WATER DEMAND IN CERRO PATACON

TOPOGRAPHICAL TEAM

Interactive Qualifying Project Report completed in partial fulfillment

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Submitted to:

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ABSTRACT

Water access and availability is a persistent problem in the Cerro Patacon communities due to exponential population growth and subsequent stresses placed on Panama City's public utility infrastructure. In addition, the Cerro Patacon communities do not have proper water storage capabilities or distribution systems, and with regular water cut-offs twice per week, shortages present a serious problem. In an effort to improve the quality of life in these communities, this project, sponsored by Footprint Possibilities, Inc., aims to generate a topographic study of the area using GPS and GIS systems, with demographic and socio-cultural information supplied by a partner team of WPI students. The combined data will be used to generate a full project proposal for IDAAN, the Panamanian public water authority, addressing water access in the Cerro Patacon communities by recommending optimum water tank location in each community, by noting the highest elevation in each community to optimize gravity-based water flow, and by providing an accurate and updated GPS map of Cerro Patacon. Furthermore, both sets of data will be used to generate recommendations as to how much water is needed per community and recommendations on how to deliver the required quantities.

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AUTHORSHIP PAGE

Colin Mashack, Yaw Opare-Sem, Paul Henry-Schoenhagen, and Ian Waugh have all contributed to the research, planning, writing, and completion of this project.

Colin Mashack wrote part of the Background and Conclusions & Recommendations. Colin also was our main editor.

Yaw Opare-Sem wrote the Executive Summary, part of the Background, and Conclusions and Recommendations. Yaw was the software specialist and mapped all communities and tank locations using the application Geo Tracker and Google My Maps.

Paul Henry Schoenhagen wrote the Introduction and part of the Background. In addition, Paul helped with the mapping of the communities using Geo Tracker.

Ian Waugh wrote the Methodology, Results, and part of the Background. Ian also was our chief translator and helped bridge the language gap between our group and the community leaders in each community.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

This paper contains a proposal to combat Water scarcity in a community in Panama City, Panama by using portable water tanks. Panama City is the capital of Panama and an emerging metropolitan city. The prosperity of the Panama Canal and banking industry have led many to flock to Panama City for financial opportunity. In fact about half of Panama's 3.8 million people currently live in Panama City. The shift of population to urban areas has increased water demand and put a strain on the current Panama City water infrastructure. The increased strain on the water infrastructure has caused the urban water utility company, Instituto de Acueductos y Alcantarillados Nacional (IDAAN) ("National Institute of Aqueducts and Sewers") , to periodically shut off water to communities on the outskirts of Panama City in order to revert water to commercial and residential buildings in the inner city. Our team has been tasked to investigate one of these areas on the outskirts of the city, known as Cerro Patacon.

The area of Cerro Patacon is located next to the main landfill of Panama City. Cerro Patacon has become home to many indigenous people such as the Kunas. Many of these groups have low economic standing and can be found living in conditions of poverty. Many of the communities are filled with litter and their proximity to the landfill has caused the Mocambo River, which runs through Cerro Patacon, to become polluted. In the last few years Cerro Patacon has experienced rapid population growth. Additionally, several communities have begun to develop with no clear boundaries. Little is known about the specific population and geographical size of each of these communities. Due to this lack of information and the informality of many of the communities the infrastructure to deliver water to these communities has not been completed. As a result many of the communities lack a reliable supply of portable water for drinking and proper sanitation when the water is shut off.

We will be working with our sponsor Footprint Possibilities, to propose a plan to IDAAN to utilize portable water tanks to provide the citizens of Cerro Patacon with an ample supply of water during water shut off days. Footprints Possibilities is a non profit organization that is affiliated with Engineers Without Borders which is headquartered in Saint Petersburg, Florida. Footprints has been working tirelessly to bring portable water to these communities for the past 8 years.

Our team is the Topography team, which mapped Cerro Patacon to determine the boundaries of each community and possible tank locations. We worked in conjunction with the Census Team, which collected census data for each community to determine the total population of Cerro Patacon. Collectively we determined the water demand and recommended a plan to install water tanks of appropriate sizes for each community.

Our goals were met by achieving the following objectives:

1. Reaching out to community leaders to obtain information concerning boundaries of communities

We personally visited each community and touched base with the community leaders because many of these leaders are inaccessible by phone. The community leaders were able to show us the boundaries of each of their communities.

2. Map the boundaries of all 10 communities using an application that has GPS capabilities

We used the application Geo Tracker on our phones to map the boundaries of each community. Geo Tracker is compatible with Google Maps and was used without installing any computer software. The app tracked our movements as we paced on foot the outer boundaries of each community.

3. Identify highest elevation points for possible tank locations

The app allowed us take points at any location while obtaining the location's GPS coordinates and elevation. The app was able to determine coordinates and elevation with good accuracy.

4. Determine best locations for tanks based on elevation and population density

A point of high elevation was chosen in each community such that water could be gravity-fed from the tank, eliminating the cost of pumps, which would increase the cost of the system. In addition, tank locations were put in locations that contained a high concentration of people.

After the topographical data were collected, they were integrated with data from the census team.After we collected this data we obtained population data from the census team. The census team was able to determine the number of adults and children in each community. From this data we were able to determine the optimal tank sizes for each community based on water demand. Based on research undertaken by the World Health Organization, and decided to determine the water supply needed for each community based on 3 levels. The three levels are as follows: Emergency; Optimal; and Ideal. An Emergency supply of water would allot each citizen of a community 20L of water per day. An Optimal supply of water would supply the adults of each community with 80 L of water and children with 60 L of water per day. Lastly, the Ideal level would supply each citizen of every community with 100L of water per day. Using these three levels we calculated the amount of water required for each community per day, and thus the size of the tank that would be necessary to meet those requirements.

In conclusion, both Footprint teams recommend that IDAAN supply the people of Cerro Patacon with the Optimal supply of water for each community and the installation of an appropriately sized water tank. The optimal supply of water would provide the adults of each community with 80 Liters and children with 60 Liters of water per day. This amount water would be enough for the citizens of each community to sustain themselves in case the water is shut off during the week. In addition, we advise IDAAN to not shut off the water on consecutive days, as this will deplete the supply of water in the portable tanks and not allow for enough time for the tanks to be refilled. We conclude that with the topographic data that is now available, coupled with the two WPI teams' analysis of the communities' specific water needs, IDAAN now has a much more informed basis on which to take steps toward bringing a reliable water supply to the people of Cerro Patacon.

I. INTRODUCTION

On July 28th 2010 the United Nations (UN) General Assembly officially recognized "the right to safe and clean drinking water and sanitation as a human right that is essential for the full enjoyment of life and all human rights" (A/RES/64/292, 2010). Despite the best efforts of the Institutio de Acueductos y Alcantarillados Nacionales (IDAAN) ("National Institute of Aquaducts and Sewers"), the government-owned urban water provider, Panama continues to experience difficulties providing the basic human right of water to its citizens settled on the outskirts of its capital city. Panama City. The water systems in these developing settlements are often shut off unexpectedly for indeterminate and unpredictable periods of time, they are prone to failure, and are underfunded. Our project identifies and offers potential solutions to the issues that come with providing water to rapidly growing settlements around the capital of Panama.

Over the past few years Panama City has been aggressively expanding, both economically and geographically. Expansion is partly due to the revenue brought in from the Panama Canal. As well as its location as a passageway between the Pacific and Atlantic oceans, which make the city a hub for trade, offshore banking, and retirees. The city hosts about half of the country's 3.8 million citizens, many of whom were attracted from the west of to the economic prosperity and opportunity the capital of Panama promises. Panama City's expansion has been so aggressive in the previous years that it has been likened to that of Singapore and Dubai (Sigler, 2014).

Panama City's expanding territory is comprised of many formal and informal settlements on the outskirts of the city. Cerro Patacon, named after a nearby landfill, is a settlement made up of ten smaller communities. Within each community there are several hundred makeshift homes, averaging approximately two adults and children per home. Each community has a leader who represents the community's best interests. Unfortunately, the entire settlement of Cerro Patacon lacks basic water storage systems, the adjacent rivers and streams are undrinkable due to the landfills poor waste management, and the current water system is unreliable at best.

Only one out of the ten communities within Cerro Patacon actually has legal access to the water provided by the government via IDAAN. This does not deter the other communities from illegally making connections and siphoning water meant for only one community. Coupled with the hoarding of water that runs rampant through the communities, the water system consistently collapses. This creates a vicious cycle, since the locals hoard water to prepare for days on which the system fails, but hoarding water contributes greatly to the system failing. Additionally many of these communities are informal, meaning that they are illegally settled on government-owned land, and have only come into existence in recent years. These informal settlements in particular are experiencing rather rapid growth which is proving to be problematic for the increasing water demand in Cerro Patacon.

The purpose of our project is to assist Footprint Possibilities, Incorporated to propose a water design plan to IDAAN outlining where additional water tanks should be placed in each community to better serve the increasing water demand at Cerro Patacon. Footprint Possibilities is an organization that has been working to provide water to the communities in Cerro Patacon experiencing water shortages. Last year a 10,000 gallon water storing tank and distribution system was installed in one of Cerro Patacon's main communities: Kuna Nega.

Footprint Possibilities plans on continuing its work in the surrounding communities. It is important to note that we are working in tandem with another IQP group. While our group maps the communities and potential water tank locations, the other group will collect census data for each community. Together we will combine and analyze social and topographical data for each community in order to present recommendations to Footprint Possibilities on ideal size and location for additional water tanks to address the water demand within Cerro Patacon.

II. BACKGROUND

While approaching such a case specific issue, we wanted to begin with more broad research questions and minimize the scope as we went further. Initiating the process with water scarcity research, this displayed an understanding on what the problem is and how it can occur; which is a crucial part in providing a solution to any real world dilemma. Proceeding, similar situations involving water management difficulties in various countries were found, mirroring that of Cerro Patacon. This showed a multiplicity of approaches previously attempted around the world, accompanied by the strengths and weaknesses of each method. Utilizing this information, along with the prior knowledge of illegal water activity within these ten communities, social capital research was taken up. Instead of provoking these illegal behaviors, this promotes the idea of a good communal network throughout Cerro Patacon. Furthermore, research on the community itself and prior influence on the issue was undertaken; followed by that of Panama's water authority, IDAAN, and our sponsor, Footprint Possibilities Incorporated.

A. Water Scarcity

Within the last century there has been a global shift from the rural lifestyle. In the 1800s, only 3 percent of the global population lived in cities. Today more than 30 percent of the global population lives in urban areas (BIWAS,2006). On the other hand, the population of rural communities is only expected to increase by 0.2 percent and is predicted to experience negative growth by the year 2025 (BIWAS,2006). This rapid growth of urban areas has put a significant strain on the water supply of cities and has led to water scarcity for citizens on the outskirts of the city. Water scarcity is a serious issue that plagues billions of people in the developing cities of Asia, Africa, Eastern Europe, and Central and South America. It is estimated that by the year 2050, 2 billion people in 48 countries will be affected by water scarcity (Kobayashi,2014) . In Panama the urban water supply is controlled by IDAAN. In 2013, 20 percent of the urban population did not have a 24 hour supply of water. Currently many systems have been implemented globally to mitigate the water scarcity problem in settlements outside of urban areas. In this paper we will highlight the Community Based Water Management (CBWM) system which has gained popularity for its comprehensive approach to the needs and priorities of people outside of these urban areas. The (CBWM) system uses the elements of Water Management and Social Capital to decrease water scarcity in communities and increase their own capacity to develop a water management system.

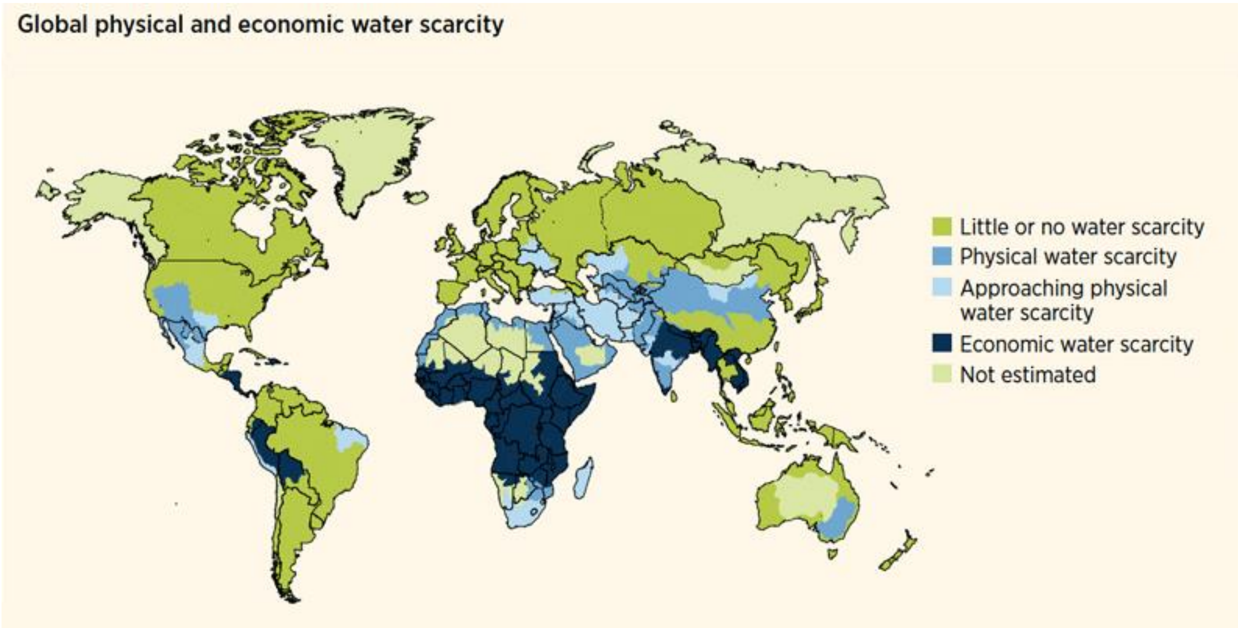

Figure A- Water Scarcity Map (World Water Assessment Programme, 2014)

B. Water Management & Literary Review

Water management is the activity of planning, developing, distributing, and managing the optimum use of water resources. Proper water management is paramount in combating water scarcity. The water management problems are often very similar from one community to the next. The authors of the book *Community based Water Management and Social Capital* (Kobayashi,2014) explored water management problems in Indonesia. The poor water management in Indonesia is due in part to the water governance shift from central to local governments. A law established in 2004 gave these local governments dominion over the water supply and distribution. This proved to be problematic because many of the local governments did not have the resources to properly manage the water supply. As a result the water systems' quality and quantity was affected by which level of government had dominion over it. The uniformity of water jurisdiction would help to eliminate this disparity in water systems' quality and quantity in Indonesia. Unfortunately for these local governments, the law is the law and they must find a way to improve the water management systems in their communities. Other countries such as India and Tanzania have found unique ways to improve water management in their communities. Mumbai, India is another global city that has been affected by water scarcity as a result of its rapid urbanization. Most of the citizens who experience the effects of water scarcity are located in the Zopadpatti or slums outside of the city (Gandy,2008). In order to combat the problem of water scarcity in Mumbai, local municipalities implemented rainwater harvesting. In addition, the city's engineers engaged the community in educational outreach programs as a way to introduce water saving technologies.

Moreover, the local government in Dar es Salaam, Tanzania was able to improve their water management system by forming committees to address water shortages in settlement outside of the city. Dar es Salaam is a city in Tanzania that is experiencing urban water shortages. The city is home to about 3 million people and about 70 percent of its population lives in informal settlements. Water management has become very difficult because of financial and managerial restraints of the Dar Es Salaam Water and Sanitation Authority (DAWASA). Local Governance was an important part in implementing a Community Based Water Management System (CBWMS) to distribute water to the settlements on the edge of the city. The settlements made committees to address the community's water shortage problem. The committees used in Dar Es Salaam were a form of Social capital that greatly improved their water management system.

C. Social Capital & Capacity Development

In order for a Community Based Water System to be effective, collective action has to be taken by the individuals in each community. Social Capital is a means for the communities to achieve collective action. Social Capital can be described as networks that allow for "information exchange, negotiations, and trustful management (Kobayashi, 2014:64). Before implementing a CBWS in a community the existing social values must be accepted and taken into account. Local communities will take collective action if they believe the people implementing the CBWS understand their beliefs and values. Increasing Social Capital can be achieved by interacting with the individuals of the community. Interaction with the people will form networks which allow for the synchronization of the CBWS to the needs and wants of the people in the community.

This kind of capacity building works to "educate, train, and to increase the individual knowledge and skills" of people in a Community based Water System (Blockland 4.2). Capacity development is essential to the CBWS sustainability. Working with individuals to develop water management techniques will require human interaction through networking. In this project, we hope to improve water management by utilizing social capital and capacity development to help the citizens of the growing community of Cerro Patacon in Panama.

D. Prior Case Study in Kuna Nega

We will model the water management system in Cerro Patacon based on one of the developing communities of Kuna Nega. Kuna Nega is a community located just outside of Panama City in the Ancon "corregimiento" in the district of Panama, within Cerro de Patacon.

The whole community of Kuna Nega is home to many indigenous people from throughout Panama. Forty percent of Panama's total population is actually made of of rural settlements just like Cerro Patacon and Kuna Nega (Kronk, 2015). This community is one of the four main formal settlements located in this area. The other neighboring settlements are known as Valle de San Francisco, and La Paz. La Paz was an additional government-created community c in 2007. La Paz consists of those affected by the Curundu fire, a neighborhood in Panama city known for its poverty and wooden infrastructure. The following map illustrates the explained territory:

Figure B – Cerro de Patacon and Kuna Nega community generated map

Together, these towns host over 7,000 inhabitants, which all have the same issue: lack of sustainable infrastructure. Kuna Nega, Valle Del San Francisco, and La Paz are located in close proximity to Panama's main landfill known as Cerro Patacon. This landfill, along with a lack of a proper sewage system in these rural settlements and villages, account for the poor living conditions and environmental impact. According to the Ministry of Health, "only 60% of Panama City's residents are served by the current sewage system. However, much of the sewage is gathered in septic tanks that are poorly maintained, and as a result the sewage is discharged into the bay with virtually no treatment" (Anywhere INC, 2016). Numerous studies have been done regarding how it affects the environment and to what extent, revealing that the biggest repercussions regarding Cerro Patacon are contamination of air and nearby water sources. As stated by epidemiologist Francisco Diaz Merida in a report for *La Prensa*, a Panamanian newspaper, "In this landfill metals such as mercury, lead and cadmium are being poorly treated, dumped in the land and river, and in long term exposure these lead to hypertension, mental retardation and cancer" (Simmons, 2015).

These creeks and rivers also supply the three Kuna communities. As it was stated by El "Siglo" (a local Panama newspaper): "in a community where you can breathe poverty in the air due to lack of basic sanitary services, potable water and dignifying households, lives Rosita, a two-year old girl who plays and bathes her body in a polluted creek"(Garcia, 2015). As one can see, Cerro Patacon is a huge preoccupation for the Kunas living near Panama City; however, this is not even their major preoccupation, which is the lack of potable water supply. As if it wasn't enough to have their nearby creeks polluted, Kuna Nega, La Paz, and Valle de San Francisco barely have access to water due to weekly government shutoffs, lack of water distribution systems or inefficiency of them (Mikals, 2016). The government shuts off their water ring twice per week in favor of high water demand in the city. This leaves the community with only 10,000 gallons in their storage tank. The government attempts to mitigate this problem by sending a tank truck filled with water to the communities located outside the city. But the truck can supply water only to one third of the inhabitants of the three settlements. One or two days without water is not an insurmountable problem, but with consistent tampering to the system mixed with water lines being shut off by the government leads to the communities greates problem; the lack or inefficiency of water distribution and storage systems.

The water pipes and connections that supply these communities are known as outer rings and basically divert a percentage of Panama city's water supply to the outlying communities. However, these connections become nearly nonexistent when the government shuts down water lines for days at a time and the communities then have to rely on the sole supply given by the water trucks which is highly problematic. Although this is an ongoing problem and has been known for a while it hasn't been quite solved. However, a few attempts have been previously made. Through the same non-profit organization, Footprint Possibilities Incorporated, the University of Pittsburgh has made an impact of their own in Panama; dealing with the installation and maintenance of water distribution valves, storage tanks, and a custom septic system.

Footprint Possibilities Incorporated originally set out, on April 21st 2008, to organize and seek funding for local, rural community efforts in Panama as a nonprofit organization. Since then, they've expanded their interests by engaging the communities surrounding Cerro Patacon. They also aid with projects that involve infrastructure and health improvement, educational opportunities, and cultural and environmental integration (Footprint, 2008). With the lead quality engineer, Rick Montanari, they've been able to partner with some of the main governmental institutions such as IDAAN (National Institute of Aqueducts and Sewage Systems), the mayor of Panama, and some other key institutions like Caterpillar and EWB-Panama (Engineers without Borders). These key partners will help evaluate the problem, devise a plan and propose a solution. Furthermore, Footprint, with the help of the University of

Pittsburgh, was able to implement a three-phase water infrastructure improvement project for the indigenous community of Kuna Nega.

The three-phase project consisted of constructing a 25,000 gallon storage tank to supplement the already existing 10,000 gallon tanks as well as the creation of a high pressure zone and a 10,000 gallon tank at the highest point in the community to supply water to the areas above the already existing water tank. The University of Pittsburgh, through Footprint and some professional engineering guidance, also installed and replaced valves to improve efficiency and simplify maintenance.

The project ran from October 2013 to Fall 2014, and the three stages were as follows: In phase 1, in October 2013 the construction of the 25,000 gallon tank started and a 625ft pipeline was installed. In phase 2, construction of the water tank continued and a high-pressure zone was created. In phase 3, the water infrastructure improvement was concluded by building the 10,000 gallon tank and implementing valves. The system was declared useful and started being used in October 2014 (Susich, 2016). However by May 2015 problems were experienced with how the network was being modified, maintained, and damaged. By September 2015, the network was not working as designed. Eventually, this left a majority of Kuna Nega's residents without access to water. The root of the problem was found to be the water committee in charge of decisions and maintenance regarding the water system. Apparently, this committee was trying to return to their old method of rationing water by re-instating measures "to cut and cap ring mains, shut off valves to the water tanks and distribution valve boxes and go back to a process where they open them manually"(Footprint Possibilities Inc/EWB-P, 2016). This eventually lead to the failure of the water system, but most importantly unveiled one of the most significant problems regarding long term success of the project; the community's lack of education in system management and water culture in general.

E. IDAAN

The National Water and Sewer Agency (*Instituto de Acueductos y Alcantarillados Nacionales*, IDAAN) mission is to "improve the level of community health, welfare and progress of the country through the provision of potable water and the collection and disposal of sewage..."(translated from Spanish)(IDAAN, 2010). IDAAN is the public government authority tasked with bringing water sanitation services to the urban areas of Panama. Its role, along with other government agencies' roles, is clearly set in a framework structured in Law No. 2 of January 1997. This law put the Ministry of Health (*Ministerio de Salud,* MINSA) in charge of overseeing water quality, high-level management, and planning policies for IDAAN to carry out. The law is also responsible for defining the Ministry of Economy and Finance (*Ministerio de Economía y Finanzas,* MEF) as responsible for international loans and executing budgets while the National Public Service Regulation Authority (*Autoridad de Nacional de los Servicios Públicos*, ASEP) is assigned to serve a regulatory role. Unfortunately the framework fails to address actual problems within Panama's urban areas. MINSA has had trouble having a leadership role and developing a clear and consistent vision for Panama's water situation, AESP has been far less involved in water than it has been in things such as electricity, and MEF has provided immense subsidies for IDAAN'S operational and investment costs. The framework also limited the financial autonomy of IDAAN, despite Law No. 77 of December 28, 2001, which gave

IDAAN managemental and financial autonomy when it was re-organized to be a public and autonomous entity (World Bank, 2010).

Additionally the tariffs on water have not been updated since 1982, which contributes significantly to IDAAN's unstable and underfunded water systems. IDAAN charges a flat rate of $6.40 for a minimum consumption of 30 cubic meters of water per month, thus encouraging the hoarding and overconsumption of water, which can lead to the collapse of water systems installed by IDAAN. The stagnant tariff level has failed to generate the necessary amount of revenue needed to pay for the costs of services provided by IDAAN. Another factor related to the growing deficit is a lack of cost-efficient services in low-income regions. In several cases the water system in place is simply a mainline meant for one community, with several illegal connections that support the surrounding informal communities. Other communities can only be served through water trucks which, due to the tropical climate and lack of properly paved roads in low-income communities, is also an inefficient and expensive service that provides minimal coverage (World Bank, 2010). In 2013, all of these issues lead to a situation whereby more than 20 percent of the population served by IDAAN did not have a 24-hour supply of water, around 30,000 relied on water trucks, and 49 percent of the water managed by IDAAN was lost. And only 56 percent of the water met the required standards for drinking water (Rucker, 2014). In addition, IDAAN often does not collect the money owed by the community. Such neglect only compounds a consistently growing operating deficit, which has grown from US$16.3 million in 2007 to US$34.0 million in 2008 (World Bank, 2010). It has since plateaued a bit, having a US$31.5 million in 2013 (OOSKAnews, 2013). This extreme and persistent deficit has forced MEF to provide immense subsidies in order to keep the water at such a low price.

F. Footprint Possibilities, Incorporated

Footprint Possibilities is currently headquartered in Saint Petersburg Florida, and since 2008 they've grown strictly through volunteer work. When the corporation was first establishing itself, it worked on small scale projects revolving around small groups of approximately one hundred to just below a thousand people. More recently however, they've been taking on larger towns and villages with around three thousand residents affected by each project. Currently Footprint Possibilities affects around ten thousand lives in total throughout their rural focus in Panama (Footprint, 2008). As a nonprofit organization, one would imagine how these medium scale projects could actually be accomplished. Footprint has a multiplicity of affiliates that are more than willing to make donations and offer aid where needed such as the University of Panama, Google for Nonprofits, Coselecto, Engineers Without Borders-Panama, and Caterpillar. The University of Panama offers student volunteers who can aid with these projects Footprint sets out to do. Caterpillar Corporation and Coselecto, on the other hand, offer infrastructure tools and materials that range from items such as forklifts to concrete (Products, 2010). Google for nonprofits acts as a free advertising platform to make Footprint accessible and known on a global level as a charitable organization. Lastly, Engineers without Borders grants students from around the world a funded opportunity to travel to Panama and get first hand experience, while helping Footprint succeed in each project area (EWB, 2014).

However, within the past few years Footprint has made water management and distribution a key focus and since then, additional key affiliates have been welcomed. With this new focus, Footprints has named four main stakeholders with whom they work very closely on almost every project that requires funding:

Stakeholder	**Description**
Mayor's Office for Social and Community Work	Provides approval for projects while funding certain aspects where needed
Ministry of Housing	Provides and logs census data to keep track of community population density
IDAAN	Panama's water authority
Ministry of health	Aid in water sanitation and living condition aspect of projects

(Table 1: Footprint Main Stakeholders)

This focused research increases our understanding of the problem as a whole, how to approach it, and what recommendations can be made based on prior knowledge and experience to reduce pitfalls in the process for years to come. Now that the background information is collected, the methodological objectives can be established.

III. METHODOLOGY

· Objective 1: Reach out to community leaders in Cerro Patacon to obtain information of how each community is managed and whether they have or don't have any previous mapping performed before.

· Objective 2: Map out the communities in Cerro Patacon accurately using GPS software to determine boundaries of each settlement whether it's formal or informal. (10 total, formal: 8, informal: 2).

· Objective 3: Identify highest points, lowest points and a possible tank location at a high point in each community to avoid using valves and pressurized zones to supply water.

· Objective 4: By using a demographic study of the communities generated by fellow WPI students, we will decide which is the optimum tank location out of the possible ones. Ideally the tank will be placed as near as possible to a high concentration of people. Furthermore, Identify where in each community the tank can be connected to IDAAN's main water ring.

Objective 1: Community Leaders

As we arrived in Panama and made formal contact with our sponsor we were told that in order to start the field study of the communities we would have to contact their community leaders due to lack of formal information on the communities. None of these people have access to Internet and only a few had a reachable phone therefore we were able to reach out to them by visiting their houses, which Tomas Guerrero (local ambassador for Footprint Possibilities) pointed out to us. After contact was made, community leaders were eager to help and answer every question we had for them.

Objective 2: Map out communities in Cerro Patacon

In order to map out all the communities in Cerro Patacon we used a smartphone application called Geo Tracker, which is able to give coordinates and elevation of requested points as well as mapping out every place walked. Based on these possibilities we asked local leaders to help us walk around the communities to generate a polygon of each one and place them all in a main plot.

For the specific case of Kuna Nega, since it was the only community we were able to get a formal map of, we walked around its perimeter corroborating the previously set coordinates for its boundaries.

Objective 3: Identify Highest points for tank location

By using Geo Tracker we were able to request the elevation of any place, therefore once the polygon was set for each community we visually identified its highest point and lowest point. The highest point was always considered as a possible tank location since we were aspiring to use gravity for water distribution instead of valves to generate pressurized zones. For every community we pointed out at least two possible tank locations that met the following requirements: high point, open space, as close as possible to the community.

Objective 4: Verification of tank location

While we were generating the polygons for the communities, another group of WPI students was simultaneously carrying out a census in each community asking the following questions:

1. How many adults live in the house?
2. How many children (age 15 or less) live in the house?
3. What is the house number?

These 3 questions were asked in order to identify were the highest concentration of people was within the community and to generate a demand calculation of how much water is needed to supply the community. Based on how many people there are in the community, tank size was calculated by estimating that each adult needs about 80 liters of water per day and children 60 liters. These two figures were suggested since according to the World Health Organization (WHO), between 50 and 100 liters of water per person per day are needed to ensure that most basic needs are met and few health concerns arise.

A tank size recommendation was then generated for each community and the tank location was chosen to be the one closest to the highest concentration of people, unless water connection to IDAAN's main water ring seemed compromised.

By identifying in the main map plot where IDAAN's main water ring go through we can speculate where the tank will get its water supply from and determine how far it is from the tank.

IV. RESULTS

In order to minimize GPS error our team downloaded offline google maps of Cerro Patacon to ensure the consistency of each point. To further eliminate error, we had two people track points using the app to ensure the validity of the data. The application Geo Tracker was compatible with Google My Maps and made mapping very convenient because no software was needed to be downloaded. All in all we were pleased with the ease of use and plotting accuracy of the app.

By using the Geo Tracker application the following results were obtained regarding community size, location of highest point, and alternate tank location for communities without water storage.

Community	Size (Ha.)	Highest Point	Alternate Tank Location
Maser Nega	1.61	Coords: 9.057702, -79.56009 Elevation: 236 ft	Coords: 9.056604, -79.55934 Elevation: 236 ft
Calle 50	4.65	Coords: 9.055724, -79.561005 Elevation: 259 ft	Coords: 9.055074, -79.56107 Elevation: 253 ft
Genesis	5.57	Coords: 9.065042, -79.56689 Elevation: 344 ft	
Colinas de la Paz	2.44	Coords: 9.061659, -79.558174 Elevation: 331 ft	Coords: 9.061656, -79.557655 Elevation: 315 ft

La Esperanza	20.8	Coords: 9.064525, -79.5569 Elevation: 420 ft	Coords: 9.063559, -79.55591 Elevation: 348 ft
Bendicion de Dios	6.21		
Villa Cardenas Abajo	3.27	Coords: 9.061016, -79.55441 Elevation: 361 ft	-

(Table 2 Data Collected in Each Community)

Highlighted locations show suggested tank location.

For the remaining communities, (Kuna Nega, La Paz, and San Francisco), water tanks have already been assembled and are supplying these communities. However an accurate mapping was required for these three communities to determine and corroborate their boundaries.

Community	Size (Ha.)	Primary Tank Location	Secondary Tank Location
Kuna Nega	16.6	9.05798, -79.55679	9.05831, -79.55644
San Francisco	7.23	9.05877, -79.55421	9.05700,-79.55471
La Paz	49.2	9.062667, -79.560684	

(Table 3 Data Collected)

Based on the research of a fellow group of WPI students working simultaneously in the communities, the following information was compiled regarding population in each settlement:

Community	Children	Adults	Total
Maser Nega	121	138	257
Calle 50	154	250	404
La Paz	335	446	781
Colinas de la Paz	56	69	125
Genesis	432	216	648

La Esperanza	896	448	1344
Bendicion de Dios	648	324	972
Villa Cardenas Abajo	94	124	218
Kuna Nega	295	626	921
San Francisco	722	809	1531

(Table 4 Census data obtained from Footprint Team 2)

"According to the World Health Organization (WHO), between 50 and 100 liters of water per person per day are needed to ensure that most basic needs are met and few health concerns arise."

Furthermore, the WHO also states that a person needs at least 15 liters of water per day to survive an emergency where he/she would be able to use this amount for drinking, basic hygiene, and basic cooking needs.

Based on these figures, we devised three hypothetical scenarios in order to calculate how much water was needed to supply for a day the entire population for each community for one day. These three calculations were based on the following water quantities per person per day:

- Emergency figure: 20 liters per person per day;
- Ideal commodity figure: 100 liters per person per day;
- Optimized figure: 60 liters per child per day, 80 liters per adult per day.

Emergency figure: 20 Liters per person a day

Based on the figure supplied by the WHO of 15 liters of water daily needed to survive in case of emergency we added an extra 5 liters in our proposed calculations to compensate for water misusage, waste, etc. Thus generating the 20 liters per day figure. If one estimates an amount of 20 liters per person a day for each community, by simply multiplying 20 liters by the total population of each community, we obtain how much water must be stored on cutoff days in tanks to supply each community.

The following table shows the previously stated results:

Community	Amount of Water Needed (L.)
Maser Nega	5140
Calle 50	8080
La Paz	15620
Colinas de la Paz	2500
Genesis	12960
La Esperanza	26880
Bendicion de Dios	19440
Villa Cardenas Abajo	4360
Kuna Nega	18420
San Francisco	30620

(Table 5 Water Needed 20L a person)

Ideal Commodity Figure: 100 liters per person per day

An ideal figure to ensure sufficient water as a commodity would be to estimate 100 liters per person each day. By using this figure the following tables were generated showing how much water would need to be stored on cutoff days in tanks to supply each community:

Community	Amount of Water Needed (L.)
Maser Nega	25700
Calle 50	40400
La Paz	78100
Colinas de la Paz	12500
Genesis	64800
La Esperanza	134400
Bendicion de Dios	97200
Villa Cardenas	21800
Kuna Nega	92100
San Francisco	153100

(Table 6 Water needed 100L a person)

Optimized Figure: 60 L for children and 80 L for adults per day

Community	Amount of Water Needed (L.)
Maser Nega	18300
Calle 50	29240
La Paz	55780
Colinas de la Paz	8880
Genesis	43200
La Esperanza	89600
Bendicion de Dios	64800
Villa Cardenas Abajo	15560
Kuna Nega	67780
San Francisco	108040

(Table 7 Water Needed 60L per child and 80L per adult)

Tank Dimensions:

Based on these three models we were able to generate recommendations on tank dimensions for every community that would hold the needed amount of water per community. In order to produce these we used a “tank dimension calculator” generated by Regal tanks were diameter and length are factored in and tank capacity is generated based on these values. Tank dimensions are shown the following table:

	Tank Dimensions		
Community	20 L	60L & 80L	100L
Maser Nega	L: 120in. D: 60in. TV: 5,560 L	L: 180in. D: 90in. TV: 18,765 L	L: 200in. D:100in. TV: 25,741 L
Calle 50	L: 130in. D: 70in. TV: 8,198 L	L: 230in. D: 100in. TV: 29,602 L	L: 240in. D: 115in. TV: 40,851 L
Colinas de la Paz	L: 100in. D: 45in. TV: 2,606 L	L: 145in. D: 70in. TV: 9,144 L	L: 170in. D: 76in. TV: 12,638 L
Genesis	L: 160in. D: 80in. TV: 13,179 L	L: 255in. D: 115in. TV: 43,404 L	L: 225in. D: 150in. TV: 65,156 L
La Esperanza	L: 210in. D: 100in. TV: 27,028 L	L: 310in. D: 150in. TV: 89,771 L	L: 363in. D: 170in. TV: 135,019 L
Bendicion de Dios	L: 190in. D: 90in. TV: 19,807 L	L: 282in. D: 134in. TV: 65,170 L	L: 315in. D: 155in. TV: 97,401 L
Villa Cardenas Abajo	L: 120in. D: 55in. TV: 4,672 L	L: 170in. D: 85in. TV: 15,808 L	L: 212 in. D: 90in. TV: 22,101 L

All tanks were designed to be horizontal cylinders. D= diameter, L= length, and TV= total volume. *(Table 8 Tank Sizes)*

Ideally, we conclude that IDAAN should aspire to install tanks in each community that supply everybody with 100 liters per day per person and place a water meter in each house to ensure no more than 100 liters per inhabitant is distributed to each house.

However, based on Panama's high water demand and usage, it is understandable that supplying this quantity as a solution for cutoff days may be impractical. Hence, we recommend that IDAAN takes action on tank installation based on the Optimized figure model in order to ensure sufficient quality of life on cutoff days while causing less of a stress on the overall water supply. This plan also adjusts in a fitting way to each community because as can be seen in the population census, some communities have a predominantly young community while others have a predominantly older community and it's safe to assume that children (under 15 yrs. of age) consume a lower total volume of water. Therefore, water waste can be reduced by supplying varying quantities of water to children and adults without compromising either group's health, thus justifying the proposal of a supply of 60L of water for children and 80 L of water for adults per day.

Furthermore, an Emergency figure model was developed as a fast response plan since Cerro Patacon inhabitants claim they are experiencing days with no access to water at all. This figure provides a fast temporal solution that corresponds to a minimal stress to the overall water availability of the country and can either be carried out through the installation of small tanks in each community or through water trucks, since water quantity that has to be delivered is not a significantly high quantity (26,880 L being the most for La Esperanza).

V. CONCLUSIONS & RECOMMENDATIONS

A. Recommendations

Based on the census and topographical data collected in each community, we recommend that IDDAN put a tank in every community that does not currently have a tank. In addition a public fountain should be placed in each community so that the citizens of each community can police those who are hoarding water. Secondly, we recommend that water should not be shut off on two consecutive days. This will prevent the communities from blowing through their supply of water without enough time to refill the tanks. Lastly, we recommend that in the near future the communities of Cerro Patacon become clients of IDDAN and pay for the water they are receiving.

B. Scope of work

Upon arrival both of our teams visited Cerro Patacon to gain familiarity with the area. We quickly learned that the remoteness of Cerro Patacon would prove difficult to obtain consistent transportation to our work site each morning. In addition, the capricious nature of the tropical weather caused us to revise the original scope of our project. Our original goals were to evaluate problems from a poor water delivery system, identify short fallings in the water system, and generate designs for a water system. Lastly we wanted to distribute pamphlets that informed the community about the water system, conservation, and management. We were able to complete our first two goals however the element of time caused us to abandon our other goals. From our experience, we feel that the communities would benefit from a brochure that will give them the information about how much water their tanks hold and the rules on how to manage their water. While in the communities, we realized that water tanks were being used to hoard water thus limiting the amount of water available for use by other citizens. Giving citizens' this informational brochure would give them the tools to police those who abuse their privilege to have water by hoarding it in barrels.

C. Sponsor conflicts

Another aspect of the project that presented conflict at times was miscommunication with our sponsor and contacts during our time in Cerro Patacon. Within an IQP, it's paramount that communication, workload, and labor focus be straightforward and have good balance between sponsor demand and project group demand. However, in our situation, that was not consistently the case. This year was actually the first year our sponsor, Footprint Possibilities Incorporated, has worked with WPI on one of the IQPs, so it definitely proved as a challenge from both ends. Essentially, the director of Footprint never accompanied to the communities during work hours. Instead, he assigned that task to one of the ambassadors of the charity. This approach proved fairly confusing when expressing data or daily tasks to the director. These communities are constantly growing, so community names, leaders, and locations are parallelly changing from what the director previously had thought accurate. Along with difficulty exchanging information, the ambassador would often be busy with other community affairs. This led our group to reach out to various community leaders to provide data about particular areas.

In addition to the lack of communication with our sponsor, his plan for our project weighed much more toward the physical labor as opposed to having that good balance of social work that makes an IQP. However, after some time working together a compromise was reached to provide the social aspect our project was previously lacking. All of the conflicts presented were a direct result of the infant relationship Footprint has with the IQP. Ultimately, ironing out these kinks is a crucial step in the evolution of the type of projects Footprint will aid with in the years to come.

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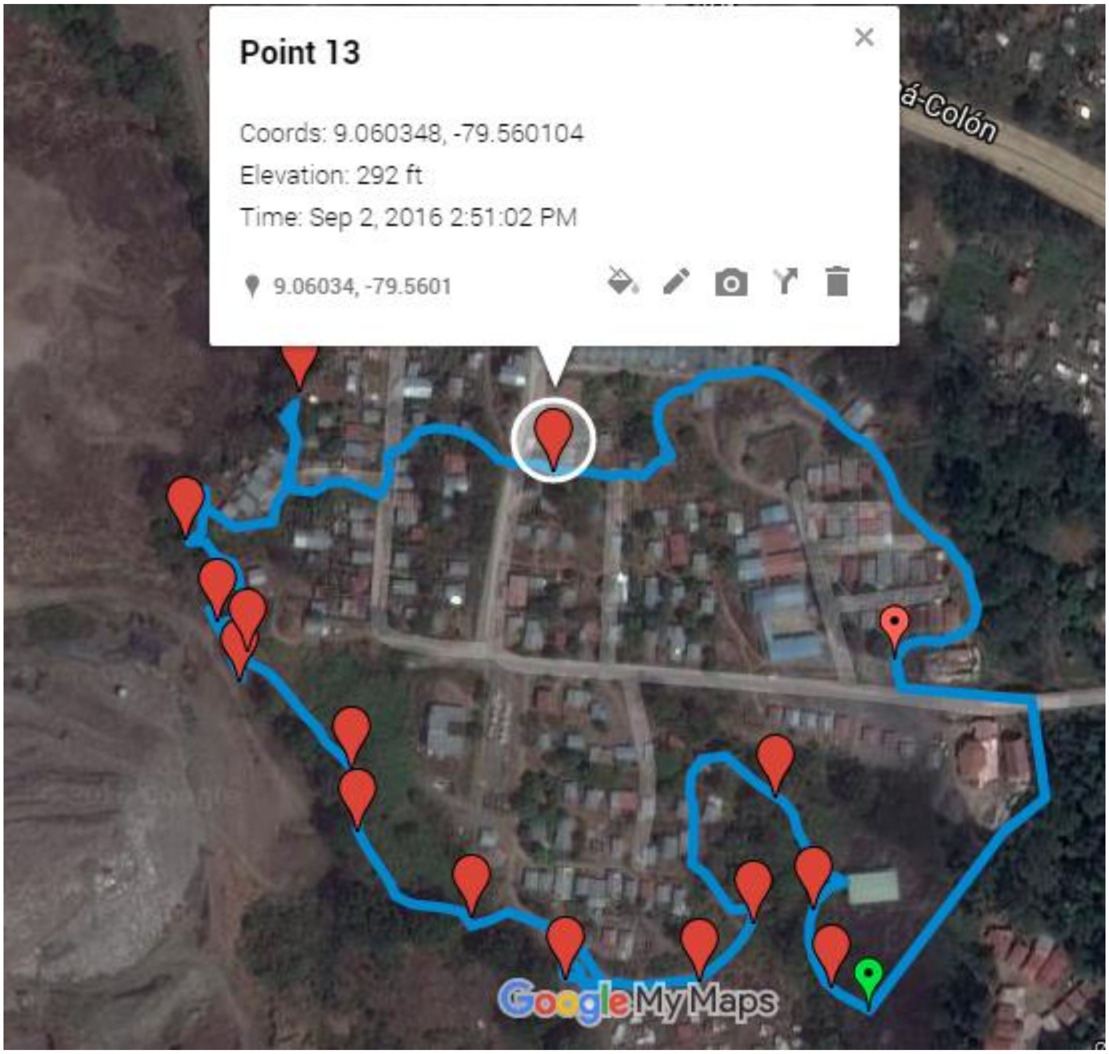
APPENDICES

A. Map of Cerro Patacon

B. Kuna Nega


2
9
Carr. a Cerro Patacón
Congregacion Villa Cardenas
1
Carr. a Cerro Patacon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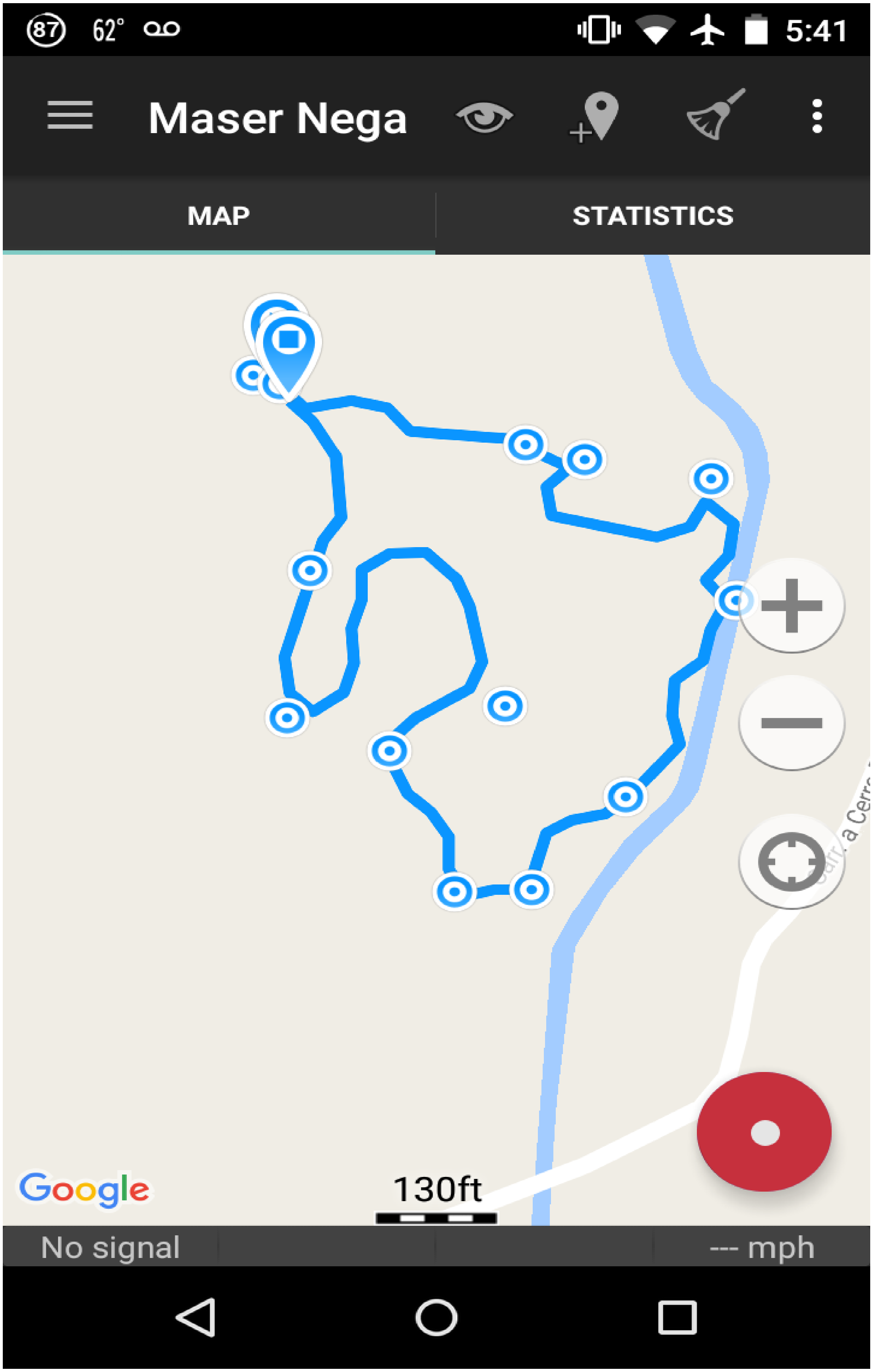
á-Colón
Google My Maps

C. Maser Nega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Maser Nega
MAP
STATISTICS
Google
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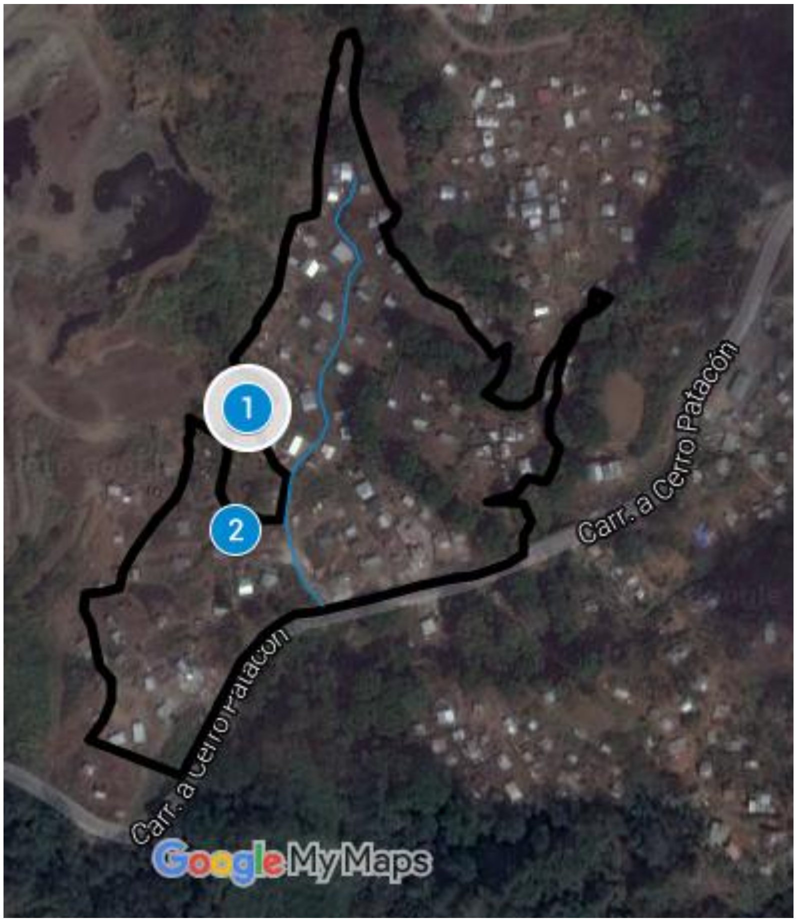
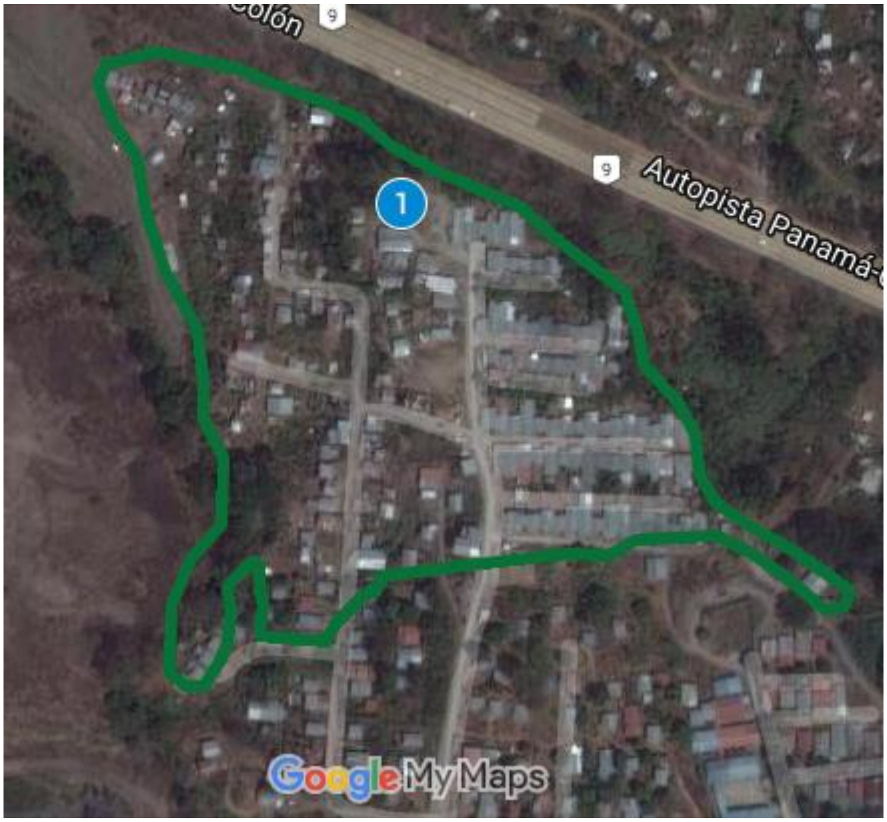
No signal
--- mph

D. Calle 50



(View from possible tank location in Calle 50)

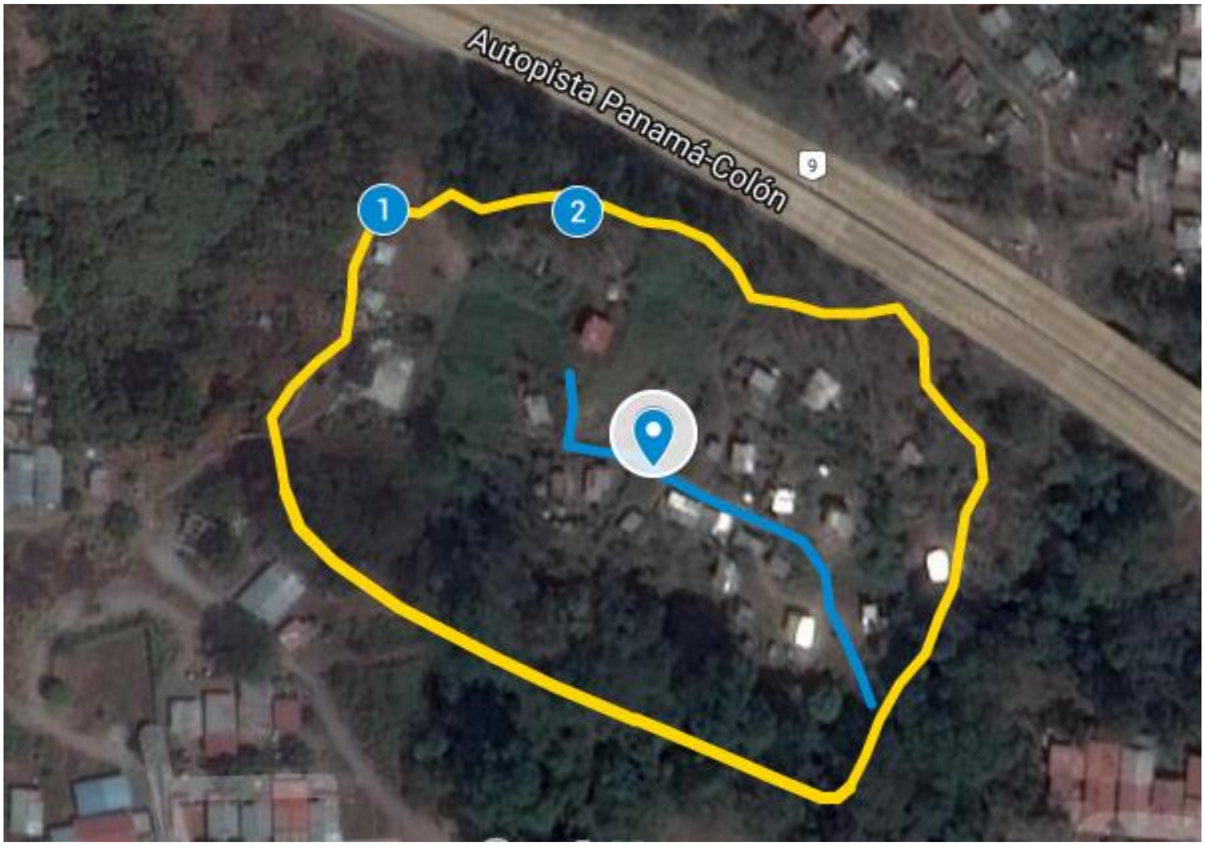
E. La Paz



(100,000 Liter Tank in La Paz)

F. Genesis

G. Colinas de la Paz



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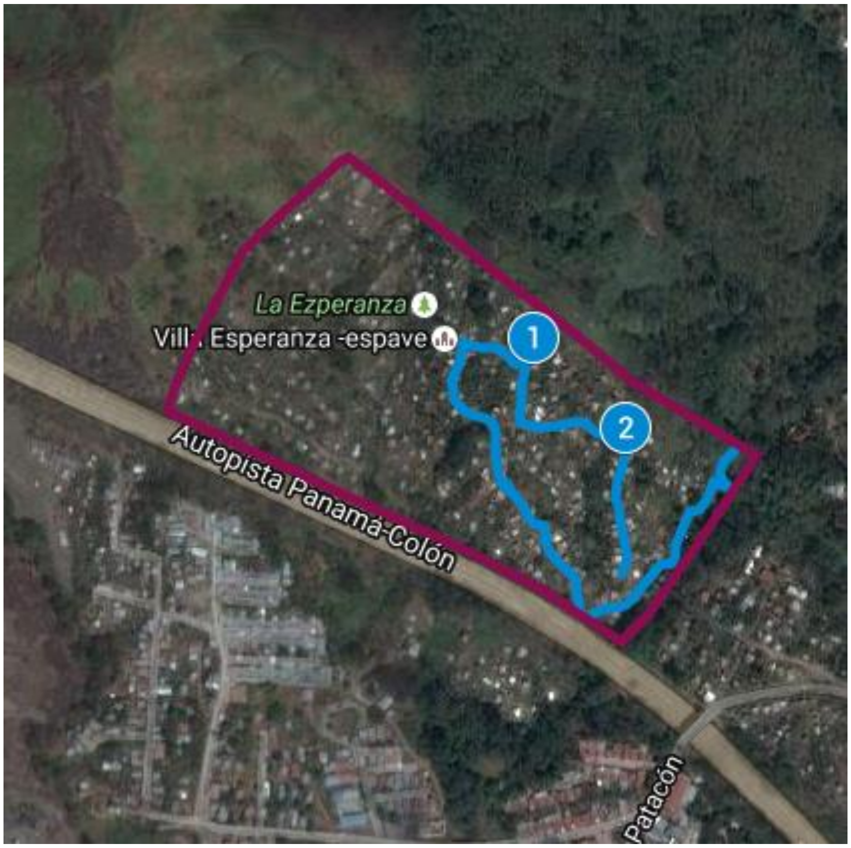
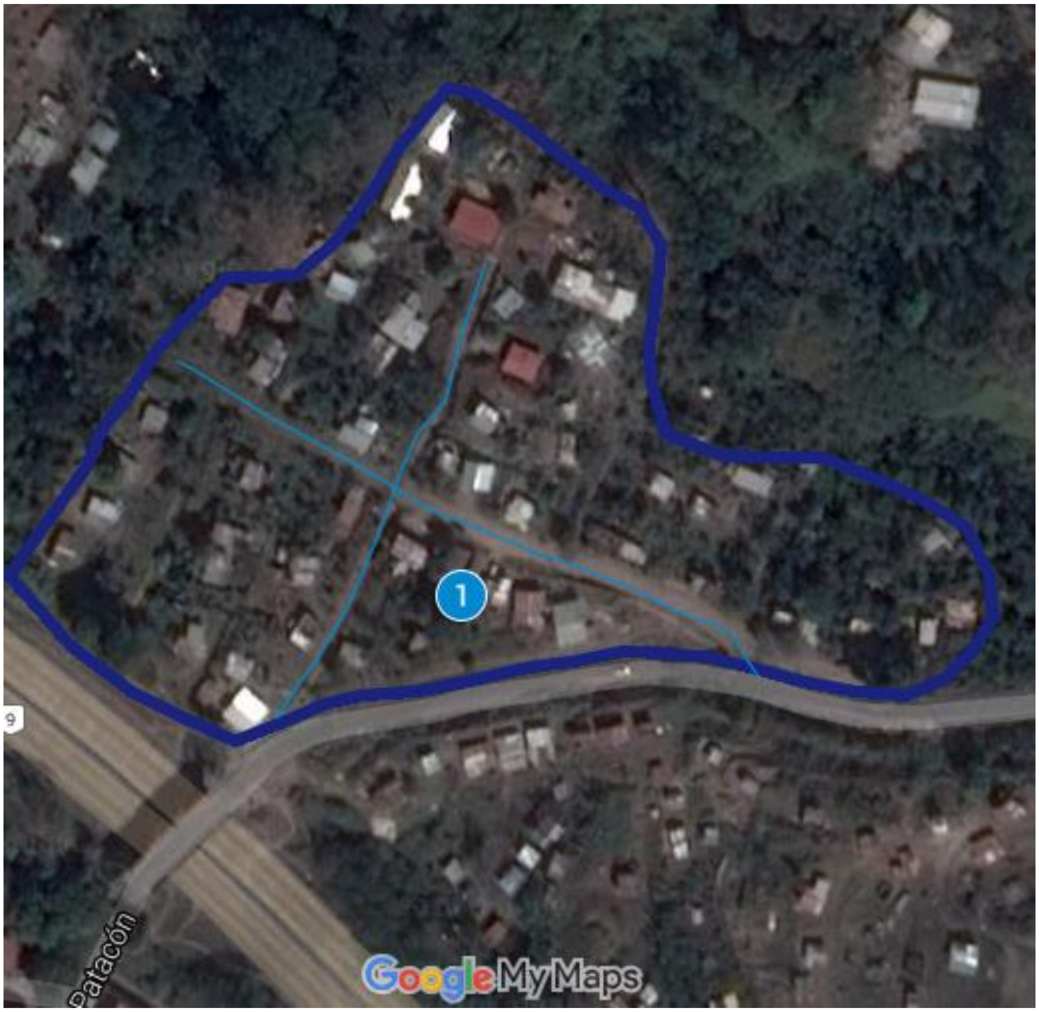


I. Villa Cardenas Abajo



J. Bendición de Dios

K. San Francisco