The Zimri Project: Running Water and Bathroom Facilities for a Rural Moroccan School

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Abstract

Lack of education in rural communities is one of the most prominent problems facing the developing world. In Islamic countries such as Morocco, girls are pulled out of school because their parents are concerned about the lack of privacy when it comes to going to the bathroom. This lack of education for all children, especially girls, is a serious problem for such communities, causing them to lag behind the rest of the world and perpetuating the cycle of poverty. This project develops a plan for bringing running water to a school in Zimri, Morocco and for building an enclosed bathroom facility. It is recommended that this plan be proposed to funding institutions for the purpose of obtaining financial resources to realize the project and enhance the quality and opportunity of education for all the children in the village of Zimri.

Acknowledgements

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Executive Summary

Throughout the third world, lack of basic facilities due to limited investment in isolated rural communities has created an economic divide that leads to many social problems and hinders human development. Education is seen as a means of breaking the cycle of poverty that perpetuates itself. One of the focuses of our project is to combat female illiteracy in a rural Moroccan community, since about 80% of females in rural Morocco are illiterate (F. Agnaou). Increasing the number of women who can read, write and perform basic arithmetic will greatly improve the prosperity of communities due to women's key role as caregivers. Educated women will have the potential to reduce the incidence of diseases (due to their increased understanding of health) and increase the opportunity of education (due to their influence upon the perceived importance of learning) among future generations.

The project team was first presented with the problem of the lack of pumped water and sanitary facilities at a rural school in Morocco by Mohammad Elbaz. The lack of running water required the villagers to bring water to the school by loading donkeys with large cylinders filled from a nearby well. This process is both time consuming and poses health risks, as the water has the risk of getting contaminated. To fix this, plans were created for a pumping system that would transport water from a nearby well to the school. Another problem is the lack of privacy for young girls as there is no enclosed bathroom facility, which causes parents to pull their daughters out of school. This report proposes options that would be both safe and hygienic for the children to use.

For the pumping of water, the project team investigated solar powered systems and diesel engine powered systems to be used in Zimri. Both had advantages and disadvantages that had to be considered. The solar pumps can produce usable energy without any cost after installation and

they rarely need maintenance. However, the installation of solar pumps is expensive and solar systems are not available locally. On the other hand, diesel pumps are available locally, the villagers are familiar with them, and they are cheaper to install. However, they are not appropriate for the small water usage and flow rate requirements of the Zimri system, and they would require the villagers to continuously pay for fuel.

Different types of bathroom facilities were also investigated through the course of this project, including pit latrines, compost toilets, and a septic tank. Pit latrines and compost toilets were considered to be short term solutions because they do not need any water to function and do not require piping for waste disposal as would a flush system. However, both designs would call for the villagers to handle waste. In that respect, a septic tank would be more desirable because it allows the use of a flush system, yet it would cost more, be harder to build, and require larger amounts of water.

The findings from the research pointed to the conclusion that a solar powered pumping system along with a compost toilet would work best for the conditions of the Zimri village. The solar pump will not burden the villagers with the expense to have to continuously buy fuel every time the villagers need water. More importantly, the solar pump is more suitable for the system than is a diesel engine powered pump because it can handle the low flow rate at the required depth of the well. As for the bathroom facility and sanitation system, the team has recognized both a long term and short term solution. The long term solution would be a septic tank as it would have the benefit of completely disposing of the human waste from the site of the facility. The villagers would not need to come into contact with human feces. A short term solution to the lack of a bathroom is a compost toilet. Even though the villagers must handle the waste to dispose of it, a compost toilet is easy and relatively inexpensive to construct and maintain, and furthermore will be hygienic without requiring the use of water. Importantly, it would address the issue of privacy until a more advanced system can be built.

Along with the installation of a solar pump and a compost toilet, the team recommends that a questionnaire be distributed to gauge the accuracy of the hypotheses concerning girl's increased attendance due to the availability of a private bathroom facility. An instructional program is also recommended for the villagers to learn about the use of the new technology and to provide general information about health and hygiene to complement these establishments. Unfortunately, the villagers do not possess the funds needed to realize the proposed improvements to the school, so the team created a proposal and is currently in contact with interested Non-Governmental Organizations to obtain the resources necessary to implement the project.

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1. Introduction

The primary objective for this project was to provide clean pumped water and a proper bathroom facility for the Zimri School, a primary school located about 80 kilometers southeast of Rabat in the rural village of Ait Alla. The hope is to create a private sanitary space for the children, especially the girls, through access to clean, tapped water and an enclosed human waste facility that will ensure girls' privacy while at school. An enclosed bathroom will hopefully encourage them to continue their education and will improve the health of all students who attend the school. This project is a continuation of a multi-phase project initiated by Mohammed ElBaz focused on addressing the students' needs for water and privacy, which students in developed nations take for granted, and making them a reality at the Zimri School. This report presents these needs and a detailed plan for creating a proposal to present to interested organizations in hopes of obtaining funding for implementing this project.

The importance of this project originates from the need to increase primary education among the children of the rural community and to bridge the gap between the number of girls and boys attending the Zimri School, since girls currently make up only about one third of the student body. This problem does not only affect Morocco, but is prevalent throughout the developing world. The lack of a bathroom facility is one reason for the discrepancy between the genders since privacy is considered a greater necessity for girls than boys. Without an enclosed bathroom, girls have to go to the bathroom outside in the open without being able to conceal themselves. Islamic culture, which places great importance on women's privacy, and general safety concerns emphasize the need of privacy for women, causing concerned parents to pull their daughters out of school early, especially if the girls reach puberty before finishing all six grades of the Zimri School. A private bathroom facility will not only help improve the ratio of the number of girls attending the school, but will help encourage all of the children in the village to attend school, a small step towards universal primary education in Morocco.

The project team decided that the project should be broken down into two main parts: choosing an appropriate energy source with a matching water pump and determining the best type of bathroom facility. For both of these tasks, the team limited numerous possibilities and decided to concentrate on the two or three best options. Solar energy and a diesel engine were thought to be the most feasible to power a pump because of the lack of electricity in the village. As for a bathroom, facilities that require no or little amounts of water were investigated, considering the scarcity of available water. The most appealing sanitation systems were the pit latrine, compost toilet, and a septic system. These options were compared and contrasted to understand the unique benefits that each would bring to the Zimri School, and suggestions were made as to the best overall option.

The village of Ait Alla, also known as Sidi Zimri, is a rural Berber (Amazigh) village that is comprised of 167 families, who all work as farmers and grazers. Since these families need all available sources of human labor, children often are required to stay home to help with farm and housework, preventing them from attending school. Only about half of the children of school age actually attend classes at the Zimri School. The village, including the school, lack modern technologies like electricity and running water. To obtain water for cooking, drinking, and cleaning, the people of the village must take a domesticated animal or a tractor to a water source with a large container to fill up and bring back. This problem is compounded by the lack of indoor bathroom facilities, which requires the villagers to go to the bathroom out in the open. The villagers usually have privacy on their own property, but at the school, there is very little to conceal a person which is undesirable in the group setting.

About two years ago, the villagers recognized the need for improvement and ended up contacting Mohammed ElBaz, who has since established the project to improve the school, the one he himself attended as a kid. With just his help and the will of the villagers, small improvements have already been made, including constructing a new school building, putting gravel down on the road that leads from the closest paved road to the school, and buying a cistern to store emergency water. The funds for these projects were gathered from the villagers' meager incomes, Mr. Elbaz's own contributions, and grants from non-governmental organizations.

Although the progress made so far has been an important and necessary first step, more needs to be done to improve the condition of the school to encourage all the children in Sidi Zimri to go to school. The village, like many in the developing world, still faces the problem of keeping its youth in school, a problem that leads to the youth being unable to break out from the cycle of poverty that perpetuates itself due to this lack of education. Solving this problem is not only important for the small isolated village, but it is also necessary for Morocco to reach its Millennium Development Goals (MDG), eight goals recognized by the United Nations Summit in 2000 to be achieved by 2015 ("What Are They"). This project, to supply water for improving sanitation and providing a private bathroom to encourage girls to continue their education, is related to three MDGs:

1. To achieve universal primary education,
2. To promote gender equality and empower women, and
3. To reduce child mortality.

Pumping water to the school would make it the only place in Zimri with pumped water and clean sanitation facilities, hopefully enticing the parents of the village to send their children to study at an institution that is valued because of such improvements. Also with the availability of a private bathroom, young girls would no longer have to be pulled from school, allowing them to finish their primary education and ideally continue onto further schooling. This is important because education has the ability to enrich women's lives allowing them to be more knowledgeable, effective care-givers or to be economically self-sufficient by becoming members of the work force. Educating women and allowing them to become better care-givers will give them the skills and knowledge to promote health for their children, reducing child mortality. These basic needs, which many in developed nations take for granted, are unfortunately absent in many rural Moroccan communities as well as throughout the developing world. This project is one small step in Morocco's initiative to achieve the UN Millennium Goals, but, more importantly, it will allow all the children of Zimri to be healthier and to attain an education.

2. Background

To bring water and an enclosed bathroom to a school in a small Moroccan village, a number of issues needed to be explored that are relevant to the project including water, women, climate, health, education and similar previous projects. What are the cultural practices of this village? What are the current methods for bringing water to individual households and disposing of human waste? How much water does the village receive through rainfall? How does the presence or lack of resources affect the villagers and how important is resource depletion? How can education change cultural norms for the betterment of the community and how does running water affect health? These are some of the issues involved while working with the Berber people, a people with a unique cultural heritage, indigenous to the Middle Atlas region of Morocco. The background research focuses primarily on these topics so the project can be successfully initiated.

2.1 Berber Culture

Zimri is a Middle Atlas Berber village that still holds on to some of the typical Amazigh traditions but has made adaptations to their way of life with time. The villagers in Zimri are categorized as Middle Atlas Berbers, even though Zimri is not located in the Middle Atlas, because they share similar characteristics, such as their lifestyle and their primary language. For example, the village is organized in a tribe-like structure, meaning the village functions as an autonomous group led by a governing council. Even though the village complies with Moroccan law by voting for people to fill government positions and following the mandated primary school curriculum, it is still relatively independent and receives minimal help from the region's public representatives. The village also used to be semi-nomadic, another tribe-like feature, as it would relocate into the mountains for the winter to have better land for their farm animals to graze and would return in the summer for farming. However within the past 50 years, the village has stopped this practice and now just remains settled. Another aspect concurrent with the Middle Atlas customs is that all of the residents, including the children, work on farms growing cereal, corn, and peas and raise livestock including goats, sheep, and cows. They live as sustenance farmers, only producing enough of a surplus that can be sold at daily souks, or markets, to earn an annual income of $500-$1000 (ElBaz). The most defined trait that firmly connects Zimri to its Berber ethnicity is the villagers' primary language called Tamazight (Crawford). It is common for a member of the village to know only Tamazight and not the national language of Arabic although some villagers learn Arabic either in school or later in life.

However, Zimri does not share all of the traditional Berber beliefs and practices. Historically, Middle Atlas Berber tribes would isolate themselves and reject any new comers until the new comers accepted their inferior position in society and lived according to the Berber way (Venema). This defensive attitude toward outside customs was to ensure the survival of their lifestyle and traditions. In contrast, Zimri, recognizing the need for improvement, welcomes the help of outsiders and is willing to cooperate with any endeavors and adapt to new practices for the betterment of the village, especially the school. Also, children learn Arabic and even some French in school, giving the village the ability to improve communication with neighboring villages and towns in the future. Although it is important for all Berber communities to preserve their cultural heritage, it is crucial for Zimri to step out of rural isolation and into the greater global political and economic community, so that future generations may benefit from the development of Morocco. For development not to be limited to major cities, rural villages like Zimri need to have the ability to effectively communicate with the rest of the country. The ability to voice their problems and concerns is an essential first step in the community's social and economic improvement.

Even though the villagers are more accepting of change compared to their ancestors, understanding the independent nature of the Berber people is highly important for anyone wishing to collaborate with the villagers. Though globalization has undoubtedly had an effect on every village in Morocco, visitors should come to expect a resistance to social/cultural change that will arise when new projects are introduced. Any village located anywhere in the world may not be willing to accept changes introduced by outsiders. An example that illustrates this issue involved a project done by English construction workers to build a schoolroom in a Kenyan village. (Hodgson) The villagers were at first deeply suspicious as to why these foreigners, who were usually seen lazing around on vacation all day, were doing work without any compensation. It is quite understandable that villagers may come to see an outside presence with suspicion. Fortunately in the case of the Kenyan village, this suspicion eventually subsided and was replaced by respect and gratitude, ensuring the success of the project. Similarly, the team for the Zimri project was careful to respect the traditions and customs of the Zimri villagers to avoid any "clash of culture" with the Berber people.

2.2 Climate/Weather:

Morocco has a semi-arid/sub-tropical climate, making the little rain that falls highly valued for agriculture. Only 1 million out of 9.2 million hectares of Morocco's farm land is irrigated (Moré), which doesn't include Zimri, and makes the farmers there depend on the rains for their livelihood. The rainfall in Zimri and its surrounding region experiences seasonal fluctuations. The winter months of December, January, and February receive the most precipitation. Where as, the summer months of July and August receive almost no rainfall ("Average Rainfall"), severely affecting the rural farmers without irrigation. Since water is scarce, it has become an integral part of Moroccan culture, and is celebrated on a day known as the “Water Holiday,” or Ahydood. This is when people ask for rain for their new growing season and children, especially, get involved in the celebration and carry squirt guns, water buckets, and any other gadget that holds water and allows for quick dispensing and soaking. This celebration is more common in the urban areas of Morocco, where there is a greater access to water (Powell). In Zimri, there is no running water. The villagers fetch water from a water source using mules, donkeys and tractors using tin cans and cisterns. The disparity in access to water between the rural and urban areas of Morocco is something that the government is trying to address by making universal access to tap water a priority. In the near future, Zimri will also have access to tap water, but the water will likely be not supplied to the school, and if it is, the cost will restrict the amount the school can use. For agriculture, the farmers of Zimri rely on the rainfall, which restricts abundant harvests that they can sell, thus limiting their disposable income. A lot of the money the villagers have saved has already been spent on building a gravel road and a new school building, limiting the amount of money that they can provide for a motorized water pump and a bathroom facility at the Zimri School.

2.3 Education

As of a 2004 census, only 54% of the total population of Morocco could read and write. The gender gap is quite significant. While 65.7% of the adult male population is literate, only 39.6% of the female population can read and write (Spratt). Morocco has recently made significant strides in education, though still lags behind its Arab North African neighbors in the level of education. Enrolment in primary schools increased from 52% to 92%, in the middle school level from 18% to 32%, and in secondary education from 6% to 15% during the years 1990-2004 (Samantajay). The formal education system in Morocco however, is still facing many challenges. Morocco has not witnessed the same level of positive changes as have been seen in countries in Asia and Latin America, particularly in literacy rates and enrolments in secondary schools and universities (UNESCO Institute for Statistics, Data Centre, May 2008). The World Bank has said the quality of education in Morocco is falling behind other regions and needs urgent reform if it is to tackle unemployment. Gender and geographical disparities still exist at all levels of the education system, something which can be seen at the Zimri School, located in a Berber and rural geographic location, putting it at a huge disadvantage when it comes to obtaining public funding.

The most interesting aspect of the Moroccan education system is that it is a blend of the East and West. It is where the Western education model, as practiced by the French during colonial times meets and integrates with the traditional Islamic methods of teaching. These two methods of teaching are in stark contrast to one another. It is important to note that both French and Islamic teaching attempts to impart values drawn from their respective cultures on the student being taught. The French style of teaching, which is based on the Western model, complements the Arabic style of teaching, resulting in an educated population that is not only bilingual, but also deeply immersed in and understanding of both cultures. This is perhaps the greatest advantage that such a system provides. Due to its colonial history, the French education system has provided the basis on which much of Moroccan public education has been built. However, the present education system is also preceded by almost a thousand years of Islamic education that is still common in many parts of Morocco today.

These seemingly theoretical ideas about the Moroccan school actually manifest themselves in reality and can be seen and observed in any Moroccan school setting. For example, even in more progressive schools, the centrality of the teacher is a theme that pervades the Moroccan education system at all levels, from primary to higher education. At Zimri, the centrality of the teacher is something that was observed during visits to the village, especially as schooling is only being done at the primary level, finishing with the sixth grade. This practice has its historical origins in Islam, which stresses the importance of the teacher. Since the rise of colonial and nationalist schools, and then with the tremendous expansion of the national public school system, the dominance of the Islamic style of teaching has slowly eroded in Morocco and has been replaced by a more European style of teaching. During the trips to Zimri, we found an education setup that struggles to keep up with the modern style of teaching and is somewhat outdated due to the lack of funding. Although the Ministry of National Education has made primary and secondary schooling compulsory and free and guarantees it as a fundamental right by the Constitution to all citizens of Morocco, many children, particularly in rural areas such as Zimri, still do not attend school. Recently, with the succession of a new monarch in the early 1990s who sought to bring political reforms to the country, the Mudawanna, or Family Code has brought greater gender equality and has had far reaching effects on the Moroccan education system (Sabir).

The curriculum at the school is the standard Moroccan elementary school program which is offered on two parallel tracks: the modern track (*l'enseignement général moderne*) and the original track (*l'enseignement originel*). The latter emphasizes Islamic disciplines, national identity and the sciences, and enrolls far fewer students than the former. The school follows the modern track (*l'enseignement général moderne*) model, as no Islamic training occurs there. According to the Moroccan government requirements, in the modern track, basic education is divided into two cycles of six and three years respectively. Arabic is the language of instruction and French is introduced as a second language in the third grade. The first six-year cycle is taught at primary schools (*école primaire*) and students attend class for 28 hours a week. The second stage of basic education (*enseignement collégial*) is generally taught at *collèges*, (French-style high schools) and students attend class for 33-35 hours a week. We will only concern ourselves with the first six year cycle, which is taught at the primary level as this is only what is available to the students at the village school. The curriculum of the primary education of the modern track is shown below in Table # 1 (Clark).

Subject	1st and 2nd Year	3rd and 4th Year	5th and 6th Year
Islamic education	4 hrs.	3 hrs.	3 hrs.
Arabic	11 hrs.	6 hrs.	6 hrs.
French	-	8 hrs.	8 hrs.
Art and technical studies	2 - 2.5 hrs.	1 - 1.5 hrs.	-
Civics, Hist.-Geo.	-	-	1.5 hrs.
Mathematics	5 hrs.	5 hrs.	5 hrs.
Physical education	2 hrs.	2 hrs.	2 hrs.
Sciences	1.5 hrs.	1.5 hrs.	1.5 hrs.
Recreation	2 hrs.	2 hrs.	2 hrs.

Table 1: Curriculum of Moroccan school system (Ministry of National Education, retrieved from <http://194.204.205.38/den/home> March 2006)

Morocco introduced sweeping reforms in the Mudawanna, or Family Code, recently in 2004. The new Family Code used the law to make great strides in promoting gender equality. The new Code has come to impact the educational system by recommending reforms to new textbooks with regard to gender equality and human rights. The theoretical framework for the change in the textbooks stems from the fact that textbooks can be a powerful tool for influencing ways in which both children and adults think about core human rights concepts and values, the image of women/girls, and the concept of gender equality. A study titled, “Review of Moroccan School Textbooks for Gender Equality and Human Rights: Project Results,” was conducted in this regard addressing questions such as,

- Who authors the textbooks and which writers are included in textbooks?

-How are women and girls represented in textbook pictures, text and exercises?

-How do gender roles and functions differ in textbooks?

-How is gender and language used, specifically are stereotypical adjectives used?

The study concluded that:

1) Women are clearly marginalized in most of the spheres reviewed,
2) Men are prioritized over women in pictures, drawings and text and,
3) Gender stereotypes continue to exist and negative characteristics tend to be widely attributed to women and girls.

The study recommended that the Ministry of National Education should require textbook publishers to conform to certain regulations that ensure women are not marginalized in the textbook literature (Sabir). In December of 2005, the report was adopted and endorsed by the Ministry of National Education, and it is now required that all schools have textbooks that conform to these standards. However, it cannot be expected that every school in Morocco complies because small villages, like Zimri, would not be able to undertake the great financial burden to replace all the textbooks. This example, though, does show the Moroccan government’s recognition of the problem and its substantial level of commitment to even the playing field for boys and girls in school.

2.4 Previous Projects

Before beginning the project, the team thought it would be beneficial to look at similar projects that have already been conducted throughout the developing world. Even though some of these projects encompass broader problems and more people then the project in Zimri, learning about them helped the team avoid set backs these projects faced and to learn about the technology available to provide the Zimri school with water and bathroom facilities.

2.4.1 Water Pump Projects

The need to pump clean water is a widespread problem that many rural villages face because the sole water source is either contaminated or far away. Many organizations, including NGOs and other schools, have realized this issue and have worked to solve it in various locations, including villages in Nicaragua, Guatemala, and Egypt. These organizations usually install a water pump powered by a renewable energy source to supply large, or even multiple, communities.

An international NGO called Green Empowerment worked with a local Nicaraguan NGO called Asofenix and other organizations to provide the rural village of Candelaria, Nicaragua with a clean water supply in 2004. Similar to many villages in need, the only water source for the people of Candelaria was a far away, shallow well. The water was visibly dirty with pollutants from the surface of the ground and the women of the village had to spend most of their energy and time everyday walking back and forth from this well to collect enough water for their family. Green Empowerment decided to construct an entire water pumping system, including a new well and pipes running to every individual home. The entire project consisted of a new 140-foot (43m) deep well, solar panels, a solar powered submersible pump, a water tank at a higher elevation than the village, piping to transport water, and an education program to teach Asofenix and the community about the system, in particular the photovoltaic equipment. They designed the system to be run completely on renewable energy such that the water is pumped from the new well using the solar powered pump to the water tank on top of a hill and it is distributed from there to the villagers' homes by a gravity-driven network. For the project, twelve Isofoton 94W 24V panels with the ability to produce 1128W and a Grundofos 11-SQF-2 pump capable of pumping 8 gallons per minute with a total dynamic head (TDH) of 210 ft (64m) were used. The project supplied 240 people with water and cost $44,665, which includes the cost of the education of the villagers and Asofenix about the solar powered system. Green Empowerment is a strong believer in the benefits of education and thinks that if the village can maintain the system themselves and know how to use it properly, they will gain the most from the technology ("Nicaragua Solar Water Pump").

The Candelaria project was so successful that Green Empowerment and Asofenix teamed up again from 2005 to 2006 to build a similar system that would provide three Nicaraguan villages (Potreritos, La Ceiba, and San Diego) with water. This system was set up in the same fashion and used the same energy sources as the Candelaria project, except this new system had to supply 500 people and pumps 5000-7000 gallons (19-27 cubic meters) a day. The greater demand for water flow compared to Candelaria required solar panels that could produce 2866W even though the TDH of the system is 58 meters, less than Candelaria. Also, the education program for this project expanded to include information about replanting trees, general health and hygiene, and patio gardens. The total cost of this larger project was $59,806, which ends up being only $119.61 per beneficiary ("Nicaraguan Community Water").

Another project that involved a solar water pump was completed by a group of undergraduate Marquette students in 2006. The project involved installing a complete solar powered pumping system that would provide the majority of the water to the 100 residents of the

Santa Maria de Guadalupe Orphanage. This systems differs from the other solar powered system mentioned in the section because at night or during other conditions that would prevent the solar pump from running, the pre-existing electricity powered pump, which used to supply the orphanage with water, would turn on automatically. This set-up negates the need for a holding tank or a gravity-driven distribution system, since pressure is provided whenever necessary, even when the sun doesn't shine. The solar powered system included two 69' by 39' by 5' BP 3160 Solar 160W PV Module panels, costing $1000 each, a Dankoff Solar Force 3040-24PV PV-Direct Surf Pump, which cost $1,523.44, and PVC piping to transport the water. To optimize the productivity of this system, the Marquette project team researched the angle that the sun would be at different times of the year and calculated two different angles that would allow the panels to absorb the most amounts of sun rays during the rainy season and during the dry season (McDonald).

In Egypt, other villages were suffering from a shortage of water, except these villages already had a water pump that ran on diesel fuel. The problem existed because the fuel was too hard to obtain and too expensive. The Egyptian Solar Energy Society, a NGO, decided to use wind energy to supply the villages with enough water for household activities and agricultural needs. Another goal of this project was to further develop wind technology and make it more available, considering this project took place between 1995 and 1997 and there wasn't much known about this technology then. Since wind turbines were rare, the Egyptian Solar Energy Society teamed up with the Arab Manufacturing Company, who decided to produce multiple turbines at the same time to reduce the cost of each individual turbine. Six turbines, produced at $2,500 each, were placed in six villages. These wind turbines did not produce electricity for the water pumps, but they supplied them with mechanical energy, meaning that the water pumped was directly related to how fast the turbine was spinning. Depending on the average wind speed in the village, 700 to 9800 liters would be pumped daily, even though the pumps were designed to be able to reach 12000 liters an hour. Since the amount of water pumped was not regulated by the system, the project report mentioned the need to keep track of the water used so that the sources would not run dry. Similar to the projects above, plans were set to teach the communities using the wind turbine water pump about the technology so it can be maintained properly ("Small-Scale Wind Turbines").

Besides solar and wind turbine pumps, another pump that uses renewable energy exists. It is called the ram pump and it uses the pressure generated by a sudden stop of a relatively large amount of running water to send a small percentage of that water to a higher elevation. In 2008, this type of pump was implemented by the NGO called Border Green Energy Team (BGET) for a primary school attended by 130 students in a village named Poblaki, located in the Song Yang district in Thailand. Two water streams were used as a source for the system, which consisted of two water tanks, the ram pump, PVC piping, and some steel piping. The two water sources, after being combined by a dam, fill up the first water tank, which supplies the ram pump located six meters below the tank. After the pressure builds up in the ram pump, the water then travels up a vertical distance of 70 meters and over a total distance of 336 meters to the storage tank located on the school's premises. Currently, the water is pumped at a rate of 1.2 liters per minute, supplying the school with more than 1500 liters a day. However, this rate was only achieved after returning to the project site a month after completion to make adjustments. The original configuration only allowed for 0.5 liters per minute during the rainy season, and it did not work during the dry season. Even though one of the attractions of a ram pump is the limited amount of moving parts reducing maintenance costs throughout its lifespan, it must be properly installed by trained personal in order for it to work efficiently (Tracy).

Along with describing preferred methods to solve this type of problem, these NGO projects indicated key characteristics of certain systems, such as the requirement of a water tank in a renewable energy source system. Solar and wind powered pumping systems need an accessible storage of water available to the villagers for times when the sun does not shine and the wind does not blow. A ram pump needs a collection tank even though it runs continuously because it flows in pulses and at a slow rate which might only provide enough water for a day after an entire night's worth of pumping and collecting. In these systems, the addition of a gravity driven distribution systems is preferred to transport the water from the tank to its destination, requiring the tank to be at a higher elevation than the village or buildings being supplied. For solar powered system, researching the position of the sun is required to optimize the productivity of the PV panels by placing them at the appropriate angles. Other aspects these projects emphasized were the need for correct installation and the importance of educating villagers about the technology being installed in order for the pump to work efficiently.

2.4.2 Sanitary Bathroom Facilities

Researching previous projects to determine solutions to the sanitation problem in the Zimri village, the team first came across diverse solutions that had relevance to the project, specifically to the limiting factors that influence the building of an enclosed bathroom facility, the lack of running water and the inexistence of a sewerage system.

The company, Envirolet® has their own line of composting toilets, and is promoting the use of the technology to help solve the world's sanitation and water problems. The Envirolet® Waterless Toilets use no water at all. Because no water is wasted for flushing, the user has more water for the purpose of other activities, such as drinking, cleaning and cooking. Though this is not an issue in the developed world, in impoverished communities with little or no running water, this is a huge advantage. The company conducted a project in a South African village using these toilets. Further details on the project unfortunately were not given (Smith).

In the Samuthiram Village in the southern Indian state of Tamilnadu, Quality of Life Trust constructed environmentally friendly toilets known as eco-san compost toilets, for the purpose of reducing the use of water in toilets, prevention of contamination of underground water and above all efficient utilization of urine and human excrement for composting to enhance soil fertility and agricultural productivity. The project was a success and greatly benefited the community (Musiri).

Another project that was of great relevance to us was one that was conducted by EWB-USA, with the help of the village of Santa Rita and the NGO P.E.R.U. The project implemented a sanitation upgrade for a toilet building for the elementary school. The village had a fresh water supply system but no facilities for in-home bathing and wastewater removal. The villagers expressed that their first priority was to install a sewage collection and treatment system so that the people could install flush toilets and bathing facilities in their own homes. Because of a limited water supply and limited land availability, an alternative sanitation system was required. Pour-flush toilets were selected as an appropriate and sustainable alternative to conventional flush toilets, as these toilets use a third of the water needed for the conventional toilets, and still dramatically improve the sanitary conditions. Supplemental health education for the school children and educating the townspeople on the construction and maintenance of the pour-flush toilet facilities was also conducted. The project ran the course of 9 months, and built upon work done on two prior EWB projects (Tumey).

2.5 Health effects of running water

After conducting the research into previous projects discussed above, the team came to understand the importance of fresh drinking water to ensure good health for a community. Thousands of children around Africa and across the world die because of the lack of this amenity and proper facilities. The IQP team concluded, with the available information at hand, that the Zimri village lacks basic resources that ought to be its right, and is in fact more impoverished than the average Moroccan village. Many villages in the third world are unaware of their rights, such as safe drinking running water and electricity, and thus do not actively voice their concerns and problems to the government, whose responsibility it is to provide them.

It is important to provide such basic rights considering the fact that widespread and indisputable evidence exists of the causal links between lack of safe water and sanitation and problems such as increased water related disease, women's burden through carrying water long distances, undermining of education through lost school days, and high infant mortality, to name a few. Not surprisingly, the cost-benefit assessments of investment in water and sanitation are generally very positive – one recent study showed an average eight fold economic net benefit (Haller). Bringing running water to the school in the rural village of Zimri will undoubtedly positively influence the health of the children who attend the school. The effect of piped water on children's health is something that has been well documented. An example is a research study done in India that attempts to answer the question of whether piped water reduces diarrhea for children in rural India. The article comes to the conclusion that the prevalence and duration of diarrhea among children under the age of five are markedly lower in households with access to running water compared to similar households without it (Khanna). Interestingly, the benefits of piped water, when coupled with the education of women has a far greater impact in reducing the prevalence of diarrhea among children than does either one of these factors alone. This means that if the women of a certain household have the knowledge about how to assure that water is safe to drink, and how best to treat illnesses, along with access to safe drinking water, which is best assured through piped water, then that household can see vast improvements in their children's health. As our project addresses two concerns, improving girls attendance by providing an enclosed bathroom facility and bringing running water to the school, the project hopes to eventually improve the livelihood of the villagers in Zimri. The project will benefit the village directly by contributing towards the health of their children due to the access to clean drinking water and indirectly by improving the education of a future generation of mothers, who due to their improved education will be better able to look after the health of their sons and daughters. An important statistic that demonstrates the importance of a safe water supply is the fact that unclean drinking water is the world's second biggest killer of children. The simple task of washing hands, something that will be made readily possible with running water, has been observed to greatly reduce diarrheal incidence by a reported value of 43% (WHO).

2.6 Recent Improvements and Funding

Before Mohammad ElBaz's efforts to improve the condition of the school, classes were held in a building that had no doors or windows and was not structurally sound. If children needed a drink of water, they had to walk to the closest water supply, which is about 400 meters away. There were no school supplies, such as pens, notebooks, or text books, for the children, but they had three dedicated teachers, two of which commuted and one who lived on-site (ElBaz).

Conditions slowly started to get better once Mr. ElBaz involved himself, but the improvements were greatly limited to the small amount of funds that the villagers and Mr. ElBaz could contribute and the donation of equipment from local businesses. However, some progress has been made. The villagers were able to contact UNICEF (United Nations Children's Fund), who occasionally bring food for the children as an incentive to attend school. Since the lunches only consist of lentil soup (hareera), rice, beans, and sardines and as the meal is not provided everyday, the children are unfortunately still unable to get the nutrition that they need in spite of the efforts made.

Seeking larger improvements, such as providing school supplies and making emergency water available to the school, Mr. Elbaz successfully requested funding from non-profit organizations. The first group of supplies was obtained from the Morocco Foundation in May 2007. Mr. Said Bouayad, the Morocco Foundation's vice-president in Casablanca, traveled to the Zimri School to deliver 16 school bags containing basic school supplies to the children who needed them the most. A month later, the school children received a donation from Mr. Jamal Takadoum, who is a professor at ENSMM in Besancon, France. He supplied all 55 children attending the school with school supplies. For the task of supplying emergency water, the Morocco Foundation was the first to contribute, donating 350 U.S. dollars, which was sufficient to buy a plastic water holding tank, filling it, and transporting it to the school. The full tank was delivered in January 2007. Next in May 2007, the Morocco Foundation composed and sent a proposal to the Mosaic Foundation for additional funding. The Mosaic Foundation responded in December 2007 with a grant of $2,000. This contribution along with a private donation of 500 Euros (about $700) made by Ms. Dominique Tynevez allowed for the purchase of a mobile water tank and a diesel pump to fill the stationary tank. Excess funds were put to use to build a fence around the school and to buy material to build a foundation for a private bathroom. The fence was useful to keep animals from feeding on the grass, trees and other vegetation that the students and teachers had planted inside the school compound. As for the private bathrooms, no further advancements are possible at this time due to the lack of funding ("Accomplishments").

3.0 Research

As this project was to create a plan for future implementation, a large part of the project involved researching feasible solutions to the problems. As mentioned before, the two main parts of the project are the water pump and the bathroom facility. The bathroom facility can be investigated as a single entity. However before looking into specific solutions for a water pump, it was necessary to fully understand what the pumping system would need to accomplish and the different components it would need to include. To gather the necessary information, the team took trips to the village of Zimri and researched different aspects of a water pumping system.

3.1 Visits to Zimri Village

There were three trips that the IQP team took to the Zimri village. The details of these trips, specifically the invaluable data and information that was obtained concerning specifications for our project will be outlined below.

3.1.1 First Trip – August 27th

The first trip that the team conducted to the village of Zimri occurred only a couple of days after the IQP group arrived to Morocco. The IQP team was accompanied by Professor El Korchi, a Professor from Worcester Polytechnic Institute and an adviser for this project. We were met at the town of Tiflet by the Mohammad ElBaz's nephew, Mustafa. The road to the village from the town was only partially paved, as the car had to travel through a rocky dirt road towards the end of the trip. The IQP team reached the village at approximately 10:30am. The school at the village at this time was unoccupied due to the summer holidays. We observed the location of the proposed bathroom. A ditch had been dug up for this purpose. A picture of this is shown below (All photograph that appear in this report were taken by members of the IQP team or their advisers).

Figure 1: The location of the bathroom facility on the Zimri school premises

The IQP team surveyed the school and learned where the classes were held, where the teacher lived and where the water was stored. By request, Mustafa showed us the water source that could be used for the purpose of our project. He first took us to the site where the water from the well was being used by the villagers. Here, we observed women from the village involved in cleaning activities. They were also collecting water for the purpose of drinking, cooking and other home needs, to bring back with them to their homes. The IQP team was able to talk to one school girl, who attended the Zimri School, and learned what she was being taught. She was shy, but told us that she was learning French and that she attended the school for only four hours a day. From here, Mustafa lead the IQP team to the site of the well. The area around the well had some vegetation, which indicated that there was a small underwater stream at that site. The well was able to tap in at this underwater stream. There seemed to be only a limited amount of water at this well, which was already being used by the villagers. A picture of this water source is shown below.

Figure 2: The water source that is being used by the villagers already

From this visit, the IQP team also understood that the amount of water in that specific area had decreased dramatically over the past years. Apparently, there was once enough water in the area for children to go swimming in a small pond. This was no longer the case, as the area had completely dried up due to the on-going Moroccan drought. The IQP team also understood that the lack of infrastructure posed an obvious difficulty for the villagers. Little public investment meant that important needs of the villagers had not been met. There was no running water or electricity at the village. The school itself was in a dilapidated state, and what improvements had been made were privately funded. This was especially surprising as the village was only 80km southeast of Rabat.

Coming from Rabat and Casablanca, it was clear to see that there is a huge economic gap between different parts of the country, something which is common in developing countries. Traveling over the next two months across Morocco confirmed this fact. National economic growth in developing nations and its effects on inequality is a topic that has been extensively researched. In a compilation of academic research on this subject called *Inequality and Growth: Theory and Policy Implication*, the authors remark in the preface "even if growth is achieved, its benefits may not be shared equally. Some may gain less than others, and a fraction of the population may actually be disadvantaged by the enhanced growth performance of the economy" (ix). This phenomenon has been observed in Morocco, where some communities have gained a greater advantage from the economic growth of the country than others. Villages like Zimri have been left struggling and neglected. The authors further remark that "On the other hand, despite the diversity of topics, one policy prescription is virtually common in just about all papers: It is the importance of education in reducing inequality and increasing economic growth" (x). So, when it comes to national policy, the most direct way of inducing growth that does not foster inequality is to increase the education of the people. This is exactly what our project intends to do.

3.1.2 Second Trip – September 7th

For this project, two students from Al Akhwayan University (AUI) in Ifrane, Morocco helped the IQP team throughout the project by translating and contacting various companies in Morocco to retrieve information. When the IQP team made a second trip to the village a couple of weeks later, on September 7, the AUI contributors, Abderraham and Yassine accompanied the IQP team, so that they could translate what the villagers said. Once again, the team met Moh's cousin, Mustafa, in Tiflet and drove to the village from here where the team met Moh's younger brother, Lahcen, at the school and talked to him about the importance of the bathroom facility. He commented that although some parents pulled their girls out of school due to the lack of privacy when the girls have to relieve themselves, this was only part of the problem, and some parents may simply use this as an excuse to keep their daughters at home. Parents at the village may believe that daughters need to be prepared for marriage, and training for tasks such as cooking and cleaning start at an early age. This may be a reason for parents to neglect the importance of a scholastic education. Lahcen informed the IQP team of the presence of another well that was in the opposite direction to the original well, and the team walked with Lahcen and some other villagers to see it. Here system measurements were taken. Using the GPS device, the distance from the school to this well and the elevation difference was recorded. Then a rope was lowered into the well to determine the distance between the surface of the water in the well and the ground level and the total depth of the well. The measurements obtained are all shown in the schematic below.

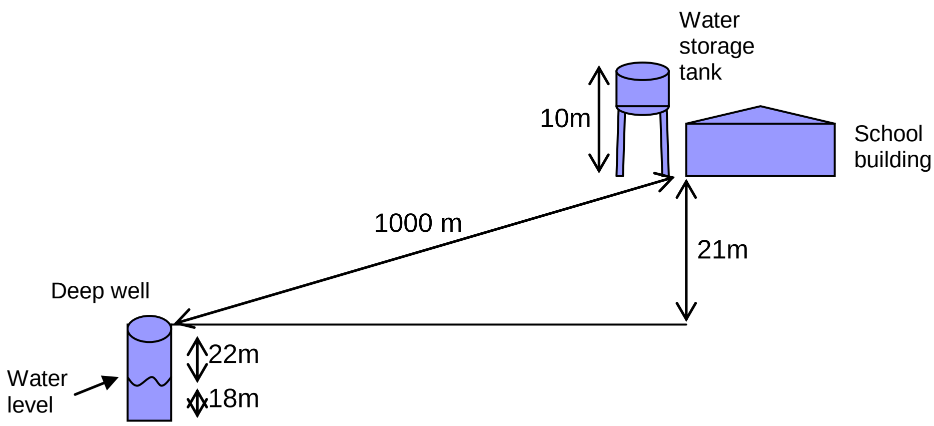

Figure 3: Schematic of the Zimri water pumping system

Since the IQP team had the GPS available during this trip, the distance from the school to the water source investigated on our first visit was measured to be approximately 390 meters. Also, the elevation difference from this water source to the school was determined to be only 24 meters.

3.1.3 Third Trip – September 25th

On the third trip to the village, the IQP team met with a teacher of the school and interacted with the students. This was a very personal experience for the IQP team, as it was the first time that the team was actually able to interact with the students who would benefit from the project. Through talking to the teachers, it was determined that there were a total of 79 students studying at the school, with only 22 of them girls. The huge discrepancy between the number of girls and boys attending the school lead the IQP team to believe that girls are being purposely kept from attending school. However, Abdullah, the teacher of the school present at the time, said the unequal ratio of girls to boys was coincidental, and that some years more girls than boys attend school. Because there is no readily available documentation, this information is difficult to validate. Either way, Abdullah agreed that girls were more likely to be kept out of school compared to boys. He remarked that it was a complicated issue. Though privacy was a part of the issue, there were other reasons involved. Similar to Lahcen, the teacher remarked that the parents had a "what's the point" attitude and also believed that daughters were needed at home.

In addition to the discussion about the students, Abdullah informed the team that the two teachers who were not at the school during the visit went to the district director to discuss unrevealed problems. The IQP team also inquired about the purpose of the ditches that were dug from the town of Tiflet to the village. The teacher and a parent present at the school said these ditches were for the purpose of bringing piped water to the Zimri village, but only to households that could pay for it, and that it was unlikely that it would be brought to the school. Once again, this information is hard to confirm. Finally in regards to the project, the teacher requested that water be piped into the bathroom facility, so that he and the children could wash up in private

3.2 Components of the Pumping System

The entire system contains multiple components, including the energy source, the pump, the piping from the well, a water storage tank, distribution piping from the tank, and a faucet. The energy source and the pump are the major variables of the system, but these other parts are still necessary to complete the system and are important to investigate because they affect the requirements for the pump.

An important supplementary component that can be easily overlooked is the water storage tank on the school premises. This feature can be used with diesel and solar systems and has advantages for both. A benefit unrelated to the energy source that is gained from the addition of the water tank is that there will always be a supply of water on the school property. The team proposes to use the cistern that is currently there and being filled by a rain water catchment system and by the villagers manually. The cistern has a volume of 2,000 liters, enough water to sufficiently supply the school for approximately two to three days. Since it would take a few days to deplete the water in the storage tank, the water pump would not need to be consistently running, a benefit for both systems. For solar powered systems, the pump cannot run if the sun is not shining. This means that if there was not a storage tank, the school would not have water during the night or on cloudy days. The presence of the storage tank allows the solar pump to fill the tank when it is sunny, and when it is rainy, the excess amount of available water would be adequate for the school until the sun shines again. In essence, the purpose of the pump would be to fill up the water tank when necessary, not to pump water out of a faucet for use. This benefits a diesel powered system as well by allowing the pump to only be run when it is convenient. If there was no tank, the engine would have to start and stop every time a person wanted water from the faucet, requiring an electrical on/off switch to be installed at the school and wires to run a kilometer in order to connect the switch with the engine. The storage tank would eliminate the necessity of the extensive starting system stretching to the school property because the pump could just be run at a convenient time of day, for example everyday after school, until the tank was full. The school would then have access to the water they would need for the time period before running the pump again.

After providing an accessible supply of water on the school property, the next step was figuring out how to distribute it to the people at the school. Since it would not be feasible to employ the use of a second pump, a gravity driven distribution system was decided upon. In order for it to work, the water tank would have to be elevated so that the bottom of the tank would be about seven meters from the ground (Yago). This distance is necessary in order to create the desired water flow and pressure out of the faucet. Since the pipe between the tank and the faucet will need to be continuously sloping down, it would make the most sense to have it either directly underneath the tank or close by it. Considering water is necessary for cleaning oneself after using the bathroom, an appropriate location for the tank and water spout would be next to the new bathroom facility. However, for some facilities, which will be discussed in more detail later in the report, air circulation and/or sun exposure is required in order for them to work properly. This must be taken into consideration when choosing the final placement of the elevated water tank.

Another important component to the water pumping system is the piping. The dimensions and material of the pipes have a significant impact on the cost of the system and the requirements of the pump. The water system in Zimri requires approximately 1000 meters of piping. The piping, starting at the pump, will go underground and will travel to the school at a consistent depth of at least one meter below the surface as to not interfere with any possible farming that needs to be done with the land the pipe travels under. Once at the school, the piping will need to curve up out of the ground to the top of the storage tank so that the tank can be filled completely. Knowing the length and material of the pipe is important for calculating pump requirements because these characteristics contribute to a friction force that the pump will have to overcome. More friction is produced with longer pipes and with rougher material. Corrosion build-up on the inside walls of the pipe will also increase friction and restrict flow. Choosing a certain material can help reduce friction produced by the pipes.

Polyvinyl chloride (PVC) was considered to be the best material for the pipes because it is a material that is easily produced and can be combined with various chemicals, or plasticizers, to slightly alter the physical properties of the material in order to suite specific needs. Since it is simple to manufacture, it is relatively inexpensive and easily obtained. It is ideal to work with during construction because it is light weight and is a strong material that can withstand impacts and other forces on it. When the system is actually in use, PVC pipes are resistant to mineral deposits on the inside walls, and since PVC is a type of plastic, it will not rust. Unfortunately, there are some disadvantages associated with PVC pipes for this project. Polyvinyl chloride without any additives cannot withstand extended exposures to UV rays from the sun (Lenntech). Even though the majority of the pipes in Zimri will be underground, to protect them and to permit farming to continue on the lands that the pipes must travel under, some sections of the piping will be above ground. For example, the piping that comes from the pump before going underground will be exposed to sunlight along with the piping that leads to and from the elevated water tank. However, plasticizers can be added in order to help with this problem and covers can be constructed to keep the pipes shaded. PVC in general is used in many applications and it has gone through and passed many tests to ensure that it is safe to use (Kutz). PVC is both safe and appropriate for the Zimri project and many NGO's have used PVC pipes to complete similar projects.

Even though the parts of the system described above are simpler and less significant compared to the actual pump, they are important because they determine how the pump will be used and they add to the challenges that the pump will have to overcome. The addition of the water storage tanks allows for pumping to occur as appropriate for the system. Also, the extra elevation of the water tank along with the friction produced by the pipes all contribute to the specifications of the pump.

3.3 Estimated Water Usage

In order to accurately size the pump, the team had to estimate how much water the school was going to use on a daily basis. The estimate was based on adding up every person's total daily water needs; however the fact that most people who attend or work at the school do not spend full days there was taken into account and is discussed later in this section. Considering the school does not have any machines that use water, the daily water usage was based on the necessities of drinking, sanitation facilities, bathing, cooking, and cleaning. A method to determine the amount of required drinking water is to measure the amount of solutes in a person's urine to discover how much water per kcal (Calorie) would prevent dehydration (Manz). Using a minimum requirement of 1 to 1.5 mL of water per kcal and a normal diet of 2,000 to 3,000 kcal, it can be calculated that a person living in a moderate climate and participating in average activities requires a minimum of three liters of water per day. However, the villagers in Zimri live in a hot dry climate so an extra two liters is added onto the projected daily requirement. Also, since the villagers, including the children, do laborious tasks on the farm, another liter is added. This makes the Zimri villagers require an estimated six liters of water per person per day for drinking.

The amount of water required for sanitation depends greatly on the system used. A person who uses the high water consuming western-styled toilets can use around 75 liters a day. However, the sanitation facilities expected to be installed at the Zimri School require no water in order to function properly and only a little to maintain cleanliness. Twenty liters per person per day should be an adequate supply of water for maintaining hygienic sanitation practices such as cleaning oneself after going to the bathroom and washing one's hands. The next water consuming activities taken into consideration are bathing and cooking, which only the on-site teacher would need to do. For a bath, fifteen liters is considered to be an adequate amount of water, however, in developed countries, a person is likely to use anywhere from 45 to 100 liters a day for bathing. Considering this range, 45 liters is allocated for the teacher's daily bathing needs. As for cooking, the estimated amount required for one person each day is 30 liters, which is more than sufficient for food preparation and cleaning dishes since 10 liters is considered the minimum necessary for both activities (Gleick). The last activity requiring water at the school would be general surface cleaning, requiring an estimated 50 liters a week. This figure was reached by assuming a normal household bucket capable of holding ten liters of water would be required to clean each room each week. Since there will be five rooms including three classrooms, a teacher's residence, and a bathroom facility, five buckets would be required, totaling 50 liters a week or 10 liters for each school day.

Liters of Water Required per Person per Weekday*					
Activity	Drinking	Sanitation	Bathing	Cooking	Cleaning
Liters of Water	6	20	45	30	10

Table 2: The estimated amount of water used throughout a day for each activity

*Weekday includes Monday through Friday. Saturday and Sunday are not considered in this calculation because no one is at the school on the weekends.

These estimated values seen in Table 2 are based on how much a person uses throughout the whole day, yet most of the people at the school are only present for a portion of the day. The students are only there for four hours a day, either from 8am to noon or from 2pm until 6pm, and the two commuting teachers are at the school for at most ten hours a day if they teach both sessions. Even the on-site teacher leaves the school premises on the weekends. Also, most of the people present at the school do not do all the activities. For example, the children and the commuting teachers do not bath or cook at the school, since they have the ability to do that in the privacy of their own homes. These factors had to be taken into account for the estimation of water usage or else the end result would have been much larger than actually needed.

To accurately measure how much water would be used at the school, the people attending the school were broken down into three categories: students, commuting teachers, and on-site teachers. For each category, the total amount of water used per person was added depending on the activities of the category. This amount was multiplied by the number of people in the category to obtain the total amount of water that would be used by this group throughout an entire day. Since not every category stayed on school property for a full 24 hours each day, the total amount was then multiplied by the fraction of hours spent at the school over hours in a day. For example, there are two commuting teachers who will be at the school for ten hours a day and will drink and use the sanitation facilities. Since the teachers do only two activities, each teacher would use 26 liters of water, six liters for drinking and twenty liters for sanitation, throughout the entire day (52 liters for both of them). However, the teachers are only there for ten hours a day, so 52 is multiplied by 10/24 obtain the estimated average amount of water used by both teachers while at school. This calculation results with the commuting teachers using a total of about 22 liters of water per day. Table 3 shows the calculations for all the categories of people.

Liters of Water Used While at School per Weekday					
Category	Activities	Water Used Daily	Number of People in Category	Hours per Day Spent at School	Water Used while at School
Students	Drinking, Sanitation	26 L	100[&]	4	434 L
Commuting Teachers	Drinking, Sanitation	26 L	2	10	22 L
On-site Teachers	Drinking, Sanitation, Bathing, Cooking	101 L	1	24	101 L

Table 3: Calculation of water used by each category while at school

[&]Currently only 79 children attend the Zimri School, yet there is an estimated amount of 100 children of school age living in the village. 100 were used in the calculations in order to ensure that there would be enough water for every child in the village at the school in hopes they will all attend.

The calculated amount of water used while at school for each category is added together along with the estimation of water required for cleaning to get a total of 567L of water per weekday, or a little less than 3 cubic meters per week. However, it is good to keep in mind that estimations about water usage tend to be less than the actual required amount (Gliek).

3.3 Calculating Pump Requirements

The final step in designing a water pumping system is choosing the correct pump because its requirements are based on the all the details of the system. The first two details of the system that will greatly narrow the options of suitable pumps are the water source and the available energy sources (“Determining Pumping Requirements”). Different water sources include deep wells, shallow wells, rivers, or pipes filled with tap water which put their own unique demands on pumps. In some systems, the water source can also provide the energy needed to run the pump. An example of this is a ram pump system where a river can provide the water to be pumped and the energy for the pumping through the water’s velocity. Besides water, other energy sources are wind, solar, gravity, fossil fuels, and electricity. The availability of these types of water and energy sources depends on the location of the project site. In Zimri, the preferred water source is a deep well in a valley between hills, eliminating the options of wind, gravity, and water to be sources of energy. Also, the village does not have any electricity, which leaves solar power and diesel fuel as the two available energy sources.

Once the two location-dependent criteria are chosen, the pump's capabilities must be calculated from the demands of the system. The factors that create the pump requirements include the flow rate of the water, characteristics of the well, and the total dynamic head (TDH) of the system. The flow rate can be calculated by determining the amount of water needed for an entire day and dividing it by the amount of time that the pump can run (Serafinchon). Earlier in this report, the required amount of water to meet basic needs was calculated to be less than 600 liters per day. Since this is such a small amount for an entire day, the team decided to stipulate a minimum flow rate of 1.5 liters per minute with higher flow rates being acceptable if necessary.

The next step is determining what limitations the water source puts on the system. Important well characteristics include the size, the static water level, the pumping water level, and the well capacity (the maximum rate which the well can refill with water). In the case of a deep well like the one at Zimri, the dimensions of the well may limit choices depending on suction capabilities or the physical size of the pump if it is required to fit inside the well, which is especially important when using a submersible pump. A well with a diameter larger than four inches can support most pumps inside the well ("Article 302"), and, considering the well in Zimri has a diameter of 1.75 meters, the physical size of the pump is not restricted. The next three characteristics are directly related to the amount of water available and even contribute to the TDH of the system. The static water level is where the surface of the water in the well is located without pumping. Currently, the deep well in Zimri has a recorded static water level of

22 meters below the top of the well. However, when pumping starts the water level is inevitably going to drop until it reaches equilibrium at the pumping water level. As pumping increases, the pumping water level drops, and the rate at which water flows into the well goes up to balance the increase in pumping speed. If the rate of water being removed continues to go up, eventually equilibrium will not be reached and the well will go dry. The maximum rate that water can be pumped out while still maintaining equilibrium is called the *well capacity*. The pump chosen for the system should not exceed the well capacity. Therefore, if a higher flow rate is required, the system must be compensated with a large storage tank that can hold enough water to supply high demand periods and fill up during low demand periods ("Article 302"). Considering the required flow rate for the Zimri system is so low, exceeding the well capacity is not a concern. Knowing the pumping level is also important when it comes to calculating the total dynamic head of the system.

The total dynamic head (TDH) is one of the most important factors that determine the size of the pump. The TDH is a concise numeric value, stated as a length, which describes the obstacles that decrease the flow rate. It is calculated by adding the elevation the water has to travel and the head loss, which can be conceptualized as the elevation that is mathematical equivalent to the resistance created by the friction and configuration of the pipes. The elevation that the water has to travel is measured from the water surface to the height where the water leaves the pipe, the top of the storage tank. The pumping water level, instead of the static water level, must be used for the location of the water surface for these calculations ("Article 302"). The water level in Zimri is estimated to drop a maximum of a meter from its current location when pumping occurs.[1] With the estimated pumping level of 23 meters below the top of the well,

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[1] Since no production tests have been performed with the well, the "draw down" (difference between static and pumping water levels) is estimated based on the weekly usage of the school. It would take more than three weeks of

a vertical distance of 21 meters between the top of the well and the school, and an estimated 10 meters to the top of the storage tank[2], the difference in elevation equals a total of 54 meters.[3]

The next step is determining the head loss, which is a measure of additional obstacles that the pump has to overcome. It is broken down into two categories: friction loss, which is due to friction in the pipes and minor losses, which are due to the components in the system. Friction loss is dependent on the roughness, diameter, and length of the pipe, where as minor losses are created by any bends, valves, or other fixtures the pipe has. The magnitude of both types of head loss depend on the velocity of the water and whether the flow is laminar (smooth) or turbulent. For this pumping system for Zimri, it is safe to assume that the flow is laminar, causing the friction loss in the system to equal four meters. As for minor losses, each structure or configuration has an equivalent distance that is added onto the TDH (Streeter), for example a 90 degree bend in the Zimri system adds an additional .5 meters. Assuming that there are four 90 degree bends and two broader ones throughout the piping system, the minor losses can be calculated to equal three meters. Finally, the elevation, friction loss, and minor losses are all added up to equal 61 meters for the total dynamic head for this system.

Sometimes, pumping companies list other capabilities, such as the maximum pressure that the pump can handle and the horsepower produced by the pump's engine. The pressure in pounds per square inch (psi) can be figured out by dividing the TDH in feet by 2.31 (Yago). The HP required for the pump in the system can be calculated by the equation HP = (Q*H)/ (76*e),

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pumping, without the well refilling at all, for the water level to drop a meter. Considering the pump should not be running on the weekends, giving the well time to refill each week, a maximum draw down of a meter seems adequate.

[2] A drop of 7 meters is required to provide sufficient pressure for the faucets in the small gravity driven system (Yago). The cistern expected to be used is about three meters tall.

[3]This elevation was calculated during the dry season and might decrease slightly in the rainy season if the water level goes up with the increase amount of rainfall.

where Q is the flow in liters per second, H is the TDH in meters, 76 is a constant, and e is the pump efficiency. To obtain an estimate for HP without knowing the specific efficiency of a pump, 60% can be used ("Determining Pumping Requirements").

As with any machine, all pumps have an expected life span. To ensure that a pump lasts for its full predicted lifetime, it must be the correct size for the system. Pumps are designed to work best within a range of flow rates and TDH values. Each pump has a plotted curve of flow rate versus TDH to show this acceptable range. If a pump is chosen to operate to either side of this curve, its lifetime will reduce significantly. For example, given a specific flow rate, a pump would fall outside of its range if it is placed in a system that either has too much or too little TDH ("Article 302"). The life span of the pump can also be reduced if the pump is required to frequently turn on and off because the most wear occurs when pumping begins and ends. This wear can be slightly reduced if a larger storage tank is used, since it will take longer to empty and thus need to be filled less often (Wellcare).

4.0 Findings

Going to the Zimri village to gather measurements and to talk to the villagers gave the IQP team the necessary information about the water pumping system in order to complete calculations to determine the key characteristics necessary to size of the pump. Also during the visits to the village, the site was surveyed to observe general characteristics of the area, such as the dry arid climate, the best location for the facilities and the proximity of the nearest water source, which all have an effect on various types of sanitation systems. With the newly acquired knowledge of the pumping system and the area for the bathroom facility, the team was prepared to investigate suitable water pumps and bathroom facilities for the Zimri School.

4.1 Water pumps

There are many different types of water pumps that were explored for the purpose of the project. The most important factor with regard to pumps is the type of energy source that should be used to pump water from the well to the school. Diesel, electricity, solar and wind powered pumps are some of the options that were considered. The project team focused primarily on solar and diesel powered pumps, due to the lack of electricity at the village and the insufficient amount of a wind in the Zimri region to power a pump.

4.1.1 Solar Powered Pumps

There are many advantages to using a solar powered pump. These include unattended operation, low maintenance, easy installation, minimal running costs and a long running life. There are also some disadvantages that need to be highlighted, particularly, the high initial capital costs, the requirement of a storage facility for cloudy days and repairs required by skilled technicians in the case of a mechanical failure. These factors, both the benefits and the disadvantages, were taken into consideration when determining which pump is best for the needs in Zimri.

There are many types of pumps that use solar technology and are appropriate for wells. These include the submerged multistage centrifugal motor pump set, the submerged pump with surface mounted motor, the floating motor pump set, the reciprocating positive displacement pump, and the surface suction pump set. These different types of pumps vary in the placement of the pump and motor, and each is designed for different applications. We are most interested in the reciprocating positive displacement pump, which is suitable for high head, low flow applications, and the submerged multistage centrifugal motor pump set, which has the advantage of being easy to install, with the additional advantage of the pump set being submerged away from potential damage and theft. For these reasons, the submerged multistage centrifugal motor pump set is the most widely used.

How do solar powered pumps work and how will they be used to supply electricity to the Zimri School? The schematic below in Figure 4 gives a basic understanding to the system that we hope to set up. Photovoltaic arrays (solar panels) are set up near the water source, collecting the sun’s energy. They are connected by electric wiring to the motor, providing it with the electric power needed to pump water from the well to a water storage facility. From this water storage facility the water is gravity fed to the location of use.

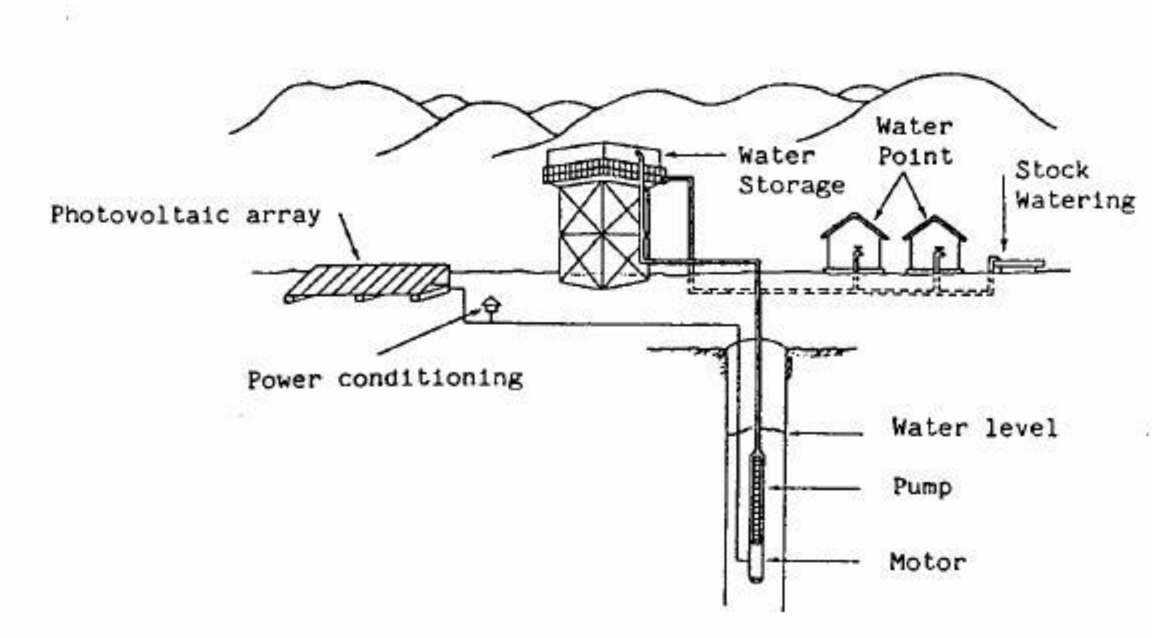

Figure 4: Schematic of basic solar pumping system (Practical Answers)

To determine the cost estimate, the team needed to determine the pump's requirements, which were calculated in the previous chapter. The total dynamic head of the system ended up being 61 meters and the required flow rate was extremely low, causing the team to use the lowest flow rate available to size the solar pump. Online quotes for suitable pumps, with flow rates at specified pumping capacities are shown below in Table 4.

Model	Lorentz PS600 (350 Watts)	Lorentz PS600 (480 Watts)	ETA-04-300
Pumping Capacity (TDH)	230 feet	230 feet	250 feet
Flow Rate	2.6 GPM	3.4 GPM	2.2 GPM
Price	**$5,199.00**	**$5,999.00**	**$4,038.00**

Table 4: Solar Pump prices, capacities and flow rate (Solardyne)

4.1.2 Diesel Engine Powered Pumps

The search for an appropriate method of pumping water included looking into internal combustion engine powered pumps. Engine-powered pumps were considered one of the top options for this project for three reasons:

1. Internal combustion engines are easily accessible and commonly used in many villages similar to Zimri.
2. The villagers are familiar with the technology.
3. Spare parts, mechanics, and fuel for these engines are all available locally.

The team believed that an internal combustion engine power source would be a logical solution that could be implemented quickly and relatively cheaply. A diesel engine is preferred out of the two types of available engines: petrol engines and diesel engines.

A diesel engine was chosen to be the better type of internal combustion engine because it is the most efficient. Just like petrol engines, diesels engines operate by igniting a compressed fuel and air mixture to push down pistons in order to rotate a crankshaft. However, the timing of mixing the fuel with the air and the method of igniting the mixture is the difference between the two and is the key as to why diesel engines are more efficient. In a petrol engine, the fuel and air is mixed before the compression stroke in the typically used four stroke design. Therefore, the pressure created during this stroke has to be limited to avoid combustion happening at the wrong time, and a spark plug is necessary to initiate combustion. In diesel engines, the air is compressed before the fuel is introduced, allowing for the possibility of much higher pressures without the fear of untimely combustion. The fuel, which is directly injected into the chamber full of hot, highly compressed air, is ignited by the heat created from compression and the timing of the fuel injections keep the engine in the correct rhythm ("Just the Basics: Diesel Engines"). The more compressed air is the more energy it contains, which means it can create more power when burned. Since diesel engines use higher compressed air, they required less fuel than petrol engines to get the same amount of power, thus making diesel engines more efficient.

Another reason why diesel engines are more efficient than petrol engines is the composition of the fuel. Diesel fuel contains 18% more joules of energy per unit volume than petrol does (Fraenkel). This means that more power is produced from using diesel fuel than using the same volume of petrol fuel. Diesel engines combine higher energy containing fuel with the highly compressed air to be more efficient than petrol engines overall.

Even though diesel engines are an efficient type of internal combustion engines, it does not mean that a diesel powered pumping system is highly efficient. The range of efficiency of the entire pumping system spans from a measured 0.5% to a theoretical 27% (Fraenkel). These low percentages are due to the fact that the system loses efficiency at every step of the pumping system. For example, the mechanism to transmit the power created by the engine to the pump, the head loss in the piping, and the inefficiencies of water pump itself all take away from the total efficiency of the system in addition to the engine and pump themselves. Some of these additional contributing factors to the low efficiency of the system will apply to any water pumping system, considering every system will include pipes and a pump. However, it is important to note that the diesel engine is the least efficient step out of the whole process. Another small factor that contributes to the inefficiency specific to diesel systems is human error in spilling fuel. These losses in efficiency can be seen in Figure 5.

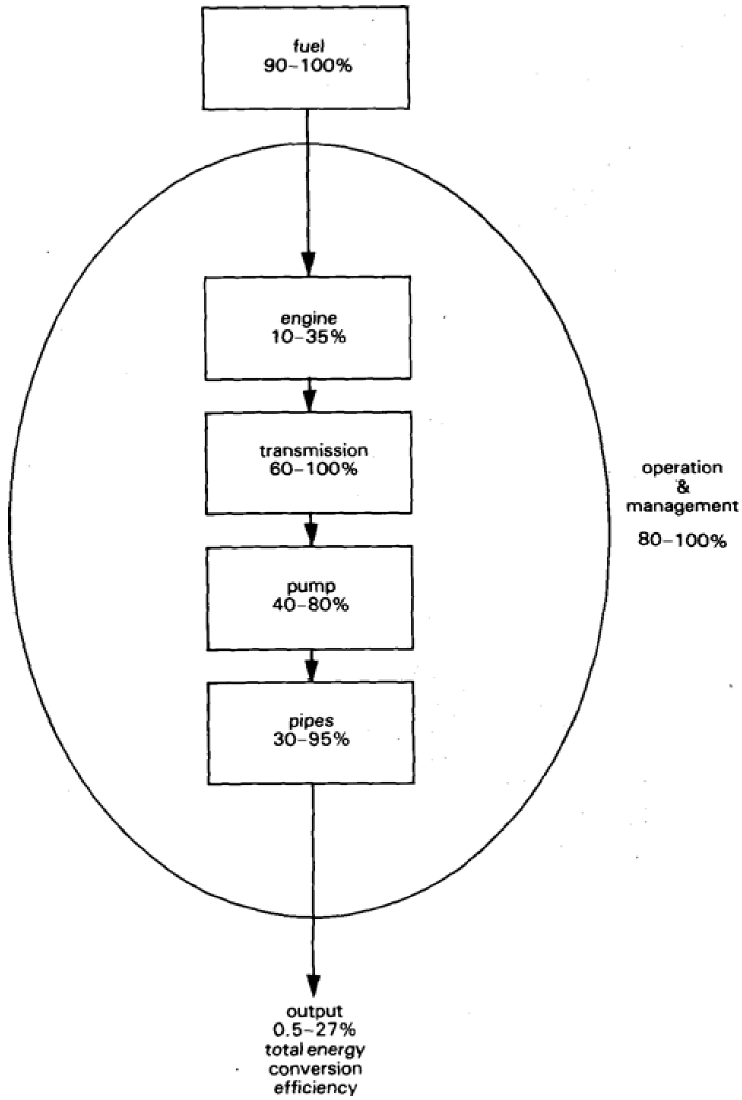

Figure 5: Map of efficiencies in diesel engine water pumping system (Fraenkel)

When discussing a diesel engine as a power source for a pumping system, more has to be discussed than efficiency. One major factor includes the types of pumps that can be paired with an engine. Diesel engines can only power limited types of pumps since the pump needs to be level with the engine in order to receive the mechanical energy produced by the engine. This requirement limits the options of pumps to two types: centrifugal pumps and jet pumps (Morse). These options are further restricted to the jet pump for the Zimri project because simple centrifugal pumps can only retrieve water from a vertical distance of 7.5 meters (Morse) , which is much shorter than the required 21 meters of suction lift required for the system. A jet pump works by recycling water through a pipe loop to create enough suction to lift water out of deep wells. First, a centrifugal impeller spins creating a low pressure area at the top of the pipe called the suction line and sending a portion of the water being pushed through the impeller back down the well through another pipe, known as the drive line. Deep in the well, the drive pipe curves around and forms a nozzle that accelerates the water in it and shoots it into the suction pipe. The accelerated water sucks more water from the well into the suction pipe through a submerged valve, called the foot valve, located lower than the nozzle at the bottom of the suction pipe. Then the accelerated water along with the new water from the well goes through a venturi, a short stretch of piping that has a smaller cross sectional area, to increase the pressure at the bottom of the suction pipe. The pressure difference created by the venturi and the centrifugal impeller cause that water to move up the pipe (Murray).

Although this type of pump is capable of handling large suction lifts with the usual maximum acceptable distance being 80-90 feet (24-27 meters) (Morse), the pump looses efficiency as the required suction lift increases. Therefore, the jet pump required for the Zimri well would have a comparatively low efficiency since it needs to operate close to the accepted maximum with an approximate 21-meter suction distance. Other disadvantages include the location of the nozzle and foot valve being deep in the well. These features are easily clogged or damaged by sand introduced into the system, and if cleaning or repairs are necessary, the whole configuration has to be pulled out of the well (Morse). However, the pump's moving parts, which are more likely to need repairs or maintenance, are conveniently located at ground level and are easily accessible.

An important factor that needs to be considered when discussing diesel engines is the cost of fuel. Even after the initial set up, the villagers will need to continuously gather money to pay for the fuel to run the diesel engine. Paying for fuel has become a major concern in many cities in developed countries let alone rural villages in developing countries where a disposable income is nonexistent. In addition to limited incomes, the villagers in Morocco have had to deal with fuel prices consistently higher than those in surrounding African countries, which can be seen in Table 5. Between 1991 and 2002, the average cost of diesel fuel in Morocco was 0.50 USD per liter ($1.82 per gallon) (Metschies). After that, the crude oil price increased rapidly resulting with the present day price of 0.90 USD per liter ($3.41 per gallon) ("Gasoline and Diesel Fuel Update"). It is predicted that fuel prices will remain at these high prices, but it is difficult to distinguish any particular trends since fuel prices are so variable ("Diesel Fuel Prices"). The Moroccan government is trying to help its struggling citizens by issuing subsidiaries. However, the continuously increasing prices are straining the budget and have recently caused the Moroccan government to raise prices for petrol fuel and 350 diesel fuel on July 2008. The government, though, is still managing to hold on to its commitment to its people. The subsidiary budget has now doubled since it was first created in order to keep the cost for the fuel used for most transportation and power generation from going up (Touahri).

Retail Price (USD/liter)					
Year	Algeria	Egypt	Morocco	US	UK
1991	0.04	0.07	0.45	-	-
1993	0.09	0.09	0.41	0.28	-
1995	0.23	0.12	0.47	0.33	0.85
1998	0.16	0.12	0.47	0.27	1.11
2000	0.15	0.10	0.53	0.48	1.22
2002	0.10	0.08	0.55	0.39	1.20
2004	0.15	0.10	0.70	0.57	1.60
2006	0.19	0.12	0.87	0.69	1.73
2008	0.20*	0.11*	0.9*	1.02**	-

Table 5: Timeline of diesel retail prices in various countries (Information obtained from Metschies, Scott(*) and "Gasoline and Diesel Fuel Update"(**))

Another disadvantage about diesel engines, which is more significant than fuel costs, is the fact that diesel pumps are not designed for small systems, such as the water pumping system in Zimri. More appropriate systems require 5,000 gallons (about 19 cubic meters) of water per day, which is about thirty times as much as the amount of water needed at the Zimri school. This is due to the fact that diesel engines operate the best at a designated speed, which usually causes the pump to produce a flow rate of at least 10 gpm (38 liters per minute). At this minimum flow rate, it would take less than an hour to fill the 2,000 liter cistern and only 15 minutes to pump the required daily amount for the Zimri School. This is a problem because diesel engine powered pumps work the best if they are used for more than just a few hours a day. Eight hours would be a more appropriate length of time (Brown).

4.2 Bathroom Facilities

The issue of sanitation in a bathroom facility needs to be addressed – specifically, how can cleanliness be ensured in an enclosed bathroom facility? The concern here is that there is no sanitation system set up to dispose of the fecal waste. The team thus needed to determine a cheap and efficient way of disposing waste, one that will not harm the environment, is practical to implement and operate and ensures the health of the students and the teachers who attend the school. There are many methods that can be employed to properly manage waste. Simple latrine systems, compost toilets and septic tanks will be discussed as three options that can be implemented by the school.

4.2.1 Pit Latrines

Latrines are structures that collect feces in one place, prevent access by insects, keep water from being contaminated, give some privacy to the users, and in some cases, provide useable fertilizer. Due to potential groundwater contamination, latrines should be a bare minimum of 30m from any well, body of water or potential drinking source. They should also be a reasonable distance from dwellings—no less than about 5 meters because of possible smell problems. They should also preferably be downwind of dwellings. The site of the latrine must also not pose the potential of being flooded.

The simplest type of latrine is a pit, with some covering. In a wilderness setting, with few people, feces can simply be buried shallowly in the soil, at least 30 meters (100 feet) from surfaced water sources. This way the feces will be broken down by soil organisms easily. Sizing the pit is important. A good general estimate is to assume that one person will give 0.04 m^3 (1.4 cubic feet) of solids per year. For 40 people, we will need a pit volume of approximately 1.6 cubic meters. An additional 50 cm of depth is needed from the surface in calculating the pit volume. This space is needed to put dirt back into. After the pit is dug, a basic structure can be built on top of the pit. An example is shown below. It is important to have a close-fitting cover for the pit to reduce odors and keep out flies. A small hole is made, with a hole cover placed on top, as shown in Figure 6. Because small children are involved, the hole needs to be appropriately sized so that no child poses the risk of falling inside the pit.

The ventilated improved pit latrine, as is also shown below in Figure 6, is an enhancement of the basic pit latrine, which addresses smell and fly problems. A ventilation pipe is added (as shown) which extends at least 50 centimeters (20 inches) above the top of the shelter roof. As air moves across the top of the pipe, it draws air up out of the shelter and pit. A mosquito net on top of the pipe traps flies inside, where they die. The interior of the shelter should be relatively dim, so that flies are attracted to the light from the pipe.

There are advantages and disadvantages to this system. An advantage of this type of latrine is that it can be constructed quickly and easily. They are relatively safe, provided that they are not close to a food or water source. Sanitation is aided by the fact that no one has to handle the feces and urine, the hole is simply refilled. However, they are likely to introduce pathogens into the groundwater. The breakdown of the feces is mostly an anaerobic (without air) process that produces a variety of unpleasant gases such as methane and hydrogen sulfide (which smells like rotten eggs). And the nutrients in the feces and urine are lost in the pit, which means that farmers cannot use this as a source of valuable nutrients like nitrogen. (McBay)

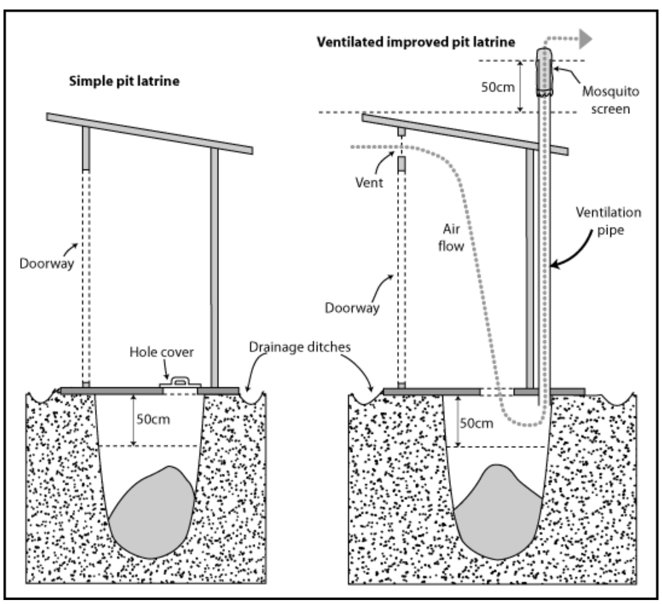

Figure 6: Pit latrines (inthewake)

4.2.2 Compost Toilets

Another system that was considered is the composting toilet. Composting is an aerobic process, which means it takes place in the presence of air. For a compost toilet to be operational, it needs to be in sunlight to keep the compost at an appropriate temperature. A properly operating composting toilet does not produce unpleasant smells or gases, a desirable characteristic compared to the pit latrine. The warm temperatures reached inside the compost break down the fecal matter and aide in killing any diseased organisms that might be present. Composting toilets also conserve the nutrients in the feces and urine, so that they can be used by the villagers and returned to the land. The essential ingredients of good composts are sufficient moisture, oxygen, a warm enough temperature, and a good balance between carbon and nitrogen.

A suitable level of moisture needs to be maintained. If the compost material is too dry, the microorganisms that break down the fecal mater will not be able to grow properly, and valuable nitrogen will be lost to the air. If it is too wet, lack of air circulation will cause the process to become anaerobic and create foul odors. "A compost should be about as damp as a wrung-out sponge." If the compost is too dry, a little water can be added. If the compost is too wet, some dry material like straw or ash can be added. Temperature is important because the thermophilic composting microbes need a certain minimum temperature to operate, and because an elevated temperature can kill pathogens. An example of a compost toilet is the Jenkins Sawdust toilet. It is shown in the Figure 7 (McBay).

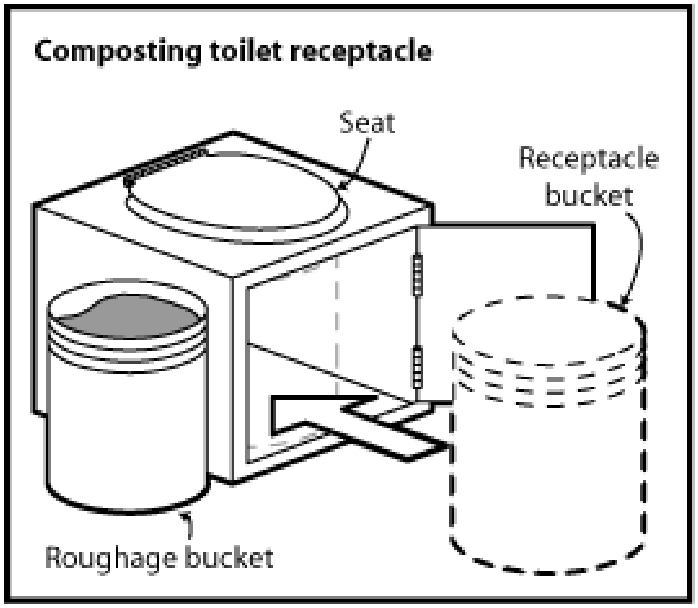

Figure 7: Composting toilet receptacle (inthewake)

After each "deposit", add roughage to cover the feces and urine should be covered. This is done because carbon is required for microbial decomposition and ideally should be in a proportion of about 30 parts carbon to 1 part nitrogen. This toilet does not require an airtight or fly-proof lid, since the roughage keeps out flies and minimizes smells. When the receptacle is full (or almost too heavy to carry) it can be dumped into a compost bin and buried in the top layer of the compost pile.

There are a number of designs for the compost bins, many of which vary by climate. People in hot, dry climates, like Zimri, may need to dig a pit to put their compost in to conserve valuable moisture. Jenkins suggests a simple rotating multi-bin system, as shown in Figure 8. This multistage system, where the receptacle is first filled and then emptied into compost bins further ensures cleanliness.

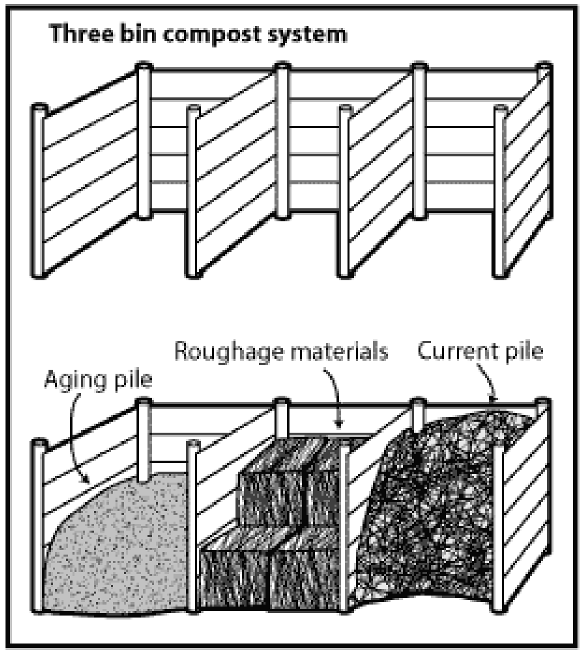

Figure 8: Three bin compost system (inthewake)

When starting a new *humanure* compost pile, it is recommended that at least 18 inches of roughage is put down. This "sponge" will soak up any fluid leaching from the pile to prevent contamination.

The Two Chamber toilet is essentially an outhouse version of the general system described above. The "bathroom" is located directly above the composting chamber, as shown. There are two seats (or holes), one for each chamber. The chambers are used one at a time. While one chamber is composting and closed off, the other is in use. After each deposit, roughage is dropped into the chamber. The chamber can be made out of cement, wood, bricks or any other material that can support such a structure. The Two chamber toilet is shown below in Figure 9 (McBay).

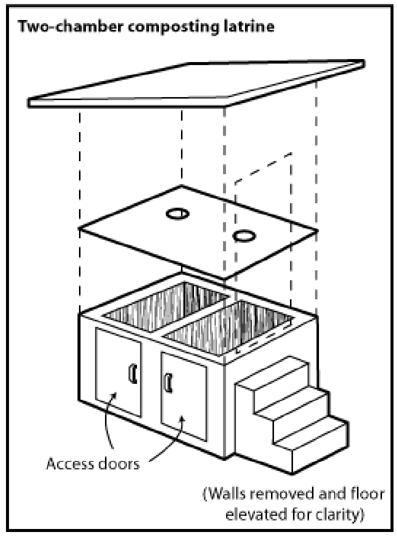

Figure 9: Two-chamber composting latrine (inthewake)

4.2.3 Septic Tanks

Though pit latrines and compost toilets present a short term solution, both systems have the disadvantage of requiring contact human waste, which is both unhygienic and high maintenance. It would be preferable for the school to have an automated system. For a flush system to work, we would need a proper sanitation system. Because there is no public sanitation disposal system in the area, a septic tank would have to be built. Though a septic system provides an onsite sewage facility, they are extremely expensive to build and maintain. Thus, it is proposed as a long term solution to the problem, once suitable funds are available.

A septic tank is a small scale sewage treatment system common in areas with no connection to main sewage pipes provided by private corporations or local governments. In the United States, approximately 25% of the population rely on septic tanks, predominately in suburbs and rural areas (Criterium Engineers). In Europe, they are generally limited to rural areas only.

Unlike the system used in a compost toilet to break down the waste, the septic system involves an anaerobic bacterial decomposition process. Supplemental bacterial agents may be added to the tank to accelerate the digestion of solids in the tank. Preventive maintenance is required periodically to remove the irreducible solids which settle and gradually fill the tank. Solids that are not broken down need to be pumped out of the system and failure to do so can result in expensive repairs which pose health risks and can cause water pollution.

A septic tank is usually between 1000 and 2000 (4000 - 7500 liters) gallons, depending on the amount of waste produced. The tank is connected to an inlet wastewater pipe at one end and to a septic drain field at the other. A septic system works by allowing waste water to separate into layers and begin the process of decomposition while being contained within the septic tank. Bacteria begin to digest the solids that have settled to the bottom of the tank, transforming up to 50% of these solids into liquids and gases (Criterium). These liquids then enter the drainage system and the effluent is then distributed throughout the drain field through a series of subsurface pipes. Further treatment of the effluent occurs as the soil absorbs and filters the liquid and microbes break down the rest of the waste into harmless material.

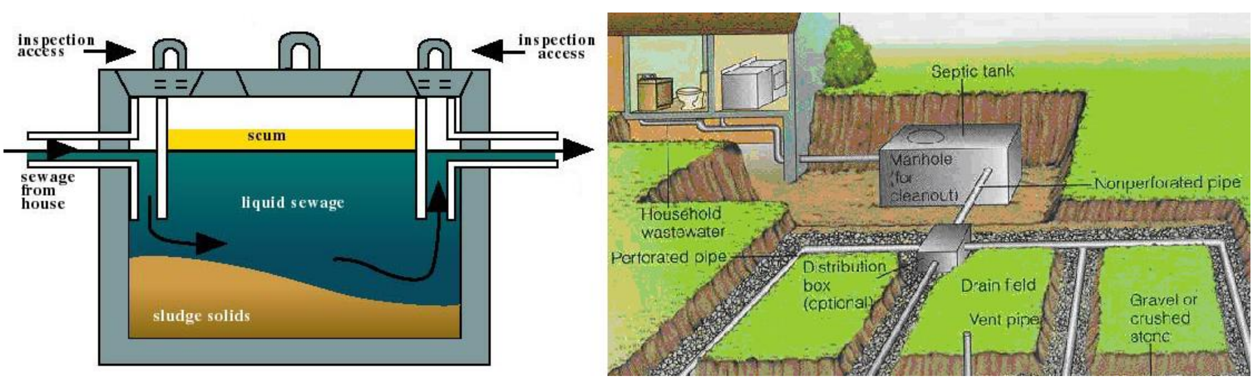

Figure 10: Septic tank system (Pictures obtained from "*B&B Pumping Services*" and "*Environmental Health*")

Most systems use gravity to distribute the effluent from the tank, though other types of systems such as low pressure distribution or mound systems are sometimes used (Criterium).

5.0 Conclusion

From the research for this project, the IQP team decided that a solar pump would be best for the purpose of the school. Even though it has a larger initial cost, it has numerous advantages for the village of Zimri. With this system, the villagers will not need to continuously pay for fuel, since it uses a free renewable resource as a power source. Also, the photovoltaic panels convert the solar energy into electricity, enabling them to power a variety of pumps. This is beneficial because one can choose from many options in order to find an appropriate size and design. In contrast, a diesel engine usually powers pumps that produce high flow rates, which are not necessary for the Zimri pumping system that only has to supply a school as opposed to an entire village. Also, different designs will require the pump to be located in different areas in the well, allowing it to be place at an optimal level in reference to the water. This is important because of the depth of the well in Zimri. The efficiency of water pumps improves when they are placed closer to the water source. With a higher efficiency, the pump does not need to work as hard, thus less energy is used and fewer repairs are needed over time. Over time, a solar pump will provide an easily maintained system that would pump clean water to the school and have positive health benefits for the children.

As for the bathroom facility, the IQP team believed that a compost toilet will be the most beneficial for the Zimri School in the near future. The enclosed facility will address the issue of girls' privacy, which contributes to the fewer number of girls than boys attending school. Also, a facility like this uses minimal amounts of water, a very important characteristic considering the scarcity of this resource in and around Zimri. Finally, a properly maintained and operating compost toilet does not produce unpleasant smells and gases, a common detriment of many non-flush systems. However, the compost toilet requires the user to handle human waste, which may disturb the villagers of Zimri. Because of this, the IQP team proposes a septic tank as a long term option, since it will be expensive and take a long time to build. Flush toilets along with a septic tank will allow the waste to be disposed of away from the site of the bathroom facility and will not require the villagers to continuously handle human excrement. Only once sufficient funding is available can this option be implemented. In the meantime, a compost toilet would be a sufficient option.

This Project taught us the importance of understanding the large differences in the way of life and culture between our own and rural communities within the developing world. By understanding the various and considerable challenges the Zimri School has to overcome, the IQP team was able to recognize the particular needs of these villagers in planning the necessary sanitary facilities for the school. Relating this to the broader theme of human development, the team learned the importance of bottom-up development. Instead of implementing some policy measure derived from arbitrary statistics, field research was conducted to determine an appropriate solution for the Zimri School and the villagers. It is important to recognize that the villagers' views and opinions regarding the development of their village must be respected. However, the IQP team believes that making improvements for the betterment of a future generation and preserving a rural community's cultural heritage can go hand in hand and may even help to preserve its culture by allowing it to prosper within the ever advancing world.

6.0 Recommendations

At the completion of the IQP team's project, no physical changes or construction have been done on the school premises. Further work needs to be completed to actualize the construction of an enclosed bathroom facility and have running water in the school. As many WPI initiated projects are multi-phased we hope that this project will be further pursued by IQP teams in the future. We have listed recommendations for individuals who are interested in further pursuing this project as a guide to what needs to be done to help the children of Zimri School.

6.1 Instructional and Educational Programs

Once the construction plan created from this project is put into effect and the pumping system and bathroom facility are built, the IQP team recommends that instructional programs be provided for the villagers. These programs should include classes training the villagers about the use and maintenance of the solar pumping system and the compost toilet. Furthermore, educational programs should complement the implementation of the proposed facilities by teaching the villagers, focusing on their children, about general health and hygiene.

With these programs, the villagers will know how to properly maintain the pumping system and the compost toilet. Education about the pumping system will make villagers capable of operating it effectively, making small necessary repairs, and getting the greatest possible benefit out of the new technology. For compost toilets, it is especially important that education is provided because they require a lot of effort and input from the villagers on a daily basis. If they are not maintained in the correct manner, the human waste will not decompose properly, causing the facility to start smelling and the harmful pathogens to continue living in the excrement. Also, learning about compost toilets, such as proper methods to empty the compost containers and informing them of the fact that they are commonly used in many rural villages, may help to quell any negative feelings that the villagers may have about compost toilets. Of course if the villagers do not approve of dealing with human waste from the start, education about the compost toilet should come before constructing it, so if their opinions do not change, another type of facility can be built.

Providing general education about health and hygiene would be beneficial for the villagers even if this project was not implemented. Teaching simple practices such as washing one's hands can help improve community health greatly. The program about general health and hygiene would be an appropriate and helpful class to include with the construction of and instructions on the use of sanitary facilities and the introduction of piped water at Zimri School, since one of the main purposes of implementing this project is to reduce the occurrence of childhood disease. Even with the new facilities, if the children and villages are unaware of potential health risks that still exist and of the ways diseases spread, the health of the children will not improve as much as it potentially could.

6.2 Financing

Without the finances to build a bathroom facility and provide running water to the school, it is impossible to make our plans a realization. The IQP team is currently in the process of proposing to aid organizations for this purpose. Organizations that we are in contact with include, The Mosaic Foundation, Hand in Hand (AUI), the *U.S. DEPARTMENT OF STATE MIDDLE EAST PARTNERSHIP INITIATIVE* (MEPI) and the Morocco Foundation, which has no funding but has indicated that they would be willing to help with the logistics of the implemented project. The team has written a formal Letter of Intent to be submitted to the

Mosaic Foundation. This is the first step in the process of obtaining funding from this organization. Details are given in the Appendix.

A formal (non-profit) business plan will need to be developed. The financing of such a project is a complex issue. Besides obtaining funding from an aid organization, it will also be highly important to financially involve the villagers. The villagers need to have a real stake in the project, as a free ride will result in neglect and indifference to the infrastructure of the built bathroom facility and the piped water. As a solar powered pump will incur no fuel costs, but a large initial investment, one can possibly collect finances to cover a portion of the cost from the villagers in increments over the life of the solar pump (i.e. the long run). For such a plan, a lot of work needs to be done to determine how much the villagers are willing to pay, and how the funds will be collected. Furthermore, the issue of parents who cannot pay but want to send their children to school needs to be addressed. Such issues need to be investigated and understood by talking to the villagers. This study alone is an IQP in and of itself, and the benefits of such a study would be significant, as such plans could be used as a guideline for rural schools and villages across Morocco, Africa and the entire Developing World.

6.3 Proposed Questionnaire

The purpose of the questionnaire is to better understand how the villagers feel about what we wish to see changed in their village school and to determine whether the villagers feel that there has been any benefit to their community once these changes have been completed. Finally, it will allow the researchers to gauge the benefits of the project to the rural community.

The questionnaire consists of two questions that will be asked to the parents before implementation of the project proposals. Question #1 involves understanding whether the parents see the lack of an enclosed bathroom facility as an issue that prevents them from sending their daughters to school. This question can only be asked to parents who have daughters in school, and to parents who have daughters who do not attend school on a regular basis. This question will allow predictions to be made about whether building such a facility will increase female attendance or not. The IQP team expects that if the parents see this as an issue, attendance will increase. Another question that will be asked is whether they believe that running water and an enclosed bathroom facility will have advantageous health benefits for their children. This is question #2 in the proposed questionnaire. This can be asked to both parents with daughters and sons at the school. Here again, if the parents believe that our project will benefit their children, than we believe that school attendance will increase after the construction of the facilities. Having positive answers to these questions will show that improving the school will give it greater importance in the eyes of the villagers as a valuable social institution. It will stand out in the community as a place which is superior technologically to the rest of the community, which currently has neither running water nor electricity. This will create a greater incentive for the villagers to entrust their children in the hands of the school teachers.

After the construction of the sanitary facility and the introduction of running water, there are two questions that should be asked to the villagers, one to the parents of the students and one to the teachers. These questions attempt to draw objective conclusions about the benefits of the project. Unfortunately, because it will be difficult to obtain numerical data from the villagers, these questions will only be semi-objective, as the bias of the individual who is asked the question may come into play. Nonetheless, we believe that useful information can be drawn from the responses of the villagers. The three teachers will be asked independently whether female attendance and total attendance has changed in the school, and whether he believes that this is a result of the implemented project. This is question #3 on our questionnaire. Finally, the parents will be asked whether the occurrence of disease and sickness has decreased among their children who attend school. This is question #4 of our questionnaire and would allow one to determine whether the project has had any health benefits among the children who attend school.

This Questionnaire will not only allow future researchers and those who seek to help Zimri to understand the benefits of this project at the village, but also allow them to determine if the implementation of such projects around Morocco and the developing world will have a positive health impact and a positive social impact, by increasing female attendance along with overall attendance. As government policy is highly dependent on case studies, such micro-projects will allow policy makers to determine which projects will have the greatest impact on the development of an impoverished community.

The project team believes that real change in the village of Zimri is possible. From the interactions with the villagers, they deeply care about their community and want to see positive change. But they either do not have the know-how or the expertise to implement such change. Being granted the privilege of a higher education, it is our responsibility to help disadvantaged communities like Zimri. Continuing the pursuit of these problems with the objectives and recommendations highlighted in this report and with the aid of people like Mohammad Elbaz, who deeply cares about the problems at hand, the IQP team believes that implementation of our proposed project can be a reality in the near future. This is what the team hopes will be possible, or as the Moroccans say, Berber and Arabic alike, “Inshallah.”

Appendix

Note: We **will not accept any letters of intent that are not in this format.

Letter of Intent

ORGANIZATION INFORMATION

- **Project Title**
- **Amount Requested**

- Organization
- Address
- City
- State/Province
- Country
- Zip Code
- Primary Contact
- Contact Title
- Phone Number
- Fax Number
- Email Address
- Website URL
- IRS Tax Identification #

ORGANIZATION DESCRIPTION

- Mission/Purpose and Brief Description of Organization

- Names of Governing Body Members
    - President
    - Treasurer
    - Secretary
    - Project Information

PROJECT INFORMATION

- Brief description of proposed project (include description of community need/problem; project's approach; project start & end dates; projected outcomes;)
- Cost of Project
- Funds Requested
- Other proposed and secured sources of funds (include amounts)
- Other organizations that are collaborating, and their roles
- Past work and/or grant experience with Mosaic

Shown above is the format of the Letter of Intent as presented by the Mosaic Foundation.

The purpose of the Letter of Intent as defined by the Mosaic Foundation representative the team talked to on the phone was for the organization to determine whether the project concerned had the same objectives as the organization. The vision statement of the Mosaic Foundation on their website is,

"To be an innovative, inclusive and effective organization that works to improve the lives of women and children throughout the world and to enhance the understanding and the appreciation between peoples of the United States and the Arab World."

The Foundation's Primary Objectives are:

- To provide financial and other assistance to organizations working with women and children.
- To undertake education programs about Arab culture.
- To work in alliance with other national and international organizations with similar objectives.

The Letter of Intent is read by the board members of the foundation, who are the 17 spouses of the Arab Ambassadors to the United States. If they believe the project matches their objective, a formal proposal is requested. We also determined by communicating with the Foundation was that any NGO could only give grants and financial support to other federally registered NGO [501 (3) (c)]. For this reason, we will submit our Letter of Intent under the name of the Morocco Foundation, an NGO that we have been in contact with throughout the project and have communicated with regarding this issue. It has previously worked with Mohammed Elbaz for the benefit of the Zimri village. The funding, if obtained, will be channeled through this organization. Final confirmation for permission to use their name needs to be obtained before we can submit our Letter of Intent.

The Letter of Intent is shown below. The project description is basically is basically the Executive summary, with a few changes.

Letter of Intent

Organization Information

Project Title: The Zimri Project: Running Water and Bathroom Facilities for a Rural Moroccan School

Amount Requested: $10,000
Organization: The Morocco Foundation
Adress:
6423 Richmond Hwy, # 301
Alexandria
VA 22306
USA

Primary Contact:
Haseeb Ali
Phone #: 857-204-7718
haseeb@wpi.edu

Morgan Guardino
Phone #: 860-836-4137
morgang@wpi.edu

IRS Tax Identification #: 0400069194 (Morocco Foundation)

Organization Description

At Morocco Foundation, we promote children's schooling and education. We help the underprivileged with the basic necessities such as water, food, and clothing.
We would like to spread awareness among the Moroccan community in the U.S about the necessity to help underprivileged people in Morocco, in an attempt to alleviate and improve their quality of living.

Names of the Governing Body Members
President - Mr. Ali Bettahi
Vice-President - Mr. Said Bouayad
Treasurer - Mr. Amine Benneftah
General Secretary - Mrs. Nadia Serhani
Communication and Public Relations Director - Mrs Zeineb Mammou

Project Information:
Throughout the third world, lack of basic facilities due to limited investment in isolated rural communities has created an economic divide that leads to many social problems and hinders human development. Education is seen as a means of breaking the cycle of poverty that perpetuates itself. One of the major focuses of our project is to combat female illiteracy in a rural Morocco community, since about 80% of females in rural Morocco are illiterate. Increasing the number of women who can read, write and perform basic arithmetic will greatly improve the prosperity of communities in developing nations due to women's key role as caregivers. Educated women will have the greater potential to

reduce diseases (due to their increased understanding of healthcare issues) and increase education (due to their own recognition of the importance of learning) of future generations.

The project team, (which is a team of Worcester Polytechnic Institute students and their advisors) was first presented with the problem of the lack of pumped water and sanitary facilities at a rural school in Morocco by Mohammad Elbaz. The lack of running water required the villagers to bring water to the school by loading donkeys with large cylinders filled from a nearby well. This process is both time consuming and poses health risks, as the water has the risk of getting contaminated. To fix this, plans were created for a pumping system that would transport water from a nearby well to the school. Another problem is the lack of privacy for young girls as there is no enclosed bathroom facility, which causes parents to pull their daughters out of school. In this report, options are thus proposed for an enclosed system that would be both safe and hygienic for the children to use.

For the pumping of water, the project team investigated solar powered systems and diesel engine powered systems to be used in Zimri. Both had advantages and disadvantages that were considered. The solar pumps can produce usable energy without any cost after installation and they rarely need maintenance. However, the installation of solar pumps is expensive and solar systems are not available locally. On the other hand, diesel pumps are available locally, the villagers are familiar with them, and they are cheaper to install. However, they are not appropriate for the small water usage and flow rate requirements of the Zimri system, and they would require the villager to continuously pay for fuel.

Different bathroom facilities were investigated through the course of the project, including pit latrines, compost toilets, and a septic tank. Pit latrines and compost toilets were considered to be short term solutions because they do not need any water to function and do not require piping for waste disposal as would a flush system. However, both designs would call for the villagers to handle waste. In that respect, septic tanks would be more desirable because it allows the use of a flush system, yet it would cost more, be harder to build, and require larger amounts of water.

The findings from the research pointed to the conclusion that a solar powered pumping system along with a compost toilet would work best for the condition of the Zimri village. The solar pump will not burden the villagers with the expense to have to continuously buy fuel every time the villagers need water. More importantly, the solar pump is more appropriate for the system because it can handle the low flow rate and the depth of the well much easier than a diesel engine powered pump could. As for the bathroom facility and sanitation system, the team has recognized both a long term and short term solution. The long term solution would be a septic tank as it would have the benefit of completely disposing of the human waste from the site of the facility. The villagers would not need to come into contact with human feces. A short term solution to the lack of a bathroom is a compost toilet. Even though the villagers must handle the waste to dispose of it, a compost toilet is easy and relatively inexpensive to construct and maintain, and furthermore will be hygienic without requiring the use of water. Importantly, it would address the issue of privacy until a more advanced system could be built.

Along with the installation of a solar pump and a compost toilet, the team recommends that a questionnaire be distributed to gauge the accuracy of the hypotheses concerning girl's school attendance and an educational program be provided for the villagers to learn about the new technology implemented in the village and some general information about health and hygiene. As the villagers do not have the funding available for implementing these measures, we propose to the Mosaic Foundation to provide the finances to make this project a realization.

Estimated Cost of Project:
Solar Pump: $6000
Piping and labor: $1000
Water Storage Tank and Labor: $1500-$2000
Enclosed Compost Bathroom Facility: $1000-$1500
Total Cost: $9500-$10500

Funds Requested:
$9500-$10500

Past work and/or grant experience with Mosaic

Morocco Foundation: $2,000/2008 funding the library and infirmary for their *Schools without Borders* project (Zimri School in Tiflet, Morocco).

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