Alternative Analysis

Executive Summary	
Community:	Los Churuneles II
Country:	Guatemala
Chapter:	Kansas City Professional Chapter
Submittal Date:	01/19/2020
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REIC and other mentors:	Scott Struck, PhD (REIC), Stephen Collins (professional mentor)
Scope of Work for the project (50 words) [1]	This project includes the design of modifications to an existing water supply system in a community of 480 people with a naturally occurring spring as the source. The implementation of the project includes the installation of water distribution piping, a water storage tank, and a water treatment system.
Scope of Work for the analysis (100 words) [2]	This report will evaluate and select between (3) water treatment technologies, (3) storage tank designs, and (3) options for redesign of the water distribution system. Each alternative is designed to about 20%, including a quantity and cost estimate, to compare and select the most beneficial alternative. The water treatment technologies analyzed are chlorination, water filtration using corn husks, and no water treatment. The storage tank alternatives are a new concrete tank, a concrete pad with HDPE tanks, and continued use of the existing tank. The alternatives for the distribution system are implementation of a use schedule, separating the community into two zones, and separating the community into three zones.
Proposed Next Step (100 words) [3]	After water treatment method, storage tank design, and water distribution system selections and approvals, the Kansas City Professional Chapter will advance designs to 100% with a detailed budget and list of materials. Communication with the EWB-Guatemala office will continue to locate and procure the required materials to be delivered to the community ahead of the team's arrival for implementation. Preparation of the Draft Construction Drawings and Draft Implementation Trip Plan will begin after the selection of alternatives. The project is tentatively slated for construction in May/June 2020.
Describe Recent Contact with Community, NGO, and in country partners.	Primary contact is through the EWB-Guatemala office. Members of the project team regularly schedule, send and receive messages via Whatsapp with EWB-Guatemala. Contact with the community is maintained by the working relationship between EWB-Guatemala and COCODE through in-person visits. In November, members of

(100 words) [4]	the EWB-Guatemala office visited the community and conducted water distribution tests in order to better understand the current workings of the distribution network. The experiment confirmed that all taps within the community receive water given a low enough demand. Additionally, information was gathered from the community regarding the layout of the existing distribution system.
Describe the Chapters current fundraising goals and milestones. (100 words) [5]	Several fundraising milestones were reached in 2019. The chapter received a $20,000 privately funded grant for international work. It was the first year that each quarter had a public fundraising event. The fundraising events reached the largest community involvement in the history of the chapter, with more individual participants and small donations. Goals for the future include more community outreach to develop relationships with an expanding network of sponsors and donors. The Kansas City Chapter is growing steadily, as are the opportunities to increase donations from new markets. The goal is to continue growing monetary support from 2019 to 2020.
☒ [6]	**IS THE PROGRAM STILL ON TRACK TO MEET THE EWB PROJECT EXPECTATIONS?**

Privacy: EWB-USA may release this report in its entirety to other EWB-USA chapters or interested parties. Once the report is approved any member in Volunteer Village will be able to find and view the plan. Please do not include personal or sensitive information.

Project Timeline [1]			
Major Milestone	**Original Date [3]**	**Current Date [3]**	**Description**
Program Adoption Date	02/26/2019		
Project Approval Date	05/02/2019		
Completed Assessment Trip	08/25/2019		Trip to complete data collection and to form relationships with community, contractors, and suppliers.
Planned Implementation Trip	08/15/2020	06/01/2020	Trip to construct water supply infrastructure.
Planned M&E Trip	02/31/2021	02/31/2021	Trip to monitor the system performance and conduct any necessary adjustments or repairs.

Table of Contents

1.0 Project Description

1.1 Project Background and History

The program in Guatemala was opened in early 2019. The project in Los Churuneles II kicked off in the second quarter of 2019, and the project team traveled to the community in August 2019 for an assessment trip. This assessment trip collected data on the water quality from the natural spring that the community is using and surveyed the community members to learn more about their water usage and the timing of the water through the existing distribution system. During the assessment trip, the team also formed relationships with the leaders of Los Churuneles II and its community organizations, including the Community Development Council, COCODE. Since the inception of this project, partnerships have been formed with the EWB-Guatemala office and its constituents and regular communication is maintained between the Kansas City Professional Chapter and the EWB-Guatemala office.

1.2 Project Context

Los Churuneles II is a small, conservative, and rural community in southwestern Guatemala with a population of approximately 480 people. Traditionally, men are involved in agriculture farming of corn and beans, and women weave, make clothes and take care of the children. However, need for and training in skilled labor in surrounding towns is a growing demographic and some people leave the community to work elsewhere. The community has a significant need to overhaul and replace the current water system for it's failure to meet the demands of the people. The existing water infrastructure is supplied solely by the local spring through a series of limited distribution channels, which are estimated to be 30 years old. The spring box supplies water to two other local communities, although this diversion is not likely to be the cause of the lack of water quantity in the Los Churuneles II community as the infrastructure developed to divide the quantity of water evenly between the three communities is well designed and established. The existing storage tank in Los Churuneles II that is connected to the distribution network receives and distributes spring water at a rate of 0.51 L/second.

It is the goal of the Kansas City Professional Chapter to support this community with its immediate water storage, distribution, and treatment needs. Specifically, the project team assessed the benefits and community desire for a new storage tank on a plot of land that was purchased by COCODE along with an improved distribution system and the implementation of a treatment method. Through a new piping network, storage tank, and treatment system, potable water may be supplied to the community to meet domestic needs.

1.3 Project Goals and Objective

The overall project objective is to bring the people of Los Churuneles II an improved and consistent, reliable supply of water year round from a centralized system. This objective can be divided into three actionable design areas shown below. Proposed changes to each design area are evaluated in the alternatives analysis.

1. Water storage tank
2. Distribution piping network
3. Potable water treatment system

The design of a new water storage tank is necessary to provide the capacity that supports the growing population of the community. Also, an improved tank location at a higher elevation will provide the distribution system more necessary head pressure to better serve more households.

The distribution network will be designed to - as much as possible - divide equally the available water throughout the community so that each family can anticipate when and how much water they are getting throughout the day.

A potable water treatment system will be implemented so that the community will have a long-lasting supply of clean water. Community perceptions and preferences on treatment methods, water taste and water appearance could have a large impact on the direction of the design of this system and therefore will be given extra sensitivity.

1.4 Scope of Work

The central focus of the scope of work is to provide the community with more reliable access to water. The existing system consists of a spring catchment box and distribution piping from the box directly to the homes. The community is marked by large differences in elevation, and this existing system design creates inconsistencies in water supply. Specifically, homes at higher elevations suffer from extreme lack of water and have reported that they often only have water between midnight and 3 am.

A preliminary design was developed for a new system by Agua Para La Salud in 2018 at the village's request. This information was shared with the KC Professional Chapter by EWB-Guatemala who subsequently sent the design drawings to the team for reference. This proposed design consists of a conduction line, water storage tank, chlorination system, and distribution network with meters. This new system would rely on the same spring box source for water supply. The flow at the water source has been measured as 0.51 liters/second. If the Guatemalan government standard of 80-120 liters per person per day is followed, this would provide enough water for approximately 550 people. The approximate cost of the proposed system was determined to be $35,000 by the Agua Para La Salud 2018 report.

This preliminary design encompassed the different scopes of work for the project. These scopes can be best defined as Source, Transmission, Storage, Distribution and Treatment. The source, or springbox, is necessary for collection of water while the transmission and distribution systems allow water to flow from the spring box to the homes of the community. The storage system would consist primarily of a water storage tank. The final portion of scope may include a treatment system in order to provide water that can be safely consumed by the community. All four portions of scope will need to be executed thoroughly in order to provide the community with the improved water supply that they need.

1.5 Potential Solutions Considered

The first set of alternatives - for the storage tank design - evaluate three options. These three options are to build a new storage tank out of concrete, use the existing storage tank, and construct a concrete pad to support HDPE tanks.

The first alternative for the water distribution system design involves no construction and implementing a schedule of the community. Alternative two divides the community into two zones and builds one new pipeline to serve a second zone. Alternative three divides the community into three zones and adds two pipelines to service zones 2 and 3.

The water quality design has three options for this set of alternatives. These options include chlorination, water filtration using corn husks, and no additional water treatment.

1.6 Project Team

The Responsible Engineer In Charge is Scott Struck. The professional mentor is Stephen Collins. The internal reviewers are Adam Byrnes and Audrey Freiberger of the Kansas City Professional chapter. The Project Lead is Jake Sanders and the Director of Projects is John Kelley. The design lead for the water distribution system is Andrew Doerflinger. The design leads for the storage tank are Abe Fangman and Helen Wehner. The design lead for the water treatment is Jillian Gallagher. Each of the leads have resumes on their respective Volunteer Village member profile.

1.7 Community Partners

The Community Development Council (COCODE) is the official organization legally recognized by the municipality of Sololá and the state and will be serving as the Community-Based Organization (CBO) for this project. The board of directors of this organization is elected every four years, and the current board of nine members was elected in early 2019 to address the need of improved potable water system in the community. The COCODE board of directors are elected for four year terms by community members through a voting process that includes every person. Once they are elected, they need to be legalized by the municipality. Once they have the municipality's recognition, they begin their community mandate. The community is represented through COCODE and everyone in the community is able to share their opinions and ideas. COCODE in conjunction with the community will have the ultimate decision authority for this project. The COCODE will work with the municipality, EWB-KC, and EWB-Guatemala to provide unskilled labor during the project implementation and will be responsible for maintenance, operation of the system, and planning the implementation of collection fees for the drinking water once the service gets established. COCODE will also coordinate all the logistics for the community's contribution to the project.

The Non-Governmental Organization (NGO) that EWB-KC will be working with for this project is the Engineers Without Borders Guatemala office. Their primary function will be to facilitate the in-country aspects of the project as well as help and advise the chapter for critical project decisions. The deputy director, Waleska Crowe, is the primary contact from EWB for the Municipality of Sololá and the COCODE of Los Churuneles II.

The local government partner is the Municipality of Sololá. The municipality will provide 25% of the cost for materials. They are also open to help the community with any paperwork that they need to complete to get the construction permissions. When the construction is completed, the municipality will be able to provide assistance if the community needs it.

2.0 Alternatives

2.1 Storage Tank

The storage tank will be designed for a capacity that stores the supply from the source in a 24 hour timeframe. With the current flow rate of 0.51 L/second, this yields a design capacity of 44,000 L. The EWB-Guatemala standards require a range of 80-120 L/person/day. Using the lower bounds of this requirement and an estimated population count of 550 people, this requires a capacity of 44,000 L which is approximately 1,560 ft^3.

2.1.1 Alternative 1 - Build New Concrete Storage Tank

Building a new concrete tank would follow the design laid out by the Agua Para La Salud report that aligns with the community expectation of building a new storage tank. This alternative would be similar to the existing tank but larger in size in order to meet the demand of the community. Excavation of the newly purchased plot of land would be required so the top of the tank could be easily accessible without a ladder. Backfill would then be required once the construction is complete. The storage tank would include a base that would also act as the foundation. Keeping with similar designs in the region, the tank would be square in shape with all the walls made of concrete and connected to the base. The tank would also require a top cover with an opening to prevent contaminants from entering the water supply while still allowing access down into the storage tank itself for maintenance. As this would be a new build, the capacity of the tank could be designed to be sufficient for the needs of the growing community with the only limiting factor the size of the plot of land where it will be constructed.

The community has purchased a new plot of land at a higher elevation than the existing tank for the construction of a new water storage tank. In the eyes of the community, this is the only option to be considered. By purchasing this new plot of land, they have a monetary investment in this alternative. The alternative of constructing a new storage tank should require only minimal maintenance. Simply ensuring the protective coating on the inside of the tank maintains its integrity and cleaning the interior of the tank would be the extent of the regular maintenance. The community should already be accustomed to this with the existing tank and spring boxes at the source.

The construction of the new concrete tank will require approximately 198 ft^3 of cement, 347 ft^3 of gravel, 298 ft^3 of sand, 1819 linear feet of #4 rebar, and 16768 ft^2 of formwork. The total estimated cost of this alternative is $9,200. The detailed quantity and cost estimate is included in Attachment B.

Cement is readily available and concrete construction is representative of typical tank construction in the area. Rebar is also readily available and typical of the area as it is used as reinforcement in structures where CMU (Concrete Masonry Unit) is the primary structural element. Most structures are constructed entirely with CMU on a concrete foundation. Rebar, CMU blocks, plywood, sawn lumber, and a concrete mixer were all seen in the community during the assessment trip. Sawn lumber and plywood for the formwork, cement, aggregate and rebar should be available at the ferretería in Sololá.

For the construction of the new concrete tank, a cement mixer would be required and this could be brought in on a truck since the community is accessible from the main highway. The labor will be intensive and the time commitment for constructing this alternative will be demanding. Construction of this alternative will likely take longer than the duration of one implementation trip. The construction of this tank can be scheduled so that EWB-KC is in the community at a certain point during construction allowing the chapter to act as field support or quality control or labor depending on the timing of the implementation trip with the construction schedule. Timing of construction and the implementation trip need to be heavily dependent on the season. For example, if implementation were to take place during the rainy season, it is unlikely that construction would be possible due to the saturation of the soil and the limited length of time during the day when there is no rainfall. Curing concrete in the rain is also not ideal and can lead to strength problems with the finished structure.

2.1.2 Alternative 2 - Use Existing Storage Tank

The main reasons for wanting a new storage tank are that the existing storage tank is not holding any water and the owner of the property where the storage tank is currently located would like it moved. Based on the distribution system alternatives, this alternative will likely involve the water being cut off to the community during the night hours, allowing the storage tank time to fill. This would eliminate the problem of the tank not holding any water as it would have ample time to reach capacity. The downside to this would be the existing tank likely not having the capacity to hold the necessary water volume that accumulates over night while the distribution system is closed off.

The one community member who owns the land where the existing storage tank resides has requested that the tank be removed from his field. In response, COCODE purchased a new plot of land so the tank could be moved. It did not appear that the community as a whole had any problem with the location of the existing tank. Various options exist to compensate the farmer if this alternative were to be selected.

Other than regular maintenance of the tank, the potential other cost would be compensation to the farmer to retain the existing tank on his land. They could always sell the plot of land back or exchange it with the community member so that piece of land can be used for farming. If the existing storage tank were to be used, there would be no new maintenance required. The community would have to ensure there are no leaks in the tank and periodically clean the tank, but these should be tasks that they are already accustomed to doing. This alternative would not require any materials to be purchased and it would require only one implementation trip to ensure the logistics and agreements between the community and the landowner go well.

2.1.3 Alternative 3 - Concrete Pad with HDPE Tanks

Similar to Alternative 1, building a concrete pad and purchasing HDPE tanks would meet the expectations of the community that the purchased plot of land would be utilized for a water storage tank. Like the alternative of constructing a new concrete storage tank, buying storage tanks would allow us to ensure that the capacity of water stored meets the demand of the community. It would also reduce the amount of construction needed and could require less maintenance, as it would not be susceptible to cracking. This alternative would require concrete to be purchased and set, along with purchasing and placing the HDPE tanks on the pad. The hillside would have to be leveled for the placement of the foundation pad. A retaining wall will potentially be required to ensure the slope of the hillside does not collapse during the rainy season and damage the tanks. This alternative will also require the use of tie downs or other methods to adhere the tanks to the foundation for protection against larger wind events. These tanks can also come with the built in water filter which could act as part of the water treatment system.

The community wants to use the purchased plot of land for the storage tank and this alternative would satisfy that desire. Five households in the community have their own personal storage tanks so the concept of multiple large storage tanks should not be too foreign to them.

The construction of the concrete foundation will require approximately 640 ft^3 of cement, 1120 ft^3 of gravel, 960 ft^3 of sand, 6478 linear feet of #4 rebar, 640 ft^2 of formwork and four HDPE Rotoplas tanks each costing $2,020. The total estimated cost of this alternative is $10,900. The detailed quantity and cost estimate is included in Attachment B.

HDPE is an easily welded plastic so with the resources that are available in the community, repairs to the tanks should be possible. If the design life of the project is longer than the length of time that the tank maintains its structural integrity, the tank will need to be replaced. The Rotoplas tanks have a fully refundable guarantee of five years, but their expected lifetime is longer. There are currently five Rotoplas storage tanks at houses in the community so the concept of one or more large storage tanks that looks similar to the existing ones in the community should be acceptable. The HDPE tanks are common in Guatemala, however, the transportation of the tanks themselves may present challenges to get it into the community based on their location off the main highway.

A concrete mixer will be required to pour the foundation and based on the location of the community, it would likely be possible to get one into the community. Similar to the construction of a concrete storage tank, this foundation would require cement, large aggregate, rebar, sawn lumber and plywood for the formwork, and time to cure. Ideal curing would be best if construction was done during the dry season. Similar to Alternative 1, the full duration of the construction of this alternative will require more time than the team is available to be present in the community. Based on the construction schedule, EWB-KC can act as quality control, field support, or labor during the implementation trip.

2.2 Distribution Piping Network

The water supply to the current distribution network and each of the household taps is limited by the small storage tank. Since the current tank is not sized to hold a 24 hour supply of water, once the tank is empty the distribution network can only receive the 0.51 L/second flow rate that is coming from the spring. Once a new storage tank is constructed and is allowed to fill overnight each day, the instantaneous flow into the distribution network will be controlled by the number of taps open.

The existing pipeline is constructed entirely of 1 ½” PVC. Using the heuristic of a maximum desired water velocity of 2.4 m/second (8 ft/second) in order to reduce frictional losses, this results in a maximum flow rate of 2.78 L/second (44 gpm).

2.2.1 Alternative 1 - Schedule & Ad Hoc Adjustments

In this alternative, very few, if any, physical changes would be made to the existing distribution system. Instead, a schedule would be implemented for each house in the community to govern when they would be able to access the water. This is a feasible solution, as the experiment that Arturo of EWB-Guatemala conducted last month showed that every house was able to receive water when all other taps were shut off. However, it's possible that once other taps open, some houses may not be able to receive adequate flow due to their specific piping arrangement. In this alternative, these specific households would be fixed on an ad-hoc basis by rerouting portions of the pipeline that connect to their respective taps.

This solution would have little to no cost. Even in the event that a handful of houses need to be rerouted, this would still result in a lower material cost and less construction than the other alternatives considered of dividing the community into zones. However, this alternative would instead require a larger commitment from the community to follow and enforce the schedule. Further analysis would be required to develop an optimized schedule that evenly distributes the demand throughout the day while staying below the maximum flow rate of 2.78 L/second. This would likely require some houses to limit access to water to less ideal times. However, the schedule could be designed in such a way that it rotates. For instance, a house that has access to water at a less ideal time one day would have a time slot during the daytime on another day. No houses would be scheduled overnight so as to give the storage tank time to refill.

Since limited changes would be made to the existing distribution system, there would be no change in the required maintenance tasks. Required maintenance could include periodic repairs to the pipeline in the event that part of it becomes damaged. However, the community is likely expecting an engineered solution, and may not be receptive to simply implementing a schedule. This solution has the potential to lead to conflict within the community if there are issues in getting everyone to follow and abide to the schedule, and it could be difficult to enforce. Consideration would need to be made to simplify the schedule as much as possible in order to reduce confusion and make it as easy as possible for the community members to follow the schedule.

2.2.2 Alternative 2 - 2 Zones

This alternative would involve dividing the community into 2 different zones. Each zone would service roughly half the community, with one zone coming from the existing distribution network and the second zone coming from a new pipeline. Each zone's pipeline would begin at the storage tank and flow would be turned on or off with a valve station on each zone. In order to give the storage tank time to recharge, the system would be designed on a schedule with only one zone active at a given time. Overnight, neither zone would be active so that the tank can replenish. This would effectively cut the instantaneous demand in half. The existing pipeline, which would become Zone 1, would serve the houses that are known to receive good flow in the current distribution system. The new pipeline, Zone 2, would serve the houses that don't receive good flow currently due to the piping arrangement. To reduce materials cost, the new pipeline (Zone 2) would be designed to preferentially serve houses that are close in proximity to the storage tank, while the existing pipeline (Zone 1) would preferentially serve houses that are further away from the storage tank. This solution would require a member of the community to manually turn the zones on and off each day at an agreed upon time.

The community is receptive to this concept and is already familiar with it as it aligns with the preliminary design completed by Aguas Para La Salud. The community's input on the timing of the zones would be vital and would ultimately be left up to them to decide and operate. This solution would require daily operation and would likely involve three actions per day: (1) Turn on Zone 1 at the beginning of the day, (2) Turn off Zone 1 and turn on Zone 2 around midday, and (3) turn off Zone 2 at night. This would then allow for the storage tank to fill up overnight. Precautions would likely be taken to secure the valve stations and ensure that only the approved/elected member of the community is able to adjust the valves controlling the flow to each zone.

Minimal maintenance would be required to maintain and operate the system. The only maintenance required would be periodic repairs to the pipeline and valves, should any damage ever occur to the system. With the community's participation during the implementation, they will have all the necessary knowledge to perform these repairs. This information would also be contained within the Operations & Maintenance guide that will be prepared. Minimal to no training would be required and spare parts could be left in the community should there ever be damage needing repairs.

Necessary materials for a 2 zone solution would include piping (likely PVC), couplings, and valves. Additionally, concrete boxes would likely need to be constructed to protect and secure the valve stations, which would require plywood and lumber for the formwork, cement, aggregate, and rebar. These materials are all commonplace and should be available at the Ferreteria in Sololá. Depending upon the length of the implementation trip, this would be able to be constructed in a single trip. The estimated cost of this alternative is approximately $2,300. Cost details are included in Attachment B.

2.2.3 Alternative 3 - 3 Zones

This is a similar solution as Alternative 2, except instead of 2 zones, there would be 3. This would effectively divide the instantaneous demand into thirds, making it easier for the water supply to be sufficient for the demand. Again, the existing pipeline would become Zone 1, and two new pipelines would be designed to serve Zones 2 and 3. With 3 zones, each zone would only be active and have flow roughly 2/3 of the time that a 2 zone solution would provide. This would also require more work for the community, as they would have to manually turn on/off the valves an extra time.

Much of what was discussed in the 2 zone solution would hold true for a 3 zone solution as well. The daily routine would likely require 4 actions: (1) Turn on Zone 1 at the beginning of the day, (2) Turn off Zone 1 and turn on Zone 2 in the late morning, (3) Turn off Zone 2 and turn on Zone 3 in the afternoon/evening, and (4) turn off Zone 3 at night. Similar to the 2 zone solution, this would allow for the storage tank to refill and replenish overnight.

This would require additional materials to route an extra pipeline and construct an additional valve station, as well as require an extra action be taken each day by the community for the system's operation. The geography of the community does lend itself to 3 zones, as there are 3 relatively distinct groupings of households within the community. The same types of materials would be required as discussed for the 2 zone solution, and the maintenance and upkeep activities would also be the same. The estimated cost of this solution is $3,900. Details of this estimate are included in Attachment B. Given that this solution would require an additional pipeline, it may be necessary to phase the implementation across 2 trips. The construction schedule will be more closely examined and optimized should this alternative be selected in order to minimize construction time and attempt to finish the implementation in a single trip.

2.3 Water Treatment

2.3.1 Alternative 1 - Chlorination

There are different methods to implement this alternative. Chlorination can be done at the system level, which benefits the whole community, or at point-of-use. Each method treats bacteria and viruses in the water, which will help with making the water quality system sustainable, but with different risks and responsibilities. Even though the water quality is currently high in the community, there are many factors that could lead to a change in the current quality. Thus, chlorination would be a reliable solution because this method is well known and an acceptable treatment methodology. At a system level, chlorine is applied to the community's water supply, whether that be in the pipeline or in a storage tank. The point-of-use method is basically the same as treating the water community wide. Instead of installing a chlorinator in the main line or at the storage tank, a chlorine tablet is placed directly into the water where it's stored at each household. The health risk of selecting this method is addition of the incorrect dosage to the water. Chlorination at the system level would be desired for this type of water treatment in this case. Each household would not treat their own water. A higher concentrated chlorine solution than standard would be needed to be more efficient. A standard chlorine solution would require the community to refill the chlorine about every three months.

Chlorine affects the taste and smell of the water. Thus, the community's input is important to this solution. During the assessment trip, COCODE did not seem to have any reservations with this method.

There is minimal cost for this alternative. This water filtration system is estimated to be $1,600 for the materials. Training would be needed for the proper dosage of chlorine and how to determine if the system needs maintenance. The full quantity and cost estimate can be found in Attachment B.

A dry pellet side stream chlorinator is required for this filtration system. The chlorinator includes a chlorine feeder, chlorine tablets, PVC, PVC ball valve, extra O-Rings, extra filter, and mesh filter system. These materials would be purchased prior to the implementation trip and shipped to the community. Chlorine tablets would be easy to replenish when the community runs out of the material.

The chlorination system could be completed during one implementation trip. Connecting the chlorine system to the new storage tank would be the most challenging aspect of this alternative. If the new storage tank cannot be completed due to the rain, the ability to finish construction would be an issue. The schematic of this design can be found in Attachment A.

2.3.2 Alternative 2 - Water Filtration Using Corn Husks

In this alternative, corn husks would be used for water filtration. Corn is a staple crop in the community and thus there is an abundance of corn husks available for use. Corn husks have porosity, which is essential for this type of water filtration. After the corn husks are burned, the open space in corn husks makes an efficient activated carbon adsorbent. An empty 2L soda bottle, cheese cloth, and corn husks would be needed for this solution. The empty soda bottle would be cut into three equal pieces to make a tier. Then, the cheese cloth would be placed over the cut soda bottles. The corn husks would be divided into three different groups, each group would be its own layer. The top layer would involve ground up husks, the middle layer would be plain corn husks, and the bottom layer would consist of corn husk that were burned into ashes. When water goes through the bottom layer, activated carbon goes out of the corn husks.

This solution is locally sourced and sustainable because it uses materials that are found in the community. The community would have to be fine with using some of their agriculture for water treatment. The use of the corn husks could be a part of the waste product after cooking. With water quality being so high, only a small amount of corn husks would be needed.

The cost would be much cheaper than alternative 1 because availability of the materials. This system is estimated to cost around $300 for all 52 households. The full quantity and cost estimate can be found in Attachment B.

Training would be required to setup this carbon water filter. Training for this system would be conducted during the implementation trip. Maintenance would require reassembling the whole system as well as husk preparation.

The required equipment for one carbon filtration system includes an empty 2L soda bottle, cheese cloth, corn husks, screws, and rustic board. In total, 52 soda bottles would be purchased as this is a point-of-use system. During the assessment trip, corn husks and plywood were observed in the community. Screws and rustic board should be available at a hardware store in Sololá. Cheese cloths and soda bottles would be purchased in a grocery store in Sololá. Replacements of the soda bottles would also be available at the tiendita in the community.

One implementation trip would be needed to construct these water filtration systems. Even though 52 devices would require construction during the trip, the task can be completed in one trip. Construction would not depend on rainfall because it could be assembled inside. The sketch of this water filtration system can be found below in Attachment A.

2.3.3 Alternative 3 - No Water Treatment

This alternative would consist of no changes to the water quality system. Based on the EWB-KC assessment trip in August, the water quality was high. In November, EWB-Guatemala visited Los Churuneles to take another set of water samples to test for coliform and E. coli. The results of this water quality analysis came back negative. Currently, the personal storage tanks use a water filter that is included with set up. These water filters don’t have that much effect on the water quality. The quality of water at the households without a storage tank does not differ much from households that do have a storage tank with the water filtration system.

The community would not prefer this option because water treatment is a part of the agreed scope. Also, having a high quality of water with no contamination over decades with no water treatment system in place is not guaranteed. According to the EWB-USA Guatemala Potable Water Standards, the required design life for a system is 20 years. There could be a decrease in water quality within those 20 years.

There would be no additional costs for this alternative because the current system won’t be changing. Little to no maintenance or training would be required for this alternative.

This alternative would not require any additional materials to be purchased. One implementation trip would be required to make sure that the current personal water filters attached to the storage tanks are working properly.

2.4 Other Alternatives

Other Distribution System Alternative: Loop

This alternative would be similar to a zoned solution in that an additional pipeline would have to be run throughout the community. However, where a zoned solution would have separate pipelines that are only connected at the storage tank, a loop solution would have the two pipelines connect at the end of each pipeline, creating a loop. A normally closed valve would be located at the point where the two pipelines loop together, effectively rendering the solution congruent to a zoned solution. This solution creates redundancy in the system, as it would allow for water to still reach houses during periods of maintenance or repairs on the pipeline or if there was some sort of damage and a break in the pipeline. However, with the current supply and the current understanding that the system is operating as a gravity-fed system, the advantages of the loop would not be realized as the water would not be able to flow uphill. But, if there was a larger supply and the system was functioning as a pressurized system, then the redundancy would function as intended. Unless an additional supply of water is found and implemented, this is not a feasible solution.

3 Comparison

3.1 Criteria

Table 3.1.1 Storage Tank Alternatives

Criteria	Alternative 1: Build New Concrete Storage Tank		Alternative 2: Use Existing Tank		Alternative 3: Concrete Pad with 3 HDPE Tanks	
Ability to solve identified need	5	We have the ability to design whatever they need	2	If we do a zoned system we have to build more infrastructure and it doesn't have the required capacity	4	Design life of system may not be long enough
% of community impacted	5	Everyone will get water	5	Everyone will get water	5	Everyone will get water
% of need met	5	Everyone will get water	5	Everyone will get water	5	Everyone will get water
Community Input	5	This is what they expect	1	They do not want this option	4	Not what they are expecting, but shouldn't be too foreign
Construction Cost	1	Would require the most material and construction cost would be high	5	No construction	1	Tanks would be more expensive and would have to be transported to community

Maintenance Cost	5	Minimal	5	Minimal	4	Might require some upkeep because it is plastic
Operation and Maintenance Difficulty	5	Should be very accessible for any needed maintenance	1	The tank is difficult to get to, especially in poor weather, and the landowner doesn't want it there	3	Could require a change in the tank, which could require ordering a new one
Regional Experience with Technology	5	Similar systems have been constructed before	5	N/A	5	These systems exist throughout the community
Material Availability	5	Concrete is widely used in and around the community	5	N/A	3	HDPE tanks exist in the community, but not the size we need. We'll probably need one shipped in
Expandability and Scalability	1	We would need to purchase more land, and expanding a concrete tank is very challenging	1	No land is available	3	Could purchase a larger tank(s), but would have to have it shipped in
Impact of Climate Change	5	Concrete should not be impacted by any changing climate	5	Concrete should not be impacted by any changing climate	5	HDPE should not be impacted by any changing climate
Totals	47		40		42	

Table 3.1.2 Distribution System Alternatives						
Criteria	**Alternative 1:Schedule**		**Alternative 2: 2 Zones**		**Alternative 3: 3 Zones**	
Ability to solve identified need	3-5	Depending how increased storage impacts distribution, everyone may or may not be able to receive water	5	Rerouting new zone to houses that don't currently receive water will provide water to all households	5	Rerouting new zone to houses that don't currently receive water will provide water to all households

% of community impacted	3-5	Depending how increased storage impacts distribution, everyone may or may not be able to receive water	5	Everyone should get water	5	Everyone should get water
% of need met	3-5	Depending how increased storage impacts distribution, everyone may or may not be able to receive water	5	Everyone should get water	5	Everyone should get water
Community Input	3	The community is expecting an engineered solution	5	Community is accepting and familiar with zoned solution	5	Community is accepting and familiar with zoned solution
Construction Cost	5	Limited or no construction	3	Lower construction cost	1	Highest construction cost
Maintenance Cost	5	Shortest total pipeline length, lowest maintenance cost	4	Longer total pipeline length, larger maintenance cost	3	Longest total pipeline length, largest maintenance cost
Operation and Maintenance Difficulty	3	Difficult to enforce schedule necessary for proper operation, but least maintenance	3	Operation requires 3 valve actions daily	2	Operation requires 4 valve actions daily
Regional Experience with Technology	3	The community essentially operates on a schedule now, with some community members only getting water overnight	1	No known experience with zones	1	No known experience with zones
Material Availability	5	Materials available in Sololá	5	Materials available in Sololá	5	Materials available in Sololá

Expandability and Scalability	1	Flow rate limited to single pipe's maximum flow rate	3	Higher maximum flow rate if both zones open simultaneously	5	Highest maximum flow rate if 3 zones open simultaneously
Impact of Climate Change	5	Negligible impact	5	Negligible impact	5	Negligible impact
Total	39-45		44		42	

Table 3.1.3 Water Treatment Alternatives						
Criteria	**Alternative 1: Chlorination**		**Alternative 2: Water Filtration using Corn Husks**		**Alternative 3: No Water Treatment**	
Ability to solve identified need	5	We have the ability to design for water treatment	5	We have the ability to design for water treatment	3	Design life of system may not be long enough
% of community impacted	5	Everyone will get filtered water	4	Not everyone would get filtered water on a regular basis	2	Not everyone would get filtered water
% of need met	5	Everyone will get filtered water	4	Not everyone would get filtered water on a regular basis	3	Not everyone would get filtered water
Community Input	5	This is what we discussed on assessment trip	4	The community would have to agree to use their agriculture for water treatment as well as a part of waste	1	They do not want this option because water treatment is a part of the agreed scope
Construction Cost	4	Would require the most material, but would not be super expensive	4	This is a point-of-use system, so every household would need this filtration system. Thus, would require the most material and construction would be high	5	No construction

Maintenance Cost	5	Minimal	5	Minimal	5	N/A
Operation and Maintenance Difficulty	5	Should be very accessible for any maintenance	2	Maintenance would require reassembling the whole system	5	Maintenance on current water filtration system would be minimal
Regional Experience with Technology	3	Chlorination systems have been used in Guatemala	1	Similar systems have not been used before	5	This exists throughout the community
Material Availability	4	Components for chlorination can be purchased and shipped in	5	Corn husks are used for agriculture in the community. The other materials would be purchased in Sololá	5	N/A
Expandability and Scalability	5	Chlorine dosage would need to be adjusted	2	We would need to construction more filtration systems	1	No water treatment would be available
Total	51		41		40	

3.2 Climate Change

3.2.1 Summary of Anticipated Climate Change

According to the United States Agency for International Development's climate risk profile for Guatemala, there are several major effects of climate change that will be observed in the next 10+ years to the country. The country is predicted to experience and increase in temperatures and more frequent extreme weather. By 2050 there could be up to a 4 degree Celsius rise in temperature. More frequent, intense rainfall events, droughts and floods may occur. Also, reduced rainfall and increased temperatures are expected to reduce surface water quantity by 10-50% by 2030. Increased extreme rainfall is predicted to increase runoff and in turn can result in a decrease in water quality. It should be noted that during the assessment trip, the community did not note any abnormally large storms or changes in temperature over the last 10 years. They did, however, indicate that in the past few years there have been changes to the timing of the rainy season. In general, it has been starting later and ending sooner than normal. This is consistent with the research done on climate change and is expected to continue and result in a longer dry season in the region.

3.2.2 Summary of Impact of Climate Change

The climate change that is expected to be observed will have several impacts on the direct source of the water that this project is planning on providing. If the overall supply of surface water is decreased, the community could run the risk of outgrowing the supply very quickly. The increase in temperature will make it more likely for bacteria to be found in the water. For this project, it should be considered that the quantity of water from the source may not always be fully available and that the water quality is expected to decrease as well.

The anticipated changes due to climate change are not expected to change the design considerations for the storage tank design. The impact of climate change on the source could be severe with the source quickly decreasing in quantity with the potential of no longer being a viable source to provide water to the community. Climate change is not expected to have a major effect on the water quality design.

3.3 Matrix

Table 3.3.1 Storage Tank Alternatives

Criteria	Alternative 1: Build New Concrete Storage Tank	Alternative 2: Use Existing Tank	Alternative 3: Concrete Pad with 3 HDPE Tanks
Ability to solve identified need	5	2	4
% of community impacted	5	5	5
% of need met	5	5	5
Community Input	5	1	4
Construction Cost	1	5	1
Maintenance Cost	5	5	4
Operation and Maintenance Difficulty	5	1	3
Regional Experience with Technology	5	5	5
Material Availability	5	5	3
Expandability and Scalability	1	1	3
Impact of Climate Change	5	5	5
Total =	**47**	40	42

Table 3.3.2 Distribution System Alternatives			
Criteria	**Alternative 1: Schedule**	**Alternative 2: 2 Zones**	**Alternative 3: 3 Zones**
Ability to solve identified need	3-5	5	5
% of community impacted	3-5	5	5
% of need met	3-5	5	5
Community Input	3	5	5
Construction Cost	5	3	1
Maintenance Cost	5	4	3
Operation and Maintenance Difficulty	3	3	2
Regional Experience with Technology	3	1	1
Material Availability	5	5	5
Expandability and Scalability	1	3	5
Impact of Climate Change	5	5	5
Total =	39-45	44	42

Table 3.3.3 Water Treatment Alternatives			
Criteria	**Alternative 1: Chlorination**	**Alternative 2: Water Filtration using Corn Husks**	**Alternative 3: No Water Treatment**
Ability to solve identified need	5	5	3
% of community impacted	5	4	2
% of need met	5	4	3

Community Input	5	4	1
Construction Cost	4	4	5
Maintenance Cost	5	5	5
Operation and Maintenance Difficulty	5	2	5
Regional Experience with Technology	3	1	5
Material Availability	4	5	5
Expandability and Scalability	5	2	1
Impact of Climate Change	5	5	5
Total =	51	41	40

3.4 Description of Comparison Results

The storage tank Alternative 2 of keeping the existing tank is not a desired alternative because the community purchased land with the intent to relocate the supply. The community has a monetary investment in using this new plot of land and this investment is highly weighted when comparing the alternatives. The existing storage tank is also unlikely to have the required capacity to meet the demands of this growing community. Although the cost associated with this alternative is the most economical, it does not achieve the main goal of this project to provide more reliable access to water.

Comparing the new concrete storage tank (Alternative 1) to the concrete pad foundation with purchased HDPE storage tanks (Alternative 3), the new concrete storage tank is the preferred alternative because it gives the flexibility to design a tank size to meet the community's needs while also costing less than Alternative 3. The HDPE storage tanks are available for purchase in set capacities and four of the largest available tanks along with a smaller tank would be required to store the design volume. Furthermore,the surface area of concrete required for these five tanks would produce foundation dimensions encroaching on the perimeter of the available plot of land while the footprint required for Alternative 1 is 16% of the total area required for Alternative 3. Lastly, construction of a new concrete tank is the typical design of water supply tanks in the region and is similar to the existing tank. The community is most familiar with this alternative and would have a better understanding of the construction and maintenance.

There is not an obvious solution to the distribution system with the current information available, as it is not clear how the increased capacity of the new storage tank will impact the distribution system. It is quite possible that after increasing the capacity of the storage, that the current system will be able to deliver water to all of the households within the community with limited adjustments to the pipeline. This would be the most desired solution from a cost and construction perspective. If, however, the increased capacity still results in numerous households not receiving adequate water, then a zoned solution will be required. If necessary, both a 2 zone solution and 3 zone solution are technically feasible and scored very similarly in the above matrix. Both are viable solutions if implementing a schedule proves to not be possible after the new storage tank is constructed. It is proposed that the implementation of this project be phased and that the storage tank be constructed prior to making a final decision on the selected distribution alternative.

The three treatment methods for water quality evaluated were chlorination, corn husk filtration, and no additional treatment. If the quality of water decreases over time, chlorination would be an effective solution. The chlorine dosage would need to be adjusted, not the whole system. The corn husks solution was not selected because similar systems have not been used before there is uncertainty in the scalability of this solution. Even though the initial cost of this system would be minimal, more filtration devices would be needed as the community continues to grow. The no water treatment alternative was not selected because of potential water source contamination in the future. Currently, the quality of water is high, but it cannot be guaranteed that it will stay that way for the anticipated design life of 20 years.

Based on the comparison of results, the chlorination option is the most feasible and long term solution with minimal maintenance required of the community. Possible rainfall during the implementation trip will not have a negative impact of this alternative because this system can be assembled indoors. Also, this method of water treatment was discussed with COCODE during the assessment trip.

3.5 Preferred Alternative

The selected alternative for the storage tank design is to build a new concrete storage tank, Alternative 1. The selected alternative for the distribution system is to divide the community into three zones with the existing pipeline serving as the first zone and constructing two more pipelines, Alternative 3. The selected alternative for water quality is chlorination, Alternative 1.

4 Next Steps

The next step is to take each selected alternative that is currently at 20% design to 100% completion. A phased implementation approach has been proposed to the EWB-Guatemala office. The first phase would be to implement the storage tank and water treatment system. The second phase would be to construct the distribution piping for a zoned approach. Acceptance of this approach will determine deadlines. Nevertheless, the draft pre-trip plan for the storage tank and water treatment system are the next things to do. Travel by June to implement the first phase of the design would be idea. Implementation of the second phase in December would be ideal.

5 List of Attachments

Attachment A: Drawing Package

Attachment B: Material Pricing and Detailed Cost Estimates

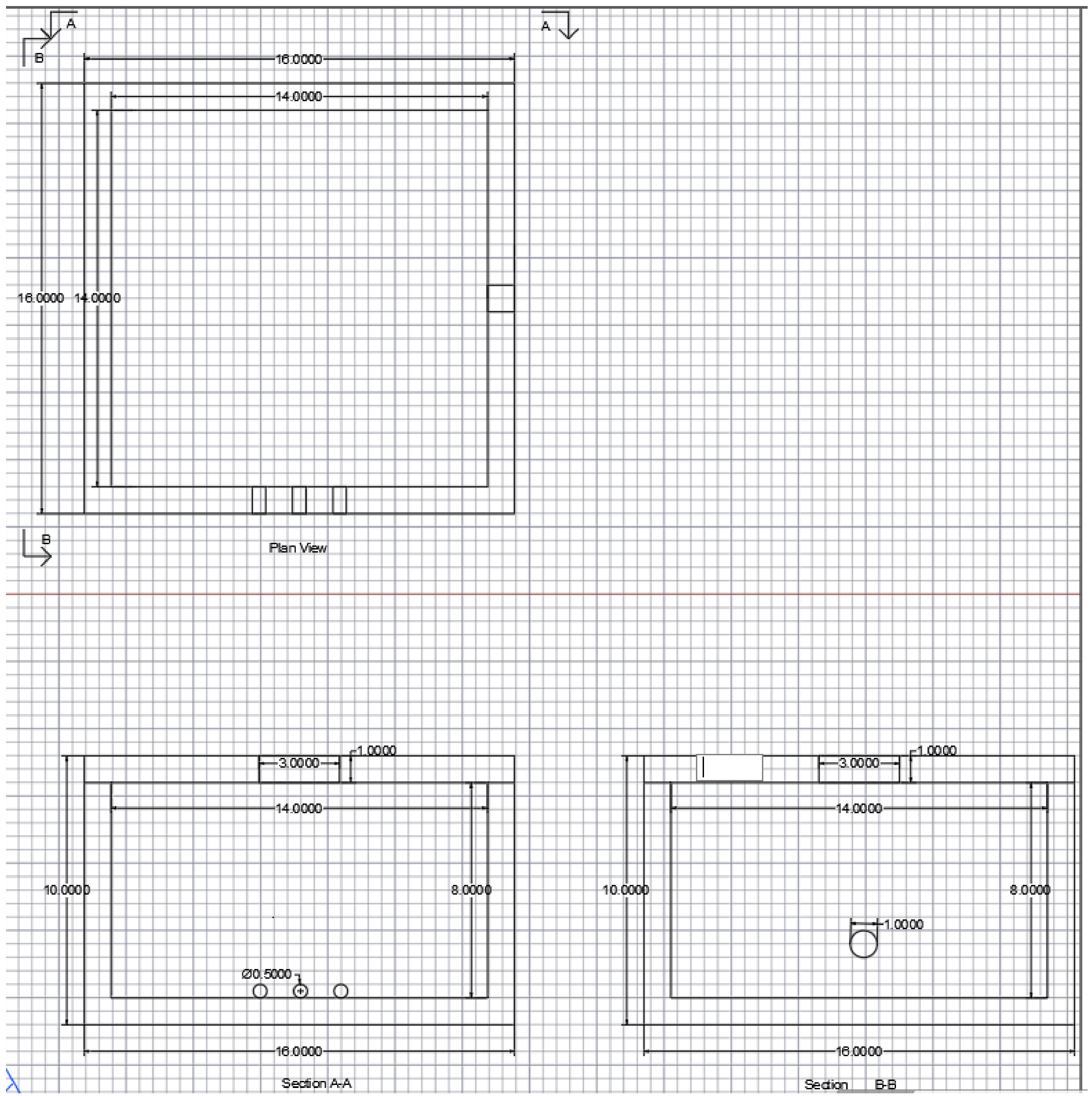
Water Storage		
Alternative 1		
Material	**Quantity**	**Cost**
Cement	198 ft^3	$57.96
Gravel	347 ft^3	$231.38
Sand	298 ft^3	$94.08
Formwork	16768 ft^2	$8,384.00
Rebar (#4's)	1819 ft	$346.88
	Total =	$9,114.29
Alternative 3		
Material	**Quantity**	**Cost**
Cement	640 ft^3	$187.34
Gravel	1120 ft^3	$748.44
Sand	960 ft^3	$304.64
Formwork	640 ft^2	$320.00
Rebar	6478 ft	$1,233.75
10,000L tank	4 tanks	$8,080.00
	Total =	$10,874.16

Distribution		
Alternative 2		
Material	**Quantity**	**Cost**
2" PVC pipe	150	$2,008.50

PVC Cement	20	$139.80
Ball Valve	3	$37.50
90° Elbow	30	$42.00
45° Elbow	20	$33.00
Cement	2 ft^3	$0.58
Gravel	4 ft^3	$2.31
Sand	5 ft^3	$0.94
Formwork	175 ft^2	$83.84
Rebar (#4's)	20 ft	$3.47
	Total =	$2,351.94
Alternative 3		
Material	**Quantity**	**Cost**
2" PVC pipe	250	$3,347.50
PVC Cement	30	$209.70
Ball Valve	4	$50.00
90° Elbow	45	$63.00
45° Elbow	30	$49.50
Cement	3 ft^3	$0.87
Gravel	6 ft^3	$3.47
Sand	8 ft^3	$1.41
Formwork	300 ft^2	$125.76
Rebar (#4's)	30 ft	$5.20
	Total =	$3,856.41

Water Quality		
Alternative 1		
Material	**Quantity**	**Cost**
Chlorine Feeder	1	$520.00
Chlorine Tablet	100	$315.00
PVC Ball Valve	1	$15.00
PVC Ball Valve	2	$25.00

Extra O-Ring	1	$5.00
Extra Filter	1	$299.00
Mesh Filter	1	$299.00
90° Elbow	4	$5.60
Tee	1	$1.96
2" PVC Pipe	20 ft	$24.40
	Total =	$1,509.96
Alternative 2		
Material	**Quantity**	**Cost**
Rustic Board	9 ft	$122.72
Cheesecloth	52	$152.36
Steel Screw	100	$6.94
2L Soda Bottle	52	$93.08
	Total =	$252.38



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WATER STORAGE, DISTRIBUTION, & TREATMENT

STORAGE SYSTEM
NEW CONCRETE TANK STORAGE ALTERNATIVE

DRAWING NO.:

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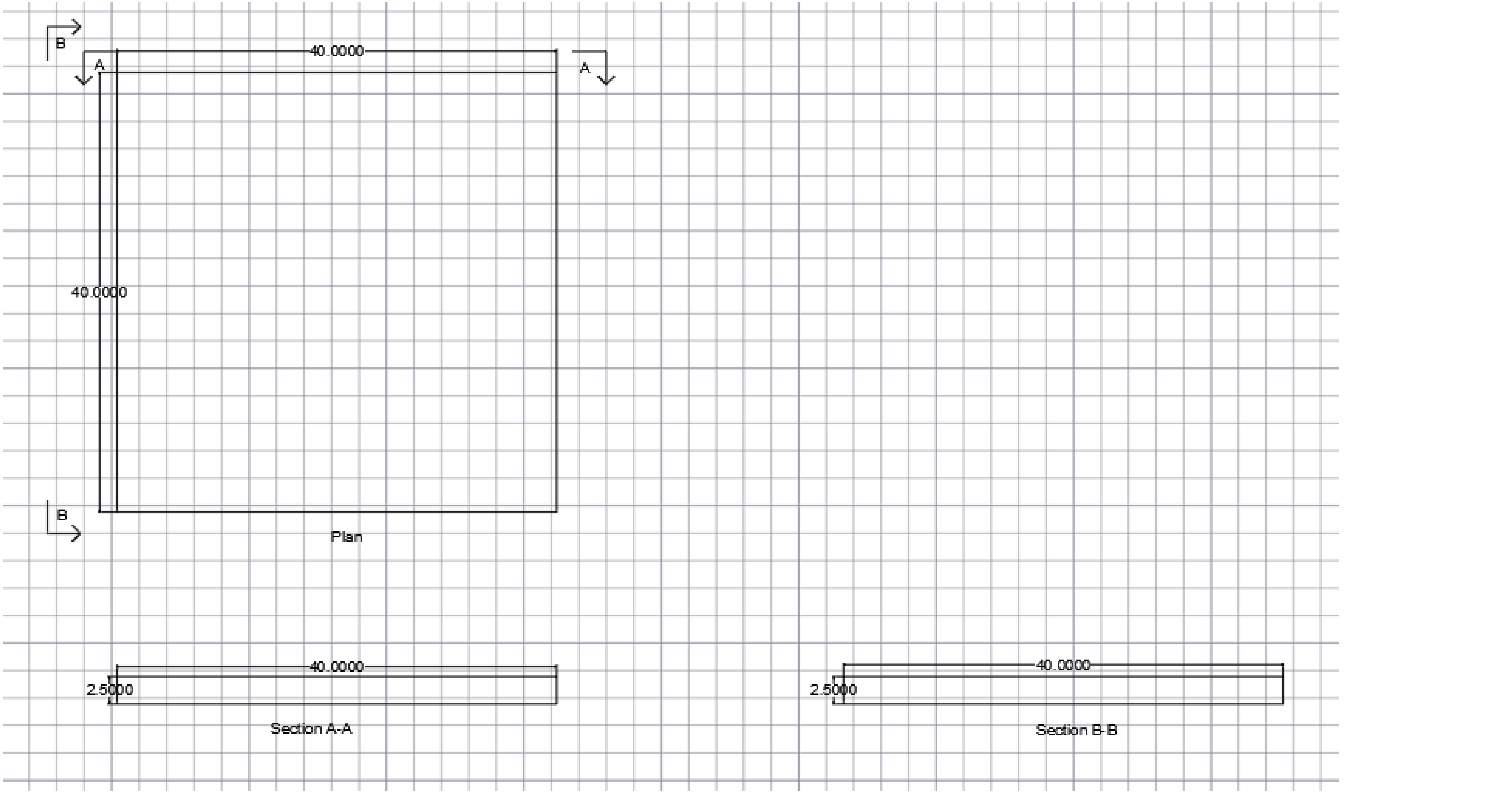

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STORAGE SYSTEM
NEW CONCRETE TANK STORAGE ALTERNATIVE

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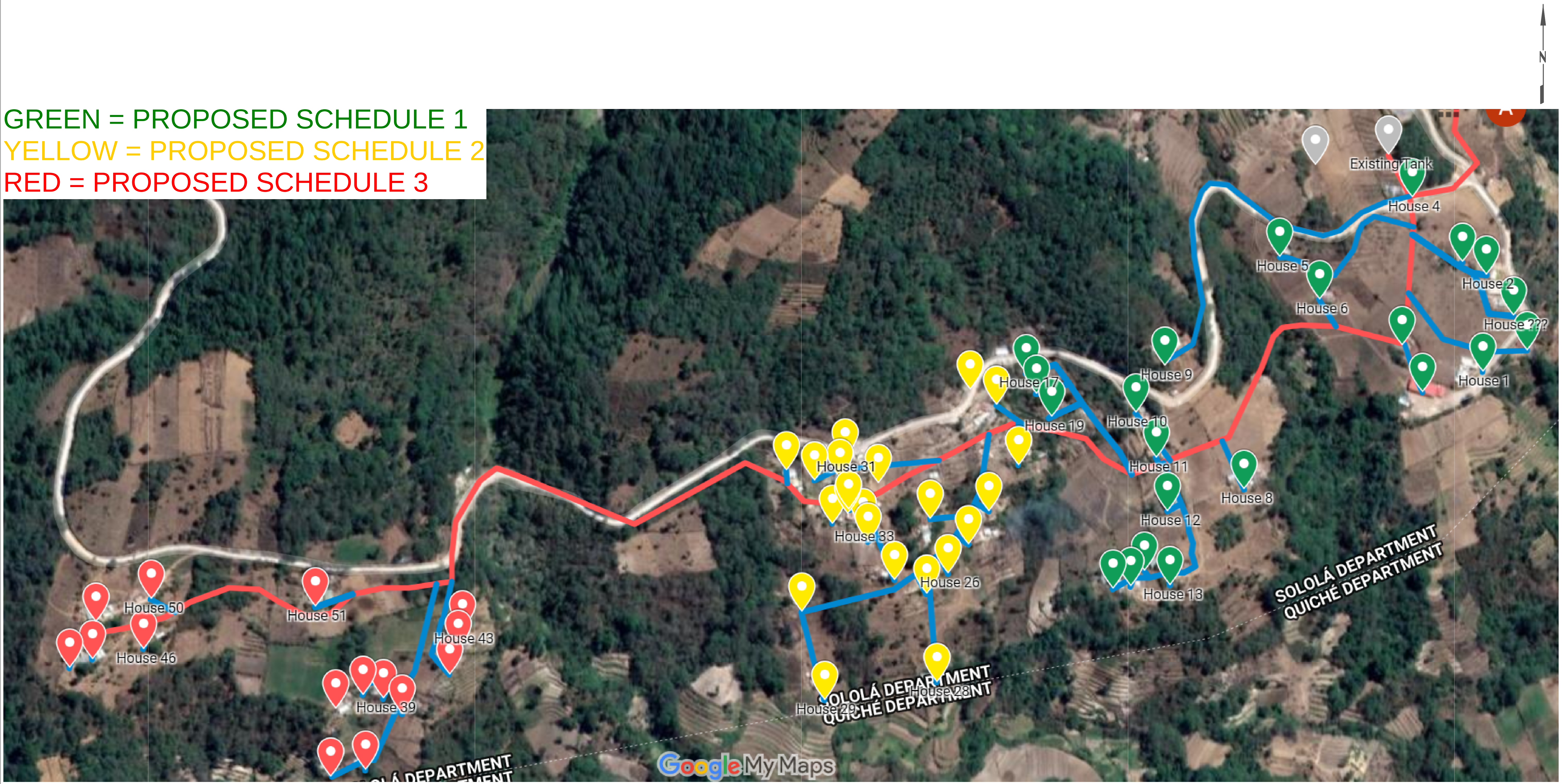

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WATER STORAGE, DISTRIBUTION, & TREATMENT

DISTRIBUTION SYSTEM
SCHEDULE ALTERNATIVE

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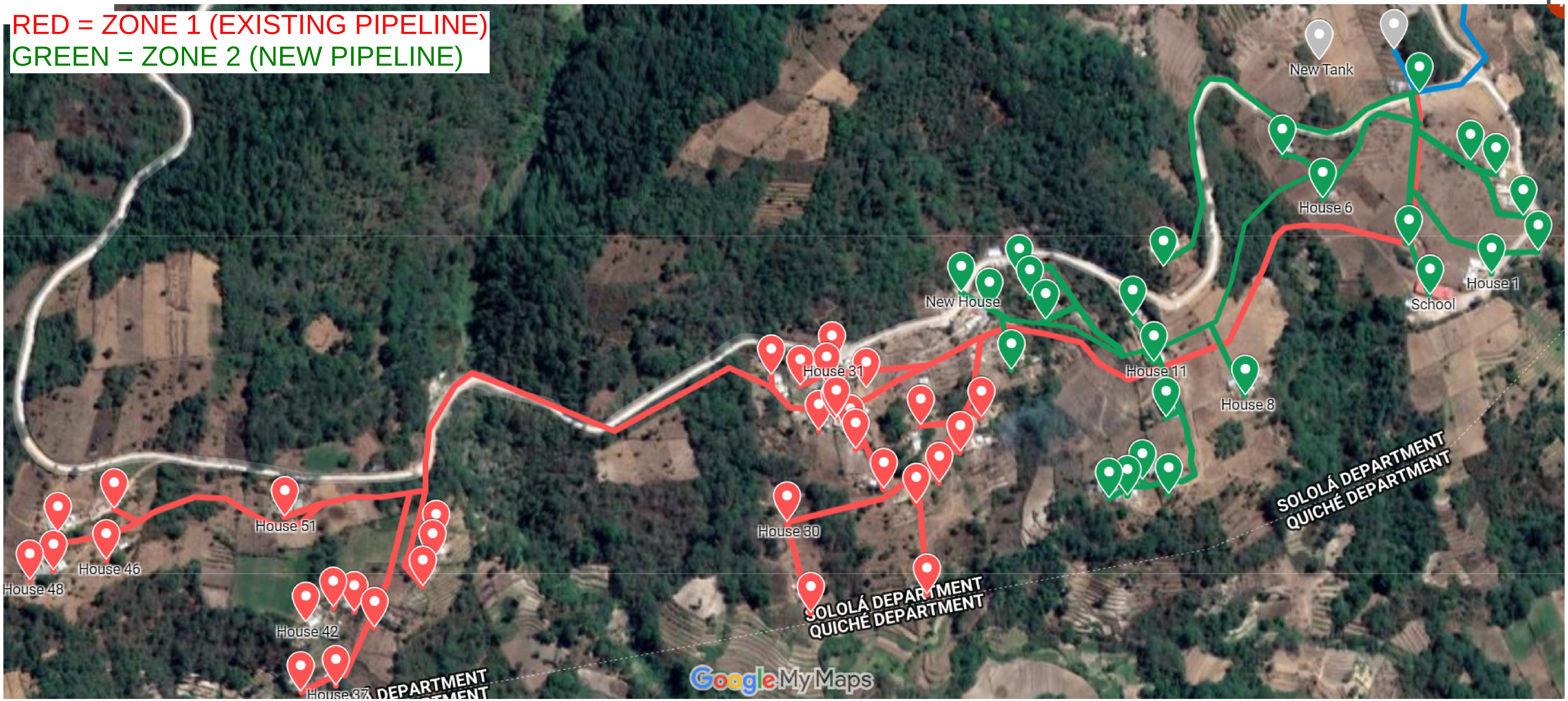

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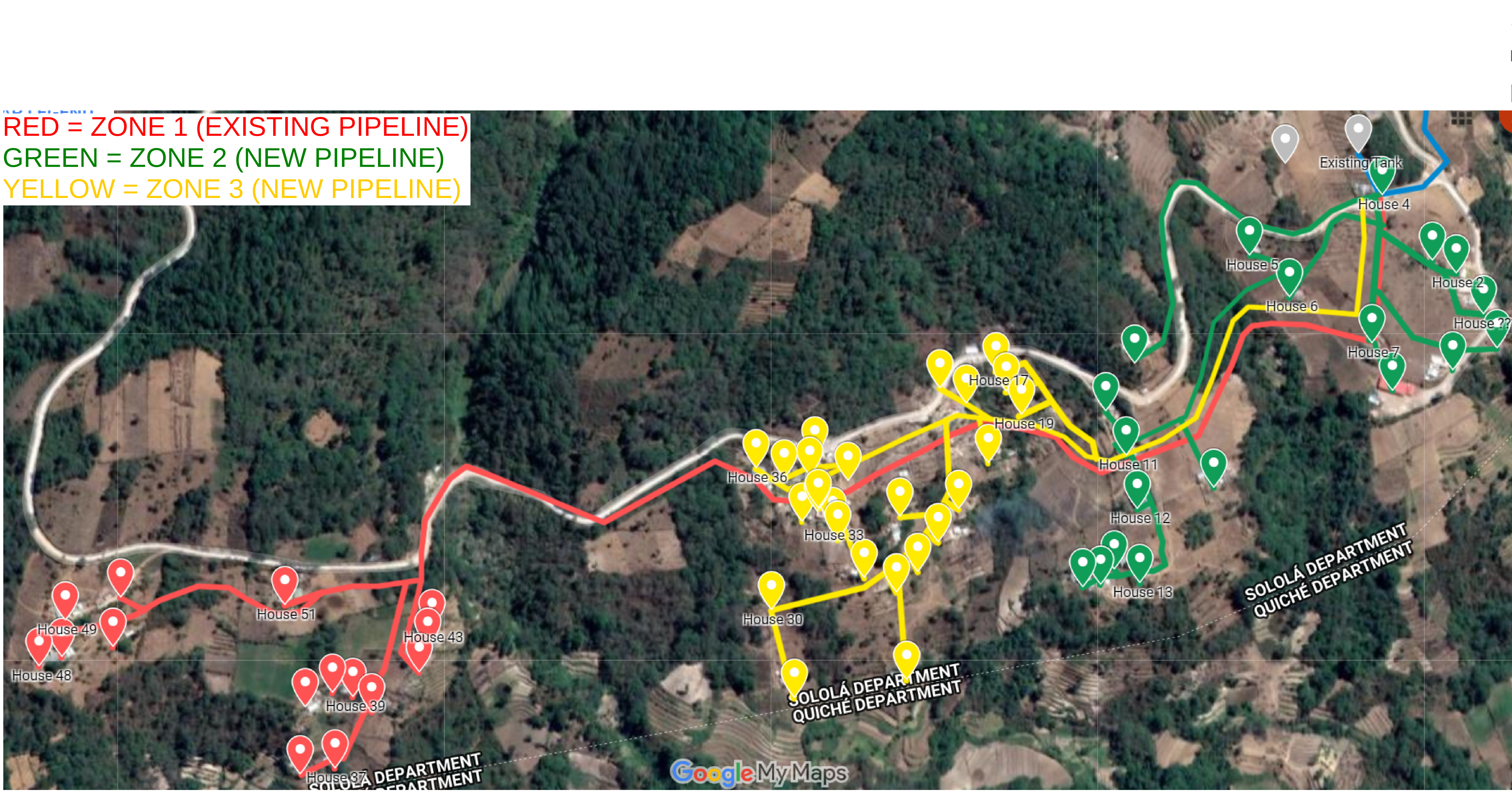

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WATER STORAGE, DISTRIBUTION, & TREATMENT

DISTRIBUTION SYSTEM
3 ZONE ALTERNATIVE

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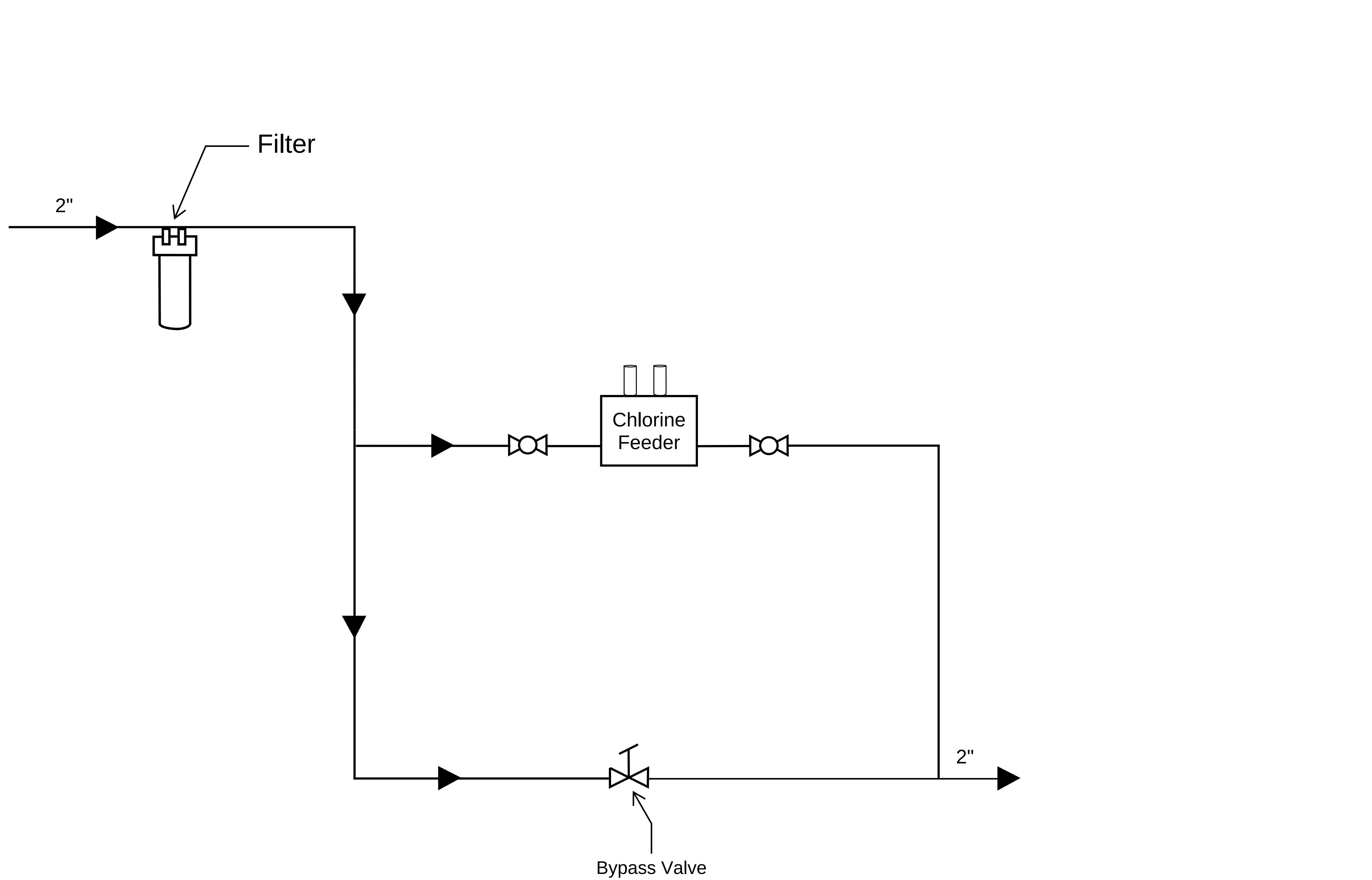

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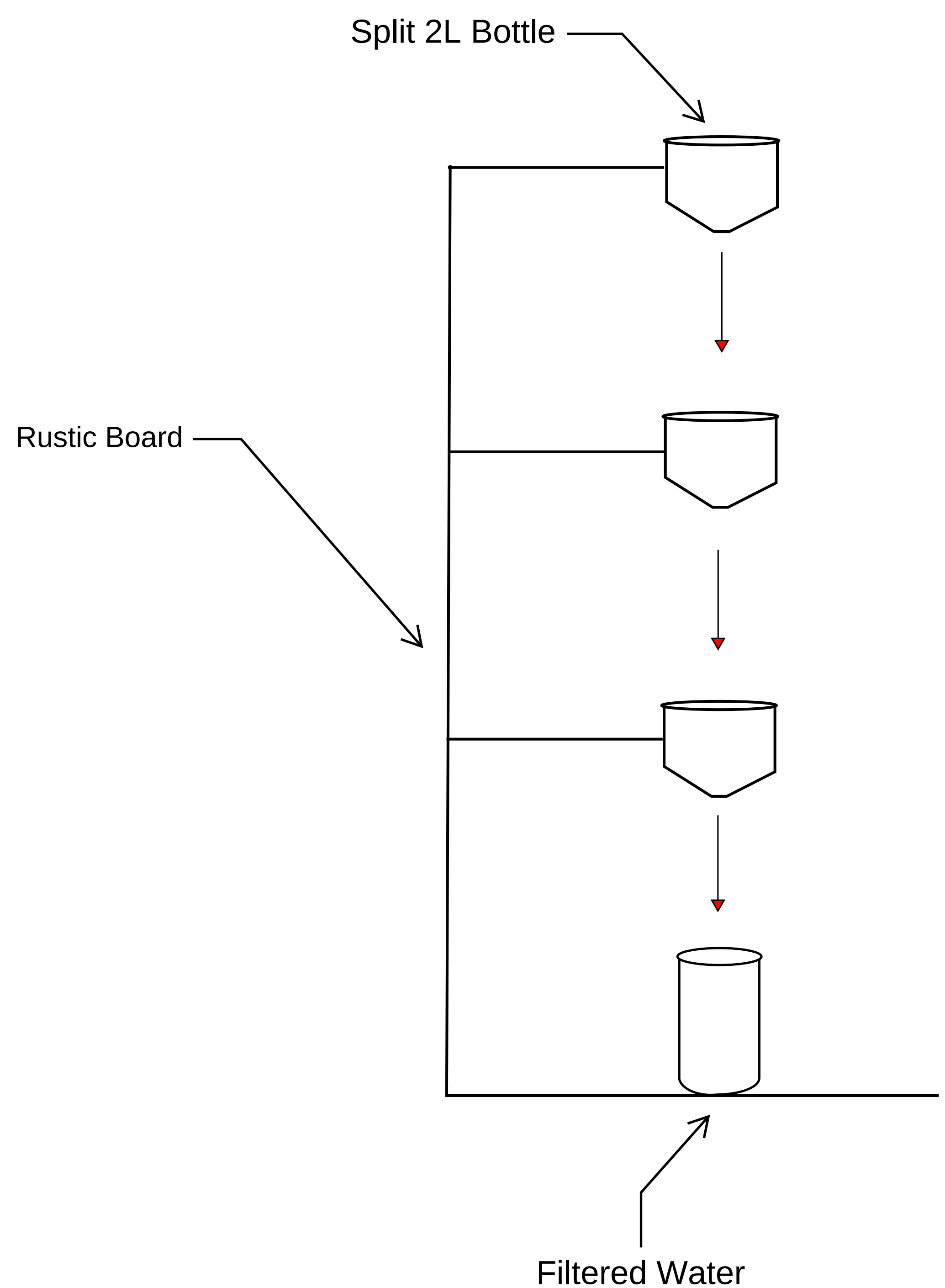

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