CLIMATE CHANGE & WATER SECURITY

IN TIMOR-LESTE

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Executive Summary

The 2013 Engineers Without Borders (EWB) Challenge was issued to students in partnership with Plan, Timor Leste. The challenge was to design an innovative and sustainable solution for the problem areas in Codo, a small village situated in the Lautem district of Timor Leste. The solution should benefit the people of Codo and increase the quality of life for the community.

There were seven suggested design areas: infrastructure, water supply and sanitation systems, energy, transportation, information communications technology, energy and climate change. This report focuses on climate change with a secondary focus on water supply.

Timor Leste is one of the countries most affected by climate change. It is predicted that within 50 years the area will be 1.5°C warmer and about 10% wetter (Molyneux *et al* 2012). As climate change effects worsen, the wet seasons experienced by Timor Leste will become more unpredictable and create more damage through the loss of crops and landslides caused by the monsoonal rains.

Taking this information into account the team decided to investigate water supply and crop protection in the area. After looking at five design options and evaluating them against four design criteria (cost, sustainability, environmental impact and community involvement) it was decided that the implementation of slope contouring would most benefit the community of Codo.

Slope contouring would greatly reduce sedimentation and the loss of fertile soils from the mountainous areas surrounding Codo. When combined with a dam to store water, the solution not only protects the crops but also provides water to be used in times of low rain or drought.

This report contains details about our design selection and development process as well as an overview of the implementation and the costs involved with the project. Overall the design is cheap and has few disadvantages for the area of Codo.

Team Reflection

It was felt that our main strength was cooperation and participation. Everybody in the group believed that the main objective of the EWB challenge is to improve the livelihoods of the people as Codo, but ensuring that this is done in a cooperative and client focused way. Communication for the team as a whole was managed via social media, where sections of the report could be uploaded and shared, or new ideas could be discussed. Text messages and phone calls were also used between individuals who were collaborating on one section of the report, to both discuss ideas and arrange meeting times.

As previously mentioned, the main strength of the group was a feeling of acceptance and that people would listen to each other. This meant that at group meetings everyone got a say and so the maximum number of inputs and ideas were discussed. A further strength of the group was that everyone came to the group initially with a sound knowledge of both Codo and their own design solution. This made selection of one final solution easier, as well as saving time due to the fact that most of the work was already done.

The team faced some difficulties, which mainly revolved around not being able to meet very often. Meetings were at the most once per week, which meant that piecing together the work that had been completed in between meetings was quite a large task. However, despite the infrequent meetings, the task could be completed due to delegating tasks to different group members. This meant that when the team did meet up, all the work was done and just had to be stitched together.

The EWB challenge taught the group a lot about the role of engineers, particularly since our solution is intended to be built by the locals. Through this task the group realised that communication between not only other members of the group, but also between the engineer and client is crucial to the success of the design. Furthermore, the group came to realise that not all engineering problems involve large corporations and multimillion-dollar contracts, instead engineering can often involve helping those who are less fortunate than us, for little or no payment from the client.

Overall it was felt as though the group did a good job, and certainly felt that the report and design is of a high standard. There is one thing that upon reflection would be changed if the task was to be done again, and that is creating an action plan from the start. Although the tasks were delegated to individuals to complete, it would have been more convenient and structured if the group knew which sections would be needed to be completed by what date before the due date.

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1.0 Introduction

Engineers Without Borders (EWB) is a communal based organization of people who provide inspiration and insight to combat poor quality living conditions, with appropriate technology. They identify problems in developing countries and present them to engineering students who consider possible solutions. To be an engineer, there are certain responsibilities and roles that need to be fulfilled. Helping those with poor living conditions and less fortunate circumstances is one of them. Engineers should be able to provide the tools, skills and knowledge needed.

1.1 Background Information

The small island of Timor Leste is located in South-East Asia, and has a central backbone made from a large mountain range, with peaks as high as 3000 m (Molyneux *et al*, 2012). Figure 1 shows that the village of Codo is located in the north west area of the district of Lautem. Codo is a small village established on steep terrain and is an "area punctuated by hills and mountains" (Engineers Without Borders, 2013c). A variety of agricultural climates have developed due to large peaks in the area as seen in Figure 2 (Plan, 2008).

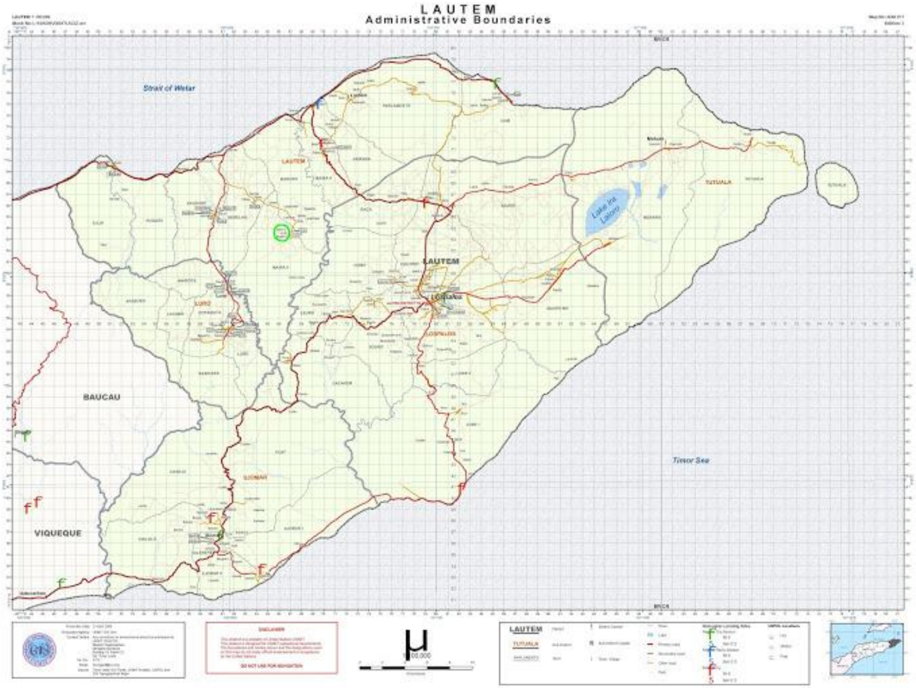

Figure 1: Shows the Lautem district of Timor Leste with Codo highlighted by a green circle. Photo courtesy of EWB.

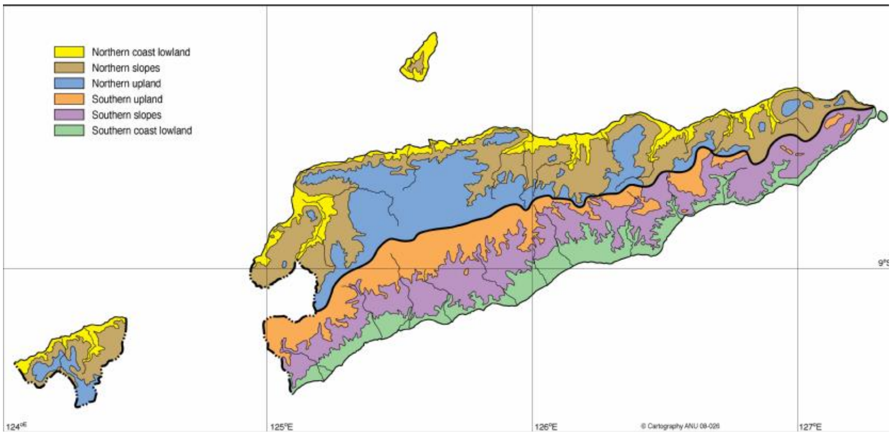

Figure 2: Agriculture climate zones of Timor-Leste (Plan, 2008)

Engineers should be able to utilize and take into consideration the ability of local's knowledge, otherwise, upon reflection; it may be found that the intended beneficiaries have not been served (Hollander *et al*, 2010). There are distinctive ethics and value systems that need to be considered to ensure the community has full cooperation and understanding. 'There is a powerful connection between individuals, communities, the environment, history and cultural traditions. Like many cultures in the region, Timorese people share a common set of beliefs and values linked to belonging to a certain place' (Engineers Without Borders, 2013b). 70% of the population reside in rural areas, and because of the cultural connotation, it is imperative to reflect design options that will not destroy any ethnic significance.

1.2 Purpose of the Report

The purpose of this report is to recognize the developing problems in Timor-Leste, and develop solutions to design areas where a solution is essential. The aim is to improve the quality of life of the locals, by being able to provide a reliable and adequate source of collecting and storing water which can be subsequently used during times of low rainfall to reduce the loss of crops and vital food sources. Hollander *et al* (2010) examined the importance of knowing "technical, environmental, social, political, cultural, ethical" influences to be able to implement strategies successfully, for countries in need of help. In summation, the report aims to investigate these contributing factors in order to find successful solution to help Timor Leste cope with issues they cannot handle such as the on-going climate change.

2.0 Problem Definition

The climate in Timor Leste is currently defined as temperate with a short wet season where copious amounts of rainfall occur. However this is changing as stated in a study by Tol (2011) who says "Timor Leste is hurt most by climate change on average across the 20th century". Another study, by Molyneux *et al* (2012), predicts the country will "become about 1.5°C warmer and about 10% wetter by 2050". Codo is located on the southern slopes where the wet season lasts around four months with an excessive amount of 300mm per month, as depicted in Figure 3.

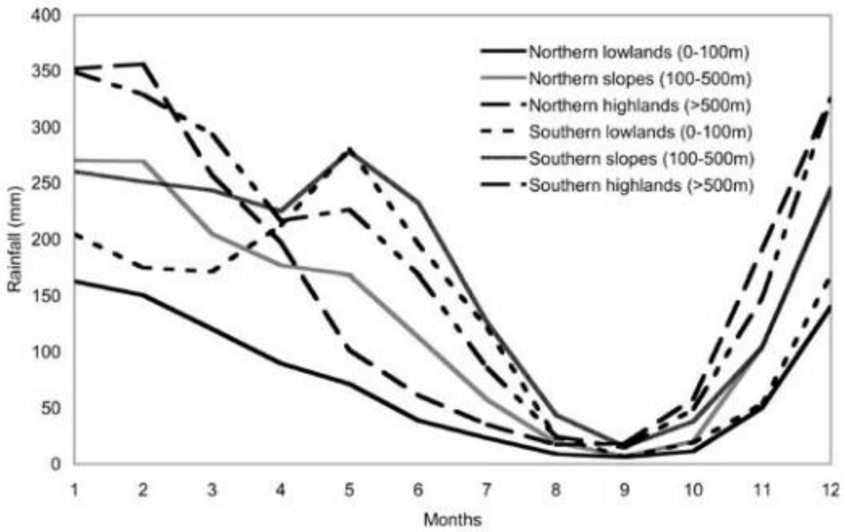

Figure 3: The rain cycles for key districts in Timor Leste, (Barnett *et al*, 2007, pp.374)

Figure 4 portrays Codo's soil composition, formally known as *ustalf* meaning it is reasonably fertile. However the soil has a high clay content (Soil Survey Staff, 1999). Codo is located on the Eastern side of the country where the terrain is steep. Due to these features of Codo, large sums of the fertile topsoil are washed from the mountains. This is problematic as it causes:

- Crops to fail
- Pollution of water
- Landslips

Furthermore, if the climatic predictions prove to be correct, it "may exacerbate East Timor's existing problems with drought, floods, and water quality" (Barnett *et al*, 2007). The procuring of safe drinking water will not only be difficult in today's climate, but will become more challenging in the future.

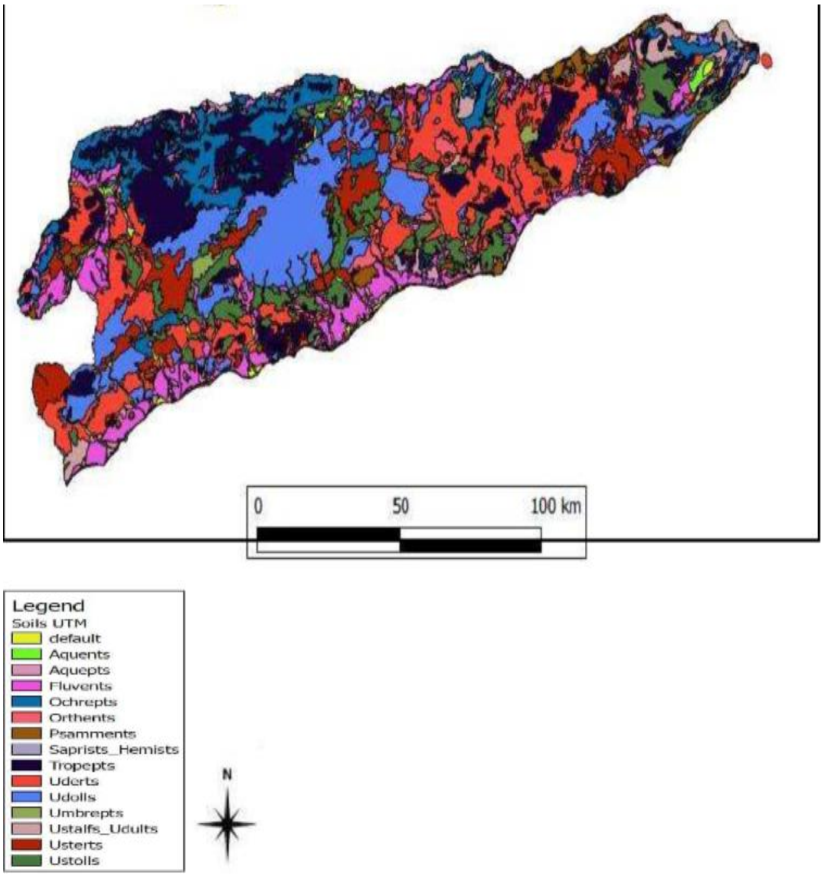

Figure 4: Shows the soil composition for Timor Leste, (Soil Survey Staff, 1999)

Despite Lautem's current stable food stores, the district "shows food shortage for the highest amount of months indicating that mobility of food, transport infrastructure and markets all require further growth" (Engineers Without Borders, 2013a). Kumaresan *et al* (2011) states that the World Health Organisation (WHO) discovered that the change in climate has health related outcomes including:

- Crop failure
- Diarrheal disease
- Malaria
- Flooding

Other natural disasters that Timor Leste suffers from include mudslides, drought, and pest outbreaks. These disasters have led to decreases in crop production of up to 50% in the Lautem district (Plan, 2008). Correspondingly, lack of "access to safe drinking water and sanitation undermines labour productivity" (Plan, 2008).

The on-going climate change outcome will decrease the availability of water and food for Timor Leste villagers. Despite water being accessible to the people of Codo, the sources are likely to be predisposed to impurities and contamination. As stated previously the heavy rainfall can cause the water pipes to erode due to the surrounding soils, exposing them to harmful components. Additionally unclean storage containers are a source of microbial contamination. Thus 'bottled water is often purchased as it is faster than filtering or purifying water to drink' (Engineers Without Borders, 2013d).

As climate change is not sustainable at a local level, design solutions that can improve the access to water and reduce the loss of crops will assist in recuperating the quality of life for the people of Timor-Leste.

The cultural and social aspects of the designs need to be deliberated in the future resolution as 'There is also cultural significance attached to the spring – people from other communities don't usually go into the area where the spring is' (Engineers Without Borders, 2013d).

2.1 Key Considerations

2.1.1 Social

It is important to recognise social boundaries and barriers. A large percentage of the locals are illiterate (Plan, 2008), which will complicate the process in educating the locals on how to maintain the design solution.

There is only one tap in the village of Codo, which is connected to a pipe that is regularly damaged. It is critical to be able to recognise this issue, and overcome language barriers through ways such as diagrams for the locals to be able to follow.

2.1.2 Environmental

The surrounding environment and instability of the climate need to be considered immensely. The washing away of soils causing erosion needs to be prevented and is taken into account in the design solution. In addition, the tropical and humid climate conditions, mountainous ranges and torrential rains causes floods and landslides, which need to be considered.

2.1.3 Cultural

Cultural beliefs may have an immense impact if the design is to be successfully implemented in the community. Some land has cultural significance, and the designs will need to be approved by locals.

2.1.4 Economic

The people of Codo have a low-income population (Plan, 2008). They do not have sufficient funds to be able to improve their quality of living. Therefore the design solution needs to be reasonably cost effective, in order for the locals to be able to maintain it.

3.0 Design Assessment Criteria

3.1 Cost

As Timor Leste is a third world country, it suffers from financial difficulties. Cost will be a significant factor when evaluating design options as the solutions must be affordable for the community in the long term. In particular, the initial costs and the cost of any maintenance required afterwards should be considered when selecting the proposed solution. An affordable solution would be seen to be best fit for the community of East Timor (Engineers Without Borders, 2013e).

3.2 Sustainability

When selecting the solution, its sustainability should be examined. It should be able to perform efficiently in the future with little maintenance. Ideally, the chosen solution should aim to be built with minimal reliance on any environmentally dangerous or non-renewable resources as well as allow the community to maintain the solution themselves. Therefore, educating the people of East Timor on maintenance would provide more success (Asia Development Bank, 2005).

3.3 Environmental Impacts

The environmental impact is an element that should be considered when selecting a design as the lower the impact, the more likely problems are to be avoided. On the other hand, the existence of climate change in East Timor results in an unstable environment, thus, a negative impact on the environment could possibly worsen some of the effects of climate change (Asia Development Bank, 2009).

3.4 Community Involvement

As stated by Ramaswami in Hollander *et al* (2008), the local community's knowledge is a key component in the success of any project. If society's knowledge is absent from the design implementation, the sustainability of the result will not be met. The design is intended to benefit the community as they are, after all, the ones to apply and sustain the design. Therefore, it is important for the community to be involved from the outset of the design implementation and to be capable of maintaining the solution themselves.

4.0 Design Options

4.1 Slow Sand Filter

This system is described in the publication by da Silva (2007). Unlike other filtration methods, slow sand filters (seen in Figure 5) use a biological film that grows naturally in the top 10 cm of the sand. This method requires no pressure or electricity for operation. Cleaning is usually accomplished by use of a mechanical scraper, which is driven into the bed once it has dried out. Multiple systems are required to give a constant supply of water whilst one is being cleaned. The simple design and use of common materials such, as sand and gravel as a filter medium, makes this method very useful for Codo as the materials can be found locally, and requires no particular skill to construct.

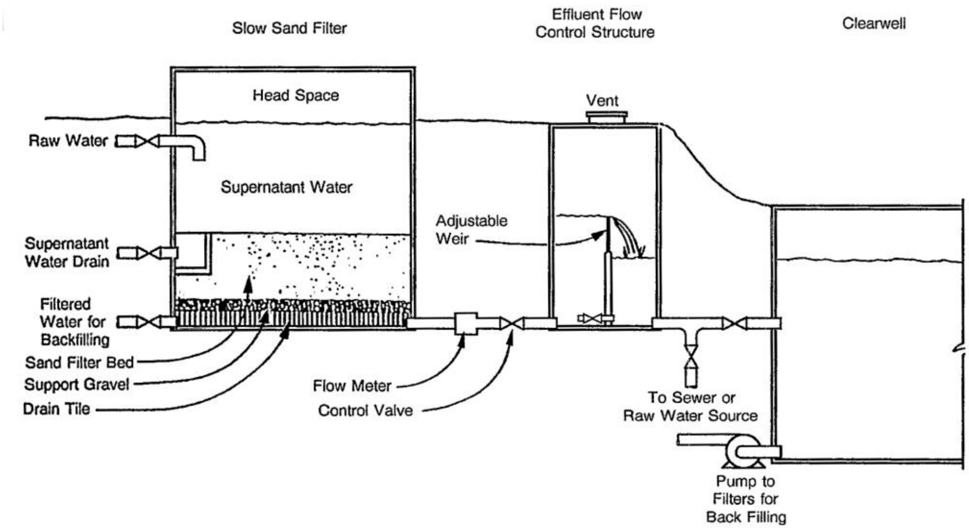

Figure 5: Schematic diagram of the slow sand filter (Da Silva, 2007)

4.1.1 Evaluation

Table 1: Evaluation of the slow sand filter against the design criteria

Criteria	Justification	Score /10
Cost	The materials required are cheap but would need to be transported from the coast, thus transport will be the main cost as labour can be done by the village itself.	6
Sustainability	Once installed the only maintenance required is stirring once every 6 months.	9
Environmental Impact	The impact will depend on its location however it can cover a relatively large area which Codo does not have.	4
Community Involvement	The community would be heavily involved throughout implementation as well as the maintenance.	8
Total		27/40

4.2 SONO™ Filter

The SONO™ filter is a two-stage pour-collect filtration system as seen in Figure 6. The top bucket is comprised of an arsenic-scavenging composite-iron matrix (CIM) sandwiched between two layers of sand (Hussam *et al,* 2008). The bottom bucket is comprised of sand and a charcoal filter, which disinfects the water of residual iron and further contaminations that may have drained from the first bucket. Contaminated groundwater is filtered through the sand while the CIM, charcoal and brick chips work to remove toxins (Smithsonian Cooper-Hewitt, National Design Museum, 2011).

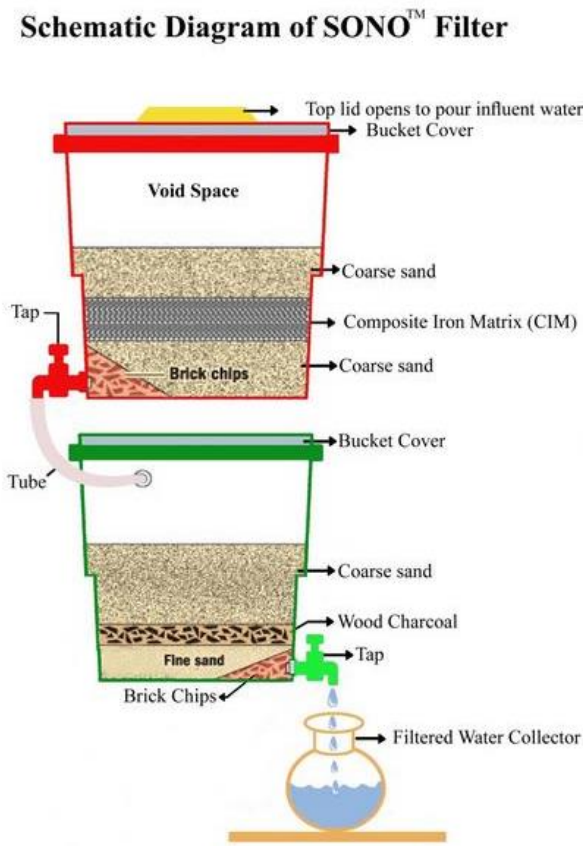

Figure 6: Schematic diagram of the SONO**™** filter (Smithsonian Cooper-Hewitt, National Design Museum, 2011)

4.2.1 Evaluation

Table 2: Evaluation of the SONO™ sand filter against the design criteria

Criteria	Justification	Score /10
Cost	The initial cost is relatively cheap and operating the filter is costs no more than $10 a year, since they do not require consumables or chemicals.	7
Sustainability	There is no need for maintenance for at least 12 months, and the setup does not need any special skills. However the filter only last around 5 years before needing replacement.	6
Environmental Impact	All materials are natural however waste removed during maintenance may be harmful to the environment	6
Community Involvement	Since it is easily maintained; the locals can involve themselves in the process of maintaining it.	8
Total		27/40

4.3 Water Recycling System

A variety of different filtration techniques could be used together to form a system resulting in safe water for use by the community as suggested by Stewart *et al* (2013). The system could include such filters as sand and charcoal filters or a variety of chemical filters. Water from domestic uses could be collected and placed through this system to obtain water suitable for use on gardens and other such purposes. The system would involve some chemicals to help remove impurities as well as charcoal and sand filters. Alternatively, the system could be connected to a rain collecting system and tank. Due to the relatively pure quality of this water it could be filtered and used as clean drinking water.

4.3.1 Evaluation

Table 3: Evaluation of the water recycling system against the design criteria

Criteria	Justification	Score /10
Cost	The establishment cost of some parts of the system would be costly and although the chemicals used may be cheap to purchase, on-going costs would quickly add up.	6
Sustainability	There is a requirement for filters to be replaced and chemicals continually added however these are relatively small maintenance requirements.	7
Environmental Impact	By the time any chemicals were replaced they would be inactive and would most likely cause no impact.	7
Community Involvement	There would be little community involvement required except for the on-going maintenance required.	6
Total		26/40

4.4 Slope Contouring

Slope contouring is the process of adding small ridges to a slope, which block the water flowing down the hill and direct the water into a central channel. Slope contours will be specifically planned for the individual slope, since they have to follow the natural contours of the slope at regular intervals. Once the water pools on the upper face of the contour it can then flow into a central channel which can then direct the water into a larger storage facility. Contour banks have a number of secondary benefits, one of which is the entrapment of sedimentation in both the crops and on the upper face of the contour. Slope contouring is a process which is extensively utilised in Australia; this is mostly because Australia has dry hard soils, with a high clay content, a characteristic which is shared with Codo.

4.4.1 Evaluation

Table 4: Evaluation of contouring against the design criteria

Criteria	Justification	Score
Cost	Monetary costs would be low since all materials are sources locally.	9
Sustainability	Uses local dirt for construction increasing the option's sustainability. Seeds used for farming can be annually renewed at harvest.	8
Environmental impacts	Environmental impacts are hard to gauge. The biggest impact on the environment will be the redirecting of water into more stable channels, as well as reducing sedimentation.	7
Community Involvement	Ideally the first field with contouring would be constructed with help from an outside source to teach the community how to build slope contours, however after that it would be the community's job to expand and maintain their fields with their new knowledge.	8
Total		32/40

4.5 *Fanya Juu* Terracing and Cut Off Drainage

Fanya juu terracing has been successful in the Kenyan district of Machakos (United Nations Environment Programme Division of Technology, Industry and Economics, 2013). Drains are placed in an hilly area subject to widespread sedimentation. Over time the sediment will be deposited in the drainage area and create terraces. Figure 7 shows the initial land profile and the final developed terraces. Cut off drains can be used in conjunction with the terraces to safe guard them against surplus rainfall. These drains would redirect the water to a central collection point. The stored water could then be used at a later date when there has been no rain for a long period.

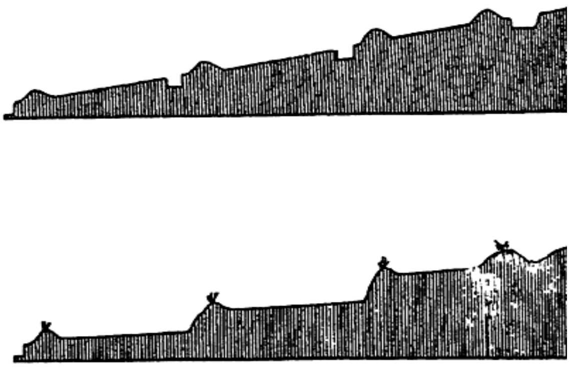

Figure 7: Initial and final profiles of *Fanya juu* terraces (United Nations Environment Programme Division of Technology, Industry and Economics, 2013)

4.5.1 Evaluation

Table 5: Evaluation of *Fanya juu* terracing against the design criteria

Criteria	Justification	Score /10
Cost	Cost effective technology but the requirement of labour in order to implement this technology is great	9
Sustainability	Due to the sedimentation process this option may require a lot of on-going maintenance, but at low costs	6
Environmental Impact	The system would remove excess sedimentation from the environment, but cuttings could have an adverse effect.	7
Community Involvement	Due to the large amount of manual labour required for establishment, this option would require a large community involvement	8
Total		30/40

4.6 Design Selection

Table 6: Summary of the design options and their evaluations

	Cost /10	Sustainability /10	Environmental Impact /10	Community Involvement /10	Total /40
Slow sand filter	6	9	4	8	27
SONO filter	7	6	6	8	27
Recycling system	6	7	7	6	26
Slope Contouring	9	8	7	8	32
***Fanya juu* terraces**	9	6	7	8	30

Although all options scored relatively well, it can be seen from table 6 that slope contouring was the best scored design option, followed by terracing and drains. This is primarily because they are the lowest cost options because they mainly require labour rather than materials. Compared to other options these could also result in a larger amount of water being collected while protecting the crops in the Codo area.

In a practical sense, these two options are very similar and so offer very similar benefits. It was decided that the solution should include both options; slope contouring principles will be employed in the operation and collection of the water, while terracing principles will be employed in the construction of the contours. Through this approach, the system will both contour the slope to reduce erosion, and create secure waterways to divert water to a collection point.

5.0 Slope Contouring

Slope contouring is a process used around the world in agricultural areas to reduce the flow rate of water down a hillside, hence reducing top soil loss and sedimentation. The implementation of slope contouring in Codo has several possible benefits. For example, according to the Queensland Department of Natural Resources and Mines (2004), proper slope contouring can collect up to 80% of the soil sedimentation that would otherwise flow down the slope. This means that less of the fertile upper soil will be lost to downhill locations, as well as reducing the risk of landslips due to unstable soil. Another possible benefit from slope contouring is the increase in fertile and workable land for farming. With permanent water ways and the collecting of fertile soil on contour banks, slopes that were once unstable and useless can now be utilised for farming to increase food and cash output. The effectiveness of slope contouring will be increased by the planting of crops on the intermittent land, as well as planting crops in the waterways. Furthermore, this can be maximised by growing cover crops on the land, since these plants have tight root systems which stabilise the land, as well as growing close together to collect sediment.

5.1 How It Works

The basic principle of slope contouring is to add small upwards slopes spaced along the hillside. A typical contour cross section can be seen in figure 8.

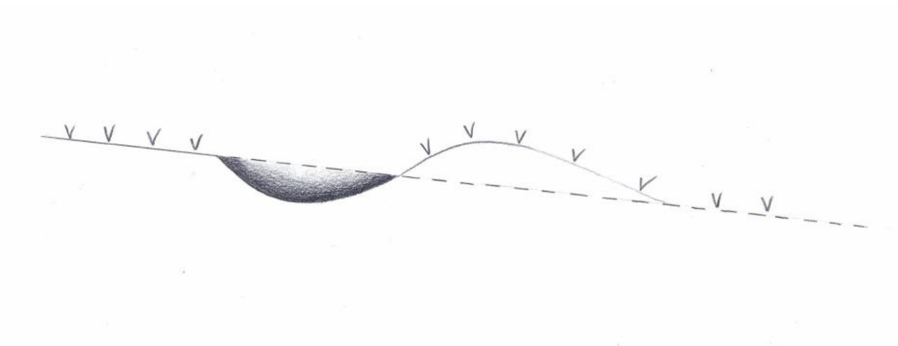

Figure 8: Typical contour cross section (drawn by Krystal Thuy Tran).

Depending on the slope gradient, soil composition and weather pattern, the construction of contours must be carefully considered to maximise the water collected and minimise damage and hence maintenance. As Table 7 shows, the spacing of slope contouring is directly proportional to the slope gradient. Since Codo is dominated by steep slopes, from the table it can be concluded that the average spacing of the contours is likely to be 3m vertically and 30m horizontally. Single spacing has been chosen for this project because of its durability, meaning once the contours are set up they will require approximately half the maintenance of double spaced contours, the only negative being that the contours will take longer to establish since there are more of them.

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Table 7: Recommended contour slopes (Queensland Department of Natural Resources and Mines 2004)

Average land slope (%)	Single spacing		Double spacing	
	Vertical Interval (VI) (metres)	Horizontal Interval (HI) (metres)	Vertical Interval (VI) (metres)	Horizontal Interval (HI) (metres)
1	0.9	90	1.8	180
2	1.2	60	2.4	120
3	1.5	45	3.0	90
4	1.6	40	3.2	80
5	1.8	36	3.6	72
6	1.9	32	3.8	64
7	2.1	30	4.2	60
8	2.4	30	4.8	60
9	2.7	30	5.4	60
10	3.0	30	6.0	60

After contours are established, one thing that must be considered is how the water will be controlled after collecting in the troughs. This will require an irrigation system/channel system which will take the water downstream in a controlled manner. These channels can either be small and regular or larger and less regular, depending on the needs of the individual slope. For this project, larger channels will be required due to the torrential nature of the rain in Codo, as well as to make the directing of the water towards collection easier. The specific configuration of the channels is something which is hard to predict without further analysis of the gradients of the slope in question, however some general solutions are given below.

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Two further additions must be added to the waterways to increase stability. The first is the overall gradient of the waterways. The lower the gradient for the waterways the better, in this case, since the purpose of the channels is to reduce erosion. Gradients of 10% would not be suitable for waterways, so instead of the waterways heading directly downhill, they will need to run diagonally down the hill. This will cause the water to flow a greater distance to go down the same height, meaning the gradient will be lower and hence the overall velocity will be reduced. This could be achieved by one of two methods. Design one would have the main artery waterway run down one side of the field, while both horizontal and diagonal veins flow into it as seen in Figure 9. Design two would have two main artery waterways flowing diagonally down the slope in a 'V' shape, with the horizontal contour waterways flowing into these as seen in Figure 10. As previously stated, of these two it is hard to decide without knowledge of the specific slope it will be utilised on, however it can be shown that the former layout would require greater work to setup and the latter would be a simpler, faster design to implement.

The second important component of the waterways is the addition of stubble in the channels to further slow the water and increase the stability of the soil. Tough, close growing grass can be used for this purpose, however a better option would be to use the crop which is already growing in the fields to stabilise the waterways further. Growing stubble in the waterways has a duel effect: the stalks and low foliage of the plant slow the water down while the roots of the stubble stabilise the soil in the waterway to ensure little sedimentation occurs.

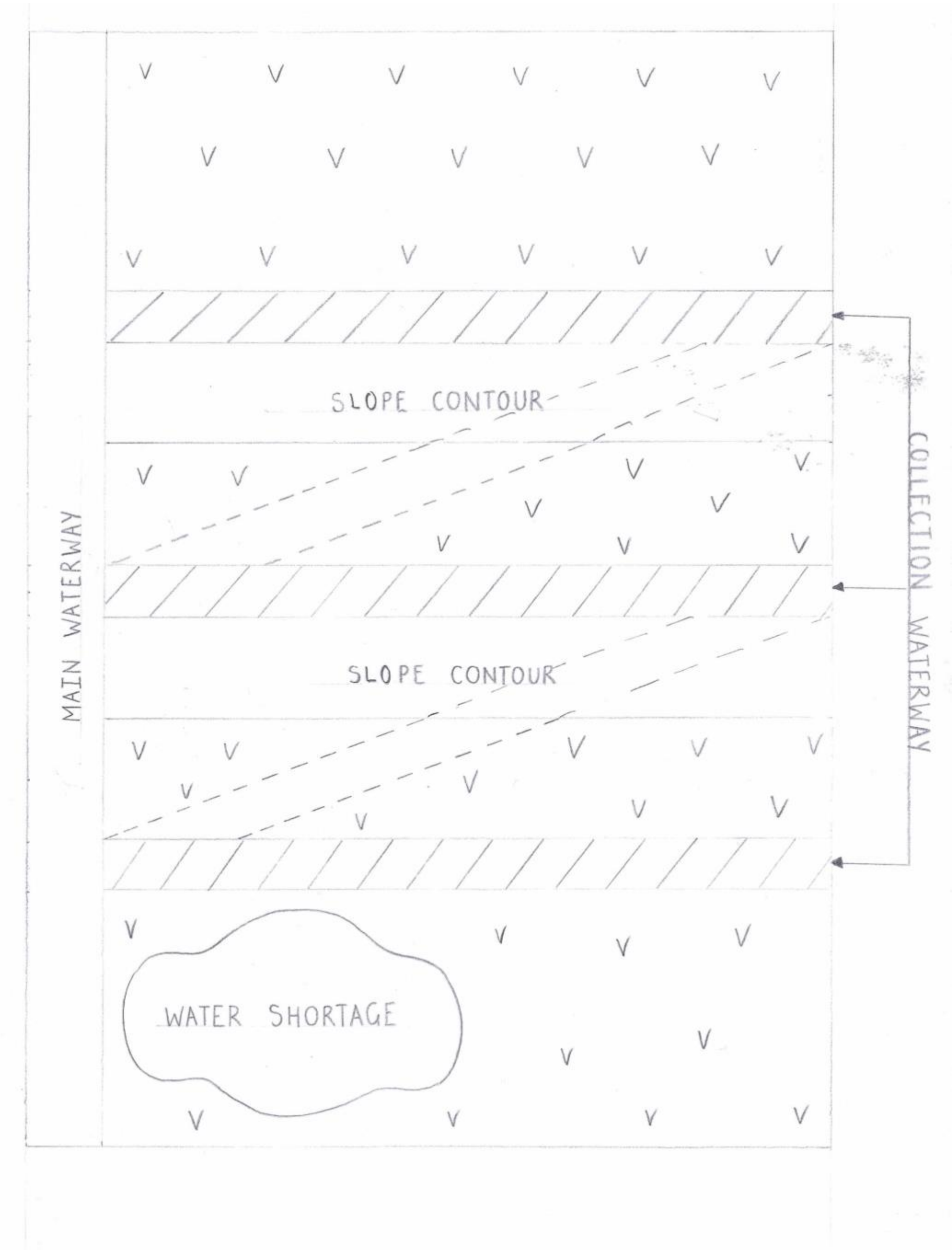

Figure 9: Design one diagram – side channels (drawn by Krystal Thuy Tran)

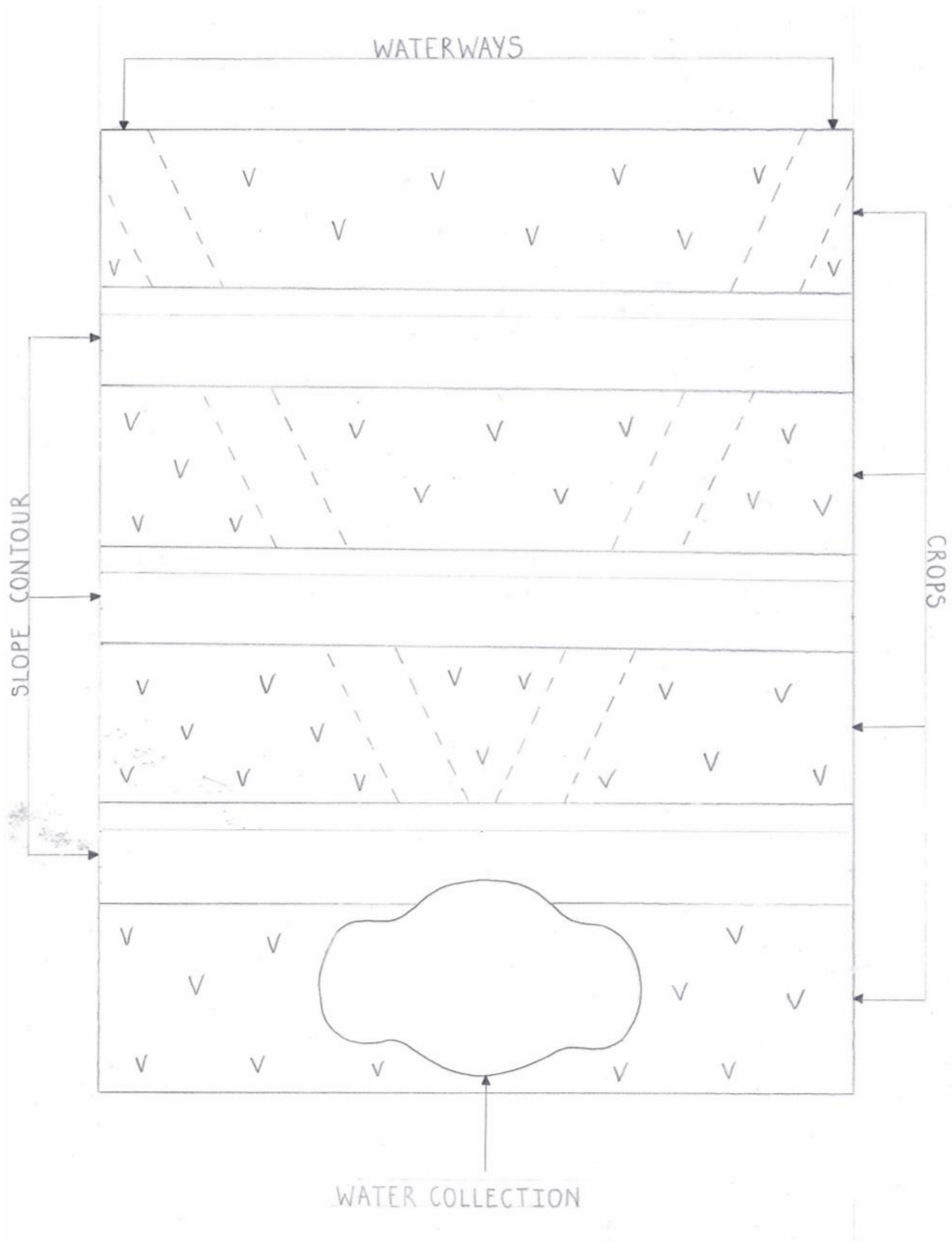

Figure 10: Design two diagram – V channels (drawn by Krystal Thuy Tran)

The final component of the design solution is the addition of cover crops to the system. Cover crops are a particular group of crops that are used when soil is unstable, suffers from water loss due to evaporation and/or weeds are an issue and need to be controlled. By nature, cover crops have thick foliage, grow closely together and have strong root systems. According to the Victorian Department of Environment and Primary Industries (2013), the two main types of cover crops are cereal and legume plants: “Cereals and grasses have an extensive, fibrous root system that adds more organic matter and biopores (soil pores created by roots) than legumes. Cereal crops are easier to establish and are less prone to insect attack than medics” (Victorian Department of Primary Industries, 2013). Furthermore, according to the Seeds of Life 2012 annual report (Seeds of Life, 2012), cereal crops are the normal crop for communities in the higher altitude areas of Timor Leste. From these two sources it was decided that a cereal crop would be sown on the fields, and subject to success of the initial crop, will also be planted in the waterways for erosion control.

This flowchart summarises the system that is to be implemented in Codo:

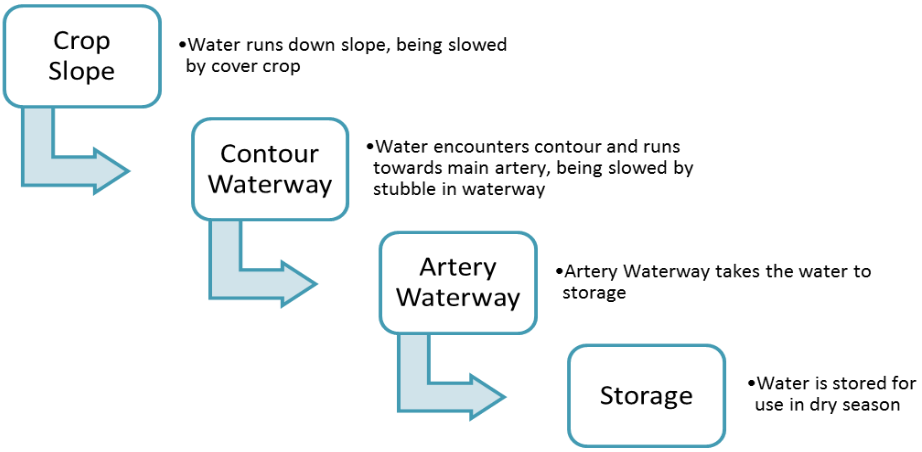

Figure 11: Flowchart summarising the contouring system (created by Paul Benson)

5.2 Implementation

The first task which must be accomplished is the successful explanation to the locals of Codo as to what the design is and how it will benefit them. Since they are the ones who will build, use and maintain the design, it is crucial that the first thing that is achieved is their support in the matter.

After the locals have been consulted and an appropriate time for construction is arranged around their schedule, a location must be chosen. The location around the village is important for a number of reasons. Firstly, the slope which the design is constructed on has to be in the range of 8-12 degrees. Secondly, the slope must also be close enough to the village so that the locals can easily tend to the crops and also collect water from the storage dam.

The storage dam will be located at the bottom of the hill, ideally located in a gully to reduce the amount of work needed to store the water. The process for building a farm dam is provided by The Australian Office of Environment and Heritage (1997):

1. Mark out the location of the dam carefully, detailing where the main wall will be and where the waterways from the slope will meet the dam.
2. Clear the vegetation and ensure that no large trees are near the dam wall as they can damage it.
3. Remove topsoil and stockpile for later use.
4. Dig a trench approximately 30cm deep where the damn wall will be. The trench will prevent water from seeping out from under the dam.
5. The wall of the dam will then be built first in the trench and then slowly upwards with layers of clay excavated from the dam site.
6. Do not place large objects such as rocks and logs in the dam wall as they can cause leakage.
7. Rock exposed on the bottom of the dam should be covered with clay to avoid seepage into the ground.
8. After the dam is constructed, any damaged land near the dam should be covered in topsoil from the stockpile and then planted with grass to stabilise the soil.
9. Dig a small channel in the dam wall to allow excess water to flow out and down the gully, this will minimise damage to the main dam wall.
10. The dam wall should be at least 1 metre higher than expected max water level.

Next the slope contours will be formed; this will ideally be done shortly before the wet season, to ensure they are formed promptly. A trench of approximately 600mm wide by 600mm deep will be dug along the contour where the lower edge of the contour is intended to be. The soil excavated is to be deposited in mounds uphill of the trench. These trenches will capture eroded soil and along with the pile of excavated soil, they will form contoured hills after a period of time.

After the contours are formed, waterways will have to be dug promptly to ensure that water collected on the upper face of the contour will be drawn away from the contours, rather than pooling and then spilling over the lip of the contour, causing damage. These waterways will be positioned so that they can flow into the storage dam at the bottom of the slope.

Once all the permanent structure fixtures are in place, the crops and stubble can be planted on the field, on the contour, around the dam and in the waterways, completing the build.

It should be noted that although the main phase of the design is over, a large portion would be left for the locals to build later. The hope is that in the construction and subsequent benefits of the initial design, the locals will see the value in the design and will continue to operate it and expand upon it, with their new knowledge on land management, water collection and crop management.

5.3 Cost

This design was intended to be a low cost option, which can be continued and built upon by the locals well after EWB has left. As such, all the materials for the actual build are sourced locally in the form of excavated soil. The main cost will come from the price of tools and labour.

For the first field and construction of the dam, outside help will be needed to aid the locals in both the labour, but also in teaching and instructing on the best way to build the contours and dam. On the assumption that this labour can be sourced by humanitarians and volunteers, the only cost will come from the equipment needed to both excavate and transport the soil. Costing for such equipment is difficult to source from Timor Leste; however estimates can be taken from Australian stores. Such estimates are listed in Table 8.

Table 8: Estimated costs

Item	Individual Cost	Number Needed	Total Cost
Shovel	$5.00	20	$100
Pick and hoe	$30	5	$150
Wheelbarrow	$50	3	$150
Seeds/fertilizer/labour*	$163.25/acre	5^	$816.25
Total			$1216.25

***Based on prices sourced from Ontario Ministry of Agriculture, Food and Rural Affairs (2013).**
^based on a slope length of 100m (i.e. 3 slope contours) and 200m wide

This table is a very rough estimate and is based on the cost of construction and operation in Australia, less machinery. The prices for the table are estimated as a full year of production of 5 acres of land, as well as factoring in the cost of construction for the initial slope contours and dam. If the retail price of the barley produced is considered, than the number is not that unrealistic, since the field will be produce approximately 1.51 tonnes/hectare. This equates to 3 tonnes for one yield for the size field proposed. Further deductions from this high price can come from the cost of living in Australia compared to the cost of living in Timor Leste, where in Australia a wheelbarrow costs $50, in Timor Leste it may be more than half that price. Further, labour is factored into the price per acre of the field, another deduction can be made here since the people of Codo mostly harvest for personal use and do not utilise outside labour with harvests.

Another consideration which must be taken into account is whether or not the people of Codo need these tools, since they may already possess many of them. If this were the case than the cost would be dramatically reduced. Even if the tools were purchased for this project, they can be utilised in the future, either by EWB or left with the people of Codo to help them to maintain and expand the field.

5.4 Solution Evaluation

Table 9 shows the overall advantages of the slope contouring design. It can be seen that the design has many advantages mainly related to increased output for crops. The main disadvantage of this solution is the high labour requirements, which may be a problem if the community is not willing to give their time during implementation. It is expected, however, that as the solution is designed to help the people of Codo they will be willing to be involved.

Table 9: Advantages and disadvantages of slope contouring design

Advantage	Disadvantages
• **Cost effect** • **Long term sustainability** • **Increase in crop yield expected** • **Decrease in soil erosion including important fertile soils** • **Reduce risk of landslides** • **Increased workable and fertile land** • **Simple design which can easily be replicated or modified to suit different environments.**	• High labour requirements • Periodical maintenance required

The solution also met out four design criteria: cost, sustainability, environmental impact and community involvement.

The cost criteria was met due to the fact that the design requires a lot of labour orientated tasks which with the help of the local volunteering organisation, the EWB and the local community will decrease the cost barrier.

The design is largely sustainable because seeds used for farming can be annually renewed at harvest and the design solution as a whole will last for a long period of time. However due to the fact that "around 44% of Timor-Leste may have a slope of approximately 40%, which, combined with heavy rainfall, encourages soil erosion" (EWB, 2013c) the design solution needs periodical maintenance.

Slope contouring has little environmental impact, mainly due to the land clearing required to construct the contours and dam. However, the design reduces erosion and hopefully will also reduce the area's reliance on slash/burn harvesting which is a positive impact on the environment.

The local community's background in farming falls in line with our design solution which will help with the development of the solution implementation. This community involvement and that of the community hopefully providing the labour to construct the contours and dam will ensure that this is a successful solution.

6.0 Conclusion

After exploring many different design solutions slope contouring stood out as the most relevant and required solution to the people of Codo. This design solution aims to reduce the damage of agricultural land as a result of the torrential wet season. By using slope contouring on the agricultural land water flow will be slowed thus eliminating problems such as soil sedimentation and degradation. This water will be then channelled to a storage tank for reuse during the dry season.

This solution was also chosen because of its cost effectiveness and its sustainability, given that the requirements for building and maintenance can be found within the village itself. It benefits the environment by the slowing down and collection of monsoonal rainfall thus giving the surrounding area better soil quality and promoting plant growth.

This project will give the community increased independence and because of their role in the building and maintenance they will understand how it works and might be able to reproduce this concept in other areas of their lives.

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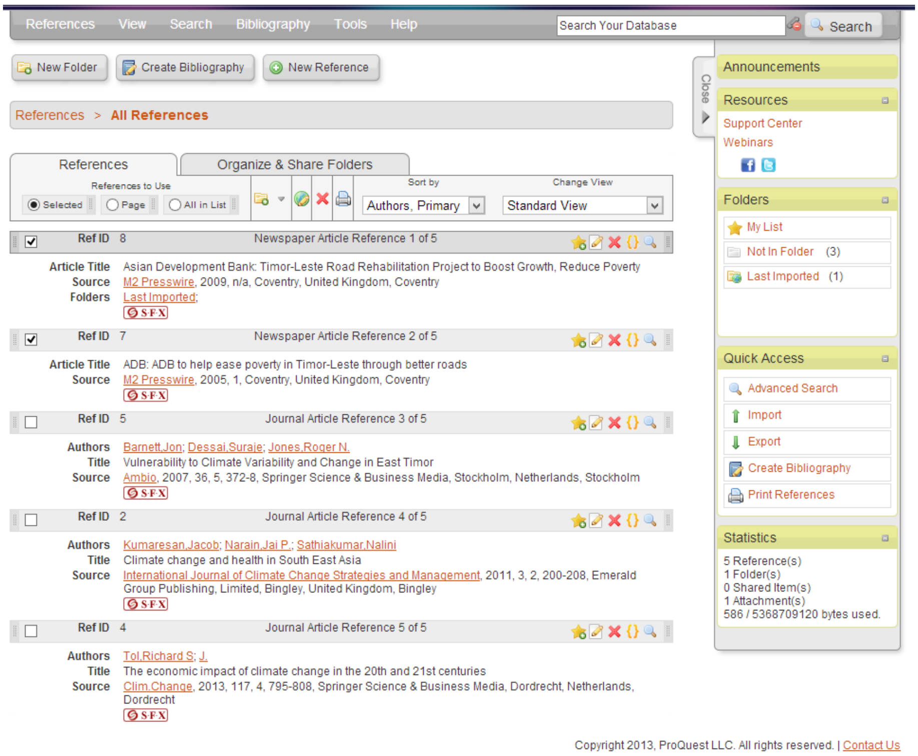
Appendices

Evidence of using REFWORKS



Minutes of Meetings attached