Post Implementation Report Part 1 – Administrative Information

1.0 Contact Information

<table>
<thead>
<tr>
<th>Name</th>
<th>Email</th>
<th>Phone</th>
<th>Chapter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Lead</td>
<td>Jacob French</td>
<td><a href="mailto:frenc248@umn.edu">frenc248@umn.edu</a></td>
<td>(314) 629-5100</td>
</tr>
<tr>
<td>Project Lead</td>
<td>Rebecca Herron</td>
<td><a href="mailto:herro084@umn.edu">herro084@umn.edu</a></td>
<td>(319) 431-5517</td>
</tr>
<tr>
<td>President</td>
<td>Kelly Stifter</td>
<td><a href="mailto:stift032@umn.edu">stift032@umn.edu</a></td>
<td>(651) 328-1937</td>
</tr>
<tr>
<td>Mentor #1</td>
<td>Kevin Miller</td>
<td><a href="mailto:kevin.g.miller@urs.com">kevin.g.miller@urs.com</a></td>
<td>(612) 644-1170</td>
</tr>
<tr>
<td>Mentor #2</td>
<td>Jed Greenwood</td>
<td><a href="mailto:jgreenwood@barr.com">jgreenwood@barr.com</a></td>
<td>(763) 263-6650</td>
</tr>
<tr>
<td>Faculty Advisor</td>
<td>Tim La Para</td>
<td><a href="mailto:lapar001@umn.edu">lapar001@umn.edu</a></td>
<td>(612) 624-6028</td>
</tr>
<tr>
<td>Week 1 Health and Safety Officer</td>
<td>Brian Anderson</td>
<td><a href="mailto:and01106@umn.edu">and01106@umn.edu</a></td>
<td>(507) 696-3452</td>
</tr>
<tr>
<td>Week 1 Assistant Health and Safety Officer</td>
<td>Kevin Miller</td>
<td><a href="mailto:kevin.g.miller@urs.com">kevin.g.miller@urs.com</a></td>
<td>(612) 644-1170</td>
</tr>
<tr>
<td>Implementation Health and Safety Officer</td>
<td>Rachel Orlovsky</td>
<td><a href="mailto:orlov006@umn.edu">orlov006@umn.edu</a></td>
<td>(262) 498-8413</td>
</tr>
<tr>
<td>Implementation Assistant Health and Safety Officer</td>
<td>Alex Motley</td>
<td><a href="mailto:motle016@umn.edu">motle016@umn.edu</a></td>
<td>(314) 704-9058</td>
</tr>
<tr>
<td>NGO/Community Contact</td>
<td>Elizabeth Howland</td>
<td><a href="mailto:lizh@lwhome.org">lizh@lwhome.org</a></td>
<td>01150249328889</td>
</tr>
</tbody>
</table>

2.0 Travel History

<table>
<thead>
<tr>
<th>Dates of Travel</th>
<th>Assessment or Implementation</th>
<th>Description of Trip</th>
</tr>
</thead>
<tbody>
<tr>
<td>August 10-23, 2011</td>
<td>Assessment</td>
<td>Met with representatives from the APROMAC within the community. Discussed the existing design and use of current Irrigation Dams and ram pumps, as well as their future goals for the system. Introduced them to EWB mission and process and confirmed their desire to form a partnership. Additionally, performed preliminary analysis of the Irrigation Dam integrity and surrounding soil quality.</td>
</tr>
<tr>
<td>March 10-19, 2012</td>
<td>Assessment</td>
<td>Met again with the APROMAC and established the foundation for further assessment with objectives to</td>
</tr>
</tbody>
</table>
strengthen water distribution and storage infrastructure as determined feasible. The focus of interaction was strictly to discuss possibilities. Irrigation Dam measurements and benchmarks were taken for each of five Irrigation Dams. GPS readings were taken over various locations to create geographical survey of the land. Community surveys were conducted from members of the Irrigation Dam association and community members who were as of yet unaffiliated.

| August 17 – 27, 2012 | Assessment | Met again with the APROMAC and signed an MOU for second assessment. Data collection from the March 2012 assessment was continued with GPS surveys, land surveys, community surveys, water testing, soil testing, and hydrologic measurements. Much work was done on the land surrounding the third Dam due to the possibility of collapse of the Dam. |

3.0 Travel Team

<table>
<thead>
<tr>
<th>#</th>
<th>Name</th>
<th>E-mail</th>
<th>Phone</th>
<th>Chapter</th>
<th>Student or Professional</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Brian Anderson</td>
<td><a href="mailto:and01106@umn.edu">and01106@umn.edu</a></td>
<td>(507) 696-3452</td>
<td>UMN</td>
<td>STUDENT</td>
</tr>
<tr>
<td>2</td>
<td>Anirudh Srivasta</td>
<td><a href="mailto:sriva047@umn.edu">sriva047@umn.edu</a></td>
<td>(763) 202-6592</td>
<td>UMN</td>
<td>STUDENT</td>
</tr>
<tr>
<td>3</td>
<td>Leah Smith</td>
<td><a href="mailto:smit7189@umn.edu">smit7189@umn.edu</a></td>
<td>(217) 836-5144</td>
<td>UMN</td>
<td>STUDENT</td>
</tr>
<tr>
<td>4</td>
<td>Rachel Orlovsky</td>
<td><a href="mailto:orlov006@umn.edu">orlov006@umn.edu</a></td>
<td>(262) 498-8413</td>
<td>UMN</td>
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</tr>
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<td>Alex Motley</td>
<td><a href="mailto:motle016@umn.edu">motle016@umn.edu</a></td>
<td>(314) 704-9058</td>
<td>UMN</td>
<td>STUDENT</td>
</tr>
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<td>Jacob French</td>
<td><a href="mailto:frenc248@umn.edu">frenc248@umn.edu</a></td>
<td>(314) 629-5100</td>
<td>UMN</td>
<td>STUDENT</td>
</tr>
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<td>Kevin Miller</td>
<td><a href="mailto:kevin.g.miller@urs.com">kevin.g.miller@urs.com</a></td>
<td>(612) 644-1170</td>
<td>MN</td>
<td>PROFESSIONAL</td>
</tr>
<tr>
<td>8</td>
<td>Mustafa Igdelioglu</td>
<td><a href="mailto:migdelioglu@barr.com">migdelioglu@barr.com</a></td>
<td>(267) 471-1133</td>
<td>MN</td>
<td>PROFESSIONAL</td>
</tr>
<tr>
<td>9</td>
<td>Jed Greenwood</td>
<td><a href="mailto:jgreenwood@barr.com">jgreenwood@barr.com</a></td>
<td>(952) 769-7488</td>
<td>MN</td>
<td>PROFESSIONAL</td>
</tr>
<tr>
<td>10</td>
<td>Cameron Klos</td>
<td><a href="mailto:kloscg@teamtsp.com">kloscg@teamtsp.com</a></td>
<td>(612) 465-7621</td>
<td>MN</td>
<td>PROFESSIONAL</td>
</tr>
<tr>
<td>11</td>
<td>Isaac Murphy</td>
<td><a href="mailto:murp0494@umn.edu">murp0494@umn.edu</a></td>
<td>(612) 239-5981</td>
<td>UMN</td>
<td>STUDENT</td>
</tr>
</tbody>
</table>

4.0 Health and Safety

During the recent implementation trip no incident reports needed to be filed due to the fact that no major injuries occurred. Before traveling, each member of the team was required to sign the HASP to confirm that they had read and would abide to the information inside. This was a top priority because everyone was informed and educated on what their specific responsibility was to ensure the team would have a safe trip.
Injuries were prevented due to following the HASP. They were mainly prevented by each person wearing their personal protective equipment in the specific scenario of construction. Injuries were also prevented by everyone using common sense and being aware of their surroundings which included the environment and the other members of the travel team. Communication was also a key factor in preventing injuries. This was demonstrated by making sure a health and safety officer was present when tasks were divided as well as checking in hourly to make sure members of the team as well as the environment was safe.

4.1 Incident Reports
No incidents of note occurred during the implementation.

5.0 Monitoring

<table>
<thead>
<tr>
<th>Project</th>
<th>Date Built</th>
<th>Description</th>
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<tbody>
<tr>
<td>Rainwater Harvesting System</td>
<td>August 2010, 2011</td>
<td>Rainwater harvesting system in Simajhuleiu, a neighboring town of Agua Caliente. The system was built on the primary school, allowing the children of the community to attend school every day. We will be checking the pump system, testing the water, and clearing the flush system and filters. We will also be installing bolts on the first flush caps so the children won’t take them.</td>
</tr>
</tbody>
</table>

6.0 Budget

6.1 Project Budget
Please see attached spreadsheet for the complete implementation budget. The implementation cost was $9,085.65. A summary of the categorical costs is listed below.

<table>
<thead>
<tr>
<th>Categorical costs</th>
<th>Amount (USD)</th>
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<tr>
<td>Services</td>
<td>$206.76</td>
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<tr>
<td>Lodging</td>
<td>$1,514.42</td>
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<tr>
<td>Meals</td>
<td>$1,066.94</td>
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<tr>
<td>Supplies</td>
<td>$5,294.78</td>
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<tr>
<td>Transportation</td>
<td>$1,002.75</td>
</tr>
<tr>
<td>Total</td>
<td>$9,085.65</td>
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6.2 Professional Mentor/Technical Lead Hours

<table>
<thead>
<tr>
<th>Name(s) of Professional Mentor(s) (student chapters)</th>
<th>Pre-trip hours</th>
<th>During trip hours</th>
<th>Post-trip hours</th>
<th>Total Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical Lead(s) (professional chapters)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
7.0 Project Disciplines
This was a civil works dam improvement project. The whole system includes irrigation pumps, irrigation lines, and water storage. The implementation focused solely on repairing a dam.

8.0 Project Location
   **Agua Caliente Community Center:**
   Longitude: 14° 48' 18.76”
   Latitude: 90° 51' 71.23”

   **Dam 3:**
   Longitude: 14° 48' 40.32810” N
   Latitude: 90° 51' 15.16093” W
Post Implementation Report Part 2 – Technical Information

1.0 Executive Summary

Expanding Agricultural Opportunities is an ongoing structural and mechanical project by the University of Minnesota Engineers Without Borders Chapter (EWB-USA UMN). It is based on an existing agricultural water system originally designed by the community of Agua Caliente, which consists of a series of five dams that vary in size, design, and structural stability. Installed on each of the dams are several ram pumps that deliver water to agricultural fields at elevations above the river that flows next to the community. This enables the community to grow crops in the dry season, increasing their yield and profit. This allows their children to go to school longer, it improves the nutrition of the town, and it improves the economy of the community and surrounding area because the farmers with ram pumps hire outside workers to tend their fields in the dry season. The community reached out to EWB-USA UMN in order to reinforce and improve the system, which is quickly falling apart because of lack of structural knowledge and experience. One of the dams (Dam 1) was designed by a local engineer, and each subsequent dam is based on its design. The rams were developed by the community based on an encyclopedia entry on Persian pumps. Because everything was originally built by the community, we know they have invested significantly in the system already. It is extremely important to them that their livelihood be protected.

The overall goal of this project is to improve the entire agricultural water distribution system. For our first implementation in the community we completed a repair of the dam in the most critical condition, Dam 3. The two other proposed projects were the improvement of the hydraulic rams to pump further with more volume which will be our next implementation, and a system for drip irrigation in order to conserve water resources and man hours. Due to the importance of the dams in relation to the entire system, our group determined the most crucial implementation of the system was to ensure that the dams will not fail in the near future. From two previous assessment trips EWN-USA UMN had determined that Dam 3 was in the most critical need of repair of all the dams. It was for this reason that we began with this implementation.

The community of Agua Caliente has invested a large amount of money to construct the dam and were worried that their investment would go to waste after only four years of use. Our NGO, Long Way Home, has a long-standing relationship with Agua Caliente, and helped us with communication with the community. EWB-USA UMN signed a Memorandum of Understanding (MOU) with the community in August 2012 for the assessment and future implementation, including tasks leading up to implementation such as setting up a staging area, materials acquisition, and planning and information. Over the design process, we kept up with the proposed monthly calls, checking in on materials, fundraising, and plans. Our group wrote and signed a second MOU before the beginning of implementation that covered the rest of materials acquisition, labor for building, and monetary responsibility.
2.0 Introduction
Since August 2011, EWB-USA UMN has been working in the community of Agua Caliente to improve a deteriorating agricultural water system, which has been functioning since 1990. The system is operated by a local farming cooperative called APROMAC and consists of 42 ram pumps and five dams, as well as a handful of fields which contain water storage tanks and micro-irrigation pipes. EWB-USA UMN has been working closely with APROMAC and our NGO, Long Way Home, to determine the best way to improve the system. In March and August 2012 it was determined that Dam 3 was in critical need of reinforcement or it would soon fail. This was EWB-UMN’s third implementation in the area, and first implementation in the community. We plan on several more following this implementation to improve other parts of the system.

The current system allows farmers to grow crops during the normally unproductive dry season. Before, many farmers had to travel to the coast or other regions of the country to find work during the dry season; now, they are able to find work within the community year-round. This has allowed what once was subsistence farming to turn into a commercial venture. Currently, the APROMAC has invested the most in the system (Q7000 per pump, Q200,000 per dam) and is therefore the greatest beneficiary to any improvements done to it. However, expanding the system extends benefits to the rest of the community. Our implemented reinforcement design allows for more farmers to be added to the dam, expanding the impact of the system to more users.

This document clearly lays out the executed implementation for the reinforcement of Dam 3, the dam in the most critical need of repair. The construction process involved pouring an extended base below the dam to reduce erosion and support the structure, buttresses to reinforce the integrity of the structure and prevent further bank erosion, and eight meters of riprap in order to prevent any downstream erosion in the future. This document details the executed repairs and future plans with the community.

3.0 Program Background
The University of Minnesota has worked in the Comalapa/San Juan region since 2006. During this time two implementation projects have occurred (a spring box and pump in Chimiya, and a rain water harvesting system (RWHS) in Simajhuleu). In August 2011 we visited a new community, Agua Caliente, to meet with community members and gather preliminary assessment data.

Our group decided on the reinforcement of Dam 3 as our first implementation in the community over two other proposed projects. The alternative projects were improving the efficiency of the existing ram pump design, or adding a drip irrigation design to their system. In order to pump farther with more volume and therefore add people to the system, it is imperative to have an improved valve design for the ram pumps. The drip irrigation system will allow the farmers in APROMAC to allocate more time to other farming tasks because their water cannot touch blackberries that get exported to the United States. For this reason, they currently use a hose to water the base of each plant by hand, something that could be done with drip irrigation. Drip irrigation also saves valuable water resources because it is a more efficient process.
The long term goal of the project is to improve the whole system including the proposed alternatives, but because of the time sensitivity of the Dam’s repair, we chose to start with this project for the first implementation in Agua Caliente.

3.1 Project Partners

Long Way Home (LWH). “LWH is a non-profit organization which uses sustainable design and materials to construct a self-sufficient school that promote education, employment and environmental stewardship”, and is based out of Comalapa, Guatemala. EWB-USA UMN has been partnered with LWH for several years and has worked with them to install a spring box and pump in Chimiya. They have continued to work with us as translators, planners, and advisors throughout the Agua Caliente project.

Asociacion de Desarrollo Integral de Productores de Mora Agua Caliente (APROMAC). The APROMAC is a farming cooperative that has funded the irrigation dam and ram pump system that is located on the stream leading from Patzá. They are forward-thinking and community-minded, and have shown a lot of interest in working with EWB-USA UMN. Although they already have an irrigation water system, much of it was designed without the aid of engineers and is quickly falling apart, thereby causing erosion and becoming a danger to their investment and lifestyle.

COCODE. The COCODE is the official local leadership board which oversees the community, including the chlorinated drinking water system of Agua Caliente. Some members of the COCODE are also members of the APROMAC, and both groups seem interested in working with EWB-USA UMN to improve their irrigation system. Though EWB-USA UMN is not working in direct relationship with the COCODE authorities, the president of the COCODE is a member of the APROMAC and we continue to listen to COCODE members for suggestions or community-wide goals.

EWB-USA MN Professional Group. Once every three months, the EWB-USA MN Professional group attends a EWB-USA UMN project meeting. The EWB-USA MN Professional group also provides mentorship to our group and acts as a reference for structural designs. EWB-USA UMN has a very strong relationship with this group.

3.2 Community Priorities

The APROMAC has invested a substantial amount of time and money into the current irrigation system and their top priority is to protect their investment from being degraded or destroyed, such as by a heavy rainfall. Once this prerequisite is met, the APROMAC has expressed interest in the following projects, listed in descending order from most important to least important (approximately, according to APROMAC leaders during the first two assessment trips):

1. Ensure that the dams will not be destroyed in a high rainfall event.
2. Replace the current system of sprinklers with water storage tanks and micro-irrigation pipes. This will allow farmers to use less water, which will further allow them to water more fields in a day than they are currently capable of or water multiple fields at once.
3. Add more pumps, and therefore families, to the dams. This will allow more fields to be watered.
4. Improve ram pump efficiency and pumping power. This will allow more fields to be reached and will shorten the time required to water a field or fill a water storage tank.

5. Replace the current black rubber hosing that connects the ram pumps to the sprinklers with PVC or another, stronger material. The current range of some pumps is limited because the rubber hoses break under pressure, and by switching to PVC more fields will gain access to water.

3.3 Water Sources
There are at least two sources of water that the community uses. One is a hot spring, Patzá, which flows into the Rio Agua Caliente, and the other comes from a neighboring stream. Potable drinking water for the community is provided from the neighboring stream and is chlorinated, and community feedback has indicated that the water is perfectly safe to drink. However, there are some community members, especially the elderly, who do not like the taste of the chlorination and continue to boil their water before drinking.

4.0 Trip Description
During this trip, the travel team implemented their proposed improvements to help reinforce Dam 3 in Agua Caliente. The team also took measurements to assist in a potential Ram Pump trip in the future.

The first part of the trip was focused on acquiring materials as well as constructing the water bypass. Some of the materials were brought from the United States that would have been difficult to obtain in Guatemala. The other materials needed for implementation were purchased in country.

The first week of implementation was focused on preparing the staging area and constructing the bypass by the first group of the travel team. The travel team cut and assembled all the wooden pieces necessary to create the bypass. Members of APROMAC focused on bringing down rip rap that will be used to help prevent erosion near the dam. The bypass was put into place in preparation for phase two of the implementation.

The rest of the travel team arrived to assist with the construction portion of the implementation. Since the bypass was in place preparations for the base pour could start. The ground was leveled and tamped down to have a smooth base for the concrete. Rebar was tied and the forms were in place to start the base pour. However, due to torrential rain the bypass fell resulting in all the work in preparation for the pour being destroyed.

In result, the team had to redesign the ground chute as well as uncover all of their previous work. A winch was used to remove the bypass from the bottom of the river. It was reinforced and reattached up by the spillway to ensure it would not collapse again. All the rebar that was previously tied was dug up from the bottom of the river and placed in its original position. The formwork was rebuilt and placed around the rebar for the first pour. Finally, everything was back in place and the base was successfully poured.
The next step was to pour the buttress. The team built the formwork for the first pour of the buttress. They also assembled and tied the rebar to ensure a successful day one pour of the buttress. The buttress was then poured leaving the last pour to APROMAC and Long Way Home. The travel team built the rest of the formwork for the additional buttress pours to assist in the final pours of the implementation.

Long Way Home and APROMAC successfully poured the final pieces of the buttress completing all of the proposed project except for the laying of the rip rap. Currently the chapter is creating a new rip rap proposal to complete the final task of the implementation

5.1 Community Information

5.1 Description of Community
Agua Caliente is composed of 200 families and is located on the Rio Agua Caliente. The total population of the community is estimated to be around 1400 people, which averages around seven people per family. There are two schools, a basic school and a middle school, but no health clinic or market. For trade or for serious medical problems they go to the neighboring villages of Simajhuleu or Poaquil, and if necessary, to the city of Comalapa. Their political system is typical of others in the area and is composed of an Alcaldes and a COCODE.

Twenty years ago the community used to sell wood and carbon products but, after noticing the rate of deforestation, decided to look for a more sustainable source of income. In response, 70 families organized to create a farming cooperative called the APROMAC, which also helped to improve the health of their crops and protect them from larger buyers by selling crops as a group. Since 1990, the APROMAC has successfully installed five irrigation dams, with several ram pumps on each dam, in the stream that leads from Patzá. This enables them to irrigate their crops in the dry season and, as an added benefit, creates several agricultural jobs for the community as a whole. They have asked EWB-USA UMN to partner with them to protect the integrity of the irrigation dams, to help them to improve and expand the ram pumps, and to possibly add water storage for micro-irrigation in the future.

EWB-USA UMN has decided to define the APROMAC as our community and work with them apart from the rest of the community of Agua Caliente for several reasons. First, the members of the APROMAC have invested the most time and money into the system and collectively own all of the dams and most of the ram pumps. Second, the APROMAC has shown a lot of interest in working with EWB-USA UMN to improve the quality of the system and is willing to provide labor and materials for an implementation. Third, the APROMAC desires to expand the system to include as many families as possible, thus helping the entire community of Agua Caliente.

5.2 Community Relations
During the repair and monitoring trip for the rainwater harvesting system in Simajhuleu, the community of Agua Caliente learned about our presence in the area and approached Long Way Home with interest in working with our group. EWB-USA UMN took a day trip to Agua Caliente during this trip to see the agricultural system for the first time. We took our first assessment full assessment trip in March 2012 to examine the system and meet with leaders from
From the first assessment trip it became clear that two of the dams, hereafter referred to as Dam 2 and Dam 3, were in danger of collapse. To gather more data we took a second assessment trip in August 2012. Our primary tasks included: a more extensive GPS survey of the surrounding area; a land survey of the area surrounding the dams, especially Dam 3; conduction of another 25 community surveys, bringing the total number of community surveys to 45; further water and soil testing and qualification, especially around Dam 3; analysis of the hydrologic structure surrounding the dams.

This paper details the first implementation for EWB-USA UMN of the structural repair of Dam 3 in Agua Caliente. The following pages detail information about the execution of the implementation with the community.

6.0 Project Summary

6.1 Project Description

The completed implementation was the reinforcement of an existing irrigation dam in Agua Caliente, Guatemala. The construction was broken into three components: Extending the base of the dam with a shear key and constructing a lip dissipater to reduce erosion, adding buttresses to reinforce the existing dam wall in regard to sliding and overturning, and installing riprap to prevent further erosion on the banks directly adjacent to the dam as well as downstream in the stream bed. This design required formwork and pouring to be done in a very narrow, steep stream bed, which added complexity to aspects of staging and construction. To bypass the river, a bypass trough was installed at the output of the spillway, preventing the construction area from being directly affected by the upstream water. The bypass transported the water to a distance sufficiently downstream from the construction site, with a structure to retain water from traveling back upstream. Because the design was an addition to the existing structure, the main goal of the executed design was sustainability, both in structure and in downstream integrity. The extended base and the riprap act to dissipate water in order to minimize erosion and maintain downstream integrity. The buttresses reinforce the structure against overturning and sliding as well as reinforce the stream banks just downstream of the dam, which have experienced critical erosion since the dam’s original construction in 2009. The riprap provides stability downstream, thus preventing erosion and sediment build-up downstream. These considerations were based on a spreadsheet given to us by a professional structural engineer created for the reinforcement of a similar retaining wall structure in the United States. Our design for the dam reinforcements in Agua Caliente were based on his design.
The existing dam most closely resembled a retaining wall. It was roughly a slab of concrete poured in the middle of a river with a heel to prevent it from overturning. Several pictures of the existing structure can be seen in Appendix F. Of the five dams, Dam 3 is the largest and single most important dam to the community. It serves 15 ram pumps and because of its central location in the community, it has the potential to hold many more after the reinforcements are made. The structure is 39 ft. across, with a 3.5 ft. wide and 6 ft. tall spillway. The downstream side of the dam stands 17 ft. high. There were three severe structural issues with the dam:

1. Insufficient reinforcement caused severe erosion around the sides of the dam, with a flow of water around the sides through the embankments.
2. Insufficient riprap and reinforcement downstream of the dam caused over a foot of scour in front of the dam, leaving the original toe, or “energy dissipater”, basically useless, and the stream bed downstream of the structure severely soured and damaged.
3. There were several cracks in the dam, particularly at cold joints that leak small amount of water when the stop logs are placed in the spillway. This is not a great structural threat immediately, but overtime could pose a problem for the structure if not taken care of.

Pictures of the construction in Agua Caliente are included in the appendices at the end of the document. Below is a before and after picture of the dam with and without reinforcements.

6.2 Summary

Materials Acquisition (August 8th – 15th)

When the materials acquisition team arrived in Guatemala, the area surrounding Agua Caliente was experiencing an atypical two-week dry spell. Materials acquisition progressed on schedule with the purchase of lumber and acquirement of tools from LWH, as well as various other materials and tools. It was decided that the water bypass would be constructed at Feliciano’s hotel due to the availability of electrical outlets and protection from rain, so lumber was staged at Feliciano’s instead of Agua Caliente. As the EWB-USA UMN team was gathering these materials, APROMAC gathered sand and gravel and transported them to the Dam 3 worksite. EWB-USA UMN constructed a filter out of wire mesh and, with the help of APROMAC, began
to filter the gravel out of the sand. The staging area around the dam was covered with a tent of plastic to protect against rain, which started becoming a factor shortly after beginning work on the water bypass.

Excavation of the worksite began by removing some of the right abutment, which encroached upon the area set aside for the base pour. Due to a miscommunication, the energy dissipator at the base of the dam was removed before the water bypass was installed, so riprap was placed at the base of the dam to prevent further erosion. However, as this was being done it was discovered that the dam was not supported by rock underneath, but instead rested on hard sandy clay which is typical in the region. This prompted a recalculation of the force equations on the dam to see if the design was sufficient. Riprap was also transported by hand to a location downstream of the worksite and within the river.

Work progressed on the water bypass from the 11th until the 14th, and on the 15th the water bypass was installed. This signaled the end of the materials acquisition phase.

**Base and Buttress Construction (August 16th – 30th)**

The ground underneath the water bypass was prepared by filling in any large scour holes with riprap, then the area was brought to a consistent elevation with gravel. This gravel was then tamped to create a solid subgrade to pour on, and the shear key trench was dug. The formwork was constructed and then lowered into place and secured using kickers. Rebar was pre-bent and then tied in place.

On the 20th, everything was set to pour the base, but upon arrival, it was discovered that the bypass had fallen, and the formwork, subgrade, and rebar had been washed away. Upon further investigation, it was determined that the bypass failure was due to three factors, that all failed together. The first failure point was the lack of connection between the weir and the chute. Originally the weir was designed to be bolted to the chute, but lack of communication lead to a failure to attach the two pieces. This left the chute sitting on the dam spillway, rather than being structurally attached to the dam. The second failure point was the bad seal between the chute and the base of the bypass. After the chute and base of the bypass were connected, it became apparent that a significant amount of water was coming out behind the bypass base due to several gaps in the connection of the bypass chute and base. A berm was set up to keep this water from flooding the pour area, but after several days of moderate rain, scour caused by this leaking water shifted the ground chute slightly. The final failure point was a large rainstorm the night of August 19th. On the 20th there was a clear water line 20’ from the top of the dam, indicating a rain event larger than the bypass was designed for. It is believed that the significantly more scour occurred behind the bypass base during this rain event, which caused the bypass to shift away from the dam enough for the chute to slide off the dam spillway and fall to the prepared base below.

After a day of planning, a new bypass base was designed and over a period of 3 days the bypass chute was lifted from the stream bed using a system of pulleys and rope. It was discovered the chute was in fairly good shape, and so it was lifted and put back in place on the dam spillway. The chute was then bolted onto the weir in 4 separate structural locations. The redesigned bypass base was placed underneath the chute and the bottom filled with riprap, to prevent scour or shifting of the bypass.

The base subgrade had to be rebuilt, and only the bottom half of the rebar was salvageable from before the bypass failure. New form work was constructed and with the new bypass in place the buttress base was successfully poured.
Next, the first section of the buttresses was formed off, and the remaining rebar was tied in place. On the last day in county the first buttress section was poured. Long Way Home volunteered to send two of their workers, along with one of their heads of construction to help the community finish the other two pours. The community has had a significant amount of experience pouring concrete and so we felt confident that they could complete the pours.

Several days after returning to the States, we received confirmation that the remaining two buttress sections were completed as planned by the community. APROMAC requested a two week break, to tend to their crops and calibrate the Guatemalan independence day, while we sent them detailed drawings for the riprap. One of Long Way Home’s heads of construction will bring these plans to the community and supervise the riprap placement.

6.3 Differences Between Planned and Actual Implementation

The major differences between the implementation as it was planned and how it was executed can be attributed to schedule changes and the collapse of the water bypass. When the materials acquisition team initially arrived in Guatemala it became obvious that the original schedule would need to be reworked to account for personnel who were leaving earlier than anticipated. Therefore, construction of the water bypass was begun earlier in an attempt to finish construction and installation by the 13th. During this period, many tasks were executed concurrently and the team worked long hours to ensure that the bypass was installed in time to start pouring.

The water bypass was installed on the 15th and remained in good working condition for four days. On August 19th, heavy rains caused the ground underneath the bottom support of the structure to erode, and the main chute fell on top of the rebar and formwork that was installed underneath. This necessitated a redesign of the water bypass base and a reevaluation of the project schedule. The team was able to reinstall the bypass on the 23rd, and work was appreciably increased over the remaining week to finish constructing formwork and concrete pouring.

Due to the scheduling setbacks imposed by the collapse of the water bypass, the team was unable to achieve all of the implementation goals while in-country; however, enough progress was made to allow local workers to finish the remaining tasks. When the implementation team left Guatemala, they had succeeded in pouring the base and the first tier of the buttresses. As a result, two buttress pours and riprap installation were the only tasks remaining to be done. To aid the local workers, the team built the remaining formwork for one side on the buttresses so that it could be duplicated for the other side. Instructions were also given as to the installation of riprap. Two local construction workers were hired, in addition to the labor provided by the APROMAC, and were placed under the guidance of LWH, our in-country NGO. As can be seen in the pictures below, the buttresses were successfully poured, leaving riprap installation as the only remaining task. Arrangements have been made to send LWH a detailed riprap plan, and for LWH to supervise the placement of the riprap by the community.

Other significant differences between the plan and execution of this implementation included using over-dimensioned lumber, redesigning the water bypass spillway structure due to dam geometry, and transportation to and from Agua Caliente. When the lumber was ordered, it was assumed that the dimensioning would be the same as it is in the States, i.e. that a 2x4 actually
measures 1.5”x 3.5”. When we received the lumber, it was cut to the actual dimensions of 2”x4”. This necessitated redimensioning the water bypass to ensure that it fit inside of the spillway. Additionally, the spillway structure had to be redesigned due to the spillway being larger than expected. Luckily, both of these changes were implemented without the purchase of additional materials.

Transportation to and from Agua Caliente was cheaper than expected due to the use of Feliciano’s truck. This allowed us to construct major components of the water bypass at Feliciano’s and transport them to Agua Caliente in large sections. It also allowed us to bring many other tools and equipment to the worksite much more quickly than would have otherwise been possible.

6.4 Drawings
The original drawing set for this project is titled Agua Caliente Buttress Repair and is included as a separate document. The design for the water bypass was slightly modified in-country in response to larger than anticipated spillway dimensions, and these drawings are titled Modified Water Bypass Drawings. Furthermore, after the initial collapse of the water bypass, the ground chute was further modified to allow with the continuation of the project. These alterations were not drawn up. Since the water bypass is a temporary structure the final design of the ground chute does not affect the future effectiveness of the dam or its safety.

6.5 Operation and Maintenance
Maintenance of the dam will be critical to keep the system sustainable. An ongoing problem has been water leaking through the base of the dam, and through the many holes that allow water to travel from the upstream side to the downstream side. Those holes were somewhat plugged during the implementation, and if the holes reoccur, those holes must be plugged again. Also, if a huge storm occurs, such as a tropical storm or hurricane, the riprap in the stream bed has the possibility of washing away. If the riprap does wash away, more riprap has to be placed in the stream bed to prevent scour. There will be rampant scour especially if another huge storm occurs before the riprap is replaced.

6.6 Education
The Guatemalans were using improper methods when using the dam. When the stop logs are in place, and need to be removed, the removal process is not up to par. We taught them to take the stop logs out over a longer period of time. Roughly 5 – 7 minutes after taking out a stop log, before removing the next stop log. The Guatemalans are taking out the stop logs too quickly creating more flow, and that would cause the riprap in the streambed to wash away. We also taught the Guatemalans how to place riprap on the embankments. The embankment will be smoothed out to create somewhat of a constant slope, and then the geo-tech fabric will be placed down first, and then a 6 inch aggregate base. Smaller riprap rocks will be placed over that, and the larger, heavier rocks will be placed on top up to roughly 1 meter from the ground. In the gaps that the larger rocks create, smaller rocks will be tightly placed to keep the riprap in place, and so we can place riprap on a higher slope.
7.0 Monitoring Approach

7.1 Current project monitoring
The dam reinforcements were all designed with sustainability of the system in mind. Everything from the initial decision to start with the dam reinforcements to the design of the riprap extending 8 meters downstream has taken sustainability of the structure, the river bed, and the community lifestyle into consideration. The buttresses provide strength to the structure to prevent overturning and sliding. They also provide a guide for the water from the spillway to prevent further erosion on the abutments on either side of the dam. The dam will be monitored on our next trip to the area for a ram pump improvement project by EWB-UMN in late spring or early summer. The community also has a responsibility to monitor several things about the health of the dam. Their upkeep includes:

1. Making sure sediment doesn’t build too high behind the dam.
2. Making sure the erosion doesn’t occur on the downstream sides of the dam.
3. Sealing cracks that occur.
4. Keeping the undercutting cracks sealed.
5. Upkeeping riprap as it settles or flows downstream after large storms.

It is our hope that the community takes the idea of a riprap design and uses it on their other dams to prevent erosion in other places.

8.0 Community Agreement
Ingenieros Sin Fronteras
División de la Universidad de Minnesota - las Ciudades Gemelas
Minneapolis, Minnesota

el 1 de agosto de 2013
APROMAC de Agua Caliente
Agua Caliente, Guatemala

Respecto a la adquisición, la implementación, la operación y el mantenimiento de la presa 3.

Este contrato es un acuerdo acerca de la adquisición para e implementación de la presa 3 y los requisitos de mantenimiento que se centran en la integridad de la estructura y su longevidad por lo más tiempo posible. Ingenieros Sin Fronteras y APROMAC asumirán las responsabilidades indicadas para la adquisición, implementación y el proceso del monitoreo.

APROMAC proveerá:

- 35 metros cúbicos de piedra
- 18 metros cúbicos de piedrin
- 5 metros cúbicos de arena
- El transporte de las materias primas
- 5 carretillas
- Las palas y otras herramientas para desplazamiento de tierras

Ingenieros Sin Fronteras proveerá:

- Los materiales para el encofrado
- El cemento
- Los materiales para el circunvalación
- La varilla
- El equipo de seguridad

APROMAC:

- Proveerá 20 trabajadores para echar la base (1 día), 10 trabajadores para cada día que echan el concreto (3 días) para los contrafuertes, 4 trabajadores para cada día del encofrado del curado del concreto (3 días), 10 trabajadores para cada día de trabajo en el enrocado (3 días).
- Adquirirá las materias primas para la reparación, las cuales incluyan la arena, piedrin y piedras y las trasladará al sitio de trabajo.
- Contribuirá por lo menos el 10% del costo para los materiales. Para estar incluida como parte del costo total, cada compra debe tener una factura, la cual debe estar proporcionada a los Ingenieros sin Fronteras. El costo de la arena y piedra no forma parte de la contribución del 10% pagada por APROMAC.
- Seguirá con la búsqueda de fuentes de financiamiento para las reparaciones y el mantenimiento futuro.

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- Seguirá con las llamadas mensuales a los Ingenieros Sin Fronteras acerca de las noticias y cambios en la comunidad.
- Seguirá con frecuencia el procedimiento proporcionado por los Ingenieros Sin Fronteras para mantener la presa y hacer las reparaciones.

Ingenieros Sin Fronteras:

- Proveerá 5 trabajadores cada día durante el proceso de la adquisición, y 8 trabajadores cada día durante el proceso de construcción de dos semanas.
- Proveerá materiales y pagar los costos resumidos el la pagina adjuntada.
- En el caso que la comunidad (la Presa 3 como una parte del APROMAC) no puede proveer los materiales los cuales incluyen la piedra, el piedrín, y la arena, y el transporte para los materiales, y si puede comprobar su inhabilidad, ISF-EEUU financiará hasta el 90% del costo directo de los materiales para este proyecto.
- Seguirá con la comunicación mensual con la comunidad para discutir el mantenimiento de la implementación de ISF-UMN y las preparaciones para la cooperación futura.
- Proveerá para la comunidad un plan de mantenimiento para la sostenibilidad y longevidad del sistema.
- Hará el monitoreo de la presa por los 5 años y se responsabiliza por la reparación de los defectos estructurales o de diseño.

Tanto los Ingenieros Sin Fronteras como APROMAC cumplirá con las citadas responsabilidades para evitar que se retrasa la construcción de la presa 3. Al momento de la construcción firmarán un acuerdo de monitoreo.

[Signatures]

Presidente de APROMAC

Líder Estudiantil de ISF UMN

Vice Presidente de APROMAC

Presa 3

Líder Profesional de ISF UMN
Regarding: The Acquisition, Implementation, Operation, and Maintenance of Dam 3.

This contract is an agreement on the acquisition and implementation of Dam 3 and the maintenance requirements that focus on the integrity and longevity of the structure for as long as possible. Engineers Without Borders and APROMAC will undertake the stated responsibilities for the acquisition, implementation, and monitoring process.

APROMAC will provide:

- 35 cubic meters of rock
- 18 cubic meters of gravel
- 5 cubic meters of sand
- Transportation for the raw materials
- 5 wheelbarrows
- Shovels and other earth moving tools

Engineers Without Borders will provide:

- Formwork materials
- Cement
- Bypass materials
- Rebar
- Safety materials

APROMAC will:

- Provide 20 laborers for the pouring of the base (1 day), 10 laborers for each pouring day (3 days) of the buttresses, 4 laborers for each curing/formwork day (3 days), 10 laborers on each riprap day (3 days).
- Acquire raw materials including sand, gravel, and rock and transport them to the work site.
- Contribute at least 10% of the material costs. Receipts must be provided to EWB for all purchases made in order for them to be included in total project costs and eligible for reimbursement. The cost of sand and rock does not count toward the 10% of material costs to be covered by APROMAC.
- Continue to pursue funding sources for future repairs and maintenance of the implemented EWB-UMN repairs.
• Continue having monthly contact with Engineers Without Borders about updates in the community, maintenance of the system, and future coordination with EWB-UMN.
• Regularly follow the monitoring procedure provided by Engineers Without Borders to preserve the dam and perform repairs.

Engineers Without Borders will:

• Provide 5 laborers each day of the acquisition process, and 8 laborers each day of the two week construction process.
• Provide and cover the cost of the materials outlined on the attached page.
• In the event that the community (Dam 3 as a part of APROMAC) cannot provide the raw materials of rock, gravel, and sand, and transportation of these materials, and can prove their monetary shortcoming, EWB-USA will fund up to 90% of total direct material cost for this project.
• Continue to maintain monthly contact with the community to discuss maintenance of the EWB-UMN implementation and preparations for future coordination.
• Provide the community with a maintenance plan for the sustainability and longevity of the system.
• Monitor the dam for 5 years and be responsible for repairing any damage directly resulting from design or structural flaws.

Both Engineers Without Borders and APROMAC will uphold their stated responsibilities or the construction of Dam 3 could be at risk delayed. At the time of construction a monitoring agreement will be signed.

[Signatures]
President of APROMAC
Vice President of APROMAC

Student Lead of EWB UMN
Professional Lead of EWB UMN

9.0 Photo Documentation
Members of the APROMAC reviewing the construction plans after a meeting

The streambed after the side was excavated to create room for the buttresses
The staging area for construction, located just above the dam

The original ground chute in place in the streambed, before the bypass chute was installed
Installing the water bypass chute

Placing the spillway structure of the water bypass system
Preparing the ground for the pouring of the base

Formwork and rebar in place for the base pour (before the water bypass failure)
The water bypass failure

The water bypass system back in place with the new ground chute
During the pouring of the base section

The base section poured and rebar in place for the buttresses
The first section of the buttress pours (the state of the project when we left)

Installing the formwork for the second buttress pour
10.0 Lessons Learned

As the first project to be implemented in Agua Caliente, there were many lessons that were learned. A document was created at the beginning of the trip and was added to throughout the implementation to record lessons learned or advice from any and all people involved. These have been organized into four categories: Travel, Construction-related, and Miscellaneous.

10.1 Lessons Learned Relating to Travel:
1. Don’t pack cardboard tubes of boxes in checked luggage. A box of oatmeal, pasta, and many boxes of nails were destroyed in transit and had to be sorted by hand.
2. Put all liquids in separate plastic bags when flying.
3. On travelers checks: I would recommend for EWB trips for the chapter, or someone on the travel team, to open a Schwab checking account, free- the ATM card that comes with it can be used in any ATM, anywhere in the world, no fees- and if the ATM itself charges you a fee, Schwab reimburses you. This is what I and a couple others have in Bolivia, and it works great. Someone on the travel team could get the cash advance, deposit most of it into this account, and withdraw as needed. Of course you'd have to double check that that's okay for one person to deposit it, but I don't see why it wouldn't be. (I guess someone would have to do that anyway for the Traveler's Checks.)
4. Oatmeal and pasta are cheap in Comalapa.
5. Feliciano’s house has mugs and other dinnerware. If it is not present you must ask for it.

10.2 Lessons Learned Relating to Construction:
1. To achieve passable quality sand for use in concrete mix, make stand-up structure out of two lumber A-frames and wire mesh to filter sand. During use, throw the sand against the mesh, and use the sand that comes out the other side.

2. At a minimum, double check all lumber order purchases with LWH and Feliciano, or any other purchaser.

3. Lumber comes in the exact dimension specified, and during the rainy season is incredibly wet. Therefore, a 2x4 measures 2”x4”; however, the cuts are usually very rough. To achieve better quality cuts, a person must be present with the lumber worker as they are cutting the pieces. Lumber is usually cut within a few days of the order.

4. The lumberyard receives pieces in 12’ sections, so they prefer to not cut 11’ pieces.

5. Feliciano has a kiln that can be used to dry and straighten the lumber once it is cut.

6. When working in the rainy season, be sure to buy plastic tarping before lumber is purchased.

7. Do as much lumber cutting at Feliciano’s as possible.

8. Prep all tools and materials the day before so that time is not wasted waiting around in the morning.

9. Go over the next days’ work with APROMAC workers at the end of every work day to minimize confusion.

10. A generator costs Q350 for one day and Q450 for two days.

11. Don’t leave tools outside overnight in any circumstance.

12. On future student chapter projects, if construction or installation of a structure is required, a licensed Structural Engineer should be present.

13. Use phillips head screws (or square head or star head screws) not nails or flat head.

14. Use self-tapping screws only.

10.3 Miscellaneous Lessons Learned:

1. Make sure that everyone knows all aspects of the build. It is tough when people leave early or come at a later date.

2. Detail all connections on drawings. If there is an assumption or addendum to the documents after the implementation is started, confirm that the team knows the addendum.

   Add a signature page to the HASP

### 11.0 Project Status

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### 12.0 Next Phase of the Program

The next phase of the program will be to implement an improved ram pump design in Agua Caliente. Currently, the ram pumps cannot reach all farmers who would like to be a part of APROMAC, and so with an improved ram pump design, pump technology can have a wider impact in the community, along with allowing existing pump owners greater pump range.
Rather than implement improvements to the approximately 130 existing pumps, we will bring down example valves with the suggested improvements and assist with the fabrication of several new pumps. This approach will allow us to explain, in detail, the new design, and help facilitate the transfer of information to the community.