Quebrada Platano & Rio Oeste Abajo Water Systems Improvements Bocas del Toro, Panamá

International Senior Design Project

Melody Harmon
Jacob Herzog
Christine Wood
Daniel Woodall

Michigan Technological University

December 10th, 2018
CEE 4916 Fall 2018
Advisors: David Watkins, Mike Drewyor

LUCY-CHEN INC.

Michigan Technological University

This report, titled "Quebrada Platano & Rio Oeste Abajo Water Systems Improvements, Bocas del Toro, Panamá", represents the efforts of undergraduate students in Civil and Environmental Engineering and Mechanical Engineering Departments at Michigan Technological University. While the students worked under the supervision and guidance of associated faculty members, the contents of this report ***should not*** be considered professional engineering.

Table of Contents

List of Tables

List of Figures

Executive Summary

International Senior Design at Michigan Technological University (MTU) provides a program in which MTU students have the opportunity to identify and develop sustainable designs working alongside economically disadvantaged communities around the world. The Lucy-Chen Inc. water team traveled to Bocas del Toro, Panama to work with two native Ngobe communities and their respective Peace Corps Volunteers. The purpose of the site visit was to assess the existing water supply reliability and water quality of the sources. Lucy-Chen Inc. has prepared designs to propose to Quebrada Platano and Rio Oeste Abajo which are oriented to satisfy the needs of each community. The objective of each design is to improve the existing water systems in terms of water supply reliability and water quality.

Quebrada Platano and Rio Oeste Abajo were the two communities that the team worked with for the duration of the project. The water sources of each community (three in Quebrada Platano and one in Rio Oeste Abajo) were topographically and hydraulically surveyed, way-pointed via GPS, and were tested for coliform and E.coli. The team developed design proposals for each community's water sources with the collected information. Lucy-Chen Inc.'s goals for the proposed designs include plans to decrease turbidity (solids), incorporate a proper intake structure for the Quebrada Platano spring source, perform a hydraulic analysis of each system using EPANET, and design inlet alternatives for each source. The importance of water quality improvement through community or in-home water treatment systems is also discussed.

The proposed design recommendation for Quebrada Platano includes construction of sedimentation tanks for their existing Big Tank and School Tank sources. Additionally, the spring source at Quebrada Platano can be utilized by constructing a spring box and storage tank to capture the high-quality water of this source. Lastly, inlet alternatives are discussed in the report which are intended to decrease the solids and frequency of clogging of the intake structures.

Similar to Quebrada Platano, a sedimentation tank is also a proposed for Rio Oeste Abajo. Construction of a new storage tank at the local health center will increase consistency of

the community's water supply. Inlet alternatives are also recommended for the Palo Seco intake structure to improve the filtration and intake reliability at the *toma*.

The goal of these designs is to satisfy the needs of the community while considering maintenance capabilities. Successful implementation of these projects will be dependent on the consistent monitoring and maintenance of each component. Overall, the proposed designs aim to improve the existing water systems in Quebrada Platano and Rio Oeste Abajo, and prove a clean, reliable water supply for years to come.

1.0 Introduction

The Lucy-Chen Inc. team was part of the International Senior Design program at Michigan Technological University. The team worked with Peace Corps Volunteers (PCVs) to connect with communities and identify projects, and the team will rely on the PCVs to implement proposed designs. The team spent a total of two weeks immersed in two rural and economically disadvantaged communities in Bocas del Toro, Panamá. This enabled the team to live and work alongside the native Ngobe communities to understand their history, cultural, and societal structure. The first Ngobe community was Quebrada Platano, indicated in yellow in Figure 1. This community is up in the mountains with two existing aqueducts and one potential spring source. The second Ngobe community was Rio Oeste Abajo, indicated in blue in Figure 1. This community is along a paved road about 20 minutes away via bus from Almirante which allows for easier access to town. Data collection during the site visit was crucial for the development of effective water system improvement designs. The two communities' aqueduct systems were relatively similar to one another, and many of the proposed designs can be suggested for both systems. Appendix A contains detailed information on the existing systems, elevation profiles, and source photos and models.

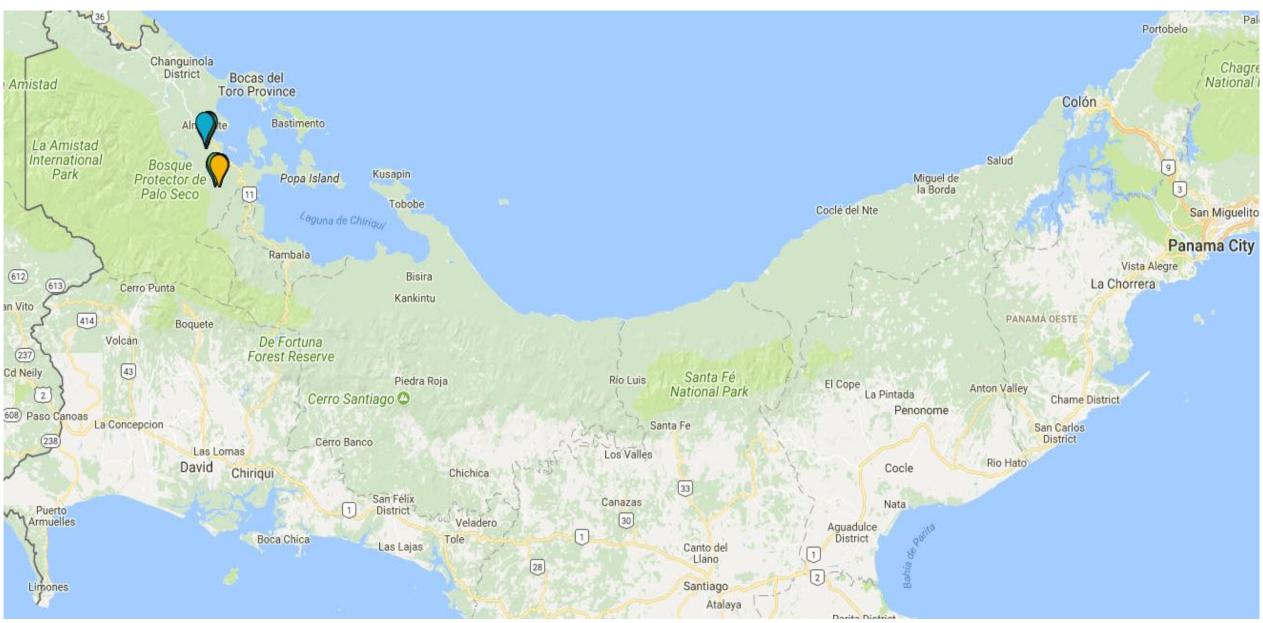


Figure 1. Quebrada Platano (yellow) and Rio Oeste Abajo (blue) Site Locations in Bocas del Toro, Panama.

The purpose of the project was to assess the existing water supply reliability and water quality of the sources. Lucy-Chen Inc. has prepared designs to propose to Quebrada Platano and Rio Oeste Abajo which are oriented to satisfy the needs of each community. The objective of each design is to improve the existing water systems in terms of water supply reliability and water quality. Lucy-Chen Inc. was focused on meeting the specific needs with consideration of public health, safety and welfare, along with environmental impacts and economic means. The following report discusses the process of data collection and analysis, design proposals, and project implementation for Quebrada Platano and Rio Oeste Abajo.

1.1 Site Visit Information

Site 1 - Quebrada Platano

Quebrada Platano is located in the Bocas del Toro province of Panama. Almirante is the closest town, which is about a 30 minute taxi drive on paved and rocky roads. Once at the trailhead, it is about an hour of vigorous hiking through a muddy, hilly road with no river crossings structures. The community is divided into two main locations of Quebrada Platano separated by an approximately 20-minute hike through the forest, mud and small rivers. Quebrada Platano was settled by a man and his family in the 1970's. The community was initially split by two families separated by the 20-minute walk. Since then, the community has grown to around 200 people between the two locations. The school in this community is for Kindergarten through 6th grade. It was built by U.S. soldiers in the 1990's. If students want to continue their education beyond 6th grade, they must hike down the muddy road to the next community. Quebrada Platano also has a community center which is used for meetings and gatherings.

Gregorio, son of the community's founder, was eager to be the team's host during our site visit. He was the president of the water committee in Quebrada Platano, making him an influential person within the community, especially with concern to our project. Gregorio and the community PCV, Micah, showed the team the two water systems and one potential spring water source within the community. Each water system supplies water to different parts of the community, including the residents' homes, local school, and community center. The source on the west side of the community previously supplied water to the whole community, and this source is referred to as the Big Tank. The pipe network runs to the east side of the community as well, but it is not functioning due to breaks. The other source on the east side of the community supplies the east side homes, school, and community center and is referred to as the School Tank. The location of each of the water sources is shown in Figure 2.

Both water systems were constructed in the 1990's by the Panamanian government. There is one water source structure and storage tank in each system. The government also evaluated the potential spring water source, which is referred to as the Spring Source in Figure 2. They concluded that it was not a suitable source because it did not have enough elevation to deliver the water to the full community. Due to this, the government did not implement an inlet structure or network system for the source. Some community members have taken it upon themselves to utilize this source and have created a pipe system that supplies a few of the homes on the West side of the community.

Figure 2. Map of Sources and School in Quebrada Platano from GPS coordinates.

Site 2 - Rio Oeste Abajo

Rio Oeste Abajo is located in Bocas del Toro, the northwestern province of Panama. The team took a small bus ride of about 20 minutes from Almirante to get to this site. The team met Elizabeth, the PCV in this community, who housed the team while the team was in Rio Oeste Abajo for the site visit. Rio Oeste Abajo is just minutes off the main road, and it also happens to be a meeting place for several of the other communities in the area. Soccer games are held at the field in the community every Sunday during the less rainy season. Cheers from the bystanders in the valley can be heard at the community health center (Centro de Salud), which is located at the highest point in the community.

This community has easy access to supplies with only a 20 minute commute into town. This has allowed the community to be able to build larger homes and avoid food scarcity. The ease of access to supplies has also led to a considerably larger amount of litter compared to the Quebrada Platano community. Due to the proximity to Almirante, Rio Oeste Abajo is more modern than Quebrada Platano. Some families have propane stoves in their kitchens, whereas Quebrada Platano families mainly use a wood fire to cook their food. Rio Oeste Abajo also has the accessible health center located directly in their community, while Quebrada Platano has to travel to another community for health care.

The primary school located in Rio Oeste Abajo serves a couple communities in the surrounding area. High school education in this area is located on the other side of the mountain, which requires a bus fare to be paid for each time the student attends school. The income of the family will ultimately determine whether they can send their children to get a high school education. Income is not a factor for families from the Quebrada Platano community who seek a higher education for their children. The children in the Quebrada Platano community do not need to take a bus, but must walk one hour to the neighboring community for a high school education.

The water source for Rio Oeste Abajo supplies water to the community homes, local school, and health center. This source is called Palo Seco and has a storage tank referred to as the Union Tank. The Union Tank is a 5,000 gallon storage tank that is used to supply water to about 250 - 300 people. Approximately 60% of this population is under the age of 20 and the population is expected to grow in the coming years. This Union Tank does not have a chlorination system, nor do the people filter or chlorinate the water that they drink in their homes. The locations of the Palo Seco *toma* and community buildings are shown in Figure 3.

Rio Oeste Abajo, located in a valley, eventually diverged and grew into two communities: Rio Oeste Abajo and Valle Risco. Several years ago, Valle Risco created a *toma* which is located above the Rio Oeste Abajo source which runs into Rio Oeste Abajo's *toma* source. Rio Oeste Abajo did not inform the government of the construction of the Valle Risco *toma* during the allowable window of debate; therefore, Valle Risco maintained the capability to disregard the downstream *toma*. Water did not reach the Valle Risco communities aqueduct due to insufficient pressure when the intake was constructed and connected. Valle Risco took their intake structure out of commission but has the ability to reconnect to their *toma* at any time. Water supply may be cut off to the downstream Rio Oeste Abajo water intake structure if the system is reconnected.

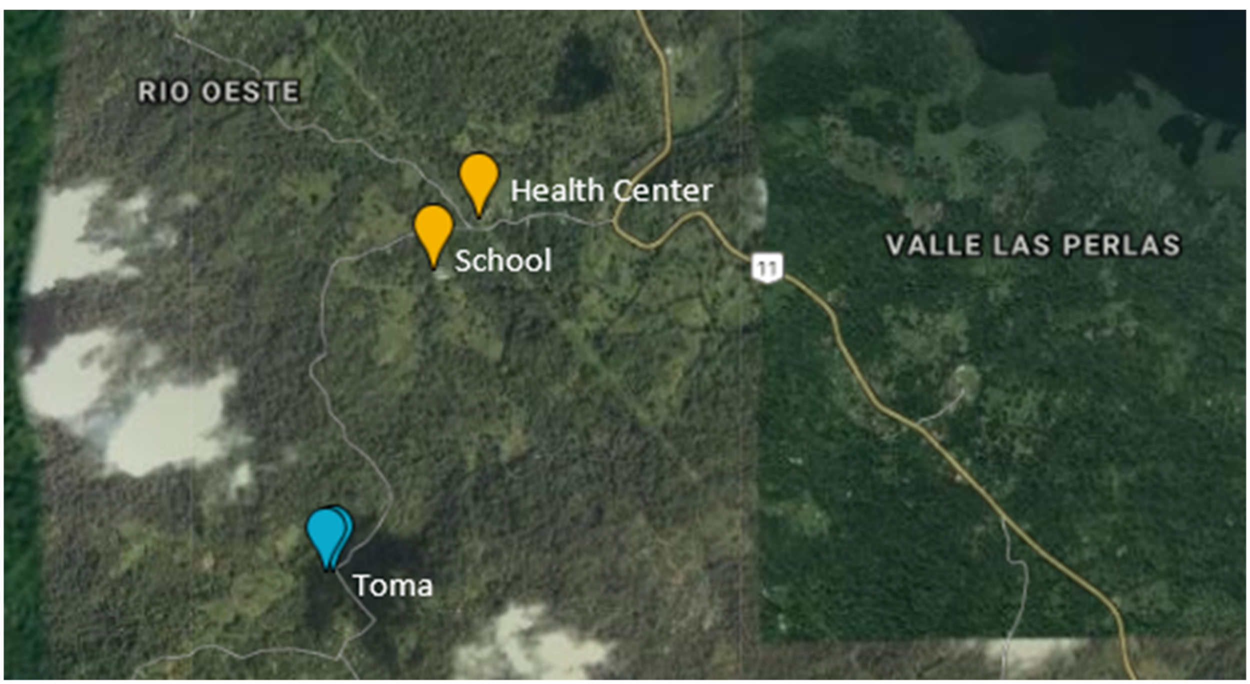


Figure 3. Map of Source for the School and Health Center in Rio Oeste Abajo.

1.2 Problem Description

Site 1 - Quebrada Platano

Quebrada Platano faces several problems that have caused setbacks in development and growth within the community. The difficulty of bringing in supplies is the challenge that the Quebrada Platano community faces. Vehicle transportation, especially during the rainy season, is very limited. Due to the challenging and long hike from the gravel road, bringing even basic supplies is a Herculean task. This limits trips to the nearest city of Almirante to biweekly in the dry season and monthly in the wet season.

The community deals with health problems due to an inadequate water supply and lack of water treatment. This stems, in part, from lack of accessibility and feasibility of transporting materials. Each aqueduct experiences blockages due to sediment and debris whenever there is heavy rainfall. To remove the blockage, a community member must hike up to the aqueduct source to clean out the *toma*. The sediment and debris cause turbidity of the water which can host the growth of harmful bacteria.

Addressing these issues is crucial to the reliability and quality of the water for the community. Initiative and action by the community must be taken to address these problems. However, some residents are reluctant to take action because they are either unmotivated, think these issues do not concern them, or are waiting for leadership or organization by others.

Site 2 - Rio Oeste Abajo

The problems faced in Rio Oeste Abajo pertaining to water reliability and quality are similar to those in Quebrada Platano. The Union Tank is located about one hour from the community. The pipe network runs from the Union Tank to the school and then continues further to the community's homes. The piping is not buried which leaves the pipe exposed to livestock, falling rocks and trees, mudslides, and the possibility of being washed away during the rainy season. Due to high pressures in the system, holes are drilled in the pipe to release the air and pressure. This adds to the concern of exposure to potentially harmful bacteria.

Additionally, there are no erosion control measures at the *toma*. The source has steep banks located on each side which causes sediment, rocks, branches and other debris to be washed into the *toma*, especially during the rainy season. Since there is no retaining wall structure, there is a direct path for debris to get into the inlet retention area. There is no filter on the inlet to prevent debris from entering, which causes the inlet to clog easily. Additionally, the more turbidity these solids cause, the more the water quality of the source will decrease. During the rainy season, sediment builds up daily, and regular clean outs are needed. The distance of the *toma* from the community becomes a deterrence for upkeep to occur regularly.

There is a water committee in the community, but organization and accountability for broken piping causes the pipe network to be unreliable. Broken PVC pipe may go days before it is attended to, although all breaks should be an urgent concern as exposure increases. The community needs to better define expectations and responsibilities. The PVC piping that breaks on a community member's property is the resident's responsibility to fix. Often, the community expects the water committee to fix and provide the materials, which is not the case. Getting the community to come together and work on a project can be difficult. The common opinion of the community members is that someone else can do it, or they should not have to help with the project that everyone in the community will use.

During the site visit, the team learned from the PCV that there also appears to be a lack of education in this community pertaining to water quality. Many community members do not understand the importance of filtering or chlorinating their water. However, they do understand that their water has harmful bacteria in it which causes young people to get sick. It is believed that one must drink the water in order to strengthen their immune system. Therefore, the community is generally not concerned with the possible adverse health effects of the water.

2.0 Data Collection and Analysis

A survey of the water network and surrounding area was necessary to calculate the hydraulic potential of the system. The team utilized a Garmin eTrex GPS which provided the latitude and longitude points, as well as elevation (barometric pressure); a rangefinder, Abney level and 100’ measuring tape; and a one liter bottle and stopwatch to measure flow rates.

Water flow rates for each source were calculated by timing how long it took to fill a one-liter water bottle. There were nine measurements taken and averaged for each of the sources. The physical dimensions of each water source intake structure or location were measured using a tape measure.

Water quality was tested throughout the community utilizing 3M Petrifilm E.coli/Coliform Count Plates (3M Products). Coliform bacteria is commonly used as an indicator species in many water quality tests. Although unlikely to cause illness, the bacteria survive in the same conditions as disease causing organisms that are more difficult to detect. E.coli is found in water that is contaminated by feces, which is a major health concern in the communities. Various water sources were tested using 1 mL samples. The plates were kept flat in a notebook and were allowed to incubate for 24-48 hours. Analysis of the samples was performed in good lighting and by the same team member for data consistency. Results were compared relative to one another in terms of lower or higher levels of contamination between sources in the same community. The purpose of the water quality testing was to identify the source(s) that affect the health and safety of the community and to help demonstrate the need for water treatment in the communities.

The next section discusses survey results Quebrada Platano and Rio Oeste Abajo, respectfully. Waypoints were downloaded and imported into Google maps. There were cases in which the GPS would make several waypoints for a single location, and these were averaged and shown as a single point in the figures. Once the team had the map markings, the linear distance between the points could be determined to be used in further calculations.

2.1 Data Analysis

Site 1 - Quebrada Platano

Survey

The existing Big Tank network is on the West side of the community, composed of Aqueduct 1, Side Points, and Tank 1 as shown in Figure 4. The hike for this site visit followed an irregular path through the landscape, making calculations for hydraulic values difficult and uncertain. The existing School Tank network is on the East side of the community, composed of Aqueduct 2, Tank 2, Casa Communal and the School.

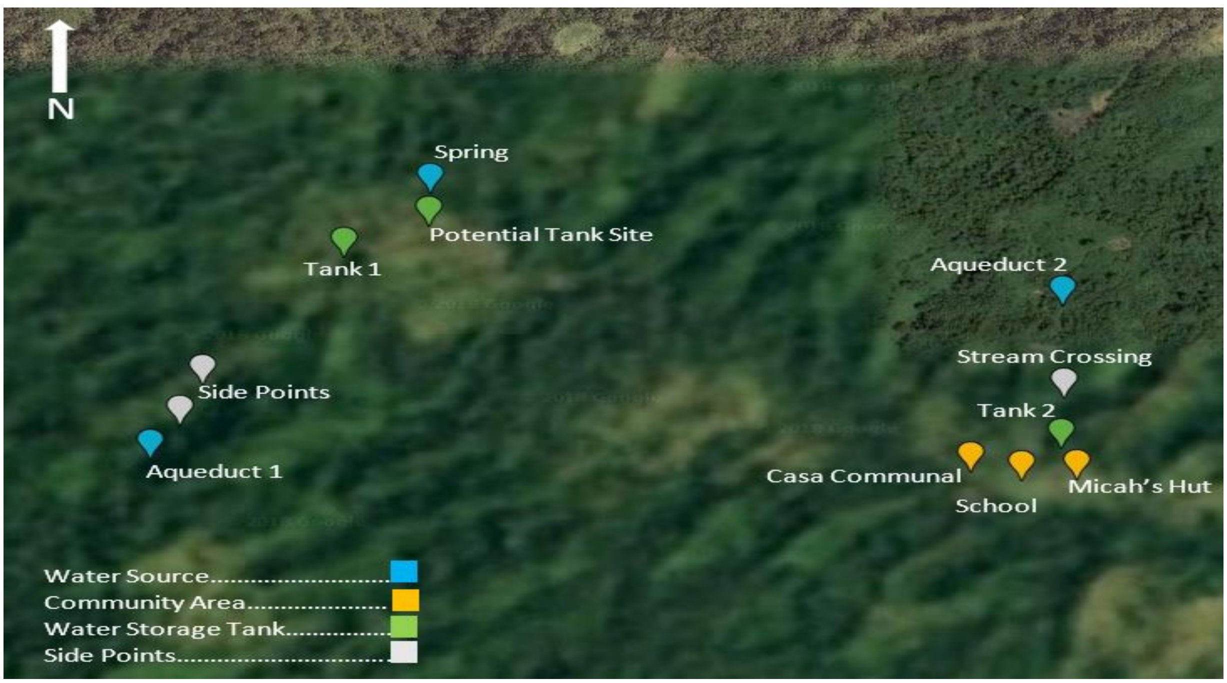


Figure 4. Site Map of Quebrada Platano (Google Maps coordinates).

Hydraulic Potential

The hydraulic potential was calculated for the first aqueduct in order to estimate the available pressure throughout the aqueduct systems. The Darcy-Weisbach head loss equation was used because it includes the length of the pipe and the pipe roughness. The head loss (h_L) equation that was used to calculate total head loss of the first aqueduct is shown below.

$$h_L = 16f\left(\frac{LQ^2}{2g\pi^2 D^5}\right)$$

Where, f is the unitless Darcy friction factor of 0.008 (for PVC),

L is the length of pipe used in feet,

Q is the flow rate in ft/s^2,

g is the gravity constant of 32.2 ft/s^2,

D is pipe diameter standard of 2 in.

The flow rate measured at Aqueduct 1 was 1.00 L/s, or 0.264 gal/s. The exact length of pipe is unknown due to a lack of construction drawings. Pipe lengths were estimated based on the elevation change and the horizontal (latitude/longitude) distance between two points (i.e. the hypotenuse). Using these constants, a maximum head loss of 217 ft from source 1 to the storage tank was calculated, and a head loss of 3 ft was calculated from the storage tank to the first house. The flow rate for Aqueduct 2 was recorded by the PCV, Micah, at the School Tank to be 9 gpm. At this flow rate, undeveloped spring has a head loss of 13 ft from the spring to a potential tank site, followed by a head loss of 3 ft to the first house from the tank. The elevations of each point can be seen in Table 1.

There is some bias with the elevation readings. Unlike the longitude and latitude GPS coordinates, the elevation readings are taken from the barometric pressure. The pressure varies throughout the day causing discrepancies in the readings. This can cause variations in the data depending on what the atmospheric conditions were during the time of the reading. These variations in elevation readings should be noted when implementing designs. The designs for Quebrada Platano are based on the GPS- surveyed elevations in Table 1.

Table 1. GPS Elevations for Key Locations in Quebrada Platano.

Point	Elevation (ft)
Source 1	864
Storage Tank 1	288
Spring	320
Potential Tank	250
1st House	234
Aqueduct 2	346
Storage Tank 2	223
Casa Communal	158
School	134
Micah's Hut	139

The head loss was subtracted from the change in elevation to get the total head available in feet as shown in Table 2. The flow rate was assumed to be constant throughout the pipe since the diameter is assumed consistent throughout the network.

Table 2. Head Calculations for Quebrada Platano.

Point to Point	Change in Elevation (ft)	Length (ft)	Head Loss (ft)	Total Head Available (ft)
Source 1 to Storage Tank 1	576.2	1985.0	216.8	359.4
Storage Tank 1 to First House	54.0	180.5	19.7	34.3
Spring to Potential Storage Tank	70.0	241.2	3.8	66.2
Potential Storage to House	10.0	194.2	3.0	7.0
Source 2 to Tank 2	123.0	715.6	25.2	97.8
Tank 2 to Casa Communal	65.0	240.8	8.5	56.5
Tank 2 to School	89.0	780.0	27.5	61.5
Tank 2 to Micah's House	84.0	482.1	17.0	67.0

Rangefinder, Abney Level & Tape

The rangefinder, Abney level and tape were used to survey the Spring Source in Quebrada Platano. This source is not developed yet and only has one family using it as a water source. Table 3 summarizes the data that was recorded using the rangefinder, Abney level and tape. Table 4 summarizes the elevation data for various locations pertaining to the spring source.

Table 3. Survey Data Collected for the Spring Source in Quebrada Platano.

Point	Angle (%)	Angle* (degree)	Horiz. (ft)	Notes
1	69%	-33.8	45.5	spring to tree
2	21%		12.6	tree to bottom of river
3		0.2	618	across river
4		11.2	405	up to existing tank
5		-10.4	255.5	tank to tree
6		-4.8	193.5	tree to house

*negative angle is going downhill

Table 4. Elevation Data for the Spring Source in Quebrada Platano.

Location	Elevation(ft)
Spring Source	320
River	270
Proposed Tank Site	250
Big Tank Site	288
1st House	250

Water Quality

Analysis of the water concluded that all water sources tested at Quebrada Platano are contaminated. Although a chlorination system is installed at the Big Tank, treatment is not occurring at any locations in the community. Table 5 below shows coliform and E.coli levels for each of the tests. As expected, the farther the water from the water source, the more contamination is seen due to growth and/or increased exposure. The spring inlet, which does not have an existing *toma*, was the least contaminated source. Figures A-12 to A-22 in the Appendix A illustrate the test plates for Quebrada Platano.

Table 5. Water Quality Summary Results for Quebrada Platano

Sample Location	Contaminant Count (colonies per 1 mL)	
	Coliform	E.coli
Site 1: Quebrada Platano		
Big Tank	4	23
Inside Inlet Box	21	23
Stream Inlet	TNC	TNC
Pool Above Stream Inlet	12	47
Spring Inlet	5	0
Spring Pipe	9	0
Host Family Tap	43	10
Santi Water Tap	18	0
School Sink	25	1
School Supply Tank	30	1
School Inlet	3	1

TNC – too numerous to count

Table A1 and Figures A-12 to A-31 of Appendix A show the full results of the water quality tests for Quebrada Platano and Rio Oeste Abajo.

Site 2 - Rio Oeste Abajo

Survey

The existing Palo Seco network, composed of one Toma, the Union Tank, and is connected to the School as shown in Figure 4. The water committee president, Taco, was building his own *toma, shown* in the northwest corner of Figure 5, to service his family. This network included Taco's Toma and Taco's family home. The team was able to visit the *toma* under development. The team gave Taco input and suggestions during the time of the site visit.

Figure 5. Site Map of Rio Oeste Abajo (Google Maps coordinates).

Hydraulic Potential

Using the same approach as discussed above, the head loss calculated from the Palo Seco *toma* to the Union Tank was 321 ft, from the Union Tank to the school it was 284 ft, and from the Union Tank to the health center it was 392 ft. However, these are approximate values due to unmarked changes in pipe diameter throughout the system. Also, as mentioned previously, there were locations where the holes are drilled in the pipe to act as a pressure release which can cause some deviation from the theoretical calculations. The PCV mentioned that at times the pipe diameter can range from 2.0” to 1.5” and back to 2.0” randomly, depending on what was available at the time within the community, and the smaller diameter would increase head loss within the pipe. There is also a river crossing that requires 90-degree elbows in the pipe. These bends increase the head loss in the system, and there can be high forces on the bends.

The multiple elevation readings taken from the GPS for the Union Tank, aqueduct, and cow pasture were averaged for each location when used in the head calculations.

Table 6. Elevations of Locations in Rio Oeste Abajo.

Location	Elevation (ft)
Palo Seco *Toma*	816
Union Tank	384
Downstream of cow pasture	957
Upstream of cow pasture	1033
Private Spring Box (Taco’s)	475
Health Center	67
School	7
River Crossing	7

Next, total head available was calculated. The same equation (Extended Bernoulli Equation) from the Quebrada Platano calculations was used. Table 7 describes these values for Rio Oeste Abajo. Majority of the Rio Oeste Abajo water system flows downhill, however the system encounters negative head when water travels from the Union Tank to the Health Center. The negative head available suggests there will not be enough pressure to transport the water from the Union Tank to the Health Center.

Table 7. Head Calculations for Rio Oeste Abajo.

Point to Point	Change in Elevation (ft)	Length (ft)	Head Loss (ft)	Total Head Available (ft)
Palo Seco to Union Tank	432	2339	320	112
Union Tank to River Crossing	377	2600	283	91
Union Tank to Health Center	317	3589	392	-75

Water Quality

Similar to Quebrada Platano, analysis of the water in Rio Oeste Abajo concluded that all water sources tested were contaminated. No treatment of the water sources occurs before reaching the taps. Table 8 below shows coliform and E.coli levels for each of the tests. The most coliform contamination was found at the school kitchen tap. The aqueduct was turned off temporarily at this site due to a break in the line. The water was turned on for the duration of the sampling but had been stagnant for a few hours prior to the test. The test at the health center appears to be unrepresentative based on the other community samples. The tap is inaccessible to the community and is only utilized while the center is in use once a week on Fridays. It is possible solar UV disinfection occurred in the holding tank prior to sampling which occurred on a Monday. Figures A-23 to A-31 in Appendix A illustrate the test plates for Rio Oeste Abajo.

Table 8.Water Quality Summary Results for Rio Oeste Abajo.

Site 2: Rio Oeste Abajo		
Sample Location	Contaminant Count (Colonies per 1 mL)	
	Coliform	E.coli
Health Center	0	1
School Kitchen	43	0
Union Tank	15	4
Palo Seco - Rocks	27	3
Palo Seco - Pool	19	3
Palo Seco - Tank	26	3
Palo Seco - Tank	28	0
Inlet	21	4

Table A1 and Figures A-12 to A-31 of Appendix A show the full results of the water quality tests for Quebrada Platano and Rio Oeste Abajo.

3.0 Proposed Designs

Lucy-Chen Inc. has prepared designs to propose to Quebrada Platano and Rio Oeste Abajo which are oriented to satisfy the needs of each water systems. The objective of each design is to improve the existing water systems in terms of water supply reliability and water quality. The information provided throughout this report and the attached appendix was used to determine the designs for the sources. Lucy-Chen Inc.'s goals for the proposed designs for the communities include decreasing turbidity (solids), incorporating a proper intake structure for the Quebrada Platano spring source, performing a hydraulic analysis of each system using EPANET, and designing inlet alternatives for each source. A summary list of proposed design projects for each water system is provided below.

Summary List of Proposed Designs

- Quebrada Platano
    - a. Big Tank Network
        - i. Sedimentation Tank
        - ii. Inlet Alternatives
        - iii. Pipe System
    - b. Spring Network
        - i. Spring box
        - ii. Storage Tank
        - iii. Pipe System & Taps
    - c. School Network
        - i. Sedimentation Tank
        - ii. Inlet Alternatives
- Rio Oeste Abajo
    - d. Palo Seco Network
        - i. Sedimentation Tank
        - ii. New Storage Tank
        - iii. Inlet Alternatives
        - iv. Pipe System

Sedimentation tanks were designed for each surface water source to decrease the suspended solids in the water before being delivered to the communities. Figure 6 shows the general design for the sedimentation tanks. The tanks are designed with an influent baffle to create laminar conditions. The baffle is a collection of tubes or holes to allow for water to pass through creating even flow distribution and laminar flow conditions. A secondary baffle wall is positioned after the curve to redistribute the uneven velocities due to this pattern of the tank. The baffle walls that are to be built in the sedimentation tanks will be made from 1” PVC piping or tubing, stacked up to 35 cm from the top of the tank. An image of a proposed baffle design is included in Appendix B for reference. The interior walls for the tank need to be as smooth as possible in order to prevent undesirable flow conditions (e.g. eddies, dead spaces). The hydraulic retention time for the designed system is 20 minutes. This is the required settling time for a water system with a sedimentation and storage tank recommended from the *Handbook of Gravity Flow Water Systems* (Jordan 1980). Sample engineering drawings for the sedimentation tank are provided in Figure 7. The sedimentation tanks are relatively small designed for the flows being experienced at this retention time. This can cause complications in construction and maintenance. Modifications should be made to the tank design as needed to increase the feasibility of cleaning out the deposits. The design specifications are shown in Appendix B.

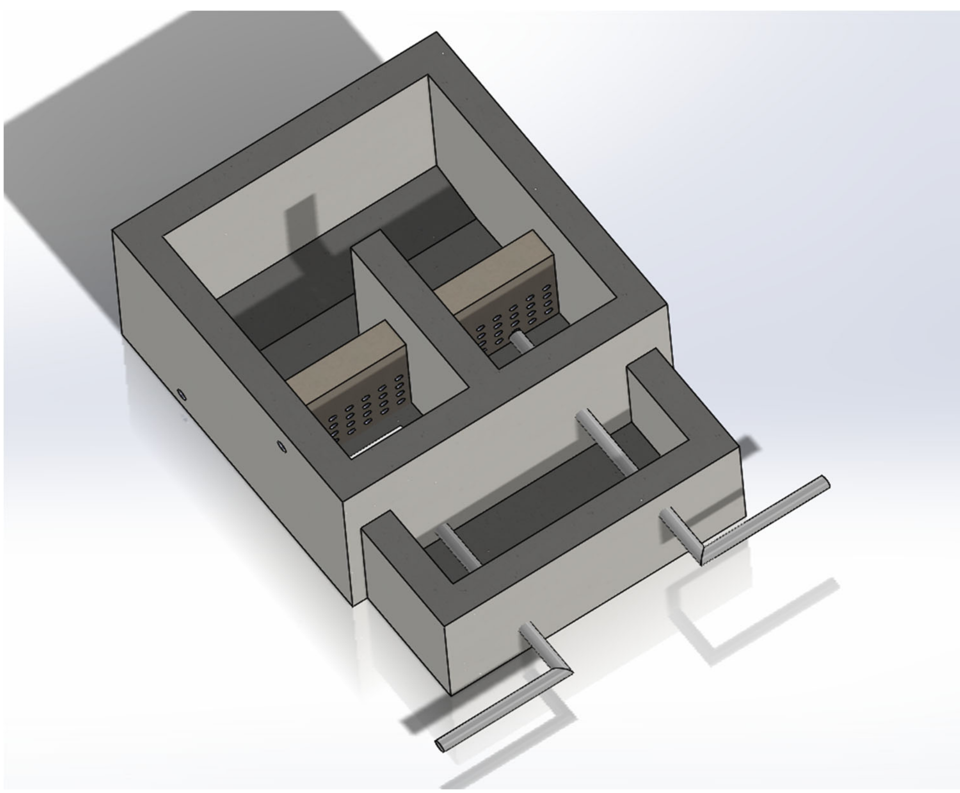


Figure 6. General Design for Sedimentation Tank

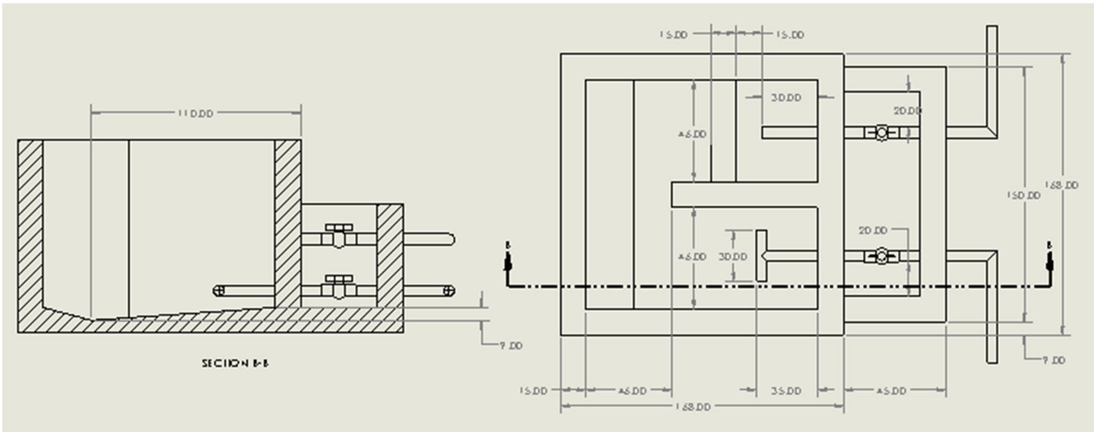


Figure 7. Engineering Drawing for Sedimentation Tank Design.

The sedimentation tanks can also act as a pressure break within the system if placed properly. Some sort of pressure break is recommended for every 300 feet of elevation change in order to avoid excessive pressures. This added benefit of the tank decreases the needed for additional pressure breaks throughout the network.

Sedimentation tanks are proposed for the Quebrada Platano Big Tank and School Tank systems, as well as the Palo Seco system in Rio Oeste Abajo. The sedimentation tanks will be placed within the aqueduct system between the inlet source and the storage tank. Areas of high pressure and/or high sediment buildup should be considered as potential sites for the sedimentation tank. It is necessary to ensure that the inlet for the sedimentation tanks is higher than the outlet pipe and is facing uphill to ensure proper flow into the tank. The outlet to the storage tank will be on the opposing side facing down the hill and lower on the sedimentation tank wall. A three or four part reinforced concrete cover can be used to cover the main compartment of the tank, and sealed with a mortar. More details are provided in the detailed drawing found in Appendix B.

When assessing the Spring Source, construction of a storage tank on top of the small hill across the river from the Quebrada Platano spring source would not be feasible. There is not enough head to transport the water from the potential tank on the hill to the highest house since the elevations are nearly equal. A storage tank should still be constructed in order to have a reliable flow of water from this source. The tank should be constructed between the spring source and first house elevations at approximately 280 feet, shown in Appendix A. Since this elevation is greater than that of the initial proposed location of the tank, a new location needs to be identified. Based on the elevation data taken during our site visit, the tank could be located on the same side of the river as the spring source to obtain the necessary head. An alternative location is on the same hill as the existing Big Tank at an approximate elevation of 280 feet.

A spring box should be constructed to protect the spring and inlet piping. The spring box design is described in Appendix C and is based on recommendations in Jordan (1980). This intake is similar to the other existing *toma* intakes in the community. The water flows from the spring source within the rocks and into the enclosed concrete structure. The area within the concrete structure should be excavated before the concrete is poured. The secondary tank was added to the design for additional sedimentation that may be needed in the future but can be omitted from the design of the spring box if desired. The first tank fills with water for quick sedimentation before being transported to the storage tank. The majority of the sedimentation will occur in the first tank, but it is not expected that much sedimentation will occur at the spring source due to the current water quality. The first basin will have a short pipe for transfer of water, and the second basin will have the outlet to the storage tank, if the second basin is built. Both the first and second basins should have lids to allow access and cleaning, which should occur regularly. Although the source cannot provide water to the entire community, it is important to utilize the spring source because the water is much cleaner than the other sources in the community.

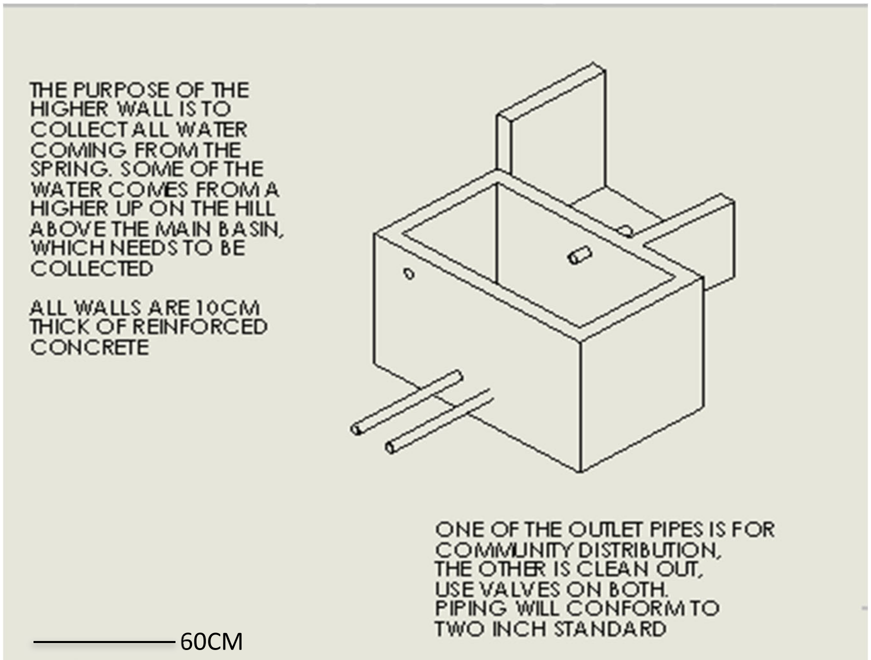


Figure 8. General Design for Spring Box.

The Rio Oeste Abajo has a health center (Centro de Salud) located in their community. Community members have the opportunity to visit the center each Friday to address health concerns. The center is located at the highest point in the community that was surveyed during the site visit. A storage tank, similar to the Union Tank, should be constructed near the health center to store and distribute water throughout the community. Having both of these tanks will improve water distribution throughout the entire community. This would also ensure there is always adequate water at the health center. The center currently has its own supply tank and would not need to be connected to the new supply tank, but modifications could be made to the tank to provide water to the center as well.

Each of the four aqueduct systems, three in Quebrada Platano and one in Rio Oeste Abajo, were modeled using EPANET in order to insure the proposed designs were feasible (EPANET 2 User Manual 2000). EPANET is a program that models water distribution systems over an extended period of time (e.g. 24-hour day). A pattern was used over the 24-hour period to model the expected water usage of the system. During the site visit, it was observed that the majority of the water usage happened during breakfast, lunch, and dinner periods. Due to this, the team modeled the usage from 6am-9am, 11am-2pm, and 5pm-10pm. The time period was increased in the evening to account for showering, chores, or other water usage activities. The flow rate at the nodes was based on a usage rate of 30 gallons per day per capita.

Appendix D shows the network maps, usage patterns, and results of the EPANET analysis. Networks were made up of nodes, tanks, pipes, and supply sources to represent each of the sources. EPANET calculates the pressure, head, velocity, and flow throughout the network. These simulations estimate the hydraulic behavior throughout the network. All of these variables are considered in the final storage tank designs. Tables D-1 and D-2 in Appendix D describe key data for each system in Quebrada Platano and Rio Oeste Abajo.

The results from EPANET will help in the design of the sedimentation tanks and storage tanks. These tables include the average flow rate, velocity, the maximum pressure, minimum pressure, maximum head, and minimum head of each system in both communities. The results from the EPANET simulations suggest that the systems can provide an adequate amount of water to each community and that there is enough head throughout each system for reliable water delivery to the storage tanks. Water can also be delivered to the highest house located in each community; therefore it is assumed that sufficient water can be delivered throughout the community. A summary of the simulated head and pressures each system is provided in Table 9.

Table 9. Summary EPANET Analysis of System Head and Pressures.

	Min. Head in System (ft)	Max. Head in System (ft)	Min. Pressure in System (psi)	Max Pressure in System (psi)
Quebrada Platano: Big Tank	40.9	43.9	17.7	19.0
Quebrada Platano: Spring Source	33.0	36.0	14.3	15.6
Quebrada Platano: School Tank	78.0	80.7	33.8	35.0
Rio Oeste Abajo	18.0	66.0	7.8	28.4

Additional improvements to the water systems include improved source intakes that would also improve water quality and reliability. There are various designs for each inlet source. Generally, a reinforced concrete lid is recommended for all water intakes. However, the intake at the School Source is too large to construct a concrete lid. The technical data for each design can be found in Appendix D. In addition, the source for the Big Tank in Quebrada Platano is below a steep hill and a canopy of trees. There is potential for leaves and other debris to fall into the source. The path up to the source is also treacherous and requires an extreme amount of effort to traverse. A steel sheet is easier to transport to the source and may be preferred over a reinforced concrete lid. It is also easy to cut and shape to properly fit the area. To improve the intake, medium aggregate will act as a filter to separate the large and medium debris out of the water while still allowing adequate flow to the inlet *toma,* with the steel sheet in separating the filer into two halves in the existing *toma* and above it. This expanded steel cover can be used for multiple designs at any inlet, but the concrete is preferred.

There are two different options for the School Source in Quebrada Platano which could also be implemented at other sources if necessary. The first option is to build a concrete enclosure around the inlet pipe with holes in the side for water entry. This option would help with keeping large debris out of the water such as sticks and leaves. The second option is creating a rock dam around the enclosure. Figure 9 shows the general design for the rock dam. This design would keep medium to large debris out of the water. This option could also filter out suspended sediment depending on the size and type of rocks used in the dam. An expanded steel sheet, which would be a sturdy alternative to chicken wire, is recommended to cover the water source is recommended for the Big Tank. The sizing of holes in the expanded steel should be within 0.5 cm to 3 cm to prevent as much debris as possible from entering the intake area, see Figure E-1 and E-2 for examples. In the structure, put medium to large aggregate into the *toma* maximum 5 centimeters from the top, and place the expanded steel on the aggregate inside the *toma*. The sheet will have to be bent and cut to fit proper within the area of the *toma*, then add more large aggregate on top to ensure that the sheet does not fall out. More detail can be found in Appendix E, drawing E-1 to E-4.

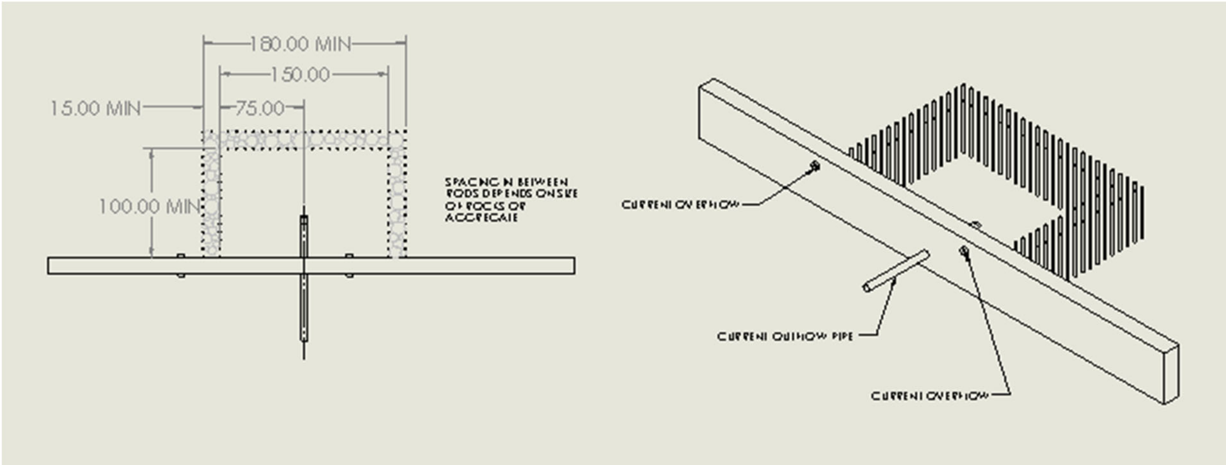


Figure 9. General Design of Proposed Intake Alternative for Quebrada Platano.

The existing structure at Rio Oeste Abajo should be retained since there are no current concerns with water demand. Developing a rock filter bed in the pooling area upstream of the inlet structure would decrease the sediments that make it to the inlet. The rock filter would be composed of a variety of rock sizes and gravel to decrease the pore size that the water travels through. Implementing an inlet structure is a trade-off between filtration and intake capacity. This inlet structure would enable high flows during the rainy season to be diverted past the structure without creating undesirable hydraulic conditions at the intake source, while still providing filtration of the intake water.

Water Treatment

Although each of these designs address necessary problems with each community's water systems, water quality is still a large concern for water consumption from each of these sources. The existing chlorine dosing system at the Big Tank in Quebrada Platano was not in use during the site visit, but it is still in operating condition. Chlorine tablets should be obtained and used in the chlorinator on the Big Tank. A chlorinator should be implemented at the School Tank in Quebrada Platano, as well as the Union Tank in Rio Oeste Abajo. Each community would have to obtain the free chlorine tablets from the government for the chlorination systems to work.

Until adequate water quality is reached, or if the community disinfection method is not feasible, it is recommended that consumed water should be treated at home using Chloro. During the flooding season of Panama, many of the surface waters and therefore the aqueducts become polluted with debris and suspended solids. These solids enable for the growth of bacteria and viruses which can be harmful to humans. Another in-house water treatment option is the use of an activated charcoal filter. This option uses three stages of filtration to get rid of small debris in the water depending on the quality of charcoal used. The first stage is a layer of gravel to filter out larger sediment. Followed by a layer of sand for the second stage to capture smaller impurities in the water. Finally, there is a layer of charcoal with a cloth that holds back the carbon and lets the water through. The charcoal removes impurities and contaminants through chemical absorption. This cleans the water relatively well but does not get rid of all bacteria that exists in the water. A full description of materials needed and how to activate charcoal is listed in Appendix F.

Summary

Overall, the Lucy-Chen Inc. proposed designs aim to improve the existing water systems in Quebrada Platano and Rio Oeste Abajo. Lucy-Chen Inc's goal is to satisfy the needs of the community while considering maintenance capabilities. The intent of the sedimentation tanks is to decrease the overall solids in the system as well as relieve high pressures. The tanks will not only improve aesthetics, but they will also improve water quality by decreasing the surfaces for bacterial growth. Since the existing *tomas* at Quebrada Platano and Rio Oeste Abajo are both in good condition, the implementation of inlet area covers and improved intakes should reduce sedimentation and clogging. The improvements to the existing structures would reduce the number of the trips necessary to clean out the inlet structures and sedimentation tanks, although they will still need to be maintained regularly. The overall water quality of these communities will improve with the removal of sediments from the water sources along with chlorine treatment.

4.0 Cost Estimate and Schedule

Project Cost Estimate

The materials, equipment and labor costs were calculated for each project and can be found below in Table 10. The material costs for the sedimentation tanks and storage tanks were calculated using a 1:2:4 concrete mix design: one part cement, two parts sand and four parts gravel. Community members will be providing the labor needed to build these projects. One foreman will be required to oversee the work to make sure it is built to the specifications. If the Peace Corps Volunteer acts in this role, the labor cost for each project will reduce significantly. The equipment consists of all small tools which can be purchased and brought to the community using a taxi. Materials can be delivered directly to Rio Oeste Abajo and by truck to the end of the gravel road near Quebrada Platano and can be carried by horse to the community.

Mobilization is not included in the table below but can be found in the Appendix G with the complete breakdown of the cost estimate. A taxi to the village carrying supplies is estimated to be $5 round trip. Delivery cost for a load of sand or gravel to the communities is estimated to be $10 round trip. Overall, the mobilization for each community is very low due to no heavy equipment needed. The contingency for each community is 20%, which was included in the final cost provided in Appendix G. There is no bond, overhead, or profit needed for these projects due to the community members completing these projects.

Table 10. Summary of Project Cost Estimates for each Source.

	Labor	Equipment	Material	**Total Estimate**
Big Tank	$ 1,010	$ 140	$ 430	**$ 1,600**
Spring Source	$ 1,830	$ 280	$ 700	**$ 2,800**
School Tank	$ 1,350	$ 230	$ 460	**$ 2,100**
Palo Seco	$ 2,350	$ 370	$ 990	**$ 3,700**

Project Schedule

The Quebrada Platano Big Tank, School Tank, and Rio Oeste Abajo Palo Seco sources are practically identical in project schedule. These three sources will each have a sedimentation tank and an improved water intake at the *toma*. Each of these projects can be started at the same time. Table 10 gives a summary of each project schedule estimate. Each sedimentation tank will take approximately 21 days to complete. The water intakes at the Big Tank and Palo Seco *tomas* will take approximately 4 days to complete. The water intake at the School *toma* will take 15 working days. The site and material preparation for the sedimentation tanks will take 9 days. The tanks' foundations, walls and covers will also take around 9 working days. Once the foundation construction is complete, 3 days will be allowed for the foundation to settle and partially cure before the walls are built. The total time for the concrete to completely cure is 28 days. Once the walls of the sedimentation tanks are completed, 28 days will be allowed for the walls to cure. The covers for the sedimentation tanks can be constructed as soon as the materials are prepped. The covers should also have 28 days for curing before placement on top of the tanks.

The Quebrada Platano Spring source will require more work than the other systems due to the implementation of a spring box and storage tank as previously discussed. The spring box construction will take about 3 months, while the storage tank will take 4 months. Site preparation and material collection and preparation for the spring box and storage tank will take 13 days. The construction for the foundation of the spring box will take 4 days, with 28 days of curing and settling. On day 3 of the foundation curing, the spring box walls can be constructed. The construction should take about 2 working days, and the curing should take about 28 days. The covers for the spring box should take about 1 working day, and the curing also needs to take about 28 days. The storage tank is on a similar schedule as the spring box, but the cover for the tank should be started 3 days after the tank walls go up. The tank cover will be attached to the top. The spring box and storage tank can be connected to the designated water system once both are complete and sufficient time has been allowed for curing.

Table 11 below shows a summary of the estimated schedules for each of the project sources. Included in Appendix H are Gantt charts for each system, along with detailed schedules for each project component.

Table 11. Summary of Project Duration Estimates for each Source.

Project	**Estimated Working Days**	**Estimated Non-Working Days**	**Estimated Total Duration (days)**
Big Tank	21	8	29
Spring Source	38	14	52
School Tank	28	5	33
Palo Seco	49	14	63

5.0 Project Implementation and Sustainability

Implementing the proposed designs in Quebrada Platano and Rio Oeste Abajo will require the assistance of the PCV in each of the communities. The PCVs will present the proposed designs to their respective water committees and other involved parties. They will also seek assistance from government officials, heads of the water committees, local officials, and each of the schools. Funding will need to be raised from the communities and/or from grants to help support the construction of each project, as specified in the community agreement. This will be the limiting factor for which projects they will be able to complete and when they can be implemented. Once local officials have decided on the projects, project sites, and have acquired appropriate funding, construction may begin. It is advised that construction happens during the dry season (January-April) of Panama.

Monitoring and maintaining these new systems after construction will be crucial to their success. Sedimentation tanks should be cleaned out once a month, the inlets need to be checked on at a minimum of once every two weeks, and more often during rainy season as more sediment will be suspended in the water. Only a small chisel and hammer should be necessary to break open the mortar seal used on the cover when cleaning the sedimentation tanks. The tanks should be resealed once cleanout is complete to keep debris and vermin out of the tanks. The intakes can be easily modified by adding screens, masonry filters, or cages surrounded by gravel (Jordan, 1980). It is up to the PCV to decide what they feel is the best option for their respective intakes.

6.0 Conclusion

It was essential to understand the needs of the community as well as the functionality of the existing systems in designing water system improvements for Ngobe communities of Quebrada Platano and Rio Oeste Abajo. The design improvements are not meant to give them an advanced water treatment plant, but progress their current system in an affordable manner which best accommodates their current needs. Although each community was unique, the technical similarities in Quebrada Platano and Rio Oeste Abajo have allowed the team to apply similar design concepts.

The Big Tank design includes a sedimentation tank and inlet alternatives. These projects will decrease the sedimentation within the network, which will not only increase the aesthetics of the water but improve water quality. In addition, the sedimentation tank will act as a pressure break tank to reduce the overall pressure in the system, which will reduce the risk of breaks and water loss. According to the EPANET analysis, there will be enough head to allow the water to reach the highest house in the community. It is assumed that there will be enough head to reach the houses located lower in the community. The pressure at the highest house was 17.7 psi. It is estimated that the improvements for the Big Tank source will take 79 days to complete at a cost of approximately $1,600.

The Spring Source system project will include a spring box and storage tank which will provide relatively clean water to a portion of the community. Although the flow at this source will not sustain the entire community, it would benefit the western sector of the Quebrada Platano community to utilize this source. The EPANET analysis showed that there will be enough head to allow the water to reach the highest house in the community. It is assumed that there will be enough head to reach the houses located lower in the community. The pressure at the highest house was 33.8 psi. If the pressure at the houses becomes too high, adjustments can be made using the valves at the storage tank to control pressure. It is estimated that the improvements for the Spring Source will take 107 days to complete at a cost of approximately $2,800.

Similar to the Big Tank project, the School Tank system design proposal includes a sedimentation tank and inlet alternatives. This system is essential to the community as it provides water to the school and community center. Improvements to this system will increase the reliability of water to these centers while improving the overall water quality. The EPANET analysis showed that there will be enough head to allow the water to reach the highest house in the community. It is assumed that there will be enough head to reach the houses located lower in the community. The pressure at the highest house was 14.3 psi. It is estimated that the improvements for the School Tank source will take 79 days to complete at a cost of approximately $2,100.

Projects were identified at the Palo Seco source in the Rio Oeste Abajo community. Design components include a sedimentation tank, new storage tank, and inlet alternatives. The sedimentation tank will be located upstream of the existing Union Tank. This placement will decrease the sedimentation in the Union Tank and act as an additional pressure break tank for the system. Proper sedimentation within the aqueduct will improve the efficiency of the system along with the aesthetics and water quality. The addition of a new storage tank located near the community health center will enable more reliable flow and even distribution to the school and community. The inlet alternatives will improve the intake and filtering of water into the Palo Seco *toma.* In addition, this will decrease the clean out maintenance that is required. The EPANET analysis on the Palo Seco system shows that there will be enough head to allow the water to reach the school and highest house in the community. It is assumed that there will be enough head to reach the houses located lower in the community. The pressure at the school node was 27.3 psi, and at the highest house it was 7.8 psi. It is estimated that the improvements for the Palo Seco source will take 79 days to complete at a cost of approximately $3,700.

Although these proposed designs will have a positive influence on the quality of the water being delivered to the homes, it is still recommended to treat the water before consumption. Water treatment is critical to the public health and welfare of these communities. It should be a priority to implement aqueduct chlorination with the in-line chlorinator. Until adequate water quality is reached, or if the community disinfection method is not feasible, it is recommended that consumed water should be treated at home using Chloro.

Peace Corps Volunteers will facilitate the successful implementation of these projects in their respective communities. It is crucial that modifications and adjustments are made to the systems as needed for top effectiveness. System maintenance should be completed periodically, in addition to an as needed basis.

The improvements have to been designed in a manner that fit the communities' needs, wishes, and abilities. It is Lucy-Chen Inc.'s hope that motivation and organization concerning the water systems will improve and be maintained following project implementation.

References

"EPANET 2 User Manual." EPA, United States Environmental Protection Agency, 2000, nepis.epa.gov/Adobe/PDF/P1007WWU.pdf.

Jordan, Thomas. Handbook of Gravity Flow Water Systems. United Nations, 1980.

"3M™ Petrifilm™ E. coli/Coliform Count Plates" 3M Products, 2018, https://www.3m.com/3M/en_US/company-us/all-3m-products/~/ECOLICT-3M-Petrifilm-E-coli-Coliform-Count-Plates/?N=5002385+3293785155&rt=rud

Appendices

APPENDIX A

Site Assessment

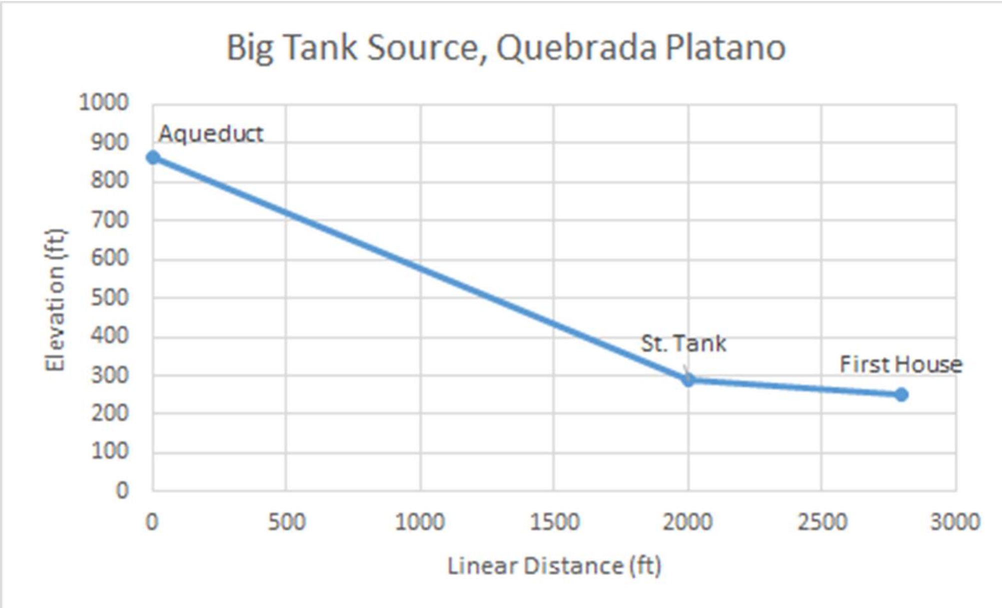


Figure A-1. Elevation Profile for Quebrada Platano, Big Tank Source.

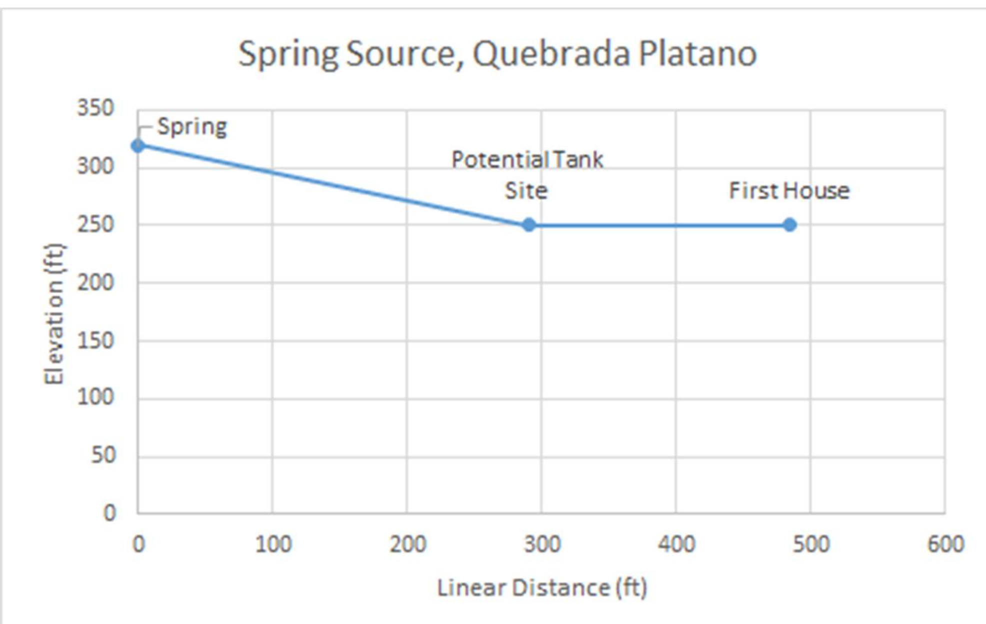


Figure A-2. Elevation Profile for Quebrada Platano, Spring Source.

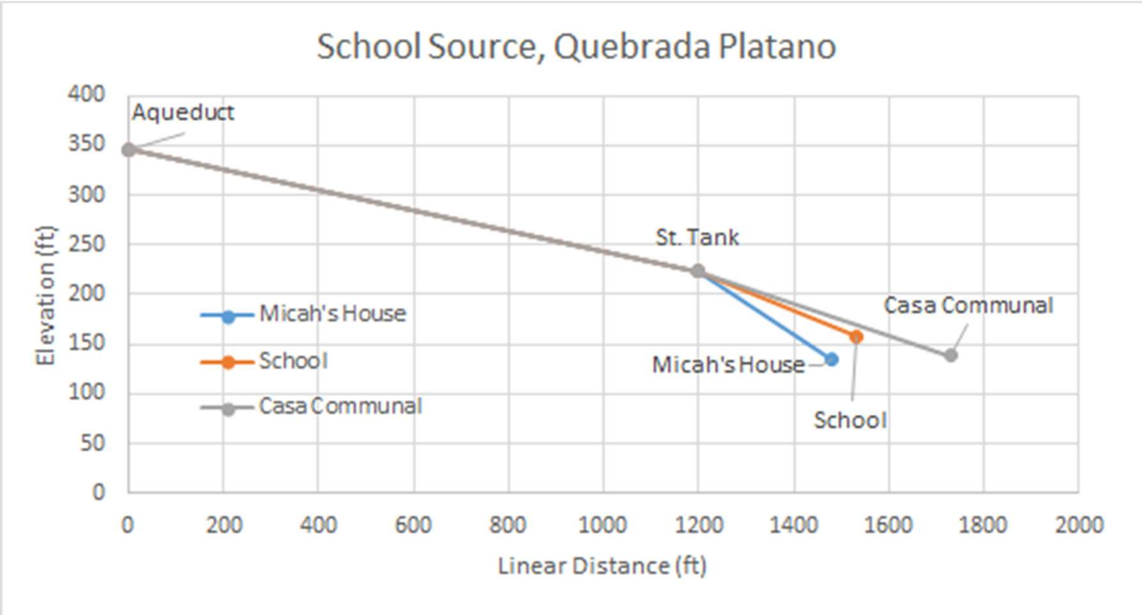


Figure A-3. Elevation Profile for Quebrada Platano, School Tank Source.

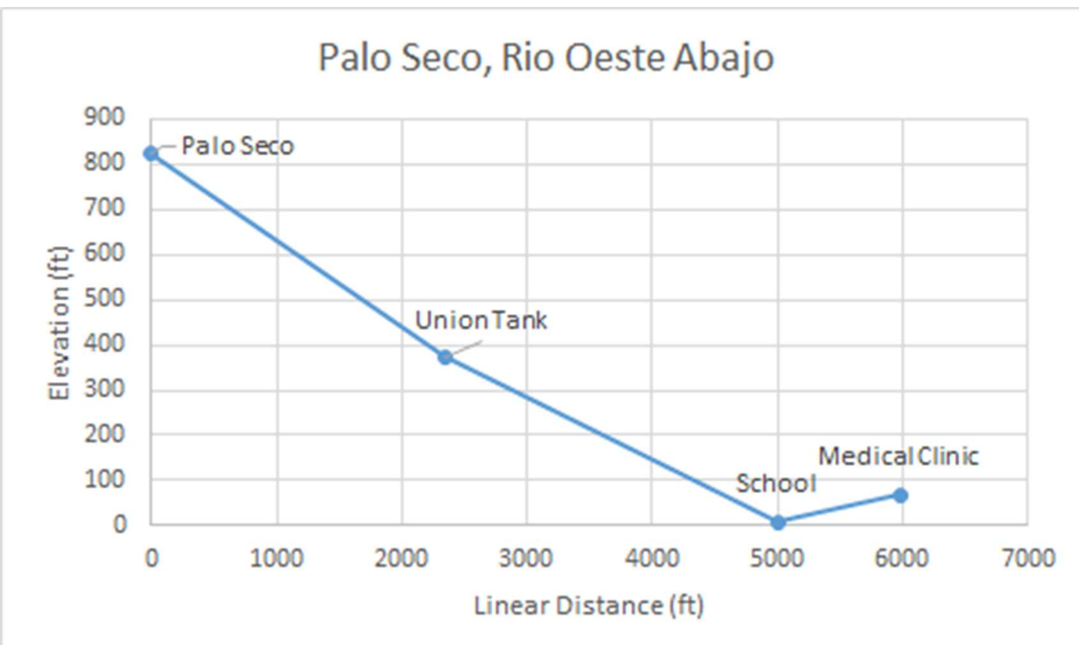


Figure A-4. Elevation Profile for Rio Oeste Abajo, Palo Seco Source.

For all of the elevation profiles, GPS coordinates were taken using the Garmin eTrex ID. Manual surveying was done at the spring in Quebrada Platano for a check since the GPS elevation can vary depending on the time of day (i.e. barometric pressure).

Figure A-5. Existing Quebrada Platano Big Tank Intake

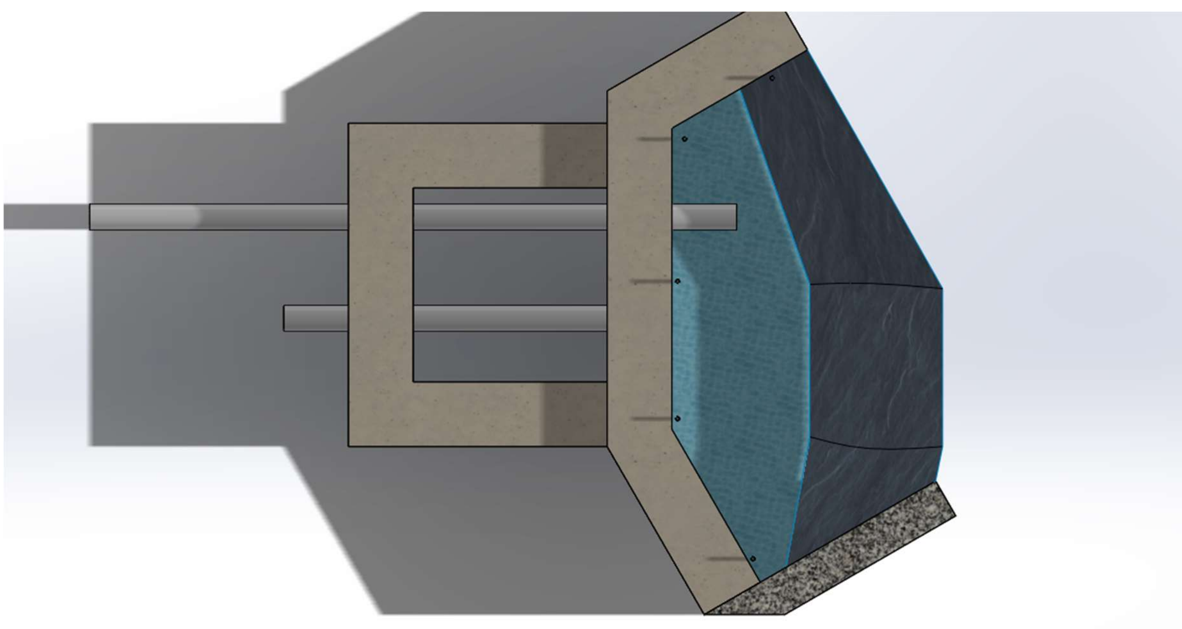


Figure A-6. Existing Quebrada Platano Big Tank Intake. For sizes and dimensions, see engineering drawing in Appendix E

Figure A-7. Quebrada Platano Spring Source. Approximate size of pool is 2ft x 3ft.

Figure A-8. Quebrada Platano School Tank Source.

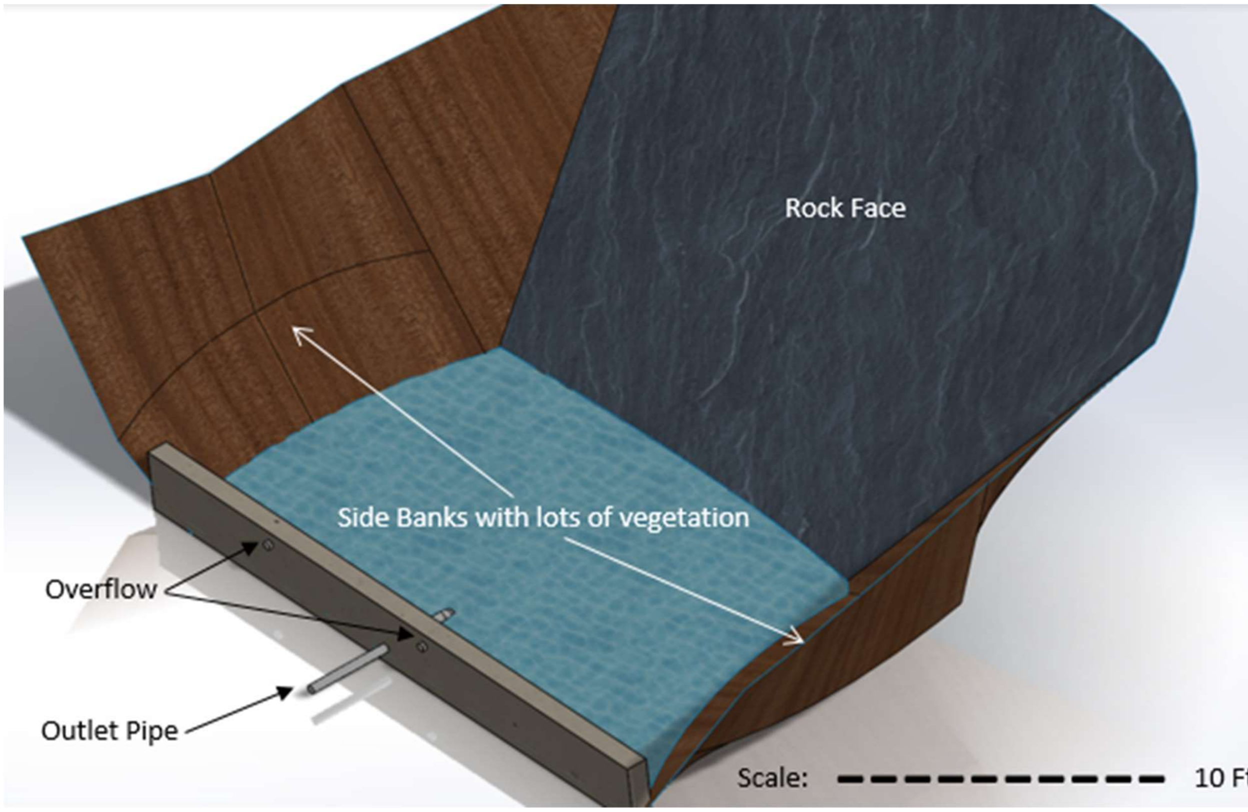


Figure A-9. Existing Quebrada Platano School Tank Source Model. Main dam is 16 ft long and 6 in thick. Area where water is pooling is open and adjacent to steep slopes with heavy vegetation. For sizing and dimensions of dam wall with improvements, see Appendix E.

Figure A-10. Palo Seco Toma Serving Rio Oeste Abajo

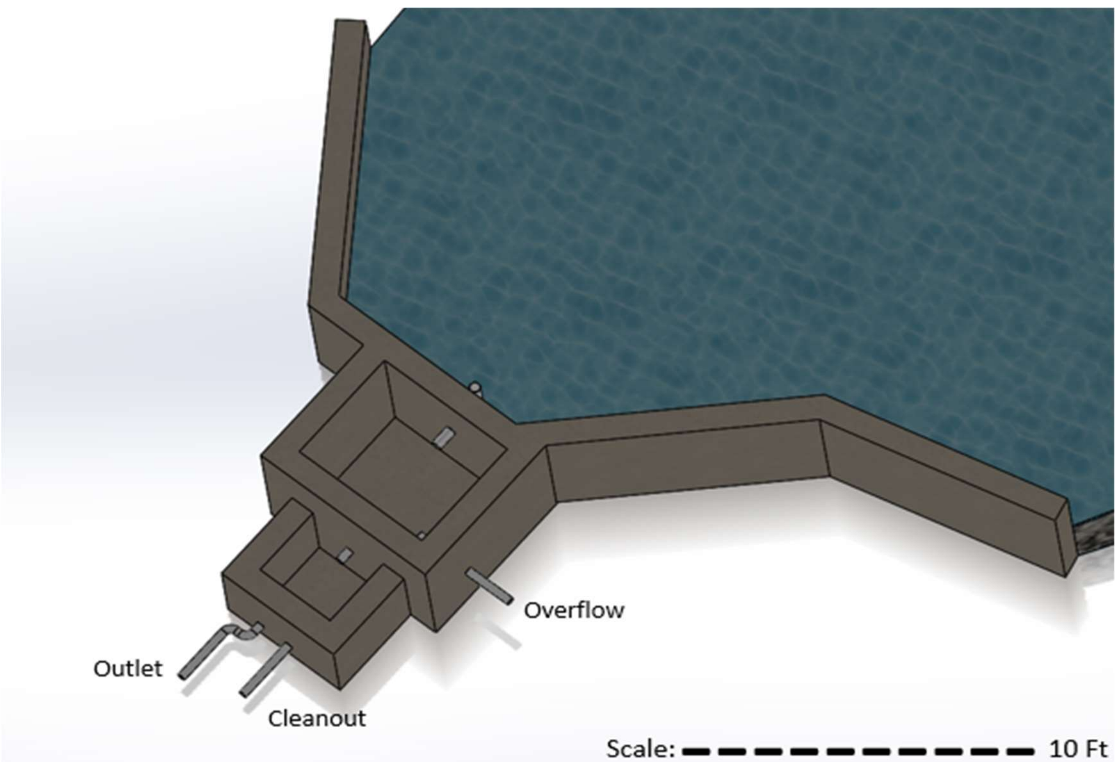


Figure A-11. Rio Oeste Abajo Palo Seco Toma Model (existing). The main compartment is 26" x 32" x 32" (W x L x H). The smaller compartment is 18" x 25" x 25", each with 6" thick walls. The dam walls are illustrative, as they were partially buried and full dimensions were not measured.

Table A1. Water Quality Test Results

Sample Location	Collection Date	Collection Time	Count Date	Count Time	Contaminant Count	
					Coliform	E.coli
Site 1: Quebrada Platano						
Big Tank	8/17/18	8:10	8/18/18	13:05	4	23
Inside Inlet Box	8/17/18	9:20	8/18/18	13:06	21	23
Stream Inlet	8/17/18	9:25	8/18/18	13:07	TNC	TNC
Pool Above Stream Inlet	8/17/18	9:25	8/18/18	13:08	12	47
Spring Inlet	8/17/18	10:50	8/17/18	13:09	5	0
Spring Pipe	8/17/18	10:50	8/18/18	13:10	9	0
Host Family Tap	8\17\18	12:40	8/18/18	13:11	43	10
Santi Water Tap	8/17/18	13:50	8/18/18	13:15	18	0
School Sink	8/17/18	14:05	8/19/18	8:36	25	1
School Supply Tank	8/17/18	14:15	8/19/18	8:37	30	1
School Inlet	8/17/18	14:40	8/19/18	8:39	3	1
Site 2: Rio Oeste Abajo						
Centre de Salud	8/20/18	8:30	8/21/18	13:55	0	1
School Kitchen	8/20/18	8:55	8/21/18	13:56	43	0
Union Tank	8/20/18	9:35	8/21/18	13:58	15	4
Palo Seco - Rocks	8/20/18	10:15	8/21/18	13:59	27	3
Palo Seco - Pool	8/20/18	10:16	8/21/18	14:00	19	3
Palo Seco - Tank	8/20/18	10:17	8/21/18	14:02	26	3
Palo Seco - Tank	8/20/18	13:30	8/21/18	14:07	28	0
Inlet	8/20/18	12:45	8/21/18	14:05	21	4
Miscellaneous						
Filtered Water	8/18/18	9:50	8/19/18	8:40	1	0-2
Chlorinated Water	8/18/18	9:50	8/19/18	8:42	0	0

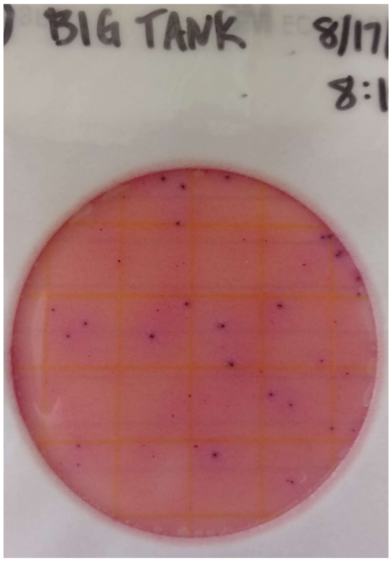


Figure A-12. Quebrada Platano - Big Tank Water Quality Result

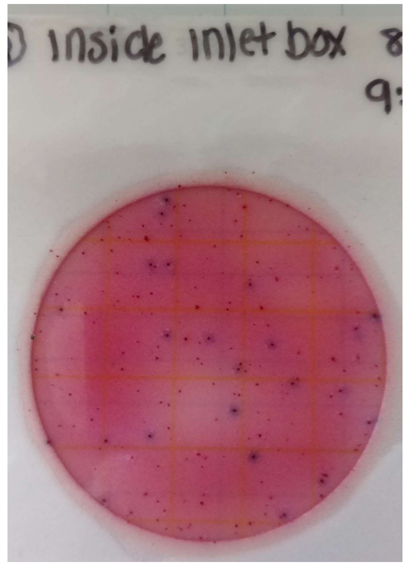


Figure A-13. Quebrada Platano - Inside Inlet Box Water Quality Result

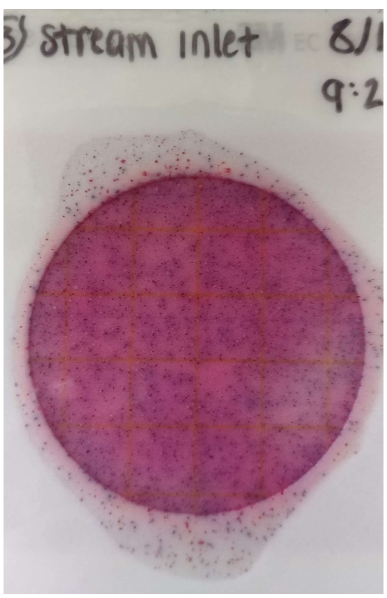


Figure A-14. Quebrada Platano - Stream Inlet Water Quality Result

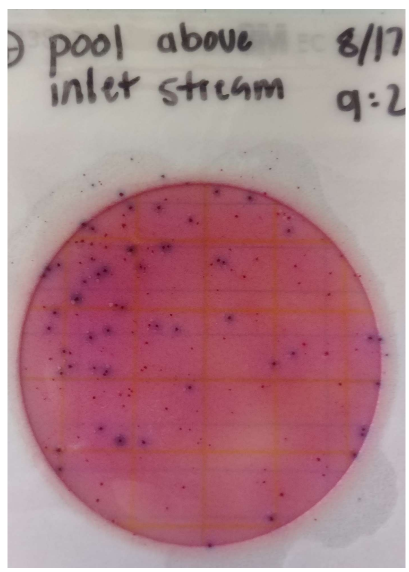


Figure A-15. Quebrada Platano - Pool Above Inlet Stream Water Quality Result

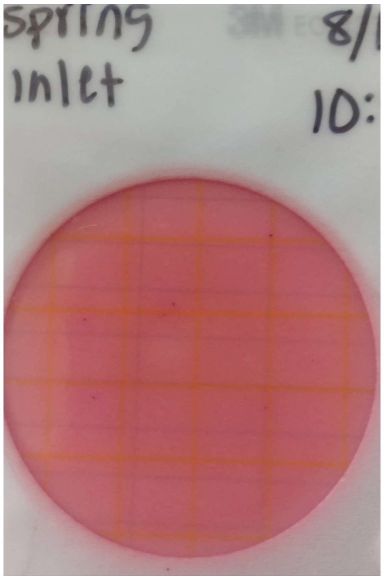


Figure A-16. Quebrada Platano - Spring Inlet Water Quality Result

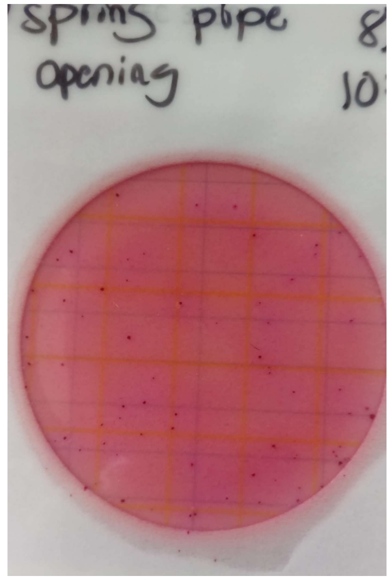


Figure A-17. Quebrada Platano - Santi Family Water Quality Result

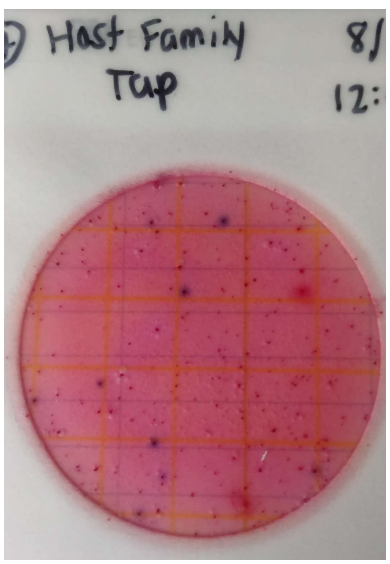


Figure A-18. Quebrada Platano - Host Family Tap Water Quality Result

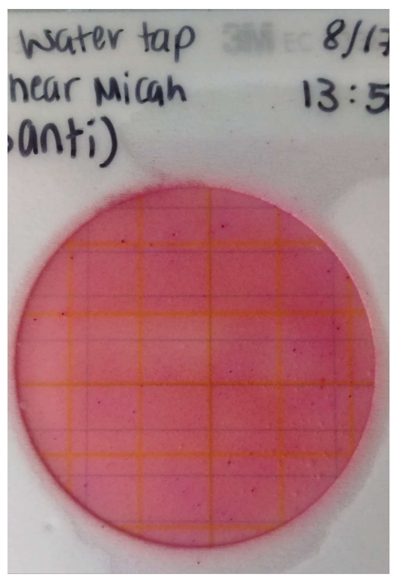


Figure A-19. Quebrada Platano - Santi Water Quality Result

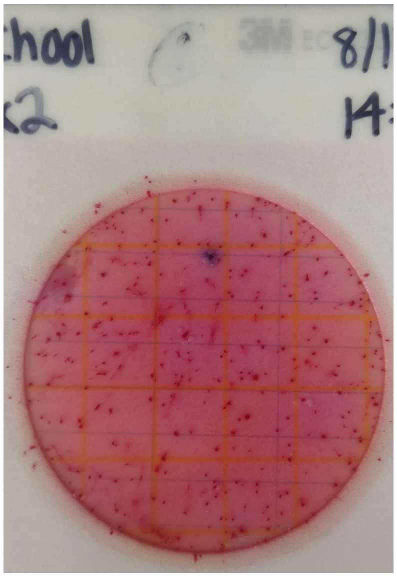


Figure A-20. Quebrada Platano - School Sink Water Quality Result

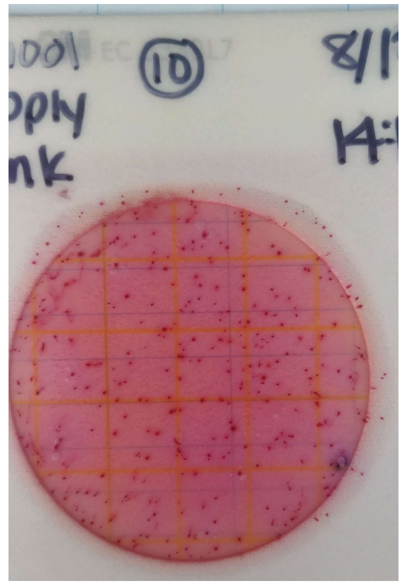


Figure A-21. Quebrada Platano - School Supply Tank Water Quality Result

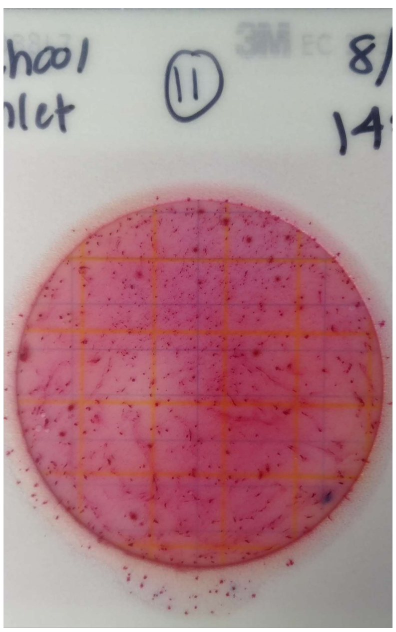


Figure A-22. Quebrada Platano - School Inlet Water Quality Result

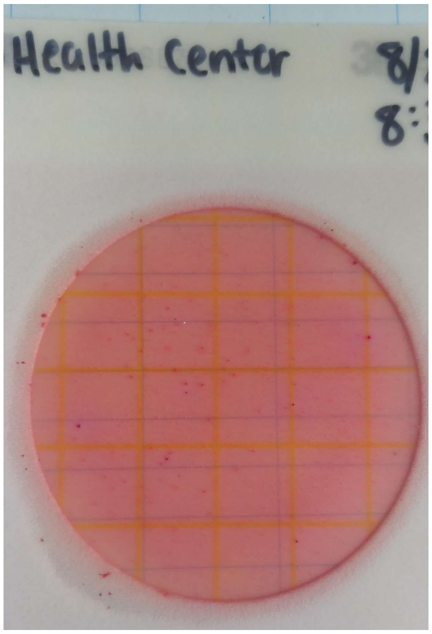


Figure A-23. Rio Oeste Abajo - Health Center Water Quality Result

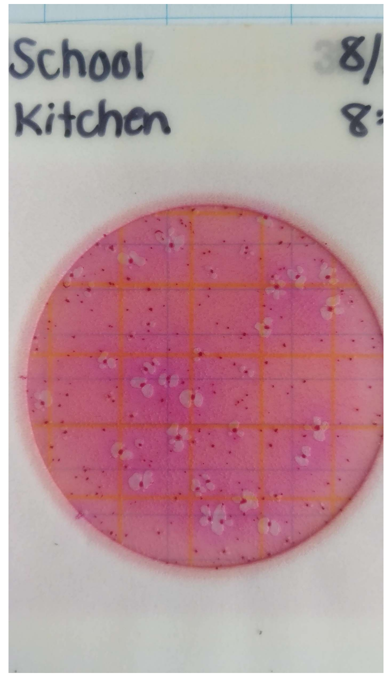


Figure A-24. Rio Oeste Abajo - School Kitchen Water Quality Result

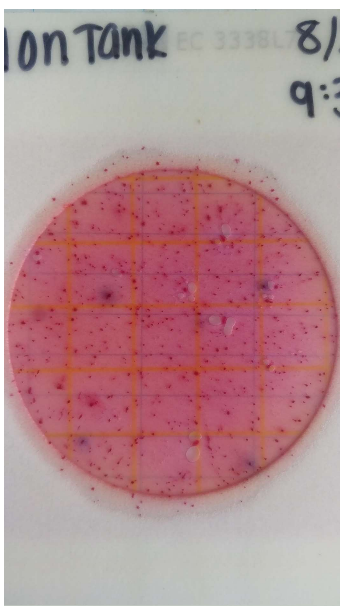


Figure A-25. Rio Oeste Abajo - Union Tank Water Quality Result

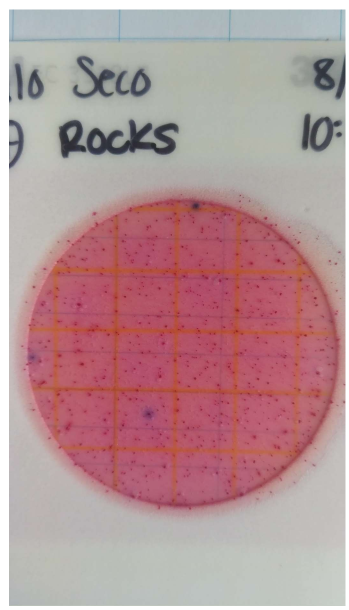


Figure A-26. Rio Oeste Abajo - Palo Seco - Rocks Water Quality Result

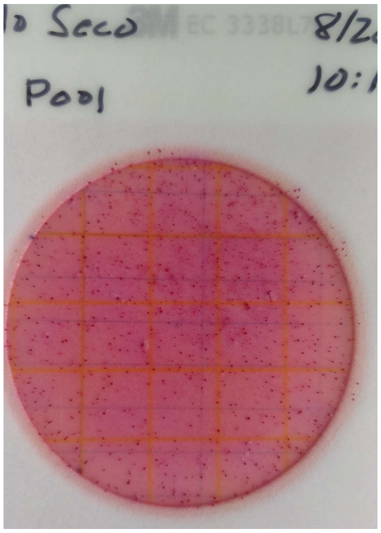


Figure A-27. Rio Oeste Abajo - Palo Seco - Pool Water Quality Result

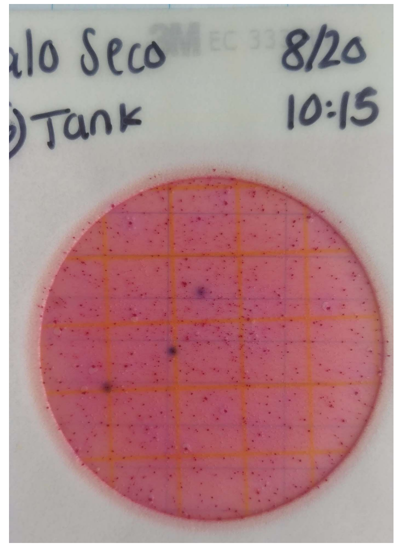


Figure A-28a. Rio Oeste Abajo - Palo Seco - Tank Water Quality Result 1

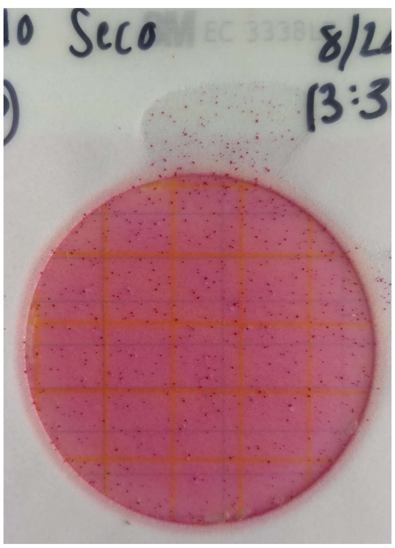


Figure A-28b. Rio Oeste Abajo - Palo Seco - Tank Water Quality Result 2

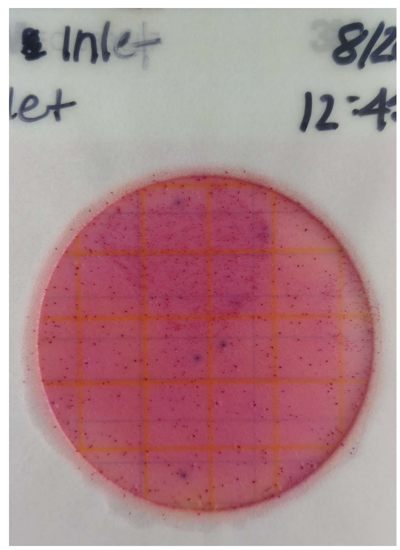


Figure A-29. Rio Oeste Abajo - Inlet Water Quality Result

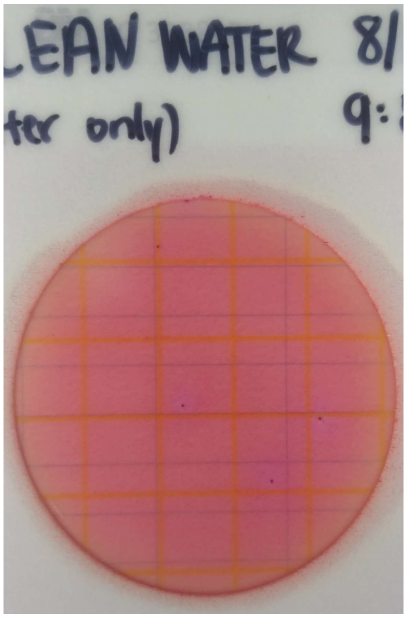


Figure A-30. Miscellaneous - Filtered Water Water Quality Result

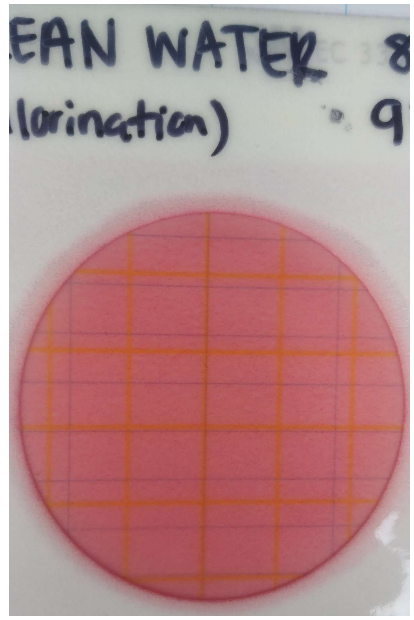


Figure A-31. Miscellaneous - Chlorinated Water Water Quality Result

APPENDIX B

Sedimentation Tanks

Figure B-1. General Design for Sedimentation Tank
Figure B-2: Example of Baffle Wall for Interior of Sedimentation Tank

Engineering Drawings
Quebrada Platano Big Sedimentation Tank
School Tank Sedimentation Tank Drawing
Rio Oeste Abajo Sedimentation Tank Drawing
Sedimentation Tank Cover Drawing

Sedimentation Tank Sizing Calculations

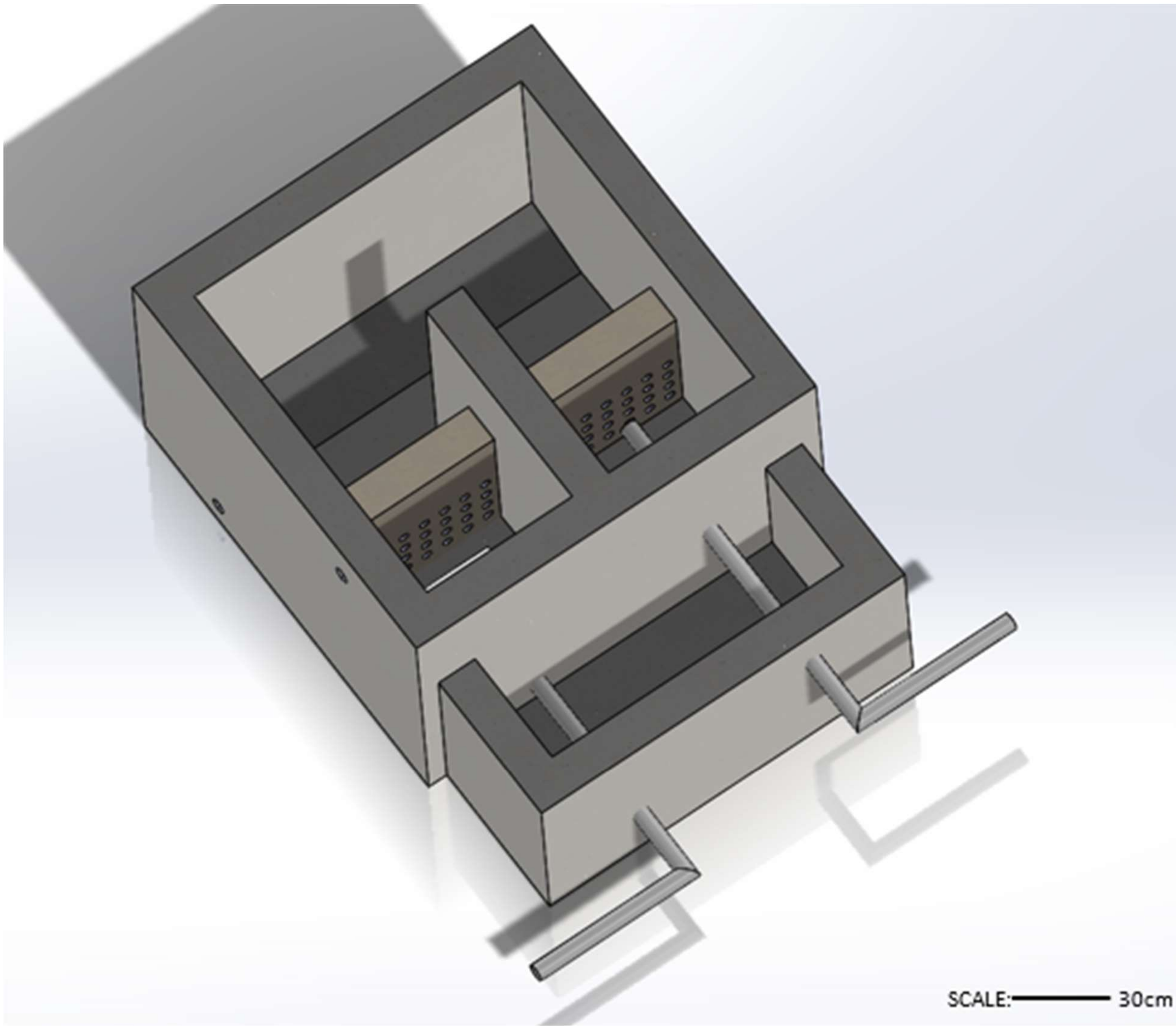
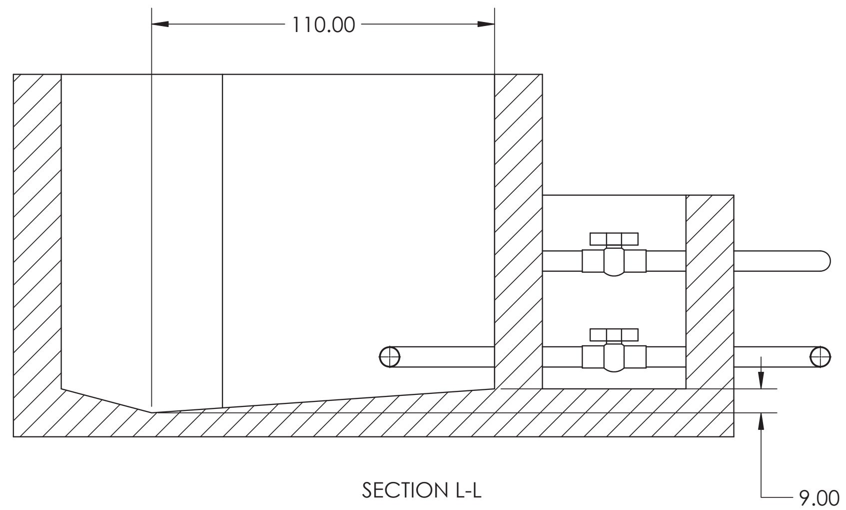
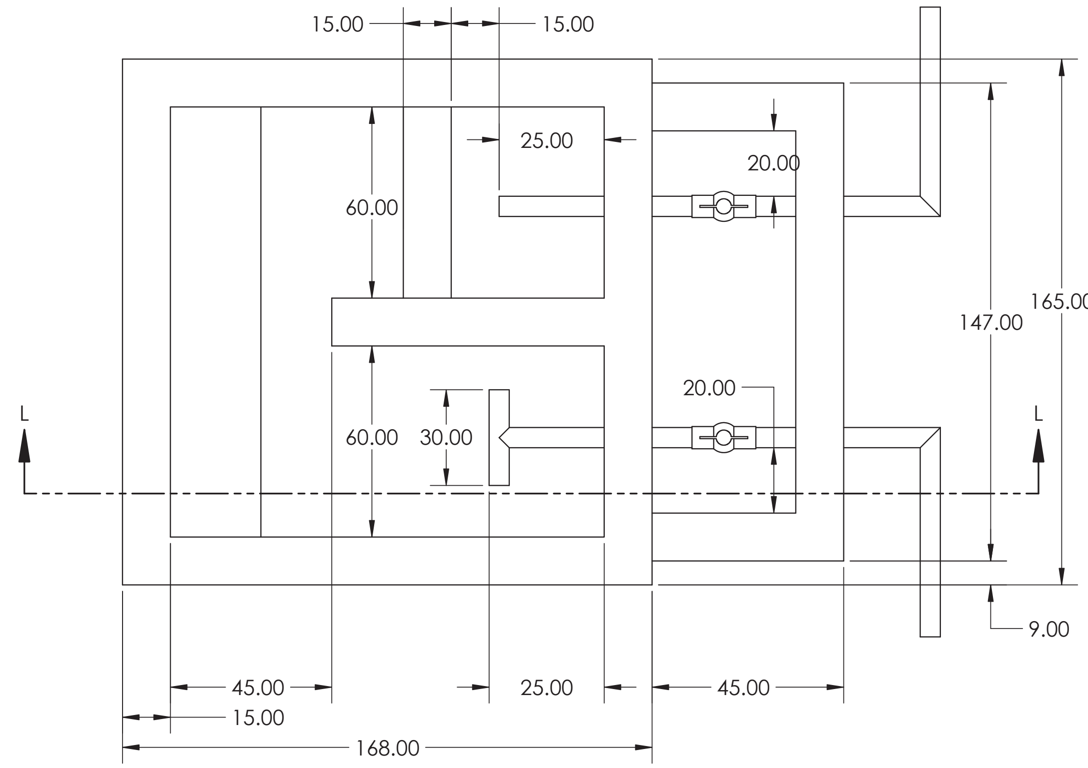


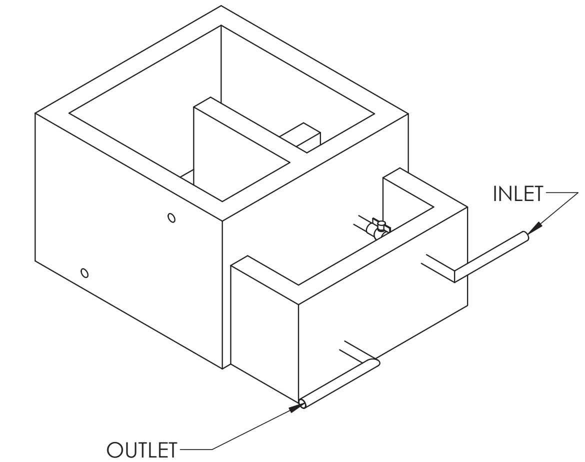
Figure B-1. General Design for Sedimentation Tank

This figure shows the two baffle walls that are designed in the tanks. The section view shown in Drawings B1-B3 allows the user to see the piping for the outlet of the tank that will go to the storage tanks. The drawings exclude the second baffle to show the piping outlet that will connect to the storage tank. The engineering drawings then further show which pipe is the outlet and inlet, the overflow, and the cleanout, Drawing B-4 shows how to construct covers.



SECTION L-L

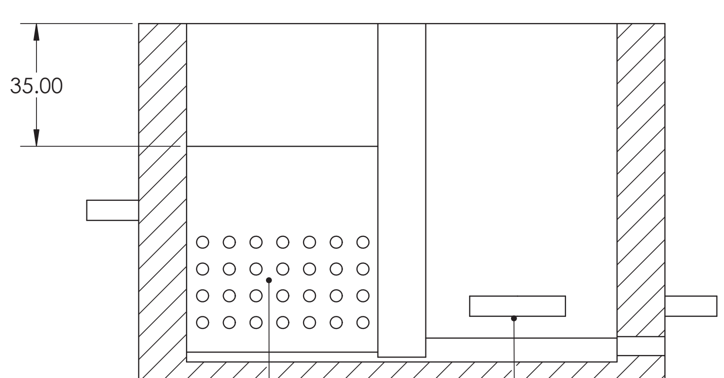




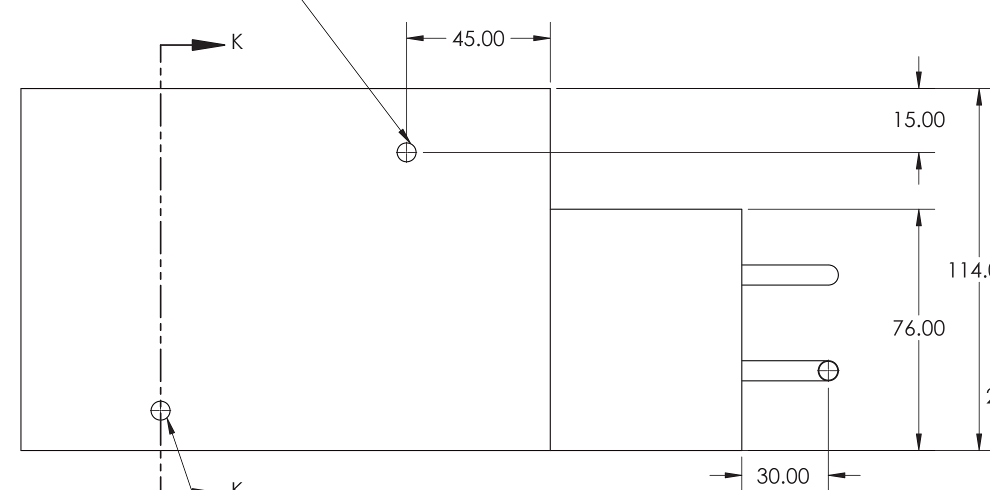
OVERFLOW VALVE
TWO-INCH PVC PIPING GOING
THROUGH THE SIDE, FACING
DOWN THE HILL

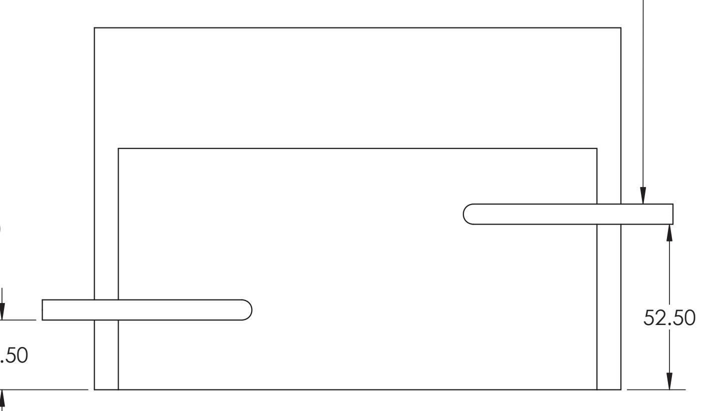
ADD PIPING SO OVERFLOW
WATER STAYS AWAY FROM BASE OF TANK

INLET WILL BE HIGHER ON THE TANK
WITH RESPECT TO OUTLET. STANDARD
TWO INCH PVC PIPING IS USED TO
CONFORM WITH PIPING ALREADY IN USE.



SECTION K-K





USE MULTIPLE HOLES ON TOP OF AND IN FRONT OF
OUTLET FOR EVEN FLOW INTO SYSTEM

CLEANOUT VALVE
TWO-INCH PVC PIPING GOING
THROUGH THE SIDE, FACING
DOWN THE HILL

ONLY OPEN VALVE FOR CLEANING
OUT SEDIMENTATION TANK

BAFFLE WALL:
VARIOUS MATERIAL OR DIMENSIONS
MAY BE USED BASED ON FUNDS AND
RESOURCES AVAILABLE
SEE REPORT AND FIGURE B-2 FOR FULL
DETAILS

ADD SECOND BAFFLE WALL TO
OPPOSITE SIDE OF TANK

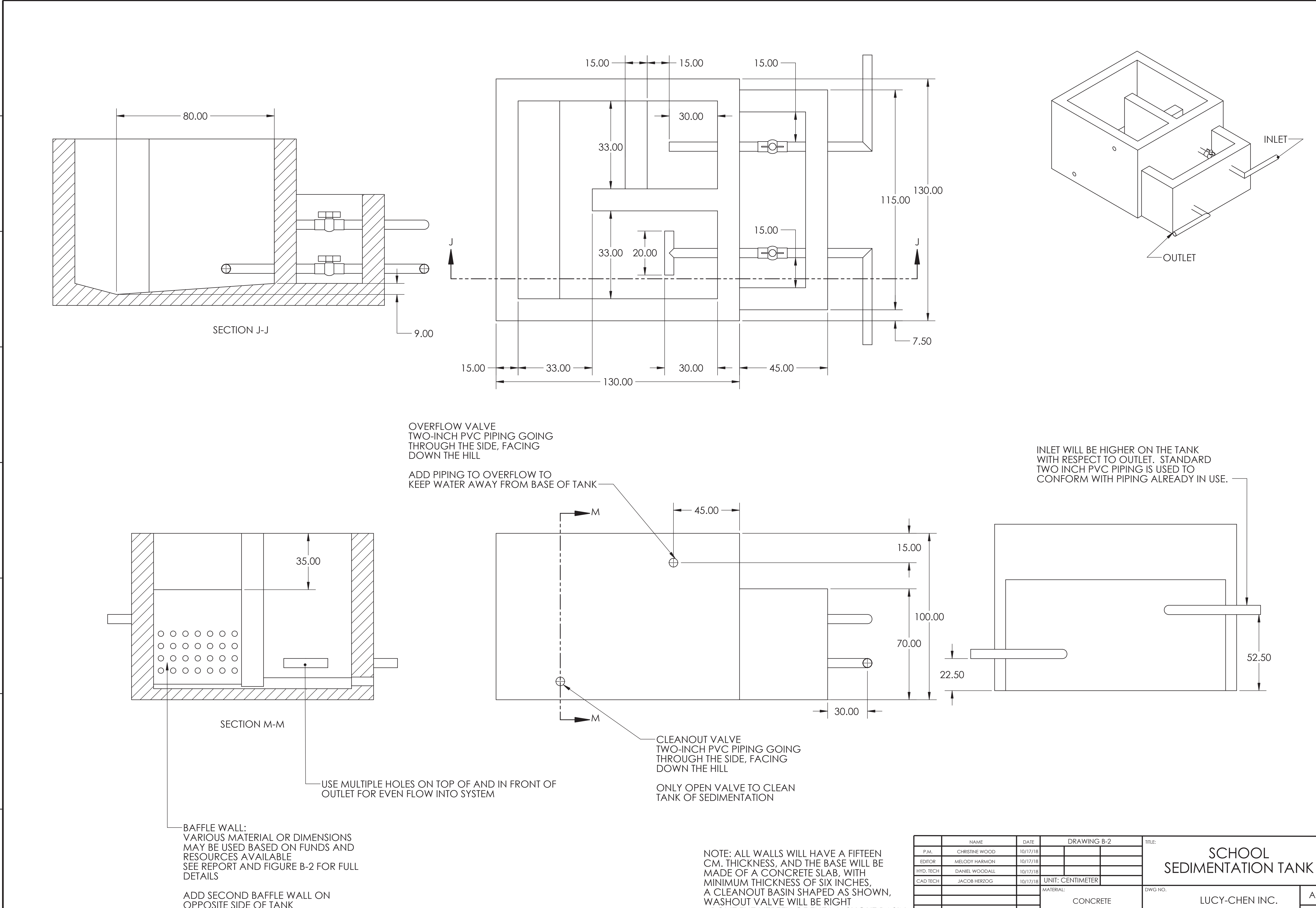
NOTE: ALL WALLS WILL HAVE A FIFTEEN
CM. THICKNESS, AND THE BASE WILL BE
MADE OF A CONCRETE SLAB, WITH
MINIMUM THICKNESS OF SIX INCHES,
A CLEANOUT BASIN SHAPED AS SHOWN,
WASHOUT VALVE WILL BE RIGHT
ABOVE THE VERTEX OF THE WASHOUT BASIN

	NAME	DATE	DRAWING B-1
P.M.	CHRISTINE WOOD	10/15/18	
EDITOR	MELODY HARMON	10/15/18	
HYD. TECH	DANIEL WOODALL	10/15/18	
CAD TECH	JACOB HERZOG	10/15/18	UNITS: CENTIMETER
			MATERIAL: CONCRETE
			WEIGHT:

TITLE: QUEBRADA PLATANO BIG SEDIMENTATION TANK

DWG NO. LUCY-CHEN INC. A2

SCALE:1:16 SHEET 1 OF 3



NOTE: ALL WALLS WILL HAVE A FIFTEEN CM. THICKNESS, AND THE BASE WILL BE MADE OF A CONCRETE SLAB, WITH MINIMUM THICKNESS OF SIX INCHES, A CLEANOUT BASIN SHAPED AS SHOWN, WASHOUT VALVE WILL BE RIGHT ABOVE THE VERTEX OF THE WASHOUT BASIN

	NAME	DATE	DRAWING B-2
P.M.	CHRISTINE WOOD	10/17/18	
EDITOR	MELODY HARMON	10/17/18	
HYD. TECH	DANIEL WOODALL	10/17/18	
CAD TECH	JACOB HERZOG	10/17/18	UNIT: CENTIMETER

TITLE: SCHOOL SEDIMENTATION TANK

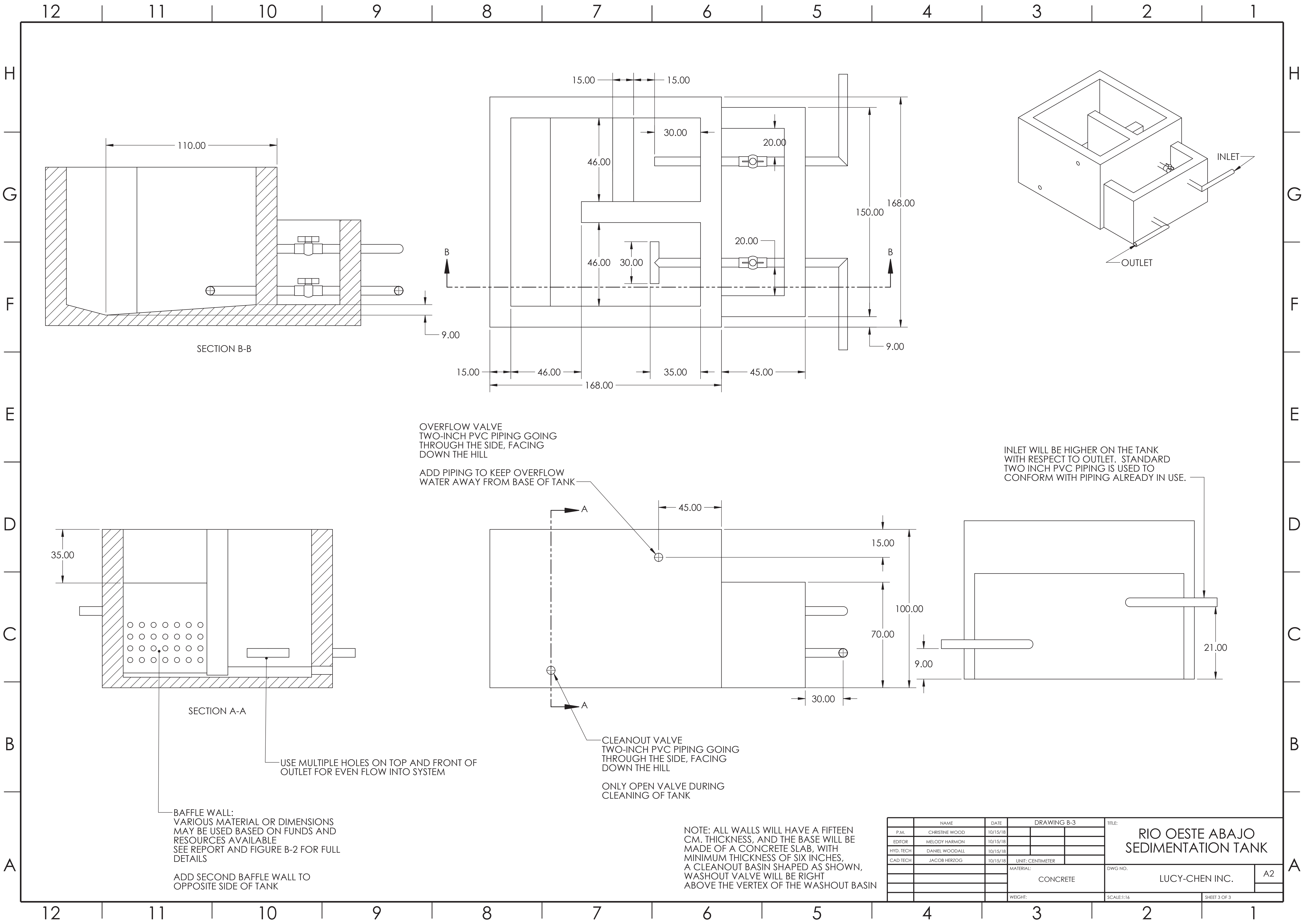
MATERIAL: CONCRETE

DWG NO. LUCY-CHEN INC. A2

WEIGHT:

SCALE:1:16

SHEET 2 OF 3


110.00
SECTION B-B
9.00
15.00
15.00
30.00
20.00
46.00
46.00
30.00
20.00
150.00
168.00
B
B
9.00
15.00
46.00
35.00
45.00
168.00
INLET
OUTLET
OVERFLOW VALVE
TWO-INCH PVC PIPING GOING THROUGH THE SIDE, FACING DOWN THE HILL
ADD PIPING TO KEEP OVERFLOW WATER AWAY FROM BASE OF TANK
INLET WILL BE HIGHER ON THE TANK WITH RESPECT TO OUTLET. STANDARD TWO INCH PVC PIPING IS USED TO CONFORM WITH PIPING ALREADY IN USE.
35.00
SECTION A-A
45.00
A
A
15.00
100.00
70.00
9.00
30.00
21.00
USE MULTIPLE HOLES ON TOP AND FRONT OF OUTLET FOR EVEN FLOW INTO SYSTEM
CLEANOUT VALVE
TWO-INCH PVC PIPING GOING THROUGH THE SIDE, FACING DOWN THE HILL
ONLY OPEN VALVE DURING CLEANING OF TANK
BAFFLE WALL:
VARIOUS MATERIAL OR DIMENSIONS MAY BE USED BASED ON FUNDS AND RESOURCES AVAILABLE
SEE REPORT AND FIGURE B-2 FOR FULL DETAILS
ADD SECOND BAFFLE WALL TO OPPOSITE SIDE OF TANK
NOTE: ALL WALLS WILL HAVE A FIFTEEN CM. THICKNESS, AND THE BASE WILL BE MADE OF A CONCRETE SLAB, WITH MINIMUM THICKNESS OF SIX INCHES, A CLEANOUT BASIN SHAPED AS SHOWN, WASHOUT VALVE WILL BE RIGHT ABOVE THE VERTEX OF THE WASHOUT BASIN
NAME
DATE
DRAWING B-3
P.M.
CHRISTINE WOOD
10/15/18
EDITOR
MELODY HARMON
10/15/18
HYD. TECH
DANIEL WOODALL
10/15/18
CAD TECH
JACOB HERZOG
10/15/18
UNIT: CENTIMETER
MATERIAL:
CONCRETE
WEIGHT:
TITLE:
RIO OESTE ABAJO SEDIMENTATION TANK
DWG NO.
LUCY-CHEN INC.
A2
SCALE:1:16
SHEET 3 OF 3

Sedimentation Tank Sizing Calculations (Jordan, 1980) for Quebrada Platano Big Tank

$$Flow\ Rate = 1\frac{L}{s}$$

$$Settling\ Time = 1200\ seconds = 20\ min$$

$$Capacity = Flow\ Rate * Settling\ Time$$

$$Capacity\ = 1\frac{L}{s} * 1200\ s = 1200\ liters = 1.2E6cm^3$$

$$Height = 100\ cm$$

$$Wall\ Thickness = 15\ cm$$

$$Surface\ Area = \frac{Capacity}{Height} = Length * Width$$

$$Surface\ Area = 2x^2 + 2x^2 + x(2x + 15) = 1.2E4\ cm^3$$

$$0\ = 6x^2 + 15x - 1.2E4$$

$$x = dimension\ multiplier = 43.5\ cm$$

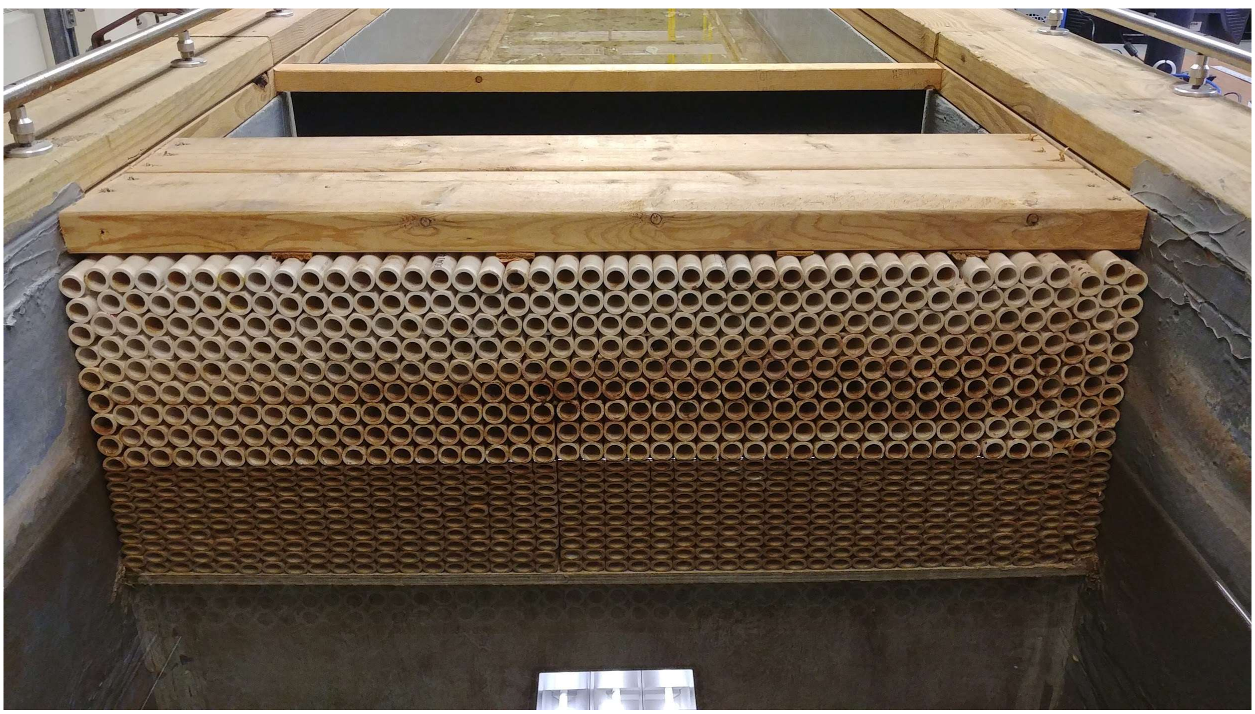
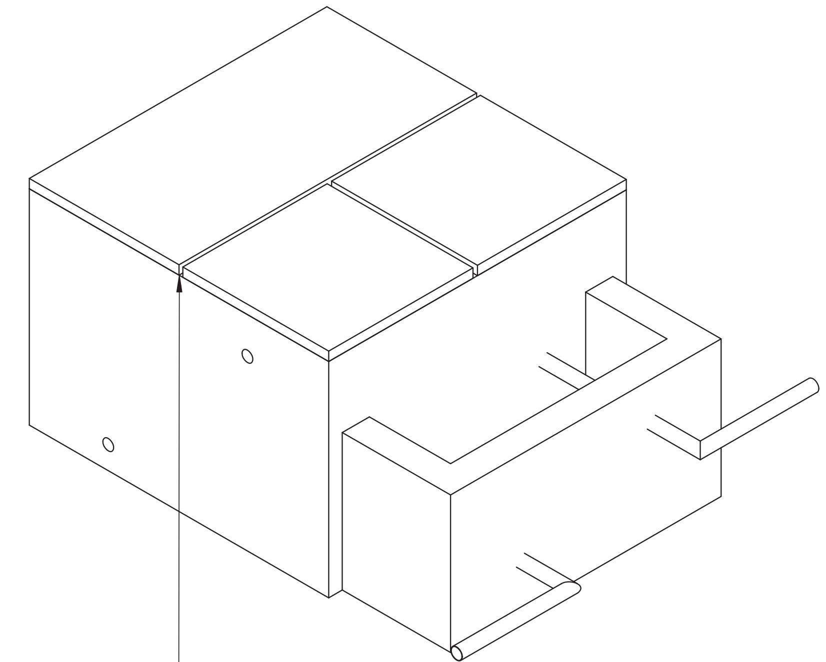


Figure B-2: Example of Baffle Wall for Interior of Sedimentation Tank.

THIS SECTION MAY BE SPLIT INTO TWO HALVES TO MAKE FOUR EQUAL TOPS TO COVER THE SEDIMENTATION TANK

THE SEDIMENTATION TANK WILL USE CONCRETE COVERS. THE THREE OR FOUR PART DESIGN IS MADE FOR EASIER USE AND MOVEMENT OF THE PARTS. ONE SECTION COVERS THE WHOLE REAR OF THE TANK, AND TWO OTHER SECTIONS COVER THE OTHER PORTIONS, USING THE BISECTING WALL AS A BRAEAK POINT.

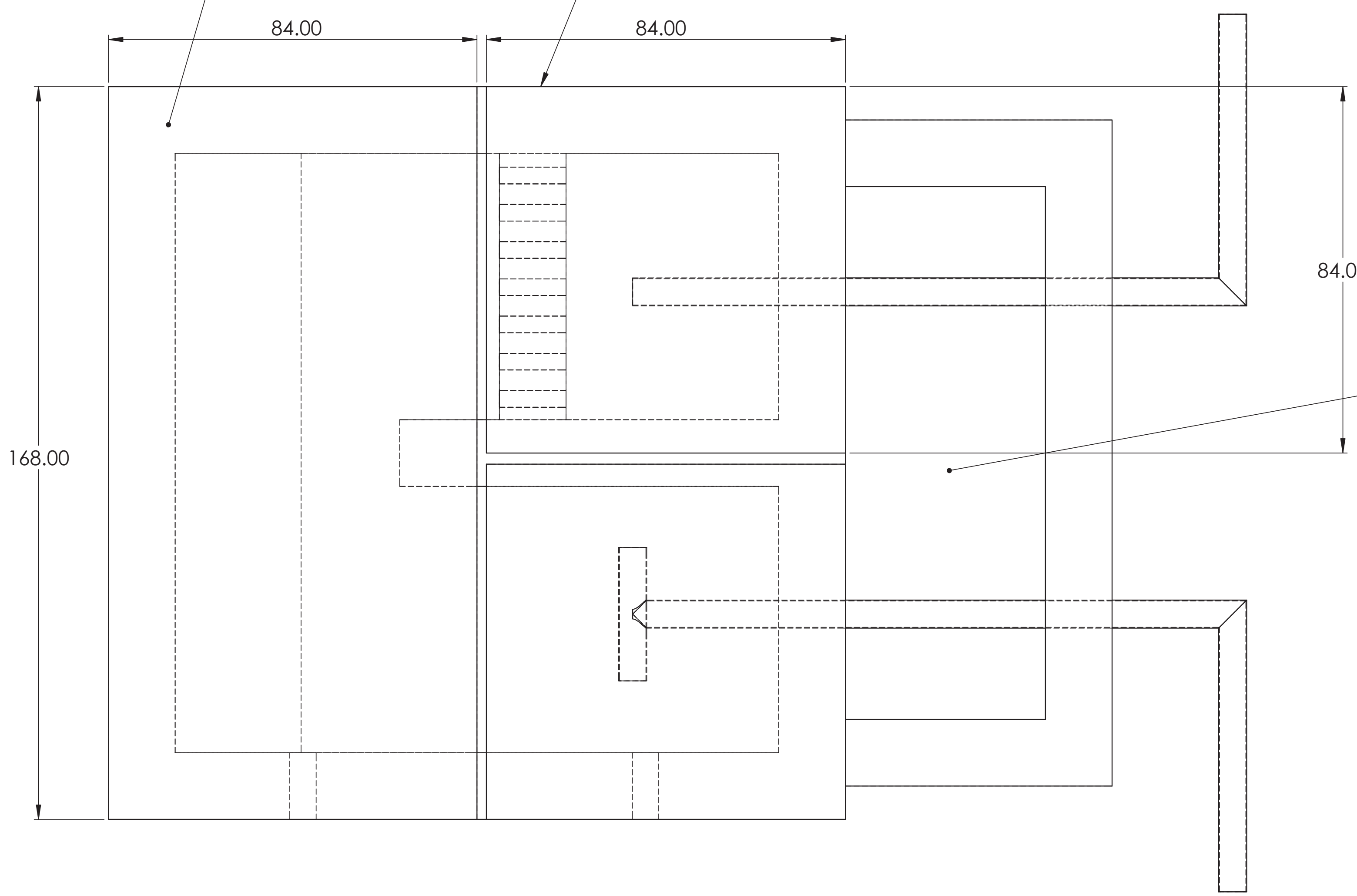
DIMENSIONS WILL VARY DEPENDING ON THE SIZE OF THE TANK. SMALLER SECTIONS ARE HALF OF THE SIDE LENGTHS. BIG SECTION HAS AN LENGTH OF THE WHOLE BACK SIDE OF TANK. EXAMPLE DIMENSIONS SHOWN



ADD THIN LAYER OF MORTAR TO SEAL TANK FROM WILDLIFE

GAP IS EXAGGERATED TO SHOW SEPARATION OF SECTIONS

BREAK OPEN TO CLEAN OUT SEDIMENTATION



FRONT COMPARTMENT OF TANK MAY NOT REQUIRE A COVER, IF EXTRA MATERIAL IS LEFT, OR A LOT OF VEGITATION IS OVER AREA, THEN A COVER SHOULD BE USED.

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN CENTIMETERS	DRAWING B-4		DEBURR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING / REVISION
	NAME	DATE		TITLE: SEDIMENTATION TANK COVERS
PM	CHRISTINE WOOD	10/21/18		
EDITOR	MELODY HARMON	10/21/18		
HYD. TECH.	DANIEL WOODALL	10/21/18		
CAD TECH	JACOB HERZOG	10/21/18		
			MATERIAL: REINFORCED CONCRETE	DWG NO. LUCY-CHEN INC. A2
			WEIGHT:	SCALE:1:20 SHEET 1 OF 1

APPENDIX C

Quebrada Platano Spring Box

Figure C-1. General Design for Spring Box

<u>Engineering Drawing</u>

Spring Box Drawing

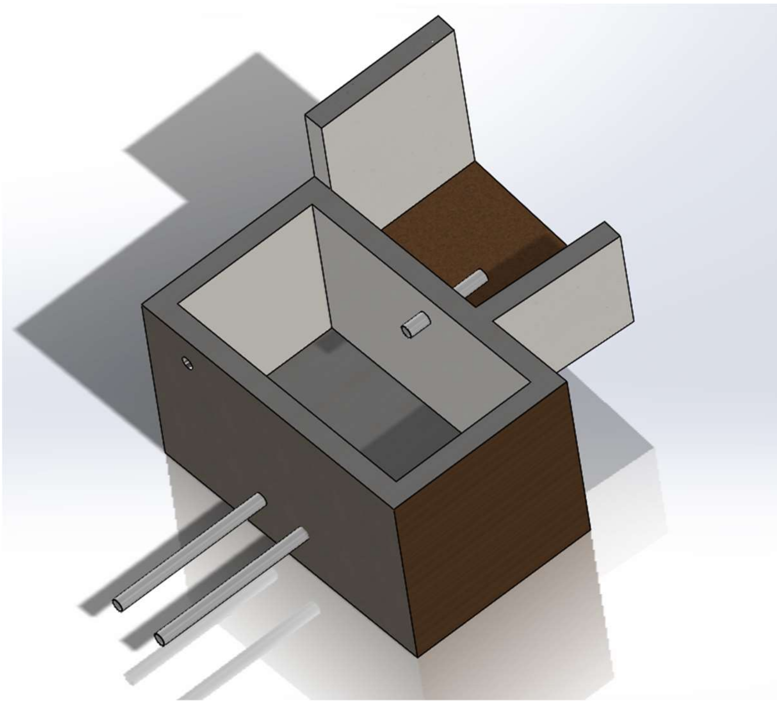


Figure C-1. General Design for Spring Box

DIMENSIONS ARE APPROXIMATE, SINCE INCOMPLETE DATA ON THE SPRING WAS TAKEN. BUILD A DAM LARGE ENOUGH AROUND WATER POOLING CURRENTLY

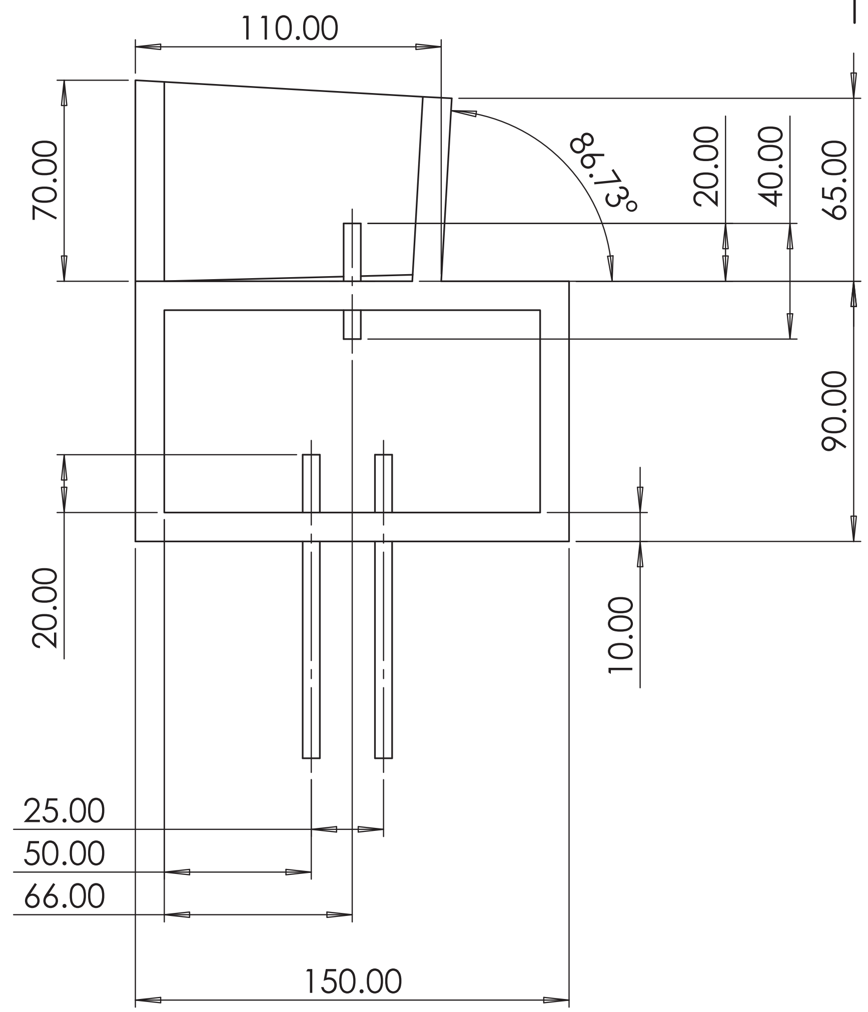
A COVER SHOULD BE ADDED TO THE DAM WITH A SMALL GAP BETWEEN THE HILL SIDE AND THE EDGE OF THE COVER. EXPANDED STEEL MAY BE USED TO HELP SEAL THE GAP

EXCAVATION WILL BE NEEDED IN THE AREA

TO SAVE TIME, MATERIAL, AND MONEY; LARGER COMPARTMENT CAN BE BYPASSED

CLEANOUT AND OVERFLOW VALVE WILL NEED TO BE ADDED TO THIS SECTION THEN. IF WATER BECOMES TOO DIRTY, ADD LARGER COMPARTMENT

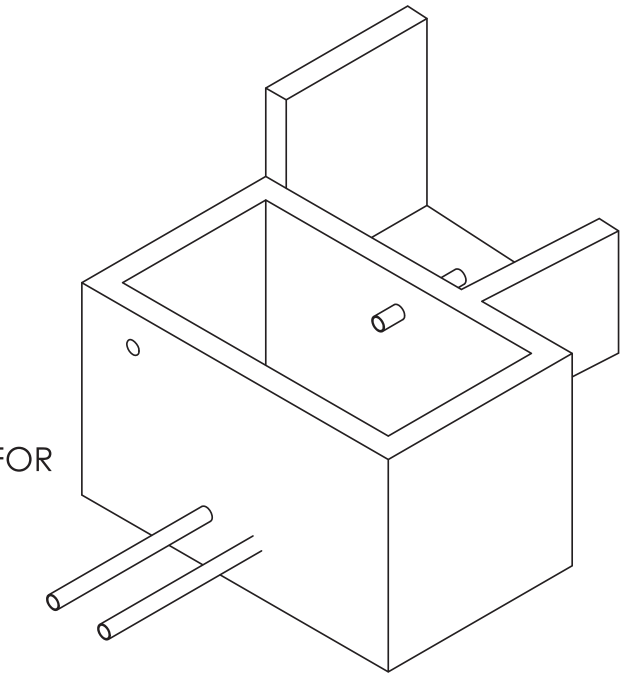
IF USED, A COVER WILL BE NEEDED. THE SIZE WILL BE 150 x 90 X 5 CM

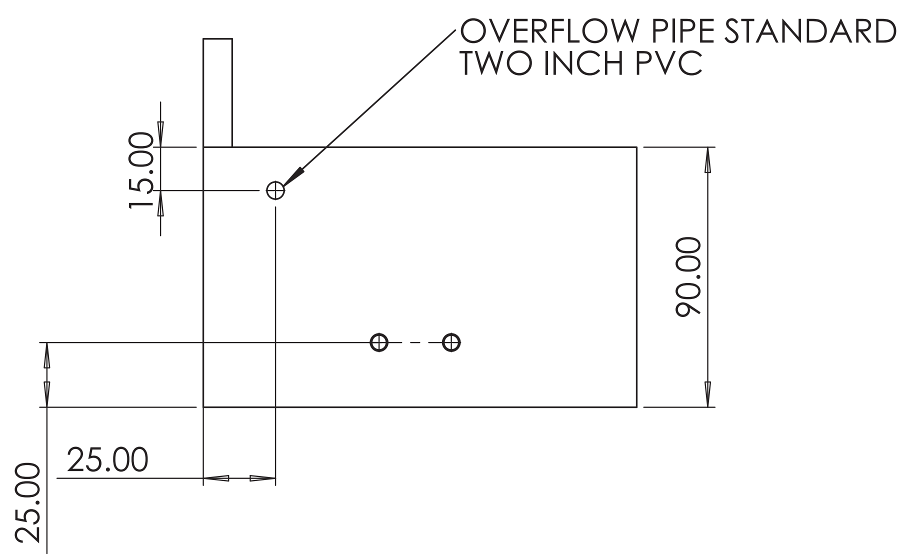


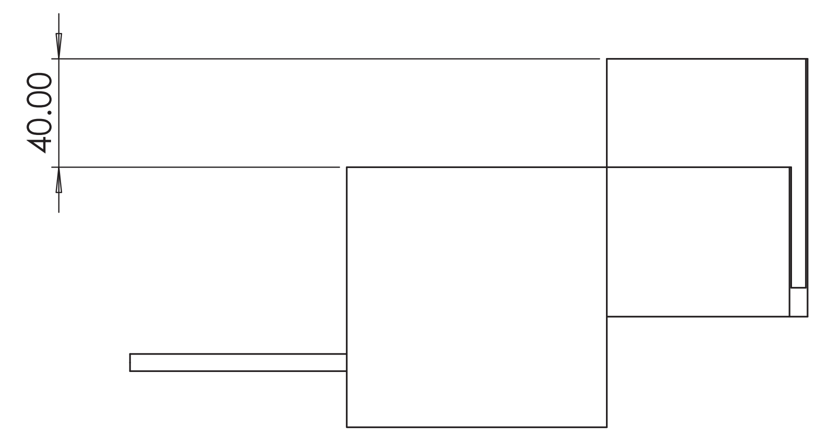
THE PURPOSE OF THE HIGHER WALL IS TO COLLECT ALL WATER COMING FROM THE SPRING. SOME OF THE WATER COMES FROM A HIGHER UP ON THE HILL ABOVE THE MAIN BASIN, WHICH NEEDS TO BE COLLECTED

ALL WALLS ARE 10CM THICK OF REINFORCED CONCRETE

ONE OF THE OUTLET PIPES IS FOR COMMUNITY DISTRIBUTION, THE OTHER IS CLEAN OUT, USE VALVES ON BOTH. PIPING WILL CONFORM TO TWO INCH STANDARD







UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN CENTIMETERS	DRAWING C-1		DEBURR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION
	NAME	DATE		TITLE: LUCY CHEN	
PM	CHRISTINE WOOD	10/17/18			
EDITOR	MELODY HARMON	10/17/18			
HYD. TECH	DANIEL WOODALL	10/17/18			
CAD TECH	JACOB HERZOG	10/17/18			
			MATERIAL: CONCRETE	DWG NO. SPRING BOX	A3
			WEIGHT:	SCALE 1:25	SHEET 1 OF 1

APPENDIX D

EPANET Hydraulic Analysis

Table 1. EPANET Analysis for Quebrada Platano Sources

EPANET Model	Measured Source Flow Rate (gpm)	Average Flow Rate in Pipes (gpm)			Average Velocity in Pipes (fps)			Pressure at Node (psi)	Minimum Pressure in System (psi)	Maximum Pressure in System (psi)	Minimum Head in System (ft)	Maximum Head in System (ft)
Quebrada Platano												
		link 1-2	link 2-3	link 3-4	link 1-2	link 2-3	link 3-4					
Big Tank Source	15.84	136.7	107.8	2.1	14.0	11.0	0.2	17.7	17.7	19.1	291.0	294.0
School Source	9.0	-55.1	35.4	2.1	5.6	3.6	0.2	33.8	34.7	34.8	236.0	238.4
Spring Source	6.0	115.55			11.8			14.3	14.3	15.6	283.0	286.0

*link 1-2: source to sedimentation tank
*link 2-3: sedimentation tank to storage tank
*link 3-4: storage tank to node

Table 2. EPANET Analysis for Rio Oeste Abajo Sources

EPANET Model	Measured Source Flow Rate (gpm)	Average Flow Rate in Pipes (gpm)					Average Velocity in Pipes (fps)					Pressure at Node (psi)		Minimum Pressure in System (psi)	Maximum Pressure in System (psi)	Minimum Head in System (ft)	Maximum Head in System (ft)
Rio Oeste Abajo																	
Palo Seco Source	17.76	link 1-2	link 2-3	link 3-4	link 5-node 1	link 5-node 2	link 1-2	link 2-3	link 3-4	link 5-node 1	link 5-node 2	node 1	node 2	7.8	27.3	70	70.1
		0.09	0.09	0.09	0	0	0.01	0.01	0.01	0	0	27.3	7.8				

*link 1-2: source to sedimentation tank
*link 2-3: sedimentation tank to storage tank
*link 3-4: storage tank to node
*node 1: school
*node 2: community

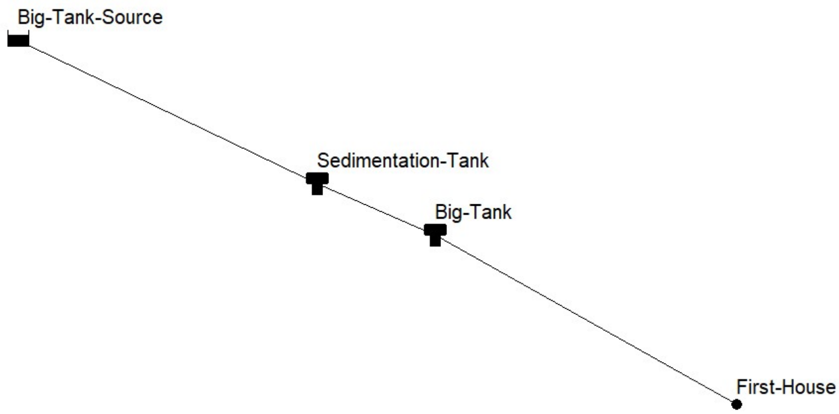


Figure D-1. Quebrada Platano Big Tank Source Network Map

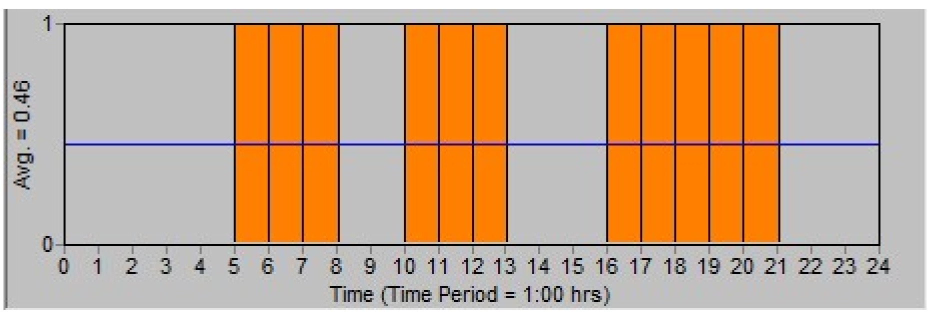


Figure D-2. Quebrada Platano Big Tank Usage Pattern

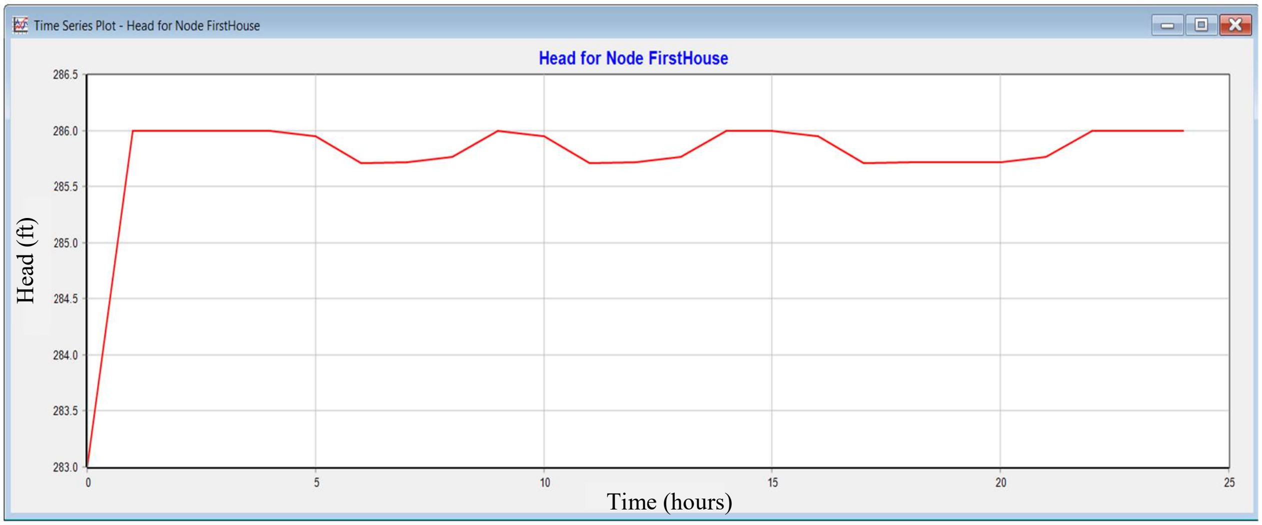


Figure D-3. Quebrada Platano Big Tank Source Head Graph

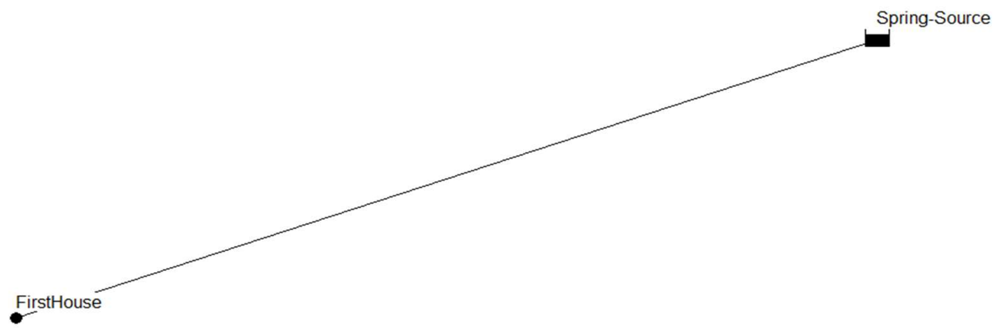


Figure D-4. Quebrada Platano Spring Source Network Map

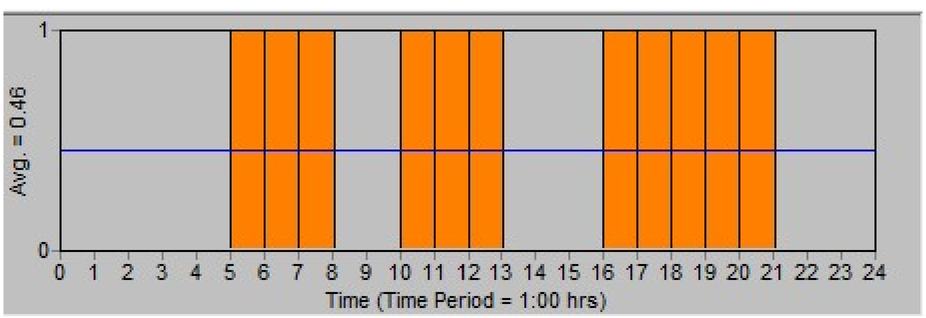


Figure D-5. Quebrada Platano Spring Source Usage Pattern

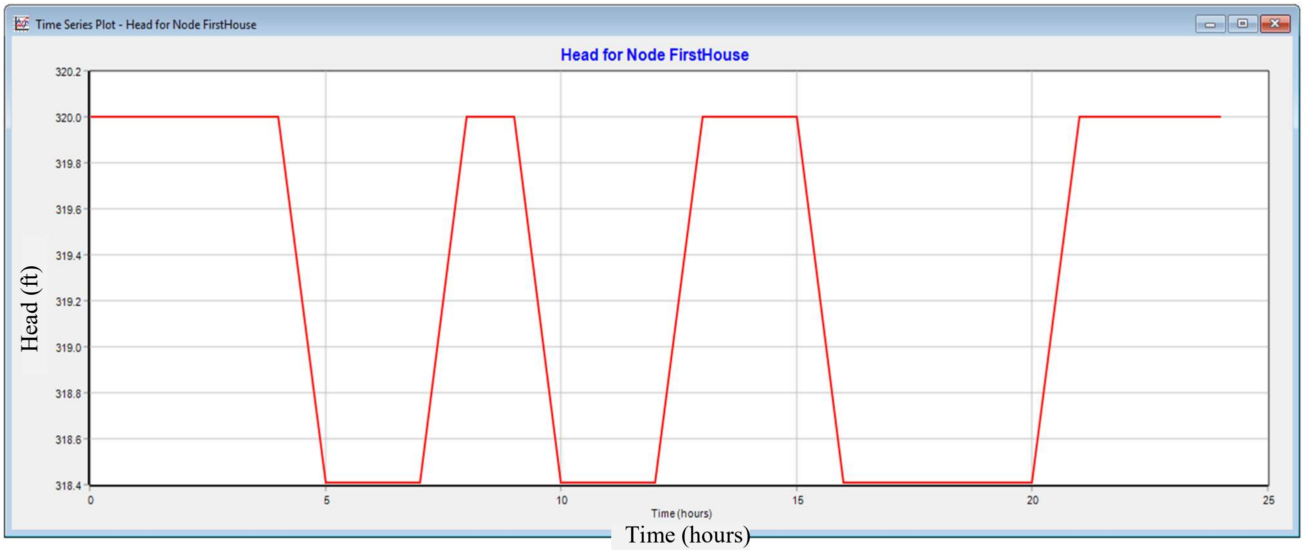


Figure D-6. Quebrada Platano Spring Source Head Graph

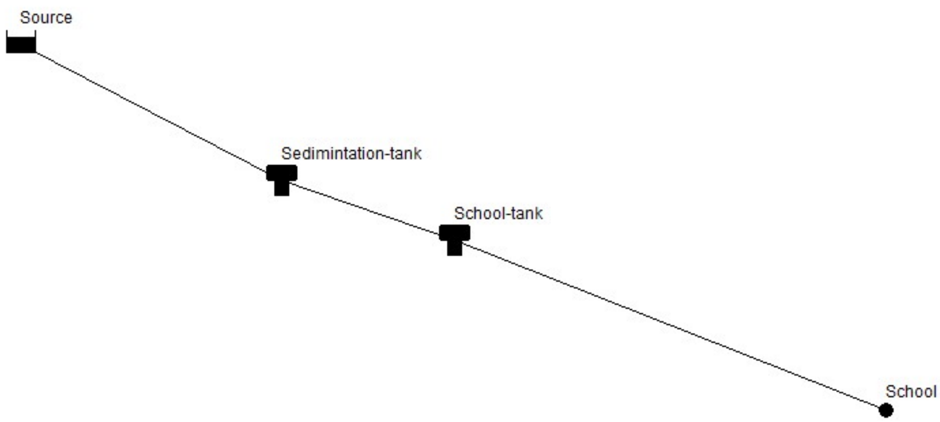


Figure D-7. Quebrada Platano School Source Network Map

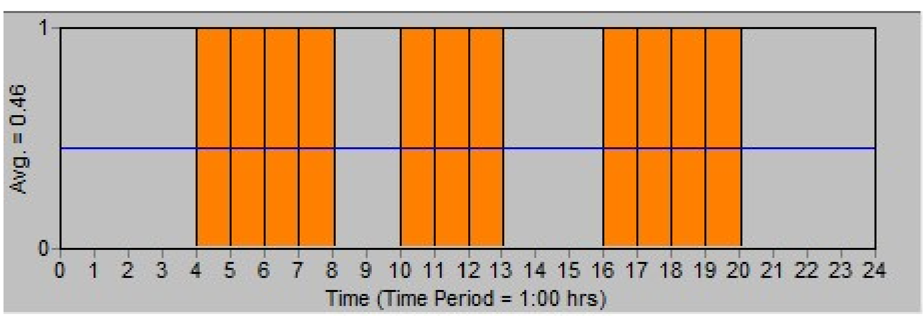


Figure D-8. Quebrada Platano School Source Usage Pattern

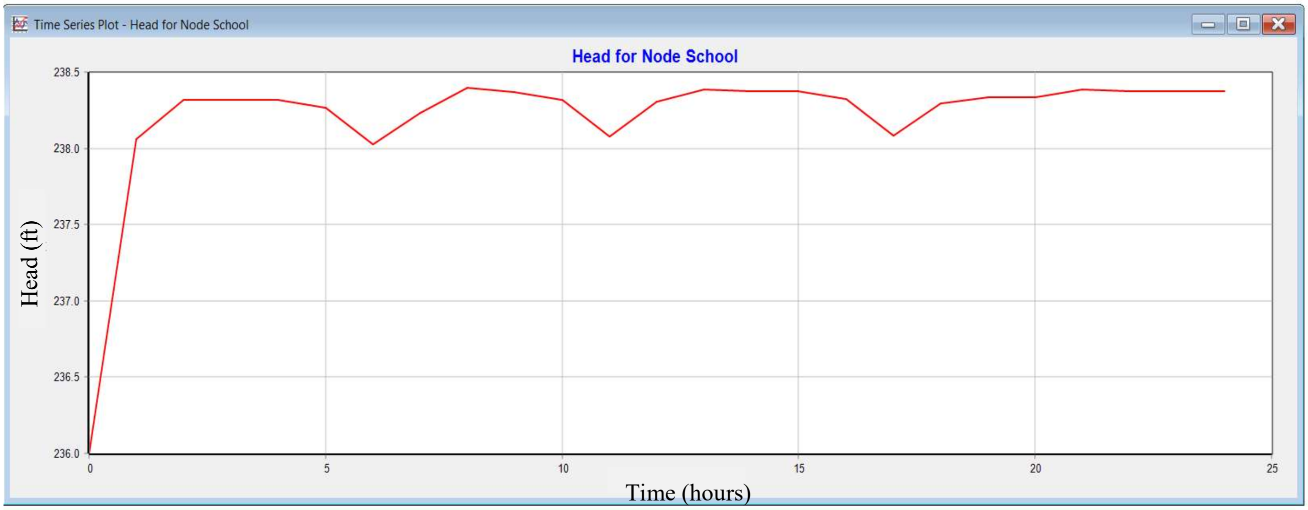


Figure D-9. Quebrada Platano School Source Head Graph

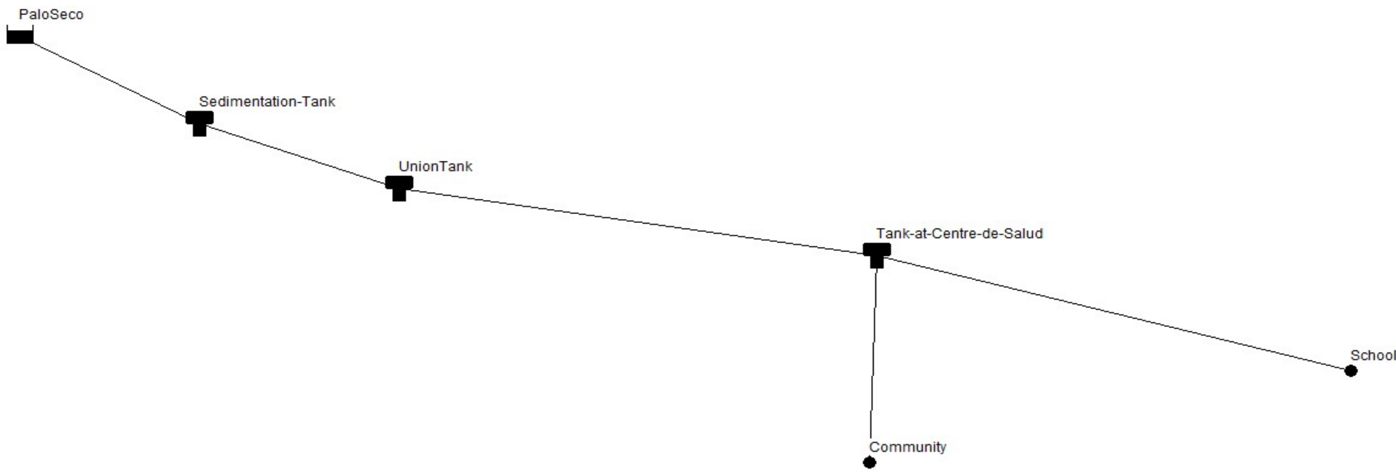


Figure D-10. Rio Oeste Abajo Palo Seco Source Network Map

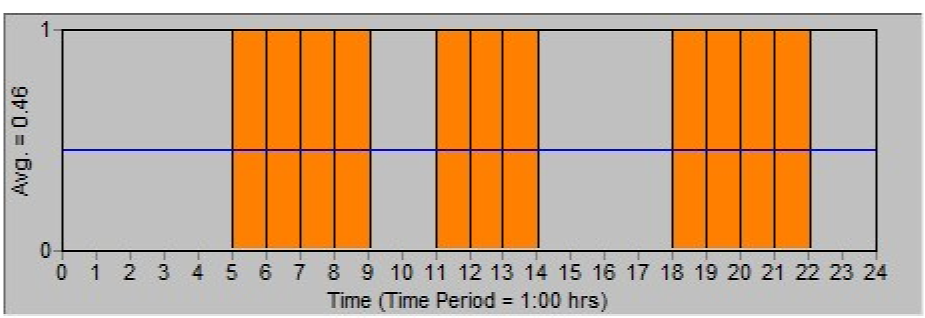


Figure D-11. Rio Oeste Abajo Palo Seco Source Usage Pattern

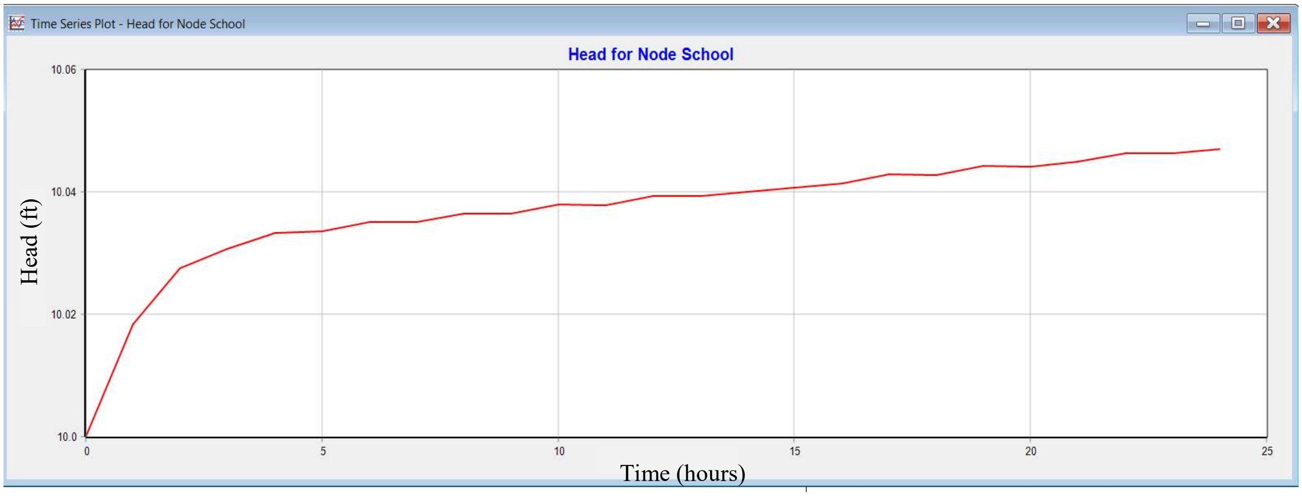


Figure D-12a. Rio Oeste Abajo Palo Seco Source Head Graph for School

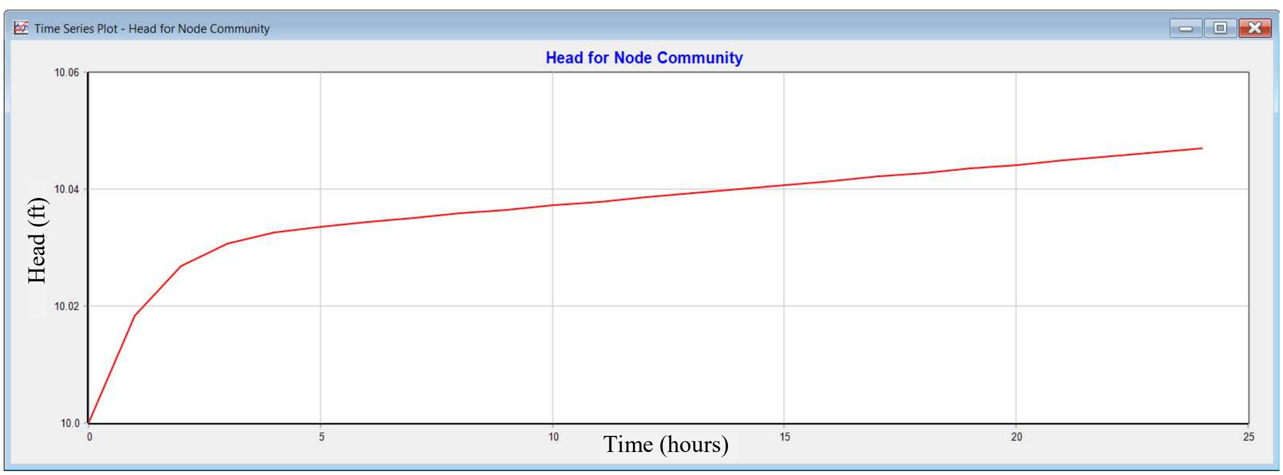


Figure D-12b. Rio Oeste Abajo Palo Seco Source Head Graph for Community

APPENDIX E

Source Intake Alternatives

Engineering Drawing

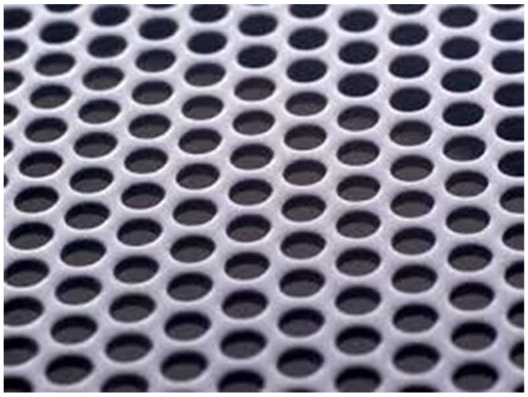


Figure E-1. Option One for Expanded Steel (0.75 cm opening diameter)

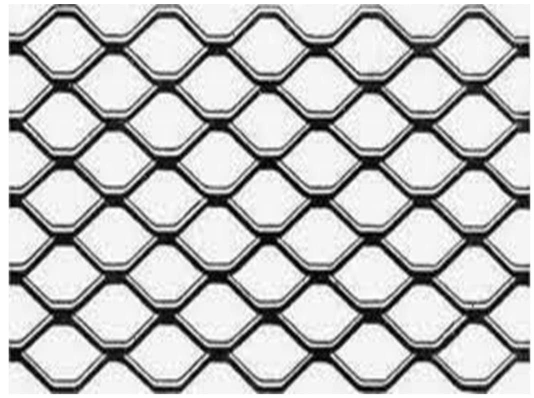


Figure E-2. Option Two for Expanded Steel (2 cm opening diameter)

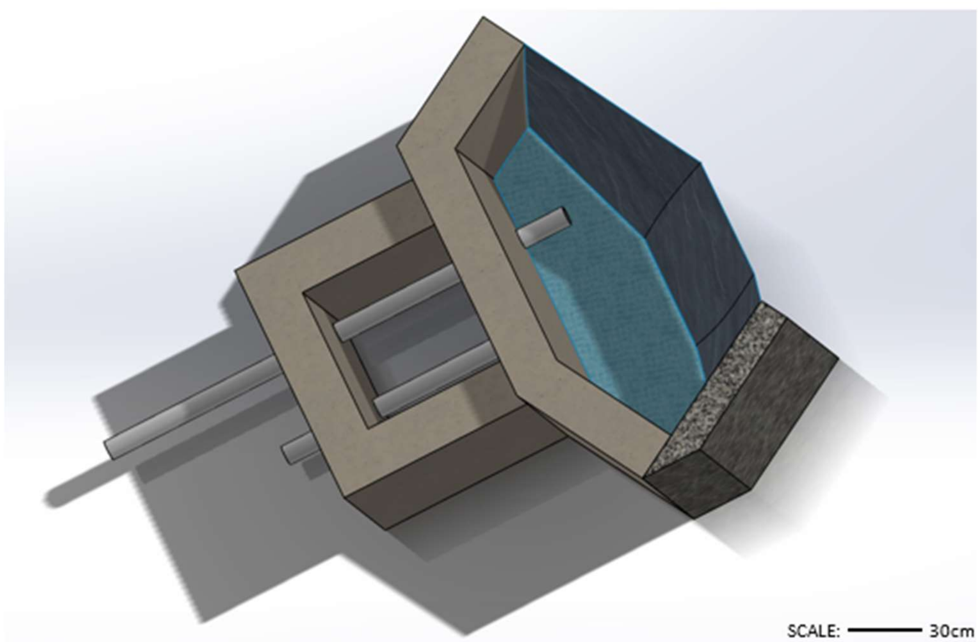


Figure E-3. Existing model of Quebrada Platano Big Tank Source

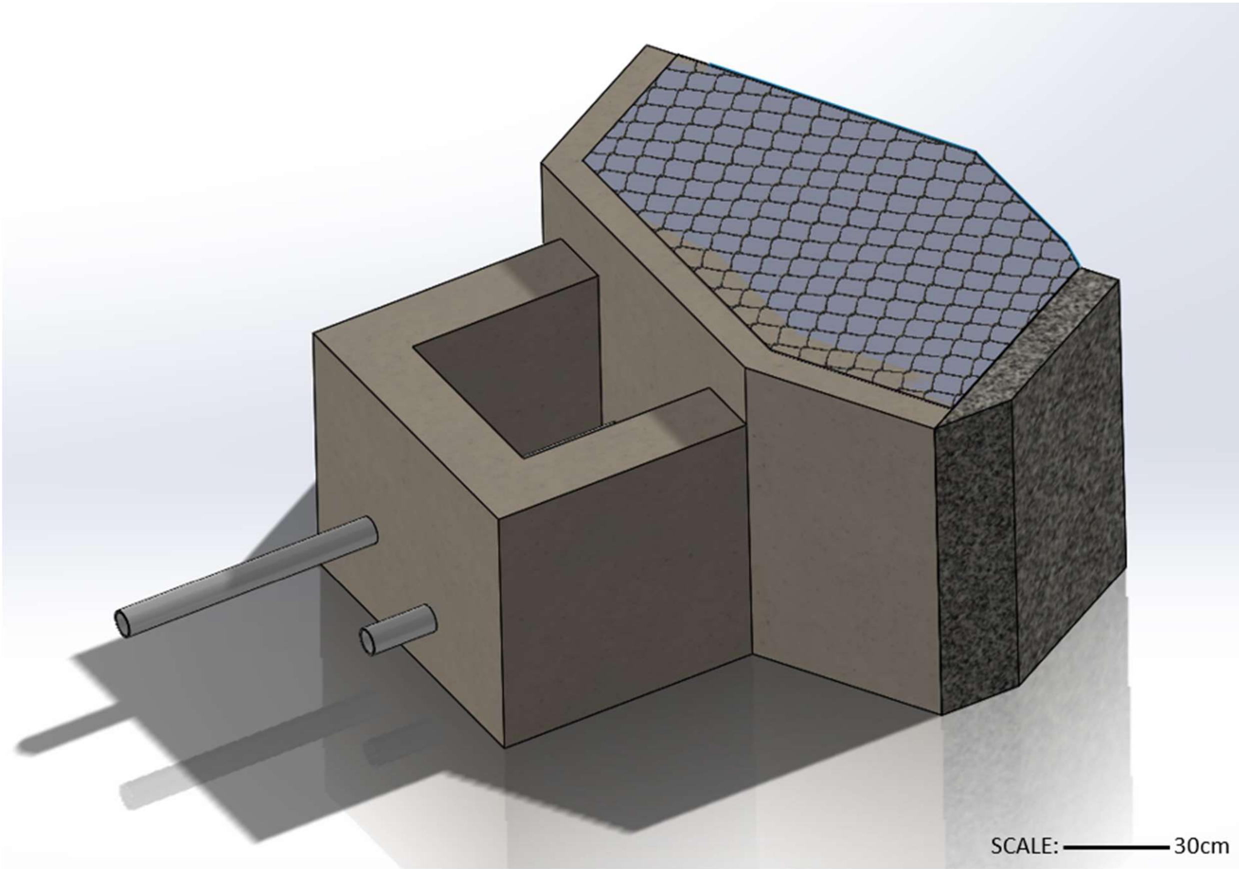
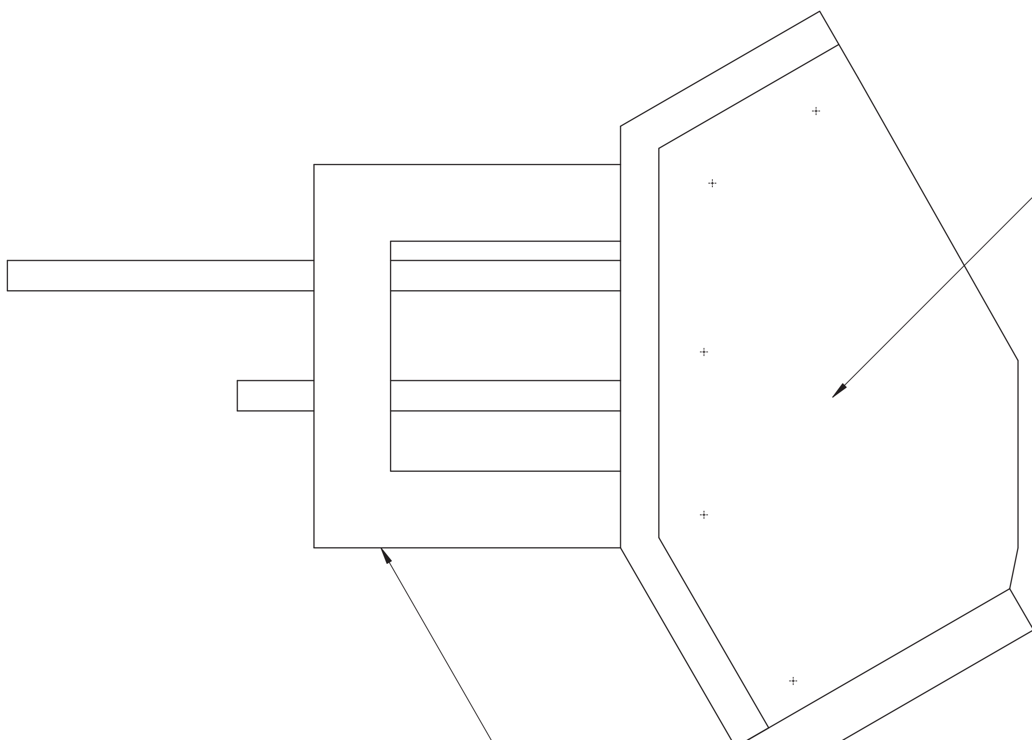


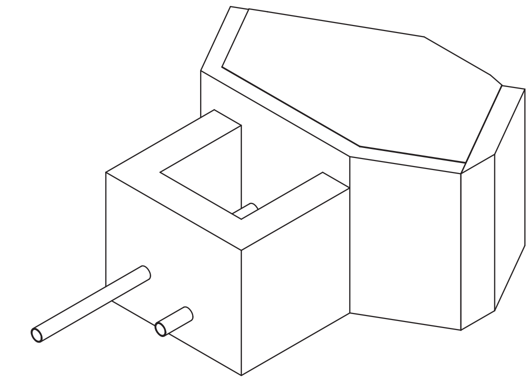
Figure E-4. Existing model of Quebrada Platano Big Tank Source with Intake Improvement.

The expanded steel (shown as fencing in Figure E-4), will be set on top of an aggregate filter, that will be inside the main basin. The steel will need to be cut and/or bent to fit the shape of the area and placed in line with the top of the existing structure, or up to five centimeters below the top. Additional aggregate should be placed on top of the steel to ensure that the sheet does not move or shift.



PLACE MEDIUM TO LARGE AGGREGATE IN THE EXISTING MAIN BASIN, WITH LARGER AGGREGATE AT THE BOTTOM. STACK UNTIL MINIMUM FIVE CENTIMETERS FROM THE TOP OF THE TOMA. CUT AND BEND THE EXPANDED STEEL TO FIT THE AREA OF THE BASIN, AND PLACE INSIDE. THEN STACK MORE MEDIUM AGGREGATE ON TOP OF THE STEEL TO STABILIZE.

CURRENTLY THIS AREA IS USED TO HOUSE VALVES, BOTH OUTLET AND CLEANOUT. THIS AREA COULD BE CONVERTED INTO A SEDIMENTATION BASIN BY MOVING THE VALVES TO THE OUTSIDE OF THE BOX AND LETTING THE WATER SIT IN THIS AREA BRIEFLY BEFORE DISTRIBUTION TO THE STORAGE TANK



UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN CENTIMETERS

DRAWING E-1

DEBURR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

	NAME	DATE
PM	CHRISTINE WOOD	10/18/18
EDITOR	MELODY HARMON	10/18/18
HYD. TECH	DANIEL WOODALL	10/18/18
CAD TECH	JACOB HERZOG	10/18/18

TITLE: QUEBRADA PLATANO BIG AQUEDUCT

MATERIAL: EXPANDED STEEL

WEIGHT:

DWG NO. LUCY-CHEN INC.

A2

SCALE:1:20

SHEET 1 OF 1

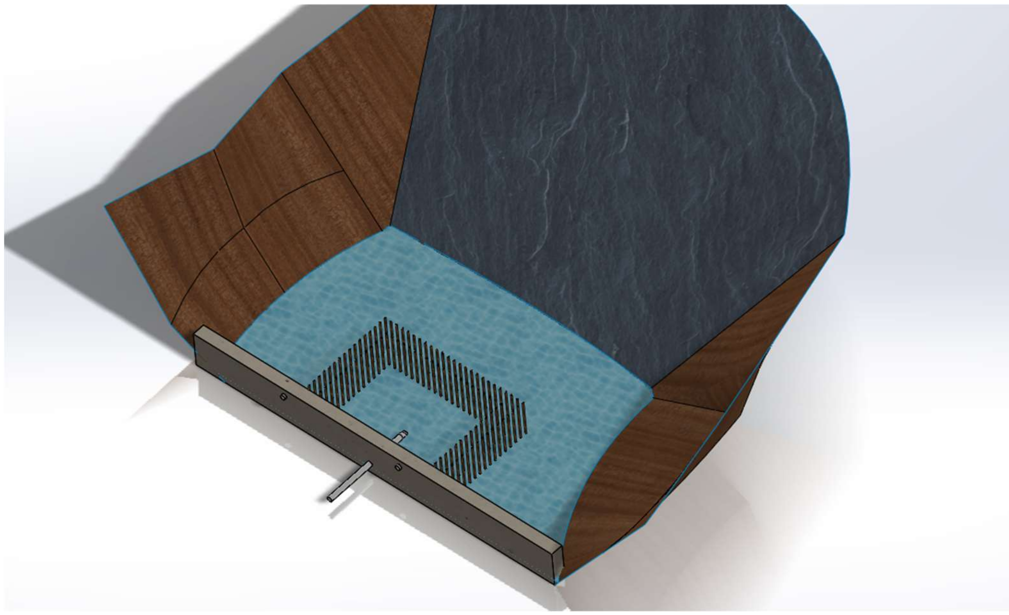
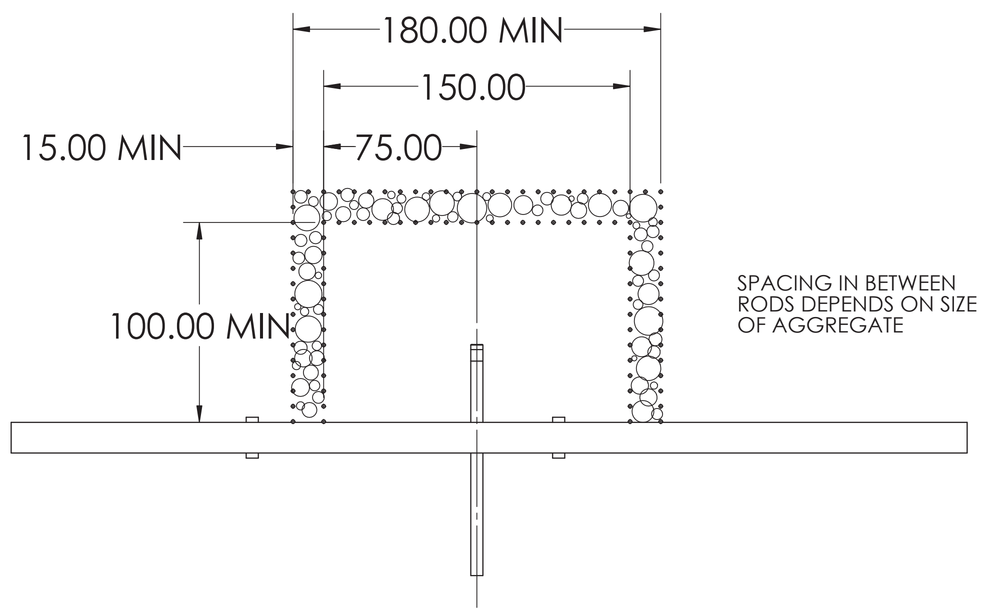
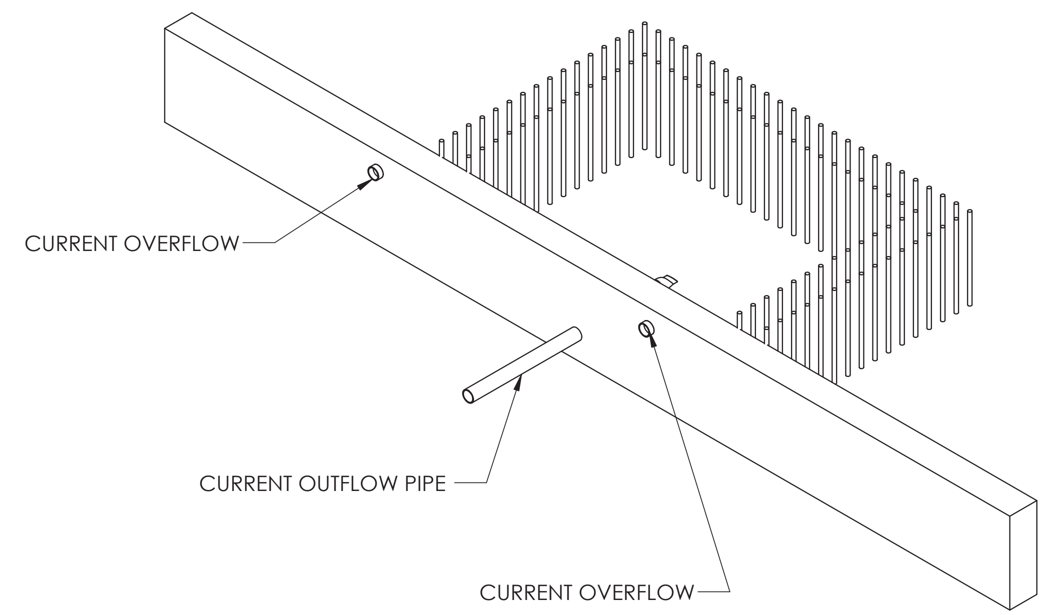


Figure E-5. Option A for School Intake at Quebrada Platano. The hatched area represents area of aggregate pre-filter, held in place with stakes. This is a cheaper alternative and one that can be constructed faster without having to wait for concrete to cure. Producing a cover for this option may be difficult due to how durable the stakes are and rock structure is built.



SPACING IN BETWEEN RODS DEPENDS ON SIZE OF AGGREGATE



THE PURPOSE OF THIS DESIGN IS TO BUILD A FENCE USING STEEL RODS OR SMALL PVC PIPING, ADD LARGE ROCKS OR AGGREGATE BETWEEN THE ROWS TO ACT AS A FILTER FOR MEDIUM TO LARGE DEBRIS

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN CENTIMETERS	DRAWING E-1A		DEBURR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING / REVISION
	NAME	DATE		TITLE: SCHOOL TANK OPTION ONE
PM	CHRISTINE WOOD	10/18/18		
EDITOR	MELODY HARMON	10/18/18		
HYD. TECH.	DANIEL WOODALL	10/18/18		
CAD TECH.	JACOB HERZOG	10/18/18		
			MATERIAL: CONCRETE	DWG NO. LUCY-CHEN INC. A2
			WEIGHT:	SCALE 1:15 SHEET 2 OF 2

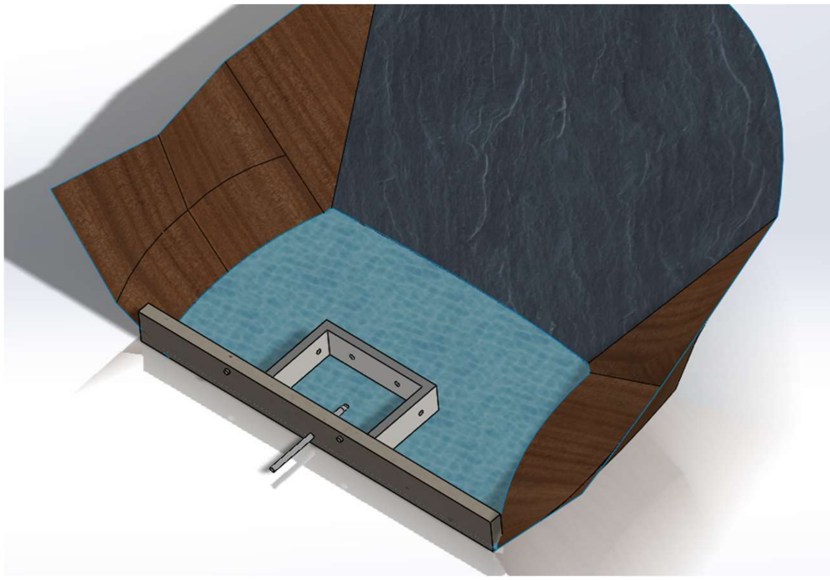
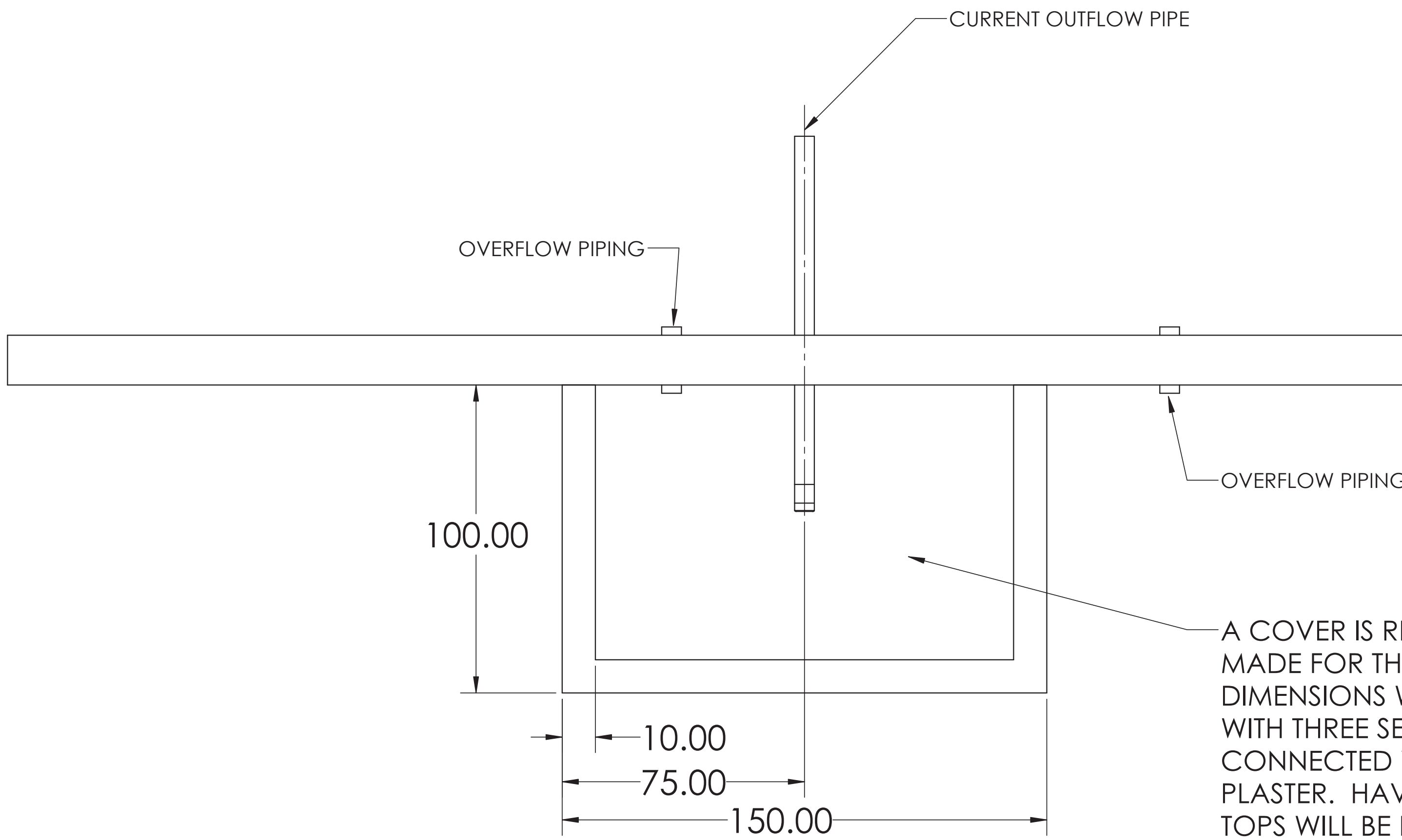
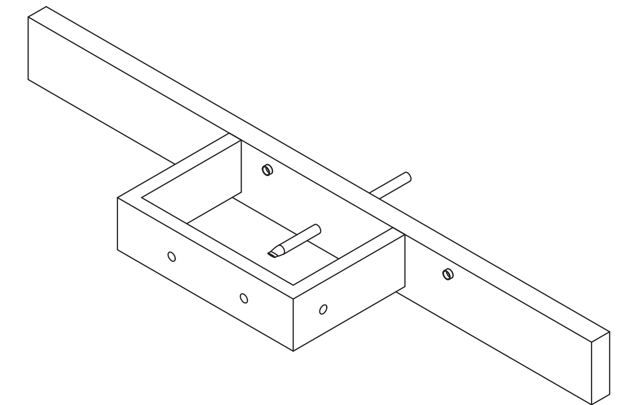
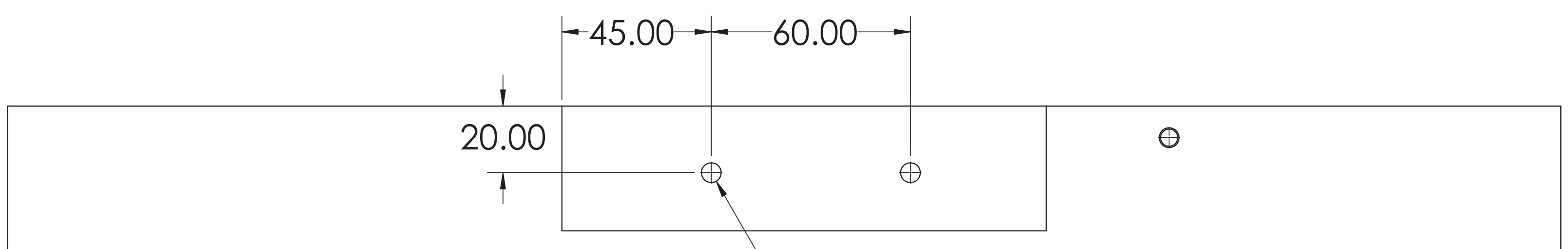


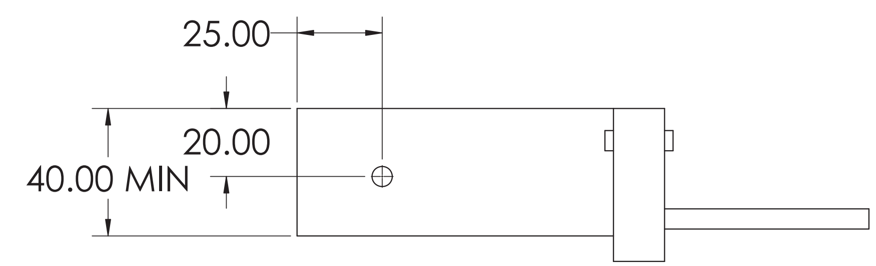
Figure E-6. Option B for School Intake at Quebrada Platano. Build a reinforced concrete box around intake with four holes in wall to allow water to enter while keeping out floating debris, and allowing some sedimentation to occur. A cover should also be constructed for this option. See Drawing E-1b for details.



A COVER IS RECOMMENDED TO BE MADE FOR THE TOP OF THE BOX. THE DIMENSIONS WILL BE 50 X 100 X 3 CM, WITH THREE SEPARATE COVERS AND CONNECTED WITH A THIN LAYER OF PLASTER. HAVING THREE SEPARATE TOPS WILL BE EASIER FOR MOVEMENT AND CLEANING







INCOMPLETE DATA ON HEIGHT OF DAM. NEW WALL NO LESS THAN 10 CM BELOW EXISTING WALL.

2" STANDARD PIPING
4 INSTANCES

SCREENS MAY BE ADDED INFRONT OF EACH PIPE FOR EXTRA FILTRATION

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN CENTIMETERS	DRAWING E-1B	DEBURR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING / REVISION

	NAME	DATE
PM	CHRISTINE WOOD	10/18/18
EDITOR	MELODY HARMON	10/18/18
HYD. TECH.	DANIEL WOODALL	10/18/18
CAD TECH.	JACOB HERZOG	10/18/18

TITLE: SCHOOL TANK OPTION ONE

MATERIAL: CONCRETE

WEIGHT:

DWG NO. LUCY-CHEN INC. A2

SCALE 1:15

SHEET 1 OF 2

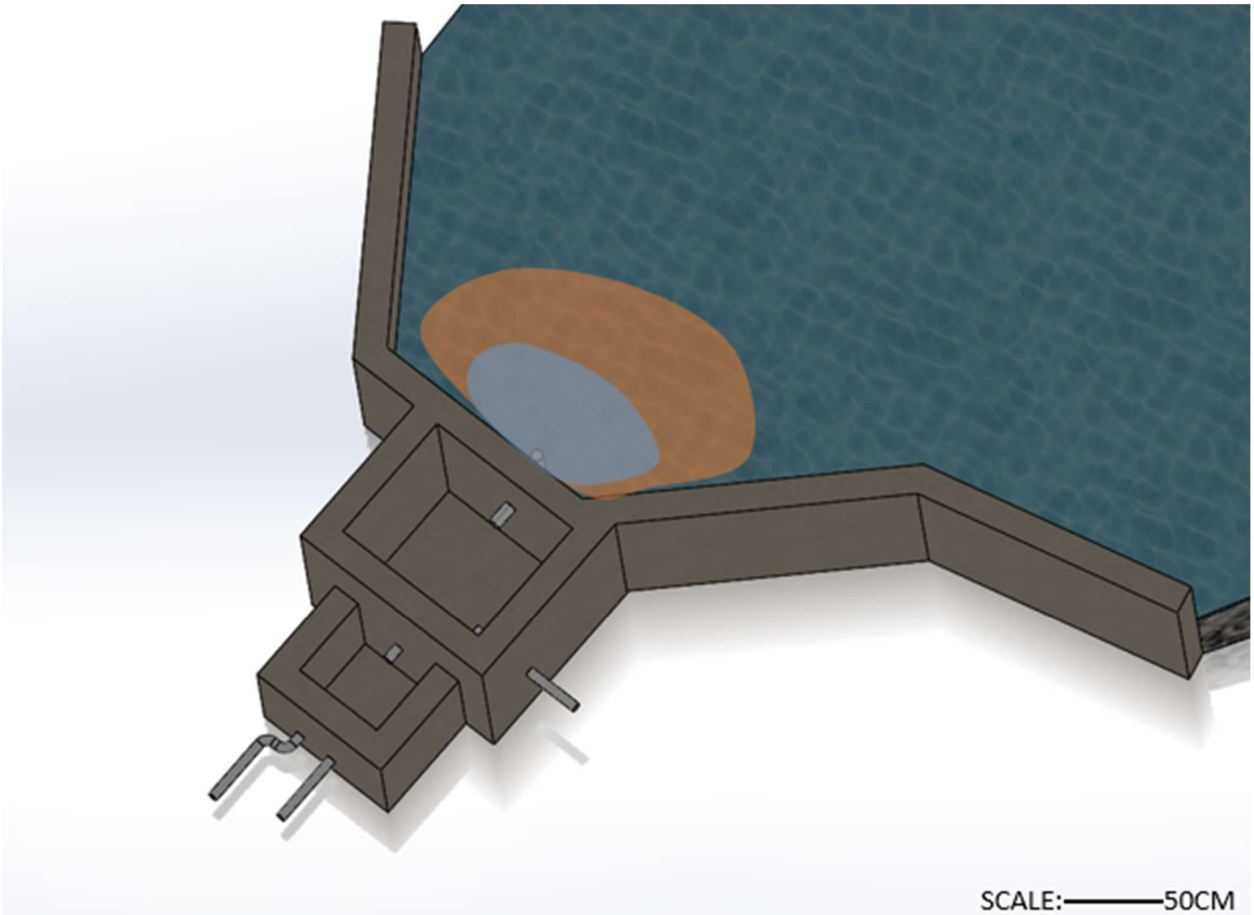


Figure E-7. Model of Existing Intake at Rio Oeste Abajo, where the addition of an aggregate filter around the intake pipe is recommended. Arrangement of rocks and gravel (shown by coloring) will provide partial filtration of debris.

Two transparent areas are shown in Figure E-7, representing where aggregate is to be placed, with the medium aggregate being in the blue area closer to the inlet, and large aggregate outside of the medium aggregate (orange area).

APPENDIX F

Treatment/Filtration

Five Gallon Bucket Filter

Treatment References

During the flooding season of Panama, many of the rivers and aqueducts become filled with dirt and other debris, which contaminates the water more so than usual. This report will detail a procedure that individual homes may follow to provide safe drinking water for their families.

Five Gallon Bucket Filter

Using four 5-gallon pails, you can create a charcoal water filter that can remove sediment and other contaminants from the water, while adding some minerals that make the water more appealing and better tasting. These systems are inexpensive and easy to maintain.

The items needed will be:

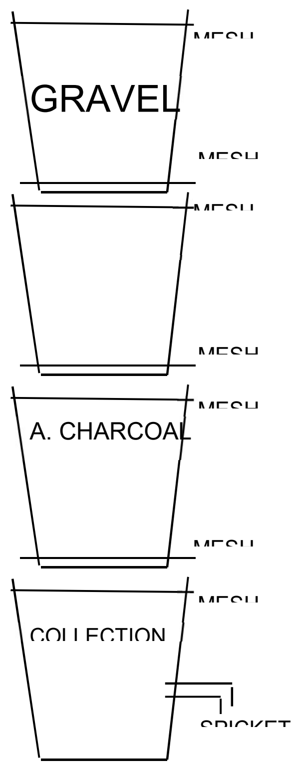
-Four 5-gallon pails
-Mesh with low porosity
-Gravel (1cm-3cm diameter)
-Sand
-Activated Charcoal
-Spicket
-Water proof adhesive or glue for mesh and spicket

Below are the steps to make activated charcoal.

1. Cut a hardwood or coconut shells into small, 2”x2”x2” chunks at most. Make sure the burn pieces are as dry as possible.
2. Put the burn pieces into a pot and cover it, while making sure air can escape, but do not leave the pot open.
3. If you do not have a fire going already, start one and put the pot on top of it. Make sure the fire is hot enough to burn the wood or coconut. Note that may take several hours to complete. Once smoking stops, this part of the process is complete.
4. Let the charcoal cool, then rinse any ash or debris off.
5. Grind the charcoal into a powder, some small pieces are okay to leave in, but under 0.25” is good.
6. Using bleach, calcium chloride, or lemon juice; combine with at least three times as much water, making a 3:1 ratio.
7. Make sure to make enough water solution to completely cover the charcoal and let it sit for 24 hours.
8. After the 24 hours, drain all of the water solution from the charcoal and place back onto a fire for about 3 hours. This is enough for the charcoal to be activated.

Activated charcoal increases the surface area available for absorption of contaminants.

To make the filter system, drill 4-0.5” holes into the bottom and lids of three pails. Next secure a layer of mesh on the bottom of the pails and the top of the lids. Third, put 4 gallons of gravel, 1cm-3cm in diameter into one pail; 4 gallons of sand into a second pail; and 4 gallons of activated charcoal into a third pail. Drill a hole into the side of the fourth pail big enough for the spicket to fit into, and 5 inches from the bottom. Stack the pails from top to bottom: gravel, sand, activated charcoal, spicket. The system is now ready for filtration. Ensure that the gravel and sand is cleaned with sanitary (boiled) water before use to get rid of existing bacteria. Every six months, materials should be cleaned out or replaced using these steps.



References for filter

Activated Carbon From Homemade Charcoal, Survival News Online, 7 Jan. 2014, www.survivalnewsonline.com/index.php/2014/01/activated-carbon-from-homemade-charcoal/. Accessed 30 Oct. 2018.

How to make an Emergency Water Filter, Five Gallon Ideas, 27 Feb. 2017, fivegallonideas.com/emergency-water-filter/. Accessed 30 Oct. 2018.

M, Rich. *Building The Three Bucket Bio-Water-Filter*, Ask a Prepper, 6 Oct. 2015, www.askaprepper.com/building-the-three-5-gallon-bucket-bio-water-filter/. Accessed 30 Oct. 2018.

APPENDIX G

Project Cost Estimates

Quebrada Platano Cost Estimate (2 pages)

Rio Oeste Abajo Cost Estimate (1 page)

Lucy-Chen Inc. Cost Estimate
Quebrada Platano Water System Improvements
Bocas Del Toro, Panama

LUCY-CHEN INC.

Quebrada Platano - Big Tank Network						
Sedimentation Tank						
Labor:	**Quantity**	**Unit**	**Unit Price($/unit)**	**Total($/hr)**	**Duration (hrs)**	**OVERALL COST**
Laborer	2	worker/hr	$1.00	$2.00	136	$272.00
Forman	1	worker/hr	$4.00	$4.00	136	$544.00
Equipment:						
hammer	2		$9.50			$19.00
hack saw	1		$5.95			$5.95
short shovel	2		$8.95			$17.90
large level	1		$9.50			$9.50
wheelbarrow	1		$65.00			$65.00
measuring tape	1		$9.50			$9.50
float	2		$6.50			$13.00
Material:						
cement (cemento)	8	80 lb. per sac	$8.41			$67.28
gravel (gravilla)	1	C.Y.	$40.00			$40.00
sand (arena)	2	C.Y.	$40.00			$80.00
rebar (varilla)	22	3/8" by 30"	$4.10			$90.20
plywood (madera contrachapada)	2	1"x12'x12'	$17.95			$35.90
nails (clavos)	1	lb	$1.25			$1.25
PVC	140'	1"x20'	$2.31			$16.17
Glue(small bottle)	2	bottle	$2.85			$5.70
Wire	5	lb	$1.00			$5.00
		Total for Source Sedimentation Tank at Quebrada Platano				**$1,298.00**
Source Inlet Cover						
Labor:	**Quantity**	**Unit**	**Unit Price($/unit)**	**Total($/hr)**	**Duration (hrs)**	**OVERALL COST**
Laborer	2	worker/hr	$1.00	$2.00	32	$64.00
Forman	1	worker/hr	$4.00	$4.00	32	$128.00
Equipment:						
Material:						
sheet metal (hoja de metal)	1	4'x8'	$89.60			$89.60
		Total for Big Tank Source Inlet Cover at Quebrada Platano				**$282.00**
Quebrada Platano - School Network						
Sedimentation Tank						
Labor:	**Quantity**	**Unit**	**Unit Price($/unit)**	**Total($/hr)**	**Duration (hrs)**	**OVERALL COST**
Laborer	2	worker/hr	$1.00	$2.00	136	$272.00
Forman	1	worker/hr	$4.00	$4.00	136	$544.00
Equipment:						
hammer	2		$9.50			$19.00
hack saw	1		$5.95			$5.95
large level	1		$9.50			$9.50
short shovel	2		$8.95			$17.90
wheelbarrow	1		$65.00			$65.00
measuring tape	1		$9.50			$9.50
float	2		$6.50			$13.00
Material:						
cement (cemento)	8	80 lb. per sac	$8.41			$67.28
gravel (gravilla)	2	C.Y.	$40.00			$80.00
sand (arena)	1	C.Y.	$40.00			$40.00
rebar (varilla)	22	3/8" by 30"	$4.10			$90.20
plywood (madera contrachapada)	2	1"x12'x12'	$17.95			$35.90
nails (clavos)	1	lb	$1.25			$1.25
PVC (ft)	140	1"x20'	$2.31			$16.17
Glue(small bottle)	2	bottle	$2.85			$5.70
Wire	5	lb	$1.00			$5.00
		Total for School Sedimentation Tank at Quebrada Platano				**$1,298.00**

Source Inlet Cover						
Labor:	**Quantity**	**Unit**	**Unit Price($/unit)**	**Total($/hr)**	**Duration (hrs)**	**OVERALL COST**
Laborer	2	worker/hr	$1.00	$2.00	88	$176.00
Forman	1	worker/hr	$4.00	$4.00	88	$352.00
Equipment:						
Wheelbarrow	1		$65.00			$65.00
Shovels	2		$8.95			$17.90
Material:						
gravel (gravilla)	3	C.Y.	$40.00			$120.00
		Total for School Source Inlet at Quebrada Platano				**$731.00**
Quebrada Platano - Spring Source Network						
Storage Tank						
Labor:	**Quantity**	**Unit**	**Unit Price($/unit)**	**Total($/hr)**	**Duration (hrs)**	**OVERALL COST**
Laborer	2	worker/hr	$1.00	$2.00	168	$336.00
Forman	1	worker/hr	$4.00	$4.00	168	$672.00
Equipment:						
hammer	2		$9.50			$19.00
hack saw	1		$5.95			$5.95
short shovel	2		$8.95			$17.90
large level	1		$9.50			$9.50
wheelbarrow	1		$65.00			$65.00
measuring tape	1		$9.50			$9.50
float	2		$6.50			$13.00
Material:						
cement (cemento)	16	80 lb. per sac	$8.41			$134.56
gravel (gravilla)	3	C.Y.	$40.00			$120.00
sand (arena)	2	C.Y.	$40.00			$80.00
rebar (varilla)	35	3/8" by 30'	$4.10			$143.50
plywood (madera contrachapada)	2	1"x12'x12'	$17.95			$35.90
nails (clavos)	1	lb	$1.25			$1.25
Wire	5	lb	$1.00			$5.00
		Total for Spring Source Storage Tank at Quebrada Platano				**$1,669.00**
Spring Box						
Labor:	**Quantity**	**Unit**	**Unit Price($/unit)**	**Total($/hr)**	**Duration (hrs)**	**OVERALL COST**
Laborer	2	worker/hr	$1.00	$2.00	136	$272.00
Forman	1	worker/hr	$4.00	$4.00	136	$544.00
Equipment:						
hammer	2		$9.50			$19.00
hack saw	1		$5.95			$5.95
large level	1		$9.50			$9.50
short shovel	2		$8.95			$17.90
wheelbarrow	1		$65.00			$65.00
measuring tape	1		$9.50			$9.50
float	2		$6.50			$13.00
Material:						
cement (cemento)	5	80 lb. per sac	$8.41			$42.05
gravel (gravilla)	1	C.Y.	$40.00			$40.00
sand (arena)	1	C.Y.	$40.00			$40.00
rebar (varilla)	9	3/8" by 30"	$4.10			$36.90
plywood (madera contrachapada)	1	1"x12'x12'	$17.95			$17.95
nails (clavos)	1	lb	$1.25			$1.25
Wire	5	lb	$1.00			$5.00
			Total for Spring Box at Quebrada Platano			**$1,139.00**
Contigency						**$1,293.00**
Mobilization for Quebrada Platano						**$50.00**
		Total for all projects in Quebrada Platano				**$7,760.00**

Lucy-Chen Inc. Cost Estimate
Rio Oeste Abajo Water System Improvements
Bocas Del Toro, Panama

LUCY-CHEN INC.

Rio Este Abajo - Palo Seco						
Sedimentation Tank						
Labor:	**Quantity**	**Unit**	**Unit Price($/unit)**	**Total($/hr)**	**Duration (hrs)**	**OVERALL COST**
Laborer	2	worker/hr	$1.00	$2.00	136	$272.00
Forman	1	worker/hr	$4.00	$4.00	136	$544.00
Equipment:						
hammer	2		$9.50			$19.00
hack saw	1		$5.95			$5.95
short shovel	2		$8.95			$17.90
large level	1		$9.50			$9.50
wheelbarrow	1		$65.00			$65.00
measuring tape	1		$9.50			$9.50
float	2		$6.50			$13.00
Material:						
cement (cemento)	8	80 lb. per sac	$8.41			$67.28
gravel (gravilla)	1	C.Y.	$40.00			$40.00
sand (arena)	2	C.Y.	$40.00			$80.00
rebar (varilla)	22	3/8" by 30"	$4.10			$90.20
plywood (madera contrachapada)	2	1"x12'x12'	$17.95			$35.90
nails (clavos)	1	lb	$1.25			$1.25
PVC	240'	1"x20'	$2.31			$27.72
Glue(small bottle)	2	bottle	$2.85			$5.70
wire	5	lb	$1.00			$5.00
	Total for Palo Seco Source Sedimentation Tank at Rio Este Abajo					**$1,309.00**
Source Inlet Cover						
Labor:	**Quantity**	**Unit**	**Unit Price($/unit)**	**Total($/hr)**	**Duration (hrs)**	**OVERALL COST**
Laborer	2	worker/hr	$1.00	$2.00	88	$176.00
Forman	1	worker/hr	$4.00	$4.00	88	$352.00
Equipment:						
short shovel	2		$8.95			$17.90
wheelbarrow	1		$65.00			$65.00
Material:						
gravel (gravilla)	4	C.Y.	$40.00			$160.00
	Total for Palo Seco Source Inlet Cover at Rio Este Abajo					**$771.00**
Storage Tank						
Labor:	**Quantity**	**Unit**	**Unit Price($/unit)**	**Total($/hr)**	**Duration (hrs)**	**OVERALL COST**
Laborer	2	worker/hr	$1.00	$2.00	168	$336.00
Forman	1	worker/hr	$4.00	$4.00	168	$672.00
Equipment:						
hammer	2		$9.50			$19.00
hack saw	1		$5.95			$5.95
short shovel	2		$8.95			$17.90
large level	1		$9.50			$9.50
wheelbarrow	1		$65.00			$65.00
measuring tape	1		$9.50			$9.50
float	2		$6.50			$13.00
Material:						
gravel (gravilla)	3	C.Y.	$40.00			$120.00
cement (cemento)	14	80 lb. per sac	$8.41			$117.74
sand (arena)	2	C.Y.	$40.00			$80.00
rebar (varilla)	27	3/8" by 30"	$4.10			$110.70
plywood (madera contrachapada)	2	1"x12'x12'	$17.95			$35.90
nails (clavos)	1	lb	$1.25			$1.25
wire	5	lb	$1.00			$5.00
	Total for Palo Seco Source Storage Tank at Rio Este Abajo					**$1,619.00**
Contingency						**$748.00**
Mobilization for Quebrada Platano						**$40.00**
	Total Cost for all projects in Rio Este Abajo					**$4,487.00**

APPENDIX H

Project Schedules

<u>Quebrada Platano</u>

Big Tank Source Project Schedule

Spring Source Project Schedule

School Tank Source Project Schedule

<u>Rio Oeste Abajo</u>

Palo Seco Source Project Schedule

<u>Breakdown Schedules</u>

Sedimentation Tank

Spring Box

Spring Box Storage Tank

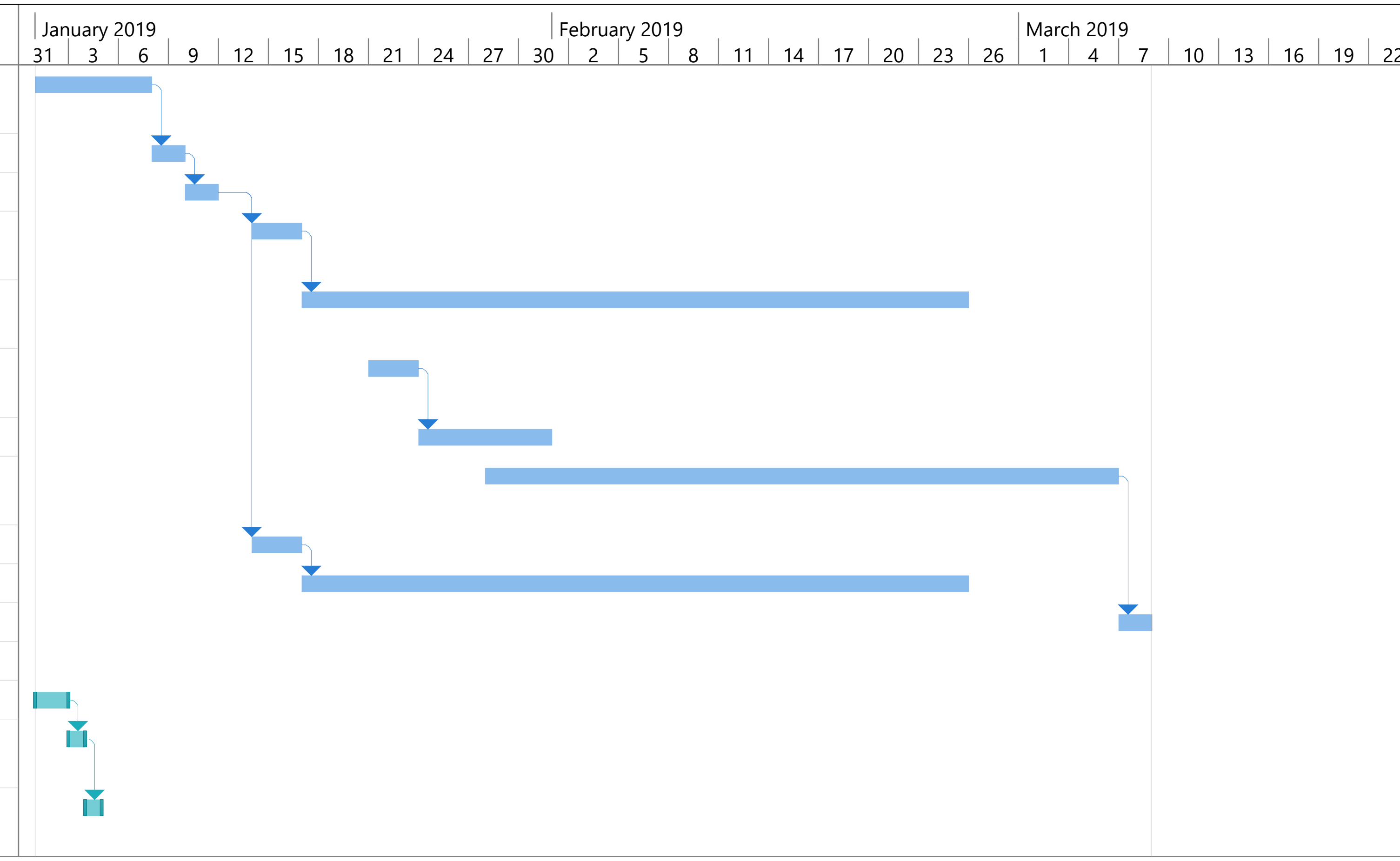
Quebrada Platano Big Tank Aqueduct Cover

School Intake Alternatives

Quebrada Platano Big Tank Schedule

LUCY-CHEN INC.

ID	Task Name	Duration	Start	Finish	Predecessors	Resource Names
1	Sedimentation Tank: Site Preparation	5 days	Tue 1/1/19	Mon 1/7/19		
2	Material Collection	2 days	Tue 1/8/19	Wed 1/9/19	1	
3	Material Preparation	2 days	Thu 1/10/19	Fri 1/11/19	2	
4	Tank Base Construction	3 days	Mon 1/14/19	Wed 1/16/19	3	
5	Tank Base Settling and Curing	28 days	Thu 1/17/19	Mon 2/25/19	4	
6	Tank Wall Construction	3 days	Mon 1/21/19	Wed 1/23/19		
7	Tank Wall Settling	6 days	Thu 1/24/19	Thu 1/31/19	6	
8	Smoothing Inside and Curing	28 days	Mon 1/28/19	Wed 3/6/19		
9	Construct Covers	3 days	Mon 1/14/19	Wed 1/16/19	3	
10	Cover Curing	28 days	Thu 1/17/19	Mon 2/25/19	9	
11	Connect to System	2 days	Thu 3/7/19	Fri 3/8/19	8	
12						
13	Aqueduct Cover: Excavation	2 days	Tue 1/1/19	Wed 1/2/19		
14	Drilling into Landscape	1 day	Thu 1/3/19	Thu 1/3/19	13	
15	Cutting/Bending Expanded Steel	1 day	Fri 1/4/19	Fri 1/4/19	14	



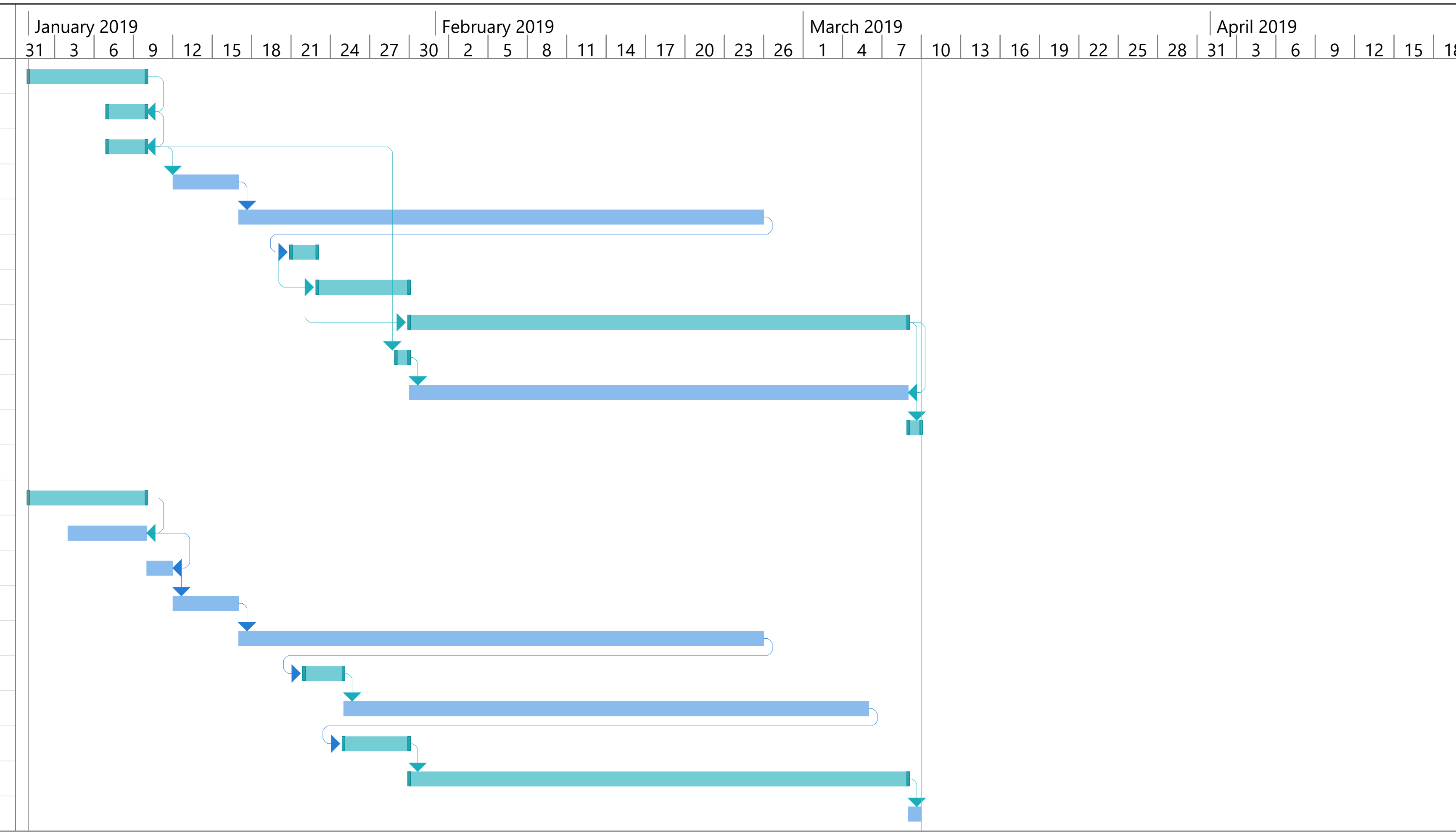
Project: Big Tank Source
Date: Mon 12/3/18

Task | Split | Milestone | Summary | Project Summary | Inactive Task | Inactive Milestone | Inactive Summary | Manual Task | Duration-only | Manual Summary Rollup | Manual Summary | Start-only | Finish-only | External Tasks | External Milestone | Deadline | Progress | Manual Progress

Quebrada Platano Spring Source Schedule

LUCY-CHEN INC.

ID	Task Name	Duration	Start	Finish	Predecessors
1	Box: Site Preparation and Excavation	7 days	Tue 1/1/19	Wed 1/9/19	
2	Box: Material Collection	3 days	Mon 1/7/19	Wed 1/9/19	1FF
3	Box: Material Preparation	3 days	Mon 1/7/19	Wed 1/9/19	2FF
4	Box: Tank Base Construction	4 days	Sat 1/12/19	Wed 1/16/19	3
5	Box: Tank Base Settling and Curing	28 days	Thu 1/17/19	Mon 2/25/19	4
6	Box: Tank Wall Construction	2 days	Mon 1/21/19	Tue 1/22/19	5FS-26 days
7	Box: Tank Wall Settling	5 days	Wed 1/23/19	Tue 1/29/19	6SS
8	Box: Smoothing Inside and Curing	28 days	Wed 1/30/19	Fri 3/8/19	7SS
9	Box: Construct Covers	1 day	Tue 1/29/19	Tue 1/29/19	3
10	Box: Cover Curing	28 days	Wed 1/30/19	Fri 3/8/19	9,8FF
11	Box: Connect to System	1 day	Sat 3/9/19	Sat 3/9/19	8
12					
13	Tank: Site Preparation and Excavation	7 days	Tue 1/1/19	Wed 1/9/19	
14	Tank: Material Collection	4 days	Fri 1/4/19	Wed 1/9/19	13FF
15	Tank: Material Preparation	2 days	Thu 1/10/19	Fri 1/11/19	14FF
16	Tank: Tank Base Construction	4 days	Sat 1/12/19	Wed 1/16/19	15
17	Tank: Tank Base Settling and Curing	28 days	Thu 1/17/19	Mon 2/25/19	16
18	Tank: Tank Wall Construction	3 days	Tue 1/22/19	Thu 1/24/19	17FS-25 days
19	Tank: Tank Wall Curing	28 days	Fri 1/25/19	Tue 3/5/19	18
20	Tank: Construct Covers	3 days	Fri 1/25/19	Tue 1/29/19	19FS-28 days
21	Tank: Cover Curing	28 days	Wed 1/30/19	Fri 3/8/19	20
22	Tank: Connect to System	1 day	Sat 3/9/19	Sat 3/9/19	21



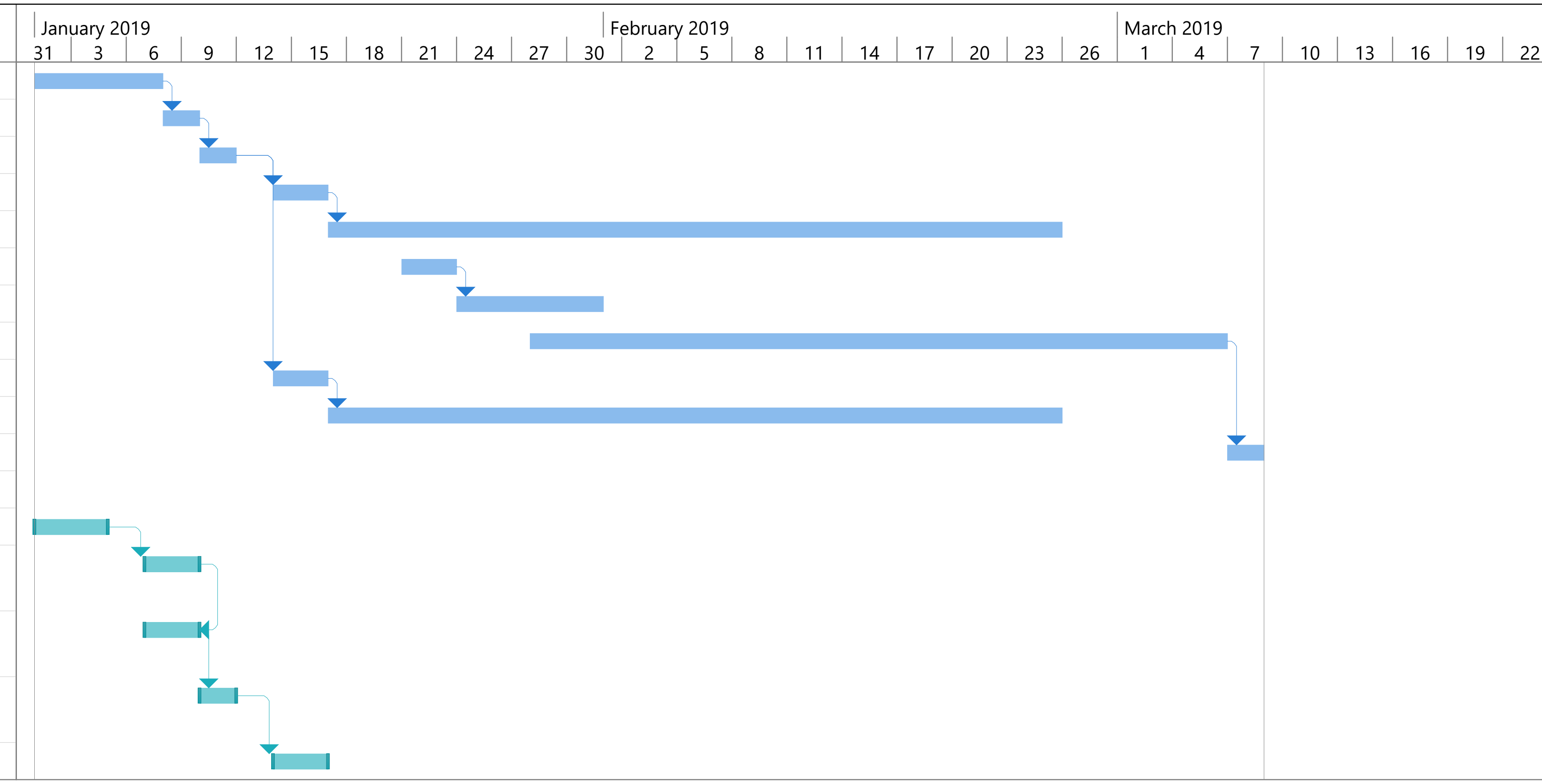
Project: Spring Source
Date: Mon 12/3/18

Task	Project Summary	Manual Task	Start-only	Deadline
Split	Inactive Task	Duration-only	Finish-only	Progress
Milestone	Inactive Milestone	Manual Summary Rollup	External Tasks	Manual Progress
Summary	Inactive Summary	Manual Summary	External Milestone	

Quebrada Platano School Tank Schedule

LUCY-CHEN INC.

ID	Task Name	Duration	Start	Finish	Predecessors
1	Sedimentation Tank: Site Preparation	5 days	Tue 1/1/19	Mon 1/7/19	
2	Material Collection	2 days	Tue 1/8/19	Wed 1/9/19	1
3	Material Preparation	2 days	Thu 1/10/19	Fri 1/11/19	2
4	Tank Base Construction	3 days	Mon 1/14/19	Wed 1/16/19	3
5	Tank Base Settling and Curing	28 days	Thu 1/17/19	Mon 2/25/19	4
6	Tank Wall Construction	3 days	Mon 1/21/19	Wed 1/23/19	
7	Tank Wall Settling	6 days	Thu 1/24/19	Thu 1/31/19	6
8	Smoothing Inside and Curing	28 days	Mon 1/28/19	Wed 3/6/19	
9	Construct Covers	3 days	Mon 1/14/19	Wed 1/16/19	3
10	Cover Curing	28 days	Thu 1/17/19	Mon 2/25/19	9
11	Connect to System	2 days	Thu 3/7/19	Fri 3/8/19	8
12					
13	Rock Dam: Site Preparation	4 days	Tue 1/1/19	Fri 1/4/19	
14	Rock Dam: Material Collection	3 days	Mon 1/7/19	Wed 1/9/19	13
15	Rock Dam: Material Preparation	3 days	Mon 1/7/19	Wed 1/9/19	14FF
16	Stake Wall Construction	2 days	Thu 1/10/19	Fri 1/11/19	15
17	Rock Buildup	3 days	Mon 1/14/19	Wed 1/16/19	16



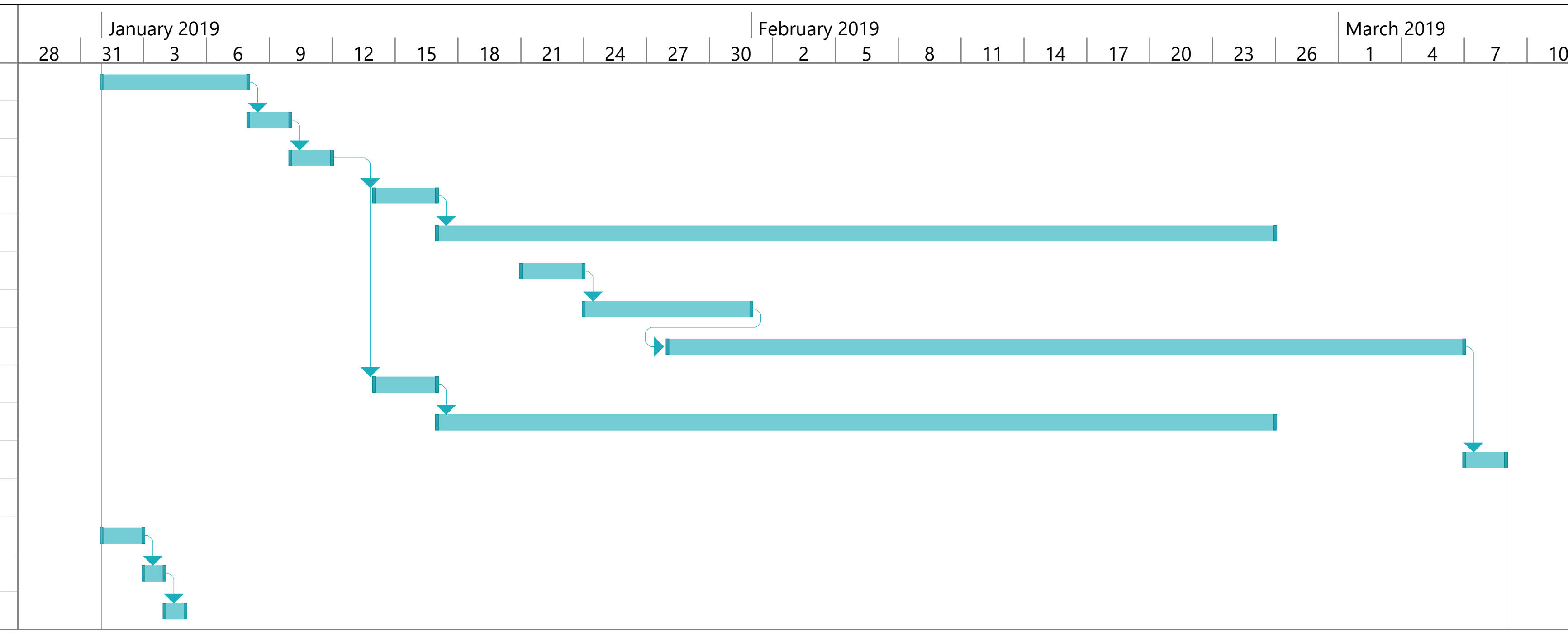
Project: School Intake
Date: Mon 12/3/18

Task	Project Summary	Manual Task	Start-only	Deadline
Split	Inactive Task	Duration-only	Finish-only	Progress
Milestone	Inactive Milestone	Manual Summary Rollup	External Tasks	Manual Progress
Summary	Inactive Summary	Manual Summary	External Milestone	

Rio Oeste Abajo Palo Seco Schedule

LUCY-CHEN INC.

ID	Task Name	Duration	Start	Finish	Predecessors
1	Sedimentation Tank: Site Preparation	5 days	Tue 1/1/19	Mon 1/7/19	
2	Material Collection	2 days	Tue 1/8/19	Wed 1/9/19	1
3	Material Preparation	2 days	Thu 1/10/19	Fri 1/11/19	2
4	Tank Base Construction	3 days	Mon 1/14/19	Wed 1/16/19	3
5	Tank Base Settling and Curing	28 days	Thu 1/17/19	Mon 2/25/19	4
6	Tank Wall Construction	3 days	Mon 1/21/19	Wed 1/23/19	
7	Tank Wall Settling	6 days	Thu 1/24/19	Thu 1/31/19	6
8	Smoothing Inside and Curing	28 days	Mon 1/28/19	Wed 3/6/19	7FS-4 days
9	Construct Covers	3 days	Mon 1/14/19	Wed 1/16/19	3
10	Cover Curing	28 days	Thu 1/17/19	Mon 2/25/19	9
11	Connect to System	2 days	Thu 3/7/19	Fri 3/8/19	8
12					
13	Aqueduct Cover: Excavation	2 days	Tue 1/1/19	Wed 1/2/19	
14	Drilling into Landscape	1 day	Thu 1/3/19	Thu 1/3/19	13
15	Cutting/Bending Expanded Steel	1 day	Fri 1/4/19	Fri 1/4/19	14



Project: Palo Seco
Date: Mon 12/3/18

Task | Split | Milestone | Summary | Project Summary | Inactive Task | Inactive Milestone | Inactive Summary | Manual Task | Duration-only | Manual Summary Rollup | Manual Summary | Start-only | Finish-only | External Tasks | External Milestone | Deadline | Progress | Manual Progress

LUCY-CHEN INC.

Sedimentation Tank Construction

	Week 1							Week 2							Week 3							Week 4							Week 5							Week 6							Week 7						
Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
Site Preparation	w	w	w	w	w																																												
Material Collection					w	w																																											
Material Preparation						w	w																																										
Tank Base Construction							w	w	w																																								
Tank Base Settling and Curing																																																	
Tank Wall Construction												w	w	w																																			
Tank Wall Settling and Curing																																																	
Smoothing Inside and Curing																	w																																
Construct Covers						w	w	w																																									
Cover Settling and Curing																																																	
Connect to system																																											w	w					

*'w' = working day
15 working days

Used to Construct Gantt Chart for:
Quebrada Platano Big Tank Schedule
Quebrada Platano School Tank Schedule
Rio Oeste Abajo Palo Seco Schedule

LUCY-CHEN INC.

Spring Box Construction

	Week 1							Week 2							Week 3							Week 4							Week 5							Week 6							Week 7						
Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
Site Preparation and Excavation	w	w	w	w	w	w	w																																										
Material Collection						w	w	w																																									
Material Preparation							w	w	w	w																																							
Tank Base Construction										w	w																																						
Tank Base Settling and Curing																																																	
Tank Wall Construction														w	w																																		
Tank Wall Settling																																																	
Smoothing Inside and Curing																			w	w	w																												
Construct Covers										w																																							
Cover Settling and Curing																																																	
Connect to system																																											w						

*'w' = working day
17 working days

Used to Construct Gantt Chart for:
Quebrada Platano Spring Source Schedule

LUCY-CHEN INC.

Spring Box Storage Tank

	Week 1							Week 2							Week 3							Week 4							Week 5							Week 6							Week 7							Week 8						
Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56
Site Preparation and Excavation	w	w	w	w	w	w	w																																																	
Material Collection						w	w	w	w																																															
Material Preparation									w	w																																														
Base Construction										w	w	w																																												
Base Drying and Curing																																																								
Wall Construction																w	w	w																																						
Wall Drying and Curing																																																								
Cover Construction																						w	w	w																																
Cover Drying and Curing																																																								
Smooth Inside																												w	w																											
Connect to System																																																				w				

*'w' = working day
21 working days

Used to Construct Gantt Chart for:
Quebrada Platano Spring Source Schedule

LUCY-CHEN INC.

Quebrada Platano Big Tank Aqueduct Cover

	Week 1						
Day	1	2	3	4	5	6	7
Small Amount of Excavation	w	w					
Drilling into Landscape			w				
Cutting/Bending Expanded Steel				w			

*'w' = working day
4 working days

Used to Construct Gantt Chart for:

Quebrada Platano Big Tank Schedule

LUCY-CHEN INC.

School Intake Construction Concrete Dam

	Week 1							Week 2							Week 3							Week 4							Week 5							Week 6						
Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
Site Preparation and Excavation																																										
Material Collection																																										
Material Preparation																																										
Dam Construction																																										
Dam Settling and Curing																																										
Smoothing Inside and Curing																																										
Construct Cover (Optional)																																										
Cover Settling and Curing																																										
Open to system																																										

School Intake Construction Rock Dam

	Week 1							Week 2						
Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Site Preparation	w	w	w	w										
Material Collection					w	w	w							
Material Preparation						w	w	w						
Stake Wall Construction								w	w					
Rock Buildup									w	w	w			

*'w' = working day
11 working days

Used to Construct Gantt Chart for:
Quebrada Platano School Tank Schedule