COMMUNITY ESSAY

Developing a sustainable water-delivery system in rural El Salvador

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Michael Wing's Personal Statement:

Engineers Without Borders-USA (EWB-USA) consists of over 50 professional chapters throughout the country and over 100 student chapters at engineering universities. The goal of EWB-USA is to assist developing communities implement sustainable engineering projects that foster quality-of-life improvements while developing internationally responsible engineers and engineering students. An EWB-USA chapter at Oregon State University (EWB-OSU) has focused efforts on designing a sustainable water system to provide clean water for two communities in El Salvador. The communities are located in remote and mountainous terrain and have little available data describing local resources. The health of the communities has suffered due to a lack of clean drinking water. Small teams from the EWB-OSU chapter have now twice visited the communities to collect data using global positioning system (GPS) receivers. Financial support for travel costs has come from a variety of sources. The local community has helped field teams locate important resources and verify information to support the design process. Although considerable project progress has occurred, challenges have resulted from working in remote and rugged landscapes and also from land use and ownership considerations in the communities. We describe in this essay EWB-OSU activities to design and implement an engineering project to provide freshwater to rural communities in a remote, rural community.

Introduction

Engineers Without Borders-USA (EWB-USA) originated in 2001 at the University of Colorado at Boulder and is a member of EWB International (Amadei, 2004). Dr. Bernard Amadei, a professor of civil engineering, learned that a village in Belize needed access to freshwater to improve living conditions for local inhabitants. Amadei formed a group of student volunteers and, in collaboration with a professional engineer, designed a sustainable solution for providing freshwater to the community. The success of this effort encouraged Amadei to launch EWB-USA. Over 100 student and more than 30 professional chapters have since formed, with new chapters forming regularly. The primary goal of EWB-USA is to help developing communities implement sustainable engineering projects that improve quality of life while fostering the education of internationally responsible engineers and engineering students. The majority of projects undertaken by EWB-USA chapters involves supplying water to rural communities, although other initiatives have addressed energy, transportation, and food-production issues.

Students at Oregon State University (OSU) established Engineers Without Borders-OSU (EWB-OSU) during the spring of 2005. A Peace Corps volunteer in El Salvador asked EWB-USA to assess the feasibility of implementing a potable water-delivery system for the communities of El Naranjito and Las Mercedes. EWB-OSU applied for and was ultimately granted the project by EWB-USA. The Peace Corps volunteer represented an *Asociación para el Desarollo Comunitario* (ADESCO), a group of community members devoted to the development of El Naranjito and Las Mercedes. ADESCOs are common in Central American villages as a means for community members to cooperatively bring in developmental assistance for their locales.

The El Naranjito and Las Mercedes communities reside in the northwest region of Ahuachapán, El Salvador (Figure 1). The area is rural, mountainous, and isolated. Women and children walk long distances daily to gather water and residents subsist on local farming and low incomes (less than US$70 per month) from work on nearby coffee plantations. Illness from water-borne pathogens and parasites is a constant threat to village members. Local children are undernourished and often suffer from diarrhea and

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Figure 1 Central America and El Salvador.

other ailments caused by drinking unclean water. Several natural springs are located within community boundaries, but, given the large geographic extent of their surrounding vicinity—approximately 16 square kilometers (km) of mountainous terrain—access is challenging and time consuming.

With only a general description of the region available, EWB-OSU began assessing the feasibility of a sustainable water-delivery project. The plan would need to be designed through “appropriate technology,” such that community members would be encouraged to take responsibility for the system and its upkeep (Hazeltine & Bull, 1999). EWB-OSU required information regarding community locations and basic topographic measurements for the feasibility assessment. Necessary data included housing sites, transportation networks, spring source and distribution locations, community-meeting places, and schools. Having accurate and reliable measurement information was essential, not only for identifying potential solutions and their feasibility, but also for eventual project design and implementation. There were many potential solutions to providing a sustainable freshwater-delivery system, requiring varying types of water pumps, filtration systems, and general water-routing infrastructure depending on the particular intervention. Few data were available given the remoteness and small size of the communities. Although EWB-OSU found a coarse scale topographic map, it was over 20 years old with uncertain information regarding the villages and surrounding landscapes. Community knowledge was necessary to help locate features of interest to the project.

Previous studies have used a process known as participatory mapping to help locate community resources in developing countries (Duvail et al. 2006; Shrestha, 2006). Participatory mapping involves local residents in externally sponsored projects by encouraging direct engagement in the creation and management of maps or spatial databases. Participatory mapping seeks to recruit people to identify features of interest and to locate or verify the specific positions of these sites on hardcopy and digital maps. This collaborative approach to documenting community resources became widely recognized for encouraging effective participation during the early 1990s and has since been extensively used in natural resource applications and in many other disciplines (Chambers, 2006). Participatory mapping is also sometimes described as participatory geographic information systems (GIS) and can include many different types of geospatial information including hand-drawn maps, aerial photographs, satellite imagery, and GPS. Participatory mapping attempts to use the expert knowledge of community members regarding resource locations and resource-use history. This methodology can also involve residents in decision-making processes and encourages community empowerment and innovation (Rambaldi et al. 2006).

Due to the lack of available data and the need to engage the community in identifying key water and other local resources, field visits were required to collect location and topographic data. Field crews would have limited time to collect data and would face landscape and equipment challenges in assembling information efficiently. After evaluating several alternatives, EWB-OSU selected mapping-grade GPS receivers as the most viable option for collecting measurements of community resources. The use of these GPS receivers has encouraged community support for the overall project.

Working in remote and rugged landscapes poses unique challenges for providing potable water resources. In addition, land-use patterns, ownership holdings, and other societal considerations further complicate project efficiency. This article describes how EWB-OSU designed the water-delivery project and the group’s progress moving toward implementation.

Data Collection Team Preparations

Faculty advisors and student officers selected several EWB-OSU students and a practicing engineer from the EWB Portland professional chapter to travel to the El Salvadoran communities for the initial data collection in March of 2006. Project requirements would involve locating and measuring the elevation and horizontal positions of existing springs, villages, transportation corridors, and other relevant infrastructure over the 16 square km study area within approximately five days. Both professional and student members rely on funding support for participation in EWB projects. The financial resources for student involvement was provided initially by a combination of fund-raising efforts such as bake sales, international dinner fundraisers, and OSU athletic event assistance. Additional support for student-travel costs came from individual donations, the OSU College of Engineering, and the OSU Foundation. Specific requirements for the students included Spanish proficiency and previous international travel experience. In addition, students from different engineering disciplines were included to ensure breadth of expertise.

Mapping-grade GPS receivers were selected as the data-collection tool for the field visit due to their compact size, relative ruggedness, and measurement accuracy (typically 1–5 meters horizontally) with differential correction of field data collected under forest canopy (Bolstad et al. 2005). Trimble Navigation, Ltd, an established manufacturer of mapping-grade GPS, agreed to provide the data-collection team with two GPS receivers. The choice of a mapping-grade GPS receiver for data collection offered several advantages over other potential equipment. Its small size is easy to manage; it is lightweight when compared to traditional survey equipment; and it is convenient to manipulate in the field. It is also possible to learn to operate the receiver in several hours and accurate measurements can be taken by following a few basic protocols. Also of significance, the system can create spatial databases of resource features as they are collected, a capability that enabled the creation of a large hard-copy map for use during a participatory mapping session with community members.

Initial Site Assessment

EWB-OSU had several goals for the initial site-assessment trip to El Salvador: build a community relationship, observe the basic health of residents, and collect baseline GPS data related to supporting water delivery-system infrastructure such as water tanks, water-source points, and major roads. Pursuing these goals would provide familiarity with community members, pressing local issues, and regional geography, while also generating baseline data to be analyzed for the project-feasibility analysis.

While in El Salvador, the four group members on the data-collection team spent considerable time visiting homes and meeting residents, asking community members to help identify water and other resource locations, and answering questions about the group or project objectives. While conducting their visits, the team collected GPS data, making sure to include major infrastructure such as schools, churches, and water-related resources. The team eventually used the data to create a community map during its site visit that included trails, springs, and major landmarks. Team members frequently returned to trails they had traversed earlier to assure data consistency. Each subsequent pass closely followed previously recorded data.

Hydrographic features, such as streams and springs, were among the most challenging features to measure with the GPS receivers. Water naturally follows the easiest path downwards due to gravity and, as a result, many watercourses are located in small ravines or valleys that branch off of the main mountain ridge. Thus, a large portion of the required data was for sites that had low satellite visibility and sometimes none at all. Satellite visibility was reduced primarily by the small ridges themselves, but also by the forest canopy that grows in these ravines due to the presence of water. If an insufficient number of satellite signals was received when standing directly over a feature, the data collector would climb to a location that allowed satellite communications and measure an offset distance and elevation difference from the desired data point.

Fostering Community Involvement

While the field team conducted home visits and recorded the locations of trails and springs, community members inevitably took an interest in the GPS receivers. While collecting data at a spring, the team would frequently encounter children. The youngsters were usually quite shy but nonetheless curious about the field-team members walking around poking at a "yellow block" (our GPS equipment) with a pen. Several people asked how the features on the GPS-receiver screens were being created and seemed to have at least a rudimentary understanding of satellites, perhaps through familiarity with cell-phone technology. Some of the residents understood that the GPS receivers were communicating with satellites and using a set of calculations to measure and locate community features.

Near the end of the visit to El Naranjito and Las Mercedes, the EWB-OSU representatives were invited to an ADESCO-led community meeting. During the meeting, the team presented some basic information about the chapter and its plans to design a sustainable water-delivery system. Over 60 community members attended the meeting, a record turnout according to the local Peace Corps volunteer. The team had created a rough map of the communities and water-related resources from the data collected on the GPS receivers during the week. The map was drawn and scaled onto a large piece of paper and community members were invited to comment on it. Villagers were able to indicate population distributions, important information when considering potential water-distribution sites and access. Additionally, residents identified several water sources that EWB-OSU had not visited or known about (Figure 2).

Figure 2 Community members interact with OSU-EWB members in El Salvador.

The map had a strong effect on the community. Only two area maps had been previously located and both of them were at coarse scales. Furthermore, due to limited opportunities for formal education, few residents had even seen a road map before. However, some meeting participants caught on very quickly and made helpful contributions, suggesting local resources to include on the map. The map helped many people understand the purpose of the "yellow blocks" and demonstrated the EWB-OSU team's interest in the community, contributing to one of the team's primary goals: to build relationships with residents and engage them in assisting with the project. The map caught the attention of the community members, encouraged them to contribute data, and helped them to visualize improvements in their well-being.

Upon the team's return to the United States, data from the GPS receivers were processed and used for initial design analysis. This information was also integrated with the census-style geographical inputs that had been gathered from the community. GPS-processing software was used to output the data, complete with elevation measurements for mapping and analysis applications. Additionally, students converted a topographic map of the study area that had been obtained from the *Geogragrafico Nacional, Ministerio de Obras Publicas* into a digital format. The map was at a published scale of 1:25,000 and contained details on transportation infrastructure, hydrological resources, and population centers. GPS-collected coordinates that could be associated with prominent features on the digital map were used to produce a geo-referenced database for input into a GIS. The GPS-collected positions were then overlaid on the topographic map in a GIS so that both data sources could be compared. The two data sources agreed in general about the location of roads and villages (Figure 3). Topographic maps are typically created from aerial photography, a technique that generally results in varying levels of data quality. Larger features, such as major transportation or river networks, will often be better represented than secondary roads or trails in the final product. Nonetheless, GPS measurements created using the data-collection protocols followed in this study should be more accurate than most features on a 1:25,000 scale topographic map (Oderwald & Boucher, 2003).

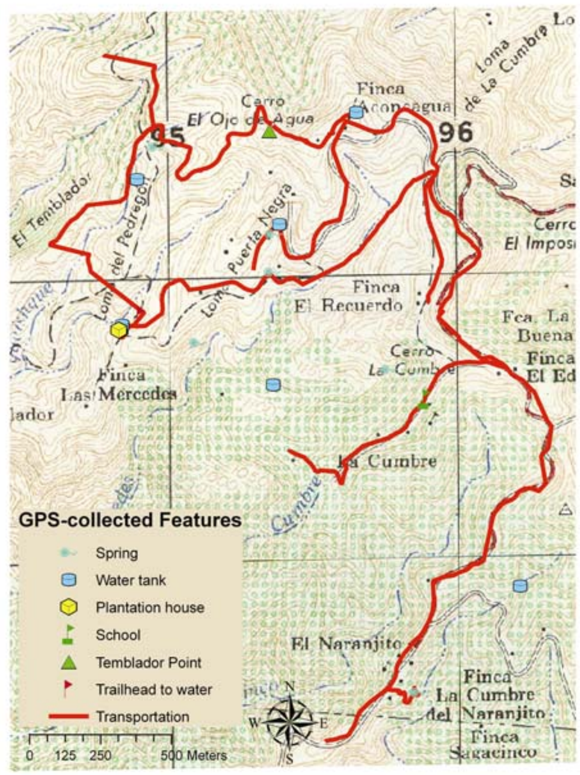

Figure 3 GPS-collected positions plotted on a 1:25,000 scale topographic map.

The processed field data have also been essential in formulating solutions for supplying safe water to the Las Mercedes and El Naranjito communities. The visual site assessment and analysis of the data gathered during the first team visit revealed that the geographic extent and distribution of homes was greater than had been expected, making a single solution for all local inhabitants impractical. The site- assessment team identified several potential locations for initial

Table 1 Evaluative matrix used to prioritize potential water-delivery projects.

	Dam at El Naranjito	Los Patios tank renovation & gravity-feed pipes	Los Patios tank renovation & wash/treatment station	Several large rain water-storage tanks	Individual rain water-storage tanks	Stream pumps
Capital cost	3	4	5	1	1	1
Maintenance cost	4	4	3	2	4	1
Ease of use	4	5	2	4	3	2
Construction ease	3	2	5	1	2	1
Chapter feasibility	3	4	5	1	2	1
Sustainability	4	2	4	3	3	2
Score for # homes/people	2	1	4	4	5	4
Total (higher is better)	**23**	**22**	**28**	**16**	**20**	**12**

water projects (Table 1). These proposals were subsequently analyzed through an evaluative matrix that included the number of homes or people that would benefit, environmental impacts, feasibility/constructability, economic factors (i.e., implementation cost), and sustainability features (i.e., long-term costs to the community).

Each of the seven evaluation considerations received a score between one and five, with five indicating the highest potential. Scores were initially based on the perceptions of the site-assessment team and later fine tuned during EWB-OSU meetings. Although the matrix resulted in seven numerical scores and a summary statistic for each possible water-delivery project, the evaluations weighed some considerations more heavily than others. For example, maintenance and sustainability carried a greater weighting than other factors. These issues were judged to be more important since they would more significantly influence the long-term success of any water-delivery project. The methodology also weighted most heavily the number of homes or people that would benefit. In addition, although the scoring system included subjective criteria, the matrix made possible a relative comparison of project parameters. EWB-OSU decided on which projects to pursue by comparing the leading summary scores and the individual tallies of the more heavily-weighted factors. As a result, three primary projects were selected: the El Naranjito school (which does not currently have a water source) and two clusters of homes. A second site assessment was subsequently planned to collect more detailed information in preparation for water-system design at these locations.

Second Site Assessment

Several EWB-OSU students and two engineers from a professional EWB chapter visited El Salvador for the second site assessment six months after the initial visit. Unexpected issues arose with regard to land ownership and usage permissions during this subsequent trip. The region surrounding El Naranjito and Las Mercedes is mainly dedicated to coffee cultivation, with farm owners controlling large portions of the landscape. During the first visit an unused tank connected to a year-round stream had been verbally confirmed for drinking-water storage at one of the primary project sites. However, the owner eventually disapproved, wanting to instead reserve the site for possible coffee processing. In addition, the assessment team noted that economic, ownership, and landscape constraints would limit opportunities not only for constructing large holding tanks, but also for locating reliable water sources that could adequately supply them. A conservative average water-use figure of 150 liters per day per home would result in a total volume of 1,095,000 liters for the year for each group of 20 homes. Even if half of this volume were stored in a tank, the tank's dimensions would be prohibitive in terms of cost and construction because of silty clay soils and relatively high local seismic activity. Finding level terrain for building would also be challenging under these conditions.

Given these findings, the site-assessment team decided to develop new approaches for providing water. Conversations with residents revealed that a three-month dry season was the critical period in which community members had to travel farthest to find water. As a result, the installation of holding tanks with the capacity to catch rainwater for use during the dry season was identified as a potential solution. Average rainfall data and an estimated water demand of 150 liters per home per day were used to calculate the water volume necessary to provide water for 20 homes during the dry season. These measurements were also used to determine the minimum surface area of the tank that would be required to catch the critical water volume.

A GPS receiver was again used during the second site assessment to map key landmarks in the areas that seemed viable for building a tank. The team also identified trees, infrastructure, and slope characteristics for these areas to help further evaluate locations for design and relative distances to homes. Site visits and mapping revealed that potential tank locations at higher elevations were often difficult to access. The distribution of residents in the region tended to corresponded closely with a series of ridges that extended radially from centralized hilltops on which signal towers were built. The signal towers service the surrounding region for radio, cell phone, television, and military communications. The GPS receiver also mapped a power station adjacent to the signal towers that may be of further interest if the design requires electricity.

Design Process

Recent project efforts since the second site assessment have involved designing water-delivery systems. Because some uncertainty remains as to which locations will receive landowner permission to build, two separate sets of infrastructure are being designed: a rainwater-catchment tank and a high-head low-flow pump system. The rainwater-catchment tank would need to hold 270,000 liters with a surface-catchment area of at least 176 square meters to provide sufficient area to fill the tank during the winter months. The tank would provide water for approximately 20 homes in the community. Another tank could be built in a different area to provide water to another 20 homes in the community during the dry months. The high-head low-flow pump system would carry water from a perennial spring to a higher-elevation centralized distribution point so that a small tank (about 30,000 liters) could be accessed throughout the year. Given the seismic activity of the region, students with structural engineering coursework, along with professors and professionals with relevant expertise, will also be involved in infrastructure design.

Water filtering will be necessary to address human-health issues among community residents. Consequently, EWB-OSU has interacted with Potters for Peace, an international organization that uses regional materials and clay mixtures to mix and fire clay pots. The pots have small small grains of flammable material that ignite during firing and form tiny channels that result in a water filtration rate of two liters per hour. The filters are then submerged in a colloidal silver mixture that kills coliform and microbacteria. The working life of the colloidal mixture is at least two years. The filters are made locally by a solidarity program in a San Salvador factory that the second site-assessment team visited. EWB-OSU is planning to implement the distribution of clay filters to families who commit to paying US$0.33/month to replace the filter every two years. A recent fund-raising banquet held on the OSU campus has also gathered financial support to subsidize costs for Potters for Peace.

To finalize the infrastructure designs, EWB-OSU will require some additional information—including the topography of water-delivery paths and a more detailed geotechnical site exploration of potential areas for water tanks—to assess soil-bearing capacity and slope stability. In addition to these empirical data, an assessment of spring-water quality and potential watershed impacts must be carried out since the effects on downstream users and communities may have political consequences. Las Mercedes and El Naranjito are also adjacent to a large national park (*Parque Nacional El Imposible*) for which ecological conditions are a concern. EWB-OSU environmental engineering students and environmental and sustainable design professionals will be involved in this aspect of the work. Consultation with groups that have previously studied *El Parque Nacional El Imposible*—including local non-governmental organizations and representatives from the national university—will also assist in this evaluation of potential ecological impacts.

Conclusion

EWB-OSU's assessment visits and the involvement of community members in identifying water-resource solutions have resulted in the creation of baseline community-resource data and progress developing a sustainable water-delivery system. Although initially proposed projects had to be modified in light of landscape characteristics and land-ownership considerations, headway continues to be made toward meeting the needs of the two subject communities. Regardless of the final design, collaboration will be necessary so that residents will be encouraged to take ownership of the infrastructure over the full course of its lifecycle. As planning progresses for the water-delivery system, the team will request input from the community regarding preferred locations, systems, and monthly costs that each family would be willing to pay. Once the designs reach the preliminary sketch stage, the community will then be contacted again for input before materials are ordered and construction planned. The final implemented design will also require a plan for periodic monitoring on the part of the students of OSU-EWB. Chapter members, in collaboration with students and faculty from the University of El Salvador in San Salvador, anticipate making annual or bi-annual visits.

Although EWB-OSU will design and implement the final systems, community residents will be trained on how to financially and mechanically maintain the infrastructure over its entire lifespan. The development of the water-delivery system through "appropriate technology" and supporting maps, instruction manuals, and other information will play a key role in the successful transition of responsibility. The project will also depend upon gathering additional data during subsequent visits to El Salvador. Throughout this process, community members will be encouraged to participate in reviewing and verifying data from local resources and in approving the design.

Acknowledgement

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