Water Supply System for Irrigation of a 3 Hectare Community Garden
Kumudu Village, Ethiopia. Summer 2006
Engineers Without Borders USA – Princeton Chapter

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Background

Kumudu Village is one of the thirty-five villages in the Arsi Negelle District of Ethiopia; it is located at approximately 8 km of unpaved roads away from the main highway that runs 225 km south from the capital, Addis Ababa. The majority of villagers practice agriculture – the main crops being maize and cereal grains – and herd cattle and goats.

Engage Now Foundation (ENF), a registered NGO in Ethiopia, has established a half-hectare community garden in the village, on a sloping hillside of 25 meters above the river. Through the provision of seeds and fertilizers, ENF encourages the community to grow a larger variety of crops for consumption so as to improve the villagers' health with more nutrients. In addition, the surplus could also be sold for profit through an ENF-sponsored micro-enterprise program for the benefits of the entire community. This community garden has been so successful that another plot of similar size located 10 meters above the river was chosen as the site for the second community garden in August 2005.

ENF estimated that there is enough space and fertile soil for the community garden to expand up to a size of three to four hectares eventually. However, this is currently limited by inadequate irrigation. Every day, women would spend several hours going up and down a steep gorge of over 25 meters deep to collect water from the Huluka River using plastic containers. Some of the fetched water would be saved for family uses, and the remaining is then spread through sprinkler cans over the gardens. This amount of water is insufficient to cover the entire land, and thus the villagers are heavily dependent on rain water for irrigation. As a result, the gardens are usually left fallow during the dry seasons from September to April. A more efficient irrigation system to gather water from the Huluka River that flows all year round would therefore promises not only a sustained supply of nutrients and income for the village, but also more time for the women to attend to their families.

Panoramic view of the landscape near our campsite

The Original Plan


Villagers have to hike up and down this steep slope to fetch water. Our campsite is seen here at the top of the slope

The average household income of Kumudu Village is less than $20 USD per month and thus poses a financial constraint on the types of feasible water-fetching methods; any machinery that has to run on diesel, gasoline, etc. cannot be employed as the villagers could not afford to maintain it. A ram pump that is powered by water pressure alone on the perennial branch of the river at the bottom of the gorge close to the women's main water collection spot was proposed as an appropriate solution that could be sustained by the community both economically and technologically. The entire system would consist of a permanent dam that could hold enough water to produce the pressure needed to drive the ram pump, the ram pump itself, a pipe line that runs up the slope to an elevation of 25 meters, a storage tank that receives water from the supply line and distribution lines that spread from the tank to the gardens.

ENF contacted Engineers Without Borders USA (EWB) for volunteers to design and build the whole system except the distribution pipes which ENF would plan and lay after the completion of the other components, and it was decided that the Princeton Chapter would take up the task. An assessment trip was conducted during the spring break to survey the site, collect samples and meet various people (village elders, community workers, ENF officers, etc.) whom we would have to work closely with for the project. In order to reduce the cost of the system, we decided afterwards that the dam and the storage tank would be built out of masonry, keeping the use of comparatively expensive concrete to a minimum.

The actual implementation trip was from 3 June to 17 July – the first group of four, including myself, was dispatched in the first week to gather the necessary materials and set up the campsite; the remaining seven members, including a licensed professional engineer who graduated from Princeton, arrived on the second week. For the five coming weeks, the eleven of us camped in four tents, except for one day during the weekends when we went to the towns (Shashemene and Awasa) to restock our food supplies, take showers and recharge ourselves.

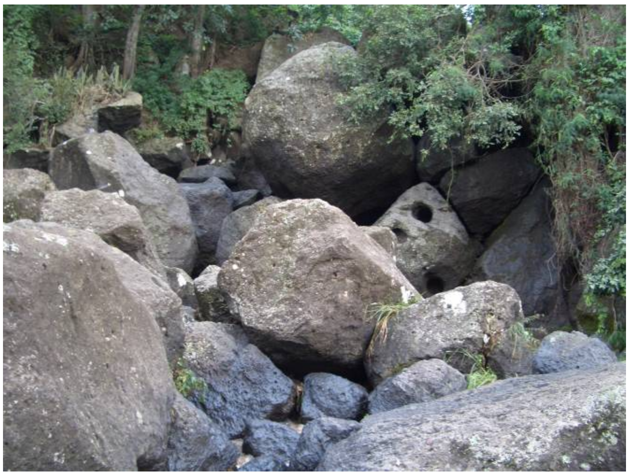
It was agreed that before the implementation, the community would have had channeled the flow of the river from the perennial branch where the permanent dam would be erected to a secondary branch that is dry even for long periods during the wet seasons; this would be achieved with the construction of a temporary diversion dam out of sandbags. Unfortunately, we were informed, without much detail, that two such attempts had failed before we left, bringing the first of a series of changes to our plans – the first group would also see to the completion of the diversion dam before the second group arrive.

Remains of the initial dams. Notice that the water level is quite low.

After several days of delays in getting our pump from the customs as well as placing the order for the pipes, the first group finally reached Kumudu Village on 7 June. The campsite we chose is located above the slope close to the dam site; the walk down takes only two minutes, but the hike back up takes considerably longer, especially when under the heat of the sun. I could easily understand how this system, when completed, would be a great help to the villagers who also have to carry containers full of water on the trips up. As we surveyed the remains of the previous dams, we thought that the remedy would be as simple as to widening the dam's base in addition to stacking up several more layers of sandbags than before. Work started at six the next morning, and with the help from over fifty villagers, the dam was close to completion by three when it started to drizzle, and we decided to finish the remaining work the next day.

The rain was not long or heavy at all over our working site, yet shortly after it stopped, we became the first foreigners ever to witness what the locals call "the river is coming." A waterfall poured down from behind boulders that are high up enough to be completely dry under normal flow. Water soon rose higher than our dam and went over it, dragging the sandbags down the river – the third diversion dam was breached. We were utterly speechless and shocked, and not knowing what better to do, we went back into our tent. We did, however, know one thing for sure – we would not give up just yet. Disappointed but not disheartened, we began to brainstorm ways to improve the dam as soon as we recovered. It was no more than two hours when we hiked down once again to check out the site. By then, the water level had totally died down; leaving no trace whatsoever of what had happened, save for those scattered sandbags downriver.

The river that "came," is actually a flash flood – a sudden and violent hydrologic response in a watershed (river basin) after a rain event. The scale of such responses is also largely dependable on the rainfall and characteristics (such as the area, slope, soil properties, etc.) of the entire watershed, which explains why the rain intensity at the dam site had not been considerably large that afternoon. As we stayed longer, we learned more about the flood – that it had in the past drowned unsuspecting children (two not long before we arrived) playing on the river banks since its coming was almost unforeseen; that there is a higher tendency for it to come if the rain is heavy upriver over the hills.



The wall of boulders at the back is dry normally.

Water gushing out from behind the boulders when "the river came" the first time

The boulders were totally out of sight when the "the river came" the second time

The modifications for the fourth diversion dam involve even more layers of sandbags and a wall of corrugated metal sheet (bottom cut to fit the shape of the bedrock) in the middle to reduce seepage through the sandbags, a major cause for failure in earthen dams. We began again on Monday morning, and in the evening, group two finally arrived. Even though we had the entire team by then, work continued until Friday since the new dam would be of a bigger scale than the previous one. By lunch, we were only one final row of sandbags away from finishing. It rained, not too heavily, when we were eating in the cooking tent.

In the beginning, I only heard lots of noises from the villagers; but as soon as I got out from the tent, I could hear the dreadful rumblings again – the river had come, this time bringing a much stronger flood than before.

Once again, the water had gone over the dam (which was already higher than the previous one), and in fact there was no sign of the dam at all, save for the two sheets of corrugated metal closest to the sides flapping under the rushing current. Like last time, the flood came and left quickly; within a couple of hours, the river had completely died down again, and there were not much of our fourth dam left to see. Our professional engineer alumnus commented that a permanent dam at that location seemed to be impossible and he would not have given the green light if we were informed about the flash flood beforehand.

The flood had gone way over the dam.

The fourth diversion dam before the flood. There were no less than 10 layers of sandbags, and it was several layers higher than the level of water held behind the dam.

The dam after the flood: most of the sandbags had been washed away and the metal sheets were misshaped.

The New Plan

With our efforts thwarted twice, we discussed about alternatives over the next two days, but there was a clear consensus right from the beginning that we would not be leaving empty-handed.

We took a short hike upstream along the river the next morning, hoping to gain some insights, and discovered a fairly accessible part of the river where the "flat land" is only a few meters above the water, but still over 50m (as later surveying showed) than where the storage tank would be. The idea of getting rid of the pump and dam completely and using a siphon system instead was thus proposed. A siphon is a pipe with two ends at different heights and high point(s) in between. When fully primed (a state when totally filled with water), water would be driven by hydraulic pressure from the higher end to the lower end over the high points. In our case, the intake end would be at the spot we discovered and the output would be at the storage tank. A couple of team members did a quick calculation to show that the highest point should be no more than 11m above the intake to prevent vaporization of water inside the pipe due to pressure difference.

Demonstrating how a siphon works to the villagers in a town meeting.

In the following week, our professional engineer alumnus Clay, Sean, Greg and I did lots of surveying to see whether a siphon could be feasible in the terrain while the rest of the team began work on the storage tank. It turned out that the highest point would only be ~8m above the intake. Encouraged by the news, we continued to locate two crucial spots (nicknamed "Little Boy Pass" and "Redman Shortcut") which would make the laying of pipes easier (in terms of shorter distance and lesser bends). Our final hesitations on whether we should move forward with a siphon were resolved when by total chance, some of us met a backhoe (a digging vehicle) on the main road during one of the town trips.They flagged the backhoe down, whose driver agreed to dig the trench for the pipes. The next day, three big prefabricated cement pipes were brought from the town of Shashemene which

The backhoe digging the trench for the pipeline.

we used innovatively for the headwall and cistern structures at the intake site. Even with the shortcuts we found, the siphon would still require over 800m of pipes in total (thus the need for a backhoe in the first place), much longer than what we had in supply for the original drive line from the pump. Therefore, Stehr and I were sent out on a four-hour drive to the capital once again to buy the extra pipes needed. Unfortunately, we were caught by a terrible storm as we left in the late evening and the truck was completely stuck in mud on its way out to the main highway. With no other options, we walked (or more accurately – slid) our way back to the campsite in the dark, getting totally drenched in the process. Nevertheless, we went back to the truck the next morning and, after getting stuck for several more times on the route that usually takes 20 minutes, managed to reached the highway 1.5 hours later, returning with the necessary materials the following night.

A stretch of pipes through "Little Boy Pass."

The first section of the cistern (a prefabricated cement pipe), fed by a 4" gravity-driven input pipeline at the intake site.

The completed intake structure with the ~3m hole in the ground backfilled. Only the headwall and the top section of the cistern are visible.

By then, we were into our fourth week of our six-week project (1st week: group one only, preparation and third dam; 2nd week: fourth dam; 3rd week: surveying and storage tank). Racing against time, we worked harder than ever over the remaining three weeks, successfully finishing both the intake structure and the storage tank, laying the pipes, backfilling the trench and putting down necessary erosion controls by lining up rocks. Unfortunately, we eventually ran out of time to put the system into operation. A siphon of such scale is more difficult to prime than we had expected and we lack the necessary tools (such as a plumber's snake) to remove the debris that might have settled behind the check valve at the exit of the cistern. Nevertheless, we have decided to spend the several coming months to research more thoroughly into siphons and acquire the tools we need, and return to Kumudu once again in December to complete the system as well as to assess on other projects – to be carried out next summer – that would further improve the lives of the villagers. ENF has also promised to look into the possibility of temporarily converting the storage tank into a rain collection tank, so that the community could still benefit from it before we are back

Foundation for the storage tank

Conclusion

While we were working in Kumudu, we often joked that we were part of the reality 24 show, facing unexpected obstacles almost every day. Personally, I believe that it was all the challenges which made the six weeks most beneficial to me. The first thing I learnt, after seeing "the river came," is the formidable power of Mother Nature. Although well aware of natural catastrophes happening around the world, I am lucky enough to have grown up in a relatively safe place; this was the first time I came face to face with nature's full force. Had we not gone back to the campsite for lunch when the flash flood came the second time, we could very likely be caught by the current, right in the river where we were working. I started to think more about the feelings of people who have to fight for survival every day and learnt to be more grateful for all that I am blessed with. At the same time, I now admire, even more than ever, engineers' determinations to overcome nature's obstacles and harness its powers. It came back to me during our transition from the dam and pump to the siphon that engineers are "problem solvers," that we have been trying to solve a problem – to bring water to the village – all along. Instead of being daunted by the failure of our dams, we had managed to turn and find a better solution – a siphon – for the same problem. All these have fortified my determination to become an engineer and engage in solving problems to improve the lives of others.

The completed masonry storage tank (with a temporary lid)

This wonderful experience would not be possible if not for many people. From the beginning, the community of Kumudu Village had welcomed and supported our presence. We managed to get along very well together; they even invited us to a wedding and acted as very good hosts. They had put total faith into us and were the ones who comforted us when dams failed; even though they heard that the siphon could not be completed during this summer, many of them still showed up to bid us farewell on the last day, believing in our promise to return and finish the job. On top of all, we could not have possibly accomplished what we had if not for their efforts – we were there during their growing season, but some of them were still willing to come and lend us a hand when they finished their work in the fields. In addition, our drivers, Deranjee and Esayase, also took the project to their hearts, giving us lots of help and advices and taking very good care of us whenever we were in town; all these they did beyond their responsibilities even though they have nothing to gain from the project (they do not live in the village). Finally, I would also like to express my gratitude to the Princeton International Internship Program, Class of 78 and Class of 95 for providing me with generous grants that made it possible for me to be part of this implementation team; it has been a very rewarding experience and is truly the most meaningful summer that I have had to date.

The team dancing with villagers during the wedding

A final football game just before we left Kumudu

The Kumdu project team in front of the tank