

# An intervention study to gain insight on sustainable water supply strategies in El Progreso, Panama

a Multidisciplinary Project in the Colón Province

S.M.J. Kleijn, S.A. Visser, V.C. Vollaers, J.C. Wiggins and J.P.J. van Wijngaarden

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**An intervention study to gain insight on sustainable water supply  
strategies in El Progreso, Panama**

Report for a Multidisciplinary Project in the Colón Province

by

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in partial fulfilment of the requirements for the degree of  
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An electronic version of the final report will be made available at  
<http://repository.tudelft.nl/>.

## Preface

This project was originally planned in the North Caribbean Coast Autonomous Region (part of La Mosquitia) of Nicaragua. Due to the recent outburst of violence throughout the country, following the local unstable political situation, a new location for the project had to be found. After a thorough search El Progreso was found, a small village on the northern coast of Panama. It is mostly inhabited by indigenous Emberá which reached out for help on their drinking water issues.

This multidisciplinary study is conducted by four students studying different master programs within the Civil Engineering faculty. Jeroen is following the Construction Management and Engineering master. Swaen, Joris and Vita are Water Management students. Swaen en Joris follow the Water Resources Engineering track and Vita the Urban Water Engineering track.

Besides of the research part three people helped to make this project a success. Bram Engelaar is an art student and joined this project as photographer and documentary filmmaker. All photos within this report are made by Bram. Sarah Kleijn is a Building Engineering master student en helped with construction and Lise van Leeuwen helped with the construction and public relations throughout the project.

Panama City, October 2018



Figure 1: Left to right: Sarah Klein, Swaen Visser, Vita Vollaers, Jeroen van Wijngaarden, Joris Wiggins, Lise van Leeuwen and Bram Engelaar

# 1 Acknowledgements

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Furthermore, we want to express our gratitude for the essential and indispensable help we received from de Gevulde Waterkruik, its founder Paul Akkerman and coordinator Sadjaliu Djalo. This help included learning practical building skills during a training in Guilege, Guinea-Bissau (2016) and sharing their extended knowledge and experience, gained during 12 years of working on rain water harvesting solutions in Guinea-Bissau.

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## Summary

Access to safe water and sanitation are essential to human health. In Panama, poverty and a lack of access to water and sanitation are an ongoing concern in rural areas. This project aims to provide safe drinking water for 80 members of the Emberá tribe in El Progreso (Colon Province, Panama) within 8 weeks. Rainwater harvesting (RWH) has shown to be a suitable solution and the ferrocement ‘Calabash’ tank (design adopted from de Gevulde Waterkruik) is chosen to be constructed, but more insight in water supply strategies and their impact is necessary. The quality of construction and charity projects is up for debate and will also be examined. This resulted in a research goal “Building a RWH system to gain insight in sustainable water supply strategies and identify the effect on the quality and quantity of the water and the project quality by means of an intervention study carried out in El Progreso, Panama” and research question “How does providing households with a Calabash tank impact the community, the quality and quantity of the drinking water in El Progreso and what is the project quality of constructing a Calabash tank”.

The impact study is divided in a pre-study, construction phase study and post study. In these studies, the project quality is examined through stakeholder management, requirements management and quality management using interviews and inspections as a main source. The water assessment examines both water quality (indicators and treatment) and quantity (river flow velocity, rainfall and usage) using in situ measurement equipment and interviews as a main source.

During the pre-study a stakeholder analysis and a plan for quality management was made, requirements were mapped and a first water assessment was made. The stakeholder analysis showed that for such a small charity project the actor field is positive and simple, so only engaging resources is important, due to the remoteness. The requirements management was done afterwards and showed that it is extremely difficult to discuss requirements of the past and is biased by what is offered. The water assessment revealed that the school part of the village relies on an aqueduct for their water supply and the other part on the Culebra river, although both also have various other lower capacity systems. Most villagers do not treat their water, although they do sometimes get sick and mentioned several contaminants to be present. About half of the village has a latrine or flushing toilet at their disposal.

During the construction phase study the project quality was monitored and project control lessons learned were registered. Quality assurance focused on training, auditing and inspection and an FMEA. It showed that for a significant impact on project quality, training requires more structure and much preparation. Auditing requires a translator and much time during the construction phase and therefore a full-time quality manager. This lack of capacity did however not cause many problems. The lessons learned are that more front-end loading using a pre-study is necessary to improve efficiency and positive impact. The construction phase showed to be a phase where the interactions between the local people and the project team provided mutual respect and helped the engagement of the local people in the project due to activities such as providing food during construction, getting sand together and working hard when necessary, even on Saturdays and Sundays. Even though most of the people had the same preference of the location of the tank (close to the kitchen), other requirements were very diverse and scattered and not solely focused on improving their water source.

During the post-study, the water assessment and requirements analysis are performed a second time and the quality control phase is established, mainly through interviews and in-field measurements. In addition the Universidad Tecnological de Panama (UTP) analysed chemical and biological indicators for water quality as well as concrete strength. First education and water seemed to be their main requirements, where at the end it became sanitation and electricity. Their opinion however seems to be impacted by what the project team has to offer. Therefore no solid conclusions can be made on the requirements of the tank owners and whether water was indeed their main

requirement. Quality control showed that concrete structures can rely heavily on quality control instead of assurance, as they either fail right away or are of sufficient quality. Unfortunately, the water tightness and wall thickness could not be accurately measured. The water quality analysis concluded that the river and groundwater do not meet the Panamanian Drinking water standards and can pose serious health risks. The pH of the water within the ferrocement tank lays between 9-11, which is unusually high and exceeds standards set by Panamanian water standards. All other requirements set by the standards are met by the water within the RWH tanks. It can also be concluded that temperature of the water within the tank rises during the day by approximately 1°C. Finally it can be seen that fresh rainwater dilutes the water and lowers the TDS and EC of the water. The highest measured EC is  $832 \mu S/cm^2$ .

Finally, it can be said that this project has led to various additional social impacts in the village of El Progreso such as: improvements around the household with leftover concrete, job opportunities, training in construction skills, a long-distance romantic relationship and connecting the village to an existing network for aid on various issues.

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## 2 Introduction

This intervention study provides rainwater harvesting systems to households of a small village situated in a rural area of Panama. This introduction will give an overview of the situation regarding water and sanitation worldwide, Panama in general and in an indigenous Panamanian community specifically, followed by a possible way in which these problems can be addressed.

### 2.1 Water and sanitation worldwide

Access to safe water and sanitation are essential to human health. In July 2010 it was recognised as a human right by the United Nations General Assembly. In 2015, over 90 percent of the world's population used improved drinking water sources and over two thirds of the world's population used improved sanitation facilities. In both cases, people without access live predominantly in rural areas (United Nations Development Programme, 2016). Still, worldwide 2.1 billion people lack access to safely managed drinking water services and 4.5 billion people lack safely managed sanitation services (*Progress on Drinking Water, Sanitation and Hygiene Update and SDG Baselines* 2017).

### 2.2 Rural Panama: lack of services

Even though Panama has been one of the fastest growing economies worldwide over the past decade (7.2 percent average annual growth) and poverty reduction is in progress, poverty still dominates in rural areas. The Ministry of Health of Panama acknowledges the fact that rural and peri-urban areas remain largely unserved (The World Bank Water and Sanitation Program, 2013). Particularly in the indigenous territories, the comarcas<sup>1</sup>, poverty and extreme poverty numbers are alarmingly high, above 70 percent and 40 percent respectively (The World Bank Group, 2016). According to the United Nations Development Program, 37.3% of the population in Panama lives below the poverty line (United Nations Development Programme, 2016).

Lack of services in the comarcas are an ongoing concern, particularly access to water and sanitation. Drinking water supplies are vulnerable and a lack of safe drinking water can inhibit the development of the area. The main focus of this project is to gain insight on feasible sustainable water supply strategies in rural areas inhabited by indigenous tribes. This is done by conducting an intervention study in a small village called El Progreso in the province of Colon, on Panama's Caribbean coast. The project aims to provide safe drinking water for 80 members from the Emberá tribe, living in El Progreso. The Emberá tribe is one of the three largest indigenous groups in Panama.

### 2.3 Project location: El Progreso

El Progreso is located in the Colon region, quite literally at the end of the road going east from the city of Colon, about 70 kilometres from the city. It is situated a couple of kilometres inland of the Caribbean coast, in the remains of the Panamanian rain forest. The village consists of approximately 20 houses and around 80 inhabitants. Most of the inhabitants belong to the Emberá tribe. Part of the village has a gravitational fed river water system to its disposal, others carry water from nearby streams and rivers.

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<sup>1</sup>Comarca: A Spanish subdivision of a province, but in Panama the term is used for three Indian territories that have the formal status of a Panamanian province. There are two more Indian territories that are often named comarca, but which officially do not have the formal status of being a province on its own

## 2.4 Rainwater harvesting as a solution

Water and sanitation are an essential prerequisite to economic development (Hunter, MacDonald, and Carter, 2010). In El Progreso rainwater can be harvested when running off roofs of houses and communal buildings. Previous studies (WHO/UNICEF Joint Water Supply and Sanitation Monitoring Programme, 2004; Thomas and Martinson, 2007) have shown that rainwater harvesting tanks are a suitable drinking water supply in areas as the one under consideration. When building tanks using local labour and local material, rather than buying prefabricated ready to install tanks, the construction of the storage tanks can stimulate local entrepreneurship and create employment opportunities (Stockholm International Water Institute, 2004). In this way, this project can set a first step towards a sustainable local business and lasting employment opportunities. This can eventually result in a long term development in the area around El Progreso.

The ferrocement storage tanks <sup>2</sup> of the rainwater harvesting systems built during this project are so called Calabash tanks. The Calabash tank is an, over 12 years of practice, optimised design, originating from Guinea-Bissau. During its optimisation process the design has had different names, depending on its origin, form or history. A field report (Hartung and Akkerman, 2014) shows appreciating for the tanks as source of clean drinking water. At the time of this field survey the Balanta tank was the newest design, built with a mould on the inside. The Calabash tank with its spherical bottom form only became possible from 2015 onwards, after experimenting with a mould on the outside of the tank. The design of the Calabash tank is adopted as object to be built for this intervention study. It is chosen because of the ease of the construction method, possibilities to adapt the design to local circumstances and use of solely local available building materials.

## 2.5 Quality of charity projects

Construction projects in general often show a lack in project quality, that is the degree to which a set of inherent characteristics fulfil requirements (International Organization for Standardization, 2000), especially when planned without consulting end-users and executed at a remote, foreign location by a team who is inexperienced in construction. These are characteristics of charity projects, which are therefore sometimes accompanied by doubts about the effectiveness of their projects. It is therefore important to try to improve the quality of this construction charity project to make it successful.

## 2.6 Scope of this project

This project is based upon a specific request for help in drinking water supply for a remote village, inhabited by indigenous people. As such, most of the funds were acquired. Most of the funds came with specific requirements, such as that the final product of this project must be a physical end product, and the collaboration with the NGO meant that the local community should be involved throughout the whole project. Given these problems and requests, the project will try to gain insight in sustainable water supply strategies, both from a water and a project quality perspective, and the impact of these strategies on El Progreso. The research goal is therefore formulated as follows: 'Building a rainwater harvesting (RWH) system to gain insight in sustainable water supply strategies and identify the effect on the quality and quantity of the water and the project quality by means of an intervention study carried out in El Progreso, Panama'. To successfully reach the goal of this research the following research question must be answered: "How does providing houses with a Calabash tank impact the community, the quality and quantity of the drinking water in El Progreso and what is the project quality of constructing a Calabash tank?"

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<sup>2</sup>Ferrocement tank: a building method for concrete tanks reinforced with chicken mesh, often used as a simple, low-cost water storage tank

The project consist of two main research fields: water management and project management. Regarding water management the project examines the quality and quantity of available water sources in the area (rain, ground and surface water) and the quality of the water in the Calabash tank. Regarding project management the project examines project control on construction of the tanks in El Progreso and project quality of the tanks. After eight weeks of research and construction, the water storage tanks will be delivered, to use by the individual families at each house.

## **2.7 Structure of the report**

Chapter 3 describes background information on Panama and gives a geographical and a meteorological description of the country. Also the Emberá culture is shortly explained. Chapter 4 consists of a literature study encompassing project control, project quality management and rain-water harvesting. In chapter 5 an overview is given of used materials and research methods followed. Pre-study (chapter 6), Construction phase (chapter 7) and Post study (chapter 8) together form the results section. They are followed by the Conclusion (chapter 9), Discussion (chapter 10) and Recommendations (chapter 11).

### 3 Background information Panama

In this chapter the general information about the geography and meteorology of Panama will be described.

#### 3.1 Geographical description

Panama is located on the northern hemisphere in the inter-tropical zone near the terrestrial equator. Panama is formed by a strip of narrow land oriented from East to West, lined by shores along the Caribbean Sea and the Pacific Ocean. It's latitude ranges from 7°11' to 9°39' North and it's longitude ranges from 77°10' to 83°03' West. Panama is neighbored by Colombia to the East and Costa Rica to the West.

#### Major water bodies

Panama consists for 119 billion m<sup>3</sup> of water stored in 52 watersheds, divided by more than 500 rivers. The major rivers are the rivers Tuira (which drains most of the Darién region), Chagres (which drains a watershed of 326,000 ha), San Pablo and Chepo river. The river Chagres is dammed at two locations: Gatun and Alajuela. The first dam creates a lake for the Panama Canal, named Lake Gatun (43,000 ha), and the second dam forms Lake Alajuela which is used for hydroelectric power and as water storage. The Chepo river has been dammed to create Lake Bayano, which is also used for hydroelectric power. These three created lakes are the largest lakes in Panama, indicated in blue in figure 2.

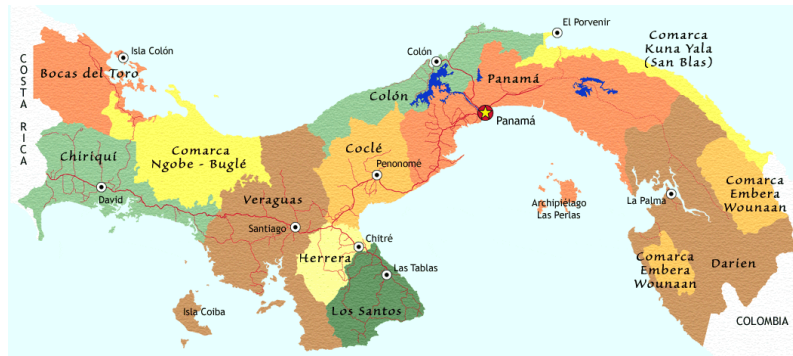


Figure 2: Overview of different provinces and comarcas in Panama, major water bodies are indicated in blue (Central Intelligence Agency Panama, 2012)

#### 3.2 Meteorological description

The Northeast trade winds originate from the semi-permanent anticyclone of the North Atlantic and noticeably affects the weather conditions in Panama. These trade winds reach the country through the lower layers of the atmosphere and have a strong influence on the weather conditions. Moreover, Panama is in the top 5 highest amount of precipitation in the world (Embassy of the Kingdom of the Netherlands in Panama and Ministry of Foreign Affairs, 2018).

#### Rainfall regime by region

**Pacific region** This region is characterised by abundant rainfall, of intensity between moderate to strong, accompanied by lightning that occurs especially in the afternoon. The rainy season

starts in May and lasts until November, with heaviest rainfall in September and October. The driest months within this season are July and August. The period between December and April is known as the dry season. The highest rainfall in this region is generally associated with depressions, tropical storms and hurricanes as well as with the Inter-tropical Convergence Zone (Hidrometeorologica de ETESA, n.d.[a]).

**Central Region** In this region, rains generally occur after midday, caused by the predominant flows from the Caribbean or the Pacific. They are moderate to heavy rain showers, accompanied by lightning and strong winds. This region is the continental zone of the country, so thermal and orographic characteristics dictate the climate (Hidrometeorologica de ETESA, n.d.[a]).

**Atlantic Region** In this region it rains almost all year round. December and February is the period with highest amount of precipitation. The period from January until March is driest. Most rain events are caused by frontal systems of the northern hemisphere towards the tropical latitudes. The rest of the year, the rains are associated with the tropical atmospheric systems that move over the Caribbean Basin, the sea breeze and the diurnal heating of the earth's surface (Hidrometeorologica de ETESA, n.d.[a]).

Long-term average annual precipitation for Panama as a whole is 2,928 mm (Food and Agriculture Organization of the United Nations, 2017).

### 3.3 Water institutions in Panama

Panama's water supply and sanitation is organised in the following institutions:

- Ministry of Health (MINSA) is responsible for policies in the water and sanitation sector
- The national water and sanitation company (IDAAN) is responsible for services in urban areas
- Rural Water Management Boards (JAARs) are responsible for drinking water services in rural areas

### 3.4 Emberá culture

In Panama 7.1% of the population consists of indigenous people (The World Bank, 2008). There are eight indigenous groups: Bokota, Emberá, Guaymi, Guna, Ngöbe-Buglé, Talamanca, Teribe and Wounaan. These indigenous groups have their own legislations and geographical regions called comarcas in which the majority of these groups live, as can be seen in figure 2.

The majority of the Emberá group lives in the Comarca Emberá Wounaan, which is situated in a preserved nature area in the province of Darien. Not all Emberá live in this region and neither do the inhabitants of El Progreso, which lies in the Colon province. Traditionally the Emberá live from agriculture, hunting and fishing, but due to the fact that they live in a region that has been announced as preserved nature, they are restricted in their daily activities. Therefore, they have adapted their way of living into working in tourism instead.

In the Emberá culture, the people believe that God has made all the water and they pray to the mother of water *Antomia*. Because it is a gift from God, the water they use is not treated but taken directly from the rain or river (Anneth Forero, 2013).

Women in the Emberá community have a more equal status in their society than other indigenous groups. They can own property and work in the fields. In addition, they are well respected and are included in making the important decisions (Hassig and Quek, 2007).

## 4 Literature study

This literature review focuses on the main topics of this intervention study: project control and project quality management of charity projects, methods used in project quality management and rainwater harvesting as chosen solution for this research project. Also sanitation and especially sanitation in Panama will be discussed. In general, the amount of cases of diarrhoea is used as a one of the measures to determine the quality of drinking water. Causes of diarrhoea are linked to both quality of drinking water as well as to hygiene and sanitation. First, research on the actual state and effectiveness of charity projects will be discussed, followed by various research on methods that can help improve the quality of such projects.

### 4.1 Project control and project quality management

This section discusses state and effectiveness of charity projects and development aid. Various research debates the effectiveness of aid. Bain et al. for example found no detectable effect of aid on progress in their research on the role of aid on universal access to drinking water (Bain, Luyendijk, and Bartram, 2013). This urges a need to evaluate and improve the quality, which is backed up by Renard who argues that a new paradigm in development aid requests better evaluation of aid policies and verification of their effectiveness (Renard, 2006). However, not all work is positive about trying to improve aid effectiveness. White (H. White, 2014) for example has criticised what he calls "fancy results-based approaches that do not work in practice". He does however not reject the approach of evaluating the effectiveness of aid but argues that it can be more effective and realistic. It is also indicated by Kusek, Rist, and E. M. White (2005) that constructing result based measurement and evaluation systems for Millennium Development Goals is very difficult in low-income countries. But, even if the effectiveness is evaluated, what can then be done to improve the quality of such projects? Killick found in his research on ineffectiveness of aid in Sub-Saharan Africa that one of the four reasons of this ineffectiveness are weaknesses in aid-donor agencies. Suggestions for improvement are better ex post evaluation and improved learning processes (Killick, 1991). So, research has shown that the effect of development aid is doubtful and evaluating and improving its efficiency is difficult, but at the same time crucial. The next paragraphs will therefore study literature on improving aid projects in regard to two more specific fields: project control and project quality. The general outline of the paragraphs will be that first literature on the importance of the field for efficiency of projects in general is discussed and then there is discussed whether there is already literature on the importance of the field for charity projects.

#### 4.1.1 Project control

This paragraph will first review literature on failed project control in aid projects and then zooms in on literature discussing ways to improve this. Frimpong examined causes of delay and cost overruns in construction of groundwater projects in developing countries and concluded that effective controlling and monitoring should be established to enhance project performance (Frimpong, Oluwoye, and Crawford, 2003). This raises the question how effective controlling can be reached, which is answered by Rozeness. He performed a literature review on project control and named the analysis of project failure as a possible way to identify project control measures Rozenes, Vitner, and Spraget (2006). So, the analysis of project failures and gathering lessons learned will be used to improve project performance. But has research on project control lessons learned for aid projects not been performed before? Although there is extensive research done on project control lessons learned, such as Zhang (2005), Sanvido et al. (1992), Kog et al. (1999), Pinto and Slevin (1987) and even on less developed and less western locations as by Okpala in Nicaragua (Okpala and Aniekwu, 1988), no work has been found focusing specifically on development aid. And as shown in the previous



paragraph, extensive research is also done on the performance of charity work, but not specifically on lessons learned for charity construction work.

#### **4.1.2 Project quality**

Trying to improve the effectiveness of charity projects does not only mean improving project control, but can also include improving the project quality. The following paragraphs will therefore review literature that suggest various ways of improving project quality. This literature is divided over three research fields which might help improve project quality: stakeholder management, requirements management and project quality management. First, however, a definition of quality will be given: according to Nicholas and Steyn (2012), quality implies meeting specifications and requirements, but ideally aims beyond this and tries to delight the client.

##### **4.1.2.1 Stakeholder management**

This paragraph will first discuss literature on the importance of stakeholder management for various projects and then show a method for stakeholder management. A more recent study from Bryson (John M Bryson, 2004) argues that stakeholder analyses have always been important and backs this up with the findings from Nutt (Nutt, 2002). Nutt analysed 400 decisions from which half failed, which was largely due to a lack of keeping stakeholders interests in mind. Older studies from Bryson et al (John M. Bryson, Bromiley, and Yoon Soo Jung, 1990), Bryson and Bromiley (John M. Bryson and Bromiley, 1993), Burby (Burby, 2003) and Margerum (Margerum, 2002) showed similar results in respect to the effect of stakeholder analyses on decisions. Especially for natural resources, as river water and rain water, and economic development it shows that no one is fully in charge and no one fully contains the problem (Kettl, 2002). So, literature has shown that stakeholder management might help to improve quality of projects in general, but not specifically for aid projects. This report will therefore examine whether stakeholder management has a positive influence on the quality of a charity project and in which way. “Policy Analysis for Multi-Actor Systems” by Enserink and Hermans (2010) e.a. is used as a basis for the stakeholder analysis.

##### **4.1.2.2 Requirements management**

This paragraph will again discuss the importance of requirements management for projects in general and thereafter for charity projects. According to the PMI several studies showed that requirements management improves projects and day-to-day business by reducing cost and decreasing time (Coventry, 2015). Companies using poor requirements practices reported that a project of \$3 million will be on budget less than 20% of the time and the costs will on average increase to \$5.87 (IAG Consulting, 2009). Of the top five reasons for project fails, three are requirements related: (1) users are not involved enough in requirements definition, (2) requirements are incomplete or do not meet acceptance criteria and (3) requirements are constantly changing, and these changes are not managed effectively (CHAOS report, 2004). No research has been found on the effect of requirements management on project quality. This report will therefore examine whether basic requirements management also has a positive influence on the quality of a charity project.

##### **4.1.2.3 Project quality management**

This paragraph will discuss literature regarding the effect of quality management on project quality in general and afterwards regarding the effect on quality of charity projects in specific. First, however, the difference between quality and requirements management for this report will shortly be discussed. As quality management does not only imply an absence of defects, but also fitness for purpose, it can overlap with requirements management. Therefore in this report, requirements management will always be specifically addressed and quality management focuses more on meeting

specifications set by the project team and not solely on the end users requirements. Nair (2006) examined the impact of quality management by analysing 22 different papers on the impact of quality management and concluded that quality management has a positive influence on project quality in general. No research has however been found on the influence of quality management on project quality of charity projects, so that is what will be examined during this project. Lastly, there must be said that there are various philosophies and methods for quality management, such as Lean, Total Quality Management, Six Sigma and FMEA (Nicholas and Steyn, 2012). The amount and extensiveness of frameworks and methods is however so diverse that a choice for these will not be discussed here, but in the next chapter: Materials and methods.

## **4.2 Rainwater harvesting**

Where almost 70% of the earth is covered with water, only 1% of the water is available as fresh surface water (Gleick, Pacific Institute for Studies in Development, and Stockholm Environment Institute., 1993). The accessibility of fresh water sources in developing countries is limited, causing severe water scarcity (World Health Organization, 2015). In order to still meet the drinking water requirements in rural areas, alternative fresh water sources, such as rainwater, can serve as potential drinking water source in these areas (Hardy et al., 2015). Rainwater harvesting is the effective collection and storage of rainwater from rooftops and surface runoff. The rainwater can be collected and stored in buffering tanks. Over the recent years RWH has become a trend within urban environments as solution for the supply of good quality water to the world population (Nachshon, Netzer, and Livshitz, 2016). Where the rainfall pattern permits rainwater harvesting, and sufficient storage during dry periods can be provided, rainwater harvesting may serve well for household and small-scale community supplies.

### **4.2.1 Opportunities in RWH**

Well-designed RWH systems have the potential to increase water security, in terms of quantity, quality and access, for rural and peri-urban communities that remain under-served by public infrastructure (Elgert, Austin, and Picchione, 2016). RWH is often seen solely as a means of capturing rain for storage and direct use for domestic or irrigation purposes. But RWH can provide more than a source of water to increase water supplies. It can be used to involve the public in water management, making water management everybody's business (Abdulla et al., 2009).

### **4.2.2 Rainwater harvesting in practice**

To create local support for RWH systems the chosen technology should be based on local skills, materials and equipment. It is therefore important to take into account local knowledge and experience when designing and building a system (Mbilinyi et al., 2005). The design, used material, quality and practice of both the collection system as the harvesting tanks are of great importance to ensure clean drinking water with low risks of contamination (Rahman et al., 2014). When the rainwater, collected in tanks, is not maintained properly it can pose a serious health threat to humans.

In order to make a drinking water system sustainable, it needs to insure a continuity of use of the system and securing the quality of the water in the system. Important factors for long-run sustainable water systems are water board technical capacity and organisation, financial management, community participation, the condition of water system infrastructure and the available technical assistance provided during the lifespan of the system (International Water Association Publishing, 2017). The multidisciplinary element of the people working on this project will hopefully contribute to inclusion and development of all these factors.

### 4.2.3 Rainwater quality

Rainwater does not contain impurities by itself, but can be exposed to pollutants from the atmosphere. Precipitation appears to be able to transport contaminants in the atmosphere over large distances, at least hundreds of kilometres (Hageman, Bogdal, and Scheringer, 2015). This means that rainwater contains various inorganic compounds (e.g. salts), from natural origin (sea water, soil), but also of anthropogenic origin (by burning fossil fuels, industry, traffic). In addition, it can also be transporting organic contaminants such as pesticides and poly-cyclic aromatic hydrocarbons (PAHs). Rainwater also can contain (small) organic acids. The pH is therefore usually lower than 7 and seems to have even decreased in recent years (Bogan et al., 2009).

As rainwater usually is very pure by itself, it contains only a small amount of minerals. Consuming water of low mineral content (TDS < 50 mg/L) can have a negative effect on our body. The water and minerals ratio in our body are balanced and therefore water with a low mineral content can extract minerals from our body in order to regulated this ratio (Kozisek, 2005). Because of the possible adverse health effects of drinking low mineral water, the WHO standards of 1980 already recommend that the mineral TDS in drinking water should be at least 100 mg/L and the optimal TDS in drinking water between 200 - 400 mg/L (World Health Organization, 1980).

When harvesting rainwater, in tanks or reservoirs, the quality of the water can deteriorate over time due to a wide range of external pollutants from the surroundings, like faecal contamination of birds, falling leaves and living insects. Microbial contamination, usually determined by FIO (Fecal Identifying Organisms) where E.Coli serves as indicator, can be found in the rainwater directly after a rain event. During the 'first flush' the microbial contamination is usually highest in the rainwater (World Health Organization, 2014).

Moreover, the state and material of the water collection surface (roofs, gutters) impact the quality of the harvested water. An important source of contamination is the surface on which the rainwater is collected (Rahman et al., 2014). Dirt comes from the surroundings, for example from traffic and industry, and in rural areas, for example, pesticides. In addition, rainwater is relatively soft and acidic, which dissolves lime from concrete, but also metals from roof material and gutters. This can lead to too high concentrations of iron, aluminium, zinc and lead. When using materials for rainwater collection these factors must be taken into account (Leong et al., 2017).

#### 4.2.3.1 Effect of roofing material and slope on water quality

The type of roof material is an important parameter as it can influence the quality of the harvested water. Roofing materials, most commonly ceramic tiles, wood, metal sheets, galvanised steel, can influence certain water quality parameters. Some studies have shown that galvanised steel was found to be the most suitable roofing material for rainwater harvesting applications, as physical and chemical water quality parameters meet the drinking water guidelines (World Health Organization, 2017a).

Studies show however that the inorganic components in the harvested rainwater from most roofing systems match the WHO drinking water standards and do generally not exceed the maximum permissible concentrations (Yaziz et al., 1989).

Differences in runoff water quality are relevant between sloping smooth and flat rough roofs. A flat rough roof shows higher levels of pollutants ( $\text{SO}_4^{2-}$ ,  $\text{NO}_3^-$ ,  $\text{NH}_4^+$  and total carbonates) because of processes of particle deposition, roof weathering and plant colonisation. In contrast, sloping roofs present better quality (Farreny et al., 2011).

Concentration of pollutants show an increase with the age of roof materials, especially samples from painted and concrete slate roofs. When examining runoff data on seasonal changes, most of the water quality parameters, including bacterial counts, were higher both at the beginning and end of the rainy season (when both dry and wet depositions were high) than during the mid-season period (when only wet deposition was high) (Lye, 2009).

#### 4.2.3.2 Protecting rainwater quality

Methods to protect or improve rainwater quality include appropriate system design, sound operation and maintenance, the use of first flush devices and after treatment.

**System design** When designing a system, the following should be considered (Gould, 1999):

- The roof has to be made of impervious, non-toxic material. Overhanging branches and plants have to be cut away and the surface should be easily accessible for regular cleaning.
- Taps or outlets from the tank should be at least 5 cm above the tank bottom, to enable debris accumulation on the bottom of the tank without interfering with the outlet construction or clogging it.
- Every inlet or outlet structure should be adequately covered with fine mesh or otherwise inaccessible for insects, snakes and other small animals. Also every possible entry of light has to be excluded.
- The inlet structure needs to be equipped with a coarse filter to stop leaves and other debris of entering. The filter has to be easily accessible for regular cleaning.

**Operation and maintenance** Proper operation and maintenance of rainwater harvesting systems helps in several ways to protect the quality of the water.

- The roof, gutters, down pipes, connections and tank should be regularly inspected to reduce the likelihood of contamination. When leaves and other organic matter enter the tank they let the stored rainwater become too acidic, which potentially leads to dissolving of metals from the tank, tap fittings and sludge deposits.
- After a major rainfall event, microbiological contaminants will be high. It is advised to not directly drink the water from the tank without treatment, as to wait for bacterial to die off in the tank.
- Water from other sources should not be mixed with that in the tank.

**First flush** First flush systems, when properly operated and maintained, can greatly improve the quality of roof runoff. However, if poorly operated and maintained, a first flush system may result in the either loss of rainwater runoff or even contamination of the stored water supply. In reality, the use of first flush devices is limited, especially in developing countries. Finding working first flush devices in developing countries is quite rare (Helmreich and Horn, 2009).

**After treatment** To ensure a steady quality, as to use the stored water as potable water, after treatment should be considered.

- Easy methods are boiling the water for at least 1 minute or by chlorinating the water. These methods suffer from the disadvantages that they are respectively impractical in rural areas (needing lots of firewood or using great quantities of difficult to come by gas) and create an undesired taste.
- Another low cost method is using direct sunlight to kill many of the harmful bacteria in water. It is done by exposing it in clear glass or plastic bottles for several hours (Wegelin and Sommer, 1998). This method requires the water to be clear, the weather to be fine and the water needs to be cooled anew.

- A second way of using ultraviolet light to disinfect the water is a solar powered unit, which can process 1.5 litres of water per minute (Joklik, 1995).
- In remote areas without access to electricity, a solar powered electrochlorinator can be a feasible way to treat the stored water (Choi, Park, and Yoon, 2013). It produces sodium hypochlorite, which acts as a strong disinfectant, by the process of electrolysis from only salt and water. While the last two methods work well, they might be too expensive for widespread use.

### 4.3 Sanitation

When thinking of improving drinking water availability, adequate sanitation is an imperative. Worldwide, adequate sanitation systems in rural areas are substantially lagging compared to urban areas, and improved water sources alike (Chaudhuri and Roy, 2017). In some rural areas, open defecation is still preferred due to its age-old nature (Chaudhuri and Roy, 2017; Novotný, Hasman, and Lepič, 2018). Even though many countries and organisations have launched large sanitation programmes to improve sanitation, still 4.5 billion people are lacking safely managed sanitation systems and of which 2.3 billion people are still without basic sanitation services, mainly in rural areas (Zhou et al., 2018; World Health Organization, 2017b). The improvement of sanitation conditions is highly context sensitive, both in social and natural environments in rural areas, because the inputs and impacts of sanitation interventions are influenced by the interaction between psychological-behavioural determinants and parameters of natural, social, cultural, political and economic nature. Moreover, some root-cause effects have a threshold, e.g. latrine coverage needs to be overcome in order for the positive health effects to arise (Novotný, Hasman, and Lepič, 2018), which makes this issue also more complex. It is therefore key to understand the context in which the study site is situated.

Fewtrell et al. (2005) conducted thorough systematic review on water, sanitation and hygiene interventions to reduce diarrhoea in non-Class A countries according to "Methodology for assessment of environmental burden of disease" by Ezzati (2010). They found that water quality interventions, point-of-use water treatment, were more effective than thought in previous research. Additionally, a combination of interventions in water, sanitation and hygiene measures did not exceed single focus interventions in effectiveness. Consequently, a water supply intervention, which entails "the provision of a new or improved water supply, or improved distribution (such as the installation of a hand pump or household connection)" (Fewtrell et al., 2005) on household level can be an effective measure in reducing diarrhoea.

#### 4.3.1 Sanitation in Panama

In 2009, 93% of the population had access to an improved water source and 69% had access to improved sanitation. Water and sanitation management in rural areas has been organised in 3,300 Rural Water Management Boards (JAARs).

Besides the country's own water related institutions and organisations, there are also many other organisations active in drinking water and sanitation programmes in Panama, such as the Joint Monitoring Program of WHO and UNICEF (United Nations Children's Fund and World Health Organization, 2018), the joint UN programme MDG-F (MDG Fund, 2018), the World Bank Water and Sanitation Program 2013 (Eiseman, 2015) and the Inter-American Development Bank programs (Inter-American Development Bank, 2012a; Inter-American Development Bank, 2012b). Even though these organisations and institutions are active in increasing access to clean drinking water and sanitation services in rural and indigenous communities throughout Panama, the study site of this project has been left out.

#### 4.4 Conclusion of literature study

This literature study concludes that research has shown that the effect of development aid is doubtful and evaluating and improving its efficiency is difficult, but at the same time crucial. Although there is extensive research done on project control lessons learned, no work has been found focusing specifically on development aid and lessons learned for charity construction work. Literature has shown that stakeholder management might help to improve quality of projects in general, but not specifically for aid projects. This report will therefore examine whether stakeholder management has a positive influence on the quality of a charity project and in which way.

No research has been found on the effect of requirements management on project quality. This report will therefore examine whether basic requirements management also has a positive influence on the quality of a charity project. No research has however been found on the influence of quality management on project quality of charity projects, so that is what will be examined during this project.

The choice of water supply for this intervention study was made beforehand and therefore the RWH tank is used and because of that the literature review only focuses on this means of providing a household water system. Well-designed RWH system have the potential to increase water security, in terms of quantity, quality and access, for rural and peri-urban communities that remain under-served by public infrastructure. When the rainwater, collected in tanks, is not maintained properly it can pose a serious health threat to humans. The quality of the water can deteriorate overtime due to a wide range of external pollutants from the surroundings. Methods to protect or improve rainwater quality include appropriate system design, sound operation and maintenance, the use of first flush devices and after treatment. Proper operation and maintenance of rainwater harvesting systems helps in several ways to protect the quality of the water.

Sanitation is imperative when providing a water supply system, and number of cases of diarrhoea is a good indicator for the current state of sanitation. Literature showed that a water supply intervention, which entails “the provision of a new or improved water supply, or improved distribution (such as the installation of a hand pump or household connection)” on household level can be an effective measure in reducing diarrhoea.



## 5 Materials and Method

This section will describe the study site of this research (5.1), the research plan containing the research questions and the three phases in which the research is carried out (5.2) as well as the materials and methods per research field that are used during these phases (5.3 - 5.5). A collaboration with the Technical University of Panama has been initiated for equipment and analyses which were out of reach, described in subsection 5.6. Subsection 5.7 elaborates on the interviews that were held for this research.

### 5.1 Study site

The project is carried out in the village El Progreso, situated in the Atlantic region on the eastern border of the Colon region. The village consists of two parts, one built up around the school, the other around the church, shown in Figure 3. The school of El Progreso can be found at 9°31'04" North and 79°13'33" West, the church at 9°31'19" North and 79°14'09" West.

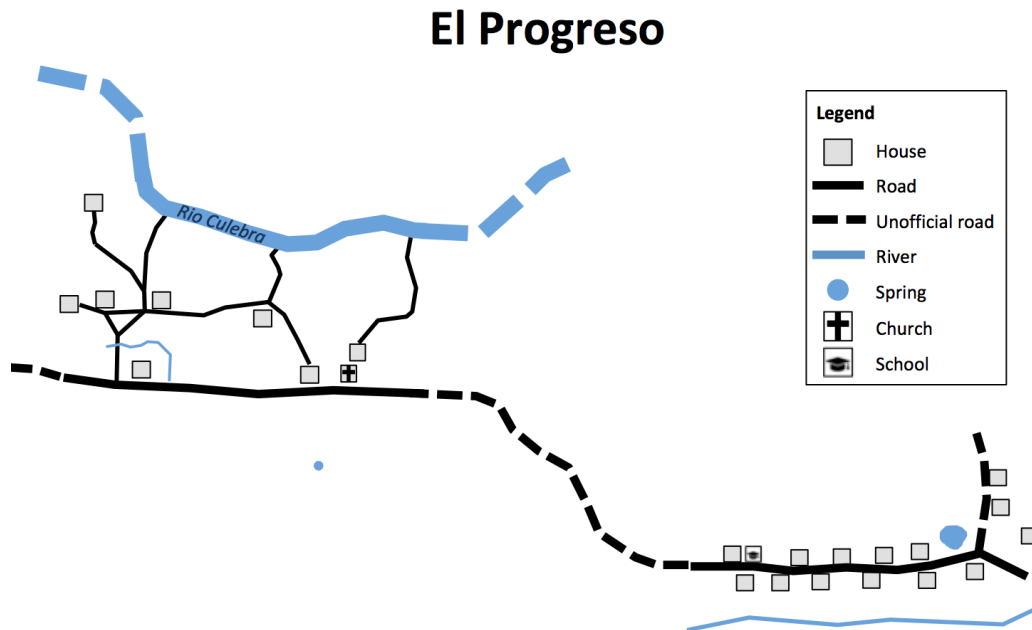


Figure 3: Map of the village El Progreso

### 5.2 Research plan

In the literature review it became clear that the effectiveness of development aid has shown to be debatable in various case studies and that it remains difficult, but very important, to evaluate development aid. It also showed that the project quality might be improved by stakeholder management, requirements management and quality management. Literature has shown that rainwater harvesting in rural environments can serve as a feasible solution for the supply of drinking water. Faecal contaminations, roofing material, gutter systems and construction methods can impact the quality of the harvested water greatly and are therefore essential to monitor.

Therefore, the research goal has been formulated as follows:

**'Building a rainwater harvesting system (RWH) to gain insight in sustainable water supply strategies and identify the effect on the quality and quantity of the water and the project quality by means of an intervention study carried out in El Progreso, Panama'.**

Tanks can be build from a wide variety of materials, e.g. fiberglass, polyethylene, cement, ferrocement, reused car tires, masonry or wood. Based on judgement on expected lifespan, availability, possibility to move, maintenance required and level of self-building ability, ferrocement is the most suitable material (Wiggins, 2016). The Calabash tank is a specific model of a ferrocement tank. It is developed by de Gevulde Waterkruik in Guinea-Bissau through 12 years of practical experience and is now widely used throughout the African continent (Hartung, 2013). The Calabash design will be adopted, partly redesigned and used as a test case in El Progreso, see Appendix A. To successfully reach the goal of this research the following question must be answered:

**"How does providing households with a Calabash tank impact the community, the quality and quantity of the drinking water in El Progreso and what is the project quality of constructing a Calabash tank?"**

This chapter will explain with which sub-questions, structure and methods the research question will be answered. There will also be discussed how the sub-questions will be operationalised: with which measurements and methods.

### **5.2.1 Sub questions**

To find an answer to the research question there are sub goals formulated. These sub goals are divided over the expertises: project quality, water quantity assessment, water quality assessment and health related issues and the sub goals will be elaborated per expertise.

#### **Project quality**

In the literature review it became clear that it remains difficult, but very important, to evaluate development aid by developing lessons learned regarding project control and that the project quality might be improved by stakeholder management, requirements management and quality management. The sub questions are therefore:

- Which lessons can be learned from project control at a remote location and culturally diverse team while building the Calabash tank?
- Who are the stakeholders and what influence does stakeholder management have on the quality of the tank?
- What are the requirements of the owners of the tank and what influence does requirements management have on the quality of the tank?
- What influence does quality management have on the quality of the tank?

#### **Water assessment**

##### **Water quantity assessment**

- Current situation
  - What are the sources, where are they and how much can they provide?

- Wet season / dry season usage; can the calabash tank offer a sufficient amount of water to overcome the dry season?
- For which purpose do the people use the different sources and who is getting the water?
- Water efficiency
  - What is the amount of water that people use? And how will it change if they have an easier source to access?

### **Water quality assessment**

- Assessment of current water source quality
  - How do the water quality parameters differ for different water sources?
  - What are the possible sources of contaminations in the different sources?
  - How do the water quality of the different sources in El Progreso changes over time and space?
- Sanitation
  - What is the current situation?
  - How can we avoid contamination of the drinking water sources by household waste?
  - What system do the people need? How can we make this feasible?
- Health related issues
  - Type of water borne diseases that (can) occur in the village/region
  - Prevention methods and knowledge exchange

### **5.2.2 Research structure**

The research is designed as an intervention research based impact assessment of the building of the Calabash tanks, investigating one case: a building project in the village El Progreso over a span of eight weeks. The impact assessment uses a framework based on Sijbesma’s design on placing a household study in an overall impact assessment (Sijbesma et al., 2011). This is adapted, as the design by Sijbesma uses an evaluation period of four years. First the adaptation of the broad, overall research design and framework is explained and then there will be presented which (part of the) research questions will be answered in which phase.

The original design is shown in figure 4 and is adapted in the following way: Combining the ‘Baseline study’ with the ‘Water Quality Tests’ to one phase named ‘Pre-study’ for clarity reasons. Renaming ‘Performance monitoring’ to ‘Construction phase study’ for clarity reasons. Combining the ‘Post construction study’, ‘Post study’ and ‘Expanded Water quality tests’ to one phase named ‘Post study’. Removal of the health impact study, ‘BAPPEDAS’ economic impact study and institutional impact study due to the shorter evaluation period. This adjusted framework, as shown in figure 5 helps to answer the sub questions in a valid and structured way.

The three different parts of the research structure will now shortly be described, including the general methods that are used for the research fields. After this, the different research fields will be elaborated in more detail.

### PLACE OF HOUSEHOLD STUDY IN OVERALL IMPACT ASSESSMENT

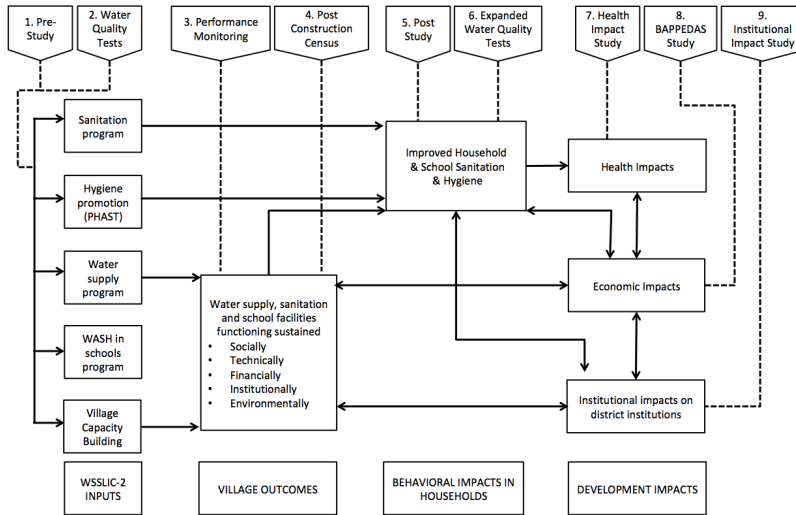


Figure 4: Impact assessment based on Sijbesma's design

### PLACE OF HOUSEHOLD STUDY IN OVERALL IMPACT ASSESSMENT

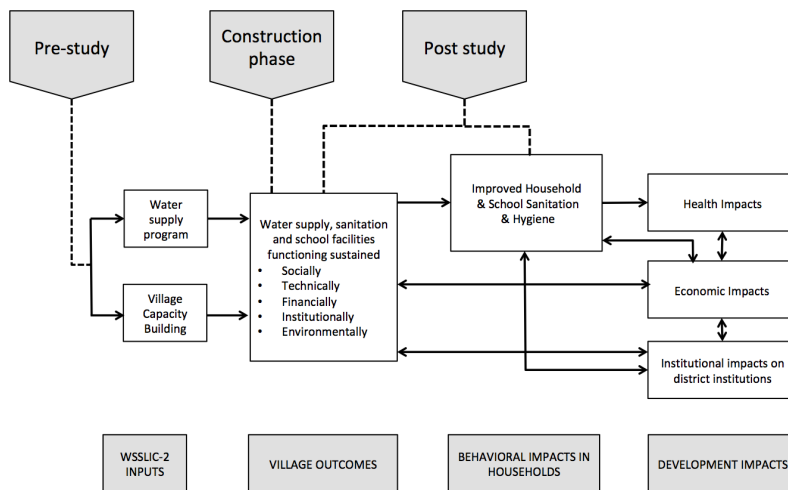


Figure 5: Adjusted impact assessment based on Sijbesma's design

### **5.2.2.1 Pre-study**

The pre-study phase of this project has five goals: gaining a clear overview of the stakeholders, their requirements, their water usage and quality of their drinking water sources and create the project quality management plan. Information on the stakeholders and their requirements is gained using interviews, which are also used to map the water habits. The interviews consist first of a general part, thereafter a water related part and a requirements part, see Appendix K. Fieldwork will be done in order to assess the quantity and quality of the already existing water sources in El Progreso. The water sources will be mapped, the usage of water measured and the sources of contamination investigated. The in situ measuring equipment will be used in order to gain insights in the overall water quality and quantity of the water sources present.

### **5.2.2.2 Construction phase study**

The construction phase consists mainly of gathering lessons learned regarding project control and monitoring project quality. Gathering lessons learned entails monitoring the construction process and finding out problems that are encountered during the construction. Monitoring project quality is done using the quality assurance part of Nicholas and Steyn's quality management framework (Nicholas and Steyn, 2012). Besides this, there are still observations made regarding requirements management and stakeholders will be tried to engage.

### **5.2.2.3 Post study**

In the post study the requirements of the inhabitants will again be analysed, using interviews, and the last parts of quality management are evaluated, using the quality control part of Nicholas and Steyn's quality management framework.

A repeated water quality assessment will be made, now including the quality of the water within the Calabash tank. The quality will be measured for several newly build Calabash tanks in order to see the effect of different locations, roofs and vegetation on the quality of the water. In addition the (possible) change in water usage of the people will become clear from the interviews as well as other impacts.

Now that the structure is clear, the materials and methods of different aspects of the research will be discussed in further detail. These aspects are project quality (including stakeholder management, requirements management and quality management), project control, the collaboration with UTP, the methods to determine water quality and quantity (including in situ measurement equipment and sampling and analytical methods) and the interviews and community meetings.

## **5.3 Project quality**

Project quality is chosen to be examined by observing the influence of three research fields on the overall quality of the project: (1) stakeholder management, (2) requirements management and (3) quality management. The research results will be presented using the pre-study, construction phase study and post study division, which will also be used to draw conclusions. However, to make the workload feasible the research on the three fields are divided over the different tanks by putting a focus on a certain field during the construction of two to three tanks. To be able to judge the change of project quality, the first three tanks are used as a baseline-study. The operationalisation of the research fields are explained in more detail below.

### 5.3.1 Stakeholder management

Stakeholder management will be operationalised following Policy Analysis for Multi-Actor Systems by Enserink and Hermans (2010). It will not include extensive problem formulation and solution search as it is already determined that water tanks will be built and there are only small aspects of the tank adaptable. During the focus period, the relationships, resources and interests will be taken more into account to try to engage certain stakeholders. During the whole project there will be observed what influence this has on the project quality.

### 5.3.2 Requirements management

Requirements management is operationalised by doing interviews in the pre-study regarding the wishes of the inhabitants for charity projects and by observing their requirements shown during the construction and post-study phase. Another interview is conducted during the post-study to see whether the requirements have changed. Due to the nature of the impact study, their requirements are mainly monitored for research purposes and not with the intention to radically adapt the project to their requirements.

### 5.3.3 Project quality management

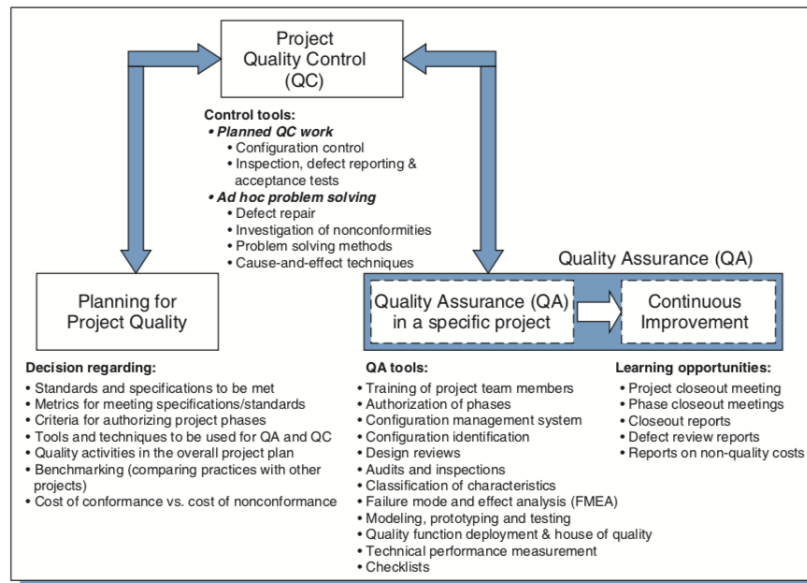
There are several methods for quality management, such as Lean, Six Sigma and Total Quality Management. Sun found that Total Quality Management is significantly less successful if not fully implemented (Sun, 2000) and it would be difficult to implement any of the systems fully in this context. For this reason and to guaranty flexibility and high applicability, the general quality management process according to Nicholas and Steyn, as shown in Figure 6(a), is used.

Project quality management will be operationalised following the three project quality management processes from Nicholas and Steyn: quality planning, quality assurance and quality control, which they perfectly explain as follows: “*Quality Planning guides future quality activities, it sets the requirements and standards to be met and the actions necessary to meet them. Quality assurance performs the planned quality activities and ensures the project utilises processes necessary to meet quality standards and end-item requirements. Quality Control ensures that quality assurance activities are performed according to quality plans and that requirements and standards are being met*” (Nicholas and Steyn, 2012). These phases can respectively be divided over the pre-study, construction phase study and post-study. Not all components shown in figure 6(a) will be used, a selection is made based on available time and available resources at the location, which led to the selection shown in figure 6(b). Of these methods, two will be explained in more detail: the Failure Mode and Effect Analysis (FMEA) and a Cause-and-Effect diagram (CE diagram).

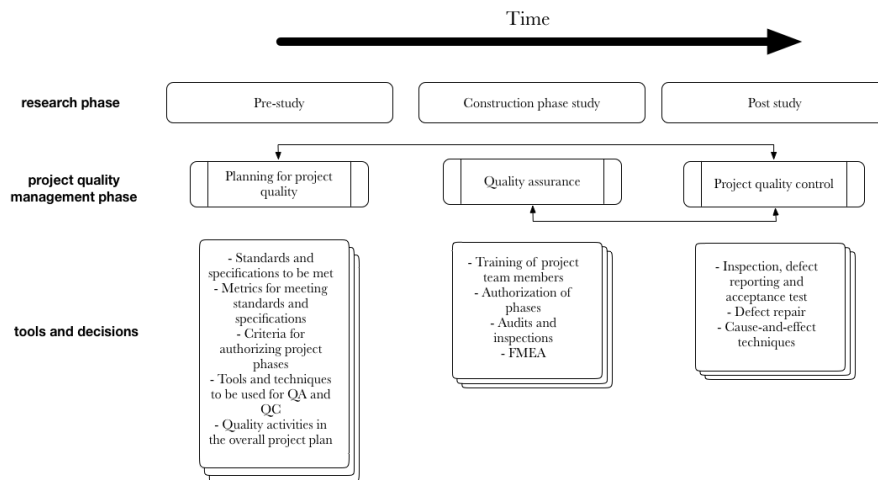
The FMEA is normally used in product development to mitigate risks of failure (Bongiorno, 2001). There is no product development phase in this impact study and even the pre-study is too late to make large changes in the design, so the FMEA is used in the construction phase study. The FMEA determines the conditions under which a system might fail to be able to use the limited resource in a way which tries to prevent these failures. An FMEA uses a physical and functional decomposition of the system to brainstorm possible failure modes with their effect and cause, to which it assigns a severity, probability and detectability which together form the risk priority number (RPN). The FMEA can then continue to form and test a plan to circumvent the failure or mitigate the effect, but due to the phase in which the FMEA is performed, the possibilities to adapt the design are limited and therefore not tested using an FMEA.

A CE-diagram is a scheme to arrange the cause for a specified effect in a logical way, which can either help identifying outcomes for a given cause or help finding causes for a giving effect (Nicholas and Steyn, 2012). The latter is used in this case.





(a) Quality framework by Nicholas and Steyn



(b) Quality framework as used in this research

Figure 6: The quality frameworks

## 5.4 Project control

Project control will be operationalised by keeping a list of observations regarding project control throughout the project to see which findings and which generalised conclusions can be drawn from these observations. This will only be part of the construction phase study.

## 5.5 Collaboration Technical University of Panama (UTP)

Some measurements and analyses during this research cannot be done without help from external parties, due to the absence of advanced measurement analysing equipment. Therefore a collab-

oration with UTP was initiated in the first stadium of this project to be able to perform these measurements and analyses and by doing so providing more quantitative data for the research. The following aspects were handled by UTP:

- Measuring tank wall thickness with ultrasonic measuring device
- Testing concrete beam samples with a pressure strength test to determine the quality of the concrete mix
- Water quality parameters are measured with the help of UTP from water delivered by the finished ferrocement tanks, the two rivers (Culebra river and Negro river) where inhabitants drink the water from and the natural spring.

The water laboratory of UTP is currently under construction and therefore several testing facilities are not in use. In order to still measure all parameters, a collaboration with AQUATEC Water Technologies in Panama city is set up, aiding UTP in their efforts.

## 5.6 Methods to determine water quality and quantity

The different research fields will now be elaborated in more detail, starting with water quality and quantity. The quantity and quality of the available water sources in El Progreso will be mapped, measured and analysed. In the pre-study phase the in situ measuring equipment will be used for direct results, comparing the quality of different water sources. In the post-study a more extensive measuring equipment from the Technical University of Panama will be used in order to test more quality parameters.

### 5.6.1 In situ measurement equipment

In order to say something about the quantity and quality of the water sources at location, different measurement equipment devices are lent by the Technical University of Delft or bought locally. These devices will be shortly described, starting with the water quantity equipment and followed by the water quality equipment.

#### 5.6.1.1 Water quantity equipment

**Acoustic Digital Current Meter: OTT ADC meter** This device is an acoustic current meter that is used to measure point velocities in open channels by means of measuring the velocity on multiple verticals along a rod over certain distances over the cross-section. The ultrasonic transducers on this meter transmit ultrasonic signals which are reflected by particles in the waterway and returned as echo signals. This is done twice, with a short pause in between, and afterwards the flow velocity is calculated by the device.

**Tipping bucket: RainWise RainLog 2.0** This measuring device is used to monitor rainfall at a specific location (point observation). Rain droplets enter through the funnel to the inside mechanism of the tipping bucket: a wedge-shaped tipping bucket with a volume of exactly 0.1 inch (2.54 mm) of rainfall depth. When the bucket is full, it tips over and an adjoining identical wedge-shaped bucket can get filled up. Each tip gets recorded by the datalogger. A location for this device needs to be chosen carefully since wind and turbulence as well as splashing can influence the recordings of the tipping bucket. This means that no obstacles can be present 5 times the obstacle height to avoid turbulence and not too low or high to avoid disturbance by wind or splashing.

### 5.6.1.2 Water quality equipment

**EC-meter: Greisinger** The Electrical Conductivity (EC) meter from Greisinger measures the EC (in  $\mu\text{ S/cm}$ ) and the Temperature (in degrees Celsius). The EC measures the ability of water to conduct electricity. The EC-meter is calibrated with calibration liquid Conductivity Standard solution before using the equipment. All settings are corrected so that the conductivity of the calibration liquid was  $1413 \mu\text{ S/cm}$  corresponding to a temperature of  $25^\circ\text{Celsius}$ .

**EC and TDS meter: Honeforest** The Honeforest can measure Total Dissolved Solids (TDS) EC and Temperature. The TDS concentration in the water is the sum of positively charged ions (cations) and negatively charged ions (anions). Principally these ions are calcium, magnesium, sodium, and potassium cations and carbonate, chloride, sulphate, and nitrate anions (World Health Organization, 1996a). TDS in water sources originate from agricultural, urban and industrial runoff and also from natural sources. The EC meter is calibrated before usage with calibration liquid.

**pH strips** In order to measure the pH, pH strips are used. The pH of rainwater is an important parameters for the acidity (pH lower than 7) and therefore solubility of heavy metals in water. For this project pH is therefore an essential parameters to determine on sight whether the water is too acidic to drink.

### 5.6.2 Sampling and analytical methods

In this subsection the choice of the sampling and analytical methods will be explained, this will first be done for water quantity measurements and then for water quality measurements.

#### 5.6.2.1 Sampling water quantity

To design a robust rainwater harvesting system one needs to know the water usage on the one hand (output) and the available area for harvesting and daily rainfall depth (input). One would prefer to use long historic time series to determine average daily rainfall. For Panama historic time series can be found with only monthly averages (Hidrometeorologica de ETESA, n.d.[b]). Closest precipitation measuring stations are situated either directly on the Caribbean coast (Nombre de Dios and El Porvenir) or a long way inland in dense rainforest in mountainous surroundings (Dos Bocas and Esperanza). Although these precipitation time series cannot be used to calculate storage in the tank on a daily basis, they can be an indicator for seasonal variation and point out how severe the drier months can be and thus for how long the storage in the tanks has to last to overcome these months. The tipping bucket can therefore be used to get an indication of the amount of precipitation in El Progreso in the period the research takes place.

The Acoustic Digital Current Meter (OTT ADC meter) will be used to determine the discharge at the rivers in the study area, in order to get a feeling about the magnitude of these rivers and also to see whether an intake for another gravitational river fed water system is feasible.

#### 5.6.2.2 Sampling water quality

The water quality assessment consist of different subsections. Firstly, in the pre-study a water quality indication will be made, directly after conducting the first interview, from the water sources that the household uses. This is done by the in situ measurement equipment in order to gain an overview of the quality of the different water sources. Secondly, in the post-study, when the first ferrocement tank is finished and filled with rainwater, the change of the quality over time will be monitored in order to say something about the quality change in time. Finally, also in the post-study, samples from all newly built ferrocement tanks and all other drinking water sources

will be analysed by the Technical University of Panama in collaboration with AQUATEC Water Technologies. The samples will be compared with the Panamanian drinking water standards, presented in Appendix C, in order to conclude whether these water sources can be treated as drinking water.

### **Water quality indication by in situ measurements**

Before or during the building process of the tank the heads of the household are interviewed and the sources from where they use water from are identified. At every source the pH, EC and TDS will be measured in order to get an indication of the quality of the water.

### **Weekly monitoring of tank**

The quality of different water sources changes over time. This can be due to a change in weather conditions or local disturbances. The quality of the water in the tank can also change over time, due to curing of the ferrocement or contamination entering via the gutter system. In order to analyse the changing quality of the water over time, the in situ measuring equipment (pH, EC and TDS) will be used to measure the quality of the water in one ferrocement tank over time. This will be done three times a day for one week.

### **Water quality sampling**

In order to see the impact of the construction of the Calabash tanks on the quality of water that people drink, samples from 6 rainwater harvesting tanks, 2 river (Culebra and Negro river), and 1 natural spring (groundwater) are tested and compared. When doing so, the quality of water within the different tanks can be compared in order to see possible quality changes in place. Most of the water parameters cannot be measured in situ and need to be analysed in a water lab (done by Technical University of Panama and AQUATEC). The investigated parameters will be discussed below, divided in physical indicators, chemical indicators and biological indicators. A table with all parameters can be found in the Appendix D.

**1. Physical indicators:** Physical parameters in drinking water are turbidity, temperature, conductivity and TDS and determine the taste, colour and odour of drinking water. The physical parameters will be measured for rain-, river and groundwater by in situ measuring devices of UTP.

**2. Chemical indicators:**

- *Alkalinity:* The most important parameter that determines the alkalinity of the water is bicarbonate ( $HCO_3^-$  in mg/L). The Alkalinity in our drinking water is important due to its ability to stabilize the pH. Therefore the concentration of  $HCO_3^-$  will be measured for rain-, river and groundwater sources by UTP.
- *Nutrients:* In order to determine the impact of agriculture on the quality of water, the following indicators will be measured: sulphate ( $SO_4^{2-}$ ), nitrate ( $NO_3^-$ ), phosphate ( $PO_4^{3-}$ ) and ammonia ( $NH_4^+$ ). These nutrients can determine the faecal pollution of the water. Excess nitrogen and phosphate can passively pollute water by leaching into the groundwater and enter the river via the erosion of soil, or actively by entering the water via the nutrient-rich animal urine or manure (World Health Organization, 1996b). Those indicators will be measured for all three water sources in the laboratory of UTP.
- *Minerals:* The concentration of minerals, such as calcium ( $Ca^{2+}$  in mg/L), magnesium ( $Mg^{2+}$  in mg/L), sodium ( $Na^+$  in mg/L), potassium ( $K^+$  in mg/L), chloride ( $Cl^-$  in mg/L) in drinking water is important for human health. Rainwater lacks minerals and

can therefore form a health risk when people only drink rainwater (World Health Organization, 2014). Therefore the concentration of minerals will be measured and compared for all three water sources in the laboratory of AQUATEC.

- *Heavy metals*: Originate from roofing material, dust or airborne pollution. Heavy metals can dissolve in water when the water is acidic ( $\text{pH} < 7$ ), but are mostly found in rainwater bound to inorganic particles. In most cases, chemical concentrations in rainwater stay within acceptable limits (World Health Organization, 2017a). The concentration of heavy metals will only be necessary to measure of the rainwater within the ferrocement tanks and not in the river or groundwater. Most roofs in El Progreso are made out of zinc, lead or iron. Therefore the concentration of Zinc ( $\text{Zn}^{2+}$  in mg/L), Lead (Pb in mg/L) and Iron (Fe mg/L) will be measured by the UTP.

### 3. Microbiological indicators:

- *Bacteria, Viruses and protozoa*: Originating from faecal pollution by animals. Can be measured by total coliforms (n/100mL) or E.Coli (n/100mL) concentration. The World Health Organisation suggests that the total coliform should be in 95% of all cases below 10 CFU/100mL. When this concentration exceeds 20 n/100 mL, further treatment is required (World Health Organization, 2014). The microbiological quality is important for all three water types and will be analysed by AQUATEC.
- *BOD/COD*: The Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) represent the amount of oxygen that is needed in order to oxidise all the organic material within the water. It determines whether rivers are affected by severe organic pollution. Therefore the BOD and COD concentration will only be measured for the river water by AQUATEC.

## 5.7 Interviews and community meetings

To get a grip on the impact of the intervention study that is carried out, it is important to get to know the social context of the study site first. The people who are living in the village, their habits and needs, can differ widely from one another even though it might come across as a homogeneous community (Bolt and Fonseca, 2001). Moreover, the impact of the intervention can differ from one household to another. Therefore it is important to set up meetings and take interviews. First, a general community meeting was set up by the local NGO to get an understanding of the size of the community and to share the rainwater harvesting project with as many community members as possible. During this meeting a list will be made containing the details of every household that wants to receive a tank as well as what they can offer in return. Starting point here is that approximately 25% of the building costs of the tank is paid by the new owner. This payment can be fulfilled in a number of ways: by means of cash (not likely), by means of housing, providing food (meals or provisions), providing laundry services and help during the construction phase. It is required that at least 1 person per household is available during construction to help mixing cement, get sand, water and assist the building professionals anywhere necessary. Receiving payment (even partially) is crucial to create a sense of ownership and responsibility and therefore care-taking, ensuring a well maintained system on the long term. After this general meeting, general interviews with households who are getting a tank will be set up containing general questions about their household, water use and sanitation facilities as well as questions about the tank and their requirements for this tank (pre-study). Near the end of the eight weeks, an evaluation interview will be conducted to reflect on the construction phase and final design of the water tank and the impact of the rainwater harvesting tank on their daily life as well (post study).

The most limiting factor for the number of systems that can be built during this project is time.

Therefore not every household in the village of El Progreso will receive a rainwater harvesting system and also, it first has to become clear if every household actually needs a system. To mitigate possible conflict issues, also interviews with households who are not getting a RWH system have been conducted.

In addition, an interview with the operator of the existing gravitational water system will help to gain insight on the current water system, which part of the village is connected to. An interview with the collaborating local NGO has been conducted to understand their intentions and scope of their projects in the village.

For knowledge exchange and a proper closure of the project a final community meeting is set up to provide the community members with extra information on possible water treatment options as well as tank and gutter maintenance and sanitation.

The data that is collected through answers given in the interviews, as well as comparing this data from the different interviews, will be used as a measure of the impact of this intervention study. The questions formulated for these interviews, the schedule of interviewing and the answers of the interviewees can be found in Appendix O.

## 6 Pre-study

During the pre-study phase of the project the current situation is being analysed and mapped. The project quality is examined in regard to the influence of stakeholder management and requirements management, and simultaneously the water usage and the quality of their drinking water sources studied.

Stakeholder management during the pre-study mainly entails the execution of the stakeholder analysis. Interviews with inhabitants during the pre-study were used as input for both the requirements management (on their general wishes) and water assessment (on their water usage and habits). Quality management in this phase entails a planning which provides a framework for the quality management further on in the impact study. The chapter will start with a process description of the research done in the pre-study.

### 6.1 Pre-study process description

This process description is intended to give a better understanding on how the pre-study was executed in practice, how the different disciplines are integrated and how the inhabitants reacted towards this process. Therefore, every results chapter (chapter 6, chapter 7 and chapter 8) starts with a process description. The pre-study process roughly consisted of a first trip to the village, the community meeting, the interviews, gathering information for the stakeholder analysis and adapting the expectations of the team, which all are described below.

The very first trip to the village served as purpose to get a general impression of what the village and the surroundings look like, what kind of people are living there and what the place to set up the camp would be like. During this visit, a first spontaneous meeting with one of the elderly people in the village took place. At that moment a place, date and time for a general community meeting about the project was communicated with him. The local NGO had also spread the word that the meeting would also include giving away clothing, collected by the NGO. The local NGO had been active with some projects in the village and was acquainted with the inhabitants, so it was an easy way in for our project. Since the meeting was planned during the weekend, so everyone would be able to attend, there were several days left. These days were spent with constructing the first tank at the school as a pilot and study case. Because the construction of the tank needs a lot of plastering skill, Joris had reached out to his former contacts in Nicaragua. He contracted Simon, a construction worker and very skilled at plastering. Exactly what we needed for this project. Besides a construction worker, the contact person of the local NGO, Daniel, was hired as a translator and local guide. Joris followed a training in Guinea-Bissau in order to learn to build ferrocement tanks. This training was organised by a NGO having 12 years of experience in the sector. In their (Guinea-Bissau) building process clay blocks, traditionally used to build houses, were used to build the mould for the tanks. It became clear that these blocks are not available in Panama, but could be replaced by concrete blocks. It turned out these concrete blocks were not available at local shops, so in order to be able to use them, they had to be transported over big distances. An alternative would have been to make them ourselves, but this process turned out to be too expensive and time consuming. Therefore, the construction method needed to change. The newly chosen method is based on a single layered mould of plywood. Besides the method, the tanks were re-sized. Due to the sudden change of location of the project, the team had no time to find accurate local long term rainfall data, in order to determine the appropriate storage capacity. We had to rely on information from our local guide, who knew the longest dry spell to be two weeks. This resulted in re-sizing the tank to a volume of 3,000 litres (2,000 litres less than the original design). The height of the tank was chosen in such a way that the inhabitants, who are on average 1.60m tall, would be able to easily access the tank and be able to maintain the system. The technical details of the tank can be found in appendix A. Calculations on the thickness of the walls of the tank in

combination with a beam failure test were done in order to determine if the design would not fail. Appendix B shows the calculations and assumptions that were used to determine the wall thickness.

When the community meeting started, the project members were introduced first and then the project was explained. By that time, the tank for the school was partly finished, with help from two men of the village, and was shown as a prototype for the tanks that were going to be built. According to the local NGO almost everyone of the inhabitants were present. The list of people who were interested in a tank was filled out, which caused some confusion considering the fact that there were no house numbers or addresses and when they wrote down the way their house could be recognised, it did not clarify the issue. Everybody described their houses as built out of wood, which was not clarifying since the majority of the houses were made out of wood. When the list was completely filled out, it turned out fourteen households were interested in a tank. The decision of the order of the construction of the tanks, and who will receive a tank, will be discussed in more detail in the stakeholder analysis in subsection 6.2.

The idea of being interviewed was received as quite exciting and a bit frightening, because the inhabitants did not really know what to expect. At the same time, it was noticeable that their voice was being heard which made it important for them as well. Unfortunately, the translation skills of the translator were lacking, which led to awkwardly phrased questions and in an attempt to make the questions more clear, sometimes suggestions in Spanish were made (even though the questions were meant to be posed as neutral). The first interview was done with only the father of the household and during the answers to the questions it became clear that the women are at least as important in the decision making in the household as the men are. Therefore, the interviews that followed were always done with both male and female heads of the household. These initial interviews contained questions about their household composition and decision of tasks within the household, following questions about their water use and sources and their wishes regarding the



(a) The meeting



(b) Filling out the list

Figure 7: The community meeting



tank. The results of these initial interviews are further elaborated in subsections 6.3 and 6.5.

To get an understanding of where which family lives and what kind of water systems they are currently using around their household, different cross-sectional walks through the village were done with and without being accompanied by a community member. The church part of the village turned out to be mostly members of 1 big family, making most of the relations in the stakeholder analysis close to a family tree. Since the expectation of an indigenous community with long practised traditions also came with the idea that the people in this village had been living there for a long time. On the contrary, the longest time people had been living there was 44 years (see interview O.5.8) and some families had moved in just a few months before the project started (see interviews O.5.1 and O.5.4). At the school part of the village, more extensive water systems were found as will be discussed in more detail in subsection 6.5.

So, in conclusion, it became clear that when a project is started a lot of things work out differently than expected. Some things went very smoothly, such as the introduction of the project to the village and the attitude of the inhabitants towards the project and the project team. Other things turned out differently such as the actual construction method of the tank, the relation between the local NGO and the village and the degree of influences of indigenous believes.

## **6.2 Stakeholder analysis**

The purpose of the stakeholder management research is seeing whether a stakeholder analysis, working with their resources or interests and organising participation has a positive influence on the quality of the project. First, the pre-analysis observations are explained, as a few tanks were build before the stakeholder analysis was started to be able to judge its impacts. Second the observations during the analysis are explained, as it takes time to complete the analysis and during this time interesting observations can already be made. This is followed by the conclusions from the stakeholder analysis and lastly the conclusions on its impact during this phase. The full stakeholder analysis itself can be found in Appendix E, only the conclusions will be presented in this paragraph.

### **6.2.1 Pre-analysis observations**

De day of the first community meeting started with Armodio (the pastor) giving us his blessing and introducing the project to the community. After this, the community was invited to the school so we could introduce ourselves and the project. We also explained why we started building at the school: it will benefit all children and therefore all the parents. Logistically it was also easy to start at the school, as the project team sleeps in one of the classrooms. Also, we anticipated on unforeseen challenges in the building process by starting close to the storage room and other facilities. With the village we discussed and agreed upon building the second tank at the church. It will build interest from the community and will not offend anyone (in the order of helping people) as the church is a respected place. Emilio worked the most for us in the beginning, so he will get the third tank. In this decision we relied heavily on the judgement of our guide and translator, Daniel. He also suggested building the next tank at Tito's place, since he also has children at school, he started helping us at the school building site and he has a lot of resources, such as a generator and a chainsaw. Later during the project it turned out Emilio and Tito came to help because Daniel had explicitly asked them to do so, and that these two men were the only ones Daniel more frequently contacted during his work in the community. Also, the gravitational system worked fine during most of the time, so building tanks at Emilio's and Tito's should not have gotten priority, since they have access to this system. Because he was already promised a tank, we decided on building him a tank, but as one of the last in the village.

The order in which the other tanks were going to be built needed to be determined (and a

decision had to be made on how many tanks in total we could built). Considering the fact that the project was managed from the spare classroom of the school and that a tank at the school would be used by all children from the village, and thus the inhabitants of El Progreso would probably not contradict this decision, it turned out to be a good choice to pick this as first building site. Since there was one other sort of public location (the church) for a tank at the other side of the village without any water system, this would be a logical next location for a tank. Thereafter, only locations at private households were left. In order to make a substantiated decision for the order of locations for tanks to be built, and who was going to be left out in this project, it was necessary to determine which criteria the household had to meet in order to get a tank, which has been described in subsection 5.7. Following the list of interest and the service offered in return, as well as the need for a water supply close to their household, the following order was decided: school, church, Emilio (where Chami jr. is the head of the household, thus named as such in the interview), Julio, Mateo, Lazaro, Demetrio, Casildo sr., Israel, Tito and at last Casildo B. Everyone seems happy with the project, and eager to win our alliance, since they bring gifts (mostly food) to the project team and are very helpful. No one seems to hold a grudge against the project, or at least they do not show it.

### **6.2.2 Observations during analysis**

During the analysis, the following was observed: the most important resource in the village is construction experience. Tools are also an important resource due to the remote location, but the availability of these in the village is very limited. The village is small and its inhabitants are closely related and the project is amiable, so the general consensus in the village is positive and not much can or has to be done to temper this. The project is also so small and low profile that besides the village, there are not many other local actors with an interest. Later on during the project people from the nearby village Palmira do show up, and point out their interest.

### **6.2.3 Results of analysis**

The stakeholder analysis, which can be found in Appendix E, resulted in the following power-interest-attitude grid, shown in figure 8. The grid shows that only the community members with a tank should be managed closely and those without a tank should be kept satisfied, due to their lower power. The nearby villages and representante should be monitored, but both the NGOs should be kept informed due to their higher power. Another result from the stakeholder analysis are the SWOT (table 1) and TOWS (table 2) which in summary showed that the knowledge from the team and the village should be combined to overcome the lack of construction experience and to quickly learn more about the circumstances. Also, the workforce can be engaged using the good image of the project and by forming groups of related people.

In conclusion a stakeholder analysis for a small charity project influences the project quality in a positive way by improving the awareness of the project in the village, as it forced the team to contact all actors, and therefore engaging workforce and maps their resources, which is of great importance due to the remoteness of these projects. However, the amiability and size of the project makes that it does not help coping with blocking actors as they are not directly encountered.

## **6.3 Initial requirements**

During the pre-study, requirements management is mainly done by means of interviews. These interviews are taken again in the post-study phase, to keep the amount of interviews manageable, but in hindsight this made it difficult to clearly derive the requirements from before the tanks were built.

The ranking of requirements regarding charity projects resulted on average in the following list:

	Strength	Weakness
	<i>Strengths</i>	<i>Opportunities</i>
	S1: The project team is academically educated in fields related to the project	O1: Most people in the village have construction experience from building (parts) of their own house
Opportunity	S2: GeoParadise already has experience operating in the region	O2: The village can learn how to construct the tanks by themselves
	S3: The project is highly likeable	O3: Families might help each other at their building sites
	S4: The expectations of the village regarding charity/government projects are low	
	<i>Weaknesses</i>	<i>Threats</i>
	W1: The project team has not performed a construction project before	T1: SamenScholen has to approve spendings
Threats	W2: Few is known about the village	T2: If the village does not provide workforce, it will be impossible to create as much tanks as planned
		T3: The village might not be as interested in water tanks as expected

Table 1: SWOT analysis

	Strength	Weakness
Opportunity	Exchange 'Western' knowledge with the village (S1/W2)	Learn to construct from the people in the village (W1/O1)
Threats	Abuse the good image of the project to be able to demand more from the people (S3/T2)	Form clusters of people receiving a tank and ask them to help each other with building (O3/T3)

Table 2: TOWS analysis

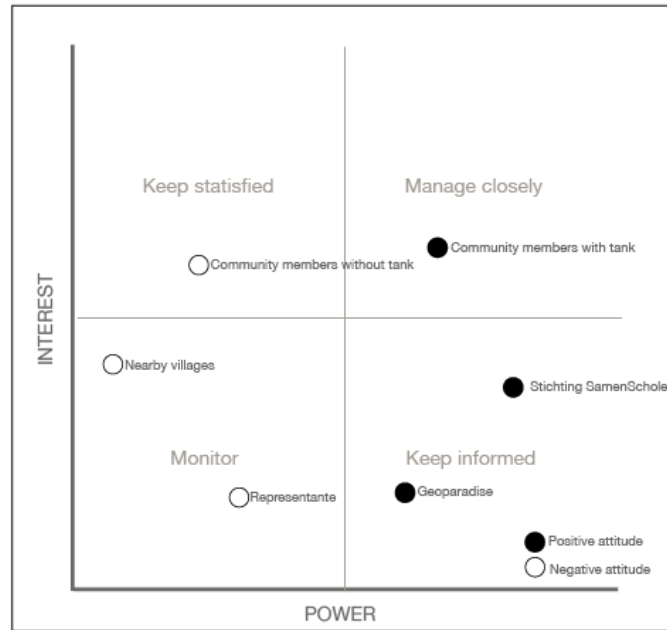


Figure 8: Power-interest-attitude grid resulting from stakeholder analysis

better education, more job opportunities, medical assistance, water and sanitation improvement, money and food. There was however often taken into account that water was already improved, so there cannot directly be said that education, work and medical assistance were more requested than improved water and sanitation. The open question on their requirements repeatedly resulted in a request for electricity (light), while also a bridge crossing the Rio Culebra was often called. It was also often said that water means life for the people. During the project it became clear how difficult it can be to find the right supplies for any construction project at such a location and therefore changing the aspects of the tank at late notice would have been very difficult.

So, in conclusion to improve project quality through requirements management a pre-study is necessary that is fully finished before construction plans are made, so that the complete project can be adapted to this. On a remote location, this seems not feasible to do during one project. It is difficult to find out what people really require and this also raises ethical concerns, but water is very important to the people. Education, work and medical assistance are also important as well as availability of electricity and a bridge, but there can not be concluded which of these was most important before the tanks were constructed.

## 6.4 Planning for project quality

During the pre-study the planning for project quality was made, which contains all that is decided upfront to create a framework for quality management. This consists of: (1) standards and specifications to be met, (2) metrics for meeting these standards and specifications, (3) criteria for authorising project phases and (4) the tools and techniques used for quality assurance and control.

1. The standards and specifications, including metrics for meeting them, are related to cement mixes, the thickness of layers and the amount of cement used per component.

Cement mix:

- Only use sieved sand laying on sandbags and stored covered,
- Mixed on a concrete surface or in a wheelbarrow
- Using a ratio of two buckets of sand on one bucket of cement
- No predefined amount of water is used as this differs due to the relative air humidity.

Thickness: a minimum of 1.5 cm per layer and a total of 4 cm before taking the mould away.  
The amount of cement: 2.5 bags for the bottom, two for the top and two per inside layer, one for the outside layer and one for finishing the top.

2. The criteria for authorisation of phases is 4 days of drying before the top mould is taken off and the lid is put on the tank. 12 hours to take the bottom mould off, 12 hours to take the top mould off and one week after the last layer to stop wetting and covering the tank.
3. The tools and techniques for quality assurance are the training of the local team. This means that certain people in the project group learned to oversee the construction of certain components and new workforce was explained how to create a cement mix. In addition phases will be authorised, audits and inspections will be performed as well as an FMECA and checklist will be constructed.
4. The tools and techniques for quality assurance will be inspections and a cause-effect analysis.

## 6.5 Water assessment during pre-study

According to information gathered from the inhabitants, half of the community in the study area consumes unsafe water during the dry season, which proves that it indeed is necessary to come to a safe solution together. This research will be carried out during the wet season, so the system can only be monitored during wet conditions. A strategy to overcome the dry season will be needed. Therefore the water quantity and quality will be assessed in the pre-study.

### 6.5.1 Available water sources for El Progreso

The available water sources and quantity of precipitation will be described for the village of El Progreso.

#### 6.5.1.1 Overview of available water sources

Information gathered before the start of the project - via the local partner NGO Geoparadise - states that members of the Emberá community installed a gravity-fed river water system a few years ago. The intake of the system is located 5 kilometres upstream of the village, in the middle of the jungle. Unfortunately the pipes often get clogged, due to severe storms or pipes breaking due to landslides or fallen trees. Also it is said that negligence and bad maintenance of the gravitational system lead to malfunctioning. Repairs are said to not be carried out or with great delay. Filters used in the system are clogged and bypassed. When the system is not functioning, people turn back to their old sources of water: nearby rivers and streams and simple means of RWH.

**Local precipitation data** The nearest available weather station is found in Nombre de Dios (No 117-001 from Empresa de Transmisión Eléctrica S.A.). Recorded data shows precipitation data from 1911 to 1998 with an average precipitation of 2668 mm per year. The drier months are January to March with rainfall of 35-70 mm per month, as seen in figure 9. Highest amount of precipitation is measured in November: 370 mm per month. Other months vary from 174-327 mm per month. The monthly average is 222 mm (Hidrometeorología de ETESA, n.d.).

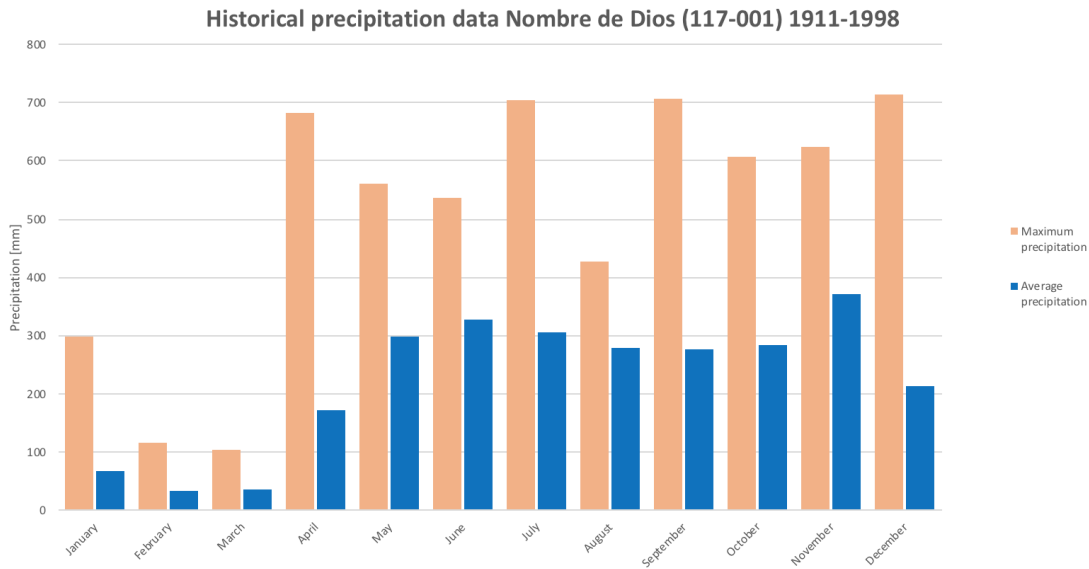


Figure 9: Historical precipitation data Nombre de Dios 1911-1998

**Rivers** There are two main rivers within El Progreso: ‘Rio Negro’ or Negro river and ‘Rio Culebra’ or Culebra river. The source of the Culebra river is in Chagres National Park and it flows down through the mountains to the town of Santa Isabel, where it enters the Caribbean Sea. The river flows past the church part of El Progreso and the road towards Cuango (from either sides of the village) crosses this river. The Negro river flows from the dense jungle in the mountains and is crossed by the road going from El Progreso after which it joins the Culebra river before flowing to Santa Isabel.

**Land use** Cultivation of the land, mainly for agricultural use, is spreading from its town centers. Rain forest is cut away by machete or burned by fumigation. The land is used as fields for cows and horses or for cultivation of crops. The agricultural fields are surrounded by dense rain forest, to the southwest bordered by the Chagres National Park.

### 6.5.1.2 Water usage in El Progreso

El Progreso consist of two parts approximately 1.5 km apart from each other (the school part and the church part). The available water sources of these two parts differ. In this chapter the water sources will be discussed first for the school part of El Progreso and afterwards for the church part of El Progreso.

#### Water usage school part of El Progreso: the gravitational system

The part around the school is connected to a water system that delivers river water by gravity, taken 5 kilometres upstream from the village. Therefore the people living in this part have running water to their disposal, at their premises or in their houses. The water system was originally designed for Palmira, a bigger town situated directly at the beach. The other part of town relies solely on the nearby river as main water supply. All households use different sized open containers to catch rain as it falls from their roofs.

The gravitational fed system gets its water from the river, some 5 kilometres upstream from the village, via a small dam and inlet with coarse screen, see figure 10. This screen prevents big organic

material (leaves, large woody debris, fish and stones) from entering the system. After passing the screen the water falls into a sedimentation tank. In this tank the sediment has the ability to settle down and come to rest at the bottom of the tank. A valve is thereafter installed to control the flow of the water, see figure 10. The water is transported by a 2-inch PVC pipe at surface level through the jungle. Before the pipe enters El Progreso, there is another valve and storage tank installed. Two big filters are present but disconnected from the water system. These filters are already out of service for 2 years according to the inhabitants of the village. When the pipe enters the village, the pipe is located 30 cm under the upper soil layer. At some places the pipe is visible because of local erosion.

The gravitational system is designed approximately 10 years ago for the community of Palmira and El Progreso by the sitting ‘representante’ or representative of the government. According to the villagers, the 2-inch pipes in the main road were constructed by the government and the house connections are made by the inhabitants themselves. The main pipe between the school part and the church part of El Progreso did not have sufficient pressure at the church part of El Progreso and therefore this part did not have access to the running water.

This gravitational system is, 2-5 years ago, renewed for the village Palmira, where the 2-inch pipes were replaced by 5-inch pipes. The renewal of the system did not reach El Progreso due to political struggles, according to the inhabitants of El Progreso. Therefore El Progreso still use the old system with 2-inch diameter. The church part of El Progreso is still not connected to the system. Later it turned out, connecting El Progreso to the system was never officially planned, at it seems the village took in into their own hands to get connected.

The gravitational system is throughout the year not always a reliable water source. In the summer

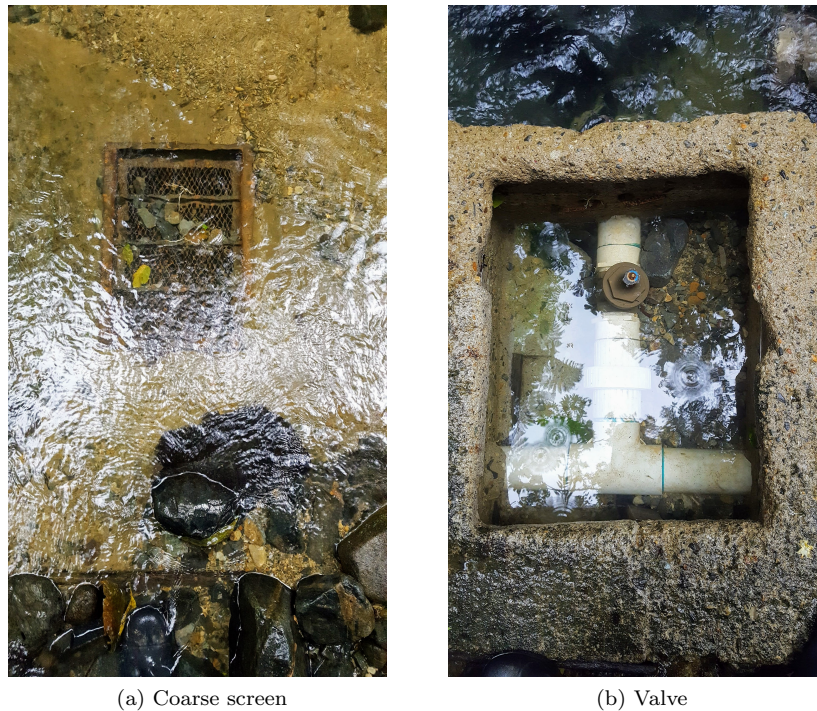


Figure 10: Details of the intake of the gravitational river water fed system

months, December to April, the gravitational system works very well. But in the winter months, April to December, the system does not work properly. Due to heavy rainfall the pipes break or the system gets clogged. When the gravitational system does not work the inhabitants of El Progreso use the water of the Negro river or from a small stream nearby. Both the Negro river and the small stream are surrounded by farmland. The small stream also contains a lot of plants and the water flow is close to being stagnant. The water sources and systems are mapped in figure 11.

### Water usage church part of El Progreso

The second part of El Progreso (Church part) is not connected to the gravitational system and therefore do not have running water to their disposal. The inhabitants of this part of the village use different sources of water for different purposes, which are displayed in figure 12. The water sources will be discussed below.

**Rainwater** Almost all households collect rainwater by putting buckets or small plastic tanks under the edges of their roofs. The water from the rain is used for drinking and cooking. The water from the rain is trusted by the inhabitants and the interviewees. When the rainwater in the buckets runs out, the water from the biggest nearby river will be used for drinking and cooking.

**River water** The Culebra river is located close to the church part of El Progreso. The river water is used by almost every household for different purposes: drinking, cooking, laundry and washing. Besides, several small streams flow through the land where the exact starting and end point cannot be seen. These small streams are never used for drinking, only for washing and doing laundry. The river water is not fully trusted by the inhabitants.

**Groundwater** There is one source of groundwater available. This water is used by the family of the pastor. The so-called spring is situated in a valley in the middle of a cattle field and the water is at time of observation stagnant and small fish and plants can be seen in the pond.

From the interviews it was difficult to get an idea how much water they really use per day. Since household sizes vary a lot (from 2 up to 12 persons) and the amount of water each household says to use differs greatly and does not correspond well with the number of inhabitants. One reason can be that when people are at the river for other activities, they also drink some water and thus do

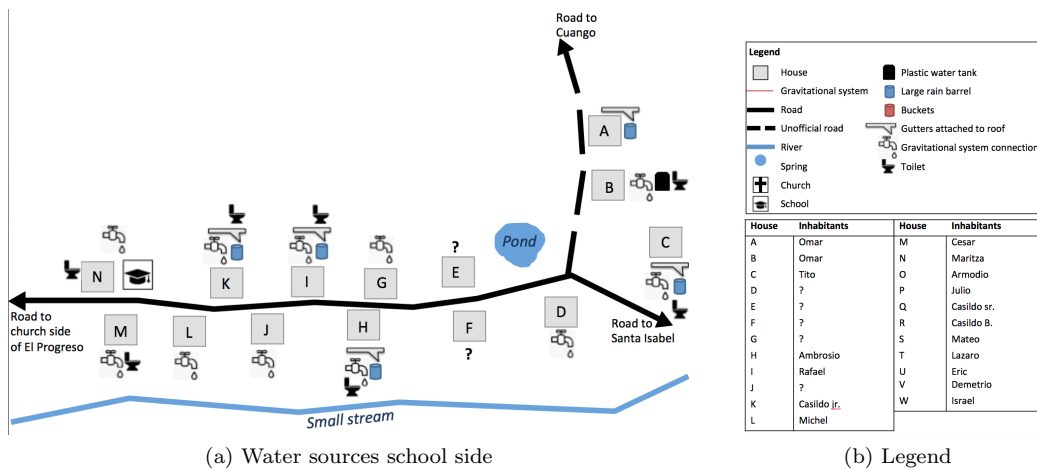


Figure 11: Water sources and systems of the **school part** of El Progreso



not count this amount with their daily use. Due to the fact that they have to carry the water in buckets or containers from the river to their household, it makes them more aware of the amount of water used.

According to the inhabitants that have lived in El Progreso for several decades, the amount of rainfall during the rainy season has decreased over the past decades.

### 6.5.2 Water quality of sources used in El Progreso

In order to describe the impact of this intervention project on the quality of the water that the inhabitants consume, the quality of all three water sources and possible health hazards within the water systems in El Progreso will be assessed in this pre-study and assumptions will be made what type of contaminants are possibly active. This knowledge is gained from interviews, by the experience of the local inhabitants and by conducting fieldwork.

The quality of the river water (Culebra river), rainwater and groundwater in El Progreso are important considering the fact that inhabitants drink the water from all these different water types. As discussed above, two main rivers are present in El Progreso, where the Culebra river is used everyday by several people and the Negro river only when the gravitational system is not working.

#### 6.5.2.1 Possible contaminants

Observations showed that the rivers, streams and spring are surrounded by agricultural land, which is either regularly fumigated or occupied by cattle.

From the interviews a couple of things became clear. The inhabitants are aware of the changing quality of the river water and the possible reasons for the sometimes bad quality of the water. They name agriculture, pesticides and chemicals as the main contaminants of the river water. Also the fact that after heavy rainfall the water in the river is not clear has been a source of their concern.

The Culebra river flows through agricultural land where cows and horses graze. After heavy rainfall the water level in the Culebra river rises unexpectedly fast and leading to dangerously high dis-

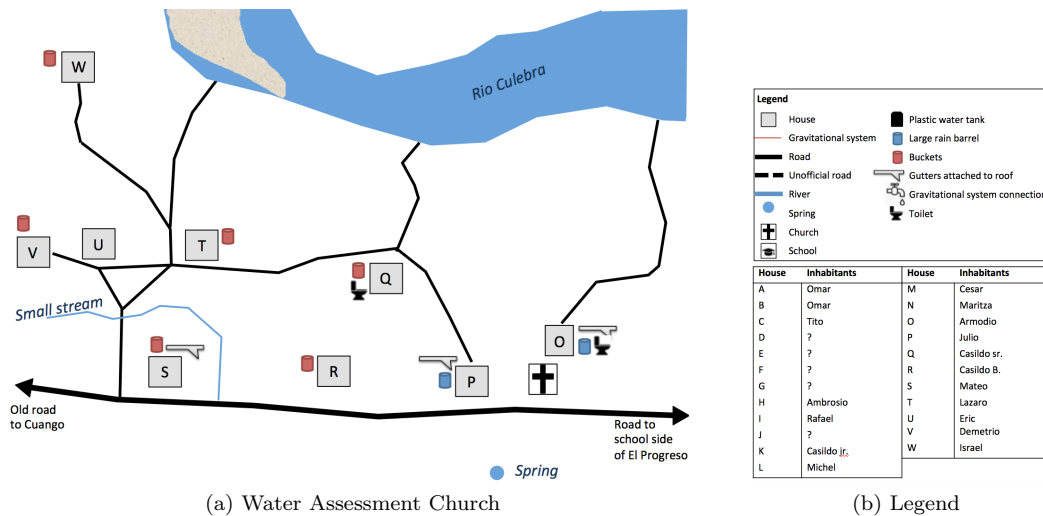


Figure 12: Water sources and systems of the **church part** of El Progreso

charges and floods the agricultural land. Faeces of cattle end up in the river water, where after the water can be contaminated by different types of bacteria, viruses and protozoa. Not only biological contamination but also chemical contamination can be the results of such heavy rainfall. As the inhabitants described, fumigation of the land is done on a large scale. Despite of the noticeable effects of this fumigation on their water sources, some inhabitants work as fumigators in the surrounding lands themselves, or fumigate their own gardens.

Another way of contamination by agricultural means, mentioned at multiple interviews, are dead animals that are either thrown in the river or eventually end up in the river.

Not only agriculture, but also humans directly have an influence on the quality of the river water. The Culebra river is according to the inhabitants contaminated by the remains of cleaning articles and human faeces from an upstream village. Even though most of the community members see human faeces and other excrements as a source of contamination, a lot of them contribute to this pollution at the same time due to a lack of sanitation services around their houses and at their working locations in the fields.

Contaminants of the rainwater are barely identified by the inhabitants. The majority see rainwater as very pure and clean, *Demetrio*: "*Rainwater is pure, because it comes directly from god*". One family (family of Casildo jr.) expressed their concern about the water being collected via the roof. They argued that drinking water from the roof was not good because of all metals on the roof.

#### **6.5.2.2 Adverse health effects**

The biological and chemical contamination of the river can have adverse health effects on the inhabitants drinking the water. The interviews helped to understand in which way, and when during the year the people experience complaints.

Almost all families interviewed indicate that they themselves, or their children sometimes get sick from drinking the river water. They name vomiting, dizziness, nausea and diarrhoea as main complaints. The pastor explained that first the children got sick, where after the parents follow. The main period when people get sick from the water is after heavy rainfall and during the summer. They explain that during summer the river flow is minimal. In this period of time they firstly use the rainwater they catch, and otherwise they still go to the river because there is no other source of water.

There are numerous pathogenic micro-organisms that can cause the gastrointestinal effects that the inhabitants of El Progreso encounter. People can get contaminated by the river water in three routes: ingestion (drinking), inhalation (aerosols) or direct contact (bathing). The most common pathogens in river water caused by surrounding cattle are the bacteria: *Salmonella*, *Campylobacter* and *Escherichia Coli* (*E.Coli*) and the viruses: *Giardia* and *Cryptosporidium* (World Health Organization, 2014). As discussed in the literature review, *E.Coli* is an indicator for Faecal Identifying Organisms (FIO) in the water. The *i.o.* *E.Coli* concentration therefore can say whether other types of pathogens are present in the water.

#### **6.5.2.3 Water treatment**

In most of the households, the water that is used for drinking is not treated before consumption. Some households boil water for the small children but do not treat it for the older children or adults. Armodio his household used to have a natural filter but because it got broken, they only boil water for children instead. A few households only take action when somebody gets sick.

Even though she had a negative answer to the question if she treats her drinking water, Exilda

filters the water she uses through her shirt. Either she does not see this as real treatment (even though some suggestions were made when posing the question) or she does not know that she is actually treating it in some sort. Casildo Berugate explained during his interview that he had learned when he gets water from the river that he should let the sediment settle before he could drink it.

Marcia and Israel do not treat their water but sell bottles of chlorine in their mini store at home. It apparently is used for cleaning purposes.

Some people do not see any option when people get sick from the water, for example Demetrio: “In summer, there is not much rain and not that much flow in the river, kids get sick first, sometimes adults too (diarrhoea, vomiting). But we keep drinking it, because there is no other water.”

#### **6.5.2.4 Indication quality water sources by in-situ measurements**

During the first general interview the main water source households use is discussed. After the interview the quality of the water sources that the use is measured by the in-situ water quality measuring equipment. The TDS, EC, Temperature and pH of all available water sources are presented in Appendix I.

Some interesting findings about the quality of the water after these measurements are presented below.

1. From the measurements it can be seen that there is a clear difference between the EC and TDS from rain and river water.
2. The lowest EC found is 14.2  $\mu\text{S}/\text{cm}$  corresponding to a TDS of 7 ppm (or 7 mg/L). This is measured from the rainwater that the family of the pastor uses as drinking water. The conductivity is very low for drinking water and corresponds to distilled water from a reverse osmosis quality. As discussed in the literature review water with TDS < 50 mg/L can be named low mineral content water and can have a negative effect on human health when used over long periods of time. It has to be mentioned that the measurements are taken during several days, therefore results from different locations at different days and have to be compared with caution, they only give an indication.
3. Besides this low TDS in the rain barrel of the pastor, four other sources contain a TDS lower than 50 mg/L. These are the rain barrel of Emilio, two small streams and the spring. This suggests that not only the water harvested from the rain, but also the river and groundwater have a low mineral content.
4. The highest EC found is 173  $\mu\text{S}/\text{cm}$  corresponding to TDS of 89 ppm. This water comes from the gravitational system fed by the Negro river.
5. The pH of all available water sources measured are between 7 and 8, and therefore can be seen as neutral water source.
6. The temperatures measured vary between 26.7 - 33.2 °C. The water measured within the rain barrels have the highest temperatures.
7. The Culebra river is the drinking water sources from 5 households. The EC and TDS for the Culebra river are measured 5 times. The EC lays between 116.3 and 136.0  $\mu\text{S}/\text{cm}$  and the TDS between 62 and 78. The small difference can be caused by heavy rainfall or point pollution. No extreme changes of the same river are found.

### 6.5.3 Sanitation

There is a big difference in the sanitation between the school and the church part of El Progreso. Since the inhabitants of the school part have running water to their disposal, connecting a toilet and bathroom belongs to the possibilities. The largest part of this side of the village therefore have a toilet and shower connected to the gravitational system. At the property of the school, a small house is build for the teacher, where a toilet and shower are located. Kids from the school have the possibility to use this toilet. In the interview with the current teacher, Maritza Bernalle, it became evident that although there is a toilet, not all the kids use this toilet. According to Maritza there is need for toilets attached to the school building especially for the kids. She names three main reasons for this necessity: 1) The kids are shy and therefore do not dare to go to the toilet from the teacher 2) When it rains, the kids cannot visit the toilet because they will become totally wet 3) when new toilets will be build attached to the school, this also will become an educational learning process for the kids.

At the other part of the village, the inhabitants do not have running water to their disposal, making good sanitation a more complicated challenge. Two out of the nine families living in this part have build a simple toilet with septic tank (latrines). The other households have no toilet and none have a shower. The family of the pastor does have a septic tank, but one big problem they are dealing with is heavy rainfall results in flooding of the septic tank. Marcia and Israel did not build a septic tank in the first place because according to them, the water level rises so high that having a septic tank would cause overflow every time heavy rainfall occurs.

The inhabitants that do not have a toilet pee close to the house and dig a hole at the Culebra river shore in order to defecate. The main reason for wanting a toilet resulted from the interviews. First of all, according to the inhabitants is better for the health when a toilet is build, because contamination risks gets smaller. Secondly it provides privacy, which is more comfortable. Inhabitants now do it as fast as possible in order for nobody to see it. Finally having a toilet protects you from getting attacked by animals.

In conclusion of the water quality assessment in the pre-study, the inhabitants of El Progreso name cattle (both faeces and dead animal), pesticides (from fumigation), heavy rainfall and up-stream villages as main contaminants of the river water. From these contaminants they get sick mostly after heavy rainfall or in the dry summer period when the water level is low. In most of the households, the water that is used for drinking is not treated before consumption. Some households boil water for the small children but do not treat it for the older children or adults. The TDS of harvested rainwater from some household is very low and therefor lacks minerals. This can cause adverse health effects. Finally sanitation differs strongly between the two sides of the village. Inhabitants with running water do usually have a toilet, inhabitants without running water relieve their selves in nature.

## 6.6 Conclusion of the Pre-study

During the pre-study multiple analyses were conducted. It became clear that when a project is started a lot of things work out differently than expected. Some things went very smoothly, such as the introduction of the project to the village and the attitude of the inhabitants towards the project and the project team. Other things turned out differently such as the actual construction method of the tank, the expected relation between the local NGO and the village and the degree of influences by indigenous believes.

The stakeholder analysis helped the project by mapping scarce resources for the remote project,

but due to the small size and charity character, no blocking or not positive actors could be found. So the stakeholder analysis only helped engage actors who already had similar interests and might have helped without these insights. Interviews showed that it is difficult to find out what people really wanted in the past, as these interviews were held after the tanks were completed. Combined with the finding that the requirements are heavily biased by what we offer, makes it difficult to judge whether a latrine, electricity or the water tank was initially their biggest requirement. The same interviews, together with the observation walks, provided an overview of their current water sources: the school part relied primarily on the gravitational system and had some own water systems and the church part relied on different water sources, where the water in the Culebra river was mainly used because their own systems did not have the capacity. Possible contaminants of their water sources (cattle, pesticides, heavy rainfall) were also mentioned by the inhabitants and how they end up in their sources and that it makes them sick from time to time, nevertheless most households do not treat their water. Half of the inhabitants do not have a toilet to their disposal (only at the school side) and go to the toilet in the fields or along the river bank, which is also kind of private due to its remoteness.

Furthermore, due to El Progreso's location, adaptation of the project because of different requirements of the inhabitants would have been very difficult. Before the construction phase could start, a framework for project quality management was made. Altogether, this showed that many research, especially requirements management, could have had more impact when performed in an earlier pre-study separate of the construction project.

## 7 Construction phase

The construction phase consists mainly of gathering lessons learned regarding project control and monitoring project quality. Besides this, there are still observations made regarding requirements management and stakeholders will be tried to engage.

Stakeholder management in this phase mainly entails observing the effects of trying to engage actors and their resources. Requirements management entails observing small deviations in the construction due to wishes of the owner. Quality management, the most important part of the construction phase, consists of quality assurance. The chapter will start with a process description of the research done in the construction phase study.

### 7.1 Construction phase process description

The construction phase consists of the actual building of the RWH tanks and everything that comes with constructing these tanks. Observations on the building sites and interactions with the inhabitants provided to be important aspects of this phase.

In the pre-study the building order of the tanks was roughly made. In the construction phase, before the start of the building process at each household, conversations were held with those in charge of the household. The starting date, the accessibility of the house by car (several houses needed to prepare a road in order for the car to access the house) location of the tank and the general expectations in the form of help from the household are discussed. This can solve much confusion, Casildo Berugate for example, first thought that we were building septic tanks instead of RWH tanks. The help from the household can have various forms: cooking, laundry or physically helping the construction team with construction. The reason for asking help from the household is creating ownership whereby they feel responsible for maintenance in the future. In order to try to be honest and transparent, the expectations towards households not receiving a water tank are expressed during so called ‘bad news’ conversations. In this conversation the time span of the project is addressed and the reason for others receiving the tank explained. The agreements made during these initial meetings were however not always honoured, for example on the day that Israel promised to be available together with extra helpers to finish his tank, his house was found empty, so it was decided to work on another tank. Furthermore, after five agreements to make him clean a path to his house, the project team ended up doing this themselves. Knowing this was far from how we wished it to be or how we agreed upon doing things, it was the only way to proceed. Given more time, we would just have waited. Requesting lunch when working at a house was another favour that was often asked and offered in order to increase their involvement and therefore ownership, and this also means that the team does not have to bother with cooking and can eat near the construction site. After a few disappointments, it became clear that it was for certain households a problem to buy food for the complete group. This was solved by bringing our own food, which was then prepared by the household, often also used for the rest of the household. Further, when half of the group was in Colon to visit the hospital because Lise had fallen ill, more people were willing to serve lunch. This might have also had to do with the fact that all the woman of the group were then gone, making preparing the lunch seem a more urgent problem to the village. People from the village, especially Marcia, did express their disliking of so many people not being able to deliver on their promise as a village. Remarkably, she was not always able to change much of this during the construction of her own tank.

During the weekdays (Monday to Friday) the largest part of El Progreso is working, children go to school, women are taking care of the household and man are going out into the mines or fields. This means that during the weekdays, less people are available to help with the construction. The project group therefor decided to switch their weekend to Tuesday and Wednesday, and work from Thurs-

day to Monday. This results in help from all inhabitants of El Progreso on Saturday and Sunday. During the construction of the tank a few inhabitants that do not have a job helped almost full-time with the construction. Building the tanks then becomes a learning process, training local people in order to someday reproduce the knowledge, or be able to work in construction in a broader sense.

Sand as a resource plays an important role in the construction of the storage tanks, where one tank requires approximately 90 bags of sand. There are several locations in the neighbourhood where sand can be found. The weather circumstances and location of building site determines from which location the sand will be fetched. For example after heavy rainfall, some sand locations were completely flooded, which resulted in loss of sand. Getting sand is something where everyone can help, therefore everyone was asked to help and contribute to the building process in this way. The starting phase of the construction only men helped with getting the sand, although everyone was asked. When they noticed that also the females from the project group helped, the women from the village also contributed. Getting sand with the car became, besides a necessity, a social event where almost all inhabitants helped, even children.

During the construction of the tank, more opportunities arise to talk to the local people. The family connections, relationships and the stakeholders and their resources are gradually identified. Also the political bonds with other communities or neighbouring villages are explained. Moreover, observing and actually taking part in the lifestyle of the local people led to more insights regarding water use.

## **7.2 Stakeholder management during construction**

During the construction there were interesting interactions with two stakeholders. First, Omar and his resources were tried to get engaged and positive about the project. Second, Tito was tried to keep engaged in the project.

Omar is one of the more wealthy community members, he has a car and cellular receiver at his house, he starts his generator to power this receiver. From the start, he liked the project, but it was tried to get him more engaged to ensure that his car and cellular receiver could be used when necessary. He was kept interested by talking about helping (with knowledge) to construct a tank, while he has to pay for the cement and workforce himself. Also, the team helped him fix his car and many groceries were bought at his store, which in the end often were given for free. The cellular receiver made that it was less often necessary to leave the village. It eventually turned out that he did not expect a tank and already has a large plastic one, but that he just liked the project.

Tito has a chainsaw and helped us construct the wooden mould. He also helped a lot with Emilio's tank, which is why it was chosen to give him a tank too, but Emilio got a tank before construction at the other part of the village started and Tito did not get it that soon. He was insulted by this and was afraid that he would not get a tank. It was then promised that one would be build, but a promise is not worth much in the Panamanian culture, as it turns out. So, it was decided to keep better contact with him and a plan on when building would start was made. This did not take all his concerns away, but it did mean that he was available to help with his chainsaw whenever necessary.

So, in conclusion stakeholder management helped to engage some actors, but this was not necessarily a result of the stakeholder analysis, but merely the attention for stakeholder management in general.

### 7.3 Requirements management during construction

During the construction several requirements were communicated and observed, mainly having to do with the tank or with leftover construction supplies. The observations will be shortly described in the following paragraphs.

Most people chose to put their tank as close to their kitchen as possible as long as it is not in the way of a walking path or a future house expansion. Demetrio wants his tank slightly elevated on a foundation, he mentioned this himself and the reason for this was pure aesthetics. He will have to build it himself and this was the reason to build Lazaro's tank first. Casildo Chami senior wants to connect his tank to kitchen tap. We explained that there would not be enough pressure and it is outside the scope of this project to supply this. After this explanation he was satisfied having the tank situated as such, it was not in the way around the house, though still accessible.

Often leftover cement was used to make small improvements to the houses, such as plastering, creating steps and kitchen stoves. Only Demetrio used leftover cement to make improvements to the tank, namely a concrete floor near the tap of the tank. Israel is the only one who asked attention for other requirements during construction, he said better education and more attention to the circumstances in the village were necessary, also to preserve the Emberá culture.

So, in conclusion the people show very diverse and scattered requirements in practice and not solely focused on improving their water sources. Some of these requirements might be seen as less urgent and even status related, but this is said purely from a western point of view and this difference might be explainable by the fact that they are used to their circumstances.

### 7.4 Quality assurance

During construction, quality management mainly consists of quality assurance. This entails training of project team members, authorisation of phases, audits and inspections and an FMEA. The realisation of these steps will be described in this section.

1. *Training of project team members* was done very briefly in practice and came down to assigning certain persons to the same tasks to make them specialists on the topic. This training could have been more elaborate.
2. *Authorisation* of phases was included in the planning to make sure that no new phase was started before enough drying time had elapsed.
3. *The audits and inspections* were done by spending two full days at two different construction sites to observe how the work is done and whether this is according to the specifications of the quality plan. The two inspection days resulted in a lot of focus on cement mixing with the right ratio, which is often at first neglected when under time pressure, and on the thickness of the layers. This resulted in extra layers for the inspected tank to reach the specified thickness. Besides these two inspection days, regular measurements were taken during the rest of the phase and after these rough measurements were validated, there could be deducted whether the wall thickness of the tank was sufficient. These measurements are shown in Appendix F, but unfortunately these could not be validated as the measurement equipment used for the validation did not function. So, eventually the audits of wall thickness did not fully succeed and only gave a rough indication of the thickness.
4. *The FMEA* that was performed, can be found in Appendix F. The most important result is the possibility of a failure of filtering particles in the gutter system, leading to undrinkable water. Although the probability is only moderate, the detectability and severity is high, leading to the highest RPN. This is followed by the tank becoming not air-tight due to wear



of plastic or cement and leading to the water becoming not drinkable. Thereafter comes a tie of water leakage due to too thin walls, leaking gutters (or connections) due to wear. This resulted in the intention to improve the quality of the gutter system, and while doing so also upgrading the tap, but no higher quality of these two could be bought. There was eventually decided to only hang gutters with hardwood and replacement taps were left in the village. To reduce the probability of too thin walls the additive Sika was added to the cement mix for the outer layer, which improves water tightness. Also, a more watertight connection of the tap was constructed in the five latest tanks.

It was noticed that combining research with construction on multiple building sites makes it very difficult to inspect and audit properly, as the construction takes a lot of time and combining this with inspections results in low attention for the audits. Also, for good inspections and thorough audits there has to be communicated in detail about the building process with the local workforce, which requires the translator. It is recommended for a new project to make a good plan including workshops and diplomas regarding construction knowledge for the local workforce, reserve more time for non-building activities such as quality management and put more effort in having translation capabilities, either by learning Spanish or by hiring more (experienced) translators. When these results became clear during the project, the translator was used more at building sites to explain building steps and educate the local workforce, instead of solely helping with building.

So, in conclusion, at a small, foreign charity project, quality management based on audits and inspections is not feasible, as this is a full time job which also requires a translator. Even then it could be difficult with multiple sites. More preparation, leading to workshops and checklists, could solve this for repeated projects. The responsibility can then be given to a site supervisor. An FMEA can help to improve the quality, but the results are most useful before the project starts, while it is difficult to make an accurate FMEA when the resulting tank has not been seen yet.

## 7.5 Project control lessons learned

A full list of project control observations can be found in Appendix H, in this chapter only the findings and conclusion can be found.

First of all it showed that for an inexperienced project group at a foreign project location, there will be many known and unknown uncertainties and especially to address the latter ones it is useful to do a pre-study before the actual project starts. This gives insight in the available (natural) resources around the project site, such as the quality of the sand which is of great influence to the quality of the tank, and it gives the inhabitants time to prepare for the project.

Proper education and workshops also showed to be necessary for the workforce to improve construction speed and quality of the work, but materials for this need to be translated and preferably printed before the project starts. Comparable to this, more preparation should be put in the start of every new construction site: meeting people long before construction, discussing the planning, arranging the site and delivering the building supplies already. It also became clear that the project team is very dependent on the supply of workforce from the village and this should be asked from the village without negotiating. The project team needs a rigid and demanding attitude in this, as the viewpoint from the village can otherwise become that you are bringing free improvements to them for which they do not have to contribute anything. Lastly, it became clear that coordinating between building sites and helping becomes a full time job when working on three building sites, this can be solved with better construction training to reduce questions, a separate set of tools for every building site and communication equipment such as radios.

So in conclusion, the lessons learned can roughly be summarised that more front-end loading is necessary to improve efficiency and positive impact, which can amongst other be done through a pre-study.

## **7.6 Conclusion construction phase**

The construction phase showed to be a phase where the interactions between the local people and the project team provided mutual respect and helped the engagement of the local people in the project due to activities such as providing food during construction, getting sand together and working on Saturday and Sunday. The special resources of Omar and Tito were proven to be very useful, so they were kept engaged. Even though most of the people had the same preference of the location of the tank (close to the kitchen), other requirements were very diverse and scattered and not solely focused on improving their water source. The quality assurance proved to be challenging due to the fact that the combination of audits, inspection and construction work was not feasible, translation availability was lacking and preparation time was too short to prevent all inconsistencies. This short preparation time at location has also resulted in the project team being more dependent on the local community, instead of the other way around.

## 8 Post study

In the post study a repeated water quality assessment has been made, now including the quality of the water within the Calabash tank. The requirements of the inhabitants are again analysed using interviews to be able to judge the impact the tank had on their requirements and whether the management of this had a positive impact on the project quality. Lastly, the last parts of quality management are evaluated, using quality control. Entailing inspections and defect repair, including concrete sample testing by UTP, and a cause effect (CE) analysis. The chapter will start with a process description of the research done in the post study.

### 8.1 Process

In the process of the post study first the expectations from the project, the construction, the water quality and the integration are compared to the actual situation in order to learn from this intervention. Thereafter the process after the construction of the tank is described, where quality control plays an important role. Finally the evaluation interviews and final workshop are described.

Firstly, before the arrival in El Progreso the only link between the project group and inhabitants of El Progreso was the local NGO GeoParadise. The expectation from the project group was that this NGO knew all families and the main stakeholders within the village. This turned out not to be the case, causing more effort in the start up phase of the project to meet all inhabitants and make the stakeholder list complete. This as well made conversation on social level more difficult in the beginning. Secondly, it was expected that after building one or two tanks, the inhabitants of the village would take over the construction work in way, that we would assist them by carrying out the work. To the contrary, the help of the inhabitants was not enough for the project group to step aside. Therefore the project group stayed in charge of the construction the whole project although most of us planned to do research. Thirdly, beforehand it was expected that the tank construction would follow a similar process as in former projects building the Calabash tank. Lack of resources and available materials led to several changes to the construction that were not planned beforehand. Finally, the expectation was that the Emberá culture within the El Progreso community was strongly practised. In literature it was found that the Emberá culture has a strong cultural belief regarding water. In the interviews therefore we tried to find evidence for this statement, but surprisingly was not found. It became evident that because of the remote location of the village, far away from any relatives, the Emberá traditions had vanished over time.

The post study starts with an evaluation of the first tank that is finished. The quality of the first tank (at the school) is tested in terms of construction, water quantity and quality. The quality of the construction impacts the quantity and quality of the water in different ways. Firstly, the presence of contaminants in the concrete will impact the strength of the tank and will also impact the quality of the water inside the tank. Secondly, the water tightness of the concrete impacts the strength and quality of the tank but also impact the quantity of the water inside the tank. This is handled in the quality control chapter. When the quality control measurements of the tank are finished, the tank needs to be cleaned from the inside by the household owners themselves. After this is done, the gutter is finished and connected to the system and the manhole cover is sealed. This can only be done at this point, as the water level has to be measured several times to be able to judge the water tightness. During this period the tap would be closed and sealed with a tie-wrap to restrict people from using the tank. However, it proved difficult to convey the importance of this, as many of the seals were taken off to use the tank, making the measurements impossible. After this moment, the tank is delivered to the family and it becomes their full responsibility. Some time after the completion of the system, evaluation interviews were held in order to determine what the owners think of the construction and aesthetics of the tank and the quality of the water.

The tank, after it is cleaned by the owner and filled naturally by the gutter system, is monitored for five days in order to see the impact of the curing of the concrete and impact of storage on the quality of the water. When almost all tanks are finished, the overall water quality analysis of all available water sources is performed. During the construction phase, a collaboration with UTP was set up and resulted in a delegation of the university visiting the project location. They took samples from six water tanks, two rivers and one ground water source (natural well). Beforehand it was discussed on which water quality parameters the water needs to be tested. In appendix K the results of the analyses can be found.

During the interviews the people were asked whether they would like to know more about water and how to treat it. Everyone, the one more enthusiastic than the other, responded positively. On the final day of the project, a workshop was held about water usage, water quality, water treatment and the maintenance of the RWH systems. The reason for this workshop was to transfer knowledge about water quality and treatment possibilities in order to minimise the risk of people getting exposed to contaminated water. Also some suggestions were made, such as which sources were not to be trusted. For example, one source that is used by the family of the pastor as drinking water is the groundwater spring. Professor Barranco from UTP personally told the pastor that drinking this water was not safe as fish live and algae grow there. Two weeks after the project, when the study site was one more time visited, it was observed that the pastor still got his water from the spring. The reason for this trip was measuring the thickness of the concrete wall by an ultrasonic measuring device in order to say something about the quality control measurements in the start of the post-study. This trip was combined with measuring the pH, EC and TDS from several water storage tanks to determine the possible changes over time. Also some interviews were carried out to find out what the inhabitants think of the quality of the water. The post-study ends in Panama City where the results of the water quality parameters will be analysed and discussed with dr. Barranco.

In conclusion, expectations from the local situation in El Progreso were in the post-study compared to the actual situation. The finished tank was evaluated by quality control tests, water quantity and quality in situ tests. After the tank was delivered to the household, the professional water quality sampling was executed by UTP. During the final phase of the project the results from the fieldwork, analysis and interviews were examined in Panama City as well as a general reflection on the impact of the intervention was done.

## 8.2 Requirements during post-study

During the post study, interviews and observations on the use of the newly build tank resulted in new information on the requirements. This new information is described in this section, starting with the observations and closing off with the interview results.

- Observations
  - Emilio has filled his tank with water from the gravitational system and will only use the system as a buffer in times the gravitational system is not working.
  - Tito wanted a tank because he had the opportunity to get one, because he helped building the first two tanks and because the team built them and not because he necessarily needed one.
- Interviews
  - Almost all people named toilets or latrines, or improved toilets, as their current biggest requirement now that the tanks are finished, but for various reasons.

- Armodio wants an improved septic tank for his latrines, as the latrines as they are now often get flushed by the river. Others want a toilet or latrine because it is easier and safer than having to go into the bush, it is more private, it is better for their health, protects them from wild animals and it looks better with visitors or a combination of these reasons. The teacher gave various reasons why a toilet would be important for the school: (1) the children will be less ashamed to go to the toilet, (2) it gives an opportunity to educate them on hygiene and (3) during heavy rainfall the children will not be soaked when going to a nearby toilet. Casildo Jr. already has a flushing toilet with septic tank, but wants more toilets<sup>3</sup>.
- After water, light (or electricity) is most requested and also a bridge was repeatedly named.

So, in conclusion the requirements seem to have shifted towards sanitation and are very much biased by what the project offered. However, as the requirements during the pre-study did not become very clear, there cannot be concluded whether tanks were or were not the main requirements during the pre-study.

### 8.3 Quality control

During construction, quality management mainly consists of quality control. Quality control consists of inspections, defect repair and a cause-effect (CE) analysis. This paragraph will start with the results of inspections and defect repair, followed by the CE conclusions.

*Inspection and defect repair results:*

- Structural quality
  - The tank at the school shows cracks.
  - The tank at the church shows small spots of corrosion, the chicken fence was not covered well enough by the cement and started to corrode.
  - Multiple tanks show wet spots: from small leaks in the gutters and from within the tank. The measurement method for the water tightness of the tanks are however not precise enough to say whether the tanks are waterproof.
  - Some parts of the gutters are hanging too low, due to the necessary slope of the gutters, to catch all the rain in heavy showers, this results in overshooting water which will not end up in the tank.
  - The lid of Julio broke in multiple pieces when it was being lifted for placement. A CE-analysis was performed on this failure.
    - \* After construction, the lid was very thin and a small extra layer was added to after a few days to compensate for this lack of thickness, this layer disassembled.
    - \* The first two layers were in total 3.3cm thick.
    - \* It is expected that the first two layers were made with too much time in between and also
    - \* This lid was meant to be thinner to make it easier to handle.
  - The manhole cover at Julio's tank started to crack when it was taken out (approximately 2 hours after making it).
  - The cover at Emilio showed cracks and therefore had to be made again.

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<sup>3</sup>These results indicate a flaw in the interviews, which can be explained by the fact that this question was often translated in a way that toilets were given as an example, while this was not as such posted in the English question.

- The concrete sample testing showed that the quality of the used sand had a very high impact on the concrete strength, but due to the testing method not all results are valid and no conclusions on the effect of the rebar type can be drawn. The details on these tests can be found in Appendix G.
- Water tightness
  - Several field measurements of water tightness were taken after construction, but those were not significant or took too much time. The size of the tank is too big to measure accurately: a difference of 2cm can be measured, so approximately 85 litres or 3 percent has to leak in 24 hours. To solve this, the tank would have to be filled up to the overflow, so there can be measured in a 4 inch pipe, but it takes too much time to wait until the rain has filled up all tanks until the overflow.
- Water quantity
  - The water quantity was assessed as part of the water assessment 8.4 and the relevant results for quality management are summarised here. In regard to quality management, these measurements can be seen as inspections.
  - The system will suffice any dry spell of 29 days or shorter based on the measured rainfall during the project (figure 13) and assuming a use of 95 litres and 30m<sup>2</sup> connected roof area). During the interviews all the households indicated that this would be more than enough, although some said that they will be careful when necessary. No one said that the tank should have been bigger.
- Water quality: The water quality was assessed as part of the water assessment and the relevant results for quality management are summarised here. In regard to quality management, these measurements can be seen as inspections. The water quality was inspected twice, at completion of the tanks and after two weeks.
  - The highest measured pH was 11 and after two weeks again 11. This can possibly cause adverse health effects and is higher than allowed according to the Panamanian drinking water requirements.
  - The highest measured EC is 90.3 and after two weeks 832  $\mu\text{S}/\text{cm}^2$ , this can be due to contaminants in the sand used for the concrete or contaminants transported by the roof and gutter system.
  - The highest measured TDS is 51 ppm and after two weeks 484 ppm and although 20 ppm is standard for rainwater, 300-600 ppm is considered good by the WHO.

*The CE-analysis*, elaborated in appendix G, showed that the causes in the process and management domain had to do with the fact that this was one of the earlier tanks, so the process was not optimised yet and no measurements were in place yet. There were already plans for project control lessons learned and planning for quality management that cover these aspects. Regarding the materials domain, there was tried to find a better quality of sand, but this was not available. This leaves the people domain, communication difficulties and low experience and education.

So in conclusion, concrete structures can rely heavily on quality control (afterwards), as they either fail right away or are of sufficient quality. Field measurements of water tightness are not significant or takes much time, as the size of the tank is too big to measure accurately (two centimetres can be measured, so approximately 85 litres or three percent has to leak in 24 hours, then the tank would empty in 33 days) So it would have to be filled up to the overflow, so there can be measured in a four inch pipe, but it takes too much time to let the tank fill up so far.

## 8.4 Water assessment during post-study

In this part the impact of the RWH tanks on the quantity and quality of the water will be assessed. Appendix M shows the post study water assessment map.

### 8.4.1 Water quantity results

Rainfall depth during the construction phase was recorded using a tipping bucket, placed in an open field nearby the village. Results are plotted in figure 13, showing daily rainfall values in mm depth. From August 24 to September 26 (34 days) a total amount of 528 mm rainfall was recorded. The quantity of water in the tanks is indicated by the orange graph. The grey line indicates maximum storage capacity (2700 litre). The storage in the tanks is calculated as follows:

- Potential volume for storage is determined by multiplying recorded rainfall depth with the connected roof area
- Daily output is usage, estimated by tank owner
- This gives a net volume entering or exiting the tank, giving cumulative values shown in the graph in 13.
- Calculations are done assuming an empty tank on August 24.

From the figure it becomes clear that for this period in time the built system with a tank of 2700 litre storage capacity and a connected roof area of 30 m<sup>2</sup> is sufficient, assuming a daily usage of 95 litre of water per household. Such a system would suffice any dry spell of 29 days or shorter.

### 8.4.2 Water quality results

When the construction of the ferrocement tanks is finished, the tanks are naturally filled with rainwater by the gutter system. In order to determine the quality of the water over time, the first tank (built by the school) is monitored three times a day, for five days. The results of this monitoring is visible in Appendix J. In order to determine whether the harvested rainwater inside the tanks serves as safe drinking water and meets the Panamanian Drinking water requirements (see Appendix C), an extensive water quality analysis is carried out in this post study. Two weeks

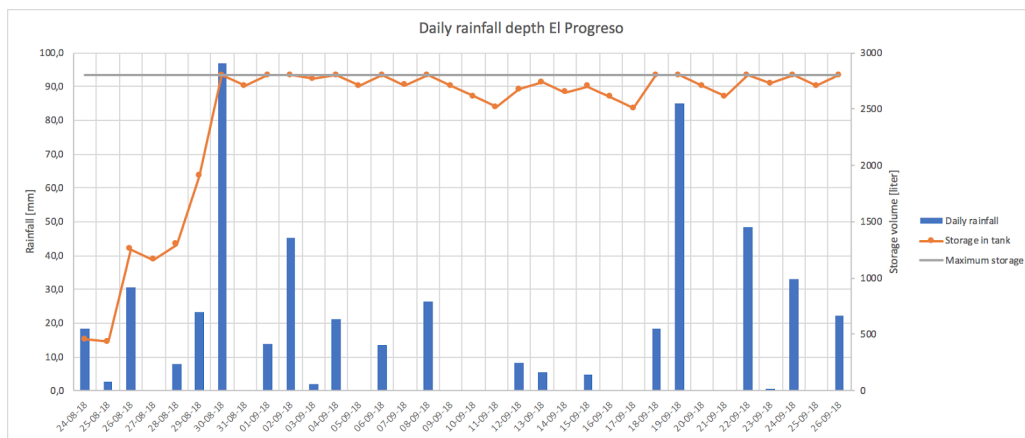


Figure 13: Daily rainfall values for El Progreso from August 24 to September 26, orange graph indicates quantity of water in the tanks and the grey line indicates maximum storage capacity

after the samples are taken, the TDS, EC and pH will be determined again in order to see whether these parameters changed over time.

#### 8.4.2.1 Weekly monitoring results

The weekly monitoring resulted in some interesting findings. Some trends are spotted as can be seen in the figures below. The results will be discussed below.

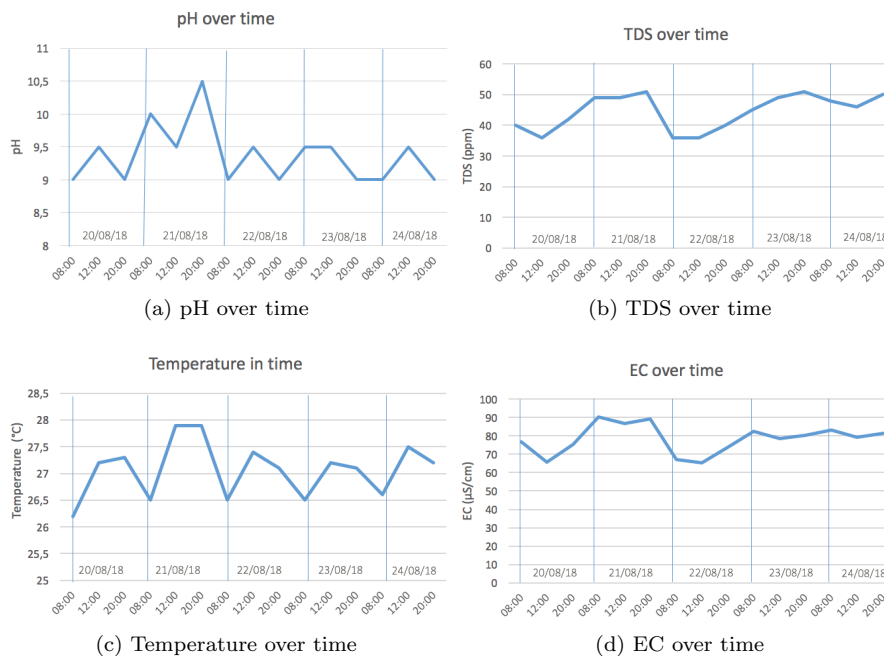


Figure 14: Weekly monitoring

**pH:** The pH of the water lays between 9 and 11. The possible reason for this extreme high pH are insufficiently cured cement or cement applied when the alkalinity of the water is low according to the WHO (World Health Organization, 2017a). The effects of exposure to extreme pH values in drinking water can have adverse health effects to humans. Among other things irritation to eyes, skin and mucous membranes (World Health Organization, 1996b). Dr. Nelson Barranco of UTP made clear that after some more time, the cement will be hardened out completely and the pH will most probably stabilise.

**Rainfall:** As can be seen from the local rainfall data measured by the installed tipping bucket, 48.3 mm rainfall fell on the night between the 21st and the 22nd of August. This resulted in a visible drop in EC, TDS and pH. The freshly entered rainwater diluted the water and thereby lowered the three values.

**Temperature:** The temperature at midday is 0.5 - 1°C higher than in morning. During the night the temperature dropped again and stabilises around 26.5°C. The water in the tank only rises by a maximum of 1.4°C during the day. There is a clear trend visible in the temperature data from this monitoring week.

**TDS:** The TDS is in the evening highest. The highest TDS measured within the rainwater harvesting tanks is 50 ppm. For natural rainwater the standard TDS is 20 ppm (mg/l) or lower (Tanji,



1990). It therefore can be said that storing the rainwater in ferrocement tanks increases the TDS of the water.

**EC:** The EC is usually high in the morning, lower in afternoon and high in the evening again.

In conclusion, during a time period of 5 days in the week after the ferrocement tank was filled for the first time, the EC, TDS, temperature and pH are measured. The pH of the water within the ferrocement tank lays between 9-11, this can cause adverse health effects. It can also be concluded that temperature of the water within the tank rises during the day by approximately 1°C. Finally it can be seen that fresh rainwater dilutes the water and increases the TDS and EC of the water.

#### 8.4.2.2 Water quality analysis

The results of the water sampling analysis made by both UTP and AQUATECH are presented in table 18. The results are be compared with the Panamanian drinking water standard (presented in Appendix K) in order to conclude whether this water is safe as drinking water. This subsection will describe the findings and conclusions based on these results.

**Indicator parameters:** First of all, it can be seen that the pH of all water tanks (M4 - M9) is above the maximum allowed Panamanian drinking water standard. As described above is the possible reason for this the curing of the cement. Dr. Barranco expects that this value will drop after the cement of the tank is fully cured. Secondly, the turbidity of almost all samples is too high compared to the Panamanian drinking water standards. The WHO describes that the turbidity of drinking water should not be above five, and ideally below one (WHO, 1997).

When using five as maximum value, the turbidity of the water in all tanks is considered acceptable. The turbidity of the groundwater and river water however, is substantially higher and is not conform both the Panamanian and the WHO drinking water standards. The indicator values show us that contamination of cattle, farming and neighbouring villages do not seem to cause health problems as the concentrations of nitrate, sulphate and ammonia are not exceeding the standards.

**Chemical parameters:** As reported earlier, minerals in water are important for human health. The Panamanian drinking water standards do not present standards for sodium, calcium, magnesium and potassium. When looking at the WHO standards, the concentrations of these minerals in water have a minimum and a maximum value. As can be seen in the table, all measured locations have values that are too low to meet the WHO minimum value. However, this is not set in the drinking water standards for Panama.

The concentrations of the heavy metals iron, zinc and lead within the RWH tanks all meet the Panamanian drinking water standards. Therefore it can be assumed that the roofing material does not negatively impact the quality of the water.

**Microbiological parameters:** The concentration of biological pollution however, does not meet the standards for all samples. The E.Coli concentration is extremely high for samples M1, M2, M3 which represent respectively the spring, Rio Culebra and Rio Negro. As E.Coli is a faecal coliform bacteria commonly found in the intestines of humans and animals, it indicates contamination by animal or human waste. Drinking water with this amount of microbiological pollution causes adverse health effects to humans. Not only E.coli but many other microbiological substances are found in both ground and river water as can be seen in the total coliform bacteria. It can be seen that no microbiological pollutants have entered the RWH tanks. This makes the water in the rainwater harvesting tanks more safe to drink.

In conclusion, the rivers and groundwater spring cannot be seen as safe drinking water sources

due to their high turbidity and high microbiological contamination. Drinking this water is dangerous to humans because it could lead to severe adverse health effects. The water within the RWH tanks however, can be seen as drinkable water but has some negative sides, such as a high pH, and according to the WHO levels too low levels of minerals. Remarkably, the use of bottled "agua pura", purified drinking water (lacking minerals, thus similar to the rainwater), is widely used, not only in Panama but also most of Central and South America. It seems industries, who need water in a similar mineral-free composition for their purposes, are selling it now widespread advertising it as healthy, purified drinking water.

#### 8.4.2.3 Evaluation measurements

Two weeks after leaving El Progreso, a trip to El Progreso was made in order to determine the wall thickness. This could be easily combined with a small evaluation and water quality assessment. The water from four tanks was tested and the results are presented in Appendix L. The results of these measurement will be described below.

**pH:** The pH of all four tanks is 10 or 11. It can be concluded that the pH of the water within the tanks has increased over time. As described above in the weekly monitoring, a high pH can have impact on human health.

**TDS:** The TDS of the water within the tanks has increased greatly over time. The TDS value of the water from the school tank was measured to be 180 ppm. Three weeks before this, during the weekly monitoring of the tank at the school, the TDS value was 50 ppm. It can therefore be concluded that during the storage of the rainwater, the TDS value increases greatly. While carrying out the research, one woman mentioned that it did not rain for one and a half week. The high TDS can be explained by the reason that no fresh water has entered the tank for a longer period of time. Another remarkable finding is the TDS difference between the tank at the school (180 ppm) and the tank at the church (404 ppm). What can explain this difference? There are some possibilities: 1) It can be due to overhanging trees that are present at the church and are not present at the school. Trees introduce more organic material (small leaves, sediments) and small insects which can lead, when entering the tank, to an increased TDS value. 2) At the church another type of sand is used than at the school. This can result in changes in the quality of the water. Finally, it should be noted that for drinking water a TDS value between 300-600 mg/L is described 'good' by the WHO (World Health Organization, 1996a).

### 8.5 Social impacts of RWH tank on, and changes within the community

Besides the water quality measurements, interviews are held with the households about how they perceive the quality of the water from the tank and whether having access to a new water source resulted in a change in their daily lives. From the interviews follows that the water of the tank is used for showering, cooking, cleaning dishes, doing the laundry and for drinking. Not all families use the water as drinking water. The taste of the water was mostly described as 'bitter' and 'old'. After cooking the water, one family explained, the bitterness is gone but there is a light white film at the water surface. All interviewed families boiled the water before they give it to their children, but drink it directly themselves. The family of the pastor still uses the water from the natural spring as drinking water, but the tank at the church is used for drinking by people that go to the church. The heads of the households explained that because they have the tank now, they have more time to cook and more time for other chores in the household, and accordingly life becomes easier. Even some families explain that they have time now to read the bible and other books. Anecdotic evidence however showed that the presence of the RWH tank did not result in as much free time as expected, as Grizelda, Julio's wife nicely pointed out: 'Everything involving getting

water goes quicker. But I am not now playing the piano or anything' (see interview in O.5.3). At the question if problems have appeared so far with the tank, all responded with 'no'. All households reported a great relief in labour that previously had to be allocated towards carrying of several 20 litre water buckets each day and especially elderly are reported to benefit.

So in conclusion, the quality of the water has changed over time and differs in place. Households do not see any problems with the tank so far, although they think the taste of the water from the tank is 'old' and 'bitter'. The water is used as drinking water, but some households do not use the water from the tank for drinking but more for doing laundry, dishes and cleaning. The accessibility of water close to the house is the main advantage.

All families showed willingness to participate in the building process and some more than others. Demetrio showed up at the first building site at his side of the village, and participated at every building site thereafter. He became the apprentice of Simon (our foreman) during the project, which resulted in acquiring the skills needed to pursue a career in construction. His perspective of finding a suitable job greatly improved.

This project also resulted in some positive side effects that were not at all expected. A side effect of the intervention study was that Simon (our foreman) was offered several jobs: in the gold mine where Casildo B. works, renovating Lazaro's house and building the house expansion of Israel. In the weeks following the project, Simon gave up his house in Panama City and moved to El Progreso. Furthermore, Lise fell in love with Conce, the son of Demetrio and is currently having a dedicated, long distance relationship with him. Also, the leftover, freshly mixed concrete at the building sites was used by villagers in a wide variety of purposes: to improve their fireplaces, expand their terraces and improving entrances to their homes or even building complete stairways.

Another unexpected consequence of our project was the involvement of Dr. Nelson Barranco in the development of El Progreso. He feels very sympathetic towards Embera and has extensive experience in finding funds for aid in multiple areas of aid. He now is working on connecting the village to the appropriate governmental office "Viceministerio de Asuntos Indígenas" (Vice Ministry of Indigenous Affairs). It coordinates and executes plans, programs and projects that promote the public policy and integral development of the indigenous people, their identity and fundamental values as part of the multiculturalism the state of Panama wants to promote. The people of El Progreso were not aware of the existence of this office, nor the help they provide. We contacted the office and it turned out, they had no knowledge whatsoever about El Progreso and its inhabitants of Emberá origin. Dr. Nelson Barranco will check that the contact made leads to actual help.

Lastly, we discovered that local government parties refused to continue their sanitation project on the church side of town, because of the lack of running water at or near the house, which appears to be demanded by law. It seems the RWH system complies to their definition of running water near the house, which opens up possibilities to reinstate and continue the sanitation project. First steps were made during the project to contact the appropriate officials involved. Daniel, our local guide, will pursue this contact as to ensure actual help is given.

## 8.6 Conclusion of the post study

The post-study led to conclusions about the requirements of the tank owner, quality control, the quality of the water in time and place and the social impacts of the intervention study. First of all, the requirements of the tank owners seemed to change throughout the project, but due to the fact that interviews are only carried out in the post study, this conclusion is debatable.

First education and water seemed to be the villagers main requirements, where at the end it

became sanitation and electricity. Their opinion however seems to be impacted by what the project team has to offer. Therefore no solid conclusions can be made on the requirements of the tank owners and whether water was indeed their main requirement.

Second of all, the control of the construction quality in the post-study can determine concrete structures for the largest part, as concrete is brittle and breaks immediately when the quality is not sufficient. The water tightness could not be measured properly by field measurements due to the size of the tank and the available time.

Thirdly, the quality of the water within the tanks changes in time and place. Weekly monitoring shows that the pH of the tank water is constantly high, the temperature is fairly constant and only rises by a maximum of one degree. Monitoring also showed that after rainfall the water dilutes, which lowers the TDS and EC. The water quality analysis concluded that the river and groundwater do not meet the Panamanian drinking water standards and can be very dangerous for humans, especially for infants. The water within the RWH tanks does meet the standards set by Panamanian law, it only shows too high values for pH, as already discussed. Evaluation measurements show that over a couple of weeks the TDS value of a particular tank increased from 50  $\mu\text{S}/\text{cm}$  to 180  $\mu\text{S}/\text{cm}$ , which can be due to particles dissolving from the tank wall. Also it can be concluded that the quality of the water of different tanks differs in place, as TDS values of 180  $\mu\text{S}/\text{cm}$  and 404  $\mu\text{S}/\text{cm}$  are found in different tanks.

Finally, it can be said that this project has led to various additional social impacts in the village of El Progreso such as: improvements around the household with leftover concrete, job opportunities, a long-distance romantic relationship and connecting the village to a network to receive aid from its own government.

## 9 Conclusions

During the pre-study multiple analyses were conducted. Some things went very smoothly, such as the introduction of the project to the village and the attitude of the inhabitants towards the project and the project team. Other things turned out differently such as the actual construction method of the tank, which was completely revised just before starting at the first building site, and the relation between the local NGO and the village and the degree of indigenous influences were very different from expectations. It has to be concluded that the indigenous influences are virtually absent in daily life in El Progreso.

The stakeholder analysis helped the project by mapping scarce resources for the remote project, but due to the small size and charity character, no blocking or not positive actors could be found. So the stakeholder analysis only helped engage actors who already had similar interests and might have helped without these insights. Interviews showed that it is difficult to find out what people really wanted in the past, as these interviews were held after the tanks were completed. Combined with the finding that the requirements are heavily biased by what we offer, makes it difficult to judge whether a latrine, electricity or the water tank was initially their biggest requirement. The same interviews, together with the observation walks, provided an overview of their current water sources: the school part relied primarily on the gravitational system and had some own small water systems. The church part heavily relied on the Culebra river, mainly used because their own small systems did not have the necessary capacity. Possible contaminants of their water sources and how they end up in their sources (cattle, pesticides, heavy rainfall) were mentioned by the inhabitants and they acknowledge getting sick from time to time from drinking the river water, nevertheless most households do not treat their water. Half of the inhabitants do not have a toilet to their disposal (only houses at the school side do) and go to the toilet in the fields or along the river banks.

Furthermore, due to El Progreso's location, adaptation of the project because of different requirements of the inhabitants would have been very difficult. Before the construction phase could start, a framework for project quality management was made. Altogether, this showed that a lot of research, especially requirements management, could have had more impact when performed in an earlier pre-study separate of the construction project.

The construction phase showed to be a phase where the interactions between the local people and the project team provided mutual respect and helped the engagement of the local people in the project due to activities such as providing food during construction, getting sand together and working on Saturday and Sunday. Even though most of the people had the same preference of the location of the tank (close to the kitchen), other requirements were very diverse and scattered and not solely focused on improving their water source. The quality assurance proved to be challenging due to the fact that the combination of audits, inspection and construction work was not feasible, translation availability was lacking and preparation time was too short to prevent all inconsistencies.

The post-study led to conclusions about the requirements of the tank owner, quality control, the quality of the water in time and place and the social impacts of the intervention study. First of all, the requirements of the tank owners seemed to change throughout the project, but due to the fact that interviews are only carried out in the post-study, this conclusion is debatable.

First education and water seemed to be their main requirements, where at the end it became sanitation and electricity. Their opinion however seems to be impacted by what the project team has to offer. Therefore no solid conclusions can be made on the requirements of the tank owners and whether water was indeed their main requirement.

Second of all, the control of the construction quality in the post-study can determine concrete structures for the largest part, as concrete is brittle and breaks immediately when the quality is not sufficient. The water tightness could not be measured properly by field measurements due to

the size of the tank and the available time.

Thirdly, the quality of the water within the tanks changes in time and place. Weekly monitoring shows that the pH of the tank water is constantly high, the temperature is fairly constant and only rises by a maximum of one degree and the after rainfall the water dilutes which lowers the TDS and EC. The water quality analysis concluded that the river and groundwater do not meet the Panamanian drinking water standards and can be very dangerous for humans, especially infants. The water within the RWH tanks does meet the standards set for Panama, only the high pH values are troublesome. Evaluation measurements show that over a couple of weeks the TDS value of a particular tank increased from 50  $\mu\text{S}/\text{cm}$  to 180  $\mu\text{S}/\text{cm}$ , which can be due to insufficient cleaning of the tank before filling or dissolving impurities from the concrete. Also it can be concluded that the quality of the water of different tanks differs in place, as TDS values of 180  $\mu\text{S}/\text{cm}$  and 404  $\mu\text{S}/\text{cm}$  are found in different tanks.

The villagers use the water from the tank for showering, cooking, cleaning dishes, doing the laundry and for drinking. Not all families use the water as drinking water. The taste of the water was mostly described as 'bitter' and 'old'. All interviewed families boiled the water before they give it to their children, but drink it directly themselves. The family of the pastor still uses the water from the natural spring as drinking water. The heads of the households explained that because they have the tank now, they have more time to cook and more time for other chores in the household, and accordingly life becomes easier. Even some families explain that they have time now to read the bible and other books. Anecdotic evidence however showed that the presence of the RWH tank did not result in as much free time as expected, as Grizelda, Julio's wife nicely pointed out: 'Everything involving getting water goes quicker. But I am not now playing the piano or anything'. Providing the tanks brought a great relief in labour that previously had to be allocated towards carrying several 20 litre water buckets each day and especially elderly benefit.

After living two months in El Progreso, more and more became clear about El Progreso's past and how the current situation regarding water and sanitation came to pass. Also, by expanding our network in the country during the project, we learned important knowledge about the governmental office "Viceministerio de Asuntos Indígenas" (Vice Ministry of Indigenous Affairs). The people of El Progreso were not aware of the existence of this office, nor the help they provide. It can be concluded that, when sufficient time was given and a thorough pre-study had been conducted, this knowledge would have accelerated the project to great lengths, or even would have led to a very different project. We contacted the office and it turned out, they had no knowledge whatsoever about El Progreso and its inhabitants of Emberá origin. Dr. The contact now has been established.

Unexpectedly, but most importantly, we discovered that local government parties refused to continue their sanitation project on the church side of town, because of the lack of running water at or near the house, which appears to be demanded by law. It seems the RWH system complies to their definition of running water near the house, which opens up possibilities to reinstate and continue the sanitation project. First steps were made during the project to contact the appropriate officials involved. Daniel, our local guide, will pursue this contact as to ensure actual help is given.

In genera we can conclude numerous beneficial connections are made and relations are forged between the village, several important stakeholders, charity projects and the university in Panama City and Delft. Also more knowledge about resources and logistics in the area are now known at the university, making a new project more feasible. So, the project impacted the village in a way that makes it a better candidate to receive aid from more projects or research in the future.

The village is now mainly waiting for light and sanitation. This means that the intervention impacted their requirements and the waiting indicates that some residents have a waiting attitude towards these services and expect the government to provide this. The intention of the project was

to demand effort and input from the village to contribute to the project to ensure responsibility towards maintenance on the long run. And although it is impossible to say whether this project improved their self reliance or that bringing free (in a monetary sense) water tanks decreased their self reliance, it most likely did impact it.

Finally, it can be said that this project has led to various additional social impacts in the village of El Progreso such as: job opportunities, a long-distance romantic relationship and connecting the village to a network to receive aid from its own government. Also, in El Progreso nothing goes to waste. Villagers of El Progreso have a great and wide assortment of ideas how to use leftover plywood, chicken mesh freshly mixed concrete and broken tools. Numerous improvements around the households can be observed to prove this statement.

## 10 Discussion

In this section the results of the intervention study will be discussed. The expectations and information gathered during the interviews in the pre-study are compared with the observations during the construction phase and the information gathered during the evaluation interviews, and thus the impact of the intervention study can be discussed. In this project assumptions are made in the beginning. These assumptions are also discussed in this section.

In the preparation phase of this project, the only information known was the request for help for a sustainable water supply, requested by the inhabitants of El Progreso. The village is serviced by a water supply system, but this was said to be working inadequately. The fact that the gravitational system worked fine most of the time in one part of the village, was not clear before the project started. When arriving in El Progreso, the exact situation became clear, so we thought. The request for help was done through Daniel Vaisabel, who became our direct contact person for GeoParadise. Daniel joined the project, and was hired as translator and local guide. Daniel had already worked with the inhabitants of El Progreso for 2 years and therefore has some prejudices about the local inhabitants and their knowledge. This emerged when the interviews with the local people were held. Even though the inhabitants were eager to answer all questions from the interviews, sometimes the questions that were translated contained suggestions added by the translator in order to make it easier for the interviewees (which was not the intention), which led to biased answers.

The in situ measurement equipment used can give slightly incorrect results, mainly the pH measurement strips are not very exact. This measurement equipment therefore is only used to give an indication of the pH. Moreover, only temperature, electrical conductivity, total dissolved solids and pH is measured by the in situ measuring devices during the project, therefore no statements about the drinkability of the water could be made. The EC and temperature is measured by the two different devices, the HoneForest and the Greisinger installation. The results for temperature and EC differs quite substantially. The EC meter from Greisinger is calibrated with calibration liquid and therefore is more reliable. The EC concentration and temperature within this report given from the EC value from the Greisinger measurement device.

The water samples for the water quality analysis are taken under normal circumstances, so the quality is determined for normal weather conditions in the winter months. The quality of the water in the summer or directly after a heavy rainfall event can differ remarkably. No conclusions can be drawn about the water quality under these extreme conditions.

Pure rainwater does normally not contain high concentration of minerals. The Panamanian drinking water standards present maximum allowed values of parameters, not for minimum amount of for example minerals. But what is the (long term) effect on health when too little minerals are present in drinking water? Dr. Barranco from UTP strongly discourages using rainwater as (only) drinking water source due to the lack of minerals. He reasons that in water quality standards, only maximum values are mentioned and not minimal. Literature does not explicitly conclude that rainwater cannot be used as drinking water due to the lack of minerals. It became evident that drinking water without minerals is in Panama actually very common, as bottled, purified drinking water without minerals is sold nationwide.

When starting the project in El Progreso it became evident that the standard, beforehand chosen size of the RWH tank was too large and probably not necessary for the average household in El Progreso. Based on assumptions the decision was made to decrease the size of the tanks in order to use the available construction material as efficient as possible. Therefore the construction time per tank decreased and more households could receive a RWH tank. However, the impact of decreasing the size of the RWH tank on the quality control and the water quality is not known.



There were difficulties getting to the core of peoples requirements and there were moral challenges in choosing which requirements to fulfil. It can in general be difficult to really get to the core of peoples requirements instead of discussing what they perceive as the best solution, but this is even further increased due to the cultural difference, the language barrier and the relatively late timing of the interviews. When some requirements were tried to be fulfilled (although not the intention of the project), choices had to be made how and to which requirements exactly would be adapted. This provides moral and ethical difficulties. For example, although there was a need for water tanks, the project decided that this was the most urgent problem and that this should be solved using the Calabash tank. An extended pre-study and better understanding of the language and culture might have resolved parts of these problems.

Stakeholder management used a baseline study, but this did only run in the beginning of the project and during the project more connections were made and new stakeholders were involved, making that the baseline study can not properly decipher what can and cannot be accounted to stakeholder management. This makes the conclusion which results can and can not be accounted by the stakeholder management debatable.

The quality management focused on specifications set by the team and not the end-users, which was due to the lack of a pre-study and relatively late mapping of requirements. This raises the question: how much can really be set about the quality of the tank when the standards are necessarily dose of the end-users? Also a problem was the execution of quality management during audits, inspections and concrete sampling.

Some interviewees from the school side of the village said that they will use the RWH tank as a storage tank for the gravitational system, so when the system would be broken for some time they could use the stored water from the tank. If they are planning to fill the tank to its maximum once in a while or if they are planning to attach the complete system to the tank and use the tap of the tank as their main tap is still unknown. Some interviewees from the church side of the village mentioned that when (or if) the gravitational system is extended to their part of the village that they would also attach that system to their tank. The impact of filling the tank with rainwater is not investigated yet. River water is less pure and contains more dissolved organic matter from itself, which can impact the quality of that water.

During the eight weeks of intervention the behaviour of women against the construction work changed. Where in the beginning of the intervention the women from the village only helped the project with cooking and doing laundry, throughout the intervention they started to help with construction works as well.

The project increased the knowledge of constructing tanks and working with concrete in a way, that if there would be resources available, the village might be able to construct a tank on its own now. Help from the local NGO, which was also trained by us in the construction method, would make this even more feasible. Although it stays uncertain whether they will succeed, until they have proven it themselves, transferring knowledge was an important goal of the project.

## 11 Recommendations

The following recommendations follow from our research for future intervention studies in small, remote communities.

First of all, the preparation of an intervention study is of utmost importance, where for example the institutional and social structure can be understood and mapped. This will create an understanding of where significant impact can be made with what interventions and how to achieve them. In this project, if there would have been more time in the village of El Progreso before the project would have started, an alternative solution for a water system at household level might have emerged, such as extending the aqueduct system to the church side of the village. In addition, it would have been more clear why the church part of the village did not have a connection to the aqueduct from different points of view (political, social) and who are "most in need for a household water system" (difficult to determine this, what makes one person more in need than another?). More preparation might have also resulted in an earlier active participation of the community members and more observations on daily life in El Progreso. Moreover, more time for the post study would have provided us with a better evaluation of the impact of the RWH tanks on the people and their lives as well. A longer evaluation period would also have led to a critical evaluation of the design of the RWH tank and possible improvements for construction.

In the evaluation interview, it became clear that the people are waiting and requesting for more projects to help them. More techniques on making them more aware of the actions they can take themselves as well as connecting them to the useful institutions might be of higher impact than delivery of another project or aid (such as providing electricity) for long-term development in the area.

Involving a (local) knowledge institute such as a university from the start will be useful because there will be more people involved with their respective resources and also possibly a smaller language barrier between the team and the villagers. On the other hand, this might not result in the strong connection that we have made with the villagers during our time there.

A last recommendation is to hire more skilled construction people for a construction project such as this one, so the project team can focus more on observations, study and research instead of being much needed in the actual construction work. On the other hand, helping in construction work strengthens the connection and relationships with the people, necessary for them to share their stories with us.

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## A Technical details RWH system

The amount of rainwater that can be harvested depends on roof area, rainfall depth and roof runoff coefficient, which in turn depends on roof material and design. The size of the storage tank is determined by this input, water usage and levels set for how long the stock has to last. The calculations were performed for systems in rural northeastern Nicaragua. Due to the sudden obligated change of location, limited timeframe and lack of detailed information, the same design is adopted for El Progreso, since the circumstances, climate and surroundings are comparable. Some numbers are updated based upon assumptions which in turn are based upon information provided by the local partner NGO. These numbers are presented here.

### A.1 Dimensions of the RWH system

**Water usage** World Health Organization (2007) gives the following estimates for household water usage in Litres per Capita per Day (Lpcd):

- Minimum ‘ survival’ allocation: 7 Lpcd (sustainable for only a few days)
- Drinking: 3-4 Lpcd
- Food preparation, cleanup: 2-3 Lpcd
- Total: 14 Lpcd

On average a household in El Progreso consists of 7 persons, leading to a daily minimum required amount of 98 litre.

**Rainfall depth and dry spells** Maximum length of dry spell in the dry season (January - March) is estimated to be 14 days, based on data which was not available before the project. In the report above the 29 days dry spell is mentioned, because this was the then only available information. 14 days thereby is the longest period in which the storage capacity of the tank has to last. Long term average monthly rainfall depth is estimated to be minimum 60 mm (January, February and March). April - December have an estimated rainfall depth of 280 mm / month, resulting in 2700 mm on a yearly basis.

**Estimation storage capacity** With an estimated connected roof area of 35m<sup>2</sup> this leads for the driest months (January - March) to 2100 litre / month available for storage. Monthly usage requires roughly 3000 litre. Assuming a full tank at the end of December, the water level will gradually decline during January - March. To ensure water availability by the end of March, a tank with a storage capacity of 2800 litre is needed, as calculated in table 3 on the following page. To account for estimated values and uncertainties which at the beginning of the project could not be narrowed down as well as a collection efficiency of 95% a safety factor of 1,3 is applied, leading to a desired 3600 litre of storage capacity. The inside maximum height of the tanks is set to 1,7 m to ensure easy maintenance and enough vertical distance between top of the tank and lowest point of the gutter system. Above mentioned numbers lead to an inside radius of 0,82 m of the tank.

### A.2 Calabash tank

The Calabash tank was developed by de Gevulde Waterkruik, its founder Paul Akkerman, coordinator Sadjaliu Djalo and with help of many others in Guinea-Bissau. The design was optimised during 12 years of developing, building and experimenting. The newest design was the 5th major step in the development of the Guinea-Bissau tank. Among others, the goal of de Gevulde Waterkruik is to spread their knowledge, experiences and lessons learned. The Calabash tank is now being built

Month	Rainfall depth mm	Available storage litre	for Average monthly usage litre	Net available storage litre	Possible storage litre
January	60	2100	3000	-900	1900
February	60	2100	3000	-900	1000
March	60	2100	3000	6800	100
April	280	9800	3000	6800	2800
May	280	9800	3000	6800	2800
June	280	9800	3000	6800	2800
July	280	9800	3000	6800	2800
August	280	9800	3000	6800	2800
September	280	9800	3000	6800	2800
October	280	9800	3000	6800	2800
November	280	9800	3000	6800	2800
December	280	9800	3000	6800	2800

Table 3: Calculation for minimal required tank storage

in 8 African countries and with being part of this project, made the leap over the Atlantic ocean. The design of the Calabash tank is adopted for this project because of the ease of the construction method, possibilities to adapt the design to local circumstances and because of the use of solely local available building materials.

A major change compared to the African building style is the use of a mould built out of water resistant plywood, in contrast to stacked clay blocks used in Africa. The mould in Panama is constructed out of thirteen rectangular pieces (1700mm by 400mm), which gives the tank a distinct, round, thirteen-sided shape.

The Calabash tank is a ferrocement tank, built up in layers of mortar (fine sand and cement, mixed 2:1). The original design uses a 3:1 mixture rate, this was changed to account for the poor quality of available sand for the mortar. The first layers are held by chicken mesh adjusted on a wooden mould, which can be taken away after a minimal curing time of 1 day. The chicken mesh reinforces the concrete. The tank is constructed from inside the mould, with a first layer of 2 inches of mortar. The inside is finished with a smooth layer of 1 inch. After taking the mould away, the outside is finished with another layer of 1 inch. A hole is drilled for the tube connecting to the tap. The top of the tank is built separately and later laid on the constructed wall. A manhole for maintenance is covered with a concrete cover, to ensure complete darkness in the tank. A 3-inch PVC is built in the top, to connect to the down pipes.

### A.3 Gutters, down pipes and overflow construction

Each house is fitted with PVC gutters of Amanco (Colonial type). Between 5 and 7 m of gutter length are installed, according to household size. The gutter is fitted with a coarse sieve and a construction where discharge can freely enter, but insects and small animals are kept out. The 3-inch PVC down pipes connect the gutter to the tank. At the lowest point, just before entering the tank, the down pipes are fitted with an overflow construction, which consist of a 1-way valve. The system is designed without a first flush device.

## B Calculation wall thickness

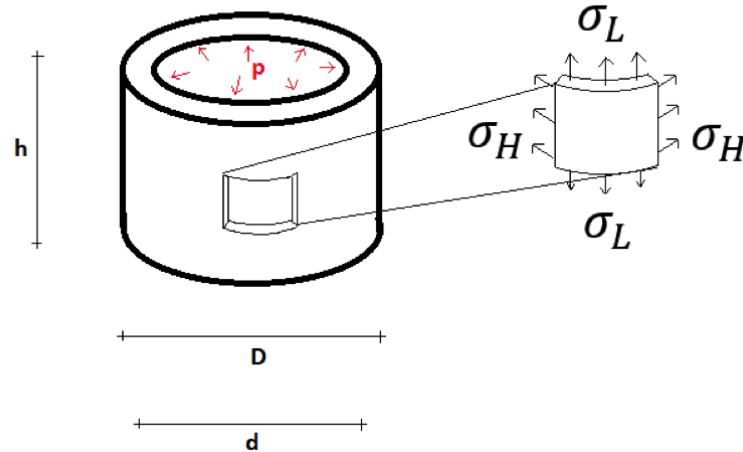


Figure 15: Forces acting on the wall of the tank, where  $\sigma_H$  is the hoop stress and  $\sigma_L$  is the longitudinal stress

The forces need to be in equilibrium, so the construction does not fail, this can be used to calculate the stresses in the wall of the tank. The horizontal component of these forces is called the hoop stress; the vertical component of these forces is the longitudinal stress. Below, the calculation of the hoop stress (equation 1 and 2) and longitudinal stress (equation 3) are shown.

### B.1 Hoop stress

$$2 * \sigma_H * t * h = p * d * h \quad (1)$$

$$\sigma_H = \frac{p * d}{2 * t} \quad (2)$$

### B.2 Longitudinal stress

$$\sigma_L = \frac{force}{area} = \frac{p * \pi * \frac{1}{4} * d^2}{\pi * d * t} = \frac{p * d}{4 * t} \quad (3)$$

As can be seen from the equations the hoop stress is twice as large as the longitudinal stress, and thus dominant.

### B.3 Water pressure

At a depth of 1.5 meters the water pressure is calculated:

$$p = \rho * g * h = 1000 * 10 * 1.5 = 15,000 N/m^2 = 0,0015 N/mm^2 \quad (4)$$

This water pressure is used in the calculation of the hoop stress, leading to the following calculation:

$$\sigma_H = \frac{p * d}{2 * t} = \frac{0.015 * 1600}{2 * t} = \frac{12}{t} \quad (5)$$

## B.4 Chicken mesh

The yield strength of the chicken mesh that is used for the construction of the tank is unknown. Therefore an estimate of  $10 \text{ N/mm}^2$  is used in further calculations. One chicken mesh wire has a diameter of 1 mm. So, the cross sectional area is:

$$A = \pi * 0.5^2 = 0.785\text{mm}^2 \quad (6)$$

One chicken mesh wire is capable of carrying  $0,785*100=78,5 \text{ N}$ .

## B.5 Concrete

Normally, the tensile strength of concrete is left out of consideration. But because in this case the thickness of the wall depends on the water tightness of the tank, and not on the strength, the wall is much thicker than it would need for the strength. That is the reason why it is taken into account in the tensile capacity of the wall. To test how strong the concrete is what was used in El Progreso, a trial has been set up. A beam has been tested by simulating a point load with water bottles. By adding water until it collapses and by determining the weight of the concrete and adding it as  $q$  load, it was possible to determine how large the maximum point load could be in the centre of the beam. Knowing this, the maximum moment and hence the maximum tensile stress can be calculated. From this test a result of  $1.8 \text{ N / mm}^2$  was obtained as the maximum tensile stress of the concrete.

The wires of the chicken mesh are each a centimetre apart. The lowest centimetre of the tank therefore has only one chicken wire, which can take 78.5 N. The lowest centimetre of concrete is capable of handling:

$$1.8 * 10 * t = 18 * t \text{Newton} \quad (7)$$

## B.6 Normal force

The normal force  $F_N$  on the lowest centimetre is:

$$F_N = \sigma_H * 10 * t = \frac{12}{t} * 10 * t = 120\text{N} \quad (8)$$

Together, the chicken mesh and concrete have to be capable to handle this 120 N force:

$$78.5 + 18 * t \geq 120 \quad (9)$$

$$t \geq 2.3\text{mm} \quad (10)$$

The tanks are built with a minimal thickness of 5 cm in the walls. This is more than the required 2.3mm, so it will be strong enough.

*Note: in this calculation an estimate is made for the yield strength of the chicken mesh and no safety factors (for either load or material) are included. However, because the required thickness is much smaller than the thickness than the walls of which the tanks are constructed of, this is also not necessary.*

## C Panamanian drinking water requirements

The tables below show required biological characteristics, maximum allowed values of the organoleptic and physical characteristics and maximum allowed values of the inorganic chemical characteristics for drinking water in Panama (Ministerio de Comercio e Industrias, 1999). These values will be used to compare the results of analysing all existing and new sources for drinking water in El Progreso.

Table 4: Biological characteristics for drinking water for water not distributed by tubes

Characteristic	Unit	Number of units
Fecal coliform bacteria	No. of colonies / 100 mL	0
Total coliform bacteria	No. of colonies / 100 mL	10

Table 5: Values of the organoleptic and physical characteristics for drinking water

Characteristic	Maximum allowed value	Unit	Observations
Odour and taste	Acceptable to most consumers		
Colour	15	Units of colour	Units of colour on the platinum-cobalt scale
Turbidity	1.0	UNT	Preferably less than 1.0 UNT
Hydrogen potential	6.5 - 8.5	Units of pH	
Oil and fat			Must be exempt

Table 6: Maximum allowed value of the inorganic chemical characteristics for drinking water

<b>Characteristic</b>	<b>Maximum allowed value (mg/L)</b>	<b>Observations</b>
Alkalinity	120	As calcium carbonate
Aluminium	0.20	
Antimony	0.005	
Arsenic	0.01	
Barium	0.7	
Cadmium	0.003	
Cyanide	0.001	
Residual chlorine	1.5	Minimum value 0.8 mg/L
Chloride	250.00	
Copper	1.00	
Chromium	0.05	
Total hardness	100	As calcium carbonate
Fluoride	1	
Iron	0.3	
Manganese	0.1	
Mercury	0.001	
Molybdenum	0.07	
Nickel	0.02	
Nitrate	10	
Nitrite	1	
Silver	0.05	
Lead	0.01	
Selenium	0.01	
Sodium	200	
Total dissolved solids	500	
Sulphate	250	
Zinc	5	

## D Water quality parameters

Table 7: Water quality parameters to be tested categorised after water source: river, rain or ground water

Parameter	Unit	Water sources		
		River	Rain	Ground
pH	-	x	x	x
Temperature	C	x	x	x
EC	$\mu$ S/cm	x	x	x
Turbidity	FTU	x	x	x
TDS	ppm	x	x	x
Na <sup>+</sup>	mg/L	x	x	x
K <sup>+</sup>	mg/L	x	x	x
Ca <sup>2+</sup>	mg/L	x	x	x
Mg <sup>2+</sup>	mg/L	x	x	x
Cl <sup>-</sup>	mg/L	x	x	x
HCO <sub>3</sub> <sup>-</sup>	mg/L	x	x	x
SO <sub>4</sub> <sup>2-</sup>	mg/L	x	x	x
NO <sub>3</sub> <sup>-</sup>	mg/L	x	x	x
PO <sub>4</sub> <sup>3-</sup>	mg/L	x	x	x
Fe <sup>2+</sup>	mg/L	x	x	x
Mn <sup>2+</sup>	mg/L	x		x
NH <sub>4</sub> <sup>+</sup>	mg/L	x		x
Zn	mg/L		x	
Pb	mg/L		x	
Total Coliform	n/100 mL	x	x	x
E-Coli	n/100 mL	x	x	x
BOD	mg/L	x		
COD	mg/L	x		

## **E Stakeholder analysis**

This stakeholder analysis starts with a problem formulation that is chosen for the stakeholder analysis. Then follows a short explanation of the involved actors, including their interests and an overview of their problem formulation. This is followed by an overview of the issues that are important for which actor, which is added. Then follows the formal relations of the actors and an overview of their dependencies, which shows the criticality of actors. The actor field is finally made clear with a power-interest-attitude diagram. Lastly, these insights are used to perform a SWOT and TOWS which gives options on how to use the stakeholders and their interests in advantage for the project. The stakeholder issue diagram and SWOT/TOWS are not part of the original method from CITEP. The stakeholder issue diagram is added because the analysis showed very different reasons for actors to have an interest in the project, which needed to become insightful. The SWOT/TOWS analysis was added to find suggestions on how the project can engage its actors using a method.

### **E.1 Involved actors**

The actor analysis starts with a short description of the involved actors and their interests. These actors are: community members with a tank, community members without a tank, nearby villages, the representante of the community, the American NGO GeoParadise and the Dutch NGO Stichting SamenScholen.

#### **E.1.1 Community members with tank**

There are 11 households with a tank. In the church part this is Casildo Chami seniors household, Demetrio Abrego's household, Julio Zarco's household, Israel Zarco's household, Lazaro Chami's household, Armodio Abrego's household, Matteo Abrego's household and Casildo Berugate, while in the school part this is Tito Caballero's household and Casildo Chami juniors household. Many of the households in the church part are family, as Casildo Chami senior and Helena Zarco have many children and grandchildren there and also Casildo Chami junior, living in the school part, is a son. In total, of the eleven households which received a tank there are seven direct family, meaning that they are brothers or sisters. During the study, the inhabitants often explained that everyone in the church part is family, by which they either mean that they treat each other as family or that they are family in a less direct way.

The interests of these community members are whether their tanks are of high quality and finished in time. A small part already has running water, but most have to carry their water from a nearby river.

#### **E.1.2 Community members without tank**

There are about twelve houses in the community that did not receive a tank, with seven of which there was significant contact. These were the houses of Ubaldino Ontura, Alberto Quis, Cesar Lopez, Michel Arenas, Omar, Ambrosio Pascual and the brother of Emilio Zarco.

In general the community members without a tank still had a positive attitude towards the project, as they still liked the improvement for the rest of the village and because they have low expectations. Some people said this was due to the government often promising them improvements which eventually are not carried out.

#### **E.1.3 Nearby villages**

There are two villages nearby El Progreso: Palmira and Santa Isabel. Both villages lie at the Caribbean coast and are bigger than El Progreso. There are several links between the villages.



First of all, Santa Isabel used to be El Progreso's connection to the outside world, as a dirt road goes from El Progreso to Santa Isabel and from there a boat can be taken. However, since three years a road from Cuango to Palmira and a dirt road from Palmira to El Progreso is available, making El Progreso's reachable by car and this the preferred connection to the outside world. Another link between the villages is the school system: before El Progreso got it's own school, Santa Isabel used to be the closest school, and Palmira is still the closest option for a middle school. This makes that especially the elder people in El Progreso feel more connected to Santa Isabel, however El Progreso is officially part of the same municipality as Palmira. Several people from Palmira asked for a tank and knew about the project, as the team often drove through Palmira and a Chami family member lives in Palmira and often visits here family in El Progreso. Only one person from Santa Isabel, Alberta Quis, requested a tank, by filling out the form at the initial meeting at the start of the project, but we never managed to find him. Palmira has electricity and is connected to the same gravitational system as a part of El Progreso is, so the interest in the tanks was to use it as a buffer. Santa Isabel has its own

#### **E.1.4 Representante: Louis Williams**

Louis Williams is the representative (Spanish: representante) of Palmira. The small community of El Progreso officially falls under his responsibility. However, a part of the village living near the church has decided to vote in the municipality of Santa Isabel. This probably has to do with the fact that the elderly people feel more connected to Santa Isabel. As a result of this, the representative feels less responsible for the church part of the village. The representative gets elected together with an assistant (Spanish: ayudante) and for Palmira and El Progreso this is Tito Caballero. Tito lives in El Progreso and received a tank. During the project a new representative was elected, but the results are not known yet. Th representative was the only government official which whom there was repeated contact, but there also was a short meeting with the mayor (Spanish: Alcalde) of the Santa Isabel District, to which the municipality of Palmira belongs. He wrote a letter of approval for the project including names and passport numbers of the group. This was only done for security reasons and to make it easier to pass police checkpoints.

#### **E.1.5 Geoparadise**

Geoparadise is an American NGO who operates in the region to maintain indigenous tribes all around the world by inviting them to a cultural festival at a beach an hour away from El Progreso. They chose Panama and Colon as it is Central in the world, easy to reach and Colon offered affordable beach locations. The vicinity of the Embera tribe was not on purpose and only found out afterwards. The have a base camp near their beach at half an hour from El Progreso with three permanent employees living there. During the festival they employee around 150 locals temporarily, including people from El Progreso. At their base camp they have an extensive inventory of construction tools and camping equipment. Their interest in El Progreso is mainly due to the workforce of base camp (not the higher management) who try to improve the quality of life in El Progreso by giving jobs and education since they are nearby anyways.

#### **E.1.6 SamenScholen**

Stichting SamenScholen is a Dutch NGO with the goal to strive towards sustainable education improvement at the east coast of Nicaragua. The NGO was formed 2007, is based in Utrecht and got in contact with TU Delft students in 2008. In 2014 Joris Wiggins performed a feasibility study in collaboration with Stichting SamenScholen in Bum, Nicaragua on water storage for a school that the NGO was building. They have currently constructed six schools. The interests, problem perceptions, goals and means are summarised in table 8.

Table 8: Problem formulations of actors

Actor	Interest	Objective	Situation	Cause	Solution
Community members with tank	Getting a good quality tank	Improve their quality of life	Carrying water from nearby stream (when gravitational system is not working)	Not having a water system	Getting a tank
Community members without tank	Getting a tank	Improve their quality of life	Carrying water from nearby stream when gravitational system is not working	Building process is too slow	Faster building, with priority for them
Nearby villages	Getting a tank	Improve their quality of life	Carrying water from nearby stream when gravitational system is not working	They village is not chosen to help	Extent the project to their village
Representative	Increase image through project	Getting re-elected	Not sure of re-election	Image is not good enough	Be seen as connected to a good project
Geoparadise	Improving the living circumstances of the Embera tribe	Maintaining indigenous communities	Indigenous communities are lost	Not enough awareness	Organising a festival for indigenous tribes
SamenScholen	Sustainable improvement of living circumstances of disadvantaged groups	Improve the education level	Slow development of El Progreso	Lack of water	Build water-tanks together with community

## E.2 Stakeholder-issue diagram

Now that the actor field is known, it shows that there are very different reasons for the actors to have an interest in the project. The representative is only involved because it might help him to get re-elected and also the community members with and without a tank show very different objectives for the project, namely a high quality tank and a high quantity of tanks. This analysis will therefore map which issues are important for which stakeholders. Three issues are identified: (1) the quality of the improvement of the living circumstances in El Progreso, which in practice comes down to the quality of the tank, (2) the quantity of improvement of the living circumstance in El Progreso, which in practice comes down to the amount of tanks the project manages to build and (3) the impact of the project on the image of the actors. The community members with a tank are only

Whether an issue is of importance for an actor is summarised in table 9. The conclusions from this analysis are that the representative only feels involved in one issue, while both the NGO's are interested in all issues. It also shows the most important difference between the community

members with and without a tank: namely their preference for a high quality improvement and a higher quantity of improvement. This however only indicates whether the actors find something important and does not show whether the stakeholders are important for the project. The following paragraph will give more insight in this.

Table 9: Stakeholder issue diagram

	Quality of improvement	Quantity of improvement	Impact on image
Community members with tank	x		
Community members without tank		x	
Nearby villages		x	
Representative			x
Geoparadise	x	x	x
SamenScholen	x	x	x

### E.3 Actor formal relations

Now that the actors interests and problem perceptions are clear, it is essential to know the relations between the actors to understand the actors and their environment better. This is done by mapping their formal relations and in this case, this will also encompass family ties, as they are important in this context. This has resulted in figure 16.

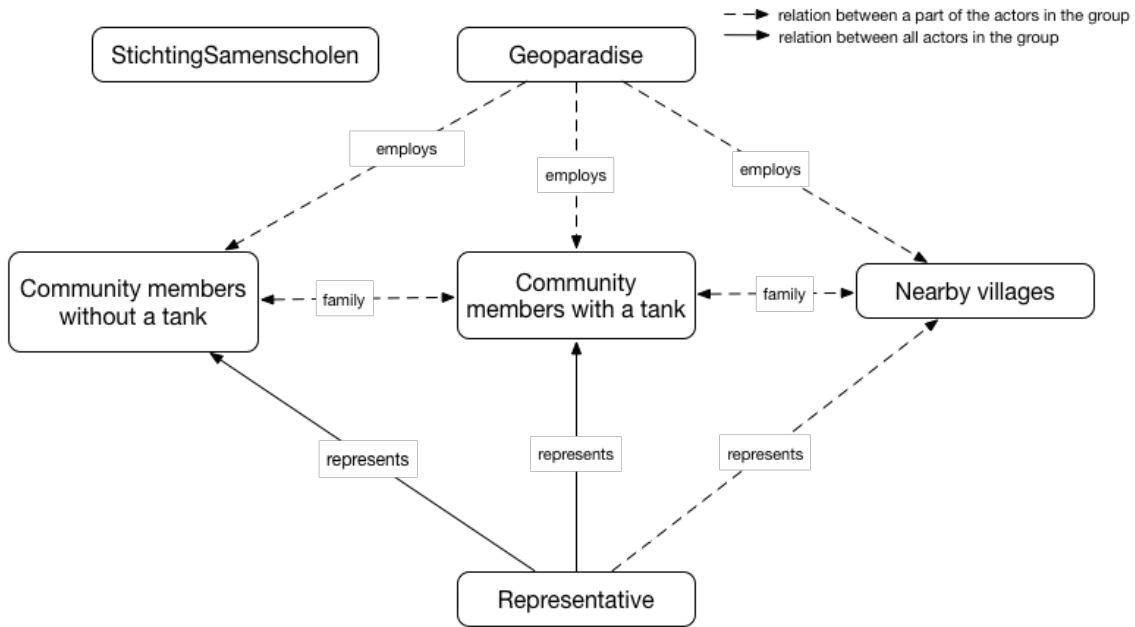


Figure 16: Formal relations including family ties

### E.4 Actor dependency

Now that the actor field and their interests are known, there will be analysed whether the project depends on certain actors as well as which formal relations exist between the actors. For every

actor, there is decided how replaceable and how dependent the project is on their most important resource. If a resource is difficult to replace, while the project is dependable on it, the actor is marked as critical. This results of this are shown in table 10.

Table 10: Resource dependency

Actor	Important resource	Replaceable	Dependency	Critical
Community members with tank	Workforce	medium	high	yes
Community members without tank	Food	high	high	no
Nearby villages				no
Representante	Governmental support?	low	low	no
Geoparadise	Tools and camping equipment	medium	high	yes
SamenScholen	Financial support	medium	high	yes

This concludes that the representante and nearby villages are not critical, due to their replaceability and dependency. While both the community members and NGO's are critical, mainly due to the projects dependence on them, which is mainly due to the remote location.

## E.5 Power-interest

Now that the criticality, dedication and interests in the project are known, this can made clear in a graphical form using power-interest-dedication diagram. When graphically represented, this results

Dedicated	Non-dedicated			
	Critical	Non-critical	Critical	Non-critical
Similar interests	CMWT		Geoparadise SamenScholen	
Conflicting interests		CMWoT		Representante, other villages

in the power-interest-attitude diagram show in in figure 17, where a negative attitude indicates that the actors want a high quantity of improvement instead of a high quality, which does not mean that they are against the project in general, but merely indicated that they have different objectives for the project.

## E.6 SWOT and TOWS

A SWOT analysis (table 11 is used to get more insight in the strength and weaknesses of the project that became clear from the stakeholder analysis and a TOWS analysis (table 12 to find practical ways on how these can be combined to engage stakeholders to the advantage of the project.

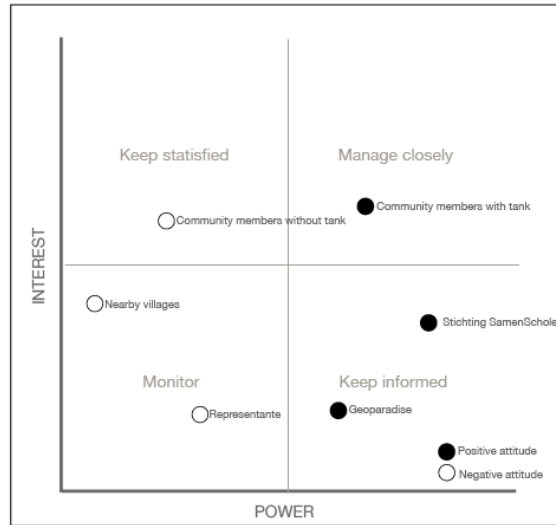


Figure 17: Power-Interest-Attitude grid

	Strength	Weakness
	<p><i>Strengths</i></p> <p>S1: The project team is academically educated in fields related to the project</p> <p>S2: GeoParadise already has experience operating in the region</p> <p>S3: The project is highly likeable</p> <p>S4: The expectations of the village regarding charity/government projects are low</p>	<p><i>Weakness</i></p> <p><i>Opportunities</i></p> <p>O1: Most people in the village have construction experience from building (parts) of their own house</p> <p>O2: The village can learn how to construct the tanks by themselves</p> <p>O3: Families might help each other at their building sites</p>
Threats	<p><i>Weaknesses</i></p> <p>W1: The project team has not performed a construction project before</p> <p>W2: Few is known about the village</p>	<p><i>Threats</i></p> <p>T1: SamenScholen has to approve spendings</p> <p>T2: If the village does not provide workforce, it will be impossible to create as much tanks as planned</p> <p>T3: The village might not be as interested in water tanks as expected</p>

Table 11: SWOT analysis

	Strength	Weakness
Opportunity	Transfer 'Western' knowledge to the village (S1/W2)	Learn to construct from the people in the village (W1/O1)
Threats	Abuse the good image of the project to be able to demand more from the people (S3/T2)	Form clusters of people receiving a tank and ask them to help each other with building (O3/T3)

Table 12: TOWS analysis

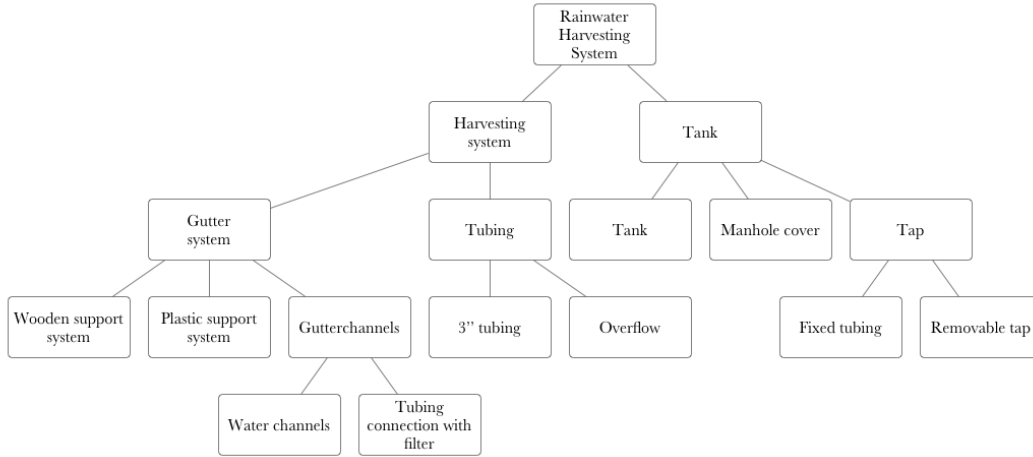


Figure 18: Physical decomposition of the rain water harvesting system

## F Quality assurance

Quality assurance is the second part of the three quality management processes described by Nicholas and Steyn and it performs the activities planned in the previous process (planning for project quality) and ensures that the necessary processes are used to meet the prescribed specifications. In this project, it consists of an Failure Mode and Effect Analysis (FMEA) and audits and inspections. The FMEA will be explained in more details in this appendix, including the physical and functional decomposition on which the FMEA is based. Also, the findings during audits and inspection are registered in more detail in this appendix.

### F.1 FMEA

To perform an FMEA the following physical (figure 18) and functional decomposition (figure 19) have been made. These functional decomposition resulted in the use of five functions for the FMEA that could fail: catch uncontaminated rainwater, filter large particles from rainwater, be closed of from UV-light, be airtight and be watertight. The physical decomposition resulted in eight parts of the tank that helped brainstorming possible failure modes. Together, these decompositions to brainstorm possible failure modes and causes led to the FMEA as shown in figure 20.

The most important result of the FMEA is the possibility of a failure of filtering particles in the gutter system, leading to undrinkable water. Although the probability is only moderate, the detectability and severity is high, leading to the highest RPN. This is followed by the tank losing its air-tightness due to wear of plastic or cement and leading to the water becoming not drinkable. After these comes a tie regarding RPN of three failures: water leakage due to too thin walls and leaking gutters (or connections) due to wear. This resulted in the intention to improve the quality of the gutter system, and while doing so also upgrading the tap, but no higher quality of these two could be bought. There was eventually decided to only hang gutters with hardwood and

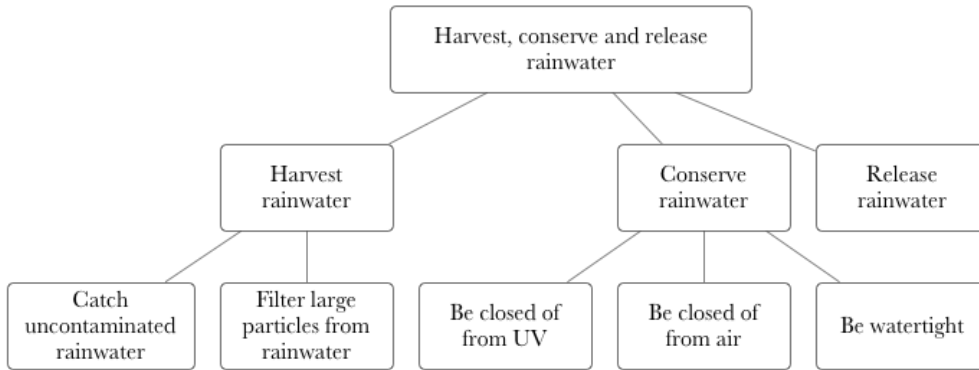


Figure 19: Functional decomposition of the rain water harvesting system

Functions	Failure mode	Effects	Severity	Cause	Probability	Detectability	RPN
Harvest rainwater	Not filtering particles	Water not drinkable	10	Wear of plastic filter	5	8	400
Conserve rainwater	Not air-tight	Water not drinkable	10	Wear of cement or plastic	3	6	180
Conserve rainwater	Wall leaking	Tank runs out of water	4	Too thin walls	5	7	140
Harvest rainwater	Gutters leak	Tank does not fill up	4	Wear of plastic	7	5	140
Harvest rainwater	Gutters leak on connections	Tank does not fill up	4	Wear of plastic	7	5	140
Conserve rainwater	Cracks leaking	Tank runs out of water	4	Drying too fast	6	5	120
Conserve rainwater	Tap leaking	Tank runs out of water	4	Not water tight connection of tap	6	5	120
Conserve rainwater	Cracks leaking	Tank runs out of water	4	Bad quality of cement mix	5	5	100
Conserve rainwater	Cracks leaking	Tank runs out of water	4	Bad quality of sand	5	5	100
Conserve rainwater	Cracks leaking	Tank runs out of water	4	Rust of metal parts close to surface	4	5	80
Conserve rainwater	Cracks leaking	Tank runs out of water	4	Too small layers	4	5	80
Conserve rainwater	Cracks leaking	Tank runs out of water	4	Unevel construction	2	5	40
Harvest rainwater	Gutters fall of	Tank does not fill up	7	Wear of wood	5	1	35
Release water	Tap fails	Tank does not give water	2	Impact on tap	7	1	14
Conserve rainwater	Not UV-tight	Water not drinkable	10	Wear of manhole cover	1	1	10
Release water	Tap fails	Tank does not give water	2	Wear of tap	3	1	6

Figure 20: Failure Mode and Effect Analysis

replacement taps were left in the village. To reduce the probability of too thin walls the additive Sika was added to the cement mix for the outer layer, which improves water tightness. Also, a more watertight connection of the tap was constructed in the five latest tanks.

## F.2 Audits and inspection results

Audits The following parameters were registered during inspections.

- Thickness at tap (cm)
  - Pastor: 6,3 cm
  - Emilio: 4 cm
  - Julio: 5 cm
  - Matteo: 7 cm
- Thickness at four points at top of bottom (cm)
  - Demitrio: average 2,3 cm (1,5; 2; 2; 3,5)
  - Israel: average 1,6 cm (2;1;3;0,5)
- Thickness at four points at top of middle part (cm)
  - Israel: average 5,9 cm (6; 6.5; 6; 5)
  - Julio: average 4 cm
- Thickness at four point of top (cm)
  - Lazaro: average 3,1 cm (3;3;2.8;3.5)
  - Demitrio: average 5 cm (3; 3; 4.5; 3.5)
- Quality of wettening tank
  - low: Pastor
  - medium: school, Julio
  - high: Emilio, Lazaro, Matteo, Demitrio

It showed to be difficult to realise the metrics that were chosen while planning for project quality in the pre-study. The inspections do show a large spread in the measurements, especially regarding thickness. To improve the validity of the measurements there is tried to measure the wall thickness and water tightness during project quality control in collaboration with UTP. There could then be deducted which results during this phase leads to good quality. However, during the expedition with the university, the measuring equipment did not function properly, so no results were obtained.



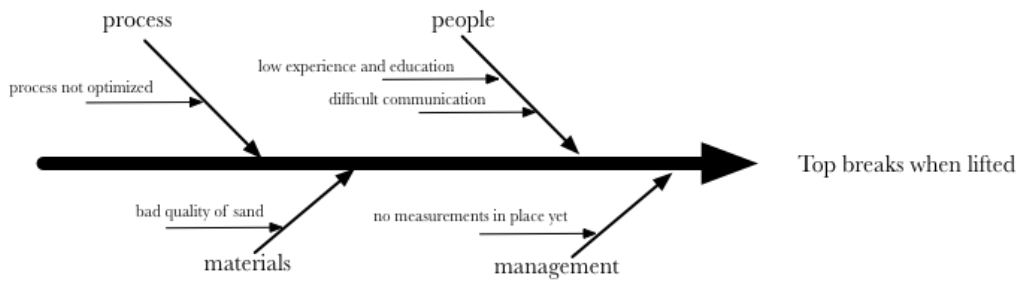


Figure 21: Ishikawa diagram of the failure of breaking a top

## G Quality control

Quality control is the last part of the three quality management processes described by Nicholas and Steyn and entails all that is done at the end of the project to ensure that the quality can be fixed if it is not high enough. Continuous improvement is not part of quality control, as only one project is performed, but does include inspections, defect repair and a cause-effect analysis.

### G.1 Cause effect analysis

An cause effect analysis was performed on the biggest failure encountered in the project: a top that broke while it was tried to be put it on the tank. The analysis is performed using a Fishbone or Ishikawa diagram, with the standard six dimensions of process, people, materials, management, environment and equipment. No causes were found in the equipment and environment domain, so these are excluded.

The causes in the process and management domain had to do with the fact that this was one of the earlier tanks, so the process was not optimized yet and no measurements were in place yet. There were already plans for project control lessons learned and planning for quality management that cover these aspects. Regarding the materials domain, there was tried to find a better quality of sand, but this was not available. This leaves the people domain, communication difficulties and low experience and education. This resulted in the diagram shown in figure 21

It is therefore again recommended for a new project to make a good plan including workshops and diplomas regarding construction knowledge for the local workforce as well as putting more effort in having more translation capabilities, either by learning Spanish or by hiring more (experienced) translators . During this project the translator will be used more at building sites to explain building steps and educate the local workforce.

### G.2 Inspections

This section shows all additional details on the inspections that were performed as part of the quality control. These inspections are the (in situ) water tightness measurements and the concrete sample testing performed by UTP. The water quality measurements performed by UTP are also used as part of the quality control, but these results can be found in a separate Appendix: Appendix K.

### G.2.1 In situ water tightness measurements

The in situ water tightness measurements were performed by, after at least half filling of the tank, marking the water level on the tank wall and measuring this again after 24 hours. In these 24 hours, the tap was closed with a tie-wrap and the gutters were disconnected and closed off with plastic and tape. Having to wait for the tanks to half fill up by rain did however mean a delay of the start of the usage of the tank by the owner. This meant that these owners could not be interviewed regarding their use of the tank and to prevent this, only the first four tanks were measured. This resulted in the following results:

- School: no significant decrease
- Emilio: 2 cm decrease (measured in 4 inch pipe)
- Pastor: fault in measurement (mark not found)
- Matteo: fault in measurement (tap seal broken)

Unfortunately these measurement showed unsuitable in these circumstances to generate useable results. Most importantly the size of the tank is too big to measure accurately: a difference of 2cm can be measured, so approximately 85 litres or 3 percent has to leak in 24 hours, which is very unrealistic. To solve this, the tank would have to be filled up to the overflow,so there can be measured in a 4 inch pipe, but this could take weeks and would this take too long. In two instances the measurements were already corrupted: one tap seal was broken and one mark could not be found, which probably meant that the gutter was reconnected and the water level increased to above the mark. Emilio's tank did deliver a measurement, as he had filled his tank as far as possible with his garden hose and therefore the measurements could be done in time in the 4 inch pipe connecting to the gutter. The conclusion is that his tank is watertight, but this one measurement can unfortunately not be generalised to eleven tanks.

### G.2.2 Concrete sample testing

The concrete sample testing was supposed to be tensile strength testing using beam samples, but unfortunately the supplied beam samples were too small, so only pressure strength tests could be executed with them. The design of the tank makes that the tensile strength of the used concrete is a critical parameter while the pressure strength test is not, but fortunately there is a relatively reliable relation between pressure strength and tensile strength. Therefore, although not optimal, conclusions on the differences in tensile strength can be drawn using pressure strength tests. The samples were sawed in squares, which made them too small to make efficient use of some of the rebar types, making these results unreliable. The results of the different sand types, drying circumstances and the failed top are usable, but the samples were not constructed in a lab and therefore for example thickness and drying circumstance have varied unintentionally. For this reason, only differences of more than 20% are seen as significant. No suitable tests on water permeability were available at UTP at the moment of testing. The results can be seen in table 13 It showed that the type of sand can more than double the pressure strength and that the Rio Culebra road samples show no significant differences with either of the different drying circumstances nor with Julio's broken top. This is remarkable, as the drying circumstances of samples 10 and 11 were intentionally worsened and a lower strength was expected, as in reality worse drying circumstances resulted to cracks in the tanks surface. It is due to this observation that there can not be concluded that the drying circumstances are not important for the strength of the tank. Regarding the broken top this means that none of the inspections resulted in a single clear cause of why this top failed. It is not weaker than the most comparable sample (the Rio Culebra road sample without rebar, which is constructed following all appropriate steps), so it assumed to be a combination of causes (thin, suboptimal drying circumstances, bad sand and cement mix quality and high stress during

ID	Description	Load (kN)		Stress (MPa)	
		1st run	2nd run	1st run	2nd run
Sand type					
1	Rio Culebra road	27,8	34,5	10,79	13,34
2	Playa Chiquita	43,6	44,9	16,91	17,4
3	Rio Culebra cowfield	71,4	69,6	27,66	26,97
12	Playa Cuango	70,8	62,4	27,43	24,17
Rebar type					
4	Single steelwire	38,9	35,5	15,07	13,75
5	Braided steelwire	31,8	31,5	12,31	12,18
6	Fine chickenfence	34,3	40,9	13,29	15,87
7	Medium chickenfence	33,7	53,1	13,06	20,59
8	Coarse chickenfence	39,8	23,3	15,43	9
Drying circumstances					
10	Not wettened	28,6	29	11,08	11,11
11	Not covered	29,1	24,3	11,26	10,19
Miscelaneous					
9	With Sika (never added)	-	-	-	-
13	Broken top Julio	31	32,6	12	12,63

Table 13: Concrete sample pressure strength results

lifting) that are not crucial on itself but together resulted in the failing of the top. It can thus be concluded that a search for the highest quality of sand is crucial to increase strength, which can give opportunities to optimise the amount of cement used in a future project, but no conclusions related to the quality management of the tanks can be drawn, because all the constructed tanks are standing and have therefore already shown to be strong enough to fulfil its functions.

## H Project control observations

Project control is examined by gathering lessons learned regarding project control.

### Week 1

- The sand is of lower quality than what was known in the previous project in Africa, therefore the cement is less sticky and chicken mesh is needed to get it attached to the mould. This effect is strengthened by the use of wood instead of cement blocks for the mould, which is already less sticky. This was done because wood is lighter and less expensive in Panama.
- Some of the steps take longer than expected, such as the installation of the tap and the side of the top of the tank. These were perceived as small tasks, but especially the first time it takes quite some time to complete them with the resources that we have.
- Simon is very grateful for his job and wants to do everything perfectly, therefore he prefers not to say if something is wrong. For example, we got sand at a river which actually was of a bad quality, but he said that it was fine, because nothing else was available.
- Getting construction supplies is expensive, due to gasoline, and takes a lot of time (1,5 hour), but is still necessary quite often as it often appears in the morning something is needed for the work today.

### Week 2

- One of the workers, Emilio, speaks a strong Panamanian dialect, so no one of the group except Daniel and Simon can speak with him.
- The translator does charity work in the community, so he sees it as his own community in which he knows how work should be done, which makes it hard to try new methods when he is present

### Week 3

- Make it clear whether the local workforce is working on the project or free for other work. Both so that they don't miss a day of paid work and that when they are expected for the project they really do work for the project.
- The workers like to learn new skills, but it is difficult to find a balance between letting them do the work they know and investing time in explaining more difficult tasks.
- The workers do a better job when they understand why something should be done and a big part has experience with construction work and therefore understands the tasks quite quickly if they understand the reasoning.

### Week 4

- One of the tank owners, Julio, has, after working on two tanks, learned enough to be able to finish some small tasks at the end of the day himself.
- Sometimes the manhole covers don't fit, as in practice they don't retain the exact same shape as the manhole in which they are made.
- When building sites need to share it's own tools and supervisor, they will often have to wait for these resources.
- It becomes a full time job of coordinating between building sites when there are three building sites.

## Week 5

- Demitrio has learned enough to finish most tasks himself, he also roughly knows the complete process of building the tank and can do some tasks without any help.
- The tanks are often not wettened well enough (the schools tanks also has cracks) and therefore they need to do it three times a day. It is difficult to do this ourselves, so Lise explains them that it otherwise gets cracks and will check this everyday.
- Manholes covers need scratch to fit
- Workshops and diplomas are needed to educate the local workforce in a structured way.
- Every construction site needs a supervisor, to keep an eye on the construction tasks, including graphics with the most important construction lessons in Spanish.
- Extend pre-construction meeting with a planning of workforce: demand a certain amount of workers per day and adjust whether you will build there accordingly.
- Checklist for packing and also for during the workday (what to check when) to ensure sufficient quality. These must be translated to Spanish to.
- Tips and tricks must be exchanged between the team.
- Building in a tropical climate first day build big tarp against sun and rain.

## Week 6

- When during the project different volunteers are working in construction, they must be properly educated, just as with the local workforce, but as the volunteers speak English, more can be explained during construction. Taking their education into account give extra opportunities, for example some volunteers were architect and afterwards told that they would have preferred to know more technical details.

## I Water quality during pre-study

**Building site (BS) 1: School**    **Building site (BS) 6: Lazaro**  
**Building site (BS) 2: Church**    **Building site (BS) 7: Demetrio**  
**Building site (BS) 3: Emilio**    **Building site (BS) 8: Chami**  
**Building site (BS) 4: Julio**    **Building site (BS) 9: Israel**  
**Building site (BS) 5: Mateo**    **Building site (BS) 10: Tito**

Table 14: In situ measurements done right after each interview with head of households of the respective sources

Location	Date	Greisinger		HoneyForest			pH-strips
		EC ( $\mu\text{S}/\text{cm}$ )	T ( $^{\circ}\text{C}$ )	EC ( $\mu\text{S}/\text{cm}$ )	TDS (ppm)	T ( $^{\circ}\text{C}$ )	pH (-)
Distribution system	13-08-18	173.4	26.7	189	89	29.7	7
BS 2 - Rain barrel	15-08-18	16.2	29.6	14	7	31.7	7-8
BS 2 - Rio Culebra	15-08-18	132.7	28.9	142	68	30.6	7-8
BS 2 - Drinking water from spring	15-08-18	62.0	29	59	28	31.3	7-8
BS 3 - Rain barrel	19-08-18	52.5	31.7	48	23	32.0	7
BS 3 - Small stream	19-08-18	114.8	27.7	127	47	29.9	7
BS 4 - Rain barrel	25-08-18	68.0	33.2	32	33	32.6	7
BS 4 - Small stream	25-08-18	106.1	29.7	123	58	33.9	7-8
BS 4 -Rio Culebra	25-08-18	136.0	31.1	165	78	33.5	7-8
BS 5 - Rain barrel	27-08-18	142.7	30.4	168	79	32.2	7-8
BS 5 - Small stream	27-08-18	93.3	32	102	48	33.0	7
BS 6 - Rio Culebra	31-08-18	120.0	30	140	66	32.8	7-8
BS 7 - Rio Culebra	03-09-18	127.3	28.8	148	70	32.2	7-8
BS 8 - Rio Culebra	07-09-18	116.3	27.3	131	62	29.5	7-8

## J Weekly monitoring results

To monitor water quality change in time, measurements are performed during 5 days on the stored water in the tank at the school. The results are presented in the tables below.

Table 15: Water quality change in time, TDS and EC measurements

Date	TDS (in ppm)		
	Morning	Midday	Evening
20-09-18	40	36	42
21-09-18	49	49	51
22-09-18	36	36	40
23-09-18	45	49	51
24-09-18	48	46	50

Date	EC (in $\mu\text{S}/\text{cm}$ )		
	Morning	Midday	Evening
20-09-18	76.7	65.8	75.4
21-09-18	90.3	86.8	89.2
22-09-18	67.0	65.5	73.8
23-09-18	82.4	78.6	80.3
24-09-18	83.1	79.1	81.4

Table 16: Water quality change in time, temperature and pH measurements

Date	T (in $^{\circ}\text{C}$ )		
	Morning	Midday	Evening
20-09-18	26.2	27.2	27.3
21-09-18	26.5	27.9	27.9
22-09-18	26.5	27.4	27.1
23-09-18	26.5	27.2	27.1
24-09-18	26.5	27.5	27.2

Date	pH (-)		
	Morning	Midday	Evening
20-09-18	9	9.5	9
21-09-18	10	9.5	10-11
22-09-18	9	9.5	9
23-09-18	9.5	9.5	9
24-09-18	9	9.5	9

## K Lab results water quality

The water samples are numbered as can be seen in table 17 below. In table 18 on the next page the results from the water quality analyses in the laboratories of LABAICA (water lab at UTP) and AQUATEC can be found.

<b>Sample name</b>	<b>Sample location</b>
S1	Ojo de agua en comunidad
S2	Rio Culebra
S3	Rio Negro
S4	Tank Lazaro
S5	Tank Mateo
S6	Tank Julio
S7	Tank Church
S8	Tank Emilio
S9	Tank School

Table 17: Sample name and location



Parameter	Unit	MIN	MAX	S1	S2	S3	S4	S5	S6	S7	S8	S9
<b>Indicator parameters</b>												
Temperature	degrees			27.2	26	25.2	26.4	26.3	26.2	26.1	27	26.1
Conductivity	$\mu S/cm$		2500	88.3	135	79.4	318.2	274.6	338.1	44	213.6	105.2
pH	pH units		6.5-8.5	5.5	7	6.85	10.53	10.48	10.62	10.75	9.86	9.98
Turbidity	NTU		1	47.6	2.64	56.4	1.38	1.4	2.56	1.02	1.11	0.65
TDS	mg/L		500	44	93	54	58	68	71	107	129	34
Sulphate	mg/L		250	8.44	3.17	2.63	1.34	1.3	1.56	1.74	2.81	1.65
Nitrate	mg/L		10	<0.03	<0.03	<0.03	0.07	0.07	0.09	0.07	<0.03	<0.03
Alkalinity	mg/L		120	6	54.6	30.1	71.1	71.7	81.6	108.6	89.9	30.6
Ammonium	mg/L		0.3	<2.00	3.5	2.5	-	-	-	-	-	-
Manganese	mg/L		0.1	<0.06	<0.06	<0.06	-	-	-	-	-	-
<b>Chemical parameters</b>												
Sodium	mg/L		200	8.93	9.6	5.94	2.13	2.822	2.697	6.597	13.213	2.519
Calcium	mg/L		80	1.399	7.817	3.394	15.36	17.949	17.776	19.844	11.93	5.504
Magnesium	mg/L		30	1.37	5.43	2.72	0.074	0.062	0.08	<0.06	3.42	0.07
Potassium	mg/L		-	3.12	<0.70	<0.70	1.184	2.272	2.251	7.069	8.119	1.898
Chloride	mg/L		250	6.7	7.8	7.8	3.93	<0.15	2.5	2	7.35	1.8
Iron	mg/L		0.3	1.1	0.11	0.47	0.011	<0.01	<0.01	<0.01	<0.01	<0.01
Lead	mg/L		0.01	-	-	-	<0.084	<0.084	<0.084	<0.084	<0.084	<0.084
Zinc	mg/L		5	-	-	-	0.024	0.873	0.845	0.432	0.108	0.012
Arsenic	mg/L		0.01	<0.026	-	-	-	-	-	-	-	-
<b>Microbiological parameters</b>												
E.coli	NMP/100mL		0	5200	860	6700	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Total Coliform	NMP/100mL		10	325500	20640	155310	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
BOD	mg/L		5	-	<1.0	4.5	-	-	-	-	-	-
COD	mg/L		5	-	<3.0	8.3	-	-	-	-	-	-

Table 18: Water quality lab results by LABAICA (water lab at UTP) and AquaTec, where the colour green indicates that the measured value is conform the Panamanian drinking water standards, the red colour indicates that the measured value is not conform the Panamanian drinking water standards and the orange colour represents values that are close to the standards set by the Panamanian government

## L Evaluation measurements

**Building site (BS) 1: School**    **Building site (BS) 6: Lazaro**  
**Building site (BS) 2: Church**    **Building site (BS) 7: Demetrio**  
**Building site (BS) 3: Emilio**    **Building site (BS) 8: Chami**  
**Building site (BS) 4: Julio**    **Building site (BS) 9: Israel**  
**Building site (BS) 5: Mateo**    **Building site (BS) 10: Tito**

Table 19: Overview of results of measurements of water quality during usage

Location	Date	Greisinger		HoneyForest			pH-strips
		EC ( $\mu\text{S}/\text{cm}$ )	T ( $^{\circ}\text{C}$ )	EC ( $\mu\text{S}/\text{cm}$ )	TDS (ppm)	T ( $^{\circ}\text{C}$ )	pH (-)
BS 1 - Storage tank	10-10-18	299	28.9	382	180	29.2	10
BS 2 - Storage tank	10-10-18	669	27.4	859	404	27.9	11
BS 4 - Storage tank	10-10-18	832	29.7	1029	484	30.6	11
BS 5 - Storage tank	10-10-18	632	28.9	770	362	29.4	11

## M Post water map

The water sources and systems present in El Progreso during the post study are shown in figures 22 and 23 below.

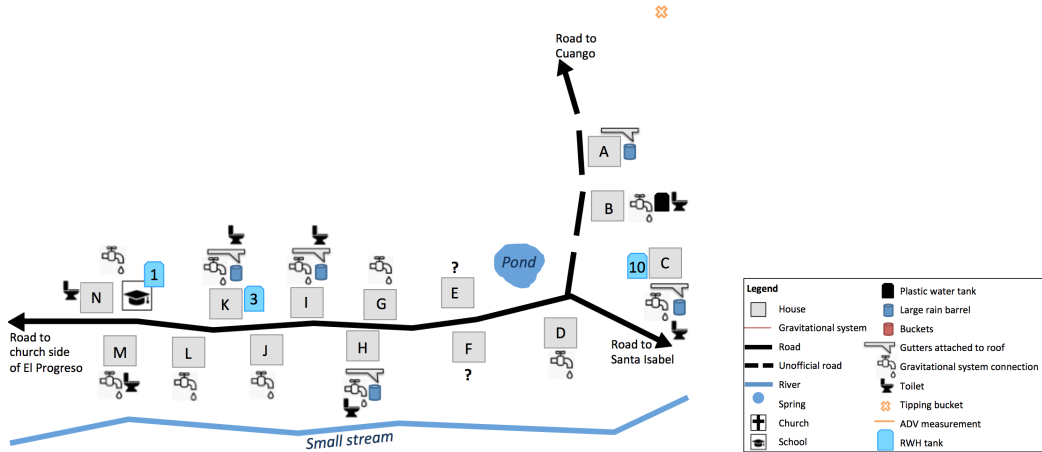


Figure 22: Water sources and systems of the school part of El Progreso - Post study

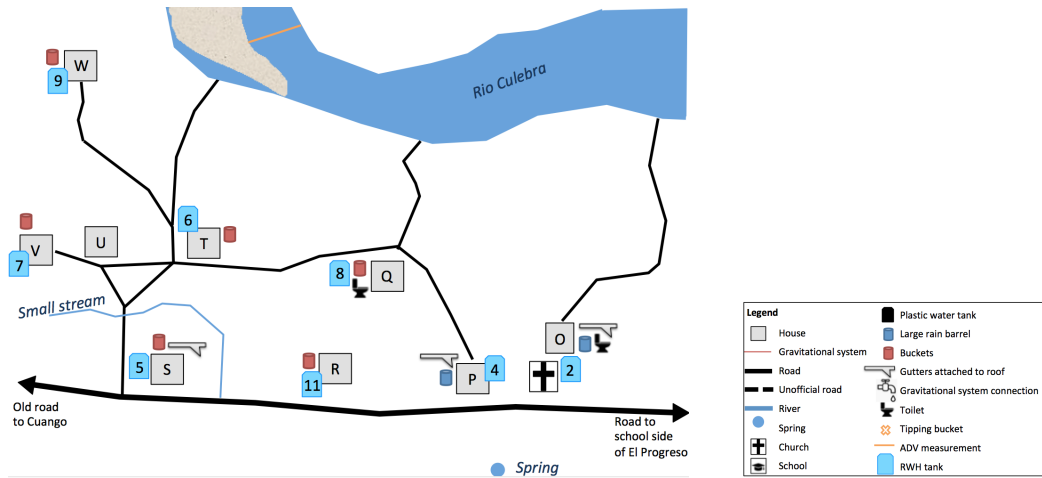


Figure 23: Water sources and systems of the church part of El Progreso - Post study

## N ADV measurements

### N.1 Measurement and calculation method

According to the manual of the measurement device, the number and position of the verticals are dependent on the geometric shape of the measurement cross-section and the intended measurement and evaluation method. The rules according to EN - ISO 748 apply, as specified in table 20.

Table 20: Number of verticals in relation to the waterway width

Waterway width (m)	Number of verticals
>0 and <0,5	3-4
>0,5 and <1	4-5
>1 and <3	5-8
>3 and <5	8-10
>5 and <10	10 - 20
>10	>20

### N.2 Measurement data

Table 21: ADV measurement Rio Negro

Point (m)	Total depth (m)	Velocity (m/s)			
		0.2*depth	0.4*depth	0.6*depth	0.8*depth
0	0.73	0.01	0.00	-0.01	-0.01
0.48	0.90		0.01	0.00	0.01
0.96	1.15	0.01	0.01	0.01	
1.44	1.28	0.03	0.01	0.02	0.02
1.92	1.22	0.05	0.04	0.03	0.03
2.40	0.93	0.03	0.03	0.01	0.01
2.88	0.64	0.03	0.02	0.02	0.02
3.36	0.48	0.01	0.02	0.03	0.02
3.84	0.23	-0.01	0.00	0.00	0.00
4.32	0.09		0.04		
4.48	0				

This table shows the measured point velocities at respectively 20, 40, 60 and 80 % of the water depth at 11 verticals at a distance of 0.48 meter along the width of the river Rio Negro

**Relevance** To get an understanding of how much water flows into the inlet of the gravitational system.

**Measurement site description** This measurement was carried out in Rio Negro at a location just before the water flows into the inlet of the gravitational system. At time of measurement, the water level was not at its maximum; at one side pebbles of the riverbed were exposed.

**Observations at measurement site** When arriving at the intake point for inspection and in preparation for taking measurements, it was discovered that the main pipe of the system was disconnected. Probably this was because of the tension in the pipe, due to a slight bend around a big rock formation. The pipe was connected before proceeding.

**Calculations** Since the discharge for a relatively small water course is calculated, the used number of measuring points in the vertical is limited to three. The average velocity over the vertical for three point measurements can be calculated using either of these two methods:

$$\bar{u} = \frac{1}{3}(u_{0,2} + u_{0,6} + u_{0,8}) \quad (11)$$

or

$$\bar{u} = \frac{1}{4}(u_{0,2} + 2 \cdot u_{0,6} + u_{0,8}) \quad (12)$$

The discharge  $Q$  of the river now is calculated by means of the velocities ( $u_i$ ), representative for the part  $A_i$  of the area ( $A$ ), using:

$$Q = \int^A u dA \approx \sum^n u_i \cdot \Delta A_i \quad (13)$$

From table 21 the width of each segment is determined: 0,24m for the first and last, 0,48m for all (1/s).other segments. To calculate the area  $A$  for its segment, these widths are multiplied by the averaged depth (between to measurement points). Using (11), (12) and (13) the discharge is calculated, giving for method 1 and 2: 0,053  $m^3/s$  and 0,051  $m^3/s$  respectively, or 53,5 l/s and 51,5 l/s.

**Relevance** To get an understanding of the magnitude of the discharge in this river, in order to determine if this river might be suitable for a second gravitational system, where the inlet will be constructed a fair bit upstream.

**Measurement site description** This measurement was carried out in Rio Culebra at a part at which half of the river bed consisted of pebbles and a sandbank and a part with fast flowing water, which was a bit turbulent due to the velocity of the water and larger rocks in the riverbed.

**Observations at measurement site** Biggest part of the river was dry. Flow concentrated through roughly 1/3 of the whole width.

**Calculations** Following the same approach as described under calculations for the discharge of Rio Negro, the calculated discharge for Rio Culebra is 2,35  $m^3/s$  or 2,36  $m^3/s$ , for method 1 and 2 respectively. The used widths of the segments is 0,25m (first and last segment), 0,50m (for segment 2 to 16) or 1,0m (segment 17 to 21).

Table 22: ADV measurement Rio Culebra

Point (m)	Total depth (m)	Velocity (m/s)			
		0.2*depth	0.4*depth	0.6*depth	0.8*depth
0.5	0.58	0.22	0.09	0.06	0.02
1.0	0.76	0.13	0.08	0.04	0.01
1.5	0.90	0.14	0.15	0.08	0.19
2.0	0.93	0.26	0.17	0.22	0.18
2.5	0.96	0.47	0.43	0.52	0.44
3.0	0.99	0.63	0.70	0.71	0.60
3.5	1.03	0.73	0.68	0.61	0.57
4.0	1.02	0.55	0.51	0.53	0.49
4.5	0.91	0.51	0.46	0.50	0.44
5.0	0.92	0.42	0.41	0.49	0.43
5.5	0.80	0.38	0.39	0.44	0.39
6.0	0.68	0.36	0.38	0.36	0.28
6.5	0.59	0.34	0.35	0.30	0.29
7.0	0.42	0.34	0.31	0.33	0.30
7.5	0.35	0.29	0.29	0.26	0.23
8	0.33	0.26	0.30	0.24	0.18
9	0.25	0.24	0.22	0.17	0.14
10	0.18	0.18	0.16	0.06	0.02
11	0.12	0.12	0.14	0.15	0.09
12	0.11	0.08	0.12	0.06	0.04
13	0.07	-	-	-	-

This table shows the measured point velocities at respectively 20, 40, 60 and 80 % of the water depth at 21 verticals along the width of the river Rio Culebra

## O Interviews

This section gives an overview of all questions asked during the interviews. Per household two interviews are conducted: a first to gather general information, assess the current water and sanitation situation and gather information on requirements of the interviewee regarding the project. A second interview is conducted as an evaluation: changes in requirement and water usage are assessed.

### O.1 Interview questions current situation

This section shows the questions asked to assess the current situation.

#### General

1. What is your name and what do you do for a living?
2. Who are you living with? (children, age, sex)
3. Where do your children go to school?
4. What kind of education did you have? (Summary of education - did you go to school here?)
5. How long have you been a part of El Progreso community?
6. Do you have any special resources that can help our project? (Generator, connections, skills)
7. What are your responsibilities in this household?

#### Water

1. What is the main source (/what are the main sources) of water for this household? If you use different sources, where do you use the different sources for? (Drink; Wash/prepare food; Cook; Bathe; Brush Clean; Brush teeth; Dishes; Laundry)
2. Do these sources change throughout the year?
3. How close is the source to the household?
4. Do you treat water from your source? If yes, how? (Filter, boil, through shirt)
5. How much water do you use per day?
6. Do you think the water is safe? If not, why? Do people get sick because of the water?
7. What role does water have in your community? (Spiritual, Religious, something else, not extra than anything else)
8. Which of the following is close to your water source? (Farm, pesticides, upstream village, garbage, latrines)

#### Tank

1. How did you choose the location of the tank? (And who chose it? Man/woman)
2. What is your interest in this tank?
3. What is your opinion about the following aspects of the tank?

- Size tank;
  - size manhole;
  - shape;
  - tap;
  - collection system and roof material;
  - maintenance
4. Where are you going to use the water from the tank for? Does this need extra requirements?
  5. Do you think you will use more water once you have the tank?
  6. What do you think of the fact that you got (rank number) tank? So before, after ....?

### **Requirements**

1. Is there anything you want to learn from the building of the tanks?
2. What do you expect of the design and construction of the tank?
3. What do you think the tank will last?
4. Do you have experience with charity? If yes, how well were your requirements met?
5. What do you think about the project?
6. Do you expect resistance against the project?
7. Do you want to learn more about water and how to treat it?

### **Extra added questions**

1. What kind of food do you eat during breakfast/lunch/dinner?
2. What kind of sanitation services do you have to your disposal?

## **O.2 Evaluation interview**

This section shows the questions asked during the evaluation interview.

### **Requirements**

1. What kind of support do you need the most?
2. Rank the following fields of support in order of importance to you: work, food, medical, education, money, water and sanitation.
3. Do you have problems regarding water or sanitation in your life and if so, what are these problems?
4. What would you require to improve this situation?
5. Did you ever think about a water tank?
6. What do you think of the size?
7. What do you think of the tap?



8. Did your opinion on the location change after usage?
9. What do you think of the aesthetics of the tank?
10. What do you think of the maintenance of the tank?
11. Are there any requirements on the tank that are not fulfilled?

#### **Water**

1. Do you already use the water?
2. Where are you using the water in the tank for?
3. What do you think of the taste of the water?
4. Do you still use the water from your other water source? yes for which purposes?
5. Do you treat the water from the tank before you use it?
6. How do you use the time you would normally go to the river?
7. Do other people, besides your household, use the water from this tank?
8. Who gets the water from the tank?
9. How did you cleaned the tank?
10. Do you see maintenance as a burden?
11. Which part of the tank is most vulnerable in your opinion?
12. Which part of the tank needs most maintenance in your opinion?

### **O.3 Final interview during usage**

#### **Water**

1. Did you already use the water from your tank?
2. Where are you using the water from the tank for?
3. What do you think of the taste of the water?
  - (a) Did you notice any changes in taste or quality of the water of the tank?
4. Do you still use the water from the other sources?
  - (a) And if yes, what for?
5. How do you use the time that it would normally take for you to get water from the river?
6. Do you treat the water before you use it?
7. Do other people besides your household use the water from this tank?
8. Have there been any problems so far with the system?

## O.4 Interview overview

Table 23: Overview of interviewees with interview numbers, tank number, date and type of interview specified

Interview number	Name	Tank number	Type of interview	Date
1	Armodio Abrego	2	General Evaluation	15-08-18 21-09-18
2	Casildo Chami jr. & Encida Zarco	3	General Evaluation	19-08-18 23-09-18
3	Julio Zarco & Griselda Chajito	4	General Evaluation	25-08-18 22-09-18
4	Mateo & Dania Abrego	5	General Evaluation	27-08-18 21-09-18
5	Lazaro & Exilda Chami	6	General Evaluation	31-08-18 22-09-18
6	Demetrio Abrego & Sixta Chami	7	General Evaluation	03-09-18 23-09-18
7	Casildo Chami sr. & Elena Zarco	8	General Evaluation	07-09-18 24-09-18
8	Israel Chami & Marcia Cardena	9	General Evaluation	09-09-18 23-09-18
9	Tito & Erika Caballero	10	General	16-09-18
10	Daniel Vaisabel	-	Collaboration local NGO	20-09-18
11	Omar Romero & Celina de la Espada	-	No-tank	22-09-18
12	Ambrosio Pascual	-	No-tank	22-09-18
13	Pablo Ramiro Guzman	-	Gravitational system	23-09-18
14	Casildo Berugate	11	General	23-09-18
15	Ubaldo Ontura	-	No-tank	23-09-18
16	Maritza Bernalle	1	Teacher/general	24-09-18
17	Cesar Lopez	-	No-tank	25-09-18
18	Michel Arenas	-	No-tank	25-09-18

## O.5 Interview answers per household

### O.5.1 Armodio Abrego

#### O.5.1.1 General interview on 15th of August

##### General information



Name:	Armodio Abrego
Profession:	Pastor
Age:	Unknown
Lives with:	Wife and 5 children
Education:	Unknown, 2 children attend El Progreso primary school
Part of El Progreso :	4 months, before Bocas del Torro
Special Resources for project:	Experience in construction and mixing cement
Responsibilities in household:	Everything around the church, reconstructing his house, selling fruits and cooking meals

##### Water

1. What is the main source (/what are the main sources) of water for this household? If you use different sources, where do you use the different sources for? (Drink; Wash/prepare food; Cook food; Bathe; Hand wash; Brush teeth; Clean house; Wash dishes; Wash clothes) *My predecessors told me that the river (Rio Culebra) is fine, but after two days of using it my family and I got sick ((diarrhoea, nausea, vomiting and dizziness). Now we use another source, a spring, for drinking water and food preparation, which is nearby. The water from Rio Culebra is used for other purposes.*
2. Do these sources change throughout the year? No answer.
3. How close is the source to the household? *It is about 5 minute walking distance.*
4. Do you treat water from your source? If yes, how? (Filter, boil, through shirt) *First we had a natural filter, the children played with it and it got broken. Now I boil the water for my kids and drinks untreated water myself.*
5. How much water do you use per day? *My family uses 60.6 liters for drinking and cooking and 2 buckets, 18.9 liters, to do the dishes.*
6. Do you think the water is safe? If not, why? Do people get sick because of the water? *I have some concerns about the water.*
7. What role does water have in your community? (Spiritual, Religious, something else, not extra than anything else) No answer.
8. Which of the following is close to your water source? (Farm, pesticides, upstream village, garbage, latrines) *Close to the water source is farmland with cattle and pesticides, I am worried that after heavy rainfall this will get into my (drinking) water. I think that these uses of land can make people sick.*

## Tank

1. How did you choose the location of the tank? (And who chose it? Man/woman) *I did not want it to be standing in the way (so it will not get damaged). First I wanted the tank to be on the other side, but my wife wanted it to be on this location because it will have a more central location when the new church is finished.*
2. What is your interest in this tank? *At the moment, I have to walk 200 meters, or take my horse, to my main water source. With too much rainfall, the source is contaminated with too much sediment. This project will provide clean water (without sediment) from the rain, also for my religious brothers and sisters.*
3. What is your opinion about the following aspects of the tank? (Size tank; size manhole; shape; tap; collection system and roof material; maintenance) *The roofing material is not an issue, but I want to change it anyways to painted zinc (because everyone else has this kind of roof).*
4. Where are you going to use the water from the tank for? Does this need extra requirements? *I am going to use the water from the tank for drinking water and cooking and everything else if needed.*
5. Do you think you will use more water once you have the tank? *The size of the tank is 4 times bigger than the amount I am currently using on a daily basis. I am happy that I have more water when the tank is full. Now I am more relaxed with having water more close by.*
6. What do you think of the fact that you got the second tank? (So after the school and before every other household) *The church gets a tank first, everyone agrees on this.*

## Requirements

1. Is there anything you want to learn from the building of the tanks? *I want to know how the construction of the tank is and how the construction steps will lead to a final tank.*
2. What do you expect of the design and construction of the tank? *No answer.*
3. What do you think about how long the tank will last? *I think that the tank will last a long time and I understand that maintenance comes along with having a long functioning water tank.*
4. Do you have experience with charity? If yes, how well were your requirements met? *I have no experience with charity.*
5. What do you think about the project? *I have confidence in the construction team.*
6. Do you expect resistance against the project? *I do not expect resistance towards the project.*
7. Do you want to learn more about water and how to treat it? *I am very interested in learning more about water and sanitation.*

### O.5.1.2 Evaluation interview on 21st of September

#### Requirements

1. What kind of support do you need the most? *A sanitation project would be a good project after this project, it is most important.*
2. Rank the following fields of support: work, food, medical, education, money, water and sanitation. *1. work, 2. education, 3. water and sanitation, 4. medical and money, 5. food*

3. Do you have problems regarding water or sanitation in your life and if so, what are these problems? *It is a problem when the water runs out. When the water level in the river goes up, the toilet can get flooded and then the area will be contaminated.*
4. What would you require to improve this situation? *A septic tank would be a solution.*
5. Did you ever think about a water tank? *Yes, I thought about buying a plastic tank in 2019.*
6. What do you think of the size?
7. What do you think of the tap? *Perfect (even though a bucket needs to be tilted in order to get filled up with water).*
8. Did your opinion on the location change after usage? *Still good.*
9. What do you think of the aesthetics of the tank? *No answer.*
10. What do you think of the maintenance of the tank? *I understand what the maintenance includes and I think I will replace the old part of my roof because at the moment it is oxidized.*
11. Are there any requirements on the tank that are not fulfilled?

#### **Water**

1. Do you already use the water? *Not yet.*
2. Where are you using the water in the tank for? N/A
3. What do you think of the taste of the water? N/A
4. Do you still use the water from your other water source? yes for which purposes? N/A
5. Do you treat the water from the tank before you use it? *We do not know yet, it depends if it is necessary.*
6. How do you use the time you would normally go to the river? N/A
7. Do other people, besides your household, use the water from this tank? *Not yet, but church-goers who need water can use it.*
8. Who gets the water from the tank? N/A
9. How did you cleaned the tank? N/A
10. Do you see maintenance as a burden? No answer.
11. Which part of the tank is most vulnerable in your opinion? No answer.
12. Which part of the tank needs most maintenance in your opinion? No answer.

### O.5.1.3 Final interview during usage

#### Water

1. Did you already use the water from your tank? *Yes.*
2. Where are you using the water from the tank for? *To take a shower, to cook, to do the dishes and the laundry.*
3. What do you think of the taste of the water? *The water tastes bitter.*
  - (a) Did you notice any changes in taste or quality of the water of the tank? *A white layer appears on top of the water after boiling. In food we do not taste the bitterness.*
4. Do you still use the water from the other sources? *Yes.*
  - (a) And if yes, what for? *We still use the river (for laundry and bathing) and the spring (as drinking water source).*
5. How do you use the time that it would normally take for you to get water from the river? *The cooking goes quicker because the water is nearer but I do not do things differently now.*
6. Do you treat the water before you use it? *I use the water from the tank for cooking and for making coffee, so that it is cooked. Otherwise I do not treat the water.*
7. Do other people besides your household use the water from this tank? *Churchgoers use it for drinking.*
8. Have there been any problems so far with the system? *No, no problems with the system. But we had no rain for 1,5 weeks so I am afraid the water will run out.*

## O.5.2 Casildo Chami jr. and Encida Zarco

### O.5.2.1 General interview on 19th of August

#### General information



Name:	Encida Zarco
Profession:	Working at the cacao farm
Age:	41 years old
Lives with:	Husband, daughter, husband of daughter and their 3 children
Education:	Did not go to school, children attend El Progreso primary school
Part of El Progreso :	30 years
Special Resources for project:	-
Responsibilities in household:	Cooking, grabbing fruits from garden

#### Water

1. What is the main source (/what are the main sources) of water for this household? If you use different sources, where do you use the different sources for? (Drink; Wash/prepare food; Cook food; Bathe; Hand wash; Brush teeth; Clean house; Wash dishes; Wash clothes) *Our main water source is the gravitational system. When this does not work, I use the rain barrel for drinking and the small stream for everything else.*
2. Do these sources change throughout the year? No answer.
3. How close is the source to the household? No answer.
4. Do you treat water from your source? If yes, how? (Filter, boil, through shirt) *I boil every source of water before I drink it.*
5. How much water do you use per day? *I use 5 buckets, 94.6 liters, of water for the whole household every day.*
6. Do you think the water is safe? If not, why? Do people get sick because of the water? *I think the water is very safe, no one ever gets sick from the water.*
7. What role does water have in your community? (Spiritual, Religious, something else, not extra than anything else) *No answer.*
8. Which of the following is close to your water source? (Farm, pesticides, upstream village, garbage, latrines) *I worry about dead animals ending up in the river and that this will pollute the water.*

#### Tank

1. How did you choose the location of the tank? (And who chose it? Man/woman) *I chose the location for the tank because we are building a house next door so maybe I can connect the new house.*

2. What is your interest in this tank? *I want to use the tank so I can connect the tap to the tank.*
3. What is your opinion about the following aspects of the tank? (Size tank; size manhole; shape; tap; collection system and roof material; maintenance) No answer.
4. Where are you going to use the water from the tank for? Does this need extra requirements? No answer.
5. Do you think you will use more water once you have the tank? *I will use more water once I have the tank, because when the tap is not working I can always use the tank.*
6. What do you think of the fact that you got the third tank? (After the school and the church and so it will be the first private tank)No answer.

### Requirements

1. Is there anything you want to learn from the building of the tanks? No answer.
2. What do you expect of the design and construction of the tank? No answer.
3. What do you think the tank will last? *I think the tank will last a long time.*
4. Do you have experience with charity? If yes, how well were your requirements met? No answer.
5. What do you think about the project? *I am very happy in thankful for this project and this tank, because now I do not have to carry water from the stream when the tap is not working.*
6. Do you expect resistance against the project? No answer.
7. Do you want to learn more about water and how to treat it? No answer.

### O.5.2.2 Evaluation interview on the 23rd of September

#### Requirements

1. What kind of support do you need the most? *We miss a toilet (most important) and sanitation services. And also light.*
2. Rank the following fields of support: work, food, medical, education, money, water and sanitation. *1. money, 2. medical and everything else we already have. Question not really answered.*
3. Do you have problems regarding water or sanitation in your life and if so, what are these problems? *Yes there is a problem, we only have one toilet, want another one for visitors.*
4. What would you require to improve this situation? *Another toilet.*
5. Did you ever think about a water tank? *No, because we have the gravitational system and only use buckets (not really large containers because that is too expensive) in times when the gravitational system is not working. It is good to have some storage.*
6. What do you think of the size? *Good, we have water available every day.*
7. What do you think of the tap? *Good as it is.*
8. Did your opinion on the location change after usage? No answer.



9. What do you think of the aesthetics of the tank? *Beautiful design, it looks good. It is important that it looks good.*
10. What do you think of the maintenance of the tank? *No problem.*
11. Are there any requirements on the tank that are not fulfilled? *At the moment, the bad part of the roof is attached to the gutter system, which is bad.*

#### **Water**

1. Do you already use the water? *No, because we have not checked the water level yet.*
2. Where are you using the water in the tank for? *We will use it for drinking and cooking. The gravitational system we will use for showers and washing.*
3. What do you think of the taste of the water? *N/A*
4. Do you still use the water from your other water source? *yes for which purposes? N/A*
5. Do you treat the water from the tank before you use it? *N/A*
6. How do you use the time you would normally go to the river? *N/A*
7. Do other people, besides your household, use the water from this tank? *N/A*
8. Who gets the water from the tank? *Everyone can get the water from the tank.*
9. How did you cleaned the tank? *N/A*
10. Do you see maintenance as a burden? *N/A*
11. Which part of the tank is most vulnerable in your opinion? *Everything is fine, it is well constructed. Maybe the manhole cover will break.*
12. Which part of the tank needs most maintenance in your opinion? *N/A*

We do not see a reason why the other part of the village deserves a water tank more than we do.

#### **O.5.2.3 Final interview during usage on October 11th**

#### **Water**

1. Did you already use the water from your tank? *Yes.*
2. Where are you using the water from the tank for? *For cooking and drinking. When I cook the water, white things appear on top of the water.*
3. What do you think of the taste of the water? *It tastes like cement, like old water.*
  - (a) Did you notice any changes in taste or quality of the water of the tank? *No, no changes.*
4. Do you still use the water from the other sources? *Yes.*
  - (a) And if yes, what for? *we use the river for bathing and doing the laundry.*
5. How do you use the time that it would normally take for you to get water from the river? *Everything involving getting water goes quicker. But I am not now playing piano or anything.*
6. Do you treat the water before you use it? *Yes, for the children we cook the water. The adults drink it directly.*
7. Do other people besides your household use the water from this tank? *No one other than us.*
8. Have there been any problems so far with the system? *No, everything is good.*

### O.5.3 Julio Zarco and Griselda Chajito

#### O.5.3.1 General interview on 25th of August

##### General information



Name:	Julio Zarco
Profession:	Cleaning agricultural fields, works for a hotel cleaning the beach
Age:	Unknown
Lives with:	Wife, 7 daughters and 3 sons
Education:	Went to school until 16th birthday in Darien
Part of El Progreso :	From age of 16th onwards
Special Resources for project:	Wants to help building the tank
Responsibilities in household:	Providing food for family (hunting, fishing, gathering)

##### Water

1. What is the main source (/what are the main sources) of water for this household? If you use different sources, where do you use the different sources for? (Drink; Wash/prepare food; Cook food; Bathe; Hand wash; Brush teeth; Clean house; Wash dishes; Wash clothes) *I use the water from the river (Rio Culebra) for everything.*
2. Do these sources change throughout the year? *When the river is dirty we use water from the rain barrel.*
3. How close is the source to the household? *200 meter walking distance.*
4. Do you treat water from your source? If yes, how? (Filter, boil, through shirt) *I boil the water for my children, for adults the water is not boiled.*
5. How much water do you use per day? *I use 2 buckets, 37.9 liters, for everything.*
6. Do you think the water is safe? If not, why? Do people get sick because of the water? *I have strong health, but sometimes we get sick from the water in the river (nausea, vomiting).*
7. What role does water have in your community? (Spiritual, Religious, something else, not extra than anything else) *Not anything special.*
8. Which of the following is close to your water source? (Farm, pesticides, upstream village, garbage, latrines) *Farms and pesticides.*

##### Tank

1. How did you choose the location of the tank? (And who chose it? Man/woman) *Together with my wife we decided to have the tank located near the kitchen, that will be built later.*
2. What is your interest in this tank? *No answer.*

3. What is your opinion about the following aspects of the tank? (Size tank; size manhole; shape; tap; collection system and roof material; maintenance) *The size and shape of the tank are good (for now), have to see later if it is not good. Our roof is made out of zinc.*
4. Where are you going to use the water from the tank for? Does this need extra requirements? *We are going to use the water for the tank for drinking and cooking. We will keep doing our laundry in the river.*
5. Do you think you will use more water once you have the tank? *Yes, because it is closer to the house.*
6. What do you think of the fact that you got (rank number) tank? So before, after ....?

#### **Searching info**

#### **Requirements**

1. Is there anything you want to learn from the building of the tanks? No answer.
2. What do you expect of the design and construction of the tank? No answer.
3. What do you think the tank will last? *No clue.*
4. Do you have experience with charity? If yes, how well were your requirements met? No answer.
5. What do you think about the project? *Good. I have been fighting with authorities/government for a better water system for a long time. It is a miracle from god that you are here. It is important to have a safe water system.*
6. Do you expect resistance against the project? No answer.
7. Do you want to learn more about water and how to treat it? No answer.

#### **Extra added questions**

1. What kind of food do you eat during breakfast/lunch/dinner? *Yucca, plantain, rice, eggs, fish, beans, peas and meat.*
2. Where do you take a shower and how do you go to the toilet? *We bathe in the river and dig a hole in the ground (not close to the river) as a toilet.*

#### **O.5.3.2 Evaluation interview on the 22nd of September**

##### **Requirement**

1. What kind of support do you need the most? *Light (electricity)*
2. Rank the following fields of support: work, food, medical, education, money, water and sanitation. *1. Education, 2. Medical, 3. Work, 4. Food, 5. Money, 6. Water (because they now already have water).*
3. Do you have problems regarding water or sanitation in your life and if so, what are these problems? *Yes there is a problem, we do not have a toilet. Very bad for health reasons.*
4. What would you require to improve this situation? *Toilet + septic tank.*
5. Did you ever think about a water tank? *No, but we were planning on getting a pump to get the water from the river. He will not buy the pump anymore because he thinks the tank is enough.*

6. What do you think of the size? *Good, we do not worry about the 26 days because it never happens.*
7. What do you think of the tap? *It fits, its okay. From experience that the screwing will break.*
8. Did your opinion on the location change after usage? *It is good. We want to connect the tank to the kitchen.*
9. What do you think of the aesthetics of the tank? *Pretty and important that it is beautiful. But with paint it is even more beautiful, so we will paint it.*
10. What do you think of the maintenance of the tank? *I didn't know, but I will do it when it is necessary.*
11. Are there any requirements on the tank that are not fulfilled? *Connect tank to kitchen.*

### **Water**

- 1.
2. Do you already use the water? *Yes. Very happy that the children didn't have to go to the polluted river today.*
3. Where are you using the water in the tank for? *Drinking and cooking.*
4. What do you think of the taste of the water? *Fine.*
5. Do you still use the water from your other water source? *yes for which purposes? For bathing, washing.*
6. Do you treat the water from the tank before you use it? *Boil for small children.*
7. How do you use the time you would normally go to the river? *Tasks around the house. Cooking is so much easier and faster now.*
8. Do other people, besides your household, use the water from this tank? *Family.*
9. Who gets the water from the tank? *Not the small children, only adults and big children. They will break tap and spill a lot of water.*
10. How did you clean the tank? *Yes.*
11. Do you see maintenance as a burden? *No, easy.*
12. Which part of the tank is most vulnerable in your opinion? *Tap.*
13. Which part of the tank needs most maintenance in your opinion? *Gutters.*

## O.5.4 Mateo and Dania Abrego

### O.5.4.1 General interview on 27th of August

#### General information



Name:	Mateo Abrega; Dania Abrega
Profession:	Working with machete; taking care of household
Age:	23 years old; 19 years old
Lives with:	Together with 3 children
Education:	In Chiriqui; children are too young
Part of El Progreso :	three months
Special Resources for project:	Unknown
Responsibilities in household:	Unknown

#### Water

1. What is the main source (/what are the main sources) of water for this household? If you use different sources, where do you use the different sources for? (Drink; Wash/prepare food; Cook; Bathe; Brush Clean; Brush teeth; Dishes; Laundry) *Rio Culebra for drinking water and cooking. The small stream close to the house is used for everything else.*
2. Do these sources change throughout the year? *When it rains, we use rain water, otherwise the river. We prefer rain water.*
3. How close is the source to the household? *Rio Culebra 100 meters, small stream 15 meters.*
4. Do you treat water from your source? If yes, how? (Filter, boil, through shirt) *No.*
5. How much water do you use per day? *We use 1 bucket, 18.9 liters, per day.*
6. Do you think the water is safe? If not, why? Do people get sick because of the water? *Sometimes it makes us sick.*
7. What role does water have in your community? (Spiritual, Religious, something else, not extra than anything else) *We are from Bocas del Torro (The question is not really understood).*
8. Which of the following is close to your water source? (Farm, pesticides, upstream village, garbage, latrines) *When it is not raining people get sick from horse shit and animals. When the water does not look good, we do not use it.*

#### Tank

1. How did you choose the location of the tank? (And who chose it? Man/woman) *We want to have the tank in front of the house near the kitchen, therefore more convenient.*
2. What is your interest in this tank? *We want to use the water for drinking and cooking*
3. What is your opinion about the following aspects of the tank?

- Size tank; *Good*
  - size manhole; -
  - shape; *Good*
  - tap; -
  - collection system and roof material; -
  - maintenance; -
4. Where are you going to use the water from the tank for? Does this need extra requirements?  
*We want to use the water for drinking and cooking*
  5. Do you think you will use more water once you have the tank? -
  6. What do you think of the fact that you got the fifth tank? So before, after ....? -

### **Requirements**

1. Is there anything you want to learn from the building of the tanks? *Not really.*
2. What do you expect of the design and construction of the tank? -
3. What do you think the tank will last? *A long time.*
4. Do you have experience with charity? If yes, how well were your requirements met? -
5. What do you think about the project? *We really like it*
6. Do you expect resistance against the project? -
7. Do you want to learn more about water and how to treat it? -

### **Extra added questions**

1. What kind of sanitation services do you have to your disposal? *We shower in the river and we don't have a toilet so we just go wherever.*
2. Do you like living in this community *Yes, because of the church everybody treats us as family.*

### **O.5.4.2 Evaluation interview on 21st of September**

#### **Requirements**

1. What kind of support do you need the most? -
2. Rank the following fields of support: 1. Work, 2. Money, 3. Food, 4. Education, 5. Medical, 6. Water and sanitation
3. Do you have problems regarding water or sanitation in your life and if so, what are these problems? *We don't have a toilet, that bad. We want one. Now it is dangerous because of animals and health.*
4. What would you require to improve this situation? *A toilet.*
5. Did you ever think about a water tank? *Yes we thought about it, but we didn't have any money.*
6. What do you think of the size? *Perfect.*

7. What do you think of the tap? *Good.*
8. Did your opinion on the location change after usage? *No.*
9. What do you think of the aesthetics of the tank? *No answer.*
10. What do you think of the maintenance of the tank? *No answer.*
11. Are there any requirements on the tank that are not fulfilled? *No answer.*

### **Water**

1. Do you already use the water? *Yes*
2. Where are you using the water in the tank for? *For drinking and cooking.*
3. What do you think of the taste of the water? *It tastes differently than river, better.*
4. Do you still use the water from your other water source? yes for which purposes? *For bathing, laundry.*
5. Do you treat the water from the tank before you use it? *We boil water for the kids, not for us.*
6. How do you use the time you would normally go to the river? *Reading the bible and reading the dictionary.*
7. Do other people, besides your household, use the water from this tank? *When I can I will share it with other people.*
8. Who gets the water from the tank? *Only adults can get the water.*
9. How did you cleaned the tank? *With water, very easy.*
10. Do you see maintenance as a burden? *No.*
11. Which part of the tank is most vulnerable in your opinion? *Tap.*
12. Which part of the tank needs most maintenance in your opinion? *Gutters.*

## O.5.5 Lazaro and Exilda Chami

### O.5.5.1 General interview on 31st of August

#### General information



Name:	Batista (Lazaro) and Exilda Chami
Profession:	Agriculture (plantains, corn, bananas) and preparing cattle field lands for use; Household tasks, taking care of children, helping Lazaro in the jungle
Age:	37 years; Unknown
Lives with:	Together with 3 sons and 3 daughters
Education:	Both went to school, 4 children are in school (others too young)
Part of El Progreso :	37 years; 23 years
Special Resources for project:	Experience in construction; none
Responsibilities in household:	Providing food; household tasks, taking care of children

#### Water

1. What is the main source (/what are the main sources) of water for this household? If you use different sources, where do you use the different sources for? (Drink; Wash/prepare food; Cook food; Bathe; Hand wash; Brush teeth; Clean house; Wash dishes; Wash clothes) *We use the water from Rio Culebra for everything.*
2. Who is getting the water? *Everyone gets water equally in the family.*
3. Do you combine getting water with other activities? (e.g. bathing, doing dishes, etc.) If yes, do you think this will change when the tank is built? *Every morning we go to the river just to get water and do nothing else but getting water. So either getting water or do other activities, not both.*
4. Do these sources change throughout the year? *When it is raining and the river is dirty we drink rain water. During the dry season the river does not get flushed a lot. Especially in March and February there is almost no rainfall.*
5. How close is the source to the household? *100 meter walking distance.*
6. Do you treat water from your source? If yes, how? (Filter, boil, through shirt) *We do not treat the water. But when the water is dirty, Exilda filters the water through her shirt.*
7. How much water do you use per day? *We use 1 bucket, 18.9 liters, of water per day.*
8. What do you think of the quality of the water? *When there is no flow in the river we get diarrhoea (especially the children). There are periods when we get sick a lot and then there are periods that we are not sick for a long time.*
9. What role does water have in your community? (Spiritual, Religious, something else, not extra than anything else) *Water is alive. But mainly it is a necessity.*



10. Which of the following is close to your water source? (Farm, pesticides, upstream village, garbage, latrines) *A lot of pesticides, cow shit, horse shit.*

### **Tank**

1. How did you choose the location of the tank? (And who chose it? Man/woman) *We made the decision together. The tank will be located near the kitchen.*
2. What is your interest in this tank? *We always have to get water from the river.*
3. What is your opinion about the following aspects of the tank? (Size tank; size manhole; shape; tap; collection system and roof material; maintenance) *Big enough. We have never seen such a big one. The material of the roof is painted zinc.*
4. Where are you going to use the water from the tank for? Does this need extra requirements? *Cooking and drinking. Washing will still be done in the river.*
5. Do you think your water use will change once you have the tank? *We will probably use more water, but mainly for drinking and if we want to wash our clothes more firmly too.*
6. What do you think of the fact that you got second tank? (So after the school and before every other household) *The decision is made by you and that is good.*

### **Requirements**

1. Is there anything you want to learn from the building of the tanks? *I want to know more details of the tank and also learn from the construction work.*
2. What do you expect of the design and construction of the tank? No answer.
3. What do you think the tank will last? *A lot of years.*
4. Do you have experience with charity? If yes, how well were your requirements met? No answer.
5. What do you think about the project? *I am amazed by the work and very grateful.*
6. Do you expect resistance against the project? No answer.
7. Do you want to learn more about water and how to treat it? *Yes, we would like to learn more about clean water and how to maintain the tank.*

### **O.5.5.2 Evaluation interview on 22nd of September**

#### **Requirement**

1. What kind of support do you need the most? *The church, important for the children to be raised within a well managed environment.*
2. Rank the following fields of support. Ranking:
  - (a) Medical
  - (b) Education
  - (c) Money
  - (d) Food
  - (e) Work

(f) Water and sanitation

3. Do you have problems regarding water or sanitation in your life and if so, what are these problems? *We don't have a water problem any longer (due to our project) therefor this comes last. But sanitation still is a problem, they want their privacy.*
4. What would you require to improve this situation? *A private toilet.*
5. Did you ever think about a water tank? *No, but we really like it.*
6. What do you think of the size? *Big enough to overcome dry period.*
7. What do you think of the tap? *Good, well protected.*
8. Did your opinion on the location change after usage? *No.*
9. What do you think of the aesthetics of the tank? *Looks good.*
10. What do you think of the maintenance of the tank? *Necessary to clean the roof often.*
11. Are there any requirements on the tank that are not fulfilled? *No, it is good as it is.*

**Water**

1. Do you already use the water? *No, because it was not full yet. My daughter checked today and told that we can now use it.*
2. Where are you using the water in the tank for? *For drinking and cooking.*
3. What do you think of the taste of the water? *N/A*
4. Do you still use the water from your other water source? yes for which purposes? *For bathing, laundry.*
5. Do you treat the water from the tank before you use it? *N/A*
6. How do you use the time you would normally go to the river? *N/A*
7. Do other people, besides your household, use the water from this tank? *N/A*
8. Who gets the water from the tank? *Only adults and big children can get the water.*
9. How did you cleaned the tank? *With water, very easy.*
10. Do you see maintenance as a burden? *No.*
11. Which part of the tank is most vulnerable in your opinion? *Tap.*
12. Which part of the tank needs most maintenance in your opinion? *Roof.*

## O.5.6 Demetrio Abrego and Sixta Chami

### O.5.6.1 General interview on 3rd of September

#### General information



Name:	Demetrio Abrego and Sixta Chami
Profession:	Machete cutting of agricultural fields ; around the house, fruit and vegetable garden
Age:	Unknown
Lives with:	Together with 2 children (16 and 13), 3 children live elsewhere and visit (20, 23, 24)
Education:	Did not go to school ; School in Santa Isabel
Part of El Progreso :	15; 42 years
Special Resources for project:	Experience in construction; none
Responsibilities in household:	Providing food; household tasks, taking care of children

#### Water

1. What is the main source (/what are the main sources) of water for this household? If you use different sources, where do you use the different sources for? (Drink; Wash/prepare food; Cook food; Bathe; Hand wash; Brush teeth; Clean house; Wash dishes; Wash clothes) *We use the water from Rio Culebra for everything.*
2. Who is getting the water? *Only Demetrio and the kids, too heavy for Sixta.*
3. Do you combine getting water with other activities? (e.g. bathing, doing dishes, etc.) If yes, do you think this will change when the tank is built? *First trip water, next trip the rest. So not combining.*
4. Do these sources change throughout the year? *with rainfall and dirty river, we collect the rainwater. We put a tank under the roof (several buckets).*
5. How close is the source to the household? *100 meter walking distance.*
6. Do you treat water from your source? If yes, how? (Filter, boil, through shirt) *We do not treat the water, sometimes they know that the water is unsafe but they drink it anyway because they do not have a choice.*
7. How much water do you use per day? *We use 1 bucket, 18.9 liters, of water per day.*
8. What do you think of the quality of the water? *Summer, not much rain and not that much flow in the river, kids get sick first, sometimes adults too (diarrhoea vomiting). But we keep drinking it, because there is no other water.*
9. What role does water have in your community? (Spiritual, Religious, something else, not extra than anything else) *Not really, god provides everything, also the water.*

10. Which of the following is close to your water source? (Farm, pesticides, upstream village, garbage, latrines) *A lot of fumigation, animals and cow shit.*
11. Where will you use the water from the tank for? *For drinking and for cooking.*

### **Tank**

1. How did you choose the location of the tank? (And who chose it? Man/woman) *Overland flow of water to the house. When it is raining, the water that flows over land is flushing on this side faster, that is the reason why we wanted to build a foundation (also because it looks nicer)*
2. What is your interest in this tank? *We always have to get water from the river.*
3. What is your opinion about the following aspects of the tank? (Size tank; size manhole; shape; tap; collection system and roof material; maintenance) *Big enough (We have never seen such a big one). The material of the roof is zinc (not painted)*
4. Where are you going to use the water from the tank for? Does this need extra requirements? *Cooking and drinking. But also when I (Demetrio) need to go to work very early, I can clean myself from this water.*
5. Do you think your water use will change once you have the tank? *Use more water. When the river is dirty, washing clothes and cleaning also with water from the tank.*
6. What do you think of the fact that you got 6th tank? And that no everyone get a tank? *We trust your decision, not questioning people who are helping, they are very grateful.*

### **Requirements**

1. Is there anything you want to learn from the building of the tanks? *I want to know more details of the tank and also learn from the construction work. We think we have now enough experience to build more tanks.*
2. What do you expect of the design and construction of the tank? *Size is good. Roof material is zinc.*
3. What do you think the tank will last? *No idea.*
4. Do you have experience with charity? If yes, how well were your requirements met? *Not asked.*
5. What do you think about the project? *very grateful.*
6. Do you expect resistance against the project? *People from far away helping and other communities find it a great project. Palmira likes the project, they are very jealous but they don't understand that not everyone can get a tank.*
7. Do you want to learn more about water and how to treat it? *Yes, we would love to know more.*

### O.5.6.2 Evaluation interview on the 23rd of September

#### Requirement

1. What kind of support do you need the most? *Electricity.*
2. Rank the following fields of support: work, food, medical, education, money, water and sanitation. 1. water and sanitation, 2. education, 3. food, 4. work, 5. money, 6. medical.
3. Do you have problems regarding water or sanitation in your life and if so, what are these problems? *We do not have a toilet and it is important to have because when visitors come, they cannot go to the toilet.*
4. What would you require to improve this situation? *With help we could make a nice toilet so that it will not contaminate the water of the river.*
5. Did you ever think about a water tank? *Yes, I thought about it but there is not enough money.*
6. What do you think of the size? *Perfect.*
7. What do you think of the tap? *Perfect at the moment, might break over time.*
8. Did your opinion on the location change after usage? *No, still good.*
9. What do you think of the aesthetics of the tank? *Very beautiful and it is important how it looks.*
10. What do you think of the maintenance of the tank? *We are not worried about the maintenance.*
11. Are there any requirements on the tank that are not fulfilled? *In the future when the gravitational system will be connected to this part of the village, we want to connect the water from that system to the tank so we can store water in the tank.*

#### Water

1. Do you already use the water? *Not yet.*
2. Where are you using the water in the tank for? N/A
3. What do you think of the taste of the water? N/A
4. Do you still use the water from your other water source? yes for which purposes? N/A
5. Do you treat the water from the tank before you use it? N/A
6. How do you use the time you would normally go to the river? N/A
7. Do other people, besides your household, use the water from this tank? N/A
8. Who gets the water from the tank? N/A
9. How did you cleaned the tank? N/A
10. Do you see maintenance as a burden? *It is our turn to do the heavy work, so no.*
11. Which part of the tank is most vulnerable in your opinion? *The gutters (sun, deterioration).*
12. Which part of the tank needs most maintenance in your opinion? *Everything.*

## O.5.7 Casildo Chami sr. and Elena Zarco

### O.5.7.1 General interview on 7th of September

#### General information



Name:	Casildo Chami sr. and Elena Zarco
Profession:	Retired and working on own land, household tasks
Age:	89 years old; 86 years old
Live with:	Each other
Education:	Unknown
Part of El Progreso :	Unknown, have founded the part of the village they are living in
Special Resources for project:	Unknown
Responsibilities in household:	Everything around the house and on the land (corn, rice)

#### Water

1. What is the main source (/what are the main sources) of water for this household? If you use different sources, where do you use the different sources for? (Drink; Wash/prepare food; Cook food; Bathe; Hand wash; Brush teeth; Clean house; Wash dishes; Wash clothes) *We use the river water (Rio Culebra) for everything.*
2. Who is getting the water? *I (Casildo) get the water.*
3. Do you combine getting water with other activities? (e.g. bathing, doing dishes, etc.) If yes, do you think this will change when the tank is built? *Sometimes we combine getting drinking water with other water related activities.*
4. Do these sources change throughout the year? *We use water from the river all year round. We harvest rainwater for cooking and drinking in wintertime, but in summertime it is dry so we use the river.*
5. How close is the source to the household? *The river is 30 meters walking distance*
6. Do you treat water from your source? If yes, how? (Filter, boil, through shirt) *We do not treat the water.*
7. How much water do you use per day? *We use 3 buckets, 56.8 liters, per day.*
8. Do you think the water is safe? If not, why? Do people get sick because of the water? *I (Elena) do not think the water is safe, because of dead animals upstream. People kill animals and throw them in the water. Cattle also pollutes the water.*
9. What role does water have in your community? (Spiritual, Religious, something else, not extra than anything else) *Water is important for drinking.*
10. Which of the following is close to your water source? (Farm, pesticides, upstream village, garbage, latrines) *There is a lot of agriculture close to the water source.*

11. Where do you shower? *In the river.*
12. Where do you go to the toilet? *We have a latrine with a septic tank in our garden.*

### **Tank**

1. How did you choose the location of the tank? (And who chose it? Man/woman) *I (Elena) chose the location, this location is close to the entrance and the location Casildo proposed to me was on the way for a lot of people to the river.*
2. What is your interest in this tank? *No answer.*
3. What is your opinion about the following aspects of the tank? (Size tank; size manhole; shape; tap; collection system and roof material; maintenance) *The size is very nice and good. Thank god for this project. Our roof is made out of zinc.*
4. Where are you going to use the water from the tank for? Does this need extra requirements? *We are going to use the water for drinking and cooking. We will not use the water from the river anymore for drinking, only for washing clothes and washing.*
5. Do you think your water use will change once you have the tank? *We will use the same.*
6. A What do you think of the fact that you got (rank number) tank? So before, after ....? *We understand the decision.*

### **Requirements**

1. Is there anything you want to learn from the building of the tanks? *No answer*
2. What do you expect of the design and construction of the tank? *No answer*
3. What do you think the tank will last? *No idea*
4. Do you have experience with charity? If yes, how well were your requirements met? *No answer*
5. What do you think about the project? *No answer*
6. Do you expect resistance against the project? *No, but Palmira (village nearby) is jealous.*
7. Do you want to learn more about water and how to treat it? *We would like to know.*

Do they like the fact that everybody helps each other? *They really think it is great to work together and that they will help in the future each other.*

### **O.5.7.2 Evaluation interview 24th of September**

#### **Requirement**

1. What kind of support do you need the most? *Toilets (/bathroom).*
2. Rank the following fields of support: work, money, food, education, medical, water and sanitation. *A toilet is most important, more important than education. There is not enough work and no money. I (Casildo) divided my land and gave it to my children so they could plant food.*

3. Do you have problems regarding water or sanitation in your life and if so, what are these problems? *Our current toilet is not good. The political party has been given false promises every time they come, which is just before elections. In the 40 years we have lived here we have not had any running water. We were attached to the old gravitational system for a short time but it did not work. They have promised me a beautiful bathroom with a ceramic toilet and everything.*
4. What would you require to improve this situation? *If we could afford it and if we would have a car to get it here we would have done it.*
5. Did you ever think about a water tank? No answer.
6. What do you think of the size? *Content.*
7. What do you think of the tap? *We have not seen it yet (it was not installed when this interview took place).*
8. Did your opinion on the location change after usage? *It is not possible to put it closer to the kitchen (because of the road).*
9. What do you think of the aesthetics of the tank? *Casildo: It looks very nice and it is important for your health. Elena: it looks all good.*
10. What do you think of the maintenance of the tank? *Our children will help us. We want it to be well maintained.*
11. Are there any requirements on the tank that are not fulfilled? *No.*

#### **Water**

1. Do you already use the water? No.
2. Where are you using the water in the tank for? N/A
3. What do you think of the taste of the water? N/A
4. Do you still use the water from your other water source? N/A
5. Do you treat the water from the tank before you use it? N/A
6. How do you use the time you would normally go to the river? N/A
7. Do other people, besides your household, use the water from this tank? N/A
8. Who gets the water from the tank? N/A
9. How did you cleaned the tank? N/A
10. Do you see maintenance as a burden? No answer.
11. Which part of the tank is most vulnerable in your opinion? *I (Elena) do not know, it will take some time before something breaks.*
12. Which part of the tank needs most maintenance in your opinion? *Gutters.*



## O.5.8 Israel Zarco and Marcia Cardena Cabrera

### O.5.8.1 General interview on 9th of September

#### General information



Name:	Israel Zarco and Marcia Cardena Cabrera
Profession:	Farming coffee, fumigation; artisan, household tasks, selling pastry
Age:	44 years old; 51 years old
Lives with:	Each other and son and his wife
Education:	Until 6th grade; No education; children until high school
Part of El Progreso :	44 years; 20 year
Special Resources for project:	Experience in construction (built own house)
Responsibilities in household:	Farming, providing food; cooking, grabbing fruits from garden

#### Water

1. What is the main source (/what are the main sources) of water for this household? If you use different sources, where do you use the different sources for? (Drink; Wash/prepare food; Cook food; Bathe; Hand wash; Brush teeth; Clean house; Wash dishes; Wash clothes) *Our main water source is the river (Rio Culebra), we use this water for drinking, cooking, doing laundry and washing the dishes.*
2. Who is getting the water? When I (Israel) am at home, I get the water. Otherwise, Marcia is getting the water.
3. Do you combine getting water with other activities? (e.g. bathing, doing dishes, etc.) If yes, do you think this will change when the tank is built? *We combine things with getting the water sometimes.*
4. Do these sources change throughout the year? *We do not have a large rain barrel to capture the rainwater so even in the wet season we have to go to the river. We capture too little water to be enough for drinking. I (Marcia) think that when we have a bigger tank we will use more water. In summer the water is dirty.*
5. How close is the source to the household? *50 meters*
6. Do you treat water from your source? If yes, how? (Filter, boil, through shirt) *No, we drink it raw.*
7. How much water do you use per day? *We use 6 buckets, 113.6 liters, of water every day.*
8. Do you think the water is safe? If not, why? Do people get sick because of the water? *In summertime we often have stomach ache due to cow shit and snakes. One time, the whole village got sick.*
9. What role does water have in your community? (Spiritual, Religious, something else, not extra than anything else) *No.*

10. Which of the following is close to your water source? (Farm, pesticides, upstream village, garbage, latrines) *Farms, fumigation, other people upstream, animals. Next to our house there is a farm with pesticides an it flows in the river.*
11. Where do you shower and go to the toilet? *We bathe in the river and do not have a toilet. In the rainy season, the finca can get flooded so it is not suitable to have a toilet here. But we do need a toilet here. A septic tank would be useful but it is too expensive.*
12. Have people their lives in El Progreso changed over the last two generations? *Life before was difficult because there was only one road, otherwise you had to go by boat or horse. This village used to be a jungle but we cut it down because there were not many jobs and now we have better opportunities.*
13. Did the role of women and men change over time? *The role did not change but the tradition changed. We do not perform any traditional Embera practices anymore (painting, topless, other haircut).*
14. What happened over time with regards to cultural heritage, religion and diseases? *My father Casildo had traditional hunting gear (blow gun and spear with snake or frog poison) and he built traditional boats. Regarding diseases, we had a good diet and ate well but there are so many sources where you can get sick from. When sugar was introduced a lot of people got diabetes, now we have learned to eat less of that.*
15. Was there a noticeable change regarding water availability, rainfall and water pollution? (summer/winter, over generations) *Years ago there was much more rain during the rainy season, now the rainy season is getting more dry.*

### **Tank**

1. How did you choose the location of the tank? (And who chose it? Man/woman) *We are planning to have a bigger family and a bigger house so the location is chosen in such a way we can use it then as well.*
2. What is your interest in this tank? *We really need a tank. We were waiting for the government to give a system (they had promised). We do not have the resources to build one ourselves.*
3. What is your opinion about the following aspects of the tank? (Size tank; size manhole; shape; tap; collection system and roof material; maintenance) *Excellent size, it is perfect. The gutters are a brilliant idea, it is great how engineering can do these things. If we would have gotten a bigger tank we could also shower with the water but for now this is a good storage for water for drinking and cooking. Our roof is made out of painted zinc.*
4. Where are you going to use the water from the tank for? Does this need extra requirements? *We are going to use the water from the tank for drinking and cooking. I (Marcia) do not want to abuse it for other purposes.*
5. Do you think your water use will change once you have the tank? *We will use less water because we want to cherish it just for drinking.*
6. What do you think of the fact that you got the 9th tank? *I (Israel) was worried that we would not get a tank because I am away during the week for work and was not able to help during weekdays.*

## Requirements

1. Is there anything you want to learn from the building of the tanks? *I (Israel) want to know how you sized the tank (how the volume was calculated). I am very amazed about the design and the mould.*
2. What do you expect of the design and construction of the tank? No answer.
3. How long do you think the tank will last? *Forever, but everything that men create, will break down finally. If I (Israel) have to guess I would say 18-20 years.*
4. Do you have experience with charity? If yes, how well were your requirements met? No answer.
5. What do you think about the project? *We are very happy about the project and understands that it is a luxury to have safe water.*
6. Do you expect resistance against the project? *The majority of the village gets a tank so we think that in the future others will also be helped, so not really any resistance.*
7. Do you want to learn more about water and how to treat it? *Yes, especially if we can paint the tank (inside/outside) and if we can install filters or can clean it with chlorine.*

### O.5.8.2 Evaluation interview on the 23rd of September

#### Requirement

1. What kind of support do you need the most? *English classes in school and Embera language classes.*
2. Rank the following fields of support: work, food, medical, education, money, water and sanitation. *1. education, 2. work, 3. medical, 4. money, 5. water and sanitation, 6. food.*
3. Do you have problems regarding water or sanitation in your life and if so, what are these problems? *A water tank goes hand in hand with a flushing toilet.*
4. What would you require to improve this situation? *When the gravitational system is connected to this part of the village, we will connect this to the water tank for hygiene and health. Visitors can use it as well and there will be no smell or insects.*
5. Did you ever think about a water tank? No answer.
6. What do you think of the size? *Sufficient, it will be difficult in the dry months, which is a short period. We are only with the four of us living here so we think that we will be okay. Other families might not.*
7. What do you think of the tap? *Beautiful, if we take care of it, it will last a long time.*
8. Did your opinion on the location change after usage? *It is good.*
9. What do you think of the aesthetics of the tank? *It is attractive and that is also important.*
10. What do you think of the maintenance of the tank? *I (Israel) understand that maintenance is important and I will brush off the rust from the roof.*
11. Are there any requirements on the tank that are not fulfilled? *It is a good system, would not change anything on design.*

## Water

1. Do you already use the water? *Not yet, waiting for the first rain to clean it.*
2. Where are you using the water in the tank for? N/A
3. What do you think of the taste of the water? N/A
4. Do you still use the water from your other water source? yes for which purposes? N/A
5. Do you treat the water from the tank before you use it? N/A
6. How do you use the time you would normally go to the river? N/A
7. Do other people, besides your household, use the water from this tank? N/A
8. Who gets the water from the tank? N/A
9. How did you cleaned the tank? *We have not cleaned it yet.*
10. Do you see maintenance as a burden? No answer.
11. Which part of the tank is most vulnerable in your opinion? *I (Israel) think that a child might smash or break the turning part of the tap, so just in case I will fill all my buckets once in a while so we will not have to use the tap that often. We are thinking about getting a hose so we can connect it to something in the house.*
12. Which part of the tank needs most maintenance in your opinion? *Gutters and pipes because green stuff will be growing on it and also inside of the tank.*

## O.5.9 Casildo Berugate Zarco

### O.5.9.1 General interview on 23 September

#### General information



Name:	Casildo Berugate Zarco
Profession:	Works in mine (part-owner(?)), machete work in the jungle and cleaning fields
Age:	49 years old
Lives with:	Alone
Education:	In Darien, until third grade
Part of El Progreso :	30 years
Special Resources for project:	A little bit of experience in construction
Responsibilities in household:	Everything, since I am alone

#### Water

1. What is the main source (/what are the main sources) of water for this household? If you use different sources, where do you use the different sources for? (Drink; Wash/prepare food; Cook food; Bathe; Hand wash; Brush teeth; Clean house; Wash dishes; Wash clothes). *I use rainwater only for drinking and river water for everything else and if I run out of stored rainwater.*
2. Who is getting the water? *I am.*
3. Do you combine getting water with other activities? (e.g. bathing, doing dishes, etc.) If yes, do you think this will change when the tank is built? *No answer.*
4. Do these sources change throughout the year? *During the year it changes, I use water from different rivers. I tried to use rainwater for drinking.*
5. How close is the source to the household? *It depends. Rio Culebra is 200 meters walking distance.*
6. Do you treat water from your source? If yes, how? (Filter, boil, through shirt). *No.*
7. How much water do you use per day? *I use 1 bucket, 18.9 liters, of water per day. I drink 2 liters of water per day.*
8. What do you think of the quality of the water? *I do not have any choice so quality is not important. Now I am very happy with the tank. Sometimes I get sick (diarrhoea). I learned that you have to wait if you take water with sediment so it will settle.*
9. Which of the following is close to your water source? (Farm, pesticides, upstream village, garbage, latrines) *With farming upstream the water gets contaminated so I do not drink it when it has rained.*
10. Do you have a toilet? *No, I use the toilet/latrine of Casildo sr. and Elena.*

11. Do you have a shower? *No, I shower/bathe in the river.*

### **Tank**

1. How did you choose the location of the tank? *This location is the easiest to build on, because it is more flat.*
2. What is your interest in this tank? *No answer.*
3. What is your opinion about the following aspects of the tank? (Size tank; size manhole; shape; tap; collection system and roof material; maintenance) *The size is good. I have to find a woman and get children, then this size is needed. The gutters are good. The material of my roof is zinc.*
4. Where are you going to use the water from the tank for? Does this need extra requirements? *I am going to use the water for the pig and chicken.*
5. Do you think your water use will change once you have the tank? *I will use only a little bit*
6. What do you think of the fact that you got last tank? *That is good, I am only a one person household.*

### **Requirements**

- 1.
2. Is there anything you want to learn from the building of the tanks? *I want to see and learn.*
3. What do you expect of the design and construction of the tank? *The new mould is only for his tank, he likes it. I do not know about the quality and design.*
4. How long do you think the tank will last? *Until god stops it from working.*
5. Do you have experience with charity? If yes, how well were your requirements met? *Not asked.*
6. What do you think about the project? *I am content and for the quality of the water it is important.*
7. Do you expect resistance against the project? *Other people (from Palmira and Cuango, two villages nearby) are questioning why they do not get tanks because they are poor. He told them that they have the aqueduct. Usually the representative builds something in bigger cities, now it is our turn to receive help. In El Progreso no progress (bitter joke).*
8. Do you want to learn more about water and how to treat it? *Yes. God will pay us back with good health.*

## O.5.10 Ambrosio Pascual

### O.5.10.1 No-tank interview on 22nd of September

#### General information



Name:	Ambrosio Alfaro Solis Pascual
Profession:	Cleaning field, planting platanoyuca
Age:	82 years old
Lives with:	Alone (since 3 years) Every 3 months visit from family
Education:	Unknown
Part of El Progreso :	50 years
Special Resources for project:	-
Responsibilities in household:	Unknown

#### Water

1. What is the main source (/what are the main sources) of water for this household? If you use different sources, where do you use the different sources for? *Aqueduct. Two taps connected, in and outside the house. Also a shower and a toilet.*
2. Who is getting the water? *Both.*
3. Do you treat water from your source? If yes, how? *No. The filters of the gravitational are new, only need to be connected but the government people won't fix it.*
4. What do you think is the best water to drink? *Rio Negro.*
5. Do you think the water is safe? If not, why? Do people get sick because of the water? *Water is good, comes from the mountains.*
6. Where do you use the rainwater you are collecting for? *For cleaning my machete and doing dishes. I miss a cover for my rain barrel, otherwise mosquitoes can breed in the water. When the system doesn't work my grandchildren can use the rainwater collected within the rain barrel.*
7. What role does water have in your community? *Water is life.*
8. Do you have a toilet? *Yes, flushing toilet (septic tank) and shower. I built my own septic tanks. I use acid to clean it from bacteria.*
9. When the system does not work which water do you use? *Rainwater with a large plastic tank. We want to build a tower for the tank and fill it with water from the aqua-duct.*

#### Interests

1. What do you think of project? No answer.
2. What do you think that the rest of the village thinks of the project? No answer.
3. What do you think of the quality of the tank? No answer.

4. What do you think of not getting a tank? No answer.
5. Why do you think you did not get a tank? No answer.
6. Do you currently have any problems with water or sanitation and if so, what are these problems? No answer.
7. What would you require to solve this problem? No answer.
8. Did you have plans for a water tank before the project and why did you have these plans? No answer.
9. What is your opinion on roof runoff collection? No answer.
10. Would you have liked to learn how to construct a tank? No answer.
11. If a new project group would come here to help you and you could choose what they would improve, also not water related, what kind of support would you chose? *Light, electricity. Important for children because then they learn how to use technology and they can keep up with the world.*
12. How did the attachment to the gravitational system work? *Government paid for the old system, and also for the connections up to the first switch. But I needed to connect myself to the system.*
13. Why did other part of the village did not received the connection? *Other part of the village did not want to help for free. They had to fix a construction at the river crossing with steel wire, but they did not do it.*
14. Do you pay for the connection? *Supposed to pay USD 5 dollar fee but nobody comes to collect. People use the water for other stuff and purposes, so they have to pay more. It is important to pay so the guys get paid to fix the system when it is broken.*



### O.5.11 Omar Romero and Celina de la Espada

#### O.5.11.1 No-tank interview on 22nd of September

##### General information



Name:	Omar Romero and Celina de la Espada
Profession:	Agriculture ; Household
Age:	65; 59
Lives with:	Togheter with daughter, her husband and kid
Education:	None ; EPTC. Children did get education, but not in El Progreso
Part of El Progreso :	38 years. First 22 years in other house in El Progreso
Special Resources for project:	-
Responsibilities in household:	Work, money ; Cooking, around the house

##### Water

1. What is the main source (/what are the main sources) of water for this household? If you use different sources, where do you use the different sources for? *Aqueduct.*
2. Who is getting the water? *Both.*
3. How close is the source to the household? *The source is in the house. We had to connect the house connections ourselves. The representante only made 2 inch pipes in the main road.*
4. Do you treat water from your source? If yes, how? *No. But there is a lot of sediment coming from the system. Therefor the system needs to be repaired often, the costs are USD 5,00 to the Palmira guys.*
5. How long ago the aqueduct was designed? *The system has been renewed after 10 years. The new system is in place for 4 years. Filters and tank were built for the old system.*
6. Where did you get water before the aqueduct was designed? *At the Rio Negro, with the car.*
7. Do you think the water is safe? If not, why? *Do people get sick because of the water? Very little people get sick from drinking the aqueduct water.*
8. What role does water have in your community? *Water is life.*
9. Do you have a toilet? *Yes, flushing toilet (septic tank) and shower.*
10. When the system does not work, which water do you use? *Rainwater with a large plastic tank. We want to build a tower for the tank and fill it with water from the aqueduct.*
11. What do you think is the best water to drink? *Rainwater, this can be taken directly.*

##### Interests

1. What do you think of project? *Very nice, good for community, but he has plastic one so don't need it.*
2. What do you think that the rest of the village thinks of the project? *Very nice.*
3. What do you think of the quality of the tank? *Good.*
4. What do you think of not getting a tank? *I am okay with it, we have a tank.*
5. Why do you think you did not get a tank? -
6. Do you currently have any problems with water or sanitation and if so, what are these problems? -
7. What would you require to solve this problem? -
8. Did you have plans for a water tank before the project and why did you have these plans?  
No new plans, I like the one I have.
9. What is your opinion on roof runoff collection? -
10. Would you have liked to learn how to construct a tank? Yes, he would like them, very good looking.
11. If a new project group would come here to help you and you could choose what they would improve, also not water related, what kind of support would you chose? *A hanging bridge and finish school/roof.*

## O.5.12 Cesar Lopez and Nela Rosa

### O.5.12.1 No-tank interview on 25 of September

#### General information



Name:	Cesar Lopez and Nela Rosa
Profession:	Agriculture ; Retired
Age:	65; 59
Lives with:	Only the two of them. Have a total of four children (one in Spain, three in Panama) all of them living out of the house
Education:	None ; medical university. Children did get education, but not in El Progreso
Part of El Progreso :	10 years ; 5 years
Special Resources for project:	-
Responsibilities in household:	-

#### Water

1. What is the main source (/what are the main sources) of water for this household? If you use different sources, where do you use the different sources for? (Drink; Wash/prepare food; Cook food; Bathe; Hand wash; Brush teeth; Clean house; Wash dishes; Wash clothes) *The main and only source is the tap from the gravitational system, which also fills a 55 gallon tank to bridge the periods where the gravitational system is not working. This is used for everything, including cooking*
2. Who is getting the water? *Nela is getting the water*
3. How close is the source to the household? *The source is in the house*
4. Do you treat water from your source? If yes, how? (Filter, boil, through shirt) *A washed old sock as a filter combined with chlorine, namely three bottle caps for a 55 gallon tank and three drops for one gallon.*
5. How much water do you use per day? *Two or three buckets (37,9 - 56,9 litres), but this is a very rough estimate as the tap is the main source and the tap is not always used with buckets, an extra bucket is used for cooking and an extra gallon for drinking.*
6. Do you think the water is safe? If not, why? *Do people get sick because of the water? No, they only drink their own water. He did get sick this weekend when he drank water from other people and he treated its sickness by adding lime to the water. The teacher also only drinks their water (besides bottled water).*
7. What role does water have in your community? (Spiritual, Religious, something else, not extra than anything else) *Water is really important for everything and is also a big part of their live.*

8. Do you have a toilet? *Yes, a flushing toilet connected to the gravitational system, a septic tank, shower and laundry machine connected to the tap.*

### Interests

1. What do you think of project? *The project is very important, the local people are not educated for these situations. She thinks that rainwater is more pure and needs less treating, while in the rivers and aqueduct there are many pesticides.*
2. What do you think that the rest of the village thinks of the project? *Everyone is positive, but the people with a tank need to maintain the tank to make them last and they expect it will not last at Casildo as he is gone often.*
3. What do you think of the quality of the tank? - Not asked
4. What do you think of not getting a tank? *We have the aqueduct here together with a small tank, but we have worked for that ourselves. We started building the new gravitational system without permission of the representante and did the building without getting payed for it, while the other part of the village wanted to get payed to built it.*
5. Why do you think you did not get a tank? *Because we have the aqueduct.*
6. Do you currently have any problems with water or sanitation and if so, what are these problems? *They do not have any problems as they built a toilet as the first thing when they got here. A latrine outside the house would have been abused by everyone or get stolen.*
7. What would you require to solve this problem? N/A
8. Did you have plans for a water tank before the project and why did you have these plans? *We thought about it, but we did not have the money for it.*
9. What is your opinion on roof run off collection? *It is perfect and clean.*
10. Would you have liked to learn how to construct a tank? *Not extremely interested to built it ourselves.*
11. Do you have construction experience? *No and did not built our house themselves.*
12. (Extra question) If a new project group would come here to help you and you could choose what they would improve, also not water related, what kind of support would you chose? *The community needs light, not solar but cables from Palmira because solar needs new batteries every few years. She even petitioned for it, but the representante lost the petitions. Having light will improve education and the quality of food storage.*

### O.5.13 Michel Arenas

#### O.5.13.1 No-tank on 25 September

##### General information



Name:	Michel Angel Arenas
Profession:	Agriculture
Age:	77
Lives with:	Alone, his wife left, but he has five sons who were raised with the help of the teacher and who sometimes visit.
Education:	Went to school first in El Progreso, then in Colon
Part of El Progreso :	20 years
Special Resources for project:	None, only helping
Responsibilities in household:	Everything

##### Water

1. What is the main source (/what are the main sources) of water for this household? If you use different sources, where do you use the different sources for? *The gravitational system and otherwise the Rio Negro or by filling a bucket with rainwater. The source that is available is used for everything.*
2. Who is getting the water? *I am.*
3. How close is the source to the household? *The source is next to the house.*
4. Do you treat water from your source? If yes, how? *No, but I only use clean buckets, not from for example fertiliser. I only drinks tea, that has boiled for several minutes.*
5. Do you think the water is safe? If not, why? *Rainwater is less safe, as it is contaminated by the air, so I do not drink it.*
6. What role does water have in your community? *No water, no life.*
7. Do you ever get sick from the water? *Yes, sometimes.*
8. How much water do you use per day? *10 gallons*
9. When the system does not work, which water do you use? *Rainwater with a large plastic tank. We want to build a tower for the tank and fill it with water from the aqueduct.*
10. What do you think is the best water to drink? *Rainwater, this can be taken directly.*

##### Interests

1. What do you think of project? *It is a good project and I am happy that you do this, but I am also sad that I did not let you stay in my other house, especially since it eventually did not get sold.*

2. What do you think that the rest of the village thinks of the project? *Very nice.*
3. What do you think of the quality of the tank? *Fine.*
4. What do you think of not getting a tank? *I am sad about that. Especially because if I did let you stay in my other house, you probably would have restored the house and built a tank there.*
5. Why do you think you did not get a tank? *Because I did not let you stay in the house.*
6. Do you currently have any problems with water or sanitation and if so, what are these problems? *I need a latrine, as the flushing toilet which I had was stolen.*
7. What would you require to solve this problem? -
8. Did you have plans for a water tank before the project and why did you have these plans? *Yes, I want an elevated 300 gallon tank, but I have no money for it.*
9. What is your opinion on roof runoff collection? *It is fine.*
10. Would you have liked to learn how to construct a tank? *Yes.*
11. If a new project group would come here to help you and you could choose what they would improve, also not water related, what kind of support would you chose? *Improving the gravitational system.*

## O.5.14 Daniel Vaisabel

### O.5.14.1 Interview regarding collaboration with local NGO on 20th of September

#### General information



Name:	Daniel Vaisabel
Profession:	Projectmanager for GeoParadise
Age:	31
Lives with:	Single
Education:	Master degree in Engineering
Part of El Progreso :	1,5 years
Special Resources for project:	Contacts with local people, familiar with surrounding area, access to camping and kitchen equipment
Responsibilities in household:	Everything around the church, reconstructing his house, selling fruits and cooking meals

1. How long have you been part of GeoParadise group? *From February 2017. Main focus is working on the festival.*
2. How did you found GeoParadise? *Met them in Panama, February 2017. Full moon party in my house, up to 300 people, where Geoparadise was promoting the festival.*
3. How did GeoParadise end up here in the Colon region in Panama? *First tribal gathering was organised in jungle in Panama, interior in Panama. Thereafter they start for looking for beach place. Economic stability, therefore choose panama. Also central in America. Good country to have a base.*
4. How long have they been active here? *2011 company registered, 2013 first festival*
5. What kind of interest does GeoParadise have in El Progreso? *Help community and indigenous tribe, small project to help them. Improve quality of life, education for children.*
6. Do you, besides the interest of GeoParadise, have interest in El Progreso your own? *Find them interesting as tribe, they are in need of help. They requested help, it is within my power to fulfil these tasks. In general interest in indigenous tribes, want to help them. In June 2017 first time here.*
7. Do you think these interests have had an influence on your translation work, both during interviews as well as during construction work? *It might have, everything what I do is influenced by my personal feeling. Example: When there is no rain at all, I disagree, I am 100% sure that there is rain, almost every week. What he experiences his feeling is not in line with them.*
8. Can you shortly describe the type of resources GeoParadise has globally and in El Progreso? (Monetary, human etc.) *Permanent crew of GeoParadise consists of 4 people, other people employed by Panamanian company. During festival, 100 people volunteer for GeoParadise, get reward in food and accommodation. Panamanian company (wavy tribe) holds the permits. They hire 150 people during festival period. Yearly for everything 500.000 dollar.*

9. If any, what sort of relationships does GeoParadise (and you personally) have with the village El Progreso? *We are friends (Tito, Emilio and Lazaro) with some people, with some we have work relationships. Hire for the festival (Everyone who lives in Emilios house, Emilio's brother, Casildo B, Demetrio refused) Everybody was asked, women and male.*
10. Did these change during the project and do you want them to change? *During this project personal relations got better and new relations. Everyone we build a tank for.*
11. Do you think these relationships have had an influence on your translation work, both during interviews as well as during construction work? *No.*
12. What is your view on collaborating with the people in El Progreso? *It is really successful, happy with collaboration. Opening their houses and heart. Under these circumstances with this the best we could. If we would have more time, I would tried to contact representante and government funding. Ministry of development and education to get some funding.*
13. Do you think El Progreso in any way needs GeoParadise? *No they don't need it. They lived before and after we are here.*
14. How do you help the community of El Progreso? *Finding volunteers to do small maintenance, painting, replacing the roof. From other side personally created job opportunity for the people of El Progreso.*
15. In the future, how do you ideally see the collaboration between El Progreso community and GeoParadise? *In projects get people more involved, providing local food. Other part does some workshops, agriculture, farming, making coffee. I would like the people to facilitate this.*
16. What do you think of this project? *Really nice.*
17. What is your vision on good charity work and do you think that this project fulfils this vision? *Yeah it is definitely charity work. More service work than actually research project. Sustainable and people will keep up their tank. All aspects are fulfilled.*
18. Does charity become better when you add research? *Yes*
19. How do you think the life of the people here in El Progreso changes because of this project? *They now work together better, I believe they will work together in the future better to help each other. More open to outside work, for new projects. As they were in the beginning doubtful, they no longer doubt anymore. I am afraid that they keep asking more from my organisation. Reaching more, small things, they don't stop asking. We don't have that many resources to fulfil their expectations. It will be fine, but we will see.*
20. What do you think of the quality of the construction work? *Really durable and good. There is nothing more we can do better for the tanks.*
21. If you were in the lead of the project, what would you do differently? *I would hire another Simon (plasterer).*
22. Do you think these differences have had an influence on your translation work, both during interviews as well as during construction work? *No.*
23. How did you experience the past 2 months? *It was really interesting to work close with different types of people. Learned a lot, definitely positive experiences, definitely helps myself.*
24. Did this project live up to your expectations? *First week brainstorming, but I was not stressed or missed overview. I have worked with crews and different types of people. We are group that can overcome problems and listen to each other in a way that we can change plans and are open minded.*



## O.5.15 Pablo Romero Guzman

### O.5.15.1 Interview on 23 September

#### General information



Name:	Pablo Romero Guzman
Profession:	Head of Water committee Palmira
Age:	56 years old
Lives with:	wife and step sons
Education:	Unknown
Part of El Progreso :	Lives in Palmira
Special Resources for project:	-
Responsibilities in household:	-

1. What is your job concerning the gravitational system? *The water committee started out with 7 people, but the group got smaller every time. Now I have to do the job alone. When fixing the problem, I need to pay someone to accompany me to the jungle. In total I receive 70 dollar a month usually, sometimes more and sometimes less. The payment comes from the people who are using the gravitational system. The price is 5 dollar per month for each household. In El Progreso almost nobody (except for Omar and 1 other man) pays the 5 dollar a month. From this money I need to:*
  - (a) Pay material to repair the system
  - (b) Pay people to accompany him
  - (c) Live
2. Can you describe the history of the aqueduct? *This aqueduct is two year old. Before they pumped up the water from the Rio Culebra, this was the responsibility of the old representante. This well was constructed 3 years ago. But the pump broke, and the new representante didn't want to repair the pump but decide to build a new system in 2015. Difficult political situation*
3. Can you describe the way the system work and who is connected to this system? *Intake point 5 km upstream, transported by 2 inch pipes. There a two valves to regulate the water and to clean the sediment. One before Progreso and one after Progreso. A new company is supposed to come to fix the system. Because there are a couple of problems:*
  - (a) The pressure and water is not equally distributed in Palmira
  - (b) A new sedimentation tanks need to be built
4. How can you make new house connections? *First consult me, I can help them to connect the pipes the right way. The people have to pay for the house connections themselves.*
5. How often is the system not working? *There is hardly maintenance needed from December to April. The system is hardly working from May to December. During this period it rain very often and therefor:*

- (a) *System clogs*
  - (b) *System is damage by flooding*
6. What do you think is the biggest problem? *Sediment is the most common problem.*
  7. How do you reach the system? *I reach the system by foot, 2 hour hike to the system from Palmira.*
  8. What do you think the future will bring to this system? *It will be the same system. There is plan to connect the system of Portobelo with a long pipe along the coastline to every household here. I want to try and fix the sediment system. Start at the beginning and clean the whole system. But he can't do anything before he has an accord from his boss.*
  9. What do you think of the quality of the water? *The quality of the water is measured before the system was designed and now in hands of the Ministry of Health.*
  10. Are there cases where people got sick from drinking the water from the gravitational system? *There are always issues, but no prove that is comes from the water. Only possible pollution can be the valve tank. This tank is not maintained well and therefor bacteria can possible grow here.*
  11. For how long is the system designed? *Can't really say, only god knows.*
  12. Who is the client who asked, ordered and paid for the system? *The last representante Luis William. Each community gets yearly money from the government. They saved up to 3 years and could then afford to build the aqueduct system. System costs are 200.000 dollar. The other part of El Progreso is requested to be connected to the system, but when the new company comes is a big question.*
  13. Why is the other part of El Progreso not connected? *Political struggles*
  14. When the system is broken, who alarms you? *When the system is broken Omar tells me. When he tells me still in the morning, fixed same day and when in afternoon, fixed day after.*
  15. How did you get involved with the water system? *I am part of the JAAR (Junta committee de Agua). You can get elected and authorized by the Ministry of Health with a certain certificate and there a no political strings. The current representante is family of his wife.*

## O.5.16 Maritza Bernalle

### O.5.16.1 General interview on September 24th

#### General information



Name:	Maritza Bernalle
Profession:	Teacher at primary school in El Progreso
Age:	49 years old
Lives with:	In Progreso: with granddaughter and a child from Palmira In Panama City: with husband and a daughter
Education:	University of Education, 8 years and still needs to attend university
Part of El Progreso :	1,5 years
Special Resources for project:	No
Responsibilities in household:	Unknown

#### Water

1. What is the main source (/what are the main sources) of water for this household? If you use different sources, where do you use the different sources for? (Drink; Wash/prepare food; Cook food; Bathe; Hand wash; Brush teeth; Clean house; Wash dishes; Wash clothes) *I bring bottled water from Panama City for drinking, because people told me that the water is not good here. I use the water from the gravitational system for everything else and if that does not work I go to the river.*
2. Who is getting the water? N/A
3. Do you combine getting water with other activities? (e.g. bathing, doing dishes, etc.) If yes, do you think this will change when the tank is built? N/A
4. Do these sources change throughout the year? N/A
5. How close is the source to the household? *In the house.*
6. Do you treat water from your source? If yes, how? (Filter, boil, through shirt) *I boil the water for cooking from the gravitational system.*
7. How much water do you use per day? *I use 3 buckets, 56.8 liters, of water per day. For cooking I use 22.7 liters per day.*
8. Do you think the water is safe? If not, why? Do people get sick because of the water? *I do not think the water is dangerous but I am not used to this water. And if the water is clear, you still do not know if it is safe.*
9. What role does water have in your community? (Spiritual, Religious, something else, not extra than anything else) *Water is life.*

10. Which of the following is close to your water source? (Farm, pesticides, upstream village, garbage, latrines)
11. Where do you shower? *In my house.*
12. Where do you go to the toilet? *In my house.*

### **Tank**

1. How did you choose the location of the tank? (And who chose it? Man/woman) *I chose the location on this place because the tank is more hidden and by-passers will not use it and abuse it.*
2. Did you already have plans for getting a water tank? Yes, I would have gotten a plastic tank if there was enough money for it.
3. What is your interest in this tank? not asked.
4. What is your opinion about the following aspects of the tank? (Size tank; size manhole; shape; tap; collection system and roof material; maintenance) *It is excellent. I think it is a great idea to get water directly from the sky. The size is good, it is big and it looks like it will not deteriorate. I think there will be algae growth if it is not well maintained.*
5. Where are you going to use the water from the tank for? Does this need extra requirements? *For everything when the gravitational system is not working. For drinking water for the kids they will use the gravitational system because they otherwise will drink water from the river.*
6. Do you think your water use will change once you have the tank? *Yes.*
7. A What do you think of the fact that you got the first tank? *So before everyone else? I think it does not matter where you start, the children live at the other side and go to school here so either way they will be able to use the water from the tank.*

### **Requirements**

1. Is there anything you want to learn from the building of the tanks? no answer.
2. What do you expect of the design and construction of the tank? *I have never seen anything like it. I really like the way you made the mould with the materials.*
3. What do you think the tank will last? *If someone will not smash it, it will last a lifetime.*
4. Do you have experience with charity? If yes, how well were your requirements met? not asked.
5. What do you think about the project? *The project is perfect, it brings a solution. Imagine that the gravitational system is not working for 3-4 days and the water in the river is dirty.*
6. Do you expect resistance against the project? *Not really, everyone is positive and happy. Some people asked me if they could also get a tank and I told them that it was not possible to give everyone a tank.*
7. Do you want to learn more about water and how to treat it? *Yes.*

### O.5.16.2 Evaluation interview

#### Requirement

1. What kind of support do you need the most? *The village needs electricity and a bridge over the river (Rio Culebra). A higher fence for the school would be good so it will protect the children.*
2. Rank the following fields of support: work, food, medical, education, money, water and sanitation.
  - (a) *Work*
  - (b) *Medical*
  - (c) *Food*
  - (d) *Water and sanitation*
  - (e) *Education*
  - (f) *Money*
3. Do you have problems regarding water or sanitation in your life and if so, what are these problems? *The children do not have a toilet. We have the material to build a toilet but labour is needed to build it. It is important for the children, for 3 reasons.*
  - (a) *I only have one toilet in my house and shy children will not use it, and other children might abuse it*
  - (b) *It is also part of education because they will learn that it is important and*
  - (c) *When it is raining, the children will have to walk longer to the toilet and with a new toilet they do not have to (because it will be constructed next to the school).*
4. What would you require to improve this situation? *A toilet for the children.*
5. Did you ever think about a water tank? *Yes, I thought about it but there is not enough money.*
6. What do you think of the size? *Perfect.*
7. What do you think of the tap? *I do not think it will break. It is nicely made. A little bit higher would have been better because I think the bucket will/might not fit below the tap.*
8. Did your opinion on the location change after usage? *No.*
9. What do you think of the aesthetics of the tank? *It is beautiful. Yes, it is important because when people walk by and see the tank next to the school it looks good.*
10. What do you think of the maintenance of the tank? *I believe that it will need to be cleaned regularly (the pipes and gutters) and I want to know how so I can give instructions to people so they will do it.*
11. Are there any requirements on the tank that are not fulfilled? *No.*

#### Water

1. Do you already use the water? *Yes.*
2. Where are you using the water in the tank for? *For cooking.*
3. What do you think of the taste of the water? *No answer.*

4. Do you still use the water from your other water source? if yes, for which purposes? No answer.
5. Do you treat the water from the tank before you use it? No answer.
6. How do you use the time you would normally go to the river? N/A
7. Do other people, besides your household, use the water from this tank? *Yes the children from the school will use it and adults if they come along.*
8. Who gets the water from the tank? *Everyone can take water, but children need to be supervised. Children break everything.*
9. How did you cleaned the tank? N/A
10. Do you see maintenance as a burden? *No, I will not clean it, other people will.*
11. Which part of the tank is most vulnerable in your opinion? *The tap because children are always curious. I suggest that you build a cage from mesh around the tap so they can only open or close it and everything else is protected.*
12. Which part of the tank needs most maintenance in your opinion? *Gutters. When the tank and system are maintained well it will last a long time.*

### **O.5.16.3 Final interview during usage on October 10th**

#### **Water**

1. Did you already use the water from your tank? *Yes, during last week*
2. Where are you using the water from the tank for? *I use the water for bathing.*
3. What do you think of the taste of the water? *I do not drink the water.*
  - (a) Did you notice any changes in taste or quality of the water of the tank? N/A
4. Do you still use the water from the other sources? *Yes, I use the gravitational system when it works. Last week it did not work.*
  - (a) And if yes, what for? *Cooking, washing, bathing and flushing toilet.*
5. How do you use the time that it would normally take for you to get water from the river? N/A
6. Do you treat the water before you use it? *No, I do not treat the water.*
7. Do other people besides your household use the water from this tank? *No, not that I know of.*
8. Have there been any problems so far with the system? *No, no problems so far.*

## P Finances

Figures below show details of the budget of the project.

COSTS		EXPECTATION		REALISED
	amount	unit price	total	total
<b>Rain water harvesting tanks</b>				
Materials	20	\$ 336,40	\$ 6.728,00	
<i>Foundation</i>		\$ 116,00		
<i>Gutters and pipes</i>		\$ 58,00		
<i>Tank (ferrocement)</i>		\$ 116,00		
<i>Other equipment (faucet)</i>		\$ 46,40		
<b>Subtotal</b>			<b>\$ 6.728,00</b>	<b>\$ 5.979,87</b>
<b>Water quality research (ground and surface)</b>				
Measuring equipment	2	\$ 522,00	\$ 1.044,00	
Materials, field laboratory	1	\$ 580,00	\$ 580,00	
<b>Subtotal</b>			<b>\$ 1.624,00</b>	<b>\$ 3.374,23</b>
<b>Building wit Ferrocement - training</b>				
Ferrocement training (Guinea-Bissau)	1	\$ 812,00	\$ 812,00	
Additional travel costs	1	\$ 116,00	\$ 116,00	
<b>Subtotal</b>			<b>\$ 928,00</b>	<b>\$ 928,00</b>
<b>Local workforce</b>				
Building costs (mason)	40	\$ 45,00	\$ 1.800,00	
Translator	2	\$ 580,00	\$ 1.160,00	
<b>Subtotal</b>			<b>\$ 2.960,00</b>	<b>\$ 2.910,00</b>
<b>Travel and transportation</b>				
Vehicle 4x4 rent	2	\$ 1.450,00	\$ 2.900,00	\$ 2.419,32
<i>Panama pass</i>	1	\$ 40,00	\$ 40,00	\$ 17,53
<i>Gasoline (car + generator)</i>	1	\$ 350,00	\$ 350,00	\$ 958,12
<i>Taks</i>	1	\$ 40,00	\$ 40,00	\$ 13,80
<b>Subtotal</b>			<b>\$ 3.330,00</b>	<b>\$ 3.408,77</b>
<b>Accommodation &amp; Food</b>				
Accommodation	2	\$ 600,00	\$ 1.200,00	\$ -
Food	1	\$ 2.000,00	\$ 2.000,00	\$ 1.745,49
Unforeseen costs	1	\$ 2.000,00	\$ 2.000,00	\$ 59,52
<b>Subtotal</b>			<b>\$ 5.200,00</b>	<b>\$ 1.805,01</b>
<b>SUBTOTAL</b>				
Cost	expectation	%	realised	%
Rain water harvesting tanks	\$ 6.728,00	32%	\$ 5.979,87	32%
Water quality research (ground and surface)	\$ 1.624,00	8%	\$ 3.374,23	18%
Local workforce	\$ 2.960,00	14%	\$ 2.910,00	16%
Building wit Ferrocement - training	\$ 928,00	4%	\$ 928,00	5%
Travel and transportation	\$ 3.330,00	16%	\$ 3.408,77	19%
Accommodation & Food	\$ 5.200,00	25%	\$ 1.805,01	10%
<b>TOTAL</b>	<b>€ 20.770,00</b>	<b>100%</b>	<b>\$ 18.405,88</b>	<b>100%</b>

Figure 24: Overview of costs, both expected and realised values

<b>EARNINGS</b>			
<b>Sponsors</b>	<b>amount</b>	<b>unit price</b>	<b>total</b>
BRITE	1	\$ 5.800,00	\$ 5.800,00
Bredius	1	\$ 2.900,00	\$ 2.900,00
Bakkerij Carl Siegert	1	\$ 2.320,00	\$ 2.320,00
Nacht van de Fooi	1	\$ 2.320,00	\$ 2.320,00
Wilde Ganzen	1	\$ 2.320,00	\$ 2.320,00
Students4Sustainability - TU Delft	1	\$ 3.480,00	\$ 3.480,00
Particuliere schenkingen	1	\$ 391,52	\$ 391,52
<b>Subtotal sponsors</b>			<b>\$ 19.531,52</b>

<b>Fundraisers</b>	<b>amount</b>	<b>unit price</b>	<b>total</b>
High school lectures	1	\$ 1.160,00	\$ 1.160,00
Kingsday Utrecht	1	\$ 2.088,00	\$ 2.088,00
Charity diner	1	\$ 928,00	\$ 928,00
<b>Subtotal fundraisers</b>			<b>\$ 4.176,00</b>

<b>SUBTOTAL</b>		
<b>Earnings</b>	<b>total</b>	<b>percentage</b>
Sponsors	\$ 19.531,52	79%
Fundraisers	\$ 4.176,00	21%
<b>TOTAL EARNINGS</b>	<b>\$ 23.707,52</b>	<b>100%</b>

<b>TOTAL EARNINGS</b>	<b>\$ 23.707,52</b>
<b>TOTAL COSTS</b>	<b>\$ 18.405,88</b> -
	<b>\$ 5.301,64</b>

Figure 25: Overview of earnings from sponsors and fundraisers, total earnings, total costs and total budget for the project