Sustainable engineering requires community collaboration

Many communities in the developing world struggle to cope with insufficient water distribution, variable supply, seasonal scarcity, and contamination. The non-profit humanitarian organization Engineers Without Borders (EWB) collaborates with such communities on projects to improve their quality of life. EWB volunteers ***Teresa DiGenova, Bitsat Yohannes, David Hill, William P. Ball, Regina Shklyan****, and* ***Yang Li,*** *and* ***David Alcock*** *of the Church Agricultural Project report on two successful projects that improved water supply and increased agricultural productivity for communities in South Africa and Thailand.*

Engineering challenges in developing communities are very different than those typically associated with projects in developed nations. Although EWB projects are often technically straightforward, they must also be environmentally equitable and economically sustainable. A successful project ultimately requires strong, effective, and ongoing collaboration between the project team and the community. The project team must tap local community expertise when making design decisions. Designs should make use of locally available materials to ensure that the community will be able to repair or replace damaged system components. In areas inaccessible by vehicle, transportation and installation of materials is an important consideration. The technology used for the system construction and operation depend on available energy sources. Most critical to project success, the community must be included from the assessment to the project conclusion, so that their support and contributions reinforce their ownership of the project.

In addition to executing successful projects, EWB seeks to develop internationally responsible engineers and engineering students. Working on these projects, team members gain valuable project leadership experience, technical experience, and field experience. More importantly, the teams forge ties with project communities through shared challenges, communication, and labor.

Potable water for a hill-country village

Baan Bo Mai is a poor farming village in the northern hill country of Thailand, located 10 miles from the Myanmar border. The village is situated in the middle of the area known as the Golden Triangle in the Kae Noi Calley at approximately 1067 m above sea level. An estimated 210 people live in Baan Bo Mai, including an orphanage housing 30 children. The villagers are members of the Lahu hill tribe, ethnically Burmese refugees whom the Thai government has allowed to settle in Thailand. A Lahu refugee, Japhu, founded the orphanage to house the Lahu children whose parents were killed by the Myanmar military. The orphanage was dependent upon charity for food and other necessities.

The village needed a safe, dependable, potable water supply. Villagers had used excess government agricultural water for their needs, a supply that was undependable and of poor quality. The source reservoir was subject to fecal contamination from farm animals. In addition to potable water, irrigation water for its agricultural fields would help the orphanage to produce its own food and become self-sufficient.

In January 2006, an EWB project team from the University of Maryland, College Park (USA) chapter traveled to Thailand to meet with villagers and assess their water needs. During this trip, the water source location was selected and the pipeline route was surveyed using a hand level and bamboo rod. The team returned to the village for three implementation trips, progressing on the construction of a 3-km pipeline with an unevenly distributed elevation difference of approximately 122 m. Roughly half of the pipeline route is inaccessible by any vehicle; all material must be carried to its point of use.

A .3-m (1 ft) by 4.47-m (15 ft) impermeable dam was erected at the intake from stream rocks and concrete strengthened with deformed steel rebar. Villagers excavated the site until a clay level was reached. Dam walls were built up along both sides of the stream bank. Four-inch (10.16 cm) perforated pipe into which additional holes had been drilled was wrapped in metal mesh and used to capture water collected at the base of the dam.

Two- and three-inch (5 and 7.6 cm) PVC pipe was installed at a depth of nine to 18 inches (22.9 to 45.7 cm) between nodes along varying and difficult terrain. In areas of rocky terrain where pipe would have to be exposed, 2-in and 3-in galvanized iron pipe was used. The GI pipe was used unsupported to span three separate ravines, each roughly 9 m across. This piping was secured to trees and bedrock by 12.7-mm (1/4in) steel cable.

The pipeline route followed 305 m of steep and rock hillside, along which 50 sections of galvanized pipe were laid and connected with unions and sockets. The 45-kg lengths of pipe were bent around trees to follow the contour of the hillside; con-

In Patadel, Ecuador, a volunteer crew of 130 men, women, and children dug a 650-m-pipeline trench, scheduled to take an entire week, in three hours, as part of a EWB project to improve the village water supply system. The community assisted EWB with spring source location, capture construction, water tank excavation, and water tank assembly. ***Photo by EWB-UMCP***

In Baan Bo Mai, a new potable water pipeline would supply clean drinking water for the village of Burmese refugees, and help the orphanage of Lahu children, now dependent upon charity, to produce its own food and become self-sufficient. *Photo by EWB-UMCP*

crete anchor blocks secured the pipe along the ground.

The route also included a 12-m stream crossing, executed during the lower flows of the dry season. The team used rocks and mud to divert half the stream, dug a trench across the available half of the streambed, laid 7.6-cm galvanized iron (GI) pipe in the trench, and poured concrete to encase the pipe. After the first half of the crossing was completed and cured, the other half of the stream was diverted and the process was repeated. A washout was placed downstream of the crossing and housed in a brick valve box.

During the summer 2007 implementation trip, the University of Maryland project team began collaborating with another student team from the Villanova Chapter of EWB, who will continue their involvement with the project on upcoming installations. To date, approximately 2500 meters of pipeline has been successfully installed from the intake to the orphanage. Future implementation trips are planned to install a distribution system to the village; a pipeline to carry irrigation water to the orphanage fields; storage; slow sand filter; and a sanitation system.

The collaboration of the villagers was essential to the project implementation. Villagers located a safe, appropriate drinking water source and helped project team members to map the most appropriate pipeline route. Villagers and team members carried all materials (including GI pipe!) to their points of use along the challenging route. Construction of the intake dam, excavation of the stream crossing, and installation of the pipe along steep and rocky terrain would have been impossible without the villagers' labor and expertise.

Ram pumps help community "grandmothers" to garden

Zulus in the South African province of KwaZulu-Natal endured years of political violence and now face an HIV/AIDS pandemic that has decimated a generation. Rural communities in the province have little in the way of industry and employment, forcing capable adults to leave their villages and seek jobs in large cities. The surviving elderly women in many of these villages are left to raise the remaining young children. In the villages of Inchanga and Maphephetheni, groups of elderly women maintain community gardens to feed over 300 children, including their own grandchildren.

The local inkhosi of the village of Inchanga, Chief Mlabe, had provided land for a community garden to a self-organized women's assembly called the Isthembe (Commitment) group, who are collectively responsible for the wellbeing of approximately 100 orphaned children. Members share the work and produce of the cooperative garden. Any income generated is returned to the garden through the purchase of seeds, tools, and other necessary items.

In the Maphephetheni community, "grandmother" Mrs. Mbamba and other women of the community had established a cooperative garden supporting 200 local children on land provided by the tribe's inkhosi, Chief Gwala. This garden is divided into five-row individual plots, for which each member is responsible. Initially, only half of the enclosed garden land was in use due to the lack of irrigation. Although there is no shortage of water in the area, both communities lacked adequate irrigation systems. Consequently, the women spent hours each day carrying heavy buckets of water uphill from nearby streams to irrigate their community gardens.

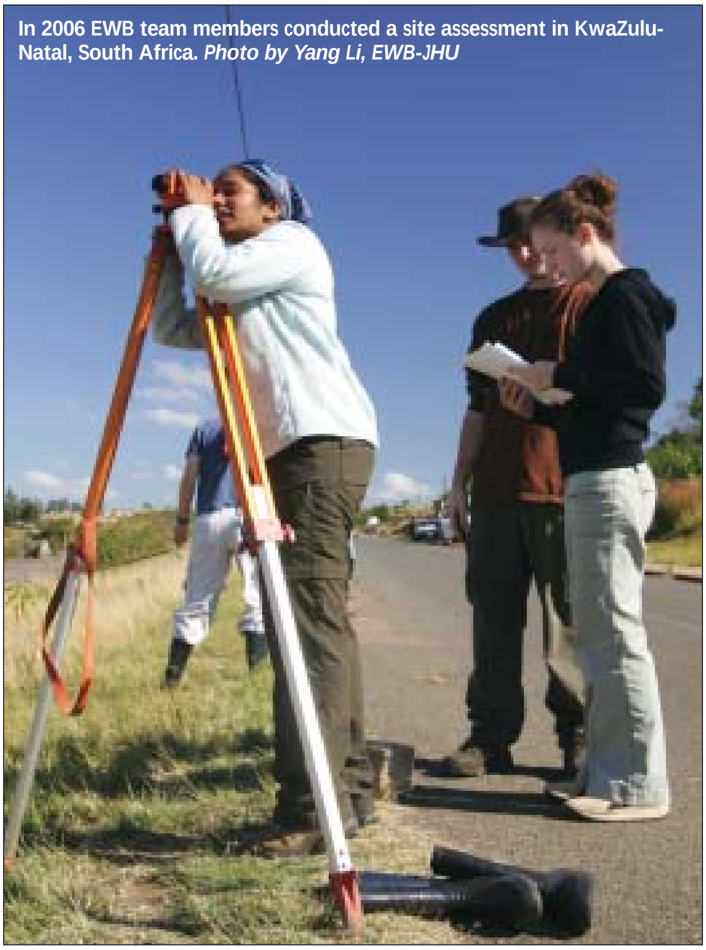
In January 2006 two project team members from the Johns Hopkins Chapter (USA) of EWB conducted a site assessment trip to determine the site topography and environmental, social, and cultural factors that could affect project design and implementation. During the assessment trip they conferred with local team member David Alcock of the Church Agricultural Project, an organization which promotes sustainable agricultural practices and development in KwaZulu-Natal.

Mr. Alcock, who has been designing, testing, and developing ram pumps for more than 20 years, recommended using a pump he had designed for similar conditions. This ram pump has only two moving parts: a conventional check valve and, most importantly, a robust and easily maintained "waste valve" that is made entirely of inexpensive, locally available materials. The waste valve uses dome-shaped cutouts from sidewalls of recycled vehicle tires as the disc sealant of the lift-check valves. The domed shape provides improved lift and seal while the rubber provides a longer lasting and sustainable alternative to traditional sealant materials. A simple vertically oriented rod-and-weight system provides the main force for valve opening between pressure pulses.

The project team proposed

"The "grandmothers" spent hours each day carrying heavy buckets of water uphill from nearby streams to irrigate the community gardens before an EWB/Church Agricultural Project team worked with the community to install innovative ram pump irrigation systems." – *Teresa DiGenova, Black & Veatch*

A grandmother carries water to irrigate the community garden before the EWB project helped to install a ram pump system that drew water from a nearby stream. *Photo by Yang Li, EWB-JHU*

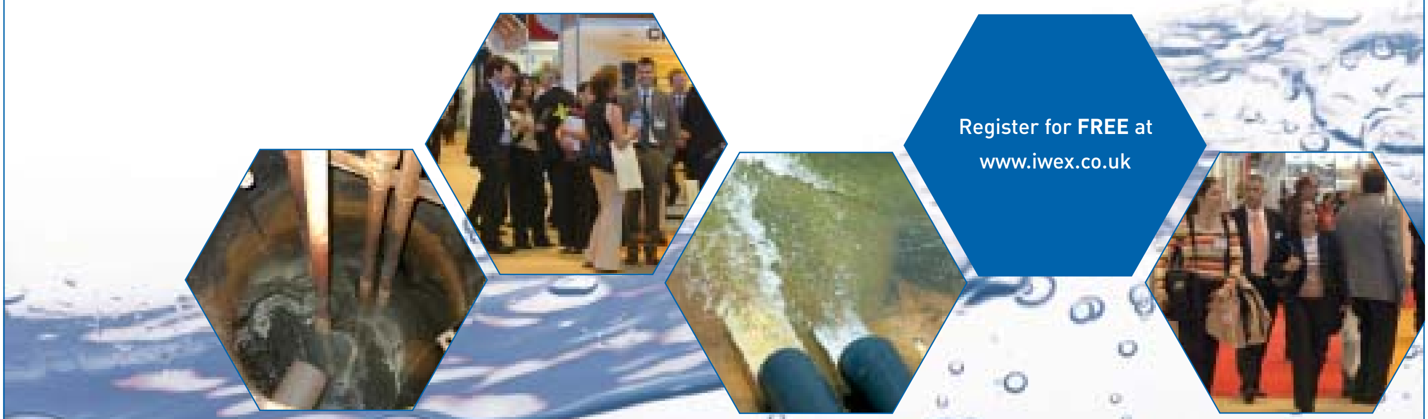

In 2006 EWB team members conducted a site assessment in KwaZulu-Natal, South Africa. *Photo by Yang Li, EWB-JHU*

installing a ram pump near the southern corner of the Inchanga garden and further expanding the existing garden along the road to the southwest. For the Maphephetheni garden, the project team proposed installing at least one ram pump system to draw water from the stream northwest of the garden. The irrigation design effectively harnesses the available hydraulic energy from nearby streams to pump water uphill without requiring manpower or fuel. Such a system is easily maintained and spares the grandmothers needless physical labor, allowing them to contribute to other aspects of community life, such as improving the education of the children.

The first ram pump installed at the Inchanga site fed into a 1000-L tank in the southwest corner of the existing garden still functioned properly. The existing PVC feed pipe remained in excellent condition after eighteen months of use and was sufficient in size to supply an additional pump; however debris buildup at the weir limited intake flow. To reduce future flow restriction at the intake filter, engineers expanded the weir. Upstream of the weir, three branches of perforated piping were laid into the water table in order to channel additional water to the weir. A new 30-cm diameter stainless steel can with 1-cm intake holes replaced the original intake filter. The existing air break T-joint was raised in order to increase the hydraulic head and reduce erosion at the junction due to waste flow. A concrete-encased elbow was installed to divert the supply to the two drive pipes leading to the old pump and the new pump.

Forty-millimeter galvanized piping was used for the drive pipe due to its durability and ability to retain energy from the water hammer. To protect the new pump unit from flash floods, a 1.5-m pit was dug along the stream bank. The decreased elevation of the pump unit relative to the air break improved the hydraulic head and increased pump output. Water was delivered to a new 5000-L reservoir tank via 40-mm buried rubber piping.

The southern fence was fenced and gated, expanding the garden area to nearly 0.200 ha. In the northwest corner of the garden adjacent to the old tank, a 1-m-high elevated stand was installed for the new 5000-L reservoir tank. An overhead connection was installed to feed overflow from the new tank to the old tank. Overflow from the old tank



For further information please see Advertiser Contact List on page 58

was directed to water a row of banana plants in the garden. The pump system was tested and proved capable of filling the reservoir tank in fewer than two days.

With the assistance of Mr. Alcock, the project team taught the Isthembe group system operation, basic maintenance, and repair procedures, including removal of debris buildup at the filter and flushing the valve box/pump. Mr. Alcock and local student representatives from the Durban Institute of Technology and Zakhe Agriculture Institute continue to visit the project site regularly to meet with the community, assess the system's productivity, and assist with any necessary repairs. All materials and tools needed for the project, including PVC piping, galvanized steel piping, lift-check valves, recycled tires, plastic storage tanks, and various related plumbing supplies, were procured locally, and so will be available if needed for maintenance.

Mr. Alcock and the team presented their project to the KwaZulu-Natal Department of Agriculture to increase awareness of the needs of these communities. In spring of 2007, the project team revisited the original project sites in Inchanga and Maphephetheni and found that the irrigation systems were performing as designed and were aiding their communities. The team implemented new ram pump systems in the villages of Patheni and Siwmenzomeni near the township of Richmond to serve the water needs of 30 gardeners and 500 children. In addition, the team plans to implement biogas digester generator projects in the area to provide an affordable source of power for poor communities.

Gauging project success

EWB's partnership with these communities in South Africa and Thailand demonstrates the importance of effective collaboration to ensure long-term project success. In each of these communities, project implementation required strong, effective, and ongoing collaboration between the project team and the community. Because the intent of these projects is to improve the overall community health and quality of life, the success of a project cannot be gauged immediately upon project completion. Project teams must maintain a continuing relationship with communities after the project ends to gauge whether their project has positively impacted overall community health. When completed, the field irrigation in Baan Bo Mai will enable the orphanage to grow food to consume and sell, reducing their dependence on outside charity. In KwaZulu-Natal, increased irrigation supply doubled the size of the Maphephetheni community garden. These water projects will allow communities to realize their potential through improved health, productivity, education, and economics.

Black & Veatch engineers Teresa DiGenova, PE, and Bitsat Yohannes, EIT, volunteered their services to EWB to work on the projects covered in this article, along with David Hill, PE of Catholic Relief Services; William P. Ball, PE, PhD, Regina Shklyan, and Yang Li of Johns Hopkins University; and David Alcock of the Church Agricultural Project.

The authors would like to thank the project teams who have designed, executed, and documented the EWB projects in Baan Bo Mai, Thailand; and KwaZulu-Natal, South Africa. A special thanks is offered to the owners of the projects for their assistance, enthusiasm, and wisdom.

Mrs. Mbamba tests the new water system installed in the Maphepheheni community garden that supports approximately 200 children. ***Photo by Yang Li, EWB-jhu***

For further information please see Advertiser Contact List on page 58