Document 523
ALTERNATIVES ANALYSIS REPORT

CHAPTER: Boston Professionals
COUNTRY: Honduras
COMMUNITY: Guaimaca
PROJECT: Potable Water System for Colonna, Maraquito, and Aguacatillo

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PREPARED BY
Names of report authors

Submittal Date

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Alternatives Analysis Report Part 1 – Administrative Information

1.0 Contact Information

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2.0 Travel History

Dates of Travel	Assessment or Implementation	Description of Trip
May 2009	**Assessment**	**First Trip for health surveys, water sampling and meetings with villagers and town officials**

3.0 Project Location

Longitude: 86 degrees 49 minutes, 39.13 seconds
Latitude: 14 degrees, 32 minutes, 58.30 seconds north

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Boston Professionals
Guaimaca, Honduras
Potable Water System for Colonna, Maraquito, and Aguacatillo

Alternatives Analysis Report Part 2 – Technical Information

1.0 INTRODUCTION

The purpose of this EWB Boston Professional Chapter project is to improve the quality and quantity of the potable water systems and the health of people in the villages of Colonna, Maraquito, and Aguacatillo through collaboration with the Dominican Sisters in Guaimaca, Honduras, the neighboring city to these villages.

The current system of potable water is 12 years old and consists of a 150-foot deep well with a submersible pump in the adjacent barrio of La Figueroa that includes piping to bring the water to a 7000 gallon tank in the village of Colonna, about 1 km away from the well. The water is gravity-fed from the tank to homes in the villages of Colonna and Maraquito. The village of Aguacatillo, which is the farthest from the Town of Guaimaca and the existing well, does not have any piping to its houses.

Precise data is not available on the number of homes connected to the system, but it appears to be a majority of those in Colonna and Maraquito. The system uses an electric pump; residents have told us that the cost of the electricity has restricted the use of the well to once a week. Another problem is deterioration in the piping; residents of Maraquito told us that they have not had water delivered in over a year. There may be other problems with the current system that limit its use.

On paper, the rate structure is 30 lempira per family per month. However, because families are not receiving water, it is not clear if they are paying this charge or what an affordable rate structure would be.

The system is currently run and managed by the Moncada family of Colonna; they are receiving maximum benefit from it because they live closest to the well and tank. The other residents of Colonna and all of the residents of Maraquito and Aguacatillo have a tremendous need for a new centralized public water supply system. They currently travel into the hills to get water from springs and shallow wells. Families with cars or other transportation drive to get water from a free well operated by the Baptist Church in Guaimaca.

We have included two maps of the area including a government map the greater region (Appendix 1)and schematic drawing of the town of Guaimaca, the barrio of La Figueroa, and the villages of Colonna, Maraquito and Aguacatillo (Appendix 2).

The following pages provide background information on the project and an analysis of four alternatives for providing drinking water to these communities. We conclude the report with rationale for our preferred alternative.

The four options analyzed are as follows:
Alternative 1: One well → One tank → One tap stand shared by three villages
Alternative 2: One well → One tank → One tap stand in each village
Alternative 3: Multiple Wells → Multiple Tanks → One tap stand in each village
Alternative 4: Multiple wells → Multiple tanks → Household distribution

2.0 PROGRAM BACKGROUND

Project Partners:

A. The requesting organization or NGO for this project is the Dominican Sisters of Presentation (the Mission), which has operated in Guaimaca for over 7 years. It assists Guaimaca and surrounding villages and barrios including Colonna, Maraquito and Aguacatillo with services such as a Girls' School, a medical clinic, an organic farm and a coffee co-operative.

B. The local government of Guaimaca and its Mayor (a medical doctor) have been very supportive of the project. They will attempt to provide funding and labor for the project; during our assessment trip, the Mayor committed to providing the piping and other materials for a new system. The government will also assist in setting up the village water boards, based on existing Leadership Councils from the villages that participate in the Guaimaca government.

C. Residents of Colonna, Maraquito and Aguacatillo are the most important partners in this project, because a successful, sustainable system depends on their investment of resources and sense of ownership of the system. Best practice research has concluded that users need to really feel the cost of a system in order to be invested in its success.

   In order to choose a preferred system, residents will need to understand the advantages, disadvantages and costs of the different alternatives. Financially, they will need to contribute to the initial construction with funds, labor or other resources, and commit to a rate structure that will sustain the system. They will need to form water boards and develop a management structure to operate and repair the system.

   Construction and ongoing administration of the water system will need to account for current tension between the villages resulting from inequitable water distribution from the existing system. Although residents of Maraquito helped build the system, they often receive no water from it (none in the past year), while some families in Colonna continue to receive water when the pump is operated. Aguacatillo was supposed to be included in the distribution system, but piping was never extended to the village. In contrast to the tension among different villages, our assessment trip revealed strong relationships within villages: we witnessed numerous occasions of neighbors sharing water sources they had either inherited or found themselves.

D. The University called UPI located in Tegucigalpa participated in our sampling program during the initial assessment trip and we anticipate that they will continue to be involved. They have provided assistance after being contacted through Matt Verbyla – our Honduran contact for EWB. The University has worked with several EWB chapters on projects in Honduras and was instrumental in obtaining test results for our water samples in May of 2009. Matt Verbyla works for the NGO Global Development and we hope he will also continue to be involved in the project.

E. EWB. The Boston Professionals Chapter has made a five-year commitment to provide design expertise and sufficient capital to supplement the local government's contributions to construct the initial basic water supply system.

Once the project partners have agreed on the desired option, we will use EWB procedures to design a system. During the construction phase, some funding will be available though the local government but will be supplemented through funds raised by the EWB Boston Professionals Chapter to cover the capital costs of the water project.

After construction, EWB will help train members of the local water boards formed by village residents. Our training will focus on operation and maintenance of the wells, pumps, and distribution systems. We will collaborate with the water boards to determine the affordability of the system, to ensure that sufficient funds are collected for operation and maintenance as well as for future repairs. The goal is to provide a self-sustaining system that will ensure future upgrades without the aid of EWB.

Project Location and Population:

The three villages of Colonna, Maraquito, and Aguacatillo are just outside of the Town of Guaimaca (population 15,000) within the region of Francisco Morazon, Honduras (Appendix 1 & 2). The villages are located along the unpaved main road that stretches 6 kilometers from Guaimaca through Colonna, Maraquito and finally to Aguacatillo. Colonna is 1.5 km from Guaimaca, and each village is approximately 1.5 km in length. Homes are located along the road with some clustering where families have built houses together.

Latest Population Estimates

	Number of Homes	**Population Range**
Colonna	34	204-360
Maraquito	36	216-360
Aguacatillo	15	90-150
Totals	**85**	**510-870**

Household size ranges from 6-10; the population is very young, with an average age in the low 20s. Future population growth rates are estimated at 2-3.5% annually based on regional and national studies. Local leaders note that proximity to Guaimaca, the recent provision of electricity to Colonna and Maraquito, and a reliable water source could increase the annual growth rate to 7% as it has in other villages in the area.

Existing Water Supplies:

1. Public supply: the existing public potable water supply source is a well on private land in a barrio adjacent to Guaimaca. Electric pumps deliver the water to a tank in Colonna 1 km from the source. From the tank, water flows by gravity to houses in Colonna and Maraquito. Likely due to the high cost of electricity, water is pumped to the tank only once every 7 days. In addition, there are so many losses within the piping system that the people in Maraquito have not been able to receive water since 2008. There is no piping to the village of Aguacatillo.
2. Private wells: a few facilities including the Mission and the Baptist Hospital in Guaimaca have deep wells. Some facilities make this water available to villagers, although there is no distribution system. A number of villagers use shallow wells (20-30’) on their property or on open land.

3. Surface water: the Jalán River and tributary streams flow from Guaimaca through the three villages, roughly parallel to the main road. Residents use river and stream water for washing and to water crops but not for drinking.
4. Water deliveries: some families collect water from the well belonging to the Baptist Church in Guaimaca, or have water delivered from other sources.

Water Quality, Quantity, and Demand:

Below are sampling results for fecal coliform from our May 2009 Assessment Trip. In summary, the river water is highly contaminated, shallow well water is somewhat contaminated, and the deep wells do not show contamination from fecal coliform. Water quality from the system's current well is unknown. For all sources, there is potential for contamination between the source and tap and between the tap and final use. The fact that a number of residents boil water or use chlorine drops for disinfection indicates a significant overall level of contamination, but it also demonstrates that residents have a basic understanding of how to disinfect their drinking water.

Sample #	Time	Date	Fecal Coliform (col/100ml)	Pesticides	Flouride (mg/l)	Location
SL-1	12:45	5/13/2009	Non Det.			Marie Poussepin School
SL-2	12:48	5/13/2009	Non Det.		0.17	Convent In Guiamaca
SL-3	12:30	5/13/2009	*Lost Sample*			Hospital Baptiste Well - Guiamaca
SL-4	10:31	5/13/2009	9			Shallow Well Along Road
SL-5	10:50	5/13/2009	*Lost Sample*			River Sample Maraquito
SL-6	11:40	5/13/2009	1,100	Non Det.		River Sample Colonna
SL-7	10:21	5/13/2009	15			Shallow Well at Colonna
SL-8	11:27	5/13/2009	23			Shallow Well Along Road

	Not Sampled
Non Det.	Not detected at Method Detection Limit
Lost Sample	Sample appears to be lost by the Laboratory

Water quantity is a major concern for several reasons:

- Many of the streams and shallow wells dry up seasonally (dry season is April-December).
- The flow from the public well is sporadic and it is not clear that it is sufficient to meet current demand.
- Although solid information about the existing aquifers is not available, several residents note a general drop in aquifer levels and express concern that future growth in demand will further reduce supplies.

It appears that the deeper wells have clean water and the shallow wells are generally polluted with bacteria. We do not know if there are separate shallow and deep aquifers in the area. There may be no confining layer and deeper wells are cleaner simply because of the additional distance from pollutant sources and the filtration characteristics of the ground. We hope to locate the well in the area of a fault shown on a geologic map of the area, a location that is more likely to yield more water.

There is no local database of well locations and flow. As part of our project, we may discuss with the local government the value of collecting this information and how to set up a data collection system. EWB can begin this data collection process by installing monitoring wells at different radial distances from the new supply well in order to gather data on the drawdown in the cone of depression during the initial pump test and periodically during the next few years. We are targeting the well to the area of a fault that shows up on a geologic map of the area. While this location may help achieve a well with sufficient water yield, the well influence zone may be complicated by the fault.

As part of our work, the EWB project team will look for potential sources of contamination in the well area and educate the villagers on how to protect the well area from pollutants such as used motor oil, pesticides, and fertilizers.

Design Criteria:

We use a 20-year planning period for the project. The population projection for 2030 is 1,700 people, based on an initial population of 723, a 7% annual growth rate for 5 years and a 3.5% annual growth rate for the remaining 15 years. Our initial population estimate assumes an average household size of 8.5 people.

To perform our calculations, we used a per capita demand per day of 25 gallons for drinking, cooking and washing. We estimate that current water use for drinking and cooking is 10-15 gallons per day per home. Most families are using the river water for washing. The project will not provide water for agricultural use. Based on the design flow of 25 gpcpd, the current total daily water use for all three villages would be 18,075 gallons; total daily water use for all three villages in 2030 would be an estimated 42,500 gallons.

3.0 DESCRIPTION OF COMPARISON METHODOLOGY

Our initial step in evaluating different alternatives for the project was to conduct a brainstorming session during which all potential options were vetted by the project team. The pros and cons of each alternative identified before and during the meeting were discussed and documented. The meeting revealed that each alternative was comprised of three distinct Water System Components, each with different Options:

Water System Component	Options for Each System Component
Water Source	Three Options: Modify existing well One new well shared by all villages Multiple new wells
Storage Method	Two Options: One tank shared by all villages One tank in each village
Distribution Method	Three Options: Truck delivery to homes Tap stands Piping to homes

We evaluated and compared the Options for each System Component before combining them into a complete system alternative, using the following ranking scale:

3. Most favorable;
2. Neutral;
1. Unfavorable or least favorable;
0. Not applicable (N/A).

Five different categories of criteria were identified for the preliminary screening of Options. These categories and the criteria specific to each are listed below.

A. Technical Feasibility:
   - Reliability;
   - Capacity of source;
   - Complexity of planning/design;
   - Complexity of construction;
   - Operational needs;
   - Redundancy;
   - Length of time to implement;
   - System expansion capabilities.

B. Environmental and Health Issues:
   - Potential for contamination (source to tap);
   - Potential for contamination (tap to use);
   - Ease of disinfection;
   - Potential for water waste.

C. Financial Viability:
   - Capital required
   - Operation & maintenance (how much the villagers will need to pay);
   - Operating structures (payment system);
   - Operating structures (payment dispersal).

D. Social and Cultural Issues:
   - Affordability;
   - Potential for political issues;
   - System familiarity;
   - Community acceptance (meeting expectations);
   - Sense of ownership;
   - Ease of use/accessibility;
   - Ease of maintenance;
   - Ease of management (end user).

E. Education Requirements:
   - Education required – end user;
   - Education required – water board staff;
   - Community involvement;

- Water board involvement (during planning & construction);
- Water board involvement (after implementation).

We rated each Option against these criteria, and then summed the individual ratings to determine an overall ranking of each Option. The intent of this preliminary screening was to judge all the Options within a Water System Component against the other Options using equal weighting for all criteria. For example, using this comparative methodology, we were able to evaluate separately the implementation time, operational needs and complexity of construction of each Option for the Distribution Method Component.

For the most part, the four final alternatives described in Sections 4.0 and 5.0 include the highest-rated Options. In the case of Distribution Method, a lower-rated Option, piping to homes, was included since it was particularly favorable with regard to a specific criterion. In addition to the rankings, we used feedback from the villages and local NGO leaders to develop the final alternatives presented in this report.

The analysis of final alternatives was very similar to the analysis of the components of each system. The assessment matrix allowed us to compare the advantages and disadvantages of each alternative as a whole. We assigned to each alternative a 3 (most favorable), a 2 (neutral), a 1 (unfavorable or least favorable) or a 0 (not applicable) for each criterion in the assessment matrix, which resulted in an aggregate score for each alternative. Section 5.0 explains how each alternative scored. Further definition of each criterion and the results of the preliminary evaluation of each system component are presented in the Matrix Evaluation Tool in Appendix 3.

Sustainability was not included in the assessment matrix or the preliminary evaluation because of its qualitative nature and its applicability to a system as a whole rather than to individual Options within a Design Component. Our evaluation of the sustainability of each alternative takes into account costs, technical requirements, and water available from the aquifer compared with likely water demand, and meeting the 20-year needs of the villages without affecting the quality of life of future generations. We specifically look at the following factors:

- Likelihood of short and long-term success of the project
- Long-term cost and technical sustainability
- Ability of the alternative to meet current and future water demands without significant environmental impacts.

4.0 DESCRIPTION OF ALTERNATIVES

This section summarizes the four most feasible design alternatives the EWB-Boston team has developed for a potable water system for the villages of Colonna, Maraquito and Aguacatillo.

Because the existing water system is in serious disrepair and is not providing water as originally intended, we have not incorporated it into any of the four alternatives. We assume that new water sources will be found and that the alternative chosen will provide water to all three villages. For all the alternatives, developing new water sources will require finding a suitable location for one or more wells and then actually finding water. This step may require land surveying and hydro-geologic studies. Once a well is drilled, pump tests will be done to determine its capacity.

Water quality testing will also be needed. The need for and best method of disinfection to achieve potable water cannot be determined in advance, since it will depend on the number of wells, the quality of the sources and the type of distribution system. In general, water treatment can occur either at each tank with an inline chlorinator or at the point of use in each home using biosand, ceramic, or other filters. Disinfecting the water at point of use will be more complicated with systems that use public tap stands rather than household distribution. If a piping network is used, higher costs will be associated with maintaining a disinfectant residual throughout the system.

We note in Section 5.0 that some of these alternatives are more amenable than others to expansion and improvement in the future. For example, Alternatives 1 provides a solution that is affordable now and can completed most rapidly; and Alternative 2 can be considered as a future expansion if the villages are able to provide additional resources in the future.

Alternative 1 → One well → One tank → One tap stand shared by three villages

Alternative 1 provides one well for all three villages in the most centralized and accessible location suitable for a well. A site in the village of Maraquito is preferred because of its central location; however, the precise location will depend on finding a suitable water source and land that can be acquired. In the vicinity of the well, there will be one storage tank and one public tap stand, or water distribution point, to which the residents of each village will come and collect water. Well water will be pumped into the storage tank, and will then flow by gravity from the storage tank to the distribution point.

Alternative 1 does not provide a distribution system to each village. In order to control water usage, the villages can set up a system to have water collected at certain times of the day, with monitoring by villages representatives or members of the water board. Type of disinfection (source or point of use) is to be determined.

Alternative 2 → One well → One tank → Tap stand in each village

Alternative 2 is similar to Alternative 1 except that from the storage tank, piping will be extended to each village and each village will have its own distribution point which can be monitored by its own representatives or members of the water board. Type of disinfection (source or point of use) is to be determined.

Alternative 3 → Multiple wells → Multiple tanks → Tap stand in each village

Alternative 3 will have a well in each village as well as a pump, tank and a tap stand. Each village will have its own distribution point which can be monitored by its own representatives or members of the water board. This alternative gives more control to each village's water board control over the well and water supply. Type of disinfection (source or point of use) is to be determined.

Alternative 4 → Multiple wells → Multiple tanks → Household distribution

As with Alternative 3, Alternative 4 has a well and a tank in each village. Alternative 4 does not use a tap stand in each village but adds piping for a household water distribution system. Type of disinfection (source or point of use) is to be determined.

5.0 ANALYSIS OF ALTERNATIVES

This section presents a detailed analysis of each alternative and its advantages and disadvantages. In addition, we assign a score to each alternative based on the criteria from our assessment matrix. As explained in Section 3.0, each system Component was ranked as most favorable (3), neutral (2), unfavorable or least favorable (1) or not applicable (0) with regard to each evaluation criterion. In this section, instead of assigning scores to specific system components, we assign an aggregate score to each alternative as a whole based on the six assessment categories described in Section 3.0. The following table shows the assessment categories, total possible points for each category, and how each alternative scored.

Category and Total Possible Points for Each	**Alternative 1**	**Alternative 2**	**Alternative 3**	**Alternative 4**
Technical Feasibility, 24	18	18	16	14
Environment and Health Impacts,12	10	11	8	6
Financial Viability, 12	10	10	6	4
Social and Cultural Issues, 24	17	18	19	19
Education Requirements, 15	11	11	9	8
Sustainability, 10	4	6	4	3
Aggregate Score, 97	**70**	**74**	**62**	**54**

Alternative 1 → One well → One tank → One tap stand shared by three villages (70/97)

A. <u>Technical Feasibility</u> (18/24)

Alternative 1 is the most efficient and has the lowest capital cost. As long as the single well has enough capacity, this solution is the least complex to plan, design and build. One pump will also require fewer administrative resources and lower operation and maintenance fees than a solution that involves multiple wells and pumps and/or a distribution system. If the well is located in Colonna, electricity is already available in the village to provide a power supply for the pump. If the system is located in Maraquito, the preferred central location, providing electricity to the system will be an added capital cost.

Another advantage of Alternative 1 is that only one site needs to be identified and secured for the well and storage tank. However, our limited knowledge of the aquifer and local conditions may make it difficult to determine if a single well can supply sufficient quantities of water for all three villages for the 20-year design life of the project.

A technical disadvantage of Alternative 1 is its lack of redundancy and reliability in case the pump needs to be repaired, the tank needs to be cleaned, or the water flow is reduced due to environmental conditions or overuse. Maintenance of the system by well-trained operators will reduce the risk of malfunction as well as shorten repair times.

B. **Environmental and Health Impacts (10/12)**
The use of one well and one storage tank with Alternative 1 allows for easier and less expensive disinfection. There is less potential for contamination from source to tap but more potential for contamination from tap to use, because residents are responsible for bringing the water to their homes and ensuring that their water containers are not contaminated. Most village residents are currently carrying water to their homes and are likely familiar with the risk of contamination from dirty containers. Community education will be needed to reinforce that a public tap stand from a clean water source does not mean the water will be clean at the point of use.

From a conservation standpoint, one public tap stand will likely yield less wasted water than a piping network, which has a greater potential for leaks and for excessive water consumption. Also, a system with a single tap stand will allow for easier monitoring and control of usage.

C. **Financial Viability (10/12)**
A one well, one tank system is much more affordable than a multiple well system, which is why Alternative 1 ranks high in financial viability.

A well-structured management and payment system that residents accept as fair will be essential to the financial viability of a new system. However, with one tap stand shared by the three villages, it may be difficult to implement a rate structure to ensure sufficient funds for ongoing operation and maintenance and replacement of the system at the end of its design life. For example, what if there is a difference in financial status of villagers, and all the villages are not able to invest the same amount in the initial project? What if different villages consume different amounts of water? Should the water rates take into account these differences? Who will collect the fees and manage the funds when the three villages share the system? The answers to these questions will be explored during our upcoming trip.

D. Social and Cultural Issues (17/24)
The advantages of Alternative 1 are system familiarity and affordability, and this system scores high in these two criteria.

Alternative 1 scores low on community acceptance for several reasons. First, it does not meet the desire of residents to have water access in their homes or at least in their village. Second, a majority of residents in Colonna and Maraquito have a history of water access in their homes, so it may be hard for them to accept a less convenient system than the one they had when the existing system functioned. Finally, the existing tension between the villages and the history of unequal access to water may increase the difficulty of sharing the water system.

If Alternative 1 is adopted, it will be essential to have the water boards in each of the villages deeply involved in planning and building the system. Village leaders will also need to involve as many village residents as possible.

Although developing a sense of ownership will be more difficult when one system is shared instead of each village having its own system, it is possible that their experience of unequal distribution of water in the past will encourage residents to develop a more equitable solution to their water problems. Villages will have to contribute money, labor, technical support or other resources to the project. Some of the potential issues they will face include the following: What if one village can contribute more than another? Will its residents feel more of a sense of ownership for the system and/or feel they have rights to more water? How will the water boards interact so that there is equal distribution of water? Will there be more or fewer problems in the future if these communities share the system but not all of them contributed equally? The water boards will need to determine who is responsible for running the pump and managing the payment system to deal with some of these operational issues.

E. **Education Requirements (11/15)**

Many of the social and cultural concerns noted above can be mitigated through an education program for residents about the benefits of sharing the system. Education will be needed in the following areas:

- Understanding how water usage will be measured, monitored, and controlled.
- Understanding the rate structure, accepting its fairness, and committing to fees that will finance the system over its 20-year life.
- Understanding and committing to proper operation and maintenance of the system so that it continues to function properly. This is essential to ensure the sustainability of the system and its future operation without outside involvement.

In terms of the training required for maintenance, a single pump, storage tank and distribution point presents both an advantage and disadvantage. On one hand, fewer people need to be trained, since there are fewer system components to operate and maintain. On the other hand, adequate training and good ongoing maintenance are particularly critical because the system provides no redundancy.

F. **Sustainability: (4/10)**

The sustainability of Alternative 1 will largely depend on the capacity of the aquifer and the financial capacity of residents to support operation and maintenance of the new system. A rate structure and administrative mechanisms that monitor and control water usage will be critical to the system's sustainability. In addition to the village water boards, a regional water board will be needed to perform maintenance on the well and borehole and manage the payment system and finances.

In terms of financial sustainability, Alternative 1 has the advantage of the lowest capital and operating costs. The costs of maintaining the system will be shared among the villages, with payments based on usage, population, or expected growth.

From the standpoint of water conservation and environmental impact, Alternative 1 may be the most sustainable. Research shows a tendency to overuse water when it is more readily available. The requirement to travel a longer distance to collect water results in less water consumption. In areas without developed sanitation systems (i.e., no sewer collection and treatment system), using less water and producing less wastewater reduces environmental degradation.

Alternative 2 → One well → One tank → Tap stand in each village (74/97)

A. **Technical Feasibility (18/24)**
In terms of technical feasibility, this solution is slightly more complex than Alternative 1, but still provides a quick and low capital cost system.

Alternative 2 presents the same costs and technical challenges as Alternative 1in drilling a well. If the well is located in Colonna, electricity is already available in the village to provide a power supply for the pump. If the system is located in Maraquito, the preferred central location, providing electricity to the system will be an added capital cost. The distribution system is more challenging and costly because it involves laying pipe from one storage tank and bringing gravity-fed water to each village. The complexity of the system is increased due to the requirement for a secure site in each village for a tap stand.

Concerns about reliability in case of reduced well capacity, and redundancy when service needs to be interrupted for repairs are the same as with Alternative 1.

B. **Environmental and Health Impacts (11/12)**
As with Alternative 1, the one well and one storage tank approach creates less potential for contamination from source to tap. Alternative 2 further reduces the potential for contamination from tap to use because there will be less travel time from tap to use. Having a tap stand in each village makes possible a village-based disinfection system and also could increase the control that each water board has over water use.

C. **Financial Viability (10/12)**
Alternative 2 may provide a more acceptable way to share a one well one tank system since each village has control of its own supply point. Alternative 2 scores higher in this category than Alternative 1 because three separate payment systems may reduce tension between villages related to sharing a single distribution point and rate structure. It also scores higher than Alternative 1 because separate financial systems would already be in place in case wells were ever installed in the other villages.

D. **Social and Cultural Issues (18/24)**
A distribution point in each village reduces the distance people have to travel for water, thereby making the system more convenient. Having a separate distribution point for each village even though the well and tank are shared may ease some of the political tension and debate over who controls the system. On the other hand, having three distribution points from a single storage tank could introduce the same issues Colonna and Maraquito have now: that is, one village might use the water more often and leave insufficient supply for others. The water boards will have to determine how to share the water equally among the three villages so that every family has access to water at scheduled times. One regional water board in addition to the village boards may help with communication and decision-making around these issues.

Alternative 2 may lead to a stronger sense of village ownership of the water system, because each village will have its own tap stand and be responsible for developing its own payment collection system and operating schedule. The water boards will have to determine how each village is going to contribute to the digging of the well and borehole (including location) and where the tank will be located. After the borehole and well are ready, each village will have to help lay the pipe to its own tap stand. This involvement and additional financial commitment may help ensure that every village takes ownership of the system and supports its ongoing maintenance.

E. **Education Requirements (11/15)**
Most requirements for community education described for Alternative 1 apply to Alternative 2. In addition, this system will require education on the maintenance of the piping system to each village. The goal of education will be to teach the skills residents need in order to operate and maintain the system for its design life without outside involvement.

F. **Sustainability: (6/10)**
The sustainability of Alternative 2 depends on creating a long-term solution in which water is distributed to all three villages. Its technical sustainability will largely depend on the capacity of the aquifer and the ability of residents to fund, operate and maintain the new system. The village and/or regional water boards will need to decide together how to monitor water use and how to divide among themselves the operational and maintenance work. The regional board might best be equipped to perform regular checks on the well, pump and gravity-fed distribution system, with the village boards collecting payments and ensuring that each village tap stand is functioning properly.

A rate structure and administrative mechanisms will have to be developed to monitor and control water usage. Alternative 2 will likely require village water boards to monitor use at the distribution point and a regional water board to develop a system to share the water between villages, perform maintenance on the well and storage tank, and manage the payment system and finances.

In terms of cost sustainability, Alternative 2 ranks somewhat lower than Alternative 1 because of the cost of additional piping and tap stands.

In villages like Colonna, Maraquito and Aguacatillo without developed sanitation systems, using less water and producing less wastewater reduces environmental degradation. Education about sanitation, environmental pollution, and water conservation would be able to mitigate some of these long-term concerns.

Alternative 3. Multiple Wells → Multiple Tanks → Tap stand in each village (62/97)

A. Technical Feasibility (16/24)
Alternative 3 has the advantage of providing more redundancy and reliability in case of a problem with one well, if villages are willing to share their water sources. Multiple wells also reduce the required production from each well, which could help preserve water levels in the aquifer. Three completely separate systems also allow for easier monitoring and control by each village.

Alternative 3, however, is considerably more complex than either Alternative 1 or 2. Three wells will require surveying multiple sites in different villages to determine suitability for a well and availability of the land for a public system. Additional well drilling will be needed to determine the borehole and well location. Also, pump tests and water quality analysis will be needed for three wells. Three individual systems may also make operation and maintenance more difficult since technical resources may not be as easy to share.

B. Environmental and Health Impacts (8/12)

A storage tank in each village allows for disinfection of the source in a manner similar to Alternatives 1 and 2. As with Alternative 2, the potential for water contamination from tap to use (i.e., carrying water from the well to houses) is greatly reduced by having one tap stand in each village. Compared to a system that distributes water to each home, the potential for water waste is reduced by having a single tap stand at each village.

C. Financial Viability (6/12)

Alternative 3 is at a financial disadvantage for several reasons. The estimated capital required for three wells, three pumps, and three tanks with tap stands in each village is significantly higher. The goal of Alternatives 1 and 2 requires the extension of electricity to Maraquito. Alternative 3 requires extending electricity to Aguacatillo as well, and investing capital funds in three transformers instead of one. In total, the amount of labor and capital investment required may triple, which will increase both EWB fundraising time and the time needed to build the system. These disadvantages are particularly important given the immediate need for clean water.

Operation and maintenance of a more complex system also presents higher costs and user fees as well as significant management challenges. For example, with each village responsible for the disinfection of its tank, there is a greater possibility of the tank not being disinfected if there are financial constraints in that village. Given the small number of users, electricity costs to power three separate pumps could be onerous.

On the other hand, having an entire system within a village allows each water board to manage its own funds and to more closely measure and control usage.

D. Social and Cultural Issues (19/24)

Since every village will have a well, a tank, and a tap stand, the potential for political dissent among villages is greatly reduced. Alternative 3 also ranks higher in terms of ease of use with a tap stand in each village. As noted above, community water boards will also have more control over the treatment system, usage and overall administration and maintenance of the system.

Due to both high capital and maintenance, Alternative 3 scores very low on affordability, one of the most important social and cultural criteria.

Alternative 3 does not offer any advantages in terms of system familiarity, ease of maintenance and management. Although residents in Colonna and Maraquito may be used to wells and tanks like those in the existing failing system, few of the residents in any of the three villages are likely to be familiar with maintenance of pumps, tap stands and disinfection systems. Affordability and system familiarity may be reflected in ownership issues, since residents may not have a sense of ownership for a system they can't afford to use or in which they had no active participation in developing because of its high cost. It is essential that the system chosen by the villages be one which they understand and can afford to develop and maintain.

Contrary to Alternatives 1 and 2, where ownership across villages is the main issue, ownership issues for Alternative 3 revolve around individual village ownership of the project. Since this alternative will have higher costs as well as more technical complexity, residents of each village will need to contribute more resources to the development of the project: labor, food and accommodation for workers, money, or construction supplies. With a more complex project, it is even more essential that residents are involved in its development from the very early stages and that they understand how it functions, in order to ensure their commitment to fund and maintain it for 20 years.

E. Education Requirements (9/15)

Training the water board to maintain and administer the entire system will be more complicated than with Alternatives 1 and 2. Although all village residents don't have to learn exactly how the pump and water distribution system will work, members of each village water board have to understand the system very well. A complete understanding of the system includes the mechanics of gravity-fed distribution systems, the electronics of pumps and their connections, the maintenance of piping and tap stands. Education about system maintenance needs to cover training for retrofits and maintenance of the system, establishing a maintenance team to regularly check each village's distribution system, and buying spare parts to fix leaks or malfunctions in the system. Measuring and managing water demand and usage are other important topics for education.

A positive aspect of Alternative 3 may arise from the involvement of village water boards and residents during and after implementation. If the system is located in each village, it will be much easier to train more residents and easier for the water board to maintain it and control overusage of water. Participation by the entire village in the development of the project can be a significant boost towards a strong sense of village ownership.

F. Sustainability (4/10)

The sustainability of Alternative 3 depends on providing a long-term solution in which each village has full control over its own water source and distribution and treatment system.

Regarding cost sustainability, Alternative 3 presents a challenge to implement a successful rate plan for each village to operate, maintain, and eventually replace the well, pump, storage tank, and distribution system. In general the cost to maintain the system throughout the next 20 years will be higher by having wells and tanks in each village. Residents will need to pay higher user fees, which may present challenges to many families.

The environmental sustainability of Alternative 3 is difficult to predict. Three wells and tanks mean that people will have regular and more frequent access to clean water. It has been shown in the literature that proximity to and greater availability of water can reduce a community's sense of its value and can lead to waste of water. This could result in villagers using water for uses other than those intended (e.g. irrigation of crops) and an increase in per capita water demand, which could eventually reduce the amount of water available from the aquifer. In addition, in areas where there is no wastewater infrastructure, using more water and producing more wastewater increases environmental degradation.

Alternative 4. Multiple Wells → Multiple Tanks → Household Distribution (54/97)

A. Technical Feasibility (14/24)

Similarly to Alternative 3, this system provides more redundancy and reliability for the villages and decreases the water demand for each well. However, the complexity of design, construction, implementation and operation and maintenance are much greater for three separate systems that includes a home water distribution system. Not only does the village have to provide its share of labor or materials to drill the well and build a storage tank, it also has to provide piping and faucets to every household. The distribution system also requires significantly more land surveying, and it is not clear if piping to all homes is feasible, given the rolling terrain.

Maintenance of the system is more complicated with a home distribution system since the piping needs to be monitored and pipe repairs made regularly. Additional land acquisition for the pipe routes is also required. Finally, building a village distribution system raises the possibility that houses farther from the village storage tank will receive less water than those closer to the tank.

B. Environmental and Health Impacts (6/12)
Contamination from source to point of use is reduced under Alternative 4, since water is conveyed directly to homes. However, the integrity of the piping system has to be maintained to ensure there is not contamination from inflow. Disinfection at the water tank in each village remains the same as Alternative 3. The potential for water waste is greatest with Alternative 4. Without metering or intrusive vigilance, it is very difficult for a water board to regulate household consumption if each home has its own faucet.

C. Financial Viability (4/12)
The capital required for the wells and tanks are similar to Alternative 3, except that the capital investment required for a water distribution system (pipes, pumps, faucets) increases with household distribution. Furthermore, the village water boards may encounter problems with residents when determining responsibility for maintenance and repair of the water distribution system, including the pipes and the faucets in individual homes. Not only are overall costs to the village higher because of construction and overall system maintenance, but they are also higher for households if each one treats its water at point of use and maintains and repairs its own faucet and internal piping. The ability of each water board to measure water use, manage water use and collect user fees based on consumption is reduced since each household is able to use as much water as it wants.

Electricity costs for Alternative 4 are very similar to those for Alternative 3. It will be necessary to provide electricity for the pumps to send water to a storage tank in each village as well as a transformer so that power from the grid can be used for the pumps.

D. Social and Cultural Issues (19/24)
Similar to Alternative 3, household distribution from separate systems scores high in community acceptance and in preventing political disputes between villages. Residents will gladly accept and adapt to having water available in their homes. However, village water boards will have less control over water distribution and will be less able to measure usage and collect funds based on usage by individual households under this alternative. This could cause more issues within villages if adequate distribution to downstream houses cannot be maintained.

The affordability of Alternative 4 scores lower than the other systems, due to a larger water distribution system. It does not offer advantages over other alternatives relative to to system familiarity, ease of maintenance and management. As with Alternative 3, many residents in Colonna and Maraquito might be used to wells and tanks like the current failed system, but few of the residents in any of the three villages are likely to be familiar with maintenance of pumps, tap stands and an entire water distribution system.

In addition to the issue of ownership of the project by individual villages, Alternative 4 adds questions related to the ownership by each household. These include: Who fixes the faucets and point of use system - the water board or the household? Who pays for this type of maintenance? Who controls the water - the household or the entire village? What if some residents start using well water for irrigation? What will happen when households of the same size use more water than others? Should they pay more, and if so, how much more?

If all households have water in their homes, all should contribute to the development of the system. However, not all of them can contribute equally. Should they all have equal access to water? These questions can only be answered by the villagers and the village water boards.

E. Education Requirements (8/15)

Education and training requirements for this system are more extensive and require the participation of more people than do other alternatives. This fact is both an advantage by involving more village residents in their water system, and a disadvantage by requiring participation by all households and not just the village's water board.

All residents will need training on how the water distribution system works, including piping and treatment, particularly treatment at the point of use. As with Alternative 3, it will be necessary for each village water board to have a complete understanding of the water distribution system. A complete understanding of the system includes the mechanics of gravity-fed distribution systems, electronics of pumps and their connections, and maintenance of piping and tap stands. Education and training about system maintenance needs to include the following: retrofits and maintenance at each village, establishment of a maintenance team to regularly check each village's distribution system, acquisitions of spare parts to fix leaks or malfunctions in the system. It will also be necessary to train households or a separate team to regularly monitor water quality and perform technical checks in every home.

In addition to technical training for all residents, education for the water boards on measuring and managing water demand and usage will be particularly important with a household distribution system.

F. Sustainability: (3/10)

The sustainability of Alternative 4 requires a long-term solution in which water is distributed to each home, with each village having full control over its own water supply, distribution and treatment system. Each village will disinfect its water at the storage tank, at the household point of use or at both locations. The village water boards will have to develop the technical and administrative infrastructure needed to control distribution of the water as well as pay in full for ongoing operation and maintenance. The technical sustainability of three separate systems with long runs of distribution piping and faucets at each home is questionable.

In addition to the challenges of a multiple well, multiple tank system as in Alternative 3, this system has the challenge of sustainability due to household distribution. Regarding cost sustainability, the high cost of maintaining the piping and faucets for each household and the inability to meter water at each home will make it even harder to implement a successful rate structure to operate the system. Determining who is responsible for paying for and performing retrofits and/or repairs to the household taps makes this alternative even more complicated.

As with Alternative 3, the environmental sustainability of Alternative 4 is difficult to predict. Having household distribution could mean that people become carefree about water usage, thereby increasing demand without population growth or actual need. This could result in using water for other uses than intended and possibly reducing the level of water in the aquifer. In areas where there is no wastewater infrastructure, using more water and producing more wastewater often increases environmental degradation. Of all the alternatives evaluated, this one presents the greatest risk in this area and the greatest need for education about sanitation, environmental pollution, and water conservation.

6.0 DESCRIPTION OF PREFERRED ALTERNATIVE

Each alternative presented in this report has its advantages and disadvantages. While it is difficult to determine the best option without knowing additional details, every effort was made to understand this unique situation and the challenges it presents. Once the hydrology, detailed topography and the characteristics of the local aquifer are known, the options may change or, at the very least, their rankings may shift.

It is important that the residents of the three villages take ownership of this project and are therefore involved in the decision making process. This chapter of EWB is looking to use this 523 report as a way to organize and present the gathered information to the residents of the three villages that are a part of this project. The Honduras team believes that community involvement in this process is the best way to ensure that this project and all of its parts will be useful for the residents for the entire life of the estimated 20 year period.

The preferred alternative, based on the analysis performed to date, is Alternative 1. Alternative 1 provides one well for all three villages in the most centralized and accessible location suitable for a well. A site in the village of Maraquito is preferred because of its central location.

This alternative does not provide a distribution system to each village and ranks lower than Alternative 2 because Alternative 2 is more convenient in terms of accessibility: he physical location of each tap in relation to the individual homes is more convenient.

Alternative 1 is the preferred alternative because:

1. Of all the alternatives, this is the easiest to construct and requires least amount of infrastructure.

2. It is the first building block to Alternative 2 which is ranked higher than Alternative 1.
   a. It must be implemented as the first step before Alternative 2 can be constructed.

3. A secure site has not been officially acquired, but our NGO in Guaimaca is confident a site in Maraquito will be secured in the near future.

4. The proximity of the working farm (run by the local NGO) to the future site of the well is ideal. The adjacent farm is considered to be a more secure site, as theft and vandalism must be considered.

5. It is centrally located.
   a. The village of Maraquito is between Aguacatillo and Colonna.

6. The cost is lowest.

7. This model can act as an indicator for the success of future projects.

For the reasons stated above, the Boston professional EWB Chapter Honduras Team believes that Alternative 1 is the best option. After we present our findings to the community, this assessment may change, since it is the community that will ultimately be left in charge of the system. Any changes or modifications to this plan will be incorporated into the final plan at a later date and will be submitted for review with the National Chapter of EWB.

Draft 3 Feb 23 Document 523 - Alternatives Analysis Report

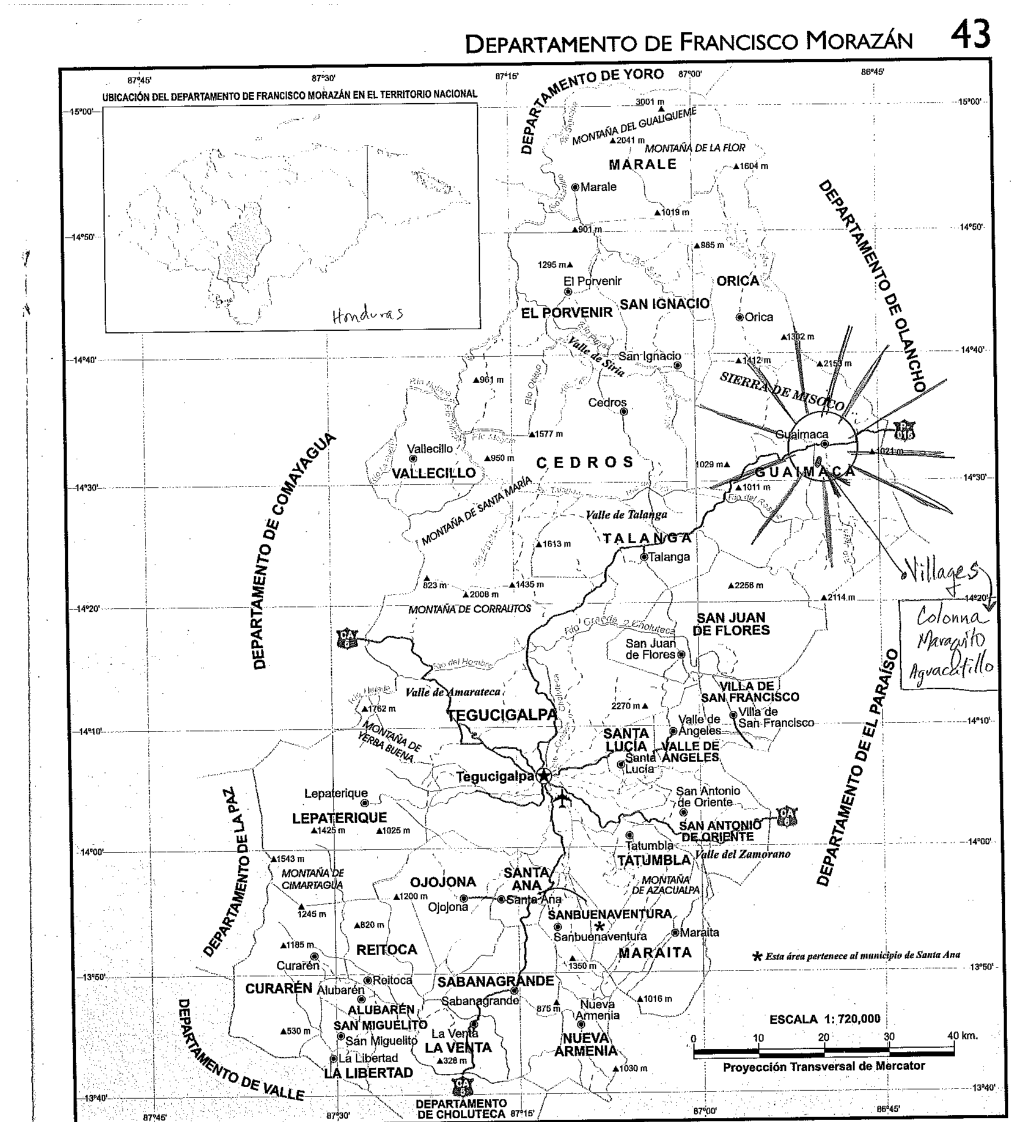
Boston Professionals

Guaimaca, Honduras

Potable Water System for Colonna, Maraquito, and Aguacatillo

Appendix 1:

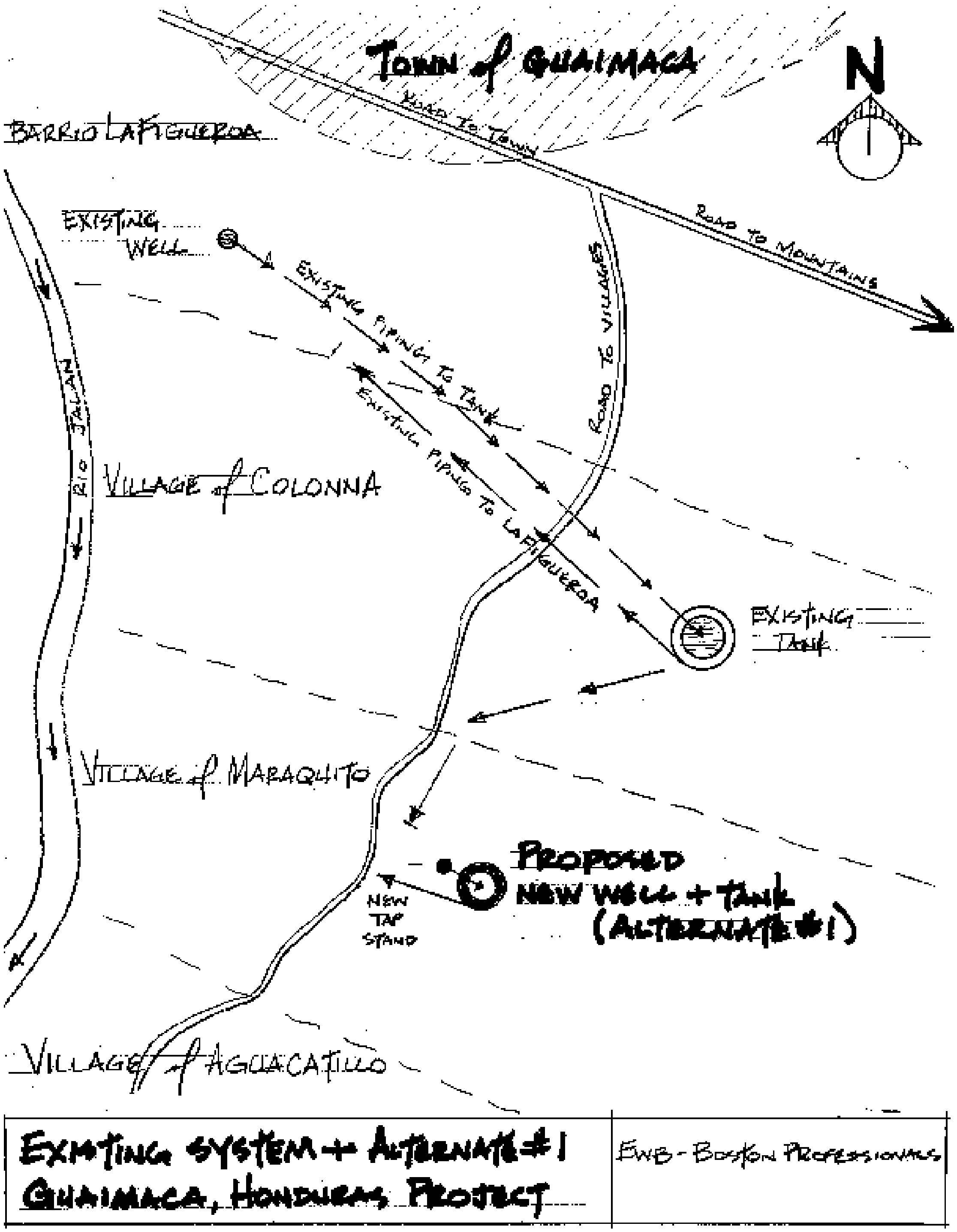
Map of the region containing the city of Guaimaca. We have highlighted the city and its villages of Colonna, Maraquito, and Aguacatillo with a circle and arrows (upper right of the map).



Cabecera Departamental: Tegucigalpa, M.D.C.
Extensión Territorial: 8,619 Km^2.
Población Actual : 1,132,266 habitantes.
Fecha de su Creación: Junio 28 de 1825.
Municipios (28): Alubarén, Cedros, Curarén, El Porvenir, Guaimaca, La Libertad, La Venta, Lepaterique, Maraita, Marale, Nueva Armenia, Ojojona, Orica, Reitoca, Sabanagrande, San Antonio de Oriente, San Buenaventura, San Ignacio, San Juan de Flores, San

Sierras: de Misoco (2,155 m).
Montañas: del Gualiqueme, de la Flor, de Santa María, de Corralitos, de Yerba Buena, de Azacualpa, de Cimartagua.
Valles: del Zamorano, de Amarateca, de Talanga, de Siria.
Ríos: Grande o Choluteca, Guayape, Agua Caliente, Jutiapa, Netapa, Grande, del Hombre.
Parques Nacionales: Montaña de La Flor, El Chile, Misoco, Montaña de Corralitos, La Tigra, Yerba Buena, El Uyuca.
Límites:

Appendix 2:
A schematic map of the villages of Colonna, Maraquito, and Aguacatillo. The map includes the existing well and piping; in addition to our preferred alternative choice location for a future well system.



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Appendix 3:
The matrix that we developed in order to determine the ranking and evaluation of the different components of a water distribution system.