autonomous decentralized agency to ensure all water standards and laws are adhered to. They carry out technical testing, routine water quality monitoring and review water management practices throughout the country. In addition to this, they are also responsible for overseeing new water source operations, for example, they would classify a body of water based on its intended use and propose management regulations for the project. They additionally propose guidelines regarding the waters quality.

According to title seven of the Nicaraguan Water Laws, every individual is responsible for the conservation of all water sources. Part of this includes conducting a hydrogeological studies of the environment, as well as full physical, chemical and biological analyses of heavy metals, pesticides and other potential contaminants for every well or river proposed as a source of drinking water. These factors will be used to determine if the source is safe, and then decide the level of waste and toxic substances the source can be subject to, while maintaining safe and sanitary levels.

To ensure the upkeep of the ANA, Nicaragua has established The National Water Resources Council (CNRH), comprised of representatives from twelve different organizations, some of which include, the Ministry of Environment and Natural Resources (MARENA), which presides over the Council, the Ministry of Agriculture and Forestry (MAGFOR), the Ministry of Health (MINSA) and the Ministry of Development, Industry and Trade (MIFIC). The council primarily focuses on National Policy, opposed to the more case-by-case approach done by the ANA. Additionally, they oversee large-scale projects dealing with multiple sectors of government or situations where substantial or multiple water basins are involved (National Water Law, 2010).

2.6.2 United States Law

In the United States, the Environmental Protection Agency (EPA) set water quality standards based on a three-component system, designated use, criteria, and antidegradation requirements. The designated usage component is the classification of a source of water based upon intended end usage. Common designated use classifications include public water supplies, industrial, agricultural supply, recreation and preservation. For the project, the source of recycled water is obtained through recapturing systems at the camp, with the intended usage being to redistribute the water back to the general population. Based upon this, the designation would fit that of a public water supply. In the US, the EPA has states establish numerical criteria once a designation is set, to do this, states have the option to either use EPA recommended guidelines, apply site specific criteria modifications to reflect concerns and usages, or use other scientifically backed criteria that is accepted by the EPA.

Criteria established for a Native American reservation site for water distribution in 2016, based on EPA guidelines, included: being free of settling to form objectionable deposits, free of debris, scum, oil, or other matter forming nuisances, cannot produce objectionable color, odor, taste, or turbidity, or cause injury to, are toxic to, or produce adverse physiological responses in humans, animals, or plants (Segura-Bonilla 2002). Criteria such as these will likely resemble that of the Costa Rican emergency encampments, due to its broad and basic characteristics for safe water.

The antidegradation policy should not apply to the project work, because the recycling system we are developing is a temporary water source that will be monitored and tested based on the site-specific guidelines. As they are temporary and only in use when disaster occurs, there should not be sufficient time for degradation to occur, unless camps have a prolonged operation time.

2.6.3 Local Laws

Recently, water laws in Costa Rica have been a highly turbulent topic, with groups working to repeal and replace outdated laws from 1942 governing the usage of water. Old water laws focused strictly on surface sources of water, despite the fact that nearly 70 percent of Costa Rican water comes from groundwater sources. In addition to having incomplete water laws, they are also fragmented, creating confusion over agency responsibilities and ill-defined governing roles. New laws look to create a more unified system by incorporating metering equipment to record usage and waste and then calculate needs and purposes for future water usage.

Additionally, it is known that water quality differs depending on the location throughout the country of Costa Rica. Heavy rain and the lack of infrastructure often results in potable water issues arising due to the damages aqueducts take. This is often the case on the Caribbean side of the country in cities like Limón, Talamanca, and Sarapiquí (Chacón, K. 2017). The Bomberos always treat water they gather from fire hydrants in order to ensure these waters are proper for the intended usage. They cannot risk having rescuers get sick during a time of emergency.

The President of Costa Rica, The Health Minister (MINSALUD), and the Environment and Energy Minister (MINAE) have worked together to write laws regarding quality and parameters of local water on every aspect of its use. The Bomberos wish to gain knowledge and understand these laws in order to ensure that the USCO and the institution has the appropriate equipment and system that will allow the emergency camps to comply with the regulations necessary and avoid any issues that might emerge if these laws are not followed.

2.7 Water Contamination

After a disaster, it is very easy for water to be contaminated by outside sources including physical, chemical, and biological pollutants. Sources consist of dirt, organic matter, and gasoline. Depending on the location, or the season of the storm, there are a number of variables that are able to contaminate the water supply. These contaminants enter water sources by the means of runoff and leaching through soil into surface level and groundwater sources. For the USCO camps, contamination is likely to occur if cleaning products or human excrete are disposed of without proper treatment or positioning. To ensure a cleaner water supply, it is crucial to have an understanding of what is contaminating the water and the best way to prevent it.

2.8 Groundwater Contamination

In the specific case of USCO relief camps, it is common practice to dig trench latrines for defecation purposes. If constructed improperly, this can lead to the contamination of groundwater surrounding the latrine and if the location is not chosen correctly, surface source can be degraded. The main cause of contamination comes from human feces, which harbors a large number of microbes, including bacteria, archaea, microbial eukarya, viruses, and potentially protozoa and helminths. Above all, the largest concern caused by feces is Nitrate. (Graham, 2013). Typical nitrate levels for groundwater do not exceed 10 mg/l, but with the presence of feces can rise to dangerous levels, with the capability of preventing red blood cells from transporting oxygen. This is why the positioning of trench latrines is vital to a healthy camp.

At the very least, defecation should not be allowed where it can contaminate a water supply or food chain. Defecation should not be along riverbanks, within 30 meters of wells or boreholes within 10 meters of taps; on or above the surfaces prepared for rainwater catchment; within 30 meters uphill of a spring or 10 meters downhill; or within 10 meters of any water-storage tank or treatment plant. Maintaining the cleanliness of the camp's water is crucial for the health and state of mind of the rescuers. In order for this contaminated water to be potable for public access, it must be assorted to the appropriate treatment, and be tested before use.

2.9 Costa Rican Water Access

With a growing population of over 4.3 million people and nearly 60% living in urban areas, Costa Rica possesses a water infrastructure system with a high percentage of accessibility. Approximately 99% of the urban population and 92% of the rural community are connected to a water supply system (Black, 2012). The outstanding efforts made to provide water access to Costa Ricans have been effective. Today, the water production is almost equal to current demand. There are nearly 2300 water supply operators in Costa Rica, these results in a high percentage of access to potable water for 91.2% of the population (PEN, 2016). The risk of water deficiency is not a considerable issue for the future of Costa Rica.

Despite the excellent water access, Costa Rica faces infrastructure problems that are threatening the quality of water. Currently, more than 20 government agencies are in charge of water management. These institutions also look at the regulation of the framework that is in control of water conservation and management in the country. This framework was possible through the General Water Law, No. 276, which was approved in 1942 (Esquivel-Hernández, 2017). Since its approval until 2015, 275 additional water regulations have been ratified with the mission to target the public use of water resources. These mainly concerned the control of public services (65%), energy generation (17%), and agricultural activities (5%)(Esquivel-Hernández, 2017). The Ministry of Health (MINSALUD) is the lead agency responsible for the water sector, other ministries like the Regulatory Authority for Public Services (ARESEP) and The Ministry of Environment, Energy and Telecommunications (MINAE) also play a role in water management (Black 2012). However, these responsibilities cannot be performed adequately under government agencies due to the lack of human and financial resources (USEPA, n.d). Another main reason for this is the small amount of funding that goes to the maintenance and improvement of water service infrastructures. This has led to a decrease in the quality of the water in Costa Rica (Blomquist 2007).

In Costa Rica, responsibilities of water used for human consumption fall mostly under the Costa Rican Institute of Aqueducts and Sewers (AyA). They are the principal drinking water and wastewater systems operator in the nation. At a local level, there are small administrative operators throughout the country; these are called Administrative Associations of the Aqueducts and Community Sewerage Systems (ASADAS) (Guzman-Aries, 2013). Before operating, ASADAS must receive an approval from AyA to make sure they comply with their guidelines and the Law of Associations (Esquivel-Hernández, 2017). This often results in a slower process for rural communities and can present a real issue. The AyA takes on a huge financial burden when working in rural areas. The cost of constructing systems that provide access to water are of much higher cost than in urban sites. No form of compensation have been given to the AyA from the Costa Rican government for playing an important role as the leading provider of subsidies in rural sectors (Black, 2012). Wastewater sanitation is another major issue with the water system in Costa Rica. Only 25% of the population is connected to a sewage system and only 4% has the appropriate treatment. Infrastructure problems post a constant thread to the quality of the water. For example, the AyA only has occasional water quality monitoring in 21% of the pipelines supply 73% of the population's water (Esquivel-Hernández, 2017). Costa Rica is a country blessed with water abundance; the need lies on having a proper managing system, distribution, and conservation for more efficient and quality water system.

2.10 Disaster Relief Organizations

2.10.1 International Disaster Relief Assistance

In past disaster scenarios, both national and international organizations have worked in providing assistance for relief efforts from natural disasters. One organization, La Comisión Nacional de Prevención de Riesgos y Atención de Emergencias (CNE), or The National Commission for the Prevention of Risks and Emergency Care, is the leading public institution with regard to coordination of work related to emergency response situations. During disasters such as volcanic eruptions, earthquakes, and tropical waves such as Hurricane Otto, the CNE is able to provide alerts as well as temporary hostels for victims whose homes were destroyed. Furthermore, the CNE maintains constant communication with technical institutions such as the

National Meteorological Institute, the universities and Technical Advisory Committees to reduce the impact a disaster has on a community.

The CNE is able to fulfill its functions at three levels: Regional, Municipal and Communal. The Regional Emergency Committees (CRE) are integrated by the directors of the first response state institutions that have already established their regional dependency in the area, along with representatives of the non-governmental organizations such as the Red Cross. Regional coordinating committees were formed in a number of Central American sectors including San Jose. The Municipal Emergency Committees (CME) corresponds to the territorial division of the country but is not limited to it since the type of threat determines the geographical coverage of said committee. The coordination of the CME is carried out by the mayors or their representatives. Lastly, Community Emergency Committees (CCE) support the formation of relief organizations at a communal level, specifically in places where threats are expected and require a sufficient response from the population. When disaster strikes, the committees that are affected the most keep their coordination centers in operation in which the different operations (evacuation, rescue, shelter habilitation, damage assessment, needs analysis, distribution of humanitarian assistance) are organized. At the national level, the Emergency Operations Center (COE) coordinates with the regional level for logistical and operational support when managing a disaster. Along with this, the CNE provides provisions such as food and bottled water.

Depending on the severity of the emergency, the CNE may activate the Emergency Fund to support other institutions involved in the relief effort. Once the emergency is over, the CNE is responsible for partaking in the actions to recover the affected areas throughout the national territory. This stage of rehabilitation involves reconstruction of crucial structures such as bridges and roads. Through the assistance of a network of relief delegations, first response tasks were able to be carried out in an orderly fashion in emergency situations (Comisión Nacional de Emergencias. (n.d.)).

2.10.2 U.S. Foreign Disaster Assistance

On October 10, 2017, just a few days after Tropical Storm Nate hit Costa Rica; U.S. Ambassador Sharon Day declared a disaster on the region. The U.S. Foreign Disaster Assistance (USAID/OFDA) responded with $150,000 towards supporting immediate humanitarian efforts. In addition, the disaster organization sent out a disaster assessment and response team in Costa

Rica to coordinate with the local government officials on potential response actions (Costa Rica | Disaster Assistance, n.d.).

Costa Rica is a hotspot for natural disaster, so it is beneficial that the Latin American and Caribbean regional office of the USAID/OFDA is located in San Jose. Through the USAID/OFDA Training and Technical Assistance Program, the U.S. Government has been able to train thousands of firefighters and first responders, expand the course offerings related to risk management at universities, and take action to further prepare government authorities and non-profit organizations to better respond to natural disasters. USAID/OFDA also provides assistance for people affected by man-made disasters such as civil conflicts and terrorism. It provides funds for activities to reduce impact of periodic natural disasters as a whole. As shown, action has been taken in the past towards disaster relief, so our project will have a focus on building off the operations implemented by organizations such as the USAID/OFDA (Office Of U.S. Foreign Disaster Assistance, n.d.).

A major organization that helps with Natural Disasters is the Red Cross. There are many branches in the world that help different areas. The American Red Cross can be sent anywhere in the world for major natural disasters, and are known globally for their assistance in the Haiti Earthquake(2010), Japan Earthquake(2011), Typhoon Haiyan(2013), Hurricane Maria(2017), and Hurricane Matthew in Haiti(2012). The main goal of the American Red Cross is to meet the immediate disaster-caused needs of individuals, families, and communities by providing clean water, safe shelter, and hot meals (Disaster Relief).

The International Federation of Red Cross and Red Crescent Societies (IRFC) covers 190 countries, with Costa Rica having its own branch. The volunteers from this organization live in the communities they serve. Volunteers are present before, during and after a crisis, and know how to best comfort and support the affected people, because they are the affected people. By having the volunteers living in the community, they have the greatest motivation in helping the community recover. It is essential to the IRFC that disaster response activities do not foster dependency or destroy the existing community-support mechanisms. If the community becomes too dependent on aid then they will struggle to fully function on their own. They should instead lay the foundations for recovery with the already established community infrastructures. Without rapid assistance, a disaster could destroy health infrastructure, self-help networks, and even markets. (Responding to Disasters)

3.0 Methodology

Our project aimed to collaborate with the Bomberos to design and develop an economically feasible water treatment system for varying landscapes/environments that builds on the existing infrastructure for approximately 150 rescuers per camp. Additionally, the team must study the average amount of wastewater produced and the applicable laws for the disposal of wastewater. It was essential to our project to understand how an adaptable water treatment system potentially impacted these camps, and in order to accomplish our goal, we set out several objectives:

1. Determine the areas in need of improvement within the Bomberos emergency relief camps, so that the appropriate actions may be taken to upgrade the current situation, by conducting interviews with reliable sources.
2. Analyze the existing infrastructure and gauge water demands for the population by looking at the current treatment systems being implemented, along with other emergency organizations that are taking action toward treating wastewater.
3. Produce portable methods to treat and test water at campsites that comply with Costa Rican and Central American laws.
4. Develop methods for the disposal of effluent wastewater produced by the camp, which are not harmful to the environment, adding minimal strain on the USCO members erecting the camps.
5. Determine the cost for the material to be used when developing our system.

Plans were constructed for the completion of our project based on the information gained from interviews and research, past organizations/infrastructures and total material cost. We planned to present to Norman Chang Díaz, Mariam Monge Mora, and Rubén Sáenz Vargas, as well as our advisers Alex Sphar and James Chiarelli, once a week to adjust our design according to their comments. Our goal was to access the filtered water demands per rescuer in an emergency leading to a decrease in health risks normally caused by dirty water, and improve overall living standards at encampments if implemented. By interviewing people who have a deeper understanding of the challenges at hand, we had the opportunity to implement the ideas of many into this paper. Our interviewing process and selection of interviewees was based off of the missing information that we struggled to gather through online research. Being an emergency situation in Costa Rica, the best sources we could find are people who have had to endure these camps, professors who have done similar projects in Costa Rica, as well as the organizations that are responsible to treating the water.

3.1 Interviews

The team interviewed the AyA Director of Water Harvesting & Treatment, Eng. Álvaro Araya García; and Professor Clemens Ruepert, the Laboratory Coordinator for the Analysis of Pesticide Residues and Regional Institute Sub-director for Studies on Toxic Substances of the Universidad Nacional Costa Rica (UNA). These interviews helped to gather knowledge on water handling, hygiene methods and product recommendation to implement in emergency scenarios.

In order to target the right amount of water demands, learn more about typical practices and norms at the rescuer camps, and get additional recommendations on how to improve living conditions, an interview with the USCO was scheduled. We divided the interview questions to target two different groups: the cooks and the general population. This allowed us to compare results between the two groups and understand the importance of the kitchen. Afterwards, we gathered additional information on particular products and materials to improve the overall quality of the rescuer camps through an interview with the Director of the National Water Laboratory of the AyA, Dr. Darner Mora Alvarado.

The information we gathered from these interviews allowed us to provide multiple options in our final proposal that will allow the Bomberos to adapt to the emergency at hand, and stay within their budget. It is a known fact that there is not a single solution to this project. The proposal for a system to treat wastewater at these camps will vary depending on the environment, duration of stay, and emergency. The team believes that by providing a variety of solutions, the Bomberos will be able to decide on the best option to fit the appropriate scenario at hand. After finishing our interviews and gathering research, our first target was to figure out the water demands of an emergency camp for 150 rescuers. This is vital information for the selection of the correct treatment practices for both recycling and disposal of the wastewater. The camp needs a specified amount of potable water every day, in the next section is the research we did to conclude that amount.

3.2 Gauge Water Demands

The World Health Organization, the coordinating authority for international health within the United Nations system, released a study in 2013 on water demand in emergency situations (WHO). Costa Rica has been a member of the United Nations since 1945 (UN); therefore, the water demands necessary for the encampment comply with the World Health Organizations standards. In an emergency case scenario, including those due to natural disasters, safe water access is crucial in order to maintain stability to the camp population.

The United Nations recognized individual rights to water access and sanitation in 2010. This right to water access is based upon five key factors; these include having sufficient supply, safe quality, acceptable presentation, an accessible location within 1000 meters of distance, and affordability (WHO). On average, a person consumes between 50 to 100 liters of water per day for basic needs and health (WHO). When the appropriate water access is provided, the community will use it on a variety of daily activities ranging from crucial water services like cooking to secondary uses like gardening. In an emergency scenario, this quantity of water consumption can be altered depending on the circumstances and term of survival of an individual. In the case study, the WHO provided a hierarchy pyramid of water demands ranked on the priority of each activity (Figure 1).

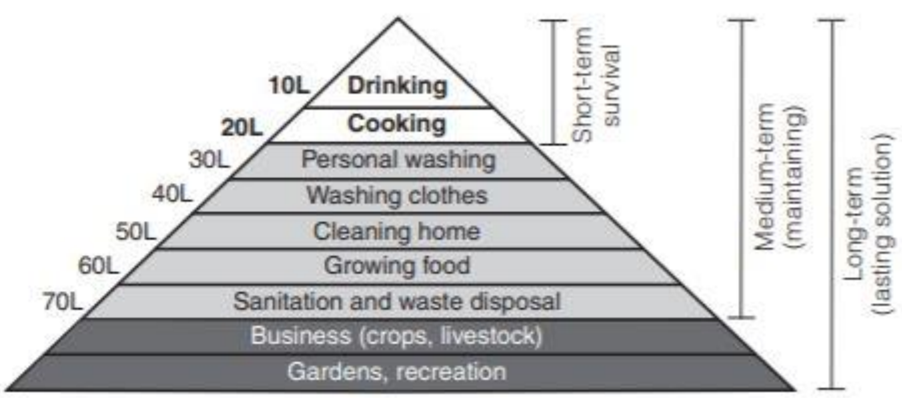


Figure 9.1. Hierarchy of water requirements (after Maslow's hierarchy of needs)

Figure 5: WHO's hierarchy of water usage (Reed, B. (2011))

As seen in the figure above, water consumption is divided into a variety of activities based on the time of survival. These divided sections include actions accounting for survival of a short, medium, and long-term period. Research done by the WHO points at an average water usage of 20 liters per capita per day in order to reach the essential levels of health and hygiene. Of the 20 liters, the minimum amount of drinking water per person per day is 2 liters. The medium term survival sections add an additional 50 liters, resulting in around 70 liters. This is the ideal and most common ground for an individual's water consumption (Reed, 2011).

At the relief camps in Costa Rica, the typical duration of residency ranges from one to 4 weeks. Our project provides a wastewater treatment plan in relief camps with a population of 150 individuals. This would result in a daily water usage of around 3000 liters for a range of short term to medium term survival period. Activities like showering and cooking require a system able to properly treat greywater while activities for waste disposal require a blackwater treatment system. When taking into consideration the wastewater treatment systems being placed in relief camps in Costa Rica, the team has to take into account that the water sources, water quality and amount differ depending on the location, water usage, and term period (UN, n.d.). Certain areas of the country may not have consistent access to water, which can affect the amount of water consumption. Different locations also provide environments where other types of water needs exist. For example, a relief camp in a tropical area of the country that is prone to more diseases requires extra water usage for medical services. It is crucial to understand these terms in order to address wastewater systems at the relief camps in a satisfactory manner that accounts for the population's needs. Understanding the correct amount of water required was the first step of our selection of a water treatment system. Now that we knew the water demands, it was time to develop the legal baseline sanitary levels. Eighty percent of the water that goes through the camp needs to be treated properly; the next section highlights the main components of our hygiene composition.

3.3 Determine Baseline Sanitary Levels

In Order to establish an effective wastewater recycling design, it is imperative to first establish baseline sanitary levels. Our system required high standards because we could not risk the possibility of the entire camp of rescuers becoming ill. In emergency camps, without the proper sanitation and hygiene levels, sickness and dehydration could run rampant through the camp. All drinking and cooking water will be held to the highest standards, and receive multiple levels of filtration. Because the entire emergency camp will be reliant on this water, maintaining a healthy water source is crucial in improving physical health, morale and can save money to use on other emergency qualities.

Standards are quantified based on multiple qualities. The amount of drinking water per person per day is the first and most important water quality. The minimum amount for an average person to drink in one day is two liters. The average person consuming the water is 70 kilograms or 154 pounds. Most limits are measured in mg/L or mg/kg with contaminants limit being set based on their ability to cause health concerns over the course of a lifetime of a consumer. However, in an emergency situation with the rescuers doing physical work every day, it is critical that there is a surplus of water to rehydrate the workers. By doubling the minimum requirement for the average person, that is requiring four liters of drinking water per person per day, results in a need for at least 600 liters of potable drinking water per day.

The United States Environmental Protection Agency (EPA) has created tables that set limits for every contaminant and microorganism possible in drinking water. When ensuring that the water is treated properly, it is vital to know what contaminants need to be treated, as well as how well they need to be treated. By using these data, the group established goals for our wastewater recycling system. The EPA has set a secondary standard that affect taste and color (USEPA, 2018). Taste and color are not essential to health standards, but it improves camp morale to incorporate these secondary standards into the final design. (FIGURE below)

In order to determine what treatment to use, a sample of the water that will be treated needs to be tested. Depending on the environment, contaminants, climate, and organic material, we would be able to determine the correct system. Based upon these standards we will recommend multiple systems to choose from, depending on the content. This will allow the Bomberos to have multiple options from which to choose the best fit based on every potential contaminant in the water. In an emergency, it is necessary to have the right equipment ready to implement in a short amount of time. A quick, efficient, sanitary process is needed for a range of potential situations.

The supply of water should be tested multiple times to ensure that the water has not been contaminated while in storage. Often times, the filter can infect the water supply if not treated carefully. For example, chlorine is an effective tool to sterilize water, but too much chlorine is a problem in potable drinking water. It is often followed by a carbon filter that eliminates the chlorine content, which then leaves the water vulnerable to bacteria and other harmful organic contents. The best way to prevent this from happening is making sure to change the filter cartridge as recommended, and apply the test every two weeks. In order to uphold these standards, the tests mentioned above must be easily done. The Bomberos asked us to research potential test kits that can account for most of the tests necessary to ensure clean water use. The kits need to be simple and quick enough for any rescuer to be able to understand with only minimum training.

Secondary Drinking Water Regulations

Chemicals	CAS Number	Status	SDWR
Aluminum	7429-90-5	F	0.05 to 0.2 mg/L
Chloride	7647-14-5	F	250 mg/L
Color	NA	F	15 color units
Copper	7440-50-8	F	1.0 mg/L
Corrosivity	NA	F	non-corrosive
Fluoride	7681-49-4	F	2.0 mg/L
Foaming agents	NA	F	0.5 mg/L
Iron	7439-89-6	F	0.3 mg/L
Manganese	7439-96-5	F	0.05 mg/L
Odor	NA	F	3 threshold odor numbers
pH	NA	F	6.5 – 8.5
Silver	7440-22-4	F	0.1 mg/L
Sulfate	7757-82-6	F	250 mg/L
Total dissolved solids (TDS)	NA	F	500 mg/L
Zinc	7440-66-6	F	5 mg/L

Figure 6: Secondary drinking water regulations (Summary of the Clean Water Act, 2018)

3.4 Quality Control Kits

Testing the water in an emergency situation needs to be a quick and efficient process. Ensuring water is sanitary is one of the largest concerns for any sized community. Often times, to do so requires substantial testing to ensure that water sources are free from microbiological organisms, along with harmful chemicals. Most of these tests are costly, time consuming and need laboratory standards to ensure that results accurately reflect the samples. They also need to confirm that no outside contamination has occurred. With the majority of these emergency camps being operational for roughly a 30-day period or less, the benefits of testing water through typical methods are vastly outweighed by the drawbacks. Alternative methods are available that are less accurate, though they can be effective when applied properly.

To determine the most effective means of testing water, interviews with the AyA and Professor Clemons, along with research of local laws and practices, were conducted to determine a range of contaminants to be identified. This provided valuable information on key parameters that the proposed kits must be able to detect. In addition to highlighting parameters for testing, it was crucial to determine feasibility factors. This was primarily focused around interviewing members of the Bomberos who had extensive knowledge of how the camp operated, combined with our requirements that the testing kits had to be easy to operate, portable and have the ability to deliver results quickly. With all factors determined, it was now possible to propose kits that were potentially capable of fitting the needs of the Bomberos and USCO. The next section includes practices that will aid in maintaining the necessary standards for water quality.

3.5 Hygiene Practices

Affected people of all ages, sexes, or ethnicity must be aware of key public health risks. Measures to prevent the deterioration of hygienic conditions and maintain the facilities must be taken by all. Important measures include washing of hands after defecation, before eating, and while preparing food. A major concern is ensuring every camp has the appropriate disposal methods for feces, food, and wastewater which are crucial to maintaining health standards.

3.5.1 Excreta Disposal

Since feces disposal is such a key factor in maintaining a sanitary emergency camp, the group investigated current practices to determine how they could be improved. This began by discussing the current system with members of the Bomberos who have been a part of the rescue camps. From here, it was possible to look into means of improvement. First, local and international laws were studied to establish standards that could be applied to latrine style feces disposal. The excreta disposal practices for the Bomberos should be acceptable and compliant throughout the entire region of Central America.

With the baselines on latrine layouts established, it was now possible to research how specific terrains and natural disasters could influence the effectiveness of the proposed latrine systems. For example, different soil compositions will affect how excreta flows and a disaster such as a flood could render trench style latrines useless. To account for this, research on soil composition was conducted so that safety factors could be applied to the dimensions of latrines ensuring poor soil quality would not degrade the effectiveness of the latrines. In the case of varying natural disasters, the most common disasters were investigated, such as forest fires, flooding and hurricanes. Then the proposed latrine system was analyzed for each type of disaster to determine if it was still feasible and effective. In the case of a disaster rendering the latrine ineffective, alternative methods were investigated.

3.5.2 Organics Disposal

As these camps should be highly self-sustaining, it was important to investigate proper practices for disposing of organic matter, primarily in the form of food waste. Similar to the disposal of feces, knowledge of current practices was obtained through interviews with members of the Bomberos. Next, through interviews with the AyA and Professor Rueperts, proper techniques for the on-site disposal of organic matter was obtained. This was then verified through researching local laws.

3.5.3 Cleaning Products

As the prevention of disease is crucial in emergency scenarios, research on sanitation products and practices was conducted. This included how much washing was needed for each activity that took place in the camp, and determining what products would work most efficiently. By using the minimal amount of water required to match the needs of the situation, as well as choosing the most environmentally friendly sanitation products, we can minimize the environmental impact when the water runoff is discharged. The process of selecting sanitary products was roughly the same for every type of product: soaps, detergents, shampoos and other hygiene products. Information regarding ideal products was gathered using laboratory recommendations from the AyA.

In addition to determining ideal products and frequency of use, we looked into alternative methods of cleaning. For example, in desert climates it is common practice to scrub dishes with dry sand until clean and then wipe them with a disinfectant. Methods such as this were investigated to potentially save water and lessen pollutants entering soils. All alternative methods were also investigated for potential drawbacks when compared to more traditional methods, to further determine feasibility. Subsequent to finding the water demands, local pollutants, Costa Rican laws, and hygiene practices, we were ready to start analyzing different water treatment systems. In this methodology section, we provided basic information regarding wastewater treatment to aid the reader in the understanding of our selection process.

3.6 Wastewater Treatment Plan

3.6.1 Wastewater Basics

Water that is considered raw can come from sources such as an underground aquifer or a surface water source. Surface water sources include lakes, rivers, or any freshwater resource. There are three stages of water treatment: primary, secondary, and tertiary treatment. Primary treatment is the stage where heavy solids and oils are separated from the water. The oil, grease, and lighter solids float to the top, while the heavier solids are separated to the bottom. The next form is the secondary treatment. Water-borne microorganisms in a managed habitat target dissolved and suspended biological matter. Finally, the water is put through tertiary treatment. Any further treatment that is required beyond the secondary stage is termed tertiary treatment. In order to release the treated water into highly sensitive or fragile ecosystems, the water is subject to an extra chemical or physical disinfectant, depending on the water supply.

Water usage is typically comprised of drinking/cooking water, bathroom/toilet water, cleaning water, medical water, and waste disposal. In the United States, the average household pays $1.50 per 1,000 gallons, or $0.0015 per gallon. The reason wastewater needs to be treated cautiously is because of the potential health consequences of mistreated water. The CDC has warned against the top disease outbreaks related to drinking water being: Giardia intestinalis, hepatitis A, norovirus, diarrhea, and Shigella. This is only a small portion of potential diseases caused by drinking poorly treated water. Organic and inorganic matter, bacteria, and viruses, along with other pollutants can cause massive problems in the sanitation of water.

3.6.2 Primary Treatment through Use of Physical and Mechanical Principles

When it comes to recycling water, the treatment process can vary in effectiveness. When designing a water collection and treatment system, the Bomberos concerns were stressed that the system needed a method of filtering out large sediments early on in the process. Through simple mechanical and physical processes known as primary treatment, nearly half of the contaminants can be removed from wastewater. This process begins with simple bar screens that intercept large solids such as sticks, rags and any plastic material from the incoming stream of wastewater. The concept is a horizontal rake that is driven by a toothed gear which rakes up the solid material and deposits it onto a conveyor that is transferred to a dumpster for removal to the landfill (San Antonio Water System, n.d.). From here, the wastewater can then flow into aerated grit chambers, which are long narrow tanks that are designed to slow down the flow so finer solids such as sand, or coffee grounds can settle out of the water. This removal is paramount for busy cities like San Jose due to the considerable amount of sand, dirt and gravel that wash off the streets after rainfall (Nathanson, J. A., & Ambulkar, A., 2018). Once these solids have been suspended by grit chambers, they move on to primary clarifiers. These tanks depend on gravity to settle the solids to the bottom of the tank. This "primary sludge" is then scraped along the bottom of the tank by mechanical means and deposited in hoppers to be pumped out. This process is relatively inexpensive and simple to implement. In addition, it is all physical and requires no use of chemical products that could potentially do harm to the water. Bio solids removed from the wastewater can be used for composting and treating soil as well. (San Antonio Water System, n.d.).

3.6.3 Water Harvesting

Water harvesting is the process of capturing rain where it falls and taking necessary measures to prevent pollutants and other harmful toxins from contaminating the water. It is an effective method of utilizing Costa Rica's wet season for collecting enough water to sustain an emergency camp. For roughly 150 people, it is crucial to provide a substantial amount of water, especially since we are dealing with rescuers who engaged in physically draining work. Effective water harvesting can be done through a number of techniques such as capturing runoff rainwater from rooftops or harvesting from local catchments where water will collect after rainfall. The Bomberos strategically set up camp in locations where they can gather water themselves. However, this can take a substantial amount of time. During seasonal rains, it is feasible to collect flood waters from local streams or at the camps themselves by using the rainwater runoff from the tent's roofs. Methods were developed later on in the reading that would be used to collect rainwater.

The wet season brings large quantities of rain, which can increase the *water harvesting potential*. The *water harvesting potential* is the amount of water that can be effectively harvested considering the amount of rainfall that is received over an area, otherwise known as *rainwater endowment* of an area. This can be expressed in the form:

Water Harvesting Potential (WHP) = Amount of Rainfall (in mm) * *Collection Efficiency* where *Collection Efficiency* is a measure of how effectively water is harvested while taking into account potential factors such as evaporation and spillage (Chawla, n.d). Keeping this in mind aided in our development of an effective water collection system that would take advantage of the wet season.

Without rainwater capture systems, water would go directly to storm sewers as runoff. With an average of 3000mm of annual precipitation (1901-2015), collecting rainwater for treatment is highly practical (Kuzda, 2013).

For these camps to be mobile, developing a harvesting/treatment system that is fairly portable, and can be easily set up and taken down, was an aim for our final design. Camps can hold up to 3000L of water daily which must be replenished everyday. The Bomberos currently have no system in place for harvesting water, so a functional design that allows water to be collected at the camp itself can save the crew time and effort needed to gather water from another location.

3.6.4 Implementation of Sediment Traps

Sediment traps provide a perfect opportunity to take advantage of the wet season in Costa Rica; they are devices used to prevent debris and dirt from entering rainwater storage. A typical design for residential rainwater sediment trap involves streaming rainwater down the side of a building from a roof into PVC piping and into a holding tank (onlinetips, 2017). These tanks can be made of plastic or cement; no matter which one is used, the holding tank should be filled halfway with gravel or sand for drainage. The top of the holding tanks can also be opened if they are covered with mesh wire to ensure falling debris or insects are kept out. Once water enters the holding tanks, it is then redirected to another PVC pipe to a sediment trap tank and a storage tank (onlinetips, 2017). The water collected in this system is suitable for showering, and laundry usage; further treatment is necessary for potable water systems. In the case of drinkable water, sterilization and extra filtering units are added. Our final step in this process is to offer a cost analysis that compares products for similar situations. The final cost analysis section can be located in our findings section of the paper.

3.7 Cost Analysis

In order for our wastewater recycling design to be considered successful, it must be economically feasible for the Costa Rican Bomberos to implement. As the recycling of this wastewater is done under emergency circumstances, it was imperative that the final design remained relatively inexpensive, so that resources are not taken away from other areas of the encampments. To ensure this, we provided pricing breakdowns for particular aspects of our design. These included material takeoffs, with estimated quotes on pricing along with potential suppliers, and included cost of labor and maintenance overtime. To further support our minimal economic impact, we produced a 20-year cost analysis of the system.

The 20-year cost analysis compared the system we developed to what is in place now. This included estimated opportunity lost cost for running camps without our system, which was compared to the installation plus maintenance cost over the 20-year time period. If determined to be more applicable, a cost analysis will be done for individual camps over their lifespan during a natural disaster, which is approximately two weeks. This analysis type could be more effective if these camps are set up after a disaster opposed to being permanently established facilities. This cost analysis combined with our performance of our design showed how satisfying our solution is.

To support our estimates and pricing, we contacted construction suppliers to receive product quotes as well as product information. These product reports, helped us to determine the lifespan and maintenance cost for the product.

Currently, The Bomberos have no specific budget limit, however, the more low-cost, the better. Their current expenses for water are 211,700 Colones (400 USD) for 1100L of potable water and 3,836,800 Colones (6000 USD) for food (includes water).

Details that were kept in mind when analyzing potential products:

- Potential supplier information;
- How maintenance is managed (we believe it could be the Bomberos);
- What exactly is our budget;
- What are they currently working on;
- How will environmental concerns affect cost;
    - Disposal of harmful material;
    - Construction concerns.

It was important for us to concentrate our energy towards investigating the amount of water used throughout the camp for different activities as well as how cost efficient the products were in these areas. Thus, we compiled a list of activities that use water:

- Washing tents;
- Kitchen/medical supplies;
- Drinking water;
- Laundry;
- Showers;
- Washing Dishes;
- Cooking;
- Toilets;
- Sanitation;
- Waste Disposal.

With these activities in mind, we were able to predict how much water the camps might use daily. In addition, this also aided in finalizing our decisions on what products would best fulfill these activities while also taking into account the current systems in place. A list of simple hygienic products is given below as well as the approximate amount that is used over the span of five days.

PRODUCT	BRAND	APPROXIMATE AMOUNT OF SPENDING PER MOVEMENT (5 DAYS)
Dishwashing Soap	Generic Brand/AXION in Liquid	2 bottles of 750ml or 3 units of 1000g cream
Degreaser	M Y R PROFESSIONAL/ MR MUSCLE	3 gallons (cleaning surfaces and supplies in the kitchen)
Soap Powder	No brand/ Irex	10 bags of 1k each (use in laundry and washing of supplies)
Liquid Handwashing Soap	Protex	12 bottle of 221 ml (for washing hands)
Liquid Hand Washing Soap	Cristalin	1 gallon (replace hand washing bottles and wash supplies
Chlorine	Clorox, Irex, BlanKita	2 gallons (chlorination and cleaning)
Disinfectant	Lysol, Irex, Florex, Clorox	2 gallons (washing and disinfection of surfaces)

Table 1: List of hygiene products used at the emergency camps (L. Ramírez Barquero, 2019)

With a list of the different products and the amount of each used, we were able to produce an estimated cost for a two-week life span of the camp.

Currently, the Bomberos store their water in a few different types of containers. They have two vertical tanks that hold up to 750L of water, a horizontal tank that holds 1000L as well as two water bags that hold 1000L (water bags only hold potable water). It is at this point in the process that the water is filtered. As of now, they use carbon filters and chlorine that is installed manually, and even if they buy potable water, it still must be run through a filter. This was crucial for us to know because the more water that is run through the filters, the higher the cost will be. It also makes the process less time efficient having to replace and reinstall chlorine filters. We spoke with Lineth Ramirez Barquero, an instructor at the Academia Nacional de Bomberos who informed us that they are looking for a chlorination system that is automatic and portable as well as a kit for testing the water's conditions. Above all, these systems must be environmentally neutral, as they do not want to leave a large footprint as a result of deploying these camps.

As alluded to in the section on water harvesting, the Bomberos currently have no system in place for collecting rainwater to be reused for the camps. From this, we developed collection systems that would allow them to use materials that are already available. However, when the need to use outside materials arose, a simple price for each material was presented.

The above sections present the initial research needed for development of our water treatment network as well as proposing different products desired for our final system. The following sections pose the methods we developed based on the above research.

4.0 Findings/Analysis

4.1 Wastewater Norms/Laws

When investigating laws, the team researched regulations and limits of parameters on the disposal of ordinary residual waters and potable water in Central America. Additional information obtained through local Costa Rican organizations is given. The information provided in this section targets laws in the countries of Costa Rica, Nicaragua, and Panama. The team targeted the countries of Nicaragua and Panama because they are the two neighboring countries and therefore the most accessible ones for the Costa Rican Bomberos.

4.1.1 Infiltration Trenches

The importance of international laws falls under a scenario where the Bomberos are deployed to another country with the purpose of providing extra assistance. Many activities carried out in the emergency camps in Costa Rica may or may not comply with the laws of these two neighboring countries. In rescuer emergency camps in Costa Rica, residual waters are disposed of in trenches. In our interview with an AyA representative, Eng. Álvaro Araya García, we were informed that infiltration trenches with the appropriate dimensions suffice the needs for domestic greywater in temporary emergency camps. In order to obtain the proper dimensions for these trenches an infiltration test must be performed in the location of the desired emergency camp. The dimensions obtained through an infiltration test allows treating the required volume of greywater produced at the camp. Residual waters coming from the kitchen require additional treatment. A grease trap needs to be installed in the drainage system. The purpose of a grease trap is catch floating particles, oils and fats that come from sinks and ultimately allows wastewater to oxidize and be disposed properly into an infiltration trench.

When investigating about infiltration trenches in the countries of Nicaragua and Panama, the team learned that standards are similar to Costa Rica. The Pan American Health Organization (PAHO), the international health organization for the Americas and a branch of the World Health Organization (WHO), defines infiltration trench as the element used to discharge the liquids from the septic tank and the grease trap in the subsoil, allowing its oxidation and final disposal (PAHO. (n.d.)). Additionally, they state that an infiltration trench is an absorption system, which represents the tertiary and final treatment of wastewater (MINSAL, 2015).

The previous definitions states that an infiltration trench is a proper manner of wastewater disposal as long as the water is discharged from a septic tank. Transporting a septic tank is not convenient in an emergency camp due to its heaviness, space required, and installation. Having a septic tank in the rescuer emergency camps is not necessary. The definition of a septic tank by the Cambridge Dictionary is “a large, usually underground container in which solid waste and urine are dissolved by the action of bacteria”. In the emergency camps, human waste such as solid waste and urine is disposed in latrines. Not having human and solid waste enter these infiltration trenches results in an appropriate system for greywater at the camps. The Pan American Health Organization also recommends including a grease trap for any facility that supplies food for more than 50 people. This would apply to the kitchen area of the emergency camps that on average feed a population of 150 people (MINSAL, 2015). Infiltration trenches with a grease trap in the kitchen and no solid waste entering it provides sufficient treatment for greywater produced at the camp.

4.1.2 Wastewater in a Receiving Body of Water

The proper functioning of an infiltration trench depends on the type of soil and saturation of location. When the ground is considerably rocky, water is not able to filter through these infiltration trenches at an appropriate rate. Another situation that would not allow for appropriate functioning of an infiltration trench occurs when floods clog the ground. When similar cases like the ones previously mentioned occur other forms of disposal must be implemented. An example of another form of wastewater disposal is through a receiving body of water such as a river, lake, swamp, etc. This type of action has laws that have been established by the President of Costa Rica, The Health Minister (MINSALUD), and the Environment and Energy Minister (MINAE) in the “Regulation of Wastewater Discharge and Reuse” document.

Parameters and limits have been established in this document. Article 17, General characteristics of the limits for wastewater discharge, states that the Health Minister will accept a range of variation that will be established by the 95% confidence limits of the respective parameters. The table below provides the information on these parameters and their limits.

MAXIMUM PERMISSIBLE LIMITS FOR THE UNIVERSAL PARAMETERS OF OBLIGATORY ANALYSIS OF WASTEWATER DISPOSED IN A RECEIVING BODY (COSTA RICA)	
Parameter	**Limit**
Biological Oxygen Demand (BOD)	50 mg/L
Chemical Oxygen Demand (COD)	150 mg/L
Suspended Solids	50 mg/L
Oils & Greases	30 mg/L
Potential of Hydrogen (pH)	5 to 9
Temperature	15°C $\leq$T $\leq$ 40°C
Settleable Solids	1 ml/L
Methylene blue active substances	5 mg/L

Table 2: Maximum permissible wastewater parameters in a receiving body of water in Costa Rica (Sistema Costarricense de Información Jurídica, 2006)

If wastewater disposal in a receiving body of water is implemented at the camp, the Bomberos will have to filter these residual waters through a portable treatment plant in order to comply with the limits stated above. Furthermore; Article 34, Minimum frequencies of sampling and analysis of ordinary wastewater, states how often monitoring of the effluents of ordinary wastewater treatment systems are carried. The frequency and parameters are established on the table below.

MINIMUM FREQUENCY OF SAMPLING AND ANALYSIS FOR WASTEWATER OF

ORDINARY TYPE	
Parameter	**Water Flow (□$^{□}$/□□□)** **≤ 100**
Potential of Hydrogen (pH)	Monthly
Settleable Solids	
Temperature	

Table 3: Minimum frequency of sampling for wastewater of ordinary type in Costa Rica (Sistema Costarricense de Información Jurídica, 2006)

Non-compliance with these limits will result in a sanction, suspension and further develop of treatment plans in accordance to the Health Minister.

In Nicaragua, the decree "Regulation in which the Provisions for the Wastewater Disposal are Established"; provides information on parameters and limits. Article 24 of Chapter 5, Discharges from Treatment Systems to a Receptor Bodies, states the permissible limits of fecal coliforms for present times and years to come with the objective to progressively decrease fecal coliforms concentrations in bodies of water. Time periods and limits are established on the table below.

Time Period	2017-2022	2023-2026	2027-2029
Fecal Coliforms	$(1 * 10^5)$	$(1 * 10^4)$	$(1 * 10^3)$

Table 4: Fecal coliform projection limits in Nicaragua (REGLAMENTO EN EL QUE SE ESTABLECEN LAS DISPOSICIONES PARA EL VERTIDO DE AGUAS RESIDUALES, 2017)

Article 26 of Chapter 5, provides parameters and limits of domestic wastewater treatment systems discharged in receiving bodies of water. Permissible ranges and values are provided on the table below.

MAXIMUM PERMISSIBLE VALUES OF WASTEWATER IN A RECEIVING BODY OF WATER (NICARAGUA)	
Parameter	**Maximum Permissible Ranges & Values**
pH	6-9
Total Suspended Solids	80 (mg/L)
Settleable Solids	1 (mg/L)
Floating Material	Absent
Biological Oxygen Demand (BOD)	110 (mg/L)
Chemical Oxygen Demand (COD)	220 (mg/L)
Total Nitrogen	30 (mg/L)
Total Phosphorus	10 (mg/L)
Oils & fats	15 (mg/L)
Temperature	No more or less than 3°C of the receiving body of water

Table 5: Maximum permissible wastewater parameters in a receiving body of water in Nicaragua (REGLAMENTO EN EL QUE SE ESTABLECEN LAS DISPOSICIONES PARA EL VERTIDO DE AGUAS RESIDUALES, 2017)

In Panama, values for parameters and limits of wastewater disposed in a receiving body of water are established in the document "Water. Discharge of Liquid Effluents directly to Surface and Subterranean Water Bodies and Masses". Prohibited materials to discharge in a receiving body of water includes explosive and flammable liquids, and chemical substances such as pesticides. Maximum permissible values of discharged wastewater in a receiving body of water are given on the table below.

MAXIMUM PERMISSIBLE VALUES OF WASTEWATER DISCHARGES TO RECEIVING BODIES OF WATER (PANAMA)	
Parameter	**Maximum Permissible Ranges & Values**
pH	5.5 - 9.0
Total Suspended Solids	35 (mg/L)
Settleable Solids	15 (mg/L)
Floating Material	Absent
Biological Oxygen Demand (BOD)	35 (mg/L)
Chemical Oxygen Demand (COD)	100 (mg/L)
Total Nitrogen	19 (mg/L)
Total Phosphorus	5 (mg/L)
Oils & fats	20 (mg/L)
Temperature	No more or less than 3°C of the receiving body of water

Table 6: Maximum permissible wastewater parameters in a receiving body of water in Panama (“AGUA. DESCARGA DE EFLUENTES LÍQUIDOS DIRECTAMENTE A CUERPOS Y MASAS DE AGUA SUPERFICIALES Y SUBTERRÁNEAS”, 2000)

4.1.3 Potable Water

In order to avoid any risk that might arise from providing contaminated drinking water to the emergency camp staff, the Bomberos buy potable water and transport it to emergency camps.

This action results in a lot of wasted time and additional work for the staff at the camp. In our proposal, we provide multiple methods to treat water into potable standards. It is important to be able to test and understand the adequate parameters and limits of potable water so that an additional safety factor is added.

The President of Costa Rica and the Health Minister (MINSALUD) decree laws on the "Regulations for the Quality of Potable Water". Article 6 of the document classifies the control for the quality of water in four different levels. The first level (L1) corresponds to the basic control program along with the sanitary inspection, to evaluate the operation and maintenance of the source, storage and distribution of drinking water. Second level (L2) corresponds to the expanded basic control program (L1), the analysis of temporary trends of quality variations in the sources of supply, to be applied in drinking water samples at the source, storage and distribution. Third level (L3) corresponds to the advanced control program of drinking water. It includes the execution of (L2) level parameters extended with: nitrite, ammonium, arsenic, cadmium, chromium, mercury, nickel, antimony, selenium and pesticide residues. Lastly, fourth level (L4) corresponds to occasional programs executed by special situations, emergency or when the sanitary inspection identifies an imminent risk of water contamination.

In the emergency camp scenario of the Bomberos the first level (L1) program is the one that applies. The Bomberos tend to usually get all their water from fire-hydrants, meaning the water is of good source. The selected staff will only have to deliver a basic control program along with the sanitary inspection. Table 1 in the Annex 1 section of the "Regulations for the Quality of Potable Water" document points out the parameters and limits of potable water quality in the first level control (L1); these values are given in the table shown below.

QUALITY OF POTABLE WATER - L1 (COSTA RICA)			
Parameter	**Unit**	**Recommended Value**	**Maximum Value**
Fecal Coliform	NMP/100 mL or UFC/100 mL	Absent	Absent
E-coli	NMP/100 mL or UFC/100 mL	Absent	Absent

Color	(U - Pt - Co)	5	15
Turbidity	UNT	<1	5
Smell	-	Must be acceptable	Must be acceptable
Taste	-	Must be acceptable	Must be acceptable
Temperature	°C	18	30
pH	pH value	6.5	8.5
Conductivity	µS/cm	400	400
Free Residual Chlorine	mg/L	0.3	0.6
Mixed Residual Chlorine	mg/L	1	1.8

Table 7: Potable water parameters in Costa Rica (Reglamento para la calidad del Agua Potable, 2015)

Chapter 5 of the "Regulations for the Quality of Potable Water" touches on disinfection. Article 12, Use of disinfectants, mentions that disinfecting is only applied in natural water of excellent quality (groundwater or spring water) to guarantee the absence of indicators of fecal contamination between the point of application and the point of delivery. The disinfection must also be applied to maintain a residual level, as indicated in Article 13, which guarantees the good quality of the water from possible contaminations throughout the distribution system. Article 13, Dosage of disinfectant, states that the dose of disinfectant which corresponds to the amount in parts per million (mg / L) that is applied to water. The dose applied varies with the demand of each particular water.

The Bomberos' most common form of disinfection is through chlorination; this ensures that the water collected from fire-hydrants maintain a proper quality. Section 13.1, Chlorine disinfection, of "Regulations for the Quality of Potable Water" mentions disinfection as a function of the type of residual present. It is always desired to use the minimum amount of chlorine in the network distribution. Chlorine amounts depend on the pH of the water and minimum contact time; these values are given in the following table.

pH Value	Free Residual Chlorine (mg/L), 20 minutes of minimum contact time	Combined Residual Chlorine (mg/L), 60 minutes of minimum contact time
6.0 - 7.0	0.3	1.0
7.1 - 8.0	0.5	1.5
8.1 - 9.0	0.6	1.8

Table 8: Chlorination disinfection based on pH levels and minimum contact period (Reglamento para la calidad del Agua Potable, 2015)

Chapter 3, Section 10.3 talks about frequency of collection samples. In order to ensure the water supply meets the required regulations, it is necessary to collect the samples with the periodicity established in Table B of Annex 2 of the “Regulations for the Quality of Potable Water”.

TABLE B. MINIMUM FREQUENCY OF ANALYSIS AND NUMBER OF SAMPLES		
Supplied Population	Analysis (L1) - Frequency / Number of samples in	
	Source - Storage	Water Network
Less than 2000	Semester / 1	Semester / 3

Table 9: Minimum frequency of potable water analysis in Costa Rica (Reglamento para la calidad del Agua Potable, 2015)

The technical regulation, “Water. Drinking Water, Definitions and General Requirements”, states the limits and characteristics of potable water parameters in the country of Panama. The maximum limits of the parameters for potable water are provided on the table below.

POTABLE WATER PARAMETERS (PANAMA)		
Parameter	**Unit**	**Maximum Value**
Fecal Coliform	NMP/100 mL or UFC/100 mL	Absent
E-coli	NMP/100 mL or UFC/100 mL	Absent
Color	(U - Pt - Co)	15
Turbidity	UNT	1
Smell	-	Must be acceptable
Taste	-	Must be acceptable
pH	pH value	6.5 - 8.5
Hardness	mg/L	100
Residual Chlorine	mg/L	0.8 - 1.5

Table 10: Potable water parameters in Panama (*AGUA. AGUA POTABLE. DEFINICIONES Y REQUISITOS GENERALES*, (n.d.))

Nicaragua follows potable water parameters and limits set by the Regional Coordinating Committee of Drinking Water Institutions and Sanitation of Central America (CAPRE). Their mission is to “Dictate technical norms of product quality in potable water and sanitation between countries that are members and affiliates" (CAPRE, (n.d.)). The countries of Guatemala, Honduras, El Salvador, Nicaragua, Costa Rica, Panama and the Dominican Republic are members of this organization. According to the Committee of Drinking Water Institutions and Sanitation of Central America (CAPRE), potable water parameters and limits are the displayed on the table below.

POTABLE WATER QUALITY (NICARAGUA)			
Parameter	**Unit**	**Recommended Value**	**Maximum Value**
Fecal Coliform	NMP/100 mL or UFC/100 mL	Absent	Absent
E-Coli	NMP/100 mL or UFC/100 mL	Absent	Absent
Color	(U-Pt-Co)	1	15
Smell	-	Must be acceptable	-
Taste	-	Must be acceptable	-
Temperature	°C	18	30
pH	pH value	6.5	8.5
Turbidity	UNT	1	5
Conductivity	µS/cm	400	400
Residual Chlorine	mg/L	-	*5

(*) 5 mg / l based on scientific evidence that proves this "residual" value does not affect health. On the other hand each country should take into account the economic and organoleptic aspects in the interpretation of this value.

Table 11: Potable water parameters in Nicaragua (*Normas de Calidad del Agua para Consumo Humano*, (n.d.))

Every wastewater activity requires a report with at least a section explaining the method of disposal of wastewater, results of water parameters' measurements, an evaluation on treatment plant units, and a registry of water production. The Bomberos already provide a general report of each emergency camp. The current report includes a description of the location, duration of stay, a section on nutrition and hydration, water & hygiene, telecommunications, expenses, transportation, and supplies at the camp. Adding a section with methods of wastewater disposal and quality tests performed would result in a complete report.

4.1.4 Parameter Comparison

A comparison between parameters and limits from all three countries; Costa Rica, Nicaragua, and Panama is necessary in order to come up with a stricter and more sophisticated range of values for all parameters. Wastewater disposal to a receiving bodies and potable water parameters and limits are compared in the tables below.

QUALITY OF WASTEWATER DISPOSAL IN A RECEIVING BODY OF WATER (ALL 3 COUNTRIES)			
PARAMETER	**COSTA RICA**	**NICARAGUA**	**PANAMA**
Biological Oxygen Demand (BOD)	50 mg/L	110 mg/L	35 mg/L
Chemical Oxygen Demand (COD)	150 mg/L	220 mg/L	100 mg/L
Suspended Solids	50 mg/L	80 mg/L	35 mg/L
Oils & Greases	30 mg/L	15 mg/L	20 mg/L
Potential of Hydrogen (pH)	5 - 9	6 - 9	5.5 - 9
Temperature	15°C ≤T ≤ 40°C	No more or less than 3°C of the receiving	No more or less than 3°C of the receiving

		body	body
Settleable Solids	1 ml/L	1 ml/L	15 ml/L
Methylene blue active substances	5 mg/L	N/E	1 mg/L

Table 12: Comparison of maximum permissible wastewater parameters in a receiving body of water in Costa Rica, Nicaragua and Panama

POTABLE WATER QUALITY (ALL 3 COUNTRIES)			
PARAMETER (UNIT)	**COSTA RICA**	**NICARAGUA**	**PANAMA**
Fecal Coliform (NMP/100 mL or UFC/100 mL)	Absent	Absent	Absent
E-coli (NMP/100 mL or UFC/100 mL)	Absent	Absent	Absent
Color ((U - Pt - Co))	5-15	1-15	15
Turbidity (UNT)	1-5	1-5	1
Smell	Must be acceptable	Must be acceptable	Must be acceptable
Taste	Must be acceptable	Must be acceptable	Must be acceptable
Temperature (°C)	18 - 30	18 - 30	-
pH	6.5 - 8.5	6.5 - 8.5	6.5 - 8.5
Conductivity (µS/cm)	400	400	-
Residual Chlorine	1.3 - 2.4	*5.0	0.8 - 1.5

(mg/L)			

(*) 5 mg / l based on scientific evidence that proves this "residual" value does not affect health. On the other hand, each country should take into account the economic and organoleptic aspects in the interpretation of this value.

Table 13: Comparison of potable water parameters in Costa Rica, Nicaragua and Panama

The values highlighted in green represent the stricter parameter limits. If the Bomberos comply with the selected limits, then they will be able to comply with the standards set in the other countries and avoid any penalties and sanctions.

4.2 Water Treatment

Water quality is a multifaceted topic, which requires a specified treatment system dependent on the source of the water. The source of groundwater may be contaminated by chemicals leaching from landfills, septic systems, or improper disposal of agricultural or household chemicals. Seawater is contaminated with a high concentration of NaCl, which requires different treatment than groundwater. River water has the potential to be infected with large quantities of E. coli and dangerous viruses due to dumping from lack of wastewater treatments in Costa Rica. Parameters that should be checked for to determine the best treatment are as follows: Dissolved Oxygen, turbidity, total solids, pH level, temperature and Flow rate, nitrates, fecal coliform, biochemical Oxygen Demand, and phosphorus. (See Water Quality Tests).

4.2.1 Portable Filters/Decentralized

The 12 microclimates of Costa Rica make it a breeding ground for natural disasters, and they can occur anywhere at any time. The Cuerpo de Bomberos need to be ready for deployment with an average response time of only 1 to 3 days. In addition, they intend on eventually becoming a disaster relief organization for the surrounding Central American countries, as well as in Costa Rica. In order to be the most efficient in time and resources, their wastewater treatment system needs to be portable and mostly automatic. That way both the system set and delivery to the locations will be cheap and straightforward after the initial cost of purchase. Systems that utilize these attributes are known as decentralized systems.

A decentralized system minimizes the wastewater collection network, and will maintain the solid and liquid fractions near the point of origin. The design can be easily modified to allow the operation of the system to fit various site conditions and scenarios. Another characteristic of a decentralized system is on-site greywater reuse systems. These systems are viewed as a more sustainable practice due to the lack of need to transport the water to be treated. This allows for treating the water at the point of use, and decreases the overall costs. Because of the shorter pipelines and higher pressures, they are less prone to breakages or leaks.

Decentralized systems are widely used and currently increasing in the United States. If the housing unit is too far away from a centralized plant, it is more beneficial to treat the small neighborhood than attempt to connect it to the existing sewer network. It is common that the water treated can be reused for activities ranging from low-value crops to toilet flushing. (National Research Council).

4.2.2 Chlorine Filters

Chlorine is often used as a treatment to transform grey water into potable, drinking water. The reason chemicals such as fluoride, chlorine, or chloramines are used to treat water, is their ability to help protect your teeth by keeping the water free of harmful germs on its way to and from your tap. However, it can also be used in the treatment of sewage water. It is a strong oxidant and works well for treatment of oxidation and disinfection. (Water Treatability Database). The ability to control biological growth, remove color, taste/odor, iron/manganese, and other inorganic compounds like arsenic, make chlorine a valuable filter option when treating water sources. A chlorine filter usually takes the roll as a primary disinfectant to control the microbial activity in the distribution system. However, chlorine is often used multiple times during treatment. During the secondary stage, it is used to inhibit microbial growth on the filter media that could potentially cause a pressure build up. (Chlorine Chemistry).

The main factors that affect chlorine application are concentration, contact time, pH and temperature. Concentration and contact time are the most important operational parameters in disinfection and inactivation. There are pros and cons to increasing either factor. For example, increasing the dosage of chlorine improves its ability to oxidize and disinfect, but therefore it may lead to taste and odor issues due to chlorines reaction with natural organic matter. Other factors that are important to consider are the application point, chlorine demand of the water, and the desired residual concentration.

Chlorine comes in multiple forms as a way of treatment. It can be a compressed elemental gas, sodium hypochlorite solution (NaOCl) or solid calcium hypochlorite (Ca(OCL)2). In high doses, these chemicals are harmful, but when added to water, they are diluted. This results in low levels that kill germs but are still safe to drink. According to the CDC (Centers for Disease Control and Prevention) chlorine levels up to 4 milligrams per liter or 4 parts per million are considered safe in drinking water. It is very common for a carbon filter to follow a chlorine filter due to its ability to remove excess chlorine. *(Centers for Disease Control and Prevention)*

4.2.3 Carbon Block Filters and Granular Activated Carbon

Carbon molecules have the ability to interact and keep a position. A process called adsorption is when the polluted molecules in the fluid are trapped in the carbon substrate. Active carbon filters are used to effectively treat chlorine, sediment, volatile organic compounds, as well as taste and odor from the water. Minerals, salts, and dissolved inorganic compounds cannot be filtered through this system. Carbon filters are often used in sequence with other filters in order to increase the quality of water. The medium often used to create these filters are always carbon based materials, but is often petroleum coke, bituminous coal, lignite, wood products, coconut shell, or peanut shells. Subjecting these materials to high temperatures reaching 2300 degrees Fahrenheit with no oxygen activates the medium. The activation creates carbon with many small pores and a large surface area. That product is then crushed to produce a granular carbon product. Carbon block filters reduce particulates, microscopic cysts, lead, volatile organic chemicals, along with other contaminants. Its relative low cost, compact size, ability to remove contaminants, use of renewable resources, and resistance to bacteria growth are traits that are more important than the aesthetics and improvements of drinking water. The particles now have a larger surface area available, which the compounds can absorb, resulting in greater contaminant removal. The activation method determines which type of contaminants are targeted. (Neb Guide)

Due to the smaller particle size and uniform pore structure of a carbon block, it has a higher effectiveness in a smaller size than the Granular Activated Carbon at the same flow rate. A Granular Activated Carbon Filter exploits physical adsorption, as the liquid comes into contact with the activated carbon, the intermolecular forces are filtered into the millions of pores and pockets on the surface of the carbon. Many small pollutants are adsorbed by the carbon, while the larger impurities are too big to pass through the compact pores. A chemical reaction occurs, as chlorine comes into contact with the carbon, they form chloride ions, which effectively removes the chlorine from the water. (Carbon Block Technology). The benefits of the smaller system help with the treatment and removal of taste, odor, and color. The Activated Carbon filter usually follows a chlorine filter. The problem with chlorine filters is the chlorine is able to react with organic matter in the water and create harmful byproducts. The EPA demands that the content of chlorine in the water not exceed the 80 parts per billion. Carbon is the solution for these byproducts; it removes chlorine, chloramines, and some of the byproducts produced by the chlorine reaction. Using carbon technology, with longer contact time, the more adsorption of contaminants. Once the filter becomes full with contaminants, the filter has become saturated and has reached its capacity. At this point, the contaminants are able to breakthrough in to the treated water, due to lack of adsorption. In order to prevent this from happening, the filtration unit should shut down the water supply after a specified number of gallons have been treated. Another method of prevention of breakthrough would be to install multiple carbon filters. (Carbon Block Technology).

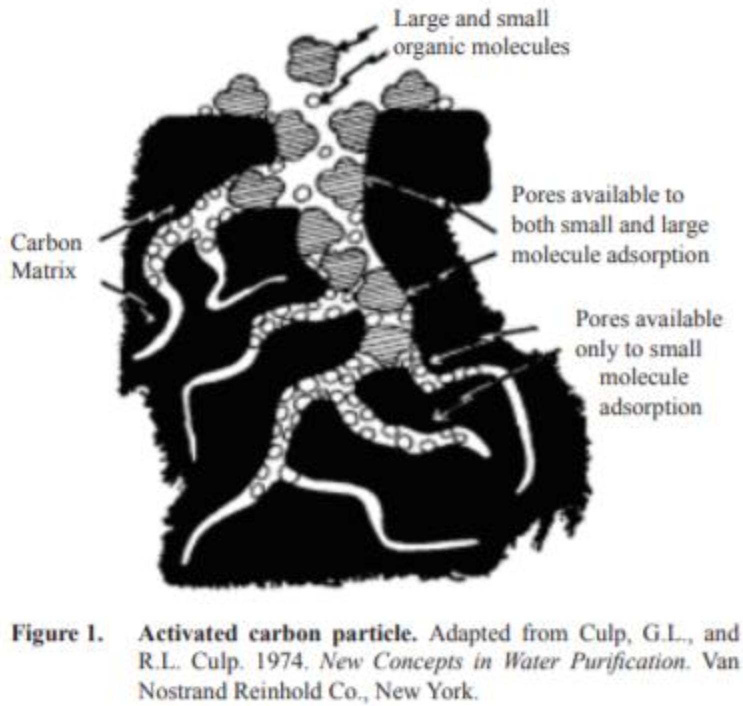


Figure 7: Showing an activated carbon filter (Neb Guide, 2014)

It is imperative when using a carbon block system to check the filter and quality of water often. Bacteria and organic compounds can breed fairly easily because of the lack of chlorine in the water. Most of the time the filter is the infected source of poor quality water. Solutions to this problem include changing the filter often, and doing continuous water quality tests when something about the water color, quality, or taste seems to have changed. (Carbon Block Technology, (n.d.))

4.2.4 Ultraviolet Disinfection Methods

Ultraviolet (UV) light is a band of the electromagnetic spectrum with a wavelength range of 10- 400 nm. The rays of UV light are longer than X-rays, but shorter than that of visible light. The benefit of harvesting UV light as a filtration method comes from its ability to break chemical bonds. Through ionization, UV photons can cause electrons to break away from atoms. The vacancy of an electron then causes them to either form or break chemical bonds that would otherwise stay in contact. This makes UV a beneficial tool for disinfecting surfaces, but harmful to skin and eyes. (Lucas, Jim). In order to harvest UV light, an electric current is passed through vaporized mercury or some other gas. Powering a UV disinfection system requires a continuous power supply to the light bulb. Continuous power decreases the risk of untreated water consumption. For best results, the UV lamp should be on for several minutes before reaching full UV output. The UV system uses approximately the same amount of electricity as a 40-watt light bulb. This systems lamp has an effective battery life of 9000 hours, or about 375 days before needing replacement. However, beyond this timeline, the lamp degrades quickly and the disinfection process is no longer reliable. (UV Dynamics). Without continuous power, the UV light intensity will fail and the system will no longer be effective. "The Department of Health recommends that UV light systems are interconnected to water pumps so that in the event of a power failure untreated water will not be supplied." (Government of Western Australia)

The water entering the UV system should be filtered previously. Suspended particles and microorganisms will not be removed from the water because UV light is not a filter. A characteristic of UV light is that it travels in a straight line, any shadow or obstruction will disrupt its efficiency. Shadows or obstructions include iron, manganese, and suspended particles that can either absorb or scatter the UV light. Microorganisms are able to pass through, protected by shadows created by dirt or debris.

Harnessing this technology as a filter has many benefits as well as drawbacks. The way a UV filter works is by destroying the microorganism's cellular function so it will not be able to grow. This is an effective method against viruses, bacteria, and protozoa. Some troubling microorganisms have thick cell walls that some UV systems are not powerful enough to destroy. Microorganisms such as Cryptosporidium and Giardia have that protective thick wall that causes this to be troublesome. Using a UV system should be a secondary treatment closest to the point of use after a primary filtration. The UV disinfection method is only effective at the point of contact. When the water leaves the system, it is vulnerable to recontamination. Causation of recontamination is back flow, breaks and biofilms that can occur because of the lack of residual disinfectant of the water. To keep this system well maintained, and avoid the creation of biofilms, the pipes should be flushed with a 1 mg/L solution of chlorinated water. After flushing, open all taps to allow all chlorinated water to drain. UV light tubes will also need maintenance. (Government of Western Australia). The tubes and lamps will require regular replacement. The Teflon and quartz glass tubes will need to be cleaned to remove algae as well as other deposits. Based on the manufacturer of the product, maintenance will be instructed for that specific product. To ensure the water is being disinfected properly, it is recommended that the water should be tested every month.

Treatment Class	***Microbiological Treatment***	***Level of Disinfection***
lla	Bacteria removal	Remove or inactivate bacteria
llb	Virus removal	Remove or inactivate viruses
llc	Protozoa removal	Remove or inactivate Cryptosporidium and Giardia

Table 14: Treatment classes of water followed by necessary action needed

"Australian/New Zealand Standard AS/NZS 3497 also specify the level of performance each water treatment and disinfection system can achieve."

4.2.5 Reverse Osmosis

Reverse Osmosis is a process that utilizes membrane filters to reduce the levels of total dissolved solids and suspended particles within water. It targets materials such as ions and metals, salts, Pesticides, Asbestos, Protozoan cysts, Cryptosporidium, as well as Radium and Uranium. This system is only used for coliform-free water to avoid contamination through pinhole leaks in the membrane. The downside of this system is it cannot filter out dissolved gasses, chlorine, or organic chemicals. Reverse Osmosis filters are often paired with Activated Carbon filters and sediment filtration. (Neb Guide, 2014).

Functionally, reverse osmosis is when pressure is applied to the contaminated side of the membrane. The osmotic pressure is reversed, causing pure water from the contaminated side to enter the diluted side. The treated product is then collected in a storage tank. The leftover water on the contaminant side is then treated as wastewater.

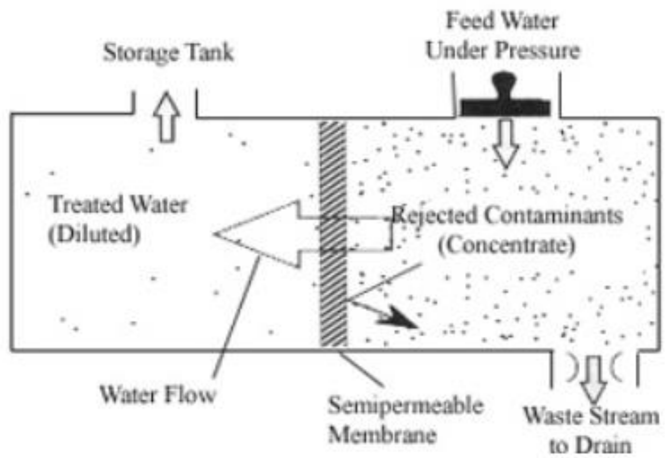


Figure 8: Depicts the process of osmosis (Neb Guide, 2014)

Only part of the water fed into the system is recovered as potable. For emergency situations, this system is not recommended due to the low retaining rate of the amount of water wasted while trying to make it potable. However, if it were a salt water system, it would not be a waste because of the large mass available. Utilizing a reverse osmosis desalination system could provide water in situations near the coast that have no other solution. In most households are designed to recover between 20 and 30 percent of the amount of water added. The recovery rate can be calculated using the following equation:

% Recovery = (Volume of treated water produced / total volume of feed water) x 100

4.2.6 Environmental Impacts

The goal of a green system is to decrease the amount of waste and energy used to run the system. Many filters can achieve their goal of clean water, but use excess water, energy, and produce too much waste. When treating water, you are often trying to recycle or dispose of it. Whichever use of the water requires sanitation at different levels in order to respect the environment. Sanitation and wastewater treatment systems are developed to protect and promote human health by preventing the spread of disease and considering the surrounding environment. When developing a system, key factors to reflect upon revolve around the community, resources, as well as pollutants. In order to have an effective system, it needs to be economically viable, socially acceptable, and technically/institutionally appropriate. Following these guidelines, a system can be developed that protects the environment and its natural resources. The design or improvement of a sanitation, or wastewater system is an opportunity to either help or harm the environment. Making sure it is done properly should be a focus for any development. Aspects such as health and hygiene, as well as environmental and natural resources can lead the development in the right direction.

Health and hygiene focus on disease prevention by limiting exposure to pathogens and hazardous substances. All points in the sanitation system from the excreta trenches to water being disposed of from cleaning meat could carry these harmful pathogens. Downstream populations will be most affected if the water is not treated properly. Other characteristics to recognize are the required energy, water, and other natural resources required to run the system. Aspects such as construction, operation and maintenance of the system, as well as discharge from the treatment system entering the environment need to be accounted for. Any water that can be reused or recycled should not be wasted. (Wendland, Claudia). Even if it is treated to the point that the water can return nutrients and organic material back to the agriculture.

Our proposed water treatment plants took into account the benefits of each filter listed in this section, as well as the environmental impacts that could occur as a result to the practice selected. With these factors in mind, our proposed systems are efficient, and conscious of the materials they require.

4.3 Proposed Water Treatment Systems

With the demand for clean water being so high at encampments, it was important for us to design/research a water treatment system that was effective but also compact and easy to use. In an emergency, the workers are the camp do not have time to figure out how to use a complicated system. Rather, they prefer something that is easy to setup and use so they can fulfill their other duties. As alluded to earlier, it is just as important to have a system that is capable of treating for harmful bacteria and other contaminants that can leach into the desired source of water whether it be a lake, river, creek etc. This section includes more insight on our top products and systems in order to provide more options for the Bomberos to implement.

4.3.1 Desalination Solutions

Costa Rica is bounded by both the Pacific and Atlantic Oceans. There is approximately

800 miles of coast that encompasses the country. This resource has been underutilized for water potential. The main complication with seawater is the treatment. It can be expensive if trying to treat water for large communities. However, for an emergency camp of 150 rescuers, Desalination is a reasonable solution.

In case of an emergency, the location of a camp will not be set up if there is not a water source within a reasonable distance. It is crucial to keep the rescuers hydrated and healthy while they are off to help people in need. Keeping treatment options simple is also a key factor in saving time for more important matters. The Bomberos enlightened us with the idea of utilizing seawater to expand the scope of emergencies they could respond to. After sorting through multiple products and various quotes, we found two products we feel fit the demand of the camp well.

4.3.2 Larger Scale Desalination model

The Emergency Portable Seawater Desalination Watermaker Model: SWTRO-2000 is a solution to treating saltwater. After reaching out to AMPAC USA, they responded with a proposal with the specifications and pricing. Portability was one of our top priorities when picking systems and is one of the highlights of this model. Including the case and accessories, this product only weighs 200 Kg. The dimensions of this case is 101.6 cm in length, 96.52 cm in width, and 86.36 cm in height. The make of the system includes pre-filters and Seawater Water Desalination Reverse Osmosis using best industrial practice and following the manufacturer’s guidelines for every component.

Figure 9: The Emergency Portable Seawater Desalination Watermaker Model: SWTRO-2000

The capacity of this machine is 2000 gallons per day, which is 7,570 Liters. According to the World Health Organization, a camp of 150 people requires 3,000 liters of water for the complete maintenance of the camp. The system is based off the utilization of seawater under 45,000 ppm NaCl feed water, and between the 3.0-11.0 pH ranges. The average seawater NaCl concentration is 35,000 ppm. This treatment would be able to prepare for multiple days without the need of gathering water. The total power consumption per day would be 16.1 Amps.

To be more technical, the standard features included in this model are: On-Demand Feed Supply Seawater Pump, Spin Down Screen Filter with Manual Flush Valve, 4” x 10” Sediment Pre-Filter 5 Micron, 4” x 10” Carbon Block Pre-Filter 5 Micron, Inlet Actuator Valve with Bypass, High Pressure Plunger Pump w/ safeguards, 4” x 40” FRP High Pressure Vessels, TFC 4” x 40” Membrane Elements, 4” x 10” Carbon Post Filter, 5 GPM (Gallons per Minute) Ultra Violet Disinfection Sterilizer, and Powder Coated Welded Aluminum frame will conform to AISC Manual of Construction. Additional benefits of this product comprise of an Auto Flush Cycle, which will help to keep contaminants from growing in the filters, along with a complete panel for easy controls.

Of the seawater put into the device, an estimated 30% of the water is recoverable. Often times this would be a waste of fresh water, but because the oceans are so vast and have untapped potential the only struggle would be to transport that much water to the camp. The 30% recoverable water is a standard when using reverse osmosis, and is the best way to treat seawater that has been developed so far. On the plus side, 98% of the salt is rejected. The feed flow for this machine is 238 GPH or 900.8 liters per hour. Of that, you get approximately 315.4 liters an hour. The Desalination Machine can run for 24 hours a day.

A Post Treatment System that is included with the purchase, includes a solution for the rather acidic pH of the permeate water. By Re-Mineralizing the water with Calcite and Corosex Media Post-Filter to bring the pH level to neutral. Calcite is a self-limiting, naturally occurring calcium carbonate media. It does not have the capacity to overcorrect but rather reach a non-corrosive equilibrium. Corosex is normally added with Calcite to prevent the risk of cementing, known as the NS mix.

If purchased, the Seawater Desalination Watermaker SWTRO-2000 has a warranty of one year. Beyond the year, it includes all the information you need to select, specify, install, and operate any Reverse Osmosis system from the company. In addition, it contains relevant technical information about the Components used for case studies, references, and Authorized Sales and Service Representatives Worldwide.

4.3.3 Smaller Scale Desalination Method

The same company has a smaller model that might better suited for the expected price range. The Emergency Portable Desalination Watermaker Model: SW150 is designed to output 23.7 liters per hour, or approximately 575 liters per day. The system can convert Seawater, well water, or surface water to potable drinking water within seconds. This model can be run 24 hours a day, 7 days a week. From the date of purchase, this device would be ready for shipping in approximately 3-4 weeks from the day of the formal purchase order and initial deposit. This is important to purchase and store before an emergency occurs, otherwise it will not be in stock when needed.

The recovery rate is the same 30% of the machine mentioned above. The feed flow is 68.13 liters per hour, producing approximately 23.8 liters an hour. The minimum feed pressure is 40 psi, and the maximum is 80 psi. This model is a lot lighter as well as smaller dimensions. With a weight of only 40.823 Kg and the dimensions being 56 cm in length, 48 cm in width, and 41 cm in height, this model is extremely portable and can help produce the required level of drinking water every day. This model also has a max capacity of 45,000 ppm of NaCl feed water, with a pH range of 3.0-11.0.

Figure 10: The Emergency Portable Desalination Watermaker Model: SW150

This model includes an Auto-Flush screen filter with 50 Micron Porosity. It has an easy maintenance plan that allows long intervals between cleaning. However, there is an option to add a Multimedia GAC-Anthracite-Silica Quartz Pre-Filter. This pre-treatment will help eliminate suspended particles in raw water by using a sand filter as a pretreatment for the Reverse Osmosis system. The load on the cartridge filters will be reduced and would filter the water at a 20-25 micron size of suspended solids. This filter will result in water less than 0.1ppm NaCl as well as adjust the pH. It is fully automated in operation, and the Reverse Osmosis System will automatically shut down when the GAC (Granular Activated Carbon) System backwashes. The Desalination SW150 also includes a Sediment & Carbon Cartridge Filter housing 5 micron, an Aquajet Variable Frequency Feed Pump, a Reverse Osmosis High Pressure Pump, a Membrane Element, Pressure Vessels, a UV200-12VDC Ultraviolet System (featuring a low cost replaceable lamp), and piping. Depending on the feed and water quality, it is recommended that you change the filters every 3 to 6 months. AMPAC USA offers a replacement filter kit for $125.95, or 76,100.50 colones, which includes everything needed to replace the filters.

https://www.ampac1.com/replacement_filters/APC-SW16

4.3.4 Four Step Filtration System

This extremely portable, lightweight, 10-inch filter costs a low price of $240.00 or 145,500 colones. While utilizing four different filtration technologies, this product can produce 230 liters per hour, or 5,520 liters a day. Included in the system is a leak protection system that allows set up to be effortless and quick. The safety system also has an emergency disc that will auto shut off when the filters are no longer useful. The filter cartridges are NSF certified in a standard 2.5-inch x 9.75 inch size, and compatible size filters are readily available at most hardware stores. This system can be easily mounted under a sink.

Figure 11: The Four-Step Filtration Method (Walmart, (n.d.))

In the figure above, there are three chambers side by side, and a fourth chamber along the top of the assembly. The first chamber is a one Micron Sediment Filter. The purpose of this filter is to remove any of the larger solids that may be in the water. This is an effective first step crucial to the performance of the following filters. If there are solids in the water, the other three systems are not designed to treat or dispose of them. The second filter is a Granular Activated

Carbon (GAC) combined with a KDF-55 filter. These two work together to improve the carbons function of adsorption. The KDF 55 media aids in the removal of chlorine, extends the carbon's life, and limits the bacterial growth in the filter. KDF also adds the benefit of removing water-soluble cations with the oxidation-reduction process, resulting in a cost efficient alternative to chemical treatment.

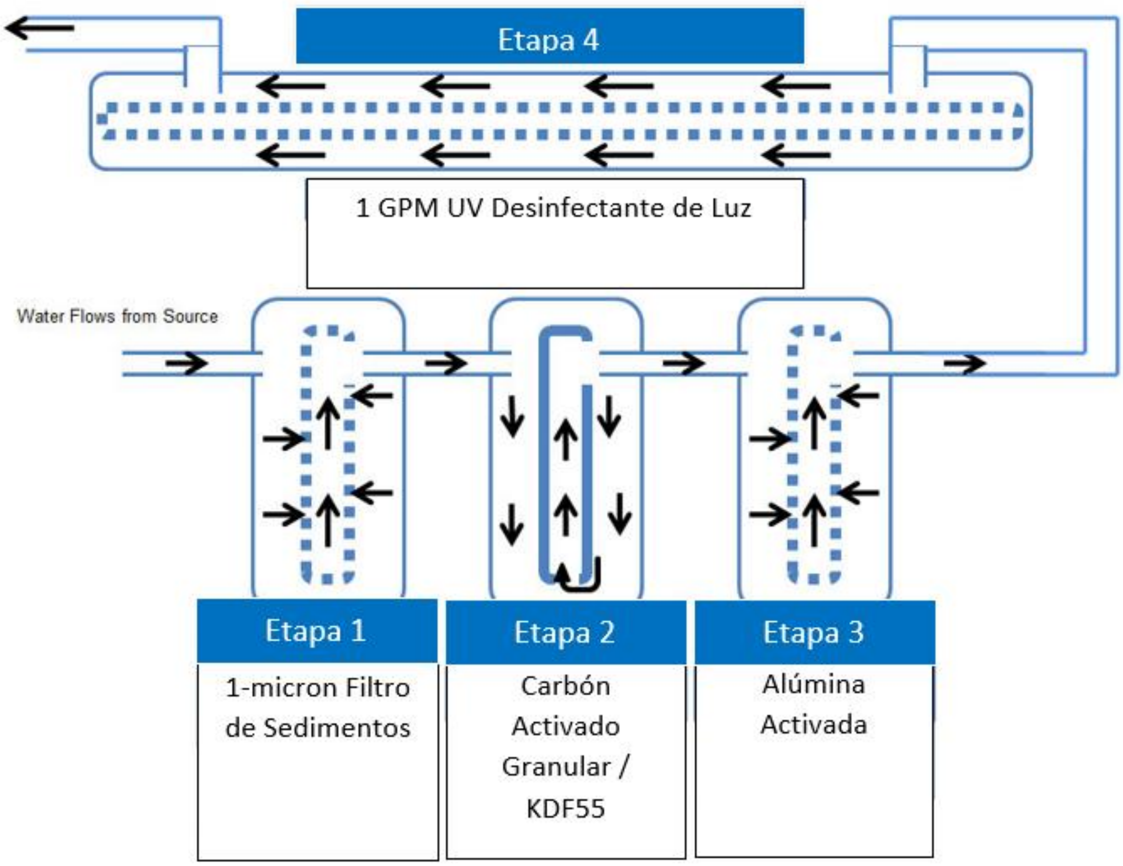


Figure 12: A visual representation of the flow of water through each stage of filtration.

GAC is used to adsorb natural organic compounds, taste and odor compounds, and synthetic organic chemical in drinking water treatment. Following the GAC/KDF-55 filter is an alumina filter that removes fluoride and arsenic to levels below FDA recommendations. (ARIES *FilterWorks*)

The final stage of this filtration process utilizes a one GPM, 6-watt UV light disinfection that kills 99.9% of most bacteria and viruses, including E.coli, Giardia, cryptosporidium, and coliform. UV light travels in a straight line, so at this point there should be no suspended solids in the water. Any solids could block the treatment and allow harmful particles to hide in the shadow of the solids. This is an effective method against viruses, bacteria, and protozoa. This final step should be closest to the point of use, because once it leaves this filter, it is vulnerable to recontamination. In order to dispense your treated water, Push down on the lever release and it closes, or lift up and the lever to lock it open. (Walmart, (n.d.))

The 1-micron sediment filter, GAC/KDF-55, and activated alumina filter can be replaced for $59.00 or 35,900.25 colones. The average life of these cartridges last 6 months, but may be less depending on water use and quality. The UV bulb last between 12-18 months, and only costs $49.00 or 29,828.75 colones. These products can be bought from Walmart, or a cheaper alternative if found. These filters in combination make a very efficient system and will lead to potable water. The cons of this system are only if it is used improperly, or if it is in use too long without proper maintenance. In an emergency situation this combination should not fail, however it should be maintenanced after every emergency to ensure the safety of the rescuers.

4.3.5 P&G Purifier of Water

Included in Proctor and Gamble's vast catalog of products is the P&G Water Purifier packets. Each packet contains 4g of powder that is capable of treating 10L of water at a time. However, experimenting by pouring multiple packets of powder into a larger volume of water can be done to purify more at once in order to keep up with the high demand of potable water at the camps. The powder consists of some of the same ingredients used in municipal water systems such as iron sulfate and calcium hypochlorite, deeming it as a "mini-water treatment plant in a packet."

Figure 13: The P&G Water Purifier Packet (P&G Packets, (n.d.))

The way the packets work is quite simple with only a few steps. First, the powder it poured into the dirty water. This can be done in any container such as a bucket. Once that is done, one must stir the mixture for up to 5 minutes during which the dirty sediments will separate from the clean water. Allowing the mixture to sit for 5 more minutes causes the particles to settle, giving a clear indication of the flocculation process taking effect. Once there is visible separation, the water can then be run through a simple screen filter where it will come out purified on the other end and after 20 minutes, it is safe to drink.

This product fits well for the situations the Bomberos find themselves in. It takes up very little space and is very easy to use for anybody at the camp. Packets could be handed out to everyone and they could filter their own water on their own time. We were informed during our project that it would be extra beneficial if our system could treat sea/salt water. The P&G packets are not intended to treat salt/ocean water, unfortunately. However, they are capable of removing dirt, cysts and pollutants from creeks, rivers, lakes and ponds as well as killing bacteria and viruses in water from said environments (P&G Packets, (n.d.)).

4.3.6 LifeSaver Jerry Can

Lifesaver is a company that specializes in water filtration devices whose implications involved aid deployment in situations such as natural disasters. Lifesaver strives to utilize more cost effective and sustainable solutions in their designs. For our project, we looked at the LifeSaver Jerrycan; a 18.5L microbiological water filter/jug that uses ultra filtration technology to filter out viruses, bacteria, cysts and parasites from contaminated sources of water such as rivers, ponds and creeks. Ultrafiltration (UF) is a form of filtration that utilizes a membrane in which pressure forces liquid against a semipermeable membrane. The membrane used for the LifeSaver water filters are thin layers of material with a number of pores that is capable of separating harmful substances from the clean water. Even though the LifeSaver will remove all microbiological contamination from seawater, it will not remove the salt. This is due to the fact that the technology is capable of filtering out suspended particles, not salt that is already dissolved within the water.

The Jerrycan would be another beneficial option due to its compact design and its ability to carry dirty water. Once water is cleaned, there is still a risk for recontamination, however, the Jerrycan allows one to filter water when you need to drink it. The filtered water that comes out of the Jerrycan can be used for drinking, washing and an easy cooking solution with the additional shower attachment.

Figure 14: The LifeSaver Jerrycan 10000UF (LifeSaver JerryCan 10000UF (n.d.))

This product uses activated carbon filters as part of the purification process. These filters are capable of processing 500L of water before needing replacement. Also, if one does not plan to use the Jerrycan for a month or more, then it is recommended to discard of the activated filter while making sure to store at least 0.025m of water in the can at all times. Even though there are already a few small maintenance requirement concerns, the LifeSaver implements Failsafe technology, which is an automatic indication of when the cartridge needs to be replaced (LifeSaver JerryCan 10000UF (n.d.)).

4.3.7 Versa Sea Pack

The team researched and concluded our third prime water filtration product. The Versa Sea Pak 360 Water Treatment System is a portable purifier in a box essentially that is capable of purifying up to 1362L of water per day from ANY water source. This includes sea water. The Versa Sea Pak is also a part of Darley Exclusive gear, which is a private label line of fire fighting equipment. This product being designed around the demands and needs of firefighters may be something the Bomberos are interested in investing in.

Figure 15: Versa Sea Pak 360 Water Treatment System (Versa Sea Pak 360 Water Treatment System, (n.d.))

The Sea Pak 360 utilizes a 3 stage reverse osmosis treatment system: Pump strainer for filtering out larger particles, sediment pre filter for particles at a micron scale and then finalizing the process with a reverse osmosis membrane. Included in its design are hydraulic intensifiers which increase the intensity pressure of the liquid while remaining energy efficient. Water can be drawn from its source at a rate of up to 60L per hour (Versa Se Pak, (n.d.)). It is capable of being powered through a few different methods. Truck/generator power (12 or 24 VDC) is an option producing approximately 605 Liters per day after 20 hours. There is also an optional 124 watt foldable solar module that is capable of purifying 378 Liters per day after around 6 hours of sunlight. If nothing is available for power, the unit includes an emergency 12VDC internal battery which can produce 283 Liters per day after approximately 5 hours (Versa Sea Pak 360 Water Treatment System (n.d.)).

All of the previously mentioned system options have their positive aspects as well as negative. For these reasons, we created a chart that presents the individual specifications as well as pros and cons for our top treatment products/systems.

Product	Price	Specs	Pros	Cons
P&G Water Purification Packets	Regular Price $99.99 (60.879 Colones) for 240	0.1133981 kg 0.2286x0.1524x0.0127m	-Easy to use for anyone at the camp. Can be easily	-Cannot treat salt/ocean water. -Shelf life of 3 years

	packets $19.99 (12.175 Colones) for 12 Pack		distributed throughout the camp for people to treat their water themselves. -Single packet can treat 10L of water. -Simple process only requires 5 minutes of manual work then a simple screen filter to separate the sediments.	from date of manufacture. -Must continue to purchase more to match demands.
Lifesaver Jerrycan	Lifesaver 10000UF for $261.61 (159.266 Colones)	4.35 kg 0.36x0.18x0.51m	-Hold up to 18.5L at one time. -Capable of filtering 10,000 Liters of water. -Has Failsafe which is an automatic indicator when the cartridge needs to be replaced. -Reduces turbidity of cloudy, muddy water. -Once the product is primed and water is filled, the outward flow of clean water is instant.	-Carbon filters need replacing and discarding, specifically if not used for a month or more. -Filters must remain well maintained as per the care instructions given in the package. -Particularly turbid water can reduce the life of the carbon filter.

Versa Sea Pak 360 Water Treatment System	$8,950 (5.448.715 Colones)	31.75 - 40.82 kg 0.8128x0.4064x0.5588m	-Energy efficient systems(hydraulic intensifier). -Purifies up to 1362L of water per day from any source, including sea water. -Green to red prefilter monitors.	-Prefilter needs to be serviced on a regular basis while the membranes need to be cleaned only when biological growth piles up. - Need to purchase additional solar panel attachment or connect to truck or generator of 12 or 24 VDC.
Four Step Filtration System	$239.00 per unit; 145.502 colones	10 inches x 12 inches; 25.4 cm x 30.48 cm	-Low cost and certified by walmart - 1 year warranty, local to Costa Rica -No electricity to operate -Energy efficient, drinking water quality from fresh water sources -230 liters per hour -Easily replaced filter cartridges, can be found at many stores, replacement every 6 months.	-Requires monthly maintenance -Small in size, could need multiple filters to meet the needs of the camp. -Needs fresh/potable water to treat -Requires a constant flow of water

Emergency Portable Seawater Desalination Watermaker Model: SWTRO-2000	$ 29,850.00; or 18.220.290.75 colones	200 Kg; 101.6 cm L, 96.52 cm W, and 86.36 cm H.	-7,570 Liters per day, more than double the amount of daily requirement. -Treats salt water to an effective rate of 98% NaCl -With purchase comes with all information to select, install, and operate. -Easy control after initial set up.	-Expensive to purchase -30% retention rate on the water, requires 900.8 liters and hour to produce 315 liters. -Treat water near ocean then bring back product to camp. -Maybe too large for camp demands
Emergency Portable Desalination Watermaker Model: SW150	$ 6,850.00; or 4.181.205.75 colones	40.823 Kg; 56 cm L, 48 cm W, and 41 cm H.	-23.7 liters per hour, or 575 liters per day. -Only requires 68.13 liters an hour -Lightweight and easily portable. -Has an additional filter option for only $680 or 415,068 colones which improves the system by lowering salt content and auto adjust the pH. -Treats salt water -Membranes last approximately 2 years.	-30% retention rate -Max capacity of 45,000 ppm NaCl feed water (avg. ocean water is 35,000 ppm) -Without the filter upgrade, a lot of pressure on cartridge filters. -Water needs to be treated at the ocean. -Not quite the demand of potable water required per

				day.

Table 15: Chart displaying pros and cons as well as specifications for water treatment/purification products

4.4 Rainwater Harvesting

4.4.1 Strength Testing

In order for our rain harvesting system that connects between two tents to be applicable, we had to test the strength of the tent pole. Our design is based off the idea that two tents would be set up close enough together to connect the gutter tarp material as shown in the previous figure, and direct the rainwater into a connected barrel system. We need to know how much weight these poles can withstand in case there is ever a block in flow water flow.

For our test, we used the exact size and material as the poles that would be used during an emergency situation. We started by measuring the length of the pole and found it to be 118, 11/16 inches. To find the break of strength at the weakest point of the pole, we would need to apply a point weight exactly in the middle of the pole. So, by dividing the length by two, we found the center to be 59.343 inches. By applying weight at this point, the maximum bending point of the weakest part of the beam could be found. Each end of the pole was then secured by cinder blocks, to simulate the joints that the pole would normally be attached to. The next step of prep was to attach a clip to the marked center so that we can apply weights. Using a nylon rope, we would attach 45 pound plates until the pole could no longer support the weight.

Figure 16: Process of lifting the heavy weights, required 3 people to help and a block support.

The first weight added to the system was 2, 45 pound weights. The weights hung about 3 and a half feet from where the pole was positioned. After applying this load, the pole showed no deformation. The process for adding loads required us to fully lift the already applied loaded rope off of the clip, and then add another desired load. Since there was no deformation, we felt confident in adding 2 more 45 pound weights. With the help of three people, we were able to lift 180 pounds onto the clip to test. At this point, the pole showed a slight deformation, but still was fully capable of handling the point load.

Figure 17: Slight deformation when 180 pound load applied to the weakest point of pole.

However, because of the slight deformation, we decided to add one 45 pound plate at a time to have a more accurate estimate of the max load that can be supported. When the applied load reached 225 pounds, the pole bent faintly more than it had at 180. The weight was not enough to affect the structural support. Our last weight added to the beam was a final 45 pound plate, creating a total of 270 pounds. At this point, we slid the weights down the rope so that they were approximately 5 feet away from the clip. When this final weight was added, the beam bent to a point that compromised the structural integrity of the tent, and lowered the weights all the way to the ground. So the maximum weight we can expect the tent to be able to hold is 225 pounds.

Figure 18: The bending point of our system occurred with a a weight of 270 pounds.

4.4.2 Water Volume capacity

Our model is based off of the fact that the tarp is connected to two separate tents. That means that the weight can be distributed to two beams rather than one. This doubles our maximum weight from 225 to 450 pounds. The conversion from pounds to gallons is:

1 pound of water = 0.12 gallons of water

450 pounds of water x (0.12 gallons of water/1 pound of water)≈ 54 gallons at a time

The maximum amount of water that can be held in our tarp system at one time is 54 gallons. The next step is to convert gallons into cubic feet to determine the largest volume our system can cover without compromising its structural integrity. The conversion from gallons to cubic feet is:

1 gallon of water = 0.133681 cubic feet

54 gallons of water x(0.133681 cubic feet/ 1 gallon of water)≈ 7.21875 cubic feet

This means that the cubic volume of the funnel should not exceed 7.21875 cubic feet.This should not be an issue when developing this system because the water would most likely overflow on the top of the structure before reaching this volume. This calculation is to acknowledge the limits of the system and ensure that the tents are not put under too much force.

4.4.3 Water Capturing Technical Insight

The Bomberos of Costa Rica set up emergency camps in a variety of environments which sometimes offer different resources. These environments could be located in mountainous areas, tropical jungles, and close to the ocean; it could also be during the dry or wet season of Costa Rica. With the potential to collect 18% of annual rainfall that falls on a catchment area such as a roof, the team thought it would be ideal to install a gutter system for the wet season. A surface with a size of 7x12 meters can average about 600 gallons of water in 1 hour of moderate rainfall. Currently, the Bomberos use 6x12m tents for their dormitories which means that they have the potential to collect hundreds of gallons of water in medium rainfall with an adequate water capture system. From this, the team designed potential rainwater harvesting systems that allows water to be collected and reused for consumption.

Currently the Bomberos have a gutter system that consists of a tarp-like material that connects to the edge of two adjacent tents. This method has previously served as a system that redirects rainwater from the tents themselves in order to avoid any floods. This practice results in a significant loss of water that could be collected for other activities in the camp such as showering. The team's design allows for the current gutter system to be implemented while ensuring the runoff water is collected and stored for further use. As shown in the figures below, a series of blue barrel bins ($80/48.718 colones each) are placed underneath the gutter allowing for runoff to be collected and flow through the separate containers until they are all filled with water. At the end of each bin is a spout through which the water can be extracted. Depending on the circumstances and how many of these blue barrel bins along with the attachments are available, the bomberos can place different sets of these barrels on opposite sides of the gutter.

In addition, the main barrel where the water first enters will have a simple screen filter attached to the top in order to provide initial separation of the large sediments from the water. It is important for large particles to be sifted out of the mixture early on in the process in order to make the following purification processes easier. The figure below presents how the screen is attached to the barrel.

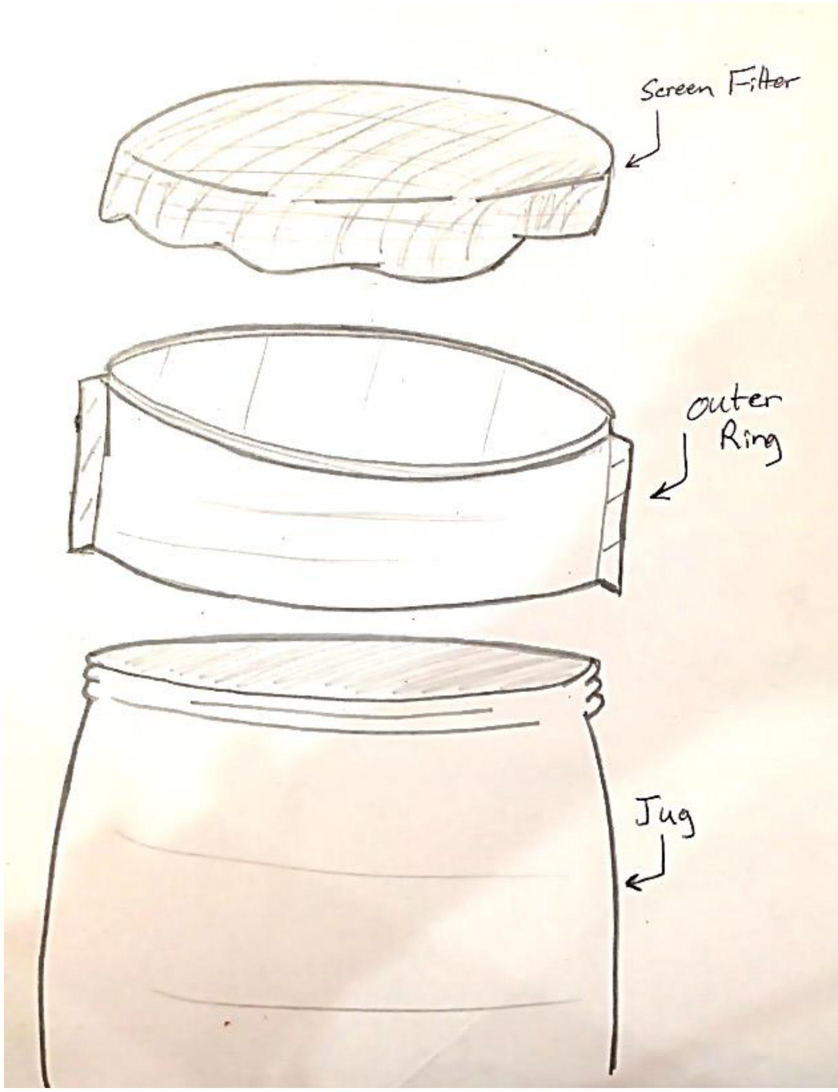


Figure 19: Exploded View of the Screen Filter Assembly

A screen would lay over the top of the barrel and be held in place by a metal ring that fits over the edge of the barrel.

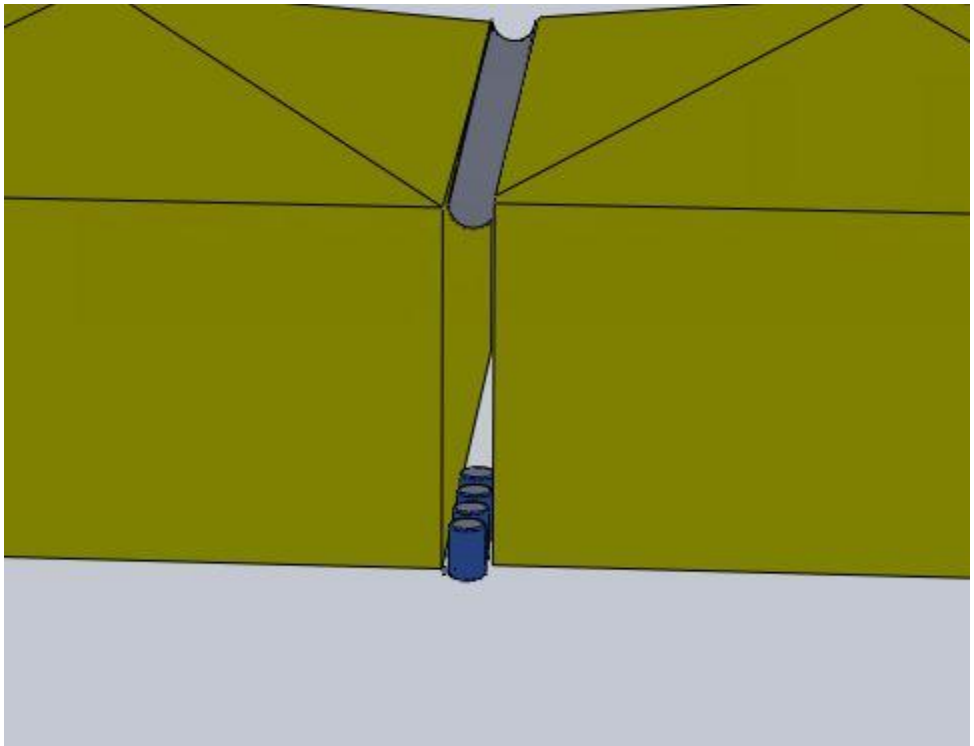


Figure 20: Overhead View of the Proposed Collection Design

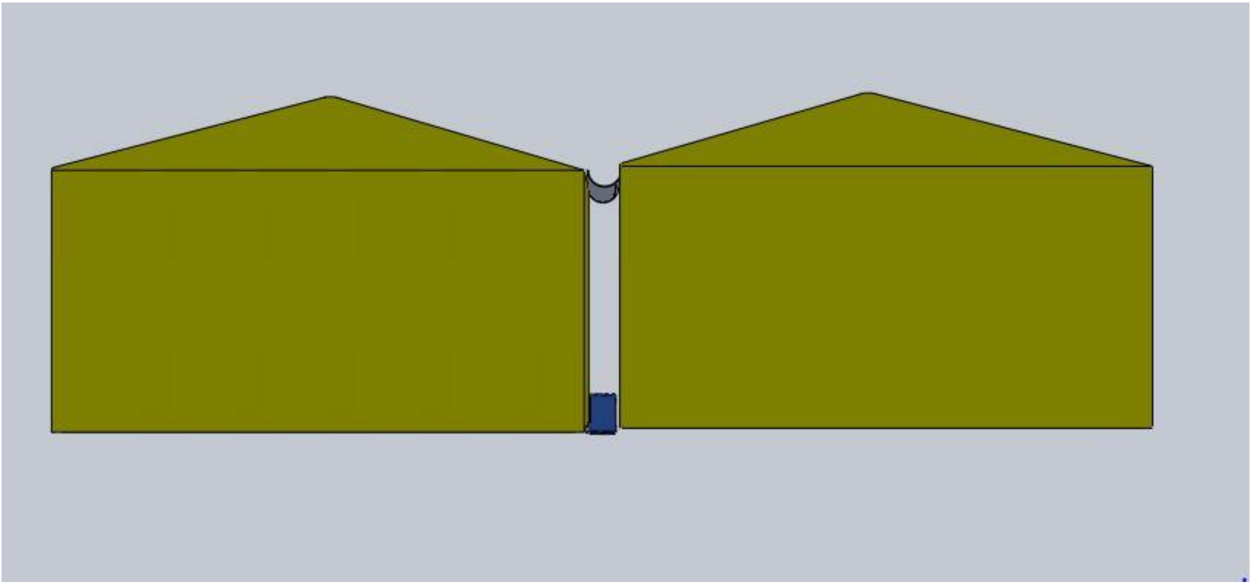


Figure 21: Front View of the Proposed Collection Design

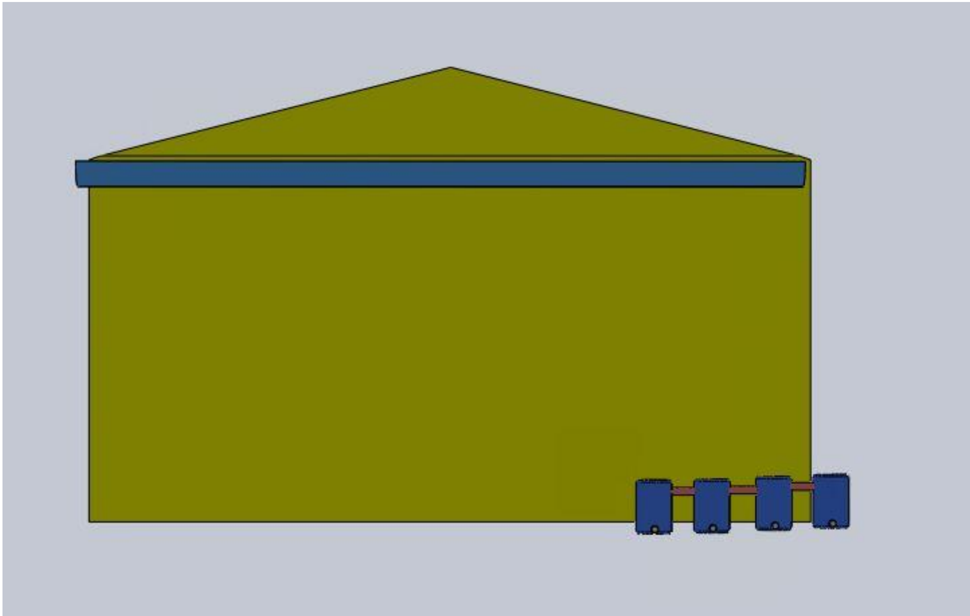


Figure 22: Section View of the Proposed Collection Design

As seen in the images above, the blue barrels are in place at the same level and linked through connector pipes. This is done in order to distribute the collected rainwater from the closest barrel all the way down to the furthest one and prevents water from being wasted. The system of rain harvesting mentioned above works for environments where tents are adjacent and close to one another; However, not all the tents are able to be placed directly next to each other as shown in the figures above. Occasionally, the Bomberos set up camps in a mountainous region that may require tents to be placed apart from one another. From this, we configured a design that would allow the tents to still have gutters. The following images depict this design:

Figure 23: The Gutter Hook Attachment

These gutter hooks are designed to fit over the 1.5in poles that hold up the tent. They would be made out of a lightweight metal such as aluminum or a plastic material in order to ensure there is not too much weight concentrated on the outer edges of the tent. They are small and compact allowing for quick and easy setup and take down in an emergency situation. A piece of PVC cut in half forms a gutter that can slide through the hooks for extra stability. PVC piping usually costs around 2-3 dollars per 0.3m.

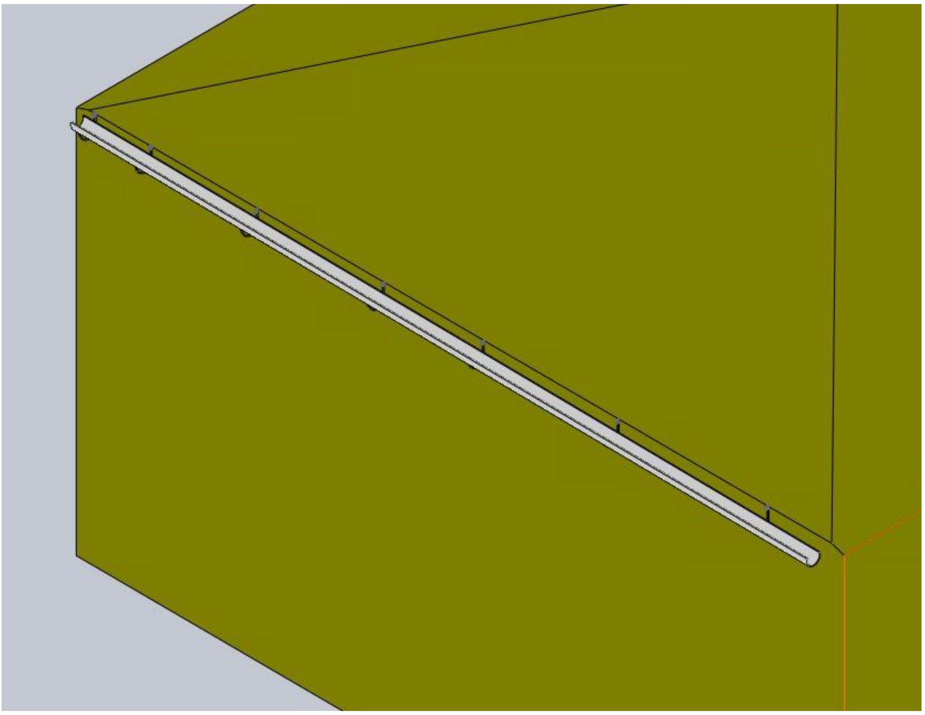


Figure 24: Showing the PVC Pipe in Place

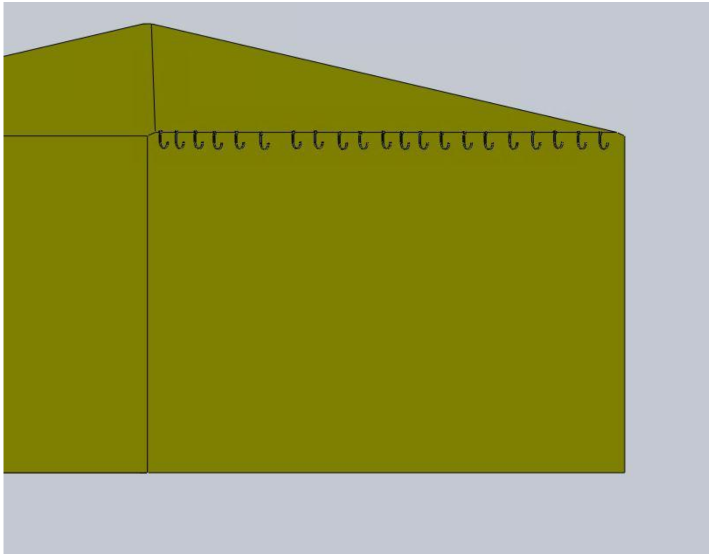


Figure 25: Showing the Hooks in Place

The figure above shows the configuration of the gutter hooks when attached to the edge of the roof in a series. At each of the four corners of the tent would be a collection bin for catching all the falling water that flows off the end of each gutter. Another optional bin collection system would be the previously mentioned configuration where each bin is placed adjacent to one another linked through connector pipes. Possible scenarios could call for using this arrangement rather than placing four bins in each corner. For example, if the land is not level in one corner, then it would be safer to align the bins alongside one level strip of land. It may also be more convenient to keep all the collection bins close to one another in order to avoid having to periodically check all four corners of the tent. However, it all depends on the scenario and the preferences of the bomberos.

4.4.4 Determining Potential Rainfall Collection

In order to provide more insight into the amount of rainwater that can potentially be collected in a certain area, we researched and developed a simple calculation that takes into account the surface area of the tent's roofs and the weather conditions present at the time.

The largest tents at the camps are for bedrooms, so for this example we used the dimensions of its roofs. However, this calculation can be done with any surface area as long as the length and width are known. Given that for every 1 inch of rain (0.0254m) and 1,000 square feet (92.903 meters squared) of solid surface, approximately 620 gallons (2346.96 Liters) of water can be collected (Calculate Rainwater Harvesting Potential, (n.d.)). From this information, we are able to conclude that 25.26 Liters can be captured per meter squared:

The bedroom tents have dimensions 6x12m

L = 12m

W = 6m

To find m^2, multiply the L*W

$12*6 = 72m^2$

From here, setting up the equation: $72m^2 * \frac{25.26L}{m^2} = 1818.72$ L

This means that for every 0.0254m of rain, 1818.72L of water can be collected from a surface of 6x12m.

However, we wanted to know roughly how much rainwater falls per day during the wet season in order to get an idea of how much could be collected at the camp.

Figure 26: Map Showing Distribution of Average Yearly Rainfall in Costa Rica (Costa Rica Guide. (n.d.))

As shown, the east and south receive the most rain while the northwest stays the driest. In the central part of Costa Rica where a high of 240 inches (6m) or more of rain falls yearly, that is roughly .016m of rainfall per day (Costa Rica Guide. (n.d.)). Given that 1818.72L of rain can be collected from every 0.0254m of rainfall for a 6x12m tent:

$$\frac{.016m}{day} * \frac{1818.72L}{0.0254m} = 1145.6L \text{ of water/day}$$

That is 1145.6L of water that would go uncollected if a water harvesting system was not in place. This is just another source of water that we believe would save the Bomberos large amounts of time and money needed to go out and collect water from the other sources they utilize.

4.5 Infiltration Trench

In order to properly understand how water will drain and filter when being discharged into a waste water disposal pit, it was necessary to provide a method to test the infiltration rate of the soil in the field. An infiltration rate is the measurement of how fast a volume of water is absorbed into an area of soil, which is commonly measured in centimeters per minute. To start the process of selecting an infiltration test method, we looked at the document provided by the AyA, Tanques Sépticos: Conceptos Teóricos Base Y Aplicaciones (Septic Tanks: Theoretical Concepts and Applications). This document provided most of the background knowledge needed to understand what a successful infiltration rate test looked like, along with the testing method the AyA conducts.

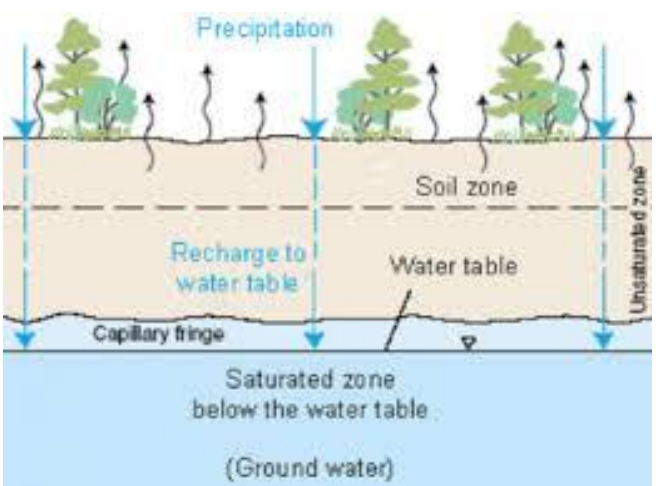


Figure 27: Groundwater leaching diagram (Sundermeier, 2018)

4.5.1 AYA Test Method

This document started by highlighting the need to understand the area that the waste water pit would be located in. This meant surveying the land for potential paths of pollution, (rivers, underground water wells, downhill slopes), where leaching of water could occur. It advised that all water sources are at least 30 meters away and uphill from the proposed pit location. Once the ideal positioning is set it is important to have a rough estimate how how much land is needed. Each test has a radius of accuracy of 30 meters and if a larger area is needed, multiple test may be conducted to ensure accuracy.

The test started by digging what is referred to as the “drawer”. It is essential a rectangular hole that is dug to allow the person performing the test to be able to take readings. The size specified for the drawer is 80 cm by 80 cm and the depth is a function of how deep the waste water pit will be. To determine the depth of the drawer, first determine how deep the test will take place, then subtract 30 cm from this depth to determine the depth. Once the drawer is constructed, the test hole can be made. They are typically cylinders with a radius of 10 centimeters and a depth of 30 centimeters. The digging of the hole applies friction to walls of the hole, which changes its properties, so it is recommended that the tester scours the sides of the hole with a knife and then removes the excess dirt from the bottom of the hole. The next step is to place 5 centimeters of course sand at the bottom of the hole to mimic natural conditions. After this the saturation process may begin. This entails filling the hole with water, preferably the night before testing. This allows the test to give an infiltration rate at a highly saturated state which is highly realistic. After the saturation process, the actual testing can begin. Simple place a measuring stick (or some other method for measuring distance) at the bottom of the hole and refill the hole with water. Take an initial height reading. After 30 minutes take another reading, and repeat this process every 30 minutes for 4 hours. Throughout the 4 hours ensure the water level does not drop below 15 cm above the course sand level. Once complete, compute the average reading. Divide the 30 minute increment by the average result to achieve an infiltration rate in minutes per centimeters. From here the infiltration rate can be converted to the desired unit (Tanques Septico).

4.5.2 Double Ring Infiltration Test

Another testing method that is often used is the double ring test. It runs very similarly to the testing procedures outlined and prefered by the AYA. The primary difference between the two test is that this method uses two cylindrical rings of different sized opposed to a using a testing hole. Once the location of testing is established and the proper soil depth and saturation achieved, both rings are driven into the ground so that the smaller ring sits inside the larger one, which will be approximately 8 inches into the soil. When driving the rings it is important to not overly disrupt the soil, to ensure accurate results. From here water may be poured into both rings and just as in the previous test, record the water level at a specified time interval only for the internal ring, refilling the rings as needed. Once testing is complete, an infiltration rate may be calculated. What makes this testing method highly accurate, is the double ring design. It prevents the water from infiltrating the soil in a conical flow (Graham). The outer ring's water is also infiltrating into the soil, which forces the inner ring's water to maintain a cylindrical flow through the soil, preserving the shape of the internal ring.

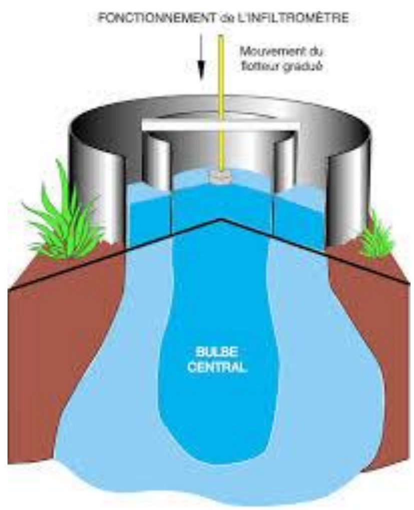


Figure 28: Double Ring Test section view (Double Ring Infiltration)

4.5.3 Turf-Tec Infiltration Test

Originally intended as a golf course management tool, the Turf-tec infiltration meter has the capability of automatically determining the infiltration rate of a soil and is now used by many professional engineering firms throughout the United States. They system is design using the same principles as the double ring test method. The base of the tester has to different sized rings which are filled with water, and after 15 minutes, an infiltration reading is given. Just as in the previous test, to get a proper reading the test must be performed at the intended depth of the trench. It is recommended that the test is run twice with the second reading being used to ensure accuracy of the test (IN2-W).

Figure 29: The Turf-tec Infiltration Measuring Device (IN2-W)

4.5.4 Comparisons

Testing Method	Benefits	Drawbacks
AYA method	Prefered method of AYA, highly accurate, inexpensive	Must be performed over the course of 2 days, highly detailed, highly level of monitoring required
Double Ring	Accurate, inexpensive	Time consuming, high level of monitoring required, error can occur if rings are not properly installed
Turf Tec	Fastest method (roughly 1 hour),	Cost $525

	automatic with no monitoring required , accurate	

Table 16: Chart comparing benefits and drawbacks on different infiltration test methods

All the methods mentioned above have the potential to perform the task of determining infiltration rates with a strong degree of accuracy, but it there are other factors that the Bomberos have outlined that are essential in the selection process. The first and most prevalent factor is that the system has to be simple. This is needed because the Bomberos and rescuers on site have a variety of task that they must perform to construct the camp and the simple the testing method, the more time and energy they will be able to spend on the other tasks. The simplicity factor ties directly into the time factor. Since these camps may only last a week on the shorter end, construction time needs to be completed as early as possible, so the two day test method recommended by the AYA may not be ideal. The final factor to consider will be the cost. Since the Turf-tec infiltration tester is the only method with any substantial price tag, it will be judged accordingly.

4.6 Disposal Trench

Working off the current method of digging a ditch for wastewater disposal, we have decided to set standards on the design, creating an infiltration trench. Infiltration trench work by using the soils natural properties to filter water as it flows downward. The pores between soil particles effectively trap pollutants, leading to clean safe water as it flows and reaches underground aquifers or surface level water sources. Although these trench systems are very effective at removing pollutants, they have a limited capacities based on their size. Because of this we established a field method for the sizing of these trenches, using the guidelines giving from the AYA, the Tanques Sépticos: Conceptos Teóricos Base Y Aplicaciones, and from the Bomberos.

The AyA along with the Septic Tank manual, provided all of the calculations necessary to go from infiltration rate to the required dimensions of the trench. Using infiltration rate and the provided table in the manual the Velocity (Vp) of infiltration can be determined. Next the flow of water into the trench must be calculated. This is simple done by estimating all the water that is used in the camp and subtracting the water that is consumed or lossed to achieve a effluent flow (Q). From here all calculations can be done.

Vp	Velocity of infiltration
Q	Flow of effluent
Ai	Area of infiltration
Ac	Safety factored Area
W	width
D	depth
Fp	Safety Factor
Pe	Effective perimeter
Lz	Length
Ls	Spacing between trenches

$$Ai = Q \div Vp$$
$$Ac = Ai \times Fp$$
$$Pe = .77(W + 56 + 2 \times D)/(W + 16)$$
$$Lz \ = Ai/Pe$$
$$Ls = Ac/Lz$$

In the calculations, both the depth and width are based upon the site specific needs. For these parameters, the Bomberos stated that the trench should not be deeper than sixty centimeters. This provided us with enough information to create several tables of sizes based on their desired depth. Additionally, the trench designs are adaptable based on the conditions of the campsite. Not all camps are going to house 150 people, so flows must be adjusted, resulting in larger trenches. Another possibility is that the soil may become increasingly difficult to dig, so we must have adjustments for a smaller depth. The goal was to develop multiple design parameters to account for the changing needs of the bomberos.

4.7 Alternatives

As is the case with most things, the infiltration trench is not a perfect solution to their wastewater disposal needs. In the wet season, flooding throughout the region is very common. This raises the water table above the surface, making digging extremely difficult and effectively renders the trenches useless. The flooding will allow the waste to flow in all directions, leading to high levels of pollution in receiving bodies of water. The proper soaps will greatly reduce the pollution factor, but damage will still be done, therefore alternative methods must be investigated. Some potential solutions include treating the effluent water to achieve the standards of waste entering a receiving body of water or the storage of water until it can be properly discharged. An additional factor that may cause the infiltration trench to fail, is the presence of clay soils that do not allow for proper infiltration flow. If this is the case, the area can effectively be treated as if there was flooding, or alternative locations can be sought out.

4.8 Hygiene Practices

4.8.1 Designing of a Human Waste program

According to the Oxfam Public Health Engineering group, an estimated 50 percent of all deaths in emergency situations occur as a result of poor hygiene practices. One of the biggest transmitters of disease from poor hygiene is diarrhea. Although ensuring clean water can reduce childhood diarrhea rate be roughly 15-20 percent, the largest reduction comes from safe excreta disposal at 36 percent. This is why safe and sanitary excreta disposal is essential to ensuring these camps stay sanitary.

4.8.2 Designing of a Human Waste program

The current system implemented by the Bomberos involves using a simple pit latrine system with basic guidelines that help to prevent the leaching of human waste into local water supplies by ensuring the pits are at least twenty meters from a source of water. This is an important aspect, but there are additional measure that must be taken into consideration. The Oxfam Public Health group devised a list of initial essential questions that can used to enact a plan. These questioned are designed for both emergency circumstances and for starting systems for underdeveloped civilizations, therefore only the applicable questioned will be taken into consideration, meaning ones that pertain to groups of rescuers with facilities ready to be erected. These applicable questions include:

1. What is the estimated population and what is the population density?
2. Is there sufficient space for defecation fields, pit latrines etc?
3. What is the topography and drainage patterns of the area?
4. What is the depth and permeability of the soil, and can it be dug easily by hand?
5. What is the level of the groundwater table?

Other key questions primarily involved long term solutions and the public perception of the project. Both these categories can be dismissed due to the typical duration that the camps operate and the fact these camps operate less like a community and more like a base for operations. To answer these questions there are five things to consider: coverage, positioning, depth of pits, accumulation rates, and location.

Coverage refers to maximum amount of people per latrine. According to the Sphere Standard (an international group committed to setting humanitarian standards) there should be one pit latrine for every twenty people residing in the camp or one hundred people per three and a half meters of trench style latrine, with a depth of one meter and a width of thirty centimeters. This prevents large volumes of faeces from accumulating, which can leads higher disease rates, as well as needing more time to fully degrade in the soil. Positioning refers to the latrines layout within the camp. The latrines should be within a range of thirty to one hundred meters away from camp dwellings. This allows for easy access, but does not account for potential smell and leaching to affect dwellings. The depth of the pit must be at a very minimum of one and a half meters above the water table so that there is sufficient space between the excrement and water so that the degradation process can occur. In the case of extremely rocky soil, ensure there is at least two meter between the base of the trench and the water table. The location aspect has to deal with the geographical features surrounding the camp. It is crucial to investigate a potential site for sources of groundwater, above water sources and perform a basic elevation check. Once identified, the location of the trenches can be established, they must be at least thirty meter away from any source of water and additionally be located downhill, if there is significant elevation change (Barnstable, 2000). With these basic question answered and the five main priorities highlighted, the sizingP of the latrine can be done.

The sizing process for a trench style latrine is an incredibly simple one, relying on only three variables: the effective life of the pit in years (N), the average number of daily users (P), And the sludge accumulation rate measured in m^3 / yr (R). From here a volume (V) can be calculated.

$$V = N \times P \times R$$

This will specify a volume, leaving the specific dimensions up to the person actually constructing the latrine (UNHCR). The depths and widths should be based upon the water table and how easily the soil can be dug. It is ideal that no singular trench exceeds six meters in length, so multiple trenches may be dug to make up for this, as long as a spacing of 2 meters between trenches is achieved. Typically the front space in front of the trench will be used as the area of defecation while the back will hold the dug up soil (Human Waste Disposal).

Figure 30: Showing the construction of a trench (Excreta Management, (n.d.))

In addition to determining a proper trench size, there are additional hygiene measures that can be taken into consideration. The simplest and most important way to ensure hygiene standards are maintained is to cover excrement with soil after every use, this helps to reduce smell and will help prevent flies from breeding. Furthermore, the Eng. Álvaro Araya García informed us that the use of calcium oxide also provides an option to prevent the presence of flies and mosquitoes. Ash may be used in combination with soil to further reduce the smell and breeding. Although insecticides are effective at keeping flies out of trenches, they affect the decomposition process, making it take longer and therefore should not be used. If the fly problem is extreme, it is acceptable to use the insecticides along the rim of the trench. In tandem with the methods mentioned above for fly reduction and odor control, lids should be provided for the best possible result. The lids may either be completely removed for access to the latrines, or they can have small openings for excrement, that can then be covered (Barnstable, 2000). Additional provisions such as hand washing are already provided by the Bomberos, in the form of portable sinks, which is an efficient hand washing procedure.

Upon leaving a site, all trenches must be completely covered with soil and clearly marked, as reopening a trench may lead to the spread of disease, the attraction of flies and additional leaching due to surface exposure (OXFAM).

4.8.3 Special Circumstances and Alternatives

In some areas, it is expected to find soil condition that do not match the specification needs for a basic trench latrine. One common circumstance that make make construction difficult, is the presence of loose soil that will not maintain shape. The United Nations High Commissioner for Refugees recommends constructing a wood perimeter, that is placed inside the top portion of the trench to ensure proper stability. The added stability should prevent degradation of the trench and provide added support for lids and users.

In the case of the soil having a high water table, there are two alternatives that can be considered, one method would be to construct a raised latrine. This involves using either wood or brick to build a frame around the trench, and then filling it with dirt so that a depth of one and a half meters above the water table may be achieved. Another solution, that is also the most effective method in flooded areas, is the use of chemical toilets, commonly referred to as port-o-potties (UNHCR).

When flooding in not a problem, but the area is still subject to rain, stormwater trenches should surround the trenches. These trenches should be at least thirty centimeters deep and backfilled with coarse gravel when supplies are available. This will prevent human waste from washing away and polluting surrounding water sources.

4.8.4 Waste Water Disposal

Currently in the typical set up for an emergency camp, there are large ditches dug so that waste water may be collected. These ditches are a set size with limited design considerations taken into account. They are essentially an extremely basic infiltration trench, using the soil to treat the effluent waste. Although soil can be an effective medium for filtration, if done improperly discharging waste water directly to soil can lead to pollutants entering waterways and underground aqueducts, which in turn damages ecosystems, along with sources of drinking water.

4.9 Potential pollutants

There are a wide variety of substances that are known to be toxic or harmful to the environment, many of which are identical to what is harmful if found in drinking water. Nutrients like nitrogen and phosphorus, heavy metals, hydrocarbons, organic matter, microbes and endocrine disruptors are the major contaminants found wastewater. In wastewater that has not been treated nitrogen can commonly be found in the form of ammonia, as well as in the form of organic nitrogen. Phosphorus is found in the form of an ion or as part of an organically bonded molecule. When these nutrients over saturate bodies of water, it is called eutrophication. This eutrophication, leads to algae blooms exceeding typical levels. The heightened levels of algae deplete dissolved oxygen concentrations in the receiving body of water. The lowering of dissolved oxygen can lead to death for almost all aquatic life. In addition, it makes the water even more difficult to decontaminate for drinking or for the rejuvenation of the aquatic ecosystem (Akpor. p3). The eutrophication process was a major concern in design of a wastewater disposal system, because the nutrients that lead to it are readily found in common detergents and soaps, including the ones currently used at the camp.

When hydrocarbons enter waterways, similarly to above normal nutrient levels, aquatic life is disrupted and ecosystems are thrown out of equilibrium. Hydrocarbons are a highly toxic chemical. Its presence in water can cause significant damage to livers, kidneys and other essential systems, such as the nervous, respiratory, circulatory, immune, reproductive, sensory and endocrine systems, leading to ecological destruction once it enters waterways in the form of wastewater effluent. This is another potential problem cause by the use of soaps and detergents in these camps.

Heavy metals such as zinc, copper and iron are vital in biochemical processes, but can become detrimental if concentrations get to high. Heavy metals have tendency to bind with proteins, effectively inactivating them and preventing them from functioning properly. This leads to major health concerns if the receiving body of water is used as s source of drinking water. Fortunately for the scope of this project, the main sources of suspended metals come from industrial waste (Akpor, p5). Therefore it is unlikely to be present in the effluent water produced by the Bomberos.

Similarly to the heavy metals, organic matter and microorganisms are unlikely to be present in the waste water due to the current practices implemented by the Bomberos in the emergency camps. From discussions with Norman Chang (President of the Bomberos Academy), it is apparent that neither potential pollutant could enter the effluent. They take great care in ensuring that all solid waste from kitchen actives are removed before cleaning of dishes and stations are done, ensuring there is primarily soap and water leaving through the kitchens water waste pipe.

4.9.1 Sources of Pollution

The primary source of pollutants in a typical camp will come from hygiene products. Products that are currently used in these camps include dishwasher soap, kitchen degreaser, powdered soap, liquid dish soap, chlorine and disinfectants. As mentioned in the section above, typical soaps contain many of the harmful substances that degrade ecosystems. Since some of these harmful aspects of soap are not essential to the cleaning process, it is important to highlight the aspects that must be present to clean at an efficient rate, so that a middle ground may be achieved. Soaps cleans by acting as a surfactant and emulsifier. This means that they act as an agent to allow the water disperse through a usually immiscible substance. Allowing for oils and dirt to be removed. This works because soap molecules have both a hydrophilic and a hydrophobic side, which are made from they hydrocarbon chains (Helmenstine pg2). Since this cannot be eliminated from soap completely it was essential to find soaps that had a good degree of biodegradability. In addition, soaps with lower levels of nitrogen and phosphorus will be favoured, to limit algae growth.

One soap and detergent manufacture that was investigated was FLOREX, a Costa Rican company specializing in environmentally clean products and manufacturing practices. Their products were a recommendation by Professor Clemons. “FLOREX products are biodegradable and free of toxins and contaminants”. To be able to place the biodegradable stamp on their products, they have obtain a sixty percent biodegradability factor over 28 days (Cr.F, 2018). When compared to the current products used by the Bomberos, many of which have safety data sheets that explicitly say their product is not to be discharged into the environment in any forms, there is clear improvement to their environmental impact, which will greatly show their commitment to the Blue Flag sustainability program.

Figure 31: Showing products by FLOREX (Cr.F, 2018)

4.10 Water Quality Tests

In order to provide the right quality of potable water and ensure wastewater discharged to a receiving body of water meets standards, the Bomberos must count with the appropriate testing kits that will allow them to measure the adequate parameters. Testing kits must have the ability to measure parameters to the most sophisticated limits so that the Bomberos can confirm that the water quality is in accordance with the the strictest limits shown in Table 12 and Table 13.

Additionally, these water test kits can provide evidence on whether or not a water treatment system or product delivers results that comply with local or international water standards. Being able to perform testing of water quality also adds a security factor. Testing kits could also be use to test the the water collected through rainwater harvesting system and assign use of the water measured depending on the results.

Through personal communication with a local water testing kit company, we were able to gain more knowledge on the different tests for wastewater and potable water quality. Parameters for the disposal of wastewater to a receiving body of water such as biochemical oxygen demand (BOD) and suspended solids are complicated analysis that requires special laboratory personnel and equipment that cannot be taken out to an encampment; furthermore, the analysis of BOD requires 6 days of testing. Other parameters such as chemical oxygen demand (COD), grease/oils, potential hydrogen (pH), temperature, sedimentable solids, active substances to methylene blue (detergents) are analysis that could be carried out on the field with ease and do not require of trained personnel. Additionally, all potable water parameters; fecal coliform, e-coli, color, turbidity, smell, taste, temperature, potential hydrogen (pH), conductivity and residual chlorine, are also analysis that can be performed at the emergency camps.

5.0 Deliverables/Proposed Items

5.1 The P&G Water Purifier

We as well as the Bomberos expressed general interest in the P&G powder packets due to its simple design, which is a major requirement for the product to possess. The figure below provides more insight on the process of purifying water using this product and what that looks like.

Figure 32: The Full Process of Purifying Dirty Water (P&G Demonstration, (n.d.))

This figure shows how clear of an indication is given when the water is ready to be run through a screen filter after the sediment particles have settled. The process requires no electrical power, only 5 minutes of manual work to stir the mixture. Its ability to eliminate bacteria, viruses and other contaminants existent in water decreases the incidence of diarrhea by 90% (Summa, 2016). Each packet is capable of remaining stable for three years from the date of manufacture. At only .11kg per packet, they would take up little space and allow for easy transportation, which is one of the primary concerns of the Bomberos as well. In an emergency situation, they want to keep things as organized as possible and that requires having small, compact devices that can be stored easily. These packets would not be substantial for providing water for the entire camp, rather, it would be better to use it in combination with another water purifying product/system or for personal use in case of an emergency need for potable water.

The company that manufactures these packets, Proctor and Gamble, is a globally recognized company that has provided relief in a number of countries across the globe. The Purifier of Water packets are available worldwide. Since 1995, P&G has been active in Costa Rica with an office located in San Jose itself (P&G- Do Something That Matters, (n.d.)). In turn, P&G employs more than 1,500 people in Costa Rica including its sales and service center.

Proctor and Gamble is involved in the "Clean Water for Children" Program through a private partnership with the AyA, who we had the opportunity to work with and is a reputable organization in Costa Rica. In fact, for every 240 pack of the P&G Purifier of Water packets purchased through retail channels, 2,400L worth of clean drinking water is donated to the Children Safe Drinking Water Program in order to support efforts related to disaster relief. This is just another step that P&G is taking to improve care that comes with disaster relief, which the Bomberos may be interested in knowing about.

5.2 Water treatment System

Of all the systems requiring filtration we recommended in the analysis and findings section of this paper, it is our proposal to utilize the Emergency Portable Desalination Watermaker Model: SW150. Although this model is not made locally, it is a product that can be purchased from the USA and delivered to Costa Rica. After initial purchase, the model comes with all necessary information required to select, specify, and operate the system. The system can convert Seawater, well water, or surface water to potable drinking water within seconds. With training, anyone would be able to do repairs on this system and would no longer need assistance from the USA company unless a major problem occured. The Desalination SW150 also includes a Sediment & Carbon Cartridge Filter housing 5 micron, an Aquajet Variable Frequency Feed Pump, a Reverse Osmosis High Pressure Pump, a Membrane Element, Pressure Vessels, a UV200-12VDC Ultraviolet System (featuring a low cost replaceable lamp), and piping.

Figure 33: The AMPAC Desalination SW150

Although only 30 % of the feed water is recoverable, this system can still produce 575 liters per day. For 150 people, that would fit the criteria for potable drinking water per day in the camp fit to the standards of the World Health Organization. Although it would not solve the entirety of the camps water needs, drinking water is the most crucial aspect of keeping the rescuers hydrated and healthy. This new system paired with the chlorine system the Bomberos currently use would cut down the necessity of replacing filters and manual work. The maintenance of this device varies for each part of the machine, but the membranes can last two years without need for maintenance, and the filters and reverse osmosis portion can last approximately 6 month without need of maintenance.

Due to the nature of the machine, this system would need to be run near the ocean, and the product would need to be shipped back to where the camp is set up. The primary reason for this would be the 70% product of seawater that is not treated in this system, needs to be returned into the ocean. High NaCl concentrations can easily off-balance ecosystems and will not be treated by the water disposal system. Also, for a product of 575 liters per day, you would need to have a feed flow of 1,635 liters. That is an excess amount of water to transport to treat at the camp and only receive 30% as potable product.

This four filtered system is priced at $6,800.00 or 4.000.000 colones. With the option of an additional Multimedia GAC-Anthracite-Silica Quartz Pre-filter that lessens the stress on the filter cartridges, balances the pH, and results in less than .1 ppm NaCl for $680.00 or 415,068.60 colones more. This device is extremely portable with a weight of 40.823 Kg and the dimensions being 56 cm in length, 48 cm in width, and 41 cm in height.

When discussing our potential solutions with the Bomberos, they stressed the importance of figuring out a way to utilize the oceans for water supply during emergency situations due to the 800 miles of cost in the country. In certain situations, there might not be treatable water close enough to the emergency, which could prevent them from being able to set up a camp for the rescuers. When we displayed this product and the price point, it seemed to fit the parameters of a new system they were looking for. The specifications of the system were impressive compared to the cost and size.

5.3 Wastewater disposal plan

As discussed with members of the Bomberos, the final waste water disposal plan is one that is does not add significant time and energy into the trench construction process, additionally the method selected works off of current site practices to limit the knowledge gape other potential solutions may entail. The selected method is a two step system, that involves determining the infiltration rate of the soil through the means of testing or using previously know values, and then sizing the trench based off of site specific parameters.

We recommend that the Turf-Tec Infiltration meter is used to determine infiltration rates when testing is necessary, using the method previously specified in the Analysis and Finding section of this report. Although this method is the only one with any start up cost, $525, it is cost efficient due to its time saving capabilities. If the infiltration rate is already known or if the soil type can be easily identified, the infiltration test may be superseded, and the sizing of the infiltration trench process may begin.

In order to determine the trench size three parameters must be defined, the population of the camp, the soil's infiltration rate or type, and the season. The infiltration rates range from 0.016 to 0.5 cm/min. The season only have to possible input, being rainy or dry season. Using this, the trench dimensions may be determined using the chart shown below.

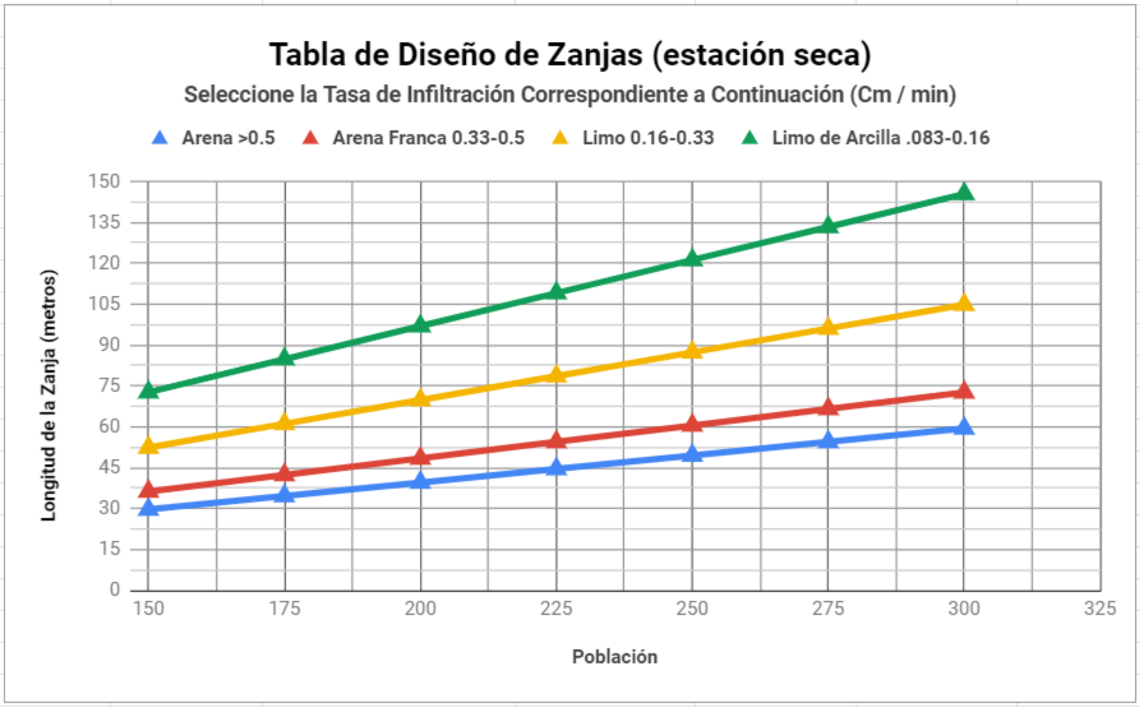


Figure 34: Trench dimensions during dry season

In addition to chart shown, there are two other tables that allow for on site adaptations based upon the workability of the soil. These additional tables have different depth and width factored in, to provide the person doing the constructing options based on what they believe is the most efficient method.

5.4 Human Waste Disposal

The recommended method for disposing of human waste, similarly to the infiltration trench build off of what the Bomberos currently enact during emergencies, using trench style latrine. We recommend estimating the volume of the trench using the formula specified in the Finding and Analysis section under Hygiene. The trench should be designed based on the specifications outlined below:

1. Within 30 to 100 meters of camp dwellings
2. Have a bottom at least 1.5 meters above the water table
3. Be at least 30 meters away from all water source and downhill
4. Use 0.13 $M^3/person/year$ as the sludge accumulation value

5. Do not have lengths exceeding 6 meters
6. Cover excrement with soil and ash after every use
7. Provide a lid that can easily be removed
8. Provide a handwashing station (the current one is suitable)
9. Completely cover latrines upon leaving a site
10. Clearly mark old latrines to prevent them from being reopened

Following these ten parameters and guidelines will provide the emergency camps with a sanitary an effective means of disposing human waste, that is also in compliance with emergency laws

5.5 Water Harvesting

With regard to the proposed water harvesting systems that the team designed, we wanted to get multiple opinions along the way in order to critique what we developed. As for the gutter clip design, it requires a large piece of PVC piping to be cut in half and transported to the camps.

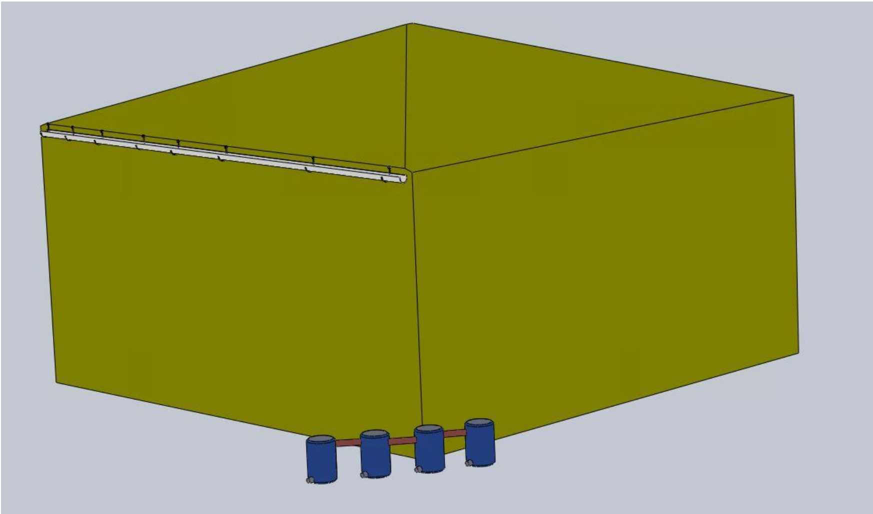


Figure 35: PVC Gutter In Place

As shown in the above image, the gutter is made up of one long piece of PVC piping that goes along the entire outer edge of the tent. Even though the piping could potentially be split into smaller portions for transportation purposes, then assembled later on at the camp, the previous design that utilizes that gutter material attached between two adjacent tents would be a more cost effective and compact option as the gutter clips would also have to be manufactured.

After speaking with different Bomberos personnel to collect their opinions on our proposed designs, the general attitude toward the PVC piping design was that it could work, however they already have material on hand to use for attaching gutters between tents. It was also brought to our attention that in an emergency situation, a rescuer may not have the time/energy needed to connect all the clips needed to install the PVC gutter. Although, that is the reason why we redesigned the gutter to be PVC piping so it can be structurally stable while using less hooks. In addition, we received feedback stating that whichever collection system ends up being utilized, it would most likely be more cost/time efficient to implement it only during the wet season as that is when the rainwater can be taken advantage of the most.

The figure below shows the gutter system currently in place.

Figure 36 : Tent Gutter System In Action (Custom Tents, (n.d.))

The water is channeled down both adjacent tents and from there flows into the collection bins. This method for water collection serves the needs of the Bomberos quite well as it does not take up much space; it actually creates more space at the camp by placing the tents closer to each other. It is also quick and easy to set up and take down when need be.

5.6 Cost Analysis

To illustrate the feasibility our proposed water treatment solutions, we performed a 20 year cost analysis. For this, we ran two different simulations, one based on the multistep filtration systems and the other based on the single phase products, the P&G packet and the Jerry Can. For both, we assumed an emergency would take place two times a year and would last an average of 2.5 weeks, based off of typical emergency rates. For the systems, a usage rate was determined to be 24 hours per day to simulate maximum usage and the products had a usage of 1800 Liters per day which accounts for all potable water used with drinking quality standards in one day. With these parameters we calculated the initial cost, maintenance costs and a 20 year cost.

Products	Four Step Filtration System	Desalinator	JerryCan	P&G Packets
Initial Cost	$239	NA	$261	$100 for 240
Replacement Cost/ Year	$167	$250	$4/ 500L	$2,700
Production Rate/Day	5520 L	575 L	1800 L	10 L/Packet
20 year cost ($)	3,383	$12,534	10,629	$54,000
20 year cost (colones)	2,057,371.00	7,622,552.00	6,504,772.00	32,840,100.00

Table 17: Cost analysis table of top four products/systems

The cost for each product is a relatively conservative estimated, except for the P&G Packets, due to their intended usage. They will primarily be used in small quantities when needed as an emergency source of water at the beginning of camp construction. Although their cost is still relatively high, their ease of use and ability to produce water promptly makes up for the drawback.

6.0 Future Recommendations

Throughout our research, we discovered that there are a lot more aspects that go into developing a treatment system than we initially figured. As time went on, we slowly discovered the concerns that go into analyzing particular details about the process as a whole from disposal laws to researching the most practical products for filtration. We created recommendations for future IQP teams who plan to do similar work/continue the work that we have done thus far. We aim to provide more insight on what to ensure one does throughout the project in order to gain the necessary understanding on how to go about it along with what we may have done differently.

There are multiple factors we think would be helpful information for developing the most efficient and long lasting solutions possible. For example, one of the first questions our group came up with was, how much water is being used for each activity, and does it need to be portable. We wanted to break up the sections of water use for showering, cooking, drinking water, laundry, the medical tent, and cleaning the dishes. The only information we were able to gather was the amount of potable water used during the emergency, and according to the cooks, 40-45 % of the water was used in the kitchen. Without more detail, we were unable to track the approximate demand of water for the rest of the activities. This knowledge would have given us a better understanding of the layout and where the water needing treatment was coming from.

We recommend the next time the camp is set up to keep track of water usage and delivery the best you can. We understand during an emergency things can be hectic, but water meters and awareness could lead to an improved system that makes the camp function simpler. This could also lead to more opportunities to recycle the wastewater by properly knowing the level of contaminants in each outflow.

Given more time, there are many aspects of our project that require further research. Costa Rica has a wide range of climates, landscapes, soils, and biodiversity. Not all of these factors reflect the products and work that we have done. Our recommendations are based off of the averages in the country and focused on dealing with the wet and dry season. However, there are zones in this country that our recommendations will work, but do not as efficiently and environmentally conscious as they could be. Having a better understanding of the whole country and mapping out the different soils, weather patterns, and water sources could greatly improve the ability to prepare and have the necessary equipment to handle the emergency in that region. That way the need for a desalination system could be analyzed versus the ability to use a freshwater source and not risk losing 70% of the feed water in the process. Additionally, gearing solutions toward a particular natural disaster will allow for further optimization.

Another aspect that could be expanded on would be the harmful effects of drinking water not being properly treated in Costa Rica specifically. We touched upon the effects of Hepatitis A in Costa Rica due to the dumping of feces and sewage into rivers. Knowing the effects on the environment when correct procedures are not followed is valuable to ensuring the importance of safe practices. There are many diseases, contaminants, and viruses local to Costa Rica that need to be further investigated when selecting the correct system.

7.0 Conclusion

With the goal in mind of researching and designing a water treatment system for a camp of 150 people while remaining in compliance with local and international laws, the team was able to generate an end product that satisfies the concerns of a number of different perspectives presented by the stakeholders. We created potential designs and models for a harvesting system that could utilize the wet season to the advantage of the Bomberos and their high demands for water at these camps. We developed a method for waste disposal as well as water filtration based on our understanding of the needs and wants of the Bomberos emergency personnel. Our proposed system required a few products to be implemented whose prices and specifications are presented in Findings/Analysis. We wanted to provide more of an overview of recommended products in order to give the Bomberos more options to choose from based on individual cost, effectiveness and portability. A specific budget was not specified, however, if the Bomberos budget allows for a wider range of purchases to be made, the academy would be able to expand their inventory with more of our suggested products in order to potentially improve the pace at which functions are carried out at the camp. Said products include water harvesting systems which we developed a product of our own that could be made and used, water treatment systems based on information we received from Professor Clemens at the National University, water treatment products such as the emergency water desalination systems and the P&G Purifier of Water Packets, water test kits intended to detect the condition of the water being used, and ultimately a product intended for measuring infiltration rate of dirty water into the trenches. Provided in the paper is also a written calculation that can be used to determine the velocity of infiltration based on site-specific dimensions.

With the recommended products and methods for water treatment and disposal, the Bomberos will be able to carry out their necessary functions in an emergency situation more effectively and efficiently. We found that the Bomberos staff was very open to working with us and were more than happy to provide an outsider's perspective to our proposals. Many of the recommended products were referred to us in part by the feedback and concerns presented to us by the stakeholders along the way. These interactions proved to be helpful in our research and continued modifications of our submissions. In the end, it all depends on the preferences of the Bomberos and what they desire to work with, and we hope we were able to provide sufficient options for the staff to choose from as well as helpful insight for future teams undertaking similar projects.

References

Amamos lo que hacemos,cuidamos lo que usted ama. (n.d.). Retrieved November 18, 2018, from https://www.bomberos.go.cr/

AGUA. AGUA POTABLE. DEFINICIONES Y REQUISITOS GENERALES. (n.d.). [PDF]. Retrieved from https://www.idaan.gob.pa/wp-content/uploads/2016/04/copanit_23_395reglamentotecnico_99.pdf

"AGUA. DESCARGA DE EFLUENTES LÍQUIDOS DIRECTAMENTE A CUERPOS Y MASAS DE AGUA SUPERFICIALES Y SUBTERRÁNEAS". (2000). [PDF]. Retrieved from https://www.corpqualityservices.com/cqs%20normas/CQS%20-%20COPANIT%2035-2000%20Descarga%20a%20Cuerpos%20y%20Masas%20de%20Agua%20Superficiales%20y%20Subterraneas.pdf

ARIES FilterWorks, "GAC Filters." *ARIES FilterWorks*, Resin Tech, 2018, ariesfilterworks.com/products/af-series/coconut-shell-gac-kdf-55.

MINSAL. (2015, November). *Propuesta de reglamento técnico salvadoreño para el diseño y construcción de sistemas de tratamiento de aguas residuales de tipo ordinario para zona rural*[PDF]. Retrieved from https://www.paho.org/els/index.php?option=com_docman&view=download&alias=1709-borrador-tratamiento-aguas-residuales-v-6&Itemid=292

Bastable, A. (2000). GUIDELINES FOR EXCRETA DISPOSAL IN EMERGENCIES. Retrieved February 21, 2019, from http://ec.europa.eu/echo/files/evaluation/watsan2005/annex_files/OXFAM/OXF7 - Guidelines for exceta disposal in emergencies.PDF

Black, J. M. (2012, April 08). The Situation with Public Water services in Costa Rica. Retrieved November 15, 2018, from https://news.co.cr/public-water-services-in-costa-rica/4853/

Blomquist, W., M. Ballestero, A. Bhat, and K.E. Kemper, 2007. Costa Rica: Tárcoles Basin. *In*: *Integrated River Management through Decentralization*, K.E. Kemper, W. Blomquist, and A. Dinar (Editors). Springer, New York City, New York, pp. 149–165. https://doi.org/10.1007/978-3-540-28355-3_8.

Calculate Rainwater Harvesting Potential & Area Needed To Absorb It, (n.d.). Retrieved from www.surfrider.org/coastal-blog/entry/calculate-rainwater-harvesting-potential-area-needed-to-absorb-it.

CAPRE. (n.d.). *Normas de Calidad del Agua Para Consumo Humano*[PDF]. Retrieved from http://www.bvsde.paho.org/bvsacg/e/normas2/Norma-Nic.pdf

Carbon Block Technology "Carbon Block Water Filter Buyer's Guide." *Carbon Block Technology*, CBT Tech, www.carbonblocktech.com/carbon-filter-buyer-guide/.

Caribbean hurricane season ends with floods in Costa Rica and Panama. (2002, December 12). Retrieved from http://www.ifrc.org/en/news-and-media/news-stories/americas/costa-rica/caribbean-hurricane-season-ends-with-floods-in-costa-rica-and-panama/

Chacón, K. (2017, October 20). Más de 1.200 personas afectadas por problemas de agua potable en Caribe. Retrieved from https://www.nacion.com/sucesos/desastres/mas-de-1-200-personas-afectadas-por-problemas-de-agua-potable-en-caribe/26H22CSRLFHT3FRTIAV5653ZAA/story/

Chawla, P. (n.d.). What is Water Harvesting. Retrieved November 17, 2018, from http://www.rainwaterharvesting.org/whatiswh.htm

"Chlorine Chemistry." *Cobalt Chloride: Colorful Moisture Detector*, 1994, chlorine.americanchemistry.com/Chlorine/Wastewater-Chlorination/.

Centers for Disease Control and Prevention "Disinfection with Chlorine | Public Water Systems | Drinking Water | Healthy Water | CDC." *Centers for Disease Control and Prevention*, Centers for

Climate Change Knowledge Portal. (n.d.). Retrieved November 15, 2018, from http://sdwebx.worldbank.org/climateportal/index.cfm?page=country_historical_climate&ThisCCode=CRI

Cohen, R. (2008). *Listening to the voices of the displaced: Lessons learned*. Brookings: Bern Project on International Displacement.

Comisión Nacional de Emergencias. (n.d.). Retrieved from https://www.cne.go.cr/

Costa Rica | Disaster Assistance. (n.d.). Retrieved November 21, 2018, from https://www.usaid.gov/crisis/costa_rica

Costa Rica and Key Environmental Issues: Water , Waste, Mining, and Climate Change. (n.d.). Retrieved November 30, 2018, from http://blogs.nelson.wisc.edu/es112-304-3/water/

Costa Rica Guide. (n.d.). Costa Rica Rainy Season & Rainfall Map. Retrieved from https://costa-rica-guide.com/travel/weather/weather-map-rainfall/

Cr, F. (2018, September 25). Home. Retrieved from https://florexcr.com/?lang=en

Custom Tents | Custom Canopy Tents. (n.d.). Retrieved from https://www.tentcraft.com/tent-accessories/weather-protection

Dictionary.com. (n.d.). Retrieved February 18, 2019, from https://www.dictionary.com/

"Disaster Relief." *American Red Cross*, 2018, www.redcross.org/about-us/our-work/disaster-relief.html.

Disease Control and Prevention, 2015, www.cdc.gov/healthywater/drinking/public/chlorine-disinfection.html.

DOUBLE RING INFILTROMETER - 09.04. (n.d.). Retrieved from https://www.sdec-france.com/double-ring-infiltrometer-for-soil-science.html

Excreta Management: Chapter 5. (n.d.). Retrieved from http://www.ben-harvey.org/UNHCR/WASH-Manual/Wiki/index.php/Chapter_5

Graham, Jay p, 2013, Pit Latrines and Their Impacts on Groundwater Quality: A Systematic Review, https://ehp.niehs.nih.gov/doi/pdf/10.1289/ehp.1206028

Glossary of Chemical Terms. (n.d.). Retrieved February 18, 2019, from https://www.hach.com/chemGlossary#e

Government of Western Australia. "Ultraviolet Disinfection of Drinking Water." *WA Health, Government of Western Australia*, Department of Public Health, 2016, ww2.health.wa.gov.au/Articles/U_Z/Ultraviolet-disinfection-of-drinking-water.

Guzmán-Arias, I. and J.C. Calvo-Alvarado, 2013. Planning and Development of Costa Rica Water Resources: Current Status and Perspectives. *Tecnología en Marcha* 26:52–63. https://doi.org/10.18845/tm.v26i4.1583.

Home Made DIY Grey Water System Water Recycling. (2017, November 08). Retrieved from https://www.instructables.com/id/Home-made-DIY-Grey-water-system-water-recycling/

Human Waste Disposal. (n.d.). Retrieved February 21, 2019, from https://gmch.gov.in/

Hund S.V., Allen D.M., Morillas L., Johnson M.S. **Groundwater recharge indicator as tool for decision makers to increase socio-hydrological resilience to seasonal drought** Journal of Hydrology, Volume 563, 2018

IN2-W - Turf-Tec Infiltrometer. (n.d.). Retrieved January 28, 2019, from http://store.turf-tec.com/IN2lit.html

Kuzdas, C., & Yglesias, M. (2013, December). Governing Costa Rica's Water Resources. Retrieved November 19, 2018, from https://www.thesolutionsjournal.com/article/governing-costa-ricas-water-resources/

LifeSaver JerryCan 10000UF (n.d.). Retrieved from https://iconlifesaver.com/product/lifesaver-jerrycan-10000uf/

Lucas, Jim. "What Is Ultraviolet Light?" *LiveScience*, Purch, 15 Sept. 2017, www.livescience.com/50326-what-is-ultraviolet-light.html

L. Ramírez Barquero, (personal communication, January 14, 2019)

Mejía, F. (2010). *NATIONAL WATER LAW LAW 620 AND ENABLING REGULATIONS FOR THE NATIONAL WATER LAW DECREE 44 - 2010* (Nicaragua, National Water Authority). Complejo Gráfico TMC.

Nathanson, J. A., & Ambulkar, A. (2018, November 29). Wastewater treatment. Retrieved from https://www.britannica.com/technology/wastewater-treatment/Primary-treatment#ref593251

National Research Council. "Small and Decentralized Systems for Wastewater Treatment and Reuse--Kara L. Nelson." National Research Council. 2005. *Water Conservation, Reuse, and*

Neb Guide. "Reverse Osmosis." *Neb Guide*, University of Nebraska, 2014, http://extensionpublications.unl.edu/assets/html/g1490/build/g1490.htm

Normas de Calidad del Agua para Consumo Humano. (n.d.). [PDF]. Retrieved from http://biblioteca.enacal.com.ni/bibliotec/Libros/pdf/CAPRE_Normas_Regional.pdf

N. Chang Diaz, (personal communication, December 11, 2018)

Office Of U.S. Foreign Disaster Assistance. (n.d.). Retrieved November 25, 2018, from https://cr.usembassy.gov/embassy/sanjose/sections-offices/ofda/

OnlineTips. (2017). Sediment trap. Retrieved November 13, 2018, from http://www.onlinetips.org/sediment-trap/

PAHO. (n.d.). *DISEÑO Y CONSTRUCCIÓN DE PROTOTIPO DE FOSA SÉPTICA PARA EL TRATAMIENTO Y DISPOSICIÓN FINAL DE AGUAS RESIDUALES EN VIVIENDAS DE ZONAS RURALES*[PDF]. Retrieved from https://www.paho.org/els/index.php?option=com_docman&view=download&category_slug=presentationes&alias=157-presentacion-fosa-septica-ops&Itemid=364

PEN (Programa Estado de la Nación), 2016. Vigésimo Segundo Informe Estado de la Nación en Desarrollo Humano Sostenible. Programa Estado de la Nación, San José, Costa Rica.
Esquivel-Hernández, Germain, . "Climate and Water Conflicts Coevolution from Tropical Development and Hydro-Climatic Perspectives: A Case Study of Costa Rica." *JAWRA Journal of the American Water Resources Association*, vol. 54, no. 2, 2017, pp. 451–470., doi:10.1111/1752-1688.12617.

P&G Demonstration Pack (4 packets). (n.d.). Retrieved from https://dayoneresponse.com/store/pg-4-pack/

P&G – Do Something That Matters. (n.d.). Retrieved from https://www.pgcareers.com/location-costa-rica

P&G Packets (12 pack). (n.d.). Retrieved from https://dayoneresponse.com/store/pg-packets-12-pack/

Recycling: Proceedings of an Iranian-American Workshop. Washington, DC: The National Academies Press. doi: 10.17226/11241.

Reed, B., & Reed, B. (2011.). How much water is needed in emergencies (R. Shaw, Ed.). Retrieved November 30, 2018, from https://www.who.int/water_sanitation_health/emergencies/WHO_TN_09_How_much_water_is_needed.pdf

REGLAMENTO EN EL QUE SE ESTABLECEN LAS DISPOSICIONES PARA EL VERTIDO DE AGUAS RESIDUALES. (2017, November 28). Retrieved from http://legislacion.asamblea.gob.ni/normaweb.nsf/9e314815a08d4a6206257265005d21f9/a35cf61591ad2d57062581f30056f9ec?OpenDocument

Reglamento para la calidad del Agua Potable. (2015). [PDF]. Retrieved from http://www.pgrweb.go.cr/scij/Busqueda/Normativa/Normas/nrm_texto_completo.aspx?param1=NRTC&nValor1=1&nValor2=80047&nValor3=101480&strTipM=TC

“Responding to Disasters.” *What Is Vulnerability? - IFRC*, www.ifrc.org/en/what-we-do/disaster-management/responding/.

San Jose, Costa Rica: Annual Weather Averages. (n.d.). Retrieved November 18, 2018, from https://www.holiday-weather.com/san_jose/averages/

Segura-Bonilla, O., 2002. Agenda Ambiental del Agua en Costa Rica. *Revista Geográfica de América Central*, 40(I–II):39–49.

SEPTIC TANK | meaning in the Cambridge English Dictionary. (n.d.). Retrieved February 10, 2019, from https://dictionary.cambridge.org/dictionary/english/septic-tank

Sistema Costarricense de Información Jurídica. (2006, August 09). Retrieved from http://www.pgrweb.go.cr/scij/Busqueda/Normativa/Normas/nrm_texto_completo.aspx?nValor1=1&nValor2=59524&nValor3=83250

Storm Nate: At least 22 dead in Costa Rica, Nicaragua and Honduras. (2017, October 06). Retrieved November 15, 2018, from https://www.bbc.com/news/world-latin-america-41520672

Summa, E. (2016, May 11). P&G Costa Rica lanza proyecto que purifica el agua para beneficiar a familias en zonas de riesgo. Retrieved from http://revistasumma.com/pg-costa-rica-lanza-proyecto-que-purifica-el-agua-para-beneficiar-a-familias-en-zonas-de-riesgo/

Summary of the Clean Water Act. (2018, March 29). Retrieved November 17, 2018, from https://www.epa.gov/laws-regulations/summary-clean-water-act

Sundermeier, A. (2018). Soil Infiltration. Ohio State University. Retrieved February 2, 2019, from https://agcrops.osu.edu/newsletter/corn-newsletter/2018-03/soil-infiltration.

Sustainable Water Supply System for Host Communities and South Sudanese Refugees in White Nile. (n.d.). Retrieved November 15, 2018, from http://sd.one.un.org/content/unct/sudan/en/home/our-stories/sustainable-water-supply-system-for-host-communities-and-south-s.html

Tanques Speticos: Conceptos Teoricos Y Base Aplicaciones (pp. 11-28, Publication). (2008). ELÍAS ROSALES ESCALANTE.

UN. (n.d.). Member States. Retrieved November 30, 2018, from http://www.un.org/en/member-states/index.html#gotoC

United Nations, Water. (2011). *Water Quality*[Policy Brief]. Retrieved November 19, 2018, from file:///C:/Users/smpet/Downloads/waterquality_policybrief.pdf

United States Environmental Protection Agency. (n.d.). *Water Quality Standards Handbook Chapter 3: Water Quality Criteria*(Tech.). doi:https://www.epa.gov/sites/production/files/2014-10/documents/handbook-chapter3.pdf

(UV Dynamics)“ULTRAVIOLET DISINFECTION SYSTEMS Proven, Affordable, Environmentally Friendly.” *Ultraviolet Disinfection Systems - UV Dynamics - FAQ - Frequently Asked Questions*, EPA, 2008, www.uvdynamics.com/faq.htm.

Versa Sea Pak, (n.d.). Retrieved from Pakwww.darley.com/pump-guide/product/versa-sea-pak

Versa Sea Pak 360 Water Treatment System (n.d.). Retrieved from catalog.darleydefense.com/versa-sea-pak-360-water-treatment-system/

Walmart, (n.d.). 4 Stage 10-inch Drinking Water Filter for Sediment, Lead, Iron, Chlorine, Chemicals, and Odors with UV Sterilizer. Retrieved from, https://www.walmart.com/ip/4-Stage-10-inch-Drinking-Water-Filter-for-Sediment-Lead-Iron-Chlorine-Chemicals-and-Odors-with-UV-Sterilizer/107122224

“Water Treatability Database.” *EPA*, Environmental Protection Agency, 5 Feb. 2007, iaspub.epa.gov/tdb/pages/treatment/treatmentOverview.do?treatmentProcessId=-1118142891

Water Recycling Treatment Process. (n.d.). Retrieved November 25, 2018, from http://www.saws.org/Your_water/recycling/centers/treatment.cfm

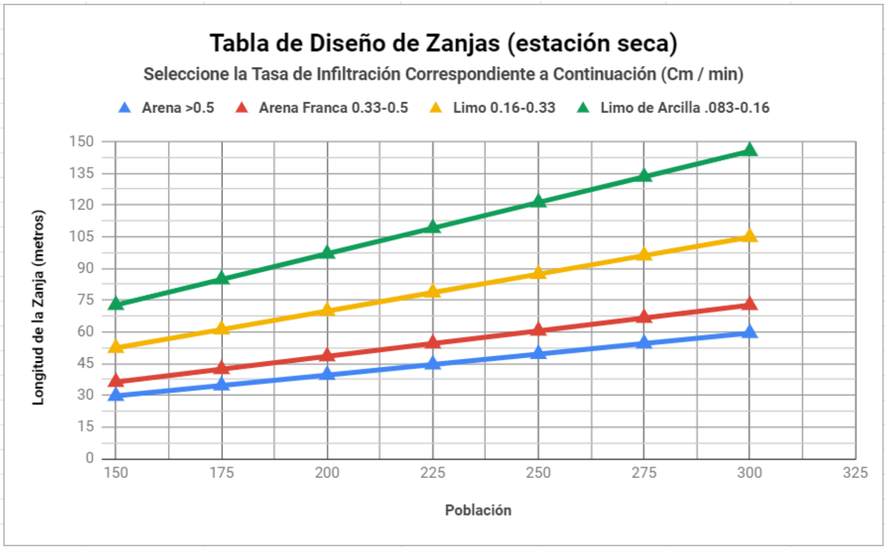
(Weather and Geography) “Costa Rica Weather and Geography.” *Pacific Trade Winds*, Trip Advisor, www.entercostarica.com/travel-guide/weather-and-geography.

WeatherSpark.com. (n.d.). Retrieved November 16, 2018, from https://weatherspark.com/y/15463/Average-Weather-in-San-José-Costa-Rica-Year-Round

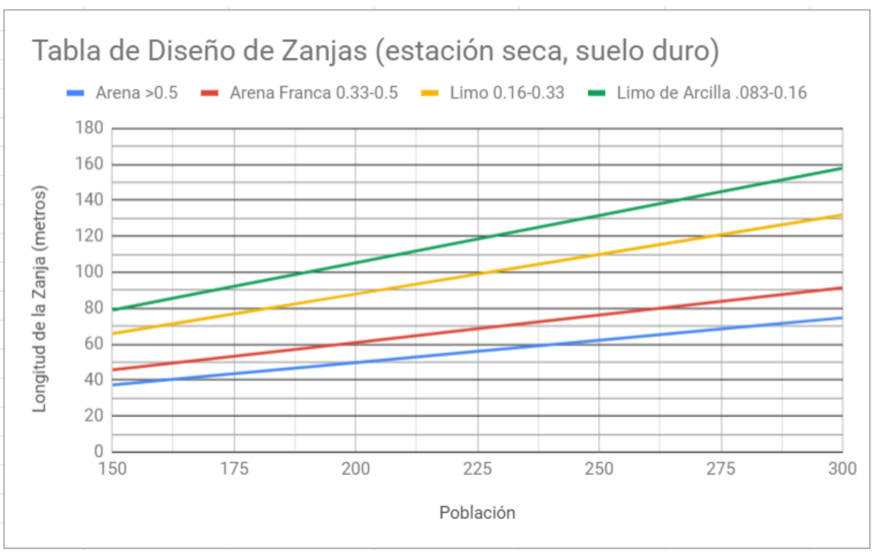
Wendland, Claudia, and Andrea Albold. “Sustainable and Cost-Effective Wastewater Systems.” *Guidance Paper Eng*, WECF, 2010, www.wecf.eu/download/2010/03/guidancepaperengl.pdf.

2018 Edition of the Drinking Water Standards and Health Advisories. (2018). Office of Water U.S. Environmental Protection Agency Washington, DC. Retrieved from https://www.epa.gov/sites/production/files/2018-03/documents/dwtable2018.pdf

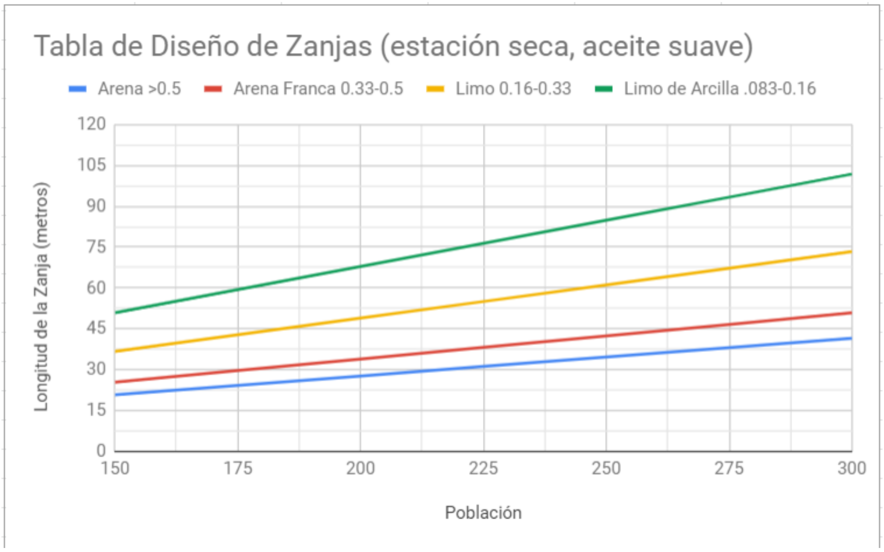
Appendix A: Infiltration Trench Dimension Charts for Different Conditions



Dry Season standard hole



Dry season hard to dig



Dry season Soft soil

Appendix B: Infiltration Trench Design Materials, Procedure and Parameters

Infiltration Trench Design

Materiales necesitados:

1. Medidor de Infiltración Turf-Tec
2. 3 litros de agua

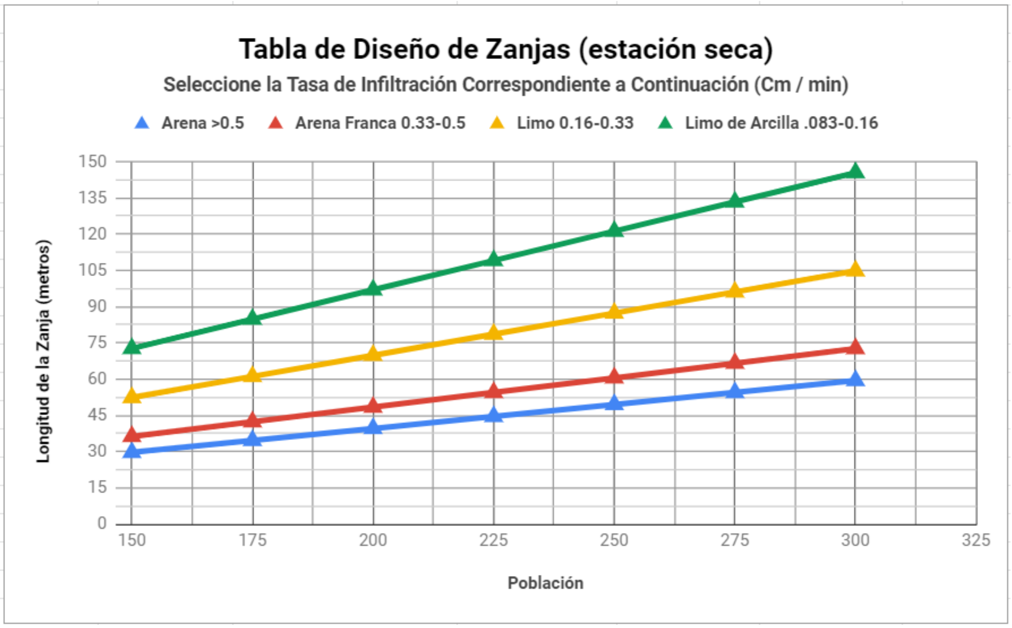
Procedimiento para la prueba de infiltración:

1. Cavar el orificio de prueba a la profundidad deseada de la zanja de infiltración (normalmente a 60 cm de la superficie)
2. Proporcionar una superficie nivelada en el fondo del agujero
3. Empuje el medidor de infiltración Turf-Tec en el suelo en la parte inferior
4. Rellene el anillo de tecnología de césped interior y exterior con agua (no se preocupe por el derrame)
5. Fije el temporizador en la pantalla de turf tec durante 15 minutos
6. Lea la pantalla después de 15 minutos y registre la tasa de infiltración que se muestra

Tamaño de la trinchera

1. Determine el rango de la tasa de infiltración correspondiente en la siguiente tabla

2. Use la charta para determinar la longitud de la zanja necesaria (ancho siempre 50 cm y profundidad siempre 60 cm)
3. Si se necesitan múltiples zanjas, use el espaciado aplicable según la temporada



Design Parameters		
Flow Q= 2700L	0.00003125	m3/s
Depth =	0.6	m
width=	0.5	m

Spacing	
Dry Season	2.1 m
Wet Season	2.6 m

Appendix C: Interview with Dr. Darner Mora Alvarado, Director of the National Water Laboratory of the AyA

Dr. Alvarado was able to give us more insight on what our focuses should be in regards to water as well as potential products to maintain hygiene of the camp. This is how the conversation went:

1. ***Which waters require treatment and which ones don't?***

I recommend the information from: Regulation of Discharge and Reuse of Residual water. There you will find the described differences between grey water, black water and soapy water. Your project is similar to a small community of approximately 30 households. The maximum time knowing before deployment to emergency situation is 2-3 days, but can also be immediately on the spot.

The use of latrines are fine as long there is a final cover at the end. You should leave a signal that there was a latrine there at some point. Depending on the soil, you will find different flow rates. Clay soil drains poorly, and depending on the soil, there will need to be different methodologies for dealing with trench placement.

An easy was of filtration is through soils. In the future I would recommend a mobile treatment plant. (Talks about new document from engineer/architect school with technology to do infiltration tests) This document will help test possible camp locations, and explain how to run soil tests, mainly where the kitchen area will be placed. We would send a few people to test where to place the kitchen, and where the holes for filtration will be. Start one day in the afternoon, make a hole and enter water in it. Then come back the next morning to do some testing. You will be able to find the filtration rate from this testing. Based on how many people will be utilizing this hole, determine the appropriate dimensions. The amount of water they use should be registered, for more accurate dimension calculations. Of the total water use, 80% of water use needs to be filtered before dumping into environment.

In the kitchen, the water should go through a grease trap before going anywhere else. When you are done eating dispose of the solids before rinsing down the drain. Keep the grease and oil in glass bottles, until you've use it to the brim. Save the oil and dispose of it differently, it needs its own disposal method.

2. Water parameters for activities like: drinking, showering, cooking, washing dishes, laundry, cleaning places

You only need potable water for drinking and cooking, the rest doesn't need to be potable. If you take a look into the Third document(Regulations of water quality for consumption). With a chlorination kit and some filters you can make potable water. Look at the quality of water and determine which kits to buy using the document. This is how to categorize the water in each kit. It is important to keep calibrating the equipment.

3. What hygiene products do you recommend (soaps, etc.)?

Products with high grade biodegradability are worth it to invest in. Looking at the market, many are biodegradable, but we should look for the highest level. It will be good to compare how this soap is beneficial to the environment to other soaps. It would be beneficial to run a test for each product by asking yourself: What do you leave behind with each soap?

4. Recommendations for recipients or storage systems for collecting water (material it should be made out of)

Everyone out there has permission from the law to be there. He recommends to buy the reinforced ones.

5. An average water consumption a person should have/ day (20 liters WHO standard)

Compare with real data and demand, if you need more water you need to go get it.

6. Recommendation for water filters

Depending on the location, a rocky and sandy terrain will filter easily. However, a clay terrain will need bigger trenches.

7. Explain current way of water disposal. What quality should water have before dumping it and where/how should it be disposed?

In the kitchen, drain it in the trench and set up a grease trap from the kitchen filter, to catch any cooking oils and make sure they aren't released into the environment. The shower and sink don't need a grease catcher because it wouldn't catch the soap scum. Without a trap, the importance of biodegradable soap becomes a major factor.

However, when mixing soap with solid residues, the grease trap would catch soap and solids. But because a shower is all liquid, it would not be able to catch it.

8. In national emergency case scenarios, what actions to follow do you have and does the organization or could the organization provide some sort of aid to the Bomberos?

In an emergency, the AyA will help with pressure in hydrants, or when there are normal citizens in need, they will also help provide places to stay for citizens and bomberos.
If inside the city the bomberos can request help with water pressure from the AyA.

9. Any possible system they might know of that can treat salt water?

Salt water systems are expensive, use a lot of energy, and there needs to be a lot of pressure from the membrane. Disposing of the salt also requires bringing it back to the ocean because it is so specific. Salt concentration can affect an ecosystem, so they need to be sure to dispose of it where it won't be harmful, or affect the areas salt concentration. For personal use or mountain climbers, a lifeStraw method where you can suck in water and treat it, is a potential solution for drinking water. The method is similar to a french press system, and only retains about 30 percent of the water run through it. More for personal use, but you should consult to see if there are any systems for 150 people.

10. What are the human waste disposal standards?

Latrines should be a good solution as long as its covered and has the correct dimensions. (REUBEN: Right now they have a fiberglass tarp) Everyday in the morning, throw in calcium oxide that should take care of insects, and when the rescuers leave there should be another layer applied. How often to apply depends on the environment and usage.

11. Can toilet paper go in trenches?

It's better to have a system for the toilet paper, like a trash can, and take it out every so often, if not, it can go into trenches. It is very important to avoid human contact with waste residues, and take consideration about the environment. A spot for toilet paper causing bad odors and mosquitoes, best way is to then dispose into the trench.

Bomberos eat a lot of fruit, and it should be buried in its own trench, the trench doesn't need dimensions, the waste just needs to be buried. If insects are a problem, add calcium oxide. Solid organic waste of food disposal, to avoid animal contact cover the trench after disposal.

In a lot of cases, pee and solid waste creates really bad odors, if you separate them, it helps disperse the smell. Have two separate latrines to help with the smell, one for urine and one for solid excreta.

12. Do you know any biodegradable bag that takes about 2 weeks to disintegrate?

These bags are not feasible in this situation. In Haiti for example, they dispose of needs, and somebody needs to come through and collect it. This is a solution when there is nowhere to dig the trenches.

Appendix D: Interview with Ruepert Clemens, Professor of Environmental Chemistry and Health at the Universidad de Costa Rica

From here, we were able to get more of a grasp on Central American water quality conditions as well as further our leads on potential hygiene solutions from an interview with Ruepert Clemens, a professor at the Universidad Nacional de Costa Rica whose focus is in environmental chemistry and health. Professor Clemens offered us some introductory comments on the current issues regarding water quality in Central America.

There are high arsenic levels in some parts of Costa Rica.

Some areas of Costa Rica have worse water quality than others. In the Caribbean area, most people have their own wells not with their own septic tank which leads to people drinking their own waste.

1. ***Which waters require treatment and which ones don't?***

Drinking water, preparing food, when washing dishes needs better quality water than the rest of the water needed at the camp. Take a look at how people in the desert take action to save water

Almost all rivers in Costa Rica are contaminated (because of the mind set that they have enough potable water) changing mind set now. The top tier of quality should be drinking water quality. In Costa Rican law, the only two criteria you have to measure are chloroform and e coli. There is a problem with Hepatitis A that comes from water, especially river water. A lot of the problem is the mindset of the people who are responsible for the contamination of the drinking water. Being mindful of what we put into our water will greatly impact the amount that will be available for drinking.

2. What hygiene products do you recommend (soaps, etc.)?

Professor Clemens recommended almond oil or other products that are biodegradable. Products like these can be found at Auto Mercado. Maybe reach out to Florex, a Central American owned company which offers environmentally friendly cleaning products.

3. Recommendations for recipients or storage systems for collecting water (material it should be made out of)?

Depends of the type of water you introduce. There should be two storage systems: One for drinking water and another for all other types of water. Drinking water should be held paramount. These systems should have tanks in which the water will always be flowing to help control the bacteria that can grow from still water.

4. How often should water stored be tested?

Water should be stored for a week until it is tested again (it also depends on the source of the water.

5. Recommendation for water filters?

Reverse osmosis would be better for washing dishes than for drinking water. Ultraviolet water purification is the most effective method for disinfecting bacteria from the water. UV rays penetrate harmful pathogens in water and destroy illness-causing microorganisms by attacking their DNA. Nano filters are another option for water purification due to the amount of time that UV filters take (last 6 months)

6. Explain current way of water disposal. What quality should water have before dumping it and where/how should it be disposed?

Try to use cleaning materials that are biodegradable, for example soap for showering, cleaning dishes and even sunscreen. Florex, Bioland (personal care products)

7. Do you know of a portable water testing kit?

HACH is a company that is responsible for selling products that can be used for water quality testing: https://latam.hach.com/

Included is a multi-parameter kit that can be used according to our specific demands:
https://www.hach.com/test-kits/multi-parameter-kits/family?productCategoryId=35547009712
Kits are capable of testing for levels of conductivity, ph, chlorine, nitrate.
In general kits last for a long time. But specific kits for e-coli don't last that long.

8. Human waste disposal standard?

It is recommended to implement banos secos, a waste disposal practice that does not use water.

9. What treatment should the recipient tank have in order to make sure the tanks are not infected?

Clean with chloride.

10. Suggestion for a chlorination system that is portable and easy to set up

Whatever system ends up being used, ideally it should eliminate suspended materials first then add chlorine. Filters can also be the source of contamination.
Ideal order of filtration would be Particle → Carbon → Chlorine→ UV Filter.

It would be a good idea to have a kit that measure chlorine
Ideal level: .3, .4 ppm

Appendix E: Interview with Members of USCO

For the USCO, we planned to ask questions directed at the cooks due to the amount of importance they have to the overall health and moral of the camp. These questions/answers helped us acquire a better idea of the amount of water used in the kitchen. We began by asking the cooking staff how they begin the process of preparing meal. They begin by disinfecting the metal plates they use to prepare and serve the food with a dry towel.

1. ***How much water is used per day to cook?***

On average, 40-45% of the camp's water is used for cooking. There are five meals served throughout the day. For one day, 15 jugs (18.9L each) are used just for cooking.

2. ***Are the plates washed by hand or by dishwasher?***

The dishes are washed by hand.

3. ***How much time do you take to wash dishes and how often do you do so?***

Dishes are washed three times a day for two hours each one. The system they use is everyone lines up and washes their dishes for 15-30 seconds each using water from the area. Same goes for lunch and dinner.

4. ***What would you change about the current system?***

A large water dispenser to make access easier. Right now, water jugs have to be manually lifted and dispensed where need be by the kitchen staff themselves.

5. ***What is your current water source?***

Water is pulled from hydrants, bottled water as well as that bladder water (1500 gallons) which is used for dishwashing.

6. ***How often do you wash your hands when cooking?***

Consistently with water, soap and gel. People have a personal rag for hand cleaning.

7. ***How often is the kitchen thoroughly cleaned (stove, oven, refrigerators, cabinets, etc.)?***

Most of the equipment is cleaned at the camp itself. They disinfect everything before each meal, as well as at night everything is cleaned. Cleaning usually takes an hour each.

8. ***What other activities in the kitchen require water?***

Washing the kitchen floor. There are plans in the future to buy flooring for the kitchen. In addition, there is an ice machine that consumes electricity and water along with coolers with water all day. Each cooler has two water drums; two for breakfast, lunch and dinner.

9. ***What is the hardest part about living in the camps/what is something you would change about it?***

Drainage is an issue due to the amount of rain that comes in. When it rains, it floods the camp.

10. ***How much water do you drink daily?***

900-1300mL is the typical amount. It also depends on the temperature and the time of day. For example, when temperatures are colder, more hot coffee is consumed.

Below is a chart of the different activities performed at the camps per day as well as frequency and duration of each.

Brushing teeth	5 times	30 seconds - 1 min
Showering	2 times	3-5 minutes
Washing clothes	For Hurricane Otto, they had a constant washing station running as well as portable dryers. They used minimum clothes for a week.	Always with a machine, not by hand.
Washing latrines	They have a logistics unit who decides on that	

11. Does the medical tent store a certain amount of water? If so, how much?

Yes, they have 12 bottles (650mL) used to take medication.