An Investigation of Water Access and Quality in the Ambovombe Area of Southern Madagascar

by
Katherine Frances Valentine

A THESIS

submitted to

Oregon State University

University Honors College

in partial fulfillment of
the requirements for the
degree of

Honors Baccalaureate of Science in Environmental Sciences
(Honors Scholar)

Honors Baccalaureate of Arts in International Studies
(Honors Scholar)

Presented December 3, 2015
Commencement June 2016

AN ABSTRACT OF THE THESIS OF

Katherine Frances Valentine for the degrees of Honors Baccalaureate of Science in Environmental Sciences and Honors Baccalaureate of Arts in International Studies presented on December 3, 2015. Title: An Investigation of Water Access and Quality in the Ambovombe Area of Southern Madagascar.

Abstract approved:

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Michael Campana

The Ambovombe-Androy region of southern Madagascar is one of the most water stressed areas in the country and is also notorious for having the worst quality water on the island. Before improvements and change can be made however, it is vital to know what infrastructure, quality, and access levels currently exist. Therefore, this project hoped to serve as a rough survey of the present water infrastructure and availability which could guide any future development, as well as provide insight into the local perceptions of water quality and desires for future infrastructure that should be taken into account. Over the course of three weeks in November 2013, personal observations supplemented numerous interviews addressing the topics of water access, quality, and infrastructure, which were performed with organization representatives and a variety of individuals in the Ambovombe area. The resulting information showed an alarming lack of organizational involvement, skewed local perceptions of water quality, varying degrees of accessibility, and basic desires for infrastructural improvement. From this investigation, it became clear that corruption at multiple levels played a role in the inadequate water access and quality in the area and that cultural factors also played a dominant role in the situation and influenced the investigation through the type of interview approach that took place and through interviewee responses. It was found that from a health and global perspective, water access and quality in the Ambovombe area was insufficient and experienced virtually no treatment before consumed. Decentralization, political unrest, corruption, and overall disorganization were the ultimate contributors to the lack of water infrastructure and the maintenance of past and present sources such as water trucks, basins, and borne fontaines. Taking this into account, Ambovombe needs water infrastructure solutions that minimize such

destructive factors. Such solutions could be a pipe that brings water from the Menarandre River to the old piping system beneath Ambovombe and water leadership, management, and maintenance groups involving women at the *fokontany* level, the lowest recognized level of governance in Madagascar. In essence, political transparency and public participation are critical to both political and resource developments in the future.

Key Words: water, water quality, water access, Madagascar, Africa,

Corresponding e-mail address: valentikf@gmail.com

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APPROVED:

_____

Michael E. Campana, Mentor, representing Earth, Ocean & Atmospheric Sciences

_____

Kate Lajtha, Committee Member, representing Crop & Soil Science

_____

Kenneth Maes, Committee Member, representing Anthropology

_____

Toni Doolen, Dean, University Honors College

_____

Larry Becker, Director, Environmental Sciences

_____

Kerry Thomas, Head Advisor, International Degree Program

I understand that my project will become part of the permanent collection of Oregon State University, University Honors College. My signature below authorizes release of my project to any reader upon request.

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Katherine Frances Valentine, Author

Acknowledgements

I would like to thank my mentor, Michael E. Campana, former International Degree Advisor – Nick Fleury, my thesis committee, Dr. Kate Lajtha, Dr. Kenneth Maes, and Kerry Thomas, my host family in Fort Dauphin, my fellow SIT (School for International Training) and CEL (Centre Ecologique de Libanona) classmates, my directors and professors from Libanona, Jim and Barry, the wonderful community of Ambovombe, and my translator, Toky Mahamaro, who endured endless walks through the sand and burning sun for the sake of social science and welcomed me into his family during my stay in Ambovombe. Thank you all for your help, hospitality, friendship, and encouragement.

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Introduction:

Inspiration:

Water is fundamental to all of life, yet every day hundreds of millions of people from around the globe struggle to obtain the water they need and/or have safe, good quality water to drink and use. Poor water quality and insufficient access to water can have vast and severe negative impacts, such as on one's physical and psychological well-being as well as one's livelihood and social position. With the social and technological capabilities of today, there should be no reason for so many people to continue to undergo such conditions. Those living in less developed countries struggle most with water access and quality and often rely on *non-governmental organizations* (*NGOs*) for aid and improvements. Yet unless water access and quality improvements are made to support communities that contribute economically to the group providing aid, combatting such a widespread concern may be considered a predominantly moral and environmental objective. Depending on resource use and geophysical elements, water insecure communities are not only closely influenced by local environmental and climatic factors, but may agitate present environmental concerns and/or initiate additional negative environmental responses.

Every case is unique, but by studying a variety of water insecure communities, a better understanding can be made of the multidimensional factors and influences involved in such communities. With a comprehensive understanding of a water insecure community's situation and the effect that different solutions have on communities of varying backgrounds and needs, effectual solutions as unique as the communities that are served can be applied and maintained to relieve water insecurity.

The town and surrounding villages of Ambovombe in southern Madagascar are dire cases of inadequate water access and quality. In an effort to supplement a greater, more complex understanding of water insecure communities and to encourage awareness and aid for this and other water insecure locales, I performed an investigation of water access/quality and the past, present, and future efforts to improve both access and quality in and around Ambovombe.

Physical Geography:

The island nation of Madagascar lies off the eastern coast of the African continent (Fig 1).

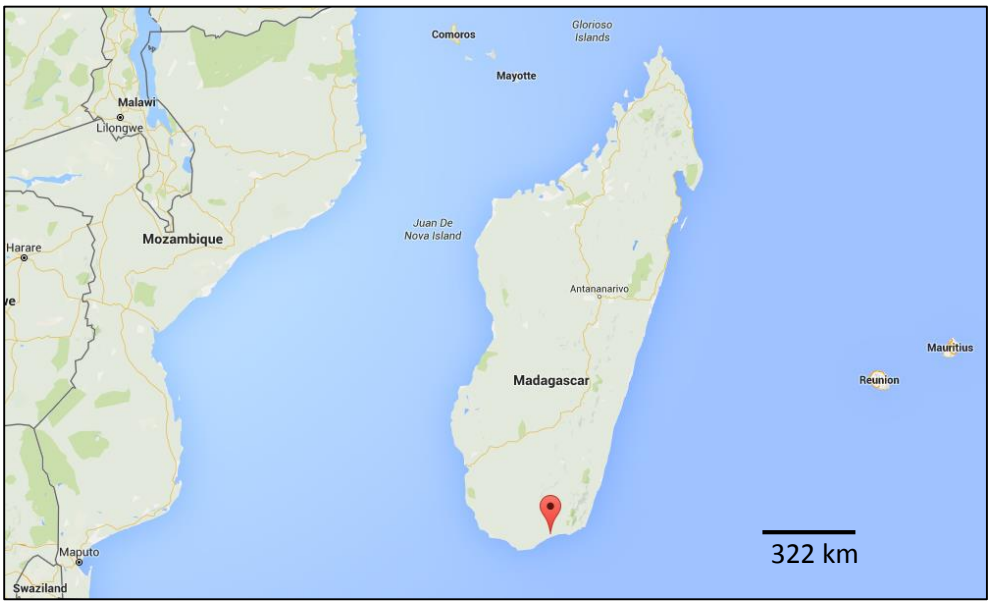

Figure 1: Area Map: Madagascar, Africa

Ambovombe-Androy, known commonly as Ambovombe town, is the capital of the Androy region in the extreme south of Madagascar, marked with a red signifier in Figure 1. The Anosy Mountains are situated to the east of Ambovombe and two rivers frame the region, the Mandrare to the east and Menarandre to the west (JICA 2004, Morlat 2009). To the south lies the Indian Ocean, about 11km from the town center of Ambovombe. Figure 2 illustrates the study area of Ambovombe town and southern villages within the red box.

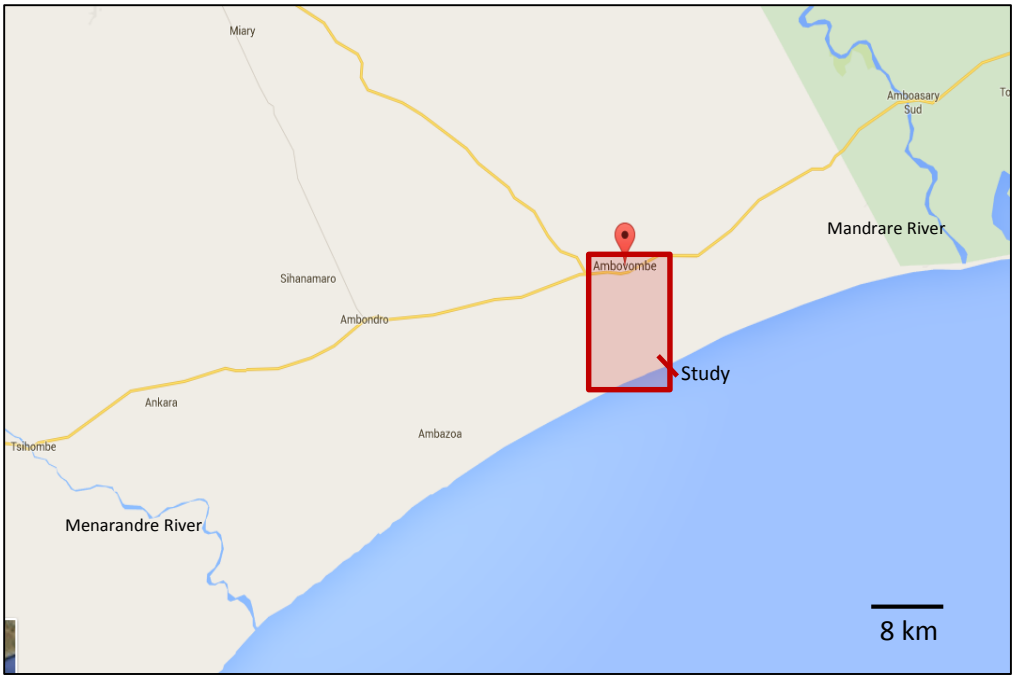

Figure 2: Site Map: Ambovombe, Southern Madagascar; Study Area shown in the box

Geology:

During the Paleozoic Era, Madagascar was located adjacent to Kenya and Tanzania on the eastern side of the Mozambique belt as part of the ancient supercontinent, Gondwana (Lardeaux et al 1999). Madagascar's basement material is hence part of East Gondwana and was separated from the supercontinent during the drifting and rifting that took place over the Jurassic-Cretaceous periods (Lardeaux et al 1999). This basement material is mostly crystalline formations of primarily metamorphic rock in the eastern 2/3 of the island (Wild Madagascar N.d.). Volcanic and intrusive basaltic formations are also found throughout and around Madagascar (Wild Madagascar N.d.). As seen in Figure 3, the Ambovombe study area consists of mostly unconsolidated sandy soils (CBI 2010, Marcus 2007). Indeed, the Ambovombe area consists of Neogene clays, sandstones, and argillaceous sands in general, with numerous Quaternary dune formations (CBI 2010).

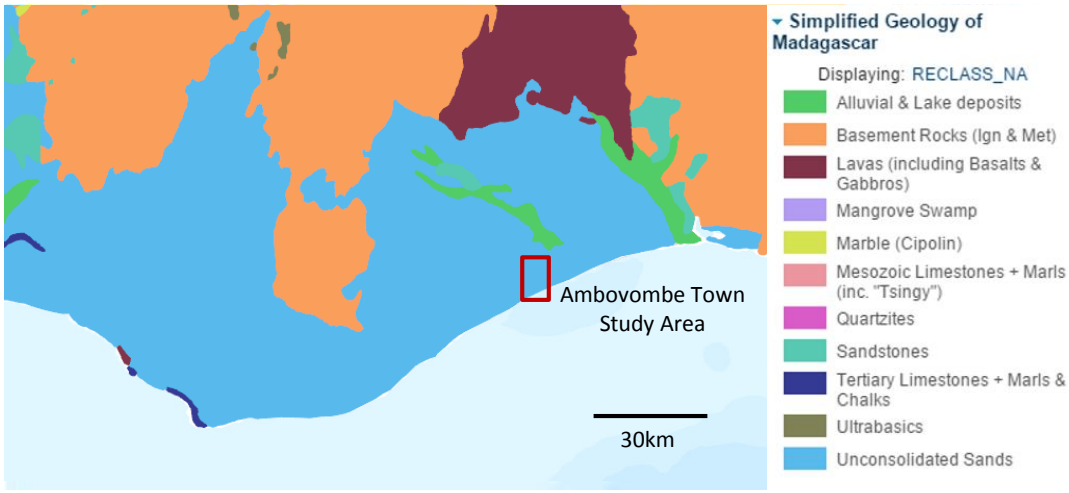

Figure 3: Simplified Geology of Madagascar. The study area is within the red box. Source: Conservation Biology Institute (CBI 2010).

Hydrology:

Although Ambovombe town is centered between two rivers, the hydrology of Ambovombe is largely subterranean and is dependent on precipitation for its hydrological inputs. The Ambovombe area is situated over a hydrologically closed basin, allowing for the use of wells, but unfortunately much of this water is saline due to over-extraction and proximity to the ocean, resulting in saline intrusion (Marcus 2012). Its upper aquifer sits about 7-10m below the surface, requiring a 10-15m well, and a second aquifer sits at about 20-25m, requiring a 25-30m well (UN 1989). Precipitation averages 561mm annually, and with an ever increasing need for water, groundwater extraction increases causing aquifer recharge rates suffer, ultimately threatening the vitality of the aquifers and the livelihoods of Ambovombe residents (AmbiWeb GmbH N.d.).

Climate:

There is a rain shadow created by the Anosy Mountains which causes the Ambovombe area to receive a modest amount of precipitation. Most of the area's precipitation arrives during the wet season, spanning December through February, which is influenced by the north-west monsoon (BGS 2002, JICA 2004, Morlat 2009). The dry season, on the other hand, is influenced by the southeast trade winds (BGS 2002). This dry climate can be described as a local steppe and is home to an herbaceous/arboraceous savanna that comprises the unique "spiny thicket" ecosystem in this region (AmbiWeb

GmbH N.d., JICA 2004, Marcus 2007). The temperature averages 23.0 °C over the year, with January being the warmest month at an average of 26.4 °C and July as the coolest with an average of 18.5 °C (AmbiWeb GmbH N.d.). The area's driest and wettest months are September with an average of 17mm of precipitation and February, with an 87mm average (AmbiWeb GmbH N.d.). Figure 4 below visually depicts Ambovombe's climate in a climograph.

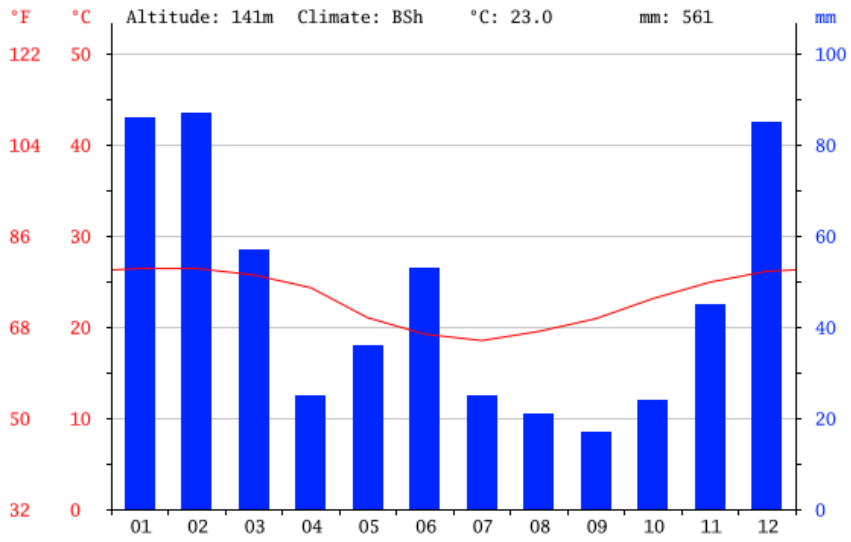

Figure 4: Climograph of Ambovombe, Madagascar.
Source: Climate-data.org (AmbiWeb GmbH, N.d.)

Human Geography:

There are about 184,000 people living in the Ambovombe-Androy district (Marcus 2007). Ambovombe town itself has a population of about 46,000 and has a very small urban area, providing a hub of economic and social activity amidst the scattered villages that encircle the town (Marcus 2007).

Cultural/Social Aspects:

The *Antandroy* (literally "the people of the thorns") get their name from their unique local vegetation and reputation. They are the dominant ethnicity in this region, hosting Antanosy, Melina, Mahafaly, and Vezo minorities (JICA 2004). The Antandroy have a historically hostile relationship with the Merina people of the central highlands,

who have tried to impose rule over the Antandroy for centuries and now host the country's capital city, *Antananarive* (Antananarivo) (Jolly 2004).

The majority of Ambovombe-Androy district residents are pastoralists, however pastoralism is largely viewed as a social activity rather than a way to make a living, since a man's social worth is connected to the number and size of cattle he possesses.

Economy:

The Ambovombe-Androy district is one of the poorest in all of Madagascar (Marcus 2007). It is not resource rich and most of the inhabitants list farming as their primary occupation, which is mostly subsistence farming, using rain fed agriculture (JICA 2004, Marcus 2007). The use of *raketa* (prickly pear cactus) has been contested since the colonial era, at first for territorial reasons, and now for environmental reasons (Marcus 2007). Today, the debate is whether this invasive species should be further introduced and utilized as a socioeconomic good or controlled/eradicated for the ecologically damaging role it plays (Marcus 2007). Recently, the availability of raketa has decreased due to environmental change and increased consumption by livestock, and occasionally people, in times of extreme water scarcity (Marcus 2007).

Water Issues:

According to the *World Health Organization* (*WHO*), as of 2011 only 48% of the population of Madagascar used improved drinking water sources (that's any water that comes from a pipe, including boreholes, rainwater, and protected springs/wells) (WHO N.d.). Ambovombe-Androy is a region that particularly struggles with access to adequate drinking water. With a population growth rate of 2.8%, the continuance of unsustainable water resource use, and climate change threatening unpredictable precipitation patterns and increased temperatures, there is an expected 2/3 decrease in water availability by 2025, meaning further pressures on water resources in the future (Marcus 2007).

Quality and Health:

Although the main concern in Ambovombe is access to water rather than quality, water quality remains a major health issue. Every day, an average of 5,000 children die globally from preventable water and sanitation related diseases (UNDP 2009). There is no denying that poor water quality threatens health, mainly due to pathogens that cause illness and even death. Mica and other contaminants in turbid water can cause illness and solids can carry pathogens such as cryptosporidium, *Escherichia coli*, and *Giardia lamblia* (Marcus 2007). According to the *Japanese International Cooperation Agency*'s (*JICA*) 2004 Sustainable Development report, 47% of the national population of Madagascar has access to safe water (JICA 2004). Madagascar's 1998 Water Code said how water should be universal and well managed, yet 15 years later, many Malagasy people still don't have adequate access to clean, potable water (Marcus 2007).

Government Involvement:

In the 1980s, the Malagasy State recognized the water crisis in the south and in 1986, a presidential decree created the program *Alimentation en Eau dans le Sud* (*AES*) which works in parallel to the Department of Water within the Ministry of Energy and Mines and is the only organization in the region involved in public water supply (Marcus 2007). In urban areas throughout the rest of the country, the water and electricity services typically fall to *Jiro Sy Rano Malagasy* (*Jirama*), a government owned and controlled provider.

Madagascar has been in the process of decentralization for over a decade, yet it has a highly centralized economy (Marcus and Onjala 2008). Water delivery is the ultimate responsibility of the Ministry of Energy and Mines, whereas the Ministry of Water and Forest maintains ultimate responsibility for surface water management, and the Ministry of Health has responsibility for potable water (Marcus and Onjala 2008). Responsibilities of development and water provisions have been passed from the central government to the regional and commune levels (Marcus and Onjala 2008). However, largely due to the lack of land titling in rural Madagascar, local governments lack the revenue to meet those responsibilities and such decentralization without financial

backing becomes much more like state disengagement and abandonment in the guise of local empowerment (Marcus 2007, Marcus and Onjala 2008).

The majority of decisions are made at the lowest level of government, the *fokontany*, which is often recognized as the community level, but "community" based water resource management committees are organized at the commune level, which is just above the fokontany (Marcus and Onjala 2008). Residents often distrust these committees, don't hold them accountable, and view them as corrupt if they are tied to the commune leadership (Marcus and Onjala 2008). Ambovombe town is in the Ambovombe commune, one of seventeen communes in the Ambovombe-Androy district of the Androy region within the Toliara province (Marcus 2012).

Access:

Ambovombe is constantly struggling with access to drinking water. Despite efforts by the Malagasy government and NGOs to provide water to the town and surrounding villages, much of the population struggles to obtain water. Access is such a dominant concern that water quality is largely overlooked. Instead of relying on NGOs or inadequate government aid, the people of the Ambovombe area have adopted a privatized water market involving the use of private wells and oxcart vendors, known as *charettes*.

Study Objectives:

Supplemented with previous research and literature on the subject, I used the results from a series of casual, semi-structured interviews to investigate the quality and accessibility of drinking water in the Ambovombe area. I include an examination of the current water market, past, present and future water projects by organizations, local desires for water infrastructure, local perceptions of water quality, a discussion on the economic and political influences on water access and quality in this region, as well as suggestions for future research.

Methods:

This study was initially performed as part of an Independent Study Project through the School for International Training based at the Centre Ecologique de Libanona in Fort Dauphin with the intention of using research towards this thesis. Data collection spanned a course of 3 weeks in the month of November, 2013. 54 interviews were performed involving 98 individuals in addition to interviews with representatives of organizations such as *World Food Programme* (*WFP*), *Christian Relief Services* (*CRS*), AES, and Jirama. Individual interviews included people at the central market, in the villages, oxcart vendors, and those using wells. Personal observations also played a role in this study.

Interviews were conducted using a translator who spoke French, English, and Malagasy. For francophone interviewees, I interviewed people directly using French, but if communication was too difficult, I would ask questions in either French or English. My questions would then be translated into Malagasy and their responses were translated into English.

Interview questions were semi-structured and based upon a predefined set of questions focused on 1) different types of interviewees; 2) access to water; and 3) water quality (see appendix B). The categories of interviewees included organizations, individual users, individual providers (such as well proprietors and oxcart vendors), health workers, and villages. As I developed a better understanding of how water was viewed and utilized in the Ambovombe area, some questions were altered while others were removed entirely. Questions catered to villages became similar to those catered to individual users and providers.

Names were not asked unless interviewees worked for an organization. It was explained to all interviewees that this study was intended solely for academic purposes and that I was not there to scout or provide water infrastructure.

When in villages or public areas such as the market, interviews often attracted attention. Large, curious crowds would quickly gather, so data from interviews were collected only from individuals who participated in the interviews. For instance, often in the villages, the population was small and enough sample data could be collected in one or two interviews. This is because interviews were directed towards a small number of

adults at one time, who would respond in either collective agreement or differing answers that were noted per individual present. In the end, many interviews became discussions between myself and the community individuals present.

Some of the interview questions had to be altered due to cultural differences which made it difficult for interviewees to respond to the questions being asked. For example, some questions that I initially intended to be addressed quantitatively became qualitative. For example, at the beginning of the investigation, the question "How would you rate the quality of your drinking water on a scale from 1 to 5 with 1 being the worst and 5 being the best?" was asked with some descriptive explanation to what might be considered the worst and dirtiest and the best and cleanest. Quantifying such a question proved too difficult for many interviewees, and instead they responded by describing their water as either *dirty*, *clean*, *sweet*, or *salty*. This realization forced me to alter my question in a more open ended manner that I could address quantitatively. Thus my question became "What do you think of the quality of your drinking water" or "How would you describe the quality of your drinking water". If they answered clean or sweet, I labeled that a 3 for favorable water quality, while I labeled a 1 for answers of dirty or salty. I gave the label of 2 if the respondent replied that they were unsure or if the water quality depended on the source of water.

In a similar manner, I had to become accustomed to the Malagasy interpretation of distance. When asked how far they traveled in kilometers to obtain drinking water, most interviewees were either unable to do so or made rough estimates (for example, I was told that it was 6-7km to the beach when in actuality it was about 11km). Instead they would answer in terms of *not at all*, *close*, *far*, or *very far* which I was eventually able to estimate into kilometers. In these terms, I was able to relate close to within 2km, far to 2-7km, and very far to 7-15km. If they didn't have to travel at all, this was because their source of water was within the community.

Findings:

Sources of Drinking Water:

Before addressing the quality of and access to drinking water in the Ambovombe area, it is important to understand where that water is coming from and how it is being collected. There are numerous sources for drinking water. Water is often collected by the bucket (about 15 liters), the barrel (about 200 liters), or yellow jerry cans (about 20 liters). Sources include *borne fontaines, impluviums*, naturally occurring rainwater storage systems that I will refer to as "*rockwater*", wells, rainwater catchment systems, dugout pits in riverbeds, and even puddles in the road. Water can also be bought from a middleman such as an oxcart vendor (Fig 5), water trucks, or bottled Eau Vive water. Most oxcart vendors obtain their water from wells, buying water there and charging a higher price, or use their own private well. Water trucks can carry more water and typically obtain it from nearby rivers such as the Mandrare.

Figure 5: A water vendor poses with his charette which carries a standard barrel of water.

Wells are often constructed by self-funded communities, but others are funded by NGOs. Depending on funding, wells may or may not have concrete walls, an open-top storage basin, and a covering for the well and/or basin. Water is collected by rope and bucket.

Impluviums are provided to communities by NGOs such as Christian Relief Services. These sources are made up of a large gently sloping slab of concrete that leads

rainwater down into a pipe connected to an underground basin. The basins have covers that can be opened and accessed by the people, who can collect the water similar to a well, using rope and bucket.

Many houses in the area have tin roofs which work very well for rainwater catchment systems. These collect rainwater from the roof into gutters and piping that lead to a storage basin where water can be accessed by bucket. However, because of the expense of building a storage basin and the extreme wet and dry seasons that Ambovombe experiences, rainwater is not a reliable long-term source.

Some naturally occurring water storage systems also exist. South of Ambovombe town is a village that uses what I call rockwater (Fig 6). It's a mix between an impluvium and a well in the sense that it collects rainwater into naturally occurring boreholes in the rock. Using cups and buckets, this water can be collected.

Figure 6: "Rockwater"

Public basins are large cemented cylindrical structures with a faucet on the side for access (Fig 7). Water is brought by water trucks or nearby wells and stored in the basins for use. There were 17 basins in the Ambovombe area at the time of this study.

Figure 7: Water Basin Provided by AES (status: broken)

Finally, 25 borne fontaines are spread about the main town of Ambovombe and the surrounding village neighborhoods. These are smaller structures created by the *United Nations Children's Fund* (*UNICEF*) and AES that obtain water from pipes or wells. Like the basins, these also have a faucet for accessing water.

Organizational Involvement:

At the beginning of the investigation, I spoke to a number of organizations to get an initial idea of the water situation in the Ambovombe area. As previously mentioned, AES is a government-funded program responsible for the distribution of water in the Ambovombe-Androy area, but although AES is the primary organization responsible for providing water to this area, they are not the only ones involved with water projects. NGOs like CRS, UNICEF, CARE, and WFP are or have been involved with humanitarian projects in the Ambovombe area. Jirama, the national corporation typically responsible for providing water and electricity, plays a minimal role in the provision of water due to the presence of AES.

Past:

In the 1990s, Madagascar's AES program worked with the Japanese government (JICA) in an effort to improve water access in Ambovombe. Twenty four water trucks were introduced. They each transported $6m^3$ of water from the Mandrare River at a time. A gravity pump-fed filling station was used and drivers would unload water in Ambovombe or fulfill private requests from communes. However, drivers often

demanded gifts for delivering the water. Over the years, the AES fell short on their maintenance responsibilities. It is also said by some that the central office of the AES was corrupt and would sell parts of the trucks or the trucks in whole for personal profit (Marcus 2007). During this study, one truck tank was observed by itself in the yard of an unknown Ambovombe resident for unknown purposes.

Outside of the Jirama office in Ambovombe, there stands a large, old, and unused water tower. The adjoint director of AES explained that this old water tower no longer works, but from 1991 to 2005, the water tower was in use and brought water to the town of Ambovombe using a subterranean piping system (Solosoa 2013). Although this system was not in use at the time, the broken water tower and all the piping remain (Solosoa 2013).

Among NGOs, UNICEF has worked with AES to build borne fontaines. CRS has built rainwater catchment systems for schools, but has never had any water projects specifically concerned with improving water quality (Armand 2013). WFP has built water basins in partnership with *CARE*, but is otherwise minimally involved in water access and quality (Alvarez 2013).

Present:

At the time of this study, three of the original twenty four AES water trucks were still working. However, they provide water only to those who request it. AES charges a high price for the water because they include the cost of gas and time in addition to the water itself. Therefore, the main AES water customers are wealthy families and businesses like the banks who can afford to pay the high price for water, rather than the faraway villages who experience greater difficulties with water access and quality. According to multiple interviews, AES used to bring water trucks out to the villages around Ambovombe, but does so no longer. This is another reason why many of the people in Ambovombe are not very favorable towards AES.

Despite UNICEF and AES's involvement in providing borne fontaines in the past, at the time of this study, many of the borne fontaines had fallen into disrepair and were not working. A villager from Mahavelo claimed that only four of the twenty five borne fontaines worked, while the adjoint director of AES claimed that nineteen of them

worked. I did not visit them all, but during my time in Ambovombe, I only saw one working borne fontaine.

For the duration of this study there was a water tower piping project in construction. The project itself is funded by Enterprise Mihaja, but the Malagasy government is funding AES to supervise. Men had been digging a deep trench from a large white water tower near the entrance of the town. Piping would later be set in place to transport water from the water tower into the town of Ambovombe, connecting to the old subterranean pipes in a closed, circular system that would keep the water in the pipes and the water tower at all times. At the time, the project was incomplete and it was assumed that the water tower, which was not yet in use, would be in working order. Assuming this is true, it would be the only working water tower in Ambovombe, out of a total of five.

At the time of this study, AES had two wells and storage basins in Mahavelo, a village about 2km south of the town's center. When speaking to the adjoint director of AES as well as another worker for AES, they both said that AES treats the water from Mahavelo with *Eau de Javel*, a sodium hypochlorite solution, and that AES tests the water once about every three months when the basins are refilled, making sure the water quality meets WHO standards (Solosoa 2013, Chambre Syndicale Nationale de l'Eau de Javel 2011).

When I visited the Ambovombe Jirama office asking about their past, current, and future role in providing drinking water, they claimed that they have nothing to do with the water in Ambovombe and do not plan on becoming involved, because drinking water in Ambovombe falls under AES's jurisdiction (Jirama 2013).

Representatives from CRS spoke vaguely about their projects and appeared to be avoiding specifics, but according to the interview discussion, they have been working on improving and repairing impluviums in the area (Armand 2013). Beyond CRS, WFP was supposedly working on developing maps of groundwater at the time of the study (Alvarez 2013).

Future:

The water for the new water tower project is expected to come from AES's water storage in Mahavelo. This water project will certainly make water more accessible to those living in the main town. However, as some of the villagers from Mahavelo commented, the project is doing nothing for the perimeter population. One man from Mahavelo claimed that the water from there was no good because one could not cook beans or wash clothes with it.

The director and other two representatives at the CRS office that were interviewed seemed to have many goals involving water infrastructure, but no realized projects, nor were there any future projects planned addressing water quality. WFP, which has been minimally involved with Ambovombe water, plans to work with the local water problems more in their five year strategy (Alvarez 2013).

Access:

After completing numerous individual interviews, I found that the primary source of water was from wells (Fig 8). All oxcart vendors that I spoke to obtained their water from wells also, primarily from the Mahavelo area.

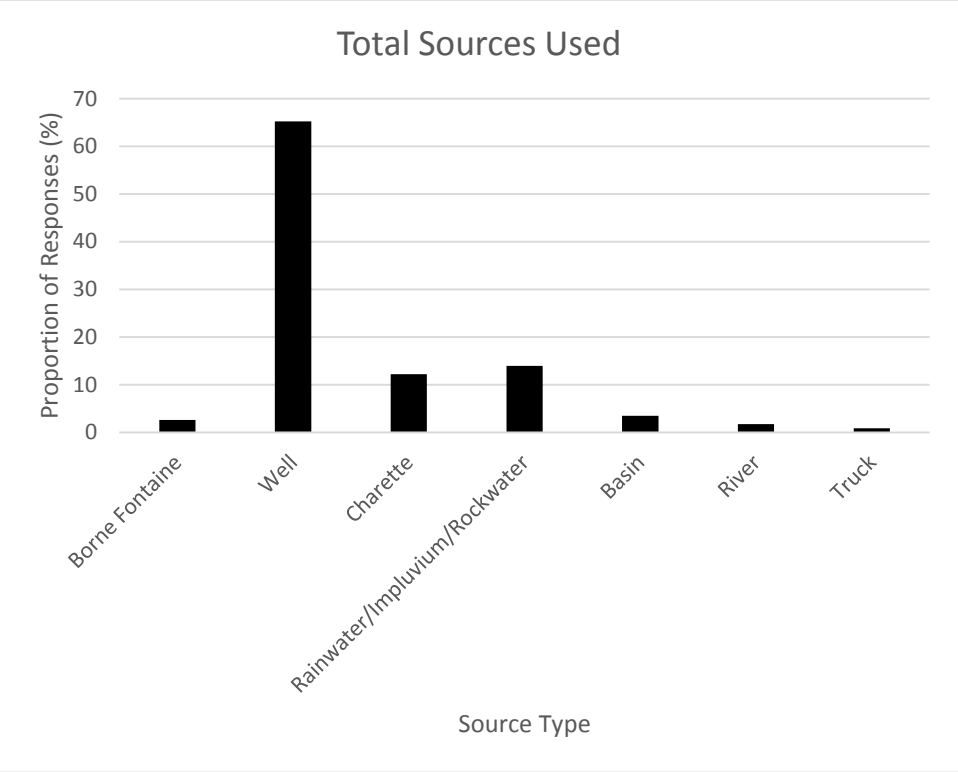

Figure 8: Of all water sources reported to be used by interviewees (N=115), the proportion of source types reported are shown**.** Note that some interviewees had multiple responses due to using multiple water sources so the number of responses here are greater than the number of actual interviewees. Rainwater, impluviums, and rockwater have been grouped together to represent sources that store precipitation in a seasonally constraining manner.

One family that I spoke to live in a village at least 10km from Ambovombe town. The well that they normally used was broken and the weather was too dry to use the neighboring impluvium. Because of this, they traveled by oxcart once a week to Ambovombe town to obtain water from the wells there by the barrel. Other families without an oxcart had to borrow one.

Oxcart vendors buy water from the wells or use their own private well for free and sell water for a higher price. At the time of my study, water could be bought most commonly for 100 *Ariary* (*MGA*) ($0.03) per bucket, but some interviewees claimed to

pay nothing or 50MGA ($0.02) up to 400MGA ($0.13) per bucket (Table 1). Water prices change depending upon the season.

Price of Water per Bucket (MGA)	Proportion of Daily Spending (%)	Proportion of Interviewees (%)
0	0	19
50	2	10
100	4.5	50
150	6.8	3
200	9	9
400	18	9

Table 1: Water Prices per Bucket in Ariary (MGA) for interviewees (N=58), consisting of individual water users. The proportion of daily spending is also shown by using 2200MGA (1USD) as the total daily spending.

Throughout Ambovombe, the streets are scattered with oxcarts carrying barrels of water. Some oxcart vendors have regular customers in the main town that they visit 1-3 times a week depending on the needs of the customer. Others visit neighboring or home villages where they have regular customers, but the majority of purchasers are miscellaneous individuals in town and in need of water.

As mentioned earlier, obtaining information on the distance people travel to reach their source of water proved to be a challenge. Ideas about distances in kilometers were often different than actuality and most could only describe distance in terms of none, close, far, or very far. From interview responses, the majority of individual interviewees traveled about 2 or fewer kilometers to collect water (Fig 9).

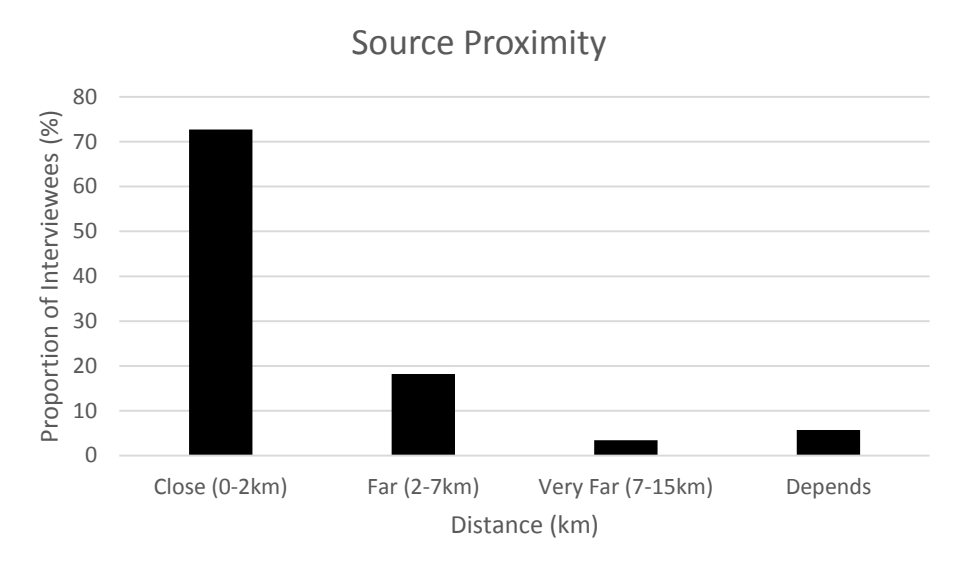

Figure 9: Proximity to nearest water source for interviewees (N=88)

Those who did not travel at all typically took water from oxcart vendors or had a working well, basin, or borne fontaine nearby. Those who traveled farther than 2km often had a broken well or other insufficient source within 2km, but were forced to travel farther due to the current situation.

Scattered about Ambovombe are 25 borne fontaines, but not all of them are in working order. There are also 17 basins, but not all of those are working either. Proprietors for the borne fontaines are responsible for selling water, but 75% of what is charged goes to AES for maintenance purposes.

Water trucks are also an option for obtaining water, but they are expensive. AES water trucks only arrive upon request, cost about 150,000 MGA, and take one week to arrive. While interviewing in one of the far southern villages, I was informed by the people there that there was another group called Antokomaintso that also brings water trucks to the village and only charges 100,000 MGA. Each truck carries approximately 6,000 liters of water.

Quality:

From interviews, most of the people of Ambovombe understand that their water is not good quality because children and Malagasy from elsewhere get sick with stomach aches and diarrhea from it. Yet because they have been drinking this water for most or all

of their life, they claim to be used to the quality of the water and as such have lower expectations of water quality.

At the *Centre de Santé de Base* (*CSB*), a health institution primarily for children and pregnant women, the doctor I spoke with informed me that of the children who visit the CSB for treatment, 18% of these children have diarrhea, one of the principal health implications from poor quality drinking water (Rabemiandrisoa 2013). He also said that although he encourages and explains the importance of treating drinking water by means such as *sûr eau*, a hypochlorite solution that is relatively accessible and used to sanitize drinking water, few people will change their ways and begin treating their water. Amusingly, he admitted that he does not treat his own personal water, but the water for the CSB is treated with sûr eau.

From interviews, most do nothing to improve their water quality. If anything, they allow the water to sit or hang so dirt and other particles can settle to the bottom of the container (Fig 10).

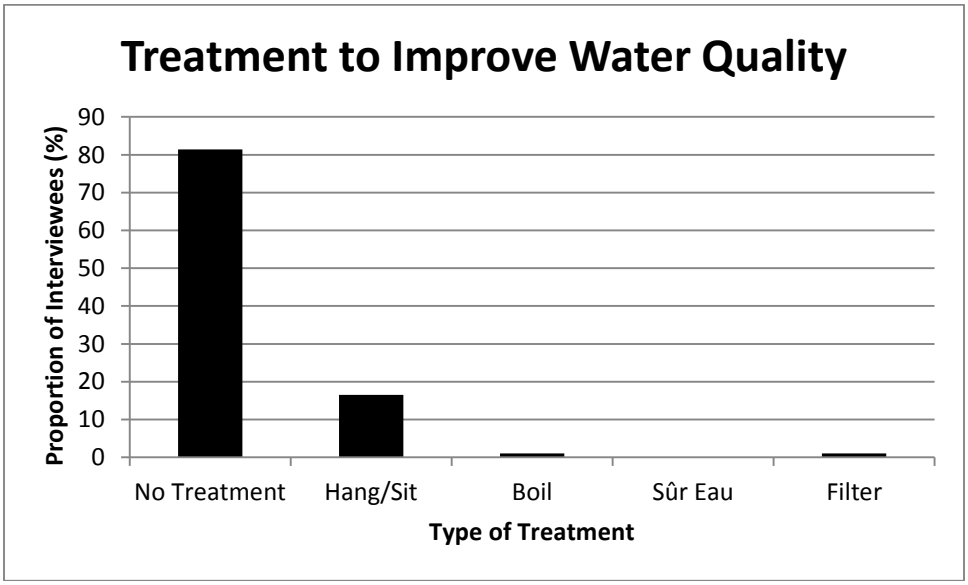

Figure 10: Drinking water treatment by percentage of interviewees (N=97)

Only one man that I spoke to claimed to boil his water before drinking it, but even then, he only boiled his water when he was sick. Two interviewees, including a school cook in one of the villages, said that they filtered the water, straining it by using a cloth such as a *lamba*, a common garment worn by women around the waist. None of the interviewees responded that they use sûr eau.

Overall perceptions of water quality appeared to be somewhat favorable, but interviewee responses about quality were often related to appearance and taste of the water, using terms such as sweet, clean, dirty, or salty, and as such didn't necessarily reflect the true conditions of the water (Fig 11).

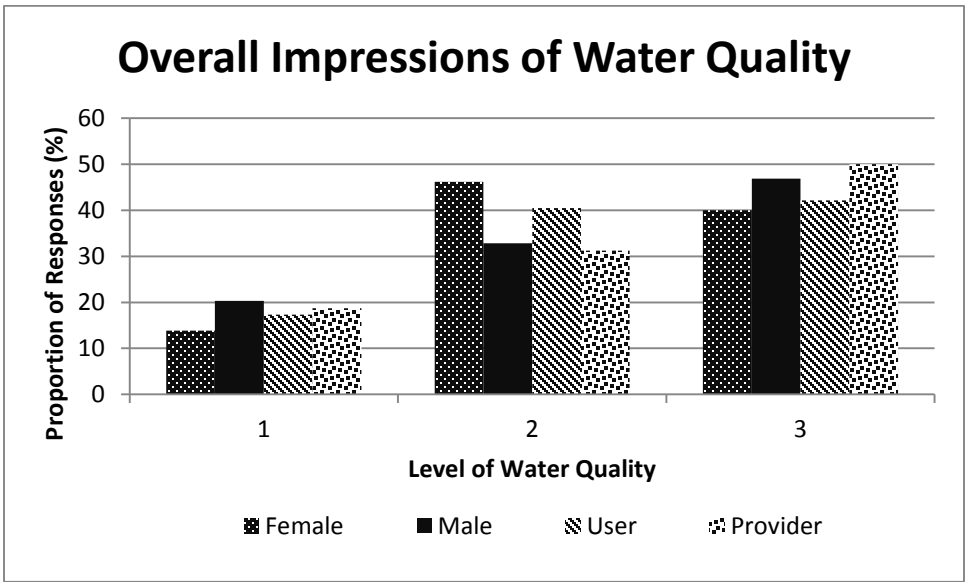

Figure 11: Proportion of interviewee responses for females (N=65), males (N=64), users (N=121), and providers (N=16) when asked to describe their water quality. A 1 reflects "dirty" or "salty" water, a 2 reflects uncertainty or temporal fluctuations in quality, and a 3 reflects "clean" or "sweet" water. Note that some interviewees had multiple responses due to using multiple water sources so the number of responses here are greater than the number of actual interviewees.

Most commonly for wells, quality depended on the well that was used and the time of year it was used (Fig 12).

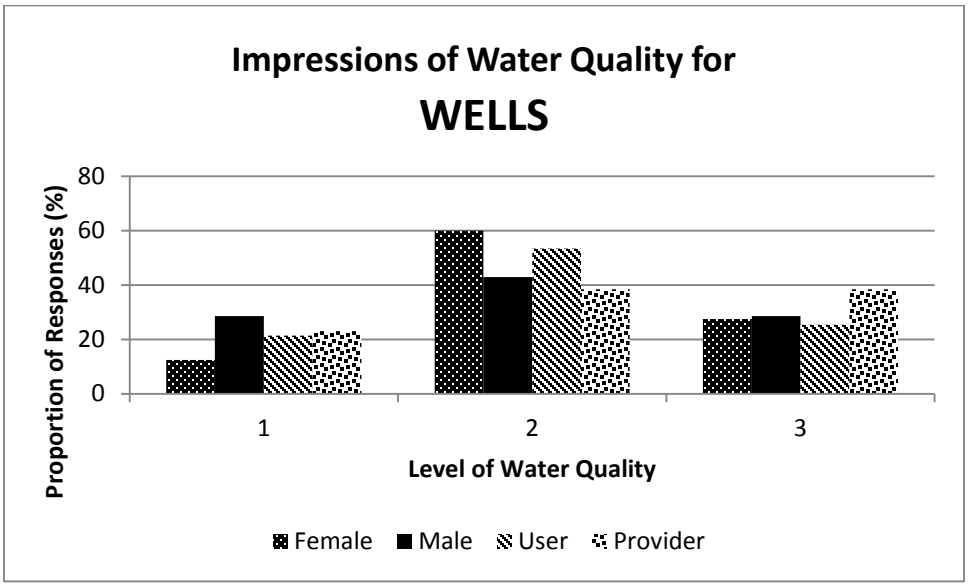

Figure 12: Proportion of interviewee responses for females (N=40), males (N=42), users (N=75), and providers (N=13) when asked to describe the water quality at the wells they use. A 1 reflects "dirty" or "salty" water, a 2 reflects uncertainty or temporal fluctuations in quality, and a 3 reflects "clean" or "sweet" water.

At times, the well water might be salty and at others it might be sweet. Also, wells with cemented walls and basins were viewed as much cleaner than those without cement. Water sources that used rainwater such as impluviums and rainwater catchment systems were particularly favored for their good quality which was believed to be better than wells or oxcarts because of the natural filtration of the earth that made rainwater more pure (Fig 13).

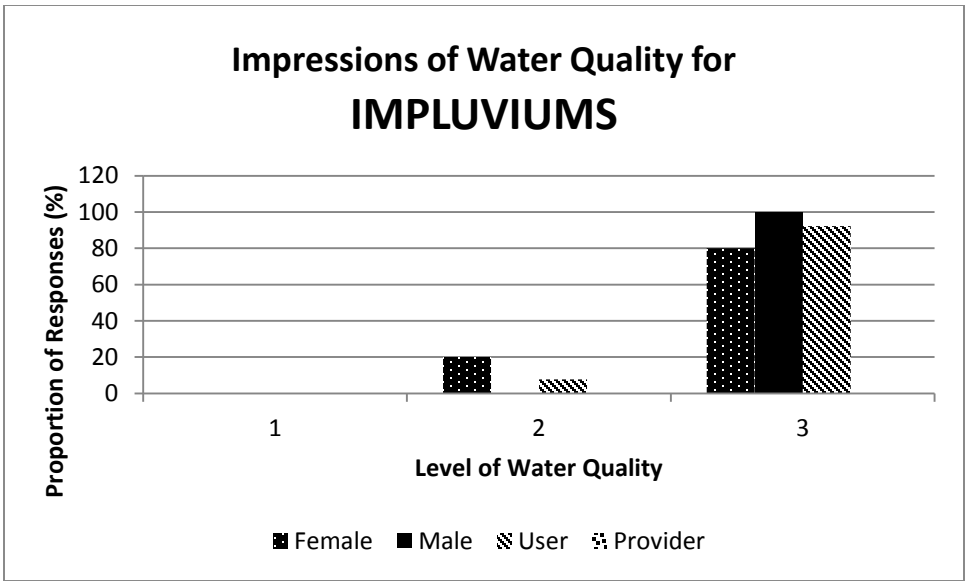

Figure 13: Proportion of interviewee responses for females (N=5), males (N=8), users (N=13), and providers (N=0) when asked to describe the water quality at the impluviums they use. A 1 reflects "dirty" or "salty" water, a 2 reflects uncertainty or temporal fluctuations in quality, and a 3 reflects "clean" or "sweet" water.

Desires for Infrastructure:

In addition to current water access and quality, I was curious about the kinds of water infrastructure that the local people wanted to see in the future. The right water infrastructure can definitely help with improving access to drinking water as well as quality. This question was difficult for some interviewees to answer, but others typically desired improvements to their current water sources. For instance, those who own or use wells without cement or basins wanted to have the wells cemented and basins for storage. Basins and cement for wells were the most popular desires, followed by the desire for impluviums. Those who relied on oxcart vendors coming to their village wished for more oxcarts vendors. Others wanted to see taps in their homes. In the end, all users simply wanted reliable and accessible water.

Providers on the other hand, did not want to see much improvement with water infrastructure because they depend on the current situation for their living. Oxcart vendors rely on the dry season and difficult access to water in order to make a living selling water. In the event of water development, JICA's 2004 report suggests that water vendors be placed as monitors at community water-supply sites to help amend the loss of jobs (JICA, 2004).

Discussion:

Ambovombe is easily recognized as the most water scarce area in all of Madagascar. These People of the Thorns have certainly earned their name by persisting in this unforgiving landscape through hardiness and resourcefulness. Climate, geography, hydrology, politics, and economics have and continue to influence Ambovombe's access to water as well as their water quality. Only by understanding the many complex factors involved in water access/quality can water scarce and insecure places like Ambovombe find effective and sustainable solutions to their water needs.

Seasonality:

Predictably, seasonality proved to play a primary role in water access and quality. During the dry season, water sources that depend on rain such as impluviums, rainwater catchment systems, and natural systems like rockwater, rivers, and puddles are insufficient to meet the needs of the people. Those who normally use such sources must travel elsewhere to other sources, buy from oxcart vendors, or request water from water trucks. These alternative sources are often more expensive and farther away, causing women and children, who traditionally are the ones that obtain water for the family, to walk longer distances and sacrifice time that could be spent on other activities.

In the wet season, when water is more plentiful, prices are much lower than in the dry season and in times of drought. Price is important, but with such an essential commodity, many are willing to pay whatever is necessary to get what they need. Still, when prices are higher in the dry season, people must employ coping strategies such as spending cutbacks, fewer showers, and using raketa as a source of water for livestock, and during extreme scarcity, for people as well.

During the wet season, water quality was considered to be much better because wells were somewhat replenished, removing the salty aspect of the water. Also, other sources such as rainwater in impluviums, rockwater, and rainwater catch systems, were made more available. Due to the natural filtration of water for these sources, such water was also perceived as cleaner.

Quality:

The water in Ambovombe is likely contaminated with pathogens, and due to its geology and its proximity to the ocean, the water is turbid and often salty. Unfortunately, during this study I did not have the resources to measure and record the water quality directly. Upon arriving to Ambovombe in a taxi van, one of the first rains of the season touched the land, leaving large puddles in the road. It was shocking to witness locals taking large spoons and cups to drink the water straight from the muddy puddles. The road there is all sand making the puddles incredibly turbid. Still, men, women, and children alike stripped down to bathe or play in the puddles. One cow was also observed drinking water from the same puddle it was urinating in, directly adjacent to a puddle that children were playing in. Such sights are real eye openers to the true scarcity of water in the Ambovombe area, the sacrifices that the people there make, and the extremes that become norms.

Poor quality drinking water can negatively impact health, often causing illnesses such as diarrhea. Although physical tests of water quality were not performed in this investigation, diarrhea is one of the most common symptoms of infected water. Unsafe water, sanitation, and hygiene contribute to 60% of deaths in children with diarrhea (Stevenson et al 2012). According to the CSB, 18% of the children that visited the center experienced diarrhea. Ambovombe locals may claim that they are accustomed to the water quality, but other Malagasy, such as a couple from Ifotaka that were interviewed, experienced stomach aches and diarrhea which were attributed to the poor quality water.

In terms of quality, many of the Malagasy interviewees laughed when asked if they treated their water by using sûr eau (a commonly found hypochlorite powder used to sanitize water) or any other means, because to them, they were used to the water, so using sûr eau was considered an unnecessary expense and something that only the fragile *vazaha* ("stranger" in Malagasy, typically in reference to white-skinned foreigners) needed.

Despite that Ambovombe's drinking water is recognized to be of poor quality, interviewee overall perceptions of water quality appear skewed, reflecting a favorable view of drinking water (Fig 11). However, this is due to the fact that water quality perceptions for all responses by all interviewees, which included a diverse array of

sources, were used in Figure 11 to illustrate overall perceptions. This fails to obtain a true representation of the perceptions of water quality from the Ambovombe area in general since it combines the perceptions of many individual sources into a single group.

In addition, given traditional gender roles, typically women are more directly involved with water collection and use than men. To demonstrate the difference in genders, 14% more men in this study rated their water at a 3 than a 2 while 6% *fewer* women rated their water at a 3 than a 2, where 3 reflects "sweet" and "clean" qualities and 2 reflects uncertainty or temporal fluctuations in quality.

As mentioned earlier, there is very little organizational involvement in improving the quality of drinking water in the Ambovombe area. The most that I came across was AES's use of eau de javel with their basins in Mahavelo. They hope to use hypochlorite solution with the borne fontaines in the future, but were vague on when exactly they were planning to start that practice.

The people of the Ambovombe area are struggling with access to clean drinking water. As the director of CRS said, "l'eau potable n'existe pas [à Ambovombe]" (Simone 2013). This translates to "potable water does not exist [in Ambovombe]." This is because there is a difference between potable water and drinking water. The drinking water in the Ambovombe area is not potable; it is turbid and salty, but it is the most accessible water there is and the only realistic option for Ambovombe residents.

Access:

Beyond the water tower project that was underway at the time of this study, there are no organizational projects to improve access to water and none are planned. When asked about infrastructure, people typically wanted small, simple improvements to current water sources such as cemented wells, more oxcart vendors, or more impluviums. The main concern is reliable access to water, and although quality is important, the focus on improving water quality is not present. Still, interviewees do want good quality water, which is why they desire cemented wells and impluviums. Cemented wells decrease the amount of dirt in the water, and impluviums, which rely on rainwater, are viewed as cleaner for that reason.

A Possible Solution:

In a study by JICA, an interregional pipeline was suggested to provide water to the area (Marcus 2012). There is already a 141km pipeline funded by the government of Japan that was built in 1999 and brings water from the Menarandre River (west of Ambovombe) east to the mining town of Tsiombe then south to Cap Saint Marie on the coast (Marcus 2007). A pipe would probably be one of the best options for providing water to the Ambovombe area because it requires minimal economic input from the central government, is easily managed, and is cost effective (Marcus 2007). In fact, one study found that a pipe from the Manamholo River, which is three times farther than the Mandrare, would be cheaper because the difference in altitude would allow for gravity pumping alone (Marcus 2007). According to Marcus (2007), JICA was considering extending the pipeline from Tsiombe to Ambovombe, beginning construction in 2015, but, probably due to political reasons, such plans appear to have been discontinued (JICA N.d.). Ambovombe residents and AES claim that there is not enough financial support to construct a pipe, but the World Bank and African Development Bank appear to have the funds and interest for supporting a pipe project (Marcus 2007). This leads to the supposition that corruption and/or ineffective organization is largely at fault for the lack of resource development in the Ambovombe area.

Politico-Economic Influence:

In 2004, JICA performed a preliminary study with the intention of developing water resources in order to improve water quality and volume, reduce risk of drought, reduce the number of incidences of water-borne diseases, and improve public hygiene and sanitation (JICA 2004). Their target year was 2015 (JICA 2004), but no projects (outside of the water trucks from the 1990s) (Marcus 2007) have been implemented by JICA (JICA 2004). In 2009, a military coup led by Andry Rajoelina resulted in a transitional government that caused international aid donors to lessen their involvement in Madagascar.

In 2004, President Marc Ravalomanana began the process of decentralization by removing power from the district level and placing it at a regional level with executively appointed leaders that report to the president (Marcus 2012). When faced with the issue

of water access in southern Madagascar, the Malagasy government began focusing on building community wells and promoting private-public partnerships, with the assumption that user fees could drive a sustainable water market (Marcus 2012). However, this doesn't take into account the willingness to pay (WTP) of Ambovombe residents or the locally accepted interpretation of community. Responsibilities are handed down to the commune level of governance to develop community based natural resource management (CBNRM) programs for water, but residents identify the lowest level of government, the fokontany, as the "community" level. Marcus (2012) found that Ambovombe residents are willing to pay more for water than they did at the time if it ensured a regular supply. Income may not influence WTP in Ambovombe, but a regularization of supply would lower WTP (Marcus 2012).

A trans-regional pipeline may be inconsistent with decentralization, but there is also a power relationship at play. As General Hubert Lyautey noted in 1901, "he who controls the water controls the population" (Marcus 2007). The Ambovombe area is not rich in resources and its physical distance from the capital only contributes to it being somewhat out of sight and out of mind of the central powers. Further, a history of rule by the Merina peoples of the central highlands during the Merina monarchy and their elitism which persisted throughout French colonization has contributed to tribal feudalism between the Merina and Antandroy (Jolly, 2004). Animosities between the groups are still present today and undoubtedly play a role, however minor, in the negligence of this region.

Water Insecurity:

The United States *Environmental Protection Agency* (*EPA*) has set the maximum affordable water bill at 2.5% of *median household income* (*MHI*) (EPA 2003). 85% of Ambovombe residents live off of less than 1USD a day (Marcus 2007) so by using an MHI for Ambovombe residents of 1USD, the equivalent of 2200 MGA, table 1 shows an estimation of the percentage of MHI that Ambovombe residents spend on water per bucket. However, when water in Ambovombe is particularly scarce, residents live off of 2 buckets per household per day, which is a mere 5 liters of water, or less than 1% of US consumption (Marcus 2007). This means that Ambovombe residents are paying roughly

9% MHI for water, 3.6 times as much as the accepted maximum in the US. Such high costs for water are likely accompanied by high emotional and psychological costs for those involved.

From a social perspective, water scarcity in the Ambovombe area is a human rights issue. Water security is recognized as a basic human right in the Universal Declaration of Human Rights (Hadley and Wutich 2009). Water insecurity is commonly defined as "insufficient and uncertain access to adequate…water for an active and healthy lifestyle" (Hadley and Wutich, 2009, Stevenson et al 2012). This is a very generic, catchall definition and leans towards a one dimensional view of water insecurity that focuses on the biological needs of an individual. Unlike nutritional intake, there is not a commonly accepted measure of water intake (Hadley and Wutich 2009), but 50 liters has been more or less accepted as the daily human biological requirement for water and accounts for drinking, cooking, and sanitation in a low technology environment (Gleick 1996). Water insecurity, however, spans multiple domains such as human development, ecological sustainability, geopolitics and international relations, and vulnerability and risk (Jepson 2013). At the household or individual scale, water security is further broken into the dimensions of access, quality acceptability, and lifestyle/affect ("the emotional, cultural, and subjective experiences of water") (Hadley and Wutich 2009, Jepson 2013). Unlike measures of food insecurity, a standardized method for measuring the multifaceted issue of water insecurity remains to be developed and accepted within the scientific community.

Potential Bias:

During the interview process, terms like "sweet," "salty," "dirty," and "clean," were used by interviewees to describe water quality. These terms were quantified to reflect water quality, but they are inadequate determinants of actual water quality and act more as comparative terms to water from other sources in Ambovombe. There is also the possibility for translational and cultural misunderstandings or misinterpretations of interview questions relating to water quality.

A certain level of local/Malagasy pride may also have played a role in biasing interviewee responses. This would help explain resulting perceptions of water quality that

were unexpectedly favorable. The Antandroy have dealt with water scarcity for generations, and as the People of the Thorns, they take pride in their ancestors, their hardiness, and resistance to outside rule. It's not atypical for people, particularly men, to over present themselves or exaggerate in order to impress others or appear strong in body, spirit, etc.

A certain degree of bias is inherent to interviews and surveys. I tried to avoid any language that could influence the respondents to answer in one way or another, but by using a translator, I had less control over the wording during interviews. Water is a hot topic in Ambovombe and many are eager to discuss it, but as a foreigner I often attracted much more attention than desired, leading to multiple interviews with curious onlookers, sometimes consisting of an entire village. This unavoidable audience may certainly have contributed towards interview bias, in addition to any bias I may have contributed unintentionally as a woman and a foreigner.

Suggestions for Future Work:

This paper focuses mainly on the physical and infrastructural aspects of water access and quality in the Ambovombe area, thereby addressing those aspects of water stress and insecurity for this specific locale. Future research should use an experience-based biocultural approach that takes into account the interrelated physiological and cultural needs in the area (Hadley and Wutich 2009). From the example of other researchers in the field of water insecurity and stress, I would advise spending more time at the study site in order to gain a greater insight to intracommunity dynamics, the challenges they face, their cultural requirements, and also to develop a rapport among the community. I would then suggest conducting community meetings, group discussion-interviews, free-listing activities (where participants identify expressions or elements related to topics such as sources of stress or responsibilities, and then rank responses by importance), and interviews with selected female household heads in order to draft a survey which incorporates household demographics, income/wealth, water usage and practices, and Guttman scalograms (a series of yes or no questions that relate to the impact of a particular topic, like water insecurity, on the respondent and increase in impact severity) concerning the different dimensions of water insecurity and coping

strategies (Hadley and Wutich 2009, Jepson 2013, Stevenson et al 2012). After reviewing the draft survey for appropriateness, word choice, translation clarity, length, and structure, it can be finalized and implemented in an unbiased way that fairly represents the population.

To help minimize bias in the future, I might suggest training locals, both men and women, to perform interviews. These trained interviewers would attract less attention in public forums and minimize language, cultural, and gender-based differences that could otherwise contribute to bias.

Conclusion:

The Ambovombe area proved to be a truly unique and water insecure community. Their oxcart water market is a novel local solution to difficult access to water, but given the climate, hydrological limitations, population increases, and an uncertain future, it is unsustainable and therefore cannot be a permanent solution. NGOs and others providing aid can build wells and provide basins and borne fontaines, but these are only short term solutions. In a place such as this, where groundwater supplies essentially all of the community's water at an unsustainable rate, an alternative source of water is crucial. Without it, life in Ambovombe simply cannot persist.

Real solutions, then, are few and far between, given the hydrology of the surrounding area. Those solutions with promise will likely need to overcome setbacks and resistance from socio-political disorganization, corruption at the individual and government levels, underfunding, and even longstanding ethnic acrimony. I believe that increased transparency between groups providing aid, such as AES, and locally selected male and female leaders from the fokontany and commune levels of governance would strongly help ameliorate the connection between community and governance as well as reduce inaction and corruption, which are central woes many Malagasy have with the government. Groups like AES also need to have more oversight, by reporting to and being inspected by a third party loyal to and trusted by the people.

Less developed countries like Madagascar tend to have the most difficult time guaranteeing access to safe drinking water since they typically lack the resources and organization to tackle large nationwide projects such as ensuring potable water for all.

For a place in so much need for improved access to clean drinking water, or drinking water in general, Ambovombe is not receiving the aid it needs. Current water infrastructure is minimal and poorly maintained, and organizations are not producing much needed water projects. The people of Ambovombe are left to build and maintain their own wells, scavenge for water, and rely on a privatized oxcart water market. There is no denying that the people of the Ambovombe area are in need. It doesn't take a miracle to help their situation and provide and maintain needed water infrastructure; it takes funding, willingness, and cooperation. I only hope that Ambovombe ceases to be ignored and receives the attention and aid it so desperately needs and that this project helps future development achieve these goals.

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APPENDICES

Appendix A:

Glossary:

AES – Alimentation en Eau dans le Sud

Antananarive – the capital city of Madagascar, also referred to as Antanarivo by anglophones

Antandroy – the dominant ethnic group in the Ambovombe area

Ariary (MGA) – Malagasy currency; about 2200 MGA to 1 USD at time of study (2013)

Borne Fontaine – water source consisting of a small stone/cement structure with a faucet and sometimes a drain beneath

CARE – Cooperative for Assistance and Relief Everywhere

CBNRM – Community Based Natural Resource Management

Charette - Oxcarts

CRS – Christian Relief Services

CSB – Centre de Santé de Base

Eau de Javel – "Bleach water;" a hypochlorite solution for sanitizing water

EPA – United States Environmental Protection Agency

Fokontany – the lowest level of government; directly beneath the commune level

Impluvium – water source consisting of a gently sloping slab of concrete that funnels rainwater into a storage basin

JICA – Japanese International Cooperation Agency

Jirama – Jiro Sy Rano Malagasy; government owned and controlled company that typically provides electricity and water services

Lamba – traditional length of cloth commonly worn by women but used for many purposes

MHI – median household income

NGO – Non Governmental Organization

Raketa – Prickly pear cactus

Rockwater – A naturally occurring water source that collects rainwater in pockets of stone

Sûr eau – Common chlorine solution for purifying drinking water

UNICEF – United Nations Children's Fund

Vazaha – "stranger" in Malagasy; used to describe foreigners, especially people of Western ethnicity

WHO – World Health Organization

WFP – World Food Programme

Appendix B:

Original Interview Questions:

Villages:

Accessibility:

- Where is your drinking water source(s)?
- What type of source(s)?
- Do you pay for water?
    - How much?
- How far is it from the village/How long does it take to walk there?
- How often is water collected?
- How much water is used per day on average per person?
- Is the water source ever insufficient?
    - When insufficient, what and where are the other sources for water?
- How have you been affected by water projects by NGOs and/or AES?
- What would you like to see happen in terms of water infrastructure in the area?

Quality:

- How would you rate the quality of the water on a 1-5 scale?

1 = Very Poor (should not be consumed, may look, taste, or smell fowl)

2 = Poor (needs filtration and purification before consumed, may taste and/or look dirty)

3 = Fair (needs filtration and purification before consumed, but may appear clean or turbid)

4 = Good (suggested purification and/or filtration)

5 = Very Good (clean water free of pathogens)

- Is there a group within the village responsible for managing drinking water? (elders, women, etc)
- Do you do anything to the water to purify it?
    - If sur eau is used:
        - Where do you get sur eau?
        - How do you use sur eau?

Organisation Interviews (Alimenation en Eau dans le Sud, World Food Programme, Christian Relief Services, Centre de Santé de Base)

Note whether interviewees are male or female.

- What is your position or relationship with the organization?
- Can you speak as a representative of the organization?

Accessibility:

- What role does the organization play in providing water to the people of the Ambovombe-Androy region? / What water projects has your organization been part of in the Ambovombe-Androy region?
- Have the projects been successful and sustainable?
    - How?

Quality:

- Has water quality been specifically taken into account in these projects?
    - What are your personal or the organization's impressions of the water quality in the Ambovombe-Androy region?

- How would you rate the water on a 1-5 scale?

- Are tests taken to check the quality of the water?
  - What kinds of tests?
  - What are the standards?
  - How often are they taken?
- What future steps might your organization take to improve water quality in the area?

Individual Interviews (people selling and buying water and owners and/or users of water basins, impluviums, private wells, rainwater catch systems, and maro):

Note what type of water source and whether interviewees are male or female

- Are you a provider or user of the water source?

Provider:

Accessibility:

- Is the source personally owned or managed through Jirama or an NGO?
- How much do you charge for water?
- How many customers do you have per day?
- How have you been affected by local water projects by NGOs and/or AES?
- What would you like to see happen in terms of water infrastructure in Ambovombe?

Quality:

- How would you rate the quality of the water on a 1-5 scale?

- Do you do anything to the water that you provide to improve quality?
- Do you test the water?
- Do you do anything to your own water to improve quality?

User:

Accessibility:

- How far do you travel to reach this water source?
- Why do you come to this source rather than somewhere else?
- How often do you visit this water source?
- How much water do you get on average when you visit?
- Do you pay for the water?
    - How much?
- How have you been affected by local water projects by NGOs and/or AES?
- What would you like to see happen in terms of water infrastructure in Ambovombe?

Quality:

- How would you rate the quality of the water on a 1-5 scale?
- Do you do anything to the water to improve quality?