Implementation – Pre-Trip Plan

Executive Summary	
Community:	Ait Bayoud
Country:	Morocco
Chapter:	Columbia University
Submittal Date:	6/28/2019
Authors:	Donald Swen, John Yatsko, Alice Wu, Nicholas Vallin, Leanne Pichay, Gabriel McCormick, Vanessa Hansen-Quartey, Justin Paik, Raayan Mohtashemi
REIC and other mentors:	Colin Barrett (REIC), Robert Prager (Geotechnical Engineer), Greg Scoby (Piping Engineer), Andrew Wedgner (Piping Engineer), Camille Rubeiz (Piping Engineer), Santiago Arnalich (Piping Engineer), Michael Conaboy (Civil Engineer), Sean Reischel (Civil Engineer), Ethan Cotton (Structural Engineer)
Scope of Work for the project (50 words) [1]	Design and implement a water distribution system for two villages in rural Ait Bayoud, Morocco. The project includes a well, solar powered water pump, HDPE pipeline, and water storage system.
Scope of Work for the analysis (100 words) [2]	This Implementation Pre-Trip Plan presents the designs, implementation schedule, and operation and maintenance plan for our solar-powered water distribution system, which is intended to provide clean water to the two douars of Ilguiloda and Izgouaren in Ait Bayoud, Morocco.
Proposed Next Step (100 words) [3]	We will continue working on securing suppliers and donations for project materials while the Final Implementation Pre-Trip Plan and Final Construction Safety Plan are being reviewed. Once we receive feedback from the review board, we will incorporate the feedback into our report as well. Zineb, our community liaison, is currently assisting with sourcing equipment in-country and is in communication with community leaders to coordinate meetings for when we arrive.
Describe Recent Contact with Community, NGO, and in country partners. (100 words) [4]	Primary contact was previously through the Peace Corp volunteers (PCVs) Keanna Cohen and Chris Bull who met with community members about once a month. The PCVs ended partnership with us in November. We are currently working with the Marrakech Rotary club.
Describe the Chapters current fundraising goals and milestones. (100 words) [5]	The program is on track to fundraise sufficient funds for the implementation. We currently have enough HDPE pellets for 6.5 km of piping donate by Borealis, which will be shipped free of charge to an extruder in Casablanca, called Plastima. Plastima has agreed to extrude the pellets to our specifications free of charge. We also received a sponsorship of $27,000 from Borealis for the rest of the project. We are working with

	local rotary clubs in both the US and Morocco to procure the rest of our budget through their grant process.
☒ [6]	**IS THE PROGRAM STILL ON TRACK TO MEET THE EWB PROJECT EXPECTATIONS?**

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

Project Timeline [1]			
Major Milestone	**Previous Date [3]**	**Current Date [3]**	**Description**
Program Adoption Date	12/23/12		
Previous Project in Program Date Constructed [2]	06/26/13		Foot Bridge in Ait Bayoud
Program Adoption Date	01/06/14		
Completed Assessment Trip	1/19/14		Survey of project locations
Completed Assessment Trip	8/23/14		Survey of project locations, bridge maintenance
Completed Assessment Trip	1/18/15		Drilled well, map piping routes.

Completed Implementation Trip	9/5/15		Began laying pipes and constructed chateau foundation
Completed Implementation Trip	1/16/16		Continued laying pipes, searched for leaks
Completed Implementation Trip	8/5/16		Laid pipe, installed well pump, televised inside of well, first time pumping water
Completed Implementation Trip	1/14/17		Piping pressure testing, bridge maintenance
Completed Implementation Trip	8/22/17		Bridge maintenance, installed temporary distribution site
Continued Implementation Trip	12/27/17		Trip to complete data collection and hydrogeologic assessment for onsite well.
Completed Implementation Trip	7/15/18		Checked for leaks in pipeline, discussed alternative power sources w/ community
Planned Implementation Trip	Not Previously Planned	7/16/19	Install solar pumping system,, lay down new pipeline from well site to Izgouaren (via Ilguiloda/Chateau site), construct two concrete tanks, construct a tap at both Izgouaren and Ilguilouda.
Planned Continued Implementation Trip	Not Previously Planned	7/14/20	Monitor and evaluate usage of Chateau site and condition of water distribution system. Finish burying the pipeline. Implement filtration system depending on results of water quality test.
Planned M&E Tip	Not Previously Planned	12/27/20	Conduct further maintenance if necessary on any joints.

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The construction of the spigots is not contingent on any other part of the project. However, the testing is set to occur towards the end of the trip in order to ensure that both piping and power have been secured, so that we can test the entire pipeline from chateau to spigot. As a result, ample time is left for this area of the trip so there is leeway for us to fix any major issues that arise. The critical path for the spigots themselves is: 41

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1. Project Description

1.1. Project Background and History

1.1.1. Inception

The Morocco Program began in 2011 when the Columbia University Chapter was contacted by Nina Morency-Brassard, a Peace Corps Volunteer stationed in Ait Bayoud. This initial connection brought our program in touch with the ABDA and laid the foundation for our collaboration. In the summer of 2013, the program completed a bridge project in this community to connect the North and South areas of the community during the flood season. The water supply project began in July 2013, shortly after the bridge was completed. There have been two assessment trips for the water supply project. Initially, during January of 2014, the team gathered information about the demand for water in each dwar, performed water quality tests, performed site reconnaissance, and recording flow rates of a nearby spring and river. Next, during the August 2014 trip, more detailed assessment was done in regards to determining a well location, meeting with a groundwater hydrology professor, meeting with well drilling contractors, and sourcing materials for the project. CU--EWB has progressed on implementation of the Ait Bayoud water project over the past four years. In January 2015, with the permission of the official government representative of the community Rais el Madi, a 140-meter-deep well was drilled and cased approximately 2 miles northwest of the nearest dwar (Figure 1). The well was constructed by the Moga Building Drilling Company and is located on the private property of a community collaborator.

Figure 1. Map of key project locations.

1.1.2. 2015 Assessment

In 2015, a memorandum of understanding and a land easement were drafted and signed by the community collaborator (Mohammad) to ensure that the well remains a public resource.There have been no major contaminants of concern detected in the water. However, more rigorous tests will be needed to meet full compliance. In preparation for installing the temporary water tanks, the project team has laid a concrete foundation at the tank site. CU--EWB has also constructed approximately 4560 feet of 2” diameter galvanized steel pipe between the water tank location and the well site. The pipeline is not buried because trench excavation was deemed not feasible. In January 2016 , a gravity pressure test which required no additional pump pressurization was conducted which showed several leaks.

1.1.3. 2016-2017 Implementation

The following trip in August 2016 was dedicated to the reconstruction of the pipeline tested in January 2016 and used a new piping procedure that utilized a combination of piping sealant (i.e. pipe dope) and Teflon tape in place of the previously used Teflon tape only procedure. To date, 2360 feet of piping has been laid from the well site towards the chateau and 2200 feet of piping has been laid from the chateau towards the well site. Much of this piping was done in partnership with the community, which has shown great initiative in leading and teaching new workers the correct pipe laying procedure. The August 2016 team also televised the inside of the well and installed the purchased well pump in hopes of performing a step-drawdown test on the well. However, issues around faulty flange gaskets purchased in Morocco delayed the testing schedule significantly. Water pumped from the well was more turbid than in the year prior. The August 2016 trip also saw the completion of an electrical building built at the well site by the community. The community president, the Rais, has promised electricity to the site upon completion of the electrical building. The next trip, in January 2017, included running the pump almost continuously for approximately five hours in an attempt to develop the well and assess the quality of the water. Local residents connected the HDPE pipe at the outlet of the well to their own pipe in order to get the pumped water into ponds lined with plastic tarps. This water was given to locals to use for washing and livestock, but not for human consumption. The turbidity of the water, measured using a turbidity tube with a Secchi disk, varied over time. Turbidity data and other water quality data were collected. Water samples collected from the well, the Tagawowt River, and a spring which arises from the same aquifer as the well were tested for nitrates, phosphates, turbidity, salinity, conductivity, dissolved oxygen content, and pH. The geological formations along the riverbed between the bridge and the spring were photographed and documented. The purpose of this is to compare the elevations and slopes of the formations to the location of the well and deduce what the formation at the well is like. Samples were also brought back to Columbia University for further information on particle size and density. No permanent components were installed during the January 2017 trip. In August of 2017, our program constructed a temporary water distribution site.

1.2. Project Context

Ait Bayoud is a rural agrarian community in the Essaouira province of Morocco. Izgouaren and Ilguiloda are two of the poorest towns in this community. In the nearby Atlas Mountains, seasonal rain rapidly floods the Tagawowt river, the normally calm central water source for Ait Bayoud. Ait Bayoud is made up of twelve douars, or communities. Amongst these douars, there are two relatively isolated communities, Izgouaren and Ilguiloda, located 85m and 220m above the river level, respectively. A water supply, storage, and distribution system currently exists in the main douars in Ait Bayoud, but Izgouaren and Ilguiloda are excluded due to their remote location and lack of a nearby, year-round water source. Thus, to satisfy their water demands for daily needs, the communities we are trying to serve have to gather water from a spring located in the riverbed. This requires slowly hiking up and down a plateau an hour each way multiple times a day in order to get the water they need. The time dedicated to gathering water is largely the responsibility of women and children. Consequently, the growth and progress of these communities are stalled as other necessities, such as healthcare and education are not given the proper attention. Currently, between the two communities, only one child attends school on a regular basis. Initial tests of the quality of the springwater indicated the presence of fecal coliform, likely due to the fact that the community members's livestock also drink from the spring and defecate nearby. This finding is consistent with the fact that the main issue that the community hospital treats is gastrointestinal illness.

1.3. Project Goals and Objective

The goal of the Water Supply project is to provide a sustainable source of water for two remote douars (communities) within Ait Bayoud, whose residents currently have to travel up to four hours a day to a spring to collect water. Both Izgouaren and Ilguiloda are on plateaus that are 85m and 220m, respectively, above the river level. The goal of our project is to provide them with an easily accessible water source. Through providing accessible water, we hope that the project will improve education rates among the children, since they will no longer have to support their families by collecting water.

1.4. Scope of Work

The purpose of this Columbia University EWB Morocco project is to provide a sustainable source of clean, easily accessible water that the communities of Izgouaren and Ilguiloda can use on a daily basis for all their water needs, including drinking, cleaning, bathing, domestic work, and providing for domestic livestock. This project was executed from 2014-2018 in collaboration with the United States Peace Corps, an organization that we have successfully used in the past on a prior project in Ait Bayoud, Morocco.

By providing a clean and accessible water source in each community, our project hopes to give the women and children of Ilguiloda and Izgouaren more time to pursue other priorities instead of collecting water for hours each day. Potable water will greatly improve the community's health by reducing their exposure to bacterial illnesses. Bringing water to the communities will also eliminate water collection responsibilities from being a barrier to children attending school regularly.

The water supply system we envision will distribute groundwater from an aquifer. The water will then be pumped through a piping system to a centrally located water storage tank and distributed by a gravity fed pipeline to the two communities. Based on previous assessment trips and past attempts at constructing a similar system by the community, we believe that the Columbia University EWB Morocco Program is ideally suited to learn from these experiences and design a sustainable water supply system that the community can use.

1.5. Summary of Alternatives Analysis

The alternative analysis examined five alternatives for the pipeline, two alternatives for the tanks, and three alternatives for the power source. For the pipeline, the options considered were the galvanized steel pipeline already started, an on-grade 2% carbon black plastic pipeline, a buried pipeline, an elevated pipeline, and hiring an in-country contractor to build the first part of the pipeline from the well to the chateau. The on-grade pipeline was determined to be the best alternative because of its feasibility and affordability. Just to review the feasibility aspect, 2940 m^3 would need to be excavated for a trench. There are 370 community members. Supposing boulder mix at best takes 1.1 man-days per m^3, 32 working days would be needed for 100 members. A fair wage must be paid for such a long period of time ($33,000). The system comes at the cost of warm water and greater vulnerability to theft and environment. The vulnerability needs to be mitigated by creating a stronger sense of community ownership of the project. PE4710 was originally determined to be the most cost-effective material for the pipeline due American sponsorship. However, we received an offer of PE100 piping from Borealis, which we ultimately chose, since PE100 is the local piping available in Morocco.

For the tanks, the materials considered were concrete reinforced and linear polyethylene. Ultimately, reinforced concrete was chosen for the tanks because (1) we believe there will be enough time during the implementation trip to build them; (2) concrete is easier to maintain; (3) concrete will be needed to construct the pressure break tank anyway, and (4) reinforced concrete is significantly cheaper over the lifetime of the tank compared to plastic. Plastic tanks also tend to heat more easily under the sun, which leads to easier development of bacteria and plastic degradation if not properly shaded.

For the power source, the options considered were extending the nearest three-phase power line in Tinilift to the well site, and replacing the current pump with a Lorentz PSk2-9 C-SJ8-44 solar pump and pump controller, along with solar panels. It was concluded that while we would like to go forward with extending the power line if possible, communications with those that must give the required approval for us to extend the power line have been very difficult and delayed. Thus, we will be going forward with installing the Lorentz pump and solar panels. This will ultimately create a more sustainable system.

1.6. Project Team

The project team consists of student members of the Morocco Program in Columbia University's chapter of EWB, led by project managers Vanessa Hansen-Quartey and Alice Wu and piping team leads Donald Swen and Nicholas Vallin; REIC Colin Barrett; mentors Santiago Arnalich, Robert Prager, Larry Bentley, Tim Bowden, Camille Rubeiz, Greg Scoby, Andrew Wedgner, Michael Conaboy, Sean Reischel, and Ethan Cotton; and faculty advisor Mohamed Haroun.

1.7. Community Partners

The Ait Bayoud Development Association (ABDA), a local group of community leaders, is a pre-existing association dedicated to improving infrastructure in the region. The association has now been expanded to involve the water committee created and centered around the fulfilment of the water distribution system, the Ait Bayoud Water Association. A memorandum of understanding between our organization and the Ait Bayoud Water Association, along with the local government, was signed that describes the roles of each organization for the project. The memorandum expires in one year, so we have drafted a new memorandum for Omar, the president of the water association, will sign.

Zineb Kouhel, a friend of PCV Keanna Cohen who traveled with us in Summer 2018, has been aiding with preliminary work and communications with community members that needs to be completed before travel team arrival this summer. She will also accompany the team during the trip as a language translator and a community liaison. She is from Hanchen, 13km away from the community.

We are in the process of establishing a collaboration with the Marrakech Majorelle Rotary club. The Rotary club will send one or two volunteers to visit the project site during our trip and help organize an educational program for the women in the community, since the women will regain several hours of free time that were previously spent on collecting water. The Rotary club will continue the community educational program after the end of the implementation trip.

1.8. Reference Projects (Conducted by EWB-USA)

CCNY Honduras Project

In 2012, the CCNY Chapter of EWB conducted a water distribution project in the Milla Tres Community of Honduras. A previous water distribution system existed, but the spring from which it was sourced was made inactive by an earthquake; leaving the residents at the lower part of the village to source from a different source and the people at the top without water. An alternatives analysis was conducted for the system type, possible sources, tank location, pipe route, conduit materials, dam materials, tank materials, and treatment and filtration options. It was determined that a gravity driven system would be best, with the tank foundation made of concrete and the conduction line being made of PVC with steel and cast iron sections. The community's piping route was chosen and the water management system would include a chlorine treatment. The team was met with problems such as designing their system to withstand major rainfall and the elevation change. These problems were solved by designing a spillway for the water containment site and by using a piping route recommended by the community that mitigated extreme elevation change.

Boston Professionals Honduras Project

The Boston Professionals EWB Chapter conducted a water distribution project in the villages of Colonna, Maraquito, Aguacatillo in Honduras. The system had many issues such as pipe deterioration and that it did not reach many communities far from the source. Since the communities did not have enough money to extend the pipeline to their area, they were only able to collect water from these far away areas. Some alternatives that were considered were 1 tap stand shared by 3 villages, a tap stand in each village, a tap stand and tank in each village, and household delivery. The preferred alternative was the single tap stand for the 3 villages because it is easiest and cheapest to construct, it is in a central location to the 3 villages, and it is key to the construction of the other alternatives.

EWB Engineering Service Corps

EWB Engineering Corps has partnered with water engineer with CH2M based in Chicago to repair half a dozen water pumps in Ethiopia. Villagers didn’t have a choice but to walk for six hours every day in order to collect water in tanks that they would then carry on their backs. The villagers did not have the proper tools needed for the maintenance and repairs of the hand pumps, which could have caused severe injuries or dropping the water pump in the well. In one instance, the community had previously tried to raise a 150-foot column of pipes, but the pipes fell back into the well. The Engineering Corps repaired the pumps, preventing their fall in the well.

2. Design

2.1. Description of Existing Infrastructure

The current water distribution system consists of a 140-meter-deep well approximately 2 miles northwest of the nearest dwar (see Figure 1 on page 6) that was drilled and cased in January 2015. The well was constructed by the MogaBuilding Drilling Company. The well is located on the property of a community collaborator A memorandum of understanding as well as a land easement was drafted and signed by the community collaborator (Mohammad) to ensure that the well remains a public resource. Initial data along with past hydrology studies of the region indicates that the water supply is potable. More rigorous tests will be conducted on this trip.

1390m of 63mm diameter galvanized steel pipe has been constructed between the well and chateau site. The pipe is installed in a shallow trench and encased in concrete at two road crossings but is mostly installed above ground. The majority of the pipeline is not buried because the rock and soil is too difficult to excavate. Foot traffic and livestock can easily step over the pipe as the dirt and rocks covering the pipe are only 15-20cm above grade.

In Summer 2015, a concrete foundation was laid down at the tank site. The August 2016 trip saw the completion of an electrical room built at the well site by the community and the installation of a purchased pump. No permanent components were installed during the January 2017 trip. The pump was run continuously to develop the well and assess the quality of the water. Water samples were collected for turbidity and other preliminary water quality data.

On the most recent trip in Summer 2017, a settling tank (1500 L) and storage tank (1000 L) were installed as a small scale temporary distribution site, which was intended allow the community to begin accessing water in a limited capacity once the nearby power line is extended to the pump on this trip. The settling tank was designed to address turbidity, allowing water usage for purposes outside of human consumption, such as for livestock. However, since the Rais has yet to arrange for the extension of the power line, the temporary distribution site has been used and is falling into disrepair.

2.2. Description of Proposed Facilities

2.2.1 Spigots

We will be constructing four tapstand sites, two at Izgouaren, and two at Ilguilouda. At both locations, we will have one domestic tapstand and one tapstand dedicated to livestock water. The domestic water sites will include slab at a slight slant on which two taps will be fixed. This slab will be surrounded by a curb of 0.3m There will be a slight depression of 0.03m occurring at a slant, leading to a hole in the curb, allowing for any water water to flow out of the facilities and into a community garden. In order to maximize the nature of these sites as a communal center, this garden will serve as a bridging point between the tapstands and a laundry station. This laundry station will be constructed by the community according to a design that we have prepared, including space for both steps on which people can do their laundry sitting down, as is done traditionally, or a standing fixture. If time does not permit this, our alternative design would be to just have a slab in place of this, still creating a space for communal laundry or other activities. See diagram in Attachment A for further details.

In order to separate domestic water use from livestock water use, we propose to have a separate tapstand space for livestock water. This will include one freestanding tap, as well as one tap that will lead into a trough that animals can access directly. If the community wishes to have this trough, we would encourage that to be part of their responsibility in constructing it.

The piping in spigots themselves would be galvanized steel, as it is more readily accessible in-country; tapstands take a lot of abuse; and it will be easier to replace. Additionally, each valve will be accessible through a valve box, in order to ensure that replacement is made possible. For the valves lying underneath slabs, valve boxes will be built into the slab prior to the concrete pour. We also plan to attach hose fittings to each faucet to prevent damage caused to the taps from people hanging buckets off of the overhang—a problem encountered by team members on previous EWB projects. To protect the upright pipes of the taps, each tap will be cast in concrete, using a 90mm PVC pipe of the same height as a mold. Check valves will be introduced at each tapstand to prevent cross contamination.

These facilities will mitigate problems identified in earlier stages by providing a direct access point for communities to get water, at a much shorter distance from their towns. This would save significant amounts of time for the community members, and would significantly reduce the travel time to collect water. We have ensured this by designing the water flow and number of taps available at each site to match the quantities of water that each community described themselves as needing, hence ensuring that our tap designs are community centered. See the minor losses sheets of Attachment K for hydraulics of tapstands.

2.2.2 Storage Tank

We will construct a reinforced concrete water storage tank on the reinforced concrete slab which was placed by a prior EWB-CU team. The tank will be approximately 29 feet long, 15 feet wide, and 8 feet high. It will have 51,432 liters of water storage capacity and 26,125 liters of water settling capacity.

The tank will be located at the top of a hill, between the pump and the break pressure tank, several kilometers from both Izgouaren and Ilguilouda. It will store enough water for two cloudy days and provide a minimum detention time of three hours for particle settling.

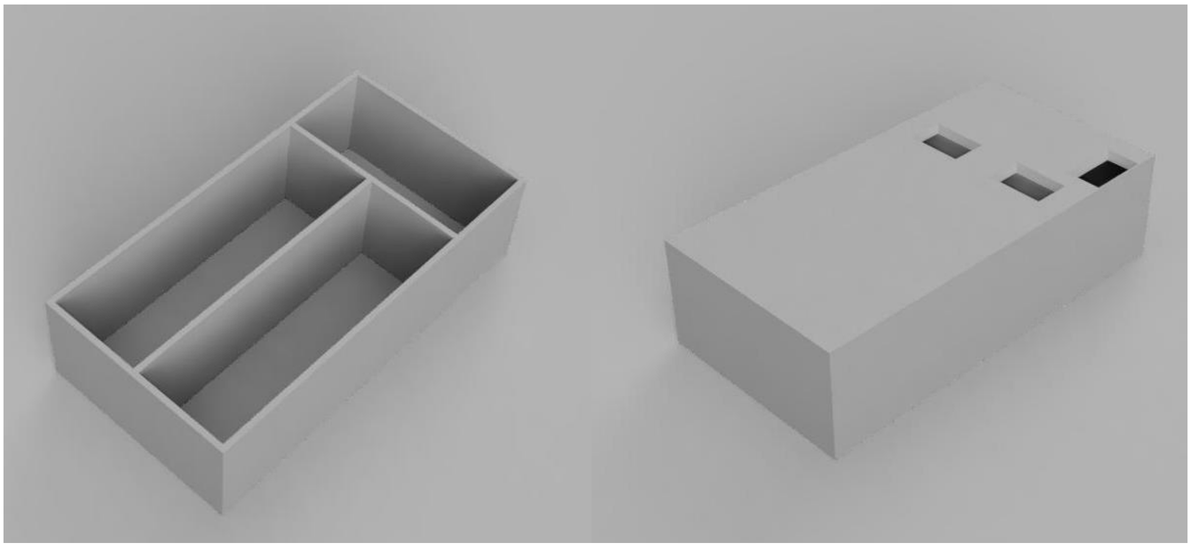

Figure 2: Storage tank with three compartments. The three manholes in the roof will be closed with a steel lid. Does not include openings for pipes. See Attachment A for CAD drawings of the formwork and rebar placement.

2.2.3 Break Pressure Tank

A 0.7 m^3 cylindrical ferrocement tank will be constructed to reduce pressure to atmospheric pressure between Ilguilouda and Izgouaren (see Attachment A, page 14 for location). The tank will be 0.9m high and 1m wide, with a carrying capacity of 705 L (Attachment A for visual depiction and Attachment Q for design calculations). A water and cement sealant will be applied on the interior to prevent leaking. A float valve will prevent drainage when water is not being used. Last, a lid secured with a lock will grant maintenance accessibility within the tank.

2.2.4 Pipeline

We will construct an on-grade 50mm, 63mm, and 90mm PE100 pipeline, dimension ratio (SDR) hybrid of 11 and 17. The pipe will follow along the road from the drilled well to the Chateau site and run parallel at a distance to the electrical line path from the Chateau site to the two villages. The pipe will lie in a 0.7m wide, 0.1m depth, sand bed free of point loading. This shallow trench will provide ample space for the pipeline to thermally expand and contract freely. A 0.1m depth will keep the pipe within the trench, which is specifically cleared of point loading. The sand will retain the trench's shape over time. The pipe will be zig zagged for a 73m section up towards Izgouaren. All control valves will be flanged and connected using MJ adapters. Air release valves will be installed at high points. Pipe will be buried at trafficked areas in village network and encased in larger diameter GI pipe at road crossings. During installation, pipe will be snaked within the trench to account for thermal contraction and expansion. See Attachment A for pipeline route and zigzag section, Attachment K for full pipeline hydraulics, and Attachment M for itemized pipeline components in sequence of installation.

2.2.5 Solar Pumping System

We will be installing forty solar panels and a Lorentz PSk2-9 C-SJ8-44 solar pump and pump controller, along with the necessary accessories to provide water for the communities. Currently, solar pumping is the most viable power solution, since the team has continued to have difficulties communicating with the community members in order to have a powerline extended, which was the original plan. The solar pump will replace the current Lowara pump in the borehole that we previously drilled, which is located on community member Mohammed's land. A cast iron well seal with will be installed to keep out debris, contaminants, and insects. The well seal will have an outer diameter of 30 cm, a 50 mm drop pipe hole, a vent pipe hole, and a cable hole.

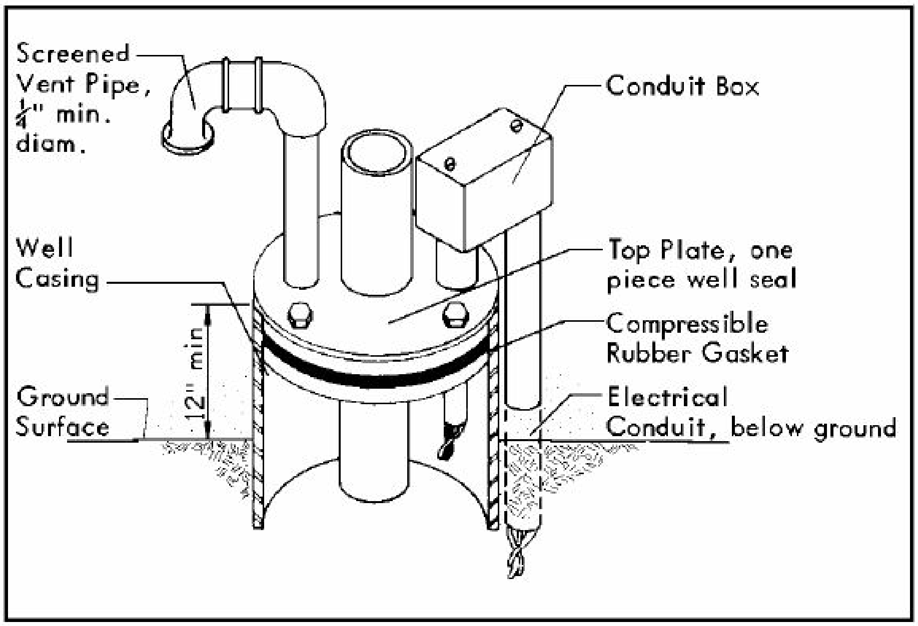

Figure 3: Diagram of well seal installation. The only difference in our installation is that the cables will not be underground, but rather, will follow the bottom of the piping into the electrical room.

The pump controller will be housed inside of the electrical room that was previously built. The room will be secured with a lock. The dimensions of the pump controller are 500 mm x 320 mm x 226 mm.

The solar panels will need to be installed next to the pump, also on Mohammed's land. We hope to discuss a new land easement agreement with Mohammed as soon as community contact is re-established. In the worst case scenario, we would have the land easement agreement signed at the beginning of the implementation trip. We believe that Mohammed will agree to the land easement, since he will benefit from having easy access to his own tapstand next to the well.

The solar panels will be mounted on a large steel rack, which will be welded together on site by a local metal worker (who will be provided with no. 11 lens welding helmet). This structure will be built to hold the solar panels at a tilt of 31 degrees from the horizontal. The dimensions of each solar panel are 1640 mm x 992 mm x 35 mm. The width of the structure will be 4 meters, the length will be 18 meters, and the height at the high end will be 3 meters. The rack will have four 18m slots in which strings of 10 panels will be slid. Each panel will be fastened to the rack by four screws. A 4m x 150mm x 12mm steel plate will be welded to one end of the slots so that the panels can only be removed from the other end. On the unsealed end, a similar 4m x 150mm x 12mm plate will be pinned at the lower end of the rack and locked at the upper. This locking gate will be free to move like the blade of a paper cutter, where all 40 panels will be locked in place when the gate is closed. As this anti-theft system is designed, the only way to steal the panels will be to unscrew each panel from the steel rack and cut the lock, which will be located 3 meters off the ground.

The structure will be composed of 50mm x 100mm x 9mm thick rectangular tubing, 75 mm x 75 mm x 6mm thick W members, and 75 mm x 35mm x 6mm thick C members. The W members will form 18m long slots for the panels and will be welded to the rectangular tubing. The rectangular tubing and C members will be bolted together to form trusses. The front legs of the rack will be embedded in concrete cylinders 500mm in diameter and 500 mm high. The rear legs of the rack will be embedded in concrete cylinders 1m in diameter and 1m high.

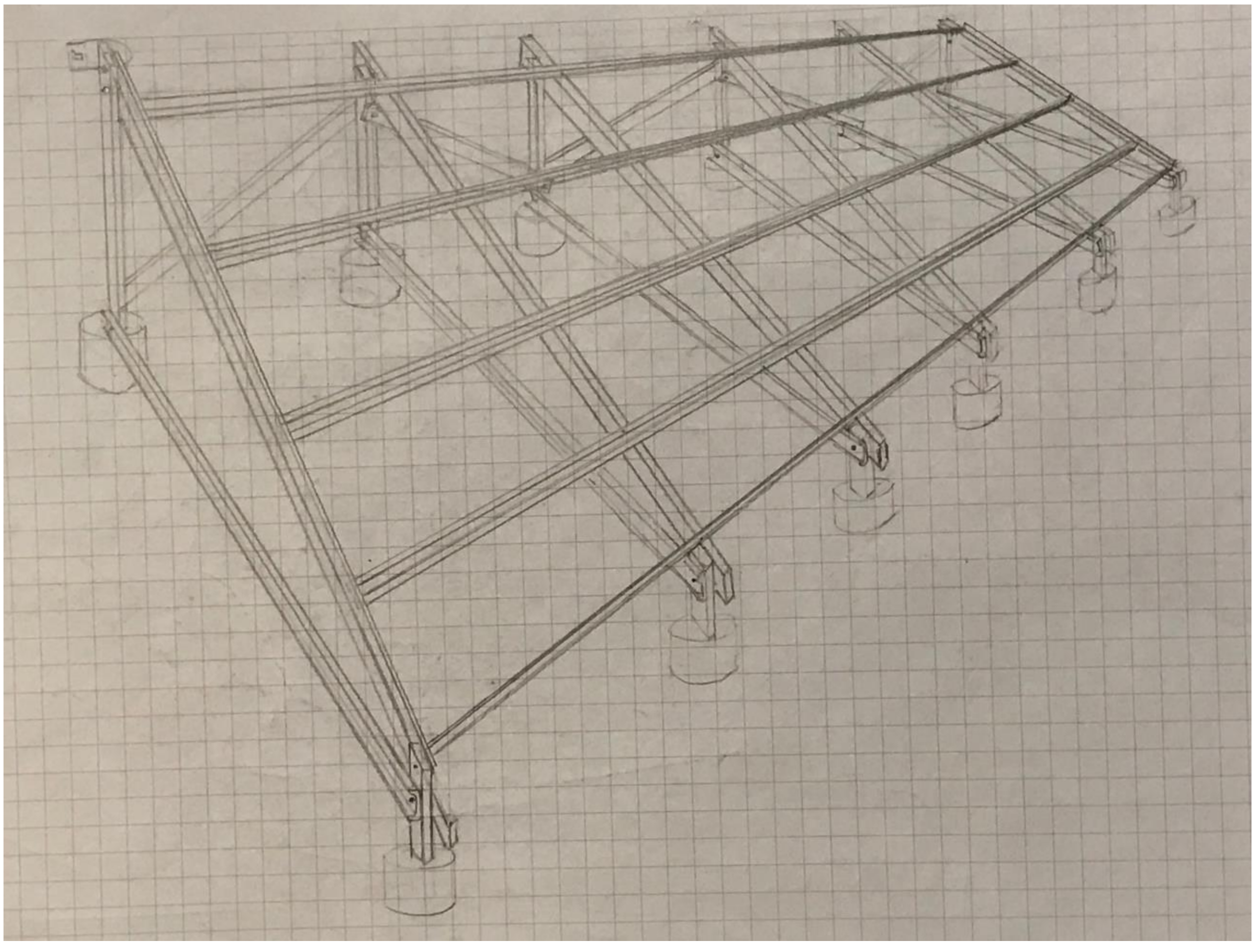

Figure 4. Sketch of the steel structure that will hold the solar panels. Ten solar panels will be slid into each row and screwed to the horizontal W members.

2.3. Basis of Design

2.3.1. List of standards, codes, and assessment data

2.3.1.1 Community Water Demand Survey (Attachment I)

In 2014, the team conducted a water demand survey of the two douars (Attachment I), which gave a daily water demand of 47,000 L for a population of 370 people. The survey asked each household to estimate how much water they collect each day in total and breaking down into human consumption versus livestock consumption. For each douar, we then took a weighted average of the total household water estimates weighted by the number of people in each household to obtain an average per person water demand for each douar. The average water demand for each douar was multiplied by the population of each douar to obtain the total water demand for each douar. Summing these two totals gave us the final water demand of 47,000 L per day.

The water demand was reassessed in 2019. Upon closer examination, there are outlier data points where in one, each member of the household consumes 140 L/day and in another, each animal consumes 37 L/day. Replacing the skewed data with averages provided by the World Health Organization (WHO), the demand decreases to 35,000 L per day.

Additionally, we considered the effects of population growth to calculate a projected water demand in 25 years. An exponential growth model was applied to a population of 370 with an annual growth rate of 1.5%[1]. In 2044, the population is expected to be 538. See attachment I. The current population is taken to be 370. Recent conversations with community members reveal a declining population due to people leaving for better opportunities elsewhere. Therefore we took the population to be the same as when initial population survey was conducted in 2014. Designing for a projected population is important because access to clean water will likely curb population decline and lead to population growth.

Five water demand models were created based on different standards. See Attachment I for full detail and assumptions made.

	Design (25 years)			Current			Overall
Model	Domestic Use (L/day)	Livestock Use (L/day)	Total Usage (L/day)	Domestic Use (L/day)	Livestock Use (L/day)	Total Usage (L/day)	L/day per capita
Base - minimum	10766.9	27968.5	38735.4	7400.0	19222.4	26622.4	72.0
Community Surveys	30354.5	38060.0	68414.4	20862.3	26158.2	47020.5	127.1
Community Surveys - fixed	16441.1	35282.2	51723.4	11299.8	24249.1	35548.9	96.1
Ideal System	24225.6	27968.5	52194.1	16650.0	19222.4	35872.4	97.0
Sphere Standards			48451.2			33300.0	90.0
Our System	13458.7	27968.5	41427.1	9250.0	18500.0	27750.0	77.0

As a base reference, 20 L/day per person is the minimum[2] to cover sanitation and domestic water needs. Our water system can provide 10,800 L/day and be complete. However, our population is unique

[1] Jordan, T. D. (1984). *A handbook of gravity-flow water systems*.

[2] World Health Organization (WHO). (2004). Minimum water quantity needed for domestic uses. *WHO Regional Office for South-east Asia: New Dehli*.

due to its large livestock population. To provide for greater livelihood and opportunities for small business and crop growing, we decided to provide 25 L/day per person as a basic water right that will cover domestic use and any excess can be purchased through schemes to be discussed with the community.

To size the excess, we decided to provide 52 L/day per capita to be used towards livestock or growing trees. This number was sized by modeling animal population and how much water each animal consumes per day. This brings a total per capita water supply to 77 L/day. For reference, the Sphere Standards regards a supply of more than 70 L/day per capita as fully satisfying all domestic water needs (drinking, cooking, growing food, sanitation/waste disposal) with enough water for business and recreation.

For further comparison of the validity of this model, our system satisfies 79% of community reported demand and 384% of the bare minimum of 10,800 L/day.

To summarize, we believe 77 L/day per capita will provide enough water to satisfy current water needs and enable greater opportunity for these two communities. 25 L/day per capita will be allocated as a water right to each individual. The rest of the water can be purchased by community members through a permit system for additional domestic, livestock, and/or agriculture needs (see Section 6.4 for details of how the water will be divided among community members).

2.3.1.2 Spigots

The design for the spigots was largely human centered due to the fact that they serve as the interface between our system and the community. For example, the decision to make the taps 1m tall was made to make them accessible to people of all heights. The use of hose fittings was to accommodate for containers of all sizes and prevent damage to the taps. The slabs that the domestic spigots are situated is going to be at a 3.8% angle to allow water to runoff. This will be sufficient to ensure that water does not pool directly under taps.

The design was also made as versatile as possible to account for the likely possibility that, in open forum with the community, changes are requested. For example, the laundry station is an aspect that is almost entirely up to community input, and the number of taps can be easily changed due to the fact that no one tap depends on another.

2.3.1.3 Storage Tank

- EWB regulations require no concrete to withstand more than 1250 psi of compression stress.
- ACI 347-04 stipulates that a design fluid pressure of 600 psf may be used for poured concrete if the rate of placement is less than four feet per hour.
  - Concrete must not be vibrated more than four feet deep.
- ¾” plywood must be used in forms, supported by 2”x4” studs spaced every 12”.
- Double wales must have a center gap between ⅝” and ¾”.
- The safe working load for snap ties is 2250 pounds.
- By ACI 318, concrete cover must be 3 inches for surfaces permanently exposed to earth, 2 inches for surfaces exposed to weather, and .75 inches for interior surfaces not exposed to weather.

2.3.1.4 Pipeline

Pipeline installation will be in accordance with ISO 21307:2017. All pipe specifications are in accordance with ISO 4427-1 2007 & 2015. Compression fittings will adhere to ISO 14236:2000. All assessment elevation data taken from Google Earth Pro and will be verified manually using an Abney level.

2.3.1.5 Electrical Wiring

Copper wire resistance values were based on IEC 60228 for Class 2, stranded conductors. Current ratings were based on IEC 60364-5-52 (2009).

2.3.2. Design Methodology

2.3.2.1. Spigots

Google Earth Pro was used to determine the locations of all spigots, to ensure that the locations we chose were accessible to all. Technical drawings were completed in AutoDesk Fusion 360. The idea to cast the PVC pipes in concrete came from a report entitled “The Design, Construction, and Maintenance of a Gravity-Fed Water System in the Dominican Republic” by Matthew A. Niskanen.

A curb around the taps themselves was included to discourage livestock crowding the taps, and ensure that the space around the taps is free for domestic use. The spaces around the taps, including the garden and laundry area, were created in order to encourage the use of the space as a community center. See Attachment A for technical drawings and CAD for the spigot stands.

2.3.2.2. Storage Tank

For the flat, reinforced concrete roof of the tank, each 12” section was designed as a beam spanning the shortest distance between parallel walls. The beams are designed to account for various boundary conditions (fixed supports and pin supports). Beams were designed by transforming the cross-section area of steel reinforcement to an equivalent amount of concrete, solving for the neutral axis, and then solving for the maximum stress in each material. Similar calculations were carried out in the walls to resist the hydrostatic pressure.

The wooden forms were designed to resist a maximum fluid pressure of 600 psf for the poured concrete (where the placement rate does not exceed four feet per hour). Beam calculations were also carried out to check that the wooden ceiling joists could hold the weight of the poured concrete roof.

Fusion 360 was used to draft the tank and forms. Google Sheets was used for the design calculations. The sheet is coded in such a way that any change to a measurement automatically updates the rest of the sheet. At the top of the sheet is a Safety Check, included below, which alerts us in the event that an alteration to the tank designs causes an unsafe design. For example, if the tank height were doubled, the table would alert us that the concrete and steel in the walls are no longer strong enough to resist the hydrostatic pressure. It would also indicate that the epoxy anchors would fail.

Safety Check	
CHECK: Is concrete in roof strong enough?	yes
CHECK: Is steel in roof strong enough?	yes
CHECK: Is concrete in walls strong enough?	yes
CHECK: Is steel in walls strong enough?	yes
CHECK: Is horizontal wooden beam in roof strong enough in bending?	yes
CHECK: Is horizontal wooden beam roof strong enough in bending?	yes
CHECK: Are epoxy anchors strong enough?	yes

2.3.2.3. Break Pressure Tank

An excel program was created to analyze stresses of different geometry ferrocement tanks. Equations for stress and bending moments come from Stresses in Shells by Wilhelm Flugge. Design of Rainwater Storage Tanks for use in Developing Countries by Stephen Turner was referenced for material constants and design methodology. The essential structural calculations are in Attachment Q. Fusion 360 was used for CAD drawings, as shown in Attachment A. ACI codes were followed.

2.3.2.4. Pipeline

Google Earth Pro was used to extract elevation and geographical data. Excel was used to create spreadsheets that update a hydraulic grade line given certain parameters. Hydraulic grade line was created following *How to design a Gravity Flow Water System* by Santiago Arnalich. The Handbook of Gravity-Flow Water Systems for Small Communities by Thomas D. Jordan Jr was followed as a reference for establishing workflows. The second edition Handbook of PE Pipe by the Plastics Pipe Institute was heavily referenced to calculate friction losses for fittings and general knowledge. Occasional surges and water hammer was verified using an in-house MATLAB program which also contains useful equations regarding beam theory, bending stresses, thermal expansion.

Excel sheet holding all hydraulic calculations can be found in Attachment K. Minor head loss due to valves and fittings was calculated to ensure adequate head of at least 10m at each tap. Natural velocities due to gravity was calculated to understand flow in each segment of the pipeline. Last, each segment or reach of pipe is checked for maximum pressure to ensure proper selection of piping.

2.3.2.5. Solar Pumping System

The pump curves were extracted from Lorentz specification sheets using WebPlotDigitizer. The system curve data points were taken from our mentor Colin Barrett's calculations. Using Microsoft Excel we created a model to determine the hourly water output of the solar pumping system for every day of the year. The line diagram of the solar pumping system was made with Microsoft Visio.

2.3.2.6 Solar Rack

The solar structure was designed to account for the dead load of the structure along with wind load, as calculated by ASCE 7-10 Chapter 29. The design wind pressure normal to the panels in both directions was taken to be 1.26 KPa (26 psf). The steel beams were designed to account for this uniform load. The concrete anchors were then sized to resist the significant overturning moment from the wind load.

2.4. Calculations

2.4.1 Spigots

To calculate the flow rates, we used assumptions from a study in Bolivia[3], stating that 65% of the water in a community is used in the morning. This study was taken from an area in Bolivia with a similar socioeconomic, rural climate, as well as with similar climate. Hence, we found it applicable as a model to implement for our design. As this was the most pressure the spigots would be under, we used this time frame to calculate the flow rates at each spigot. We assumed that morning would be 3 hours long.

[3] https://issuu.com/arnalich/docs/ligraven

We used methodology from Niskanen's report[4], referenced above, to calculate the flow rates. In the paper, the total demand for water is divided by time frame during which water is to be collected. This rate is converted into L/s to ultimately give the flow rate that needs to be available to meet these needs. We used the 3 hours of morning as our time frame, and took 65% of the total demand for water, separated into livestock and domestic uses, in order to come up with the following results.

Design (25 years): Morning Rush	Village	Water collecting hours	Total Useful Flow (L/s)
Domestic	Ilguiloda	3.0	**0.26**
	Izgouaren	3.0	**0.55**
Livestock	Ilguiloda	3.0	**0.53**
	Izgouaren	3.0	**1.10**
Total flow needed for design:			2.43

This matched the 2.5 L/s maximum flow rate that can be provided by the pipe system at any given time. From here, the flow rates were divided in two, as we had designated two taps to each site, to give the following flow rates:

Design (25 years): Morning Rush	Village	0.55 L/s taps	0.27 L/s taps	0.13 L/s taps
Domestic	Ilguiloda	0	0	2
	Izgouaren	0	0	2
Livestock	Ilguiloda	0	2	0
	Izgouaren	2	0	0

2.4.2 Storage Tank

The purpose of the tank calculations are to ensure that the concrete and steel in the roof and walls are strong enough, the epoxy anchors can withstand the pullout forces applied to them, an adequate number of snap ties are placed, and the wooden forms can hold the weight and fluid pressure of the poured concrete.

The fluid pressure of the poured concrete in the form walls was calculated by assuming that the placed concrete ceases to exert fluid pressure on the forms after roughly one hour. Therefore, when the rate of placement is sufficiently slow, the max fluid pressure of the placed concrete is taken to be 600 psf. Using this figure, we spaced snap ties in the concrete formwork at 24" horizontally and 18" vertically so that no tie holds more than 2,250 lbs. Plywood must be ¾" thick, supported by studs spaced at 12".

[4] http://horizon.documentation.ird.fr/exl-doc/pleins_textes/divers16-07/010048832.pdf

The wooden beams in the form roof must carry the weight of the 5" thick poured concrete roof, which spans a maximum of 8'. We chose 50mm x 150mm beams spaced at 12" to accomplish this, still with ¾" plywood on top.

The reinforced concrete walls were modelled with fixed supports on bottom and rollers on top, spanning vertically, with the concrete roof in tension. Both positive and negative moments as a result of hydrostatic forces were analyzed. The Ultimate Stress Design method was used to determine that number 7 rebar is necessary, spaced vertically at 12", and centered in the wall. Number 4 rebar will be spaced horizontally at 12" on the outside of the 7-bar to counter wind loads.

The number 7 rebar will be embedded 8" deep in the concrete slab and secured with epoxy. These anchors were checked for epoxy failure, rebar failure, concrete cone failure, steel-epoxy bond failure, and epoxy-concrete bond failure.

The reinforced concrete roof must also support both positive and negative moments, but of lesser magnitude than the walls. This roof will be 5" thick with number 5 rebar on a 12" grid at center depth. Number 4 L-bars will be used to reinforce the connection of rebar in the walls to rebar in the roof.

The full design calculations are included as Attachment P.

2.4.3 Break Pressure Tank

An excel program to calculate max deflection, max shear stress, max hoop stress, max bending moment, and max tensile stress showed that a jar shaped tank would be most structurally sound, however, a cylindrical ferrocement tank (the chosen geometry) also performs well and is easier to construct. It is shown that for a cylindrical geometry, max stresses occur 0.1m away from the base. Assumptions are thin walled shell structure, walls are monolithic with base, and membrane and bending theory applied. These calculations are shown in Attachment Q.

Our tank geometry is 39" width, 36" height, volume of 705 L, and wall thickness of 4.5 inches. The walls are 12 times stronger than they need be following ACI codes. See Attachment A for CAD drawings.

2.4.4 Pipeline

Our pipeline is divided into a 2830m pumped system leading into a 2970m gravity fed system. For the gravity system, the pipeline design starts with an assessment of water demand. Useful flows were then established. In our case, we assess that the peak flow rate needed is in the morning hours when an estimated 65% of daily water usage will occur. Once flow rates are established, we can work backwards to determine the flow rate throughout the pipeline.

Our pipeline is designed using Hazen Williams equation and also Darcy Weisbach, both of which reveal extremely similar head loss values. As a rule of thumb, we require 10m of head at every point of the pipeline to avoid vacuums or lack of flow. Once we know how much head we want at each point in the pipeline, we can choose pipes and respective lengths to satisfy head conditions.

A hydraulic grade line (HGL) was then generated using Google Earth Pro GPS data. There is a 9.8m relative vertical inaccuracy which is why an abney level is needed to verify or modify this design. The HGL also serves as a visual illustrator that pipes are selected correctly and can withstand pressure demands. A temperature derating factor 0.5 (1.3% for every C above 20 C) was applied to the entire pipeline. A large part of the pipeline is gravity fed, so natural velocities and flow rates due to gravity are also calculated. By knowing what is physically possible, we can design a system that can satisfy the communities.

The resulting system is 2830m of 90mm DR 11, 941m of 90mm DR 17, 804m of 50mm DR 11, and 1115m of 63mm DR 11 with a break pressure tank needed before the valley. The total pipeline route is 5690m.

Detailed hydraulic calculations are in attachment K.

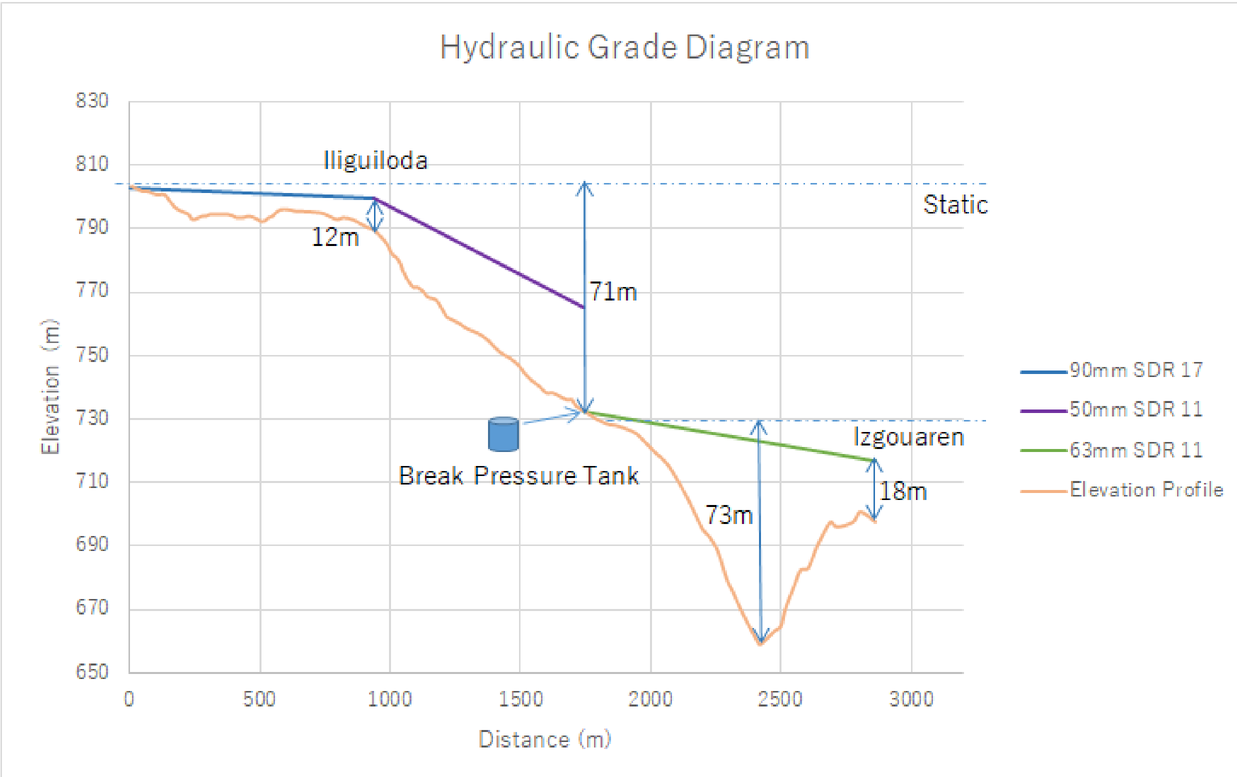

Figure 5: The elevation profile was extracted and a hydraulic grade diagram was calculated for the gravity fed portion of the pipeline. We design flows corresponding to demand and require at least 10m of head at each tap. The difference between the highest and lowest point (in the valley) requires a 0.7 m^3 break pressure tank to satisfy pressure requirements after de-rating. 90mm SDR 17 is required to provide adequate head at Ilguilouda. The first reach is followed by 50mm SDR 11. The third reach is finished with 63mm SDR 11.

2.4.5 Pump Selection

The total dynamic head as a function of flow rate was determined by our mentor Colin Barrett (Attachment J) based on the depth of the well, the altitude difference between the well site and the storage site, and the pipe diameter. In the best case scenario, when the water level is at its highest (low head condition), the static head is approximately 90 m. In the worst case scenario, when the water level is at the lowest pump-able level (high head condition), the static head is approximately 150 m, so the pump must be able to handle more than 150 m of head.

The Lorentz PSk2-9 C-SJ8-44 pump, which can handle a maximum head of 180 m per hour, meets our requirement. The next pump up that met our requirement was the Lorentz PSk2-21 C-SJ8-80, which can handle a maximum head of 280 m. The system would only hit 280 m of head if the flow rate were 15 m^3/h, which is excessively powerful for our system of 41,000 L/day, so the team settled on the Lorentz PSk2-9 C-SJ8-44 pump.

The total dynamic head (TDH) increases as the flow rate increases, so for this pump, the 180 m pump limit essentially limits the maximum flow rate under the high head condition (Figure 6). A larger 90 mm pipe diameter was chosen, so that at 180 m of TDH, the flow rate will be capped at 5.7 m^3/h, to allow for a larger water supply.

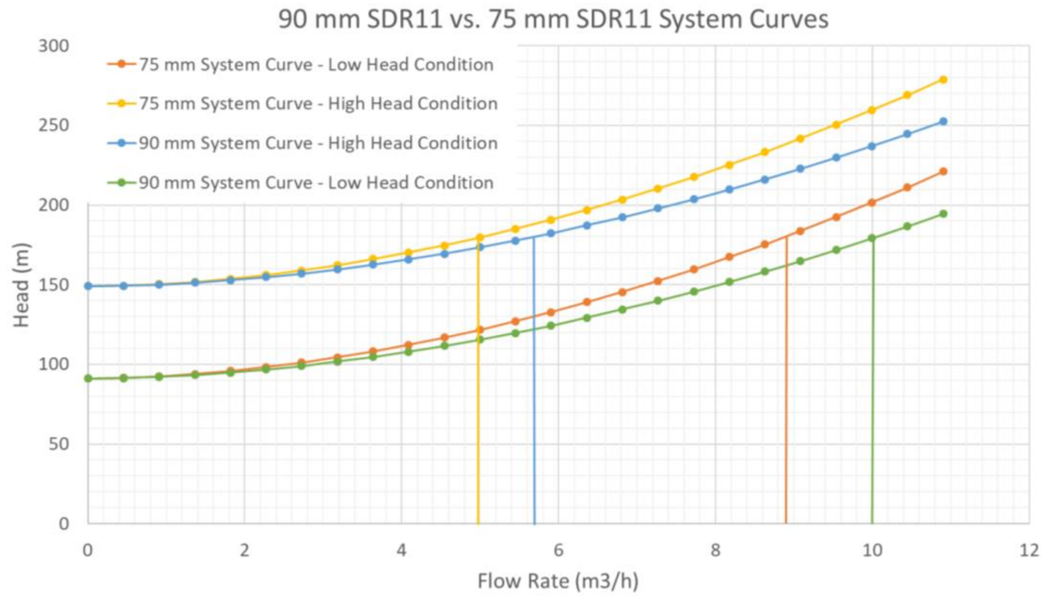

Figure 6: For the high head condition, the flow rate is capped at 5.7 m^3 for 90 mm SDR11, versus 5.0 m^3 for 75 mm SDR11. For the low head condition, the flow rate is capped at 10.0 m^3 for 90 mm, versus 8.9 m^3 for 75 mm piping.

2.4.6 Solar Array Sizing

The process used in this report to size the solar array and determine its performance was based on the Boston Professional Chapter's implementation report from July 2017.

PVWatts[5] is a free tool, maintained by the National Renewable Energy Laboratory, which can calculate the hourly DC power output of the solar array given the wattage of the array, its location, the percentage of losses, and some other factors, using a database of hourly solar irradiance values from many locations around the world. However, the nearest location that PVWatts has data for is Casablanca, which is located about 400 km away from the well site. As shown in Figure 7, Ait Bayoud receives significantly more solar irradiation than Casablanca, so the values for Casablanca had to be adjusted. MINES ParisTech provides a database of monthly mean solar irradiation for any GPS location[6]. Using the monthly mean solar irradiation values from MINES ParisTech for the well site and Casablanca, a ratio for adjustment was calculated (Table 1).

The pump controller can handle 10 kW at maximum, so when sizing the solar array, it is important to ensure that the maximum power output of the solar array will be less than 10 kW. Data for

[5] https://pvwatts.nrel.gov/index.php
[6] http://www.soda-pro.com/web-services/meteo-data/monthly-means-solar-irradiance-temperature-relative-humidity

the hourly DC power output of the solar array was obtained from PVWatts for even numbers of 270 W solar panels. Even numbers are preferred for symmetry, which allows the solar panels to be arranged into two strings. The maximum number of solar panels was determined to be forty panels, using the default loss of 14% and a tilt of 31º.

Table 1: Solar Irradiance at Casablanca, Morocco and at our well site in Ait Bayoud (31°21'30.30"N, 9°16'28.56"W).

Month	Irradiance at Casablanca per MINES ParisTech	Irradiance at Well Site per MINES ParisTech	Ratio (Well Site/Casablanca)
1	2.976	3.264	110%
2	3.648	4.08	112%
3	5.04	5.232	104%
4	6.048	6.192	102%
5	6.912	6.96	101%
6	7.296	7.248	99%
7	7.2	6.96	97%
8	6.48	6.288	97%
9	5.424	5.328	98%
10	3.936	4.032	102%
11	3.12	3.456	111%
12	2.592	2.928	113%
Avg:	**5.056**	**5.164**	**104%**

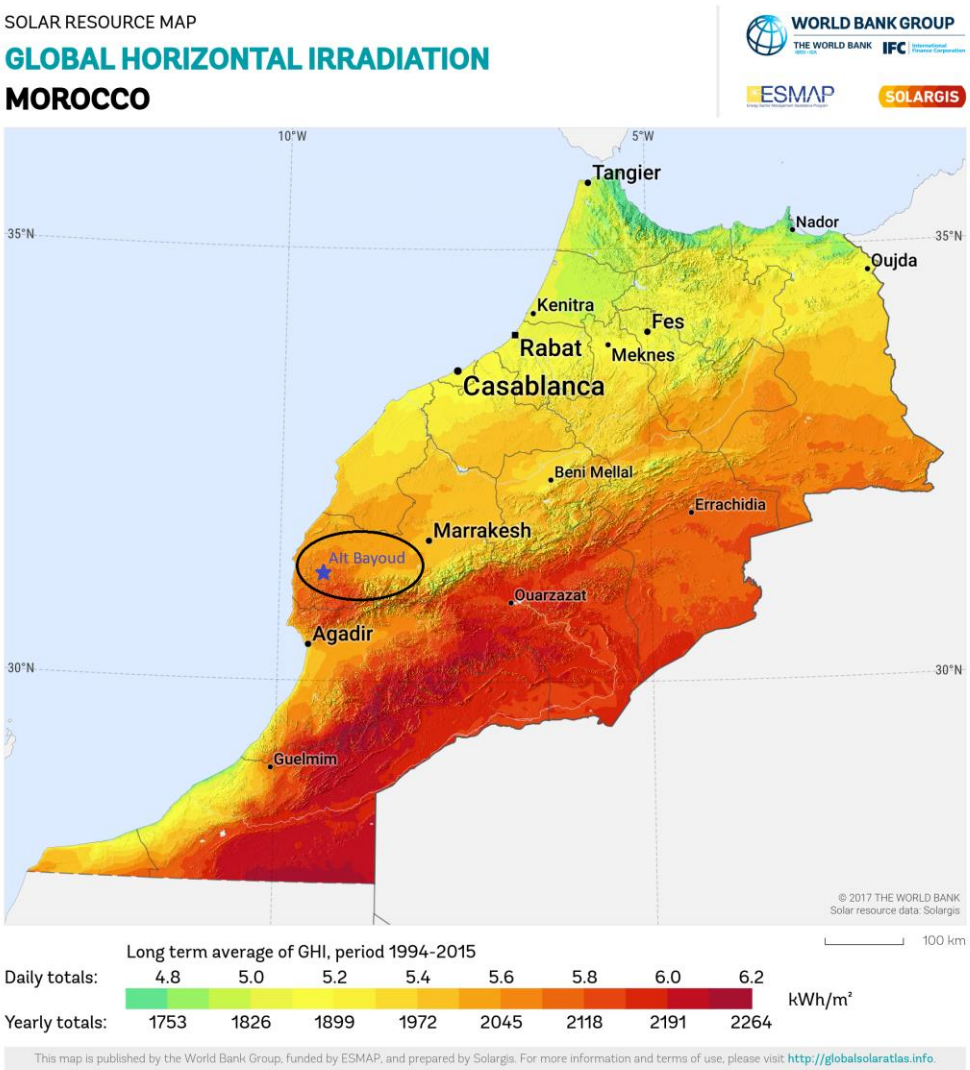

Figure 7: Map of global horizontal irradiation for Morocco. Source: Solar and Wind Energy Resource Assessment[7]

2.4.7. System Operations

Based on the Boston Professional Chapter's model of their solar pumping and storage system, the team developed a similar model of the system's water supply and demand (Attachment L). Pump curves at different DC input powers were extracted from Lorentz' specification sheets in order to determine the amount of water pumped in an hour, given the power generated by the solar array. The model also keeps track of the amount of water in the storage tank at the end of each hour. Adding these two values up yields the water supply at any hour of the year.

[7] https://openei.org/wiki/Solar_and_Wind_Energy_Resource_Assessment_(SWERA)#/

Water will be provided 7 days a week for 5 hours a day to ensure that the community has access to water every day and the wait time is never longer than the amount of time it would take community members to collect water from the river (2-4 hours a day).

Using the supply and demand, the model is able to determine the volume of water in the storage tank for any hour in the year and when water demand exceeds water supply (Figure 8). We then determined the maximum amount of water that could be withdrawn daily for each month while minimizing the number of days with a water shortage (Table 2).

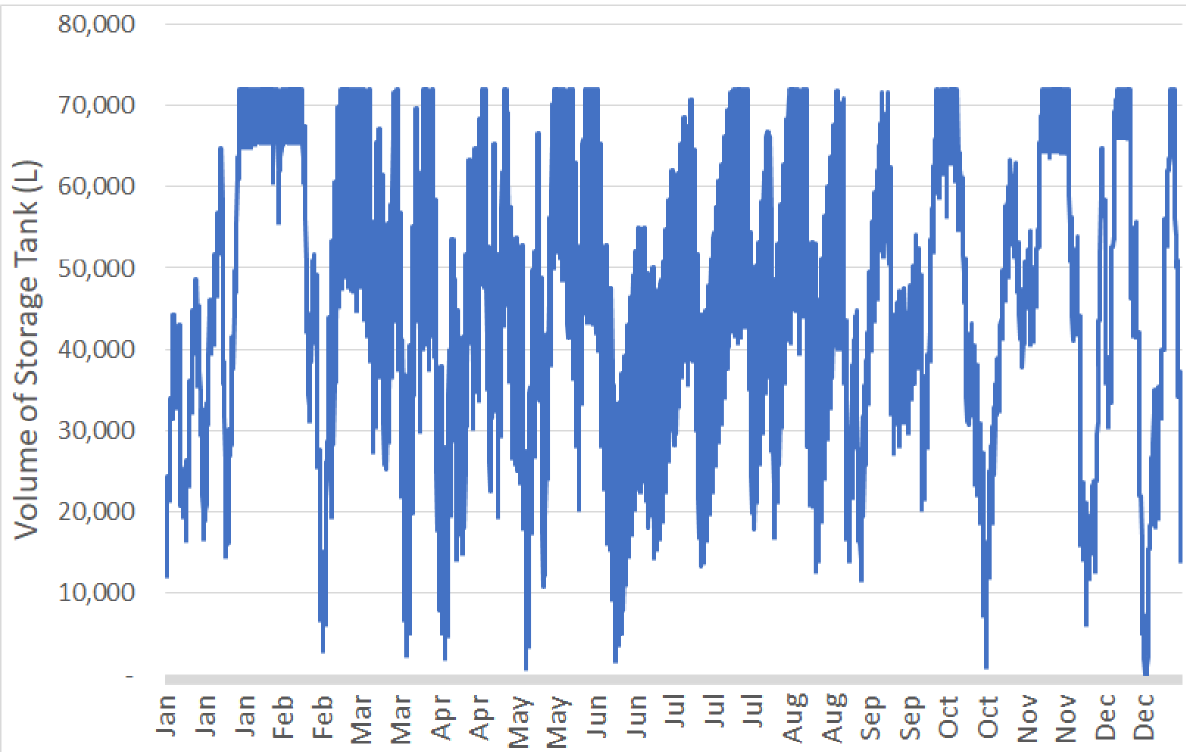

Figure 8: Using hourly solar irradiation data for Casablanca from PVWatts and adjusting for the difference in mean monthly irradiation between Casablanca and the well site, we were able to develop a model for the solar pumping and storage system. From that model, we determined the volume of water in the storage tank based on our recommended daily water withdrawal schedule.

The system we designed will be able to provide 30,000 to 53,000 L/day to the community, depending on the time of year. The average water supply available will be 43,000 L/day. To develop this design, we looked at both pre-established standards for water supply design and community survey results. A water demand survey was conducted in 2014, which yielded a water demand of 47,000 L/day. In 2019, the water demand was reassessed and skewed data points for certain households (e.g. 140L/person/day or 37 L/animal/day) were replaced with average values as established by the World Health Organization. The new water demand was calculated to be 35,500 L/day for 370 people, which includes 11,300 L/day for domestic use and and 24,200 L/day for livestock use. Taking into account population growth, the projected water demand in 25 years is 51,700 L/day for 540 people, which includes 16,400 L/day for domestic use and 35,300 L/day for livestock use. The designed system is guaranteed to meet all of the communities projected domestic water need of 16,400 L/day, or 30 L/person/day. The system provides a varied amount of additional water (13,600 L/day to 36,600 L/day) for additional domestic needs and/or livestock. Community members may choose individually how they wish to use the water provided.

Using the model of the solar pump and storage system, we developed a recommended daily water withdrawal schedule for each month in the year, which maximizes the amount of water provided, while still storing enough water to avoid shortages on overcast days, shown in Table 2. The recommended withdrawal amounts are largely dictated by the effect of the time of year, the amount of rain, and the frequency of overcast days on the average amount of solar irradiance in each month. Our system will provide 30,000 L/day at minimum in December and 53,000 L/day at maximum in June. There will be two days of water shortage in December when the demand exceeds the supply. The average shortage amount is 7,400 L out of a total demand of 30,000 L, which means that minimum domestic need of 16,400 L will still be met. At its highest point, the system is able to provide 93 L/person/day, exceeding the World Health Organization and Sphere standards.

In the future, if the community wishes the system to provide even more water, they can use AC power to supplement solar power, since Lorentz SmartSolution enables hybrid power usage. While the team has struggled to communicate with the community to have them apply for the extension of the powerline in time for this implementation trip, if the community so desires in the future, they can submit an application to the Moroccan ONEE, which oversees electrical utilities, according to the process described in the Alternative Analysis.

Table 2: Recommended daily water withdrawal amounts for each month.

Month	Free Domestic Water Guarantee (L/day)	Water Available for Purchase (L/day)	Total Water Available (L/day)
1	13500	20500	34000
2	13500	19500	33000
3	13500	33500	47000
4	13500	33500	47000
5	13500	31500	45000
6	13500	39500	53000
7	13500	38500	52000
8	13500	36500	50000
9	13500	34500	48000
10	13500	25500	39000
11	13500	23500	37000
12	13500	16500	30000

2.4.8. Electrical Wiring

There will be two strings of twenty Luxor 270W panels in series going into a Lorentz PV Disconnect 1000-40-5 (see Attachments A and D). Each panel operates at a rated voltage of 28.85 V and a rated current of 6.95 A under Nominal Operating Cell Temperature[8]. Under the sun, the temperature will

[8] Irradiance = 800 W/m^2; Wind speed = 1 m/s; Air Temperature = 20 ^{o}C; Module Temperature = 45 ± 2 ^{o}C

be higher, so the operating voltage will be smaller and the operating current will be higher. The total voltage across each string will be 692.4 V, which is within the maximum voltage of 880 V that the PV Disconnect can handle. The current going into the PV Disconnect from each string will be 6.95 A, which is within the maximum string current of 40 A that the PV Disconnect can handle. The total current will be 13.9 A, which is within the maximum total current of 40 A that the PV Disconnect can handle.

The PV Disconnect will combine the power from the two strings into one output, which will lead into a Lorentz PV Protect 1000-125 to protect the pump controller from electrical surges. The PV Protect will then lead to the DC input of the pump controller. The three-phase AC output of the pump controller will then connect to the pump.

In addition, there will be two sensors connected to the pump controller: a well probe in the well to detect the water level and prevent dry runs and a water meter to be installed at the pump discharge. A surge protector will be installed between each sensor and the pump controller.

The wire size between the solar panels and the pump controller was chosen to be 4 mm^2. The wire will run a distance of 39 m at most, resulting in a power drop of 0.36% under Nominal Operating Cell Temperature. The wire size between the pump controller and the pump was chosen to be 4 mm^2. The distance between the controller and pump is 112.0 m, resulting in a power drop of 3.86%. See Attachment E for the full calculations.

2.4.8. Solar Rack

Wind is the most significant load acting on this structure. If adequate weight is not fastened to the posts of the structure, it will lift off the ground and overturn. To calculate wind load, we used ASCE 7-10 Chapter 29. To find the design wind pressure normal to the panels in both directions, the velocity pressure was taken as 960Pa, the gust effect factor was taken as .85, and the force coefficient was taken to be 1.55. This yields a wind load acting perpendicular to the panel surfaces of 1250Pa.

The solar panels will be fastened to the W members, which span 3.5m between the rectangular tubing. The W members were modeled as simply supported with a uniform load across their entire span. Similarly, the rectangular tubing was modeled as a simply supported beam (even though there are actually 5 point loads where the W members connect). Based on the loading of the rectangular tubing, the bolt at the bottom of the tubing must hold 50,000N in sheer. A half inch steel bolt would then have a demand-to-capacity ratio of .38.

A significant overturning moment also needed to be accounted for. The rocky terrain is such that we opted in favor of above-ground anchors rather below-ground anchors. Each rear column of rectangular tubing must be embedded in a concrete cylinder .9m in diameter and .9m high. Each front column of rectangular tubing must be embedded in a concrete cylinder .5m in diameter and .5m high.

2.5. Material Specifications

2.5.1. Spigots and Piping

The mix of concrete we will be using for the slab is a ratio of 4.5 : 2.25 : 1 of aggregate to sand to cement, as used in the EWB guidelines.

All of the specific materials needed for the spigots are specified in Attachment M, alongside the materials needed for the entire pipeline. This table itemizes all items to be used for spigot/piping construction.

2.5.2. Storage Tank & Break Pressure Tank

Table 3: Material Properties for Storage Tank

Material Properties	
Concrete mix (cement:sand:gravel:water by volume)	1 : 2.5 : 3.5 : 1.6
7-day compressive strength of concrete (psi)	750
28-day compressive strength of concrete (psi)	1250
Compressive strength of concrete after 7 days curing in (psi)	750
Tensile strength of steel (psi)	36000
Maximum bending stress in wood (psi)	1406
Modulus of Elasticity of Concrete (**Ec**=57*sqrt(fc)) (ksi)	2015
Modulus of Elasticity of Steel (**Es**) (ksi)	29000
Maximum horizontal shear stress in wood (psi)	186
Ultimate pullout force of epoxy anchors (lb)	16,000
Specific weight of concrete (Cw)	150

2.5.3. Pipeline

Table 4: HDPE Pipe Standards

Outer Diameter (mm)	SDR	Wall Thickness (mm)*	Inner Diameter (mm)	Pressure Rating (bar)
90	11	8.7	73.64	16
90	17	5.8	79.41	10
50	11	4.9	40.91	16
63	11	6.2	51.55	16

*Mean values used from Table 2 of ISO 4427-2

Table 5: Hydraulics Constants

Name	Value
Friction coefficient for Hazen-Williams	150

Roughness coefficient (m)	0.0000015
Temperature Derating Factor	0.5
Kinematic viscosity @ 30C	0.0000008

2.5.4. Solar Pumping System

- Luxor 270W Polycrystalline Solar Panels
  - Under Nominal Operating Cell Temperature
    - Rated Power Pmpp = 200.40 W
    - Rated Voltage Vmpp = 28.85 V
    - Rated Current Impp = 6.95 A
  - Temperature Coefficient:
    - Voltage: -0.03% / ºC
    - Current: +0.05% / ºC
    - Power: - 0.41% / ºC
  - Dimensions:
    - L x W x H: 1640 mm x 992 mm x 35 mm
    - Weight: 18.5 kg
- Lorentz PSk2-9 C-SJ8-30
  - Maximum head = 180 m
  - Maximum flow rate = 12 m^3/h
  - Pump
    - AISI 304 stainless steel
    - Minimum borehole diameter = 6.0 in
    - Maximum water temperature = 30 ºC
  - Pump Controller
    - Maximum power = 10 kW
    - Maximum input Voltage =850 V
    - Maximum Efficiency = 98%
- Lorentz PV Disconnect 1000-40-5
  - Maximum voltage = 880 V DC
  - Maximum current per string = 40 A
  - Maximum total current = 40 A
  - Maximum number of strings = 5

2.6. Climate Change

2.6.1. Summary of Anticipated Climate Change on Design Parameters

The reinforced concrete storage tank will deflect as temperature changes, putting additional stresses on the building materials. However, these additional stresses are insignificant and are dependent on the relative temperature difference between night and day rather than on the absolute temperature. Therefore, a rise in the average temperature in the region is unlikely to affect the temperature loads.

An increase in average temperature will result in an increase in demand for water for both domestic and agricultural purposes. Based on information from the World Health Organization, we take 45 L per person per day to be the minimum acceptable water supply. Our system is designed to provide a minimum of 55 L of water per capita per day. Hence, if water demand increases by 20% due to a hotter, more arid climate, then the system will still meet the minimum demand. The unavoidable consequence would be that the people in these villages would need to make more trips to the river to water their animals.

If precipitation levels fall dramatically, the ground water level could drop below the location of the pump. If this happens, either the pump would need to be set lower in the well, the well would need to be deepened, or a new well would need to be drilled. More power would also be required to account for the increase in head. The best we can do now is anticipate a drop in ground water level and set the pump as deep in the well as possible.

2.6.2. Summary of Anticipated Climate Change on Design Parameters

We are more concerned with the impact of the project design on climate change. We have resolved to supply the system exclusively with solar power rather than attempt to connect the pump to the existing grid. Morocco gets most of its energy from non-renewable sources, so using grid power would leave a substantial carbon footprint.

3. Schedule

3.1. Schedule overview

3.1.1 Spigots

Construction of the spigots will take place from August 10 to August 30. All concrete portions of construction—including the concrete casting surrounding the taps themselves, as well as pouring of slabs at both sides—will occur towards the beginning of the period. This will allow a full seven days of curing time. Throughout this time, necessary components of spigot piping will be completed as necessary before being cast in concrete. This will include piping that will sit beneath the slab, as well as the tap fittings that will be cast in concrete using PVC pipes. Finally, we will connect the spigots to the main pipeline and run testing.

3.1.2 Pipeline

See Attachment B for detailed day by day implementation analysis. Here is a broad summary.

The first step is verifying our design due to any relative vertical height inaccuracies due to Google Earth. A full pipe route will be staked with flags every six meters. A topographic survey will be conducted along staked path using an abney level. The design will be adjusted accordingly. If there are any major changes, we can have stock shipped from Plastima. Rigorous notes will be taken to make an accurate on-plan view of the pipeline post trip.

The second step is light trenching (0.7 m wide by 0.1m depth). Due to the large rock content in the subgrade, this will be an on-grade pipeline. 10 working days, two of which are buffer days, is allotted to trench the entire 5751 meters, of which 1400 meters has already been trenched. Soft soil will be moved to the left of the light trench and rocks piled to the right (will be used later). 55 community members will be needed for this. Having a large workforce creates a sense of ownership of the project for the community. A worst case scenario is also possible by significantly reducing the trench (0.3m wide by 0.02m depth); essentially removing point loading. Six hired workers would be needed for this and can be done in roughly seven days.

The piping team will split into two once the path between well and Chateau is cleared. On July 31, Donald and Nick will begin fusing the corresponding pipeline along with interested locals, six workers, and two mentors. Before each fusion day, the valves, fittings, and pipe will be prepared and numbered such that the fusion process will be efficient. After fusion is done, on Aug 5th, Donald and Nick will spend a week on the break pressure tank. Meanwhile, Rachel will continue the work force for clearing the path from Chateau to Izgouaren. She is expected to finish on Aug 8th. On Aug 9th, she will lead the creation of rock walls for a short 83m vertical section. Zig zagging the pipe will protect the pipe and prevent pipe from falling due to own weight.

After, the break pressure tank completion, the third step is fusion of the pipeline between Chateau to Izgouaren, including all branches to domestic and livestock spigots. The fusion will stop right at but not including the transition (MJ adaptor) between PE100 and GI pipe of the tapstand structures. When the tapstand structures are complete, this single connection will be fused. Pipeline work will not occur on Holidays, however spigots will have to be in order to finish the project within six weeks.

In the last week, the pipeline and tapstands will be tested hydrostatically and a post construction disinfection process will be followed (Attachment R). A fittings workshop will be held for those who didn't get a chance to learn during installation and a ceremony will follow the completion of this project.

3.1.3. Storage Tank

We will construct the 77,557 liter reinforced concrete storage tank on top of the existing 16 foot by 30 foot slab. The appropriate amount of sand, aggregate, cement, water, and rebar will be delivered from Marrakesh. The wood for the forms will be delivered from Casablanca. From July 19th to August 3rd, our team will embed the rebar in the existing slab, construct the forms, and pour the concrete. The concrete will have one week to cure. Then the tank will be waterproofed and tested.

3.1.4 Break Pressure Tank

The excavation of the Break Pressure Tank site will begin tentatively on August 6 (possibly earlier), after the optimal location has been determined after surveying and restructuring of the pipeline construction plan. The optimal location will be chosen considering factors such as ease of site clearance/excavation, elevation, and ecological effects. About 4 workers will accompany 2 students to the site to begin clearing vegetation, surface soil and large rocks from the site. The area to be excavated will be a cylinder 0.3m deep and 1.4m in diameter. This will necessitate approximately 0.46 cubic meters of rock excavation. We anticipate that this tank will take four days to complete: one day to excavate and cast the concrete foundation; one day to construct the wall frame; one day to plaster the walls with ferrocement; and one day to construct the roof and lid with ferrocement. The tank will then be cured for seven days.

3.1.5 Well & Power

On August 3rd, a video inspection of the well will be conducted to see if there is some underlying issue that is causing the sediment. On the same day, A well yield and drawdown test will be conducted on to verify that the well can supply the amount of water we designed for. In order to do these tests, the team will rent a three-phase generator to power the Lowara pump that is currently installed in the borehole. If there is no time to do the drawdown test on August 3rd, it will be done on August 5th. In addition, on

August 5th, two water samples will be taken, one to test for bacteria onsite and one to take back to the US to be sent to a lab to test for other properties and contaminants.

Starting on August 6th, the well will be developed by a combination of pumping and backwashing. We will stop when either the turbidity stabilizes to within 10% over three successive well volumes or the end of August 8th is reached. If we are unable to achieve a water sample with a turbidity of less than 10 NTU, we will hire a contractor to surge the well on August16th. We will stop development when either turbidity has stabilized to within 10% over three successive well volumes[9] or the end of the day is reached.

From August 5th to 9th, the solar panel structure will be assembled. On August 22nd, after the well development is complete, the Lowara pump will be removed from the well and the solar pumping system will be installed by AE Photonics. The pump will then be connected to the pipeline.

On August 29th, the water distribution system will be completed, and the water distribution system will be opened to community usage.

3.2. Work Breakdown Structure

Please see Attachment B for the day-by-day task schedule and the team members involved with each task.

3.3. Detailed Task Description

3.3.1 Spigots

- Purchase materials
- Assembly: Put together the pipes, faucets, and elbow joints that will constitute the actual tap stands, by screwing them together and connecting them.
- Testing: Flush with water and test for any leakage issues. If leakage issues are found, spend time pinpointing the causes and repair them.
- PVC Molds:
    - Cut PVC into 3’ sections to use as casting molds
    - Place assembled tapstand into PVC, and fill mold with concrete
    - Leave in mold for 24 hours
    - Submerge in water for next 7 days
- Excavate 10 cm trench for concrete slab foundations
- Build slab forms
- Assemble pipes and valves to be laid beneath concrete
- Pour concrete slab
- Excavate 20m trenches for burial of pipe in community
- Lay down and connect piping in community
- Install valve boxes
- Test piping
- Construct drainage

3.3.2 Piping

- Preview route

[9] conditions provided by the EPA

- Finalize pipeline route
- Stake route
- Survey route
- Revise hydraulic grade diagrams as necessary
- Clear first half of pipeline route
- Stage and lay first half of pipeline
- Clear second half of pipeline route
- Stage and lay second half of pipeline
- Test pipeline and check for leaks
- Flush system to disinfect

3.3.3. Break Pressure Tank (ferrocement tank)

- Lay foundation
- Construct wall frame
- Attach mesh frame
- Install fittings
- Plaster walls
- Construct roof
- Wait for tank to cure
- Test break pressure tank and check for leaks

3.3.3 Storage Tank

- Cut rebar currently sticking out of foundation
- Tape site
- Mark rebar holes
- Clean site
- Cut rebar for walls if not precut
- Cut studs and baseboards
- Drill rebar holes, wedge anchor holes, and tie holes
- Cut wales
- Cut edge plywood
- Bend rebar if not prebent
- Prefabricate form sections
- Bend and cut L-bars
- Assemble outer forms
- Place and epoxy vertical rebar cages
- Place ties
- Cut and place horizontal rebar
- Build end frames for inner wall
- Assemble inner forms
- Build stairs
- Fasten snap ties
- Build roof
- Assemble roof rebar
- Pour 4’x4’x6” practice wall
- Pour inner wall

- Remove end forms for inner wall
- Pour outer wall
- Pour roof and assemble lids that go in the roof
- Keep cement wet for three days after pour
- Remove forms 9 days after final pour
- Clean and seal tank
- Test and flush system
- Troubleshoot any problems that arise

3.3.4. Water Insecurity Survey

We plan on conducting another community water survey in conjunction with the PMEL survey in order to better understand each household's experience of water insecurity. The survey is based on Northwestern University's protocol for Household Water Insecurity Experience (HWISE), which is currently under review before publication. The 12 items on the HWISE scale are

1. Worry: In the last 4 weeks, how frequently did you or anyone in your household worry you would not have enough water for all of your household needs?
2. Interrupt: In the last 4 weeks, how often has your main water source been interrupted or limited (e.g. water pressure, less water than expected, river dried up)?
3. Clothes: In the last 4 weeks, how frequently has there not been enough water to wash clothes?
4. Plans: In the last 4 weeks, how frequently have you or anyone in your household had to change schedules or plans due to problems with your water situation? Activities that may have been interrupted include caring for others, doing household chores, agricultural work, income-generating activities, sleep, education, etc.
5. Food: In the last 4 weeks, how frequently have you or anyone in your household had to change what was being eaten because there was a problem with water (e.g. for washing foods, cooking, etc.)?
6. Hands: In the last 4 weeks, how frequently have your or anyone in your household had to go without washing hands after dirty activities (e.g. defecating or changing diapers, cleaning animal dung) because of problems with water?
7. Body: In the last 4 weeks, how frequently have your or anyone in your household had to go without washing their body because of problems with water (e.g. not enough water, dirty, unsafe)?
8. Drink: In the last 4 weeks, how frequently has there not been as much water to drink as you would like for you or anyone in your household?
9. Angry: In the last 4 weeks, how frequently did you or anyone in your household feel angry about your water situation?
10. Sleep: In the last 4 weeks, how frequently have you or anyone in your family gone to sleep thirsty because there wasn't any water to drink?
11. None: In the last 4 weeks, how frequently has there been no useable or drinkable water whatsoever in your household?
12. Shame: In the last 4 weeks, how frequently have problems with water caused you or anyone in your family to feel ashamed/excluded/stigmatized?

Responses to items are scored as 0 for never, 1 for rarely (1-2 times), 2 for sometimes (3-10 times), and 4 for often (11-30 times). The scores for each item are summed to obtain a total score.

The water demand survey will be conducted by Vanessa (travel team lead) and Zineb Kouhel who has met the community members before. Based on previous research on the most effective way of conducting the survey, the items will be ordered by increasing severity or sensitivity. The specific wording of the questions will be determined Zineb according to her language expertise to ensure that the questions are understood appropriately. If a community member responds with "don't know" to any item, the surveyor will follow up with some probing questions and descriptions to ensure that the respondent can give an answer.

3.3.5. Solar Pumping System

The solar panel structures will be installed by a hired metalworker, who will weld the parts together onsite. This should take a day at most. The rest of the solar pumping system--the pump, pump controller, solar panels, and other electronic accessories--will be installed and wired together by the contractor AE Photonics. The old pump will be removed from the borehole by AE Photonics before they install the new pump.

3.3.6. Well Development

The well was not properly developed when it was first drilled, so we want to redevelop the well once the solar pump is installed. The simplest method is to use a combination of pumping and backwashing, which will create the desired water movement in both directions through the screen. Based on references[10], the procedure was determined as follows:

1. Record static water level using electric sounder
2. Begin pumping at the top of the screen with a low pumping rate. Water that is pumped out will go into a temporary pool.
3. Record the pumping rate and take regular turbidity measurements using a turbidity meter
4. When the turbidity stops decreasing, lower the pump by 10 feet and repeat steps 2-3, working down to the bottom of the well screen
5. Repeat going from the bottom of the screen to the top
6. The water pumped to the top of the well will be collected in a pool and allowed to settle
7. Record physical characteristics of well water (color, clarity, particulate matter)
8. When there is no improvement in turbidity, the well will be allowed to equilibrate
9. When the water has settled it will be rapidly dumped back into the well to break up any bridge particles
10. Repeat steps 1-8 at higher pumping rates until the well yields water with a turbidity of 10 NTU or less at the start of a pumping cycle
11. Record duration of well development
12. Measure water level 24 hours after well development

3.3.7. Water Quality Testing

We will take several samples of well water and test for bacteria and contaminants. One sample will be tested on-site for pathogenic bacteria, including e.coli and salmonella. This test can be conducted by members of the travel team with no training, since the test kit is designed for self-use at well sites without a lab. We will take another water sample and store it to be returned to the US, then mailed to the test company lab to test for metals, contaminants, and other potable water quality criteria. The results of these tests will determine later need for water purification or filtering for the system.

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[10] https://www.epa.ohio.gov/Portals/28/documents/TGM-08_final2009W.pdf
http://www.lifewater.ca/drill_manual/Section_10.htm
https://www.epa.gov/sites/production/files/2015-06/documents/welldevelp_0.pdf

3.3.8. Well Yield & Drawdown Tests

Test 1: Well Flow vs. Time followed by Recovery Time of the Well

The purpose of this test is to determine the decline of well flow as a function of time, at unrestricted discharge and measure the flow rate at time intervals and then the time it takes for the water level to return to the position of the electric sounder, using the following procedure:

- Prior to pump start, use the electric sounder to measure the static level of water in the well. Once determined, record this depth, and leave the electric sounder in position at this depth by securing it to the rising main with cable ties. (This will be important for measuring well recovery time once the pump is shut off and will show us where the water level was initially.
- All data in this test is to be collected at full pumping rate (i.e. the rate at which the existing pump flows with an unrestricted discharge).
- Start the pump and the stopwatch simultaneously. (Use two stopwatches in case of malfunction or operational error.)
- Immediately record initial well flow rate as indicated by manually measuring the amount of water filling up a bucket in a certain time (this will be the technique to record all flow rates)
- Record well flow rate at time intervals of not more than 4 minutes, continuing until the flow rate stabilizes and is declining no more (at the steady-state of the well). Be sure to record the time since pump start with each flow reading.
- When the well flow rate has stabilized, and is unchanging, record the flow rate at this point and the time since pump start. Stop the pump.
- Depending on how long this test lasts, it may fill the tank to overflow.
- There is a typical duration of 2 hours for the flow to plateau. But there may not be much difference between static and pumping well level. This test may not last very long.
- Conclude the Well Flow vs. Time test by stopping the pump either at the normal duration of well operation (users have satisfied their need), or when the well flow rate has plateaued and is unchanging, whichever occurs last.
- Mark pump shutoff time, but let the stopwatch(es) continue running as this marks the beginning of the Well Recovery Time test.

The recovery time of the well, or the duration it takes, after stopping flow following full well drawdown, for the well to return to the initial, or static level that existed prior to starting the pump, will be measured as follows:

- -Measure directly using the electronic depth sounder, which was left at the water surface depth measured prior to starting the Well Flow vs. Time test.
- Monitor the multi-meter continuously watching for positive indication that water has contacted the probe. (Be certain you know what you're expecting the multimeter to do.)
- When water touches the probe, record the time.

Test 2: Well Flow vs. Drawdown

We are not interested in the rate of flow decline, but rather the steady-state level in the wellbore at various stabilized pumping rates to determine the drawdown level. We will be able to plot the drawdown level vs. time, then once at point of well shut off, and plot the recovery level vs. time. The goal of this test is to determine if there is a "knuckle" in the curve, which would be an indication that you should not operate the well beyond the rate at which the knuckle occurs. (In such a case, normal pumping rate should be restricted in order to keep to the left of the knuckle, for most efficient operation of the well.) This data will be collected by successive tests where the pump discharge valve is pinched and the flow rate allowed to stabilize, and once it's stabilized, recording the stabilized flow rate and the water level in the well. This requires an effective means of measuring water level at greater and greater depths, and so assumes effective use of the electric sounder. We can only pump the well up to the full rate of the installed pump, and we may not see a knuckle.

3.3.10. Spigot Pressure Test

The laying of pipe for the spigots is separated into three sections: the upright stands, the pipes to be buried in the slab–containing valves and directional fittings, and the pipe connecting the spigots to the main pipeline. After each of these sections is laid, we have scheduled a checkpoint in which to perform a Pressure Test, based on Santiago Arnalich's Book on Gravity Fed Water Supply[11]. We will seal one end of the pipeline (or all but one in the case that there are multiple endpoints due to tee-joints and elbows), and fill the pipes with water. We will then seal the other end with a cap compatible with pressurizing equipment and increase the pressure in the pipes to 80% of the nominal pipe pressure limit. We will maintain this pressure for at least an hour, before checking to see if any leaks occurred in this time. If so, we have allowed for buffer time to mitigate these problems and then perform the test once more.

3.3.11. Bridge Inspection & UHMW Drilling

There is one monitoring task we need to complete on this trip for our previous bridge project to make sure the bridge ropes are not being worn down. This task will be done on August 16th.

Initial inspection:

- Inspect bridge to ensure that the C channel UHMW is not in contact with the polyester ropes
- If no abrasion is observed, this task can be deemed nonurgent and pushed off until next summer, where more time can be allotted to bridge maintenance
- However, if the UHMW is rubbing against the rope and contributing to abrasion, treat the situation as an emergency

Equipment:

- Hammer drill
- Concrete screw anchors (Ryan is confident that the screws can be found in Morocco)

Procedure:

1. Push down the UHMW channel until it touches the concrete
2. Using the hammer drill, drill a hole through the plastic into the concrete tower
3. Screw in the concrete anchors to hold down the UHMW
4. 2 to 4 holes should be drilled at the corners of each channel
5. Ensure that the concrete screw anchors are placed in a manner so that they do not come in contact with the rope
6. This entire process shouldn't take longer than half a day

[11] https://issuu.com/arnalich/docs/ligraven

3.3.12. Practice

In terms of practice, our team will be meeting in New York in July to practice a number of skills. We will practice the mixing of concrete, as well as casting the pipes using the PVC molds for the spigots as we intend to in country.

- Spigots & Tanks
  - Casting PVC molds
  - Mixing concrete
  - Members already have experience in developing concrete slabs
  - Members already have experience in connecting pipe joints
- Piping
  - A fusion training workshop was completed back in April.
- Solar Pumping System
  - Contractors will do the installation, so team members do not need to practice
- Well Tests & Well Development
  - No practice will be possible until the team arrives in country. The team will prepare by understanding as much of the pump operation, test equipment, and procedures as possible through reading guides. In-country, the team will do a short practice round of each well test and well development procedure first before officially conducting the procedures and collecting official data. This practice time is accounted for in the schedule.

3.3.13 Solar Rack

- Cut steel members to size
- Drill holes in steel members
  - 12mm bolt holes for truss connections
  - small holes for panel connections
- Assemble trusses with bolts
- Weld W members in place
- Weld end cap plate on one side
- Place panels
- Wire panels
- Check voltage in each string
- Screw panels into W members
- Construct locking gate

3.4. Schedule Analysis

3.4.1. Advance Task Scheduling

All materials for the spigots (primarily GI fittings and pipes) will be procured in-country from August 10-11 from Marrakesh. Although a store exists in Meskala, a higher quality vendor is currently be sourced with help from Borealis. Chapter members will be responsible for their procurement, and we will begin construction immediately.

The main bottlenecks for PE100 pipe is manufacturing and delivery. To remove manufacturing as a bottleneck, the pipes will be extruded prior to the start of the trip. ten tons of PE100 Pellets from Borealis will be arranged to ship to Plastima in Casablanca by July 1 and extruded by July 10. The team will meet with the extruder Plastima in Casablanca on July 17th to quality check the pipes, confirm the fittings needed, and arrange for shipment to Ait Bayoud within the week. We will ask Plastima to hold extra stock in the case we need different diameter pipes once more accurate topography data is revealed. A 220V McElroy Pitbull 14 will be brought via checked baggage by Rachel to avoid any customs trouble.

A supplier for the wood and rebar for the tanks will be found in Casablanca on July 17th, and the supplies will be shipped to Ait Bayoud. The hammer drill and epoxy for the tank construction will be brought over from the US. Drill bits, batteries, charger, transformer, and other accessories are available in our storage shed in Ait Bayoud.

Prior to the trip, We will sign a contract with AE Photonics and schedule for the delivery and installation solar pumping system. We will have to pay for 50% of the costs upon signing the contract.

Team will carry up to 510 pounds of hardware in their luggage including 1000 staking flags, butt fusion machine, steel angles, screws, concrete vibrator, dewalt batteries, drill bits, waterstops, waterstop primer, rebar tie wire, snap ties, snap tie wedges, a steel brush, a bellows, a water quality test kit, an electric sounder, and a turbidity meter.

3.4.2. Critical Path Analysis

Pipeline:

1. Verify the well yield
2. Verify pipeline path
3. (Break pressure tank can begin after verification)
4. Clear path
5. Lay pipe
6. Lay valves
7. Fusion
8. Connect to tapstand
9. Test system

Tanks:

1. Acquire rebar, wood, and rebar tie wire
2. Drill and clean holes in slab, cut wood, cut and bend rebar
3. Build inner forms and ladder
4. Assemble rebar cage
5. Build outer forms
6. Secure snap ties
7. Pour inner walls
8. Wait 24 hours to pull edge forms
9. Complete forms for final pours
10. Pour outer walls
11. Pour roof
12. Water roof for three days
13. Let set additional four days
14. Pull forms and clean
15. Waterproof tie holes
16. Connect pipes

17. Test system

The construction of the spigots is not contingent on any other part of the project. However, the testing is set to occur towards the end of the trip in order to ensure that both piping and power have been secured, so that we can test the entire pipeline from chateau to spigot. As a result, ample time is left for this area of the trip so there is leeway for us to fix any major issues that arise. The critical path for the spigots themselves is:

1. Assemble upright taps
2. Case in concrete, and begin curing
3. Assemble pipes to go beneath slab
4. Pour Slab
5. Assemble pipes leading to main pipe
6. Testing

The solar power and well activities are independent of the rest of the project. The critical path would be: (1) well yield and drawdown test, (2) well development, (3) removal of the old pump, (4) installation of the solar panel structures, (5) installation of the rest of the solar pumping system.

3.4.3. Schedule Threats

3.4.3.1. Well Yield & Drawdown Tests

The greatest risk to the project as a whole is the well itself if it is unable to supply the minimum community demand. For reference, during the January 2017 implementation trip, the well was pumped for 4.5 hours at an average flow rate of 105 L/min, or 6,300 L/h. The resulting water level was not measured. However, knowing the flow rate and pumping time, we have reason to believe that at minimum, the well should be able to yield 28,350 L continuously, which is well over the projected domestic demand in 25 years. As long as the well yield and drawdown tests confirm that the well can at least provide the projected domestic demand of 16,500 L, we will continue with the rest of the implementation.

3.4.3.2. Piping

Let's break down this risks systematically and how we plan to counter them.

Adjusting Design due Abney Level and Material Availability

A bottleneck is pipe manufacturing and delivery time. In Morocco, we should not expect guaranteed delivery or manufacturing dates; even if we are working with Borealis, the supplier of PE100 pellets to Plastima, one of the largest and most reputable pipe manufacturers in Morocco. This is a risk we cannot take. We will have to pre-order and have materials arrive well in advance of pipe lay. Now there is only one problem.

A proper topographic survey has not been conducted! In Africa, Google Earth Pro has a relative vertical accuracy of 9.8m[12]. It is recommended that Google Earth is used for qualitative studies not for quantitative design. This difference can mean no water to extremely low flows at tapstand sites. If there is

[12] *How accurate is Google Earth Elevation? - MES Innovation Sdn Bhd*. (2018). *MES Innovation Sdn Bhd*. Retrieved 12 June 2019, from http://mes100.com/blog/how-accurate-is-google-earth-elevation/

for example a 15m vertical height difference, the adjusting variable is size of pipe to influence head loss or constructing another break pressure tank. For pipe size, we need to have enough pipe of varying dimensions to accommodate any inaccuracies with Google Earth. In addition we will ask for 10% extra pipe in case of any length deviations.

To be safe, we assume +/- 15m deviation. For negative case, we would have 33m of head at Izgouaren. To reduce that head, we need to have 450m of 50mm SDR 11 PE100 between break pressure tank and Izgouaren. For positive case, we need to have 915m of 90mm SDR 11 PE100 between break pressure tank and Izgouaren. These are relatively large quantities of pipe. We will ask Plastima, our manufacturer to see if they can *stock* this quantity. If these quantities are needed, we will then purchase the pipes from Plastima or see if we can exchange existing pipe for it and pay any cost differences.

For Ilguilouda, if relative vertical difference between Chateau and tapstand at Ilguilouda is 15m deeper, then additional pipe is not necessarily needed rather a series of orifice plates (such as reducers, 90mm to 50mm and 50mm to 25mm) and 12m of 25mm PE100 SDR 11 can be used. If it is 15m higher, than the location of the tapstands needs to be moved until there is at least 12m of head. Google Earth does denote steep elevation drop after the tapstand site, so to be conservative we can say 100m of additional 90mm SDR 17 PE100 to needed.

Between the tapstand and Ilguilouda, we only need to be concerned with 15m deeper. The pressure at the break pressure tank will be quite high so similarly, we can use a reducer of 50mm to 25mm and 12m of 25mm PE100 SDR 11.

If the valley is deeper than expected (relative difference exceeds 80m), then two equal break pressure tanks will need to be built or else the derated pipes will be under too much static pressure. This either means the two students working on the break pressure tank will need to split off individually or other students need to be re-arranged. The storage tank are theoretically done at this point, but delays always happens so labor from that side cannot be relied. An additional break pressure tank is not impossible but does add a layer of difficulty and one more tank to create. Perhaps the locals can create this on their own after completing one with us.

The pumped pipe section does not matter for 15m vertical deviation.

Past students that travelled have confirmed that extreme points were the same extremums identified in the altitude in Google Earth Pro. A ball can roll down the hill, meaning water will almost certainly flow.

I do not foresee 30m vertical deviations. To entertain a relative negative 30m vertical inaccuracy, then two break pressure tanks will need to be constructed and they can be arranged such that our pipeline is similar. For a positive deviation, then, the break pressure tank can be moved to a higher elevation and more larger diameter pipe will be needed (such as 400m 63mm SDR 11 if moved 30m up).

For this project to be completed in six weeks, stock must be readily available. The other bottleneck, transportation is something we need to arrange. Options include renting a truck, hiring Shineline International to provide on-ground transport (costs $800 for a truck from Casablanca to Ait Bayoud), or coordinating with Plastima.

Pipeline Clear

It is very difficult to assess how long the pipeline clear will be. As of now, clearing a path free of point loading is feasible. 1400m is already cleared where the GI pipeline currently lays. The rationale is fully written in the implementation day by day.

We assume 55 workers. This is a reasonable ask. Our role is not to replace the government and set up a parallel economy. We are simply here to facilitate. Suppose nobody wants to help. The worst case scenario is having to hire skilled labor experienced in working in hot and dry conditions and reduce trench depth. The dimensions of a reduced path will be 0.3048m (12 inches) wide, 1 inch (0.02m) depth. We need to clear 0.3048*1390*0.02 = 8.47 m^3. This will take 13.55 man days. With 6 people, we can finish the path clearing in 2.25 days. See Attachment B for rest of calculations.

If a path proves too difficult to clear, we will purchase Gainoma protection sleeves available from our manufacturer (Plastima). This essentially cuts out excavation time, giving a week to two weeks of time to our trip. We extrude 10% extra piping in case of any deviations. If there is not enough head at a tapstand, flow rates would be reduced. If there is a mistake in valve or fitting or if valves/fittings leak then we will use the numerous buffer days built into the schedule to source another supplier with the aid of our local nonprofit partner and the local Borealis team. We plan to use hemp pipe sealant for all GI threaded connections. We will have backup generator and fusion equipment source in case our equipment fails.

Pipeline Trenching

We want to entertain the idea of trenching. We included it in this section because it is a modular component of this trip.

We must first establish our goal. Our goal is to connect the pipeline and deliver water. We also want to create a system that works, where the pipe isn't falling down the slope of the valley for instance. We must be very clear what this pipeline is and isn't. It is not the most permanent of solutions. An on-grade pipeline assumes nobody will steal pipe (anyone with a saw can do it), the community is harmonious and has a vested interest to not damage the pipe, and it will deliver warm water. Predicting how long the system will last is dependent upon how vested the community is. We cannot bury all the pipe (make its harder to steal pipe) in this six week trip, however we can do everything else. Getting water to the community is feasible. The rates of work have all been deemed feasible by our mentors.

We will propose the idea of trenching to the community. Protection of the pipe is up to community members. If they want a lasting water system, they will trench. They must meet us halfway.

A trenched pipeline is the best pipeline. Ideally, our pipeline needs to be in a trench 0.7m wide by 0.7m deep. Those dimensions specify for a 90mm pipe with 0.3m on each side for its width, and a 0.5m burial depth (how much cover is on the pipe), 0.09m for the pipe diameter itself, and 0.1m for sand bed. For reference, 1m wide trenches are very common for comfort of workers and economy, but ours need be so wide with such small pipe. The trench needs to be filled with a 10cm sandbed such that the 120 degrees of the circular pipe is in the sand bed. Any rocks must be removed or else point loading will cause the pipe to fail over time (this is in reference to PENT hours).

To be conservative, let's say the pipeline is 6000m long. 2940 m^3 must be excavated. Excavation time varies. What's worse is that a proper dig test has never been conducted. Assuming 1.1m^3/day can be excavated by a man, with 100 people, the process will take 32 working days. With 200, 16 days. Such numbers mobilized are normal in similar projects, but the two villages combined only have 370. In six weeks, this is simply not feasible. But trenching will be up to the community; that's their contribution. The only fear is that the sub-grade contains mostly bedrock, which would require nearly 70 working days for 100 workers for 6 kilometers. We will have a talk with the community about burying pipe in all village networks instead of placing it in an open shallow trench and why it's necessary for high traffic areas.

Valve Leaks

If our valves leak then we have a sourcing problem. To mitigate this, we plan to only purchase ISO certified products, which will give needed consistency to the project. During the project, however, we will need to be ready to have a list of other suppliers such that we can readily purchase these items.

3.4.3.3. Tanks

- Failure to source hardware

- We will bring as much of the power tools and hardware from the US as possible for the tanks.
- The wood will be sourced in Casablanca from Comarbois.
- Rebar should not be difficult to find, but doing so as early as possible is a priority.
- Concrete materials will be ordered and delivered from Marrakesh, but there is a lot of buffer time for this. All the concrete materials will arrive at the site one week before concrete work begins

- Material Theft
  - A night watchman will be hired to guard the site.
- Lack of labor support from community
  - If community cannot provide sufficient labor, then laborers will be hired from outside the community.
- Battery failure
  - A gasoline- powered generator will be brought onsite
- Concrete mixer failure
  - Two mixers will be run simultaneously so that if one fails, the other can keep the pour going while the second is fixed or replaced.
- Vibrator fails
  - We tamp the concrete manually using rebar

3.4.3.4. Spigots

In terms of the problems we are facing with the spigots, at each step in the process, we have accounted for extra time, leaving space for testing and error mitigation at each pipe fitting point. We also have four full working days at the end of the trip which can be used to complete any tasks if we face that many delays.

Also, we have been centering our designs of the spigots around the needs of the community in order, including current water needs of the communities and the amount of water that has been set aside both for people and for their animals. As a result, we do not foresee any major changes being made by the community, and we have set aside time to alot for potential minor changes.

Additionally, if we are unable to excavate and bury the pipeline, we would lay HDPE pipe above ground as close as we can to the spigot site, and line rocks along the side in an attempt to enclose it. We would also communicate with the community to ensure that the pipes are not run over. However, even if this conversation does not take place, HDPE pipes are very strong and can withstand heavy loads, and the transition to galvanized steel would occur underground, with none of this pipe exposed to human trampling.

For the proposed laundry facility, if we are unable to develop a full structure for this, we would simply pour a slab over the area that the originally designed facility was made. Additionally, if the community does not wish to have any of the facilities described, we have chosen locations that lead to a downward slope for all tapstands except for the domestic spigot at Izgouaren. For these, the downward slope means that we could simply create a pathway out of mortar to direct water away from the site. For Izgouaren, if this is the case we can have a collection bucket where all the drainage would lead, and the water guard would empty this at the end of the day. We do not see this as being too much of a hassle, as minimal waste water should occur, given that the community is very careful with their treatment of water.

3.4.3.5. Well Development

If pumping and backwashing fails to achieve a turbidity of 10 NTU or less, we will hire MogaBuilding Drilling Company, who drilled the original borehole, or another contractor to surge the well with a drilling rig. We will stop development when either turbidity, pH, and conductivity have stabilized to within 10% over three successive well volumes[13] or the end of the day is reached. This scenario has been scheduled for August 16th in case it is necessary.

4. Construction Budget

4.1. Material Quantity Takeoff

All material quantities for the pipeline and spigots is taken from a careful analysis of where valves ought to be. For example, after a tank, there should be a gate valve for maintenance and isolation purposes. After the pump, there should be a check valve to protect the pump. Globe valves are installed where the natural flow exceeds the designed flow. Keeping under the design flow is important to make sure we don't have too much head loss. See attachment M for detailed itemization of the pipeline. All quantities for concrete, formwork, and hardware are calculated from design geometries. All quantities for solar pumping system and well testing/development were determined by system design. All quantities for solar panel structure were determined by design geometries.

4.2. Cost Estimate Summary

Sources of construction item unit costs are listed in the comments column of Attachment C. See Attachment N for a compiled list of catalogs. Plastima is our pipe manufacturer and retailer of fittings. We are still sourcing valves and GI pipe supplier.

5. Facilities Operations and Maintenance Plan

5.1. Description of Ownership

The system is owned by the general public of community members in both Izgouaen and Ilguiloda, and governed by the Ait Bayoud Water Association. While the land on which the pump and solar panels are placed belongs to a private citizen, the water distribution system will be owned jointly by the communities of Izgouaren and Ilguiloda. We previously signed a land easement agreement with Mohammad, the community member whose land the well was drilled on. We will be drafting a new land easement agreement in both English and Arabic with Zineb's help to ease the land where the additional solar panel structures will need to be installed next to the well site.

5.2. Description of Operations Activities

The pump will be controlled solely by the availability of sunlight. An overflow pipe in the storage tank will allow excess water to leave the tank to a suitable location. We will discuss with community members in country about what they would like to do with excess water. Some ideas we have are to direct the water to nearby agricultural land or to fill an additional animal trough.

[13] conditions provided by the EPA

The Center for Disease Control recommends a mixture of 1 L of household bleach (5%-8.25% chlorine) to every 380 L of water in storage tank for disinfection.[14] The storage tank holds 19,020 gallons, so 50 L of household bleach will be necessary to disinfect. The water must be allowed to sit for at least 12 hours after chlorination. Since the community will not be able to use water while the tank is being disinfected, the chlorination process should be completed at the end of the day, so that the 12 hours of wait time occurs overnight. In the morning, the chlorinated water must be completely drained and should not be ingested. The tank can then be refilled with safe drinking water. This chlorination will be performed every month and is intended to prevent bacteria build-up in the tank, but may not sufficiently disinfect water at the taps. A proper chlorination system will be designed and implemented in the Summer 2020 trip. Community members will be advised to boil all water that will be ingested.

See section 6.4 for a description of how community access to water will be controlled by water guards to prevent over-withdrawal of water by any individual.

5.3. Description of Maintenance Activities

The tank will need to be drained periodically to muck out the accumulated sediment. During this process, any leaks can be repaired using hydraulic cement. A mixture consisting of 0.25 L of unscented household bleach (5%-8.25% chlorine) for every 38 L of water[15] will be used to rinse the tank afterwards. The exact frequency will be decided based on the turbidity of the water after well development on this trip. If 10 NTU is achieved, the tank will only need to be desludged annually. The same procedure follows for the break pressure tank.

The pipeline needs to be flushed monthly at the bottom of the valley where sediment can possibly accumulate. The surface of the pipeline will need to be visually inspected monthly to ensure that 10% of the wall thickness does not become gouged. If the damage is just a deep gouge, then a local equivalent of a product such as HYMAX repair clamps could be used. If there is destructive tampering with the valves or buried pipe in the village network (such as a shovel hitting into the ground), then the pipe can be cut and connected with locally available PE100 using MULTI/JOINT fittings, iJOINT fittings, the product line from Plastima or fused. Spare plastic piping is widely available in nearby towns and leftover pipes from the implementation will be stored by the Water Association. Proper training for butt fusion and mechanical fittings will be held for the proposed maintenance workers from the community (section 6.2) and interested community members. A maintenance guide will be written, translated, and stored with the Water Association.

Solar panels should be checked once a year for damage, such as corrosion, loose wires, cracking or broken glass, missing bolts, or erosion of system support. The solar panels should also be cleaned annually at the end of the Sirocco wind season (March-April), which causes dusty, dry conditions. The supplier AE Photonics will be able to provide more complex maintenance and replacement services for the solar pump as well as the solar panels if the community notices that the water flow rate has significantly decreased from when the system was first installed.

5.4. Part Replacement Schedule and Availability

Table 6: Replacement Parts & Schedule

Anticipated replacement parts	Availability	Schedule

[14] https://www.cdc.gov/healthywater/emergency/drinking/disinfection-cisterns.html
[15] as recommended by the Center for Disease Control in the link above

Solar Panels	AE Photonics	25 years
Pump	AE Photonics	15 years
Entire tank	Need to hire a contractor	50 years
PE100 Pipes	Plastima (Casablanca)	25 years
Control Valves	Plastima (Casablanca)	25 years

5.5. Operations and Maintenance Cost Analysis

Two water guards must monitor the water distribution sites every day, and they will be paid $10/day, so the total labor cost is $7,300. The annual cost of chlorine pellets for disinfecting the storage tank is negligible (<$20).

Two maintenance workers will spend one day out of each month to check the entire pipeline for surface damage and leakage. If repairs are needed, we estimate that two additional days out of each month can be spent towards maintenance whether that is taking repair clamps from inventory or placing an order for a part from Plastima. Lastly, they will also lead the efforts of cleaning tanks which can take one day a month. They will be paid $10/day, amounting to $960 a year for their services.

The treasurer will also need to be paid about $1,000 per year.

The maintenance cost of cleaning and inspecting the solar panels is negligible (water, soap, cloth). The lifespan of solar panels is 25 years and the lifespan of the pump is 15 years, so the community would have to raise $482 each year for the replacement parts plus the shipping and installation cost of the supplies, which we estimate will require the community to raise $70 each year at most.

The total annual operation and maintenance cost would be roughly $11,000.

5.6. Training requirements and Roles

Unfortunately, due to the loss of the Peace Corp as our NGO partner, we lost contact with the community most of the past year. In the past few weeks, we have begun to re-establish communication through phone calls conducted by community liaisons we previously worked with. However, we have yet to have direct contact with the community, so we have not been able to identify maintenance personnel.

Currently the community is trained and familiar with compression fittings and connecting GI pipe which can be sourced out of Meskala. Two maintenance workers from the Water Association will be identified for the pipeline and tank maintenance. They will need to accompany the entire piping and spigot installation, and be shown how to clean the tanks. A maintenance guide can be found in Attachment (work in progress) and will be translated by the implementation date. This maintenance guide will remain with the Water Association. The two maintenance workers, along with a student, are then expected to help lead fittings, valves, and fusion workshop which will be held for the community at the end of the trip. Specifically we will demonstrate how to use flanged connections, repair clamps, butt fusion machine, and compression fittings.

Training the community to clean and inspect the solar panels can be done in less than an hour during the last week of the implementation trip. Replacement of the solar panels and solar pump will be contracted out to AE Photonics. Ideally, a representative from the water association will join the team in supervising the installation of the solar pumping system and be introduced to AE Photonics. We will also provide the community with written instructions for what needs to be purchased and the contact information for AE Photonics.

The community is well-versed in concrete construction, so they will know in advance how to repair leaks. Community labor will be hired to help with the concrete tank construction. Two members of the water association will be chosen during the trip to routinely maintain the tanks, and the team will walk them through the process of maintaining the concrete tanks.

6. Community Based Organization (CBO)

6.1. CBO Structure

The Ait Bayoud Water Association is the organization underneath the ABDA that is responsible for organizing the long-term operation and maintenance of the system. The ABDA has a sitting president, vice president, and treasurer, and they represent the entire communities of Izgouaren and Ilguiloda in all decision made. All positions are chosen by held elections.

6.2. Roles and Responsibilities

Former Rais (president of entire commune) Si Ahmed El Madi is the current president of the ABDA, and his responsibilities include organizing meetings, collecting any funds raised by the community, and being the main contact person for EWB and Zineb. Brahim Alouch is the current vice president of ABDA, and his responsibilities include taking over all the responsibilities of the president in his absence. Ahmed Zindine is the current secretary of the ABDA, and his responsibilities include taking meeting notes and ensuring pertinent information is communicated to local community members. Tahami, ABDA member, houses EWB equipment in a storage unit on his property and served as the labor manager for the previous EWB project. Omar is the current president and treasurer of the Water Association, and his responsibilities include organizing meetings, collecting any funds raised by the community, and being the main contact person for EWB and Zineb in relation to the water system project. There is currently no vice-president who has filled the vacant position left by Mohammad. Mohammad is a community member who was removed from his position for providing misinformation that caused political tension between the two communities. He remains on the board.

6.3. CBO History of Prior Management

The ABDA was the preexisting organization centered on improving infrastructure in the community and they reached out to the Peace Corps, and eventually EWB for solutions to the issues Ait Bayoud faced. The Bridge Association, a subcommittee of the ABDA that started in 2012, was created to provide support for the construction and maintenance of the bridge, EWB's first project in the community, through labor and raised funds. According to the memorandum of understanding signed in 2012 for the previous bridge project, the Bridge Association was responsible for 15% of the materials cost in addition to labor and contractor costs, an estimate that was deemed reasonably by the EWB after their conducted surveys. This was completed successfully, so the memorandum of understanding between EWB and the Water Association also required that fund be collected for a portion of the project. Initially, they were responsible for connecting the existing water pump to electrical power, so about $4,000 was raised by the community to complete this effort. Due to inactivity by the current Rais, Rais Rachid, in extending a power line, we are proposing a new way for the collected money to be used and how future operation and maintenance costs will be collected.

Currently, the ABDA raises funds for the project by collecting monthly dues from each household. Due to difficulties in contacting the community in recent months due to the current NGO vacancy left with the Peace Corps finished their terms, we have no updates on the progress of these efforts, nor can we provide specific amounts that were raised and contributed by each member. Weakness lies in our currently inability to receive updates about the effectiveness of the current system, in each household's goodwill to pay the dues, and finally in the Rais' ability to spend the money in the appropriate manner in a timely fashion.

6.4. Sources of Operation and Maintenance Funding

The long-term sustainability of the infrastructure is dependent on the whole-hearted cooperation of the ABDA, its branch – the Ait Bayoud Water Association, and all local community members. To address the aforementioned weaknesses that will ensure long term operation and maintenance funding, we propose a payment plan that would permit a certain allowance of water based on a reasonable estimate of daily water use for necessity, and then anything over that amount required payment, especially for business purposes. The strength of the association is also in question, since it has been two years since we have last met with them. We plan to meet with them this trip, and hopefully rally the community around this project once more.

The new operation and maintenance funding plan would require a structural reorganization of the association.

<u>Water Protectors</u>

Because Morocco is a hereditary constitutional monarchy, the water board will be structured as such. At least one of the water protectors must permanently reside in each of the two villages. This position will be granted for life, and each water protector will designate an heir. Ideally, the water protector will also be a religious leader. Each new water protector will be sworn in by the following oaths:

1. *I hereby declare, on oath, that all revenue collected from water permits shall be used for its intended purpose of ensuring the sustained distribution of potable water to the people of Ilguiloda and Izgouaren. I shall receive no emoluments for this post.*

2. *I hereby declare, on oath, that twenty-five liters of potable water per day shall henceforth be entitled, without levy, to all persons residing in Ilguiloda and Izgouaren. No decision by vote nor decree may reduce these provisions. I ,______, vow to uphold these oaths.*

<u>Treasurer</u>

The treasurer will manage all financial matters, including, but not limited to, issuing permits, collecting permit fees, paying the water guard and maintenance workers, allocating funds for repair and replacement parts, and proposing adjustments to the permit system. All expenditures must be processed by the treasurer and approved by the water protectors. All revisions of the permit plan must be approved unanimously by the water protectors. This post is ideally held by a well-educated and morally reputable individual who understands the long-term replacement cycle of the system.

Water Guards

The position of water guard must be filled at each village. The water guard will be responsible for turning the taps on in the morning, ensuring that each family does not exceed their allotment of water, keeping the tapstands clean, reporting damage, and turning off the tapstands at the end of the water collection period. At least two water guards must be appointed from each village to ensure that the post is always filled.

The water guards would ideally be well-respected elders in the community with longstanding reputations of upstanding moral conduct. We recognize that this position is highly vulnerable to corruption. Other impoverished areas with water shortages, such as Mexico City, have reported extreme misconduct among the water distributors. To address this concern, water guards must never accept payment. Doing so is grounds for immediate termination. Instead, they will keep a roster of the families in the village and their permitted allotment of daily water. The water guards should also be relatively well paid so that the position is highly coveted and those who hold it have less need to accept bribes.

Maintenance Workers

Two maintenance workers will be designated before construction begins. These individuals will build the project alongside the EWB-CU team. The maintenance workers will ideally be young, able-bodied men permanently residing in the community. They will be responsible for maintaining the pipeline, checking for surface gauges, replacing and repairing the pipeline as needed, and cleaning the tanks monthly.

We will create the following system of water permits:

- Permit D is free and guarantees 25L of water per day for each person currently residing in a household. This permit will be available year-round and will be established as the right of every person residing in Ilguiloda and Izgouaren.
- Permit T is free and grants 25L of water per day to anyone caring for live trees.
- Permit A establishes the right to an additional 25L per person per day. This permit may be purchased for 10 MAD[16] per month. The number of A permits available will vary by month and must be purchased in advance on the first day of each month. Permit A will be sold in rounds, where in each round, a family elects to purchase the number of additional permits corresponding to the number of members of the household. This process will repeat until all permits are sold. The water guard will then be given a ledger with the number of permits purchased by each household.

Provided the permits sell out, this plan will generate roughly $12,000 per year, which will cover system replacement costs plus the payroll for the treasurer, water guards, and maintenance workers.

6.5. Analysis of Risks to long term Sustainability

The first risk is the misuse of funds by the treasurer and water protectors. This risk is best mitigated by accountability. Consequently, all expenditures by the treasurer must be approved unanimously by the

[16] Note: 1 MAD = 0.10 USD

water protectors. The water protectors must also publicly swear on the Quran not to misuse the funds collected from the community.

The second risk is the corruption of the water guards. It will be cheaper to bribe the guard than to pay for permits. To mitigate this risk, the water guard must be closely regulated. Any credible reports of corruption must result in the termination and replacement of the guards.

The final risk is elite capture. The wealthy members of the community may attempt to use their clout to alter the permit system. Business owners, enriched by the new system, may seek to acquire a greater share of the available water rights, and for a reduced price. If successful, they may decrease, if not eliminate, the provision of free water for domestic use. They may also reduce the price of water to the extent that insufficient funds can be raised for project maintenance. This risk is best mitigated by a strong decision-making council, appointed for life, with a high degree of accountability to the people.

6.6. Training requirements

All community members appointed to the posts specified above must be active in the construction of the project and the discussions relevant to it during the time that EWB-CU is present in the community.

7. Monitoring Data Collection

7.1. Data Collection

Baseline Data Gathering PMEL:
Functionality
Functionality Indicator 1 – Opinions about distance to water collection point for old system
Functionality Indicator 2 - Amount of water collected and the size/shape of container used
Functionality Indicator 3 - Use of the water

Periodic Maintenance
Maintenance Indicator 1 - Existence of broken components for old system
Maintenance Indicator 2 - Observed evidence of routine maintenance on the system done accurately without EWB-USA

Community Capacity
Com. Cap. Indicator 1 - Duplication of any element of the system without EWB- USA

Additional Information
1 - Number of people in each household for each community
2 - Which member collects water
3 - Amount of time spend collecting water
4 - Ease / Satisfaction of use of the system
5 - System concerns
6 - Opinion of EWB

Note that some past questions were removed due to the inactivity of the temporary distribution system implemented in summer 2017. New questions were added to accurately reflect the new permanent system.

After Construction: On the last day of the implementation trip, post-construction survey questions will be asked of community members at both water distribution sites. By this point, they will have had at least one day of interacting with the system. Physical data will also be gathered.

After Construction PMEL:
Functionality
Functionality Indicator 1 – Opinions about distance to water collection point
Functionality Indicator 2 - Rate of flow at water point
Functionality Indicator 3 - Quality of water at water point
Functionality Indicator 4 - Amount of water collected and the size/shape of container used
Functionality Indicator 5 - Use of the water
Functionality Indicator 6 - Amount of time collecting water at water collection point

Periodic Maintenance
Maintenance Indicator 1 - Existence of broken components
Maintenance Indicator 2 - Observed evidence of routine maintenance practice on the system done accurately without EWB-USA

Community Capacity
Com. Cap. Indicator 1 – Observe community members training others
Com. Cap. Indicator 2 - Duplication of any element of the system without EWB- USA
Com. Cap. Indicator 3 - Observe method of community member handling and transportation of water

Additional Information
1 - Number of people in each household for each community (for future trip)
2 - Which member collects water (for future trip)
3 - Amount of time spend collecting water
4 - Ease / Satisfaction of use of the system
5 - System concerns
6 - Opinion of EWB

Note that PMEL questions are the same but referring to the completed system where water is distributed from the spigots at each community rather than at the temporary distribution site.

7.2. Other Factors Contributing or Hindering Development

In our search to re-establish connections with the community, we essentially exhausted all possible organizations and contacts in the community. Besides the water association, the Rais Rachid is the only regional government actor involved with the project. He does not live near Izgouaren and Ilguiloda and he was not the original signatory of the memorandum when the project was established, so typically, his only involvement is to show up once during implementation trips and see how it's going. He was supposed to be responsible for taking the money the community raised and using it to extend the powerline, and each year, he promises to do so, but we have yet to observe any action on his part. To move around this obstacle, we made the decision to switch to solar power.

Since we have had limited contact with the community due to the absence of the Peace Corps, determining other local NGOs and governments that could impact our project has been difficult. We have relied on internet research to determine if such organizations in the area would have an impact in any way. We initially partnered with the High Atlas Foundation, but they were unable to go to the community and initiate a relationship with the community. Through searching for funding, we began working with Rotary International, specifically the Marrakech Rotary, who will be able to continue communicating with the community and implementing educational programs for the women when we are gone.

7.3. Beneficiary Analysis

The number of beneficiaries is currently estimated to be 370 people based on a water demand survey from Winter 2014. Based on community perspectives on past trips, we have heard that population has stagnated and possibly decreased in recent years due to community members leaving for better opportunities. As such, it seems reasonable to keep using 370 people as the estimate. Once the community has access to clean water, population will grow. In 25 years, the population is projected to grow to 540 people (see Attachment I, Population Modeling tab).

8. List of Attachments

Attachment A: Drawing Package
Attachment B: Schedule
Attachment C: Construction Cost Estimate/ Material Takeoff
Attachment D: Solar Pumping System Specifications
Attachment E: Electrical Calculations
Attachment F: Construction Safety Plan
Attachment G: Operations and Maintenance Plan
Attachment H: Partnership Agreement
Attachment I: Community Water Supply and Flow Rates
Attachment J: Revised Professional Mentor Hydraulic Calculations
Attachment K: Pipeline Hydraulics
Attachment L: Solar & Storage Model
Attachment M: Itemized Component List
Attachment N: Piping Catalogs
Attachment O: Shineline Shipping Quote
Attachment P: Three-Chamber Rectangular Tank Design
Attachment Q: Break Pressure Tank Design
Attachment R: Post-construction disinfection
Attachment S: Pipeline Lay Reasoning
Attachment T: Solar Rack Design

