





DEVELOPING SUSTAINABLE WATER DISTRIBUTION SYSTEMS IN RURAL PANAMA

iDesign 2011
Michigan Technological University

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Disclaimer:

It should be noted that this report was created by undergraduate students participating in Michigan Technological University's International Senior Design. It should not be considered a professional engineering recommendation. The purpose of this document is to offer ideas to meet the needs of the Candela Community.

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1.0 Executive Summary

Team Candela has designed engineering improvements to a water distribution system for the 400-member community of Candela within the Comarca Ngöbe-Bugle in Panama. The existing water systems do not sufficiently provide for the water needs of the community year round, and do not adequately prevent or eliminate contamination from animals, parasites, or waterborne diseases.

Team Candela spent a week in the Candela community in August 2011 to collect data required for rehabilitation designs. A series of recommendations has been developed for the short term (limited associated costs) and long term (major costs) improvements for the community.

The final design recommendations to the community include construction of three spring boxes for Systems 1 and 2, two 4500 gallon water storage tanks for Systems 2 and 3, PVC (polyvinyl chloride) piping and taps for all homes not currently connected to the system, and the connection of System 1 to System 3 by re-laid PVC and installation of a solar powered pump. These final design recommendations were formed from field data collection in the Candela community, research on available options and other sustainable projects, and finally feasibility based on funding available and costs. The total cost estimate for all recommended improvements to Candela's water distribution systems is \$12,000.

The methods for field data collection and then data analysis are to follow in this report. In parallel to data analysis, research was conducted on all aspects of design from spring box construction to water quality improvement through chlorination. The design plans resulting from this research is also given throughout this report. Team Candela will be presenting the design in several different phases to give the community feasible and attainable goals to improve their water systems incrementally and according to available funds. These design plans were made after economic feasibility and physical/theoretical feasibility was considered. After the design plan is completely outlined, along with the total recommendations to the community for water system improvement, the alternatives that were ruled out as feasible considerations are also given. From the final design plans, the cost estimate and construction schedule were derived. The project began by collecting information of the water systems through basic observations while in the Candela community. Field work in Panama yielded data that was used to design for improvements while in the US. This data would need to paint a picture of the Candela community's water distribution to ensure selection of the most appropriate design. This was the first step towards achieving a suitable and thorough design for the community. Data was then processed and analyzed in order to draw conclusions and make plans for design.

2.0 Introduction

As a part of Michigan Tech's International Senior Design Program (iDesign), Team Candela travelled to Panama to investigate the water distribution system in the Candela community of Panama. The objective of this project is to improve the water distribution for the Candela Community.

Originally, the community water distribution system was designed as one conjoined system; but, after failure, the community broke the water distribution into three parts: the original system (System 1), consisting of a spring box that is open to contamination due to dilapidation of the concrete front face, a 6,000 gallon tank, and connections to 6 homes (2 additional home not connected) and the Centro de Salud (Health Center); Marco's system (System 2), constructed by community member Marco Gonzales, consisting of an poorly constructed spring box that allows flows to run downstream to a small earth dam where water is collected and piped to the 11 homes; and water collected from an open runoff source (System 3), consisting of open ended PVC pipe (salvaged from the original system), directing water near a group of 5 homes that are separated from the rest of the community by a ridge. Throughout the following report are details regarding the three water systems currently existing in Candela (Systems 1, 2 and 3) and how, through the final design recommendations, Systems 1 and 3 are connected into one system from the same spring sources and System 2 remains independent.

2.0 Problem Statement

From the community interviews and observations the team noted several problems with the existing water supply system. Each of the three systems had various problems that kept the system from meeting the community's goal of providing year round access to safe drinkable water. Primary among the problems the team considered were the following:

Water Supply:

Systems one and three only received water during the rainy season

System two had limited water storage capabilities

Water Quality:

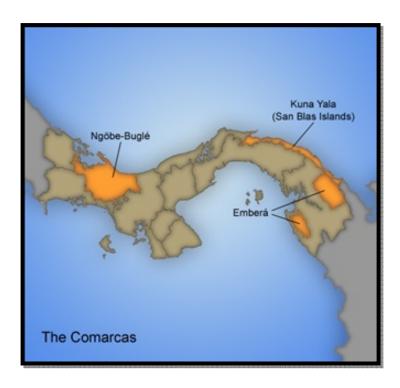
System three was collecting from a run-off source, open to contamination

Systems one and two had ineffective spring boxes, allowing potential contamination

3.0 Community Background

Candela, Panama

The community interested in this water supply project is the mountainous village of Candela. The people of Candela are part of the indigenous Ngöbe-Bugle tribe, which is comprised of two groups: the larger group of Ngöbe people, and the dwindling group of Bugle people. These two groups (which are represented as one tribe) inhabit the Comarca Ngöbe-Bugle. The Comarca is comparable to an Indian Reservation in the United States. It is a protected area with a separate political system. These Comarcas were created in 1972 when the Panamanian government was required to give land to indigenous tribes. Aside from the Ngöbe-Bugle tribe, there are six other tribes of indigenous people in Panama. Ngöbe-Bugle, being the most populous tribe, consists of approximately 190,000 people. Figure 3.1 (below) shows the distribution of Comarcas across Panama.



The village of Candela is home to approximately 250 Ngöbe-Bugle people. Traveling to the village requires a two hour hike from the nearest road, over the peaks and through the valleys of the Talamanca mountain range.

Economically, the Candela community is quite isolated. The families sustain themselves with subsistence farming. Women receive \$50 per month from the government and use that money for their family and home care and upkeep needs. One member of the community has a solar panel and charges 50 cents for community members to charge there cell phones. The Candela community members pay \$1 per month for access to the health center in the area. The health center is routinely visited by a

physician to exam patients when needed and to distribute available medication. About half of the community pays a 25 cent monthly fee to the water committee for their connection to the water system. The Panamanian currency is the Balboa. However, the currency exchange rate is equivalent to the US Dollar. Therefore, henceforth this report will present values for design plans in US Dollars.

Community diet consists of mainly rice, beans, yuka (root vegetable), and plantains. The main drink in Candela, café, is a very weak, un-boiled coffee mixed with sugar. No community member admitted to drinking the water by itself. The community members noted a higher occurrence of illness around the beginning of the wet season, which is around the month of May, and do connect the illness to their water. A hypothesis to explain the timing of such sicknesses (around the wet season) could be stagnant water in the water storage tank. During the dry season, the water in the tank is not flushed as regularly, and has longer time to sit in the tank and develop pathogens, crabs and insect larvae from an unprotected source. Once the water storage tank is drained in the dry season, the community members use the local river as a water source. Because wood is a precious resource, the community will not boil water prior to drinking or cooking. There is currently no treatment used for any water. Visual observations of some children in Candela show skinny arms and legs with a large, protruding stomach, which could indicate parasites.

Candela residents dwell in homes built out of bamboo walls, corrugated metal roofs, and dirt floors. Figure 3.2 (below) shows a typical home in the community.



Just after the team left the project site, a community latrine project was underway in Candela, which was organized by a neighboring community's Peace Corps Volunteer (PCV), Lyndsey Bunting who visits the community a few times a month for an agriculture meeting. While there are a few latrines in use

within the community, many community members use the forest or river, with the belief that this option is more sanitary. While there is no permanent PCV in the community, there are future plans for one in the Candela community who will be able to oversee implementation of final design recommendations from this project.

About half of the community members use water that is piped to their homes for all water needs: cooking, laundry, bathing, bathroom, etc. Once again, when the dry season comes around, February to April, the systems are insufficient in supply, and the river serves all the water needs. If water is stored at the homes, it is uncovered and will likely become contaminated. The other half of the community, which is on the newer water system (discussed later), has year round access to water, but only draws water for cooking and drinking. Figure 3.3 (below) represents a typical water distribution set up for a home in Candela.



History of Water Distribution

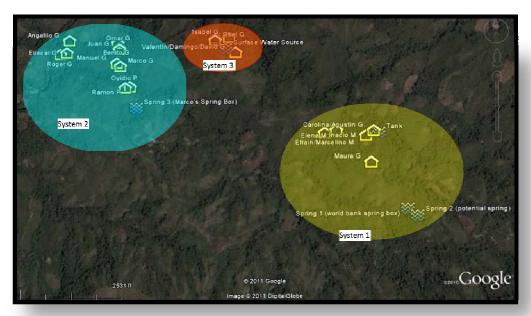


Figure 3.4 The current three water distribution systems in Candela.

According to Marco, in 1999, the World Bank funded a water distribution system for the community of Candela. Who designed and built the system is unknown, though it seems that community members (especially key members of the water committee) were largely involved and are very knowledgeable of their system.

The World Bank water system (System 1) consists of a spring box built at a natural spring source, a water storage tank nearby the community, and then ultimately piped to houses. The piping used to connect all of these components is $1 \frac{1}{2}$ " PVC pipe from the spring box to the tank and for the main lines, and $\frac{3}{4}$ " PVC running off the main pipe to the homes. The entire system is gravity fed from spring to house. Here, Figures 3.5 and 3.6 show the current spring box for System 1 and the water storage tank, respectively.



<u>Figure 3.5</u> The existing spring box on System 1. This box has been dilapidated by time and the erosion. It is not a completely enclosed, therefore is insufficient to protect spring source. Photo by Jordan Huffman.



Shortly after construction, this system failed to supply water to many of the houses installed on it, especially houses far to the west of the system. One community member, Marco Gonzales (pictured in Figure 3.7 with his constructed spring box), salvaged pipe from the non-functioning section of the distribution system and constructed his own spring box and water distribution system. This system (System 2) utilizes a natural spring source and currently serves 11 homes. Marco constructed a concrete spring box with water flow out the section of pipe down a five foot drop to stagnant water that pools due to an open earth reservoir (Figure 3.8), which is then collected into a PVC pipe and piped to homes. There is no tank in the distribution system. This system provides sufficient water supply year round, but is only utilized for cooking and drinking.





Six houses are still not receiving water in the community from either System 1 or System 3. Three of these homes are able to utilize surface runoff for about six months of the year (System 3), piped directly to their homes using 1 ½" PVC from the original malfunctioning sections of System 1. This is gravity fed from elevated pools of runoff water, and is free flowing without spigots. The remaining three houses (which are at a high elevation, making water service difficult), will manually collect water from System 3 and store it in open five gallon buckets for later use. These three houses are at an elevation difference of only 20ft from the spring source of System 1. Due to all the headlosses throughout the system (discussed in analysis), this minimal difference in elevation was one of the significant design challenge to reach these homes with water supplied from springs on System 1.



Figures 3.10 and 3.11 were drawn by community member Marco to show how homes across Candela were distributed. GPS points were taken at homes and points of interest and were later used to create a Google Earth® Map of the community (pictured above in 3.4 as well as later in this report).

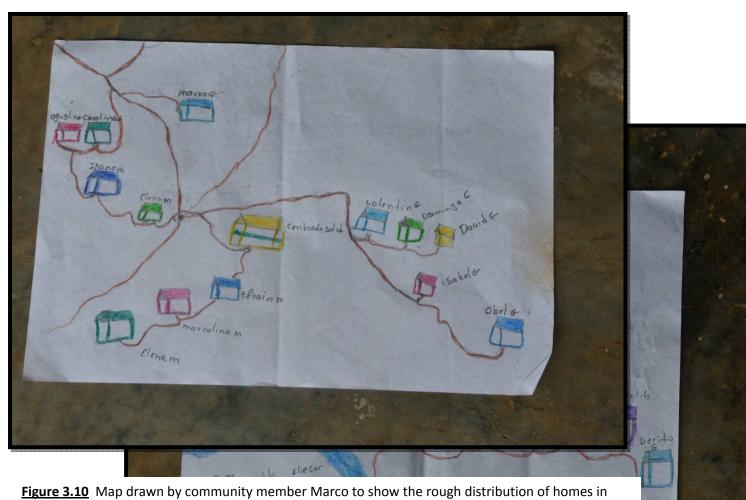


Figure 3.10 Map drawn by community member Marco to show the rough distribution of homes in Candela. This is the western side of the community served by System 1. The Health Center is located in the center. titled "Centro de Salud." Photo by Jordan Huffman.

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December 9, Figure 3.11 This second map drawn by Marco represents homes on the eastern side of the community and served by water Systems 2 and 3. Photo by Jordan Huffman.

Overall, the interaction with the Candela community resulted in identifying the following needs from improved water systems:

- Access to running water year round
- A method to treat water
- A way to keep animals/crustaceans out of the water storage tank and piping system.

4.0 Data Collection and Observations

Abney level surveying, GPS mapping, water quality tests, flow rate measurements, and community interviews were used to collect and analyze project site and community data to design recommendations. The following outlines the data collection and analysis methods used in this project.

Abney Level Surveying

Abney Level surveying was used to investigate the topography of System 1 within the Candela community. System 1 currently does not adequately provide water during the dry season, but has an additional natural spring source nearby that has the potential to be added to the system (potential spring).

Abney Level surveying was completed from the potential spring source to the existing spring box, from the existing spring box to the water storage tank, and then down to a couple homes with a piped water spigot just past the Centro de Salud.

The method of Abney Level surveying is depicted below in Figure 4.1. The tools needed include: an Abney Level, a stick (of measured height) to balance the level on, a compass, GPS and measuring tape. Even though the team carried stadia surveying equipment into the Candela community, it was decided that type of surveying was not feasible with the terrain. The tripod would have to have been reset every few feet because of the drastic changes in elevation, and that would require more time overall in the field than was available. A picture demonstrating these drastic elevation changes is shown in Figure 4.2. Some community members were particularly interested in the team's surveying equipment, so Laura Fishman, a nearby PCV, gave demonstrations on how to use an Abney Level, shown in Figure 4.3. Survey notes are included in appendix 10.22.

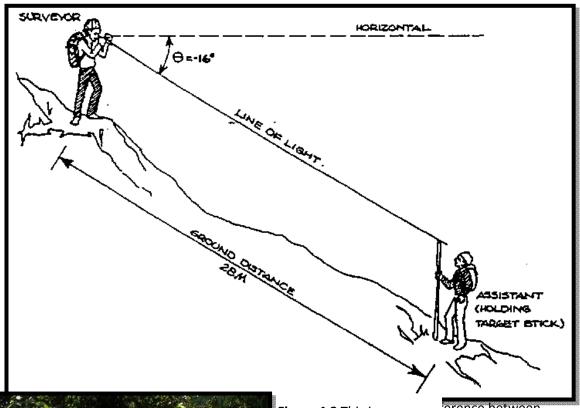


Figure 4.2 This is a picture of a walking path in Candela where the PVC pipe is running right next to the path. The drastic

erence between eam used a stick to





Figure 4.3 Laura (PCV) (left) is explaining Abney
Level use to members of the Candela community.

The rod is what is used to read elevations through the Abney Level. Photo by Stephanie Tulk.

December 9, 2011

GPS Mapping

A handheld GPS unit was used to collect a data point at each point surveyed along System 1. GPS points were also collected across various sites in the community: houses and piping along Systems 2 and 3, and sites where the original System 1 piping once existed. These GPS points could then be used to generate Google Earth spatial and topographic maps.

Water Sampling

Water quality tests were used to determine if there were any pathogens in the water of Candela, specifically E. coli and Coliform. Sources for testing included: potential spring, spring boxes, water storage tank, and spigots at homes across all three of the current water systems. The tests used were 3M Petrifilm E.coli/Coliform Count Plates, which are flat sheets of Styrofoam with a sheet cover and a circular indentation in the center with auger to encourage growth of E.coli and coliform bacteria, and indicators to stain colonies blue and red, respectively. These petrifilms take a 1 mL sample of water, collected from a source of interest using a graduated 3 mL pipette. The petrifilm cover sheet is pulled back, and sample is placed in center of test area, avoiding air bubbles, as shown in Figure 11. The cover is then gently rolled over the sample, so as not to introduce air bubbles, and a plastic "tapper" is centered on the sample and lightly tapped to displace water until the entire sample area is covered. The sample is then marked with the date, time, location and any other relevant information, and placed between two cardboard sheets and incubated on the body for 24 hours. Since the sample size collected was 1mL, to increase the reliability of the Petrifilm tests, multiple samples were collected.



Flow Rate Measurements

Flow rates were taken at each of the different water sources. These flow rates were taken by recording the amount of time needed for the water source to fill a twenty liter bucket. This process was repeated three to five times at each of the spring sources, and flow was also measured at the surface runoff source. The team collected this data during the wet season, and as such, these rates have been set as the maximum flow rates for each system. PCV Laura Fishman supplied the team with dry season flow rates based on similar methods. These dry season flow rates will be assumed to represent the minimum flow of the system, and all flow rates are included in appendix 10.1.

Community Interviews

Community interviews were conducted with the help of a PCV to translate the questions directly to collect information on the community. The questions included topics such as health, sanitation, and information on the water distribution system.

5.0 Analysis

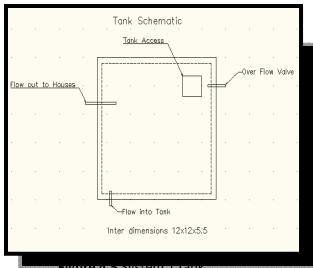
During the team's stay in Candela data collection was crucial to develop the designs to provide for the needs of the Candela community. This data includes Abney Level Surveying, Water Sampling, GPS points, and information about the existing system and water use, gathered from community interviews. From this information, the team created an EPANET Model, and Auto CAD® drawings, and various graphs and tables.

Existing System Observations

The community's water system can be said to consist of the three systems (largely discussed previously in History of Water Distribution section):

- System 1: World Bank spring box
- System 2: Marco's spring box
- System 3: surface water collection

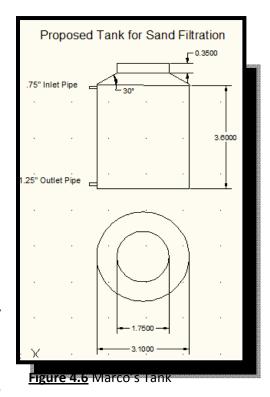
Figure 4.5 shows the schematic from the tank on System 1. The tank can hold 5925 gallons which has the capacity to supply the water demand of System 1 and 3 for 24 hours. The tank has an overflow value that community members sometimes use to wash their clothes, draining the tank. It was observed that crabs where living in the tank likely entered the system at the partially collapsed spring box.



Marco purchased a 200 gallon tank with the intentions of using it for slow sand filtration for System 2. Figure 4.6 shows the basic dimension of that tank. System 2 currently uses 1 ½" pipe to provide water for part of the community. This system has no tank to store up sand filtered water in hours when demand is low. Given these two factors, Marco will not be able to use a slow sand filter to meet the water demands of the 11 houses on System 2 with current system configuration.

Mapping

The extensive GPS data collected on the houses, water system, and topographic points were used to develop a map in Google earth. Figure 4.7 portrays Systems 1 and 3. Springs (indicated by blue waves), community homes (yellow houses), significant pipe damages (yellow wrenches), and various points of interest (blue tacks) are included for reference. The line of blue tacks from the picture center to the upper left corner indicate where pipeline originally ran from System 1 to System 3. Figure 4.8 show System 2 in relation to System 3.



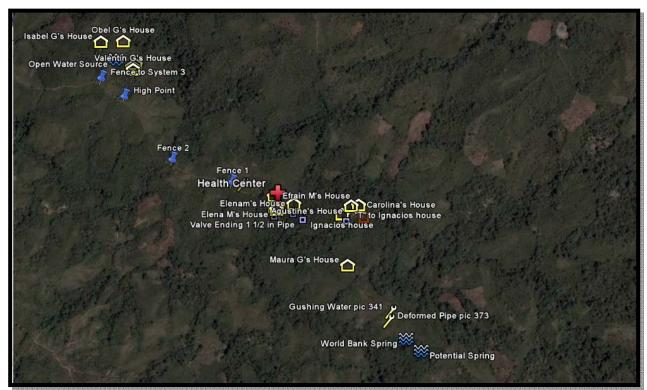
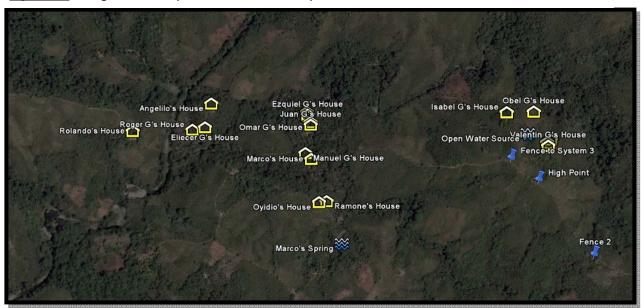


Figure 4.7 Google Earth Map of Candela's water Systems 1 and 2.



4.8 Google Earth Map showing System 2 in relation to System 3.

The GPS points were also imported into AutoCAD®. This was done to provide a spatial reference for bringing multiple elevation layers into AutoCAD®. First the points were converted from decimal degrees into feet using the following conversion (1).

$$Latitude \ or \ Longitude \ \times \frac{60 \ nautical \ miles}{1 \ decimal \ degree} \times \frac{6076 \ Feet}{1 \ Nautical \ Mile} = Feet$$

The points on AutoCAD® were then overlaid with the ground elevations from Google Earth. Using the GPS points as a reference, the map was overlaid as accurately as possible. Figure 4.9 is the same view as 4.8, but shows high and low points within the valley as references. In Figure 4.9, the major (green) and the minor (red) intervals show a change of 25 feet, and 5 feet respectively. The outer edges are increasing in elevation in all direction because the community is located in a valley. Given the topography, there is not a route to connect System 2 to System 3 that can provide enough head to serve System 3.

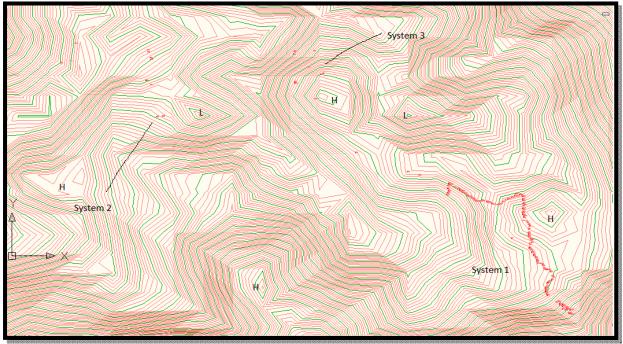
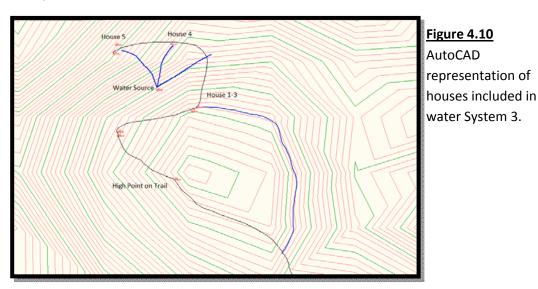


Figure 4.9 AutoCAD map generated from Google

While the houses in System 3 had originally been connected to System 1, due to the difference in elevation, they never received water. One community member believed that if the PVC pipe was placed on a different route, water might be able to make it to their houses. Using the Google terrain maps, the team was able to verify his claim decreasing the head required by 25 feet as illustrated in the Figure 4.10 (below). The line connecting the trail and Houses 1-3 would decrease the head required by about 25 feet by decreasing length and subsequent friction losses. The other blue lines are the pipe lines coming from the open water sources to the houses.



It is important to use other mapping sources to validate Google earth mapping. From the East View website, Topographic map 3841-III was ordered, which covers the Candela community. Also, GPS elevations taken on site were considered. Table 4.1 shows that the change in elevation from the beginning of System1 to the houses on System 3, about 7,900 feet away, is within 10 feet variance for each data set. This comparison helps us verify the accuracy of the topographic methods.

Table 4.1: Comparison of map data sources			
Difference in Elevation Beginning to End			
Topographic map	110 Feet		
Google Earth surface	105 Feet		
GPS Points	101 Feet		

Survey Analysis and Pipeline Elevation Profile

As noted earlier, Abney level surveying was completed from the potential spring box to the existing spring box and then to the end of System 1 (homes drawing from water system). Abney level data included a distance from the Abney level pole to the level rod (at the same heights), as well as the vertical angle. Example calculations are included in appendix 10.21.

The resulting changes in horizontal distance were summed, progressing from the potential spring (System 1) to the houses drawing from System 3. This was used to plot elevation vs. horizontal distance, shown below in Figure 4.11 (data included in appendix 10.22).

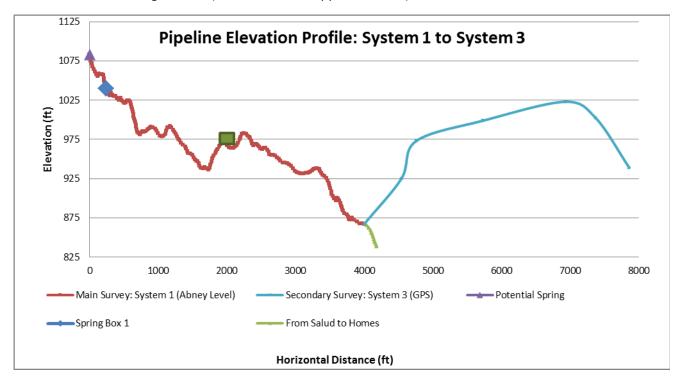


Figure 4.11 Pipeline elevation profile from surveys of pipe path from the beginning of System 1 to homes on System 3

Figure 4.11 includes some points of interest. The purple triangle and blue diamond are the location of the potential spring and current spring respectively on System 1. The green square represents the tank on System 1. A tank acts like pressure breaking device, so from this elevation of 964 is where the team got the elevation head. Using this elevation as can be seen in Figure 4.11 it's physically impossible to gravity feed the houses on system3 using the current tank configuration. However, if the tank is moved right next to the spring and the pipe rerouted as shown in Figure 4.10 above, there will be 45 feet of elevation head in which water can be gravity fed to houses on System 3. Now that the team knows it is physically possible, the headloss along the pipeline must be calculated to see if the headloss was small enough to allow for it.

From the horizontal distance data, pipe length was estimated as the sum of hypotenuses of the triangles from change in horizontal distance and elevation (data in appendix 10.2).

Pipe Length =
$$\Sigma \sqrt{(\Delta \text{Horizontal Distance})^2 + (\Delta \text{Elevation})^2}$$

From here, the team determined the length of pipe to the potential tank on System 3 to be approximately 7425 ft long.

Major System Headloss

From the length of pipe determined from the graphical analysis and the design discharge need to meet the daily demand the major headloss was calculated using the following assumptions shown in Table 4.2 below. More detailed calculations in appendix 10.4.

Table 4.2: Headloss (Darcy- Wiesbach Equation)				
Pipe Length 7425 ft				
Pipe Diameter	1.5 in			
Design Flow Rate	0.0639 ft^3/s			
Head Loss	250 ft			

For computation the team assumes f = 0.01 and ignored minor losses giving us a total headloss of about 250 feet. The team determined the available elevation head if the tank were moved to the spring box would be only 45 feet therefore a gravity fed water system connecting the homes from System 3 to System 1 is not possible.

Using a large diameter pipe would significantly reduce headloss; however, the Darcy-Weisbach equation assumes the pipe is flowing full. Due to the low flow rate of the spring, $0.0639 \frac{ft^3}{s}$, and the given slope of the pipe using a larger diameter pipe might cause the pipe to flow partially full, making the Darcy-Weisbach equation invalid and creating an open channel problem.

Water Demand Calculations

Candela has three springs available for use that were observed by the team. Two of these springs are currently used (System 1 and System 2) along with a surface water source. Table 4.3 (below) shows basic assessments of the springs. All sources need significant work to become reliable water sources, which is free of water borne contaminates and able to meet household demand year round. The recommendation section goes into further details on the design and recommendation to rehabilitate the spring boxes.

Table 4.3: Candela Springs Evaluations			
Custom 1	Spring 1	Front wall and left side collapsed in need of significant repairs	
System 1 Potential Spring		Spring box needs to be constructed	
System 2	Spring 2	Needs to be dug back into the ground and a solid cover is needed	
System 3	Open Source	Should not be used if possible	

During the site assessment the team was able to collect wet average flow rate of the springs shown in Table 4.4. The dry average flows had been collected by Laura. These flows were used to help determine if water demands can be met in both the wet and dry seasons.

	System 1		System 2	System 3	
	Spring 1	Spring 2	Spring 3	Spring 4	
Wet Season Flow Rate (L/S)	1.81	1.05	1.05	0.82	
Dry Season flow Rate (L/S)	0.25	0.1	Adequate*	0	
Total Daily Supply Wet (L)	156384	90720	90720	70848	
Total Daily Supply Wet (gal)	41317	23968	23968	18718	
Total Daily Supply Dry (L)	21600	8640	Adequate *	0	
Total Daily Supply Dry (gal)	5707	2283	Adequate *	0	

^{*}No dry season flow data was given, but community reported no dry season water shortages.

Understanding the demand on the water system in the community was quite difficult for a number of reasons. While in country, the team did in-depth water usage interviews with each of the families the team met. These interviews gathered information regarding what water was being used for, how much water was being used for what purposes, and a total daily water use estimate. Unfortunately the results from these interviews returned highly variable results, ranging anywhere from 35 to 150 gallons per day per person. This wide range of variability was supported by the day to day observations of each family's use of water. It was not uncommon for some families to leave water spigots or hoses running continuously, while other families seemed to conserve water to a much higher degree. When asked if families began conserving water during the dry season, the interviewees told us that they continued to use water in the same manner until it ran dry. At this point families would begin finding water at other sources. Due to the variability of the responses, the team decided to take the Pacific Institute recommendation of 50 liters per person per day for minimum daily water supply as the lowest allowable supply level for the recommendations. For the desired supply level the team decided to take the average of the responses to the daily water use interview and the personal observations to create a conservative estimate of actual daily use. These calculations are outlined in Table 4.5 below.

Table 4.5: Calculated System Demand					
Pacific Institute Per Person Daily Water Use					
Recommendation		L/P/D	13	G/P/D	
Average Interview Response to Personal Daily Water Use		L/P/D	36	G/P/D	
Minimum Allowable Supply - Pacific Institute Recommendations					
System 1 Current Daily Demand (50 People)	2500	L/D	662	G/D	
System 1 Expansion Daily Demand (90 People)		L/D	1192	G/D	
System 2 Daily Demand (110 People)	5500	L/D	1456	G/D	

Table 4.5: Calculated System Demand (continued)				
System 3 Daily Demand (40 People)	2000	L/D	530	G/D
Desired Supply - Based On Current Usage Rates				
System 1 Current Daily Demand (50 People)	6750	L/D	1787	G/D
System 1 Expansion Daily Demand (90 People)	12150	L/D	3217	G/D
System 2 Daily Demand (110 People)	14850	L/D	3932	G/D
System 3 Daily Demand (40 People)	5400	L/D	1430	G/D

Based on these flow rates and estimates of the demand on the system, the team found that the current spring should be able to meet the demand of the houses currently served and those houses only served on the System 3. With the total demand of those two systems being 12,150 L/D, the supply from System 1 of 21,600 L/D should be more than enough to meet the need, but the community informed us that there was not adequate supply in the dry season. It should be noted that the existing pipeline has multiple leaks and holes created for air release that would increase infiltration into the ground and depleting water supply making it to the tank. It also should also be noted that the dry season flow rate data was taken using multiple measurements, but only on one day. The true dry season flow rates could in fact be lower than the flow rates measured. Rehabilitating the pipeline may allow all of the water at the spring to effectively make it to the tank, and a second spring would not be needed. If the rehabilitated line does not increase the flow in the dry season, the other spring can be added as an additional water supply or if and when the community can afford to implement the recommended connection of System 1 to System 3. Even with a second spring adding to the system, water will not reach the tank if the rate of loss exceeds the intake rate. This should be considered a higher priority than adding the second spring, but considerations for both are included in the design.

EPANET®

The elevation data and distance between data points that were calculated in the survey analysis section were used to represent the Candela community water Systems 1 and 3 in EPANET®. This modeling software allows plotting of reservoirs, tanks, pipes, pumps, and nodes. In addition to these physical parameters, water demands at nodes (houses) were added and assigned a

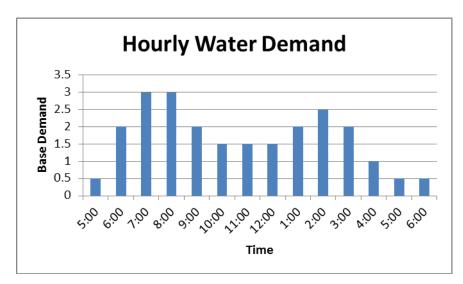


Figure 4.12 Hourly water demand

base demands of 0.25 gpm to match demand estimated in the water demand section. These demands at household vary during the day so a water demand was developed based on community interviews,

and is shown in Figure 4.12 (above). Due to the complexities of modeling all of the different time steps the peak demand of 3 times the base demand was used in EPANET® to model the low pressures in the water system. The pump curve and pump characteristics where imputed in the EPANET® model as well to accurately model the system. Figure 4.13 (below) shows the pressure output of the EPANET®. It should be noted that before tank 1, there is a negative pressure node. Since water is currently flowing to tank 1 there cannot be negative pressure before the tank. It was discovered that by adjusting the elevation at that point by 5 feet the pressure would become positive, so errors in the Abney level survey could have caused this discrepancy in pressure.

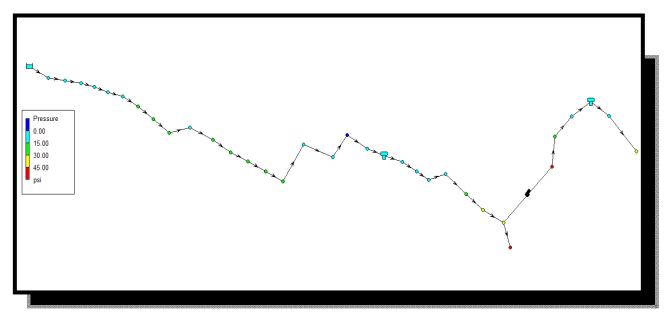


Figure 4.13 EPANET model showing from left to right: spring box 1, tank 1, pump at the end of System 1 and proposed tank for System 3.

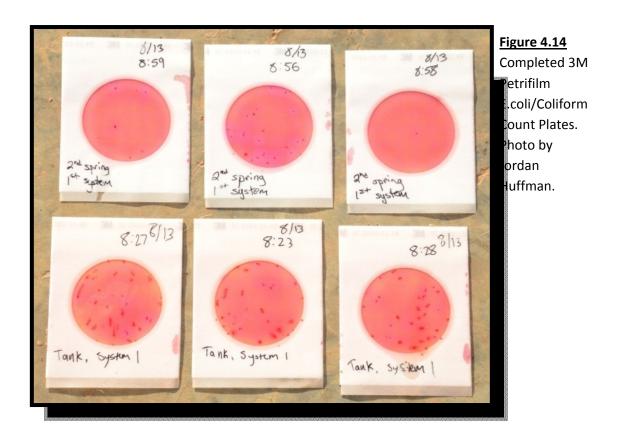
A separate model was created in EPANET® to determine if increasing the pipe diameter would allow the water to flow to houses on System 3 without a pump. It was concluded that even with a pipe sized as big as 6 inches, water was still unable to have enough pressure to get over the hill, thus requiring some means of pumping to bring water to System 3.

Water Quality Tests

The water quality test showed only coliform, and no E. coli for all samples. This does not guarantee E. coli is not present in the water, since 10 ml samples are the standard size to determine the presence of E. coli. Regardless, tests indicate the water is of relatively good quality. Three water quality samples were taken at each test site which included tank 1, System 1 spring box and potential spring, System 2, the upper and lower pools of System 3, and the spigot at the health center. A detailed report can be viewed in appendix 10.3.

Red dots on the samples signified the presence of coliform and blue dots signified the presence of E.coli. Most of the samples showed significant presence of coliform bacteria. Where the presence of E. coli would indicate a cause of great concern, the presence of coliform does not conclusively indicate

the presence of harmful pathogens. Ideally the coliform count should be less than 10 per a 100 ml sample which no tests were able to satisfy. Figure 4.14 (below) shows some of the incubated water tests.



5.0 Project Recommendations

After a thoughtful review and analysis of the current water situation in Candela and the data the team collected at the team's site, the team have developed a series of recommendations that community members could implement in an effort to improve their water access. These recommendations have been broken down into short term and long term categories, as this will allow the water quality and quantity to improve immediately as the community seeks the resources for long term upgrades. Each of the recommendations in this section includes a detailed description and cost break down of the project, step by step construction plans and timelines, and a description of why the team felt that it was important to implement each change.

5.1 Short Term Recommendations:

Burying Exposed PVC

The first of the recommendations is that the community buries the existing exposed PVC pipeline. From team observations, it appeared that most of the pipeline had at one point been buried, but over time had become exposed due to erosion. Burying the pipeline is important, as it would protect the PVC pipe from damage caused by UV rays from the sun, and also from crushing damage caused by horses, people, or falling branches. Over time, UV rays can cause PVC pipes to become brittle, and will significantly reduce the lifespan of the pipe. In a two year study performed by the Uni-Bell PVC Pipe Association, it was found that exposure to the sun's UV radiation could reduce the impact strength of a PVC pipe by over twenty percent in just two years (The Effects of Ultra Violet Radiation on PVC Pipe). This loss in impact strength is of great concern where the pipe is exposed, as this is where the pipe is most likely to be damaged in this way.

Where burying the pipeline is not a feasible option, the pipe can be covered or painted with an opaque acrylic or latex paint. Painting pipe in such a manner significantly reduces the amount of weakening due to UV damage, though not to the extent that burying would. One lower cost but more labor intensive option for covering the exposed pipe would be encasing the pipe with bamboo. This would make use of locally available materials, as the team noted several groves of bamboo and some community members using bamboo as siding for their homes. The bamboo observed also seemed to be of an appropriate size to be used for covering the 1 ½" pipe used in the pipeline, but would have to be replaced periodically as the bamboo decomposed. It should also be noted that while covering or painting the pipe would protect it from UV degradation, the pipe would still be much more vulnerable to impacts than if it was buried. As such, burying the pipe should be done in all places where possible, and covering or painting only where burying becomes infeasible, such as ravine crossings. Both of the solutions are within the abilities of the community members in Candela. These solutions would also have minimal costs associated with them, and could therefore be acted on immediately.

Reinforcing Unsupported Pipe

The second immediate recommendation would be to reinforce the pipeline where it crosses ravines and steams. Currently, much of the pipe is either insufficiently supported or unsupported as it

crosses these areas. Figure 5.1 (right) demonstrates one section of pipe that is insufficiently supported crossing a ravine. Allowing sections of pipe to cross such great spans while unsupported places a high bending stress on the pipe, leading to sagging and ultimately bending failure. This stress is of especially

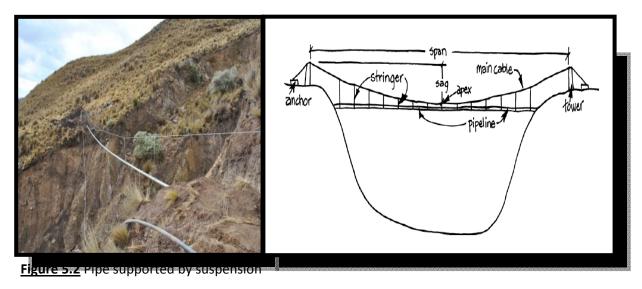


Figure 5.1
Picture of
supported PVC
pipe crossing a
ravine. Photo by
Jordan Huffman.

great concern as these pipes are often the most exposed to the sun, which will make them even less likely to be able to withstand the bending load as time progresses. Supporting these pipes could be as

simple as tying them to a stick spanning the ravine, but often times the stick will end up bending as much as the pipe. Proper support could be achieved with any method as long as the support is durable, and rigid enough to prevent bending.

Some methods of pipe support recommended for these situations include running steel cable between two trees or posts on either side of the ravine, and suspending the pipe via suspender cables every 4-6 feet connecting the pipe to the cross cable, as seen in Figure 5.2.



Where the span of unsupported area is only a short distance, four meters or less, galvanized iron pipe (GI pipe) may be employed, as seen in Figure 5.3 below. The strength of this pipe is great enough that bending stresses would not be a damaging factor, and the galvanization provides corrosion protection against the natural environment. In some cases this method may prove less expensive or more convenient than supporting the pipe with a wire cable system. For spans greater than four meters, however, wire cable suspension should be recommended.

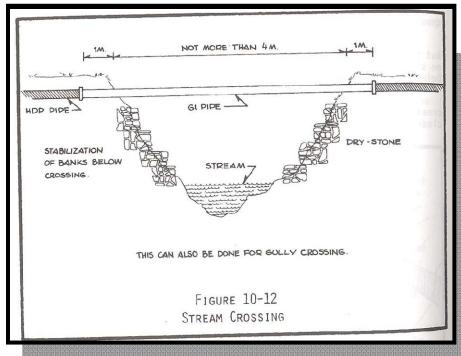


Figure 5.3 Galvanized Iron Pipe Used In Ravine Crossing (3).

Another method would be to build a rigid wood support structure underneath the pipe, offering support locations at least every six feet. This method could be completed by community members at much less cost than wire cable supports or GI pipe, as most all of the materials needed could be acquired from the surrounding forest. However, building these structures might require some construction expertise, nothing beyond what the team feel the community is capable of, but supervision

by a PCV would be recommended. These types of wood structures would also require a significantly greater amount of labor than using wire supports.

Fixing Leaking Pipe Sections and Joints

The team also noted that the existing system had many leaks from cracked pipes and broken seals. These leaks in the system caused water and pressure to be lost as water travelled between the

existing spring box, tank, and homes served by the system. Figure 21 (below) shows a joint that is dramatically bent, causing a poor seal and significant leakage in the rainy season, when water was abundant, the system seemed to have more than enough flow and pressure to keep the water storage tank full, even with the system losses due to leakage.



Figure 5.4
Leaking pipe
seal between
spring box and
water storage
tank. Photo
by Steve
Rutkowski.

However, when water is scarce during the dry season, these leaks could cause significant enough losses to prevent the system from meeting the community demand for water. It is expected that these leaking seals will continue to deteriorate over time, and should be replaced before they fail completely and cause the system to become inoperable.

In order to fix these leaking pipes, sections of pipe with cracks or holes will need to be replaced. In some cases there may be leftover pipe from the unused section of the current system that could be used for this purpose. This unused pipe could easily be reclaimed if carefully excavated from its current location. If these unused pipes are found not suitable for use as replacements for the damaged pipe, new pipe could be purchased and placed into the system in small sections where leaks are occurring. This would not require extensive amounts of pipe, as each leaking area could be replaced with only one or two feet of new pipe, but would require several pipe couplings to connect the old pipe to replacement sections. Leaking joints on the other hand may not require any replacement pipe at all, but would require new couplings and pipe sealant. It should be noted that for new pipe to be installed and joint sealants to work effectively, the system would have to be turned off and drained prior to any installation of new components.

Outlet Screens

In order to prevent large particulate from entering the system, screens should be placed over the outlet pipe in the spring boxes. These screens

SQUARE PECE
OF SCREEN
ARSH ON
REATING PLATE
HEATING PLATE AT
HOT TEMPERATURE.

Figure 5.5 Heating plate used for the connection of PVC pipe to a screen mesh (3).

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will protect the pipelines from large contaminates that might block the pipe, and also from small life forms such as crabs, frogs or snakes. A mesh of stainless steel or another corrosion resistant material can be placed on the end of the PVC pipe inside the spring box or tank. This mesh can be secured quite easily by using a plate of very hot material to press the screen onto the end of the pipe. As shown in Figure 5.5, this effectively melts the end of the pipe around the screen, securely fastening them together. Once this has been done, excess screen material can be cut away from the pipe for a smooth edge.

Boiling Water

The final short term recommendation for the Candela community would be the adoption of consistent water boiling. From the community interviews it appeared that most of the community members had heard that boiling water could be used to make it safe to drink, but few of them seemed to practice this on a day to day basis. This could be a result due to the fact that most of them only noted water related illness during the beginning of the rainy season, as contaminates that had been accumulating on the ground were suddenly introduced into the water supply with the return of heavy rains. The lack of consistent boiling could also be a result of the amount of fuel and time needed to boil the necessary amounts of water.

While the observations did not show much of an effort made to consistently boil drinking water, there was a clear interest from the community interviews in a manner of water treatment in a new system. Boiling water will ensure that it is sanitary to drink, but will require more wood to fuel fire required to boil it. In most cases this was expressed as a desire to have the ability to chlorinate the water supply system. While this is one of the team's long term recommendations, the team feels that it would be beneficial for the community to receive encouragement and education about boiling drinking water from any Peace Corps Volunteer (PCV) who might be assigned to the region.

5.2 Long Term Recommendations:

Renovation and Addition of Spring Boxes

Based upon the data analysis, the team found that it would be most advantageous to reconstruct and add new spring boxes feeding the current water system. These improvements would include the installation of improved spring boxes on the springs currently feeding System 2 and the original System 1. Sketches of proposed spring boxes and construction guides are included in

appendix10.6 and 10.8 of this document but a brief overview of the principles of spring boxes and the reasons for recommending them are included in this section.

Principles of Spring Box Construction

A spring box is basically a collection tank used to take advantage of water available at natural spring locations. These boxes need not be large in size, but must be capable of holding water to supply water in the pipeline to the tank. In some cases spring boxes are also used as storage tanks, but given the amount and irregularity of the water demand, it was easier and more efficient to construct separate tanks for the community.

For a spring box to be effective there are several things that it must be able to do. First and most importantly, it must be able to catch the flow from the spring site and force it to enter the box. In the box design this is accomplished by using two concrete collection wings that span the width of the area where water flow is present. These collection wings funnel the water to the entrance to the box, and will help prevent erosion around the sides of the tank that caused the spring box on System 1 to partially collapse. The space around this opening is normally packed with gravel to keep dirt and other materials from entering the box, while simultaneously allowing water to pass freely. Water collection is made most effective if the site of the spring is excavated completely until bedrock is reached. This allows the spring box to be built on the surface of the rock, thus preventing the flow of the spring from escaping underneath the spring box. If the flow of water is allowed to pass underneath the box it can also result in serious erosion underneath the box, as was observed at the attempted box currently in place on System 2.

The second thing a spring box must be capable of is preventing contaminates from interacting with the water. For this reason the tank itself should be solid, watertight, and not have any entrances that are openly accessibly to animals or other contaminates. In the case of the design the box itself will be a simple square concrete structure with concrete on all sides. The only direct opening to the box will be one opening on top of the box that will at most times be sealed using a concrete lid, preferably placed on top of rubber stripping. This opening, along with a clean out pipe and valve, allows for periodical cleaning of the spring box. Periodical cleaning of spring boxes in necessary to prevent excessive sedimentation within the box itself.

The third requirement of an effective spring box is that it be located at a higher elevation than the tank that it flows to, or the community that it serves. This elevation difference provides the required pressure to make flow from the spring box to the tank possible without any additional pumping equipment. Figure 5.6 shows a spring box setup similar to the type the team is proposing.

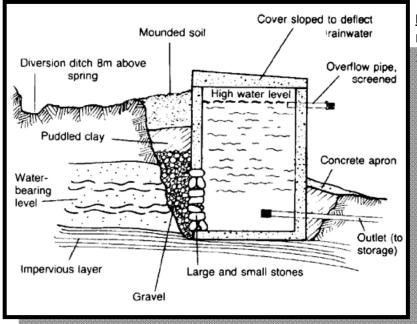


Figure 5.6 Basic Spring Box. Developed by USAID 1982 (21).

As Figure 5.6 depicts, in many cases clay is packed above the gravel near the near entrance of the box. This clay pack helps prevent surface water from gaining access to the box without first passing through enough soil to filter out contaminates. Judging from the observations about the soils present at the Candela site, clay should be readily available for this purpose. It should also be noted from the diagram that a diversion trench should be put in place uphill from the spring box. Normally several

meters up from the box, this trench helps divert surface water that might contain contaminates farther away from the box. In the next several sections further details are given about the three spring boxes the team is proposing for this project and the reasons for recommending them.

Spring Box 1: System 1 Improvement

For this spring site, an entirely new spring box is recommended. The existing spring box has collapsed, and the damage is allowing animals and other contaminates to enter the water supply. This new spring box will be dug back to the bedrock at the location of the

Side View

1.0000

1.5000

Top View

3.6667

nng box designed

"To improve the health and sanitation of the water system

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current degraded spring box, as this will allow a higher percentage of the spring flow to be captured and keep contaminates to a minimum. It would be constructed out of poured concrete with steel bar reinforcing. As mentioned above a cleanout lid that can be removed for maintenance shall be included, along with a cleanout valve to drain the box if necessary. Fencing should be installed around the spring location to prevent animal presence near the spring. Additionally, a diversion trench should be put in place several feet uphill for the spring box to ensure that surface water contaminants do not flow downhill and seep into the system and also to prevent erosion. The team feel that the reconstruction of this box will benefit the community by providing increased water supply, and also by reducing the quantity of contaminates in the water the community receives. The condition of the existing spring box is also opening the pipe system to be at risk from sedimentation and other pipe blockages. A new spring box would limit the amount of sedimentation and opportunities for materials that could clog the pipe line to enter the tank. The team estimates that this project could be feasibly completed by the community with the supervision of an onsite Peace Corps volunteer. Employing a person with construction experience might be advantageous in completing the project quickly, but would not be necessary if the project timeline was not a high priority.

Spring Box 2: System 2 Improvement

The current spring box for this system is not at all functional, requiring the installation of a completely new spring box. This spring box shall be dug back to bedrock, and constructed out of concrete and steel reinforcing mesh. It will be of the same specifications as the replacement spring for the System 1 to allow for the reuse of concrete forms. The only difference in dimensions will be that the collection wings on this spring box will cover a width of 8 feet instead of 6.5 feet, as the width of the water supply is larger in this location. At the current site water is collected from a small pool slightly downstream of the existing spring box, as erosion opened a channel for water to pass beneath the box. This collection pool is open to the air, and is easily contaminated, as it is an open source of still water. From the estimates, the team believes that approximately half of the springs flow is currently collected at this collection pool. By adding a spring box at this location, the community would be able to significantly reduce the contamination of their water supply, and also improve the amount of water collected substantially. The estimates of water usage show that when fully utilized, this spring site should provide more than enough flow than is required. As with the other spring boxes, this construction could be done using local labor under the supervision of a PCV.

New Spring Box Addition at the Potential Spring Site

Although the water supply data showed that the spring currently utilized for the System 1 should meet that system's needs, many community members had complaints about the system not meeting demand in the dry season. The many losses in the pipeline or inadequate dry season flow rates could account for this discrepancy, but in either case it would be preferable to have an additional water source. This would ensure that the system would meet demand should the dry season be extremely harsh, or if the community grew requiring additional amounts of water.

The team proposes the construction of a new spring box for this location, which could be identical in specifications to the replacement spring box proposed for the original spring site. It could also be similarly protected from contamination using fencing and a surface water diversion trench. By keeping similar specifications for both spring boxes, the concrete forms could be reused for both boxes, and the community members will gain more efficiency in the construction process when working on the second box. If the community is able to add the homes currently using the open water collection source to this system, then it will become much more important to add this spring to the system.

For detailed information on these spring boxes please refer to the technical drawings and construction guides included in appendix 10.6 and 10.8.

Construction of Water Storage Tanks

The installation of two additional water storage tanks is another recommendation to allowing the entire community adequate water access. One of these tanks would be built on System 2, and the other on top of the hill near the open source collection system.

Tank One- System 2

The team felt that it was necessary to include the addition of a water storage tank in this location because the current collection pond does not supply enough water for anything other than basic drinking needs. If this part of the community is to be able to expand their water usage to include bathing and laundry, then adding a large water storage tank will be required. This tank would be constructed to hold roughly 4500 gallons, with an inner dimension size of 10'x10'x6', with the height being six feet. The proposed tank would be constructed out of poured concrete walls, with a poured concrete base and cover as well. Reinforcing steel will be required in all of these components as there will be significant stress placed upon the walls due to the pressure from the water, along with gravity loads on the cover and base. This tank should also include a cleanout pipe and valve, along with an overflow pipe. The addition of such a tank on System 2 also will allow for a higher retention time if chlorination is to be implemented on this system, as discussed in the next section. The size of this proposed tank is rather large, and might present some challenges in construction if there is not a person with significant construction experience available to direct the process. It is likely that a PCV with adequate construction experience could provide with guidance, but a contractor or other experienced construction professional should be hired if the volunteer is not comfortable with their ability to supervise the construction of the tank.

Tank Two- System 3 Tank

This second tank is recommended for System 3 to allow water to be stored after being pumped by the solar pumping system (to be discussed shortly). Because the demand of water is irregular throughout the day, the demand can be met using a smaller pumping capacity if a tank is created that can store water while the demand is low. In the case of a solar pumping system it is necessary to store excess water for availability during the nighttime hours when the pump is not functional, or during a stretch of days with cloudy weather. The manufacturer of the pump selected for this community recommended sizing the tank to be able to serve its users for three days. Given the estimates of water usage (detailed in the data analysis section), this meant that the System 3 tank would have to be roughly

4,500 gallons to meet 3 times the daily demand. This coincidently was close enough to the size of the tank for System 2 that the team decided to make them identical in specification. Again, by making these tanks identical in specification, those building the tanks will be able to reuse the boards needed to form the concrete, and thus save a significant amount of the construction cost. As with the first tank, however, it is recommended that a person with significant construction experience oversee the project. It should also be noted that a substantial amount of time and labor will need to be spent collecting sand and gravel in order to produce the amount of concrete needed for both of these tanks.

Tank Construction General Notes

Waterproofing

As these tanks will be holding significant amounts of water for long periods of time, it would be advantageous to take steps to further waterproof the concrete walls and foundation slab. This can effectively be done by adding several thin layers of cement based plaster on the interior of each section. The cement to sand ratio in these layers should increase as each layer is added. Typically, cement to sand ratios of 1:4, 1:3, and 1:2 are effective for the first, second, and third layers, respectively.

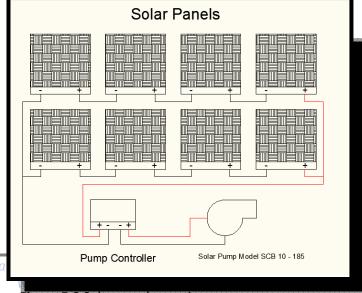
Reinforcing

While detailed reinforcing specifications are made in the construction narratives of this report, several notes are made here. First it should be noted that it is important for the reinforcing bars to tie in from the base and roof slabs into the walls of the structure. This can be achieved by bending both ends of the bars running through the walls to a right angle. Approximately one foot of steel should be bent on either end. The bent sections of these steel bars should be inserted into the foundation slab before it is poured, leaving the vertical section of the bar exposed until the walls can be poured. If bending the ends of the steel proves to be difficult or will obstruct the flow of construction, two-foot L-shaped segments can be used in the same manner and the vertical running reinforcing bars can be tied to them using wire ties.

Solar Pumping System to Supply System 3

Due to the high elevation of the 5 households that currently use System 3 (surface runoff) as their primary source of water, there proved to be an insufficient amount of head to feed water by gravity. To serve these members, some means of pumping would be required. This was an unfortunate reality, as it was clear that this would add a significant cost to the project.

In order to make a pumping system work, some form of power would



"To improve the health and so

be. Utilizing electric pumps, powered by a small array of solar panels (shown in Figure 5.8, right) seemed to be the only reasonable method of pumping for a location this isolated. This type of system would be expensive, which would make it very difficult to implement if grant funding could not be found for the project. The panel system would require periodic maintenance by someone with expertise in this area. One way to ensure that this maintenance would be using the person who maintained the solar panels powering the health clinic to also maintain the panels for this pumping system when he came into the area. Depending on who actually does this maintenance, the cost of maintenance could vary substantially. Ideally, the worker would volunteer his/her time, but would most likely have to be paid.

The pumping system that the team has designed for this project has been kept as simple as possible. Both the costs of the system, and the maintenance required have been considered in the design to keep the system operational. This system would be a basic direct solar powered pump, with the energy from the solar panels going directly to the pump without being stored in a battery. By cutting the battery out of the system, community members will not have the added costs of replacing batteries, which normally need to be replaced every few years for several hundred dollars. The downside to selecting a non-battery system is that the pump would only be operational during the daytime hours, and would have to be sized larger to supply the required amount of water in a shorter amount of time. The team found that pumps capable of delivering the amount of lift necessary to reach the homes in System 3 would already be able to provide the required volume, even when only operating for a few hours per day.

The pump selected, the SBC 10-185 Multistage Booster Pump, is capable of meeting the system demand and only costs \$833. The cost difference of this larger pump compared to a slightly smaller pump with a battery array would be easily paid back after the first set of replacement batteries had to be purchased. This pump would be wired to a pump controller, which would be connected to the solar panel array. In between the panels and the pump controller box, a grounding rod would be included to protect the pump and controller from electrical damage due to lighting and damage to the wiring.

In the solar array, seven 135 watt panels will be wired in series. The team calculated the amount of head needed to bring water to system was 101 ft., which required the team to use the 116 ft. category for selecting the amount of max panel wattage required to power the pump. This indicated that the team needed to choose panels that could provide at least 918 watts at peak performance. In the manufacturer's recommendations, this wattage was reached using eight 110-120 watt panels, but the team found the pricing of seven 135 watt panels to be somewhat cheaper. This arrangement of the seven 135 watt panels would provide peak panel wattage of 945 watts, which just more than enough to meet the 918 watt requirement. According to the manufacturer's pump specifications, this will give the pump an output of 42 liters per minute, more than enough to meet the demand on System 3. Figure 5.9 shows the manufacturer's pump specifications—Additional pump curve data in appendix 10.7.

PSI	TDH	TDH	Motor	Motor	U.S.		Motor	Peak Panel	System
	Feet	Meters	Voltage	Amps	GPM	LPM	Watts	Watts*	Efficiency
0	0	0.0	120	5.71	16.3	61.7	685	857	0%
10	23	7.0	120	5.80	15.4	58.3	696	870	10%
20	46	14.1	120	5.87	14.4	54.5	704	881	18%
30	69	21.1	120	5.99	13.4	50.7	719	899	24%
40	92	28.2	120	6.03	12.3	46.6	724	905	30%
50	116	35.2	120	6.12	11.1	42.0	734	918	33%
60	139	42.3	120	6.10	9.8	37.1	732	915	35%
70	162	49.3	120	6.02	8.4	31.8	722	903	35%
80	185	56.3	120	5.92	6.6	25.0	710	888	32%
90	208	63.4	120	5.63	4.4	16.7	676	845	26%
100	231	70.4	120	5.63	2.0	7.6	676	845	13%
110	254	77.5	120	4.58	0.0	0.0	550	687	0%

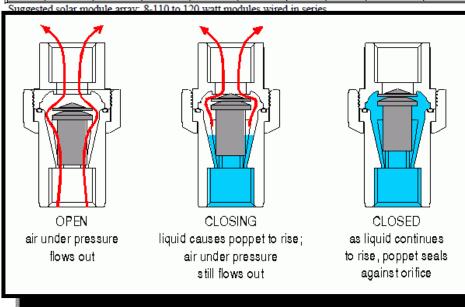


Figure 5.11 Air release alve; demonstration of how air is released (15).

Pipeline Additions Servicing System 3

In order to effectively implement the solar pumping system, or any other method of bringing water from the springs on System 1 to the community using System 3, it will be necessary to replace the former pipeline running between the two systems. The in country observations noted that the existing usable portion of the pipeline reached just beyond the health center. Beyond the health center most of the pipeline was damaged, reclaimed for use in System 2, or abandoned.

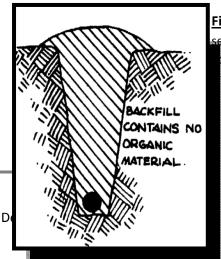


Figure 5.10 Trench section view- similar proposed pipe ench (3).

This meant that new pipe would have to be installed between that point and System 3, accounting for a distance of roughly 4,000 ft. The installation of such a pipe would be relatively simple, but quite labor intensive. It would require that a shallow trench be dug for the length of the pipeline, preferably two feet

the Candela community through sustainable stem design."

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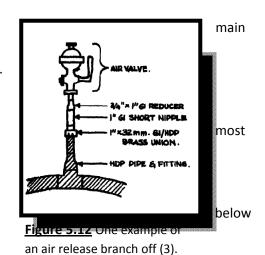
in depth. Digging and refilling this trench would account for the vast majority of the labor involved. Once this trench had been completed, or simultaneously following the trench diggers, the pipe could be laid with relative ease by someone with even a little experience working with PVC pipe. After the pipe had been installed, the trench would be backfilled to protect the pipe from the sun and impact damage. During this backfilling process care should be taken to only use inorganic fill material, as organic fill material will likely decompose and is more easily removed by environmental factors, leaving the pipe exposed (Figure 5.10, above left).

Addition of Air Release Valves along Major Pipe Segments

The only technically challenging part of this improvement would be the installation of air release valves along the length of the pipeline. The observations of the existing pipeline and interviews with community members showed that air build up within the pipe had been a problem within the system. When too much air would build up within the pipe it would become pressurized at the high points in the system until the pressure was high enough to keep additional water from passing through the line. To deal with this problem the community members had drilled periodic holes along the length of the pipe to release the air. Though these actions did somewhat relieve the issue, they also caused significant water losses throughout the system, probably contributing to the lack of water during the dryer months. These holes also offer openings in the system that could become a site of contamination in some cases.

The team recommends that these drilled sections of pipe be replaced with new pipe sections, and that air release valves be installed at the high points along the pipeline as a less problematic means of releasing built up air pressure. These air release valves operate through the use of a floating valve stop that opens when air is present, but closes again as the water level within the valve rises, as shown in Figure 5.11 (below).

These valves would be added as branches off of the pipeline, with a disconnect valve in between to allow for maintenance and replacement of the valves with relative ease. Installing these branch offs (seen in Figure 5.12, right) will require some experience with PVC pipe installation, but nothing more than a supervising Peace Corps volunteer would likely be able to offer. Based on the surveying data, the team estimates that twelve air release valves would need to be installed in order to effectively resolve the problem of air buildup. The proposed locations of these valves are shown in Figure 5.13 (below), designated as blue stars.



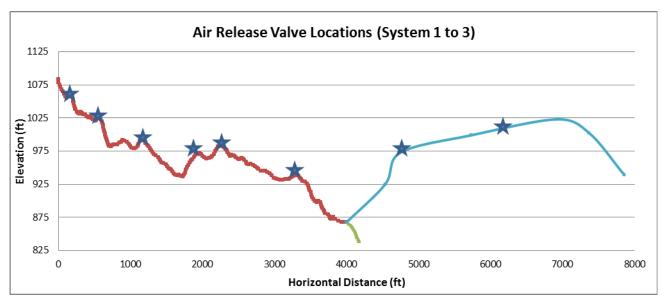


Figure 5.13 Placements of air release valves along pipeline (placement indicated by a star)

Installation of Inline Water Chlorinators

The last recommendation regarding the improvement of the current community water access is the addition of inline water chlorinators (Figure 5.14, below) immediately before the water tanks on each system. These chlorinators would supply the incoming water with low levels of chlorine to kill any unwanted bacteria before the water is used. Optimally the level of chlorine delivered would provide .3 to .5 mg/L of residual free chlorine, in order to ensure adequate chlorination without wasting chlorine (11). Placing these chlorinators before the tank will allow adequate retention time within the tank for the chlorine to take effect. The amount retention time required for effective disinfection depends on both the amount of chlorine and the amount of organic matter within the water. Since the water will be

delivered from a protected spring in this situation, the recommended chlorine levels would require roughly fifty minutes of retention time to be effective. As each of these holding tanks are designed to supply at least a full day's worth of water, it is to be expected that the water will normally be held in these tanks for at least the required fifty minutes. It is recommended that chlorine levels be tested after the instillation of these chlorinators by purchasing a commercially available chlorine level tester. The testing would likely need to be conducted by a PCV.

Inline chlorinators of this type have a chlorine tablet canister, which can be stocked with 3" calcium hypochlorite tablets. The bottom tablet within the chlorinator is exposed to the water flow, and slowly dissolves as time progresses. Many



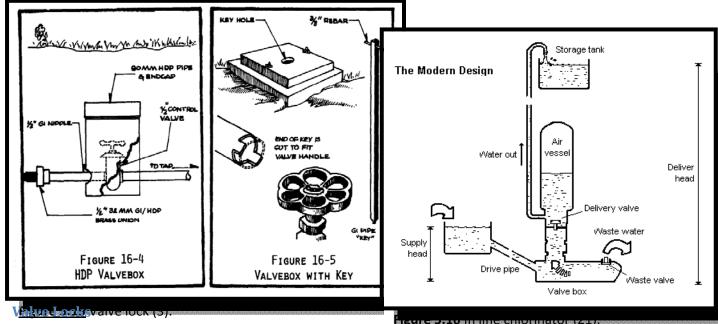
Figure 5.14 In-line chlorinator (12).

of these chlorinators, including the one recommended by the team, have dials that can be used to adjust the amount of chlorine being added to the water. Though some recommendations for the settings of this dial are included in the manufacturer's installation manual, it should be noted that this will depend on the quality of water passing through the system. As such, it is highly recommended that residual chlorine testing be done to determine what setting will provide .3-.5 mg/L of residual free chlorine at this site. This testing can be done using a color wheel residual free chlorine testing kit at a relatively low cost. With this kit, a small sample of water could be collected from the storage tank and mixed with several drops of a diethyl-p-phenylene-diamine (DPD) solution. This DPD solution will cause the mixture to turn pink in the presence of free chlorine. The intensity of the pink coloring can be measured using the provided color wheel to indicate the amount of residual chlorine in the water. Although user error and mis-calibration can cause some inconsistency in the results, multiple samples from the tank should give accurate enough results for the purposes. This type of chlorine test is available from the Hach Company at Hach.com for less than fifty dollars for a kit containing fifty tests. This company also provides test strips at a lower cost that also measure residual chlorine levels at a very reasonable price, roughly fifteen dollars for fifty test strips. Though much more affordable, these strips do not provide the level of accuracy as the color wheel tests, but would probably be sufficient in the situation.

There were several advantages to this system of inline chlorination that moved the team to select it over a different means of water disinfection for this site. First, according to the interviews, community members reported tasting chlorinated water in the past and were not opposed to the taste. This is a very important factor when designing a chlorinated system, as rejection of the treated water based on taste often results in users going to other more contaminated sources for their drinking water. Second, the Peace Corps volunteers informed us that the community members had access to free chlorine tablets from one of the governmental programs in that area. This would eliminate the primary operating cost involved in this process, making it much more economically achievable than other available methods of disinfection. Finally, as these chlorinators can be stocked with many tablets at once, they require minimal maintenance, and could probably be stocked only once a month given the flow rate in the systems.

The chlorinator selected by the team for this project is the Pure-Tech 250, though the team understand that other inline chlorinators maybe be available locally within Panama to serve that same purpose. The final selection should be made on economics and availability, though some important considerations should be made. The first of these considerations should be the expected flow rate, in this case a maximum of 45 gallons per minute, though flow restrictions due to the current size of the supply pipes in System 1 will most likely lower this value. Any chlorinator selected must be capable of providing enough chlorine that a flow rate of this size will still have adequate levels of free chlorine. The Pure-Tech 250 chlorinator that the team focused on is capable of providing 8ppm, or 8mg/liter free chlorine to water at 24 gallons a minute when set to its highest setting. The team could assume that at 45 gallons per minute the chlorine delivered would be roughly 4mg/L. This would still provide adequate levels of chlorine as the required level in this application is only .3-.5 mg/L.

The second consideration that should be made when selecting an inline chlorinator is the amount of pressure that is expected in the pipe where the chlorinator is placed. In the applications these chlorinators will be placed near the tanks, in positions with low enough pressures that this is not a concern. However, it should be noted that pressure surges due to water hammer could possibly damage the chlorinator. The chlorinator the team is recommending is recommended for use with a maximum operating pressure of under 80 psi, much higher than the pressures the team expects it to experience in use for this site.



Because the community has had issues in the past with members draining the tank by opening the clean out valve

for personal use, it is recommended that valve lock boxes be placed on the system. Lyndsey has stated that PCVs are able to make lock boxes for valves, and the material costs and quantities have been included in the final estimations.

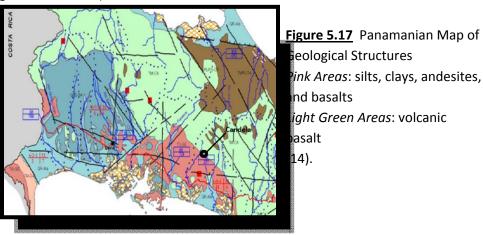
5.3 Alternative Design Considerations

To ultimately generate the most feasible and most successful design for Candela, alternatives to serve the same purpose were considered in the designs. Because, although the solar powered pump system would best ensure that the houses on System 3 receive water throughout the year, there are notable cost issues to be considered. Three alternatives to the chosen Solar Power Pumping system were a hydraulic ram pump, not using a pump at all and replacing the entire System 1 with larger diameter PVC piping, or implementing a hand dug well at System 3. The hydraulic ram pumping (Figure 5.16, below) option will require more research as this option was just stumbled upon in the Gravity-Fed Water System Handbook within the last week. The general disadvantage to this pump is that it wastes some water before pumping to the water storage tank past the actual pumping component of the ram

pump. However, for the purposes, the water would not be wasted, but added to the water storage tank existing on System 1.

The alternative of using larger diameter PVC piping throughout all of System 1 and System 3 (which will be connected to the same spring sources) was overruled. Test of 2, 4, and 6 inch PVC pipe were ran in EPANET and it was found that successful flow to System 3 was not possible. In addition, piping for 6 inch PVC was \$7,000 more than using the Solar Power Pumping system. As a disclaimer, the EPANET model does not account for leaks and water losses at joints in the system. Therefore, even if the model were to output this option this as a possibility, it is not known if this option would physically deliver water to all the homes if the leaks and joints of the PVC are not properly fixed.

The installation of a hand dug well seemed to be a less expensive more sustainable alternative for houses on System 3. This type of project, however, requires a significant amount of knowledge regarding the water table and geological structure of the area. The initial inquiries into the geological structure revealed that the site rested on the border between regions of volcanic basalts and regions where the soil consists of a mixture of silts and clay deposited by the sea with mixes of andesites and basalts (Figure 5.17, below).



While this geological data is much too general to make any clear recommendations on the feasibility of constructing a hand dug well, it does give us a rough idea about the different types of geology that could be present in the area. If the bedrock basalt was found to be present at very shallow depths, it would rule out the possibility of digging a hand dug well in this area. However, if the soil proved to consist mainly of clays or other sediments, a hand dug well might remain a cheaper alternative to the solar pump system if the soil is permeable enough to allow ground water flow. Deciding which route is most feasible will be in the hands of the local Peace Corps volunteer. They will be able to best determine if funding for the solar pump system is possible or test the depth of the water table and search for possible well sites if it is determined to be preferable.

6.0 Cost Analysis

As one of the primary concerns regarding the feasibility of this project was maintaining as low of a cost as possible, the team tried to look for ways to minimize costs on all parts of the project. This required careful estimation of the materials and labor costs associated with each part of the recommendations. This cost analysis was done using traditional quantity takeoff methods, with some special exceptions being made for this specific project situation.

6.1 Material Quantities and Costs

Determining the material quantities for this project was the first step in the development of the cost estimate. These materials included the concrete and related items for the spring box and tank construction, the components of the solar pumping system, in line chlorinators, and the materials involved in renovating and installing new pipelines.

When determining the materials required for the concrete construction items, the team assumed that the local community would be able to collect the required sand and aggregate for the project. This assumption was made with the consultation of the PCV, who told us that in past projects where the community had been responsible for sand and aggregate collection there had not been problems with the acquisition of these components. The team also assumed access to some simple tools, such as hammers, machetes, and shovels. If the PCV who would implement these designs finds a lack of these tools on site, additions to the estimated costs should be anticipated. It should also be noted that a 10% waste factor was included for the concrete quantities, but this might be lower than the actual depending on how efficient the team placing the concrete can be during construction.

In regard to some of the larger items in the recommendations, namely the solar panels and in line chlorinators, the team selected certain products that the team felt would meet the needs of this project. While attempted to find the lowest possible cost for these items, it should be noted that shipping is not included in these costs. It might be possible to buy equivalent products of a different brand locally in Panama for less than the price of the recommended products once shipping is added to their cost.

It should also be noted that while most of the prices are based on local cost data, some materials, such as certain sizes of rebar, are based on prices from other Peace Corps sites in the region. If materials are acquired primarily from David, this should not be a problem, but if acquired from San Felix, some small price discrepancies may occur. Local prices on materials are also vulnerable to sudden shifts due to demand and availability, so prices may have risen or fallen by the time the materials for this project would be purchased. To account for the possibility of such a change, the team included an inflation factor of 4% on all of the costs for each recommendation.

6.2 Labor Quantities and Costs

Calculating the costs and amount of labor required to complete each of the project recommendations was the second segment of creating the project estimate. This analysis was done in conjunction with the creation of the project schedules to develop a more accurate estimate of the

quantity of labor involved. It may be noted that the amount of billable labor days is significantly different than the total project length. This is because several of the schedule items do not require any labor for their completion. For instance, the activity of ordering materials was in most cases allotted fourteen days within the schedule, but would not account for any billable labor costs. Many of the other activities were assumed to be performed by community volunteers, which would further reduce the billable labor days in comparison to the schedule. In general, only activities requiring significant construction experience or a specific technical skill were included as labor costs for the project. These labor costs were assumed to start at seven dollars per day for a general construction laborer, and increased according to the amount of skill involved from that point. It should be noted that the labor costs associated with the installation of the solar pumping system are calculated differently, being estimated on an hourly rate of 25 dollars/hthe based on the estimated time it would take an experienced person to install each component of the system. The costs associated with bringing skilled personnel to the site would also have to be factored into this price, but the team had hoped that the person responsible for the maintenance of the current system (a government worker associated with the health service) would be able to be paid to install the system. This would allow the cost of bringing labor to the site to be disregarded, as the personnel would already be on site for scheduled system maintenance.

There of course is the possibility that more of the labor than anticipated could be performed by the community under the instruction of an experienced PCV, which would reduce the project costs for the recommendations accordingly. The productivity of the community and hired workers could vary significantly from the estimates, as the team did not have any historical productivity data for this situation. As such, considerations should be given by those implementing this design concerning the scheduling and labor estimates based on their best judgment. The team assumed that on average three to four volunteer workers would be available to work on the project, which limited the number of simultaneous activities that could occur. Should the amount of volunteer labor be much higher than this estimate, the timeline for these projects could be accelerated significantly.

6.3 Project Costs by Recommendation

Using the methods and cost analysis strategies mentioned above, the team created a cost estimate for each of the recommendations the team had for the Candela community. Because these costs have been separated by which recommendation the costs regarded, it will be easier to accurately anticipate costs if only some of the recommendations are implemented.

The implementation of only part of the recommendations could result if the community is unable to acquire adequate funding to finance the complete project. If this were to happen, even the implementation of a few of the recommendations could still benefit the community. The cost totals for each recommendation and total project costs are given here, and itemized cost data can be found in the complete estimate in appendix 10.9 of this report.

Table 6.1 -Project Costs by Recommendation										
Recommendation	Cost (\$) Quantity		Recommendation Total (\$)							
Construction of Spring Box (Each)	260	3	780							
Construction of Water Tank (Each)	1580	2	3160							
Installation of Solar Pumping System	4212	1	4212							
Installation of Waterline System One to Three	2426	1	2426							
Home Distribution Lines and Spigots	909	1	909							
Air Release Valve Additions	454	1	454							
Addition of Water Chlorinators (Each)	223	2	446							
Project Total: 12387										

7.0 Construction Scheduling

In order to aid in the efficient implementation of the design recommendations, out team broke down each recommendation and analyzed what it would take to bring it to completion. The goal of this analysis was to allow for the creation of detailed construction schedules for each recommendation. The team felt it was important to have each recommendation scheduled as a separate project because it seemed unlikely that the funding for all of the changes would be available at one time. The separate scheduling of the recommendations would let the supervising Peace Corps Volunteer have accurate scheduling information for each piece of the project if he or she decided to only undertake a few of the recommendations.

However, it should be noted that if several of the recommendations are implemented, the total project time will not be well represented by the sum of the individual recommendation schedules. This is because many of the activities in the schedule could happen simultaneously for all of the recommendations. Ordering supplies, collecting sand and gravel, and site clearing are a few of these items in particular that could easily be done for all of the recommendations simultaneously without greatly increasing the length of the activity.

It would also be possible to shorten the cumulative schedule for the recommendations by working on more than one recommendation at one time. For instance, during the time that concrete is curing for the spring boxes or water tanks, it would be possible to be making progress on the excavation

or pipe laying for the water distribution lines. All of these things should be kept in mind when considering the estimated project lengths for the recommendations outlined below. For a detailed review of the various tasks and arrangement of these tasks, please review the full schedules included in appendix 10.10 of this report.

Table 6.2 Construction Project Lengths by Recommendation								
Spring Box Construction – New and Existing	5 Weeks (x3)							
Water Pipeline Installation- System 1 to System 3 – With Home Distribution Lines	9 Weeks							
Water Tank Construction	8 Weeks (x2)							
Solar Pumping System Installation	3 Weeks							
Estimated Total Project Length – All Recommendations	6 Months							

In addition to the construction schedules, detailed construction instructions are also included in the appendices for each of the long term recommendations. These instructions are meant to supplement the construction schedules to aid in the planning of this project.

7.0 Conclusion

In closing, after a semester investigation of the water systems in the Candela community, resulting design proposed by Team Candela will cost a total of \$12,000 for all design components. The complete design recommendations consist of:

- Constructing three spring boxes (one to rehabilitate the spring box on System 1, one to enclose the potential spring source, and the last to replace the spring box on System 2)
- Constructing two water storage tanks (one for System 2, and one for System 3 to store water pumped from the solar pump)
- Replacing and burying existing pipeline as well as laying pipe from System 1 to System 3 homes
- Installation of a solar power pumping system for the homes on System 3

These design plans will reach the community and the respective PCV in the following forms:

- Steps for project completion with detailed cost estimates to complete the project in stages whenever funding is available
- Engineering drawings of spring boxes, water storage tanks and solar power pumping system layout
- Construction schedules (complete with schedule narratives) and schematics of how to build the spring boxes and tanks from the supplies and forms

The likelihood of success of this project will be greatly improved with the placement of a PC volunteer within the community. The preceding report comprises Team Candela's best recommendation for improving the existing water systems in Candela Panama. The design was formed out from considering many different alternatives to converge on the best possible option for the community to see come to fruition. The motivation for completion of this project stemmed largely from the knowledge of how motivated Candela community members are to see an improvement of their water usage. The hope is that the combination of Team Candela's best design plans put forward, an onsite PCV, and the community's interest in seeing the project succeed, will make sustainable water distribution in this community possible through the engineering design process at its center.

8.0 Acknowledgements

Team Candela's iDesign field work was successful thanks to the help and dedication of numerous individuals. Here, those people are acknowledged for their help!



Ashley Maes

Ashley Maes was just like a member of the team for the duration of the trip in Panama. She was with the team on site and offered information with her endless knowledge of the iDesign experience—and I'm sure that influence is not over yet! She was there to communicate with the Candela community members when the team was without a PCV and did so eloquently. The team has missed having her here during the fall semester! Photo by Natalie Minott.

Marco Gonzales

The Candela community members were welcoming, excited, and patient with the team and all the questions the team asked them. Perhaps the most influential community member was Marco Gonzales, pictured below. He was with team from the moment the team left the road and hiked into the mountains, and until the afternoon the team left. On the first full day, he took us around the community and showed us the entire water system, including one he built on his own to distribute water to many homes. He was there all week to help with measurements, clarify what home the team were to be eating meals at, and just to offer a hearty laugh at miscommunication and the weak Spanish abilities.



Photo by Jordan Huffman.



Lyndsey Bunting

Because Candela had no PCV on site, the team had the opportunity to work with three wonderful volunteers and hear three very different life paths and experiences in Panama. Lyndsey Bunting, shown below, worked with the community most often and actually is currently building latrines with them. As you can definitely see in the picture, she uses her boisterous laughter to lighten up any situation. She worked with the team a few days at the beginning of the week and at the end. She was constantly switching back and forth between Spanish and English and was great about conveying what speakers of each language was trying to get across. Photo by Stephanie Tulk.

Erin Kelley

Erin Kelley is a Regional Manager in the Peace Corps and helped the team translate for a day. She was able to share great stories about her time in Panama, including a recommendation for a great hike in Boquette.

Photo by Natalie Minott.



Laura Fishman

Laura Fishman also helped the team as a PCV. She came in midweek and helped show the community what the team was doing with the surveying equipment and helped in measuring flow rates. Photo by Stephanie Tulk.

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10.1 Table of Spring Flow Rates

	Average Flow Rate (L/s)						
		Wet Season	Dry Season				
World Bank	Spring 1	1.81	0.25				
Potential	Spring 2	1.05	0.10				
Marco's	Spring 3	1.05	adequate**				
Open Source	Spring 4	0.82	0				

10.2 Survey Analysis and Pipeline Elevation Profile

Abney level data included a distance from the Abney level pole to the level rod (at the same heights), as well as the vertical angle. This distance is the hypotenuse of a triangle with the adjacent leg being the horizontal distance. The horizontal distance was obtained by the following equation:

$$Horizontal\ Distance\ (Abney\ Level) = Hypotenuse * cos(angle)$$

Example:
$$13.2ft * cos(13.5^{\circ}) = 12.84ft$$

GPS data included Northing and Westing (DD.MM.mm; ie, degrees, minutes and decimal minutes) and elevation (ft) data. Taking a path of data, Northing and Westing were first converted into feet (Hypernews.org), then a change in Northing and Westing was found, and the horizontal distance was taken to be the hypotenuse of this triangle:

$$latitude \ or \ Longitude \ \times \frac{60 \ nautical \ miles}{1 \ decimal \ degree} \times \frac{6076 \ Feet}{1 \ Nautical \ Mile} = Feet$$

$$Northing(ft) = \left[(00.MMmmm*100/60^{\circ}/min) + DD.00 \right] * \left(\frac{69mi}{1} ^{\circ}N \right) * \left(\frac{5280ft}{1mi} \right)$$

$$Westing(ft) = \left[(00.MMmmm*100/60°/min) + DD.00 \right] * \left(\frac{69mi}{1} °N \right) * \left(\frac{5280ft}{1mi} \right)$$

$$\Delta Northing = N_2 - N_1$$

$$\Delta Westing = W_2 - W_1$$

$$\Delta Horizontal\ Distance = \sqrt{[(\Delta Northing)^2 + (\Delta Westing)^2]}$$

Example:

Doint #	Northing		Northing	J	A NI		Δ Horizontal
Point #	(GPS)	(GPS)	(ft)	(ft)	ΔΝ	ΔW	Distance (ft)
1	8.23627	81.53920	3058023	29837322			
2	8.23630	81.53913	3058041	29837280	18.22	-42.50	46.24

$$Northing(ft) = 08.23627(DD. MMmmm)N$$

$$= [(00.23627min * 100/60°/min) + 08.0°] * (\frac{69mi}{1}°N) * (\frac{5280ft}{1mi}) = 3,058,023ft$$

$$Westing(ft) = 81.53920(DD. MMmmm)W$$

$$= [(.53920min * 100/60°/min) + 81°] * (\frac{69mi}{1}°N) * (\frac{5280ft}{1mi}) = 29,837,322ft$$

$$\Delta Northing = 3058041ft - 3058023ft = 18.22ft$$

$$\Delta Westing = 29837322 \text{ ft} - 29837322 \text{ ft} = -42.50 \text{ ft}$$

$$\Delta Horizontal\ Distance = \sqrt{[(18.22ft)^2 + (-42.50\ \text{ft})^2]} = 46.24ft$$

10.21 Survey Calculations

Abney level data included a distance from the Abney level pole to the level rod (at the same heights), as well as the vertical angle. This distance is the hypotenuse of a triangle with the adjacent leg being the horizontal distance. The horizontal distance was obtained by the following equation:

$$Horizontal\ Distance\ (Abney\ Level) = Hypotenuse * cos(angle)$$

Example:
$$13.2ft * \cos(13.5^{\circ}) = 12.84ft$$

GPS data included Northing and Westing (DD.MM.mm; ie, degrees, minutes and decimal minutes) and elevation (ft) data. Taking a path of data, Northing and Westing were first converted into feet (Hypernews.org), then a change in Northing and Westing was found, and the horizontal distance was taken to be the hypotenuse of this triangle:

$$latitude \ or \ Longitude \ \times \frac{60 \ nautical \ miles}{1 \ decimal \ degree} \times \frac{6076 \ Feet}{1 \ Nautical \ Mile} = Feet$$

$$Northing(ft) = [(00.MMmmm * 100/60^{\circ}/min) + DD.00] * (\frac{69mi}{1}^{\circ}N) * (\frac{5280ft}{1mi})$$

$$We sting(ft) = \left[(00.MMmmm*100/60°/min) + DD.00 \right] * \left(\frac{69mi}{1} °N \right) * \left(\frac{5280ft}{1mi} \right) = \left[(00.MMmmm*100/60°/min) + DD.00 \right] * \left(\frac{69mi}{1} °N \right) * \left(\frac{5280ft}{1mi} \right) = \left[(00.MMmmm*100/60°/min) + DD.00 \right] * \left(\frac{69mi}{1} °N \right) * \left(\frac{5280ft}{1mi} \right) = \left[(00.MMmmm*100/60°/min) + DD.00 \right] * \left(\frac{69mi}{1} °N \right) * \left(\frac{5280ft}{1mi} \right) = \left[(00.MMmmm*100/60°/min) + DD.00 \right] * \left(\frac{69mi}{1} °N \right) * \left(\frac{5280ft}{1mi} \right) = \left[(00.MMmmm*100/60°/min) + DD.00 \right] * \left(\frac{69mi}{1} °N \right) * \left(\frac{5280ft}{1mi} \right) = \left[(00.MMmmm*100/60°/min) + DD.00 \right] * \left(\frac{69mi}{1} °N \right) * \left(\frac{5280ft}{1mi} \right) = \left[(00.MMmmm*100/60°/min) + DD.00 \right] * \left(\frac{69mi}{1} °N \right) * \left(\frac{5280ft}{1mi} \right) = \left[(00.MMmmm*100/60°/min) + DD.00 \right] * \left(\frac{69mi}{1} °N \right) * \left(\frac{69mi}{1} °N \right)$$

$$\Delta Northing = N_2 - N_1$$

$$\Delta Westing = W_2 - W_1$$

$$\Delta Horizontal\ Distance = \sqrt{[(\Delta Northing)^2 + (\Delta Westing)^2]}$$

Example:

Point #	Northing (GPS)	Westing (GPS)	Northing (ft)	Westing (ft)	ΔΝ	ΔW	Δ Horizontal Distance (ft)
1	8.23627	81.53920	3058023	29837322			
2	8.23630	81.53913	3058041	29837280	18.22	-42.50	46.24

$$Northing(ft) = 08.23627(DD. MMmmm)N$$

$$= [(00.23627min * 100/60°/min) + 08.0°] * (\frac{69mi}{1}°N) * (\frac{5280ft}{1mi}) = 3,058,023ft$$

$$Westing(ft) = 81.53920(\text{DD. MMmmm})W$$

$$= [(.53920min * 100/60^{\circ}/min) + 81^{\circ}] * (\frac{69mi}{1}^{\circ}N) * (\frac{5280ft}{1mi}) = 29,837,322ft$$

 $\Delta Northing = 3058041ft - 3058023ft = 18.22ft$

 $\Delta Westing = 29837322 \text{ ft} - 29837322 \text{ ft} = -42.50 \text{ ft}$

 $\Delta Horizontal\ Distance = \sqrt{[(18.22ft)^2 + (-42.50\ \text{ft})^2]} = 46.24ft$

10.22 Tables of Survey and GPS Point Data

					Г		
					Δ	11	
Doint	Northing	Mosting			Horizontal	Horizonta	Flouration
Point #	Northing (GPS)	Westing (GPS)	ΔΝ	ΔW	Distance (ft)	l Distance (ft)	Elevation (ft)
1	8.2363	81.5392	77 IA	∆ vv	(11)	0	897
2	8.2363	81.5392	18.216	-42.504	46.24	46.24	895
3	8.2364	81.5387	48.576	-285.384	289.49	335.73	913
4	8.2332	81.5376	-1912.680	-637.560	2016.14	2351.87	1010
5	8.2330	81.5373	-170.016	-037.500	276.93	2628.80	1010
6	8.2365	81.5389	2125.200	983.664	276.93	4970.61	997
7							
	8.2365	81.5404	48.576	941.160	942.41	5913.02	945
8	8.2364	81.5409	-54.648	291.456	296.53	6209.56	925
9	8.2370	81.5417	333.960	485.760	589.48	6799.04	925
10	8.2400	81.5445	1803.384	1706.232	2482.62	9281.66	909
11	8.2406	81.5448	394.680	157.872	425.08	9706.75	842
12	8.2406	81.5453	-6.072	346.104	346.16	10052.91	855
13	8.2398	81.5497	-510.048	2629.176	2678.19	12731.10	656
14	8.2387	81.5492	-625.416	-309.672	697.88	13428.98	628
15	8.2378	81.5489	-552.552	-182.160	581.80	14010.79	702
16	8.2332	81.5375	-2787.048	-6873.504	7417.05	21427.84	1036
17	8.2332	81.5376	0.000	30.360	30.36	21458.20	1040
18	8.2332	81.5376	-24.288	6.072	25.04	21483.24	1040
19	8.2333	81.5376	42.504	-12.144	44.20	21527.44	1040
20	8.2333	81.5376	0.000	6.072	6.07	21533.51	1041
21	8.2333	81.5376	-6.072	12.144	13.58	21547.09	1029
22	8.2333	81.5376	42.504	18.216	46.24	21593.33	1024
23	8.2333	81.5377	-12.144	6.072	13.58	21606.91	1025
24	8.2333	81.5377	0.000	30.360	30.36	21637.27	1017
25	8.2333	81.5378	24.288	30.360	38.88	21676.15	1034
26	8.2333	81.5378	0.000	6.072	6.07	21682.22	1036
27	8.2334	81.5378	24.288	18.216	30.36	21712.58	1032
28	8.2334	81.5378	18.216	24.288	30.36	21742.94	1032
29	8.2334	81.5379	18.216	12.144	21.89	21764.83	1029
30	8.2335	81.5379	18.216	12.144	21.89	21786.73	1024
31	8.2335	81.5379	0.000	12.144	12.14	21798.87	1026
32	8.2335	81.5380	12.144	42.504	44.20	21843.08	1021
33	8.2335	81.5380	18.216	6.072	19.20	21862.28	1024
34	8.2336	81.5380	24.288	18.216	30.36	21892.64	1021
35	8.2336	81.5380	18.216	12.144	21.89	21914.53	1014
36	8.2336	81.5380	12.144	6.072	13.58	21928.11	1008

37	8.2336	81.5380	0.000	0.000	0.00	21928.11	1006
38	8.2336	81.5380	6.072	-6.072	8.59	21936.70	1001
39	8.2336	81.5380	0.000	0.000	0.00	21936.70	996
40	8.2337	81.5380	18.216	0.000	18.22	21954.91	995
41	8.2337	81.5380	12.144	0.000	12.14	21967.06	989
42	8.2337	81.5380	6.072	0.000	6.07	21973.13	986
43	8.2337	81.5380	0.000	0.000	0.00	21973.13	984
44	8.2337	81.5380	12.144	-6.072	13.58	21986.70	980
45	8.2337	81.5380	12.144	0.000	12.14	21998.85	979
46	8.2337	81.5380	0.000	0.000	0.00	21998.85	976
47	8.2337	81.5380	0.000	0.000	0.00	21998.85	974
48	8.2337	81.5380	6.072	-12.144	13.58	22012.43	970
49	8.2337	81.5380	6.072	0.000	6.07	22018.50	969
50	8.2338	81.5380	24.288	-6.072	25.04	22043.53	969
51	8.2338	81.5380	36.432	-6.072	36.93	22080.47	974
52	8.2339	81.5380	18.216	-6.072	19.20	22099.67	975
53	8.2339	81.5380	6.072	-6.072	8.59	22108.26	977
54	8.2339	81.5379	18.216	-24.288	30.36	22138.62	979
55	8.2339	81.5379	18.216	-36.432	40.73	22179.35	981
56	8.2340	81.5378	12.144	-6.072	13.58	22192.93	982
57	8.2340	81.5378	36.432	-24.288	43.79	22236.71	984
58	8.2341	81.5378	24.288	12.144	27.15	22263.87	984
59	8.2342	81.5379	72.864	36.432	81.46	22345.33	983
60	8.2342	81.5379	12.144	0.000	12.14	22357.48	976
61	8.2343	81.5379	30.360	18.216	35.41	22392.88	977
62	8.2343	81.5380	0.000	30.360	30.36	22423.24	978
63	8.2343	81.5380	0.000	12.144	12.14	22435.38	980
64	8.2343	81.5380	0.000	18.216	18.22	22453.60	984
65	8.2343	81.5380	12.144	18.216	21.89	22475.49	988
66	8.2343	81.5380	-6.072	0.000	6.07	22481.57	988
67	8.2343	81.5381	24.288	18.216	30.36	22511.93	988
68	8.2344	81.5381	36.432	12.144	38.40	22550.33	988
69	8.2344	81.5381	18.216	12.144	21.89	22572.22	986
70	8.2344	81.5381	6.072	6.072	8.59	22580.81	986
71	8.2344	81.5382	12.144	24.288	27.15	22607.96	984
72	8.2344	81.5382	0.000	-6.072	6.07	22614.04	984
73	8.2344	81.5382	6.072	54.648	54.98	22669.02	984
74	8.2345	81.5383	24.288	24.288	34.35	22703.37	980
75	8.2345	81.5383	18.216	-6.072	19.20	22722.57	978
76	8.2345	81.5383	18.216	6.072	19.20	22741.77	978
77	8.2346	81.5383	30.360	12.144	32.70	22774.47	977
78	8.2346	81.5383	12.144	12.144	17.17	22791.64	973
79	8.2346	81.5383	6.072	0.000	6.07	22797.72	969

80	8.2347	81.5384	24.288	30.360	38.88	22836.60	966
81	8.2347	81.5384	18.216	-6.072	19.20	22855.80	964
82	8.2347	81.5384	30.360	30.360	42.94	22898.73	961
83	8.2347	81.5384	0.000	0.000	0.00	22898.73	959
84	8.2348	81.5384	24.288	0.000	24.29	22923.02	956
85	8.2348	81.5385	30.360	24.288	38.88	22961.90	957
86	8.2348	81.5385	6.072	0.000	6.07	22967.97	958
87	8.2348	81.5385	0.000	6.072	6.07	22974.04	958
88	8.2349	81.5385	18.216	24.288	30.36	23004.40	958
89	8.2349	81.5385	18.216	-12.144	21.89	23026.30	958
90	8.2350	81.5385	42.504	6.072	42.94	23069.23	957
91	8.2350	81.5385	30.360	-6.072	30.96	23100.19	947
92	8.2350	81.5384	12.144	-42.504	44.20	23144.40	945
93	8.2351	81.5384	42.504	12.144	44.20	23188.60	950
94	8.2351	81.5384	6.072	-18.216	19.20	23207.80	958
95	8.2351	81.5385	18.216	36.432	40.73	23248.54	962
96	8.2351	81.5384	0.000	-12.144	12.14	23260.68	966
97	8.2352	81.5385	30.360	36.432	47.42	23308.10	972
98	8.2352	81.5385	18.216	6.072	19.20	23327.31	975
99	8.2353	81.5385	18.216	0.000	18.22	23345.52	980
100	8.2353	81.5385	12.144	0.000	12.14	23357.67	983
101	8.2353	81.5385	24.288	6.072	25.04	23382.70	988
102	8.2353	81.5385	12.144	-6.072	13.58	23396.28	992
103	8.2354	81.5385	60.720	-6.072	61.02	23457.30	997
104	8.2354	81.5385	0.000	0.000	0.00	23457.30	997
105	8.2354	81.5385	0.000	6.072	6.07	23463.37	995
106	8.2355	81.5385	30.360	-6.072	30.96	23494.33	995
107	8.2355	81.5385	24.288	-6.072	25.04	23519.37	990
108	8.2356	81.5385	24.288	18.216	30.36	23549.73	989
109	8.2356	81.5386	30.360	24.288	38.88	23588.61	988
110	8.2357	81.5386	24.288	6.072	25.04	23613.65	988
111	8.2357	81.5386	0.000	6.072	6.07	23619.72	992
112	8.2357	81.5387	12.144	54.648	55.98	23675.70	995
113	8.2358	81.5387	54.648	-12.144	55.98	23731.68	1001
114	8.2358	81.5387	24.288	6.072	25.04	23756.72	1004
115	8.2358	81.5386	6.072	-18.216	19.20	23775.92	1010
116	8.2359	81.5387	24.288	30.360	38.88	23814.80	1014
117	8.2359	81.5387	24.288	0.000	24.29	23839.08	1018
118	8.2359	81.5387	24.288	-6.072	25.04	23864.12	1018
119	8.2360	81.5387	42.504	0.000	42.50	23906.62	1015
120	8.2360	81.5387	18.216	6.072	19.20	23925.83	1014
121	8.2361	81.5387	36.432	6.072	36.93	23962.76	1012
122	8.2361	81.5387	0.000	0.000	0.00	23962.76	1010

123	8.2361	81.5387	12.144	-12.144	17.17	23979.93	1008
124	8.2361	81.5386	12.144	-18.216	21.89	24001.83	1007
125	8.2362	81.5387	18.216	18.216	25.76	24027.59	1007
126	8.2362	81.5387	12.144	-6.072	13.58	24041.17	1010
127	8.2362	81.5387	36.432	-6.072	36.93	24078.10	1007
128	8.2363	81.5387	12.144	24.288	27.15	24105.26	1008
129	8.2363	81.5387	12.144	0.000	12.14	24117.40	1007
130	8.2363	81.5387	12.144	0.000	12.14	24129.54	1003
131	8.2364	81.5387	36.432	-6.072	36.93	24166.48	1007
132	8.2364	81.5387	12.144	-6.072	13.58	24180.05	1008
133	8.2364	81.5387	6.072	24.288	25.04	24205.09	1016
134	8.2364	81.5387	6.072	-6.072	8.59	24213.68	1014
135	8.2364	81.5387	6.072	12.144	13.58	24227.25	1010
136	8.2364	81.5388	18.216	24.288	30.36	24257.61	1007
137	8.2364	81.5388	0.000	6.072	6.07	24263.69	1007
138	8.2364	81.5389	-36.432	48.576	60.72	24324.41	1009
139	8.2364	81.5389	12.144	42.504	44.20	24368.61	1009
140	8.2364	81.5390	-24.288	18.216	30.36	24398.97	1007
141	8.2364	81.5390	-6.072	30.360	30.96	24429.93	1007
142	8.2363	81.5391	-30.360	54.648	62.52	24492.45	999
143	8.2363	81.5391	0.000	-6.072	6.07	24498.52	1001
144	8.2363	81.5391	-6.072	30.360	30.96	24529.48	1000
145	8.2362	81.5393	-42.504	85.008	95.04	24624.52	998
146	8.2362	81.5393	-36.432	30.360	47.42	24671.95	995
147	8.2362	81.5394	0.000	36.432	36.43	24708.38	992
148	8.2361	81.5394	-18.216	12.144	21.89	24730.27	993
149	8.2361	81.5394	0.000	18.216	18.22	24748.49	992
150	8.2361	81.5395	6.072	42.504	42.94	24791.42	991
151	8.2362	81.5395	6.072	24.288	25.04	24816.46	992
152	8.2362	81.5396	6.072	18.216	19.20	24835.66	992
153	8.2362	81.5396	0.000	12.144	12.14	24847.80	992
154	8.2371	81.5420	564.696	1487.640	1591.21	26439.02	973
155	8.2377	81.5436	340.032	916.872	977.89	27416.91	999
156	8.2392	81.5447	953.304	722.568	1196.20	28613.11	1023
157	8.2397	81.5453	273.240	352.176	445.74	29058.85	1002
158	8.2399	81.5446	151.800	-461.472	485.80	29544.65	939
159	8.2405	81.5454	358.248	485.760	603.58	30148.23	871
160	8.2397	81.5453	-485.760	-24.288	486.37	30634.59	966
161	8.2401	81.5449	261.096	-242.880	356.60	30991.19	895
162	8.2362	81.5396	-2398.440	-3206.016	4003.88	34995.07	961
163	8.2362	81.5396	0.000	0.000	0.00	34995.07	962
164	8.2362	81.5397	12.144	6.072	13.58	35008.65	960
165	8.2362	81.5397	-6.072	36.432	36.93	35045.58	960

166	8.2362	81.5397	12.144	12.144	17.17	35062.76	962
167	8.2362	81.5398	12.144	12.144	17.17	35079.93	965
168	8.2363	81.5398	6.072	54.648	54.98	35134.92	967
169	8.2363	81.5399	6.072	12.144	13.58	35134.32	966
170	8.2362	81.5399	-18.216	30.360	35.41	35148.45	964
171	8.2362	81.5399	0.000	18.216	18.22	35202.12	963
172	8.2362	81.5400	6.072	24.288	25.04	35202.12	960
173	8.2362	81.5400	-6.072	18.216	19.20	35246.35	962
174	8.2363	81.5401	12.144	30.360	32.70	35279.05	959
175	8.2363	81.5401	6.072	12.144	13.58	35292.63	958
176	8.2363	81.5401	18.216	18.216	25.76	35318.39	958
177	8.2363	81.5401	6.072	6.072	8.59	35316.33	955
178	8.2363	81.5402	18.216	24.288	30.36	35357.34	954
179	8.2363	81.5402	6.072	12.144	13.58	35377.34	948
180	8.2363	81.5402	0.000	0.000	0.00	35370.91	948
181	8.2364	81.5402	24.288	18.216	30.36	35401.27	947
182	8.2364	81.5402	0.000	18.216	18.22	35419.49	945
183	8.2364	81.5403	0.000	6.072	6.07	35425.56	943
	8.2364	81.5403				35439.14	
184 185		81.5403	-6.072 24.288	12.144	13.58 30.36	35469.50	946 950
	8.2364	81.5403		18.216	8.59		
186	8.2364		-6.072	6.072		35478.09	951
187	8.2365	81.5404	30.360	36.432	47.42	35525.51	947
188 189	8.2365	81.5404 81.5404	6.072 0.000	6.072	8.59	35534.10 35534.10	939 936
	8.2365			0.000	0.00		
190	8.2365	81.5404	6.072	6.072	8.59	35542.68	929
191	8.2365	81.5404	6.072	18.216	19.20	35561.89	930
192	8.2365	81.5404	0.000	0.000	0.00	35561.89	923
193	8.2365	81.5405	18.216	24.288	30.36	35592.25	921
194	8.2365	81.5405	6.072	12.144	13.58	35605.82	920
195	8.2365	81.5405	6.072	12.144	13.58	35619.40	920
196	8.2366	81.5405	18.216	12.144	21.89	35641.29	917
197	8.2366	81.5405	12.144	0.000	12.14	35653.44	913
198	8.2366	81.5406	18.216	36.432	40.73	35694.17	921
199	8.2366	81.5407	12.144	42.504	44.20	35738.37	923
200	8.2367	81.5407	12.144	36.432	38.40	35776.78	923
201	8.2367	81.5408	42.504	36.432	55.98	35832.76	922
202	8.2367	81.5408	12.144	30.360	32.70	35865.46	921
203	8.2368	81.5408	12.144	12.144	17.17	35882.63	927
204	8.2367	81.5409	-42.504	12.144	44.20	35926.84	926
205	8.2366	81.5409	-48.576	0.000	48.58	35975.41	927
206	8.2366	81.5409	0.000	6.072	6.07	35981.48	926
207	8.2366	81.5409	-36.432	-12.144	38.40	36019.89	924
208	8.2365	81.5409	-6.072	0.000	6.07	36025.96	922

209 8.2365 81.5408 -18.216 -6.072 19.20 36045.16 91 210 8.2365 81.5409 -12.144 18.216 21.89 36067.05 91 211 8.2365 81.5409 0.000 0.000 0.00 36067.05 91 212 8.2365 81.5409 -18.216 6.072 19.20 36086.25 90 213 8.2364 81.5409 -12.144 12.144 17.17 36103.43 90 214 8.2364 81.5409 -12.144 0.000 12.14 36115.57 90 215 8.2352 81.5390 -765.072 -1147.608 1379.25 37494.83 95 216 8.2332 81.5375 -1184.040 -904.728 1490.13 38984.95 106 217 8.2332 81.5375 -12.144 12.144 17.17 39002.13 106 218 8.2332 81.5375 -12.144 12.144 17.17 39027.89 </th
211 8.2365 81.5409 0.000 0.000 0.00 36067.05 91 212 8.2365 81.5409 -18.216 6.072 19.20 36086.25 90 213 8.2364 81.5409 -12.144 12.144 17.17 36103.43 90 214 8.2364 81.5409 -12.144 0.000 12.14 36115.57 90 215 8.2352 81.5390 -765.072 -1147.608 1379.25 37494.83 99 216 8.2332 81.5375 -1184.040 -904.728 1490.13 38984.95 106 217 8.2332 81.5375 -12.144 12.144 17.17 39002.13 106 218 8.2332 81.5375 18.216 -18.216 25.76 39027.89 106 219 8.2332 81.5375 -12.144 -6.072 13.58 39041.47 103 220 8.2332 81.5375 -42.504 6.072 42.94 39106.30<
212 8.2365 81.5409 -18.216 6.072 19.20 36086.25 90 213 8.2364 81.5409 -12.144 12.144 17.17 36103.43 90 214 8.2364 81.5409 -12.144 0.000 12.14 36115.57 90 215 8.2352 81.5390 -765.072 -1147.608 1379.25 37494.83 92 216 8.2332 81.5375 -1184.040 -904.728 1490.13 38984.95 106 217 8.2332 81.5375 -12.144 12.144 17.17 39002.13 106 218 8.2332 81.5375 18.216 -18.216 25.76 39027.89 106 219 8.2332 81.5375 -12.144 -6.072 13.58 39041.47 103 220 8.2332 81.5375 -18.216 12.144 21.89 39063.36 104 221 8.2331 81.5375 -42.504 6.072 42.94 39106.30 104 222 8.2332 81.5374 30.360 -66.
213 8.2364 81.5409 -12.144 12.144 17.17 36103.43 90 214 8.2364 81.5409 -12.144 0.000 12.14 36115.57 90 215 8.2352 81.5390 -765.072 -1147.608 1379.25 37494.83 99 216 8.2332 81.5375 -1184.040 -904.728 1490.13 38984.95 106 217 8.2332 81.5375 -12.144 12.144 17.17 39002.13 106 218 8.2332 81.5375 18.216 -18.216 25.76 39027.89 106 219 8.2332 81.5375 -12.144 -6.072 13.58 39041.47 103 220 8.2332 81.5375 -18.216 12.144 21.89 39063.36 104 221 8.2331 81.5375 -42.504 6.072 42.94 39106.30 104 222 8.2332 81.5374 30.360 -66.792 73.37 39
214 8.2364 81.5409 -12.144 0.000 12.14 36115.57 90 215 8.2352 81.5390 -765.072 -1147.608 1379.25 37494.83 99 216 8.2332 81.5375 -1184.040 -904.728 1490.13 38984.95 106 217 8.2332 81.5375 -12.144 12.144 17.17 39002.13 106 218 8.2332 81.5375 18.216 -18.216 25.76 39027.89 106 219 8.2332 81.5375 -12.144 -6.072 13.58 39041.47 103 220 8.2332 81.5375 -18.216 12.144 21.89 39063.36 104 221 8.2331 81.5375 -42.504 6.072 42.94 39106.30 104 222 8.2332 81.5374 30.360 -66.792 73.37 39179.66 104 223 8.2331 81.5374 -48.576 12.144 50.07 3
215 8.2352 81.5390 -765.072 -1147.608 1379.25 37494.83 95 216 8.2332 81.5375 -1184.040 -904.728 1490.13 38984.95 106 217 8.2332 81.5375 -12.144 12.144 17.17 39002.13 106 218 8.2332 81.5375 18.216 -18.216 25.76 39027.89 106 219 8.2332 81.5375 -12.144 -6.072 13.58 39041.47 103 220 8.2332 81.5375 -18.216 12.144 21.89 39063.36 104 221 8.2331 81.5375 -42.504 6.072 42.94 39106.30 104 222 8.2332 81.5374 30.360 -66.792 73.37 39179.66 104 223 8.2331 81.5374 -48.576 12.144 50.07 39229.74 104 224 8.2331 81.5374 30.360 -18.216 35.41 39265.14 104
216 8.2332 81.5375 -1184.040 -904.728 1490.13 38984.95 106 217 8.2332 81.5375 -12.144 12.144 17.17 39002.13 106 218 8.2332 81.5375 18.216 -18.216 25.76 39027.89 106 219 8.2332 81.5375 -12.144 -6.072 13.58 39041.47 103 220 8.2332 81.5375 -18.216 12.144 21.89 39063.36 104 221 8.2331 81.5375 -42.504 6.072 42.94 39106.30 104 222 8.2332 81.5374 30.360 -66.792 73.37 39179.66 104 223 8.2331 81.5374 -48.576 12.144 50.07 39229.74 104 224 8.2331 81.5374 30.360 -18.216 35.41 39265.14 104
217 8.2332 81.5375 -12.144 12.144 17.17 39002.13 106 218 8.2332 81.5375 18.216 -18.216 25.76 39027.89 106 219 8.2332 81.5375 -12.144 -6.072 13.58 39041.47 103 220 8.2332 81.5375 -18.216 12.144 21.89 39063.36 104 221 8.2331 81.5375 -42.504 6.072 42.94 39106.30 104 222 8.2332 81.5374 30.360 -66.792 73.37 39179.66 104 223 8.2331 81.5374 -48.576 12.144 50.07 39229.74 104 224 8.2331 81.5374 30.360 -18.216 35.41 39265.14 104
218 8.2332 81.5375 18.216 -18.216 25.76 39027.89 106 219 8.2332 81.5375 -12.144 -6.072 13.58 39041.47 103 220 8.2332 81.5375 -18.216 12.144 21.89 39063.36 104 221 8.2331 81.5375 -42.504 6.072 42.94 39106.30 104 222 8.2332 81.5374 30.360 -66.792 73.37 39179.66 104 223 8.2331 81.5374 -48.576 12.144 50.07 39229.74 104 224 8.2331 81.5374 30.360 -18.216 35.41 39265.14 104
219 8.2332 81.5375 -12.144 -6.072 13.58 39041.47 103 220 8.2332 81.5375 -18.216 12.144 21.89 39063.36 104 221 8.2331 81.5375 -42.504 6.072 42.94 39106.30 104 222 8.2332 81.5374 30.360 -66.792 73.37 39179.66 104 223 8.2331 81.5374 -48.576 12.144 50.07 39229.74 104 224 8.2331 81.5374 30.360 -18.216 35.41 39265.14 104
220 8.2332 81.5375 -18.216 12.144 21.89 39063.36 104 221 8.2331 81.5375 -42.504 6.072 42.94 39106.30 104 222 8.2332 81.5374 30.360 -66.792 73.37 39179.66 104 223 8.2331 81.5374 -48.576 12.144 50.07 39229.74 104 224 8.2331 81.5374 30.360 -18.216 35.41 39265.14 104
221 8.2331 81.5375 -42.504 6.072 42.94 39106.30 104 222 8.2332 81.5374 30.360 -66.792 73.37 39179.66 104 223 8.2331 81.5374 -48.576 12.144 50.07 39229.74 104 224 8.2331 81.5374 30.360 -18.216 35.41 39265.14 104
222 8.2332 81.5374 30.360 -66.792 73.37 39179.66 104 223 8.2331 81.5374 -48.576 12.144 50.07 39229.74 104 224 8.2331 81.5374 30.360 -18.216 35.41 39265.14 104
223 8.2331 81.5374 -48.576 12.144 50.07 39229.74 104 224 8.2331 81.5374 30.360 -18.216 35.41 39265.14 104
224 8.2331 81.5374 30.360 -18.216 35.41 39265.14 104
225 9 2234 94 5274 12 444 6 072 12 59 20279 72 10/
225 8.2331 81.5374 -12.144 -6.072 13.58 39278.72 104
226 8.2331 81.5374 0.000 -24.288 24.29 39303.01 104
227 8.2331 81.5373 -18.216 -30.360 35.41 39338.41 105
228 8.2331 81.5373 6.072 -30.360 30.96 39369.37 105
229 8.2330 81.5373 -72.864 36.432 81.46 39450.84 105
230 8.2331 81.5373 66.792 -18.216 69.23 39520.07 106
231 8.2330 81.5373 -54.648 24.288 59.80 39579.87 106
232 8.2330 81.5373 -12.144 -24.288 27.15 39607.03 107

From this data, pipe length was estimated as the sum of hypotenuses of the triangles from change in horizontal distance and elevation

Pipe Length =
$$\Sigma \sqrt{(\Delta \text{Horizontal Distance})^2 + (\Delta \text{Elevation})^2}$$

			Spring			
	Horizontal	Δ	Elevation		Length	
Points	Distance	Distance	at 1040	del(elev)	of Pipe	Notes:
209	0.0		1083.0		0	spring box to potential spring
208	8.1	8.07	1078.5	9.24	9.24	
207	18.9	10.81	1075.1	11.34	20.58	

206	32.4	13.52	1071.4	14.01	34.59	
205	45.2	12.84	1067.9	13.30	47.89	
204	64.8	19.60	1064.8	19.85	67.74	
203	84.4	19.53	1061.4	19.82	87.56	
202	102.0	17.63	1057.8	18.00	105.57	
201	116.3	14.29	1055.3	14.51	120.08	
200	123.9	7.57	1057.1	7.79	127.86	
199	136.8	12.93	1058.8	13.05	140.91	
198	162.1	25.31	1057.4	25.35	166.26	
197	186.2	24.09	1057.4	24.09	190.35	
196	199.3	13.07	1056.8	13.09	203.43	
195	205.9	6.65	1053.3	7.52	210.95	
194	211.4	5.49	1050.0	6.38	217.33	
193	219.0	7.61	1046.3	8.49	225.82	
192	224.7	5.74	1042.7	6.76	232.58	
191	235.9	11.17	1039.3	11.68	244.26	
1	235.9	0.00	1040.0	0.75	245.01	From the first Spring Box
2	247.6	11.72	1037.5	11.98	256.99	
3	265.1	17.50	1034.3	17.79	274.78	
4	279.6	14.51	1032.5	14.62	289.41	
5	299.2	19.55	1031.0	19.61	309.02	
6	314.2	14.97	1034.4	15.35	324.37	
7	330.5	16.35	1031.8	16.55	340.92	
8	352.4	21.92	1030.5	21.96	362.87	
9	376.3	23.84	1029.7	23.85	386.72	none?
10	397.8	21.58	1027.6	21.68	408.40	
11	424.3	26.42	1025.5	26.51	434.91	
12	450.2	25.90	1027.5	25.98	460.89	
13	468.9	18.77	1024.5	19.00	479.89	
14	487.1	18.16	1022.5	18.27	498.17	
15	507.5	20.42	1020.9	20.49	518.66	
16	528.5	20.97	1021.9	21.00	539.65	none
17	550.4	21.96	1024.5	22.11	561.76	
18	575.4	25.00	1024.5	25.00	586.76	
19	592.8	17.30	1022.5	17.41	604.17	
20	605.0	12.24	1019.5	12.62	616.79	
21	613.8	8.83	1016.4	9.36	626.15	
22	622.3	8.51	1013.5	8.97	635.12	
23	628.8	6.50	1010.4	7.23	642.34	
24	637.2	8.34	1007.1	8.96	651.30	
25	642.7	5.54	1004.0	6.34	657.64	
26	649.6	6.84	1001.1	7.43	665.07	
27	657.0	7.42	998.8	7.78	672.85	

28	666.1	9.08	996.2	9.44	682.29	
29	673.6	7.51	993.3	8.06	690.35	
30	681.1	7.54	990.5	8.03	698.38	
31	688.2	7.11	987.6	7.69	706.06	
32	697.3	9.13	984.7	9.58	715.65	
33	710.1	12.70	982.6	12.87	728.52	
34	730.7	20.66	981.4	20.70	749.22	
35	752.1	21.38	983.5	21.49	770.71	
36	771.9	19.84	985.0	19.90	790.61	Broken Pipe (pic 341 nat)
37	793.4	21.47	984.7	21.47	812.08	
38	818.4	25.00	985.1	25.00	837.08	
39	848.9	30.51	987.5	30.60	867.68	
40	875.6	26.66	989.0	26.70	894.38	
41	896.7	21.13	991.2	21.25	915.64	out on path
42	923.4	26.69	990.2	26.71	942.35	
43	956.6	33.25	988.8	33.28	975.63	
44	980.3	23.70	985.9	23.87	999.50	
45	998.1	17.73	982.6	18.02	1017.53	
46	1019.1	21.04	979.5	21.27	1038.80	
47	1050.7	31.58	978.5	31.59	1070.39	
48	1082.2	31.49	979.5	31.51	1101.90	60's best range of error +-9 ft
49	1103.4	21.22	982.3	21.39	1123.29	
50	1118.9	15.49	986.0	15.92	1139.21	
51	1137.8	18.88	990.0	19.31	1158.53	
52	1168.7	30.94	991.9	31.00	1189.53	
53	1192.2	23.47	990.0	23.54	1213.07	
54	1217.0	24.86	986.8	25.07	1238.13	
55	1238.9	21.88	984.0	22.06	1260.19	
56	1257.9	18.94	981.7	19.08	1279.27	
57	1278.1	20.27	979.0	20.46	1299.73	
58	1294.9	16.79	975.7	17.10	1316.83	
59	1311.2	16.32	973.5	16.47	1333.30	pipe supported here with
60	1331.2	20.00	970.6	20.20	1353.50	a log about 12 ft
61	1359.3	28.09	968.4	28.18	1381.69	
62	1393.7	34.37	965.7	34.47	1416.16	
63	1407.3	13.60	962.9	13.89	1430.05	
64	1419.8	12.47	960.1	12.77	1442.82	
65	1435.6	15.83	957.3	16.08	1458.90	
66	1466.7	31.08	956.4	31.09	1489.99	
67	1500.3	33.58	955.0	33.61	1523.60	
68	1518.2	17.98	952.1	18.21	1541.81	
69	1533.3	15.07	949.4	15.32	1557.13	
70	1552.9	19.63	947.8	19.69	1576.82	

71	1573.8	20.87	946.7	20.90	1597.72	
72	1589.5	15.75	944.4	15.92	1613.63	
73	1603.8	14.25	941.3	14.58	1628.22	
74	1624.9	21.06	939.0	21.19	1649.41	
75	1652.5	27.66	937.8	27.69	1677.10	
76	1676.7	24.14	939.5	24.20	1701.30	
77	1705.5	28.83	937.7	28.88	1730.18	Missed Point some where
78	1731.8	26.35	935.9	26.42	1756.60	
79	1747.1	15.26	938.9	15.55	1772.15	
80	1764.3	17.15	942.5	17.54	1789.68	
81	1778.3	14.08	946.6	14.66	1804.34	
82	1790.9	12.58	950.8	13.25	1817.59	
83	1806.8	15.85	954.0	16.16	1833.75	
84	1830.8	24.09	957.2	24.31	1858.06	
85	1848.3	17.50	960.2	17.76	1875.81	
86	1864.1	15.75	962.1	15.86	1891.68	
87	1886.9	22.77	966.0	23.11	1914.78	
88	1905.5	18.64	969.1	18.89	1933.68	
89	1932.3	26.83	971.0	26.90	1960.58	
90	1960.5	28.16	972.5	28.20	1988.78	103?
91	1986.1	25.60	970.0	25.72	2014.49	
92	2003.9	17.80	967.1	18.04	2032.53	
93	2034.4	30.51	965.0	30.58	2063.11	
94	2061.0	26.59	963.9	26.61	2089.73	
95	2092.4	31.40	964.0	31.40	2121.13	
96	2119.6	27.17	965.3	27.20	2148.33	
97	2141.0	21.42	967.0	21.49	2169.82	
98	2164.3	23.31	970.5	23.56	2193.38	
99	2186.0	21.66	975.1	22.15	2215.53	
100	2201.8	15.80	978.0	16.06	2231.59	
101	2219.4	17.67	981.8	18.08	2249.67	
102	2246.5	27.05	983.0	27.07	2276.74	
103	2279.2	32.69	982.1	32.70	2309.44	
104	2304.8	25.58	979.7	25.70	2335.14	
105	2329.1	24.31	977.7	24.39	2359.53	
106	2342.9	13.80	976.0	13.91	2373.43	
107	2354.6	11.79	973.0	12.15	2385.58	
108	2371.5	16.81	970.0	17.09	2402.67	
109	2389.5	18.02	967.3	18.22	2420.89	
110	2407.8	18.32	969.0	18.39	2439.28	
111	2428.6	20.80	968.5	20.80	2460.09	
112	2452.4	23.78	967.5	23.80	2483.88	
113	2472.4	20.02	965.8	20.10	2503.98	

114	2491.3	18.89	963.0	19.09	2523.07	
115	2512.4	21.09	962.4	21.10	2544.17	tank
116	2532.2	19.82	963.7	19.87	2564.04	
117	2552.3	20.09	964.2	20.10	2584.14	
118	2566.4	14.08	963.6	14.09	2598.23	
119	2586.8	20.41	961.6	20.50	2618.74	
120	2606.7	19.88	958.8	20.08	2638.82	
121	2623.0	16.36	955.5	16.70	2655.52	
122	2645.7	22.70	955.0	22.70	2678.22	
123	2672.3	26.60	955.2	26.60	2704.82	
124	2704.4	32.09	954.2	32.10	2736.92	
125	2734.7	30.28	952.0	30.37	2767.29	
126	2758.6	23.89	949.9	23.98	2791.27	
127	2778.7	20.16	948.0	20.25	2811.51	
128	2815.3	36.61	945.5	36.70	2848.21	
129	2843.5	28.20	945.5	28.20	2876.41	connection for ignaccio's house
130	2879.3	35.79	944.7	35.80	2912.22	
131	2904.2	24.90	942.8	24.98	2937.20	
132	2937.7	33.48	940.9	33.54	2970.73	
133	2965.3	27.59	937.9	27.76	2998.49	
134	2991.5	26.17	934.6	26.38	3024.86	
135	3018.4	26.86	933.3	26.90	3051.76	
136	3044.8	26.40	932.4	26.41	3078.17	
137	3078.6	33.89	931.5	33.90	3112.07	
138	3116.3	37.70	931.5	37.70	3149.77	9 ft error
139	3150.2	33.89	932.2	33.90	3183.67	
140	3177.1	26.90	932.5	26.90	3210.57	
141	3196.6	19.50	932.8	19.50	3230.07	
142	3218.9	22.29	933.7	22.31	3252.37	
143	3241.1	22.22	935.5	22.28	3274.66	
144	3268.0	26.86	936.9	26.90	3301.56	
145	3295.1	27.07	937.9	27.09	3328.65	
146	3320.1	25.00	938.0	25.00	3353.65	
147	3344.6	24.50	937.1	24.51	3378.16	
148	3361.3	16.79	934.3	17.02	3395.18	
149	3375.2	13.83	932.0	14.01	3409.19	
150	3397.3	22.08	929.9	22.18	3431.38	
151	3425.3	28.03	928.1	28.09	3459.46	
152	3452.9	27.65	925.4	27.78	3487.25	
153	3470.8	17.88	922.5	18.11	3505.36	
154	3483.0	12.17	919.2	12.60	3517.96	
155	3495.0	12.05	916.0	12.48	3530.44	
156	3507.1	12.10	912.9	12.49	3542.93	

157	3521.0	13.84	908.3	14.58	3557.51	is this right?
157	3521.0	8.22	905.2	8.78	3566.28	is this right:
159	3548.1	18.89	902.5	19.09	3585.37	
160	3561.4	13.33	899.5	13.64	3599.01	
161	3586.3	24.86	897.4	24.96	3623.97	
162	3599.4	13.11	900.0	13.36	3637.33	
163	3620.4	20.99	899.5	21.00	3658.33	
164	3641.3	20.98	897.3	21.10	3679.42	
165	3652.7	11.38	894.0	11.84	3691.26	
166	3662.7	9.96	890.8	10.48	3701.74	
167	3674.0	11.29	888.5	11.51	3713.25	
168	3686.2	12.18	885.7	12.50	3725.75	
4.50	0.000.0	10.10		40.00		T pipe to house on coner
169	3696.3	10.16	884.0	10.29	3736.05	Elanam
170	3709.2	12.85	880.8	13.25	3749.30	
171	3745.2	36.07	879.0	36.11	3785.41	
172	3766.1	20.90	876.4	21.07	3806.48	194?
173	3779.7	13.55	873.8	13.79	3820.27	
174	3795.1	15.46	872.6	15.51	3835.77	
175	3819.3	24.19	874.9	24.29	3860.07	
176	3851.8	32.52	872.4	32.62	3892.68	
177	3894.6	42.72	870.0	42.79	3935.47	
178	3933.4	38.86	867.7	38.93	3974.40	
179	3974.2	40.80	867.5	40.80	4015.20	
180	3997.5	23.30	867.2	23.30	4038.50	step valve behind salud
181	4036.1	38.55	865.1	38.60	4077.10	spiggot @ salud
182	4068.9	32.82	862.0	32.97	4110.07	
183	4091.2	22.32	858.7	22.56	4132.63	
184	4107.3	16.10	855.7	16.38	4149.01	
185	4120.0	12.66	853.4	12.88	4161.88	
186	4129.2	9.23	850.6	9.63	4171.51	
187	4141.2	11.98	847.5	12.39	4183.90	
188	4153.1	11.88	844.2	12.32	4196.22	
189	4165.8	12.72	841.5	12.99	4209.21	
190	4180.7	14.94	838.5	15.25	4224.46	
180	3997.5	23.30	867.2	23.30	4038.50	Large Elev Difference Between
9	4539.1	541.60	925.0	544.68	4583.17	Abney Level and GPS (926 ft)
154	4754.3	215.19	973.0	220.48	4803.65	, , , , , , , , , , , , , , , , , , , ,
155	5732.2	977.89	999.0	978.24	5781.89	
156	6928.4	1196.20	1023.0	1196.44	6978.33	
157	7374.2	445.74	1002.0	446.24	7424.57	
158	7860.0	485.80	939.0	489.87	7914.44	
130	7800.0	403.00	939.0	403.07	7314.44	

December 9, 2011

10.3 Water Quality Test Results

Spring 1 System 1				
	Date Time E. coli Total Coliform			
Test1	12-Aug	2:10	0	6
Test 2	12-Aug	2:14	0	20
Test 3	12-Aug	2:16	0	21
		Average	0	15.67

Potential Spring System 1				
Date Time E. coli Total Coliform				Total Coliform
Test1	13-Aug	8:59	0	7
Test 2	13-Aug	8:56	0	25
Test 3	13-Aug	8:58	0	1
		Average	0	11

Tank System 1				
Date Time E. coli Total Coliform		Total Coliform		
Test1	13-Aug	8:27	0	41
Test 2	13-Aug	8:23	0	35
Test 3	13-Aug	8:28	0	32
		Average	0	36

	Spring 1 System 2				
	Date	Time	E. coli	Total Coliform	
Test1	14-Aug	10:08	0	27	
Test 2	14-Aug	10:11	0	37	
Test 3	14-Aug	10:14	0	29	
		Average	0	31	

Upper Half of Surface Flow System 3				
Date Time E. coli Total Coliform				
Test1	14-Aug	9:00	0	5
Test 2	14-Aug	9:03	0	8
		Average	0	6.5

Lower Half of Surface Flow System 3				
Date Time E. coli Total Coliform				
Test1	14-Aug	8:49	0	142
Test 2	14-Aug	8:53	0	150
		Average	0	146

Spigot at the Health Center				
Date Time E. coli Total Coliform				
Test1	14-Aug	11:34	0	80
Test 2 14-Aug		11:37	0	121
		Average	0	100.5

10.4 Major System Headloss Calculations

From the length of pipe determined from the graphical analysis, major headloss was calculated making the following assumptions:

PVC friction factor
$$(f) = 0.008$$
 (Milhelcic 209 – 27)

Flow on spring system 1 (Q) =
$$0.0639 \frac{ft^3}{s}$$
 (see existing system observations)

Pipe diameter (D) = 0.125ft (see existing system observations)

Pipe length
$$(L) = 7425ft$$

The equation for major headloss is given as follows (Mihelcic 204-27):

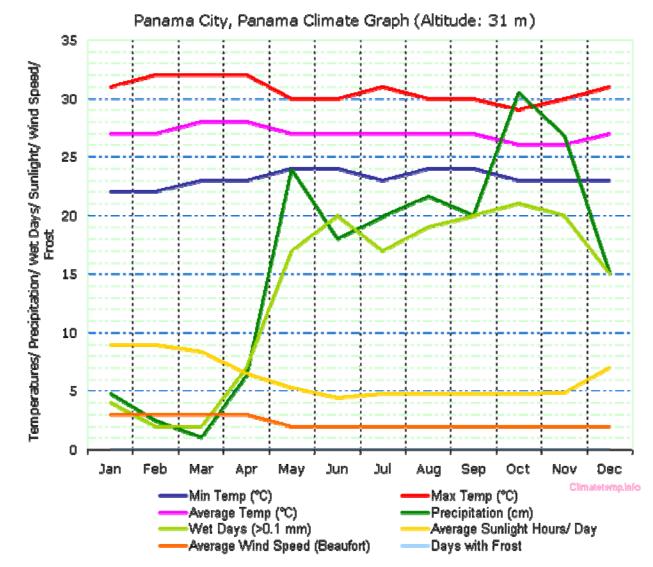
$$h_L = 16 * f * \frac{(L * Q^2)}{\left(2 * 32.2 \frac{ft}{S^2} * \pi^2 * D^5\right)}$$

Giving us:

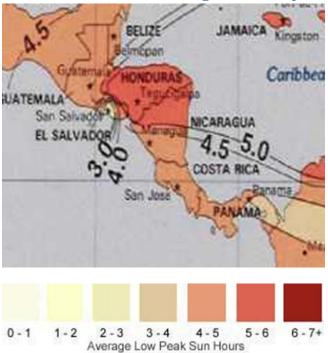
$$h_L = 16 * 0.01 * \frac{\left(7425ft * \left(0.0639 \frac{ft^3}{s}\right)^2\right)}{\left(2 * 32.2 \frac{ft}{s^2} * \pi^2 * 0.125^5\right)} = 250ft$$

10.5 Panamanian Maps and Climate Data

10.51 Panamanian Climate Graph

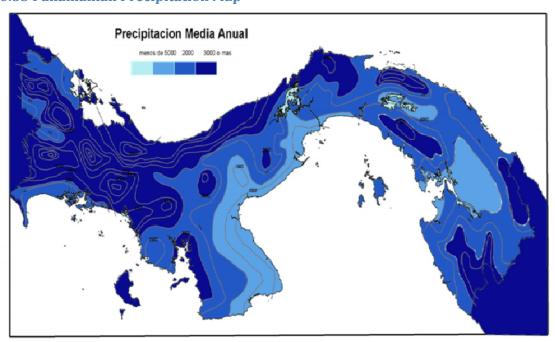


10.52 Panamanian Peak Sunlight Hours Map

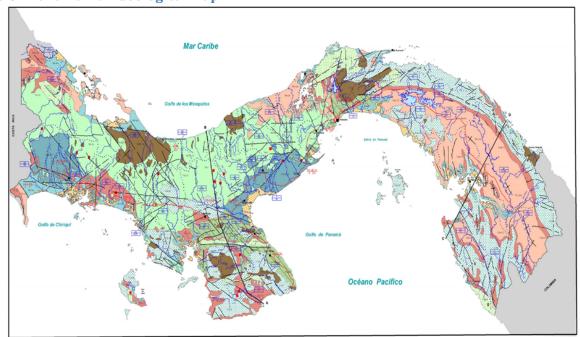


Map of peak sun hours in Central America (Advanced Energy Group)

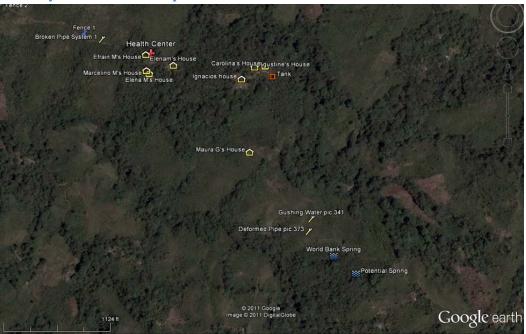
10.53 Panamanian Precipitation Map



10.54 Panamanian Geological Map



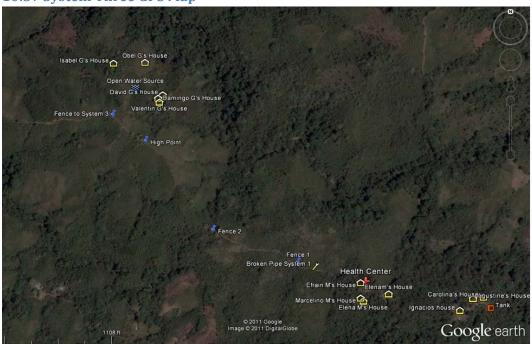
10.55 System One GPS Map



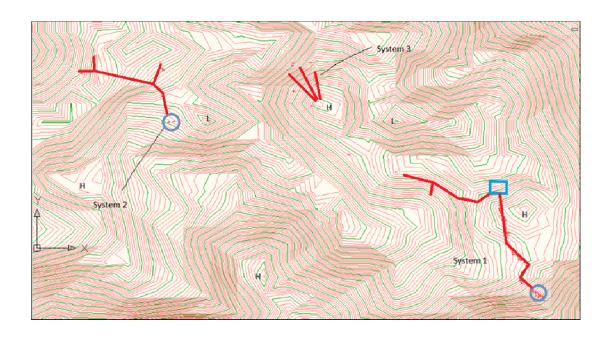
10.56 System Two GPS Map



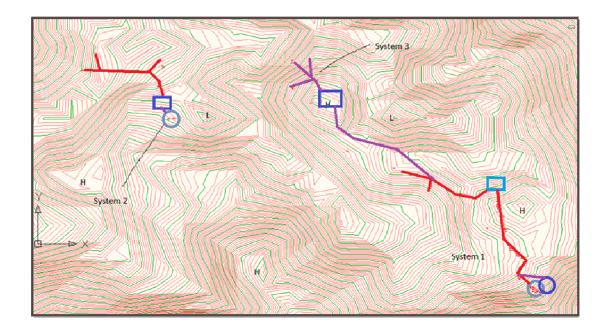
10.57 System Three GPS Map



10.58 Current System Topographical Map

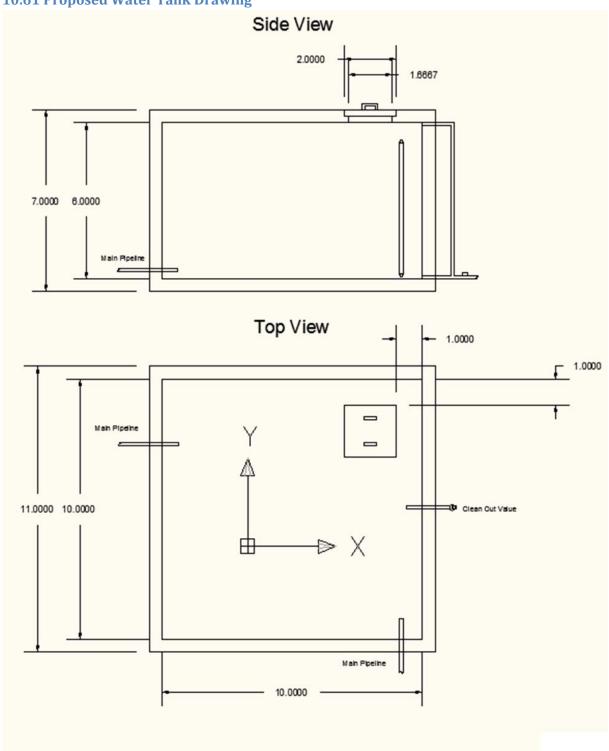


10.59 Proposed System Topographical Map

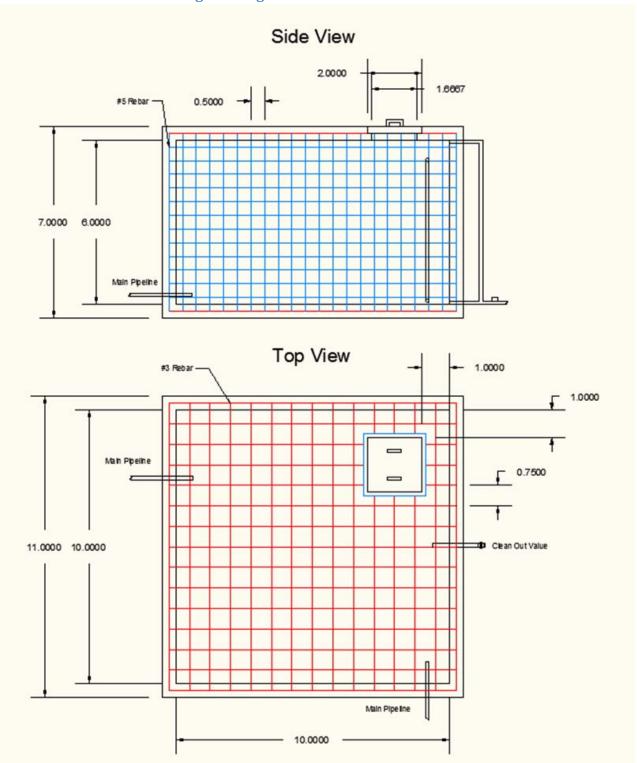


10.6 Design Drawings and Calculations

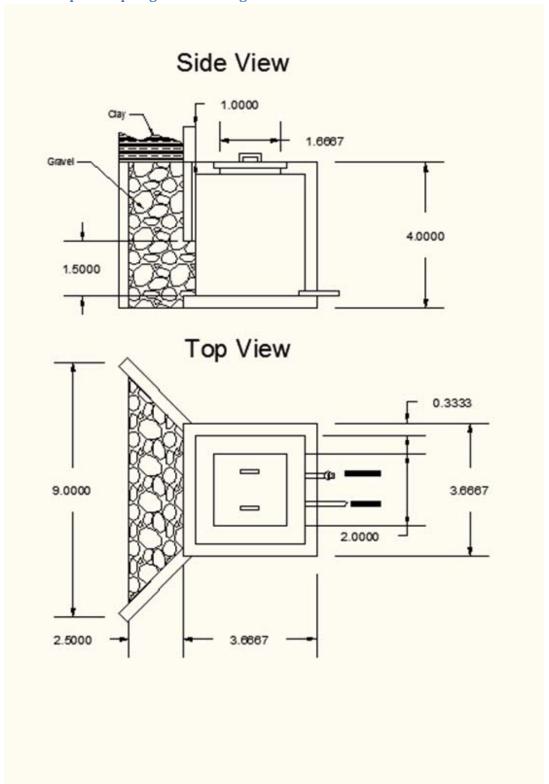
10.61 Proposed Water Tank Drawing



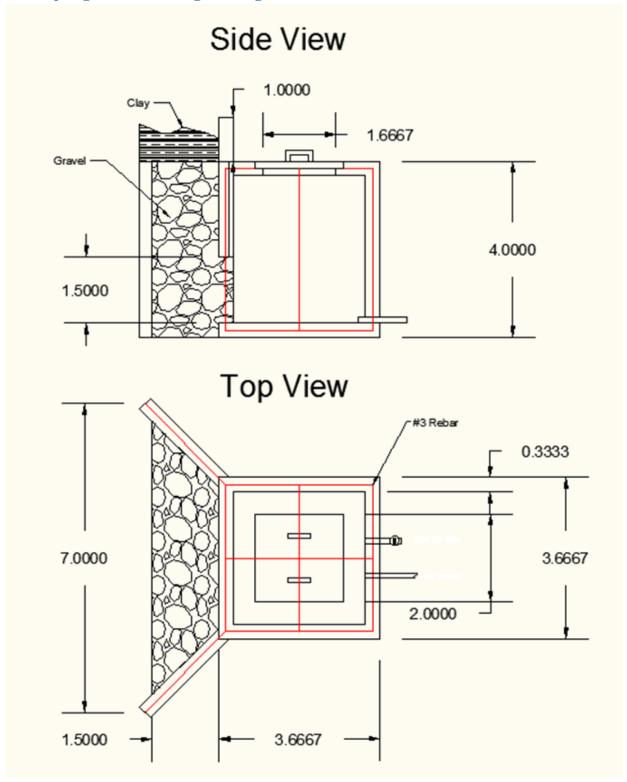
10.62 Water Tank Reinforcing Drawing



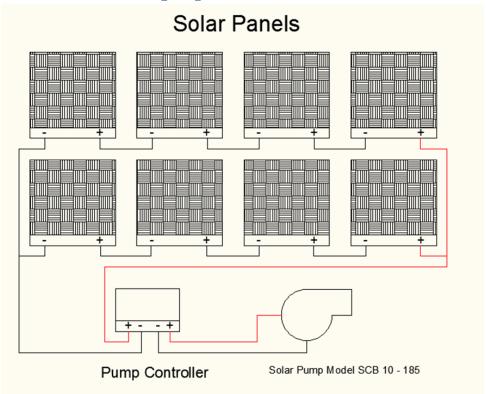
10.63 Proposed Spring Box Drawing



10.64 Spring Box Reinforcing Drawing



10.65 Solar Panel Wiring Diagram



10.66 Air Relief Valve Diagram

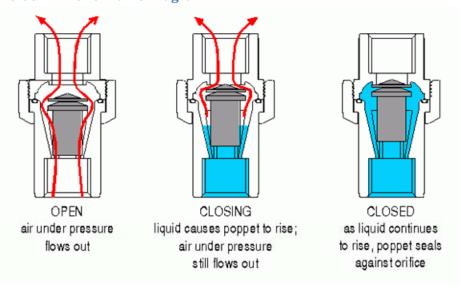


Figure 5.9 Air release valve; demonstration of how air is released

10.67 Tank Reinforcing Calculations

Structural Design Analysis -- Tank Concrete Reinforcing

Tank Wall Reinforcing

Max Moment - 20661.8 Ft*LBS Steel Strength - 20,000 lbs/in ^2 Slab Thickness- 6" Effective Depth 6" Calculation Width 1'

As=Mmax/(Fs*j*d)

20,661/(20,000*.8792*4)= 0.29375

Breadth= Mmax/ $(R*d^2)$ = 7.206264 inches

Bar Area= Bar#/8= #4/8=1/2" =D #5=5/8" 0.625

#4A= 3.14159*.25^2 = 0.196349 in^2/bar #5=3.14159*.3125^2 0.306796 in^2/bar

Recommendation = 1 #5 bar every 6 inches vertically and horizontally.

Or #4 if strength greater than 20,000 PSI tensile is available.

Roof/Tank Cover

Live Load = 1000 LBS 5 people at 1.6 safety factor

Dead Load=

concrete = 150 lbs/ ft^3

37.5 lbs/lft 10*37.5= 375 lbs

 Dead Load Moment = 2.5ft*375lbs
 937.5
 lbs*ft

 Live Load Moment = 5ft * 1000lbs
 5000
 lbs*ft

 Total Moment
 5937.5
 lbs*ft

Required Reinforcing = As= Mmax/(fs*j*d)

As= 5938LBs*FT/(20000lbs*in^2*.8792*4)

0.08442 in^2

"To improve the health and sanitation of the Candela community through sustainable water system design."

85

Breadth = 7.2 In

Area #3= 3.14159*(1.5/8)^2 =0.11045

> 1.308249656= Ratio 7.2*1.308= 9.4194

Recommendation =

1 #3 Bar every 9 " OC both directions

10.7 Manufacturers' Product Manuals

10.71 Kyrocera Solar Panel Product Data

HIGH EFFICIENCY MULTICRYSTAL PHOTOVOLTAIC MODULE



CUTTING EDGE TECHNOLOGY

As a pioneer with over 35 years in the solar energy industry, Kyocera demonstrates leadership in the development of solar energy products. Kyocera's Kaizen Philosophy, commitment to continuous improvement, is shown by repeatedly achieving world record cell efficiencies.

QUALITY BUILT IN

- UV stabilized, aesthetically pleasing black anodized frame
- Supported by major mounting structure manufacturers
- Easily accessible grounding points on all four corners for fast installation
- Proven junction box technology with 12 AWG
 PV wire to work with transformerless inverters
- Quality locking MC4 plug-in connectors to provide safe and quick connections

RELIABLE

- · Proven superior field performance
- Tight power tolerance
- Only module manufacturer to pass rigorous long-term testing performed by TÜV Rheinland

WARRANTY

- Kyocera standard 20 year power output warranty and 5 year workmanship warranty applies in USA
- Extended warranties available per project requirements
- Kyocera standard 20 year power output warranty and 2 year workmanship warranty applies outside of USA
- · Refer to Kyocera warranty policy for details

KD 135 P Series



QUALIFICATIONS AND CERTIFICATIONS

UL Listing QICU.E 173074







NEC 2008 Compliant, UL 1703, ISO 9001, and ISO 14001 UL1703 Certified and Registered, UL Fire Safety Class C, CEC, FSEC Certified IEO61215 Ed 2 IEO61730 by JET

QUALIFIED FOR "BUY AMERICAN"

Manufactured in San Diego, California

Available Upon Request

SOLAR by KYOCERA

ELECTRICAL SPECIFICATIONS

KD135GX-LPU 135 17.7 7.63 22.1 8.37 +5/-5 %

T _{NOCT}	45	°C
P _{max}	97	W
V _{mp}	16	V
l _{mp}	6.1	А
V _{oc}	20.2	V
I _s	6.78	A
PTC	122.2	W

Temperature Coef	ficients	
P _{max}	-0.45	%/°C
V_{mp}	-0.52	%/°C
I _{mp}	0.0066	%/°C
V_{∞}	-0.36	%/°C
I _{sc}	0.060	%/°C
Operating Temp	-40 to +90	°C
System Design		

System Design	
Series Fuse Rating	15 A
Maximum DC System Voltage (UL)	600 V
Hailstone Impact	1in (25mm) @ 51mph (23m/s)

NEC 2008 COMPLIANT LIL 1703 LISTED CERTIFIED IEC61215 ED2 IEC61730 BY JET





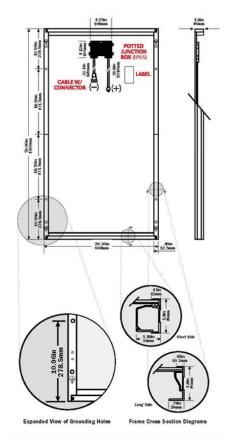




MODULE CHARACTERISTICS

PACKAGING SPECIFICATIONS

Modules per pallet:	20
Pallets per 53' container:	36
Pallet box dimensions: length/width/height	63.19in/27.56in/49.02in (1605mm/700mm/1245mm)
Pallet box weight:	632.8lbs (287kg)





081211 OUR VALUED PARTNER

KYOCERA Solar, Inc. 800-223-9580 800-523-2329 fax www.kyocerasolar.com



Quality First!

PCA & PCB SERIES PUMP CONTROLLERS



SunPumps PCA and PCB series pump controllers are high quality, micro-processor controlled DC power converters designed as the interface between a DC powered pump and the power source. The DC source may be solar modules, batteries or systems using wind generators. The main purpose of a PC series controller is to maximize the total daily water delivery while providing protection for the pump as well as the power source.

The primary function of the PC series controller is to boost the current of solar modules in low sunlight conditions while holding the voltage of the solar modules at the maximum power point. This allows a pump to start earlier in the morning and stay running longer in the evening.

SunPumps PC series pump controllers have many unique features designed specifically for water pumping. All PC series controllers include a pump speed control circuit, a remote switch circuit, a sensor-less low water cut-off circuit, an electronic circuit breaker and indicator lights. The PCB series controllers have specific models for Brushless DC as well as Brush-type DC motors.

CONTROLLER SPECIFICATIONS

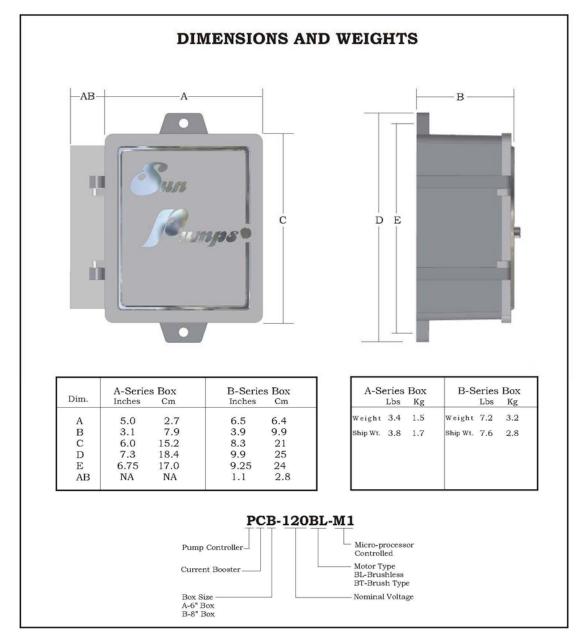
Model Number	PCA-30	PCA-60	PCB-90	PCB-120	PCB-180
Number of Solar Modules in Series	1, 2	2,3,4	3,4,5,6	6,7,8,9	9,10,11,12
Nominal voltages (switch selectable)	15,24,30	30,45,60	45,60,75,90	90,105,120, 135	135,150,165,180
Maximum open circuit voltage	45	90	200	250	300
Maximum load current (amps)	8	8	10	10	14
Maximum load power (watts)	250	500	1000	1200	2500

Independent Water Pumping Systems

Phone: 1-800-370-8115

(928) 348-9652

Fax: (928) 348-9653



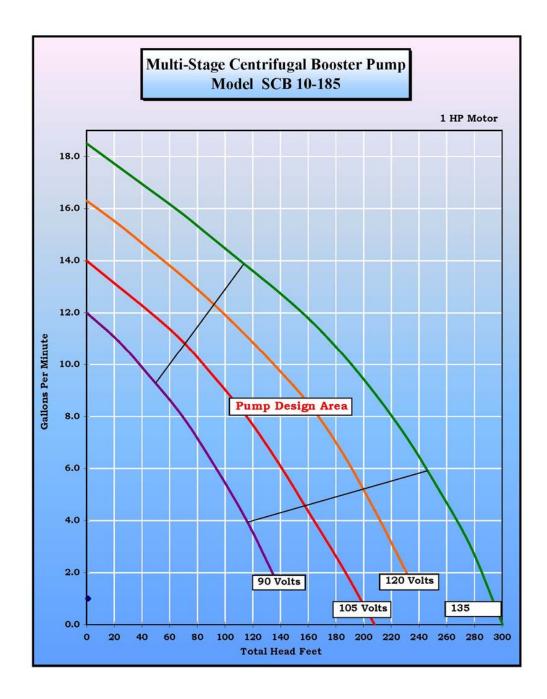


For free system sizing, technical support, or to place an order call:

Phone: 1-800-370-8115

(928) 348-9652

Fax: (928) 348-9653



Multi-Stage Centrifugal Booster Pump Model SCB 10-185

1 HP Motor 10 Stages

PSI	TDH Feet	TDH Meters	Motor Voltage	Motor Amps	U.S. GPM	LPM	Motor Watts	Peak Panel Watts*	System Efficiency
0	0	0.0	90	3.81	12.0	45.4	343	429	0%
10	23	7.0	90	3.88	10.9	41.3	349	437	14%
20	46	14.1	90	3.94	9.5	36.0	355	443	23%
30	69	21.1	90	4.01	8.0	30.3	361	451	29%
40	92	28.2	90	3.95	6.1	23.1	356	444	30%
50	116	35.2	90	3.67	4.0	15.1	330	413	26%
60	139	42.3	90	3.37	1.5	5.7	303	379	13%
70	162	49.3	90	3.10	0.0	0.0	279	349	0%

Suggested solar module array: 6-75 to 80 watt modules wired in series.

PSI	TDH Feet	TDH Meters	Motor Voltage	Motor Amps	U.S. GPM	LPM	Motor Watts	Peak Panel Watts*	System Efficiency
0	0	0.0	105	4.60	14.0	53.0	483	604	0%
10	23	7.0	105	4.67	13.0	49.2	490	613	12%
20	46	14.1	105	4.77	12.0	45.4	501	626	21%
30	69	21.1	105	4.85	10.9	41.3	509	637	28%
40	92	28.2	105	4.90	9.5	36.0	515	643	32%
50	116	35.2	105	4.92	8.0	30.3	517	646	34%
60	139	42.3	105	4.72	6.2	23.5	496	620	33%
70	162	49.3	105	4.34	4.2	15.9	456	570	28%
80	185	56.3	105	4.05	2.2	8.3	425	532	18%
90	208	63.4	105	4.00	0.0	0.0	420	525	0%

Suggested solar module array: 7-90 to 100 watt modules wired in 7 in series.

PSI	TDH	TDH	Motor	Motor	U.S.		Motor	Peak Panel	System
	Feet	Meters	Voltage	Amps	GPM	LPM	Watts	Watts*	Efficiency
0	0	0.0	120	5.71	16.3	61.7	685	857	0%
10	23	7.0	120	5.80	15.4	58.3	696	870	10%
20	46	14.1	120	5.87	14.4	54.5	704	881	18%
30	69	21.1	120	5.99	13.4	50.7	719	899	24%
40	92	28.2	120	6.03	12.3	46.6	724	905	30%
50	116	35.2	120	6.12	11.1	42.0	734	918	33%
60	139	42.3	120	6.10	9.8	37.1	732	915	35%
70	162	49.3	120	6.02	8.4	31.8	722	903	35%
80	185	56.3	120	5.92	6.6	25.0	710	888	32%
90	208	63.4	120	5.63	4.4	16.7	676	845	26%
100	231	70.4	120	5.63	2.0	7.6	676	845	13%
110	254	77.5	120	4.58	0.0	0.0	550	687	0%

Suggested solar module array: 8-110 to 120 watt modules wired in series.

PSI	TDH	TDH	Motor	Motor	U.S.		Motor	Peak Panel	System
	Feet	Meters	Voltage	Amps	GPM	LPM	Watts	Watts*	Efficiency
0	0	0.0	135	6.93	18.5	70.0	936	1169	0%
10	23	7.0	135	6.98	17.6	66.6	942	1178	8%
20	46	14.1	135	7.09	16.7	63.2	957	1196	15%
30	69	21.1	135	7.17	15.8	59.8	968	1210	21%
40	92	28.2	135	7.25	14.8	56.0	979	1223	26%
50	116	35.2	135	7.35	13.8	52.2	992	1240	30%
60	139	42.3	135	7.41	12.8	48.4	1000	1250	33%
70	162	49.3	135	7.45	11.7	44.3	1006	1257	35%
80	185	56.3	135	7.43	10.4	39.4	1003	1254	36%
90	208	63.4	135	7.41	8.9	33.7	1000	1250	35%
100	231	70.4	135	7.24	7.2	27.3	977	1222	32%
110	254	77.5	135	6.97	5.2	19.7	941	1176	26%
120	277	84.5	135	6.52	3.0	11.4	880	1100	18%
130	300	91.6	135	5.65	0.0	0.0	763	953	0%

Suggested solar module array: 18-70 to 80 watt modules wired in 2 parallel strings of 9 in series.

^{*} Peak panel watts using a 20% deration factor.

OPERATION AND INSTALLATION MANUAL

For

PCB-90BT-M1 PCB-120BT-M1 PCB-180BT-M1

PUMP CONTROLLERS

For Brush-Type Motors Only

MANUFACTURED & SERVICED BY:

SUNPUMPS

325 EAST MAIN STREET SAFFORD, ARIZONA 85546 UNITED STATES OF AMERICA

> PHONE # (928) 348-9652 FAX # (928) 348-9653

> > DC# PCB-BT-M1 REV 2001

nual

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Phone (928) 348-9652 Fax (928) 348-9653

1.0 Introduction

Thank you for selecting a SunPumps PCB series pump controller. It is the key component to a high quality solar powered pumping system. Their high quality stand-alone operation makes them an ideal solution for any remote solar pumping system using a Brush-Type DC motor.

The PCB-series controllers are micro-processor-based, solid-state DC power converters designed as the interface between a solar module array and a Brush-Type DC pump motor. The purpose of the controller is to maximize the total daily water output while providing protection for the pump as well as providing an interface with other related pumping system equipment.

Although these PCB series pump controllers are easy to install, please read this manual to become familiar with the controller features, functions, connection points and various configurations. For future reference, keep this manual and other relevant product information in a safe place.

PRECAUTIONS

- Safety First Always understand what you are doing when working with any form of electricity. Guessing at something is not worth the potential of product damage and/or severe personal injury.
- Shut down all power when working on the system.
- Do not attempt to feed live wires into the PC-series controller or product damage and/or personal injury may result.
- Do not exceed the voltage and power rating of the controller.
- Do not splash water on the controller when the cover is open.
- Mount the controller in a shaded, well vented, vertical position.
- Installation of this system, should be done by a licensed Solar Pump Contractor.

2.0 Product Overview

SunPumps PCB-XXXBT-M1 series controllers were primarily designed for solar powered, brush-type DC pump motors. When properly installed and configured, the unique features incorporated into this standalone system will automatically control and protect your pump system permitting many years of dependable, trouble free service.

2.1 Controller Features

- 1. Current boosting for matching the load requirements of the pump.
- 2. Voltage regulation of the solar electric array at its maximum power point.
- 3. Over-current protection via integrated electronic circuit breaker.
- 4. Reverse polarity protection (10 amperes maximum) on the input terminals.
- 5. Voltage and current limiting to pump motor.
- Transient protection and surge suppression.
- Adjustable pump motor voltage control for precision output flow.
- 8. Adjustable input voltage for system optimization or solar modules.
- System ON/OFF switch.
- 10. LED indicators; Red = power in, Green = power out, Amber 1 = Remote switch shutdown, Amber 2 = over current shutdown, and Amber 3 = Low Voltage Disconnect and Amber 4 = Low Water Cut-Off.
- 11. Weather resistant cast aluminum enclosure with hinged door.

- 12. Rising clamp screw terminal blocks no fork terminals required.
- 13. User selectable pre-adjusted input voltage configuration and power source selection.
- Remote switch interface float switch or remote shutdown –Normally Open or Normally Closed user selectable.
- 15. Sensor-less Low Water Cut-Off circuit
- 16. Low Voltage Disconnect circuit

2.2 Application

The only application the PCB-BT-M1 series controllers are designed for is the interface between a solar module array and a Brush-Type DC motor as well as various peripheral pump system signal devices.

No other applications or DC power sources are recommended or warranted unless written approval is provided by the SunPumps factory.

3.0 Installation and Operation

The following sections are outlined in a step-by-step format to guide you through the installation and configuration of a PCB series pump controller. The installation and operation should be in accordance with local regulations, accepted codes of good practice and common sense.

Before installing any pump system, read all product manuals and review all system components to become familiar with the physical and electrical layout. Check all equipment for any product damage. Refer to applicable figure(s) as a guide during the installation. Controller door must be closed during normal operation.

Warning

Reverse polarity on a panel system capable of producing over 10 amps will result in non-warranted product damage. Please check polarity before connecting power to the controller.

This controller is for <u>Brush-Type DC Motors</u> only. Do not use on Brushless motors or damage to the controller will result.

3.1 Location

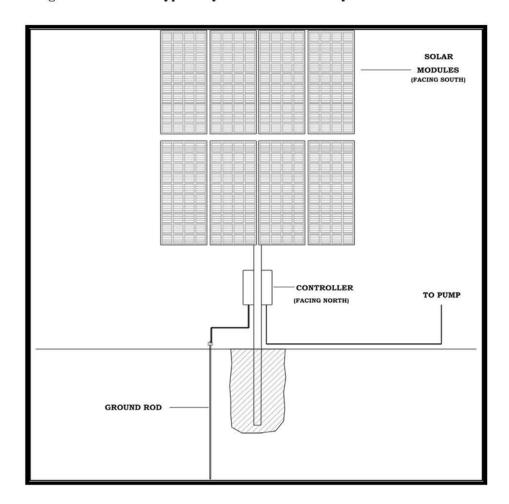
As the majority of system installations vary greatly, only general comments can be made as to location. Prior to installing the system, it is suggested to make a system layout plan. During the system layout, take into consideration any potential shading of the solar electric modules, wire runs, wire size, conduit runs, trenching, controller accessibility, tank location, pump head etc.. Shading even a small portion of the array can reduce the output of the entire array and thus reduce or completely stop the output of the pump. There is no substitute for a good plan!

The PCB-series controller can either be mounted indoors or outdoors. Locate all system equipment as close as possible to each other. Generally the controller is mounted on the north side of a pole which has solar electric modules mounted on top of it. The controller must be mounted in a vertical position for proper cooling and to keep the electronics dry. The controller should be located close to the DC motor. This general physical layout is conducive to clean installation aesthetically and electrically.

3.2 System Design Basics (Read carefully before installation)

- Never install the controller in direct sunlight. Direct sunlight on the controller may cause overheating of the controller.
- Never lay the controller on the ground or mount the controller in a horizontal position. The controller should be mounted in a vertical position only. A convenient place to mount the controller is on the north side (shaded side) of the solar module array.
- 3. The controller should be grounded to the pump motor housing, the frame of the solar modules and to an 8-foot ground rod. If the well casing is steel it may be used as the ground rod. Drill and tap a hole in the casing or weld a bolt to the casing for the ground lug. Use only a copper lug to attach the ground wire. The cemented support structure pole will not provide an adequate ground.
- Do not ground the positive or negative electrical wires.

Figure 1 Typical System Installation Layout



3.3 Wiring

Prior to connecting any wires to the controller be sure you have a system wiring diagram to use as a reference. Sample generic system wiring diagrams are included in this manual for your convenience. (See Figure 2) Guessing at polarity and connection points is not worth the risk of potential product damage and/or personal injury.

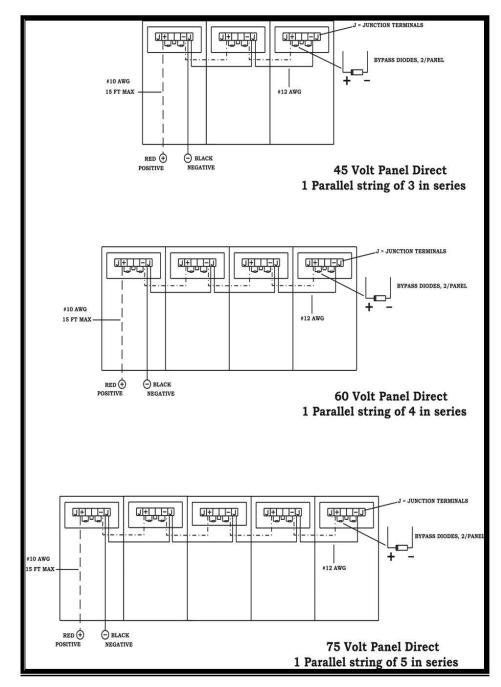
Ensure the wire sizes are of adequate diameter (gauge) to minimize voltage drop. Please refer to a DC voltage loss table or call your SunPumps dealer for assistance. Wire gauge being too small will cause excessive voltage losses to the motor and will reduce the flow rate of the pump.

All other system equipment should be installed before proceeding with wiring the controller. Pre-configure the controller switches prior to wiring. (See Figure 3) Refer to "Adjustment Procedures" for details. Double check polarity and wire termination tightness before powering up the system.

CAUTION: Photovoltaic panels produce DC electricity when exposed to sunlight. Cover the panels with a blanket or with an opaque material before wiring. Install a fused disconnect switch between the solar modules and the controller.

- 1. Switch the controller to the OFF position.
- Connect ground rod conductor to the controller chassis ground block.
- 3. Connect solar module frame ground conductor to controller chassis ground block.
- Connect pump ground conductor to controller chassis ground block.
- 5. Connect pump motor negative (-), black conductor to controller terminal labeled "LD-".
- Connect pump motor positive (+), red conductor to controller terminal labeled "LD+".
- Connect the DC source supply negative (-), black conductor to the controller terminal labeled "PV-". (NOTE: The power should be connected to the fused disconnect first and then to the controller).
- Connect the DC source supply positive (+), red conductor to the controller terminal labeled "PV+". (NOTE: The power should be connected to the fused disconnect first and then to the controller).
- Refer to the next section for "Remote Control" connections and "Adjustment Procedures" for configuration (if applicable).
- 10. At this point, all system components are installed and wired, double check conductor polarities, wire termination tightness and controller configuration. With a DC volt meter check the open circuit voltage and the module polarity before connecting power to the controller.
- 11. Switch the disconnect on if the polarity is correct the red light will be on.
- 12. Turn the "ON/OFF" switch to the ON position. The system should be operational. If the system is not working refer to the "Troubleshooting" section.

Figure 2 Sample Solar Panel Wiring Diagram (Generic)



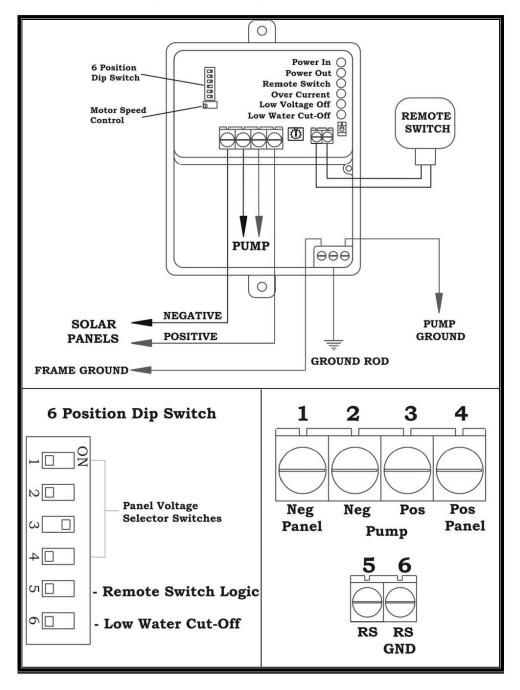
#12 AWG JUNCTION TERMINALS BYPASS DIODES, 2/PANEL #10 AWG #12 AWG 15 FT MAX RED (+)
POSITIVE BLACK NEGATIVE 90 Volt Panel Direct 1 Parallel string of 6 in series #10 AWG RED (+)
POSITIVE 180 Volt Panel Direct 1 Parallel string of 12 in series

Figure 2 Cont. Sample Solar Panel Wiring Diagram (Generic)

#10 AWG 15 FT MAX #12 AWG :#: 0 45 Volt Panel Direct RED BLK NEGATIVE 2 Parallel strings of 3 in series #10 AWG 15 FT MAX #12 AWG -·h; (1-1 T T+10) BYPASS DIODES, 2/PANEL **⊕** BLK NEGATIVE **60 Volt Panel Direct** 2 Parallel strings of 4 in series

Figure 2 Cont. Sample Solar Panel Wiring Diagram (Generic)

Figure 3 <u>Controller Wiring Diagram</u>



3.4 Auxiliary Control Circuits

The PCB series controllers feature remote peripheral interface functions with easy programming. The remote switch interface supports float switches (storage tank level), pressure switches or a remote system "ON/OFF" toggle switch. Use only "Shielded Wire" to run from the remote switch to the controller and the shield must be grounded to the controller side only. Induced voltages from lightning storms or two-way radio transmissions could damage the controller.

Remote Switch

The Remote Switch interface can serve as an automatic system shutdown when used with a water storage tank mounted float switch, a pressure switch or it can also serve as a manual system shutdown with a remote system ON/OFF toggle switch. When it turns off the remote switch light will flash at one-second intervals. The remote logic circuit allows the use of standard "Pump-Up or Pump Down" float switches. Please refer to the following operation scenarios for configuration options.

With switch number 5 in the *OFF* position, the controller is configured to accommodate a Normally Open (N.O.) float switch or remote toggle switch. In this configuration the controller will operate as follows:

PUMP ON
Float switch open = water tank low = pump ON

 $\frac{PUMP OFF}{= water tank high = pump OFF}$

With switch number 5in the ON position, the controller is configured to accommodate a Normally Closed (N.C.) float switch, pressure switch or remote toggle switch. In this configuration the controller will operate as follows:

PUMP ON
Switch closed = water tank low = pump ON

PUMP OFF
Switch open = water tank high = pump OFF

Output Voltage Control Circuit

The Output Voltage Control circuit or Motor Speed Control circuit is used to regulate the output voltage of the controller and thus the flow rate of the pump. It is primarily used for low producing wells where the pump output is matched to the production rate of the well. However it can also be used any time specific flow rates are required. (See Section 3.5 "Output Voltage Adjustment" for the correct adjusting procedure).

Low Water Cut-Off Circuit

The Low Water Cut-Off Circuit is actually a low current cut-off circuit. It monitors the current draw of the motor and turns the pump off when the current drops below the set point. This circuit has a sensitivity adjusting pot on the face of the controller for various types of motors.

With switch number 6 in the ON position, the low water cut-off circuit interface serves as an automatic system shutdown when water in the well drops below the pump intake. When the LWC circuit is activated one of the amber lights will flash and the pump will turn off. The pump will stay off for approximately 25 to 30 minutes and then turn back on. This cycle will repeat any time the water drops below the pump intake. See section 3.5 for LWC adjustment procedures.

With switch number 6 in the OFF position, the LWC circuit is disabled. The pump will continue to operate even if it runs dry.

Over-Current Shut Down Circuit

The over-current shut down circuit will turn the controller off any time the current exceeds the current limit of the controller. When it turns the controller off it will remain off for 3 minutes and then turn on again. When it turns off the over-current light will flash at one-second intervals.

When it turns on again, if it is still pulling excessive current it will continue to shut down for 3 minutes and restart for three cycles. The controller will then remain off the remainder of the day unless manually reset with the main toggle switch. In this mode the OC light will flash at a half-second intervals indicating it will not restart automatically. However when the sun goes down at the end of the day the controller will be reset the next morning.

Low-Voltage Disconnect Circuit

The low-voltage disconnect circuit turns the pump off any time the voltage drops below a functional level. This protects the pump in stall conditions and saves wear on the system when no water or very little water is being pumped.

When this circuit is activated the LVD light will flash at one second intervals indicating the controller has turned the pump off. The pump will remain off for 3 minutes and then restart. If the voltage is still low it will continue to cycle every 3 minutes until the pump voltage exceeds the LVD set point.

The LVD set points are automatically adjusted for each system when one of the first 4 dip-switches are set to the proper number of panels wired in series. The voltage at which each system disconnects is listed in the charts in section 3.5 under LVD Set Point.

3.5 Adjustment Procedures

The PCB series controllers have several adjustment features. One feature includes system configuration adjustments, which are user selectable by a six position DIP-switch located on the face of the controller. Also included are four pre-adjusted solar panel selections, remote switch logic and low water level cut-off.

The pre-adjusted DC source selection allows the user to choose the nominal input voltage and basic source configuration. These consist of four pre-adjusted voltage settings. The first four switches on the DIP-switch are used for these selections. For proper controller operation, only one of these first four switches should be in the ON position at one time. Please refer to the charts below for the switch position identification and setting options.

PCB-90BT-M1

Switch	Series		Panel Voltage		LVD	
Number	Panels	Description	Setpoint	Notes	Set Point	
1	3	45 Volt Panel Direct	40 Volts	1	13.5	
2	4	60 Volt Panel Direct	53 Volts	1	18	
3	5	75 Volt Panel Direct	67 Volts	1	22	
4	6	90 Volt Panel Direct	80 Volts	1	26	
			Function			
5		Remote Switch Logic	NO/NC	2		
6		Low Water Out-Off	Off/On	3		

PCB-120BT-M1

Switch	Series		Panel Voltage		LVD
Number	Panels	Description	<u>Setpoint</u>	Notes	Set Point
1	6	90 Volt Panel Direct	80 Volts	1	26
2	7	105 Volt Panel Direct	93 Volts	1	31
3	8	120 Volt Panel Direct	107 Volts	1	36
4	9	135 Volt Panel Direct	120 Volts	1	40
			Function		
5		Remote Switch Logic	NO/NC	2	
6		Low Water Out-Off	Off/On	3	

PCB-180BT-M1

Switch	Series		Panel Voltage		LVD
Number	Panels	Description	Setpoint	Notes	Set Point
1	9	135 Volt Panel Direct	120 Volts	1	40
2	10	150 Volt Panel Direct	133 Volts	1	45
3	11	165 Volt Panel Direct	147 Volts	1	49
4	12	180 Volt Panel Direct	160 Volts	1	54
			Function		
5		Remote Switch Logic	NO/NC	2	
6		Low Water Cut-Off	Off/On	3	

NOTES:

- The Panel Voltage Set-Point is solar module input constant voltage regulation held approximately at it's maximum power point. These voltages will work with most standard solar modules available in the marketplace today.
- 2. With switch number 5 in the OFF position, the controller is configured to accommodate a Normally Open (N.O.) float switch; float switch open = water tank low = pump water or float switch closed = water tank high = shut off pump. With switch number 5 in the ON position, the controller is configured to accommodate a Normally Closed (N.C.) float switch; float switch closed = water tank low = pump water or float switch open = water tank high = shut off pump.
- 3. To activate the Low Water Cut-Off feature, turn switch number 6 on. When the pump runs dry, the LWC feature will turn the pump off and an amber indicator light will flash. The pump will remain off for approximately 25 to 30 minutes and then it will start again. This cycle will continue any time the pump runs dry. There is a Low Water Cut-Off sensitivity adjusting pot on the front of the controller. To test this circuit you can pull the pump out of the water to verify that the pump turns off. If it doesn't, with the pump still out of the water, you can turn the adjusting screw slowly to the right until the pump shuts down. You can reset the circuit by turning the On/Off switch off and on again.

Output Voltage Adjustment

The purpose of this procedure is to adjust the output voltage of the controller to reduce the water flow of the pump. Typically this is only used for low producing wells where the pump output is matched to the production rate of the well.

If tests have shown the pump will out produce the well then the controller "Output Voltage Adjustment" feature can be used to match the flow rate of the pump to the production of the well.

- With the system installed and controller properly configured, allow the pump to run at full voltage at mid-day until the well runs dry and the pump starts surging.
- 2. Slowly turn the "Output Voltage" trimmer pot located on the face of the controller counter clockwise until the pump stops surging. This is the point where the pump flow rate equals the well production. This process will probably take a few attempts to "balance" the system for optimum water production. If maximum water is not a critical issue you may want to reduce the pump flow rate an additional 5% to 10% to insure the pump will not run dry. However if the Low Water Cutoff circuit is enabled, switch number 6, the pump will still be protected if the pump runs dry. (NOTE: The trimmer is a 15-turn adjustment pot. It usually takes many complete turns in a counter-clockwise direction before you will notice any change in output or output voltage).

LWC Sensitivity Adjustment

The purpose of this procedure is to adjust the Low Water Cut-Off circuit to turn the pump off as the pump breaks suction. (Pump runs dry). This feature is only used for low producing wells where the pump output exceeds the production rate of the well.

The LWC should be tested to verify that it is adjusted properly. The best way to test it is by pulling the pump or the pump suction line out of the water while the pump is operating. If the pump does not turn off within 5 seconds then the sensitivity must be adjusted. **CAUTION:** Do not run the pump dry very long or damage to the pump could occur. (Please note that if the pump is at very low power, it may take up to 15 seconds for the pump to turn off. This procedure should be performed at full or close to full power).

This adjustment procedure can be done with the pump outside the well in a bucket of water before installation or with the pump installed in the well. Either way will work but it is usually easier to use the bucket method.

LWC Adjustment Procedures

- 1. The system should be wired and the pump or suction pipe set slightly below the water level.
- Turn the "LWC" trim pot counter-clockwise until it stops. (Less than a turn).
- 3. Turn number 6 dip switch on.
- 4. With the pump turned on and pumping water, pull the pump or suction pipe out of the water. (CAUTION: Do not let the pump run dry for more than 20 to 30 seconds or damage could occur. Consult the pump manufacturer for specific pump dry run recommendations).
- Very slowly turn the "LWC" trim pot clockwise until the pump turns off. This is now the set-point where the pump will turn off.
- 6. To verify your adjustment, put the pump back in the water and turn the switch off and back on again to reset the controller. If the adjustment is correct the pump will remain running while pumping water and if pulled out of the water it should turn off.
- Once the pump turns off, it will not turn on again for approximately 25 to 30 minutes, unless manually reset by turning the main toggle switch off for 3 seconds and then back on.

4.0 Troubleshooting

PUMP DOES NOT RUN

- 1. Check wiring diagram for proper connections. Confirm all electrical terminations are tight and secure.
- Check for proper voltage selector switch settings on your DC source input. If the incoming voltage is less than the set point voltage, the controller will not turn on.
- 3. Check for proper controller input and output with a DC volt-meter. A quick look at the LED indicator lights will verify power coming from the DC source supply going to the controller (red), power going from the controller to the pump (green). If any of the four amber lights are flashing the pump will be turned off. They are over-current shut down, low water cut-off, low voltage disconnect or remote switch cut-off.
- 4. If the red light is on and the green and amber lights are not, make sure the system on/off switch is on, disconnect the remote switch wires and turn switch 5 off. If the green light is still not on, disconnect the pump wires, LD- and LD+. If the green light does not turn on then check voltage on LD- and LD+ with a volt-meter to confirm no output voltage. If there is still no output voltage the controller is faulty and must be sent back to the factory for repair. If the green light turns on and the output voltage is now equal to the input voltage, there is short circuit either in the wiring or the motor.
- 5. For additional pump test, if the red light is on, connect a jumper wire across terminals PV+ and LD+. This will bypass the controller and allow the pump to run directly from the DC source. This step will confirm pump operation. If the DC source is a solar array, the test must be conducted when full sunlight is available for a valid test.

RED AND GREEN LIGHTS ARE ON, AMBER LIGHTS ARE OFF AND THE PUMP DOES NOT RUN

To verify power coming out of the controller, connect a DC voltmeter across LD+ and LD-. If the open circuit voltage is measured then:

- 1. Check the splice above the pump for proper connections.
- 2. Check for broken wire leading to the pump.

NO VOLTAGE AT THE LD+ AND LD- TERMINALS

- 1. Make sure the system ON/OFF switch is ON.
- 2. Make sure none of the amber lights are flashing.
- 3. Check to see if the float switch, if used, is functioning properly.
- Check the controller for proper programming and adjustment. If the voltage setting on the controller is higher than the incoming voltage, the controller will not turn on. (See controller adjustment section)

Note: To bypass all remote switching circuits, disconnect all wires from the sensor interface terminal block in the controller housing (the small terminal block) and switch program switches 5 & 6 to the OFF position.

EXCESSIVE CURRENT DRAW (More than the rating of the pump, but less than the rating of the controller)

- 1. Check wiring diagram for proper connection.
- 2. Check for skinned wires or faulty underwater splice.
- Check for locked motor armature. With the pump out of the well, remove the pump end from the motor, bypass the controller and connect power directly to the motor leads. If the motor still does not run or runs while pulling more than 3 amps, the motor must be repaired. Contact the SunPumps Factory.

5.0 Technical Specifications

Controller

Model	Max Output Voltage	Max Input Voltage	Max Current (Amps)	Max Surge Current
PCA-90BT-N	11 90	140	8	14
PCA-120BT-	M1 120	200	8	14
PCA-180BT-	M1 180	280	10	16

Maximum ambient temperature is 110 F.

Controller Dimensions and Weight

	Wid	lth	H	eight	Leng	gth	Weig	ght
Model	Inches	cm	Inches	s cm	Inches	cm	Pounds	kg
PCB-XXXBT-M1	6.5	16.4	3.9	9.9	8.3	21	7.2	3.24

Warranty Statement

PCB Series Pump Controllers Limited Warranty – Twelve Months

SunPumps warrants to the original consumer that its products shall be free from defects in material and workmanship under normal applications and service conditions for a period of twelve (12) months after the original date of purchase, but not to exceed eighteen (18) months from the date of manufacture.

At its option, SunPumps will repair or replace any SunPumps product, which has failed due to a defect in material or workmanship during this warranty period This limited warranty shall not apply if the SunPumps product has been damaged by unreasonable use, accident, negligence, mishandling, misapplication, alteration, modification, abrasion (sand damage to pump), shipping, service or modification by anyone (other than by SunPumps), or failure which are caused by products not manufactured by SunPumps, or should the products serial number being altered, or by damage that is attributable to an act of God, or by any other causes unrelated to defective materials or workmanship. Any disassembly whatsoever of the product voids all warranty.

The original purchaser MUST complete and send in the warranty registration card, with the pump serial number and the controller serial number for warranty validation. No warranty performance will be rendered without a valid warranty card on file at the SunPumps factory.

There are no express warranties except as listed above. SunPumps shall have no responsibility for damage to property, persons, animals, or other loss or injury resulting from the use of a SunPumps product. The purchaser's exclusive remedy shall be only as stated herein. This warranty is in lieu of all other warranties expressed or implied.

Except for the warranty that the products are made in accordance with the specifications therefore supplied or agreed to by customer, SunPumps makes no warranty expressed or implied, and any implied warranty of merchantability or fitness for a particular purpose which exceeds the forging warranty is hereby disclaimed by SunPumps and excluded from any agreement made by acceptance of any order pursuant to this quotation.

UNDER NO CIRCUMSTANCES WILL SUNPUMPS BE LIABLE FOR ANY CONSEQUENTIAL OR INCIDENTAL DAMAGES, LOSS OR EXPENSE ARISING IN CONNECTION WITH THE USE OF OR THE INABILITY TO USE ITS GOODS FOR ANY PURPOSE WHATSOEVER. ALL PRODUCTS ARE SOLD AS IS WITH ALL FAULTS. SUNPUMPS MAXIMUM LIABILITY SHALL NOT IN ANY CASE EXCEED THE PURCHASE PRICE FOR THE GOODS CLAIMED TO BE DEFECTIVE OR UNSUITABLE.

SunPumps is not responsible for labor, transportation, and related costs incurred by the customer to make allegedly defective equipment available to the factory for inspection re-installation, lost profits or costs caused by interruption of service. SunPumps is not responsible for loss or damage to products, owned by customer and located on SunPumps premises, caused by fire or other casualties beyond SunPumps control.

This equipment in not to be used for anything other than it's intended purpose as stated in this manual.

For future reference, please list your system data before installing the pump.

Installation Date	Static Water Level	
Pump Model	Pumping Level	
Pump Serial No.	Additional Vertical Lift	
Controller Model	Pump Depth	
Controller Serial No.	Total Dynamic Head	
Warranty Card No.	Well Depth	



CATALOG ARV

New! Series "ARV" Thermoplastic Air Release Valve

Self-Guided Poppet Assures Dependable, Repetitive Operation

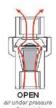


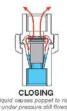
Features:

- · Safety: Allows safe expulsion of unwanted air in piping system.
- · Dependability: Unique self-guided poppet assures minimal emission of system liquid prior to sealing.
- · Convenience: Union simplifies valve inspection/removal with minimum piping breakdown.
- . Minimum Closing Pressure: Closes at 0 PSI, as long as liquid is present. Valve closes as liquid rises, after virtually all unwanted air is forced out. Seals bubble-tight at system pressures as low as 10 psi (EPDM seals).
- · Cost Efficient: Designed to improve system performance and competitively priced.
- · Superior Design Poppet seals more reliable than ball design; does not deform under pressure like a hollow ball.
- · Corrosion Resistant: Top quality thermoplastics and elastomers resist chemical attack and protect system purity. No metal components in Series ARV.

Description

Series ARV is a normally-open valve. Until your system is pressurized, the valve is simply open, and air is present. As pressure builds within the system, unwanted air is forced to the highest point in the system, i.e., the normally-open air release valve. When pressure within the system exceeds atmospheric pressure, air is expelled. As liquid rises, the poppet becomes buoyant and eventually closes. (Note, minimum specific gravity of liquid must be .9 or higher). It is possible that trace amounts of air will remain in the system, depending on the rapidity with which the valve closes. It is also likely that some trace amounts of process liquid will be emitted. At system pressure of 10 PSI (with EPDM elastomer), the poppet will seal bubble-tight against the orifice. When pressure and liquid level drop, the valve will automatically re-open.*







The poppet is guided by a series of thermoplastic ribs within the valve. The poppet is a unique design by Plast-O-Matic Valves, Inc. that is engineered to provide a balance of buoyancy and sealability. This balanced poppet is the key to the superior performance of this valve: it is dense enough to permit maximum emission of unwanted system air, yet buoyant enough to affect a

PLAST- @ - MATIC 1384 Pompton Avenue, Cedar Grove, New Jersey 07009 (973) 256-3000 • Fax (973) 256-4745 www.plastomatic.com • info@plastomatic.com

December 9, 2011

SERIES ARV - THERMOPLASTIC AIR RELEASE VALVE

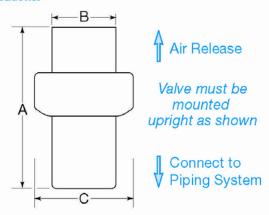
quick seal and minimize emission of the process liquid. Historically, competitive air release valves have used ball-type sealing mechanisms that either seal too rapidly or allow excessive liquid to escape.

*Note: Although Series ARV is a normally-open valve, it should not be used in lieu of a vacuum breaker due to safety considerations, such as continual emission of corrosive vapors.

Installation:

Series ARV should be installed at the highest possible point in a piping system or vessel, and it must be oriented upright. In most cases, residual liquid and/or vapor in the valve may be expelled from the outlet port just prior to valve shut-off. Therefore, it is recommended to pipe the outlet port to a safe area for hazardous liquids, or use a standpipe for non-hazardous liquids.

Dimensions and Specifications:



		SERIES	ARV - DIN	IENSIONS AN	ND MODEL I	NUMBERS	
PIPE SIZE NPT	in.	A I mm	in.	B I mm	in.	C I mm	MODEL NUMBER
1/2"	5.3	130	1.9	48	2.8	72	ARV050EPT-PV
3/4"	5.3	130	1.9	48	2.8	72	ARV075EPT-PV
1"	4.7	120	1.9	48	2.8	72	ARV100EPT-PV

Available in Geon® PVC and Corzan® CPVC

ARV(series) 050 (size) EP (material) T (threaded) - PV (body material). Part numbers shown are EPDM seals with PVC bodies. AHV(series) USU (size) EP (material) 1 (tirreaded) - FV (body material). Fall findings shown are EP bit seas with two terms are based on the 1" valve; the 1/2" and 3/4" sizes use reducing bushings.

For Viton seals, change "EP" to "V" (ARV050VT-PV).

For Buna-N seals, change "V" to "B" (ARV050BT-PV).

For Corzan CPVC body, change "-PV" to "-CP" (ARV050VT-CP).

Standard connections are threaded. For socket connection, change "T" to "S" after seal material (ARV050EPS-PV).

- For spigot or other connection types, consult factory.

ADDITIONAL SPECIFICATIONS								
Pressure required for bubble-tight seal EPDM Elastomer: 10 PSI Viton Elastomer 15-20 PSI								
Pressure Rating at 75°F (24°C)	150	PSI						
Maximum Air Flow Rate**	Air Flow Rate: 8 SCFM	Liquid Flow Rate: 60 GPM***						

^{**} Note that excess of 8 SCFM airflow out of the valve will have sufficient force to lift and close the poppet, even though more air may be in the system. Liquid pumping into the system at flow rate exceeding 60 GPM (225 LPM) will create air flow in excess of 8 SCFM.

For flow rates greater than 60 GPM use multiple units.



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www.plastomatic.com • info@plastomatic.com



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Notes	11

Pure Water Treatment, Inc.

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- 1) Flow rate control
- 2) Large 1 1/2" in and out flow
- 3) Drain to release pressure or clean unit
- 4) Clearly labeled flow direction
- 5) Easy replacement of o-ring on lid

Figure A

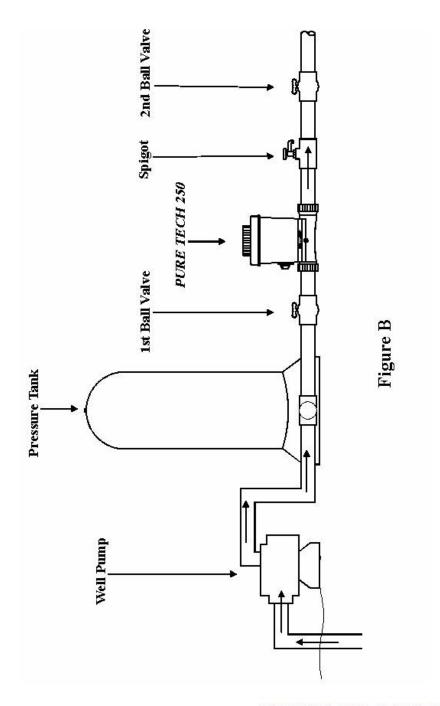
- This installation guide gives a step by step, start to finish procedure for installing the PURE TECH 250 system.
- Your new system from the PURE WATER TREATMENT, INC. comes with an
 owner/service manual, which, is enclosed along with these instructions, and will help
 explain all necessary details required for successful installation and operation of your
 system. Please refer to these instructions and the service manual supplied with your
 system during installation.
- All steps provided herein are for typical installations only. If you require additional
 plumbing to install your system, simply contact a person who is knowledgeable in
 residential plumbing or have a local plumbing company help you install, or install the
 system for you.
- There is a bit of "over-kill" in our instructions, but please bear with us as we want to
 ensure that you, our customer, fully understand the instructions and are completely
 satisfied with your installation!
- We recommend that you take a few minutes and look at the layout to help you better understand your new water system. Take your time and carefully read the instructions.
- Get all of your plumbing parts together before you start, and have an assistant help you, if possible. Typical installation should take no more than a couple of hours.

Tools and Materials needed

- 1) Pipe Cutters
- 2) PVC Glue
- 3) Two 1 1/2" x 1 or 1 1/2" x 3/4" bushings whichever your plumbing requires.
- Two Ball Valves to cut off water supply.
- 5) One spigot to release pressure from system. (see figure b)
- 6) One jug of chlorine pellets (see page 8 for list of manufacturers)

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- · First turn water supply off.
- Make a cut in your line AFTER your pressure tank.
- Install first ball valve AFTER your pressure tank.
- Teflon tape threads on each end of PURE TECH 250.
- Place rubber o-ring seal in notch then place adaptation cap and screw down tightly.
 Securely tighten, but be careful not to strip the threads.
- Install required plumbing bushings in PURE TECH 250 that matches your pipe size.
- Install PURE TECH 250 after ball valve. With this installed you will be able to cut
 the water supply off later to add chlorine.
- Install spigot after the PURE TECH 250. This will allow you to de-pressurize the unit.
- Install second ball valve after spigot. This will allow you to stop the water from back feeding from any equipment.
- Connect back into your line to your other equipment. You will need to put a carbon
 filter after this system if you do not have any other equipment. Please call us for current pricing on well equipment.
- · Turn water back on and check for leaks. (DO NOT INSTALL CHLORINE YET)

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December 9, 2011

- 1. After checking that you have no leaks, you are now ready to add chlorine.
- 2. Turn the first and second ball valves to the off position.
- 3. Open spigot to relieve pressure from PURE TECH 250 Chlorine Pot Feeder.
- 4. Open Pot Feeder and close spigot.
- 5. Add Chlorine Pellets to Pot Feeder.

(SEE PAGE 8 FOR LIST OF MANUFACTURERS)

1. Close Pot Feeder turn ball valve back to the open position.

Chlorine Dial Settings

Problem	Setting
1 ppm sulfur	1st notch
2-3 ppm sulfur	2nd notch
4-6 ppm sulfur	3rd notch
.5-1 ppm iron	1st notch
1.5-2 ppm iron	2nd notch
2.5-3 ppm iron	3rd notch
3.5-up ppm iron	4th notch

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Please contact one of these companies to find a dealer near you.

Company	D1 NL 1	Product
Company	Phone Number	Product
Company	I HOLE I UHILOCI	TTOULUCE

OSMONICS 1-800-848-1750 Well Pro Pellets

Krudico 1-800-211-1369 Pell-Chlor

Better Water Industries 1-507-247-5929 Chlorine Pellets

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- 1. Turn the first and second ball valves to the off position.
- 2. Open spigot to relieve pressure from PURE TECH 250 Chlorine Pot Feeder.
- 3. Open Pot Feeder and close spigot.
- 4. Carefully clean the feeder tube with a pipe cleaner.
- 5. Add Chlorine Pellets to Pot Feeder.

(SEE PAGE 8 FOR LIST OF MANUFACTURERS)

WARNING!! Do not mix brands of chlorine. Mixing brands may cause an explosion.

- 6. Close Pot Feeder turn ball valve back to the open position.
- 7. You will need to add chlorine to the system once every 2 to 3 months.
- 8. If the *PURE TECH 250* clogs, you may need to clean it. To do so, Use a 5 gallon bucket and mix 3 parts water with 1 part Muriatic acid.
- Soak JUST the PURE TECH 250 for 15 minutes. DO NOT put lid or o-rings in the solution.
- 10. Thoroughly rinse PURE TECH 250 in clean water.
- Install the PURE TECH 250 back in line and let run for 20 minutes before adding chlorine.

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Pure Water 10 YEAR WARRANTY Treatment, Inc. FOR RESIDENTIAL APPLICATIONS

Congratulations on the purchase of your *PURE TECH Water System. PURE WATER TREATMENT, INC.* warrants its products to be free from defects in material and workmanship according to the following terms and conditions:

What is Covered?

The PURE TECH 250 series.
 10 YEARS ON PARTS

Who is Covered?

This product warranty is transferable to a subsequent owner. The only requirement is that the system must remain at the site of original installation.

Extension of Warranty to a Subsequent Installa-

The ORIGINAL OWNER may move the system to another location. The influent water quality at the subsequent location MUST, however, be within your system's operating specifications. Please contact a local authorized PURE TECH dealer prior to installation at another location.

Registration and Service

To place your system under warranty, your authorized PURE TECH dealer should complete the owner's registration form and return one copy to: PURE WATER TREATMENT, INC., P.O. Box 730486, Ormond Bch, FL 32173-0486, within 30 days of the installation date. For service under this warranty, you should contact the dealer. Retain a copy of this warranty for reference if service is necessary.

Limits on this Warranty

Your system must be sold to you by an authorized PURE TECH dealer in order to receive coverage under this warranty. Additionally, this warranty does not cover products installed for commercial, industrial, institutional or multifamily applications.

The design of the overall treatment system and performance of your system is related to the chemistry of the water being treated; therefore, This warranty is limited to the equipment manufactured and distributed by PURE WATER TREATMENT, INC.

This Warranty does not include damage to your system due to:

- Abuse, misuse or neglect
- Excessive pressure (over 100 psi for a PURE TECH 1000 R.O. system, or 125 psi for all other PURE TECH systems)
- Excessive water temperature (over 100° for a PURE TECH 1000 R.O. system, or 120° for all other PURE TECH systems)
- Freezing, alterations or misapplication
- A change in the influent water characteristics
 Your equipment must be installed and operated in
 accordance with your owners manual's recommendations
 and applicable state and local codes.

No Other Warranties

There is no other express warranty. Implied warranties including any warranty of merchantability or fitness for a particular purpose, are limited to the duration of this warranty and are excluded to the extent permitted by law. There are no warranties other than those contained herein. In no event shall the company be liable for indirect, special or consequential damages in connection with the use of the system.

Modification of the Warranty

PURE WATER TREATMENT, INC. does not authorize any other person to assume for PURE WATER TREATMENT, INC. any other liability in connection with this product.

The dealer has no authority to make any representations on behalf of PURE WATER TREATMENT, INC. or to modify the terms of this warranty in any way.

Pure Water Treatment, Inc.

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10.8 Construction Instructions by Recommendation

10.81 Spring Box Construction Instructions

Spring Box Construction Instructions

Introduction

The following is a set of detailed step by step instructions on the construction of a spring box, such as the ones proposed on Marco's system and on the two springs near the Health Clinic.

Phase One- Ordering and Collecting Materials

This is the first thing that must be done in order to build one of these spring boxes. For this project the community will need to collect 15 cubic feet of sand and 30 cubic feet of gravel. During this collection phase other materials should be ordered as well. These materials that will probably need to be ordered are plywood sheets for form boards or equivalent lumber, 100 feet of #3 rebar, 1.5" PVC pipe (roughly 5 ft), 2-1.5" PVC elbows, and 2-1.5" PVC stop valves.

Because of the remote location of the candela community, plan on spending a significant amount of time moving the materials into the community once they are delivered.

Phase Two- Site Preparation

Once the materials have been brought to the community, the site of the spring box should be prepared for construction. First, the area immediately surrounding the spring and leading to the spring should be cleared of all obstructing plant life. Second, in the sites of the existing spring boxes, the old spring box should be disconnected from the current water line and demolished. After this is finished, and at the site without an existing spring box the team should move on to excavating the spring location. To do this the dirt around the spring should be removed deep enough that the bedrock behind the spring is exposed. It should also be removed wide enough that the entire width where water is running is exposed.

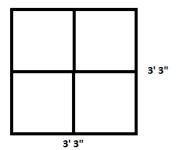
Once the site is excavated it is important to temporarily diver the water flow away from where the concrete spring box is to be constructed. This will allow for better pouring of the concrete and help prevent the flow of water underneath the spring box.

Phase Three- Preparation for Construction

During this phase formwork should be prepared for the base of the box. This base should be 3.5' by 3.5' in dimensions, at least 4" thick, and be positioned as close to the spring as possible and the forms should be built so that the top of the concrete base will be roughly level, and the bottom of the concrete base will match the existing bedrock terrain. A web of rebar should be placed into the form and positioned so that there is a square of rebar following the edge of the form with at least 1.5" of space

between the rebar and the form board. This web shall also be at least 1.5" from the top of the form boards and 1.5" form the rock beneath the form. Thin wire ties can be used to tie the rebar together and to prop or carry it off the ground and away from the form board. The interior of the web should have a rebar cross bar running in either direction through the middle of the form. See Image below for a more detailed view of the rebar design.

Spring Box Rebar Detail- Figure 1.1



Running vertically there should also be a 3'3" segment of #3 rebar at each corner and in the middle of each edge of the base rebar webbing. When completed the reinforcing in the box walls will look identical to the image above, but the bottom segment will be shared with the edge of the rebar in the base of the spring box. The vertical rebar segments for the walls should be put in place before the base concrete is poured but the horizontal segments can be added later if it would make it easier to pour the concrete in the base slab.

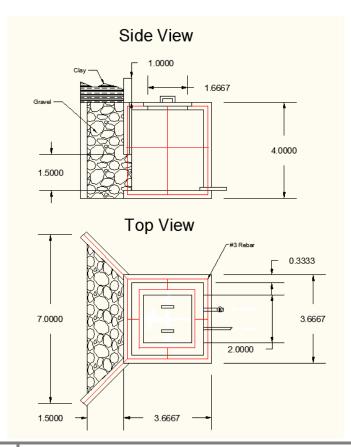
Phase Four - Spring Box Construction

Once the form work and the rebar is in place the base of the spring box should be formed. To do this, a concrete mix should be prepared using Portland cement, sand, gravel, and water. The ingredients should be mixed using a ratio by volume of one part Portland cement for every two parts sand and four parts gravel. Water should be added slowly to this mixture and mixed thoroughly until the mix does not show signs of dry Portland cement and has a stiff but slightly slushy feel to it. If there is water pooling on top of the concrete mixture's surface too much water has been added. Once prepared the concrete should be placed inside the form until it reaches the top of the form boards. Once the concrete has been put in place the edges of the form should be hit lightly with hammers to vibrate the concrete. The top of the concrete may also be hit with the flat edge of a trowel to ensure that it is packed in place. Once this has been done the top surface should be smoothed with the trowel and any excess concrete discarded.

After the base of the form has been completed form work should be put in place for the wall sections, including the collection walls. The inside of these forms should be coated with a grease lubricant -

vegetable based greases such as Crisco work well and are inexpensive. Two holes should be cut into the bottom of the front wall form and PVC pipe inserted through the inner and outer forms for connection to the main pipeline and attachment of a clean out valve. Once the wall forms and rebar are securely in place, more concrete can be poured into them until it is halfway up the wall form. At this point spare rebar sections or a stick can be used to compact the concrete with a stabbing motion. Several stabs should be used in each place to ensure the concrete is packed well. Hammers may also be used to vibrate the forms to help in the settling of the concrete. Once this is completed, more concrete may be poured and the process can be repeated to compact the upper half of the concrete wall sections. After vibration the forms should be left alone to cure until hardened.

Once hardened the form for the roof can be put in place. This form should be mad of a flat sheet of wood for the bottom of the form, surrounded by 4 board sections as walls for the cover form. These wall boards should extend four inches above the tops of the wall forms and the bottom sheet should match the tops of the wall forms, and fit snugly inside of the four walls with the interior wall forms removed. This bottom sheet should be supported with boards at each corner and in the center with boards planted against the top of the concrete base pad. On top of the bottom sheet there should be a smaller box created out of wood to leave an open square in the cover to allow for a lid to be placed in this space. Rebar should be tied in a square around this opening, leaving 1.5" of space between the rebar and the opening form board. For detailed images see the following drawing.



"To improve the health and sanitation of the Candela community through sustainabl water system design."

Once the cover form work and steel is in place concrete should be poured and vibrated using hammers until it reaches 4"s of thickness at the top of the exterior form boards. At this point it should be smoothed and left alone for several day until significantly hardened. Five days to one week should be long enough for this to happen. During this time a lid can be poured using the dimensions of the current opening. Once the strengthening process had occurred the formwork should be removed and the lid put in place. Gravel should be poured at the opening in the back of the form, with the level of the gravel reaching at least to the top and slightly beyond the opening at the bottom of the box. On top of this gravel clay should be packed to prevent water from seeping in without passing though the gravel first. Once these two steps are finished, the water can be directed back toward the spring box and dirt can be put back in place to fill in around it. A rainwater diversion trench can be created slightly uphill (at least three feet) to collect and divert surface water that might enter the box without passing through the ground. This trench can be lined with any leftover concrete to make it more permanent. A protection fence can also be put in place to keep animals out of the area, though some sites do not require this if animal access is not a problem.

Water Storage Tank Construction Instructions -

Introduction

The following is a more detailed guide to the construction of the tanks proposed on Marco's system and system three. Design drawings and diagrams included in the appendices of this report should be used as a reference to support these instructions.

Phase One- Ordering and Collecting Materials and Tools

The first step to completing this project will be the acquisition of the materials and tools required for construction. The materials and tools required for each tank are as follows.

Materials
Portland Cement –
Sand-
Gravel-
#3 Rebar-
#4 Rebar-
Form Boards (Plywood or 1"x12")-
Water-
Nails-
1 ½ " PVC Pipe- 20 ft
1 ½ " PVC Stop Valves- 2
Corrosion Resistant Pipe Screen – 1 SF
1 ½ " PVC Elbows - 5
PVC Connection Glue-1 Canister

Tools

Hydraulic Bolt Cutters (Capable of Cutting #4 Rebar) - 1

Hammers- 2

Wood Saws- 2

Machetes- 2

Concrete Trowels- 2

Shovels- 2

Wheelbarrows- 2

20 L Buckets- 10

Air Bubble Level- 1

Measuring Tape 30 ft.- 1

Rebar Bender or Other Means- 1

The tools and materials described here should be readily available, save for the hydraulic bolt cutter. This has been the recommended means for repetitive cutting of rebar without the use of torches in isolated regions. The movement of wheelbarrows to the site may also present a challenge if they are not already available, though a horse should be able to transport these items relatively easily.

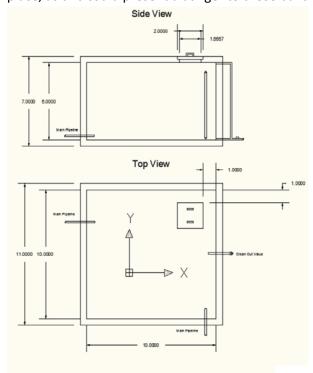
Gathering and ordering these materials and tools should begin significantly before the anticipated start date of construction, as any ordered materials will take some time to arrive. It is also expected that the community has the ability to collect the required sand and gravel for the project. The gravel collected should be sifted through a 3/8" and 1" sieve to ensure that the aggregate dimensions are within that range. Sand should be similarly sifted through a #20 sieve to ensure that it is of the recommended size for concrete construction.

Phase Two- Site Preparation

For each of these tanks a suitable site will need to be selected. For the tank on Marco's system this site should be slightly downhill from the spring box, but still at a high enough elevation to supply pressure to the system below it. The closer to the spring box that this tank can be constructed the better in this situation. Due to steep terrain changes immediately surrounding the spring area, it may be necessary to move the tank further away to find a location that can be excavated to provide for a level

foundation for the tank. For the tank to be built on system three the tank should be located at a site on top of the hill near the houses, wherever a level foundation can be built.

Once the site has been selected the surrounding area should be cleared of vegetation that might prove to be an obstruction to the construction on the tank. The scrap brush from this clearing process should be moved off site to prevent snakes from turning the downed vegetation into a home or hiding place, as this could present a danger to those building the tank.



Once the site is cleared and easily accessible, excavations for the foundation can commence. The layout of the tank should be chosen and the corners marked with stakes. The proposed foundation grade should be excavated and compacted until a solid level surface has been achieved.

Phase Three- Preparation for Construction

Once the site has been prepared, the initial form work and rebar can be put in place to prepare for the pouring of the foundation slab. The form for the foundation slab should be made of a simple 6" tall by 1" thick board, running the length of the edges of the foundation slab (11'x11'). Rebar for this base should be tied together and supported off the ground using rebar wire tires. The bar should be located roughly 1.5 inches off of the ground and should extend toward the edges of the base form, but should not ever get closer than 1.5 inches from the edge. A edge runner should create a loop around the edges of the form, being tied to the cross bars running vertically and horizontally in the base slab. Connecting L-shaped bars should also be included that will be bent to 90 degrees so that approximately 18 inches can be placed in the base slab with another 18 inches extending into the wall slabs. These should be placed wherever a vertical or horizontal bar is present. (Refer to the rebar diagram below for a visual image.)

Phase Four- Pouring the Foundation

Once the form work and rebar is in place for the foundation slab, concrete can be mixed to pour into the form. As the amount of concrete that can be mixed at one time will be limited, the mixing and pouring should be coordinated so that the mixing and pouring occurs as fast as possible. This will aid in the uniformity of the curing process and reduce cracking in the concrete. As long as there is not long delays between one batch of concrete and the next it is unlikely that this will be a problem.

To mix the concrete, one part Portland cement should be mixed with two parts sand, and four parts course aggregate. Water should be added to this mixture slowly while mixing thoroughly until none of the Portland cement is dry, and the mix seems workable but not sloppy. If water quickly accumulates on the surface of the mixture then more aggregate, sand, and cement can be added until the water no longer remains.

Once the concrete has been prepared, it should be placed in the foundation form, working from one end of form to the other. When this is finished, the surface of the foundation can be smoothed by using a long board and scraping the top of the form in a saw like motion, starting at one end and working back to the other. This should eliminate most surface irregularities, and hand trowels can be used near the edges for a better finish if required. This concrete should be left for approximately two to three days until it has achieved significant strength. Once the concrete seems to be hardened (complete hardening will take approximately 28 days), the form work can be removed and the forms for the wall sections can be put in place.

Phase Five- Preparing for Wall Construction

After the foundation has hardened and the base forms are taken away, rebar can be put in place for the wall sections. This will require a #4 bar being placed every six inches running both horizontally and vertically. In addition to the horizontal and vertical rebar, an edge piece should be added to follow the perimeter of the edges of each wall section. This edge rebar should be kept back from the nearest form by at least 1 ½ "in all locations. Once the rebar is generally in place, wall form boards can be constructed on the outside and inside surfaces of the anticipated wall. These forms shall be constructed either out of available wood boards, or out of OSB or plywood if it is readily available at the site. Creating the forms out of the ply-board would be less labor intensive, but could prove to be more costly. These forms must fit snugly up against the existing foundation slab, and should be supported at the top and center with bracing. This manner of bracing is required as the concrete pour will create significant pressures on the form boards, which might fail if not properly connected and braced. Holes should be cut and PVC pipe placed passing through them for the tank supply, outlet, and clean out locations. In order to ensure that the rebar remains in the desired position, wire ties can be threaded through the form boards to tie the rebar in place in regards to the surrounding forms. Once the rebar and forms are in the locations they will need to be for construction, concrete can be mixed for pouring the walls.

This concrete mixture should be the same 1:2:4 mixture described earlier in these instructions. Once thoroughly mixed, the concrete can be poured into the top of the wall form, using gravity to help it settle to the bottom of the form. It should be noted however that simply letting gravity force the concrete to the bottom of the form will not eliminate an adequate amount of air trapped within the mixture, resulting in air pockets and leaks through cracks in the walls. In order to prevent these types of failures, the concrete shall be poured in layers, each not to exceed more than twelve inches in depth. As the concrete is being poured in circular layers around the perimeter of the tank, a second volunteer should follow the person pouring and use a piece of rebar to stab and agitate the concrete layers below. This stabbing action will help agitate the concrete to a point where it allows the release of air bubbles trapped in the concrete mixture. In addition to this, a third worker on the project should also follow the pouring team with a mallet or some hammer like object used to strike the outside of the form. By striking the form, vibrations are sent through the concrete mixture loosening even more air that is captured within the concrete mixture. However, it should be noted that care needs to be taken to not damage the formwork in this process as it will need to be reused on the other parts of the project.

As with the pouring of the base of the tank, L shaped rebar will need to be added at the top of the form to connect the walls to the cover of the tank, and also in the corners of the walls to connect each wall section with the other. These should be positioned that each part of the L extends roughly 18 inches into both the wall and cover concrete. Of course, at this stage in the construction only the wall section will be set in place, as the cover section will still need to have formwork put in place before pouring is possible.

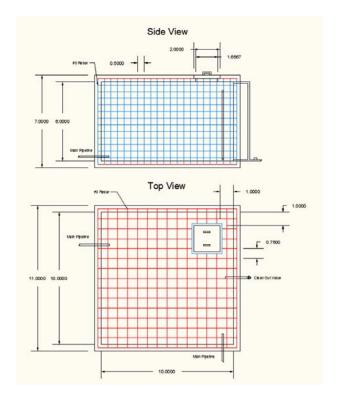
Once the pouring process is finished, the walls should be left alone for several days until hardening is complete. During this time, temporary support structures can be made on the interior of the tank that will be able to support the concrete cover forms until the cover has had time to cure. Once 3-4 days have passed, wall forms from the tank can be taken down.

Phase Six- Pouring the Tank Cover

Once the wall forms have been taken down and supports for the cover form have been put in place, boards can be used to create the formwork for pouring the cover. In order to do this there will need to be a solid base made out of boards to support the bottom of the cover. Edge forms should also be put in place around the anticipated perimeter of the tank cover. These should be at least six inches wide and will determine the thickness of the cover. Inside of the initial form, a square form- 2'x2' should be put in place out of the same 6" boards. This will serve as the opening to allow access to the cover.

During the construction of the cover form, rebar can be cut to length for the reinforcing of the cover. These will need to be #3 bars running in both directions, spaced every nine inches. There will also need to be some partial pieces cut to make a rebar square around the access door, and where it interferes with the longer bars running horizontally and vertically. As with other rebar placement, these

bars should be short enough that they do not come within 1.5 inches of the formwork on any side. A perimeter bar should also be tied into the ends of the vertical and horizontal bars around the entire outside of the perimeter of the cover.



After the form and rebar are in place, concrete can be poured into the cover form using the same technique as for the rest of the tank. Pouring should start at one side of the form and then move toward the opposite side by evenly placing a six inch concrete layer into the form. Placing a large pile of concrete in the center of the form is less effective and will place a large amount of weight on the supports, possibly causing them to fail. By placing the concrete evenly and moving from one side to another, air pockets in the concrete are also reduced. Once the pouring is complete, a board can be used to scrape excess concrete off of the top by running it along the top of the edge forms in a saw like motion. Hand trowels can be used for a smoother surface if requested, but this is not required. This form should be left in place until hardening is almost finished, at least fourteen days, as it will be placed into tension immediately after the form is released. During this time, a concrete lid for the access opening can be cast by making a 2' 4" x 2'4" square form. This form need not be more than four inches thick, but rebar or chicken wire should be placed into it in order to add strength. Once this is done and adequate time has passed, the forms and supports can be removed and the tank should be ready to use.

Pipeline Installation Instructions

Materials Required:

Shovels

Wheelbarrows (Preferable)

1 ½" PVC Pipe

1 1/2" PVC Joints

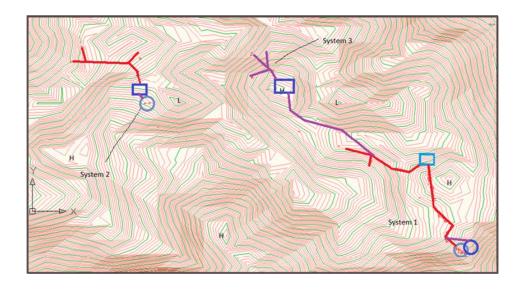
1 1/2" Elbows

PVC Joint Glue/Solvent

Air Release Valves

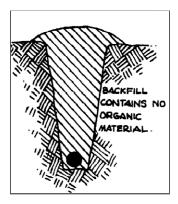
Phase One - Preparation for Pipe Installation

The first step to this project will be the clearing of the path where the proposed pipeline is to be installed. A rough map of this path is pictured below—



This path can be rerouted slightly as needed as long as the general path is maintained and drastic elevation or directional changes are not added. Though some of the pipe path follows the main trail from system one to system three, the pipe should not be installed directly in this path, but rather off to the side and out of the way of human and animal traffic. All obstructive vegetation will need to be removed to make way for the pipe. Downed brush should be kept away from this pathway as it can conceal snakes that could be dangerous during the construction process.

Once the path has been cleared, or during the clearing process if possible, a trench for the pipe should be excavated. This trench should be two feet deep and roughly one foot wide. The depth of this trench will help protect the pipe from being crushed by large animals or other risks. A cross section image of this type of trench is given below.



Phase Two-Pipe Installation

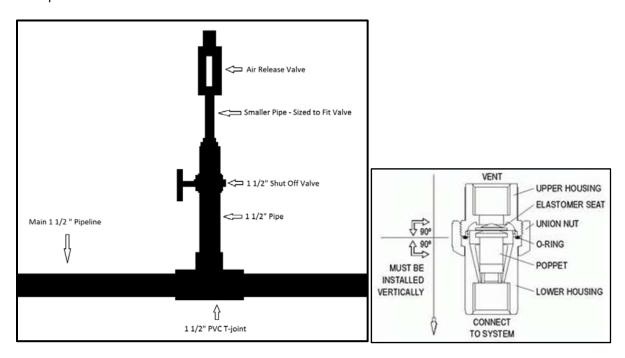
After the pathway for the pipe has been cleared, the new pipeline should be installed. This can be done either following the trench excavation team, or working in both directions from the middle of the trench, should the trench be completed before the pipe is ready to be installed. To install the pipe, the ends of the pipes that will form the connection should first be cleaned and primed with PVC primer. After this, a dry fit should be done by inserting the pipes into each other, or into a PVC joint where applicable. This is to ensure that the pipes are of the right lengths and in the right positions to be connected. Once this has been tested the PVC solvent glue should be applied to the primed areas on the ends of the PVC pipes. Once the PVC solvent has been applied evenly and smoothly on the entire surface, the pipes can be inserted into each other to form the connection. Once inserted the loose pipe should be given a ¼ " turn to ensure that the solvent is spread inside the connection, thus ensuring a tight seal. After a holding the pipe still for a period of roughly 30 seconds, the excess cement near the connection can be wiped away with a dry rag.

Once the pipeline has been put in place, the trench can be carefully refilled to protect the pipe from UV damage from the sun or other impact damage from the surrounding environment. This should be done quickly once it is certain that the pipe is installed correctly where it needs to be.

Additional Notes: Air Release Valves

It should also be noted that periodically the installation of air release valves along the pipeline will be required. These will need to be installed at the highpoints along the path of the pipe, to allow for air accumulating within the pipe to escape. To install these releases, a PVC T-joint will be used to create a branch for the valve installation. Once the T-joint is added to the pipeline, the pipe will need to be sized down to fit with the inlet on the air release valve. In between the T-joint and the air release valve a shut off valve will also need to be installed. These components should be able to be installed using the same PVC joint solvent methods described above. For a visual image of the installation of the air release valve branch refer to the image below.

Example of Air Release Valve Installation to Main Water Line



Air Release Valve Diagram http://www.thepipefittings.com

Installation of the Solar Pump System and Chlorinators

This construction of these aspects will depend greatly on the type of solar panels, pump, pump controller, and chlorinators that are selected. Our team provided recommendations on which items we felt would work best for these applications, but more available or financially feasible options may exist. Due to the technical nature of these components, detailed instructions are normally provided for installation via the manufacturers. These will be more detailed and accurate than what we are able to provide within the scope of this project. There are some things that must be taken into consideration with the construction of these parts of the project that are included here:

Notes Regarding Installation of Solar Pumping System-

- Panels should be located in an open location, near the pump location. This will maximize the amount of power produced by the panels, and minimize the amount of energy lost due to electrical transmission.
- 2. Panels should be located in a protected or fenced off area to protect them from livestock and or theft.
- 3. Locate panels on an elevated platform or rooftop to reduce the impact of shading, and to reduce the risk of damage due to falling branches.
- 4. Panels on platforms should have a means of access to allow for cleaning and maintenance.
- 5. The pump controller box and pump should be housed in protective structures to protect them from rain and damage.
- 6. Grounding should be included for the whole system to protect from electrical damage.
- 7. A rough outline of the basic wiring plan for this assembly is also included in this appendix.

Notes Regarding Chlorinator Installation

- 1. Chlorinators also should have a protective structure around them to help them last. This structure should still allow quick access for the refilling of the chlorinator.
- 2. Chlorinators should be installed with a shut off valve before them to allow for maintenance.

10.9 Project Cost Estimates

10.91 Project Estimate by Recommendation

Project Costs by Recommendation

Recommendation	Cost	Quantity	Recommendation Total
Construction of Spring Box (Each)-	260	3	780
Construction of Water Tank (Each) -	1580	2	3160
Installation of Solar Pumping System-	4212	1	4212
Installation of Waterline System One to Three-	2426	1	2426
Home Distribution Lines and Spigots-	909	1	909
Air Release Valve Additions	454	1	454
Addition of Water Chlorinators (Each)-	223	2	446
	Projec	t Total:	12387

10.92 Project Extended Estimate

		10/30/2011					
Description	Qty	Qty Unit	Labor Cost/Unit	Labor Cost	Material Cost/Unit	Material Cost	Total Cos
Existing Spring Box Improvement							
Portland Cement	671	LBS	0	0	0.0954	64	
Sand	14.2	CF	0	0	0	0	
Gravel	28.4		0				
Form Boards		SF	0			69	
Rebar #3		LFT	0			18	
1 1/2 IN PVC		LFT	0			3	
1 1/2 IN PVC Elbows		EACH	0			2	
1 1/2 IN PVC Stop Valve		EACH	0			24	
Labor	10	Laborer Days		70			_
Inflation Adjustment 4% Subtotal	_					SUB	
Subtotal	_					308	
Potential Spring Box Addition							
Portland Cement		LBS	0			64	
Sand	14.2		0				
Gravel	28.4		0			0	
Form Boards		SF	0			69	
Rebar #3		LFT	0			18	
1 1/2 IN PVC		LFT	0			3	
1 1/2 IN PVC Elbows		EACH	0	0		24	
1 1/2 PVC Stop Valves		EACH Laborer Days	-	70	12	24	
Labor	10	Laborer Days	<u> </u>	/0		_	
Inflation Adjustment 4% Subtotal	_					SUB	
Subtotui						308	
Marco's Spring Box Addition	-	<u> </u>	<u> </u>	<u> </u>	0.0050		
Portland Cement	672		0	-		64	
Sand	15.2	CF	0			0	
Gravel Form Boards	30.4	SF	0			69	
Rebar#3		LFT				18	
1 1/2 IN PVC		LFT	1 0			3	-
11/2 IN PVC Elbows		EACH		0		2	
11/2 In PCV Stop Valve	2	EACH		0	12	24	
Labor		Laborer Days	7	70	12	24	
Inflation Adjustment 4%	10	Laborer Days	<u> </u>	- "			
Subtotal						SUB	
Tanks- System Three and Marco's System	_						
Portland Cement	5473	LBS	0	0	0.0851	465.77	
Sand	116		0				
Gravel	233		0				
Form Boards	526	SF	0	0	0.75	394.5	
Rebar #4	1174	LFT	0	0	0.33333	391	
Rebar#3		LFT	0	0	0.17666	.52	
1 1/2 IN PVC		LFT	0			12	
1 1/2 IN PVC Elbows		EACH	0			5	
1 1/2 IN PVC Stop Valves		EACH	0		12	24	
Labor	25	Laborer Days	7	175			
Inflation Adjustment 4%							
Subtotal						SUB EA	1
	_						
Solar Pumping System							
Kyocera 135 Watt Panels	7	EACH	25	175	325	2275	
PCB 120 BT M1 Pump Controller Box		EACH	25		667	667	

SCB 10-185- Multi Stage Booster Pump	1	EACH	25	25	833	833	858
Wire #10 AWG	100	FT	0.1	10	0.2	20	30
Wire #12 AWG	100	FT	0.1	10	0.1	10	20
Inflation Adjustment 4%	i						162
Subtotal						SUB	4212
Pipeline to System Three							
PVC 1 1/2" Pipe	3500	FT	0	0	0.6	2100	2100
Pipe Joint Sealant	20	Bottles/EA	0	0	3.75	75	75
PVC 1 1/2 " Elbows	6	EACH	0	.0	2	12	12
PVC 1 1/2" Stop Valves	2	EACH	. 0	0	12	24	24
PVC 1 1/2" Couples	10	EACH	0	0	1	10	10
Labor	16	Laborer Days	7	112	0	0	112
Inflation Adjustment 4%							93
Subtotal						SUB	2426
Home Distribution Additions							
System 1 Additons							
3/4 " PCV Pipe	557	LF	0	0	0.3	167	167
3/4 " PVC Elbows	8	Each	0	0	0.8	6	.6
3/4" Spigots	4	Each	0	0	10	40	40
Labor	4	Laborer Days	7	28	0	0	28
Inflation Adjustment 4%							10
Subtotal							251
System 3 Additions							
1 1/2" PVC Pipe	879	LF		0	0.6	527	527
3/4" PVC Pipe	80	LF		0	0.3	24	24
3/4 " PVC Elbows	8	Each		0	0.8	6	6
3/4" Spigots	4	Each		0	10	40	40
labor	5	Laborer Days	7	35	0	0	35
Inflation Adjustment 4%							25
Subtotal							658
Pipeline Air Release Valves							
1 1/2" PVC Air Release Valves		Each		0	29	290	290
1 1/2" PVC Tee		Each		0	2	20	20
1 1/2" PVC Stop Valve		Each		0	12	120	120
Labor	1	Laborer Days	7	7	0	0	7
Inflation Adjustment 4%							17
Subtotal							454
Chlorinators							
PURE-TECH 250 1 1/2" Chlorinator	2	Each	25	50	190	380	430
Inflation Adjustment 4%							17
Subtotal							447
Grand Total All Items							12389

10.10 Construction Schedules by Recommendation

- 10.10.1 Schedule for the Renovation of Existing Spring Boxes -Pg. 140
- 10.10.2 Schedule for the Construction of New Spring Boxes-Pg. 141
- 10.10.3 Schedule for Water Tank Construction-Pg 142
- 10.10.4 Schedule for Solar Pump System Installation- Pg 143
- 10.10.5 Schedule for Pipeline Expansion Pg. 144