Team 06

Project Proposal and Feasibility Study

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Executive Summary

The Chañac Puelaso community of Ecuador currently operates a 30-year-old water system. This system supplies the five communities that comprise Chañac Puelaso, approximately 1800 people, with water from a nearby spring. Although the water quality of the spring is very high, the feedline and distribution system were poorly designed based on the current working life of the system. In general, the water needs of the community are greatly unsatisfied as the system is under producing and needs serious renovations. The organization Life Giving Water International and Team 06 are analyzing the current system with recommendations for improvements to the spring catchment and protection, water distribution, and disinfection systems. While base knowledge about Chañac Puelaso and the current functionality of individual system parts is unknown, Team 06 has been able to receive preliminary data from a local government municipality about the requirements for a completely new system. With this data, Team 06 suggests a compromise between the current functioning system and the government proposal. Team 06's recommended design will only be feasible for the community if costs are reduced at least 50% from the governmental proposal, but the overall functionality of the system is improved. Members of the team will travel to Ecuador in January to meet the community and re-evaluate assumptions made in design through cultural appropriation and data collection. This data will confirm Team 06's assumptions and allow the best alternative design to be recommended for the community.

Contents

1. Introduction

1.1. Project Description

Team 06 and Life Giving Water International will be collaborating to analyze and improve the water system of the Chañac Puelaso province in Ecuador. Chañac Puelaso is a rural area made up of 5 communities of indigenous Kichwa people. Currently, their water system is undersized and is in need of repair. Team 06 will analyze the entire water distribution system, including the spring catchment system, feed line, splitting tank, and point-of-use distribution within the 5 communities. Majority of the project consists of hydraulic re-design of the distribution system. Other aspects of the project include analyzing and improving the current feedline and splitting tank and installing flow meters at each residence. A secondary goal includes rethinking the existing disinfection methods. Recommendations for improvements to the existing system will be provided based upon the increased flow rate from the spring due to a recently upgraded spring catchment system. All recommended improvements will be suggested within a community development mindset and with significant consideration to cost. Life Giving Water will provide the translation of Team 06's design as well as further expertise, but Chañac Puelaso will be responsible for the majority of funds required for improvements.

1.2. Calvin Engineering –

Calvin College offers a unique liberal arts approach to its engineering program, which is accredited by the Accreditation Board of Engineering and Technology (ABET). The program offers four concentrations including mechanical, civil and environmental, electrical and computer, and chemical engineering. Students who complete the four-year professional program are required to take classes outside their major to fulfill the liberal arts aspect of the program, as well as complete a senior design capstone course. This capstone course is a two-semester commitment to choosing, proposing, designing, and presenting a completed design project. The intent is to bring together the knowledge acquired throughout each student's previous three years at Calvin College, incorporating both engineering knowledge and a Christian perspective throughout the entire design process. To complete the capstone, students are required to work in teams of 3-5 peers to choose and complete a design project from initial proposition to final design. This is that capstone.

1.3. Senior Design Team –

Team 06, more affectionately known as Agua de la Vida, is comprised of three senior engineering students, all focusing on the environmental track within the civil engineering concentration. The team was formed over a mutual passion for environmentally conscious international and humanitarian engineering work. The team feels called to utilize the education they have been so fortunate to receive to seek global justice, particularly concerning water rights. Each team member brings a unique skill set and background to the selected project that will contribute to the success of the team. The team members are shown in Figure 1.

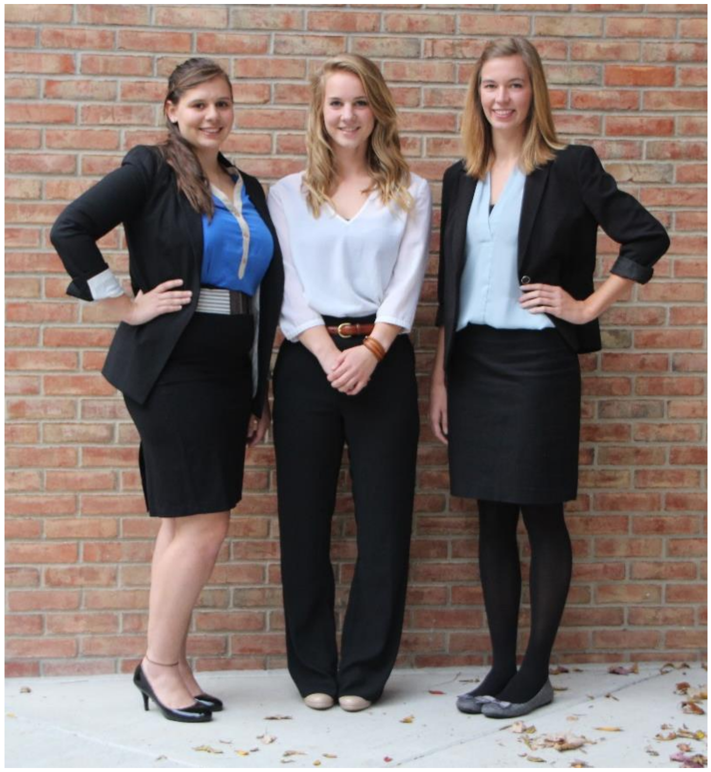


Figure 1. Team 06: Emily Lawson, Ariana Strydhorst, Jennah Maier

1.3.1. *Emily Lawson*

Emily Lawson is a senior level student majoring in civil/environmental engineering and minoring in international development studies. She grew up in Denver, Colorado with a diverse culture of immigrants, environmental activists, and passionate Christians. This upbringing has inspired her to act out her faith in love through holistic evangelism. She has traveled to Ecuador, Peru, Ethiopia, and Kenya to work on water projects varying from physical access to, cultural appropriations of, and the cleaning of water. She is passionate about human rights, justice, water, and the intersection of all three. After graduation, she hopes to pursue a career in which engineering can be used to provide humans access to water through engineering or law.

1.3.2. *Jennah Maier*

Jennah Maier is a senior level student majoring in civil/environmental engineering and minoring in environmental studies. She grew up in Grand Rapids, Michigan and spent the past summer working under the Clean Water Institute of Calvin College. For this job, she did research on the various water disinfection approaches used in developing countries, which was presented in the form of a literature review. She is passionate about the intersection of environmental and humanitarian activism and plans to pursue an environmental engineering career after graduation in May 2017.

1.3.3. *Ariana Strydhorst*

Ariana Strydhorst is a senior level student majoring in civil/environmental engineering and international development studies at Calvin College. Ariana comes to Calvin from Calgary Alberta, Canada. Growing up in the foothills of the Rocky Mountains influenced Ariana to become passionate about both outdoor physical activity and environmental consciousness. She spent the past summer, and still holds an intern position, at an agricultural engineering consulting firm in Grand Rapids, Michigan. In the fall, Ariana will be spending a semester studying sustainability and water resources in Thailand, and then one final semester at Calvin College to wrap up her international development major. Upon graduation, she plans to follow her passion for travel and international development by utilizing her engineering degree overseas.

2. Project Management

2.1. Team Organization –

Upon commencement of the selected project, the team established each member's key roles according to individual experience and strengths.

Jennah Maier is the team's disinfection expert, team manager, EPAnet consultant and will aid in field data collection. She has done extensive research in fields related to water treatment, and will therefore be the team's go-to resource for scholarly research concerning disinfection options. Jennah is also the team mom, and is thus in charge of team management-including scheduling, budgeting, and organization. For the model development and analysis, Jennah has been tasked with producing a working EPAnet hydraulic model once data has been collected.

Emily Lawson is Team 06's lead client and partner communications specialist, Geographic Information Systems (GIS) expert, and website development consultant. She has done extensive work with the team's partner at Life Giving Water, and will therefore facilitate communication with those in the field in Ecuador and the senior design team, when in the United States. Emily will also be the primary creator of the team's GIS model of the hydraulic system.

Ariana Strydhorst is the team's cultural liaison, lead AutoCAD model developer, and will also participate in field data collection. Ariana's second major in international development enables her to discern, with the aid of her team, the cultural appropriateness of the team's actions and design alternatives. As well, Ariana is in charge of developing an AutoCAD model of the system after Jennah and herself have collected the field data necessary.

While general tasks have been assigned to specific team members, it is important to note that many aspects of the project require collaborative action. Significant portions of the project will be worked on by all members of Team 06.

2.2. Schedule –

Team 06 has put significant work into making a working schedule for the year-long design project as it includes a necessary trip to Ecuador. The senior design class is split into two distinct sections, breaking neatly over two semesters. The first semester has consisted primarily of project planning, research, client development, and feasibility studies. The second semester will be heavily weighted with design work, implementation, and revision work. Team 06 will leveraged the natural break, the month of January, between semesters to complete a trip to the project site and collect the necessary data to move forward with second semester of design work. While in Ecuador, team members will collect survey data, perform a preliminary analysis of the existing distribution system, and return with information that will equip the team for the design phase to follow in the spring. During the second semester, each member of team 06 will develop a model of parts of the existing system, each using different software (EPAnet, AutoCAD, and ArcGIS) to best assess the problems with the existing system and model an improved network. Before May 6th 2017, the project end date, Team 06 will have documented design alternatives to mend the existing problems. Each proposed alteration will come with a detailed budget and will be presented to both the Calvin engineering professors and Team 06's project clients.

Currently, Team 06 meets every Monday and Wednesday to keep up with the weekly demands of the project. Each week the team discusses smaller tasks to be completed that week, and the method of approach. Occasional meetings with advisors, other professors, and the team partner have, and will continue to be conducted. For a more detailed view of Team 06's proposed project schedule, refer to the Gantt chart that can be found in the Appendix, Figure A1.

2.3. Budget –

Per the Calvin College engineering department's policies, each senior design team is allotted $500.00 from the department for the completion of the project. This money will be used primarily for team expenses including any materials, testing supplies, and/or miscellaneous items needed prior to or while in Ecuador. In addition to these expenses, the team is expecting to incur a budget of approximately $2000 for two team members to travel to and stay in Ecuador for ten days. Travel costs account for approximately half of this of this, and $50/day/person for room and board while abroad accounts for the other half. Individual team members, fundraisers, and possible scholarships will provide the extra funds required. The general budget for the project is shown, following, in Table 1. The cost breakdown for the data collection is shown in Table 2.

Table 1. Budget Overview

	Team members involved	**Estimated Cost**
Proposal	3	$10
Prototyping	3	$20
Data Collection	2	$2,000
Final Recommendations	3	$30
Total		**$2,060**

Table 2. Data Collection Cost Breakdown

	Estimated Cost	**Total (for 2 people for 10 days)**
In-country daily expenses	$50/person/day	$1,000
Flight Cost	$500/person	$1,000
Total		**$2,000**

In addition to the team budget, Team 06 will be developing a comprehensive budget for the client. Client budget is a significant contributor to the design constraints, and further implementation lies in the cost of the design alternatives. Therefore, Team 06 is required to both keep good and detailed personal finances, as well as be good stewards of the funds within the community that the design will be implemented within. This client budget is discussed in section 5.5, Cost.

2.4. Method of Approach –

Team 06 is wholeheartedly excited to approach the specified problems that exist within the community's water distribution system. Given that the following traits were instrumental in the foundation of Team 06, the whole team is passionate about environmental regulations, water rights and global justice. The project will be approached with excitement as well as with caution. While the team is comprised of students, there is much room for outside experience to speak wisdom into the final design. For this, the team will look to professors, advisors, as well as the project partner, Bruce Rydbeck, who is an engineer. The team is aware of the implications of such a project, tackling both a hydraulic problem as well as a human rights issue. While caution is to be taken to provide a safe, and equitable design, the team is excited to work on a project with real life, community implications.

The format of the project consists of many preliminary, smaller steps that will equate to the final design. First and foremost, Team 06 is committed to empathetic design when working abroad. Primarily, work and research will be done to grasp an understanding of the culture. Following this, the team will develop a preliminary analysis of the existing system and develop possible design alternatives. After this analysis and project feasibility study, two members of the team will travel to the site in Ecuador to collect all the necessary data, learn about the culture, the people, their lifestyle, as well as the existing system. With this data, the team will reassemble and develop working models that are both culturally appropriate and hydraulically sound.

Team 06 is committed to Christian witness throughout all actions taken while completing the design. This witness affects all areas of the chosen project, especially all communications with other team members, professors, industry professionals, and people within the community. Focusing on a Christ-centered approach will aid in maintaining this witness.

3. Project Background and Research

3.1. Location and Culture

Chañac Puelaso is located in Chimborazo, Ecuador, just East of Riobamba and approximately 90 kilometers West of Volcán Altar. Five separate communities use the Chañac Puelaso water system, which was built just over 30 years ago. The region covers the following communities: Cháñag San Miguel, San Francisco Palace, San Pedro de Iguazo, Santa Ana Saguer and Puelazo. These communities span an area between the White River and Lake San Martin, with elevations between 3800 and 2700 meters above sea level. The approximate location is given below in Figure 2, as seen from a satellite. Topographic maps of the area are also included in the Appendix in Figures A2-A4 and a topographic AutoCAD drawing of the area is included in the Appendix as Figure A5.

Figure 1. Approximate Location of Chañac Puelaso

(image from https://www.google.com/maps/@-1.6743318,-78.5530222,30466m/data=!3m1!1e3)

This community is almost exclusively indigenous Kichwa people, speaking Kichwa as a primary language. Due to the increase in education efforts towards the indigenous groups, some of the population speaks Spanish in addition to Kichwa. Much of the population is farmers, working along the Andes slopes. They produce crops such as quinoa, potatoes, barley, cattle, sheep, and pigs. These crops comprise most of their diet, with the occasional pork, chicken, or ceremonial guinea pig. Given the Chañac Puelaso's elevation and proximity to the equator, the climate remains cold and dry with a rainy season from mid-September to mid-January. The harsh conditions were both a protector of the Kichwa people during colonial times and a major obstacle, leaving much of the region very poor.

The five communities have a combined population of 1,855 people as of 2015, with a population growth of approximately 1% per year. 371 heads of family are recorded, with an estimated 157 'floating' population (students and teachers who do not reside in the community permanently). The average annual income is 1,225 USD/person. The average household includes five inhabitants, but water flow will be modeled at 75 L/day/person, due to a lack of sanitary systems within the communities. The number of houses connected to the system is undetermined because of a lack in system organization.

3.2. Partnership

Life Giving Water International has been working in Ecuador with the Kichwa people for over 25 years. This organization practices holistic evangelism with a strengths-based community development model. Communities invite Life Giving Water to enter as the engineering expertise for water distribution systems, spring protection, and disinfection systems. In these situations, the community agrees to provide labor and any necessary materials to construct the water system. Head engineering consultants include Bruce Rydbeck and Martin Henrich.

Life Giving Water also has an existing relationship with the local, Ecuadorian NGO Codeinse. Efrain Morocho is the Ecuadorian project manager and construction overseer. Like Life Giving Water, Codeinse provides technical assistance to indigenous communities throughout the Ecuadorian Andes.

Because of the partnership between Life Giving Water and Codeinse, it is likely that Team 06 will be working with Codeinse as well.

3.3. Client

Although Bruce Rydbeck is the main contact for this project, the client is the Chañac Puelaso province. The priest of the local parish witnessed how a neighboring community's water system implementation (clients of Life Giving Water approximately 10 years previous) functioned seamlessly. He initiated contact with Codeinse, who subsequently contacted Life Giving Water. Since Chañac Puelaso already has a functioning water system, Life Giving Water has only agreed to financially support the improvements and alterations of the spring catchment and protection area. Alterations to the splitting tank, distribution system, and/or chlorination system will be mainly dependent on what the communities are willing to contribute financially to the project, given recommendations provided by Team 06.

4. Existing System and Project Purpose

The purpose of Team 06's project is to assist the communities of Chañac Puelaso with the improvement of their drinking water system. The team's focus is designing an effective distribution system that will transport clean water from the natural spring at the top of the mountain to each of the homes in the province. This purpose can be broken down into several facets including spring protection, a feedline, a splitting tank, the distribution system, flow meters, and possible disinfection. There is an existing system in place for each of these facets that needs to be considered in the design. The existing system is approximately 30 years old and under capacity.

The water of Chañac Puelaso, assuming no additional contamination after surfacing (such as animal manure), is of acceptable quality for drinking water. The regional municipality of Carbunguayco, a subset of Riobamba, provided water analysis of the physical, chemical, and bacteriological profile of the water. The water is slightly aggressive, so no metal pipes or fittings should be advised. However, the community could use drink the water straight from the spring.

4.1. Spring Catchment and Protection

Life Giving Water has a commitment to the community of Chañac Puelaso, which includes and is limited to, partnering with them in the renovation of the community's spring catchment and protection. For this reason, Bruce Rydbeck and the other members of Life Giving Water will take the lead in the engineering of a spring catchment and protection systems. Team 06 will provide follow-up engineering and additional observation of the Ecuadorian methods used for spring catchment.

The current spring catchment is aged and undersized. At most, 80 percent of the spring's water is captured by the current system. It is estimated that the spring can produce 6.51 L/s. This flow rate will be verified after spring protection is completed by Life Giving Water. The purpose of the spring catchment design is to increase the capacity and functionality of the system so that water is more efficiently captured. At least 60% of the current catchment system will need to be replaced.

Chañac Puelaso's spring is not currently being protected from contamination in any way. The spring's water is vulnerable to quality degradation primarily by manure from animals that wander into the spring area. Life Giving Water is recommending a protection method with the purpose of keeping spring water safe from contamination. This protection will include gating around the spring. Most pollution sources are not of concern at the spring's catchment, due to the extreme elevation in which the spring is sourced. However, throughout the distribution system, exposed pipes are much more vulnerable to pollution. For these reasons, disinfection will also be considered as an improvement in conjunction with the spring protection.

4.2. Feedline and Splitting Tank

The existing feedline is the pipe that carries water from the spring to a splitting tank. Stretching 2,812 meters, the feedline consists of mostly 110-millimeter diameter PVC pipe with a split three-quarters of the way down the feedline into two 90-millimeter diameter pipes. One obvious problem with the feedline is that this split is not anchored and consistently disconnects. An additional concern is the lines exposed sections, which are neither protected nor secured to reduce line contamination. Furthermore, the current feedline has air relief valves, but at least one of them is not functional. The feedline will be assessed and improved to ensure it is functional, of adequate capacity, and properly anchored.

The existing splitting tank's intake consists of the two feedline pipes that the tank serves to split the flow to service 5 separate communities. The existing tank is of rudimentary technology and needs to be assessed for capacity and effectiveness of splitting water. Dimensions and cross sections of the splitting tank is shown Appendix, Figure A7.

4.3. Distribution System and Piping

The distribution system is defined as the portion of the water system downstream of the splitting tank. There is currently a distribution system in place, but this system is inadequate. The current system consists of 2-inch diameter pipes which split into ½-inch diameter, low-grade polyethylene pipes for home connections. The fittings between these pipes are inadequate and these home connections are in many cases, hanging in nearby trees or posts, or otherwise improperly installed. The purpose of the distribution system design is determining a piping system that suits capacity and functionality requirements. Although it is approximated that 371 homes exist, it is unlikely that all of these homes are properly connected into the distribution system.

The extreme elevation range of Chañac Puelaso provides a special difficulty within the distribution system. To account for this challenge, many pressure zones will be used throughout the five communities. According to the government survey, approximately 34 pressure breaking tanks should be used throughout the distribution system to create designated pressure zones. This will ensure that pressures are maintained between 10 and 80 psi at each connection. At this time, Team 06 does not have any planimetric maps of the homes in the area. Determining the location of each home to provide an accurate EPAnet model, is discussed in section 7, Future Work.

4.4. Flow Meters

Chañac Puelaso's water system is intended to be billed according to the demand at each home connection. This would be a fee of approximately 0.20 USD/cubic meter, according to local municipality. However, in the current system only a few water meters are still operational, and where they are not water must be billed at a flat rate. The team believes it is important for the community's ownership and responsibility toward the system that each home be billed according to usage. For this reason, included in the scope of the project is a recommendation for flow meter replacement. According to governmental regulations, flow meters must be included on all proposed connections. This simple addition will initially raise the cost of the system, but will ensure proper water usage in the community for years to follow.

4.5. Disinfection

The existing system does not utilize any type of water disinfection. Although disinfection is a long-term goal for the community and is required by the Ecuadorian government, it is not likely that the community will chose to implement disinfection in the near future. Despite this fact, the purpose of Team 06's project is for drinking water to be both effectively delivered and safe for consumption. For this reason, an evaluation of possible disinfection methods and recommendation of implementation is included in the project scope. This will allow the people of Chañac Puelaso to make their own decision about when and if they will implement disinfection methods.

The current system is structured around chlorine disinfection through the use of Calcium Hypochlorite. The spring water is of high enough quality that chlorine would only need to be available to avoid contamination through pollutants in the distribution system. A residual of 0.4% is the targeted goal. 70% concentrated granular chlorine has been provided by the municipality, given the current chlorination system. For a constant, daily application, the following relationship would be applied:

Quantity = flow by dosage / chlorine concentration
Flow of treatment = 7.16 l/s
Dosage = 1.5 ppm
Concentration of chlorine = 70%
Quantity = 7.16 (l/s) * 86400 (s/day) / * 1.5 (mg Cl/kg water) / 1000 mg/gr / 0.7
Amount = 927.94 g of Calcium Hypochlorite/day
Quantity = 27.84 kg/month calcium hypochlorite
Half of this amount, i.e. 13.92 kg/month would be used for Chañac Puelaso.

5. Design Constraints

For every aspect of the design, there are certain constraints and conditions which must be taken into account.

5.1. Topography Survey Results

Members of team 06 will do field data collection while visiting Chañac Puelaso in January. Key in this data collection will be GPS measurements of the existing system, the spring, and sources of demand. The team has been given a digital topographic map of the area, which will be used as a base map for the surveyed GPS points and can be found in the Appendix, Figure A6. This data will constrain the pressure zones of the distribution system.

5.2. Regulations

Government regulations related to drinking water systems need to be considered in the system design. It is important that the final recommendation adhere to all applicable regulations and laws of the Ecuadorian government. Team 06 will check in with Life Giving Water before recommending a final version of the design to ensure these regulations are all satisfactorily achieved.

5.3. Community Preference

Because Team 06 consists only of North Americans, it will be important to consider the cultural barriers that exist. A system that seems optimal in the eyes of the Team may not be what is preferred or optimal for the people that the project is intended to serve. One of the constraints on the project is therefore community preference. If the people of Chañac Puelaso choose to implement Team 06's proposed design, it will be a significant investment of physical resources, money, time and energy. The community may not choose to implement the project if it does not align with their values and preferences. A more precise understanding of what these preferences are will be determined during the Team's visit to Chañac Puelaso, as described in section 7.1.

5.4. Design Norms

Although the Chañac Puelaso community's values and preferences are to be held with the highest regard, there will be many technical decisions that will need to be made by the Team itself. Team 06 will uphold the below design norms to guide them in decision making.

5.4.1. Caring

Team 06 recognizes the image of God that each resident of the Chañac Puelaso community holds. All design recommendations are considered to improve a vital aspect of these communities' lives, showing how engineers in other regions can care deeply for the hurt and human rights of others.

5.4.2. Justice

The Kichwa people were a sub-servient class up until the mid-1900s. It was only then that they were granted citizenship and given minimal land ownership. Due to the hundreds of years of oppression the Kichwa faced, many of this people group live in extreme poverty throughout the Andes Mountains. Efforts to increase education, standard of living, and life expectancy have been a focus of the non-governmental organizations (NGOs) throughout the Chimborazo Region. Life Giving Water International is one such organization that uses access to clean water as a method of reconciliation for this marginalized people group. Justice flows like a mighty river, and Team 06 hopes to help direct that river to the homes of the hurting.

5.4.3. Stewardship

Although financial assistance will be provided for the alteration of the spring catchment system by Life Giving Water International, all other responses to recommendations will be funded by the community. This knowledge requires Team 06 to be very conscious of any additional costs and all community charges that will be placed with the addition of every improvement in order to be good stewards of the communities' financial resources.

5.4.4. Open Communication

Since the community is responsible for implementing the final design, the Team must be in constant communication with Bruce and the community to determine what is desired and what is feasible. This open communication accommodates the ideal that as image bearers, the community members are validated in their want to know and learn about their own water system.

5.4.5. Trust

Communities contact Bruce Rydbeck because of the large trust they hold in his organization to do things quickly, correctly, and with their best interest in mind. Team 06 guarantees to uphold the same qualities to continue to strengthen the trust between Life Giving Water International and the indigenous people of Ecuador.

5.4.6. Delightful Harmony

The water system designed by Team 06 should uphold delightful harmony by integrating seamlessly into the environmental context.

5.4.7. Cultural Appropriateness

Because the project is intended to benefit Ecuadorians and is being designed by North Americans, it will be very important to ensure the design is appropriate to be applied within the context of Ecuadorian culture. Team 06 has incorporated into their design constraints the need to value cultural appropriateness by requiring that the recommended design fit with the cultural preferences of the people of Chañac Puelaso.

5.5. Cost

Finally, cost is a significant design constraint. The economic efficiency of the project design is critical because if the community cannot afford the project, then it will not be implemented. As a primary goal, recommendations will be set at 50% of the original government proposal for a new system. That system, as analyzed by the Riobamba outlying district municipality, is shown in the budget table located in the appendix.

Specific oversights can be targeted to reduce the cost required to Chañac Puelaso. The most likely candidate for reductions in budget is the price allocated to an entirely new distribution system. The governmental surveyed assumed that the entire system would be replaced, essentially constructing a new water system from scratch. However, by utilizing the sporadic distribution system that is already in place, and building on that, Team 06 can reduce the cost by approximately $200,000. Most of these savings will be based on the community's agreement to provide excavation and installation, under the supervision of Life Giving Water International.

Additionally, the government proposal suggested the addition of two reserve tanks. The combination of these two tanks adds an additional cost of approximately $10,000. By utilizing the existing splitting tank as a reservoir and adding pressure breaking tanks to the system instead, the Team can avoid the addition of each of these tanks completely. A summary of possible areas of saving, once the system is properly evaluated, are shown in Table 3.

Table 3. Possible Savings based on Government Proposal

Description	Projected Cost (USD)	Potential Savings (USD)	Method of Saving
New Distribution Network	210,457.26	190,000	Community work and using existing system
Reservoirs	10,872.59	10,000	Omitting new tanks and renovating old splitting tank instead
Driving/Feedline	117,327.66	115,000	Community work and updating existing system

6. Design Alternatives

Alternatives for system design include no change to the government recommendation or retrofitting the current system with improvements. These alternatives are to be evaluated in depth with Team

06's design work second semester and the decision between the two will be based on observation of the quality of the current system and the cost differential between alternatives.

6.1. Government Recommendation

The Ecuadorian government started a design for Chañac Puelaso's water system in 2008, which was completed in 2015. However, it is not likely that this design will be implemented because it does not account for salvaging any of the existing system and is therefore beyond what the communities can afford. The first design alternative that Team 06 will consider is keeping the government's proposal if the team's field study of the existing system finds it to be unusable.

6.2. Retrofit Existing System

The second design alternative that Team 06 will consider is improving the current system so that it will work properly while using a minimal quantity of new materials. This design alternative involves a detailed assessment of the condition of pipes in the current system to determine which pieces of the system are salvageable. This detailed assessment will take place in future work, but the team's partner is highly hopeful that most of the system is salvageable. Given that the community is willing to provide the labor for the alterations, retrofitting the system seems to be the most feasible and culturally appropriate design choice.

7. Future Work

7.1. Trip to Ecuador

In January of 2017, team members Jennah Maier and Ariana Strydhorst will travel to Chañac Puelaso, Ecuador for ten days. While there, they will observe the current spring catchment, distribution network and splitting tank. Jennah and Ariana will live in the communities, get to know them, and assess the needs that the design will provide for. Their main data collection task will be to take a topographic survey of the existing system and communities. Also, they will collect good documentation of the existing system and recommendations from the community and professionals. Finally, they will visit nearby communities that will serve as case studies for what does and doesn't work in a context similar to that of the project. The trip will be the starting point of the design work to be completed in the spring semester. Additionally, Jennah and Ariana will research the current disinfection methods and conduct a local survey concerning the implementation of existing and proposed approaches to disinfection.

7.2. Spring Semester

During the spring semester, the team will begin design work as the data necessary to do so will have been collected. Models of the proposed system will be constructed and evaluated in EPAnet. Design recommendations will be displayed on GIS maps and modeled in AutoCAD drawings. Upon completion of a working preliminary design, the team will produce a comprehensive cost analysis for the communities.

8. Feasibility and Conclusion

8.1. Project Feasibility

Currently there are many holes in the data that Team 06 has access too. Assuming these holes will be filled during the January trip to visit the community, an appropriate design is possible. However, there will likely be many more obstacles to overcome that cannot be anticipated and must be addressed as they come up. The province of Chañac Puelaso has 5 communities in it, so it is also possible that designing for all 5 communities may be beyond the scope of Team 06's project. If this is the case, Bruce Rydbeck has indicated that he will be content with a design for however many communities are achievable in the Team's time frame. Therefore, if all goes according to plan the project proposed by Team 06 is feasible for design in the coming semester.

8.2. Implementation Feasibility

The feasibility of implementation of this design depends on if the people of Chañac Puelaso can afford the design that Team 06 recommends. To maximize the possibility of implementation, the Team's design will consider cost to the communities as a design constraint. If implementation is not feasible at the conclusion of the Team's design, the hope is that the communities will be able to work up to being able to afford implementation.

9. Acknowledgements

Team photos were taken by Kristy Bulten McWilliams of DK Photography.

10. References

All data about the community was found using the governmental proposal for a new water system. The documents used are listed as followed, and all unknown information was sourced from the translations of these documents. They are listed under the same names in which the Ecuadorian government has filed them.

10.1. AutoCAD/Various drawn documents:

- INDICE.dwg
- OB.ANEXAS.dwg
- PLAN-DEF-1-chaniag.dwg
- PLAN-DEF-1-chaniag.dwl
- PLAN-DEF-1-chaniag.dwl2
- Perfil.dwg
- Perfil.dwl
- Perfil.dwl2
- TF-10-15.dwg

10.2. Excel Tables:

- Analisis Pu Agua Potable Regional Chanag
- Calculo Hidraulico-var
- Cronograma valorado
- Cuadrilla
- Equipo
- Formula
- Mano de Obra
- Presupesto agua potable regional chanag
- RED1

10.3. Manuals or Word Documents:

- Manual de operacion y mantentimiento chanag
- Plan tarifario
- Especificaciones tecnicas
- Memoria tecnica

Appendix

Table of Contents:

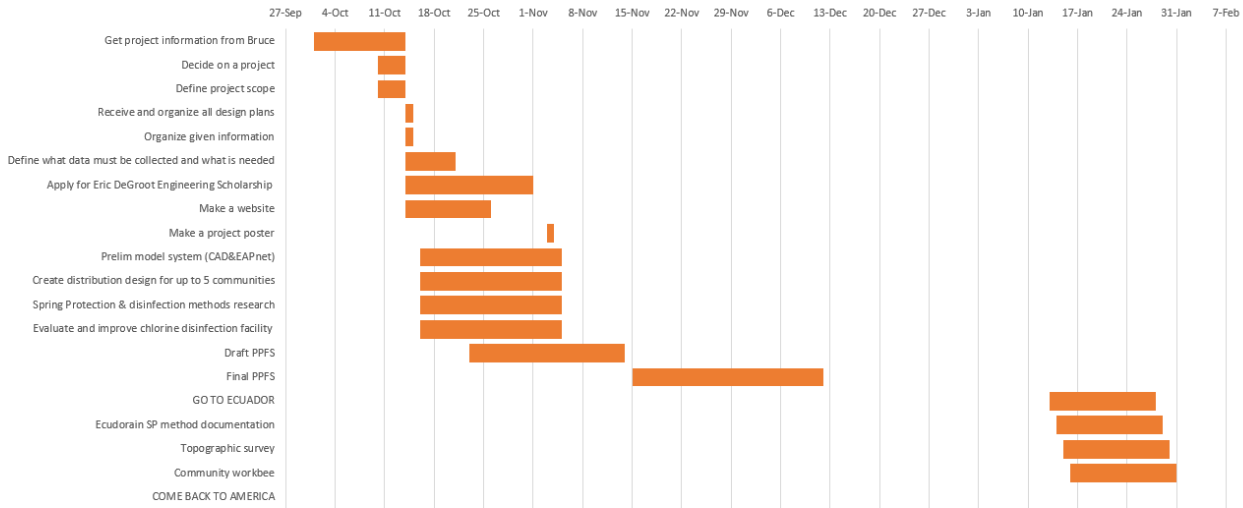


Figure A1. Team 06 Schedule

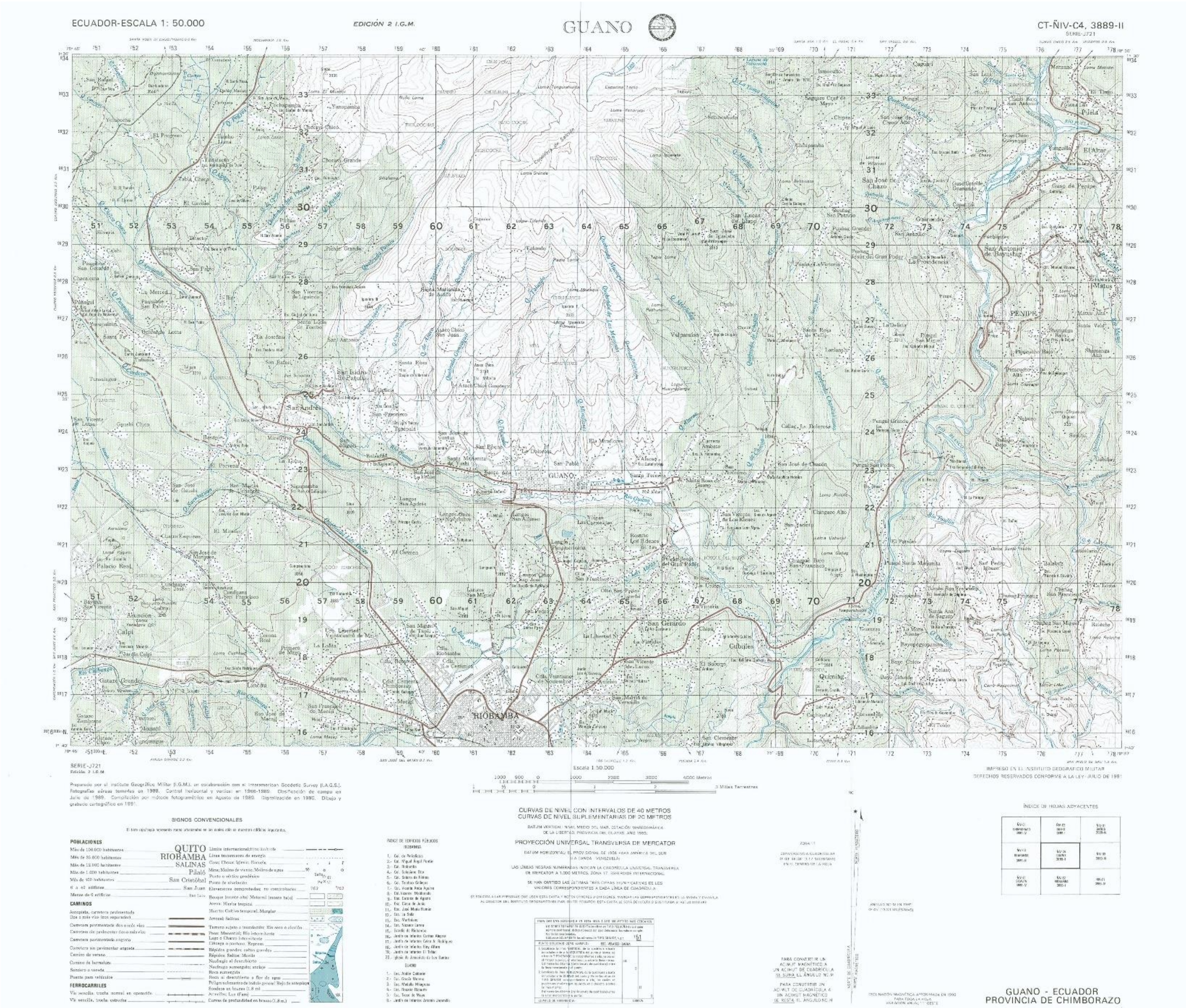


Figure A2. Topographic Map that covers the North-West Corner of the Province

(image from http://www.lib.utexas.edu/maps/topo/ecuador/txu-pclmaps-oclc-869565072-guano-3889-ii.jpg)

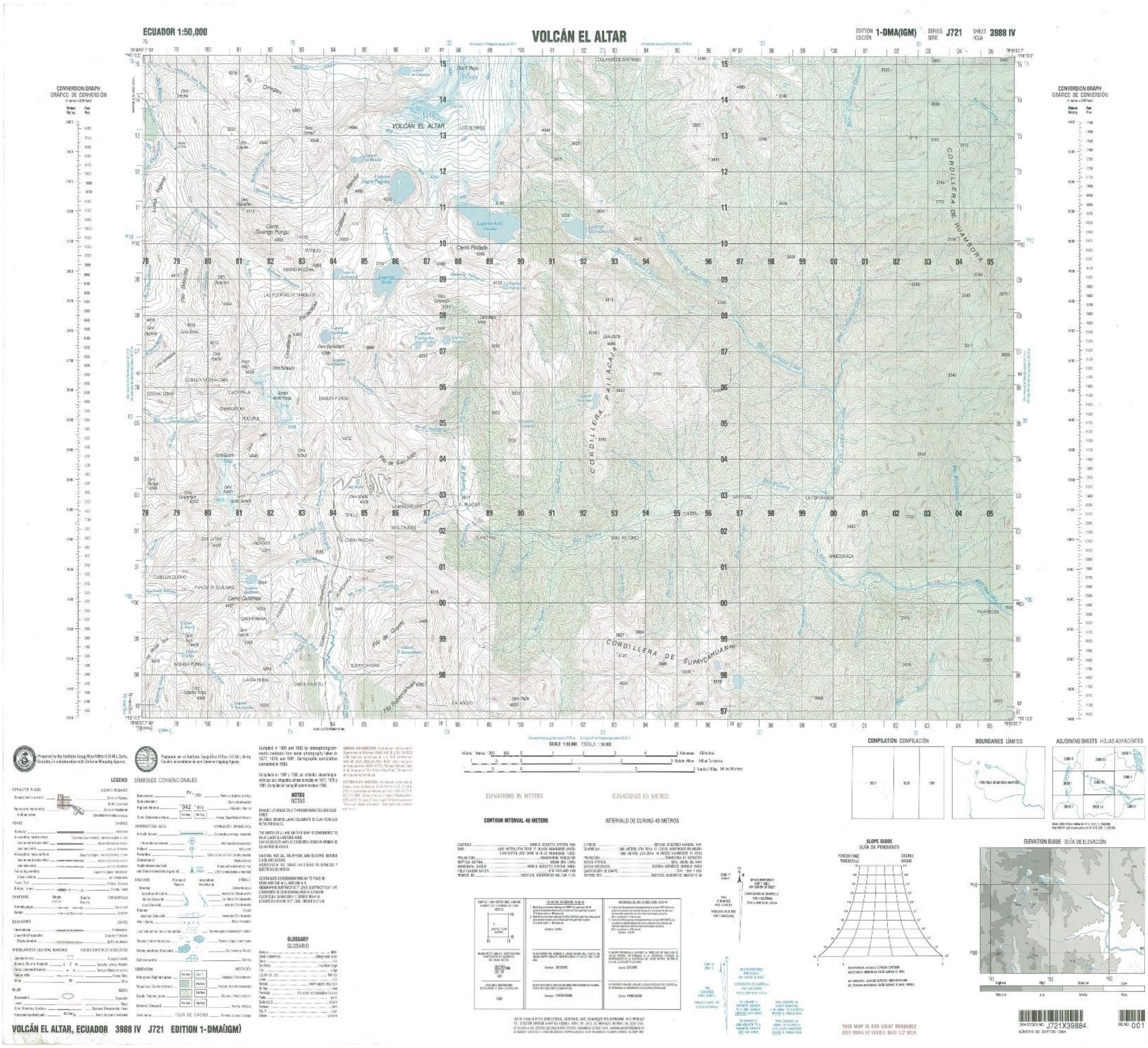


Figure A3. Topographic Map that covers the North-East Corner of the Province

(image from http://www.lib.utexas.edu/maps/topo/ecuador/txu-pclmaps-oclc-869565072-volcan-el-altar-3988-iv.jpg)

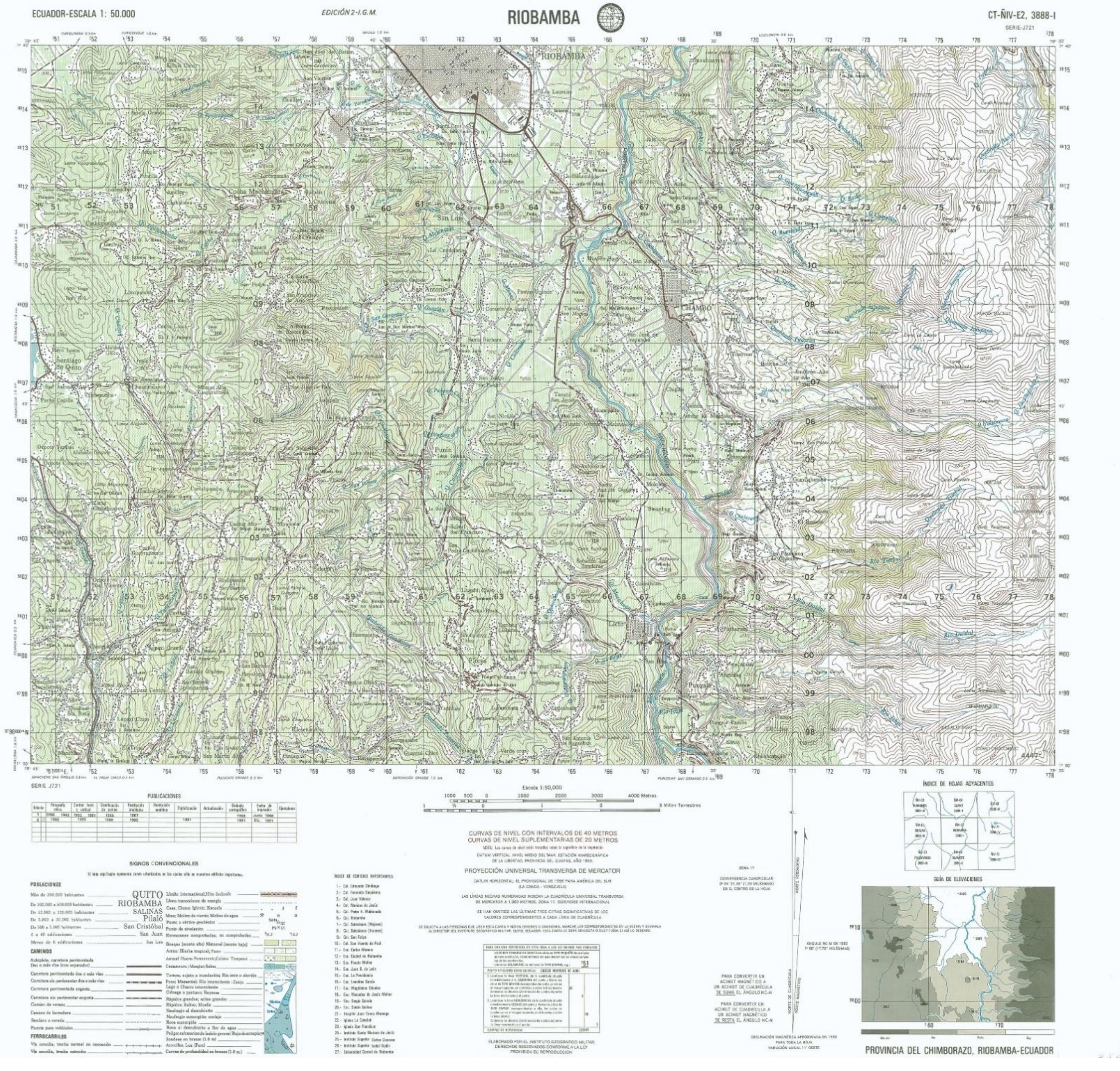


Figure A4. Topographic Map that covers the South-West Corner of the Province

(image from http://www.lib.utexas.edu/maps/topo/ecuador/txu-pclmaps-oclc-869565072-riobamba-3888-i.jpg)

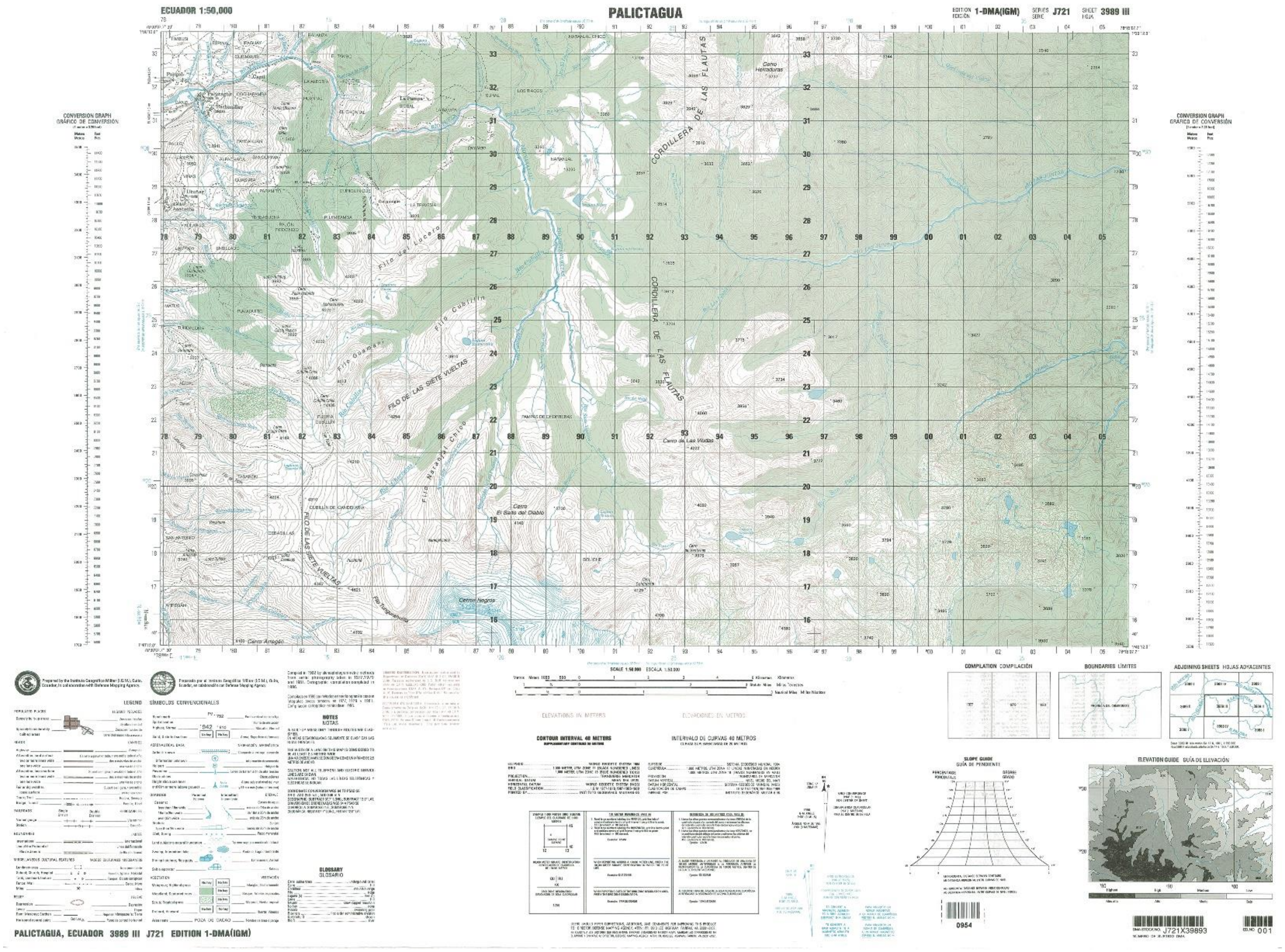


Figure A5. Topographic Map that covers the South-East Corner of the Province

(image from http://www.lib.utexas.edu/maps/topo/ecuador/txu-pclmaps-oclc-869565072-palictagua-3989-iii.jpg)

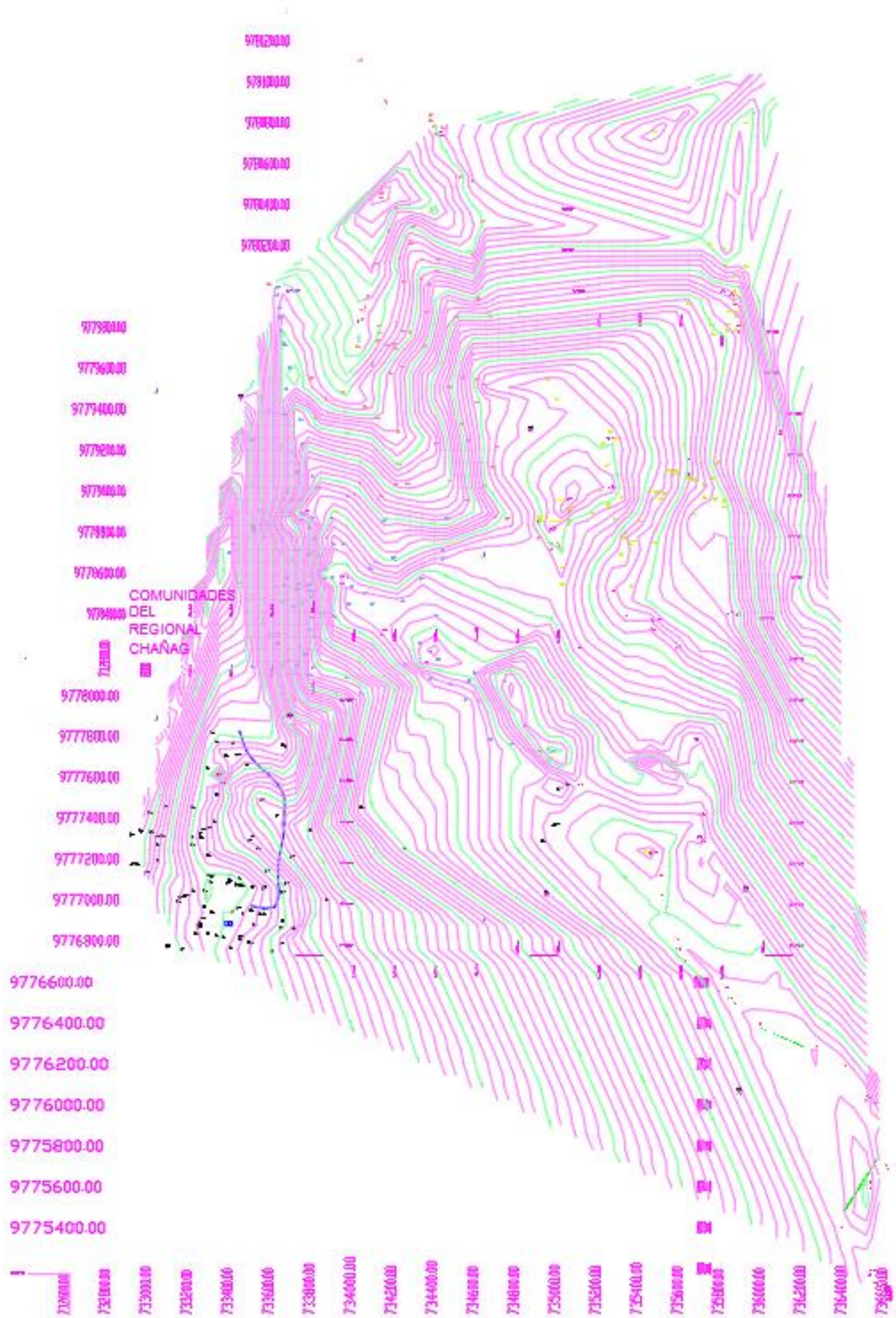


Figure A6. AutoCAD Topographic Map of Chañac Puelaso Region

Table A1. 2015 Government Design Cost Breakdown

Name	***Heading / Description***	***Unit***	***Quantity***	***Unit price ($)***	***Total price ($)***
A	**DRIVING**				
A.1	LAYOUT AND LEVELING	KM	8.13	208.06	1,691.53
A.2	EXCAVATION MANUAL	M3	4,876.20	6.01	29,305.96
A.3	Backfill MANUAL	M3	4,876.20	2.81	13,702.12
A.4	SUPPLY PIPE PVC-P EC D = 50 mm 1.00 MPa	M	2,524.00	3.32	8,379.68
A.5	SUPPLY PIPE PVC-P EC D = 63 mm 0.80 MPa	M	2,640.00	3.92	10,348.80
A.6	SUPPLY PIPE PVC-P EC D = 110 mm 0.80 MPa	M	2,112.00	10.97	23,168.64
A.7	SUPPLY PIPE PVC-P EC D = 160 mm 0.80 MPa	M	851.00	23.38	19,896.38
A.8	INST. AND TEST TUB. PVC-P EC D = 50 mm 1.00 MPa	M	2,524.00	0.95	2,397.80
A.9	INST. AND TEST TUB. PVC-P EC D = 63 mm 0.80 MPa	M	2,640.00	0.71	1,874.40
A.10	INST. AND TEST TUB. PVC-P EC D = 110 mm 0.80 MPa	M	2,112.00	1.01	2,133.12
A.11	INST. AND TEST TUB. PVC-P EC D = 160 mm 0.80 MPa	M	851.00	0.61	519.11
B	**DRAIN VALVE**				
B.1	EXCAVATION MANUAL	M3	0.80	6.01	4.81
B.2	STRAIGHT AND FORMWORK Formwork	M2	3.00	14.24	42.72
B.3	SIMPLE CONCRETE fc = 210 kg / cm2	M3	6.20	233.64	1,448.57
B.4	ACCESSORIES DRAINAGE VALVE D = 160 mm	GLB	2.00	343.10	686.20
B.5	ACCESSORIES DRAINAGE VALVE D = 110 mm	GLB	1.00	325.82	325.82
C	**AIR VALVE**				
C.1	EXCAVATION MANUAL	M3	0.64	6.01	3.85
C.2	STRAIGHT AND FORMWORK Formwork	M2	2.40	14.24	34.18
C.3	SIMPLE CONCRETE fc = 210 kg / cm2	M3	4.96	233.64	1,158.85
C.4	ACCESSORIES AIR VALVE D = 110 mm	GLB	1.00	100.76	100.76
C.5	ACCESSORIES AIR VALVE D = 160 mm	GLB	1.00	104.36	104.36
D	**DISTRIBUTION NETWORK**				
D.1	LAYOUT AND LEVELING	KM	8.44	208.06	1,756.03
D.2	EXCAVATION MANUAL	M3	6,073.20	6.01	36,499.93
D.3	Backfill MANUAL	M3	5,103.18	2.81	14,339.94
D.4	SUPPLY PIPE PVC-P EC D = 20 mm 2.00 MPa	M	6,870.00	1.07	7,350.90
D.5	SUPPLY PIPE PVC-P EC D = 25 mm 1.60 MPa	M	10,053.00	1.20	12,063.60

D.6	SUPPLY PIPE PVC-P EC D = 32 mm 1.25 MPa	M	3,721.00	1.87	6,958.27
D.7	SUPPLY PIPE PVC-P EC D = 40 mm 1.00 MPa	M	4,664.00	2.27	10,587.28
D.8	SUPPLY PIPE PVC-P EC D = 50 mm 1.00 MPa	M	5,191.00	3.32	17,234.12
D.9	SUPPLY PIPE PVC-P EC D = 63 mm 0.80 MPa	M	3,823.00	3.92	14,986.16
D.10	INST. PVC PIPE AND TESTING EC D = 20 mm 2.00 MPa	M	6,870.00	0.37	2,541.90
D.11	INST. PVC PIPE AND TESTING EC D = 25 mm 1.60 MPa	M	10,053.00	0.48	4,825.44
D.12	INST. PVC PIPE AND TESTING EC D = 32 mm 1.25 MPa	M	3,721.00	0.58	2,158.18
D.13	INST. PVC PIPE AND TESTING EC D = 40 mm 1.00 MPa	M	4,664.00	0.76	3,544.64
D.14	INST. AND TEST TUB. PVC-P EC D = 50 mm 1.00 MPa	M	5,191.00	0.95	4,931.45
D.15	INST. AND TEST TUB. PVC-P EC D = 63 mm 0.80 MPa	M	3,823.00	0.71	2,714.33
D.16	ACCESSORIES AND VALVES IN NETWORK 1	GLB	1.00	393.62	393.62
D.17	ACCESSORIES AND VALVES IN RED 2	GLB	1.00	393.61	393.61
D.18	INSTALLATION DOMICILIARIA	GLB	486.00	127.51	61,969.86
D.19	SUPPLY AND INSTALLATION HOSE FLEX 1/2 "BD	M	3,720.00	1.40	5,208.00
E	**TANK pressure-relief**				
E.1	CLEANING AND CLEARING	M2	41.48	1.40	58.07
E.2	LAYOUT AND LEVELING AREAS	M2	39.78	4.28	170.26
E.3	EXCAVATION MANUAL	M3	21.96	6.01	131.98
E.4	STRAIGHT AND FORMWORK Formwork	M2	172.38	14.24	2,454.69
E.5	CONCRETE SIMPLE f`c = 210 kg / cm2	M3	28.90	233.64	6,752.20
E.6	REINFORCING STEEL fy = 4200 kg / cm2	KG	184.08	2.20	404.98
E.7	INTERIOR PLASTER + IMPERMEABILIZACION	M2	129.54	11.45	1,483.23
E.8	EXTERIOR PLASTER	M2	81.26	9.19	746.78
E.9	RUBBER PAINT	M2	81.26	3.40	276.28
E.10	STONED BASE e = 20 CM	M2	41.48	10.03	416.04
E.11	ACCESSORIES pressure-relief (E40-S32)	GLB	3.00	209.59	628.77
E.12	ACCESSORIES pressure-relief (E32-S32)	GLB	2.00	200.29	400.58
E.13	ACCESSORIES pressure-relief (E32-S25)	GLB	1.00	199.91	199.91
E.14	ACCESSORIES pressure-relief (E25 -S25)	GLB	1.00	194.27	194.27
E.15	ACCESSORIES pressure-relief (E25 -S20)	GLB	1.00	194.21	194.21
E.16	ACCESSORIES ROMPEPERSION (E20-S20)	GLB	2.00	188.58	377.16
E.17	ACCESSORIES pressure-relief (E32-S20)	GLB	2.00	199.85	399.70

E.18	ACCESSORIES pressure-relief (E50-S50)	GLB	1.00	226.98	226.98
E.19	ACCESSORIES pressure-relief (E50-S25)	GLB	1.00	225.02	225.02
E.20	ACCESSORIES pressure-relief (E50-S40)	GLB	4.00	227.51	910.04
E.21	ACCESSORIES pressure-relief (E40-S20)	GLB	1.00	209.15	209.15
E.22	ACCESSORIES pressure-relief (E40-S25)	GLB	1.00	209.21	209.21
E.23	ACCESSORIES pressure-relief (E63-S63)	GLB	7.00	255.58	1,789.06
E.24	ACCESSORIES pressure-relief (E63-S50)	GLB	3.00	254.66	763.98
E.25	ACCESSORIES pressure-relief (E63-S40)	GLB	1.00	255.19	255.19
E.26	ACCESSORIES pressure-relief (E63-S25)	GLB	2.00	252.71	505.42
E.27	ACCESSORIES pressure-relief (E50-S20)	GLB	1.00	224.96	224.96
F	**MESH WALLS IN RESERVE L = 8.00x10.00m**				
F.1	CLEANING AND CLEARING	M2	89.25	1.40	124.95
F.2	LAYOUT AND LEVELING	M2	80.00	4.28	342.40
F.3	EXCAVATION MANUAL	M3	20.00	6.01	120.20
F.4	CONCRETE SIMPLE f`c = 180 kg / cm2	M3	0.65	155.30	100.95
F.5	REINFORCING STEEL fy = 4200 kg / cm2	KG	24.04	2.20	52.89
F.6	STRAIGHT AND FORMWORK Formwork	M2	69.00	14.24	982.56
F.7	HORMIGON cyclopean f`c = 180 kg / cm2	M3	5.87	111.08	652.04
F.8	EXTERIOR PLASTER	M2	34.50	9.19	317.06
F.9	RUBBER PAINT	M2	69.00	3.40	234.60
F.10	50/10 2.00x1.00 screen door and HG D = 1 1/2 "	OR	1.00	179.03	179.03
F.11	MESH WALLS 1.50 M	M	34.50	13.09	451.61
F.12	SIDING POSTS HG 2 "	M	16.20	41.56	673.27
G	**RESERVE TANK 10 M3**				
	SLAB BACKGROUND				
G.1	LAYOUT AND LEVELING	M2	31.72	4.28	135.76
G.2	EXCAVATION MANUAL	M3	6.28	6.01	37.74
G.3	STONED BASE	M2	48.40	10.03	485.45
G.4	HS REPLANTILLO f`c = 180 kg / cm2 e = 3 CM	M3	0.92	155.30	142.88
G.5	CONCRETE SIMPLE f`c = 210 kg / cm2	M3	4.14	233.64	967.27
G.6	STRUCTURAL STEEL SLAB BACKGROUND	KG	17.78	2.20	39.12
G.7	MESH EXAGONAL 5/8 "1.00 M	M2	15.44	3.86	59.60
G.8	PLASTER FLOOR 1: 2 + Waterproof. ESP = 2.CM	M2	12.76	7.99	101.95
	WALL PARALLEL				
G.9	CIRCULAR WALL FORMWORK	M2	40.74	14.24	580.14
G.10	MESH EXAGONAL 5/8 "1.50 M	M2	36.58	2.40	87.79
G.11	4.10 Electrically Welded Mesh	M2	17.58	14.48	254.56
G.12	PLASTER EXTERIOR AND INTERIOR E = 3 CM	M2	66.72	7.99	533.09

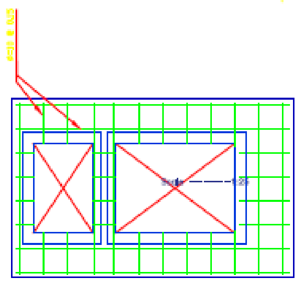
G.13	EMPORADO INTERIOR WALL AND FLOOR	M2	45.02	7.99	359.71
G.14	EXTERNAL WALL PAINTING	M2	33.37	3.40	113.46
G.15	TOP HEALTH	OR	2.00	104.11	208.22
G.16	Subdrains DRAIN PIPE D = 110 MM	M	12.00	6.00	72.00
	Capstone				
G.17	CONCRETE COLUMNS plinths and f`c = 210 kg / cm2	M3	0.68	233.64	158.88
G.18	STRAIGHT AND FORMWORK Formwork	M2	16.18	14.24	230.40
G.19	STRUCTURAL STEEL SLAB (8 MM)	KG	21.60	2.20	47.52
G.20	BEAM + SLAB puttying 1: 5	M2	13.38	7.99	106.91
G.21	MESH EXAGONAL 1/2 "GALLINERO	M2	13.66	2.40	32.78
G.22	AERATORS-VENT	GLB	8.00	311.66	2,493.28
G.23	PAINTING Antisol	M2	13.38	3.40	45.49
G.24	OVERFLOW OVERFLOW OUTPUT AND ACCESSORIES	GLB	2.00	204.17	408.34
G.25	ACCESSORIES INPUT	GLB	2.00	167.36	334.72
G.26	ACCESSORIES OUTPUT	GLB	2.00	70.86	141.72
H	**RESERVE TANK 15 M3**				
H.1	LAYOUT AND LEVELING	M2	47.76	4.28	204.41
H.2	EXCAVATION MANUAL	M3	7.76	6.01	46.64
H.3	STONED BASE	M2	63.80	10.03	639.91
H.4	HS REPLANTILLO f`c = 180kg / cm2 E = 3 CM	M3	1.24	155.30	192.57
H.5	CONCRETE SIMPLE f`c = 210 kg / cm2	M3	5.52	233.64	1,289.69
H.6	STRUCTURAL STEEL SLAB BACKGROUND	KG	35.00	2.20	77.00
H.7	MESH EXAGONAL 5/8 "1.00 M	M2	23.28	3.86	89.86
H.8	PLASTER FLOOR 1: 2 + IMPERMEABILIZANTE e = 2 CM	M2	19.24	7.99	153.73
	WALL PARALLEL				
H.9	CIRCULAR WALL FORMWORK	M2	48.32	14.24	688.08
H.10	MESH EXAGONAL 5/8 "1.50M	M2	62.86	2.40	150.86
H.11	4.10 Electrically Welded Mesh	M2	26.52	14.48	384.01
H.12	PLASTER EXTERIOR AND INTERIOR e = 3CM	M2	81.88	7.99	654.22
H.13	EMPORADO INTERIOR WALL AND FLOOR	M2	58.88	7.99	470.45
H.14	EXTERNAL WALL PAINTING	M2	81.88	3.40	278.39
H.15	TOP HEALTH	OR	1.00	104.11	104.11
	Capstone				
H.16	CONCRETE COLUMNS plinths and f`c = 210 kg / cm2	M3	1.24	233.64	289.71
H.17	STRAIGHT AND FORMWORK Formwork	M2	23.36	14.24	332.65
H.18	STRUCTURAL STEEL SLAB (8mm)	KG	44.48	2.20	97.86

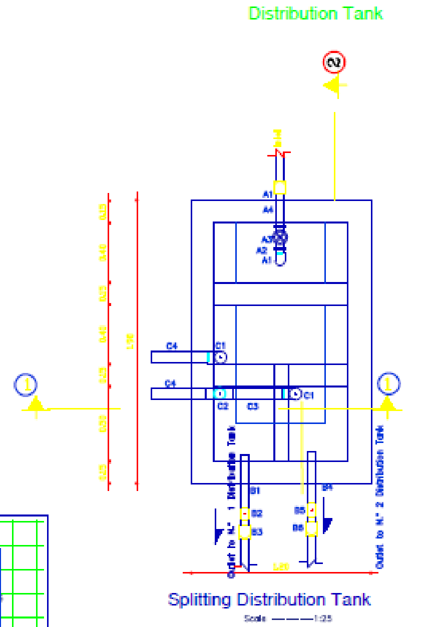
H.19	BEAM + SLAB puttying 1: 5	M2	20.16	7.99	161.08
H.20	MESH EXAGONAL 1/2 "GALLINERO	M2	20.58	2.40	49.39
H.21	AIREADORES- VENTILACION	GLB	1.00	311.66	311.66
H.22	PAINTING Antisol	M2	20.16	3.40	68.54
H.23	OVERFLOW OVERFLOW OUTPUT AND ACCESSORIES	GLB	1.00	204.17	204.17
H.24	ACCESSORIES INPUT	GLB	1.00	167.36	167.36
H.25	ACCESSORIES OUTPUT	GLB	1.00	70.86	70.86
I	**DISTRIBUTOR FLOWS**				
I.1	EXCAVATION HAND FOR MINOR STRUCTURES	M3	8.87	8.02	71.14
I.2	STRAIGHT AND FORMWORK Formwork	M2	35.85	14.24	510.50
I.3	CONCRETE SIMPLE f`c = 210 kg / cm2	M3	2.47	233.64	577.09
I.4	REINFORCING STEEL fy = 4200 kg / cm2	KG	96.00	2.20	211.20
I.5	INTERIOR PLASTER + IMPERMEABILIZANTE	M2	12.54	7.99	100.19
I.6	EXTERIOR PLASTER	M2	3.62	9.19	33.27
I.7	TOP HEALTH OF TOL 1/40 "0.75 * 0.75 m	OR	5.00	104.11	520.55
I.8	ACCESSORIES FLOW IN TANK DELIVERY	OR	1.00	413.52	413.52
				SUBTOTAL:	**370,418.05**
				VAT 12%:	44,450.17
				TOTAL:	**414,868.22**

List of Distribution Tank Accessories

Sign	ø	Quantity	Description
Inlet			
A1	1 1/2"	2	Elbow 90° HG
A2	1 1/2"	1	NEPLO CORRIDO HG
A3	1 1/2"	1	Bronze Valve
A4	1 1/2"	1	Short stretch HG L=0.35m
A5	1 1/2"	1	Short Stretch HG L=0.60m
A6	50mm	1	Female adapter PVC–HG
A7	50mm	1	Elbow 90° PVC E/C
Outlet			
B1	1"	1	Short stretch HG L=035m
B2	32mm	1	Female adapter PVC–HG
B3	32mm	2	Elbow 90° PVC E/C
B4	1 1/4"	1	Short stretch HG L=035m
B5	40mm	1	Female adapter PVC–HG
B6	40mm	2	Elbow 90° PVC E/C

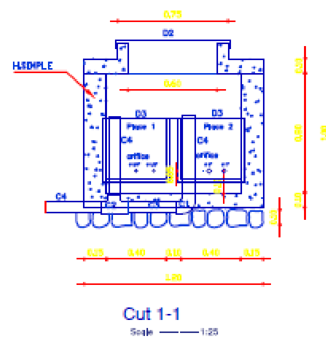
Sign	ø	Quantity	LONG.	Description
Overflow and Drain				
C1	63mm	2		Elbow 90° PVC–P
C2	63mm	1		TEE PVC–P
C3	63mm	1	0.45	Short stretch PVC–P
C4	63mm	5	0.50	Short stretch PVC–P
various				
D1		1		Sanitary Cap 0.75x0.55
D2		1		Sanitary Cap 0.75x0.95
D3		2		Galvanized board 0.45x0.50





Distribution Tank Civil Work

Description	U	quantity
Distribution Tank		
Excavation MANUAL	M3	1.40
Base stone H=0.10	M2	2.26
Simple Concrete f'c=210kg/cm2	M3	1.23
Structural steel	KG	21.00
Interior Plaster 1:2 + IMPERM.	M2	4.60
Exterior Plaster 1:5	M2	6.10
Straight formwork	M2	13.10
Rubber Paint	M2	6.10
Distribution Tank	GBL	1.00



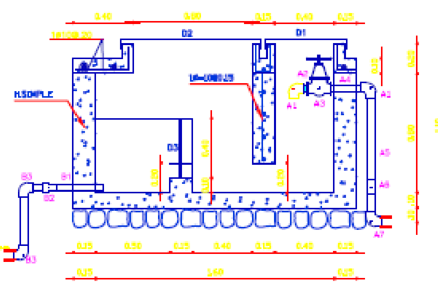


Figure A7. AutoCAD Drawing of the Existing Splitting Tank