Background

AIDFI

Alternative Indigenous Development Foundation Inc. (AIDFI) is a non-governmental organization base in Negros Occidental, Philippines (See Figure 1). AIDFI brings technologies to villages in the rural Philippines and has reached more than 150 in nearly two decades. The technologies they offer include hydraulic ram pumps, hydraulic power generators, biogas digestors, and lemongrass distillers. AIDFI works to promote "technology in harmony with nature," by offering technologies and services that harness the materials and resources available in nature and to rural Filipinos. AIDFI was founded in 1992 with the beliefs that poverty is unnecessary, alternatives must be presented to current problems, and total human development is the only way to eliminate poverty. Twenty-five workers are employed by AIDFI, including thirteen technicians who build the systems in the AIDFI workshop and later install them in the field. AID Foundation's main goal in building ram pumps is not simply to give a technology to the people, but instead to provide the tools for empowerment. Each installation is a collaboration with the local people, helping them to take ownership and feel proud of their own work.

Figure 1: Orientation at AIDFI Headquarters

Anangue

Anangue is a village in Negros Occidental that borders Tres Hermanos. It followed a similar land reform program as Tres Hermanos and most of the families are farmers. Several years ago, AIDFI built two ram pumps from a mountain spring source to Anangue, triggering lifestyle changes. Many households have since built a comfort room containing a non-flush toilet. In addition, the village has created a water association that oversees the functionality of the ram pump and fair distribution of the water. They created a water schedule, basically the time of day the tap stands will be turned on, to insure a baseline level of water in the reservoir. Each member of the association is selected by villagers, and the group is self-sustained through a monthly

maintenance fee that is collected from all households. Seeing the results of the ram pump, the people of Tres Hermanos asked AIDFI if some water could be diverted to reach their community. AIDFI promised that at a later date, when more funding was available, Tres Hermanos would get its own ram pump system.

The Ram Pump System

Both ram pump systems, for Anangue and Tres Hermanos, channel water from the same source, with much of the initial structures working side by side. Both incorporate 2 three-inch ram pumps to deliver water up a steep cliffside. Whereas Anangue sits right above the cliff, the village of Tres Hermanos lies down the road more than two thousand meters away. Hydraulic ram pumps force water from lower to higher elevations through the water hammer effect, using kinetic energy of the input flow and a pressurized chamber. A ten thousand liter reservoir then stores the water before it is distributed to tap stands around the village. A list of materials and the components of the system can be seen in Appendix A: Technical Study.

Tres Hermanos

Tres Hermanos is a village in Negros Occidental that was founded over 50 years ago. The land of Tres Hermanos was divided up through a land reform program and many long time residents have sizeable amounts of land in which they plant mainly sugarcane with some rice and other food crops. Some of the land is used for raising livestock such as carabao, chicken, ducks, and goats, but the lack of water severely limits the amount of plants and animals that a family can raise. New families that are formed (through marriage) or move into Tres Hermanos have no land. Instead, they make their living as day laborers, farming on others' lands, and making baskets and hammocks. The only language used is Hiligaynon (slang: Ilonggo), a dialect predominant in the Western Visayas. Most adults in the village have had some amount of schooling, though most only reached elementary level. There is a day care center in the village proper, but older children must walk 4 to 5 km to school in Barangay Buenavista.

Men and children must fetch water every day, but water is hard to obtain. A natural source of clean water is unreliable, varying with the seasons and open to contamination. There is one small spring that most people in the village use which has been their source for 60 years. People also have to walk through steep and treacherous terrain to get to the source. Now, since the tap stands are usually just a couple yards from the houses, families no longer have to spend time and effort to fill their 22 liter jugs. This should allow families to focus on making more income for the family and allow for a better quality of life. According to a survey made by AIDFI, there are 45 households with a total population of 206; 118 are male and 88 are female, 122 are adults and 84 children. The ram pumps will bring a significant change to their lives. Even before the system was completed, people young and old were already flocking to the outflow to bathe, wash clothes, and fill their water jugs.

Tres Hermanos Ram Pump System Construction

The main priority of the Northwestern Ram Pump team's trip to the Philippines was to participate in and observe the construction of the Tres Hermanos ram pump system (see Figure 2 and Appendix E). The system pumps water from the Anangue Spring to the village of Tres Hermanos, approximately two thousand meters away. The installed system consist of an impounding tank, diversion lines, a catchment tank, drive pipes, two three inch ram pumps, delivery lines, an intermediate tank, a reservoir, tap stand delivery lines, and tap stands. Construction of the system, which took approximately three and a half weeks, began on Saturday, June 26, 2010 and was completed on Monday, July 19, 2010. Output of the system was measured at approximately fifty thousand liters per day, which provides each Tres Hermanos household with 1,120 liters of water per day to be used for drinking, cooking, and bathing.

Figure 2: Tres Hermanos Ram Pumps

Ram Pump Site Surveys

Initial site surveys were completed by AIDFI technicians on October 13, 2009 in the villages of Anangue and Tres Hermanos. According to the AIDFI published technical study, AIDFI technicians measured the flow rate of the Anangue Spring Source as 700+ liters per minute. The drop height from the site of the catchment tank to the site of the ram pumps was 5 meters and the delivery height from the ram pumps to the site of the intermediate tank was 98 meters, where water would be stored and gravity fed to the reservoir. The estimated output of the Tres Hermanos Ram Pump System was therefore 26,976.95 liters per day. The system was

built in parallel to the already the existing Anangue Ram Pump System which utilized two 2 1/2 inch ram pumps. Both ram pump systems draw water from the Anangue Spring. AIDFI technicians laid out the Tres Hermanos system such that a third ram pump system could be installed in parallel to the two systems in the near future.

The ram pump construction site (See Figure 3) was located in a valley on the outskirts of the village of Anangue and was made up of uneven, rocky ground running parallel to a stream, which flowed through the valley. In order to reach the construction site, one must descend down a steep incline with steps cut into the mud. Many large boulders were on site and the Anangue Spring source flowed from underneath them. Bamboo, coconut, coffee, and other tropical trees and plants surrounded the clearing where the site was located on all sides. On either side of the valley, eroded cliff faces displayed the clay content in the soil, as well as the root systems of the many trees and plants.

Figure 3: Steep Foot Path to Construction Site

The planned path for the delivery lines from the ram pumps ran straight up the incline towards Anangue. The delivery line skirted sugar cane fields and followed a foot path to the site of the intermediate tank in the back yard of a family's chili farm. From here, the path of the pipe followed the dirt road to Tres Hermanos, until it reached the proposed site of the reservoir that was on the side of the road at the back of some farm lands. From there, the delivery lines to tap stands were to follow dirt roads and footpaths to their necessary locations. One delivery line was planned to be strung over a valley using steel cable to reach its tap stand destination. Locations for tap stands were decided upon by AIDFI technicians and the newly appointed Tres Hermanos Water Committee.

Site Clearing, Rock Gathering, and Foundation Building

On June 27, 2010, AIDFI technicians opened the delivery lines for the Anangue ram pump system and created a diversion line to the house in which the Northwestern team and technicians were housed. This diversion line provided the team with water for drinking (once purified), bathing, cooking, and cleaning. In the valley below, laborers constructed a tent under which to mix cement during the daily rains that were natural to the rainy season next to the site of the catchment tank.

On June 28, 2010, AIDFI technicians, Tres Hermanos laborers, and the Northwestern team began clearing the site of the ram pump by removing rocks, plants, and underbrush from the proposed path for the ram pump (See Figure 4). Bamboo trees were cut and used as markers to highlight the path to be cleared. Large to medium sized rocks were collected from the adjacent stream to be used as part of the foundation for the new catchment tank, which had to be level with the already existing one. This meant that the stone foundation would have to support the catchment tank approximately three feet in order for it to be level with the existing one.

Figure 4: Site Clearing

The site of the natural spring was underneath large boulders, many the size of living room sofas. In order to clear the site for the new impounding tank, these boulders had to be moved into position, such that they could be used as supports for the walls of the tank. In order to move these rocks, laborers used pry bars to loosen the boulders and then pushed them into place in groups of three to four men. For the largest boulders, rebar was wrapped around the rock and attached to a winch, which helped the laborer teams gain more leverage. The Northwestern team also did its share in moving rocks (see Figure 5).

Figure 5: Large Boulder Positioning

Foundations for the catchment tank and the pipe supports were built by digging approximately three feet into the ground and removing large to medium size rocks as they were discovered. Then rocks were fit together layer by layer and cemented in place. The sand and cement were necessary to make the concrete were all manually hauled down the cliffside by the laborers, with a few trips made by Jon and Joe from the Northwestern team. Concrete was mixed manually, requiring two men with shovels to churn and mix the sand and cement with water, until it reached the appropriate consistency. Sand to cement ratios of 2:1 and 3:1 were used according to the different situations and requirements. After plastering the rocks together into a foundation, concrete was poured onto the top of the foundation to create a level surface for the catchment tank. Diversion streams were dug in order to control the flow of the rain water away from newly cemented structures. Site clearing and foundation building was completed on approximately June 30, 2010.

Catchment Tank and Overflow

Figure 6: Catchment Tank Foundation

Construction of the catchment tank began immediately after construction of the foundation was completed. During the construction of the foundation, a pipe for the overflow tube was placed to run down through the foundation and out of the side to connect to the existing overflow pipe from the Anangue catchment tank (see Figure 6). With this overflow piping in place, AIDFI technician and ferrocement plastering expert Dadz constructed the walls of the catchment tank by molding and connecting wire mesh into the desired shape of the walls and attaching plywood as a backing. The catchment tank form was placed directly next to and touching the

existing catchment tank. This was done because the diversion line from the impounding tank was planned to be fed into the existing catchment tank and then overflow from that catchment tank flow into the new catchment tank. In order to direct the overflow, a pipe was placed at the bottom of the Anangue catchment tank leading to the new tank.

Holes were cut into the mesh and plywood to fit the drive pipes which were simultaneously being fitted with the ram pump and the catchment tank (see Figure 7). With these in place, Dadz plastered first the inside of the catchment tank, removed the plywood backing, and then plastered the outside of the tank, so that both sides were relatively smooth. After a day of curing, he went back to the catchment tank and re-plastered the inside walls, outside walls, and floor of the tank for optimal smoothness.

Figure 7: Catchment Tank Framing

Once the entire structure had sufficient time to cure, Dadz continued the construction of the catchment tank, using wire mesh and plywood to form the structure of the ceiling for the catchment tank. Once the forms were in place, a hole was cut for the manhole cover, made of PVC plastic. The manhole and cover were attached to the wire mesh with wire, then plastering of the ceiling began. Within 15 days from the completion of the plastering, a laborer crawled into the tank through the manhole to remove the plywood backing that supported the cement during plastering. The inside wall of the ceiling was not re-plastered for smoothness.

Figure 8: Finished Catchment Tank

Once the project was near completion, concrete was added to the area surrounding the connection between the drive pipes and the catchment tank in order to stem a leak that developed. A similar procedure was done to the connection between the diversion line and the Anangue catchment tank. The overflow for the both the Anangue and Tres Hermanos ram pump systems went through the same pipe, into the adjacent stream alongside the systems. The new catchment tank has a volume of approximately 3 cubic meters, which is equivalent to a 3,000 L capacity (see Figure 8).

Ram Pump Foundation and Drive Pipes

While Dadz worked on the construction of the catchment tank, AIDFI technician Orlan directed the construction of the ram pump foundation and the drive pipes. The ram pumps' foundation was one of the first structures that had to be built, since the cement needed the longest time to cure in order to ensure safe operation of the system. The foundation must be strong enough to absorb the shock of the ram pumps and reverberation from the hammer effect (see Figure 9). First, both three inch ram pumps and the stainless steel drive pipes were carried down the valley incline strapped to bamboo for easier carrying. Once the ram pumps were delivered to the planned site of construction, foundations were dug for each ram pump and filled with rocks. The ram pumps were placed onto these foundations and secured with bolts and rebar into the rock and concrete foundation. With the pumps in place, the drive pipe pieces were connected such that they reached from the pumps to the catchment tank. Foundations were built at strategic points along the drive pipe length in order to support and keep the pipes straight. These foundations were dug and filled with rocks and cement, upon which AIDFI made rebar supports were fitted and the drive pipes supported.

Figure 9: Ram Pump Placement

In order to insure that the drive pipes were straight and level, a string was tied from the point directly above where the drive pipes fed into the ram pump and to the point directly above where the drive pipes connected to the catchment tank (see Figure 10). Supports were then raised or lowered to straighten the drive pipes and when satisfactory, cemented down. Drive pipe pieces were bolted together with rubber washers in between to prevent leaks. When leaks occurred, plastic was forced into the gap until the leak was fixed. The drive pipes were connected to the ram pumps using bolts and washers, and after this was done, the construction of the ram pumps' foundation began.

Figure 10: Drive Pipes

The ram pumps' foundation was built up using rocks to create a semi-level ground with the foundation already supporting the ram pumps. Then, wire mesh and plywood were used to create the form for the foundation base with holes cut for the drive pipes to enter and then ferrocement was plastered on. The foundation was approximately 1 m x 1.5 m, with 1.5 m high walls surrounding foundation in order to keep the pumps submerged during operation. One small overflow vent was chiseled away from the foundation to allow overflow to occur, but still keep the pumps submerged. A 6 meter tall cage was erected over the ram pump foundation and plastered into place to protect the ram pump from falling debris and prevent any tampering of the system.

Impounding Tank and Diversion Line

Construction of the Impounding Tank began immediately after the construction of the ram pump foundation had been finished. Additional clearing and positioning of the Anangue spring site had to be done before cement was poured to form the walls of the impounding tank. Large and medium rocks were placed at strategic positions along the spring site to dam the water and cause the water level to rise. Sticks cut from bamboo trees were used to give form to the new impounding tank and to support the rocks which were being used to dam and give support to the new tank. Once the site had been partially dammed, cleaning of the "floor" for the new impounding tank was done to remove any rocks that might be there as well as any vegetation that might still be there. After cleaning, further efforts were made to dam the site of the new impounding tank by plugging up any spotted leaks with vegetation, small rocks, and sand.

Wire mesh and plywood forms were placed along the outlined markings for the walls of the impounding tank as had previously been done before for other structures (see Figure 11). For the base walls of the impounding tank that were below the raised water line, a second plywood board was placed parallel to the wire mesh and plywood already being used to mark the wall of the impounding tank. Cement was then poured into the gap between the two plywood boards in

order to form the wall. The damming made it so that only a small portion of the cement was able to flow downriver, while the rest was held in place for curing. For the portion of the walls above the water line, plastering was done as usual.

Figure 11: Impounding Tank Structure

During the plastering of the impounding tank, two pipes were placed into the side walls as drainage and waste valves, to drain the impounding tank and remove the sediment from the bottom. The diversion pipe was placed into position and plastered into place. With piping laid out, the floor of the impounding tank was evened out and leaks covered with more cement. The ceiling of the impounding tank was completed like the ceiling of the catchment tank, although instead of one PVC manhole, two concrete manholes were erected with re-bar handles for lifting (See Figure 12). While this impounding tank was constructed directly next to and touching the Anangue system impounding tank, the two tanks remained separate and were not joined.

Figure 12: Completed Impounding Tank

Placement of the diversion lines followed the path laid out by the diversion line of the Anangue system and ran directly parallel to it. The diversion pipe (See Figure 13) went from the impounding tank to the Anangue system catchment tank, where a hole was chiseled and the pipe fitted. Foundations and supports for the diversion lines were built at every connecting point between two pipes.

Figure 13: Diversion Pipe

Main Delivery Lines and Intermediate Tank

With most of the construction in the valley complete, the next step in the construction of the ram pump system was to lay the delivery lines from the ram pump to the intermediate tank, which, 98 m above the site of the ram pumps. Black rubber delivery lines were connected to each ram pump and were then strung together and brought up to the valley incline. The delivery lines were laid through a road, alongside a sugar cane field, and along a footpath, in order for them to reach the location of the intermediate tank. Delivery lines were buried along the way in order to protect them from possible damage. The trenches for the lines were dug both by hand and by a plow pulled by a carabao. Burial was done by hand.

Figure 14: Main Delivery Line Output

The site of the intermediate tank was in the corner of a chili farm owned by a household of Anangue. The site was ideal because of its high elevation and also since it was close to the road to Tres Hermanos, along which the delivery line was to be laid. Foundations were dug for the intermediate tank stand and the stand cemented into place with the intermediate tank on top. The two ram pump delivery lines were connected to the intermediate tank and the main delivery line attached as well. Telescoping pipe pieces were used to lengthen the main delivery line from the intermediate tank to the location of the reservoir in Tres Hermanos. The delivery line was laid alongside the road and left up to the community to bury under the Dagyaw (volunteer) system. With the piping in place, the ram pumps could be tested and begin to pump water to Tres Hermanos, where it would be used for mixing the cement necessary to build the reservoir and the tap stands throughout the community (see Figure 14).

Reservoir, Tap Stand Delivery Lines, and Tap Stands

With water being pumped to Tres Hermanos, construction of the 10,000 liter ferrocement reservoir could begin. Reservoir construction began by digging the foundation for the reservoir and creating a level ground floor using ferrocement. The circular form for the reservoir was created using wire mesh and plywood. Ladders were constructed with bamboo and wood so that the AIDFI plasterers could climb into the inside of the reservoir to plaster the interior walls and floor (see Figure 15). Two sets of distribution taps were fitted into the side of the reservoir, each capable of distributing water to six tap stands. A main shut-off valve on each main distribution tap allowed for the shut-off of each set of valves, while individual valves allowed for the shut off of individual taps. Input and overflow pipes were placed high on the walls of the reservoir. Plastering of the exterior walls and ceiling followed the same procedure as that followed in constructing the other ferrocement structures. When finished, a tamper-proof cage was erected over the distribution taps, so that only the local technicians could have access to the control of the water flow.

Figure 15: Reservoir Construction

Nine tap stand delivery lines were connected to nine outlets in the distribution tap and the pipes were laid out along the main dirt road and along footpaths to reach the sites of the tap stands. The reservoir was filled with 5,000 liters of water after approximately three days of curing so that the delivery lines and tap stands could be tested. Tap stands were constructed using wire mesh and plywood forms in order to create one faucet and a small collecting pool for each tap stand (see Figure 16). Locations of the tap stands were decided upon by AIDFI technicians and the newly elected water committee. Only one dispute over a tap stand location occurred and resulted in the relocation of an already constructed tap stand. All tap stands passed the initial flow tests and served approximately four households each. Before the water could be used for human consumption, a twenty-one day cement curing period had to be observed. Delivery lines were to be buried by Tres Hermanos community members under the Dagyaw system.

Figure 16: Tap Stand Construction with Dadz

Ram Pump Tuning and Local Technician Training

After completion of the system, ram pump tuning was conducted in order to provide the optimal water flow to the community of Tres Hermanos. In order to conduct the tuning (see Appendix F), the tuning screw in the waste valve was periodically turned in order to change the frequency (strokes/min) of the ram pump. Each time the frequency was changed, the output (L/min) of the ram pump and the overflow (L/min) from the catchment tank were measured in order to calculate the consumption (L/min) of the ram pump. With these measurements and the information from the technical study, efficiency of the system could be calculated at each frequency and a curve created to show the optimal frequency in order for the system to operate most efficiently. Output of the ram pump could be calculated either manually, through collection at the intermediate tank, or through the use of an AIDFI measurement tool, which simulates pressure on the air chamber equivalent to that created under normal circumstances and allows for measurement of the flow rate at the ram pump itself. Using the data, it was found that the most efficient frequency for the Tres Hermanos ram pump systems to operate at is approximately 42 strokes/min (See Figure 17: Tres Hermanos Efficiency Curve and Figure 18: Tres Hermanos Frequency vs. Output).

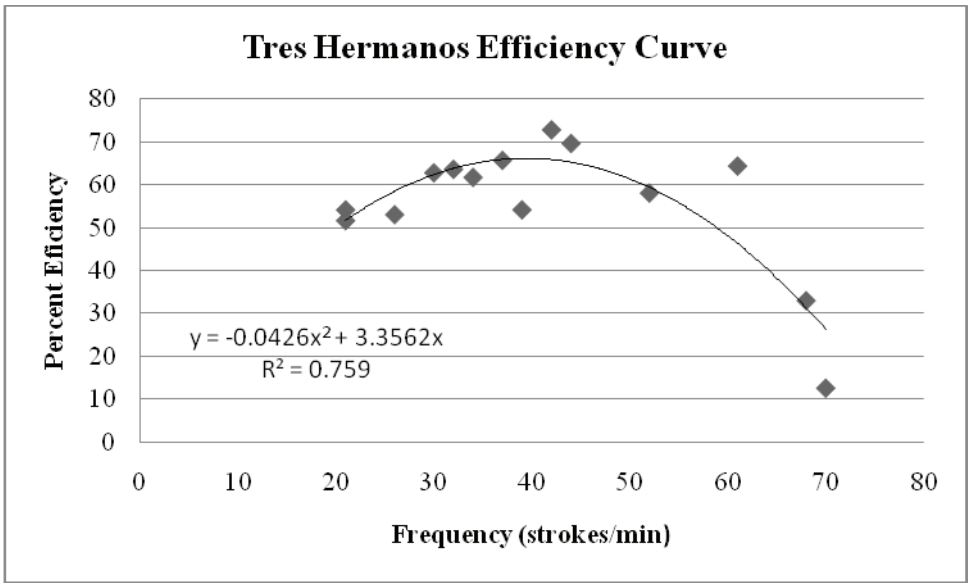

Figure 17: Tres Hermanos Efficiency Curve

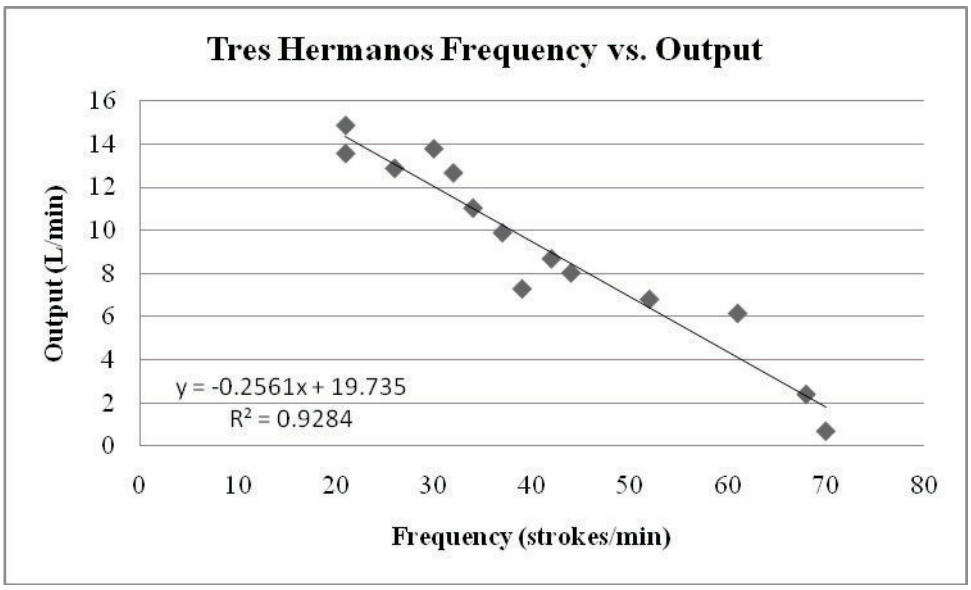

Figure 18: Tres Hermanos Frequency vs. Output

One local maintenance technician, Jo Marie (see Figure 19), was trained in the operation of the ram pump and was shown how to both disassemble and reassemble the pump. He was given the tools necessary to maintain the ram pump, along with some spare parts. AIDFI technicians also showed him how to fabricate select spare check valveparts using readily available material, such as old rubber from tires. The technician was given the keys to unlock the protective cages surrounding both the ram pump and the distribution taps for maintenance purposes.

Figure 19: Jo Marie Catalan coming out of the Impounding Tank.

Tres Hermanos System

The Tres Hermanos ram pump system delivers approximately fifty thousand liters per day from the Anangue Spring source, approximately two thousand meters away. In order to fund regular maintenance of the pump, a monthly contribution of 50 pesos per household was set by the water committee during a community meeting (see Figure 20). The penalty for non-compliance with the fee was decided to be complete shut-off of the tap stand providing water to the household that withheld payment, along with any other households that receive water form that tap stand. The water committee also set tap stand usage hours from between 6 A.M to 10 A.M. and 2 P.M. to 5 P.M. Regulation of the water flow is to be regulated by one of the local technicians and one water committee member is set to be in charge of fee collection. Nine tap stands in total were constructed and distributed throughout the village (see Appendix G).

Figure 20: The community and water committee gathered at meeting concluding ram pump construction, with Liloy at the head of the table.