Community Clean Water Access

An Interactive Qualifying Project

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Abstract

The project studied water quality and supply in Cerrito, Paraguay. The study included three groups: the Junta de Saneamiento, the local water board, Qom communities, and the Escuela Agrícola. Home test kits assessed water quality in ten wells managed by these groups. The team produced schematics of the water pipelines systems of both the Junta de Saneamiento and the Escuela Agrícola, a maintenance guide for the Junta de Saneamiento, and provided new pump equipment for two Qom communities. Recommendations include: retest water quality at three sites, conduct periodic water system cleaning, and modernize the Junta de Saneamiento system though the addition of water meters and the development of a centralized system.

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- The Junta de Saneamento for their guidance given to the team during meetings about water availability within Cerrito
- Sr. Llanes, of the Junta de Saneamiento working directly with the team; aiding in both water testing procedures and water distribution mapping.
- Indigenous leaders for giving the team information about their water systems and allowing the team to work within their communities.

Executive Summary

The small community of Cerrito in Benjamín Aceval, Paraguay, has well developed water systems. The main system is public and managed by a local non-profit volunteer board, the Junta de Saneamiento. Most community members utilize this. Others use private systems. The project worked with the Junta and two private systems: indigenous Qom communities and the Escuela Agrícola. In spite of their successes, improvements were made and recommendations were proposed.

Improvements include: a water quality assessment of all ten wells studied, pipeline schematics for the Junta and the Escuela Agrícola, a written maintenance plan for the Junta, and operational pump equipment for two Qom communities. Recommendations include: retesting water quality at three sites, conducting periodic water system cleaning, and modernizing the Junta de Saneamiento system though the addition of water meters and the development of a centralized system.

Recommendations were based on collaboration with community members and data collected. Informal interviews and meetings with Junta volunteers, community leaders, and school employees clarified issues and goals of the systems. Water quality tests validated periodic system cleaning and maintenance. The implementation of equipment and creation of schematics was done through meetings with leaders and advisors.

This project was the first in a series that will focus on water distribution systems in Cerrito. We anticipate that this will lay the foundation for other initiatives to build off from.

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1.0.0 Introduction

The availability of potable water is overestimated: only 3 percent of the water in the world is fresh (Water, 2018). This small percentage includes both safe and unsafe drinking water. In addition, much of it is inaccessible. Access can be limited by nonexistent regulation standards, extraction methods, unequal distribution throughout the community, and several other factors. Some communities have done well in addressing these problems.

Cerrito, a community within Benjamín Aceval, Paraguay, is an example. A well-run volunteer water board, the Junta de Saneamiento, services much of the community. Other community members use private systems. These include indigenous communities, the Qom, and a residential vocational agricultural high school, the Escuela Agrícola. Although the majority of the community has access to water, improvements can be made.

There are similarities and differences between the improvements for each group. Overall, individual improvements were given to three groups: the Junta de Saneamiento, Qom communities, and the Escuela Agrícola. Each group will be discussed individually. Improvements for the Junta include documentation of their system, addition of water meters, and centralization of their system. Improvements for the Qom communities include the addition of pump equipment and periodic system cleaning. Lastly, improvements for the Escuela Agrícola include water quality testing and system documentation.

The work will increase attention to the management, maintenance, and monitoring of the water systems in the community.

2.0 Background

2.1.0 Overview

Whether public or private, successful water supply systems provide water to communities or individuals reliably and efficiently. They monitor water quality and infrastructure, perform maintenance, and manage the system so water can be distributed to the community. Water within Cerrito is managed by multiple groups.

2.2.0 Water Supply Systems in Cerrito

In Cerrito, there are three kinds of supply systems: those of the Junta de Saneamiento, indigenous Qom, and private management. Each system supplies water through drilled wells, electric pumps, water towers, and the force of gravity. This section overviews general water supply, such as groundwater, wells, and towers, and introduces the three water systems worked with.

2.2.1 General Systems

Groundwater in Cerrito is extracted from the freshwater lens of Benjamín Aceval through wells typically 60-100 m deep (Houben, 2014; Rojas, 2017). Submersible or airlift pumps are generally used to move water from wells into towers storage towers. The force of gravity is used to distribute water from towers to the community. The approximate locations of the pumps and towers studied can be seen in Figure 1.

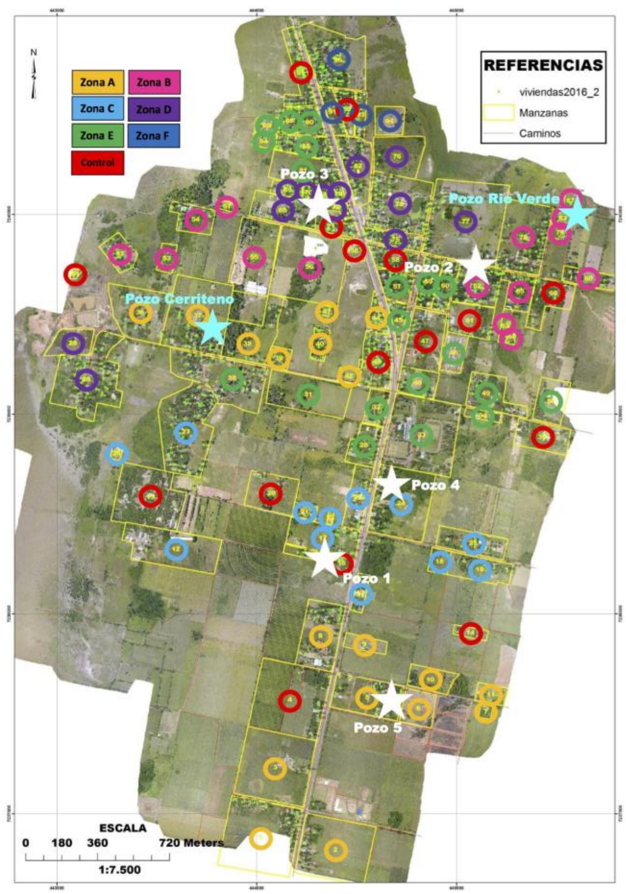

Figure 1: Location of wells (Pozos) and manzanas in Cerrito.

Factors such as income and location may influence a family's access to water. Some families have indoor plumbing such as showers, toilets, and water heaters while others may only have an outdoor spigot shared with neighbors. The Junta de Saneamiento services the greatest number of families in Cerrito with around 770 connections (Houben, 2014).

2.2.2 Junta de Saneamiento Systems

The Junta de Saneamiento is a local, nonprofit volunteer run water board that services families and businesses in Cerrito for a flat rate of 25,000 Gs monthly ($4.50 USD). Roles within the Junta include: the elected president, currently Sr. Justino Franco, the secretary, currently Sra. Candida Núñez, and technicians, such as Sr. Pacifico Agustin Gomez Llanes, who perform maintenance and repairs to the system as needed. Minor issues, such as small leaks, sometimes go unreported provided the five well-tower systems remain operational.

2.2.3 Indigenous Qom Systems

Those not connected to Junta de Saneamiento, such as the Qom, receive water from their own systems. The team worked with three of these communities: the Río Verde Qom led by Don Crispín Amarilla, the Cerriteno San Francisco Qom led by Don Alfonso Benitez, and Cerriteno Kael Sat Lecpi Qom led by Don Manuel Dominguez and Don Francisco Caceres.

The Río Verde Qom, marked in Figure 1, has an 30-50 meter deep well, submersible pump and 10 m high tower that has not been used by the community for the last few months, as stated by their community leader. The community has received water from the Junta de Saneamiento for the last 4 years without payment and have accumulated over $4000 USD in debt. The Junta proposed to forgive the debt in exchange for control of the Río Verde system. As of April 17, 2018, the pump was not functional. Water flow was restored to the system when the pump motor was replaced. Unfortunately, Río Verde water is turbid, therefore distribution to Junta customers is undesirable.

The Cerriteno San Francisco Qom led by Don Alfonso Benitez has one of the oldest submersible pump and tower systems in Cerrito, but it is fully functional, and services close to 20 families. It has a brick and mortar tower and an 8500 L fiberglass tank with a semi open top.

Cerriteno Kael Sat Lecpi Qom, led by Don Francisco Cáceres and Don Manuel Dominguez, use a newly replaced above ground airlift pump to transfer water from their 60-70 m well to their approximately 11 m, 9900 L tower for their community. Before the pump was replaced, the community experienced major issues with water supply.

2.2.4 Private Management Systems

Another example of a private water system is that of the Escuela Agrícola San Francisco— a self-sustaining agricultural school where students learn practical skills alongside a classroom curriculum. The school has two separate well-water systems: System 1 is treated with chlorine and pumped into a covered tower for human use, System 2 is pumped to an uncovered tower and tank for animal and agricultural use. Although the separation of systems reduces treatment cost and maintenance, students commonly drink water from System 2 out of convenience.

2.3.0 Water Quality

The condition of water can impact health of consumers and water system wear. Condition and potability can be determined through quality assessments that measure physical and chemical properties. Potentially non-constant properties validate periodic assessments.

2.3.1 Water Quality Standard

Quality assessments are compared to quality standards to determine potability. Paraguay has quality standards defined by the Ministry of Public Works and the Ministry of Public Health and Social Welfare. Their guidelines are as follows: the city water must be stored in a properly sealed tank and have at least one basic form of filtration before storage (MGDIFO, 2010). However, in Cerrito, this does not always occur.

2.3.2 Water Tests

Basic water tests are used to identify potential deviations to quality standards. Tests studied include: copper, iron, chlorine, pH, nitrates, nitrites, bacteria, turbidity, hardness, lead, pesticides, and turbidity. For more information see Appendix 7.1.0.

3.0 Methodology

The methods used to complete the project are discussed in this section. These included informal interviews, water quality tests, document development, and photography.

3.1.0 Informal Interviews

The project team assessed needs and ambitions of each group through informal interviews and meetings. Fundación Paraguaya volunteer, Srta. Ada Sachelaridi introduced the project team to community members leaders and the Junta de Saneamiento.

3.1.1 Junta de Saneamiento Contacts

The team worked extensively with the Junta de Saneamiento. Sr. Pacífico Agustin Gomez Llanes, a Junta de Saneamiento volunteer, aided the team with water testing and mapping. This helped Sr. Llanes and other Junta members familiarize themselves with the project team and openly discuss their personal goals for the Junta. Sr. Llanes dedicated more than a week's worth of time to the project.

3.1.2 Qom Community Contacts

Advisor Fernando Pfannl informed the team of Qom concerns regarding their water systems. The team visited each of the three communities 1-3 times with volunteer Srta. Ada Sachelaridi and occasionally with another volunteer Srta. Sedwilka Morilla to assess water systems through conversations with leaders and community members.

3.1.4 The Escuela Agrícola Contact

Advisor José Luis Salomon, chemical engineer and former director of the Escuela Agrícola, was the main source of information about the school and provided technical advice. He introduced the team to Prof. Virgilio Borges—head of general services, who supervised the water quality assessments done for the school. Prof. Borges also helped find a replacement airlift pump for the Cerriteno Kael Sat Lecpi Qom Community.

3.2.0 Water Quality Tests

Preliminary water tests were completed with WaterSafe® Well-Water Test kits by Silver Lake Research from the United States. Advisor Dorothy Wolf selected the kit because it tested for bacteria, pH, chlorine, lead, pesticides, copper, iron, nitrates, and nitrites (Watersafe, 2017).

These kits were used on the five Junta well-tower systems, the three Qom systems, and the two Escuela Agrícola systems. Because some water samples indicated the presence of harmful bacteria, a second opinion was sought. Additional samples from these sites were sent to Dr. Esteban Riera, director of Laboratorio Riera, for testing.

3.2.1 Test Sites and Trials

The team decided to test water from towers rather than wells, since tower water quality reflects the characteristics of the well water and the influence of tower storage.

3.2.1.1 Junta de Saneamento Systems

Each of the five Junta well-tower systems was tested. Tower 1 initially showed a positive bacteria result. The water was retested, and the second result was negative. Due to conflicting results, a water sample was sent to Dr. Riera for further bacteria testing.

3.2.1.2 Qom Community Systems

Each of the three Qom community towers was tested once. Retests of these systems did not occur.

3.2.1.3 The Escuela Agrícola Systems

The two Escuela Agrícola water systems were tested for bacteria a total of fifteen times over three trials: Trial 1, Trial 2a, and Trial 2b. See Tables 2 and 3 below for representation of test chronology and locations.

During Trial 1, two home tests were used on the faucet closest to Well 1 (“Little Tap”) and an access point closest to Tower 2 (“Tank Pipe”). Both showed positive bacteria results. The school reinitialized the chlorination system of Well 1 after hearing about the results. Because of the initial positive bacteria results, six samples were sent to El Laboratorio Riera (Trial 2a) to further assess bacteria levels from System 1 (5 samples) and System 2 (1 sample). The tests from El Laboratorio Riera aimed to determine if the chlorination system decreased bacteria levels in the water from Well 1. Of these six samples, one was from an access point after Tower 2, one was directly from Well 1, one was from an access point after chlorine was reintroduced to the drinking water system, and three were from access points after Tower 1. These results are shown in Table 1. While results from El Laboratorio Riera were being processed, six home tests were done at points after Tower 1 (Trial 2b). These results are located in Table 2.

Escuela Agrícola Bacteria Tests

Well	**Well 1 (System 1)**					**Well 2 (System 2)**	
System Features		Chlorine system	Chlorine & Tower 1			Tower 2	
Test Location Name	Directly from Well 1	Little Tap	Spigot After Hotel Tower	Hotel Bathroom	Kitchen	Tank Pipe	Garden Spigot
Trial 1: Home	-	Positive*	-	-	-	Positive	-
Trial 2a: Dr. Riera	Not Potable	Potable	Potable	Potable	Potable	-	Not Potable

Table 1: Initial positive bacteria tests from kits (Trial 1) led to samples sent to El Laboratorio Riera (Trial 2a) and additional home tests on living and working quarters (Trial 2b, Table 2).

- Locations that were not tested are indicated by the “-” symbol
- System features describe the location of the test site along the water system. Locations are listed in order from closest to the well to farthest from the well.

*After the positive bacteria results from Trial 1 were told to school staff member Prof. Virgilio Borges, he determined that the chlorination system was not functional. Water System 1 was cleaned, and the chlorination system was repaired before Trial 2a (above) and Trial 2b (below).

Escuela Agrícola Additional Tests

Well	Well 1						
System Features	Chlorine & Tower 1						
Test Location Name	Cabin: Mburu.	Cabin: Aleli	Admin. Building	Academic Building	Cabin: Tajy	Cabin: Pacholi	Cabin: Jasmin
Trial 2b: Home	Potable	Potable	Potable	Potable	Potable	Potable	Potable

Table 2: Initial positive bacteria tests from kits (Trial 1, Table 2) led to samples sent to El Laboratorio Riera (Trial 2a, Table 1) and additional home tests on living and working quarters (Trial 2b).

3.2.2 Test Procedure

Recommended procedures from the WaterSafe Well-Water Test kit were followed during all tests. Labeled 50 mL sterile plastic containers were used to collect samples for each test strip (five per test). All participants used hand sanitizer and those who directly handled samples or test strips wore sterile gloves for prevention of contamination.

3.2.3 Turbidity

The turbidity of water samples was noted during sampling. When turbid water was encountered, samples sat undisturbed for at least 24 hours to look for sedimentation. When sedimentation did not occur, aluminum sulfate was added in excess, swirled vigorously for 40-60 seconds, and allowed to settle for at least 30 minutes. Changes, such as sedimentation, were noted.

3.3.0 Document Development

3.3.1 Schematic Development

Preexisting maps or schematics of the water systems managed by the Junta de Saneamiento and by the Escuela Agrícola were unavailable, so they were developed. The starting point for these schematics was a skyview drone image of Cerrito provided by Sr. Hugo Huespe who produced it on behalf of Fundacion Paraguaya. To map the Junta pipelines, Sr. Llanes and Sra. Nunez showed the team the general pipeline locations that connected each of the five wells that appear on the aerial image of Cerrito. These pipelines and wells were drawn on a digital map (Figure 2). To map the Escuela Agrícola system Dr. Jose Luis Salomon walked the school grounds and indicated spigots, tanks, and wells on the map.

3.3.2 Maintenance Plan Development

Throughout the time the project team worked with the Junta de Saneamiento, the team made observations that contributed to the development of a maintenance plan. The team noticed that the Junta members were experienced and knowledgeable in their field, but they did not have a written guide to follow. An American guide for municipal water system maintenance was adapted and supplied to the Junta (Washington, 2017). It was discussed with Junta member Sr. Llanes (Appendix 7.4.0).

3.4.0 Flow Rate

The flow of water from the Río Verde well was determined by timing how long it took to fill a 67.5 liter graduated pot (graduated at 22.5 L increments). The time was recorded at each

22.5 L increment to give the flow in (Volume/time). It is possible that flow rates vary with the time of day, weather, season, or with other factors.

3.6.0 Photography

Photography was used for documentation throughout the project. Each water test result was photographed to document results. Pictures of tanks, wells and other important structures were also taken.

3.7.0 Ethics

Preceding the project, the Qom people formally consented to its execution on their lands and with their people as required by United Nations Law, the Tribal Peoples Convention no. 196 of the International Labor Organization. Additionally, a volunteer from the Fundacion Paraguaya or Junta de Saneamiento worked alongside the team whenever it was inside the community.

4.0 Results

The team tested water quality for the Junta de Saneamiento, three Qom wells, and the Escuela Agrícola system, produced schematics of pipelines for the Junta de Saneamiento and the Escuela Agrícola, measured three Qom towers, and contributed to the provision of new pump equipment for two Qom communities.

4.1.0 Water Quality Test Results

In general tests indicated good levels of water quality, but a few cases caused concern, particularly bacteria, pesticides, pH, and turbidity. Out of ten systems, two tested positive for pesticides, two showed turbidity, and the average pH of all systems was 6.2 (recommended value 6.5-7.5). No tests in Cerrito showed any copper, nitrites, or lead. Detailed results can be seen in Appendix 7.3.0.

4.1.1 Junta de Saneamiento Test Results

With regards to the Junta, water quality was good. One out of five tanks (Tank 1) initially showed a positive result for bacteria; an additional home test disconfirmed the first, and a final lab test showed potable water. The pH was close to 6.0 everywhere except for Tank 3 where it was close to 6.5. Hardness out of range was only seen in Test 1of Tank 1 (Test 1: 50-120 ppm, Test 2: 0-50 ppm, desired level: <50 ppm). Well 3 showed turbidity that could be precipitated with aluminum sulfate, but Junta members Sr. Llanes and Sr. Franco stated it was not a concern of the community.

4.1.2 Qom Test Results

The three Qom towers were tested once each using home kits. All results were in range, except for individual instances of turbidity, bacteria, and pesticides. The water from Río Verde showed turbidity that could precipitated with aluminum sulfate. The average pH of the three was 6.75. Only the pH of Río Verde (6.25) was out of the desired range (6.5-7.5). The Cerriteno Kael Sat Lecpi Qom tested positive for bacteria and the Cerriteno San Francisco Qom tested positive for pesticides. Retests were not done due to limited test kits. Results can be seen in Appendix 7.3.1.

4.1.3 The Escuela Agrícola Test Results

Results from the tests done for the Escuela Agrícola were all within range except for pH and bacteria results. The average pH of System 1 was 6, the pH of System 2 was 6.25.

The initial two home tests showed presence of bacteria from both Escuela Agrícola water systems (Appendix 7.3.1). Prof. Virgilio Borges, the head of general maintenance services at the Escuela Agrícola, was notified and determined that the automatic chlorinator for System 1 (drinking water system) was not functional. The chlorine pump was repaired by Prof. Borges and additional samples were sent to a private laboratory, El Laboratorio Riera. Results showed that water from the tank of System 2 (agricultural system) is not potable. Results from System 1 showed that water directly from the well is not potable, but water after the chlorination system is potable. These lab results are located in Appendix 7.3.3. The additional home tests done on System 1 after the chlorination system was repaired also showed potability (Appendix 7.3.2).

4.2.0 Schematics for the Junta de Saneamiento and the Escuela Agrícola

A digital version of the water distribution systems of the Junta de Saneamiento can be seen in Figure 2. Pipelines, wells, connections, and important locations are color coded, as indicated in the legend. This schematic was printed on plastic and given to Sr. Llanes for the office of the Junta de Saneamiento. The Escuela Agrícola schematic of wells and spigots can be seen in Figure 3. A digital copy of the schematic was sent to advisor Jose Luis Salomon to give to the school.

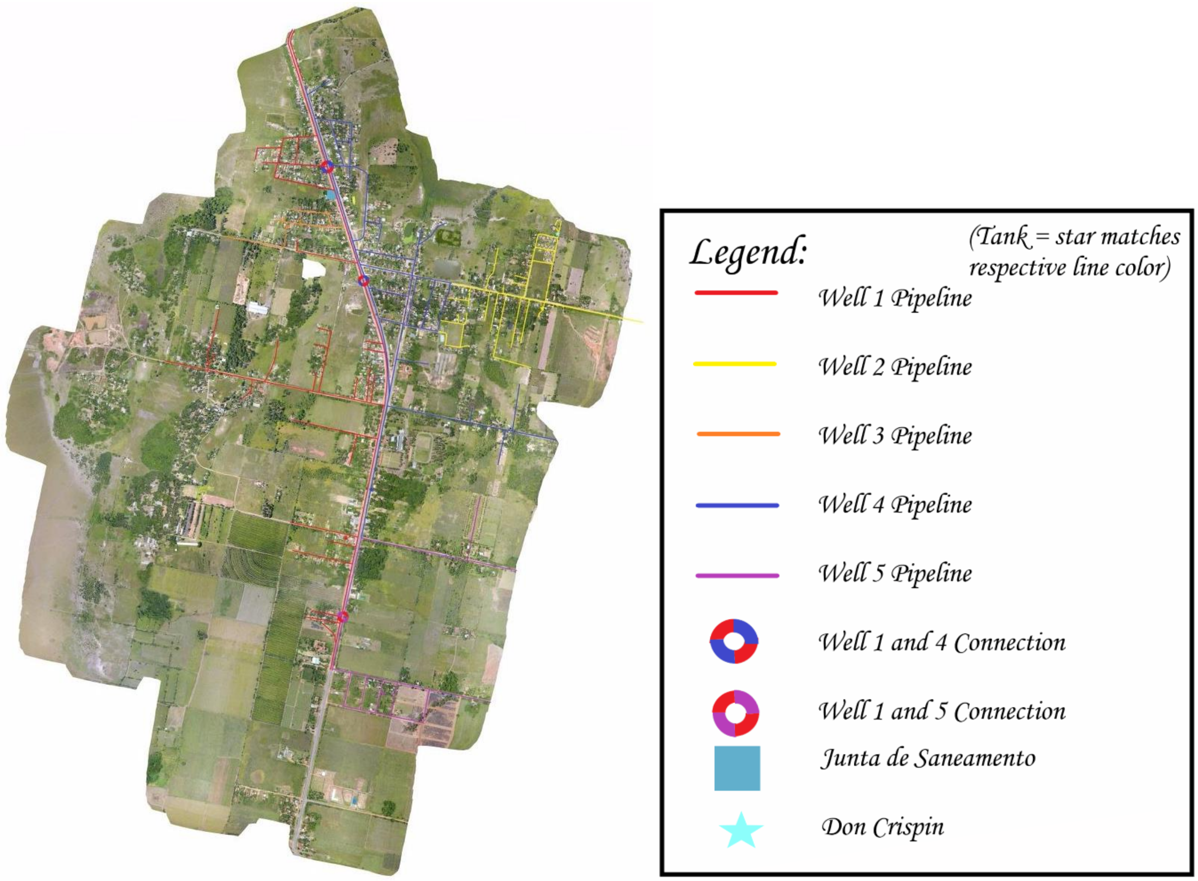

Figure 2: Schematic of pipelines for the Junta de Saneamiento.

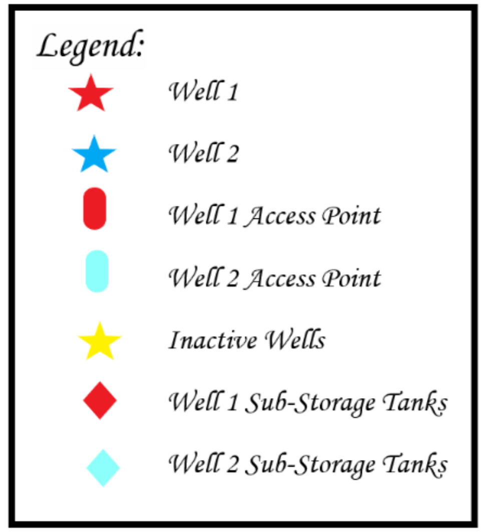

Figure 3: Schematic of well and access point locations for the Escuela Agrícola.

4.3.0 Maintenance Plan for the Junta de Saneamiento

The maintenance plan given to the Junta gave recommendations for system upkeep on a scheduled basis and described suggestions for the improvement of the system. A copy of this can be seen in Appendix 7.4.0. Eleven system upkeep topics discussed include equipment inspections, cleanliness assessments, and functionality tests. Suggestions for future improvement include the installation of water meters and the development of a scale map from the pipeline schematic.

4.4.0 Result and Recommendation Deliverables for Indigenous Communities

The team took the future sustainability of the Qom community water supply into consideration when recommendations were developed. Recommendations include: routine cleaning of water tanks and general system maintenance. Water quality test results and community specific information (such as tower dimensions and pump types) were compiled with the recommendations and given to advisor Fernando Pfannl. These documents will be further analyzed by the Fundacion Paraguaya before it is determined if they can be distributed among the Qom communities. These communities are the Cerriteno Kael Sat Lecpi Qom, the Cerriteno San Francisco Qom, and the Río Verde Qom.

4.4.1 Common Maintenance Recommendations for Qom Communities

It is recommended that all water tanks are cleaned on a regular basis. This is done by adding chlorine and sometimes scrubbing the walls of the tank. It is recommended that all water tanks are covered to prevent further contamination.

4.4.2 Recommendations for the Community of Cerriteno San Francisco Qom

The well of this community showed a positive result for bacteria, so it is recommended that the tank is cleaned, a tank cover installed, and the water is retested. A picture of the water flowing into the tank that shows some algae growth can be seen in Appendix 7.5.1. It may be beneficial to repair cracks in the tower with mortar. A mason can usually tell what type of mortar to use based on appearance (Sullivan, 2018).

4.4.3 Recommendations for the Community of Cerriteno Kael Sat Lecpi Qom

The water test in this community showed a positive test result for pesticides (Appendix 7.3.1). Because of this, the community may benefit from further quality testing. The kit tests for unsafe levels of simazine (above 4 ppb) and atrazine (above 3 ppb), but it does not indicate the exact pesticide present. After quality testing, the team looked at potential system improvements within the community.

The main improvement made was the instillation of a new airlift pump. In the past, a 1.5 horsepower air pump was used to push water into the water tower that became very inefficient over time, limiting water within the community. The team suggested that the community may benefit from a more efficient 2 horsepower air pump. With aid from the mayor and WPI students, the community purchased a 2-horsepower air compressor. The new compressor increased water accessibility to the community.

Figure 4: Previous air compressor (left) and new air compressor (right)

4.4.3 Recommendations for the Río Verde Qom Community

With the help of the Junta de Saneamiento, water pressure was restored to the water pump of the Río Verde Qom Community. Leader, Don Crispín Amarilla stated that maintenance on the system, such as this, had not been completed for at least a year. However, the Junta de Saneamiento believes that there was no water coming from the system for four to five years. The Junta restored their access to water and the quality test results show that it is safe to drink, even though it is turbid (Appendix 7.5.3). Turbidity increases the chance of bacteria, so it is suggested that the community uses chlorine or removes turbidity (WHO, n.d.).

4.5.0 Structural Analysis of Indigenous Water Systems

The structure of the indigenous water systems was determined. These included measurements of water towers, storage tanks, and height of the structures. Other observations included the material used within the structure as well as any deviations from apparent normal conditions like cracks or algae growth. These results are shown in Appendix 7.5.0.

5.0 Discussion

Throughout the term, many factors impacted the outcomes of the project. Examples discussed include social-political, economic, and technological factors present in Cerrito. Each of these aspects could be seen in different parts of the project. The development of a feasible maintenance plan for the Junta de Saneamiento incorporated all of these elements.

5.1.0 Social-Political and Economic Factors

Water is a necessity with high social-political value, especially in the close-knit community of Cerrito. The three types of water systems (public, indigenous, and independent) all had influence on the project, and sometimes each other. Each type provides the same service, but differences in management and system specifics can have an impact on performance overall.

5.1.1 Public Water Board: Junta de Saneamiento

The productivity of the Junta de Saneamiento is influenced by fact that it is non-profit and volunteer run. Current volunteers of the Junta are knowledgeable and dedicated to maintaining water supply in Cerrito, but they are not employees. The lack of employees may explain the absence of formal protocol regarding topics such as tank cleaning and preventative maintenance, but it is difficult to say if their presence would make any worthwhile improvements. Junta members also work around their personal lives and jobs whenever they can to help the community, but sometimes they are unable to do as much as they want.

5.1.2 Independent Water Systems

Independent systems, such as those managed by Qom communities, or the Escuela Agrícola, face similar system issues as the Junta, but generally on a smaller scale. Unfortunately, the independent systems do not always have the means to address certain issues, so they receive assistance. An example is the relationship between the Río Verde Qom community and the Junta de Saneamiento. The people who own these systems usually have monetary issues, or lack information.

5.1.2.1 Río Verde and Junta de Saneamiento Compromise

The Río Verde Qom have been using water from the Junta de Saneamiento for a period of time; the Junta de Saneamiento stated this was four to five years, while Don Crispín Amarilla, leader of the Río Verde Qom, stated that it was for a few months. Regardless of the perceived timeline, the Río Verde Qom have acquired a debt of over $4,000 USD for using water from the Junta de Saneamiento according to advisor Fernando Pfannl.

A proposed compromise was for the Junta to incorporate the water from Río Verde into their grid as a form of repayment for the debt. However, the Junta de Saneamiento has not pursued this solution for two main reasons: the water is turbid, and the functionality of the system is unclear. When the project team first visited Río Verde, the pump did not work. When the motor was replaced, water was pumped out, but the rate was not steady, potentially due to an electrical problem.

To resolve the turbidity issue, the water would need to be treated through aluminum sulfate flocculation and sedimentation, or a deeper well dug. The Junta does not view this compromise as something worth pursuing when they could be putting their efforts into digging a well in a more central location.

5.1.3 Potential Impact of Election on Project Funds

The Paraguayan general elections may have had some influence on aspects of the project, particularly the replacement air pump for the Cerriteno Kael Sat Lecpi Qom community. In the past, the community asked for close to $1,500 USD for a replacement pump, but the mayor declined. When the project team discovered that the community used a cheaper air lift system, it was determined that the cost was of a new air lift pump was only $550 USD. The community was informed of the lower cost by Fundacion Paraguaya and a compromise was proposed to split the cost: 50% by the government, 25% by the Qom community, and 25% by the three WPI project team members. Consequently, just two weeks before the Paraguayan general election, the community requested and received funds from the Mayor, Sr. Oscar Duarte. It is unclear if the mayor agreed because of the lower request, or if the upcoming election contributed to the decision.

5.3.0 Technological Factors

It was important to consider the longevity of the technology suggested to the communities. When choosing recommendations, it was necessary to compare the cost of the solution with its longevity and requirement for maintenance. The longevity of technology was considered when purchasing a new pump for the Cerriteno Kael Sat Lecpi community.

5.3.1 Engineering Assessment of the Pump of Cerriteno Kael Sat Lecpi Qom

With the aid of the Mayor, community, and project team, a new 2.0 horsepower air compressor was installed in the Cerriteno Kael Sat Lecpi Qom community of Don Manuel Dominguez. This air compressor is an improvement from the previous inefficient 1.5 horsepower pump. The team looked at different types of pumps that could be used and discovered that the most efficient and long-lasting solution for the community would have been a submersible pump. However, this option is much more expensive and therefore was not a feasible solution for the community. Through connections with the Escuela Agrícola, Jose Luis Salomon was able to find an affordable 2.0 horsepower air compressor that would provide enough water to the community. This solution may not be the most sustainable, with a shorter life than a submersible pump, but it provided water that the community needed now for a feasible price.

5.4.0 Maintenance Plan and Recommendations for the Junta de Saneamiento

The team considered the impact of economic, socio-political, and technological factors when the maintenance plan was developed for the Junta. The dedicated volunteers see the value and eventual necessity move towards modernization and expansion of the system, but it is not feasible in one step.

Even if a single centralized water system for the entire community of Cerrito was proposed, it may not be successful. Some communities, especially those who use independent systems, may not want to be a part of a main system for socio-political and/or economic reasons such as lack of system control and payment changes. Economically, it is difficult to fund the expansion upfront. Monthly payment from users might allow for the system to be maintained and water treated, but payment collection is not guaranteed. From an engineering perspective, an efficient centralized system would take extensive planning and computation. Even though some of these factors may hinder complete system expansion, small steps can still be made. It is not necessary to completely redesign the system, but to take steps when appropriate.

The maintenance plan based off from a guide made for small municipal systems in the United States, (Washington, 2017) describes basic upkeep of the water system. Many Junta volunteers are already familiar with techniques included but expressed that having a written guide would benefit future volunteers and allow for more growth and development. The recommendation of adding water meters to Junta wells is a relatively small investment that will allow a better understanding of water supply, demand, and loss. The recommendation of updating the pipeline schematic would allow workers to better locate all pipelines.

5.4.0 Future Project Work

Future project work on the water system of Cerrito would greatly benefit the community. A future team could further the schematic of the pipeline maps of the Junta de Saneamiento into an exact map of the pipelines. This could benefit future workers of the Junta de Saneamiento.

Another part of the project could investigate the use of backup power for water pumps. During the term, a major power outage occurred in Villa Hayes. This power outage caused all the water pumps to turn off. Many communities had no access to water due to this. It could benefit the community to have solar panels on the well pumps in cases of emergency. Solar power may be a possibility due to the large amount of sun in Cerrito. Solar panels could harness natural energy to use during power outages.

6.0 Conclusion

The project assessed water quality and water system infrastructure for the Junta de Saneamiento, three indigenous Qom communities, and the private water system of the Escuela Agrícola in Cerrito, Paraguay. Deliverables for the Junta de Saneamiento included a printed schematic their pipeline system, and recommendations in the form of a maintenance guide. A new airlift pump was installed in the Cerriteno Kael Sat Lecpi Qom community, as well as a replacement motor in the Río Verde Qom community. Reports that assessed water quality, system structure, and recommendations for each of the three indigenous communities, and Escuela Agrícola were given to Fernando Pfannl with recommendations for Qom communities.

7.0 Appendix

7.1.0 Water quality test kit

The "WaterSafe® Well-Water Test" kit made by Silver Lake Research was used to assess the quality of water. This kit provided tests for copper, iron, chlorine, pH, nitrates, bacteria, turbidity, hardness, lead, pesticides.

7.1.1 Bacteria

Bacteria present in water can have a variety of adverse effects, or little to no effects (Oram, n.d.). Potential issues include dysentery and digestive system infections that can be dangerous or deadly for the young, elderly, or ill. It is common to use a small amount of chlorine (0.5 to 4.0 ppm) in drinking water to kill potentially harmful bacteria. Some types of bacteria are more harmful than others.

The test kit uses a 5 mL flask filled with growth media powder. The liquid in the flask turns yellow (indicating it is likely for potentially harmful bacteria to be present) or purple (indicating that no bacteria were detected) after 48 hours. The kit does not indicate the type of bacteria tested (Silver, 2018).

7.1.2 Chlorine

Chlorine is sometimes naturally present in water supplies. It is also commonly added to water supplies to kill potentially harmful bacteria. The Environmental Protection Agency of the

United States says that chlorine levels under 4.0 ppm are safe to consume. Levels above this can cause stomach problems as well as eye and nose irritation (National, 2018).

The test kit uses a colorimetric paper test strip that shows colors for 0, 2.0, 4.0, and 10 ppm.

7.1.3 Copper and Iron

Copper and/ or iron can be introduced into water system when copper or iron pipes are used (Lemley, 1999). Sometimes, they are naturally present in groundwater systems.

The level of copper should be below 1.3 ppm. Above this level, stomach problems are common (Lemley, 1999). The test was a colorimetric paper strip with indicators at 0, 0.5, 1.0, 2.0, and 5.0 ppm.

The level of iron should be below 0.3 ppm. Iron is generally considered a nuisance to water and it is generally not dangerous. Iron can change the color of water to red or brown and give the water an undesirable taste or odor. Iron can be consumed by people as it is commonly found in multivitamins. It is unlikely that enough iron could be dissolved in water to be harmful (Lemley, 1999). The test for iron in the kit is a colorimetric test strip with indicators at 0.0, 0.1, 0.3, 1.0, and 5.0 ppm.

7.1.3 Nitrates and Nitrites

Nitrates and nitrites are commonly found in fertilizers and are important in the preservation of some meats. In large quantities, they can be dangerous because they pull oxygen from the bloodstream (Testing, n.d.). A range of effects exists including fatigue and paleness of skin. At higher levels of consumption, more serious problems can develop including heart problems and possibly death. The level of total nitrates and nitrites should be below 10 ppm. The level of nitrite should be below 1.0 ppm.

The kit used colorimetric paper test strips that showed results for total nitrate and nitrite on one pad (ranges 0, 0.5, 2.0, 5.0, 10, 20, and 50 ppm) and a second pad for just nitrite (0, 0.15, 0.3, 1.0, 1.5, 3.0, and 10 ppm).

7.1.4 pH

The pH of water is a measure of acidity or basicity. It is recommended that drinking water should have a pH between 6.5 and 8.5. pH can be an indicator of what may be able to be present in water. Water that is of higher acidity allows for metals to dissolve more easily (Perlman, 2016), while more basic water can have a strange taste.

The pH test included in the kit used a paper colorimetric test strips. It showed results of 6.0, 6.5, 7.5, 8.5 and 10.

7.1.5 Hardness

Hardness of water is a measure of the amount of calcium and magnesium in water (Perlman, 2016). Calcium and magnesium within a water source does not pose a human health problem but can lead to pipe and water system degradation.

The hardness test included in the kit used a paper colorimetric test strip. It showed results of 0, 50, 120, 250, and 425.

7.1.6 Lead and Pesticides

Lead is a heavy metal that can enter a water system through corroded pipes. Presence of lead in water has been linked to damaged nervous systems of infants and children. Other impacts of lead in water include impaired hearing and decreased formation of red blood cells (EPA, 2018). The lead test included in the kit used a yellow test strip with an arrow. The arrow was placed into the sample and line formation signified the presence of lead.

Pesticides can also be very harmful if present in drinking water. The danger of pesticides within drinking water is based upon the amount and type present. Long term effects, such as cancer, do exist in cases of long term pesticide exposure (NPTN, 2000). The pesticide test included a blue test strip with an arrow. The arrow was placed into the sample and line formation signified the presence of pesticides within the sample.

7.2.0 Additional Water Quality Testing

7.2.1 Turbidity

Turbidity is caused by a large number of small particles such as silt or bacteria (WHO, n.d.). Significant differences in turbidity can also be seen by the naked eye or in photographs. Turbidity is a common indicator that particles are present. To determine if the particles are harmful, water quality testing must be done.

Some cases of turbidity can be removed through filtration, while other cannot. Colloid particles are too small to filter and require some form of chemical treatment before they can be extracted mechanically.

7.3.0 Water Quality Test Data

7.3.1 Home Test Results

The Tests		La Junta de Saneamiento					Qom Wells			The Escuela Agrícola	
Test Name	Desired Level	Tower 1	Tower 2	Tower 3	Tower 4	Tower 5	Cerriteno San Francisco	Cerriteno Kael Sat Lecpi	El Rio Verde	Faucet Closest to Well 1	Tower 2
Bacteria	Negative	+, -	-	-	-	-	+	-	-	+	+
Copper	< 1.3 ppm	0, 0	0	0	0	0	0	0	0	0	0
Iron	<0.3 ppm	0, 0	0	0	0	0.05	0	0	0	0	0
pH	6.5-8.5	<6.0, 6.0	6.0	6.5	6.0	6.0	7.5	6.5	6.0-6.5	6.0	6.0-6.5
Hardness	<50 ppm	50-120, 0-50	0	0	0	0-50	0	0	0-50	0-50	0-50
Chlorine	<4.0 ppm	0-2.0, 0	0	0	0	2.0	0	0	0	0	0
Nitrates and Nitrites	<10.0 ppm	0.5, 0.5	0-0.5	0	0.5	0-0.5	0.5	0-0.5	0-0.5	1.0	0.5
Nitrites	<1.0 ppm	0, 0	0	0	0	0	0	0	0	0	0
Lead & Pesticides	Negative, Negative	-/-, -/-	-,-	-,-	-,-	-,-	-,-	-, +	-,-	-,-	-,+

7.3.2 Additional Home Test Results for Escuela Agrícola

Site	Value Desired	Aleli	Pacholi	Tajy	Jasmin	Mburu	Academic	Admin.
Bacteria	Neg	Neg	Neg	Neg	Neg	Neg	Neg	Neg
Copper	<1.3 ppm	0	0	0	0	0	0	0
Iron	<0.3 ppm	0	0	0	0	0	0	0
pH	6.5-8.5	6	6	6	6	6	6	6
Hardness	<50 ppm	0	0	0	0	0	0	0
Chlorine	<4.0 ppm	0	0	1	0	1	0	1
Nitrates and Nitrites	<10 ppm	1.25	0.25	0.5	0.25	0.25	1.25	0.5
Nitrites	<1.0 ppm	0	0	0	0	0	0	0
Lead	Neg	neg	neg	neg	neg	neg	neg	neg
Pesticides	Neg	neg	neg	neg	neg	neg	neg	neg
Turbidity	Neg	neg	neg	neg	neg	neg	neg	neg

7.3.3 Bacteria Tests for Escuela Agrícola from El Laboratorio Riera

Test	Permitted Value	Well 1 (Before Chlorination)	Well 1 Kitchen (Chlorinated)	Well 1 Hotel (Chlorinated)	Well 1 Little Tap (Chlorinated)	Well 1 Tap from Tank (Chlorinated)	Well 2 Garden Spigot (Unchlorinated)
Mesophilic Aerobic	$<=5.0*10^2$	8.0	<1	2.0	$4.7*10^1$	<1	$6.4*10^2$
Total Coliform	<1.1	9.2	<1.1	<1.1	<1.1	<1.1	$2.3*10^1$
Colif. Fecal	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	$1.2*10^1$
E. Coli	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	9.2
Pseudomonas aeruginosa	<2	<2	< 2	< 2	< 2	< 2	<2

7.4.0 Maintenance Plan for the Junta de Saneamiento

7.4.1 Introduction of Maintenance Plan

This is a recommended maintenance program adapted from the “Preventative Maintenance Program Guide for Small Public Water Systems using Groundwater”. The purpose of this maintenance program is to improve access to potable drinking water across the community, reduce cost of the system for the Junta de Saneamiento, and ensure that high quality water continues to be provided to the Cerrito community. This plan gives recommendations of maintenance on a monthly, biannually, and annual basis. Examples of maintenance include water quality testing, pump inspection, and testing the operation of the system, as well as recommendations to prepare the Junta de Saneamiento for the future.

7.4.2 Monthly

On a monthly basis, there should be basic inspection of the wells and pumps throughout the Junta de Saneamiento. This includes responding to reports of leaking pipes throughout the community as well. These tasks tend to be based on observation and can be done by any member of the Junta de Saneamiento. These monthly tasks are important in order to make sure that basic parts of the system are working.

7.4.2.1 Inspection of Wellheads

Wells should be kept free of debris that could contaminate the well. The well covers should be visually inspected to make sure that any covers for the wellheads are still attached and free of cracks. This will reduce the number of contaminants that enter the well.

7.4.2.2 Inspection of Well Pumps and Motors

Efficient well pumps can help reduce the amount of maintenance needed as well as reduce energy costs. It is important to check if the controls of the motor and pump work, for example, turning off the pump and then turning it back on. Unusual sounds, smells, or heat coming from the motor may indicate that maintenance is needed.

7.4.2.3 Inspection of Pump House Electric Meters

For any wells that have meters, it is important to compare the electric meter at the pump house. These should be compared monthly to see if cost varies over time. An increase in electricity use could signal that the well pump is working harder, and not running at its usual efficiency. The pump could need maintenance.

7.4.2.4 Inspection of Water Leaks

A member of the Junta de Saneamiento should visually observe tanks and pipes to check for any leaking water. Leaking pipes not only make the water pressure much lower for the community, but also cause the Junta to have a higher electric bill to pump the amount of water that is needed for the community at a given time. It is important that leaks be fixed as soon as possible in order to save money and provide enough water pressure for the community. It is possible that these leaks also make it more likely for contaminants to enter the water supply.

7.4.3 Biannually

Biannual maintenance is to be conducted two times a year. Examples of this maintenance include a thorough check of water tanks along with operation of the well pumps. These recommendations allow for the longevity of the water supply system run by the Junta de Saneamiento. Biannual maintenance involves a lot of visual observation from a member of the Junta de Saneamiento.

7.4.3.1 Inspection of Pumping Rates from each pump

Flow rates of each pump into the storage tower should be checked twice a year. It is recommended that these be checked during times of high demand and times of low demand. The flow rate of the water pump can be determined through a simple bucket method. A large bucket should be graduated, having lines to specify the amount of water in liters. The member of the Junta de Saneamiento can time how long it takes to fill the bucket. If they know how full the bucket gets, they can divide it by the amount of time it took to determine the flow rate of the pump in Liters per second. This will show how much the pump can remove from the well at a given time. It also makes it possible to look into supply and demand of the water. If the flow rate is not enough to provide enough water to meet the demand, then the community will not have enough water. If the pump has declined in flow rate over time, it is another signal that the pump may need repairs.

An alternative method is the use of water meters. An inexpensive flow meter could be purchased for this purpose and connected to the primary outlet of the pump. This method may be less cumbersome than the bucket method, but it may require the use of various adapters to fit the outlet. The flow rate of water can be found by dividing the volume of water that went through the meter by the time it took for that volume to flow.

7.4.3.2 Check Cleanliness of Water Tanks

The insides of water tanks can sometimes accumulate algae or other matter. Algae can supplement the growth of potentially harmful bacteria in the water. The addition of chlorine to the water tank can kill algae and bacteria in the water, making it safe to drink.

7.4.3.3 Check Water Tanks for Leaks

Leaky water tanks could contribute to water loss within the system. In the case of leaking tanks, it is important to fix them as soon as possible to avoid increased expenses for the Junta de Saneamiento.

7.4.3.4 Check aesthetic of Water within Tanks

The aesthetic of water is very important to families within the community. Turbid water could cause alarm in the community due to looking dirty. Other aesthetic issues within water tanks could include odor and change in taste. This could be due to the growth of bacteria or increased sediments. Warmer water in the storage tanks due to the summer heat increase biological growth which could in turn increase bacteria within the water. Checking the aesthetic of water in the tanks could help the Junta de Saneamiento to decide if the water tank should be cleaned in the near or far future.

7.4.3.5 Operation of All Valves in the Well Houses

It is important that the valves within the well houses be checked. This is to ensure that all of the electricity within the well house is working properly, as well as any water valves. It is important for the Junta de Saneamiento to know that the system is working properly. If one tank is not safe for the community to drink, the Junta de Saneamiento should easily be able to stop the unsafe water from reaching the pipes before it is treated. If the valves work, and are checked biannually, then water can be shut off in cases of emergency.

7.4.4 Annually

Annual maintenance includes the testing of water quality as well as the maintenance of piping and valves within the system. While these could be done more than once a year, it is important to find recommendations for the Junta de Saneamiento that are affordable.

7.4.4.1 Water Quality Testing of Each Well

Water quality tests are important to do to ensure that the water that the Junta de Saneamiento provides is safe for the Cerrito community to consume. In March and April of 2018, a WPI project group did a complete set of home water tests on each well owned by the Junta de Saneamiento. The reports of these are shown in Section 3. Basic water tests determined levels of chlorine, pH, copper, iron, nitrates and nitrites. They also determined the presence of bacteria, pesticides, and lead. Test results outside of the “normal” range indicate by the test kits could be harmful for the community. Annual water tests can show that water is safe for the community to drink as well as show if there is any change in water quality over time.

7.4.4.2 Maintenance of Facility Piping

To improve the longevity of the pipes, metal pipes could be painted to prevent deterioration. Old metal pipes could also be replaced with plastic. An increase in the redness or turbidity of water may indicate that rust may be present, indicating that the pipes may need to be replaced. Since the water is typically slightly acidic, metal pipes will also not last as long as other types.

Metal components of pipes are also at risk for corrosion. Junctions should be inspected for leaks and corrosion. If there are any metal components, these could become rusted if left out in the humidity.

While most of the pipes are plastic and less likely to erode than metal, it is important to make sure that they are not cracked or falling apart. Valves within the well houses should be maintained in similar ways. Any broken components should be replaced.

7.4.5 Recommendations for the Future

7.4.5.1 Addition of Water Meters to Each Wellhead

It would be beneficial for the Junta de Saneamiento to add water meters to each wellhead. This allows for precise water usage to be determined in the community. would make it possible to determine water usage within the community. Then, as time progresses it may be beneficial to add more water meters, potentially to each household or community group. This way, families and companies could be charged for the amount of water they use. Larger companies and farmers use more water than a family of four, but they each pay the same amount. Meters would make it so that those who use more water pay more, while smaller families may end up paying less due to their water usage.

7.4.5.2 Completion of Water Pipeline Map

The WPI Water Team is currently working with Sr. Llanes to begin mapping water pipelines within the community of Cerrito. The goal of the team is to create a baseline schematic that can be expanded upon in the future. The team plans to begin by mapping the connections to the wells that are used the most within the community, Wells 1 and 4. However, it would aid the Junta to complete the map in order to understand the system more. Having a document to show future water board members would make it easier to make repairs and expand the system. It also would help the Junta de Saneamiento to decide where another well or water tank would benefit the community the most.

7.5.0 Structural Analysis of Indigenous Wells

7.5.1 Structural Analysis of the Well of Cerriteno San Francisco Qom

The water tower is made of a brick and mortar base and fiberglass water tank. The current system shows no leaks. The base of the tower is about 4.5 m high. The water tank itself is cylindrical. It is 3 meters high and 1.9 m in diameter, so the volume was calculated to be around 8510 L. The top of the tank was covered, but there was a square opening at the top that was about 30 x 30 cm. The water appeared to be relatively clear inside the tank, although there was some algae growth that seemed to be near the opening in the lid shown by the second photo. The water tank is supported by a hollow cylinder made of brick and mortar,

with a wall width of 23.5 cm. The base was about 6.3 m in circumference, so the diameter was calculated to be 2.0 m. Upon observation, the tower appeared to be structurally solid. The brick and mortar did appear to be dry and cracked in some areas, although cracks appeared to be minor and did not go through the tower wall.

7.5.2 Structural Analysis of the Well of Cerriteno Kael Sat Lecpi Qom

The water tower currently in place is approximately 11 m tall and made of cement. The water collection basin at the top of the tower is about 9900 L, although it has not filled recently. A 1.5 horsepower air pump is currently used to pump water from the 60-70 m deep drilled well to the tower.

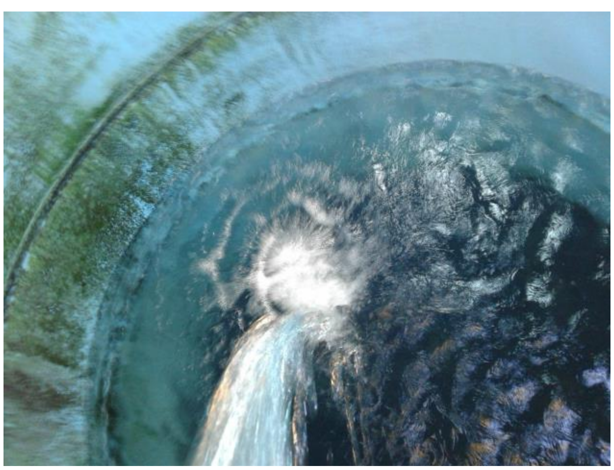

Figure 6: Water tank in the community of Don Francisco.

7.5.3 Structural Analysis of the Well-Tower System for the Río Verde Qom

The Río Verde Qom community led by Don Crispín Amarilla has used the water from the Junta de Saneamiento for about a year due to reasons that are not completely clear to the project team. The well pump has not been used in at four months, a value given to the team by the community leader. The water that comes from the well is turbid and may be undesirable to drink. It is assumed that there is no water being stored in the water tank. However, the WPI team met with a member of the Junta de Saneamiento to access the system. The Junta de Saneamiento contacted their electricians and together made an assessment. A replacement motor owned by the community was installed and water was able to be accessed from the well. The team was able to test the water and determine the flow rate of water from the well to be around 0.86 L/s. The quality test results were all within normal range, although turbidity was apparent, shown in Appendix A. Water was also tested for flocculation with aluminum sulfate. The particles did flocculate to the bottom when treated with aluminum sulfate, indicating a colloid suspension, shown below in Figure 4.

Figure 4: Water from Río Verde without aluminum sulfate (left) and with aluminum sulfate (right) after settling for less than 30 minutes.

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