ALTERNATIVE ANALYSIS

Executive Summary	
Community:	Ait Bayoud
Country:	Morocco
Chapter:	Columbia University
Submittal Date:	16 April 2019
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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, water pump, pipeline, and water storage system.
Scope of Work for the analysis (100 words) [2]	This assessment will evaluate five different alternatives for the pipeline from the well site to the two villages. Two alternatives for tanks will be evaluated. Two alternatives for power source will be evaluated.
Proposed Next Step (100 words) [3]	After the preferred alternatives have been selected and approved, we will begin preparation of the Draft Construction Drawings and Draft Implementation Trip Plan. The project is now tentatively slated for construction in late July 2019.

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 a local NGO called the High Atlas Foundation. They are based in New York and have a Moroccan branch in Marrakesh. They have agreed to work with us to facilitate any shipment of material, extension of power line, and translating services during project implementation.
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 6.5 kilometers of HDPE pipe donated by two pipe manufacturing companies in the US. We are working with local rotary clubs in both the US and Morocco to procure the rest through their grant process. Lastly, we are awaiting the results of a large grant we have submitted.
☒ [6]	**IS THE PROGRAM STILL ON TRACK TO MEET THE EWB PROJECT EXPECTATIONS?** The program is still on track and committed to meet EWB project expectations, including all design, implementation, and sustainability requirements.

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	7/22/19	Install new pump/power source, 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	12/29/19	Monitor and evaluate usage of Chateau site and condition of water distribution system. Implement

			filtration system depending on results of water quality test.
Planned M&E Tip	Not Previously Planned	7/14/20	Conduct further maintenance if necessary on any joints.

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1.0 Project Description

Project Background and History

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 (see attachment B). The well was constructed by the Moga Building Drilling Company and is located on the private property of a community collaborator.

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. Initial data and past hydrology studies of the region indicate that the water supply is potable. There have been no major contaminants of concern detected. 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 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. In January 2016 , a gravity pressure test which required no additional pump pressurization was conducted which showed several leaks.

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.

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 dwars, or communities. Amongst these dwars, there are two relatively isolated communities, Izgouaren and Ilguiloda, located 280 ft and 720 ft above the river level, respectively. A water supply, storage, and distribution system currently exists in the main dwars 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, only one child attends school on a regular basis. Our project hopes to solve this issue by providing a water supply system that distributes groundwater from an aquifer. The water is then pumped through a piping system to a centrally located water storage tank that the community can then easily access all the water needed for the day. 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.

Project Goals and Objective

The goal of the Water Supply project is to provide a sustainable source of water for two remote dwars (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 280 and 720 feet, respectively, above the river level. The goal of our project is to provide them with an easily accessible water source.

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, and providing for domestic livestock. This project was executed 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, and as of late 2018, is being executed with a local NGO called the High Atlas Foundation based in Marrakesh.

Currently, 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. This time dedicated to the gathering of water is often the responsibility of women and children. Therefore, the growth and progress of these communities are stalled as other necessities, such as healthcare and education are not given the proper attention. Currently, only one child attends school on a regular basis.

Our project hopes to solve this issue by providing a water supply system that distributes groundwater from an aquifer, and is then pumped through a piping system to a centrally located water storage tank that the community can then easily access all the water needed for the day.

Potential Solutions Considered

This alternative analysis will consider the five alternatives for the pipeline, two alternatives for the tanks, and three alternatives for the power source.

Pipeline

Alternative 1: GI Pipeline: From 2015-2017, 1365m of galvanized steel pipes were purchased, joined, and laid on the ground. Half of the pipeline runs from the drilled well toward the Chateau site and the other half runs starting at the Chateau toward the well. The section in the middle is not yet completed. The galvanized steel piping which was procured in Morocco is of low quality and prone to leaks. Under this alternative, the pipeline would be tested for leaks, repaired, and new galvanized steel pipes purchased/installed to complete the remaining section of the pipeline. All drawings from previous years are in Attachment B.

Alternative 2a: PE100RC Pipeline - On Grade: We propose an on-grade 50mm, 63mm, 90mm PE100RC pipeline, standard dimension ratio (SDR) hybrid of 11 and 17, with 2% carbon black that will replace the existing steel pipeline from the drilled well to the Chateau site, and from the Chateau site to the two villages. Pipe standard dimension ratios were chosen based on required pressures at different locations and to ensure a thick wall that could withstand abrasion of surface due to thermal expansion and to ensure the pipe walls can withstand pressure demands and occasional surging events. A proposed route is shown in Attachment A with a hydraulic grade profile of the gravity fed on page 10. The excel sheet for the grade profile is provided in Attachment O. Full hydraulic detail by professional mentor Colin Barrett is in Attachment G. Pellets would be purchased from the Moroccan distribution channels of Borealis and extruded to ISO standards in Casablanca.

Alternative 2b: PE4710 Pipeline - On Grade: We propose an on-grade 1.5", 2", 3" PE4710 pipeline, dimension ratio (DR) hybrid of 11 and 17, with 2% carbon black that will replace the existing steel pipeline from the drilled well to the Chateau site, and from the Chateau site to the two villages. Pipe standard dimension ratios were chosen based on required pressures at different locations and to ensure a thick wall that could withstand abrasion of surface due to thermal expansion and to ensure the pipe walls can withstand pressure demands and occasional surging events. A proposed route is shown in Attachment A. Full hydraulic detail by professional mentor Colin Barrett is in Attachment G.

Alternative 2c: Same as alternative 2a, except the pipes are pre-extruded, PE100 instead of PE100RC. Pipes would be purchased from Casablanca. See Attachment D for full cost analysis of these different options.

Alternative 3: Buried Pipeline: An alternative to an on-grade plastic pipeline is a buried pipeline. The advantages to a buried pipeline are limited thermal expansion, no abrasion, and no mechanical impacts. The major constraint is the cost of trenching due to the rocky subgrade and bedrock at the surface. A risk is rock damage to the pipeline during backfilling due to lack of suitable backfill material. Blasting may be required.

Alternative 4: Elevated Pipeline: An elevated pipeline would entirely avoid abrasion and point loading. The pipeline we've designed would be supported every 2 meters, totaling 1565 supports from the well site to the Chateau site. Technical calculations are listed in Attachment E. The main challenge with an elevated or supported pipeline is the labor and time involved in installation. The absence of abrasion and point loading would increase the lifespan of the pipeline significantly, however it would also entail much higher upfront costs.

Alternative 5: In-country Contractor: An alternative of the steel pipeline is hiring a local contractor to build the first part of the pipeline from the well to the Chateau This does not include the gravity fed portion of the pipeline. The pipes will be flanged and the cost is nearly $60,000.

Tanks

Alternative 1: Reinforced Concrete: A three chamber rectangular tank would be constructed using a concrete mix of 1:2.5:3.5:1.6 volume ratio of cement:sand:gravel:water, following EWB guidelines. The tank will measure 15'x29'x8'. One chamber (6.67' x 14.17', width x length) will act as a settling tank, while the two other chambers (6.92' x 21.1' for both) will act as storage tanks. A system of bypass pipes will be installed such that the water flow can bypass any one of the chambers during maintenance and cleaning. 3" deep holes in the foundation will be drilled where the vertical rebar will be embedded in the foundation and sealed with epoxy to hold the tanks to the foundation. The total cost of the concrete tank is $13,100

Alternative 2: Plastic: Three 20,000 L linear polyethylene tanks will be purchased from a local Moroccan supplier. The tanks will be rated for 1 kg/L at minimum, which is enough for water and light sediment. The local cost estimate of such tanks is $2,900 each, so the tanks would cost $8,700 total. The first tank will be used as a settling tank and the second two will be used as storage tanks.

Power Source

Alternative 1: Power Line: A proposal for extending the nearest three-phase power line in Tinilft to the well site will be submitted to the Office National de l'Electricité et de l'Eau Potable (ONEE), the Moroccan government agency in charge of electricity distribution. We will then receive a quote and pay for the government to complete the power line extension and install an electricity meter, ideally before the implementation trip. During the trip, we will hire an electrician to complete the final connections between the power line and the pump control panel.

Alternative 2: Solar Pump: The current pump would be replaced by the Lorentz PSk2-9 C-SJ8-44 solar pump and pump controller with a higher flow rate, which would be able to pump the full community demand while the sun is out. The pump will require 38 solar panels at minimum and can have up to 50 solar panels attached. For 38 solar panels, the design consists of two strings of 19 solar panels connected to a PV disconnect, which then connects to a surge protector, connected to the pump controller. A well probe will detect when the water level in the well drops below the level of the pump and turn the pump controller off to prevent dry run.

Project Team

The project team consists of student members on the water and piping teams of the Morocco Program in Columbia University's chapter of EWB, led by water team leads Vanessa Hansen-Quartey and Alice Wu and piping team leads Donald Swen and Nicholas Vallin; REIC Colin Barrett; mentors Robert Prager, Larry Bentley, Tim Bowden, Camille Rubeiz, and Greg Scoby; and faculty advisor Mohamed Haroun.

Community Partners

The Ait Bayoud Development Association (ABDA), a local group of community leaders, is a preexisting association dedicated to improving infrastructure in the region, which has now been expanded to involve a water committee. A MOU has since been drafted that outlines the roles each organization plays in the project. This Project Partnership Agreement has been approved by the local community.

The team currently works with our previous Peace Corps Volunteer Jessica Rushing and the High Atlas Foundation as the in-country NGO.

2.0 Alternatives

Pipeline

Alternative 1: GI Pipeline

The existing pipeline was proposed to be a 2 inch (50 mm) galvanized steel pipeline with two main sections: the first, a 2830 meter well pump-powered segment from the existing well that was drilled in 2014 to a chateau site near the village of Ilguiloda, and a 3050 meter-long gravity fed segment from the chateau to the village of Izgouaren. At the Chateau, the water would be stored in two 20,000 L tanks. The pipes would be joined using threaded couplings with air release valves at peaks, and placed on the ground.

From 2015-2017, 1,365m of galvanized steel pipes were purchased, joined, and laid on the ground. Half of the laid pipeline runs from the drilled well toward the Chateau site and the other half runs starting at the Chateau toward the well. They remain unconnected. After the first installation in 2015, the galvanized pipes leaked significantly. Upon further investigation, the leaking was found to be due to a combination of corrosion, thermal stress due to thermal expansion, improper installation procedure, and inappropriate sourcing of pipe from local suppliers. Sourcing is important because the thread type of the pipe and of the coupling have to be the same; any variation will cause leaks. The existing pipe is tapered threads and the couplings are straight threads. This reinforced the importance of knowing where the pipes come from, how they were produced, and that they meet ISO standards. See Attachment C Fig 3 for a documented leak example.

The cost of buying the remaining needed galvanized steel pipes would be $50,838 ($11.10 per meter) excluding connections and unions (See Attachment D). $20,000 has already been spent to purchase the existing pipe, unions, and supplies to join the pipes.

If we continue with the existing plan, we would incorporate thermal expansion loops to alleviate the 1.61 meters of linear expansion resulting from thermal expansion in the first part of the pipeline.

After installation, maintenance would be by the community and Water Association of the two villages. The maintenance activities required for this pipeline would include fixing leaks at the connections between pipes, cut off the threads, rethreading broken pipes, and reinstalling the pipeline properly by using a guide provided by the engineering project team. We would consequently train the community to use pipe threaders, sealants, caulk or other remedies to fix the pipe.

Everything to install the pipes and maintain them is available in country at the nearest city. The pipes will continue to be sourced out of Marrakesh, so that they conform to Moroccan standards. The joints will be tested before purchasing. Completing the pipeline may be delayed by leaking if that is a recurring issue and access to water will again be delayed. The major risk with this alternative, is that leaks would continue due to the poor quality of the threaded pipe and couplings that are available in Morocco. The pipeline would most likely be implemented in at least two separate trips, one for each section of the pipeline.

Alternative 2: HDPE Pipeline - On Grade

Due to the recurring problem of leaking and high cost of additional galvanized steel pipeline, we decided to assess the feasibility of high density polyethylene (HDPE) piping. Plastic pipelines have a service life of over 50 years with no pitting, cracking, corrosion, or any of the typical problems associated with incumbent pipe systems. They are joined using either butt fusion or electrofusion which applies heat and pressure to fuse two separate pieces of pipe into one monolithic material, meaning no mechanical joints and no leaking (See Attachment C Fig. 2). They are lighter to transport, require less labor in installation, and would result in a 5 times reduction of the overall project cost.

To be thorough and confident of this direction, we attended the HDPE Municipal Utilities Board Meeting in Tulsa, Oklahoma in March 2018. There we presented our project and met with piping engineers, consultants, and manufacturers from all over the United States. We were trained in butt fusion by McElroy and electrofusion methods of joining plastic pipe by Georg Fischer. From this conference visit, we determined the feasibility of a plastic pipeline.

Alternative 2a: PE100RC Pipeline - On Grade

We propose an on-grade PE100RC[1] pipeline with 2% carbon black that will replace the existing steel pipeline from the drilled well to the Chateau site, and from the Chateau site to the two villages. From the Well to the Chateau, we will use a 50mm, standard dimension ratio (SDR) of 11. From the Chateau site to a tapstand at Ilguiloda, we will use approximately 950m of 90mm eSDR 17 and from Ilguiloda to Izgouaren, we will use 800m of 50mm SDR 11, install a break pressure tank, and continue with 1300m of 63mm SDR 11. Please see the hydraulic grade line diagram, page 11-12 in Attachment A, for the proposed path of the gravity system. Please see page 13 and 14 in Attachment A for our tapstand and break pressure tank design

[1] The particular material we end up using may change but will be limited to the following: PE100, PE100RC. All of them satisfy our pressure and environmental demands with PE100RC being the strongest option.

respectively. This path was chosen based on grade profiles, ability to provide suitable tapstand locations for the community, length, and installation difficulty. A flow rate of 2 L/s is expected at Izgouaren, which means up to 10 taps with a flowrate of 0.2 L/s each could be accommodated without issues. We propose to implement two communal multi-spouted tapstands this summer, one at each village, with phased expansion within the village network in latter implementation trips. Page 3 of Attachment A details the schematic of tapstand flow rates within the village network. The exact location of the tapstands will need to be agreed upon by a majority of the member community. The contingency plan will be to construct a simple tapstand with one spout at each village. With the help of our past PCV member, communications are currently in place to determine the locations of these tapstands. All calculations have been checked by REIC mentor Colin Barrett and Mr. Andrew Wedgner of LyondellBassell.

The HDPE pipeline is designed against brittle fracture and UV radiation with a well dispersed mixture of 2% carbon black which prevents photo-oxidation and chain-scissioning. A pipe standard dimension ratio of 11 and 17 was chosen to based on properly derated pressure ratings and to ensure the pipe walls can withstand pressure demands and occasional surging events. From the well to the Chateau site, the head loss due to friction losses is 19.35 ft for 90mm SDR 11, calculated using the Hazen-Williams equation. The elevation change is 150 ft between the well to the Chateau site. The pipe from this section will need to withstand 111 psi. From the Chateau to the two villages, the highest pressure demand is 143m or equivalently 203 psi at no flow. To determine the piping needed, we first derate our pipe at a maximum operating temperature of 60C. The pressure rating of the pipes given in the standard ISO4427 is at a temperature of 20 C. The derating factor is 1.3% for every C above 20 C, giving us a temperature derating factor of 0.52. We used a factor of 0.5. Even after applying the derating factor to thickest pipe (SDR7.4), we get 12.5 bar (181 psi) which is not greater than the pressure demand of 203 psi. This means a 1m^3 break pressure tank is necessary on the downhill segment. Please see the hydraulic grade line in Attachment A for full details. The hybrid of 50mm, 63mm, and 90mm piping would fully satisfy our technical demands[2]. The pipeline will be free to snake in order to reduce thermal stresses at the end of the pipeline, but will be guided intermittently in order to reduce any severe snaking. Snaking will be especially important as the pipeline is planned to be implemented during the summer, when temperatures are highest. Where the pipeline connects with taps or solid structures, the pipeline will be anchored appropriately to mitigate expansion force. The plastic pipeline will be encased in a larger diameter (3 inch) steel pipeline at road crossings to prevent vehicular damage. A rubber padding or local material will be used to separate direct plastic to steel contact. To ensure we have the toughest material available, our ideal material is to use an anti-rapid crack propagation additive, usually suffixed as '-CR' for "crack resistant." Such crack resistant formulation would increase the raw material cost of pellets by 3 cents per kilogram. It is widely used by gas companies in rocky areas to avoid the cost of importing sand backfill[3]. The very high resistance to slow crack growth will prevent any rock impingement failures. See Attachment D for financial calculations.

The raw material pellet cost for the pipeline, excluding extrusion, is quoted to be about $15,800 by a branch of Borealis located in Morocco. Extrusion cost is estimated to be roughly $0.19/m, bringing the total to over $1000 for extrusion. Pre-extruded PE100RC does not exist, however its less tough predecessor and equally sufficient and high performing PE100 is widely available. The total cost for pre-extruded PE100 from

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[2] *Ch 5 Standard Specifications, Standard Test Methods and Codes for PE (Polyethylene) Piping Systems*. 2nd ed., Plastics Pipe Institute, 2012.

[3] Palermo, Gene. "Comparison Between PE 4710 (PE 4710 PLUS) and PE 100 (PE 100+, PE 100 RC)."

a company based in Marrakech is $16,600. The cost of the galvanized steel we have been using is $11.10 per meter, meaning just the raw material of the steel pipes would have cost $51,000, not including unions, cost of labor, and transportation. On a cost perspective, a plastic pipeline seems extremely promising. However attempts for corporate sponsorship from all the companies in the PE100+ association have been attempted with zero success.

To install the pipeline, the community would be involved to clear a path free of point loading by rocks for the pipeline. At most, this would involve some type of construction machine equipment, such as a small bulldozer, which has been previously used to clear a path for a dirt road in the community, or a hoe ram in addition to community labor with pickaxes. In highly trafficked areas, pipe in the village should be buried underground and fused monolithically. However, mentors that have previously traveled mentioned that there is still a large rock content in the subgrade at Izgouaren. The most reasonable plan would be to locate the tapstands right where the pipe enters from the backside of the slope into Izgouaren. This location would minimize pipe networks within the village however, the location needs to be agreed upon with the community. In the case that pipe networks extend into the center of the village, the schedule allots for time to pave a smooth path free of point loading. Small supports can be made in extreme terrain using local rock and mortar if needed. The pipes would be joined by trained EWB students and locals. The pipeline would be maintained by the Water Association in the Ait Bayoud region. The cost, time, and labor associated with fixing leaks in steel pipelines would be entirely avoided. Instead, the most important aspect with pipe maintenance is to ensure that 10% of the wall thickness does not become damaged. If 10% or more of the wall is damaged, then that section of the pipe needs to be removed, new HDPE pipe inserted and then connected using widely available compression fittings. One company, Amadal Azgzaw, based in Casablanca sells PLASTICA ALFA compression fittings (rated 16 bar) conforming to ISO 14236 standard for 38 MAD, 47 MAD, and 138 MAD for 50mm, 63mm, and 90mm fittings respectively. We are currently looking into high quality fittings from Meskala that conform to ISO standards. Other fittings that offer excellent mechanical performance is MULTI/JOINT couplings by Waga, a branch of Georg Fischer, which is available locally as well. Spare PE100 is widely available Marrakech and Casablanca. Nearby towns such as Meskala stock lower grade plastic piping which will need to be assessed for quality. Pipes in Meskala could potentially be used as replacement in the village network if their outer diameter is consistent and they have sufficient pressure rating. Leftover pipes and fittings will be stored by the Water Association.

Alternative 2b: PE4710 Pipeline - On Grade

An entirely local solution is most ideal. If the pipe breaks, local materials can be sourced to repair the pipeline. However, we received an offer from the Alliance for PE Pipe of America for the full donation of the entire 6 km of piping, one fusion operator, and one piping expert to ensure proper installation of the pipeline, all free of charge to our project. This donation must be taken fully into consideration for feasibility.

This PE4710 with 2% carbon black and extruded in US customary units will replace the existing steel pipeline from the drilled well to the Chateau site, and from the Chateau site to the two villages. Because PE4710 conforms to ASTM standards, pressure ratings are different and thus the pipeline design also needs to be derated and adapted correspondingly. From the Well to the Chateau, we will use a 2 inch, dimension ratio (DR) of 11. From the Chateau site to a tapstand at Ilguiloda, we will use approximately 950m of 3 inch DR 11 and from Ilguiloda to Izgouaren, we will use 700m of 1.5 inch DR 11, install a break pressure tank, and continue with 350m of 3 inch DR 11 followed by 1100m of 2 inch DR 9. Please see the hydraulic grade line diagram, page 11-12 in Attachment A, for the proposed path of the gravity system. The same flow rate of 2 L/s is expected at Izgouaren, which means up to 10 taps with a flowrate of 0.2 L/s each could be accommodated without issues. In our first implementation trip, we will build at least one tapstand at each village. With the help of our past PCV member, communications are currently in place to determine the locations of these tapstands. All calculations have been checked by REIC mentor Colin Barrett and Mr. Andrew Wedgner of LyondellBassell.

A PE4710 pipeline is also designed against brittle fracture and UV radiation with a well dispersed mixture of 2% carbon black which prevents photo-oxidation and chain-scissioning. All pipe dimension ratios were chosen based on properly derated pressure ratings and to ensure the pipe walls can withstand pressure demands and occasional surging events. Designed similarly to Alternative 2a, we applied a derating factor of 0.52 instead of 0.5. A 1m^3 break pressure tank is still necessary on the downhill segment. The pipeline will be free to snake in order to reduce thermal stresses at the end of the pipeline, but will be guided intermittently in order to reduce any severe snaking. Where the pipeline connects with taps or solid structures, the pipeline will be anchored appropriately to mitigate expansion force. The plastic pipeline will be encased in a larger diameter (3 inch) steel pipeline at road crossings to prevent vehicular damage. A rubber padding or local material will be used to separate direct plastic to steel contact.

The estimated value of this donation is well over $20,000. The most important value added to this donation is the fusion operator and the equipment needed to fuse the pipes (generator and butt fusion machine). As contingency, we also have a source for generators and fusion equipment in Marrakech. The obstacle is transporting the pipes from a domestic port to a nearby coastal port such as Agadir in Morocco. The process can be broken down into two stages: port to port and then port to door. Our benefactor manufacturers recommend two 40 ft high cube shipping containers. We've consulted with freight-forwarder company Flexport for general freight process information and also received a detailed quote from an international forwarder, Shine Line, based in Casablanca who provides port to door services. It will cost about $4200 per container to ship from port of New York to port of Casablanca, have customs handled by an agent of the company, and have the pipes be trucked and delivered to the Ait Bayoud community. The NGO working with us, High Atlas, has agreed to act as the recipient of the pipes. The detailed quote is in Attachment N.

The same procedure follows for installing the pipeline, however, this time overseen by a professional fusion operator with experience fusing pipe in extreme conditions. ASTM standard tests will be followed to ensure pipe is installed properly. The main equipment used would be a McElroy PIT BULL® 14 butt fusion machine, which the entire traveling team has been trained in. The pipeline would be maintained by the Water Association in the Ait Bayoud region. The most important aspect will still be pipe maintenance to ensure that 10% of the wall thickness does not become damaged. If 10% or more of the wall is damaged, then that section of the pipe needs to be removed, new HDPE pipe inserted and then connected using either fusion with PE100 or the excellent locally available MULTI/JOINT couplings by Waga, a branch of the international piping company Georg Fischer. These MULTI/JOINT couplings can mechanically join pipes extruded in US Customary units with that of metric standards and offers 232 psi pressure rating. Another solution is to use universal joints (iJOINT series) by Georg Fischer to convert from US customary to metric. Lastly another solution is using HYMAX repair clamps which patches any deep scratch on the pipe. These would be donated by the PE Pipe Alliance and stored with the community. If these run out, they can use the multitude of other options which we will have select community members trained in and involved in the installation process.

The transition from US customary (PE4710) to metric (PE100) will be installed near the tapstand locations. This would most likely be fusion to PE100 or using MULTI/JOINT fittings. This way, all village network tapstands and valves can be serviced using metric material. In highly trafficked areas, pipe in the village should be buried underground and fused monolithically. However, mentors that have previously traveled mentioned that there is still a large rock content in the subgrade at Izgouaren. The most reasonable plan would be to locate the tapstands right where the pipe enters from the backside of the slope into Izgouaren. This location would minimize pipe networks within the village however, the location needs to be agreed upon with the community. In the case that pipe networks extend into the center of the village, the schedule allots for time to pave a smooth path free of point loading. Locally available compression fittings can still be used such as PLASTICA ALFA from Marrakech. These MULTI/JOINT couplings will also be installed before and after the tank so that all tank specifications and respective valves can be metric based. The rationale is that control valves have a shorter service life compared to plastic, so we need these sections to be easily serviceable. These control valves will also be encased in a valve box, made to protect the valves from children and animals that may tamper or damage the system. Extra PE4710 pipes, repair clamps, MULTI/JOINT couplings and/or universal adapters will be stored with the Water Association in case of any repairs needed to the main water transmission line. The contact information of local dealers of these couplings and fittings will also be shared with the community.

Contingency plans in the absence of MULTI/JOINT couplings or fusion is using flange adapters with universal bolts or the smaller diameter universal adapters by Georg Fischer. For the latter, a reducer would be have to be fused onto PE4710 and the adapter can then mechanically join PE100 with PE4710.

Alternative 2c: Pre-extruded PE100 Pipeline - On Grade

Same as 2a, except pipe is bought pre-extruded in Casablanca. Slightly less durable than PE100RC, but high performing and comparable to PE4710.

Alternative 3: Buried Pipeline

An alternative to an on-grade plastic pipeline is a buried pipeline. The advantages to a buried pipeline are no thermal expansion, no abrasion, and no mechanical impacts. The major inhibitor is the cost of trenching due to the large rock content in the subgrade and the bedrock on the surface. Trenching can cost well in excess of $10 per foot and would raise the installation cost such that material costs would only be 10% or less of the budget. Blasting may even be required. Another problem that many gas companies facing similar situations is the need to import sand backfill in rocky areas. The risk for rock impingement damage would be high. See Attachment C Fig.1 and 4 for an example of the landscape.

If such funds could be raised, maintenance would be the most minimal out of all options. If a section of the pipeline somehow breaks then the pipeline would need to be dug out for repair. Repair would be the same as described in the on-grade pipeline. The last concern for a buried pipeline would be operation of a trenching machine. There are many variables with this alternative including the need to find a contractor with suitable excavation equipment (e.g hoe ram and bucket excavator).

Alternative 4: Elevated Pipeline

The last alternative under consideration is an elevated HDPE pipeline. An elevated pipeline would entirely avoid abrasion and point loading. The designed pipeline would be supported every 2 meters, totaling 1,565 supports from the well site to the Chateau site. See Attachment E. The vertical sag between each support including thermal variation would be 4.65 inches conservatively. The resulting bending strain on the walls would be 2.17%. All assumptions for calculations are included in the MATLAB generated file.

The supports would be made from local materials such as local rocks and mortar or concrete blocks with a hole in the center. Concrete is widely available in Meskala (20 minute drive from well site). A 50 kg bag of cement costs 75dh or at current exchange rates ($8 USD). Each bag can make seven supports. The total cost of 1,565 supports not including labor and time is at least $984.

The main challenge with an elevated or supported pipeline is the labor and time involved in installation. Over 1,500 concrete supports will have to be made with the help of the community. This is not including the procuring, transport, and mixing of the concrete. Maintenance would be the same as the buried and on-grade pipelines. The absence of abrasion and point loading would increase the lifespan of the pipeline significantly, but it also warrants greater upfront costs.

Alternative 5: GI Pipeline with Flanges

Our final alternative is a continuation of a steel pipeline from the well to the Chateau using a local contractor. The same path will be installed upon with the same GI pipes. The only difference is that the pipes would be connected with flanges and bolts and drainage valves would be incorporated. This method was proposed to us by a reputable Ait Bayoud contractor. However, there is considerable additional costs associated with it. Using a contractor will cost 564660.00 dirhams or $59,316. In this fee also includes, the contractor desire to build a water tower which makes sense given steel pipes have a rougher inner surface and would cause the head at Ilguiloda to be low.

Tanks

Alternative 1:

Alternative 1 consists of a three-chambered monolithic reinforced concrete tank with a total capacity of 77,090L. The outer dimension of the tank will be 29 feet long, 15 feet wide, and 8 feet high. The first chamber, which is 80 inches by 170 inches, will serve as a settling chamber. The water level in this tank shall never drop below 79 inches, rendering 16,715 liters of water in this chamber unavailable for storage capacity. This chamber will have allow for only 2,229 liters of storage capacity in the top 6 inches of the chamber. The second two chambers, each 83 inches by 253 inches, will primarily serve as storage tanks, but will also provide opportunity for settling. The water level in these chambers shall not drop below 8 inches, each rendering 2,736 liters unavailable for storage. Each of the storage chambers will have 26,337 liters of water storage capacity. The total settling volume of the tank is thus 22,187 liters and the total storage volume is 54,903 liters. Please see Attachment A for drawings of the tank design.

The 22,187 liters of settling volume shall be permanently held in the tank, creating a detention time of 2.5 hours for particles to settle. When additional water is pumped in, the water level will rise the two storage chambers from 8 inches to 79, where it will match the water height of the settling chamber, then the water level in all three chambers will rise together to a maximum height of 85 inches, at which time a float will be triggered, and the flow in will be stopped.

All walls will be 5 inches thick and have vertical ½ inch rebar spaced at 24 inches and extending 3 inches into the foundation. Horizontal ½ inch rebar will be spaced at 16 inches in the walls. The roof will be six inches thick with ½ inch rebar spaced every 16 inches. Please see Attachment I for the structural calculations.

The tank will be constructed by first building a large wooden box in the place of each chamber. These boxes will be constructed with ½ inch OSB sheeting and framed by 2”x8”s. All wood will be joined by steel tie plates in such a way that the box can be disassembled and removed through the chamber opening once concrete has set. The outer forms will also be constructed of OSB and 2”x8” boards, but with wedge anchors preventing form walls from sheering outward. The structural calculations for the formwork is still in the process of being designed.

The first day of pouring will be the outer walls. The second day will be center “T” of the tank walls. The third day will be the roof. Each of these will be poured in a continuous pour so that no joints form in each of the three sections. We will accomplish this continuous pour using two 6 cubic foot (170 liter) gas powered concrete mixer. Expandable rubber waterstops will be placed between each of the cold joints in the concrete. Concrete will be vibrated during pouring to prevent voids and honeycombing. A concrete mix of 1:2.5:3.5:1.6 volume ratio of cement:sand:gravel:water will be used, following EWB guidelines. Finally, a layer of waterproof mortar will be applied to the inside of the tank.

The option of using reinforced concrete is being considered because of the wide availability of concrete in Morocco and the stability and strength that the rebar reinforcements will provide. The expected total cost of this option is $13,100 and the expected lifespan is 50–100 years. Maintenance tasks that would be necessary to try to extend the lifetime of the tanks as long as possible are periodically checking up on the tanks and being able to properly identify cracks, as well as assess the severity of any cracks if they do occur. Once cracks are identified, they will need to be patched with concrete patch. Members of the local community are very familiar with working with concrete and maintaining concrete structures, so they will be fully capable of helping with the construction of the tanks and patching cracks.

It is intended that all materials for the project will come from either Agadir or Marrakech, two nearby cities in Morocco. We estimate that it will take 9 days to place the steel and construct the inner forms, 5 days to pour the concrete and construct the outer forms. The concrete will take 7 days to set to 65% strength, at which point we will be able to test the tanks in the entire system.

Alternative 2:

Alternative 2 consists of three manufactured linear polyethylene tanks, each with a volume of 20,000 Liters. Each tank will be rated for a weight of at least 1 kg/liter (weight of liquid water plus light sediment). These tanks are capable of handling liquid water with light amounts of sediment. Rotomoulage, a plastic tanks supplier in Agadir, Morocco, gave us a cost estimate of $2900 per tank, with free shipping and installation included. The cylindrical tank has a diameter of 3 m and a height of 3.13 m with a slight conical roof. The estimate lifespan of the tanks is 10 to 15 years with a canopy shielding the tanks from direct sunlight. It will take one day for the tanks to be shipped to the project site and installed. Plastic tanks require little maintenance, besides checking for cracks and clearing out sediment regularly, depending on the amount of sediment in the water.

Power Source

Alternative 1: Power Line

Our original plan to power the pump was to extend the nearest power line to the well. On previous trips, we have walked to the nearest power line in the neighboring commune of Tinilft, and confirmed that there is three-phase power available. We have developed an electrical design for the pump control panel with 380V, three-phase input power input from the future power line extension (Attachment B).

In Morocco, power distribution is under the administration of the The Office National de l'Electricité et de l'Eau Potable (ONEE). Ait Bayoud falls within the Marrakech Distribution Agency office of Mr. Omar Oussaadi. There are four types of electrical connection requests that can be applied for: Large Facilities, Local Communities, Professionals, and Individuals/Residentials. Due to our project’s situation, we would seem to fall under either the Local Community category, except instead of trying to electrify an entire dwar, we only need to power a single pump. The procedure for getting power to the pump is as follows:

1. Submit a connection request to the Marrakech Distribution Agency for a medium voltage connection of over 1km long. Necessary documents include:
    a. Power Budget
    b. Letter of Request
    c. Construction Plan
2. Have the ONEE make a site visit (cost of 1500 DH or $165)
3. Get the initial quote (within 10 days of the receival of the request, according to the website)
4. Decide on the final quote
5. Have the power line extended by ONEE and a low voltage transformer and electricity meter installed
6. Hire an electrician to connect the power line to the pump control panel
7. Submit a request for approval to start receiving electricity. Necessary documents include:
    a. Certificate of Land Ownership
    b. Letter of Request
8. Sign a contract to receive electricity

After extending the power line, we would like to add solar power in a future trip as a more sustainable power source, with the power line acting as backup for when the pump needs to work and there is insufficient sunlight.

Alternative 2: Solar Pump

The alternative to using grid power is solar power. The easiest option would be to power the currently installed Lowara 4GS30 pump with solar panels. However, in our system, the current pump would only be able to achieve a flow rate of around 3500 L/h. At this flow rate, it will take about 12 hours to pump the community’s daily water demand. This amount of time would be fine for a power line, but due to the time restriction of sunlight hours when using solar power, the current pump would be unable to meet the community demand solely using solar panels. A possible means of extending the pumping time would be to oversize the solar field and include batteries to store excess solar power for pumping outside of daylight hours. However, batteries are extremely inefficient and require replacement every 2-3 years. Moreover, batteries are also quite expensive. Based on our calculations, we determined that 52 solar panels and 14 batteries would be necessary to make this design possible (Attachment E). The cost of high quality batteries alone would be $7,700 based on price quotes from a solar power company based in Marrakech, Allianz Solar.

To avoid using batteries, we could instead replace the current pump with a solar pump. A solar pump, as opposed to a traditional pump, is a DC pump with a pump controller that varies the frequency of the motor based on the solar power available. Purchasing a new pump would allow us to choose a pump with a higher flow rate such that the community water demand can be supplied during daylight hours. This approach would eliminate the need for batteries and would be cost effective because the the purchase and replacement cost of batteries every 3 years is greater than the potential cost of a new pump. We contacted AE Photonics, a licensed distributor of Lorentz solar pumps based in Casablanca, Morocco to get price quotes for a new solar pumping system. We chose the Lorentz PSk2-9 C-SJ8-44 since it can handle up to 180 m of head. The new pump would cost $3,740. Since the current pump has already been purchased, it is a sunk cost that cannot be recovered, so our decisions only consider the future cost of making an alternative possible.

AE Photonics also provided us with data for the hourly energy output of standard 270W solar panels based on hourly solar irradiance data they have for the city of Essaouira, which is the nearest city to Ait Bayoud. From there, using the pump curves and system curves, we could determine the daily water output of the solar pumping system (Attachment E). Initially we planned to use 2 inch SDR11 piping for the segment of the pipeline running from the well to the chateau, but we realized that the high head would limit the maximum flow rate to 3.8 m^3/h, which would not be able to meet the community demand even if the pump worked at that maximum flow rate for all daylight hours each day. To accommodate the solar pump, this alternative would require 3 inch SDR11 piping for the segment of pipeline from the pump to the chateau, which would allow for a maximum flow rate of 5.6 m^3/h.

The bare minimum design for the solar pump would require 38 solar panels, which would enable a daily output of 43 m^3. The excess output would be able to cover in the worst case, one overcast day per month, and in the best case, 10 to 11 overcast days per month, depending on the water level in the well (Attachment J). We also considered a system with 44 panels and 50 panels. If more than 50 panels are installed, the peak power generated would go over the 10 kW power limit of the pump controller. The design of the 38 panel solar pumping system is shown in Attachment K. There will be two strings of 19 panels each connected with a PV Disconnect (spec sheet in Attachment K). An additional PV Protect will protect against any power surges (e.g. due to lightning). The output would then go to the pump controller.

The solar pump would only require one trip to implement, and AE Photonics would transport and supply the necessary materials. Installing the solar pump would require removing the current pump and then installing the new pump. The current pump could potentially be sold as a source of revenue to offset the costs of purchasing a new pump.

3.0 Comparison

Pipeline Comparison

Criteria for Pipeline

Ability to solve the identified need

The need is to deliver water from the well to the two villages. The galvanized steel pipeline theoretically delivers water, but leaking and a limited lifespan deter its ability to effectively solve the identified need. The toughness and hardness, however, of a galvanized steel pipeline, makes it effective at absorbing mechanical impact and point loading effectively. Laying the steel pipeline on the ground will not affect its ability to carry water except for eventual corrosion and deposit buildup.The same applies to the steel pipeline with flanges, although the flanges are slightly better since this reduces rupture chances and makes it easier to maintain. On the other hand, a HDPE pipeline does not leak and has a longer lifespan. It does not corrode, crack, and has no mechanical joints. HDPE, however, expands 10 times as much as steel. Placing HDPE on-grade will subject it to abrasion, possible mechanical impact from vehicles, and most probably human interference. However proper selection of material such as using PE100 RC would resist impingement significantly. Placing HDPE underground would protect the pipe from abrasion, thermal expansion, and mechanical impact. However the risk of rock impingement from a rocky backfill is high. Having an elevated HDPE pipeline will protect the pipe from abrasion but not thermal expansion nor mechanical impact. At the end of the day, the plastic pipeline is going to be one that effectively delivers water, leak-free, and consistently for at least fifty years and very well over 100. Both PE4710 and PE100/PE100RC would deliver water consistently. For these reasons, the GI pipeline receives a 1, the Flanged pipeline a 2, the On-Grade PE100RC will receive a 4, the On-Grade PE4710 will receive a 4, pre-extruded PE100 will receive a 4, the Buried HDPE will receive a 5, and the Elevated Pipeline will receive a 4.5.

Access to Services (% of community impacted)

In each case, both communities will receive access to water. Therefore, the scores for each alternative will be the same.

Access to Services (% of need met)

All the options will fulfill the 40,000 L daily demand of water, therefore all scores are the same.

Community Input

In the past, the community has expressed interest in building a GI pipeline, but this interest has waned over the years. The flanged pipeline receives a higher score due to its suggestion by a local contractor. After talking with the community in Summer 2018, the community favored a new plastic on-grade pipeline alternative since they have also had experience with plastic and compression fittings. They have also expressed willingness to help widen an existing roadway that the pipeline would follow, and help with pipe installation. The buried pipeline will then receive a 2, the on-grade PE100RC pipeline will receive a 5, the on-grade PE4710 pipeline will receive a 5, pre-extruded PE100 will receive a 5, the galvanized steel pipeline will receive a 1, the flanged pipes will receive a 2, and the elevated pipeline will receive a 3.

Cost

The costs of galvanized steel pipe, unions, and labor are much more expensive than that of plastic pipes, so this alternative will receive a 1. The flanged pipeline similarly receives a 1 due to its high cost. The cost of a plastic pipeline is nearly four times cheaper than a galvanized steel pipeline. The cheapest way of bringing water to the community is an on-grade pipeline. The cheapest option is to use the donated PE4710. The equipment for butt fusion and electrofusion including a generator would be included with the donation. The only costs would be transportation which is $8400 for port of New York to door of Ait Bayoud. ⅓ of the cost is due to trucking of pipe from port to Ait Bayoud. Furthermore, we are in the process of securing a freight forwarder to sponsor the transportation fees. For this reason, an on-grade PE4710 pipeline receives a 5. Using local PE100 pipes would cost at least $16,000 not including transportation, making it at least two times more expensive. For this reason, an on-grade PE100/PE100CR receives a 3. A buried pipeline requires the rental of a trenching machine, associated insurance costs, and transportation of the trencher from a nearby city. A trenching machine would be operated by a contractor which increases costs significantly. A buried pipeline thus receives a 0. An elevated pipeline requires a community effort, time, and money to build over 1500 concrete square or rock and mortar supports. The time and labor associated with this is additional cost, labor, and transportation costs, which makes it a 2. We are currently partnered with Peter Dyke, the director of the PE Pipe alliance in America, to procure all our piping and materials for free. In addition he is offering a fusion operator and pipe expert to accompany our trip. If not purchased directly from the manufacturer, the pipes alone have an estimated retail value in America of $33,000.

A discussion should be noted regarding using local metric pipes versus foreign US pipes. A local metric pipe is attractive because if there is damage to the pipe in the future, metric pipes can be obtained easier than pipes from the US. The specific type we want to be using is PE100RC, PE100, or PE4710. All of these are high performing pipes which is needed for the pressure demands of this project. At the moment, we have 6.5 kilometers of PE4710 donated by two companies based in the US. Along with the offer are two pipe fusion experts free of charge which would ensure proper fusion of pipe. Installation is the primary cause of failure in the majority of piping projects. The pipes are fully extruded, meet all pressure requirements, and are ensured for quality. The cost of overseas freight including customs is estimated to be about $5000. This price excludes cost of storage at port. Due to the United States-Morocco Free Trade Agreement, there are no tariffs. Furthermore, we are seeking a partnership to have freight shipping discounted or donated possibly leaving our total costs to just customs. However, this offer needs to be compared with the cost of using local metric pipes. The pipes that are needed is available in Marrakech in the form of pellets or pre-extruded. Pellets would need to be transported to an extruder. The estimated cost of the pellets alone would be $15,000. Including the cost of extrusion, transportation to and from the extruder, and tax would increase the costs considerably to roughly $17,000. A major risk is quality control of the extruded pipes, a problem which was unfortunately encountered with steel pipes. If we were to extrude, we would work with a local company called INES recommend to us by Borealis, a member of the reputable PE100+ association. INES would extrude pipe to ISO standards. The lack of a fusion expert to accompany the trip would further increase the chances of improper installation. Plastic pipe fails primarily due to poor installation and third party interaction. All the members of the PE100+ association including the Director of the Association have been contacted with no success. Donated metric pipes are most optimal but offers have not come forward after five months of contacting companies that sell PE100RC or PE100 in Europe, Africa, and Asia.

Maintenance Cost:

Maintenance cost will consider both the incidence and cost of repairing breaks in the pipeline. Galvanized steel pipes are very resistant to abrasion and external damage, but breaks in the pipes will occur at the pipe connections. This will be difficult to repair as the pipe will have to be rethreaded or a new pipe will have to be purchased. Flanges fare slightly better than threaded pipes due to the lack of threading, so this will receive a higher score. The replacement cost is also more expensive than plastic each time a problem occurs. The plastic pipeline is less resistant to abrasion and is more susceptible to thermal expansion. Since there are no pipe connections, there will be no breakages. 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 or fused. If the damage is just a deep gouge, then HYMAX repair clamps could be used. The only difference between PE4710 and PE100RC/PE100 would be that if the destructive damage is on the main pipeline and in the absence of fusion equipment, mechanically compliant fittings are needed such as MULTI/JOINT, iJOINT by Georg Fischer, or appropriate flange adapters. This does not necessarily mean more expensive cost but rather particular sourcing from local dealers. Of course, if fusion equipment is available then PE4710 can be fused with PE100 and mechanical fittings are not needed. Maintenance cost in the village network and tapstand connections will be the same regardless because the pipe will all be metric there. The buried pipeline will experience less external damage and avoid thermal expansion. The elevated pipeline will be subject to all the stresses of the plastic pipeline in addition to the stresses from movement restriction, but will avoid much of the abrasion and point loading from laying a pipeline directly on the ground. Lastly PE100RC is more durable than already high performing PE4710 and PE100, so it will receive a slightly higher score. Overall, the galvanized steel pipe will receive a 1, flanged pipes a 2, PE4710 will receive a 3, PE100RC will receive a 3.5, pre-extruded PE100 will receive a 3, buried pipeline will receive a 5, and the elevated pipeline will receive a 4.

Maintenance and Operation Difficulty

This section will reflect the difficulty of repairing breaks in the pipeline, the training required to repair the breaks, and the methods used to do repairs. Galvanized steel pipes will require rethreading, proper cleaning, application of new PTFE tape, or replacement of pipe entirely; all of which require proper installation procedure. A union will be needed at each joint. Furthermore, proper sourcing of the steel pipes will need to be checked. Mentor Robert Prager comments that minor leaks will always occur and major failures are likely if the project is continued with steel pipes. Leaks will have to be identified manually as they may be too small to detect. Flanged pipes will be much easier to replace due to the lack of threading, but will also share many of the same problems as the other GI pipeline. With plastic pipe, leaks would only result from a large rupture or force due to the nature of a monolithic material. The time associated with identifying leaks or breaks would be significantly less. As stated before, the most important aspect with pipe maintenance is to ensure that 10% of the wall thickness does not became gouged. If 10% or more of the wall thickness is damaged, then that section of the pipe needs to be removed, new HDPE pipe inserted, and connected using widely available mechanical adapters or compression fittings. An alternate solution is to use a repair clamp. For a monolithic solution, usually an electrofusion patch would be used which would need to be rented from a nearby city. Compression fittings are widely used by the local community. Spare plastic piping is widely available in nearby towns and leftover pipes will be stored by the Water Association. This will all require proper training, detailed in a guide we would prepare for them. If the pipes are buried, then for a rupture to occur, it would be difficult to identify leaks; it would most likely occur during installation. Although an on-grade pipeline or elevated pipeline will be easiest to maintain, they need to be carefully watched for major gouges due to environmental or external factors. The difference between PE4710 and PE100RC/PE100 will be the need for particular mechanical fittings which can be sourced locally. This gives PE4710 an added difficulty. GI pipes will receive a 1, flanged pipes a 2, on-grade PE4710 will receive a 3, on-grade PE100RC will receive a 3.5, pre-extruded PE100 will receive a 3.5, buried pipes will receive a 5, and elevated pipes will receive a 4.

Regional Experience with Technology

Locals are familiar with using galvanized steel pipelines. They are relatively simple to join and require no fusion. PTFE tape would be used as lubricant to ensure proper mechanical interlocking. After speaking with the community, we discovered that they would prefer plastic piping, and compression fittings are currently used to connect the well side end of the pipeline to a temporary distribution site. Using butt fusion to fuse HDPE will be a new technology, but only necessary for installation, not maintenance, of the pipeline. Therefore, it would not be necessary to thoroughly train the members of the community who would be maintaining the pipeline in butt fusion. Once installation is complete, all repairs would be using mechanical fittings. Both galvanized steel options receive a 5 while on-grade receives a 4. Buried piping receives a 2 because it requires trenching, which the community has no experience with. Elevated piping receives a 3 due to the extra step of making supports for the pipeline.

Material Availability

Both galvanized steel and HDPE piping are widely available however the specific formulation of HDPE pipe we end up using may not be in the region. For example, a 50mm, DR 9 or 11 PE100RC won't be available in Meskala, the closest town which has a hardware store (20 minute drive from well site), but it is available in Marrakesh in the form of pellets. Pre-extruded PE100 is however available in major cities such as Casablanca. An excess of pipes from donors can be stockpiled in the need of future repairs. A butt fusion or electrofusion machine would need to be rented from a city, so mechanical connectors, such as the compression fittings that the community already uses, can solve the problem of joining or repairing the pipe. Furthermore, MULTI/JOINT fittings can be ordered in Morocco to service between US and metric pipe if mechanical is needed. In the case that MULTI/JOINT fittings, iJOINT fittings, and fusion are not available, a guide for using international flanged fittings will be made. For buried piping, a trenching machine is not readily available. For elevated piping, concrete must be purchased and transported but it is readily available in Meskala. Due to this, on-grade PE100RC will receive a 4, PE4710 a 4, pre-extruded PE100 a 4.5, galvanized steel options a 5, and buried and elevated a 3 each.

Expandability and Scalability

Both pipelines are easily scalable. However, a plastic pipeline will better serve the community in the long run because it is cheaper to scale. Both GI options will receive a 2, and plastic options will receive a 5.

Matrix

	Alternative 1: GI Pipeline	Alternative 2a: On-grade PE100RC Pipeline	Alternative 2b: On-grade PE4710 Pipeline	Alternative 2c: On-grade Pre-extruded PE100	Alternative 3: Buried HDPE Pipeline	Alternative 4: Elevated HDPE Pipeline	Alternative 5: GI Pipeline with Flanges
Ability to solve the identified need	1	4	4	4	5	4.5	2
Access to Services (% of community impacted)	5	5	5	5	5	5	5
Access to Services (% of need met)	5	5	5	5	5	5	5
Communit y Input	1	5	5	5	2	3	2
Cost	1	3	5	3	0	2	1

Maintenance Cost	1	3.5	3	3	5	4	2
Operation and Maintenance Difficulty	1	3.5	3	3.5	5	4	2
Regional Experience with Technology	5	4	4	4	2	3	5
Material Availability	5	4	4	4.5	3	3	5
Expandability and Scalability	2	5	5	5	5	5	2
Total	27	42	43	42	37	38.5	31

Description of Pipeline Comparison Results (narrative summary)

Continuing with the galvanized steel pipeline would be cost prohibitive and extend the timeline of the project to multiple implementation trips. In addition, maintenance would be more expensive, extending the pipeline would be doubly expensive, it would require frequent maintenance, and is not favored by the community.

Comparatively, a HDPE pipeline serves as the most promising alternative to our project in Morocco. All HDPE designs are feasible and will serve the community with water. The difference lies in cost and familiarity, with an on-grade pipeline being the cheapest and also the easiest to install due to its simplicity. All other differences remain minor as shown that all three choices are close in score.

Preferred Pipeline Alternative

Based on the chosen characteristics, the on-grade HDPE pipeline scored highest. At the end of the day, an on-grade HDPE pipeline will be easiest to install, have the lowest cost, deliver water reliably without leakage, and be repairable by the local community.

The material of choice will be PE4710 after a careful risk, cost, and the feasibility of sustainability analysis. From the analysis, the difference primarily came down to cost. The existing offer of fully committed 6.5 km of PE4710 provides 10% extra pipe to be stored with the community, fusion equipment, and professionals to oversee proper installation. The pipe will be transferred to the community through freight shipping. We will work with freight forwarder, Flexport and/or Shine Line based in Casablanca, to ensure the pipe completes its port to port, customs check, and port to door transportation properly. All areas of frequent usage such as tapstands, valves, and connections to tanks will be using PE100 so that community members can easily replace and repair damage. The mechanical fittings that service PE4710 to PE100 are available locally and a guide will be written and a workshop conducted to ensure the community members can repair the pipeline. Additionally, PE4710 and local PE100 can be fused for repair otherwise appropriate mechanical fittings can be sourced locally. The crack resistant property of PE100RC is balanced out by its need to be specially extruded and PE100 would cost at least twice as much as using PE4710, which are extremely comparable and able to be fused together.

If a member company of the PE100+ association agrees to support our projects in materials and expertise, then an on-grade PE100RC will be the preferred alternative. Another way is that we raise enough funds to purchase local material. If by April 30, we do not hear from any company or raise the needed funds, then we will continue with the PE4710 alternative and work with existing manufacturers and experts who are excited to work with us and contribute to the success of this project.

A HDPE pipeline serves as the most promising alternative to our project in Morocco. If the goal is to place pipeline on the ground as inexpensively as possible and deliver water to our end users, then an on-grade plastic pipeline is the clear choice. In addition, we have a vast community of mentors and sponsors to check our calculations, designs, and decisions. A HDPE pipeline will last longer and create less problems and maintenance for community users for the years to come.

Tank Comparison

Criteria for Tanks

Ability to solve the identified need

The concrete tank is able to hold more than the full 40,000L of water needed. This 40,000L estimate is based on the community daily demand of 40,000 L (Attachment H) which meets the daily water needs for both the inhabitants and their livestock. The plastic tanks are also able to store 40,000 L, so both alternatives will meet the identified need of the communities. Therefore, both the concrete tanks and plastic tanks receive a rating of 5.

Access to Services (% of community impacted)

Both tanks will be able to serve the same region and population. The chateau site for both tanks is the same, which means the piping capabilities and region serviced would be the same for either concrete or plastic tanks. Both alternatives receive a 5 rating.

Access to Services (% of need met)

Since both alternatives provide 40,000 L of water storage, they both meet the needs of the community in regards to their daily water consumption. Since either alternative will meet the community needs, both receive a rating of 5.

Implementation Feasibility

Concrete tanks would require at least 19 days to implement and 7 days to set, and it will require a more technically difficult construction process. On the other hand, plastic tanks will take only one day to install, and no construction is required besides connecting the right valves to the tank. For the canopy, we would purchase a self-assembled canopy and assemble it on site, which should take no more than half a day. In a future trip, the canopy could be replaced with a permanent roof structure. Concrete tanks would also require community members to volunteer their labor to help construct the tanks, whereas plastic tanks could be installed with just travel team members. Due to the higher difficulty of concrete tanks and the extended time and labor it requires, we give concrete tanks a score of 3. Plastic tanks receive a score of 5.

Cost

The total cost of installing the concrete tank is estimated to be $13,100 which includes the cost of raw materials for the tank as well as wood and other supplies to construct the forms. Right now the main cost of is coming from the wood for the forms. We over-designed the formwork with a factor of safety of 1.5 and assuming that the hydrostatic pressure from concrete is the same as a dense liquid. In the following week, we will be redesigning the formwork using a modified hydrostatic pressure to factor in the gradual stiffening of the concrete as we pour, which will reduce the pressure (from ACI 347-04 “Guide to Formwork for Concrete”).

The cost of the plastic tanks would be $8,700 ($2,900 per 20,000 Liter tank) with an additional $1,000 for materials for a canopy to protect the tanks from the sun. Thus, the plastic tanks alternative would cost $9700. Plastic tanks receive a 3, while concrete tanks receive a 2.

Maintenance Cost

Either alternative will require some level of maintenance by the community. The concrete tanks will require monitoring for cracks and patching when damage is found, but if well cared for the tanks should last between 50-100 years. Maintaining the concrete tanks requires simple and inexpensive materials, such as extra concrete or concrete patching. The eventual replacement of the concrete tanks in 50 years would require community members to raise only 14 cents (USD) per person per year, which is very cost effective, so concrete tanks receive a 5.

The plastic tanks will require shelter from the sun and monitoring for cracks and holes. The plastic tanks will degrade much faster than the concrete tanks, and would require replacement every 10-15 years, raising the maintenance cost of the system significantly. The cost of materials to repair damage to the plastic tanks is also relatively high, since cracks and other damage would require plastic patching kits or even replacement of the entire tank. The shade structure also presents a major sustained cost and maintenance problem. The temporary assembly of tarps and poles would need replacement within a year. Even a more permanent structure would likely be prone to frequent maintenance. A member of our travel team built a similar shade structure out of wood on a previous trip in Ghana and had to dismantle it after only three years. No durable shade structure has been proposed or designed at this time. An additional problem, not fully elaborated thus far, is that the cost of this alternative over the first 50 years would be at least $50,000, about five times the total required cost of the reinforced concrete tanks. For these reasons, the plastic tanks receive a score of 1.

Maintenance and Operation Difficulty

The primary operation requirement of both systems will be the removal of sediment. This will be simple in the reinforce concrete tanks since they are designed for this. Removal of sediment from the plastic tanks will be more difficult. Patching of cracks in the concrete tanks will likely be more frequent and require more effort than checking for cracks in the plastic tank. On the other hand, plastic tanks will have to be replaced much more frequently than concrete tanks. As mentioned before, maintenance and replacement of the shade structure remains an unresolved design flaw for the plastic tanks. Thus, concrete tanks receive a 4 and plastic receives a 2.

Regional Experience with Technology

Community members are very experienced in building with concrete, and most of the regional water storage is constructed of concrete. However, our tank design is different from typical water tower structures in the region, so we assign a score of 4. Plastic tanks are not uncommon in the region, but the majority of water storage uses concrete structures, so we also assign a score of 4

Material Availability

Both concrete supplies and plastic tanks are readily available in-country. Materials to construct the system as well as make any necessary repairs can be purchased locally by the community. Therefore both alternatives receive a 5 rating.

Expandability and Scalability

In order to expand either the concrete or plastic tanks system, the tanks would either have to be replaced entirely by larger tanks or new tanks would need to be added in series to the old ones. Neither the concrete nor plastic tanks are easily upgradable, which is why the current design must meet 100% of the communities' needs. Due to the difficulty and cost associated with expanding and scaling the system, both alternatives receive a 1 rating.

Matrix

	Alternative 1: Concrete	Alternative 2: Plastic
Ability to solve the identified need	5	5
Access to Services (% of community impacted)	5	5
Access to Services (% of need met)	5	5
Implementation Feasibility	3	5
Cost	2	3
Maintenance Cost	5	1
Operation and Maintenance Difficulty	4	2
Regional Experience with Technology	4	4
Material Availability	5	5
Expandability and Scalability	1	1

Total	39	37

Description of Tank Comparison Results (narrative summary)

We were quoted at $2900 for each 20000L plastic tank. Each tank will have to be replaced every 10-15 years, while a conservative analysis of the concrete tank lifetime is 50 years; Thus, we can estimate that we'll have to buy three different sets of three tanks, so we'll have an estimated total price of $26,100 for tanks over 50 years compared to $13,100 for the concrete tanks. We'll also have to purchase a canopy to ensure the 15 year lifespan of the tanks.

While both the plastic and concrete tanks would be adequate to serve the needs of the community, the lifetime cost of the plastic tanks would be more expensive than the concrete tanks. The cost would similarly mushroom for both if the storage capacity need to be expanded in the future. In addition, while both plastic and concrete would be widely available, the local community would be slightly more familiar working with concrete and using concrete storage tanks.

Preferred Tank Alternative

Since (1) we believe we have the time during the implementation trip to implement the concrete tanks, (2) we will have concrete work anyway for the pressure break tank, and (3) they are significantly cheaper than the plastic tanks, we have decided to move forward with constructing concrete tanks. The size of the concrete tanks was maximized by using as much of the area of the existing concrete foundation as possible, while leaving space for forms, and making the tanks as tall as possible, while still being feasible for implementation. We recently got in touch with a potential travel mentor with experience in concrete, who may be joining us for the trip to help with the construction of the tanks.

Power Source Comparison

Criteria for Power Source

Ability to solve the identified need

Both alternatives would be able to solve the identified need and meet the community water demand, so we assign a score of 5. The concern with the power line is that the implementation and timeline is out of our control, so we are not guaranteed to have power by this summer's implementation trip. The review board has previously expressed concerns about implementing the pipeline and tanks without having a guaranteed power source. For the solar pump alternative, we would complete the implementation ourselves and have full control of the timeline, so we can ensure that project materials will be shipped in time for the trip and that there is sufficient time during the trip to execute the project.

Access to Services (% of community impacted)

All community members would have access to the water provided.

Access to Services (% of need met)

The power line would be able to meet 100% of the community demand if the community simply leaves the pump turned on for 12 hours a day, so we assign a score of 5.

The solar pump would be able to meet the fully community demand, so long as there is sunlight. In the case of overcast skies, depending on the number of solar panels and the water level in the well, the solar pumping system could produce enough excess water to cover the fully community demand for 1-15 days per month, or 3.3% to 50% of the days in a month. The region where the community is located can have 3.25% to 35.75% overcast days depending on the time of year. On average, the solar pumping system should be able to meet the community's water demand. However, if the well water level is low or if there are two or more overcast days in a row, there may not be enough excess water stored to meet the full community demand. Due to this possibility of not meeting the full community demand every day, we assign a score of 3.

Community Input

Community members have expressed a preference for solar pumping, since it is quite common in the region, so we assign a score of 4. The current rais has repeatedly promised that he would get the power line extended, since that was the originally agree upon community contribution. However, we have yet to see any action, which is why we have had to take matters into our own hands regarding the power line extension. Thus, we assign a score of 2.

Cost

The cost of the power line is unknown as of now. The High Atlas Foundation will be going to the site to measure the distance that the power line needs to be extended and submitting a request to the ONEE for a quote. The cost of an equivalent three-phase power line extension in America would be $75,000 to $80,000 per mile, so we are quite concerned about the cost of the power line.[4] Thus, we assign a score of 1.

The cost of the 38 solar panel design would be $12,000, while the 50 panel design would cost $13,700. Currently, between the community contribution and our current funds, we can afford the 38 panel design, and the 50 panel design is a feasible budget item, so we assign a score of 4.

Maintenance Cost

The power line would be owned by the utility company. Therefore, the maintenance would be their responsibility. Community members would have to pay for using the power on a monthly basis though. The average commercial electricity rate in Morocco is 11¢/kWh[5]. The annual electricity bill would be $1,765. This would cost each community member less than $5 a year, so we believe this is a reasonable maintenance cost, and we assign a score of 5.

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[4] https://www.pacificpower.net/con/lee.html
https://www.eastcentralenergy.com/content/construction-costs

[5] https://www.globalpetrolprices.com/Morocco/electricity_prices/

The maintenance cost of cleaning and inspecting the solar panels is negligible (water, soap, cloths). The lifespan of solar panels is 15 to 25 years. Assuming they last 15 years, the community would have to raise $307 to $403 each year, which would cost each community member about $1 per year. Thus, we assign a score of 5.

Maintenance and Operation Difficulty

For Alternative 1, any maintenance of the power line would be the responsibility of the ONEE. A community member, probably Mohamed since he is the nearest, would have to turn the pump on each morning and off in the evening. Since the flow rate of the pump will be around 3500 L/h, depending on the water level in the well and the storage tanks, it will take approximately 12 hour to pump the full community demand of 40,000 L/day. Thus, we assign a score of 4.

For Alternative 2, A solar pump will need the normal maintenance that our current pump would need, as well as minor maintenance of the solar panels. 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. Training for doing the annual maintenance on the solar panels would be necessary. The supplier AE Photonics will be able to provide more complex maintenance services for the solar pump as well as the solar panels if needed. No operation is necessary for the solar pumping system, since the pump will automatically turn on and off depending on the sunlight available. Thus, we assign a score of 5.

Regional Experience with Technology

The community members themselves are not technically trained on power lines or solar power. However, the ONEE has professionals who would be responsible for the maintenance of the power line, and solar pumps are common in the region, and we will give community members our contacts with professional contractors who would be able to service the solar pump. For this reason, we assign all the alternatives a score of 5.

Material Availability

The ONEE has all the materials necessary for extending the power line, and AE Photonics can supply all the materials needed for the solar pump, so we assign both a score of 5.

Expandability and Scalability

For the power line, expanding the amount of water provided is trivial, since it would simply require turning the pump on for longer. Thus, we assign a score of 5. Due to the power limit of 10 kW for the solar pump controller, the maximum number of solar panels we can attach is 50 solar panels. Assuming we implement the cheapest option of 38 panels, there is the potential of increasing the output by 4.3 m^3 per day to a maximum output of 47.3 m^3 per day. Thus, we give a score of 1.

Matrix

	Alternative 1:	Alternative 2:
Ability to solve the identified need	5	5
Access to Services (% of community impacted)	5	5
Access to Services (% of need met)	5	3
Community Input	2	4
Cost	1	4
Maintenance Cost	5	5
Operation and Maintenance Difficulty	4	5
Regional Experience with Technology	5	5

Material Availability	5	5
Expandability and Scalability	5	1
Total	42	42

Description of Power Source Comparison Results (narrative summary)

The main benefit of the power line would be that it can provide the full community demand regardless of the weather, but there is the risk of an unpredictable timeline and an excessively high cost. On the other hand, the solar pump is a cheaper and more environmentally sustainable power source, but if there are too many overcast days when the well water level is low, there may not be enough water for the community.

Preferred Power Source Alternative

Since we believe that meeting the full community water demand is more important, we will try to implement the power line alternative. The High Atlas Foundation will be traveling to the well site to measure the distance from the nearest powerline in Tinilft to the well site, and then inquiring the ONEE for a quote. We have also asked the High Atlas Foundation to inquire about the feasibility of having the power line extended by the implementation trip in August of this year. If the ONEE inform us that they can have the power line extended by August, and the quote we receive is within the amount of funds we have raised by the end of April, we will move forward with the power line. Otherwise, we will move ahead with the solar pump design, since we believe that providing the community with some water is better than no water. If we move forward with the powerline option, we will likely want to add solar panels as a power source using a grid-tie inverter in a future trip for sustainability reasons. However, we will not need to be concerned about replacing the pump or using batteries, since the powerline will supplement any extra power needed.

4.0 Next Steps:

The alternatives analysis will be submitted for a first round of mentor review on March 29, 2019, with official submission to EWB within one weeks after. Once an alternative is selected and approved for the pipeline, the materials necessary for the pipeline must be acquired. Currently, we are working closely with the director of the PE Pipe Alliance in America and have secured 6.5 kilometers of HDPE pipe. We will need to let them know by May 27th if we choose to use their piping in order to have the pipes arrive in country on time (see Attachment M). We are continuing to confer with contacts in the European pipe industry in our search for European standard pipes. McElroy has offered to loan us a butt fusion machine and Georg Fischer and ISCO has offered to loan us an electrofusion machine and some fittings. Concurrently, we will be raising funds to pay for overseas transportation costs. Materials may be purchased with existing funds from the Morocco program's account, donated directly from sponsors, acquired with funds donated by sponsors, or acquired with funds awarded from grants or other competitions with monetary prizes that the Morocco program enters.

We will work on completing and verifying the details of the design for the storage tanks and formwork for the implementation report. We will also work on completing the solar pump design to EWB guidelines in case the quote we receive for the power line is over our budget, so we will have that ready for the implementation report if necessary.

Attachment M contains a list of pre-trip logistics and timeframes for certain tasks. Additionally, a guidebook will be made for locals to show how to maintain the pipeline, tanks, and power system. Paperwork and pre-trip logistics such as travel visas will be arranged. Travel will be from July 21 to August 24. Attachment L contains a draft itinerary of the trip.

5.0 List of Attachments

Attachment A: Drawing Package

Attachment B: Previous Year's Drawing Package

- *Map of Ait Bayoud and local communities*
- *Specs of Well and Pump*

Attachment C: Pictures

Attachment D: Material Pricing Data and Detailed Cost Estimates

Attachment E: Piping Technical Calculations

Attachment F: Contractor's Estimate

Attachment G: Revised Professional Mentor Hydraulic Calculations

Attachment H: Community Water Demand Survey

Attachment I: Concrete Tank Design

Attachment J: Solar Power Calculations

Attachment K: Solar Pump System & Spec Sheets from AE Photonics (for 38 panel design)

Attachment L: Draft Trip Itinerary

Attachment M: Pre-Trip Logistics

Attachment N: Overseas Freight Quote

Attachment O: Grade Profile Excel Sheet

Attachment A

See attached .pdf

Attachment B

See attached .pdf

Attachment C

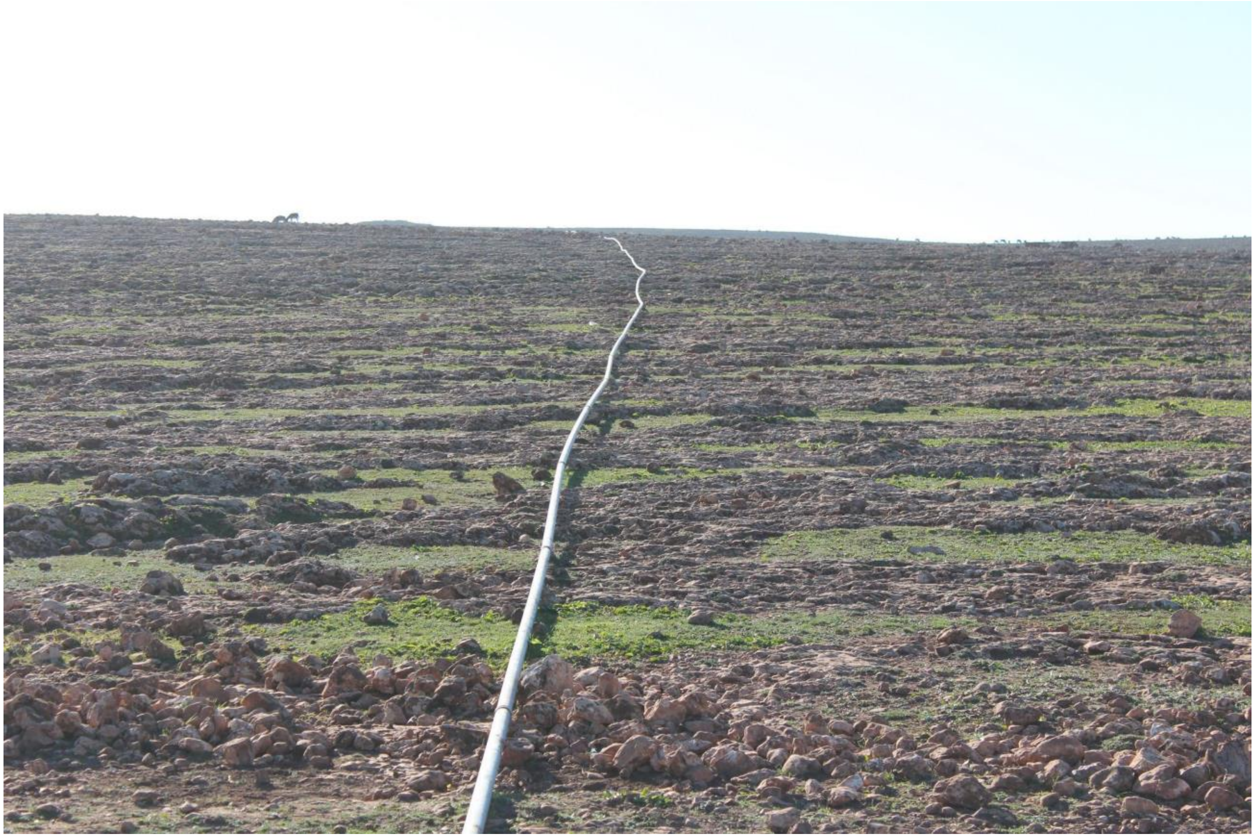

Figure 1 - Terrain

Figure 2 - Butt Fusion

Figure 3 – An example of a current leak at a pipe connection. Full documentation of all leaks can be provided upon request.

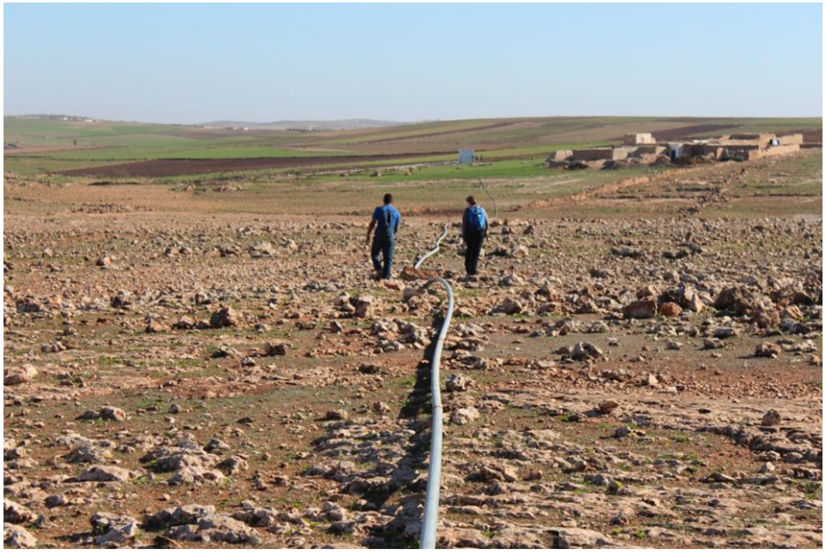

Figure 4 – Example of terrain and existing GI pipe.

Attachment D

See attached excel sheet.

Attachment E

All technical calculations methods for the pipeline were verified and checked by REIC mentor Colin Barrett. See attached .pdf.

Attachment F

See attached .pdf.

Attachment G

See attached .pdf.

Attachment H

See attached .pdf.

Attachment I

See attached .pdf.

Attachment J

See attached .pdf.

Attachment K

See attached .pdf.

Attachment L

See attached .pdf.

Attachment M

See attached .pdf.

Attachment N

See attached .pdf.

Attachment O

See attached .pdf.