Implementation – Pre-Trip Plan

Executive Summary	
Community:	Los Churuneles II
Country:	Guatemala
Chapter:	Kansas City Professional Chapter
Submittal Date:	8/12/2020
Authors:	Andrew Doerflinger, Abe Fangman, Audrey Freiberger, Jillian Gallagher, Jake Sanders, Helen Wehner, Will Clark, Tyler Jehle
REIC and other mentors:	Scott Struck, PhD (REIC), Stephen Collins (professional mentor), John Kelley (internal reviewer), Adam Byrnes (internal reviewer)
Scope of Work for the project (50 words)	This project includes design modifications of an existing potable water supply system in a community of approximately 500 people with a naturally occurring spring water source. Implementation of the project includes the installation of water distribution piping, a water storage tank, a water treatment system, and household meters.
Scope of Work for the trip (100 words)	This is the first implementation trip. Due to the EWB-USA travel suspension, it will be remote. During this phase of implementation, the storage tank will be constructed and connected to the existing water distribution infrastructure, and a constructability survey of the proposed distribution system will be conducted.
Proposed Next Step (100 words)	On a Continued Implementation Trip, system-level water treatment, water distribution piping, and household meters will be installed. The new system will be fully operational upon completion of the Continued Implementation Trip.
Describe Recent Contact with Community, NGO, and in country partners. (100 words)	Contact with the community is made through staff of the NGO, at the preference of the NGO. The project team maintains contact with NGO staff through conference calls, emails and regular messages via WhatsApp. In May 2020, the project team met with staff of the NGO via conference call to discuss implementation planning. The NGO made contact with the community on behalf of the project team as a follow-up to this call, also in May 2020.

© 2018 Engineers Without Borders USA. All Rights Reserved

Describe the Chapters current fundraising goals and milestones. (100 words)	The chapter has secured sufficient funds to complete the project. Funding sources include a company foundation grant specifically awarded for this project, and the proceeds of quarterly public fundraising events hosted by the chapter.
☒	**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

Major Milestone	Previous Date	Current Date	Description
Program Adoption Date	2/26/2019		
Project Approval Date	5/02/2019		
Completed Assessment Trip	8/25/2019		Trip to complete data collection and to form relationships with community, contractors, and suppliers.
Planned Remote Implementation Trip	6/01/2020	9/15/2020*	Remote implementation to construct water storage tank and connect tank to existing piping.
Planned Remote Continued Implementation Trip	n/a	11/15/2020	Trip to install distribution piping, water treatment, household connections, conduct O&M training, document improvements, and continue PMEL activities.
Planned M&E Trip	2/31/2021	2/31/2021	Trip to collect performance metrics and conduct any necessary adjustments.

* Date is dependent on EWB-Guatemala foreman availability due to implementation being remote. Exact date will be coordinated between the chapter and EWB-Guatemala.

© 2019 Engineers Without Borders USA. All Rights Reserved

Table of Contents

© 2019 Engineers Without Borders USA. All Rights Reserved

© 2019 Engineers Without Borders USA. All Rights Reserved

© 2019 Engineers Without Borders USA. All Rights Reserved

1. Project Description

1.1. Project Background and History

The chapter opened the program in early 2019, and initiated the first project in Los Churuneles II in the second quarter of 2019. Project leaders began forming a relationship with the EWB-Guatemala office prior to assessment. The project team traveled on an assessment trip to Los Churuneles II in August 2019. During the assessment trip, the team formed relationships with the leaders of Los Churuneles II and its community-based organization (CBO) overseeing water system improvements, the Community Development Council, COCODE. Communication between the project team and CBO is made through EWB-Guatemala office staff, at EWB's request.

1.2. Project Context

Los Churuneles II is a small, conservative, and rural community in southwestern Guatemala with a population of approximately 500 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 due to its inability to meet the demands of the population. 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 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 0.51 L/second (8.1 gpm).

1.3. Project Goals and Objective

The overall project objective is to bring the community of Los Churuneles II and its future population a reliable supply of potable water year-round, and for years to come, from a centralized system.

The objective of this trip is to remotely oversee construction of the first phase of work, to include:

© 2019 Engineers Without Borders USA. All Rights Reserved

1. construction of a ferrocement water storage tank,
2. connection of this tank to the existing distribution system, and
3. a constructability survey of the proposed distribution system

The completion of these tasks will prepare the chapter for the remaining construction in phase two:

1. installation of a new distribution system, and
2. system-level water treatment

The community's current system does not have the capacity to support their population, or their future population. An undersized storage tank results in water immediately passing through the reservoir during times of higher demand. With no stored reserves, and the output of the spring source less than the instantaneous demand, only select households receive water during daytime demand. Under-sized pipes exacerbate the issue of severely inconsistent supply between homes, to the extreme in which one household has access to high pressure water 24/7 and another only receives water off peak hours, at nighttime. Finally, the absence of water treatment, especially one with a residual effect, leaves the system susceptible to contamination, and the residents of Los Churuneles II at risk for dangerous bacterial infections.

1.4. Scope of Work

The project objective laid out above will be achieved by addressing the following infrastructure:

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

The implementation of a new appropriately-sized storage tank will mean that at peak demand there is enough reserve so that every household receives water from the tank, not directly from the source, and at times of lower demand, the tank can fully refill. Also, an improved tank location at a higher elevation will increase the head pressure in the system

The construction of a properly designed distribution network based on hydraulic modeling will equally divide the available water volume between homes and ensure the water pressure stays within the appropriate range. And finally, the implementation of a system-level chlorine water treatment system will guarantee the water is potable now and for years to come, even in light of potential future changes to the supply.

© 2019 Engineers Without Borders USA. All Rights Reserved

1.5. Summary of Alternatives Analysis

There were four alternatives considered for the storage tank design. These four options were:

1. Build a new storage tank out of concrete.
2. Use the existing storage tank.
3. Construct a concrete pad to support HDPE tanks.
4. Build a storage tank out of ferrocement.

The option of using the existing storage tank was eliminated because it would not allow for the required capacity to meet peak demands of the distribution system. The alternative of building a concrete pad to support HDPE tanks was eliminated because four HDPE tanks would be necessary to contain the required volume, making the footprint of the associated concrete pad foundation larger than the plot of land available for the tank. Although the alternative of constructing a tank out of concrete satisfied all the identified criteria of this tank, the ferrocement tank option was ultimately selected. Ferrocement water storage tanks are common in Guatemala and the associated cost is lower than that of poured concrete. The decision to select the ferrocement option was ultimately driven by the necessity of the EWB-Guatemala office to oversee construction due to travel restrictions from EWB-USA. EWB-Guatemala is most familiar with ferrocement tank construction and will be able to implement the tank without professionals from EWB-KC physically present in the community.

Water distribution system design alternatives considered were:

1. No new construction. Implement a water-access schedule.
2. Divide the community into two zones and build one new pipeline to serve the second zone. A schedule would be implemented such that only one zone was on at a time.
3. Divide the community into three zones and add two pipelines to service the two additional zones. A schedule would be implemented such that only one zone was on at a time.
4. Install new distribution piping sized so that every household is served simultaneously.

Alternative four was chosen, as this will provide all community members with access to water 24/7. Options 2 and 3 were originally considered, as there were concerns that there was inadequate supply to meet community demand (including projected population growth). Initial analysis had assumed 100 liters per person per day, which is the upper limit of suggested minimum water per person according to the World Health Organization. However, after consulting the EWB-USA Guatemala Potable Water Standards, 60 liters per person per day was used. This will ensure there is sufficient supply to meet the community demand 24/7, when coupled with a properly sized storage tank.

© 2019 Engineers Without Borders USA. All Rights Reserved

Three water treatment alternatives were considered. These options include:

1. Chlorination.
2. Water filtration using corn husks.
3. No additional water treatment.

System-level chlorination at the storage tank alternative was chosen because it is a long term solution with minimal maintenance required from the community. Alternative 2 was a viable solution as corn is a staple crop in the community. This option was eliminated because not everyone would get filtered water on a regular basis and more filtration devices would be needed as the community continues to grow. With the water quality being high, no water treatment was also considered. According to the EWB-USA Guatemala Potable Water Standards, the required design life for a system is 20 years. There could be an increase in contaminates within those 20 years, so this solution was not selected. Even though Chlorine affects the taste and smell of water, COCODE did not seem to have any reservations with chlorination. This method of water treatment is known and used in Guatemala.

1.6. Project Team

The Responsible Engineer In Charge (REIC) is Scott Struck. The professional mentor is Stephen Collins. Internal reviewers are Adam Byrnes and John Kelley of the Kansas City Professional Chapter. Project Leads are Jake Sanders and Audrey Freiberger and the chapter Director of Projects is Adam Byrnes. Project scope leads are Andrew Doerflinger, Abe Fangman, Jillian Gallagher, and Helen Wehner. These team leaders are collaborating with many other engineers and volunteers within the EWB-KC chapter to see this project through a successful implementation. Each of the team leaders have resumes on their respective Volunteer Village member profile.

1.7. Community Partners

The Community-Based Organization (CBO) is the Community Development Council "COCODE". They are an official organization legally recognized by the municipality of Sololá and the state. COCODE consists of a committee elected from within the community to complete a community improvement project. The current committee consists of nine community members. COCODE, in conjunction with the community, will have ultimate decision authority for this project. 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 collection fees for drinking water once services are established. COCODE will also coordinate logistics of the community's 5% monetary contribution to the project.

© 2019 Engineers Without Borders USA. All Rights Reserved

The Engineers Without Borders Guatemala (EWB-Guatemala) office is serving as the Non-Governmental Organization (NGO) partner for this project. Their primary function is to facilitate in-country aspects of the project, especially communication with the community, and advise the chapter on critical project decisions. Since EWB-USA's COVID-19 travel suspension is preventing the project team from travelling for at least the initial phase of implementation, the EWB-Guatemala office will have the additional responsibility of coordinating this work. The EWB-Guatemala 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, and they have offered to assist the community in completing paperwork required to obtain construction permissions. The municipality has indicated they are available to provide assistance to the community post-construction.

1.8. Reference Projects (Conducted by EWB-USA)

The Kansas State University project in El Amate, Guatemala had lessons learned to share that were beneficial to the Los Churuneles II project team. The EWB-KSU project team highlighted the advantage of having local EWB offices in Guatemala and encouraged leveraging that connection. For example, they utilized a bus/taxi service and the EWB truck while traveling. They also mentioned using the accommodations recommended by the EWB office in Guatemala. Kristen Jones of the EWB-KSU travel team reflected on their engineering design and lessons learned by stating "we probably should have gone with our gut and the design that is most common in the area. We had all our calculations and drawings finished for a traditional septic tank and leach field but ended up changing everything about a week before the report was due to incorporate plastic septic tanks instead. About a year after the project was completed, only 2/3 latrines are working, and there were many complications during construction. I think this may have been avoided if we went with a more traditional or naturalistic design." Taking this lesson learned, the EWB-KC chapter will be calculating before making last minute changes that could make or break the outcome of the project. Kristen also mentioned the challenge of communicating with in-country partners and recommended using WhatsApp group messages as an efficient way to communicate. EWB-KC will contact our in-country partners using WhatsApp.

The EWB-KC Los Churuneles II project team was in communication with Macy Scott of the University of Colorado at Boulder chapter of EWB about their ongoing water system project in Caserio Totolya, Guatemala. Macy's biggest advice was to allot more time than is thought necessary for every activity and task. The goal of the Caserio Totolya project is very similar to the goal of the Los Churuneles II project. Both are water distribution projects with the water originating at a spring that is shared by multiple communities. As both communities are located in similar regions of Guatemala, both

© 2019 Engineers Without Borders USA. All Rights Reserved

also contend with a dry season that limits the amount of water the communities receive for parts of the year. EWB-CU provided three options in their Alternative Analysis for the materials of pipe for the conduction line replacement: PVC, HDPE, and galvanized steel. The Caserio Totolya project has compared the three options and is moving forward with design using a HDPE conduction line. Implementation will occur in the summer of 2019.

Max Schmiege of the Wisconsin Professional Chapter was able to provide some insight into working in Guatemala. “I have worked on projects in Guatemala for 15+ years, mainly bridges and water systems. I would suggest using the various resources regarding water system design that EWB has available on its website. Plan plenty of time into your schedule to communicate and coordinate with the local EWB contacts and specific community leaders. Think simple as much as possible in terms of design.”

Based on the information gathered from other project teams with similar projects in similar regions of Guatemala, the Los Churuneles II project team made every effort to utilize all resources available when it came to communication with the EWB team in Guatemala and the community itself. More time was accounted for in the schedule to ensure that all necessary information was able to be collected during the trip to the community.

2. Design

2.1. Storage Tank Design

2.1.1. Description of Existing Infrastructure

The existing water storage tank is located at one of the highest elevations in the community in a corn field that belongs to a member of a neighboring community. The dimensions of this tank are approximately 4 feet long by 4 feet wide with a height of 4 feet, and it is constructed from concrete with a removable concrete lid to act as an access point for maintenance. This volume of 64 ft^3 is an inadequate storage for the community to maintain a supply commensurate with need. A photo of the existing water storage tank is provided in Figure 01 below. The community estimates that the storage tank is around 30 years old.

© 2019 Engineers Without Borders USA. All Rights Reserved

Figure 01: Location of Existing Storage Tank

Additionally, the land where the tank is located is not owned by the community and the landowner wants it removed from his property. The community has purchased a plot of land closer to their village on which the new, larger storage tank will be installed.

2.1.2. Description of Proposed Facilities

The proposed tank will be located across the corn field and at a slightly higher elevation than where the existing tank resides. The tank will have a height of 7.22 ft and an interior diameter of 17.39 ft, yielding a capacity of 1,590 ft^3 (45 m^3). The tank will also have a roof with an opening and hatch cover to provide access for maintenance. The walls and roof of the structure will be ferrocement, which is constructed out of reinforcing steel bars, welded wire mesh, chicken wire, and ferrocement plaster. The foundation of the tank will be poured concrete 12” thick bearing on compacted fill and gravel. This new water storage tank will resolve the problem of not having enough water storage by providing a capacity sufficient for the current demands, along with the required demands over the 20 year design life of the project. The use of ferrocement structures is common in Guatemala and its construction is familiar to the EWB-Guatemala office. This was an important factor in design considerations as the tank will be constructed under the direction of the EWB-Guatemala office due to travel restrictions and concerns around COVID-19.

2.1.3. Basis of Design

2.1.3.1. List of standards and codes

© 2019 Engineers Without Borders USA. All Rights Reserved

The following codes, standards, and design guides were used in the analysis and design of the storage tank structure and foundation:

1) Potable Water Standards, EWB-USA Guatemala, May 2018.
2) Large Ferro-Cement Water Tank, United Nations High Commissioner for Refugees, July 2006.
3) Ferrocement Tank Construction Manual, ferrocement.com, 2015
4) ACI 549R-18 Report on Ferrocement, American Concrete Institute, Jan. 2018
5) ACI 549.1R-18 Design Guide for Ferrocement, American Concrete Institute, Sept. 2018
6) ACI 318-14 Building Code Requirements for Structural Concrete, American Concrete Institute, 2018
7) AISC 14, Steel Construction Manual, American Institute of Steel Construction, 14th Edition, 2011
8) NES 2-10 Normas de Seguridad Estructural de Edificaciones y Obras de Infraestructura para la República de Guatemala, AGIES
9) Structural Guidelines, Engineers Without Borders - USA, 2006
10) ANSI/AWWA Standard D100-11 Welded Carbon Steel Tanks for Water Storage, American National Standards Institute/American Water Works Association
11) ASCE/SEI 7-10 Minimum Design Loads for Buildings and Other Structures, American Society of Civil Engineers, 2010

2.1.3.2. Design Methodology

The storage tank design uses the standard ferrocement design as detailed in Large Ferro-Cement Water Tank Design Parameters and Construction Details. The guide provides drawings for 45 m^3, 75 m^3, and 90 m^3, and the 45 m^3 drawings served as a starting point for this design. The calculation verifies the materials, dimensions, and structural properties using the design methods presented in the Ferrocement Tank Construction Manual along with guidance from ACI 549R-18 Report on Ferrocement and ACI 549.1R-18 Design Guide for Ferrocement. The guidance from ACI encourages a conservative design approach for structures involving ferrocement since there is a lack of knowledge and construction experience with this newer structural material. Whenever possible, conservative engineering judgement is used in the design.

The storage tank is sized following the Potable Water Standards provided by EWB-USA Guatemala. The standards require that the storage tank capacity be designed for the current population of the community plus a 2% growth rate over the design life of the project, in this case 20 years. The demand per person is selected based on the EWB-Guatemala Potable Water Standards, which suggest 60-80 liters per person per day. Conversations with the EWB-Guatemala office indicate that actual daily demand in this region is closer to 55-60 liters per person. Thus, a value of 60 liters per person per day was conservatively suggested.The population count taken on the assessment trip was 463 but this number could not be verified and has likely changed since the assessment trip taken in August 2019. The population count will be rounded to 500 people for the purpose of design. With a demand of 60 L per person per day and a population of 500 people factored by 1.49 to account for population growth over 20 years, a design capacity of 1579 ft^3 (44.7 m^3) is calculated. This size is to hold a single day's supply of water.

For analysis of ferrocement structures that use Load and Resistance Factor Design (LRFD), ACI 549.1R-18 Design Guide for Ferrocement suggests using an increased dead load factor of 2.0 and an increased live load factor of 2.0 instead of the common factors in ASCE/SEI 7-10 Minimum Design Loads for Buildings and Other Structures. The roof design is analyzed using LRFD and these increased factors are applied to the dead and live loads. Allowable Strength Design (ASD) is used for the wall design as this follows most closely with the checks exemplified in the Ferrocement Tank Construction Manual. Following typical engineering practice, ASD is also used for the foundation design.

The dead load of separate parts of the structure (roof, wall, foundation) are taken as the self-weight of each component and are determined by multiplying the unit weight of concrete, 150 pcf, by each respective area and height. According to ASCE/SEI 7-10, a roof live load of 20 psf for roofs that require maintenance access will be applied to the structure. The weight of water is calculated as the volume of water in the tank multiplied by the unit weight of water, taken as 62.4 pcf. Normas de Seguridad Estructural de Edificaciones y Obras de Infraestructura para la República de Guatemala (NES 2-10) provides the design wind speed for the water tanks location as 62 mph. Procedures and coefficients from ASCE/SEI 7-10 are then used to develop the wind load, along with the design wind base shear and the design wind overturning moment to be used in the foundation design. The load due to wind is calculated to be 9.6 psf.

Guatemala is known as a country with high seismic activity and a seismic analysis of the tank is therefore necessary. NES 2-10 provides Figure 4-1 detailing the mapped short period response acceleration and mapped 1-second period response acceleration values used in the development of seismic loads on the tank. The tank is assigned a seismic importance factor of 1.25. This magnitude of this importance factor is for tanks that are intended to remain usable for emergency purposes after an earthquake and with this tank acting as the sole source of drinking water for the community, it is deemed an essential structure. ANSI/AWWA Standard D100-11, Welded Carbon Steel Tanks for Water Storage, details a seismic analysis of tanks which is followed in this calculation. This analysis yields both the total impulsive base shear and the total convective base shear from equivalent weights and their respective centers of gravity. The combined effects of the impulsive base shear and convective base shear result in the total seismic base shear and total seismic base moment to be used in the foundation design. The

© 2019 Engineers Without Borders USA. All Rights Reserved

seismic base shear and seismic base moment are both greater than the wind base shear and wind overturning moment, therefore seismic loads will control the design.

The design of walls out of ferrocement assumes that the ferrocement mortar only serves as a device to keep the water contained and all the strength for the wall comes from the steel. Reinforcing bars span from the foundation up through the wall and then into the roof. Welded wire mesh pictured below in Figure 02 is then wrapped around the circumference of the tank in two layers with metal attaching ties to provide additional strength. Chicken wire is finally wrapped around the welded wire mesh to provide a greater surface area for the ferrocement mortar to attach to. The chicken wire is not given any structural properties in the calculation. The pressure from the water on the tank wall is compared to the strength of the combined reinforcing bars and welded wire mesh to ensure the adequacy of the tank wall.

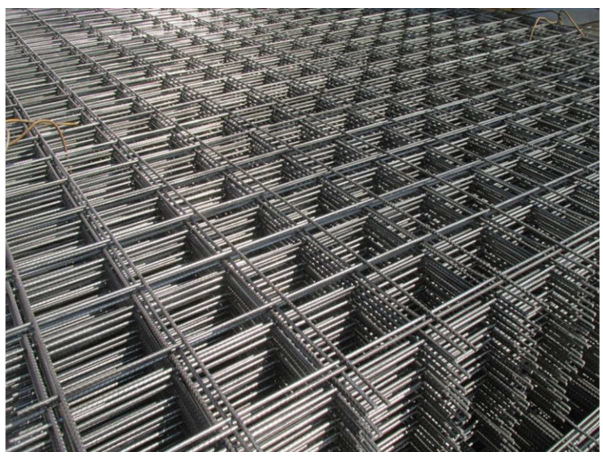


Figure 02: Welded Wire Mesh

ACI 549.1R-18 Design Guide for Ferrocement suggests analyzing ferrocement using the typical analysis methods described in ACI 318-14, Building Code Requirements for Structural Concrete. Following this guidance, the roof is analyzed as a 1’ wide beam spanning between the tank wall and the central column. The loading on the roof structure includes the self-weight of the roof and the roof live load of 20 psf. Trusses are constructed out of reinforcing bars and the same welded wire mesh and chicken wire configuration as the roof and walls. These trusses span from the central column to channels in the wall to carry the loads from the roof down into the foundation without bearing on the ferrocement wall. An extra 20% of the self-weight is added to the dead load to account for the weight of the trusses in the design although their strength will be conservatively excluded from the design moment capacity of the roof structure. Examples of determining moment capacity of a ferrocement section are provided at the end of ACI 549.1R-18 and that example is followed in the calculation. The distance from

© 2019 Engineers Without Borders USA. All Rights Reserved

the extreme compression fiber of the section to the neutral axis is determined by trial and error solving to set the tension forces and compression forces equal to one another.

The central column fills a PVC pipe with mortar and anchors it to the foundation by connecting reinforcing bars from the foundation up into the mortar filled PVC pipe. The PVC is not given any structural properties and serves only as formwork to contain the mortar. The compressive strength of the mortar mixture is compared to the axial load developed from the roof self-weight and live loading in the tributary area respective to the column location.

No geotechnical information is available for the site and the bearing pressure of the soil is conservatively selected as 1,500 psf according to recommendations from ASCE/SEI 7-10. The 12" thick concrete foundation is evaluated for bearing, sliding and overturning according to ACI 318-14. ASD load combinations containing wind and seismic loads are both evaluated. The minimum reinforcement required in the horizontal direction is determined by analyzing the hoop tension developed in the slab. Both reinforcing bars and layers of welded wire mesh are included in the foundation.

2.1.4. Calculations

Note: Detailed calculations for the storage tank are included as Attachment E.1.

The purpose of this calculation is to design a ferrocement tank to hold 1579 ft^3 (45 m^3) of water to supply the distribution system. The tank has dead, live, wind, and seismic loads applied to it as described in the previous section of this report. The ferrocement wall and roof will be three inches thick including the #4 reinforcing bars, two layers of welded wire mesh, two layers of chicken mesh, and ferrocement mortar. According to ACI 549.1R-18 Design Guide for Ferrocement, the total volume fraction of reinforcement for ferrocement must be greater than 1.8%. With two layers of welded wire mesh and the #4 reinforcing bars in a three inch thick section, the total volume fraction of reinforcement is 25.7% and is therefore adequate.

The design wind base shear is calculated as 3600 lb and the design wind overturning moment is calculated as 17,750 lb-ft. The total seismic base shear is calculated as 48,261 lb and the total seismic base moment is calculated as 106,289 lb-ft. In the case of shear and moment, the seismic loads are greater than wind and control the design.

The tank walls are analyzed by focusing on a one foot section of wall that is three feet tall as the pressure will be greater near the base of the tank. The pressure from the water is calculated as 430 psf then distributed over the circumference of the tank, resulting in a total outward force on the bottom of the tank wall of 23,490 plf. In this 1'x3' section, there are six horizontal reinforcing bars, two vertical reinforcing bars, 6 horizontal welded wire mesh strands and 2 vertical welded wire mesh strands. By multiplying the quantity of material by the strength, the total strength of the section is determined. The horizontal reinforcing bars provide 36,000 plf of strength, the vertical

© 2019 Engineers Without Borders USA. All Rights Reserved

reinforcing bars provide 12,000 plf, the horizontal welded wire mesh provides 5150 plf, and the vertical welded wire mesh provides 1700 plf. In total, the reinforcement in the wall has a nominal strength of 54,800 plf. Using a safety factor of 2.0, the interaction ratio between the required strength and nominal strength is 0.86.

Table 01: Storage Tank Dimensions	
Thickness of Ferrocement Sections	3 in.
Height of Tank Wall	7.22 ft
Height of Roof above Tank Wall	1.64 ft
Interior Diameter of Tank	17.39 ft
Diameter of Foundation	20.67 ft
Thickness of Foundation	12 in.

The tank roof is analyzed as an 8.7 foot long beam spanning between the tank wall and the central column. The design moment is calculated as a simply supported beam and results in a value of 1229 lb-ft. Solving for the neutral axis of the reinforcement layers using trial and error, a neutral axis of 0.51 inches is determined. Using this value, a nominal moment capacity of 1,084,801 lb-ft is calculated. Comparing the design moment to the nominal moment capacity reduced by the flexural reduction factor of 0.90, and interaction ratio of 0.001 for the roof section is determined. This value is adequate and the roof design is therefore adequate.

Table 02: Storage Tank Design Results	
Tank Wall IR	0.86
Tank Roof IR	0.01
Central Column IR	0.07
Roof Support Channel IR	0.91
Foundation Bearing Pressure IR	0.44
Factor of Safety for Overturning	0.09

2.1.5. Material Specifications

All reinforcing bars will be size #4 (diameter of 0.5 in.) in Grade 60 steel. They will be free from grease, oil detergents, and organic matter. All cement used in this storage tank will be Portland cement Type II. Concrete for the foundation will have a compressive strength of 3,000 psf achieved by a mix design of 1:2:4 (cement : sand: aggregate by weight). Ferrocement mortar for the wall and roof will have a mix design of 1:2:0.4 (cement : sand:

© 2019 Engineers Without Borders USA. All Rights Reserved

water by weight) and a compressive strength of 3,000 psf. The lean concrete base will have a mix design of 1:4:8 (cement : sand : aggregate by weight). The welded wire mesh will be Grade 60 with 10/10 gage with a 6"x6" square grid. It will be free from grease, oil, rust and anything that might reduce bond. The steel channels will be GHT 16 3"x1.25" Grade 72 free from grease, oil detergents, organic matter, and cracks of blow holes.

2.2. Distribution System Design

2.2.1. Description of Existing Infrastructure

The existing distribution system is shown below in Figure 03. A spring box located approximately a kilometer away from the community at an elevation of approximately 2,590 m collects water from a spring and divides the flow evenly to three different communities, including Los Churuneles II. The flowrate of water that is available to Churuneles was measured to be 0.51 L/second. The spring box is connected to a nearby tank, the Spring Tank, approximately 10 m away with a 2" galvanized iron pipe. The Spring Tank has a capacity of approximately 30 m^3. From the Spring Tank, a Conduction Line, made of a 2" PVC pipe, travels approximately 1 km to the existing Storage Tank. The Conduction Line was recently replaced in 2018. The existing Storage Tank is located immediately next to the community at an elevation of 2,530 m and has a capacity of 3 m^3. The design of a new Storage Tank is discussed in the previous section. From the Storage Tank, a Distribution Line flows throughout the community, with branches connecting to each household. The Distribution Line is made entirely of 1 ½" PVC pipe, except for an exposed portion that crosses a ravine and is made of a 1 ½" galvanized iron pipe. From the Distribution Line, service line branches connect to a tap at each household. The service lines are each ¾" PVC pipe. The Distribution Line and service lines are significantly older than the Conduction Line, with the community estimating that they are approximately 30 years old.

© 2019 Engineers Without Borders USA. All Rights Reserved

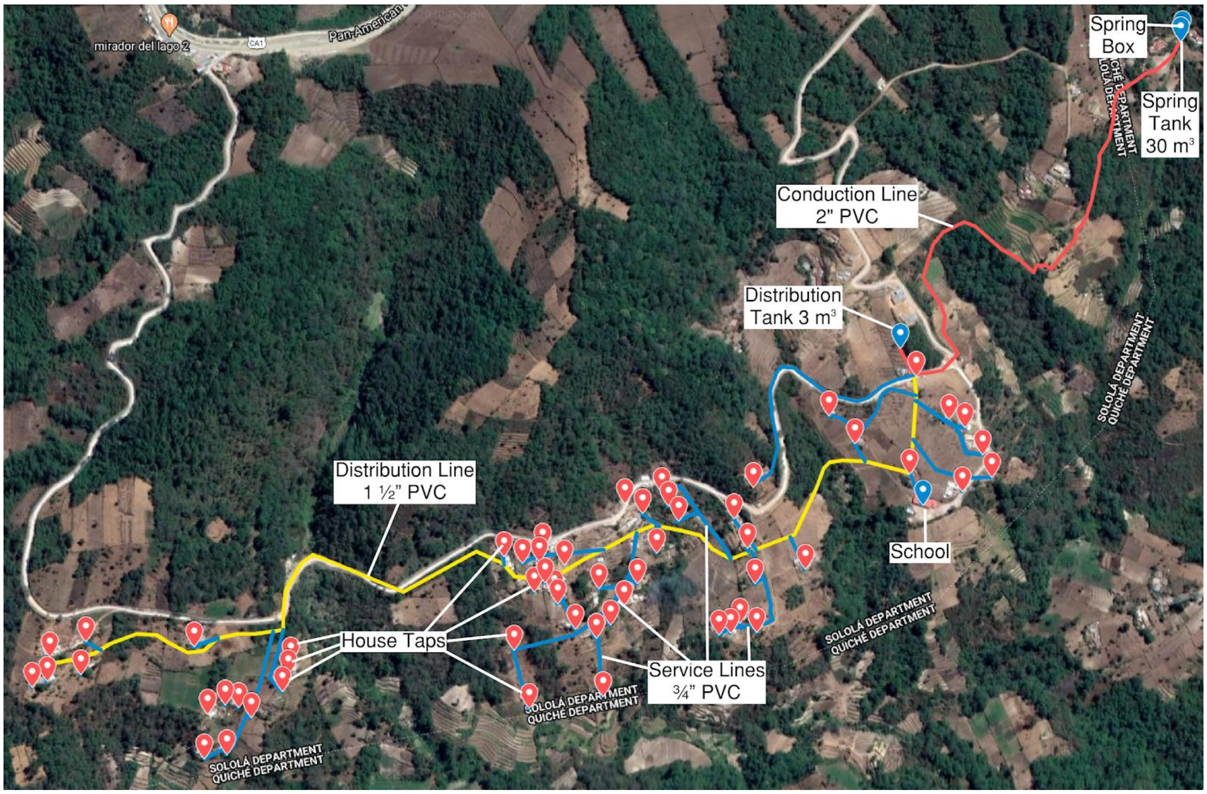


Figure 03: Existing Distribution System

2.2.2. Description of Proposed Facilities

The proposed distribution system will retain the recently replaced Conduction Line and will replace the older Distribution Line. From the new Storage Tank, two headers will provide water access to each household in the community. Header 1 will be a 2” PVC pipe that will service 30 houses, focusing largely on the houses nearest to the Storage Tank. Header 2 will be a 3” PVC pipe that will run the entire length of the community, providing water to the houses at the far western edge of the community. Header 2 will connect to 26 houses, plus the school and community center. 1” branch connections will connect groups of houses to the headers, with ¾” service lines finally connecting to each tap. Water meters will be installed at each tap to measure water usage.

Two headers, instead of a single 3” header, were chosen for several reasons. Two headers, with one sized 3” and the other sized 2”, provides additional capacity for future expansion of the system. Redundancy is added, should one header become damaged or no longer function properly in the future. Lastly, operational flexibility is added. If the supply of water to the community decreases or the demand increases beyond the future projection, the community would have the ability to implement a scheduled zone approach.

© 2019 Engineers Without Borders USA. All Rights Reserved

2.2.3. Basis of Design

2.2.3.1. List of standards and codes

For the design of the distribution system, the EWB-USA Guatemala Potable Water Standards provided the basis for design, sizing and analysis of the design. These best practice standards were developed from several sources, including the *Guia de normas sanitarias para el diseño de sistemas rurales de abastecimiento de agua para consumo humano* published by the Instituto de Fomento Municipal (INFOM) and the Ministerio de Salud Pública, EWB-USA Water Resource Guidelines, and experience from the local nonprofit Agua Para La Salud.

2.2.3.2. Design Methodology

The routing of the pipeline and the grouping of houses to the different headers was selected with the following in mind:

- Minimize total pipe distance
- Group taps together locally
- Avoid localized high points
- Follow existing roads and footpaths - avoid pipe in agricultural areas
- Provide dedicated branches to the school and community center

Both Header 1 and Header 2 follow the same path as the road. For the most part, all houses lie below the road in elevation. This helps to ensure there is adequate pressure head and will also minimize local high points in the pipe. Both headers will share a common trench, which shall be 60cm deep and located on the downhill side of the road. All efforts shall be made to avoid routing the pipe through areas at high risk of erosion. Any required road crossings shall be buried in a 120cm deep trench.

All efforts were made to avoid selecting a pipeline route with localized high points, as this creates a risk for air locks. However, due to the drastic changes in elevation throughout the community, this is difficult to completely avoid. Automatic air release valves will be installed at local high points to alleviate this concern. The exact location and design of the air release valve stations will be confirmed in the Continued Implementation Report.

Houses located at the bottom of the community can see high pressures due to the large elevation changes. To accommodate higher pressures, all ¾” service lines will use a 250 psi rated pipe. Even so, the pressure at the end user’s tap can often exceed the 60 psig maximum recommended value. Pressure reduction will therefore be required. Options considered include pressure reduction valves, partially closed globe valves, and reduction orifices. Pressure reduction valves are not readily available locally, and will not

© 2019 Engineers Without Borders USA. All Rights Reserved

be used. Restriction orifices are commonly used in Guatemala by drilling a hole in a 10 cent coin. The location of taps that require pressure reduction and the means of pressure reduction will be confirmed in the Continued Implementation Report.

2.2.4. Calculations

A daily water profile of the Storage Tank was created to ensure there is adequate storage to meet peak demands. The Agua Para La Salud hourly demand percentages were used along with the parameters summarized below in Table 03 to generate the daily water profile. The daily water profile was generated for the projected future demand of the community and is shown in Figure 04. The daily supply of water is nearly the exact projected future demand of the community.

Table 03: Daily Water Profile Inputs

Parameter	Value
Population	500
Annual Population Growth	2%
Design Life (years)	20
Future Population Factor	1.49
Spring Flowrate (l/s)	0.51
Daily Supply (l/day)	44,064
Daily Demand (l/person/day)	60
Current Demand (l/day)	30,000
Future Demand (l/day)	44,578
Starting Water Level (liters)	35,000

© 2019 Engineers Without Borders USA. All Rights Reserved

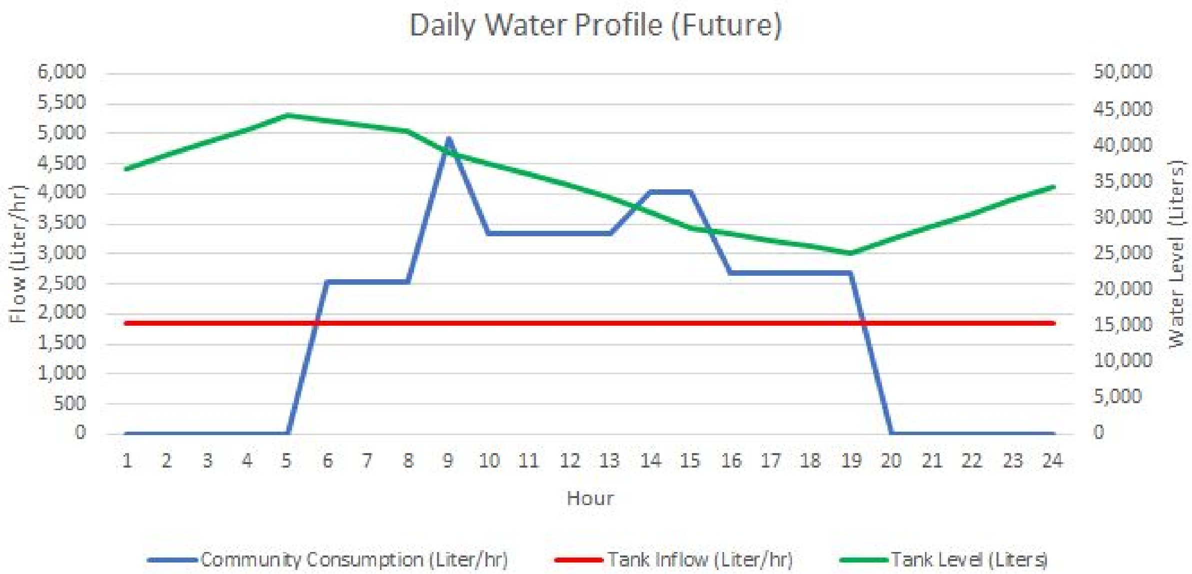


Figure 04: Daily Water Profile

Pipe sizes were determined considering a maximum velocity of 2 m/s, as recommended by the EWB-USA Guatemala Potable Water Standards. Using the calculated pipe cross sectional areas, maximum flow rates were calculated. The Agua Para La Salud value of 0.1 l/s per tap for homes was used to determine the maximum number of taps that could be served by each pipe size. The results of this analysis are summarized below in Table 04.

Table 04: Flow Capacity by Pipe Size, Class

	SDR-17 (250 psi)		SDR-26 (160 psi)	
Nom Size (in)	Max Flow (l/s)	Max # of Taps	Max Flow (l/s)	Max # of Taps
3/4	0.9	8	-	-
1	1.4	13	1.4	14
2	4.4	44	4.9	48
3	9.7	96	10.6	105

Frictional losses through the piping system were calculated to verify there is sufficient pressure head. A 25% safety factor was included in the calculation. The Conduction Line size was confirmed as 2”, with a maximum pressure of 87psig. This falls below the 160 psi pressure class limit and confirms that break pressure tanks are not necessary within the Conduction Line. The average flow rate of 0.51 l/s from the spring was used for the Conduction Line calculation. The detailed frictional loss calculation is included in Attachment E.2.

© 2019 Engineers Without Borders USA. All Rights Reserved

For the distribution system from the Storage Tank to the end users, a peak instantaneous flow rate of 0.1 l/s per tap was used. Header 1 serves 30 taps, and was thus designed for a 3.0 l/s flow rate. Header 2 serves 28 taps and was designed for a 2.8 l/s flow rate. Distances and elevations were calculated by referencing the Agua Para La Salud design (See Attachment A Reference). Again, a 25% safety factor was used in the calculation.

2.2.5. Material Specifications

PVC was selected as the predominant pipe material. It is available locally, resistant to corrosion, lightweight, inexpensive, and long-lasting. Two different pressure classes of PVC pipe are used. 160 psi (SDR-26) PVC is used for the Conduction Line, both headers, and the large header branches. 250 psi (SDR-17) PVC is used for the ¾" service line connections to each tap. PVC cement will be used to connect the pipe segments.

In areas where the pipe will be exposed and not in a trench, such as in ravine crossings, galvanized iron pipes will be used. Locations that require galvanize iron piping and the length of piping required will be confirmed in the Continued Implementation Report.

2.3. Water Treatment System Design

2.3.1. Description of Existing Infrastructure

Currently, there is no water treatment. The community retrieves the water directly from the tap without a treatment system or point-of-use treatment.

2.3.2. Description of Proposed Facilities

The proposed water treatment system will be located on the purchased land on the corner of the storage tank pad. With the chlorinator being close to the center of the community, access for operations and maintenance will be more efficient. By gravity, the water flows through the chlorinator through the inlet baffle and out the weir plate. The inlet baffle sends a small amount of the water under the support plate and the rest of the water meets the chlorine tablet. After initial installation, the water shall be tested downstream of the chlorinator for over chlorination. If the water is over chlorinated, a 2.5" space disc can be installed in between the first tablet and tablet tube.

This chlorinator will have an enclosure to protect the PVC from the prolonged exposure to the rainy conditions. The chlorinator house will be 4 ft tall and 4 ft wide with CMU

© 2019 Engineers Without Borders USA. All Rights Reserved

blocks and #4 rebar. Corrugated galvanized steel sheets will be used for the roof. Once the new storage tank is constructed, the chlorinator can be attached to the tank. The chlorination system will be located before the tank because the chlorine needs contact time with the water to activate.

2.3.3. Basis of Design

2.3.3.1. List of standards and codes

For the water treatment design, the following codes, standards, and design guides were used for analysis and basis of design:

1) Potable Water Standards, EWB-USA Guatemala, May 2018
2) Guia de Normas Sanitarias Para el Diseño de Sistemas Rulas de Abastecimiento de Agua Para Consumo Humano, Instituto de Fomento Municipal and Ministerio de Salud Pública, November 2011
3) Guidelines for Drinking Water Quality, World Health Organization, 2017
4) The CTI 8 Chlorinator - Manual of Information, Maintenance, and Operation, Compatible Technology International

2.3.3.2. Design Methodology

The quality of the water is high, thus a low dosage of chlorine is needed for treatment. Chlorination will provide sustainability for the system, so if the quality decreases, the treatment system will still be sufficient. As water quality decreases, the chlorine dosage rate increases. The dosage is a major factor in determining the number of chlorine tablets required. Thus, as the chlorine dosage increases, the quantity of tablets increase. Free Chlorine dosage was determined by using 2 mg/L for clear water, as recommended by the World Health Organization. This dosage rate was used to calculate the number of tablets needed for the chlorination system. Compatible Technology International's CTI8 Chlorinator was the basis of this design.

This specific chlorination system is located in another community in Guatemala, which is intended for 2-20 gpm (.13 - 1.3 L/s). 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/s. Once a new storage tank is constructed and is allowed to fill overnight each day, the maximum flow rate will be 2.9 L/second (46 gpm). The required chlorine dosage is very low, thus the CTI8 can treat the larger flow rate.

2.3.4. Calculations

The quantity of tablets that should be exposed to the flow was based on the capacity of the new storage tank of 45 m^3 and a dosage of 2 mg/L. This dosage is based on the

© 2019 Engineers Without Borders USA. All Rights Reserved

World Health Organization's (WHO) recommendation for clear water. Calcium hypochlorite is the basis for the disinfectant. The tablets used in the calculation were 70% Chlorine tablets, resulting in one tablet required for chlorination. Approximately, this tablet will be used every week. See Attachment E.3 for the detailed calculation.

2.3.5. Material Specifications

The main assembly for the chlorination system will be 4” Schedule 40 PVC Pipe, 3” PVC, and a 4”x4” PVC Tee. The main pipeline and bypass pipe will be 2” Schedule 40 PVC Pipe. Flat parts of the system, including the inlet baffle, weir plate, and support plate, will be cut from ¼” sheet PVC. The 3” PVC tablet tube and ¼” bottom plate will be connected with PVC cement. This chlorinator will use chlorine tablets that are Calcium hypochlorite, with 70% Chlorine.

2.4. Climate Change

2.4.1. Summary of Anticipated Climate Change on Design Parameters

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 an 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.

2.4.2. Summary of Impact of Climate Change on the Project Design

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.

© 2019 Engineers Without Borders USA. All Rights Reserved

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. The current distribution system design, with two headers, provides additional flexibility in the case of a change to the water source. Although not ideal, with two headers, a zoned approach could be used while a new water source was being developed.

Climate change is not expected to have a major effect on the water quality design. However, chlorine treatment will ensure the water remains potable despite potential changes to the source.

3. Schedule

3.1. Schedule overview

The chapter will not be travelling for implementation due to COVID-19 travel restrictions. However, in the first phase of construction (the subject of this report), the storage tank will be constructed and connected to the existing distribution network and a constructability survey of the proposed distribution network will be conducted. All work will be done remotely.

3.2. Work Breakdown Structure

Implementation trip construction activities are listed here in the order in which they should be performed, along with the party responsible.

1. **Dig trench for pipes.** Responsible: community volunteers, coordinated by COCODE
2. **Construct storage tank.** Responsible: contractor hired and overseen by EWB-Guatemala, with remote support of chapter
3. **Connect tank to existing distribution network.** Responsible: contractor hired and overseen by EWB-Guatemala, with remote support of chapter
4. **Conduct constructability analysis of the proposed distribution system routing.** Responsible: NGO Engineer, with members of community and/or COCODE (CBO)

3.3. Detailed Task Description

The following two construction activities and pre-construction activity will occur as part of this Implementation Trip. They will occur remotely due to COVID-19 travel restrictions. The tasks required to complete these activities are detailed here:

© 2019 Engineers Without Borders USA. All Rights Reserved

Construction Activity 1: Storage Tank Construction

1. Site clearance
2. Preparation of foundation
3. Preparation of lean concrete base
4. Preparation of base slab reinforcement
5. Laying base slab reinforcement
6. Erecting L-bars along the wall-base junction
7. Place vertical dowel/plate/bars for central column
8. Cast the base slab
9. Erection of vertical reinforcement and stiffeners for wall
10. Keeping openings for construction and pipe works
11. Fixing wire mesh
12. Preparation and fixing the central column
13. Plastering the wall
14. Preparation of roof shallow trusses
15. Fixing roof trusses (roof stiffeners)
16. Placing roof reinforcements
17. Fixing the roof mesh
18. Providing openings in the roof
19. Plastering roof trusses
20. Temporary formwork for plastering of roof surface
21. Plastering roof surface
22. Plastering temporary openings
23. Finishing the surface

Construction Activity 2: Connect Storage Tank to Existing Distribution System

1. Dig trench from storage tank to existing conduction line and distribution line
2. Install 3” Distribution Line PVC piping
    - 2.1. Cut PVC to size
    - 2.2. Connect PVC and seal with PVC cement
    - 2.3. Install valve at tank outlet
    - 2.4. Do NOT yet connect to existing Distribution Line
3. Install 2” Conduction Line PVC piping
    - 3.1. Cut PVC to size
    - 3.2. Connect PVC and seal with PVC cement
    - 3.3. Install valve at tank inlet
    - 3.4. Do NOT yet connect to existing Conduction Line

4. Close outlet valve on Spring Tank to the Conduction Line
5. Open service line connections at households to completely drain Conduction Line and Distribution Line.
6. Once Conduction Line and existing Storage Tank are completely drained, close outlet valve on existing storage tank to the Distribution Line

© 2019 Engineers Without Borders USA. All Rights Reserved

7. Break existing Conduction Line and connect to new Conduction Line
8. Ensure Distribution Line is completely drained. All water should have drained through household service connections.
9. Break existing Distribution Line and connect to new Distribution Line
10. Close outlet valve from new Storage Tank to new Distribution Line
11. Open inlet valve from new Conduction Line to new Storage Tank
12. Open outlet valve from Spring Tank to Conduction Line
13. Watch water level in new Storage Tank - it should now be filling with water. Look for any leaks.
14. Open outlet valve from new Storage Tank to new Distribution Line

Construction Preparation Activity: Constructability Analysis of Proposed Distribution System
this activity many be completed at any time

1. Print off Attachment A, drawings M-201 through M-207
2. With an engineer and member of the community, walk along the proposed path of the distribution system. This includes all headers, branches, and service connections.
3. Mark on the printed drawings where the routing is not feasible, or does not make sense. Draw and correct the drawings as necessary, noting the reason for the change. Note that the following should be avoided where possible:
    a. Local high points in the pipeline
    b. Pipe through agricultural areas
    c. Unnecessary road crossings
    d. Unnecessary pipe distance, in the event that there is a more direct path
4. Mark any ravine crossings on the drawings, where the piping will need to be upgraded from PVC to galvanized iron. Estimate the distance of the ravine crossing.
5. Mark any locations with localized high points. Air release valves will be considered for these locations.

The following construction activities will occur on the Continued Implementation Trip. The tasks required to complete these activities are outlined here and will be detailed in completion in the Continued Implementation Pre-Trip Plan.

Water Treatment Installation

1. Cut PVC piping for treatment system assembly
2. Create 6 slots at the bottom of the tablet tube
3. Drill pilot holes
4. Add cement to bottom plate to connect with tablet tube
5. Assemble chlorination system
6. Test for over-chlorination at tank
7. Build enclosure for water treatment system

Water Distribution Line Construction - To be included in the Continued Implementation Pre-Trip Plan

© 2019 Engineers Without Borders USA. All Rights Reserved

Home Connections Construction - To be included in the Continued Implementation Pre-Trip Plan

3.4. Schedule Analysis

3.4.1. Advance Task Scheduling

Implementation is remote and the travel team will not be in country for construction. However, skilled paid labor will be scheduled in advance, necessitating a timely construction schedule.

Immediately prior to the storage tank construction team's arrival, bulk materials for the tank should be ordered and delivered to the site on which the tank will be constructed. COCODE will be responsible for receiving the shipments and ensuring they are safeguarded until and throughout construction. Materials should be protected from the elements as necessary. The material order will be placed by EWB-Guatemala using a materials list provided by the chapter.

3.4.2. Critical Path Analysis

Section 3.3 outlines in detail the remote implementation trip construction activities in the order in which they should be executed to ensure successful completion of this scope of work.

In terms of the project overall, the critical path is to first complete the storage tank. Due to the cure time of concrete, it is a lengthy process which would last at least the entire duration of a typical implementation trip. Though due to travel restrictions, this is no longer a factor, the completion of the storage tank as the first construction activity provides other benefits. First, this process can begin while other scopes are being finalized, and second, with the tank online, its effect can be seen without the influence of other factors (i.e. new distribution pipes). Information gathered on these effects is not expected to change the distribution system design, but the chapter believes it prudent to take advantage of the opportunity to understand the effect this drastic addition has system-wide before making additional changes.

3.4.3. Schedule Threats

It is possible that travel restrictions or stay-at home orders due to COVID-19 could result in schedule delays. Supply-chain disruptions could result in materials needing to be sourced from farther away, or they could be unavailable or their availability delayed. NGO personnel overseeing construction, contractors, or other laborers could be prevented from working.

© 2019 Engineers Without Borders USA. All Rights Reserved

The NGO indicated that tank construction was feasible, and common practice, during the rainy season when construction will occur. However, exceedingly rainy conditions could still delay construction.

3.4.4. Schedule Issue Mitigation

In the event that materials are not available from the usual local supplier, the chapter and NGO will make an effort to source them elsewhere.

The well-being of NGO staff, contractors, and especially the community are a greater priority than the completion of this project. If construction cannot proceed without endangering the lives of those involved with COVID-19 exposure, the chapter will suggest that construction be postponed until it can be completed safely.

4. Construction Budget

4.1. Material Quantity Takeoff

Costs were estimated using a reference list provided by the EWB-Guatemala office. This reference list compiles items readily available in the local area and provides recent prices. A 10% margin was added to the material cost, and a 10% delivery fee was considered. For the purpose of cost estimation, an exchange rate of $1.00 USD = Q7.72 was applied.

The following section details the cost breakdown for each of the three different scopes: Storage Tank, Distribution System, and Water Treatment.

For the Distribution System, the cost was divided into the first phase of implementation (construction of Storage Tank and connection to existing Distribution System) and the second phase of implementation (replace existing Distribution System and connection to Storage Tank). Pipe lengths were calculated using the Agua Para La Salud surveying data (Attachment E.2 Reference) whenever possible. When specific pipe lengths could not be calculated using this reference, distances were estimated using the measurement tool on Google Maps. A 10% margin is added to pipe lengths.

4.2. Cost Estimate Summary

For the storage tank, steel was estimated at a cost of $1200 USD per metric ton. For a steel plate of .0108 m^3 and 8 steel channels sized at 0.011m^3 and steel weighing 7900 kg/m^3, this would reflect a unit price of $102.39 per plate, and $104.95 per channel, as shown in Table 4.2.1 below.

© 2019 Engineers Without Borders USA. All Rights Reserved

Per the reference provided by EWB-Guatemala, "Precios de Materiales Marzo 2020", 19x19x39cm, 25kg concrete masonry units (CMU) are Q3.8 per block. This size is referenced as it is the standard size block in the U.S. CMU were found throughout the community on the assessment trip.

As shown in the structural calculations (Attachment E.1), the steel channels are to be ordered from Ferromax, and the welded mesh is to be from Monolit, both of which are local suppliers in Guatemala, recommended by the EWB-Guatemala office.

The labor cost includes: three masons time for two weeks, one foreman's time for two weeks, one engineer's time for three days (to oversee, check on progress) and 15 trips to the site at a daily cost of $22.50.

Table 4.2.1 Storage Tank Material Costs				
Material	**Quantity**	**Unit Price (USD)**	**Cost (USD)**	**Cost (Q)**
Gravel (ft3)	176	$ 0.67	$ 118	911
Sand (ft3)	495	$ 0.32	$ 158	1,220
Cement (ft3)	83	$ 0.29	$ 24	185
Total Rebar (lf)	5302	$0.19	$ 1,007	7,774
Mason Blocks (ea)	150	$0.50	$ 75	579
Steel Plate (ea)	1	$102	$ 102	787
Steel Channels (ea)	8	$ 105	$ 840	6,485
Welded Mesh (ft 2)	1323	$ 0.10	$ 132	1,019
Chicken wire (ft2)	1323	$ 0.08	$ 106	818
Ladder (ea)	2	$ 110	$ 220	1,698
		Subtotal	**$ 2,782**	**Q 21,477**
		10% Contingency	**$ 278**	**Q 2,148**
		10% Delivery	**$ 278**	**Q 2,148**
		Labor	**$2,580**	**Q 19,918**
		Total Cost	**$5,918**	**Q 45,691**

The cost of gravel, sand, cement, chicken wire, and rebar are based on the cost of a previous EWB project completed by a different chapter that used a very similar design to what we are installing in Los Churuneles II. The Phase 1 materials for the Distribution System are summarized in Table 4.2.2 below. This includes the materials necessary to connect the new Storage Tank to the existing Distribution System. All prices come from the reference list provided by the EWB-Guatemala office.

© 2019 Engineers Without Borders USA. All Rights Reserved

Table 4.2.2 Distribution System Phase 1 Material Costs				
Material	**Quantity**	**Unit Cost (Q)**	**Total Cost (Q)**	**Cost ($)**
2" PVC - 160 psi (SDR-26), 20 ft length	33	80	2,640	$342
3" PVC - 160 psi (SDR-26), 20 ft length	33	137	4,529	$587
3" Gate Valve	1	60	60	$8
2" Gate Valve	1	360	360	$47
2" PVC 90° Elbow	1	11	11	$1
3" PVC 90° Elbow	2	40	80	$10
2" PVC 45° Elbow	1	15	15	$2
3" PVC 45° Elbow	1	42	42	$5
3" x 1 1/2" Reducer	1	17	17	$2
PVC Cement, 1/4 Gallon	1	60	60	$8
		Subtotal	**Q 7,814**	**$1,012**
		10% Contingency	**Q 781**	**$101**
		10% Delivery Cost	**Q 781**	**$101**
		Labor Cost	**Q 3,613**	**$468**
		Total Phase 1 Construction Cost	**Q 12,990**	**$1,683**

The costs of materials for Phase 2 construction of the Distribution System is included in Attachment C-2. This considers the materials necessary to replace the existing Distribution System. The material quantities and costs will be confirmed in the Continued Implementation Report.

Table 4.2.3 summarizes the total cost of the Distribution System, including costs for both Phase 1 and Phase 2 construction.

Table 4.2.3 Distribution System Construction Costs		
	Total Cost (Q)	**Cost ($)**
Phase 1 Material Cost Subtotal	7,814	$1,012
Phase 2 Material Cost Subtotal	75,473	$9,776

© 2019 Engineers Without Borders USA. All Rights Reserved

Phase 2 - Header 1 Material Cost	28,616	$3,707
Phase 2 - Header 2 Material Cost	46,857	$6,070
Phase 1 and Phase 2 Material Cost Subtotal	83,287	$10,788
10% Contingency	8,329	$1,079
10% Delivery Cost	8,329	$1,079
Phase 1 Labor Cost	3,613	$468
Phase 2 Labor Cost	9,048	$1,172
Total Phase 1 and Phase 2 Construction Cost	**112,605**	**$14,586**

The majority of the water treatment system was estimated in accordance with the prices of materials bought by the EWB-Guatemala office in the past months. Chlorine tablets are usually bought in bulk. Accu-Tab - Chlorine Wastewater Tablets are found in Guatemala and this specific item provides 25 lbs worth of chlorine tablets. 1/4" Sheet of PVC is used to construct the flat pieces in the chlorinator. The sheet of PVC was estimated per Guatemala Digital's website. Labor costs were in accordance with the Guatemala Country Office Labor Rates. It is assumed that a foreman will work on the enclosure for three days and a plumber will take one day to construct the chlorination system. Table 4.2.4 below includes the cost of materials for the water treatment system. The cost and materials for the enclosure will be refined in the Continued Implementation Report.

Table 4.2.4 Water Treatment Material Costs

Material	Quantity	Unit Cost (Q)	Total Cost (Q)	Cost ($)
Chlorine Tablet	25 lbs	1,264	1,264	$164
4"x4" PVC Tee	1	100	100	$13
4" PVC Pipe, 20 ft length	1	80	80	$10
4" PVC Couplings	2	9	19	$2
4" PVC Cap	1	100	100	$13
3" PVC Pipe, 20 ft length	1	132	132	$17
2" PVC Pipe, 20 ft length	1	80	80	$10
1/4" Sheet PVC	1	949	949	$123
PVC Cement	Small tube	37	37	$5

© 2019 Engineers Without Borders USA. All Rights Reserved

2" Tee	2	12	24	$3
90° Elbow	3	11	33	$4
Bypass Valve	1	11	22	$3
Isolation Valve	2	22	44	$6
#4 x 1/2" Metal Screws	11	0.2	2	$1.0
Enclosure	1	2,316	2,316	$300
		Subtotal	**5,201**	**$674**
		10% Contingency	**520**	**$67**
		10% Delivery Cost	**520**	**$67**
		Labor Cost	**2,069**	**$268**
		Total Cost	**8,310**	**$1,077**

Table 4.2.5 summarizes the total cost of all scopes, broken out between Phase 1 and Phase 2 construction. The total Phase 1 construction cost is estimated to be approximately $7,600 and the total Phase 2 construction cost is estimated at approximately $14,000. Thus, the grand total cost for both phases and all scopes of work is estimated at approximately $21,600.

Table 4.2.5 Total Cost Summary		
Phase 1	**Q**	**USD**
Storage Tank Material Costs	21,477	$2,782
Distribution System Material Costs	7,814	$1,012
Material Subtotal Cost	29,291	$3,794
10% Contingency	2,929	$379
10% Delivery Cost	2,929	$379
Labor Cost	23,531	$3,048
Total Phase 1 Construction Cost	58,680	$7,601
Phase 2	**Q**	**USD**
Distribution System Material Costs	75,473	$9,776
Water Treatment Material Costs	5,203	$674

© 2019 Engineers Without Borders USA. All Rights Reserved

Material Subtotal Cost	80,676	$10,450
10% Contingency	8,068	$1,045
10% Delivery Cost	8,068	$1,045
Labor Cost	11,117	$1,440
Total Phase 2 Construction Cost	107,928	$13,980
Grand Total Construction Cost	**166,608**	**$21,581**

5. Facilities Operations and Maintenance Plan

The operation and maintenance plan delineated below will be provided to the community as a complete manual translated into Spanish.

5.1. Description of Ownership

The people of Churuneles II are the owners of the constructed potable water system. The community paid for the plot of land on which the new tank will reside. The rest of the constructed system components are located on land that is used for the existing potable water system which confirms that it is land permitted to use by the community.

5.2. Description of Operations Activities

The tank will not require any daily operations, but will require routine scheduled maintenance. After the system is implemented, the community will need to adjust any existing behaviors of keeping taps open throughout all hours of the day. For the system to function properly, the tank needs to be able to fill so that there is a larger instantaneous capacity to draw down from during peak demand times. If necessary, daily operation of the shutoff valves at the tank discharge can be implemented to allow for the tank to refill. The shutoff valves would need to be closed at night and reopened each morning.

5.3. Description of Maintenance Activities

Quarterly maintenance checks for correct operation of valves and visual inspection of the tank, will be required to ensure the tank is operating properly. By being proactive with inspections, the hope is to prevent any need for major repairs to the tank by addressing problems early.

© 2019 Engineers Without Borders USA. All Rights Reserved

The tank will need to be completely drained and cleaned with a bleach solution in order to prevent biological growth in the water system, and to remove any sediment that settles at the bottom of the tank.

Water usage meters and taps will require infrequent maintenance. A refill of the chlorinator will be required on a regular basis. In addition, a check for the dosage mechanism on the chlorinator will need to be done at least weekly to ensure that proper concentration of chlorine is used in the water supply. Too little or too much chlorine could potentially cause health issues.

All regularly required maintenance processes are detailed further within the Operations & Maintenance Manual provided to the community.

5.4. Part Replacement Schedule and Availability

For the storage tank, there are no parts that will need to be replaced over the life of the system. Mortar will be required to repair any cracks that develop in the walls of the tank. Materials and tools for cleaning and infrequent crack repair are readily available in a nearby town.

Item No.	System	Description	Maintenance Frequency		
			Monthly	3 Months	As Needed/ Yearly
1	Storage Tank	Cleaning			X
2	Storage Tank	Inspection		X	
3	Storage Tank	Ferrocement Repair			X
4	Storage Tank	Concrete Pad Repair			X

Like the storage tank, there are no parts in the distribution system that need to be replaced over the expected life of the system. In the case that a part requires replacement, common components such as valves and pipes are readily available in a nearby town.

© 2019 Engineers Without Borders USA. All Rights Reserved

The water treatment system will require frequent refilling of chlorine tablets. These are available in a nearby town.

5.5. Operations and Maintenance Cost Analysis

The costs associated with maintaining the storage tank are provided in the table below. The community has agreed to use meters at the taps in each household. These meters will then be used to implement a fee structure based on usage. The details of the fee structure still need to be worked out by the community.

Item No.	System	Description	Annual Costs	
			Labor	**Materials**
1	Storage Tank	Cleaning	By Operator No Cost	Q400
2	Storage Tank	Inspection	By Operator No Cost	Q0
3	Storage Tank	Ferrocement Repair	By Operator No Cost	Q400
4	Storage Tank	Concrete Pad Repair	By Operator No Cost	Q400
		Total	Q0	Q1,200

The costs associated with maintaining the distribution system will include repair or replacement of faulty valves, flow limiters, leaky pipes, and other system components. The costs associated with maintaining the water treatment system will include recalibration of the chlorine dosage mechanism and any faulty valves and piping associated with the system. Detailed cost estimates for maintenance of the distribution and water treatment systems will be provided in the continued implementation trip report.

© 2019 Engineers Without Borders USA. All Rights Reserved

5.6. Training requirements and Roles

COCODE will be responsible for the upkeep of the system. They will appoint/hire people, as necessary, internal or external to COCODE to manage the maintenance. The community has proposed using a water fee to fund the labor and materials required for operations and maintenance. This includes hiring a dedicated person for the upkeep of the system.

The community already has experience with the operations of a tank like the one that will be constructed. The systems that are being constructed, with the exception of the water treatment system, are replacements of those that already exist in the community. Therefore, the community will be familiar with how to operate and maintain these systems.

People in the community who have experience with operating the potable water system will either be charged with the responsibility of operating and maintaining the new system, or those individuals will be tasked with the training of new operators.

The roles of the system operator regarding the storage tank is minimal. Inspection, cleaning and crack patching are the only responsibilities required of the operator. These tasks require minimal training. The chapter will have conversations and propose procedures to ensure proper maintenance is conducted to lengthen the life of the system.

Training will be provided to the community by the chapter to demonstrate the intended operation of the distribution system and the water treatment system. Details of this instruction will be provided in the continued implementation trip report.

6. Community Based Organization CBO

6.1. CBO Structure

The CBO "COCODE" is formed of community members elected for the purpose of completing a community mandate. These elected members are referred to as "the committee". The current committee consists of eight men, all in their twenties to early thirties. They were elected in 2018 to address the need for improvements to the potable water system in Los Churuneles II. The committee is elected in a voting process in which all community members are eligible to participate. Once elected, committee members are required to be legalized by the municipality, and only after this process can they begin their community mandate. COCODE functions as the community representative for matters relating to their mandate.

Committee members are elected for a term that lasts until project completion. This is most commonly a four-year term. The current committee has indicated their ongoing commitment

© 2019 Engineers Without Borders USA. All Rights Reserved

to following through on the project on multiple occasions, so the project team does not see desertion by the committee members as likely to threaten the stability of the CBO. It is not known how or if the community would go about filling a vacancy if that situation were to arise. Given the current number of COCODE members, the loss of one or two would likely not be significantly detrimental to the project.

The responsibilities of the committee will include ensuring the maintenance and operation of the potable water system. The chapter will work with COCODE to clearly define the exact responsibilities of a single or multiple points of contact who will assume responsibility for the maintenance and operation of the potable water system.

6.2. Roles and Responsibilities

The Los Churuneles II COCODE is: President, Efrain Quisquina Yaxon; Vice President, Santos Quisquina Queju; Secretary, Domingo; Treasurer, Nicolas; Members: Santos, Victor, and Caspar.

The role of COCODE as a whole is to fulfill their mandate to improve drinking water infrastructure in Los Churuneles II. To that end, the committee solicited the services of EWB and since, have been in regular contact with EWB-Guatemala staff, requesting updates on the progress of the chapter's work. Committee members visited the NGO's office in person in January 2020 for a progress update and to reaffirm COCODE and the community's commitment to the project. The President Efraín is solely responsible for the key which unlocks the padlock on the lid of the Los Churuneles II portion of the spring box.

COCODE also functions as the voice of the community in matters relating to the water system. As such, they have a responsibility to listen to their constituents. The travel team was a part of two such exchanges during their assessment trip, in which community members, COCODE and the travel team gathered and discussed plans for the system.

It is possible that the current and/or succeeding committee will hire out operations and maintenance responsibilities which require skilled labor, if a person with these qualifications does not exist on the committee. The chapter foresees a plumber being the most likely outsourced need. The chapter will work with the CBO through the NGO to identify a local plumber or other qualified person with the availability and desire to take on upkeep of the plumbed components of the potable water system in Los Churuneles II, and with availability during the distribution system construction and O&M training to ensure their familiarity with the system. The chapter will recommend this person is kept on retainer with a contract, and paid approximately Q520 per month (Q10 per month per tap), an amount recommended in the "EWB-USA Guatemala Potable Water Standards." The purpose of this is to ensure the plumber will always be available in a timely manner when an issue arises. Funding of the plumber's cost is discussed in Section 6.4 below.

© 2019 Engineers Without Borders USA. All Rights Reserved

6.3. CBO History of Prior Management

Due to the unique purpose of COCODE, namely that it exists to perform a predefined task, as opposed to a governing body elected to manage for a predetermined amount of time, there is not a history of this current committee having raised funds, as far as the chapter is aware.

However, the community previously organized to procure the engineering services of Agua Para La Salud, as well as those of Engineers Without Borders. They purchased a parcel of land to house the new water storage tank, and manage their portion of the spring box which they share with 2 other communities. The Guatemala office noted at the initiation of the project, on Volunteer Village, that a previous COCODE committee had achieved building paved roads in the community.

6.4. Sources of Operation and Maintenance Funding

The issue of sources of Operation and Maintenance Funding is an ongoing discussion the chapter is having with the CBO through the NGO, and which the CBO is having with the community. In May 2020, COCODE indicated that the community intended to define a monthly payment using the EWB workshops. Previously, COCODE has collected funds from the community on an as-needed basis. The funding strategy for this project will be refined on this trip in preparation for final project handoff on the subsequent Continued Implementation Trip. At that juncture, the community is responsible for raising their 5% community contribution and having a strategy in place to pay for operations and maintenance activities. Some potential approaches to addressing these two funding needs is outlined below.

The chapter's current estimate is that the project will cost approximately $21,600 USD. The community's contribution is 5% of that, or $1,080 USD (Q8,320 Guatemalan Quetzal). The assessment trip team counted 52 households during their survey of the community. Divided evenly, each household would need to contribute $21 USD (Q160) to meet the community contribution requirement. Using the "EWB-USA Guatemala Potable Water Standards" as a reference, an appropriate household monthly fee should not exceed Q50. At this rate of Q50 per month per family, the 5% contribution could be collected in 5 months. However, it is ultimately at COCODE's discretion how they will collect 5% community contribution, and whether they will collect monthly maintenance fees. If they choose to collect a monthly fee to cover maintenance, it may be the case that community contribution collection is distributed over a longer period, to ease the financial burden on payees. They may also consider making the fee per person rather than per household, to account for very large households.

The chapter expects operations and maintenance costs to be minimal, and for the majority of the costs to be incurred for preventative measures. One of the largest recurring costs is

© 2019 Engineers Without Borders USA. All Rights Reserved

expected to be the payment of an on-call plumber or other qualified person. The function and payment of this person was discussed in Section 6.2 above. If their Q10 per tap per month fee were funded with monthly payments from each household, this would be a reasonable amount to request, as it is far below the maximum recommended Q50 per family per month. There should be few, if any, costs associated with the subject of this report, the storage tank. O&M costs for subsequent scopes (the distribution network and water treatment system) will be defined in the O&M Manual accompanying the Continued Implementation Pre-Trip Plan. A funding strategy to pay for these costs will be defined during workshops between the NGO and CBO and discussed further in the subsequent Continued Implementation Pre-Trip Plan.

A potential external resource for the community is the local municipality of Sololà, which has offered to support the community post-construction. COCODE would be responsible for contacting the municipality, petitioning for its services and ensuring the municipality followed through on any agreement to provide assistance.

The most apparent area of weakness in the fundraising methodology outlined above is COCODE's unfamiliarity with collecting funds and their unfamiliarity with resolving situations which may arise from this, such as the unwillingness of residents to pay for a previously free service, inability of residents to pay due to financial constraints, and distrust of residents in COCODE to properly manage funds. A thoroughly thought-out fundraising strategy which addresses these issues in a culturally sensitive manner will be key to COCODE's sustained successful management of the water system. EWB-Guatemala provides training which addresses these weaknesses, as they are not uncommon.

The chapter will continue to work with COCODE through the NGO to develop a fundraising strategy to ensure the long term sustainability of the project. A more detailed, refined strategy addressing the as-built system will be presented in the Continued Implementation Trip Plan.

6.5. Analysis of Risks to long term Sustainability

Some factors the chapter sees as posing a risk to the long-term sustainability of the project include:

- Lack of timely repairs, rendering the system ineffectual
- Lack of regular maintenance, causing deteriorated water quality
- Misuse of water resource (i.e. use of potable water for agricultural purposes)

The first two risks, lack of timely repairs and regular maintenance, may be the result of several factors including: insufficient funds for these activities, no one qualified to perform the work, and lack of knowledge of how to perform these activities. Training provided by the NGO addresses collection and management of funds. This training also covers how to identify and address potential misuse of the water resource. In May 2020, COCODE

© 2019 Engineers Without Borders USA. All Rights Reserved

communicated that the community was accepting of the use of meters to monitor water consumption, and they agreed to participate in

As discussed above, it will be recommended that the community hire a plumber or other qualified person to be on-call to make repairs and perform system maintenance. The plumber, as well as members of the COCODE committee, will be trained on system operation and maintenance, so that in the event that the plumber or other designated person is unavailable, there will be someone available locally with familiarity with the system. Additionally, the chapter will provide a comprehensive Operations and Maintenance manual for the maintenance person's reference.

Systems operations and maintenance training and delivery of the O&M manual will occur on the subsequent Continued Implementation Trip, during the distribution network construction.

6.6. Training requirements

EWB-Guatemala puts on workshops which address many of the weaknesses identified by the chapter in the CBO. Their training covers how to read the meters, helps the CBO develop a strategy for paying for operation, maintenance and repair costs, and goes over maintenance of the system.

The forthcoming Operations and Maintenance Manual will include troubleshooting sections for new infrastructure with graphics where helpful. It will define all the required regular maintenance and operations activities and cover how to address commonly-needed repairs.

Between the NGO workshops and O&M manual, the chapter believes COCODE will be well equipped to manage, maintain and troubleshoot their new water system so that it is functional for years to come.

7. Monitoring Data Collection

7.1. Data Collection

Data collection will be performed on the Continued Implementation Trip, after construction of all scopes is complete or while final construction is in progress. At this point, the travel team will:

- Confirm baseline data by asking the same PMEL questions to community members as asked on the assessment trip in August 2019
- Collect water samples from each house tap for comparison to baseline samples collected during assessment

© 2019 Engineers Without Borders USA. All Rights Reserved

- Collect water samples from the new storage tank to compare with those from the old tank
- Collect operational data on the system to ensure it is functioning as designed. i.e. flow rate, pressure, and water quality measurements at multiple locations
- Train designated community members, likely COCODE members, on PMEL activities such as collecting flow rate measurements and water samples, so that PMEL can occur in the absence of the chapter
- Fill out the community survey

7.2. Other Factors Contributing or Hindering Development

The procedure for determining if other organizations are active in Los Churuneles II is to maintain regular communication with the NGO, CBO and other relevant chapter contacts.

The chapter and NGO will clearly communicate to the community their relationship with the community and role in the project moving forward in the Partnership Agreement. The chapter expects this will decrease the likelihood that an outside organization will hinder the successful development or use of the new water system, by clearly defining when the community should solicit the services of the chapter or NGO vs. another entity.

The organization "Agua Para La Salud" (APLS) is known to be working in surrounding communities, and they previously provided a water system design for Los Churuneles II. Chapter project leaders are in communication with APLS staff to ensure the community is receiving a constant message, namely that EWB has undertaken this project and intends to complete it. A similar approach will be taken with other entities found to be working nearby and whose work has the potential to disrupt the success of this new infrastructure.

7.3. Beneficiary Analysis

The number of direct beneficiaries is the population of Los Churuneles II, which was found to be approximately 500 in a survey of the community by the assessment travel team. The survey consisted of travel team members visiting every household and inquiring how many people lived there. The full survey was published in the Post-Assessment Trip Report.

PMEL activities on the Continued implementation Trip will include asking this same question. Due to the population growth rate in this area, the chapter expects the number of residents, and subsequently, beneficiaries, to have increased slightly.

© 2019 Engineers Without Borders USA. All Rights Reserved

8. List of Attachments

Attachment A: Drawing Package

~~Attachment B: Schedule~~ - Refer to discussion in Section 3.0

Attachment C: Construction Cost Estimate/ Material Takeoff

~~Attachment C.1 - Storage Tank~~ - Refer to Section 4.2

Attachment C.2 - Distribution System

~~Attachment C.3 - Water Treatment~~ - Refer to Section 4.2

~~Attachment D: Specifications~~ - Included in Attachment A

Attachment E: Design Calculations

Attachment E.1 - Storage Tank

Attachment E.2 -Distribution System

Attachment E.3 -Water Treatment

~~Attachment F: Construction Safety Plan~~ - Does not apply due to implementation being remote.

Attachment G: Operations and Maintenance Plan

Attachment H: Partnership Agreement

© 2019 Engineers Without Borders USA. All Rights Reserved

Tanque de Almacenamiento de Agua Potable ($45\ m^3$)

Diseñado por:

ACECOMS, IFIC
School of Civil Engineering
Asian Institute of Technology (AIT)
con modificaciónes por EWB-KC

Diseñado para:

Los Churuneles II, Guatemala

United Nations High Commissioner for Refugees (UNHCR)

Tabla de Contenidos

#	fecha	por	rv por	descripción

Para Construcción

ENGINEERS WITHOUT BORDERS USA
Kansas City Professional Chapter

fecha	detallado por
7 Agosto 2020	Helen Wehner
disenado por	revisado por
Helen Wehner	Audrey Freiberger

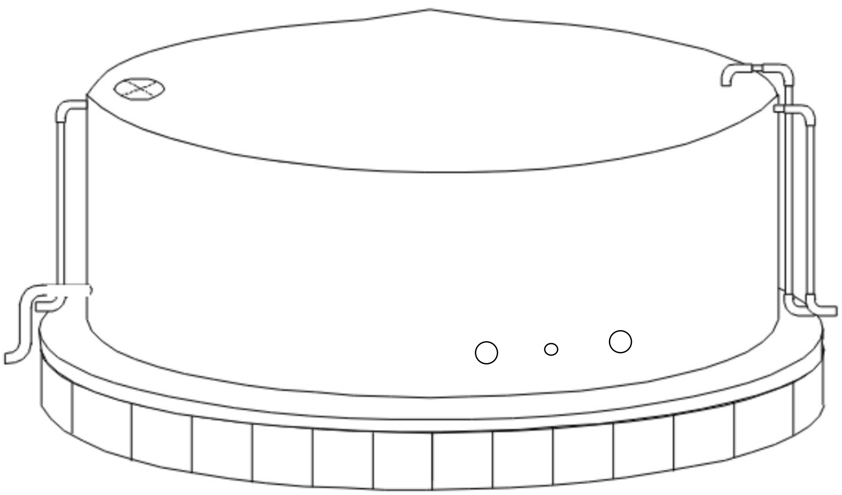
LOS CHURUNELES II
GUATEMALA

GPS: 14.827, -91.104

LOS CHURUNELES II
SISTEMA DE AGUA POTABLE

TANQUE DE ALMACENAMIENTO
DE AGUA POTABLE

dibujo: Tanque-00 — rev. A



Características

Capacidad	45 m^3
Diámetro	5.30 m
Altura	2.70 m
Cimientos	Arena y piedra bola consolidado (grosor = 0.5m)
Bloque de Concreto	Concreto con refuerzo (grosor = 0.5m)
Tapia	Ferrocement con costanera (grosor = 0.075m)
Techo	Ferrocement con armanduras (grosor = 0.075m)
Columna	PVC llena con mortero (diámetro = 0.15 m)
Abertura	diámetro = 0.6 m
Tubería	Tubo de rebose, entrada, y descarga
Final	Pintura afuera

#	fecha	por	rv por	descripción

A
B
C
D
E
F
G
H
I

Para Construcción

ENGINEERS WITHOUT BORDERS USA
Kansas City Professional Chapter

fecha: 7 Agosto 2020	detallado por: Helen Wehner
disenado por: Helen Wehner	revisado por: Audrey Freiberger

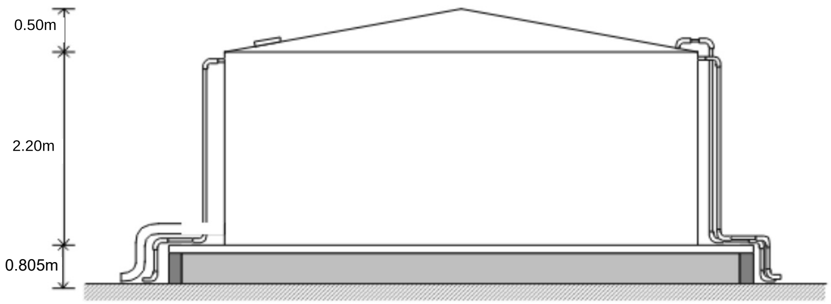
LOS CHURUNELES II
GUATEMALA

GPS: 14.827, -91.104

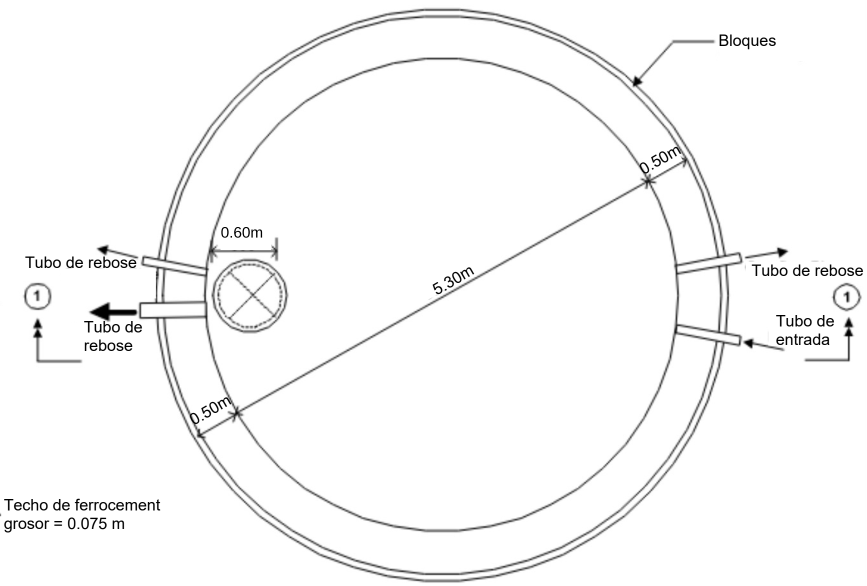
LOS CHURUNELES II
SISTEMA DE AGUA POTABLE

TANQUE DE ALMACENAMIENTO
DE AGUA POTABLE

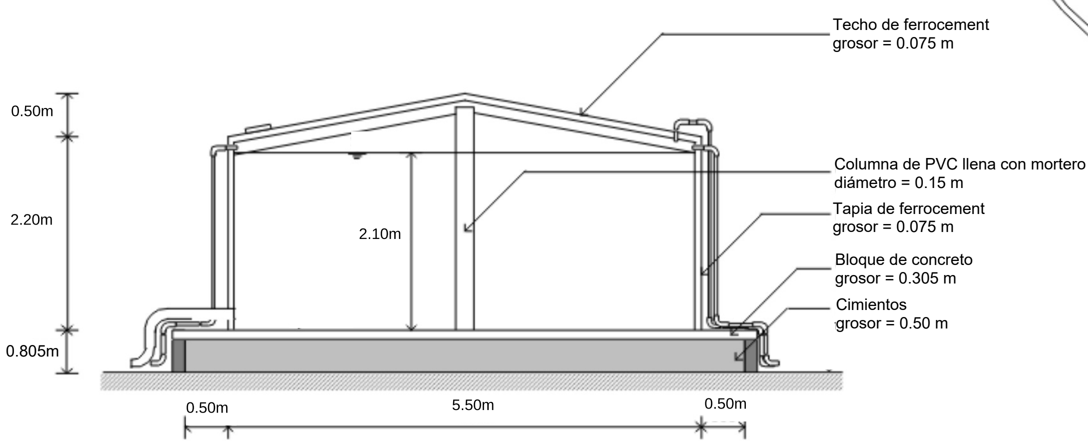
dibujo		rev.
Tanque-01	–	A



Elevación



Plano de Techo



Sección 1-1

#	fecha	por	rv por	descripción

A
B
C
D
E
F
G
H
I

Para Construcción

ENGINEERS WITHOUT BORDERS USA
Kansas City Professional Chapter

fecha	detallado por
7 Agosto 2020	Helen Wehner
disenado por	revisado por
Helen Wehner	Audrey Freiberger

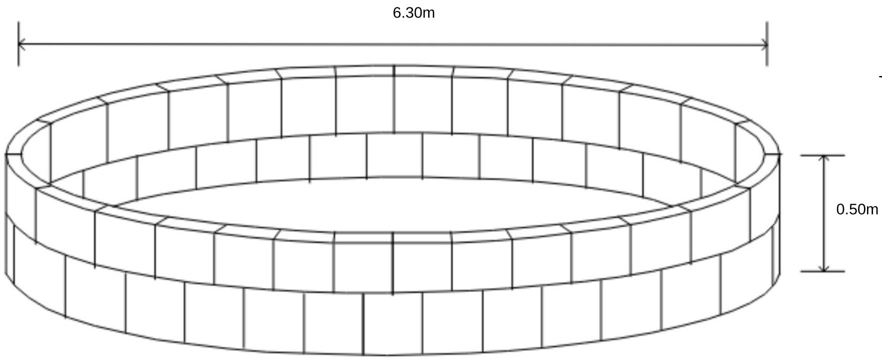
LOS CHURUNELES II
GUATEMALA

GPS: 14.827, -91.104

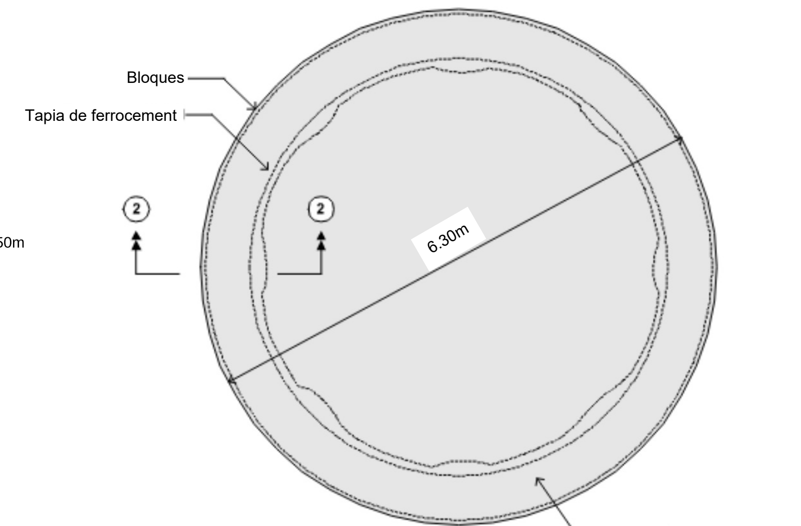
LOS CHURUNELES II
SISTEMA DE AGUA POTABLE

TANQUE DE ALMACENAMIENTO
DE AGUA POTABLE

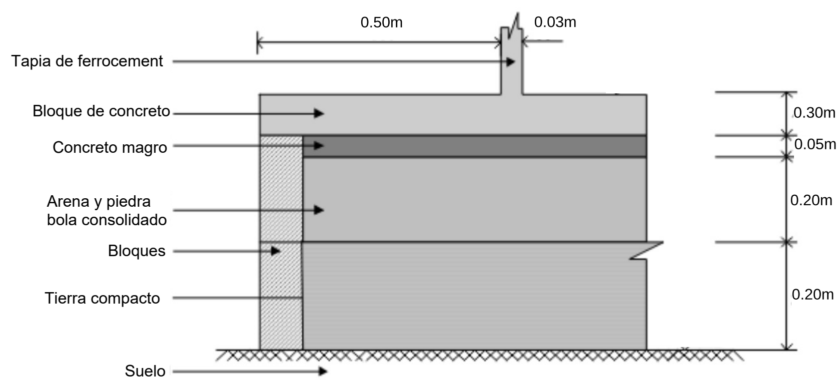
dibujo		rev.
Tanque-02	–	A



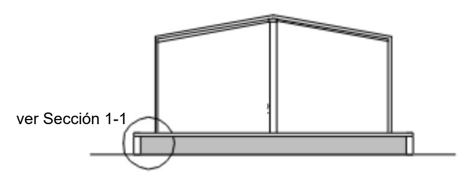
Plan de Bloques



Plano de Cimientos



Sección 2-2: Detalle de Cimientos



#	fecha	por	rv por	descripción

Para Construcción

ENGINEERS WITHOUT BORDERS USA
Kansas City Professional Chapter

fecha: 7 Agosto 2020
detallado por: Helen Wehner
disenado por: Helen Wehner
revisado por: Audrey Freiberger

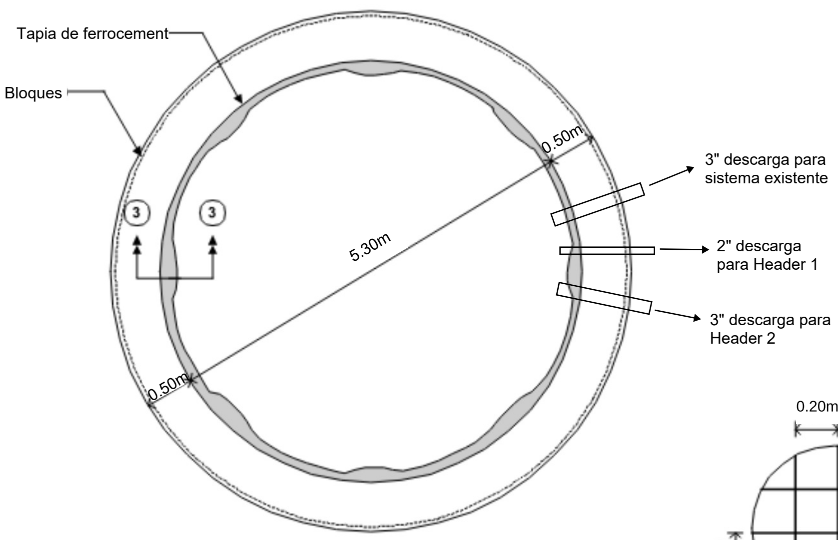
LOS CHURUNELES II
GUATEMALA

GPS: 14.827, -91.104

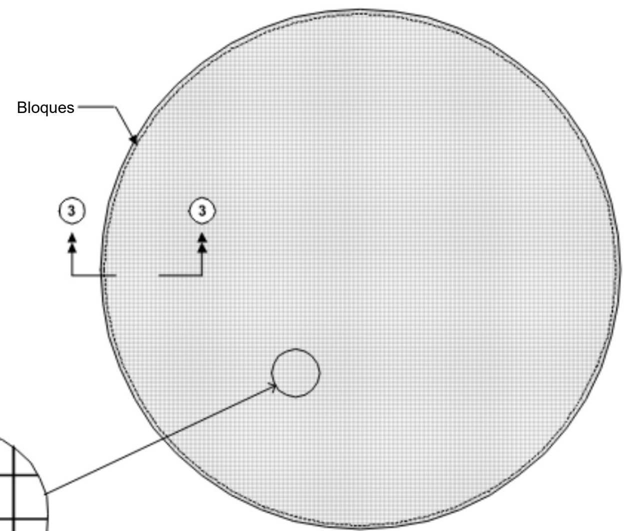
LOS CHURUNELES II
SISTEMA DE AGUA POTABLE

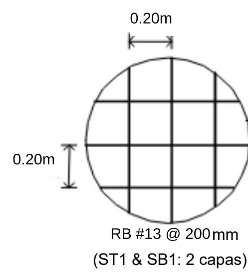
TANQUE DE ALMACENAMIENTO
DE AGUA POTABLE

dibujo: Tanque-03 –
rev.: A

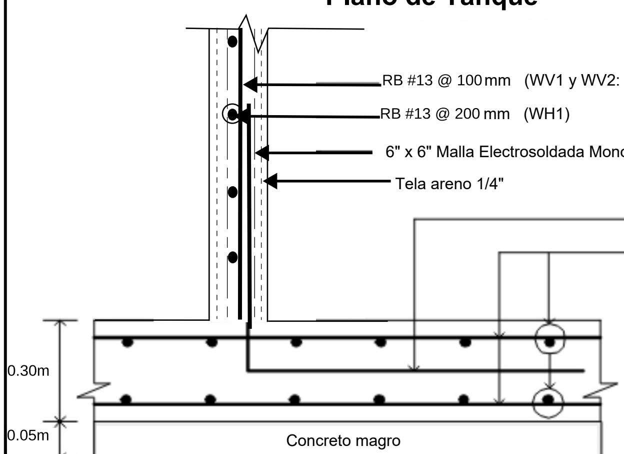


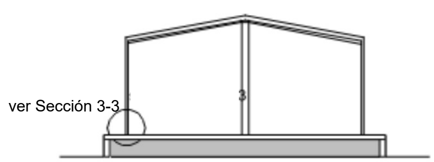
Plano de Tanque



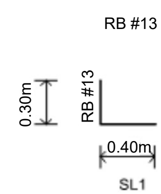


Detalle de Refuerzo de Bloque de Concreto

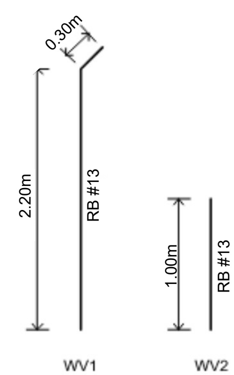




Sección 3-3: Detalle de Bloque de Concreto



Detalle 1



Detalle 2

#	fecha	por	rv por	descripción

Para Construcción

ENGINEERS WITHOUT BORDERS USA
Kansas City Professional Chapter

fecha: 7 Agosto 2020	detallado por: Helen Wehner
disenado por: Helen Wehner	revisado por: Audrey Freiberger

LOS CHURUNELES II
GUATEMALA

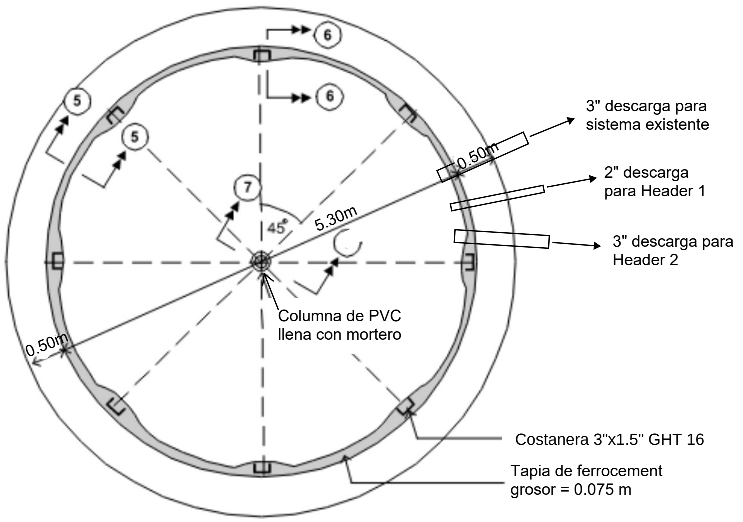
GPS: 14.827, -91.104

LOS CHURUNELES II
SISTEMA DE AGUA POTABLE

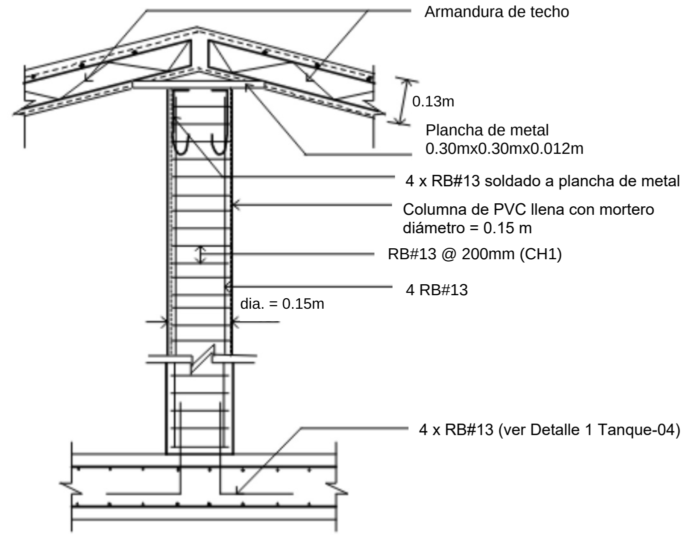
TANQUE DE ALMACENAMIENTO
DE AGUA POTABLE

dibujo	rev.
Tanque-04 –	A

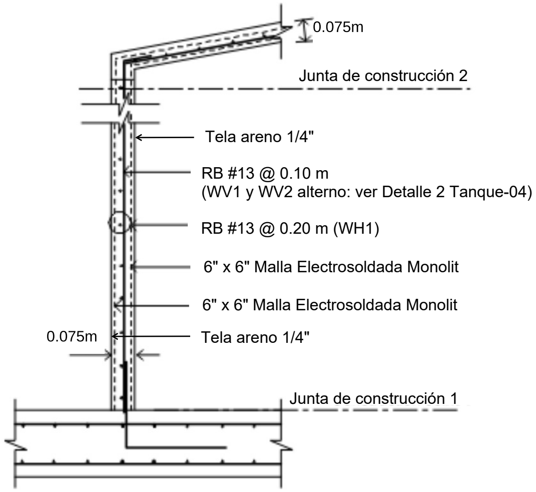
A B C D E F G H I



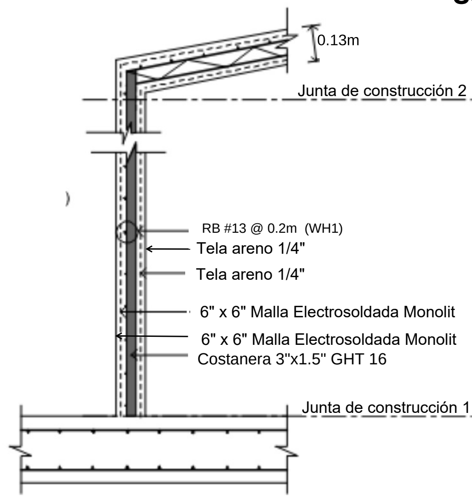
Sección 4-4: Detalle de Tapia



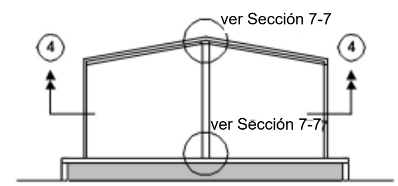
Sección 7-7: Detalle de Columna



Sección 5-5



Sección 6-6



#	fecha	por	rv por	descripción

Para Construcción

ENGINEERS WITHOUT BORDERS USA
Kansas City Professional Chapter

fecha: 7 Agosto 2020
detallado por: Helen Wehner
diseñado por: Helen Wehner
revisado por: Audrey Freiberger

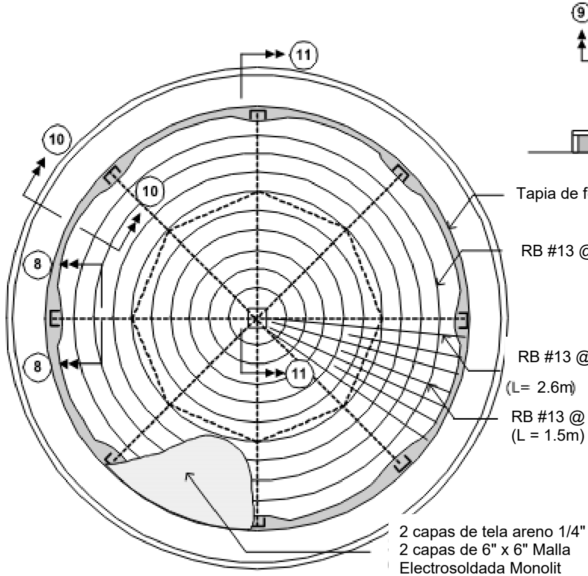
LOS CHURUNELES II
GUATEMALA

GPS: 14.827, -91.104

LOS CHURUNELES II
SISTEMA DE AGUA POTABLE

TANQUE DE ALMACENAMIENTO
DE AGUA POTABLE

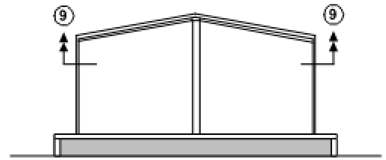
dibujo: Tanque-05 — rev. A

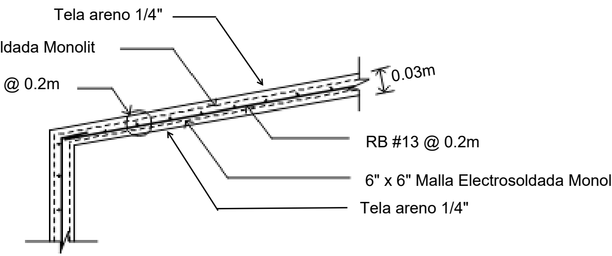


Sección 9-9: Plan de Refuerzo del Techo

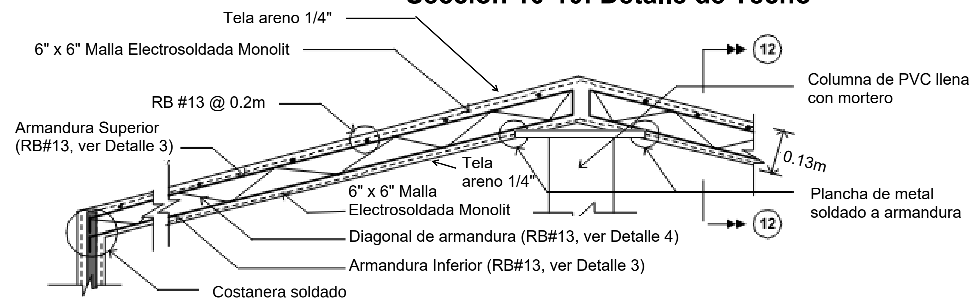
Costanera 3"x1.5" GHT 16

Armandura de techo (ver Sección 11-11)

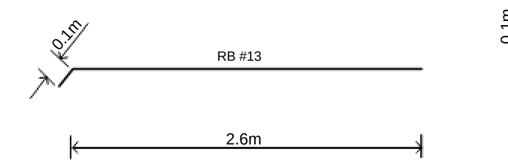




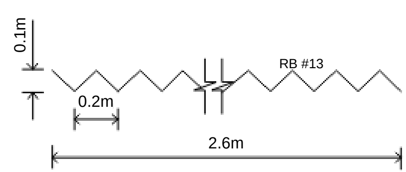
Sección 10-10: Detalle de Techo



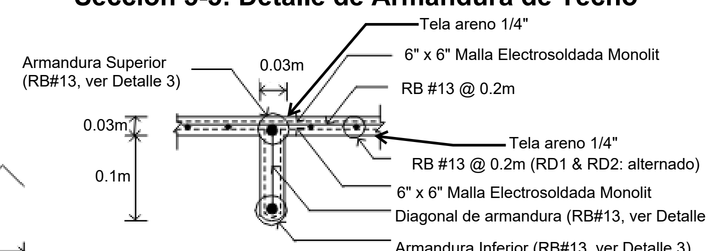
Sección 5-5: Detalle de Armandura de Techo



Detalle 3: Armandura Superior y Inferior



Detalle 4: Diagonal de Armandura



Sección 8-8: Armandura de Techo

#	fecha	por	rv por	descripción

Para Construcción

ENGINEERS WITHOUT BORDERS USA
Kansas City Professional Chapter

fecha	detallado por
7 Agosto 2020	Helen Wehner
diseñado por	revisado por
Helen Wehner	Audrey Freiberger

LOS CHURUNELES II
GUATEMALA

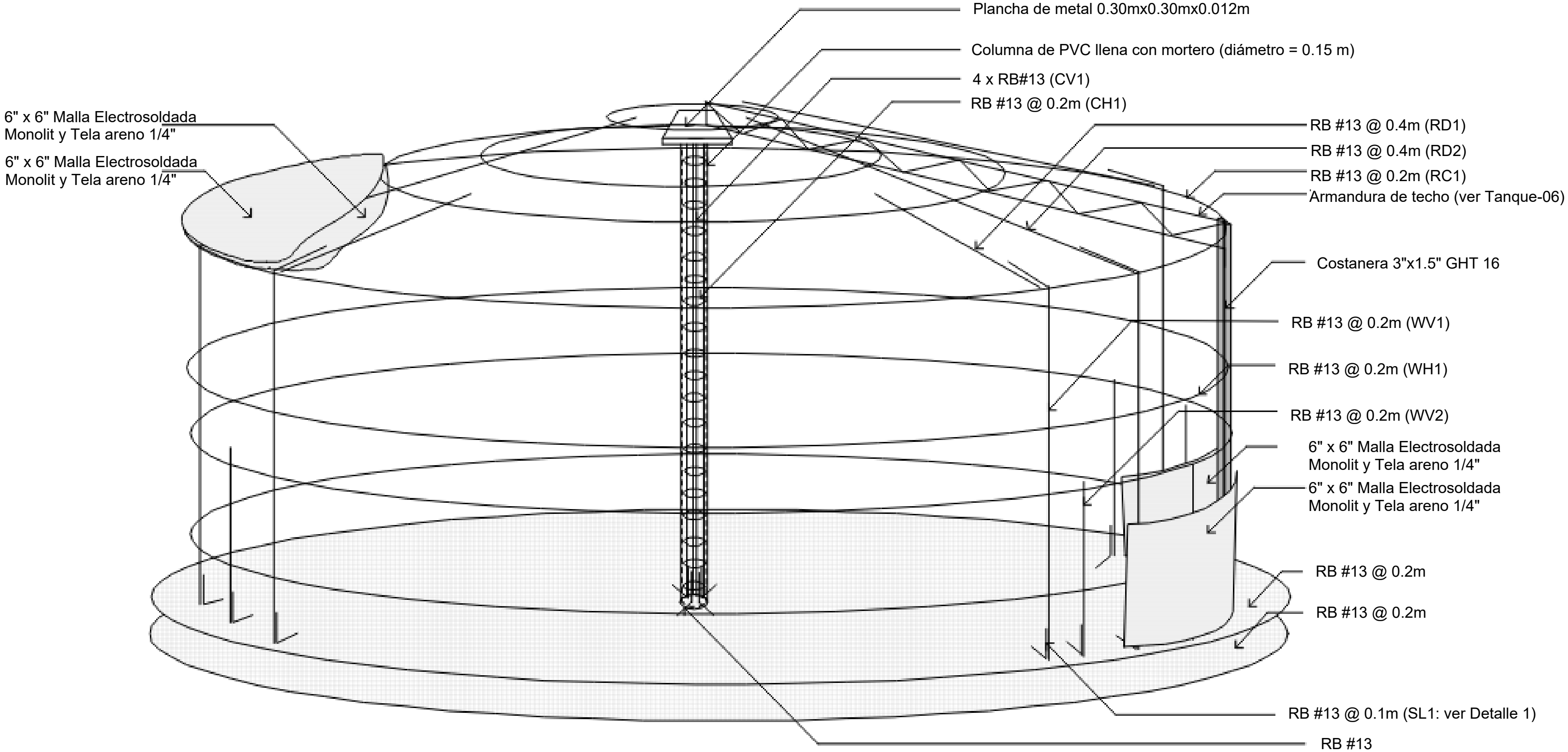
GPS: 14.827, -91.104

LOS CHURUNELES II
SISTEMA DE AGUA POTABLE

TANQUE DE ALMACENAMIENTO
DE AGUA POTABLE

dibujo		rev.
Tanque-06	–	A

A B C D E F G H I



#	fecha	por	rv por	descripción

A B C D E F G H I

Para Construcción

ENGINEERS WITHOUT BORDERS USA
Kansas City Professional Chapter

fecha: 7 Agosto 2020	detallado por: Helen Wehner
diseñado por: Helen Wehner	revisado por: Audrey Freiberger

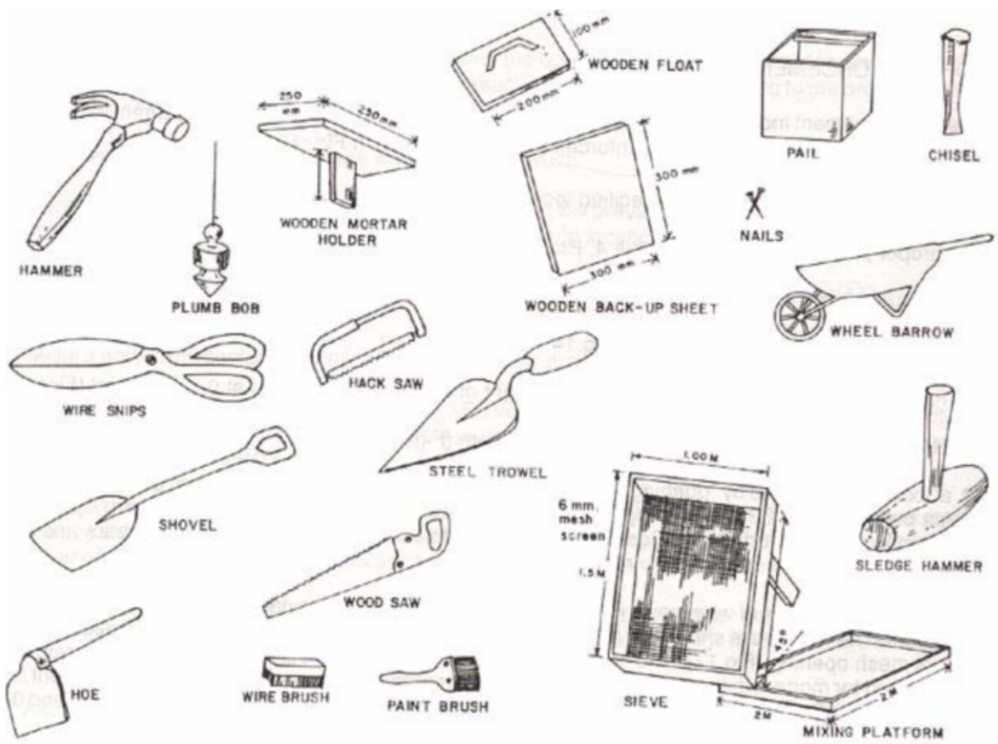
LOS CHURUNELES II
GUATEMALA

GPS: 14.827, -91.104

LOS CHURUNELES II
SISTEMA DE AGUA POTABLE

TANQUE DE ALMACENAMIENTO
DE AGUA POTABLE

dibujo: Tanque-07 — rev. A



Herramientas de Construcción

Hammer – el martillo
Plumb bob – La plomada
mortar holder – barro para panel de yeso
Wooden float – Flota, llana
Pail – el cubo
Nails – los clavos
Chisel – el cincel
wheel barrow - caretilla
wire snips - tijeras de hilo
hack saw – La sierra para metales
steel trowel – una paleta
sieve – la criba
sledge hammer – el martillo de trineo
shovel – la pala
wood saw – la sierra para madera
mixing platform – una plataforma para mezclar
paint brush – el pincel
wire brush – Un cepillo de alambre
hoe – la azada

Instrucciones de Construcción

1.Selection of Site – Selección de la obra
2.Site Clearance – Limpieza de la obra
3.Preparation of foundation – Preparación del cimiento
4.Prep of lean concrete base - Preparación de la losa de hormigón "delgado"
5.Prep of base slab reinforcement - Preparación de la varilla de la losa de hormigón
6.Laying of base slab reinforcement – Instalación de la varilla de la losa de hormigón estructural
7.Erecting L-bars along the wall-base junction - Instalación de la varilla "L" que conecta la losa estructural a la pared
8.Placing vertical dowel/plate/bars for central column – Instalación de la varilla vertical, la placa base y la varilla vertical para la columna central
9.Casting the base slab – Construcción de la losa de hormigón estructural
10.Erection of vertical reinforcement and stiffeners for wall – Instalación de la varilla vertical y refuerzos para la pared
11.Keeping openings for construction and pipe works – Marcar la ubicación de aperturas en la pared
12.Fixing chicken wire and mesh (WM1 and WM2) – instalación/unión de la malla electrosoldado monolit (WM1 y WM2)
13.Prep and fixing the central column – Preparación e instalación de la columna central de PVC
14.Plastering the wall – Aplicación del ferrocemento en las paredes
15.Prep the roof shallow truss – Preparación del la armadura del techo
16.Fixing the roof trusses (roof stiffeners) – Instalación de las armaduras del techo
17.Placing roof reinforcements – Instalación de las varillas del techo
18.Fixing the roof mesh – Unión de la malla electrosoldado monolit del techo
19.Providing openings in the roof – Marcar las aperturas en el techo
20.Plastering roof trusses – Aplicación de ferrocemento a las armaduras
21.Temporary formwork for plastering roof surface – encofrado temporaria para la aplicación de ferrocemento en el techo
22.Plastering roof surface - Aplicación de ferrocemento al techo
23.Plastering temp openings - Aplicación de ferrocemento a aperturas temporarias
24.Finishing the surface – Capa final de la superficie

#	fecha	por	rv por	descripción

Para Construcción

ENGINEERS WITHOUT BORDERS USA
Kansas City Professional Chapter

fecha	detallado por
7 Agosto 2020	Helen Wehner
diseñado por	revisado por
Helen Wehner	Audrey Freiberger

LOS CHURUNELES II
GUATEMALA

GPS: 14.827, -91.104

LOS CHURUNELES II
SISTEMA DE AGUA POTABLE

TANQUE DE ALMACENAMIENTO
DE AGUA POTABLE

dibujo		rev.
Tanque-08	–	A

Material Specification

Cement: Use ordinary Portland cement Type II

Sand:
1. Use well graded sand. Sand that is too fine or too coarse is not suitable
2. Separate sand from stone using 6.4 mm (1/4 inch) mesh screen.
3. No organic or chemical impurities. If quality is in doubt, wash with clean water.
4. Desirable sand grading is as follow:

Sieve	Percent passing
3/8 in (9.5mm)	100
No. 4 (4.75mm)	95 to 100
No. 8 (2.36 mm)	80 to 100
No. 14 (1.18mm)	50 to 85
No. 30 (600um)	25 to 60
No. 100 (150um)	2 to 10

Water:
1. Water fit for drinking is suitable.
2. Salty water should never be used.

Mesh Cloth:
1. Must be easy to handle and flexible enough to be bent around corners.
2. Galvanized wire mesh is preferred as it is less likely to rust or corrode.
3. Use 0.5 mm to 1.00 mm diameter with 10 mm to 25 mm mesh opening.
4. Free from grease, oil, rust and anything that might reduce bond.

Skeletal Steel :
1. Free from grease, oil detergents, organic matter, cracks of blow holes.
2. Bars are acceptable if no cracks appear after the following field test:
"Bend bar into U shape and then straighten it out. Bend it again in U shape in the opposite direction and straighten it out."
3. Grade 60 : Yield strength = 60 ksi

Steel Channel:
1. Free from grease, oil detergents, organic matter, cracks of blow holes
2. Size 1.25" x 3" (height x width) GHT 16 from Ferromax
3. Grade 72 : Yield strength = 72 ksi

Tie Wire: Use annealed (soft) galvanized wires of 24 or 26 gauge. Cut pieces of wire from meshes could also be used for tying.

Welded Wire Mesh:
1. Free from grease, oil detergents, organic matter, cracks of blow holes.
2. Use gage 10/10 6" x 6" mesh from Monolit

Resumen de Cantidades de Materiales (45 m^3)

Materiales	Cantidad	Unidad
Arena de Rio	18.26	m^3
Bloque	150	piezas
Cemento	3267	kg
Piedra Bola	5	m^3
Agua	1.67	m^3
RB #13	1616	m
Costanera de 1.25"x3" GHT 16	18	m
Tela Arnero 1/4"	123	m^2
Tubo PVC 6"	2.7	m
Plancha de metal	1	m^2
6"x6" Malla Electrostada Monolit	123	m^2
Escalera Fibra de Vidrio	2	-

Mix Proportions

Lean Concrete = 1:4:8 (Cement: Sand: Aggregate by weight)

Slab Concrete = 1:2:4 (Cement: Sand: Aggregate by weight)

Ferrocement Mortar = 1:2:0.4 (Cement: Sand: Water by weight)

#	fecha	por	rv por	descripción

Para Construcción

ENGINEERS WITHOUT BORDERS USA
Kansas City Professional Chapter

fecha: 7 Agosto 2020
detallado por: Helen Wehner
disenado por: Helen Wehner
revisado por: Audrey Freiberger

LOS CHURUNELES II
GUATEMALA

GPS: 14.827, -91.104

LOS CHURUNELES II
SISTEMA DE AGUA POTABLE

TANQUE DE ALMACENAMIENTO
DE AGUA POTABLE

dibujo: Tanque-09 — rev. A

Table of Contents

Reference Documents

1. Potable Water Standards, EWB-USA Guatemala, May 20, 2018.
2. Large Ferro-Cement Water Tank, United Nations High Commissioner for Refugees, July 2006.
3. Ferrocement Tank Construction Manual, ferrocement.com, 2015.
4. Assessment - Post-Trip Report, EWB-KC, Oct. 2019.
5. ACI 549R-18 Report on Ferrocement, American Concrete Institute, Jan. 2018.
6. ACI 549.1R-18 Design Guide for Ferrocement, American Concrete Institute, Sept. 2018.
7. ACI 318-14, Building Code Requirements for Structural Concrete, American Concrete Institute, 2018.
8. AISC 14, Steel Construction Manual, American Institute of Steel Construction, 14th Edition, 2011.
9. NES 2-10, Normas de Seguridad Estructural de Edificaciones y Obras de Infraestructura para La Republica de Guatemala, AGIES.
10. Structural Guidelines, Engineers Without Borders - USA, 2006.
11. ANSI/AWWA Standard D100-11, "Welded Carbon Steel Tanks for Water Storage".
12. ASCE/SEI 7-10 Minimum Design Loads for Buildings and Other Structures, American Society of Civil Engineers, 2010.

Design Parameters

The storage tank will be designed following the Potable Water Standards provided by EWB-USA Guatemala *(Reference 1)*. The standards require that the storage tank capacity be designed for the current population of the community plus a 2% growth rate over the design life. The demand per person will be selected based on Reference 1 and the demand known in the region. The selected value is conservatively selected. The population count taken on the assessment trip was 463 *(Reference 4)* but this number was not exact and has likely changed since the assessment trip was taken in August 2019. The population count will be rounded to 500 people for the purpose of design.

$Design\_Life := 20$	Design life of the project, years, *Reference 1*
$Population := 500$	Population in the community, *Reference 4*
$Population_{20} := Population \cdot 1.49 = 745$	Design population for 2% growth rate, *Reference 1*
$Demand := 60\ \boldsymbol{L}$	Water demand, /person/day
$Capacity := Population_{20} \cdot Demand = 11808\ \boldsymbol{gal}$	Design capacity of storage tank, Liters
$Capacity_{ft} := Capacity = 1579\ \boldsymbol{ft}^3$	Design capacity of storage tank, ft3

Design Basis

The storage tank design will use the standard design as detailed in Large Ferro-Cement Water Tank Design Parameters and Construction Details *(Reference 2)*. The guide provides designs for 45 m3, 75 m3, and 90 m3. The tank size required for this project is 44.7 m3 so the 45 m3 standard design will serve as a starting point for design. This calculation will check the materials, dimensions, and structural properties using the design methods presented in Ferrcement Tank Construction Manual *(Reference 3)* along with guidance from ACI 549R-18 Report on Ferrocement *(Reference 5)* and ACI 549.1R-18 Design Guide for Ferrocement *(Reference 6)*. The foundation design will follow ACI 318-14 and AISC Manual of Steel Construction.

1.0 Material Properties

1.1 Reinforcement Steel Properties

Diameter of #4 rebar:	$Dia_4 := 0.5\ \boldsymbol{in}$
Cross sectional area of #4 rebar:	$A_4 := 0.20\ \boldsymbol{in}^2$
Steel yield strength:	$f_y := 60000\ \dfrac{\boldsymbol{lb}}{\boldsymbol{in}^2}$
Unit weight of steel:	$\gamma_s := 490\ \dfrac{\boldsymbol{lb}}{\boldsymbol{ft}^3}$
Modulus of elasticity of steel:	$E_s := 29000000\ \dfrac{\boldsymbol{lb}}{\boldsymbol{in}^2}$

Allowable tensile stress in steel, *Reference 6, Section 4.3:*

$$F_s := \textbf{if}\left(0.6 \cdot f_y \le 30000 \ \frac{lb}{in^2}, 0.6 \cdot f_y, 30000 \ \frac{lb}{in^2}\right) = 30000 \ \frac{lb}{in^2}$$

1.2 Concrete and Ferrocement Properties

Concrete compressive strength for water containment tanks, *Reference 1:*

$$f_c := 3000 \ \frac{lb}{in^2}$$

Ferrocement compressive strength:

$$f_{c\_ferro} := 4000 \ \frac{lb}{in^2}$$

Unit weight of concrete:

$$\gamma_c := 150 \ \frac{lb}{ft^3}$$

Allowable compressive stress in ferrocement, *Reference 6, Section 4.4:*

$$F_f := 0.45 \cdot f_c = 1350 \ \frac{lb}{in^2}$$

1.3 Mesh Properties

Unit weight of mesh, *Appendix A*:

$$\gamma_{mesh} := 0.378 \ \frac{lb}{ft^3}$$

Effective modulus of steel mesh, *Reference 6, Chapter 5:*

$$E_{r\_mesh} := 29000000 \ \frac{lb}{in^2}$$

Yield strength of welded square mesh, *Appendix A:*

$$f_{y\_mesh} := 60000 \ \frac{lb}{in^2}$$

Allowable tensile strength of welded square mesh, *Reference 6, Section 4.3*:

$$F_{mesh\_all} := \textbf{if}\left(0.6 \cdot f_y \le 30000 \ \frac{lb}{in^2}, 0.6 \cdot f_y, 30000 \ \frac{lb}{in^2}\right) = 30000 \ \frac{lb}{in^2}$$

Effective modulus of hexagonal mesh, *Reference 6, Table 5.2:*

$$E_r := 29000000 \ \frac{lb}{in^2}$$

Global efficiency factor for welded square mesh, *Reference 6, Table 5.2.1.2*:

$$\eta := 0.50$$

2.0 Storage Tank Geometry and Geometry Checks

2.1 Reinforcement

Thickness of ferrocement material: $h := 3 \ in$

Spacing of welded wires, *Appendix A*: $s := 6 \ in$

Number of layers of mesh $N := 2$

Diameter of 10/10 gage welded wire mesh, *Appendix A*: $Dia_{mesh} := 0.135 \ in$

Cross sectional area of welded wire mesh: $A_{mesh} := \pi \cdot \left(\frac{Dia_{mesh}}{2}\right)^2 = 0.014 \ in^2$

Total volume fraction of reinforcement $V_f := \frac{N \cdot Dia_{mesh} + Dia_4}{h} = 0.257$

$Volume\_fraction\_reinforcement := \textbf{if} \left(V_f \geq 0.018, \text{“OK”}, \text{“Increase reinforcement”}\right) = \text{“OK”}$ *Reference 6, Section 4.5*

Percentage per layer of reinforcement: $V_{fi} := \frac{V_f}{N} = 0.1283$

$Cover := 0.083 \ in$

$Cover_{limit} := \textbf{if} \left(Cover \leq 0.5 \ in, \text{“OK”}, \text{“Cover should not exceed 1/5h or 3/16", whichever is smaller”}\right) = \text{“OK”}$

Reference 6, Section 4.6

2.2 Tank Geometry

Height of tank wall: $h_{wall} := 7.22 \ ft$

Depth of water in tank: $h_{water} := 6.89 \ ft$

Height of roof above shell: $h_r := 1.64 \ ft$

Interior diameter of tank: $Dia := 17.39 \ ft$

Surface area of tank bottom: $Area := \pi \cdot \left(\frac{Dia}{2}\right)^2 = 238 \ ft^2$

Circumference of tank: $c := \pi \cdot Dia = 54.6 \ ft$

$Volume := \textbf{if} \left(Area \cdot h_{water} \geq Capacity_{ft}, \text{“OK”}, \text{“Check tank dimensions”}\right) = \text{“OK”}$

2.3 Foundation Geometry

Height of concrete foundation: $h_f := 12\ in$

Diameter of concrete foundation: $Dia_f := 20.67\ ft$

Surface area of tank foundation: $Area_f := \pi \cdot \left(\frac{Dia_f}{2}\right)^2 = 336\ ft^2$

Moment of inertia of foundation footprint: $I_f := \frac{\pi}{64} \cdot Dia_f^{\ 4} = 8960\ ft^4$

Section modulus of foundation footprint: $S_f := \frac{I_f}{\left(\frac{Dia_f}{2}\right)} = 867\ ft^3$

3.0 Design Loads

3.1 Dead and Live Loads

Dead load factor for ferrocement, *Reference 6, Section 5.1:* $DL_{factor} := 2.0$

Live load factor for ferrocement, *Reference 6, Section 5.1:* $LL_{factor} := 2.0$

Tank roof live load, *Reference 12, Table 4-1:* $LL_r := 20\ \frac{lb}{ft^2}$

Tank wall weight: $W_s := h \cdot c \cdot h_{wall} \cdot \gamma_c = 14792\ lb$

Tank roof weight: $W_r := Area \cdot h \cdot \gamma_c \cdot 1.2 = 10688\ lb$

Tank foundation weight: $W_f := Area_f \cdot \gamma_c \cdot h_f = 50334\ lb$

3.2 Wind Load

Design wind speed, *Reference 9, Table 5-3:* $V_d := 62\ mph$

Exposure Category, conservative, *Reference 12, Section 26.7:* C

Importance category III, *Reference 12, Section 26*: $I := 1.15$

Gust-effect factor, conservative, *Reference 12, Section 26.9:* $G := 0.85$

Velocity pressure exposure coefficient, *Reference 12, Table 29.3-1*: $K_z := 0.85$

Tank height from ground: $H_{tank} := h_f + h_{wall} + h_r = 9.86\ \boldsymbol{ft}$

Height to diamater ratio: $\frac{H_{tank}}{Dia} = 0.57$

Net force coefficient, *Reference 12, Figure 29.4-1:* $C_f := 0.70$

Design wind pressure at tank height, *Reference 12, Equation 29.3-1:*

$$q_z := 0.00256 \cdot K_z \cdot I \cdot \left(\frac{V_d}{\boldsymbol{mph}}\right)^2 \cdot \frac{\boldsymbol{lb}}{\boldsymbol{ft}^2} = 9.6\ \frac{\boldsymbol{lb}}{\boldsymbol{ft}^2}$$

Design wind base shear, *Reference 12, Equation 29.4-1*:

$$V_{wind} := \max\left(q_z \cdot G \cdot C_f, 30 \cdot \frac{\boldsymbol{lb}}{\boldsymbol{ft}^2} \cdot C_f\right) \cdot \left(Dia \cdot H_{tank}\right) = 3601\ \boldsymbol{lb}$$

Design wind overturning moment:

$$M_{wind} := V_{wind} \cdot \left(\frac{1}{2} \cdot H_{tank}\right) = 17752\ \boldsymbol{lb} \cdot \boldsymbol{ft}$$

By inspection seismic loads govern design.

3.3 Seismic Parameters and Seismic Load Development

Mapped short period response acc., *Reference 9, Figure 4-1:* $S_{cr} := 1.65$

Mapped 1-sec period response acc., *Reference 9, Figure 4-1:* $S_{1r} := 0.60$

Short period seismic design acc., *Reference 10:* $S_{DS} := \frac{S_{cr}}{1.5} = 1.1$

Short period seismic design acc., *Reference 10:* $S_{D1} := \frac{S_{1r}}{1.5} = 0.4$

Structure seismic importance factor, *Reference 9, Table 1.5-2:* $I_e := 1.25$

Long period transition period: $T_L := 0.000092593\ \boldsymbol{day}$

Spectral acc adjustment coefficient: $K_{acc} := 1.5$

Total dead load at base of foundation: $P_{dead} := W_f + W_r + W_s = 75814\ \boldsymbol{lb}$

Tank live load on ring wall: $P_{live} := LL_r \cdot \left(\frac{\pi}{4}\right) \cdot Dia^2 = 4750\ lb$

Unit weight of water: $\gamma_w := 62.4\ \frac{lb}{ft^3}$

Specific weight of water: $SG_w := 1.0$

Water weight: $W_p := SG_w \cdot \gamma_w \cdot h_{water} \cdot Area = 102116\ lb$

Response modification factor -impulsive component, *Reference 11, Table 28*: $R_i := 2.5$

Response modification factor -convective component, *Reference 11, Table 28:* $R_c := 1.5$

Since Ti, the natural period of the tank structure, can be generally taken as 0 per Reference 4, Section 13.5.1:

Impulsive response acceleration, *Reference 11, Equation 13-9*: $S_{ai} := S_{DS} = 1.1$

Sloshing period, *Reference 11, Equation 13-22*: $T_c := 2 \cdot \pi \cdot \sqrt{\frac{Dia}{3.68 \cdot g \cdot \tanh\left(3.68 \cdot h_{water} \div Dia\right)}} = 2.542\ s$

Convective response acceleration, *Reference 11, Equation 13-12 and 13-13*: $S_{ac} := \frac{1.5 \cdot S_{D1} \cdot 1 \cdot sec}{T_c} = 0.236$

Impulsive spectral acc. parameter, *Reference 11, Equation 13-17*: $A_i := \max\left(\frac{S_{ai} \cdot I_e}{1.4 \cdot R_i}, \frac{0.36 \cdot S_{1r} \cdot I_e}{R_i}\right) = 0.393$

Convective Design acceleration, *Reference 11, Equation 13-18*: $A_c := \frac{S_{ac} \cdot I_e}{1.4 \cdot R_c} = 0.1405$

Impulsive equivalent weight coefficient of water, *Reference 11, Equation 13-24 and 13-25:*

$$W_i := \left\| \begin{array}{l} D\_H \leftarrow Dia \div h_{water} \\ \text{if } D\_H \geq 1.333 \\ \quad \left\| \dfrac{\tanh(0.866 \cdot D\_H)}{(0.866 \cdot D\_H)} \cdot W_p \right. \\ \text{else} \\ \quad \left\| (1 - 0.218 \cdot D\_H) \cdot W_p \right. \end{array} \right.$$

---->

$W_i = 45553\ lb$

Impulsive weight center, *Reference 11, Equation 13-28 and 13-29*:

$$X_i := \left\| \begin{array}{l} D\_H \leftarrow Dia \div h_{water} \\ \text{if } D\_H \geq 1.333 \\ \quad \left\| 0.375 \cdot h_{water} \right. \\ \text{else} \\ \quad \left\| (0.5 - 0.094 \cdot D\_H) \cdot h_{water} \right. \end{array} \right. = 2.584\ ft$$

Convective equivalent weight coefficient of water, *Reference 11, Equation 13-26*:

$$W_c := 0.230 \cdot \frac{Dia}{h_{water}} \cdot \tanh\left(3.67 \cdot \frac{h_{water}}{Dia}\right) \cdot W_p = 53143\ lb$$

Convective weight center, *Reference 11, Equation 13-30:*

$$X_c := \left(1.0 - \frac{\cosh\left(3.67 \cdot \frac{h_{water}}{Dia}\right) - 1}{3.67 \cdot \frac{h_{water}}{Dia} \cdot \sinh\left(3.67 \cdot \frac{h_{water}}{Dia}\right)}\right) \cdot h_{water} = 3.946\ ft$$

Shell CG:

$$X_s := h_{wall} \cdot \frac{1}{2} = 3.61\ ft$$

Roof CG:

$$X_r := h_{wall} + \frac{2}{3} \cdot h_r = 8.313\ ft$$

Total impulsive base shear, *Reference 11, Equation 13-31*:

$$V_i := A_i \cdot (W_s + W_r + W_f + W_i) = 47680\ lb$$

Total convective base shear, *Reference 11, Equation 13-31:*

$$V_c := A_c \cdot W_c = 7466\ lb$$

Total seismic base shear, *Reference 11, Equation 13-31*:

$$V_{base} := \sqrt{V_i^2 + V_c^2} = 48261\ lb$$

Total seismic base moment, *Reference 11, Equation 13-23*:

$$M_{base} := \sqrt{\left(A_i \cdot \left(W_i \cdot X_i + W_s \cdot X_s + W_r \cdot X_r\right)\right)^2 + \left(A_c \cdot W_c \cdot X_c\right)^2}$$

---->

$$M_{base} = 106289\ lb \cdot ft$$

Vertical acc parameter, *Reference 11, Section 13.5.4.3*:

$$A_v := 0.14 \cdot S_{DS} = 0.154$$

3.4 Geotechnical Information

A site soil evaluation was not completed. Conservative values will be assumed.

Soil Bearing Pressure, *Reference 12, Table 1806.2*:

$$P_{bearing} := 1500 \cdot \frac{lb}{ft^2}$$

At rest earth pressure coefficient:

$$K_0 := 0.45$$

4.0 Tank Wall Design

The design of ferrocement tanks assumes that the concrete plaster is only considered to serve as waterproofing for the steel. All the strength for the wall is assumed to be in the steel. The wire mesh and the bars which encircle the tank are treated separately since they have different structural properties. Analysis is done for a 1ft section of wall 3 feet tall as pressure will be greatest near the base. This analysis procedure follows a design example in Reference 3.

Pressure from water:

$$P := \gamma_w \cdot h_{water} = 430\ \frac{lb}{ft^2}$$

Total outward force on the bottom of tank wall:

$$F := P \cdot c = 23488\ \frac{lb}{ft}$$

Height of the wall for analysis:

$$h_{analysis} := 3 \cdot ft$$

Length of wall for analysis:

$$L_{analysis} := 1 \cdot ft$$

Spacing between horizontal bars:

$$s_h := 6 \cdot in$$

Spacing between vertical bars, type 1:

$$s_{v1} := 12 \cdot in$$

Spacing between vertical bars, type 2:

$$s_{v2} := 12 \cdot in$$

Spacing of horizonal wires in mesh:

$$s_{mesh\_h} := 6 \cdot in$$

Spacing of vertical wires in mesh:

$$s_{mesh\_v} := 6 \cdot in$$

Number of horizontal bars in first 3ft of wall: $n_h := \frac{h_{analysis}}{s_h} = 6$

Number of vertical type 1 bars per foot of wall: $n_{v1} := \frac{L_{analysis}}{s_{v1}} = 1$

Number of vertical type 2 bars per foot of wall: $n_{v2} := \frac{L_{analysis}}{s_{v2}} = 1$

Number of horizontal welded wires per foot of wall: $n_{mesh\_h} := \frac{h_{analysis}}{s_{mesh\_h}} = 6$

Number of vertical welded wires per foot of wall: $n_{mesh\_v} := \frac{L_{analysis}}{s_{mesh\_v}} = 2$

Strength in horizontal bars per in of wall: $F_h := \frac{A_4 \cdot F_s \cdot n_h}{L_{analysis}} = 36000 \ \frac{lb}{ft}$

Strength in vertical bars: $F_v := \frac{A_4 \cdot F_s \cdot (n_{v1} + n_{v2})}{L_{analysis}} = 12000 \ \frac{lb}{ft}$

Strength provided by wire mesh in horizontal: $F_{mesh\_h} := \frac{A_{mesh} \cdot n_{mesh\_h} \cdot F_{mesh\_all} \cdot N}{L_{analysis}} = 5153 \ \frac{lb}{ft}$

Strength provided by wire mesh in vertical: $F_{mesh\_v} := \frac{A_{mesh} \cdot n_{mesh\_v} \cdot F_{mesh\_all} \cdot N}{L_{analysis}} = 1718 \ \frac{lb}{ft}$

Total strength in sheet reinforcement: $F_{reinf} := F_h + F_v + F_{mesh\_h} + F_{mesh\_v} = 54871 \ \frac{lb}{ft}$

Allowable Strength Design requirements will be used to verify the adequacy of this wall reinforcement check as the loads are were not factored in this analysis. This is a conservative check.

$\Omega := 2.0$

$$Wall\_Strength := \text{if}\left(\frac{F_{reinf}}{\Omega} \geq F, \text{“OK”}, \text{“N.G.”}\right) = \text{“OK”}$$

$$IR_{wall} := \frac{\Omega \cdot F}{F_{reinf}} = 0.86$$

5.0 Tank Roof Design

The roof structure will be analyzed as a 1' wide beam spanning between the tank wall and the central column. Examples of determining the nominal moment capacity of a ferrocement section are provided at the end of ACI 549.1R-18. That procedure will be followed here with the design moment compared to the nominal moment capacity.

Strength load factor: $\phi := 0.9$

Length of roof to be analyzed: $L_r := \frac{Dia}{2} = 8.7\ ft$

Design Moment

The load combination 1.2DL + 1.6LL + 0.5LLr with factors suggested for ferrocement will be used for calculating the design moment.

Tank Live Load,
Reference 12, Table 4-1: $LL_r = 20\ \frac{lb}{ft^2}$

$$w_{LL\_r} := LL_r \cdot 1 \cdot ft = 20\ \frac{lb}{ft}$$

Self weight of tank roof: $w_r := h \cdot \gamma_c \cdot 1 \cdot ft = 37.5\ \frac{lb}{ft}$

Design distributed load: $w := DL_{factor} \cdot \left(w_r + 0.2 \cdot w_r\right) + LL_{factor} \cdot w_{LL\_r} = 130\ \frac{lb}{ft}$

Design Moment: $M := \frac{w \cdot {L_r}^2}{8} = 1229\ lb \cdot ft$

Nominal Moment

Center to center spacing of reinforcing mesh: $s := \frac{\left(h - \left(2 \cdot Cover + Dia_{mesh}\right)\right)}{N - 1} = 2.699\ in$

Effective cross-sectional area of reinforcement mesh layer i: $A_{si} := \eta \cdot V_{fi} \cdot \left(L_r \cdot 1 \cdot ft\right) = 80.342\ in^2$

$$d_1 := Cover + \frac{Dia_{mesh}}{2} = 0.151\ in \qquad d_2 := d_1 + s = 2.85\ in$$

The distance from the extreme compression fiber to the neutral axis is determine by trial and error solving to set the tension forces and compression forces equal to one another.

$\varepsilon_{cu} := 0.003$ $c_s := 0.51 \cdot in$ $\beta_1 := 0.85$

$$\varepsilon_y := \frac{f_{y\_mesh}}{E_r} = 0.0021$$

$$\varepsilon_{s1} := \left(\frac{d_1 - c_s}{c_s}\right) \cdot \varepsilon_{cu} = -0.0021 \qquad f_{s1} := E_r \cdot \varepsilon_{s1} = -61326 \ \frac{lb}{in^2}$$

$$f_{s1\_calc} := \textbf{if}\left(f_{s1} < f_{y\_mesh}, f_{s1}, f_{y\_mesh}\right) = -61326 \ \frac{lb}{in^2} \qquad T_{s1} := f_{s1\_calc} \cdot A_{si} = -4927079 \ lb$$

$$\varepsilon_{s2} := \left(\frac{d_2 - c_s}{c_s}\right) \cdot \varepsilon_{cu} = 0.0138 \qquad f_{s2} := E_r \cdot \varepsilon_{s2} = 399091 \ \frac{lb}{in^2}$$

$$f_{s2\_calc} := \textbf{if}\left(f_{s2} < f_{y\_mesh}, f_{s2}, f_{y\_mesh}\right) = 60000 \ \frac{lb}{in^2} \qquad T_{s2} := f_{s2\_calc} \cdot A_{si} = 4820508 \ lb$$

$$C := 0.85 \cdot f_c \cdot \beta_1 \cdot c_s \cdot L_r = 115340 \ lb$$

$$T := T_{s1} + T_{s2} = -106571 \ lb$$

$$ratio := \frac{C}{T} = -1.082$$

$$M_n := T_{s1} \cdot \left(d_1 - \frac{\beta_1 \cdot c_s}{2}\right) + T_{s2} \cdot \left(d_2 - \frac{\beta_1 \cdot c_s}{2}\right) = 1084801 \ lb \cdot ft$$

$$IR_{roof} := \frac{M}{\phi \cdot M_n} = 0.0013$$

6.0 Column Design

6.1 Central Column Design

The central column will be constructed out of a 6 in. PVC pipe filled with the ferrocement mortar and reinforced with four #4 reinforcing bars. According to ACI 549.1R-18 Design Guide for Ferrocement, Section 5.2.3 for members in compression, ferrocement can be analyzed the same as concrete with a stress reduction of 0.85. This procedure is followed below:

Diameter of central column: $Dia_{column} := 8\ in$

Cross-sectional area of central column: $Area_{column} := \pi \cdot \left(\frac{Dia_{column}}{2}\right)^2 = 50\ in^2$

Tributary area for central column: $Area_{trib} := \pi \cdot \left(\frac{Dia}{4}\right)^2 = 59\ ft^2$

Self-Weight of Roof: $w_{r\_dead} := h \cdot \gamma_c \cdot Area_{trib} \cdot (1.2) = 2672\ lb$

Live load on central column: $w_{r\_live} := LL_r \cdot Area_{trib} = 1188\ lb$

Axial load applied to column: $P_u := DL_{factor} \cdot w_{r\_dead} + LL_{factor} \cdot w_{r\_live} = 7719\ lb$

Length of central column: $L_{column} := h_{wall} + h_r = 8.86\ ft$

Radius of Gyration of Column: $r := \frac{Dia_{column}}{4} = 0.167\ ft$

Effective Length Factor: $K := 1.0$

Column slenderness ratio: $Slenderness\_ratio := \frac{K \cdot L_{column}}{r} = 53.16$

$slenderness := \mathbf{if}\left(Slenderness\_ratio < 200, \text{“OK”}, \text{“N.G.”}\right) = \text{“OK”}$

Tied column strength reduction factor, *Reference 7*: $\phi_c := 0.65$

Number of reinforcing bars in column: $No\_Bars := 4$

$$P_n := 0.80 \cdot \left(No\_Bars \cdot A_4 \cdot f_y + 0.85 \cdot f_{c\_ferro} \cdot \left(Area_{column} - No\_Bars \cdot A_4\right)\right) = 172946\ lb$$

Interaction ratio for ferrocement column: $IR_{column} := \frac{P_u}{\phi_c \cdot P_n} = 0.07$

6.2 Channel Column Design

The roof trusses will connect to structural channels that are specificed in Appendix B to this calculation. There will be eight roof trusses and therefore eight supporting channels acting as columns. The load from the roof will be transfered to these columns.

Strenght reduction factor for column: $\phi := 0.9$

Number of channels: $N_{channels} := 8$

Roof area tributary to each channels: $Area_{trib\_channel} := \frac{Area - Area_{trib}}{N} = 89\ ft^2$

Dead load supported by each channel: $w_{channel\_dead} := h \cdot \gamma_c \cdot Area_{trib\_channel} \cdot 1.2 = 4008\ lb$

Live load supported by each channel: $w_{channel\_live} := LL_r \cdot Area_{trib\_channel} = 1781\ lb$

Design load for channels: $P_{u\_channel} := 1.2 \cdot w_{channel\_dead} + 1.6 \cdot w_{channel\_live} = 7660\ lb$

Ultimate strength of channels, *Appendix B*: $f_{y\_channel} := 72000\ \frac{lb}{in^2}$

Allowable strenght of channels: $f_{s\_channel} := 0.6 \cdot f_{y\_channel} = 43200\ \frac{lb}{in^2}$

Cross-sectional area of channel: $A_{channel} := (0.0394\ in) \cdot (3\ in + 1.25\ in + 1.25\ in) = 0.002\ ft^2$

Nominal capacity of channels: $P_n := f_{s\_channel} \cdot A_{channel} = 9361\ lb$

Interaction ratio of channels: $IR_{channel} := \frac{P_u}{\phi \cdot P_n} = 0.916$

The loads were conservatively developed for the channels so this IR is acceptable.

7.0 Foundation Design

7.1 Bearing Pressure

Bearing pressure due to vertical dead load only: $q_{pD} := \frac{P_{dead}}{Area_f} = 226\ \frac{lb}{ft^2}$

Bearing pressure due to vertical live load only: $q_{pL} := \frac{P_{live}}{Area_f} = 14\ \frac{lb}{ft^2}$

Bearing pressure due to operating level water: $q_{pwtr} := \frac{W_p}{Area_f} = 304\ \frac{lb}{ft^2}$

Load Case (1): DL ± 0.6W

Moment at base of footing: $M_{sW} := M_{wind} + V_{wind} \cdot h_f = 21353\ lb \cdot ft$

Bearing pressure at outside face due to wind moment : $q_{c2W} := \frac{0.6 \cdot M_{sW}}{S_f} = 15\ \frac{lb}{ft^2}$

Maximum bearing pressure: $q_{max} := q_{pD} + q_{c2W} = 241\ \frac{lb}{ft^2}$

Minimum bearing pressure: $q_{min} := 0.6 \cdot q_{pD} - q_{c2W} = 121\ \frac{lb}{ft^2}$

Since qmin > 0, no uplift pressure exists.

Bearing pressure interaction ratio, load case (1): $IR_0 := \frac{q_{max}}{P_{bearing}} = 0.16$

Load Case (2): DL + LLr + OP

Maximum bearing pressure $q_{max} := q_{pD} + q_{pwtr} + q_{pL} = 544\ \frac{lb}{ft^2}$

Bearing pressure interaction ratio, load case (2): $IR_1 := \frac{q_{max}}{P_{bearing}} = 0.36$

Load Case (3): DL + OP ± 0.7E or 0.6 W

Moment at base of footing: $M_{sE} := \left(M_{base} + V_{base} \cdot h_f\right) = 154550\ lb \cdot ft$

Bearing pressure at outside face due to seismic Moment : $q_{c2E} := 0.7 \cdot \left(\frac{M_{sE}}{S_f} + 0.4 \cdot A_v \cdot \left(q_{pwtr} + q_{pD}\right)\right) = 148\ \frac{lb}{ft^2}$

Governing peak pressure: $q_{c2s} := \max\left(q_{c2W}, q_{c2E}\right) = 148\ \frac{lb}{ft^2}$

Maximum bearing pressure: $q_{max} := q_{pD} + q_{pwtr} + q_{c2s} = 678\ \frac{lb}{ft^2}$

Minimum bearing pressure: $q_{min} := 0.6 \cdot q_{pD} + q_{pwtr} - q_{c2s} = 292\ \frac{lb}{ft^2}$

Since qmin > 0, no uplift pressure exists.

Bearing pressure interaction ratio, load case 3: $IR_2 := \dfrac{q_{max}}{P_{bearing}} = 0.45$

Interaction ratio for bearing: $IR_{bearing} := \max\left(IR_0, IR_1, IR_2\right) = 0.45$

7.2 Stability Evaluation - Overturning

Load cases (1) & (3) result in meaningful overturning effect that need to be checked.

Load Case (1): DL ± 0.6W

Resisting moment: $M_{res} := P_{dead} \cdot \dfrac{Dia_f}{2} = 783537\ \boldsymbol{lb \cdot ft}$

Factor of safety: $FS_{ot\_1} := \dfrac{M_{res}}{0.6 \cdot M_{sW}} = 61$

Required factor of safety, ref 5: $FS_{req\_1} := 1.5$

Interaction Ratio for Overturning, Load Case (1): $IR_{ot\_1} := \dfrac{FS_{req\_1}}{FS_{ot\_1}} = 0.025$

Load Case (3): DL + OP ± 0.7E or 0.6W

Resisting moment: $M_{res} := \left(P_{dead} + W_p\right) \cdot \left(1 - 0.4 \cdot A_v\right) \cdot \dfrac{Dia_f}{2} = \left(1.726 \cdot 10^6\right)\ \boldsymbol{lb \cdot ft}$

Factor of safety: $FS_{ot\_3} := min\left(\dfrac{M_{res}}{0.7 \cdot M_{sE}}, \dfrac{\left(P_{dead} + W_p\right) \cdot Dia_f}{2 \cdot 0.6 \cdot M_{sW}}\right) = 16$

Required factor of safety: $FS_{req\_3} := 1.5$

Interaction Ratio for Overturning, Load Case (2): $IR_{ot\_3} := \dfrac{FS_{req\_3}}{FS_{ot\_3}} = 0.094$

Interation Ratio for Overturning: $IR_{ot} := \max\left(IR_{ot\_1}, IR_{ot\_3}\right) = 0.094$

7.3 Foundation Reinforcement - Hoop Tension Design

Liquid gravity pressure on foundation: $w_l := SG_w \cdot \gamma_w \cdot h_{water} = 430\ \dfrac{\boldsymbol{lb}}{\boldsymbol{ft}^2}$

Liquid lateral pressure on foundation: $P_{tank} := K_0 \cdot w_l = 193\ \dfrac{\boldsymbol{lb}}{\boldsymbol{ft}^2}$

Soil lateral pressure on ring wall: $P_{soil} := 0 \ \frac{lb}{ft^2}$

Minimum reinforcement in horizontal direction, Ref*erence 11, Table 11.6.1*: $A\_WH_{min} := 0.0015 \cdot h_f = 0.216 \ \frac{in^2}{ft}$

Lateral force on foundation: $F_t := (P_{soil} + P_{tank}) \cdot ft = 193 \ \frac{lb}{ft}$

Hoop tension: $Ten := F_t \cdot \frac{Dia_f}{2} = 2000 \ lb$

Factored hoop tension: $Ten_u := (DL_{factor}) \cdot Ten = 3999 \ lb$

Area of steel required, *Reference 11, Section 9.2*: $A_{s.reqd\_per\_ft} := \frac{Ten_u}{0.9 \cdot f_y} = 0.074 \ in^2$

Provided 2-lyrs reinforcement: $WH_{prvd} :=$ "#4@12"

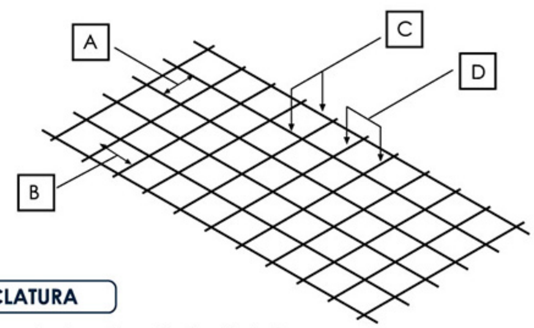
Provided reinforcement area: $W\_As\_H_{prvd} := 2 \cdot A_4 = 0.4 \ in^2$

DATOS TÉCNICOS								TABLA DE CONVERS		
NOMENCLATURA		DIÁMETRO DE VARILLA	ÁREA DE VARILLA	PESO		ÁREA DE REFUERZO	TIPO DE VARILLA	Grado 60 Fy = 4,218 kg/cm²		G Fy = 2
Cuadro	Calibre	mm	cm²	kg/m²	kg/pl	cm²/m		Refuerzo que sustituye	(cm²/m)	Refue que sus
6" x 6"	10/10	3.43	0.092	0.98	13.87	0.616	Corrugada	No. 2 @ 43	0.733	No. 2 @
6" x 6"	9/9	3.80	0.113	1.20	16.91	0.756	Corrugada	No. 2 @ 35	0.900	No. 2 @
6" x 6"	8/8	4.11	0.133	1.40	19.76	0.884	Corrugada	No. 2 @ 30	1.052	No. 2 @ No. 3 @
6" x 6"	7/7	4.50	0.159	1.68	23.75	1.060	Corrugada	No. 2 @ 25	1.262	No. 2 @ No. 3 @
6" x 6"	6/6	4.88	0.187	1.98	27.93	1.247	Corrugada	No. 2 @ 21 ó No. 3 @ 0.48	1.485	No. 2 @ No. 3 @
6" x 6"	4.5/4.5	5.50	0.238	2.52	35.53	1.584	Corrugada	No. 2 @ 17 ó No. 3 @ 0.38	1.886	No. 3 @ No. 4 @
6" x 6"	4/4	5.72	0.257	2.72	38.38	1.713	Corrugada	No. 2 @ 16 ó No. 3 @ 0.35	2.039	No. 3 @ No. 4 @
6" x 6"	3/3	6.20	0.302	3.19	45.03	2.013	Corrugada	No. 2 @ 13 ó No. 3 @ 0.30	2.396	No. 3 @ No. 4 @
6" x 6"	2/2	6.65	0.347	3.68	51.87	2.315	Corrugada	No. 2 @ 12 ó No. 3 @ 0.26	2.756	No. 3 @ No. 4 @

Se fabrican mallas especiales a pedido (aplican restricciones).

CARACTERÍSTICAS DE MALLA ESTÁNDAR

- 6.00 m de largo
- 2.35 m de ancho
- 14.10 m² de área bruta
- Cuadros de 6" x 6" (15 x 15cm)
- Fabricada con varilla de acero grado 70

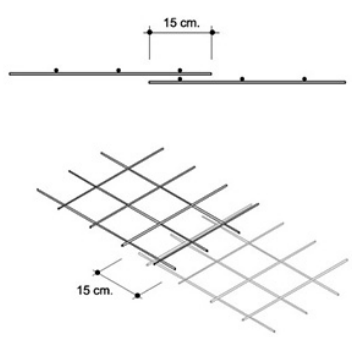


NOMENCLATURA

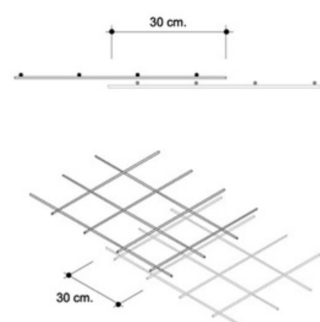
A - Espaciamiento en pulgadas entre varillas longitudinales
B - Espaciamiento en pulgadas entre varillas transversales
C - Calibre SWG de varillas longitudinales
D - Calibre SWG de varillas transversales

(SWG: Steel Wire Gauge)

EMPALMES: Según ACI 318-11, Sección 12.7, el empalme de malla electrosoldada debe realizarse según detalles No. 1 y 2



Detalle No. 1
Empalme para refuerzo por temperatura



Detalle No. 2
Empalme para refuerzo estructural

5 VSH YGASWI R &GI VS 2 SRSPM

+ROD &KDWHD FRQ QRVRWURV

FERROMAX
#1 en hierro y techos

EL TIEMPO ES ORO

AHORRE TIEMPO Y DINERO

Con nuestros Exclusivos Servicios de

FABRICACIÓN A LONGITUD EXACTA

desde 1 hasta 12 metros, sin costo adicional

Evitando:


CORTES


SOLDADURAS


DESPERDICIOS

Cotiza tus Costaneras GHT

Espesor

GHT 16 (1.00 mm)

Peralte y base

3"x 1.25"

Longitud

4 m 0 cm

Cantidad

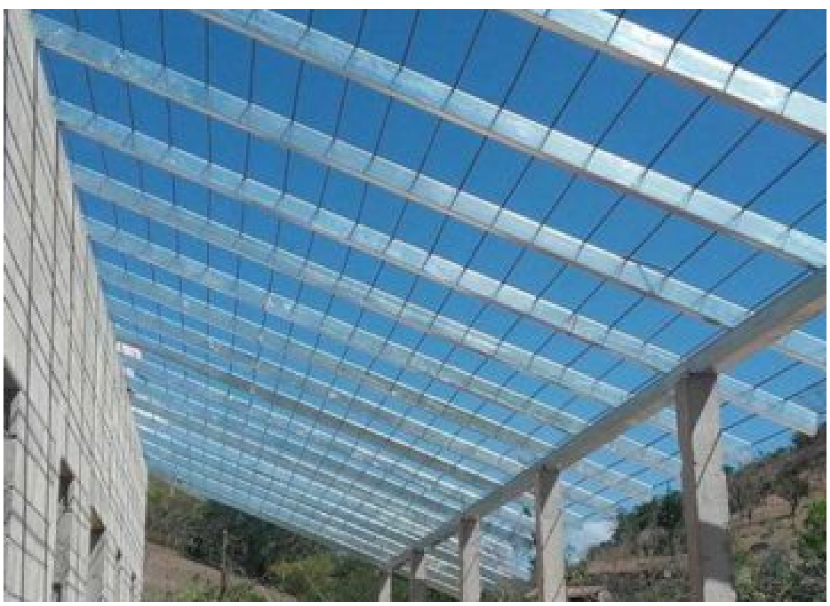
8 Unidad

Añadir a cotización

Presentaciones

Características

- Resistencia estructural: Grado 72 (72,000 psi)
- Esfuerzo último: 75:000 psi
- Ductilidad promedio 9%
- Recubrimiento de Zinc: Z 180 (180 g/m^2)
- Normas: ASTM A653 y AUS 1397



Client Name:	EWB	Page 1 of 6	
Project Name:	Churuneles II	Project No.: N/A	
Calculation Title:	Churuneles Fluid Flow Calculations	File No.: N/A	

References

1 Distances, Elevations: Diseño de Sistema de Agua Potable Caserio Churuneles II, Agua Para la Salud
2 Tank Details: Large Ferro-Cement Water Tank Design Parameters and Construction Details, UNHCR
3 Pipe sizes: https://www.durman.com/descargas/TuberiaSDR/fichas/FTtubosSDR.pdf
4 Google Map: Churuneles - 2 Header Design:
https://www.google.com/maps/d/drive?state=%7B%22ids%22%3A%5B%221ulZo-So9FU3GGQtL20ep47ErXPRvSUgz%22%5D%2C%22action%22%3A%22open%22%2C%22userId%22%3A%22100769235833365508045%22%7D&usp=sharing

*Attached

Design Basis

1 25% saftey factor used for flowrates.
2 Conduction flowrate sized using average spring supply rate (0.51 L/sec)
3 Distribution headers and service connections sized for peak instantaneous rate (0.1 L/sec per tap)
4 Distances, Elevations estimated using Ref. 4 have 25% margin added for uncertainty

Assumptions

Not used.

Definitions of Units and Constants

Not used.

Conclusions

The Conduction Line size is confirmed as 2". The highest pressure is 87psig, well below the 160 pressure limit of the pipe. No break pressure tank is required.
Header 2 is sized as 3" until Branch 6 in order to avoid excessive head loss in pipes. Downstream of Branch 6, Header 2 is sized as 2". Branch 6 and Branch 7 are both sized at 1", with service connections of 3/4".

Engineers Without Borders - Kansas City Professional Chapter

Fluid Flow Calculations

Incompressible Streams

Row								
2	**Client:**	**EWB**						**Date:**
3	**Project:**	**Churuneles II**			**Atmospheric Pressure**			**Job No:**
4	**Service:**	**Water**			14.696 psia			**By:**
5	Line Sizing Guide							
6	**LINE IDENTIFICATION**				**CONDUCTION LINE**			
7	Line ID				Liquid	Liquid	Liquid	Liquid
8	From (Upstream)				Spring Tank	Station A-20	Station A-25	Station A-35
9	To (Downstream)				Station A-20	Station A-25	Station A-35	Storage Tank
10	**PIPING**							
11	Length, ft				1634	312	1047	381
12	Net elevation increase, ft				-169	-29	-8	65
13	Nominal size, in				2.00	2.00	2.00	2.00
14	Schedule; Number(S), Std, XS, XXS				SDR-26 (160#)	SDR-26 (160#)	SDR-26 (160#)	SDR-26 (160#)
15	Lining thickness, in				0	0	0	0
16	Inside diameter, in				2.193	2.193	2.193	2.193
17	Roughness factor, ft				0.00015	0.00015	0.00015	0.00015
18	Downstream pipe ID, (for reducer calcs only)				2.193	2.193	2.193	N/A
19	**LIQUID PHASE FLOWRATE AND PHYSICAL PROPERTIES**							
20	Fluid				Water	Water	Water	Water
21	Taps Connected (0.1 L/second = 1.59 gpm per tap)							
22	Flow Rate, lb/hr							
23	Flow Rate, gpm				8	8	8	8
24	Flowrate design margin				1.25	1.25	1.25	1.25
25	Temperature, F				75	75	75	75
26	Density, lb/ft^3				62.2	62.2	62.2	62.2
27	Viscosity, centipoise				0.94	0.94	0.94	0.94
31	Surface tension, dynes/cm				73.0	73.0	73.0	73.0
44	**PRESSURE DROP TABULATION**							
45	Straight piping losses, psi				1.3	0.2	0.8	0.3
46	Valve & fitting losses, psi				0.0	0.0	0.0	0.0
53	Elevation, psi				-72.8	-12.6	-3.6	27.9
54					=======	=======	=======	=======
55	Total pressure drop, psi				-71.5	-12.4	-2.7	28.2
56	**PRESSURE PROFILE SUMMARY**							
57	Upstream pressure, psig				0.0	71.5	83.9	86.6
58	Downstream pressure, psig				71.5	83.9	86.6	58.4
60	**LIQUID PHASE FRICTION CALCULATIONS**							
61	Velocity, ft/sec				0.86	0.86	0.86	0.86
62	Velocity, m/sec				0.26	0.26	0.26	0.26
63	Reynolds number				15,393	15,393	15,393	15,393
64	Flow type				Turbulent	Turbulent	Turbulent	Turbulent
65	Friction factor				0.0291	0.0291	0.0291	0.0291
66	Kinetic specific energy, psi				0.01	0.01	0.01	0.01
67	Pressure drop, psi/100 ft				0.079	0.079	0.079	0.079
68	Density * Velocity^2, lb/ft-sec^2				46	46	46	46
86	**VALVES & FITTINGS**							
87	Elbow	90 deg	Long radius	All types	2		4	
88	Elbow	45 deg	Long radius	All types	2		2	1
89	Tee	As elbow	Standard	Flg/wld				
90	Tee	As elbow	Stub-in-type					
91	Tee	Run through	Flg/wld					
92	Tee	Run through	Stub-in-type					
93	Valve	Gate Ball Plug	Reduced trim	B=0.8	1			
94	Valve	Check	Swing					
95	Entrance	Sharp-edged			1			
96	Exit	All types						1
97								
98								
99								
100								
101								
102	**PIPE SIZE CHANGES**							
103	Expand or	Square						
104	Contract	Tapered						
105		Length of taper, inches						
106		Angle of diameter change, degrees						
107		**Standard reducer/expander**						
108	Orifice	Bore diameter, inches						
109		Thin, sharp orifice						
110		Thick orifice						
111		orifice thickness, in (thick only)						
112	TOTAL: Resistance coefficients, K or N = fL/D				2.4	0.0	1.9	1.7
113	Equivalent length, ft				14.8	0.0	11.8	10.7

Engineers Without Borders - Kansas City Professional Chapter
Fluid Flow Calculations
Incompressible Streams

Client: EWB
Project: Churuneles II
Service: Water
Line Sizing Guide

LINE IDENTIFICATION	HEADER 1					HEADER 1: BRANCH 5				HEADER 1: BRANCH 6					HEADER 1: BRANCH 1			
Line ID	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid
From (Upstream)	Storage Tank	Branch 1	Branch 2	Branch 3	Branch 4	Header 1	#21 Takeoff	#23 Takeoff	#28 Takeoff	Header 1	Road Takeoff	#33/34/35 Takeoff	#25 Takeoff	#29 Takeoff	Header 1	#4 Takeoff	#2 Takeoff	#53 Takeoff
To (Downstream)	Branch 1	Branch 2	Branch 3	Branch 4	Branch 5	#21 Takeoff	#23 Takeoff	#28 Takeoff	House #28	Road Takeoff	#33/34/35 Takeoff	#25 Takeoff	#29 Takeoff	House #29	#4 Takeoff	#2 Takeoff	#53 Takeoff	House #28
PIPING																		
Length, ft	381	375	302	607	828	243	249	75	563	377	302	217	313	406	219	193	262	82
Net elevation increase, ft	-61	-18	-5	8	-22	-80	-96	4	-185	-1	-58	-87	-41	-123	20	-6	-21	-4
Nominal size, in	2.00	2.00	2.00	2.00	2.00	1.00	1.00	1.00	0.75	1.00	1.00	0.75	0.75	0.75	1.00	1.00	0.75	0.75
Schedule; Number(S), Std, XS, XXS	SDR-26 (160#)	SDR-26 (160#)	SDR-26 (160#)	SDR-26 (160#)	SDR-26 (160#)	SDR-26 (160#)	SDR-26 (160#)	SDR-26 (160#)	SDR-17 (250#)	SDR-26 (160#)	SDR-26 (160#)	SDR-17 (250#)	SDR-17 (250#)	SDR-17 (250#)	SDR-26 (160#)	SDR-26 (160#)	SDR-17 (250#)	SDR-17 (250#)
Lining thickness, in	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Inside diameter, in	2.193	2.193	2.193	2.193	2.193	1.195	1.195	1.195	0.926	1.195	1.195	0.926	0.926	0.926	1.195	1.195	0.926	0.926
Roughness factor, ft	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015
Downstream pipe ID, (for reducer calcs only)	2.193	2.193	2.193	2.193	1.195	1.195	1.195	0.926	N/A	1.195	0.926	0.926	0.926	N/A	1.195	0.926	0.926	N/A
LIQUID PHASE FLOWRATE AND PHYSICAL PROPERTIES																		
Fluid	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water
Taps Connected (0.1 L/second = 1.59 gpm per tap)	30	24	21	19	13	7	6	3	1	6	6	3	2	1	6	5	3	1
Flow Rate, lb/hr																		
Flow Rate, gpm	48	38	33	30	21	11	10	5	2	10	10	5	3	2	10	8	5	2
Flowrate design margin	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
Temperature, F	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75
Density, lb/ft^3	62.2	62.2	62.2	62.2	62.2	62.2	62.2	62.2	62.2	62.2	62.2	62.2	62.2	62.2	62.2	62.2	62.2	62.2
Viscosity, centipoise	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
Surface tension, dynes/cm	73.0	73.0	73.0	73.0	73.0	73.0	73.0	73.0	73.0	73.0	73.0	73.0	73.0	73.0	73.0	73.0	73.0	73.0
PRESSURE DROP TABULATION																		
Straight piping losses, psi	7.8	5.1	3.2	5.3	3.6	6.8	5.2	0.4	1.6	7.9	6.3	4.4	3.1	1.1	4.6	2.9	5.4	0.2
Valve & fitting losses, psi	0.2	0.1	0.1	0.0	0.0	0.1	0.5	0.0	0.0	0.1	0.0	0.1	0.1	0.0	0.3	0.0	0.0	0.0
Elevation, psi	-26.4	-8.0	-2.3	3.4	-9.7	-34.6	-41.6	1.7	-79.8	-0.4	-24.9	-37.7	-17.7	-53.2	8.8	-2.4	-8.9	-1.9
	=======	=======	=======	=======	=======	=======	=======	=======	=======	=======	=======	=======	=======	=======	=======	=======	=======	=======
Total pressure drop, psi	-18.4	-2.8	1.0	8.7	-6.1	-27.7	-35.9	2.2	-78.2	7.6	-18.6	-33.1	-14.6	-52.0	13.7	0.5	-3.5	-1.7
PRESSURE PROFILE SUMMARY																		
Upstream pressure, psig	0.0	18.4	21.2	20.2	11.5	17.6	45.3	81.2	79.0	17.6	10.0	28.6	61.7	76.3	18.4	4.7	4.2	7.8
Downstream pressure, psig	18.4	21.2	20.2	11.5	17.6	45.3	81.2	79.0	157.2	10.0	28.6	61.7	76.3	128.4	4.7	4.2	7.8	9.5
LIQUID PHASE FRICTION CALCULATIONS																		
Velocity, ft/sec	5.06	4.05	3.55	3.21	2.19	3.98	3.41	1.70	0.95	3.41	3.41	2.84	1.89	0.95	3.41	2.84	2.84	0.95
Velocity, m/sec	1.54	1.24	1.08	0.98	0.67	1.21	1.04	0.52	0.29	1.04	1.04	0.87	0.58	0.29	1.04	0.87	0.87	0.29
Reynolds number	90,874	72,699	63,612	57,554	39,379	38,902	33,345	16,672	7,171	33,345	33,345	21,512	14,341	7,171	33,345	27,787	21,512	7,171
Flow type	Turbulent	Turbulent	Turbulent	Turbulent	Turbulent	Turbulent	Turbulent	Turbulent	Turbulent	Turbulent	Turbulent	Turbulent	Turbulent	Turbulent	Turbulent	Turbulent	Turbulent	Turbulent
Friction factor	0.0218	0.0224	0.0227	0.0231	0.0244	0.0261	0.0267	0.0299	0.0362	0.0267	0.0267	0.0293	0.0314	0.0362	0.0267	0.0274	0.0293	0.0362
Kinetic specific energy, psi	0.19	0.12	0.09	0.08	0.04	0.12	0.09	0.02	0.01	0.09	0.09	0.06	0.03	0.01	0.09	0.06	0.06	0.01
Pressure drop, psi/100 ft	2.051	1.348	1.050	0.871	0.432	2.784	2.089	0.585	0.282	2.089	2.089	2.055	0.978	0.282	2.089	1.490	2.055	0.282
Density * Velocity^2, lb/ft-sec^2	1596	1022	782	640	300	985	723	181	56	723	723	501	223	56	723	502	501	56
VALVES & FITTINGS																		
Elbow 90 deg Long radius All types		1	1		1	1	1		1	1								
Elbow 45 deg Long radius All types		1	2	2	2	1			3	2			1	2	1	1		1
Tee As elbow Standard Flg/wld																		
Tee As elbow Stub-in-type							3	1				1	1		2			
Tee Run through Flg/wld																		
Tee Run through Stub-in-type		1	1	1	1	1					1					2	2	
Valve Gate Ball Plug Reduced trim B=0.8	1								1	1				1				1
Valve Check Swing																		
Entrance Sharp-edged	1																	
Exit All types																		
PIPE SIZE CHANGES																		
Expand or Contract: Square																		
Tapered																		
Length of taper, inches																		
Angle of diameter change, degrees																		
Standard reducer/expander								1			1					1		
Orifice: Bore diameter, inches																		
Thin, sharp orifice																		
Thick orifice																		
orifice thickness, in (thick only)																		
TOTAL: Resistance coefficients, K or N = fL/D	1.1	0.5	0.8	0.5	0.8	0.7	6.0	2.1	2.3	1.5	0.2	2.1	2.5	1.4	4.0	0.5	0.0	1.0
Equivalent length, ft	9.3	4.3	6.1	3.6	5.8	2.6	22.4	6.9	5.0	5.5	0.7	5.6	6.1	3.0	15.0	1.7	0.0	2.2

Engineers Without Borders - Kansas City Professional Chapter
Fluid Flow Calculations
Incompressible Streams

Client:	**EWB**	**23-May-20**	Page 4 of 4
Project:	**Churuneles II**	**N/A.N/A**	
Service:	**Water**	**A. Doerflinger**	

Line Sizing Guide

LINE IDENTIFICATION	**HEADER 2**							**HEADER 2: BRANCH 7**				**HEADER 2: BRANCH 8**				
Line ID	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid
From (Upstream)	Storage Tank	Branch 1	Branch 2	Branch 3	Branch 4	Branch 5	Branch 6	Header 2	#43 Takeoff	#37/38 Takeoff	#37 Takeoff	Header 2	#51 Takeoff	End of Road	#47/48 Takeoff	#47 Takeoff
To (Downstream)	Branch 1	Branch 2	Branch 3	Branch 4	Branch 5	Branch 6	Branch 7	#43 Takeoff	#37/38 Takeoff	#37 Takeoff	House #38	#51 Takeoff	End of Road	#47/48 Takeoff	#47 Takeoff	House #48
PIPING																
Length, ft	381	1376	312	417	377	0	1647	210	354	63	125	315	499	381	188	150
Net elevation increase, ft	-61	-15	-16	-6	-1	0	-114	-45	-164	-13	-13	65	38	-56	-13	-13
Nominal size, in	3.00	3.00	3.00	3.00	3.00	3.00	2.00	1.00	1.00	0.75	0.75	1.00	1.00	1.00	0.75	0.75
Schedule; Number(S), Std, XS, XXS	SDR-26 (160#)	SDR-26 (160#)	SDR-26 (160#)	SDR-26 (160#)	SDR-26 (160#)	SDR-26 (160#)	SDR-26 (160#)	SDR-26 (160#)	SDR-26 (160#)	SDR-17 (250#)	SDR-17 (250#)	SDR-26 (160#)	SDR-26 (160#)	SDR-26 (160#)	SDR-17 (250#)	SDR-17 (250#)
Lining thickness, in	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Inside diameter, in	3.230	3.230	3.230	3.230	3.230	3.230	2.193	1.195	1.195	0.926	0.926	1.195	1.195	1.195	0.926	0.926
Roughness factor, ft	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015
Downstream pipe ID, (for reducer calcs only)	3.230	3.230	3.230	3.230	3.230	2.193	1.195	1.195	0.926	0.926	0.926	1.195	1.195	0.926	0.926	N/A
LIQUID PHASE FLOWRATE AND PHYSICAL PROPERTIES																
Fluid	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water
Taps Connected (0.1 L/second = 1.59 gpm per tap)	28	27	25	22	21	20	15	9	8	2	1	6	5	5	2	1
Flow Rate, lb/hr																
Flow Rate, gpm	45	43	40	35	33	32	24	14	13	3	2	10	8	8	3	2
Flowrate design margin	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
Temperature, F	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75
Density, lb/ft^3	62.2	62.2	62.2	62.2	62.2	62.2	62.2	62.2	62.2	62.2	62.2	62.2	62.2	62.2	62.2	62.2
Viscosity, centipoise	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
Surface tension, dynes/cm	73.0	73.0	73.0	73.0	73.0	73.0	73.0	73.0	73.0	73.0	73.0	73.0	73.0	73.0	73.0	73.0
PRESSURE DROP TABULATION																
Straight piping losses, psi	1.0	3.4	0.7	0.7	0.6	0.0	9.3	9.4	12.7	0.6	0.4	6.6	7.4	5.7	1.8	0.4
Valve & fitting losses, psi	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.6	0.1	0.0	0.0	0.1	0.1	0.0	0.0
Elevation, psi	-26.4	-6.5	-7.1	-2.6	-0.4	0.0	-49.2	-19.4	-71.0	-5.4	-5.4	27.9	16.6	-24.2	-5.4	-5.4
	=======	=======	=======	=======	=======	=======	=======	=======	=======	=======	=======	=======	=======	=======	=======	=======
Total pressure drop, psi	-25.3	-3.1	-6.4	-1.9	0.2	0.0	-39.8	-10.0	-57.8	-4.7	-5.0	34.5	24.1	-18.4	-3.6	-5.0
PRESSURE PROFILE SUMMARY																
Upstream pressure, psig	0.0	25.3	28.4	34.8	36.7	36.5	36.5	76.3	86.3	144.1	148.8	76.3	41.8	17.7	36.2	39.7
Downstream pressure, psig	25.3	28.4	34.8	36.7	36.5	36.5	76.3	86.3	144.1	148.8	153.8	41.8	17.7	36.2	39.7	44.7
LIQUID PHASE FRICTION CALCULATIONS																
Velocity, ft/sec	2.18	2.10	1.95	1.71	1.63	1.56	2.53	5.11	4.55	1.89	0.95	3.41	2.84	2.84	1.89	0.95
Velocity, m/sec	0.66	0.64	0.59	0.52	0.50	0.47	0.77	1.56	1.39	0.58	0.29	1.04	0.87	0.87	0.58	0.29
Reynolds number	57,585	55,528	51,415	45,245	43,189	41,132	45,437	50,017	44,459	14,341	7,171	33,345	27,787	27,787	14,341	7,171
Flow type	Turbulent	Turbulent	Turbulent	Turbulent	Turbulent	Turbulent	Turbulent	Turbulent	Turbulent	Turbulent	Turbulent	Turbulent	Turbulent	Turbulent	Turbulent	Turbulent
Friction factor	0.0222	0.0224	0.0226	0.0231	0.0233	0.0235	0.0239	0.0253	0.0257	0.0314	0.0362	0.0267	0.0274	0.0274	0.0314	0.0362
Kinetic specific energy, psi	0.04	0.03	0.03	0.02	0.02	0.02	0.05	0.19	0.15	0.03	0.01	0.09	0.06	0.06	0.03	0.01
Pressure drop, psi/100 ft	0.263	0.246	0.214	0.169	0.155	0.142	0.562	4.464	3.576	0.978	0.282	2.089	1.490	1.490	0.978	0.282
Density * Velocity^2, lb/ft-sec^2	295	275	236	182	166	151	399	1628	1286	223	56	723	502	502	223	56
VALVES & FITTINGS																
Elbow 90 deg Long radius All types		1		1			3	1	1	1			1			1
Elbow 45 deg Long radius All types		4	1	1	1		1						1	1	1	
Tee As elbow Standard Flg/wld										1						
Tee As elbow Stub-in-type	1						1		2					1		
Tee Run through Flg/wld																
Tee Run through Stub-in-type		1	1	1	1	1	1	1	2	1	1	1		1	1	
Valve Gate Ball Plug Reduced trim B=0.8	1						1				1		1			1
Valve Check Swing																
Entrance Sharp-edged	1															
Exit All types																
PIPE SIZE CHANGES																
Expand or Contract: Square																
Tapered																
Length of taper, inches																
Angle of diameter change, degrees																
Standard reducer/expander						1			1					1		
Orifice: Bore diameter, inches																
Thin, sharp orifice																
Thick orifice																
orifice thickness, in (thick only)																
TOTAL: Resistance coefficients, K or N = fL/D	2.3	1.1	0.2	0.5	0.2	0.4	3.0	0.4	4.3	2.2	0.7	0.0	1.2	2.4	0.4	1.2
Equivalent length, ft	28.2	13.2	2.5	5.7	2.4	4.3	23.1	1.5	16.6	5.4	1.4	0.0	4.3	8.5	0.9	2.5

PHYSICAL PROPERTIES - Saturated Steam and Liquid Water

Client: EWB
System: Churuneles II
Service: Water

Atmospheric Pressure
14.696 psia

Date: 23-May-20
Job No: N/A.N/A
By: A. Doerfling

CONDITIONS

Pressure, psig	0	71.53938093	83.89909194
psia	14.696	86.23538093	98.59509194

SATURATED STEAM			
Temperature, F	212.0	317.4	326.9
Liquid density, lb/ft^3	59.82	56.72	56.39
Vapor density, lb/ft^3	0.0374	0.1959	0.2231
Heat of vaporization, Btu/lb	970.3	897.0	889.5
Compressibility,	0.9827	0.9508	0.9427
Heat capacity, Btu/lb-F	0.4842	0.5696	0.5811
Heat capacity ratio	1.2882	1.2255	1.2178
Viscosity, cP	0.0122	0.0146	0.0148
Thermal conductivity, Btu/hr-ft-F	0.0143	0.0177	0.0181

LIQUID WATER			
Temperature, F	75.0	75.0	75.0
C	23.9	23.9	23.9
Density, lb/ft^3	62.22	62.22	62.22
Viscosity, cP	0.9422	0.9422	0.9422
Vapor pressure, psia	0.4326	0.4326	0.4326
Surface Tension, dynes/cm	73.0	73.0	73.0
Heat capacity, Btu/lb-F	0.9990	0.9990	0.9990
Thermal conductivity, Btu/hr-ft-F	0.3493	0.3493	0.3493

			250 psi			160 psi		
			SDR-17			SDR-26		
Nom (in)	Nom (mm)	OD (mm)	Wall (mm)	ID (mm)	ID (in)	Wall (mm)	ID (mm)	ID (in)
3/4	18.00	26.67	1.57	23.53	0.93			
1	25.00	33.40	1.96	29.48	1.16	1.52	30.36	1.20
1 1/2	38.00	48.26	2.84	42.58	1.68	1.85	44.56	1.75
2	50.00	60.32	3.56	53.20	2.09	2.31	55.70	2.19
2 1/2	62.00	73.02	4.29	64.44	2.54	2.79	67.44	2.66
3	75.00	88.90	5.23	78.44	3.09	3.43	82.04	3.23

https://www.durman.com/descargas/TuberiaSDR/fichas/FTtubosSDR.pdf

Diam. Nom.	Diámetro Promedio Externo	Espesor mínimo de pared (mm) (Tolerancia positiva equivalente al 6% del espesor mínimo)					
	(mm)	SDR 41	SDR 32,5	SDR 26	SDR 21	SDR17	SDR 13,5
12	21,34±0,10	...	...	...	...	...	1,57+0,09
18	26,67±0,10	...	...	...	1,52+0,09	1,57+0,09	1,98+0,12
25	33,40±0,13	...	...	1,52+0,09	1,60+0,10	1,96+0,12	2,46+0,15
31	42,16±0,13	1,18+0,07	1,52+0,09	1,63+0,10	2,01+0,12	2,49+0,15	3,12+0,19
38	48,26±0,15	1,18+0,07	1,52+0,09	1,85+0,11	2,29+0,14	2,84+0,17	3,58+0,21
50	60,32±0,15	1,47+0,09	1,85+0,11	2,31+0,14	2,87+0,17	3,56+0,21	4,47+0,27
62	73,02±0,18	1,78+0,11	2,24+0,13	2,79+0,17	3,48+0,21	4,29+0,26	5,41+0,32
75	88,90±0,20	2,16+0,13	2,74+0,16	3,43+0,21	4,24+0,25	5,23+0,31	6,58+0,39
100	114,30±0,23	2,79+0,17	3,51+0,21	4,39+0,26	5,44+0,33	6,73+0,40	8,46+0,51
150	168,28±0,28	4,11+0,25	5,18+0,31	6,48+0,39	8,03+0,48	9,91+0,59	12,47+0,75
200	219,08±0,38	5,33+0,32	6,73+0,40	8,43+0,51	10,41+0,62	12,90+0,77	...
250	273,05±0,38	6,65+0,40	8,41+0,50	10,49+0,63	12,98+0,78	16,05+0,96	...
300	323,85±0,38	7,90+0,47	9,96+0,60	12,45+0,75	15,39+0,92	19,05+1,14	...
375	388,62±0,41	9,47+0,57	11,96+0,72	14,94+0,90	18,49+1,11	...	...
450	457,20±0,48	11,15+0,67	14,07+0,84	17,58+1,05	21,77+1,31	26,90+1,61	...

ENGINEERS WITHOUT BORDERS-USA
KANSAS CITY PROFESSIONAL CHAPTER

Project:	Los Churuneles II
Author:	J. Gallagher
Date:	May 15, 2020
Page:	1 of 2

DO NOT WRITE IN THIS SPACE

Title: Chlorination Calculation

Purpose:

To determine the number of tablets that should be exposed to the flow.

Design Criteria:

1. Capacity of storage tank is 45 m^3.
2. The existing storage tank in the community that is connected to the distribution network receives and distributes spring water at a rate of 0.51 L/s.
3. Chlorinator shall be capable to treat a water system with a maximum flow rate of 2.79 L/s (44 gpm).
4. Chlorine dosage will be 2.0 mg/L in accordance with Reference 3.
5. Chlorine tablets shall be approximately 2.5" in diameter.

Assumptions:

1. None

References:

1. EWB-USA Guatemala Potable Water Standards
2. Guia de Normas Sanitarias Para el Diseño de Sistemas Rulas de Abastecimiento de Agua Para Consumo Humano
3. Guidelines for Drinking Water Quality
4. The CTI 8 Chlorinator - Manual of Information, Maintenance, and Operation
5. Water Treatment Math - Chlorine Dose Calculation

Summary of Conclusions:

Number of Tablets = 1

DO NOT WRITE IN THIS SPACE

Calculation:

Capacity of Storage Tank: 45 m^3
Capacity of Storage Tank: 11,880 gal
Chlorine Dosage: 2 mg/L

Per Ref. 4:
70% Chlorine per Tablet
Chlorine Weight: 100 grams
Tablet Weight: 0.220 lb

Per Ref. 5:
8.34 lb = one part per million by weight of one million gallons of water

Equation:

$$lb = (MG)\left(\frac{mg}{L}\right)(8.34)$$

$$lb = (11{,}880/1{,}000{,}000)\left(\frac{mg}{L}\right)(8.34)$$

lb = 0.20

Number of Tablets = 1