DESIGN OF POTABLE WATER SUPPLY SYSTEMS IN RURAL HONDURAS

By

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This report "Design of Potable Water Supply Systems in Rural Honduras," is hereby approved in partial fulfillment of the requirements for the Degree of MASTER OF SCIENCE IN ENVIRONMENTAL ENGINEERING.

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I would like to thank the Rivera family for taking me into their home and including me in their lives. Having their support made everything else I was trying to accomplish in Honduras much easier. Their generosity made me feel at home, and their patience made it possible for me to learn Spanish and gain an understanding of the Honduran culture. I would also like to thank Abelardo and the staff at ACPH for helping me to integrate myself into the communities, giving me the opportunity to learn and supporting me with all the projects I worked on.

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Abstract

According to a 1993 USAID report, malnutrition and a lack of access to potable water and sanitary facilities are the main factors in Honduras' low life expectancy (66 years) and high infant mortality rate (59 in 1000 live births). For many communities easy access to potable water is seen as an essential building block to making other improvements in their village. Potable water supply systems allow community members to maintain a higher level of hygiene by making it easier to bathe, wash clothes, and prepare sanitary food and beverages. The water can also be used in pour flush latrines that are more sanitary than pit latrines and have fewer odor problems. A water supply system often improves education in a community as better teachers are more likely to accept positions and stay longer in communities with easy access to potable water.

The objective of this report is to provide the most important information required to design a gravity flow potable water supply system. Practical information is drawn from the author's three years of experience working as a Peace Corps volunteer in Honduras. Technical information, including design constraints and plans developed by the Honduran government institution, National Autonomous Service of Aqueducts and Sewer Systems (SANAA), have been translated and formatted to be easily referenced and reproduced in the field.

Included, is an explanation regarding the use of an Excel spreadsheet program written by Peace Corps engineers to facilitate the design process. An example of one of the author's designs and proposals shows the different components of the Excel program's output. The actual program is available in English and Spanish on the Michigan Tech Masters International website**:** (http://www.cee.mtu.edu/peacecorps/resources.html). Helpful information is included on the topics of water quality analysis and Honduran laws concerning water projects.

The final section of the report discusses the need for appropriate technology that can be easily applied in developing countries. It also illustrates an alternative design for a break pressure tank that does not require the use of GI pipe or door valves.

This report is designed to help engineers who plan on working with gravity flow water systems to understand the most important components of the design process. The figures and Excel program output can be used to help convey design specifications and costs to community members, builders and funding agencies.

1.0 Introduction and Objectives

Gravity flow water supply systems have been built for over 4000 years to transport water from natural springs, rivers and lakes to where it was needed for domestic, industrial, and agricultural purposes. Initially the systems were designed using open channels either dug into the ground or constructed of stone or wood above ground. Open channel systems are the simplest and least expensive way to transport water, and are still used regularly in agriculture.[1] Two major drawbacks to these systems are; the water is open to the air making it susceptible to contamination between its source and destination, and it requires that the flow always be downhill. Today, with the capability to manufacture sealed pipe made of either metal or plastic, energy can be stored in the form of pressure. This makes it possible to transport water over hills between the water source and its termination. The change in altitude to which the flow can be raised is dependent on the amount of pressure the pipe can resist and the losses due to friction along the inner walls of the pipe. Since the mid-1500s the option of using a force pump has also been available to transport water.[1] Pumps can be used to raise water from streams or lakes to communities, or from ground water reservoirs to the surface. The use of pumps usually decreases the amount of pipe needed for the water project, but also increases the maintenance costs and requires easy access to fossil fuel or electricity to power them.

In many rural villages located in underdeveloped countries, easy access to electricity and fossil fuel is not available. This leaves communities with the option of building a well with a hand pump, a rain collection and storage system, or a gravity flow water supply system using a spring or stream located above the village. This paper concentrates on the design of gravity flow water supply systems, utilizing Honduras as an example. The paper is directed toward engineers doing development work in underdeveloped countries. It can also be used by social workers and health care professionals helping rural communities organize the design and construction of aqueducts.

Chapter 2 provides background information on how the economy, politics and health conditions of Honduras effect the construction of water supply projects. Chapter 3 explains the steps required to complete a feasibility study, topographic study, design, and proposal. The design Section 3.4 explains how to use an Excel spreadsheet developed by Peace Corps engineers to perform the required calculations and drawings. Chapter 3 also includes practical advise about how to stay within design constraints gained through the author's experience working as a Peace Corps Volunteer in the Masters International Program of Michigan Tech University.

The Appendices have been added to provide detailed information on various topics covered in the report. Appendix A entitled, "SANAA's Rules of Design for Rural Aqueducts," is a translation of a manual written by engineers employed by the Honduran government institution, National Autonomous Service of Aqueducts and Sewer Systems (SANAA).[2] In Appendix B, new detailed SANAA design plans have been translated and divided into sections that can be printed on a standard printer rather than a plotter machine. Information on the World Health Organization's guidelines for drinking water and an example of a Honduran water quality analysis are shown in Appendix C. Also included are practical recommendations for how to interpret water quality analysis. Appendix D contains Honduran laws that pertain to water systems and practical strategies for resolving problems with landowners effected by water projects. A summary of the work I did during my Peace Corps service is located in Appendix E and an example design completed using the program explained in Chapter 3.4 is illustrated in Appendix F.

2.0 Background

2.1 Geography and Demography

The Republic of Honduras is a Central American country with a land area of 112,492 square kilometers, about the size of Ohio, and a population of 6 million people. Its population density is around 5.5 acres per person, which is the second lowest in Central America after Nicaragua.[3] The country has access to both the Pacific and Atlantic Oceans through the Gulf of Fonseca in the south and its Caribbean ports in the north. Tegucigulpa, is the capital of Honduras and is centrally located in the Department of San Francisco Morizan. San Pedro Sula, located in the northern Department of Cortez, is the country's second largest city, and is considered to be its industrial center. The coastal plains of the north have the most productive land for agriculture and have recently become the preferred location for foreign owned assembly factories. This is due to the availability of cheap labor and the existence of tax free zones near the coastal towns of Puerto Cortez, Tela and Ceiba.[4] The beautiful coral reefs and beaches of the Bay Islands, located in the Caribbean Sea, are the most prominent tourist locations.

The eastern Departments of Gracias a Dios and Olancho are the most sparsely populated and make up a large part of the 40% of land that is still forested in Honduras.[5] To the southeast lies El Paraiso, famous for housing the Contras in the 1980s. The southern Departments of Choluteca and Valle were devastated by flooding during Hurricane Mitch in 1998 and are characterized by their extremely hot and dry climate. The western departments bordering El Salvador are covered with steep mountains and are fairly inaccessible. The tall, lush mountains of Santa Barbara and Copan provide the most production of coffee, the number one export of Honduras.[6]

Honduras is a fairly ethnically homogenous country, with *mestizos,* a mixture of indigenous, African, and Spanish races, making up 90% of the population. The other 10% is made up of small minorities of European, African, Asian, Arabic and indigenous Indian groups.[7] The Roman Catholic Church is the oldest and most powerful church in Honduras. Since the 1980's Protestant churches have been growing rapidly, the majority being of Fundamentalist or Pentecostal Evangelical denominations.[8] Both churches play a large roll in the social structure of Honduran society. Many churches receive funding from outside Honduras and use it to sponsor social service programs that work to improve education and public health in rural areas.

Figure 2.1 Map of Honduras

Source://www.lib.utexas.edu/maps/americas/honduras.jpg

2.2 Economy

Agriculture is the number one sector of both labor force and Gross Domestic Product.[9] Although some have made fortunes through the sale of coffee, bananas, and other exports, the majority of rural farmers practice a low-production form of subsistence farming. This is in part due to the geography of Honduras. Four fifths of the country is composed of mountainous terrain that is difficult to farm. This difficulty is due to the presence of low-grade rocky soils and steep hillsides highly susceptible to erosion.[10] Of the quality arable land in the valleys, it was estimated in 1988 by the Central Bank of Honduras that 48 percent had been converted to cattle pasture and a large percentage of the rest has been dedicated to plantation crops destined for export.[11] This distribution of land has left many Hondurans farming small plots on hillsides or working for large landowners at minimal pay. Currently only one of every 5 farms is tilled by its owner, the rest are tilled by share croppers, renters or squatters.[12] In a study done by the Secretariat for Coordination and Budget revealed that in 1994, 75.6% of the households fell below the poverty line.[13] This level of poverty has lead to short term planning. The farmer's future vision encompasses only four months time; the length of a growing season. Despite the efforts of many governmental and non-governmental organizations to promote sustainable agroforestry and organic farming techniques, many farmers opt for the short-term benefits of the slash and burn technique.

This economic situation has a large effect on the organization and construction of water projects. Many times the community can only provide manual labor. For large projects every man in the village can be called upon to work up to 100 days to earn the right to use the water system. For many families this is not financially feasible as fields left uncultivated will result in food shortages. Without food, the hard labor involved during construction will cause villagers to lose interest quickly and the project will not advance efficiently. This problem can be dealt with in two ways. One way is to plan the construction for a time of year when there is little farm work to be done. In Honduras, this is in the summer dry season of March, April and May. Another option is to solicit funds from an organization that donates food to communities working on development projects. In Honduras the best organization to contact is the World Food Program, Programa Mundial de Elimentos (PMA). Other considerations to take into account when writing a proposal is whether the community has access to the tools and transportation necessary for the project. A lack of proper tools will result in poor workmanship that will create maintenance problems in the future.

2.3 Government and Political Environment

Since 1981 Honduras has slowly been changing from a government dominated by military rule to a democracy with civil elections. In 1948 Dr. Tiburcio Carias gave up the presidency after a 16-year dictatorship. This was followed by 3 decades of military rule including several elections and coups. Between 1981 and the present, Honduras has had civil elections. Initially the people voted for just the political party and President they wanted in power and the party filled the rest of the government positions. In the last two elections this has changed and Hondurans can now vote for the president, the Governor (representative of the department), and mayor of their municipality. Unfortunately, Honduras has become a good example of the fact that elections alone are not a good indicator of whether a healthy democracy exists within a country. The elections of the 1980's were shrouded in controversy: deals were cut between the two major parties, president Cordova tried to change the constitution to extend his term, and the CIA and USAID were accused of tampering with the system by withholding economic aid to effect the outcome of elections. After electing several presidents that have not lived up to the people's moral expectations, many Hondurans are disenchanted with politics. This was apparent in the 1993 elections as the voter abstention rate reached 35 percent.[14]

Although the fairness of the election process has improved substantially throughout the 90's, due to an overall low level of education, the people have been slow to respond. In general, the people of Honduras have not forced politicians to clearly define their ideology or plans for the country. Instead, Hondurans have tended to vote for personable strongmen who run campaigns based on imagery.[15] Many Hondurans feel that both the Liberal Party (LP) and National Party (NP) are basically the same, leaving little hope for change in the future. Because the majority of government jobs including those within the school system are politically filled positions, many people support the political party in power, in order to maintain their jobs. This has caused families who have benefited from a particular party to become loyal to only that party regardless of other candidates running for election. Children grow up as "Liberals" or "Nationalists" without really even knowing what policies the two parties represent. Once one party is elected, government officials discriminate against towns that have traditionally supported the rival party. Although other parties have been formed representing radically different views to those of the NP and LP, because of a lack of money their campaigns have not been influential enough to make a difference. One of the more successful of the small political parties is the Social Democratic Innovation and Unity Party (PINU), which has held a few seats in the National Congress since the early 80's. In 1991 this representation played a key role in a military-reform bill written in order to bring the military under civilian control.[16]

Politics can have a large effect on the success or failure of a water supply project. One example is in the process of obtaining written permission to cross properties and use water sources. This process requires the help of the Mayor of the municipality as agreements have to be made with landowners with much more power than community members. At times a lawyer is needed if it is impossible to come to an agreement with the landowner. Because large landowners contribute money to campaign funds, sometimes Mayors are reluctant to carry out the law for fear of losing their support. Other areas affected by politics are the different government institutions that supply materials for water projects in rural villages. The villages that these groups choose to work in are related to the political importance of the town and campaign promises of the party. Ironically, the majority of the funding for these groups is from USAID and other international aid groups who expect that the materials be distributed on a need basis. Projects that are in progress during an election year are also subject to changes in agreements, as many government positions are changed, bringing to power people with different goals and political connections. Despite these problems, in general, water supply projects are very popular among politicians because they are visible improvements that they and their political party are remembered for.

2.4 Health Conditions

Health conditions in Honduras are some of the worst in Central America. According to a 1993 USAID report, malnutrition and a lack of access to potable water and sanitary facilities are the main factors in the countries low life expectancy (66 years) and high infant mortality rate (59 in 1000 live births).[17] A health study done in 1991 by the Ministry of Health indicated that 63 percent of all Hondurans suffer from some sort of malnutrition.[18] Children that suffer from severe malnutrition are not able to physically and mentally develop to their full potential, causing them to struggle academically. In 1994, 20 % of children under five years old were underweight, and 9 % were underweight at birth.[19] It was estimated in 1988, by the Minister of Health, that around one third of the country had easy access to potable water.[20]

Improving health conditions is the number one goal for many poor rural communities. Because of the added convenience that comes with the construction of a water supply system, it is usually easier to organize the community around water projects than other health-oriented undertakings. For this reason it is important to take advantage of this motivation to teach the community other important sanitation information. The importance of using latrines, chlorinating or boiling drinking water, and keeping hands and skin clean can all be easily related to water systems. Most all water supply system tanks in Honduras are built with calcium hypochlorite tanks on top to disinfect water before it enters the community. Unfortunately, many communities do not know how to properly use the tanks, resulting in over application, causing the community to reject the use of calcium hypochlorite all together. For this reason it is important that the community plumber be physically shown how to apply the calcium hypochlorite and taught why it is important to the health of the public. A large government campaign initiated after a Cholera epidemic in 1992 was successful in promoting the importance of disinfecting drinking water in rural villages. Unfortunately, since this time, fear of Cholera has subsided and the importance of disinfecting the water has faded in the minds of the people. Many communities neglect their responsibility to buy and properly use calcium hypochlorite. Informing the community on how diseases are spread can also be helpful as many rural villagers do not know what causes them to become sick.

2.5 Peace Corps Honduras

Peace Corps is a human resource organization that was started by John F. Kennedy in 1961. The three goals of Peace Corps are: to help interested countries in meeting their need for trained men and women, to promote a better-understanding of Americans in other countries, and, by telling stories to friends and family back home, give Americans a better understanding of other cultures around the world. It is possible for volunteers to solicit small amounts of funding directly from Peace Corps, but in general Peace Corps does not consider itself to be a financial aid organization. Volunteers are expected to present proposals to NGO's and government institutions to fund their projects.

Peace Corps Honduras has had over 5000 volunteers serve in country since its inception in 1963. It is currently one of the largest Peace Corps programs with over 200 volunteers. Volunteers in Honduras work to organize projects in municipal and economic development, water and sanitation, health and agriculture. The majority of volunteers are placed in the south of Honduras due to the harsher conditions and poverty of the region. After 8 years of not placing a volunteer in the northwest, I was placed in Santa Barbara . My job was to help provide potable water systems for new communities of people displaced by Hurricane Mitch, and also established communities that had outgrown the capacity of their water sources. Although Peace Corps was well known in the area, it was necessary for me to reestablish contacts and create relationships with new non-governmental organizations in Santa Barbara and San Pedro Sula. As a water and sanitation volunteer, I was responsible for helping to organize water boards to manage and maintain existing water systems, educate people about general sanitation practices and water borne diseases, and provide technical assistance by elaborating feasibility and topographic studies, designs and proposals. The water and sanitation sector of Peace Corps Honduras is somewhat unique in that it is divided into two parts, engineers and technicians. The engineers are placed in larger towns and are responsible for providing technical support for the technicians who are placed in smaller villages. I worked with technicians on all phases of the projects, but in general I was responsible for the design and proposal of the project and the technicians were involved with organizing the community and doing topographic studies.

The main counterpart organization I worked with was the NGO, Popular Cultural Action of Honduras (ACPH). ACPH is a small low-budget organization that has been funded by the Catholic Church of Holland since the early nineteen sixties. The principle goal of this organization is to help organize communities by capacitating leaders to evaluate and solve problems. This is done by teaching them how to organize community meetings, prioritize local problems, and elaborate proposals to solicit funding from other NGO’s and government institutions. They also participate in a literacy and home study program that allows children and adults who do not have close access to a high school the opportunity to earn a degree.

When several communities identified not having easy access to potable water as their number one concern, ACPH solicited a Peace Corps volunteer from the water and sanitary sector. Upon arrival to Santa Barbara I was provided with a desk, computer, telephone, fax and transportation to the ACPH sponsored communities. They helped me to get to know community members and were able to give background information about the current health and sanitation problems of each community. During my service I worked on twenty feasibility and topographic studies, 15 designs and proposals, and the construction of 5 gravity flow water supply systems.

3.0 Methods

The following section is designed to be used as a practical guide to organizing, designing and constructing a gravity flow potable water supply system. I will draw upon personal experiences during my three years as a Peace Corps volunteer in Honduras to give specific examples of possible problems to consider during the organizing and planning of a water project. I will also reference technical information provided by the Honduran government waterworks organization, the National Autonomous Service of Aqueducts and Sewer Systems (SANAA). This information is provided in a document entitled "SANAA's Rules of Design for Rural Aqueducts." A translation of this document is located in Appendix A. I will also explain how to design a water system with the help of an Excel spreadsheet program developed by Jason Neilson, former Peace Corps engineer, in coordination with other Peace Corps engineers in Honduras.

3.1 Choosing a Feasible Project

Determining the feasibility of a project requires careful examination of environmental conditions and the measurement of several basic parameters. Because these parameters are very important to the success of the project, it is recommended that the engineer or technician be present for as many of the measurements as possible. He or she should also do a personal assessment of the watershed rather then relying on the opinions of local community members. Rural villages are often desperate to bring any type of support possible into their communities. Leaders are well aware that if the project is deemed unfeasible no money will be invested into their village. This strongly influences the way the engineer's inquiries are contested!

3.1.1 Initial Altimeter Check

In Honduras there is a large demand for the building of water systems. Many times villagers have ideas of possible water sources that could be used, but do not know specifics about the quality and quantity of the water available. Because of this, the first step to any water project is to go out to the community and see if the project is feasible. An altimeter reading should be taken at the highest house in the community, at the source and any obvious high point in between along the proposed conduction line. Because changes in weather cause a change in barometric pressure, which will effect the altimeter readings, these measurements should be taken in quick succession. If it is necessary to walk long distances between measurements the engineer should take a measurement at a reference point in the morning and later repeat that measurement at the end of the day. If times are taken with each altitude measurement, by knowing the change in time and the change in altitude of a fixed reference point, it is possible to do a linear interpolation of the other measured points to adjust for the change in barometric pressure do to weather patterns. It is a good idea to investigate and measure all the possible water sources in the area so that later, when all the information has been gathered, they can be compared to choose the best option for the community.

3.1.2 Flow Measurement

It is also very important that the flow of the stream be measured during the end of the dry season to obtain a measurement of the absolute minimum flow the community will receive. In many situations there are large differences between the winter and summer flow of water sources. This is especially true for small streams that are composed of a large amount of run-off water. One of the projects I worked on was for a community called *El Diviso*. This community completed a water project 18 years ago but only received water for one year. This was due to an engineer who took a winter measurement of the flow and tried to predict the summer flow using this measurement. Due to deforestation above the water source, a large change in flow occurs between the winter and summer months in this particular watershed. The shortage of water in the summer caused conflicts between the participating communities resulting in the expulsion of *El Diviso* from the project. To be absolutely sure the minimum flow is being measured, the engineer should watch the weather closely and do as many feasibility studies as possible at the end of March and the beginning of April. The entire design is dependent on this measurement, therefore if the community already has this data, the engineer should validate that a trained person was present to oversee the measurement. To make the flow measurement, a 6-foot PVC pipe with a 3-inch diameter is inserted into the stream. A small clay dam is made around the pipe until almost all the water can be channeled into a 5-gallon bucket. The flow is calculated by timing how long it takes to fill the bucket, and is generally expressed in gallons per minute (gpm).

In order for the project to be considered feasible the measured flow needs to be enough water to fill the needs of the community for twenty years, all year around. The calculation of the design flow for the conduction line is outlined in Appendices A.3 - A.5. If the measured flow is greater than or equal to the calculated design flow, the size of the water source is acceptable.

3.1.3 Water Quality Test

The quality of the water and watershed are also critical to the feasibility of a project. One should not depend on looks alone, at times crystal clear water is contaminated with herbicides and pesticides. If possible, the best time to test the quality of the water is during the beginning of the rainy season. This is because the first storm of the rainy season flushes out contamination accumulated over the dry season. To have the water tested in Honduras an appointment is made with a local lab and sometimes the lab will request that special sterilized bags be used for the fecal coliform bacteria tests. Emptied purified water bottles can be used for the physical and chemical tests. Approximately six hours is allowed between the time the sample in taken and the time it is delivered to the lab. Because the quality of the water is dependent on the condition of the watershed, it is equally important to do an investigation of areas above the source to check for agricultural activities and small clusters of houses. Human activities can cause bacterial contamination, due to the excrement of area workers, physical contamination due to erosion problems caused by unsustainable agriculture and chemical contamination from applied fertilizers and pesticides.

In practice there are very few pristine watersheds left in Santa Barbara. For the most part this is because coffee grows better at higher elevations, which drives farmers to plant coffee to the tops of the mountains. Almost all the water quality tests I saw were contaminated with some fecal coliform bacteria. Two examples of water quality analysis are shown in Appendix C.6. If the bacteria levels are fairly low this problem can be rectified by disinfecting with a solution of calcium hypochlorite at the tank. In addition to this protective measure, farmers should be educated on the effect they have on the health of local communities and the importance of protecting watershed areas. If slash and burn techniques are used in the area of the water source, government authorities should be notified and area farmers should be educated on Honduran laws protecting natural springs, streams and their watersheds. For a list of applicable laws see Appendix D. If the water quality test is in accordance with the standards set by the World Health Organization, and the watershed is acceptable or can be brought to acceptable standards with a reforestation project, than the water source can be considered as a possibility for future use.

3.1.4 Permission to Use Water Source and Cross Properties

The final step in assessing the feasibility of a project, lies in the ability of community leaders to obtain signed permission from all the property owners affected by the project. Technically, this measure is not necessary, but in Honduras it has become standard practice. This is because not being on friendly terms with landowners has proven to put the lives of community members in danger.

An example of a community that has had many problems in obtaining permissions is *Monte Cristo*. This community has been drinking contaminated water for many years now. The board of directors has had the construction of a gravity flow water supply system as their number one priority since 1986. Unfortunately, lack of funds and technical assistance, as well as problems with landowners has caused the process to take a long time. In October of 2000 the community received signed permission from all but one of the landowners between the town and the water source. With the help of a fellow Peace Corps volunteer I completed a feasibility and topographic study. In November I finished the design and the community began to solicit funds from various government institutions. During this time, the landowner that had not given his permission told the community that unless they were willing to compensate him with 500,000 Lempiras ($32,258) he was not going to allow them to cross his property. He also threatened to kill anyone who entered his property without his permission.

This is clearly against Honduran law which states that water sources are owned by the republic and not by property owners. A community that has the right to use a water source within an estate, also has the right to access the water source without having this stated explicitly in the title for the property. For more details on Honduran laws pertaining to water systems see Appendix D. The next step of the community was to go to the mayor of Trinidad, who in theory is responsible for settling these disputes, and paying for a lawyer to represent the community. Because the mayor of Trinidad was a friend of the landowner, the mayor refused to help the community. At this point *Monte Cristo* went to the governor of the department who wrote a letter obligating the mayor to provide legal assistance to the community. Since then community leaders have not pressed the issue for fear of being killed by the opposing landowner.

The majority of communities in Honduras have to work out problems and address complaints from landowners. For this reason, the topographic study should not be done until the community has turned in signed permission forms from all the landowners affected. In several communities I worked in, the time and effort I spent on the topographic study and design were wasted due to disputes between landowners and community members. See Appendix E for details on the fate of the projects I worked on. In many cases the landowners request a tap along the conduction line as compensation for permission to cross their land. This is not recommended because if one tap is given, other landowners along the conduction line will hear about it and demand compensation as well. This short minded practice also will start a precedent which will cause problems for future water projects in the area.

3.1.5 Community Organization and Preparation

During the first couple of visits to the community, the engineer should be aware of the overall organizational capabilities of the villagers. To complete a water project they will need leaders that are respected, with skills in coordinating work groups. It is important that a fair system is put in place to distribute the manual labor evenly among participants. Labor can be divided by the number of jobs done by each person or by the number of days each person has worked. Good communication is imperative to keep all the participants informed about their responsibilities during the construction of the water system. A community that does not get along, or respect their leaders will have problems coordinating the large amount of manual labor involved in completing the project. Some communities are not ready to take on an endeavor as large and complex as the construction of a water project.

Organizations that have the goal of helping the poorest of the poor, run into a dilemma during the feasibility assessment of a community. Many times the poorest communities are living in unsanitary conditions for the same reasons that the project has been deemed unfeasible. These communities are not organized, do not work well together, do not get along well with surrounding landowners and do not have respected leaders with skills in organizing projects. Some development agencies, including my counterpart, consider water projects as a tool for working on improving critical organizational problems within the community. This style of development is commendable because the organization is not only investing in the water project, but also the community members themselves. Engineers working in this type of development should be aware that these projects are much more challenging to complete and will require a lot more of their time.

3.2 Components of Gravity Flow Water Supply Systems

Gravity flow water supply systems in Honduras are built with PVC pipe, GI pipe and either concrete or brick structures. The following section provides a brief description and a picture of each part of a water supply system. For more technical information, see Appendix A.6.2 and design plans found in Appendix B.

3.2.1 Micro-watershed

The micro-watershed component of a potable water supply system is the hardest part to maintain and control because normally it is owned by a number of people who most of the time are not beneficiaries of the project. Educating the public to take care of their micro-watershed, and obey current Honduran environmental laws, is a very important part of creating a successful project. See Appendix D for more information about Honduran laws pertaining to water projects. It is also important to delineate the watershed so that people know where its limits are. If a micro-watershed is used sometimes it is possible to do this by building a fence around the entire perimeter.

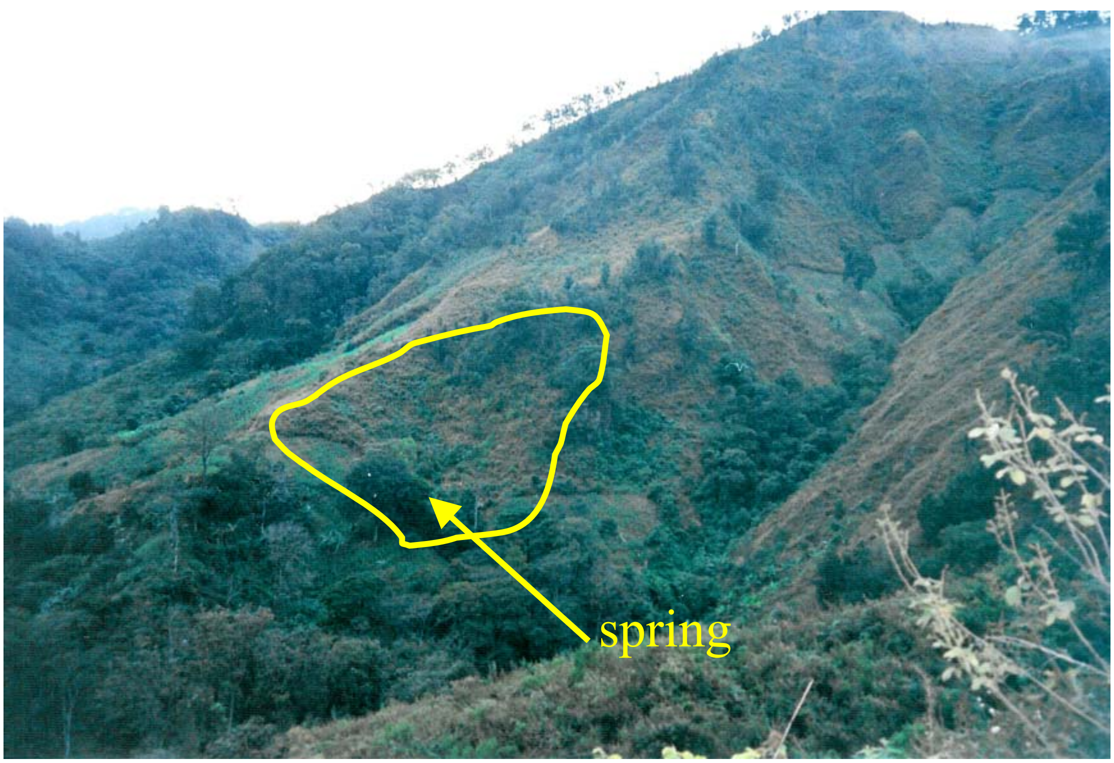


Figure 3.2.1 A typical, semi-deforested Honduran watershed with a circle that marks the area to be protected with a fence

3.2.2 Spring Box

A spring box is used when a natural spring is available to the community. The advantage of a spring box is that the groundwater never is exposed to surface ground contamination. This is because the water is captured as it is leaving the earth, and channeled directly into a pipe. When building a spring box it is important that the spring be dug-out first in order to find exactly where the impermeable layer of soil is. Once this location is found, it can be assured that the spring box is placed lower then this point so that the water will fall freely into the box. For a drawing of the proper change in elevation between a spring and spring box see Appendix B.1.5.

Figure 3.2.2 Spring box with sand filter and rainwater diversion wall

3.2.3 Dam

Dams are used rather than spring boxes when the flow of the water source varies considerably over the course of the year. This is the case with most rivers in Honduras. The advantage of a dam is that the high flow during the rainy season can easily pass over the weir without damaging the dam. The disadvantage to using a dam is that the water is more susceptible to contamination and in general carries more sediment than the groundwater that leaves a natural spring.

Figure 3.2.3 A dam built in Honduras

3.2.4 Sedimentation Tank

Sedimentation tanks are usually used in conjunction with dams because of the large amount of sediment present in river water during the rainy season. The tank is specially built in order to slow the flow of the water causing the sediment to settle out. For the tank to work properly, the plumber needs to periodically open the clean out valve to release sediment located in the bottom of the tank. Sediment in the conduction line can cause obstructions and unnecessary wear along the inner walls of the pipe.

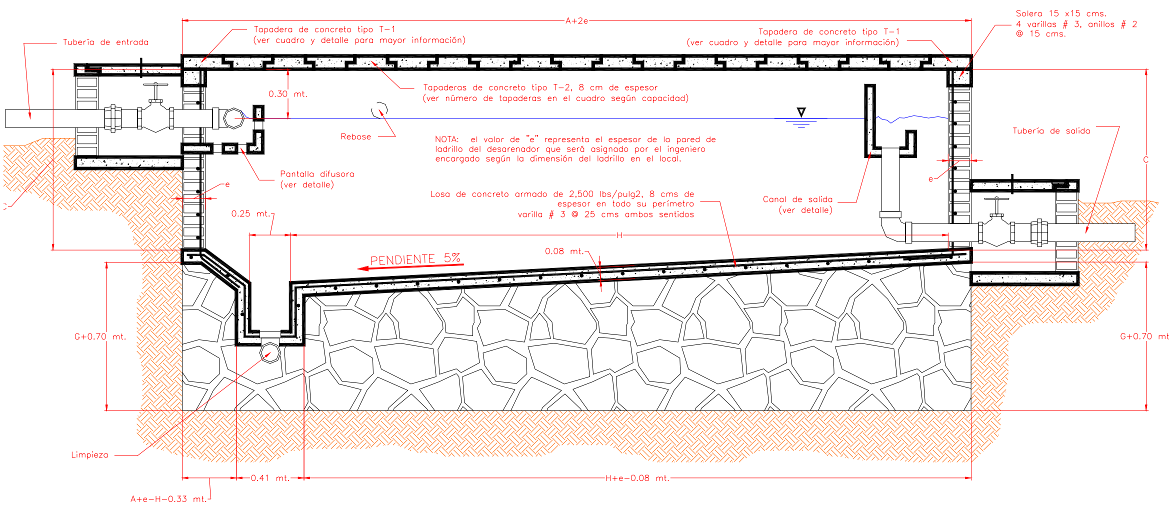


Figure 3.2.4 Profile view of a sedimentation tank

3.2.5 Conduction Line

The conduction line is the pipe that connects the intake structure to the storage tank. In Honduras the majority of systems are built with PVC pipe that is buried around 60-centimeters underground. Any area where the pipe is exposed, such as a river or rocky soil crossing, should be connected with GI pipe. PVC pipe is not resistant to high impact forces, such as falling rocks, vandals or large animals. At low points in the system clean-out valves are placed to allow the plumber to remove sediment caught in the pipe. At high points, air valves are placed to remove air obstructions.

Figure 3.2.5 The construction of a stream crossing of GI pipe, with a clean-out valve on the near side

3.2.6 Break Pressure Tank

Break pressure tanks are used to return the water in the conduction line to atmospheric pressure, and remove sediment. In general they are placed every 100-meters change in altitude.

Figure 3.2.6 Construction of a break pressure tank in Honduras

3.2.7 Storage Tank

The storage tank is used to store water at night when the demand is low, to be used the next morning when the demand is high. These tanks are usually placed around 60-meters higher in altitude then the lowest house in the distribution network. The tank site should contain a sturdy homogeneous soil so that certain areas do not settle more than others causing the tank to crack. This is especially important when building into a steep hill because the side dug into the hill tends to be more solid then the side open to the air.

In Honduras most organizations require that a calcium hypochlorite tank be built in order to disinfect the water. The calcium hypochlorite tank should be located on top of the entrance of the storage tank. As the water enters the tank, concentrated chlorinated water drops into the tank at a rate controlled by a valve, and mixes with the water. To allow for proper mixing and sufficient time for the disaffection to occur, the exit pipe should be located opposite the entrance pipe. See Appendix B.6.2 for orientation details. A common mistake in Honduras is to put the entrance and exit on the same side of the tank, which doesn't allow for proper mixing.

Figure 3.2.7 10,000 gallon storage tank built in Honduras

3.2.8 Distribution Network

The distribution network consists of the pipe and accessories necessary to connect the tank to all the houses participating in the project. If possible full circuits should be created to equal pressures in the network and create two ways for the water to reach each house. The standard taps used in Honduras can only withstand 60-meters of head. If there is a change in altitude more that 60-meters in a community, a break pressure tank with a float valve or a break pressure valve should be installed.

Figure 3.2.8 A typical water tap built in Honduras

3.3 Topographic Study

3.3.1 Route Finding

If the engineer is convinced that the project is feasible, the next step is to do a topographic study. If it is possible that the route finding will be complicated, it is recommended that a topographic map be acquired in order to investigate different possible routes. In some cases it is a good idea to walk the entire conduction line, to get an idea of how to avoid very rocky terrain and find the easiest places to cross streams. This will make the project less expensive by avoiding the use of Galvanized Iron (GI) piping, which costs three times as much as standard PVC SDR26 and is much harder to work with. The strategy of the engineer should be to take the most direct route possible without crossing valleys more than 100-meters deep. Staying within these parameters will reduce maintenance cost in the future and also allow the engineer to use less expensive PVC pipe. If it is necessary for the conduction line to climb more that 100-meters to reach the community or cross a ridge, thicker walled PVC tubing is available. For working pressure limits of various types of pipe see table A.2.6b. The conduction line should be placed along public paths and roads whenever possible to avoid problems with landowners and provide easy accessibility during construction and maintenance. When following a dirt road, the downhill side is preferable to the uphill side. When roads are refinished, tractors usually scrap the uphill side to make it wider and provide dirt to smooth out the middle. The extra dirt is deposited on the downhill side, which will further protect the piping by burying it deeper under the ground.

3.3.2 Measurement Instruments

There is a wide range of instruments available for making topographic measurements. The fastest and most high tech instrument is a global positioning system (GPS) with a built in altimeter. This method is accurate enough for most water systems, and requires less manpower then other methods. The disadvantage is, they are expensive and under some conditions are unable to receive a signal from enough satellites to triangulate a measurement. Peace Corps Honduras has bought several GPS units, but they are not yet available for use to the majority of water and sanitary volunteers. For topographic studies where there is very little change in altitude between the source and the village, the best instrument to use is a theodolite. This instrument is capable of accurately measuring long distances, but takes time to set up and is not very practical for use on rough terrain. Theodolites are also expensive and are not available to all Peace Corps volunteers. The simplest device is the Abney level. An Abney level is very practical because it is small, relatively inexpensive and easy to set up on rough terrain. Abney levels are not as accurate as theodolites, and can only measure up to 30-meter shots. For these reasons, Abney levels are best used in mountainous areas where there is a lot of rough terrain to cross, and a large change in altitude between the source and the village. The Abney level is the most widely available instrument in Peace Corps and the instrument I used for all my topographic studies.

3.3.3 Field Measurements

If the conduction line is fairly simple, and the community members are familiar with the terrain, the engineer should request that a path be chopped for the entire conduction line. This is necessary to clear the line of site needed to make Abney level measurements. If the conduction line is chopped before the study only 5-villagers will be needed to make measurements for the topographic study. If the conduction line is complex and the community does not feel comfortable chopping the line by themselves, 5 extra persons will be needed to chop vegetation in front of those measuring. It is also recommended that the engineer bring along an assistant that has previous experience doing topographic studies.

To get started, three identical sticks the height of the engineers eyes should be prepared. The engineer will use one stick to rest the Abney level on while making measurements and the others will be held by community members to mark the station in front and behind the engineer. The other two men will be used to hold each side of the measuring tape. For each station the engineer takes a front and back vertical angle measurement and a front compass measurement. If the front and back measurements are different by more then a degree, the Abney level needs to be recalibrated. The assistant is in charge of recording the measurements of both the engineer and the community member reading the measuring tape for each station. He or she is also responsible for making landmark observations, and marking each station with spray paint. For more detailed information on data to be taken on topographic studies see Appendix A.2. In order to make the vertical angle measurement, the engineer sets the target, in the site of the Abney level, on the top of the stick held at the station in front of him or her. Then by adjusting a dial, a small bubble located on the left side of the viewfinder is aligned with the target to make the final measurement. The number shown on the dial in degrees and minutes is the angle between the line of measurement and horizontal. Measurements uphill are positive and downhill are negative. A leap frog method is used in order to always have a person holding a stick in front and behind the engineer as he moves along. When the measurement behind the engineer is complete the person holding the stick behind passes to the very front, the person holding the stick where the engineer is remains there for the next back measurement to be made. To better identify where the top of the stick is in highly vegetated areas, tell the community member holding the stick in front of you to put their hand horizontally across the top and wiggle their fingers.

When measuring stations in the distribution network, mark down how many houses will be connected to each station and the names of their owners. A compass reading to the house and an approximation of the distance to the tap from the main line are helpful for creating a plan view drawing of the system. Keep in mind while choosing the location of the storage tank and branches of the distribution network that there needs to be at least 4-meters of dynamic head and no more then 60-meters of static head at each house. If possible it is always better to create full circuits within the distribution line. This causes the distribution network to equalize pressures more quickly and creates two different ways for the water to reach each house. For more information on how to use an Abney level see Brinker, RC and PR Wolf, *Elementary Surveying*, Sixth Edition, Harper & Row, Publishers, London, 1977.

3.4 Water System Design

Because all the calculations need to be repeated for every station measured in the topographic study, the design of a water systems naturally lends itself to the use of a spreadsheet program. The spreadsheet program used by Peace Corps engineers does most of the calculations automatically. It is still important that the engineer understands exactly what equations are used in the program so that he or she is able to check the accuracy of the spreadsheets output. Another reason to fully understand the program is, it will give the engineer the flexibility to customize and improve spreadsheets to fit specific designs. An example of a design made for the community, *La Colonia El Cielito* using this spread sheet program is shown in Appendix F. A copy of the actual Excel program explained in this report is located on the Masters International page of the Michigan Tech University website: (http://www.cee.mtu.edu/peacecorps/resources.html). The program is available in both English and Spanish.

The following explanation of the program is broken into spreadsheet pages that are shown in ***bold and italics***. The abbreviated titles of the columns found within each spreadsheet page are underlined.

3.4.1 Instructions (Instruc.)

The instructions page gives a brief description of how to use the various pages included in the spreadsheet.

3.4.2 Title (Title)

The majority of the title page is produced automatically from data entered into the *General Data* page. On page 1 the engineer will need to change the organization title on the top, as well as the location and telefax information on the bottom.

3.4.3 General Data (Gen. Data)

The engineer will need to fill out information next to all the titles in red and italics with data gathered during the topographic and feasibility studies. The information displayed in black is automatically calculated as the rest of the spreadsheet is completed. The numbers in green will need to be filled out by the engineer after the design is complete. The equations used to calculate this data are shown in appenices A.3-A.5. By locating the cursor on top of the small red triangle in the corner of each cell, a comment box will appear to explain how the value in the cell was calculated.

3.4.4 Conduction Line Data (Cond. Data)

All the data taken on the topographic study can be entered directly into this page. Columns the engineer needs to fill in are written in *red and italics*. In order to enter angle measurements in degrees and minutes, type the numbers in without including a decimal point. For example, to enter the angle negative 3-degrees and 0-minutes, type, -300. If the majority of a section is PVC pipe but there is a small amount of GI pipe needed to cross a stream, this extra GI pipe can be added in the far right column entitled "Extra GI."

The rest of the columns use the inputed data from the topographic study to calculate useful information for the design.

<u>Accum. Dist.</u> adds the total distance from the water source to each station.

<u>Ave.Ang</u>. takes the average of the <u>Foreword Vertical Angle</u> and the opposite sign of the <u>Back Vertical Angle</u>. This step is very important, because it reduces the effect of calibration error in the Abney level. If the Abney level is perfectly calibrated, the forward and back measurements

will be exactly the same, but will carry different signs. If the forward measurement is 10-minutes larger than the actual angle, the back measurement will be 10-minutes less then the actual angle. By taking the average of the two angles, this calibration error is reduced from 10-minutes to 0-minutes. The average angle is then converted from degrees and minutes to standard degrees by using the following equation:

$$Ang(\deg.) \equiv \frac{Ang(\deg.\min.)}{60} - \frac{2}{3} * (truncatedAng(\deg.\min))$$

where: *Ang*(deg.min.) is entered without a decimal. Ex. –3 degrees 0 minutes > -300

truncatedAng(deg.min.) is the degrees without the minutes.

Ex. 3 degrees 20 minutes > 3

Ang(deg.) is standard degrees.

<u>Terrain Elev</u>. calculates the elevation of the terrain for each station using the following equation:

$$TerrainElev. = InclinedDist. * \sin(Ave.Ang.)$$

where: *InclinedDist.* is the distance measured between stations on the topo study.

Ave.Ang. is the vertical angle explained above.

TerrainElev. Is the elevation of the terrain for that station.

<u>Direction Ang.</u> converts the compass readings from standard degrees to the degrees between north and east, south and east, north and west and south and west. This is done using a series of "if" statements. These angles are later used to calculate the projection in the N-S and E-W directions for each station.

<u>Project. E-W</u> is used to find the projection in the E-W direction of each measurement using the following equation:

$$\Pr oject.E - W = InclinedDist. * \cos(Ave.Ang) * \sin(DirectionAng)$$

<u>Project N-S</u> is used to find the projection in the N-S direction of each measurement using the following equation:

$$\Pr oject.N - S = InclinedDist.*\cos(Ave.Ang)*\cos(DirectionAng)$$

3.4.5 Conduction Line Design (Cond.)

This is the page where the most important design decisions for the conduction line are made; the size of the piping to be used and the location of break pressure tanks.

Break Pressure Tank Placement

Placing break-pressure tanks properly is one of the most important parts of a successful design. The idea is to place the minimum amount of break-pressure tanks possible, while maintaining the static head less then 100-meters and the dynamic pressure greater then zero under real flow conditions. In general, the top of a hill makes a good break-pressure tank site because the downhill side allows the water to regain momentum. Also, being in a higher location, as the dynamic pressure gradient is rotated using real flow conditions it is less likely to intersect with the top of another hill. See Figure 3.3.1 below for examples of good and poor locations for break pressure tanks, and Figure 3.3.2 for examples of the effect of real flow on the design.

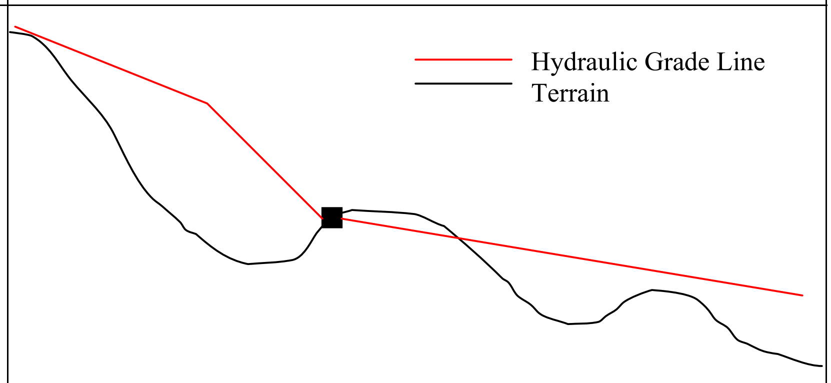
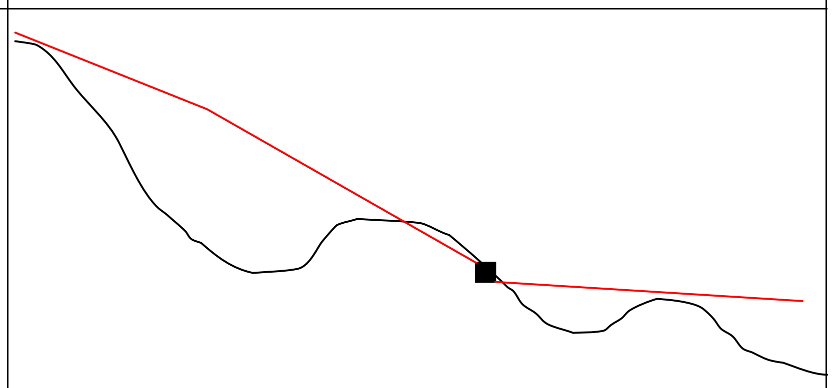
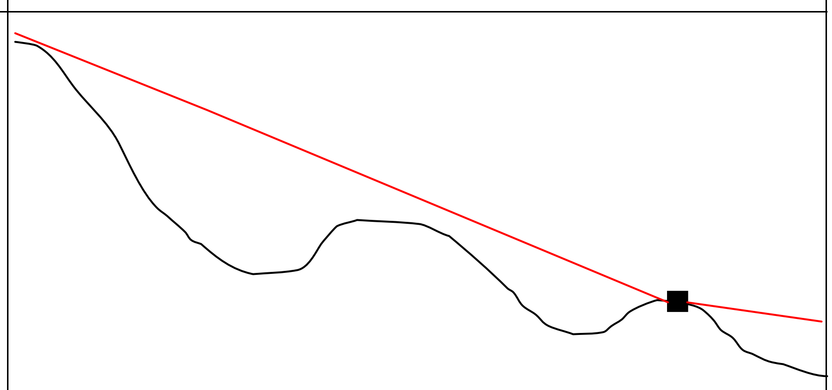
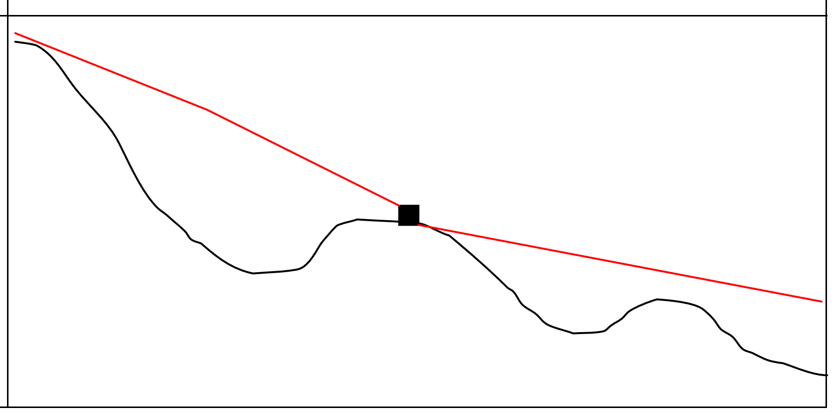
Comments	Altitude (m)	Different Placements of Break Pressure Tanks
Poor Placement The piping needs to drop in altitude after the break pressure tank in order to maintain flow.	150 50 30	
Poor Placement The hydraulic gradient intersects with the terrain under real flow conditions.	150 50 30	
Poor Placement The static head is greater than 100-meters. This will make the system more expensive because high strength PVC will have to be used.	150 50 30	
Good Placement Normally it is a good idea to place break pressure tanks on hills to avoid the problems shown above.	150 50 30	

Figure 3.4.1 Four diagrams showing the effect of break pressure tank placement on the real flow hydraulic gradient

Real Flow vs. Design Flow

In reality the flow will be more then the design flow. The design flow is calculated to have at least 5-meters of head at break pressure tanks and 10-meters of head at the storage tank. This extra head is used as a safety factor that accounts for small errors in the topographic study, added friction caused by build up on the inner walls of the pipes, and minor frictional losses in elbows and valves along the conduction line. The real pressure at the break pressure tanks and storage tank is atmospheric pressure. This means that the water system, especially for the first ten years of service, will be able to carry more water than the design flow indicates.

The maximum amount of water the system can carry is called the "real flow." In order to check if the system will work, under real flow conditions, the design flow is increased until the the head in the pipe is equal to the height the water enters the tank. When the flow is increased the pressure along conduction line decreases and the dynamic pressure gradiant rotates down toward the tank. An example of this phenomenon is shown in Figure 3.3.2. If the conduction line is crossing over hills, at times this decrease in pressure will cause the dynamic pressure gradient to intersect with the terrain resulting in negative head on the spreadsheet (less then atmospheric). This can cause a "siphon effect" in the pipe which is a health concern because it allows contaminants to enter the conduction line.

Less than atomospheric pressure can be avoided by using large pipe for the first part of the conduction line to maintain high pressure while crossing a hill and then changing to smaller pipe at the end of the conduction line to force the pressure down. When the flow is increased to real flow conditions the rotation in the dynamic pressure gradient will be small, causing little decrease in pressure. In place of the pressure lowering to atmospheric gradually throughout the whole conduction line the pressure is maintained high and then lowered rapidly only in the end of the conduction line. A small decrease in pressure as the flow is increased from the design flow to the real flow also indicates that a ecomomic design has been made, because the smallest possible pipe sizes have been used.

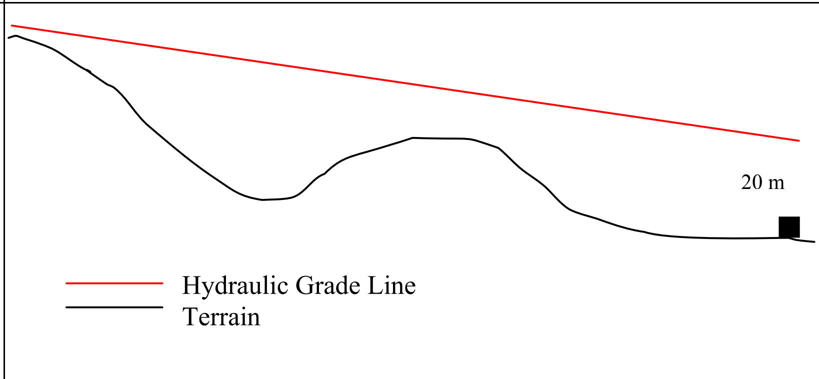
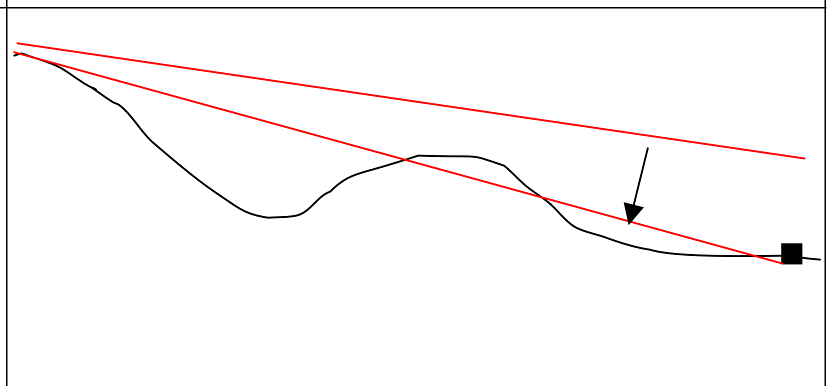
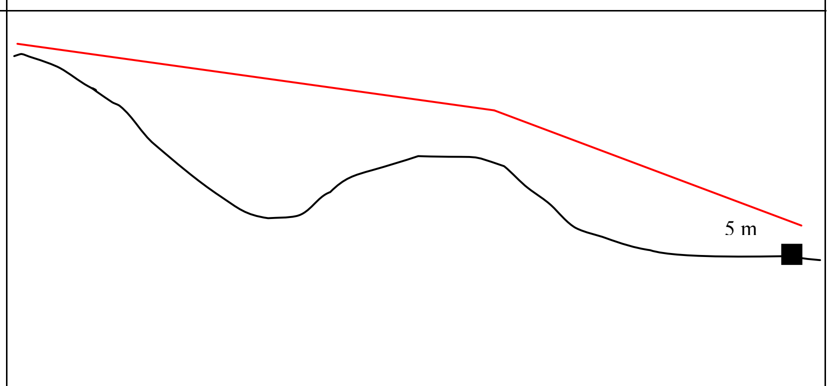
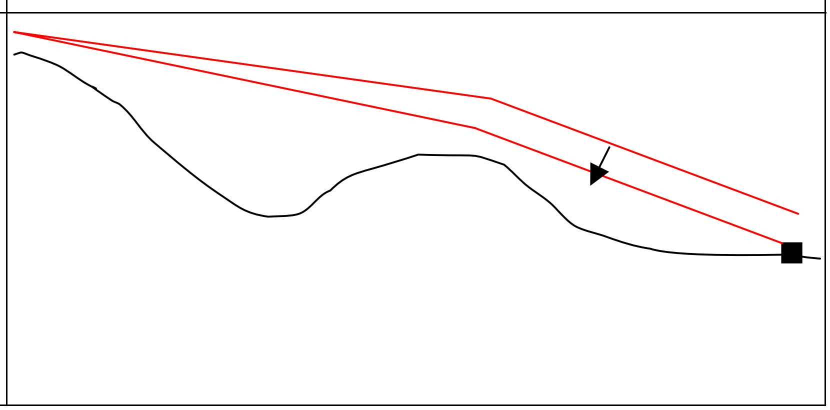
Comments	Altitude (m)	Effects of Real Flow
Design Flow Using the design flow and one size of pipe, the water arrives to the break pressure tank with 20-meters dynamic head.	150 50 30	
Real Flow In a real system the head drops to 0 at the tank. This makes the actual flow higher than the design flow, which increases frictional losses, rotating the hydraulic gradient down. If the hydraulic gradient crosses the terrain, the piping will behave like a siphon, which can cause contaminants to enter the conduction line.	150 50 30	
Pipe Size Change By decreasing the pipe size in the second part of the system, the change in pressure with an increased flow can be controlled. Under design flow conditions there should be at least 5-meters of head at the break pressure tank entrance.	150 50 30	
Real Flow Check Because the hydraulic gradient takes on a different shape with the change in pipe size, the decrease in pressure over the hill is less, avoiding pressures lower than atmospheric pressure. A small difference between the design flow and the real flow also indicates an economic design, as the smallest pipe possible has been used.	150 50 30	

Figure 3.4.2 Four diagrams showing how a change in pipe size can avoid negative pressures under real flow conditions

Placing Air Valves and Clean-out Valves

The collection of sediment and air in the pipe are the two most common types of obstructions found in water systems. If the velocity in the pipe is less the 0.5 -meters per second it is likely that sediments will collect in the lower sections of the conduction line. It is a good idea, at least for the first Section of the conduction line, to install clean-out valves in the lower parts of the system. This makes it possible for the plumber to easily clean out the pipe. Because air is less dense than water, it sometimes is retained in the higher areas of the conduction line, not allowing the water to pass through at the design flow. With an air valve, this trapped air can easily be released.

Using the Conduction Line Design page

Before starting work on this page, highlight cells A12 through Q12 and click Edit > Copy. Then highlight columns A through Q, rows 13 to the end of the spreadsheet and click Edit > Special Paste > Formulas. It is only necessary to edit the columns with titles in red and italics. The first four columns are taken directly from the ***Cond. Data*** page.

Flow MDC is the design flow for the conduction line, or the Maximum Daily Consumption (MDC) flow. This flow was calculated on the ***General Data*** page.

Diam. Rec. is the diameter recommended for a given flow. This recommendation does not have to be followed. If the diameter chosen by the engineer is less then the recommended diameter and there is enough pressure in the pipe the chosen diameter is acceptable. If the diameter is more then the recommended diameter, the engineer should check to make sure the velocity for the station is more then 0.5 -meters per second. The recommended diameter is calculated with the following equation:

$Diam.Rec. = (FlowMDC/2.38)^{0.38}$

Diam. Prop. is the diameter proposed by the engineer. It is necessary to systematically try different diameters until the dynamic pressures are within design constraints. There should be at least 4-meters of dynamic head along the conduction line. The maximum static head available will depend on the type of pipe used. Between two structures the diameters start larger at the first structure and are reduced as they approach the second structure to prevent negative pressure, or a siphoning affect, in the pipe. The profile view graph located on the page, ***Profile Cond.*** helps to visualize the effect of placing break-pressure tanks and trying different combinations of pipe sizes.

Coeffic.of Fric. is the coefficient of friction used in the Hazen-Williams equation calculated in the Frict. Losses column. The coefficient of friction has to do with the roughness of the inner walls of the pipe and is equal to 0.111 for PVC pipe and 0.207 for GI pipe.

Frict. Losses is the column that calculates how much head is lost due to friction along the inner walls of the pipe. This loss in head is calculated by using the Hazen-Williams equation:

$$Frict.Losses / Sect. = \frac{Coeffic.ofFric. * Inclin.Dist.}{100}\left(\frac{FlowCMD}{Diam.Prop^{2.63}.}\right)^{1.852}$$

Another form of the Hazen-Williams equation in shown in Appendix A.6.2. Note that this equation is slightly different because it calculates the frictional losses per 100-meter of pipe.

Piezo. Elev. is the piezometric elevation at the station. The piezometric elevation is equal to the altitude of the nearest structure above the station minus the frictional losses incurred along the pipe between the structure and the station. These elevations are plotted on the profile graph to create the hydraulic gradient of the design. If pipe size and type remain constant for a given flow along the conduction line, the slope of the hydraulic gradient will also remain constant.

Dynamic Head is the change in elevation between the piezometric elevation and the elevation of the terrain. It is the head experienced in the pipe under design flow conditions.

Static Head is the change in elevation between a given structure above the station and the terrain elevation. It is the maximum head the pipe will experienced and occurs when the flow is equal to zero.

Vel. is the velocity that the water travels through the pipe. It is equal to the design flow divided by the cross-sectional area of the pipe.

Type of Pipe is broken up into three columns. The first and third columns are taken from the data imputed on the ***Cond. Data*** page. The middle column uses the static head to determine the maximum pressure the PVC pipe will experience at that station. From this information the program assigns the proper type of PVC for that section of the conduction line. The amount of head each type of PVC can resist is shown in table A.6.2b. Once the design is complete the engineer should look and the number of changes in both size and type of the conduction line pipe, and do his or her best to make them as few as possible. Every time there is a change in the conduction line, there is another opportunity for the community to make and error during construction. Sometimes it is worth it to make the system a little more expensive or violate the real flow test (explained below) in order to create a design that will be easier to explain to the community. This is especially true if the engineer will not be able to dedicate a lot of time to the supervision the project.

Notes is where the location the various structures of the conduction line are recorded. When the engineer types, Break Pressure Tank #, where # is equal to any number 1-10, or Distribution Tank, the dynamic and static head are automatically dropped to 0 at that station. It is also a good idea to record the location of air and clean-out valves in this column.

GI Extra is automatically taken from the ***Cond. Data*.** Page.

Diam. is automatically taken from the ***Cond. Data*.** Page.

Break Pres. Tanks is the name of the structure that controls the static head for each section of the conduction line.

Static Head Elev. is where the static elevation for each structure is recorded.

QREAL=> points out were the head has been dropped to zero due to the placement of a break pressure tank or distribution tank.

QREAL is used to check the real flow of the system. In order to make sure the system has enough pressure to carry the design flow twenty years from when it is constructed, the engineer needs to allow for at least 4m dynamic head at break pressure and distribution tanks and at least 10m at the storage tank. This extra pressure is needed, to account for build up on the inner walls of the piping and to allow for some error in the topographic study data. When the system is built the head at these locations will be zero. This causes a real flow that is larger then the design flow. The increase in flow creates an increase in frictional losses. To make sure this increase in frictional losses does not create negative head, or a siphoning effect, the engineer needs to check the pressures that result under real flow conditions. This can be done by using Tools > Goal Seek, and setting the cell in the pressure column (AC) to zero, by changing the cell that QREAL=> points to in column (AA). This is an important check because suction in a section of the pipe could result in the introduction of contaminants into the conduction line.

Pres. OK? is and indication of whether a negative pressure has resulted from the real flow check.

Columns AD through BD automatically add the total length of each type of pipe needed to construct the water system.

3.4.6 Profile View Drawing of Conduction Line (Profile Cond.)

Plotting the accumulated distance from the water source against the static head, piezometric elevation and terrain elevation creates the profile view of the conduction line. The engineer will need to right click on the graph and choose >Source Data.. From there the ranges and titles of each column must be updated. Once this is completed the engineer will change the scale of the X-axis and Y-axis by double clicking on the axis and editing the >Scale tab. The final steps are to change the title of the graph and use the drawing toolbar to mark and label the various structures involved in the conduction line.

3.4.7 Plan View Drawing of the Conduction Line (Plan Cond.)

Plotting the projection of each station in the N-S direction against the projection in the E-W direction creates the plan view of the conduction line. The engineer will need to right click on the graph and choose >Source Data. From there the ranges and titles of each column must be updated. Once this is completed the engineer will change the scale of the X-axis and Y-axis by double clicking on the axis and editing the >Scale tab. The final steps are to change the title of the graph and use the drawing toolbar to mark and label the various landmarks and structures involved in the conduction line. Pictures can be copied from the ***Pictures*** page to enhance the plan view drawing.

3.4.8 Distribution Network Data (Net. Data)

The majority of this page is set up the same as the ***Cond. Data*** page. The columns that are different are explained below.

Houses per Section is where the number of houses connected to each section are recorded.

Network E-W and N-S takes data from the columns Project. E-W and Project. N-S if there are no houses connected at the station. The top cell will need to be copied to the lower cells each time a new design is entered into the program. Once the cells are copied the engineer must delete all the cells that say "delete." In the example design for *La Colonia El Cielito*, all the points were plotted because the houses were too close together to plot using the program and had to be drawn in using the drawing toolbar.

Houses E-W and N-S takes data from the columns Project. E-W and Project. N-S if there are houses connected at the station. The top cell will need to be copied to the lower cells each time a new design is entered into the program. In the example design for *La Colonia El Cielito*, none of the houses were plotted because they were too close together and had to be drawn in using the drawing toolbar.

3.4.9 Distribution Network Design (Net.)

The majority of this page is set up the same as the ***Cond***. page. The formulas for the Accum.Dist., Terrain Elev., Project. E-W and Project.N-S columns are the same as the ***Cond.*** page but are indexed according to the Row of Prev. Sta. column. Other columns that differ are explained below.

Houses per Section is taken directly from the Net. Data page

Houses Until End is the number of houses from the station to the end of the distribution network.

Flow MHC is the design flow for the distribution network, which is equal to the Maximum Hourly Consumption (MHC) flow calculated on the ***Gen. Data*** page.

Row of Prev. Sta. is the number of the row of the previous station. This column is very important as the distribution network has many different branches and can be hard to keep track of. The formula for this column looks at the names of the stations to determine how they are interrelated.

3.4.10 Profile View Drawing of the Distribution Network (Profile Net.)

The procedure for correcting the profile view drawing of the distribution network is the same as explained for the profile view drawing of the conduction line. In the example of *La Colonia El Cielito*, the houses and the points for the distribution network were plotted and later the mother line was drawn in using the drawing toolbar.

3.4.11 Plan View Drawing of the Distribution Network (Plan Net.)

To produce this drawing the column Network E-W was plotted verses the column Network N-S.from the ***Net. Data*** page.

3.4.12 Materials Document (Mat. Doc.) & Materials List (Mat. List)

The ***Material Document*** page is to be used as a template. The idea behind the template is that, as more people use this program the materials lists will be improved and expanded. The materials list is divided into three sections. The summary of the costs of each part of the water system, the manual labor costs and the summed total cost of the project. The second section includes materials lists for all the SANAA designs shown in Appendix B. The third section of the page is the Materials List and Prices at the bottom of the page.

Most of the page is automatic. The engineer will have to input the data that is in the color red. At the bottom of the page is a Materials List and Prices section that includes all the materials listed above with their respective prices. This list looks up the quantities for a given article name and sums them. Once the engineer has finished inputting the values in red, he or she should check the difference between the *Articles Total From Above* and *Articles Total From Below* cells, located in cell (B653). If this cell does not equal zero, probably the engineer named an article differently in the lists above then the price list below. In order to preserve the template as it is, the next step is to right click on the tab for the page and choose Move or Copy > ***Mat. Doc*** > Create a Copy > OK. This will create another copy of the page. Then the name of the new page should be changed to ***Mat. List*****.** Once this page is created the engineer can delete all the rows with a quantity value of zero to prepare the page for printing. If reference errors occur in some of the cells, the engineer should Copy > Special Paste > Values the cells from the ***Mat. Doc****.* page. If the engineer would like to add new materials to the list he or she needs to make sure the new article is also located in the Materials and Prices Lists at the bottom of the page, and that the appropriate formulas are copied to the new cells. The ***Materials List*** is useful for instructing the community and dividing the materials for construction.

3.4.13 Work Order (Work Order)

The work order is a list of materials needed for the entire project with the quantities and prices totaled from the individual lists made for each part of the water system. This list is created by copying the Materials List and Prices section of the ***Mat. Doc.*** page and pasting only the values onto the ***Work Order*** page (Click Edit > Special Paste > Values). The final step is to delete the rows with a quantity value of zero. To do this click the row numbers to be deleted, highlighting the entire rows, then click > Edit > Delete. By removing the prices from this list, the engineer can use it to quote up-to-date prices at hardware stores and distribution outlets.

3.4.14 Pictures (Pictures)

The pictures on this page can be used to enhance the conduction and distribution network plan view drawings.

3.5 Alternative Designs

The National Autonomous Service of Aqueducts and Sewer Systems (SANAA) has made designs for spring boxes, break pressure tanks, and storage tanks that have proven to be very durable. These designs are shown in Appendix B. The structures designed by SANAA require nipples of GI pipe for the entrance, exit, clean-out and overflow pipes. This is not a problem for projects that are constructed by SANAA because they have access to the expensive equipment necessary to cut and thread good quality GI nipples. Unfortunately, for many projects done in poor rural communities without much support from their municipalities, this is not the case.

The valves that are placed before and after the break pressure tanks in the SANAA design are there to make it easier to clean the tanks and as a way of shutting off flow to lower sections when repairs need to be made. These valves are useful but leak if not properly maintained, require three GI nipples and a universal union to install, and can easily be manipulated by vandals. All the projects that I worked on were funded by NGO's without access to the proper tools needed to carry out SANAA designs. They sometimes were able to borrow equipment from other communities to finish their projects, but usually it was of poor quality. In the end many villages had to order nipples from a hardware store at considerable cost.

After visiting many water projects in Honduras with poorly maintained leaking valves and problems with vandalism, I decided to try to design a break pressure tank that would be more feasible to build, and require less maintenance. One alteration that has been applied to the SANAA designs within the last year, is the use of a placed vertical PVC pipe within the tank. This alteration involves placing a 90-degree elbow within the floor of the break pressure tank, with a glued PVC pipe leaving the foundation horizontally. By placing a PVC pipe in the elbow vertically without using adhesive, the "L" shape pipe that results can be used both as an overflow and a clean-out pipe. When the PVC pipe is in place the water rises to the height of its upper edge and is flushed out through the bottom of the foundation. When the plumber wants to clean out the sediment in the tank, he removes the vertical PVC pipe and the sediment is washed out the bottom of the tank. This system also makes the valve at the exit of the tank unnecessary. When the vertical PVC pipe is removed the water level in the tank drops below the level of the exit pipe, shutting off the flow down the conduction line. For the majority of rural water systems the flow is small enough that it is possible to clean out the inner walls and floor without shutting off the flow to the break pressure tank. Because of this, the valve at the entrance of the tank can also be removed. The elimination of these two valves lessens the amount of maintenance needed and the vulnerability of the system to vandalism. In order to make the tank completely free of GI pipe the exit pipe was changed to leave out the bottom of the tank where it is protected underground. The entrance pipe enters the foundation underground and runs up through the wall of the tank for support and protection. Because the heat expansion coefficient of PVC pipe is different than concrete, leaks can occur around the outer edge of the pipe under some climate conditions. In Honduras this was not a problem as temperatures are fairly constant. A diagram of the plan, profile and side cross sections of the tank are shown in Figure 3.4.1.

The walls of the tank can be built with bricks using a column of concrete around the entrance pipe. The entire tank can also be made of placed concrete. This decision will depend on the materials available to the community. If there is gravel available in a nearby river, building wooden forms and placing concrete is faster. If all the gravel has to be carried a long distance and the community has a skilled mason, it is faster to build the tank with bricks. The accessories that open to the inside of the tank are threaded in order to make it possible to remove the pipe connected to them. Disassembling these ends will facilitate the removing of obstructions in the entrance and exit of the tank. For more details on the tanks accessories see figure 3.4.2.

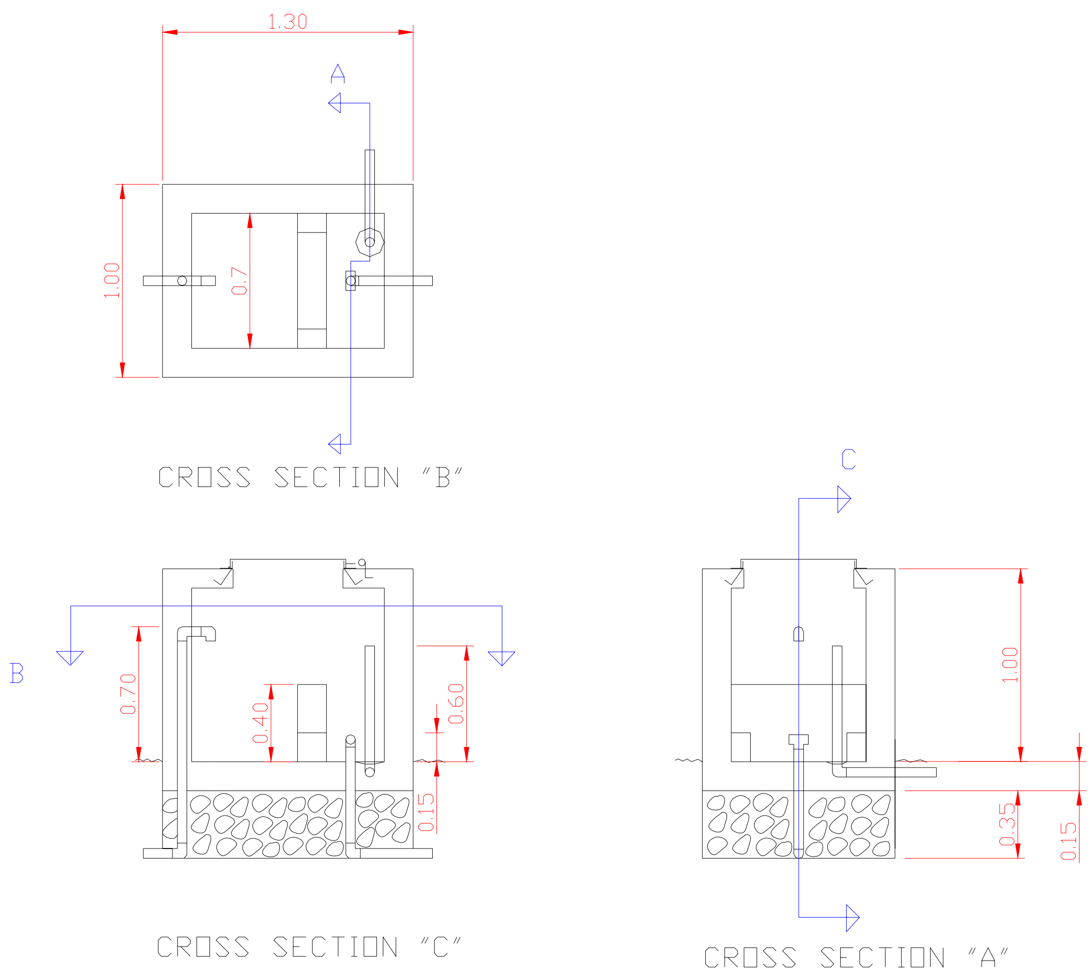


Figure 3.4.1 Plan, profile and side cross sections of an alternative design for a break pressure tank using PVC piping and accessories only

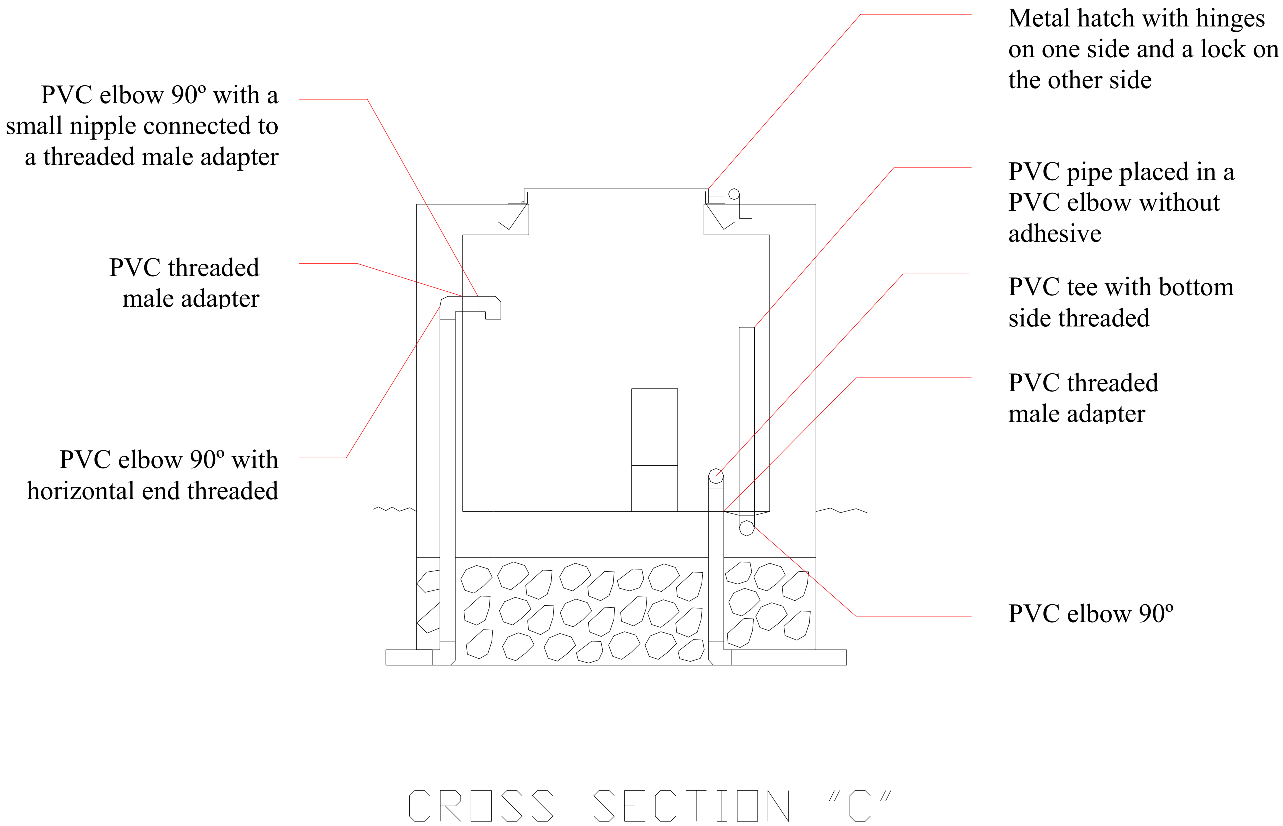


Figure 3.4.2 Profile cross section of an alternative design for a break pressure tank with details on pipes and accessories

4.0 Concluding Comments

Gravity flow aqueducts are more efficient and require less maintenance than those of gas and electrical pumps. Because of the mountainous terrain and abundance of natural springs, Honduras is an ideal candidate for gravity flow systems. Unfortunately, due to the lack of enforcement of environmental laws, many of these springs are drying up or being contaminated by agricultural activities. Unless a large-scale effort to protect micro-watersheds is undertaken in the near future, many Honduran communities will not have access to good quality natural springs. This would force them to install pump systems that are not as feasible due to their high maintenance cost.

After Hurricane Mitch, the government institutions SANAA and PROSAR were well funded by international organizations to respond to the high demand for potable water in Honduras. Recently these funds have diminished considerably as aid organizations began to focus their efforts on other more needy countries. PROSAR no longer exists and SANAA has cut back on the number of communities they accept. In the future, Honduran communities will have to depend more on NGO's to find funding for their projects. Because of this it is important that appropriate technologies be developed to make the building process as simple and maintenance free as possible.

Currently many calcium hypochlorite tanks are not being used because plumbers have had difficulties in maintaining the correct chlorine dosage. A more effective chlorinating device would greatly improve health conditions in Honduras. A lack of tools available to work with GI pipe has caused setbacks for communities attempting to build their own systems with minimal outside help. Simple designs that focus on the use of PVC and concrete are much more feasible for poor rural communities to construct and repair.

The three years of field experience I gained from participating in the Peace Corps Masters International Program through Michigan Tech University has had a large effect on the way I view engineering and development projects. Applying engineering theory to a real world problem is definitely easier imagined in a classroom than carried out in the field. Political, social and economic obstacles often dwarf technical challenges in both size and complexity. Overcoming language and cultural barriers is a very humbling experience. Many community members realized quickly that although I was there to teach them how to complete a water project, I also had a lot to learn from them about their language and culture. Gaining their confidence was very instrumental in motivating the people to devote time into organizing and building each project.

I learned through experience that there is a fine line between helping, and fostering dependence through micro-management. Many times the blatant inefficiency and injustice that goes on in Honduras tested my patience. I found that the best mode of operation was to be persistent and constantly apply pressure to each of the projects I worked on. Trying to push water projects along too fast alienated the people I worked with and was not consistent with the Honduran culture. Not pushing at all caused the communities to feel abandoned and lose confidence. Water projects should be looked at as a learning process that takes several years to complete. The process requires health education, development of problem solving skills, and cooperation among community members. Villages and organizations that take the time to go through this process will not only gain a water system but also the capability and confidence to carry out sustainable projects in the future.

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APPENDIX A

The following document, "SANAA's Rules of Design for Rural Aqueducts V.1.0" was written in 1999 by SANAA engineers to be used as a guide on how to design potable water systems in Honduras. In order to receive funding from SANAA, engineers working with NGO's must also, for the most part, follow these design standards. This document was translated and reduced in size to only include the most critical design information. Technical drawings made by SANAA for this report can be found in Appendix B.

SANAA's Rules of Design for Rural Aqueducts V.1.0

SANNA's Rules of Design for Rural Aqueducts

Republic of Honduras

NATIONAL AUTONOMOUS SERVICE
OF AQUEDUCTS AND SEWER SYSTEMS

SERVICIO AUTONOMO NACIONAL DE
ACUEDUCTOS Y ALCANTARILLADOS
SANNA

Rules of Design for Rural
Aqueducts V.1.0

Tegucigulpa, M.D.C.
November, 1999

A.1 Criteria to determine feasibility of a project

1. Quality of water:

Water that does not appear turbid, have an odor, carry a lot of sediment and is not biologically or chemically contaminated.

The owner of the land where the spring box is located should be trustworthy, educated on how his activities could effect the water source and have given written permission.

There should not be houses above the spring box as well as major agricultural activity.

The minimum flow of the source should cover the needs of the community and should not be less than the following equation.

Equation A.1.1 $$Q\min = 0.25(Pa)$$

where: $Q\min$ = Minimum flow that can be used for a community

Pa = The population at the time of the feasibility study

The values obtained in the analysis of the water should be within the range accepted by the World Health Organization. These guidelines are shown in Appendix C, along with two typical water quality analysis done in Honduras and practical information about how to interpret the results.

2. It is preferable that the spring box be above the community so that a gravity flow system can be used. If there is a large difference in altitude between the community and the spring box the resistance of the tubing needs to be considered and possibly a break pressure tank should be added. If a pump system is used the community has to have access to electricity or fuel, at a economically feasible price.

3. There needs to be a suitable place for the tank above the community that can provide water for at least 90% of the houses.

4. The members of the community should show interest and be willing to provide labor and the funds to maintain the system.

5. SANAA funds projects for communities with a population between 200 – 2000 people.

A.2 Rules of Topographic Study

The topographic study includes all the information necessary to carryout the design and construction of the project in the most efficient way possible.

It should also state information about existent installations if there was a previous water system.

2.1 Preparation for Topographic Study

Before the topographic study one should get to know the village and the areas where the tubing will pass. The field engineer should do this. While doing this the engineer will also choose the sites for the tank intake structure, conduction line and distribution line. These sites will be marked well to help with the construction phase. Detailed sketches and descriptions will be made of each area. If aerial photos are available they will accompany this information, and will be marked with points of interest.

2.2 Stages of a Topographic Study

2.2.1 Site of Intake Structure

The study should detail all the characteristics of the micro-watershed around the intake structure. In the case of streams and rivers, a cross-section will be taken every 5 m, 30-meters above and below the site. For natural springs, measurements of the area around the spring (15-meters in every direction) should be made in relation to the altitude of the spring. If available take the minimum and maximum flows of the spring throughout the year.

2.2.2 Conduction Line

1. Survey points no more than 100-meters apart (with an Abney level no more than 30).

2. Note the names of property owners for each station as well as whether the land is suitable for excavation and the amount of vegetation needed to be removed.

2. Describe details between stations on both sides every 5-meters and fringe areas every 20-meters (not only rugged areas)

3. Take details of crossings of water, ditches, gullies, summits, depressions etc. When crossing water take note of max and min levels by looking at the bank on each side.

4. Place permanent markers every 500-meters and establish land markers for changes in direction of route.

3. Take compass readings between stations. At final point pick a landmark in the direction of north.

4. Take Abney level reading both forward and backward.

5. Note changes in soil type.

2.2.3 Tank Site

Take contour lines for the site with a radius of 15m. Mark points of reference.

2.2.3 Distribution Line

Locate the street crossings, property lines, construction of public buildings, hospitals, schools, churches, recreational centers, houses and future houses. If possible a closed polygon should be formed that passes close to all the houses served, or a series of closed squares should be surveyed.

2.3 Specific Rules

1. Take 5 representative landmarks for each station.

2. Every station should be marked in 2 places permanently with distance and angle.

3. If possible measure altitude at beginning, middle end and high points.

4. The precision of the measurements should be as follows:

Tolerable error in angles of closed polygons:

Equation A.2.3a $$Ea = \sqrt{n}$$

where: Ea = acceptable error in degrees

n = number of angles in the closed circuit

Tolerable error in length of closed polygons.

Equation A.2.3b $$El = 0.05\sqrt{L}$$

where: El = acceptable error in length

L = the sum of the length in meters

Tolerable error in Abney level.

Equation A.2.3c $$En = 12\sqrt{L}$$

where: L = length surveyed in meters
En = acceptable error in millimeters

A.3 Norms of Design

The following methodology is designed to fill the needs of the developing nation of Honduras, keeping in mind socio-economic limitations. These norms have been made to facilitate engineers, but are not set in stone and can be modified to fit a given situation.

A.3.1 Parameters of Design

1. Period of Design: Taking into account the durability of the materials used, tubing, accessories and masonry, it has been determined that the design life is 22-years. This is with exception to pumps, which last around 10-years.

2. Growth Rate: A 3% growth rate can be used for Honduras. This is the average growth rate calculated by the Honduran census. If the community has unusual development the number can be modified taking into account previous censuses. For housing projects, use maximum density for the future population.

3. Calculate Population: The design of the system should be in agreement with the number of houses that resulted from the topographic study . If the population is unknown, multiply the number of houses by 6 to estimate the number of habitants. Once the population is found the future population in 22-years can be estimated using the following methods.

A.3.2 Arithmetic Growth: When the population is less than 2000 and a large increase in growth is unlikely arithmetic growth is used.

Equation A.3.2a

$$Pf = Pa\left(1 + \frac{k * n}{100}\right)$$

where: Pf = future population

Pa = actual population

k = growth rate (%)

n = design period (years)

A.3.3 Geometric Growth: When the population is greater than 2000 or it the community is experiencing abnormal growth, geometrical growth is used.

Equation A.3.2b

$$Pf = Pa\left(1 + \frac{k}{100}\right)^n$$

where: Pf = future population

Pa = actual population

k = growth rate (%)

n = design period (years)

If one has access to previous censuses the following formula can be used:

Equation A.3.2b

$$k = \frac{\left(\frac{P2}{P1} - 1\right)}{m}$$

where: k = population growth rate (%)

$P2$ = population at time 2

$P1$ = population at time 1

m = time between censuses

A.4 Water Consumption

For populations less than 2000 a consumption rate of 25-gallons per person per day is used.

In communities of more than 2000 habitants the system should satisfy the following needs:

a. Domestic needs
b. Industrial and commercial consumption
c. Public Consumption
d. Waste

A.5 Types of Consumption Rates (see figures)

a. Average Daily Consumption (*ADC*): Average daily demand required by the community.

b. Maximum Daily Consumption (*MDC*): Value of the maximum daily consumption of the year.

c. Maximum Hourly Consumption (*MHC*): Value of the maximum hourly consumption during the day of maximum consumption.

It has been found that the variation in consumption can be accounted for with a factor of 1.5.

Equation A.5a $MDC = ADC(1.5)$

Equation A.5b $MHC = MDC(1.5)$

In order to cover these consumption rates the conduction line needs to carry the MDC. The storage in the tank (30-40% of MDC) allows for a flow rate equal to the MHC in the distribution line.

A.6 Water Sources

The origin of the water can be from one of the following: runoff, subsurface, or rain. These 3 alternatives should be studied for: capacity, physical and chemical status, bacteria and cost benefit analysis.

The source flow should be measured during the dry season and be equal or more than the Maximum Daily Consumption and never less than 15-gpm.

The following amounts of water are needed for water quality testing:

Physical Chemical Test	1 – 2 L
Bacteria Test	0.16 L

The values obtained in the analysis of the water should be within the range accepted by the World Health Organization. These guidelines are shown in Appendix C, along with two typical water quality analysis done in Honduras and practical information about how to interpret the results.

A.6.1 Water Collection Structures

1. Site characteristics: To protect the structure and quality of water the site should include the following conditions:

    a. The elevation should be high enough to insure sufficient pressure in the pipes.
    b. The area above the source should not have animal, human, industrial or mineral contamination.
    c. The area should be forested.
    d. For streams it should be a straight and narrow section.
    e. The banks should not be too steep as its possible they will collapse.
    f. A spring is always preferable to a stream.
    g. The watershed should be stable above and below the collection structure.

A.6.2 Common Intake Structures in Honduras:

    a. Spring Box
    b. Dam

Other types used less frequently

    c. Galleries of infiltration
    d. Prefilters
    e. Wells

A. Spring Box:

This type of intake structure is a closed impermeable structure made of bricks, mortar, concrete and rock. The structure is used to collect the water of the source and direct it into a sealed box. This works best with natural springs but can also be placed next to a river and the water can be diverted into the box. Plans to build a spring box are located in Appendix B.1.

For smaller systems sometimes the spring box can be made larger, to also be used as the storage tank.

To insure good quality water it is important to consistently clean and protect the intake structure. Furthermore the design of the intake box should be:

a. constructed with an impermeable material
b. designed to handle the entire flow of the spring, and
c. assembled with exit, overflow and clean-out piping that are easy to inspect.

B. Dams

To collect water from streams a dam can be used with an intake box placed below the overflow weir. (See Figure 2 in Appendix I) The dam size will depend on the following:

a. Flow of the stream
b. Width of stream bed
d. Characteristics of the terrain

Dimensioning the Overflow

Knowing the minimum flow of the source, the design flow for the intake piping and overflow weir can be estimated using the following formulas.

Equation A.6.2a $Qsource = Qminimum$

Equation A.6.2b $Qmedium = 10 * Qminimum$

Equation A.6.2c $Qmaximum = 100 * Qminimum$

The lower weir is designed using *Qmedium* and the upper weir is designed using *Qmaximum* in the Francis formula:

Equation A.6.2d $$h = \left(\frac{Q}{CL}\right)^{2/3}$$

where: h = height of the weir

Q = flow (m^3/s)

C = coefficient of overflow = 1.71 (m/s)

L = Length of weir (m)

A table of *h* vs. *L* values is shown in Appendix B figure B.2.4. Different sizes of dams are shown in figures B.2.11 and B.2.12.

Dimensioning the Dam

After establishing the height of the dam according to the flow of the stream and the surrounding banks, the thickness can be determined using the following formal.

Equation A.6.2e $$I = \frac{h}{(a-1)}$$

where: I = thickness of dam base

h = Height of dam

a = 2.3

For more detailed information on dam dimensions see figures in Appendix B.2.

Dam Intake

A small box built into the top of the dam and covered with a grate of iron will serve as the water intake. The bottom of the box will be lined with a 4-inch. diameter pipe cut in half. (0.3-meters below grate). The tubing will guide the water to the outside of the dam at a 2% grade. The distance between iron bars in the grate should be 1-1½-centimeters.

C. Sedimentation Tank

A sedimentation tank is used to remove sediment particles of 0.1-millimeter diameter and larger. The tank can lengthen the life of the system by preventing particles from eroding the piping, valves and taps. It also helps to prevent clogging in the lower sections of the tubing. The tank should be located directly after the intake structure.

If you are dealing with high velocities, a metal plate with holes in it can be used to slow the flow. A similar plate can be used at the exit to take in only the water from the top layer of the tank. The general specifications for a sedimentation tank are shown in Table 1 and an example of a sedimentation tank is shown in Figure 3 Appendix I.

The bottom of the tank should be equipped with a 4-inch tube that can be used for cleaning. The bottom of the tank will have a 5% slope to direct the sediments to the clean-out tube.

The tank needs to be fenced in to prevent contamination from animals and humans.

Table A.6.2a Specifications for Sedimentation Tank

Minimum Width	0.5 m
Maximum Horizontal Velocity	3.92 cm/sec
Velocity Across Orifices	12 cm/sec
Proportion of Length to Depth	5 to 9
Overflow Rate	0.3 m^3/m^2/day

D. Conduction Line

This is the section of tubing between the intake structure and the tank. Preferably the water will be carried by the force of gravity and will have a minimum flow equal to the maximum daily load. The tubing should be closed and operate under pressure. It will also include air valves, clean out valves, break pressure tanks and anchors.

1. Type of Tubing

The tubing should be resistant to external impact loads and chemicals and be smooth on the inside. The type used will depend on the topography and water pressure. Normally PVC is used in areas that the tubing can be buried and areas that have low water pressure. Galvanized iron is used where the tubing is exposed to the environment or high pressures. Table 2 indicates the types of tubing used and the amount of pressure they can withstand.

Table A.6.2b Pressure and Head Limits For Various Types of Piping

Tubing	Pressure Limit (psi)	Head Limit (m)
GI SCH40	350	246
PVC RD13.5	315	221
PVC RD17	250	176
PVC RD21	190	134
PVC RD26	150	112

2. Hydraulic Considerations

a. The pressure in the pipes should not be greater than the working pressure of the tubing used.

b. There should never be more than 100-meters static pressure in the tubing. To reduce pressure in the tubes break-pressure tanks should be used. A design for a break-pressure tank is shown in Figure 4 in Appendix II.

d. The pressure should never go negative in any part of the system under real flow conditions, as this will result in a lower flowrate.

c. To calculate the frictional losses in the tubing the Hazen-Williams Equation A.6.2f will be used.

Equation A.6.2f

$$H_{f1000} = \left(\frac{147.85 * Q}{D^{2.63} * C} \right)^{1.852}$$

Where: H_{f1000} = Frictional Head Loss (m) per 1000-meters Tubing

Q = flowrate (gpm)

D = diameter of tubing (inches)

C = roughness coefficient (dimensionless)

The actual diameters are slightly different than they are named. When plugging in diameters to the Hazen-Williams equation, use Table A.6.2c shown below. The roughness coefficient for PVC pipe is 140 and for GI pipe is 100.

Table A.6.2c Average Inner Pipe Diameters (November 1999, Honduras)

This table should be updated with manufacturers periodically. In general values will vary by a couple hundredths of an inch between manufacturers.

Diameter (inches)	Average Inner Diameter (inches)
½	0.622
¾	0.824
1	1.048
1 ½	1.611
2	2.000
3	3.000
4	4.000

Minor losses in accessories, described below, are ignored as they are very small compared to the losses in the tubing.

d. It is recommended that the water arrive at the tank with at least 5-meters of pressure. This extra pressure will account for future frictional loss increases in the tubing due to deposits that decrease the pipe diameter and increase the pipe roughness. This extra pressure also accounts for minor frictional losses caused by accessories.

3. Accessories

To improve the hydraulic functionality and facilitate the maintenance of the system, the following accessories need to be installed.

a. Air Valves: These valves are located at the high points of the line and are especially important where the hydraulic grade line is close to the level of the terrain. The valves are used to release air that collects in the higher parts of the tubing (because it is less dense), which can block the flow of water. The valves used are ½ in and should be installed inside a protective box. An example of an air valve is shown in Figure 5 in Appendix I.

b. Clean-out Valves: These valves are used to discharge sediments that have accumulated in the low parts of the line. The minimum size used is a 1-inch gate valve. An example of a clean-out valve is shown in Figure 5 in Appendix I. For larger conduction lines a relationship of D/3, where D is the inner diameter of the mainline, can be used to calculate the size of valve needed. This accessory also should be protected with a concrete box.

c. Stream Crossings: When crossing streams, anchored galvanized iron (GI) will be used. If the gorge is wide and deep the tubing can be suspended with cables. The height will depend on the maximum height of the stream. The minimum length of GI used to cross a stream is 6 m.

d. Break Pressure Tanks: The function of these structures is to reduce the hydraulic pressure in the tubing when it exceeds the working pressure. It is a rectangle structure made of brick with the mainline entering one end and exiting the other. At the entrance the tubing turns vertical and has holes in the sides to help dissipate the pressure and protect the inside of the box from water damage. An example of a break-pressure tank is shown in Figure 4 in Appendix I. The piping for the overflow and the clean-out should be at least 2-inches diameter. All piping is galvanized iron.

E. Storage Tank

The purpose of the storage tank is to supply a resource of water to cover hourly variations in consumption, and the needs of the community during repairs of the conduction line and intake box.

a. Location: The tank should be located in a place that allows for at least 10-meters of head in the highest point in the distribution network. It is also preferable that it be in a large flat place close to the town to allow for easy maintenance.

b. Amplification Tank: When making improvements to older systems that need to expand storage capacity, it is preferable that the new tank be located next to the old and at the same level. If not, a check valve should be located at the exit of the new tank and a new analysis of pressures in the network should be made.

c. Type of Tank: The tank can be square, circular, or rectangular constructed from bricks, blocks, reinforced concrete, and masonry. The tank can be elevated, on the surface, semi-buried, or buried. The materials used will depend on what is available to the community. In flat areas where elevated tanks are needed, they are constructed from either reinforced concrete or metal.

d. Volume: The tank needs to store 30-40% of the average daily consumption for gravity flow systems. In pump systems it will depend on the size of the pump. In general, smaller pumps require larger elevated storage tanks. For this reason the tanks hold between 20-50%.

e. Tank Accessories:

   The entrance tubing will be GI, be the same size as the conduction line, and include a gate valve. The exit tubing should be opposite the entrance, made of GI and of the same size as the distribution line. It will be located 0.15 to 0.20-meters above the floor of the tank and include a control valve. The overflow tubing will be 0.2-meter from the top of the tank. It will have a series of bends insuring that part of the pipe is always full of water to prevent animals from entering. The tubing should then be extended to an area safe to receive large quantities of water. The clean-out tubing will exit the bottom of the tank and will be capped on the other end also carrying the water away from the tank to the safe drainage area. The size will depend on the tank size, as shown in Table 4, but will never be smaller than the conduction line. It also should be made of GI.

Table A.6.2d Sizing Clean-out and Overflow Tubing

Volume (gallons)	Diameter (inches)
5000	2
10000	3
15000	3
20000	4

f. The chlorinating tank will be connected to conduction line with piping from ½-inch – 1-inch.

f. Ventilation piping will be located in the roof, made of GI of size 1-inch and be curved at the end to prevent rain from entering, and also be covered with a screen on the outside end.

g. Tank Details: An example of a storage tank is shown in Figure 6 in Appendix I. The valve boxes at the entrance and exit should be at opposite ends of the tank to insure that the water stays in the tank long enough to mix evenly with the chlorine. The roof at the tank should be made of reinforced concrete and be airtight with the exception of the ventilation tubing.

The inspection entrance should be 60-centimeters by 60-centimeters and should have a sanitary cover. The exit tubing should be covered with a screen to prevent large objects from entering and clogging the distribution line.
The inside of the tank wall will have a scale that is easily seen from the entrance for measuring the water level.

Rainwater should easily drain away from the tank.

The floor of the tank will have a 2% slope toward the clean-out exit.

F. Disinfecting

The disinfecting will be performed with calcium hypochlorite ($Ca(OCl)_2$) dissolved in a small tank located above the storage tank. Design plans for a calcium hypochlorite tank are shown in Appendix B.6.

1. Period of Contact

The period of contact should be at least 30 minutes to insure that the chlorine is mixed well in the tank and complete disinfecting occurs. There should be a chlorine residual in the distribution line of 0.2-milligrams/Liter.

2. Quantity of Solution

This will depend on the quality of the water being treated. For turbid water initially try a dosage of 1.6 milligrams/Liter and clear water a dosage of 1.0-milligrams/Liter. An additional 0.2-milligrams/Liter is required for a residual. In all cases it is recommended that an analysis of the water be done for chlorine demand. The amount of calcium hypochlorite to add for a minimum time period of 8 days, for a given amount of water, is calculated as follows:

Equation A.6.2f

$$C = \frac{d * v * t}{f}$$

where: C = calcium hypochlorite (g)

d = dosage needed (mg/L)

v = volume of water to treat (m^3/day)

t = time the solution will last (days) (normally 8 days)

f = fraction of the powder that is calcium hypochlorite (normally 0.65)

3. The volume of this type of chlorinating tank is usually 384-Liters. It will usually be rectangular in shape, constructed above the tank and have a valve to regulate the flow rate of the chorine.

4. The minimum quantity of solution should last 8 consecutive days.

G. Distribution Line

The distribution line connects the storage tank to the distribution network. The hydraulic calculations and details of piping and accessories are the same as the conduction line with the exception of the design flow. The design flow for the distribution line is the maximum hourly demand. The maximum velocity in the tubes is 2-meters/second. All valves should be closed slowly to prevent damages from the hammer effect.

H. Distribution Network

The distribution network should deliver water to the population in sufficient quantity and at a manageable pressure for the entire design period.

1. Pressure

There should be enough pressure in the distribution network to deliver the water to the second floor of all the houses but there should not be high enough pressure to damage the taps and tubing. For these reasons the minimum dynamic pressure should be 10-meters and the maximum static pressure 60-meters. In order to maintain these pressures, sometimes two different networks will be needed (one high and one low), as well as break pressure tanks and break pressure valves.

2. Flow

The flows in the network are determined using the Harding-Cross method. This is done by dividing the total flow by the number of houses and then starting at the extremities of the system adding up the flows as you get closer to the distribution line. This method assumes that future growth will occur in proportion to current population densities. When future development projects are known this process should be modified. For more information on the Harding-Cross method, see Appendix III Article 2.[24]

3. Types of Networks

There are two main types of networks, open and closed. It is always preferable that closed circuits be used if possible to help equal flows and pressures.

4. Tubing diameter

This should be decided using the calculated velocity and pressure in the tubing. Velocities in the distribution network can be between 0.6 and 3 meters/second. A one-inch pipe can carry 4.5 gallons per minute at 0.6 meters/second, and two-inch 18 gallons per minute at 0.6 meters/second. In more general terms the flow is equal to the velocity times the cross-sectional area of the piping..

5. Location of valves

Valves are used outside of every house enabling the plumber to control access to the system. The valves should be enclosed in a box and locked so that only the plumber has access to the system. If the water fee is not paid, the plumber can terminate access to the system. The valve boxes will be located on public property close to the road for ease of access. Other valves should be placed to shut off water to parts of the water system during repairs. These valves can also be used if there are problems with overuse of the water. With properly placed valves access to the system can be given for part of the day to each section of the town.

6. Ditches for piping

The piping should be buried 60-centimeters deep for normal terrain and 80-centimeters deep to cross roads. In areas with lots of erosion GI should be used to cross roads. The ditches should be about 40-centimeters wide.

7. Domestic Connections

Each house will be connected with ½ inch piping from the mother-line. An example of how this is done and what materials are used is shown in Figure 7 in Appendix I.

8. Public Connections

At times because of the topography or economic constraints taps can be placed in central locations for the public to use in place of domestic connections.

A.7 Technical Report

7. Information Required to Design and Construct a Water Supply System

1. Political and geographical location

The community of _________________________________ is a part of the municipality
____ in the department of
_______________________________________.

2. Ways to access the community

____
____
____

3. Actual and future population

According to the census of __________, this community has a population of ________ habitants. Using a growth rate of 3 % and a design period of ________ years of arithmetic growth, the future population will be _______________ habitants.

4. Description of the quantity and quality of the current water supply
____
____
____

5. Future water supply

1. Source: To supply the water system, a stream/spring named, _______________________________ was chosen that has a flowrate of, ______________ GPM, according to a flowrate measurement taken on, ______________(date, time) using the following measurement
method____.

2. Gallons/Person/Day: An amount of ________ gallons per person per day is considered enough for the communities needs. The consumption rates are as follows:

a. Average Daily Consumption ___________________ gpm
b. Maximum Daily Consumption __________________ gpm
c. Maximum Hourly Consumption _________________ gpm

3. Intake Structure: There will be a distance of _________kms and a difference in altitude of ___________ between the center of the town and the intake structure. The structure will be a _____________________ with dimensions and characteristics of:
____
____It will require __________ inch tubing for the exit, ____________ inch tubing for the clean-out and ___________ tubing for the overflow.

4. Conduction Line: The conduction line is designed to carry the Maximum Daily Consumption, which in this case will be __________ gpm. The total length is ____________ km made up of the following tubing:
____
____
____
____
Also, _________ air valves, and __________ clean-out valves will be installed for improve the performance of the conduction line.
Observations:
____
____
____

5. Distribution Tank: A tank will be constructed with a capacity of _________ gallons, which represents ___________ % of the average daily consumption. The tank will be circular, made of reinforced brick walls and reinforced concrete roof.
The dimensions will be the following:

Diameter __________________ m
Total height ________________ m
Loaded height ______________ m

The following tubing will be used:

Entrance ___________________________
Exit _______________________________
Clean-out and Overflow ________________
By – Pass ___________________________

Observations:
____
____
____

6. Distribution line: The distribution line is designed to carry the Maximum Hourly Consumption, which in this case will be __________ gpm. The total length is ____________ km made up of the following tubing:

____
____
____

Using this tubing the water will arrive to the village with a head of _________m

Observations:

____
____
____

7. Distribution network: The network is designed to carry a flow of ____________gpm. Using the Harding-Cross method to calculate the flows, it was determined that the following tubing will be required:

____
____
____
____

The pressure resulted as follows:

Minimum head ______________ m

Maximum head ______________ m

which assures that the network will function well.

Observations:

____
____
____

8. Domestic connections: The installation of _________ domestic connections will cover the entire community and will require the following amount of tubing:

____
____

as well as the accessories needed for operation and maintenance.

6. Budget

The total budget for this project will be ________________ U.S. dollars which is made up of the following costs.

1. Engineering and administration		
a. Topographic study and design		__________________ U.S. dollars
b. Administration work		__________________ U.S. dollars
	sub total	__________________ U.S. dollars
2. Construction		
a. Intake structure		__________________ U.S. dollars
b. Conduction line		__________________ U.S. dollars
c. Distribution tank		__________________ U.S. dollars
d. Distribution line		__________________ U.S. dollars
e. Distribution network		__________________ U.S. dollars
f. Domestic connections		__________________ U.S. dollars
g. Administration work		__________________ U.S. dollars
h. Contingency costs (10%-20%)		__________________ U.S. dollars
	sub total	__________________ U.S. dollars

APPENDIX B

The following technical drawings were designed by SANAA engineers and plotted on large blueprint size paper. Because engineers working for Peace Corps do not have access to large plotter machines, I have broken these drawings into sections so they can be printed on a conventional size printer. The drawings are a large improvement over the ones previously distributed by SANAA and are presented in this report as a way of improving understanding among engineers. They also are a helpful teaching tool for engineers in the field who need to explain clearly how each structure should be built. I have translated all the comments and titles into English to make the drawings applicable in other countries. These same drawings are also available on an Excel spreadsheets in both English and Spanish on the Master's International internet site (http://www.cee.mtu.edu/peacecorps/resources.html).

Note: All dimensions are in meters (mts = meters) or centimeters (cms = centimeters). Diameters of piping are measured in inches. The diameter of rebar can be calculated as follows:

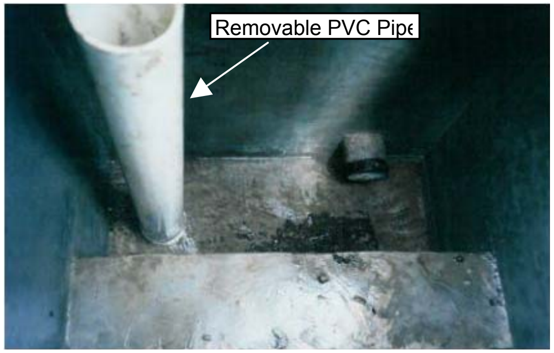
Rebar diameter(in.) = (Rebar #)*1/8"   Example: Rebar #2 = 1/4" diameter

B.1 Spring Box Figures

B.6 Calcium Hyperchlorite Tank Figures

Spring Box

Spring Box Side View



Sping Box Exit

Spring Box Front View

Spring Box Entrance

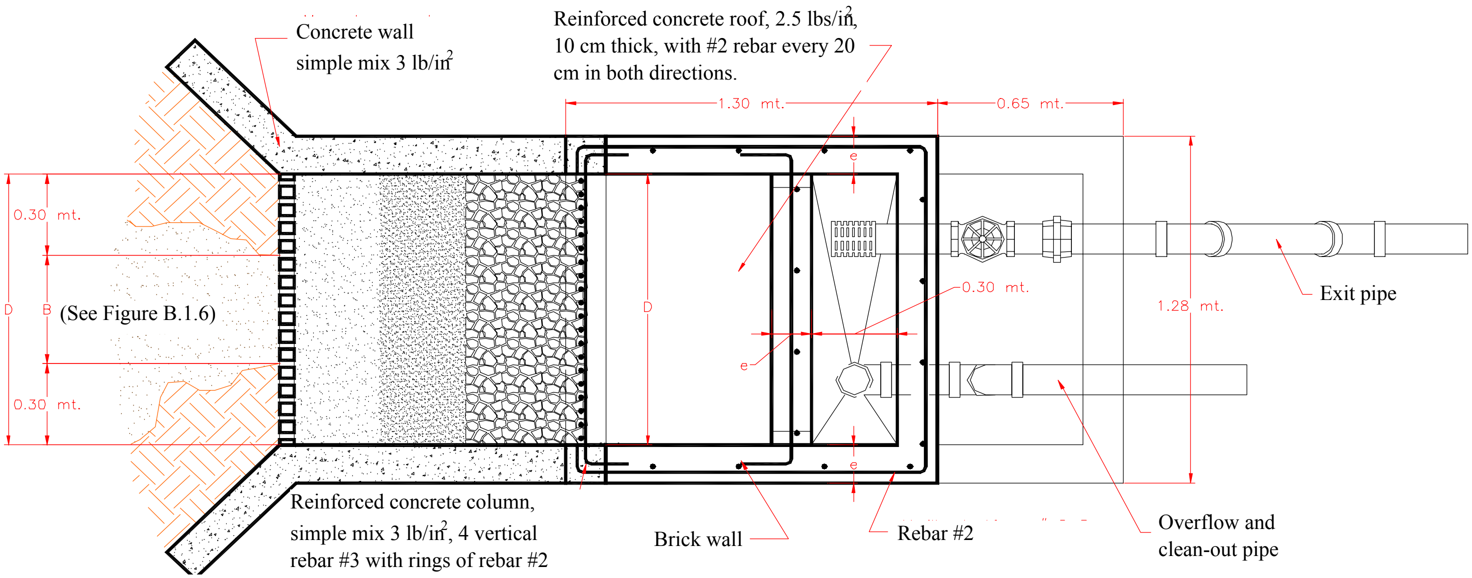


Figure B.1.1 Plan view cross section of spring box with details of rebar arrangement and concrete

Adapted from: SANAA, Servicio Autónomo Nacional de Acueductos y Alcantarillos, "Normas de Diseño para Acueductos Rurales V.1.0," Tegucigalpa, Honduras, 1999.

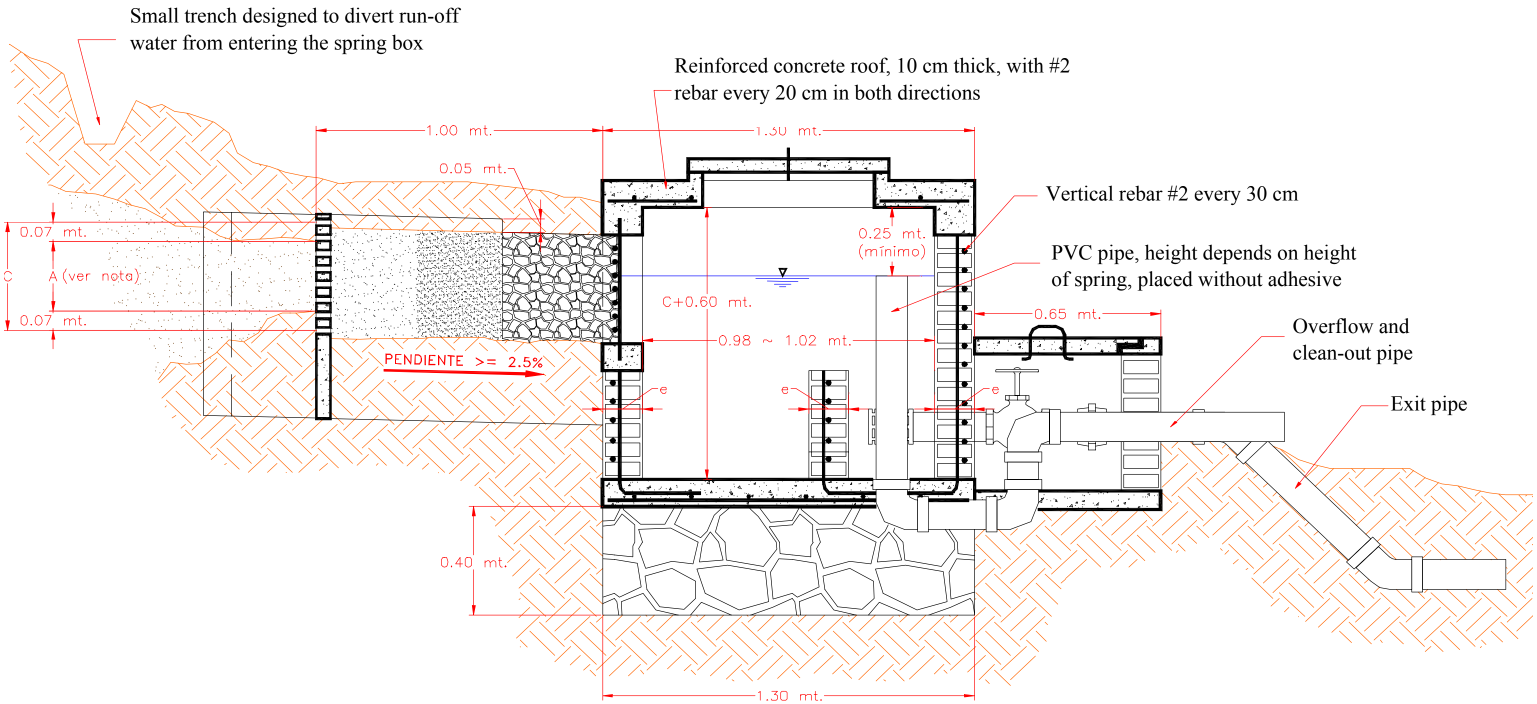


Figure B.1.2 Profile view cross section of spring box with details of rebar arrangement, plumbing and and accessories.

Adapted from: SANAA, Servicio Autónomo Nacional de Acueductos y Alcantarillos, "Normas de Diseño para Acueductos Rurales V.1.0," Tegucigalpa, Honduras, 1999.

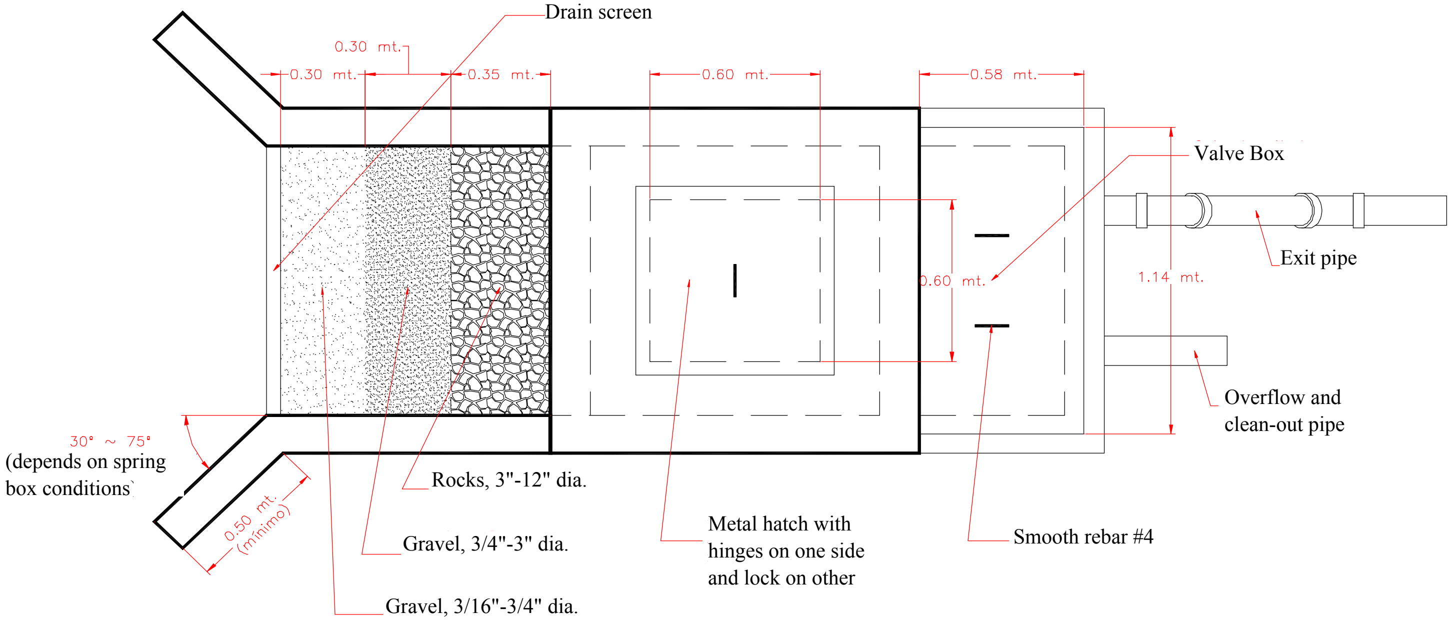


Figure B.1.3 Plan view of spring box with details on filter, inspection hatch, and valve box

Adapted from: SANAA, Servicio Autónomo Nacional de Acueductos y Alcantarillos, "Normas de Diseño para Acueductos Rurales V.1.0," Tegucigalpa, Honduras, 1999.

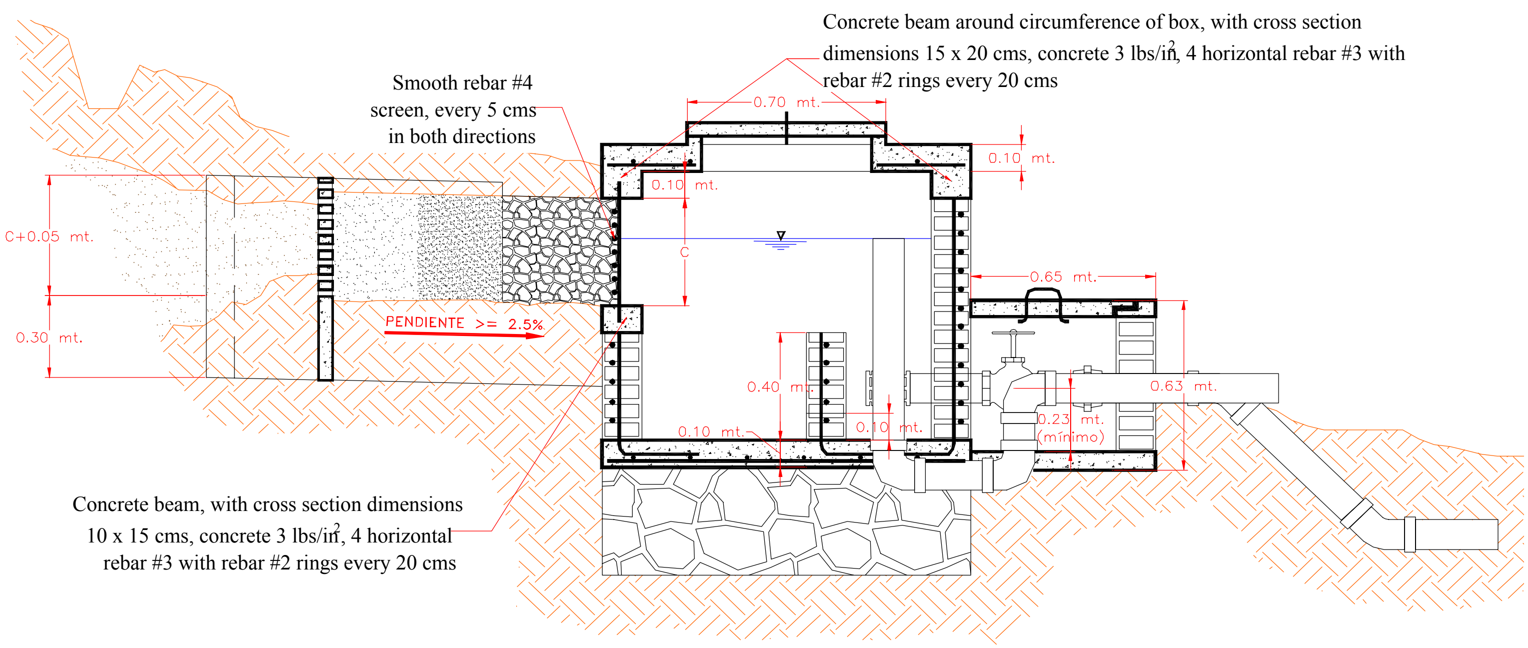


Figure B.1.4 Profile view cross section of spring box with details on concrete beams and drain screen.

Adapted from: SANAA, Servicio Autónomo Nacional de Acueductos y Alcantarillos, "Normas de Diseño para Acueductos Rurales V.1.0," Tegucigalpa, Honduras, 1999.

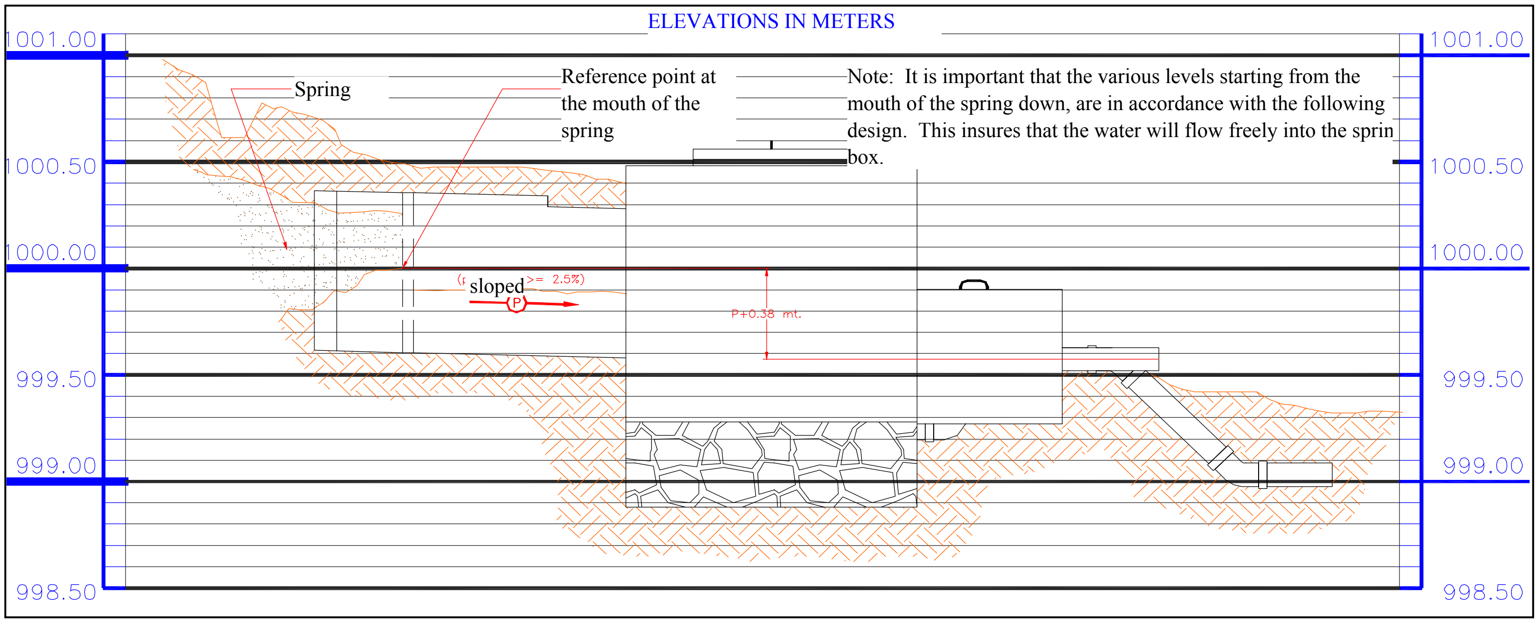
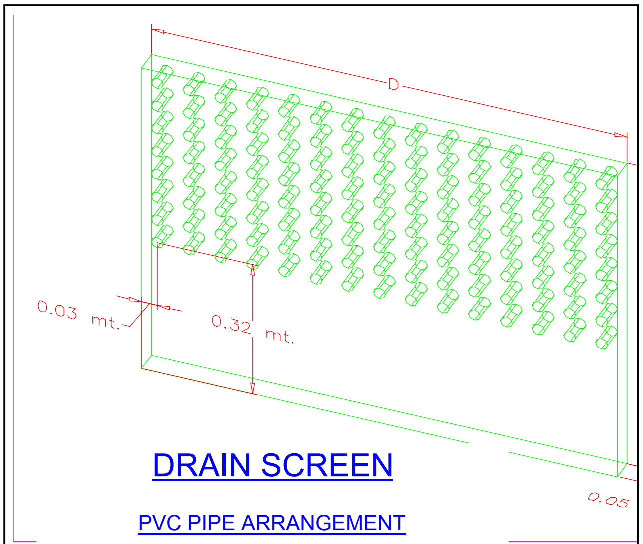


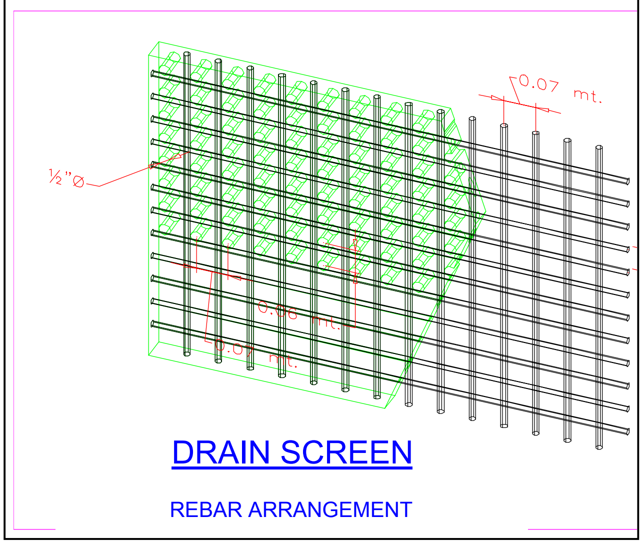
Figure B.1.5 Profile view cross section of spring box with details on change in elevation from the source to the spring box exit.

Adapted from: SANAA, Servicio Autónomo Nacional de Acueductos y Alcantarillos, "Normas de Diseño para Acueductos Rurales V.1.0," Tegucigalpa, Honduras, 1999.



SPECIFICATIONS

1) Concrete 2.5 lbs/in^2 has a volume ratio of 1:2:3 with a maximum aggragate size of 3/4."
Concrete 3.0 lbs/in^2 has a volume ratio of 1:2:2 with a maximum aggragate size of 3/4."
Concrete 4.0 lbs/in^2 has a volume ratio of 1:1½:1½ with a maximum aggragate size of 3/4."
2) All rebar used is grade 40 rebar.
3) Morter used in foundation has a volume ratio of 1:4, rock no smaller than 12."
4) Concrete slabs used to cover valve boxes use a volume ratio of 1:1½:1½ and rebar #2 every 10 cms in both directions.
5) Morter used to finish walls has a volume ratio of 1:4.



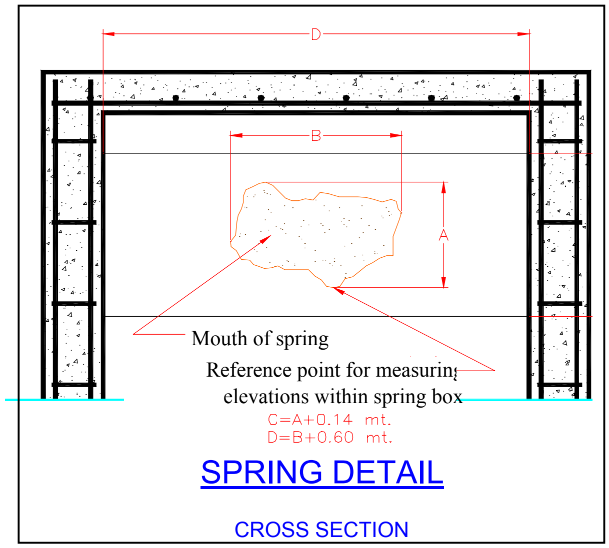


Figure B.1.6 Isometric details of drain screen at entrance of spring box, specifications for construction and a cross section detail of spring dimensions.

Adapted from: SANAA, Servicio Autónomo Nacional de Acueductos y Alcantarillos, "Normas de Diseño para Acueductos Rurales V.1.0," Tegucigalpa, Honduras, 1999.

Note: The height of the overflow pipe should be high enough to fill the spring box, without backing water up to the mouth of the spring. Water should flow freely through the spring box even under overflow conditions.

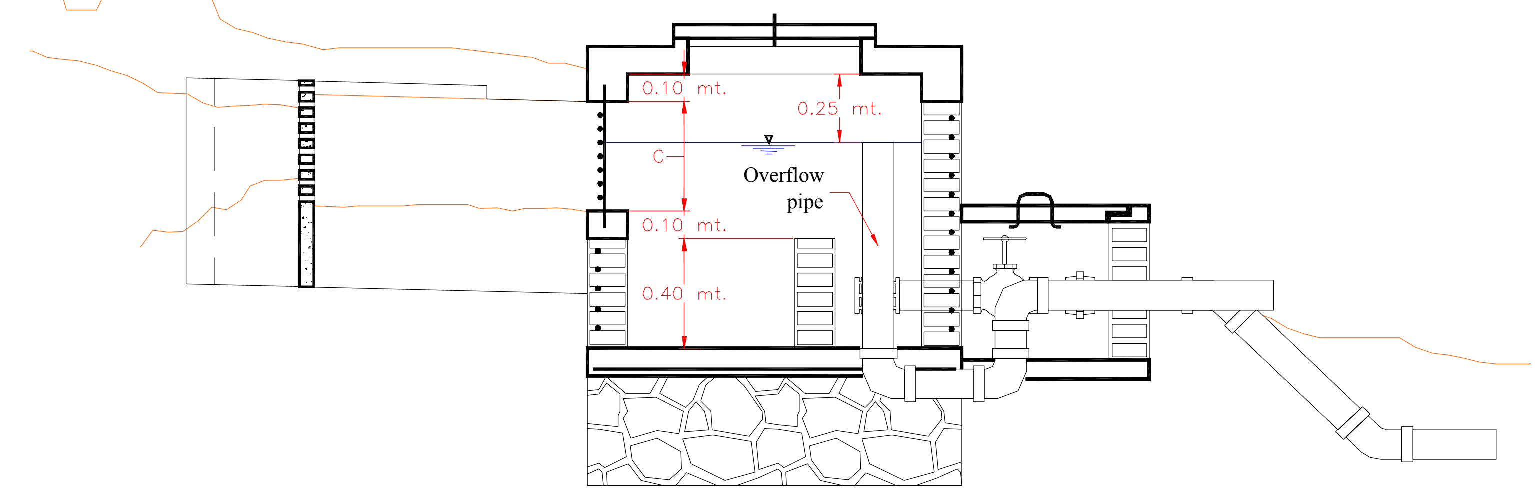


Figure B.1.7 Profile view cross section of spring box with details on inner dimensions and overflow pipe.

Adapted from: SANAA, Servicio Autónomo Nacional de Acueductos y Alcantarillos, "Normas de Diseño para Acueductos Rurales V.1.0," Tegucigalpa, Honduras, 1999.

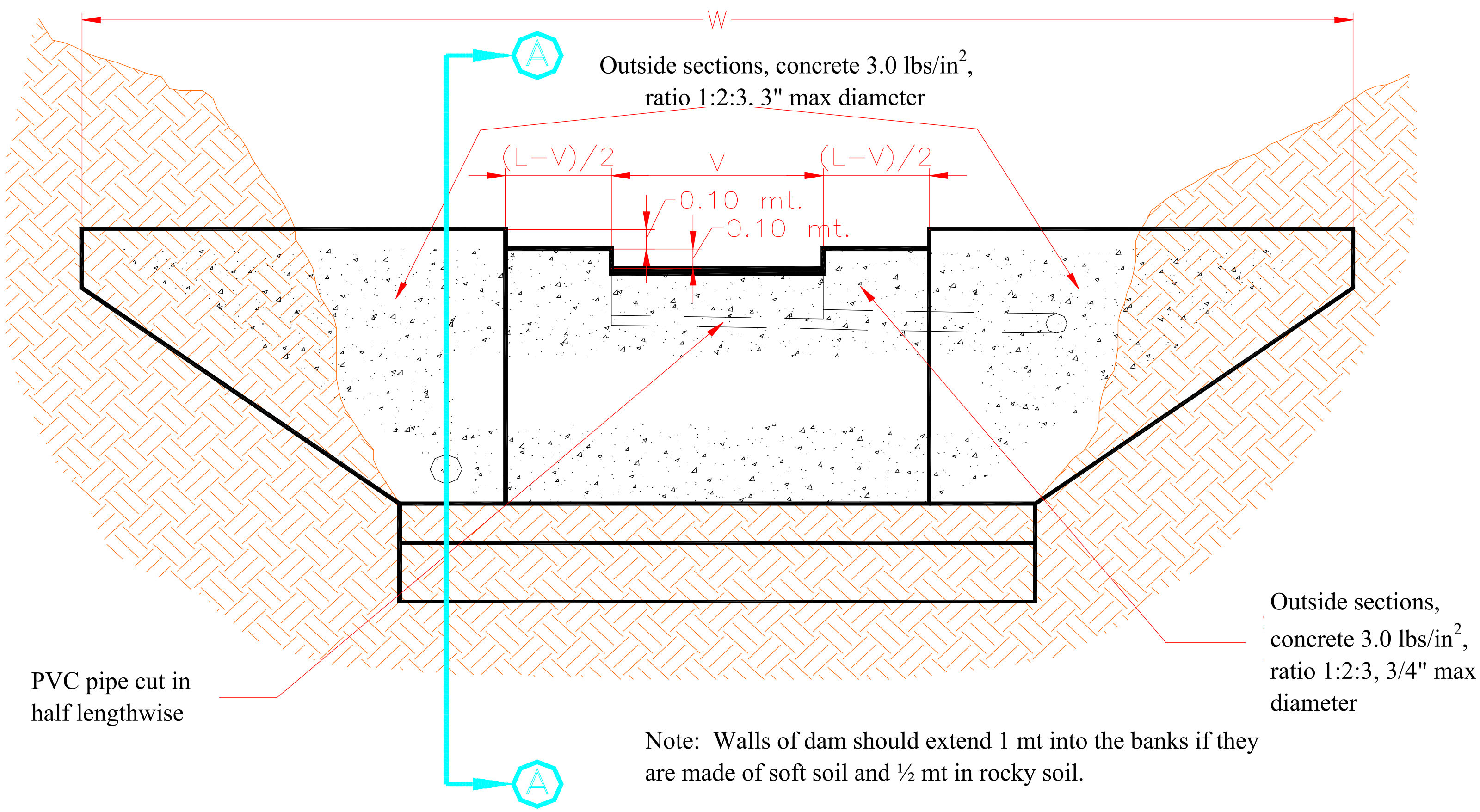


Figure B.2.1 Front view of dam with details on weir dimensions and concrete mixes.

Adapted from: SANAA, Servicio Autónomo Nacional de Acueductos y Alcantarillos, "Normas de Diseño para Acueductos Rurales V.1.0," Tegucigalpa, Honduras, 1999.

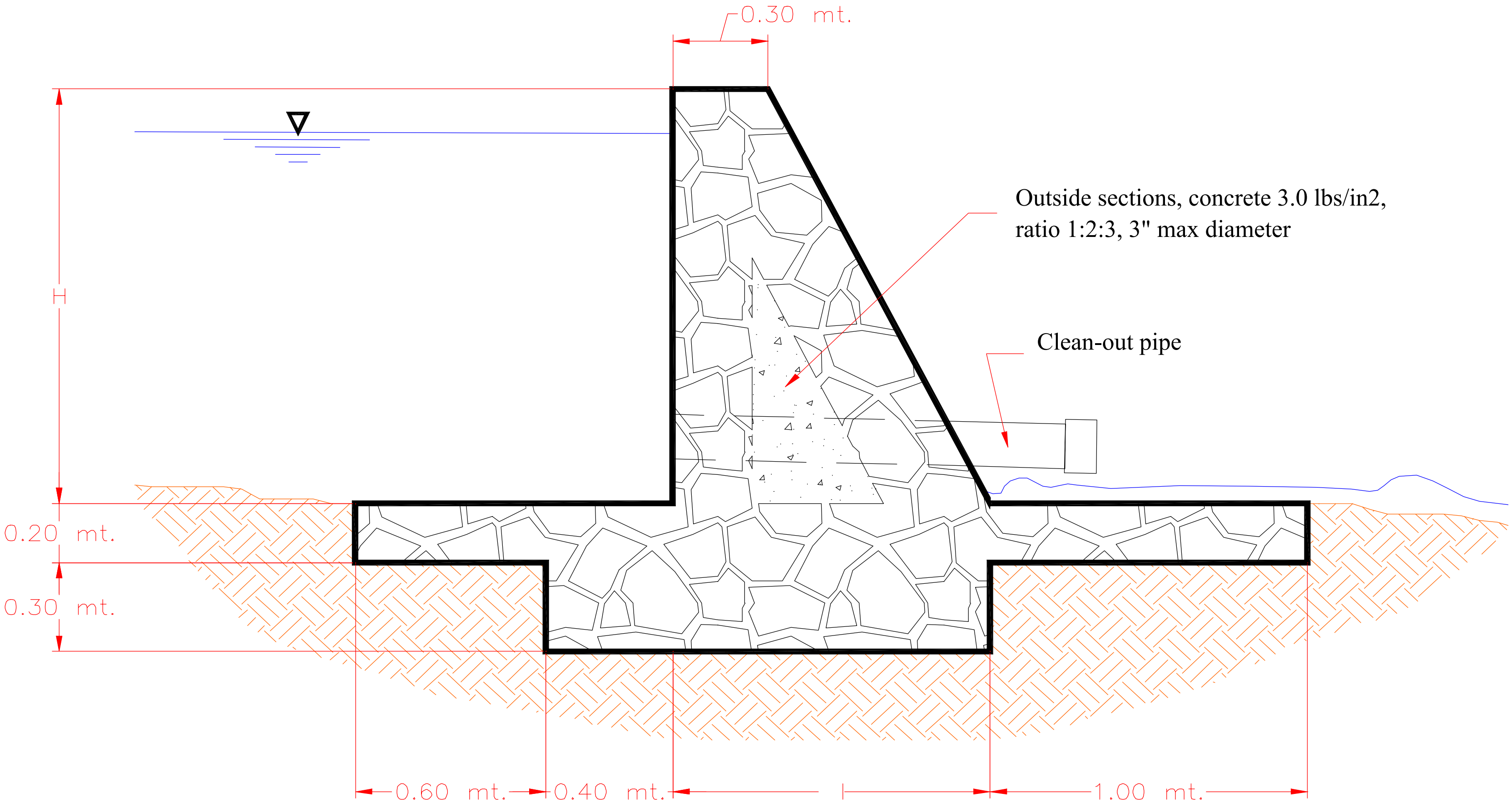


Figure B.2.2 Profile view cross section "A" of dam with details on outer dimensions.

Adapted from: SANAA, Servicio Autónomo Nacional de Acueductos y Alcantarillos, "Normas de Diseño para Acueductos Rurales V.1.0," Tegucigalpa, Honduras, 1999.

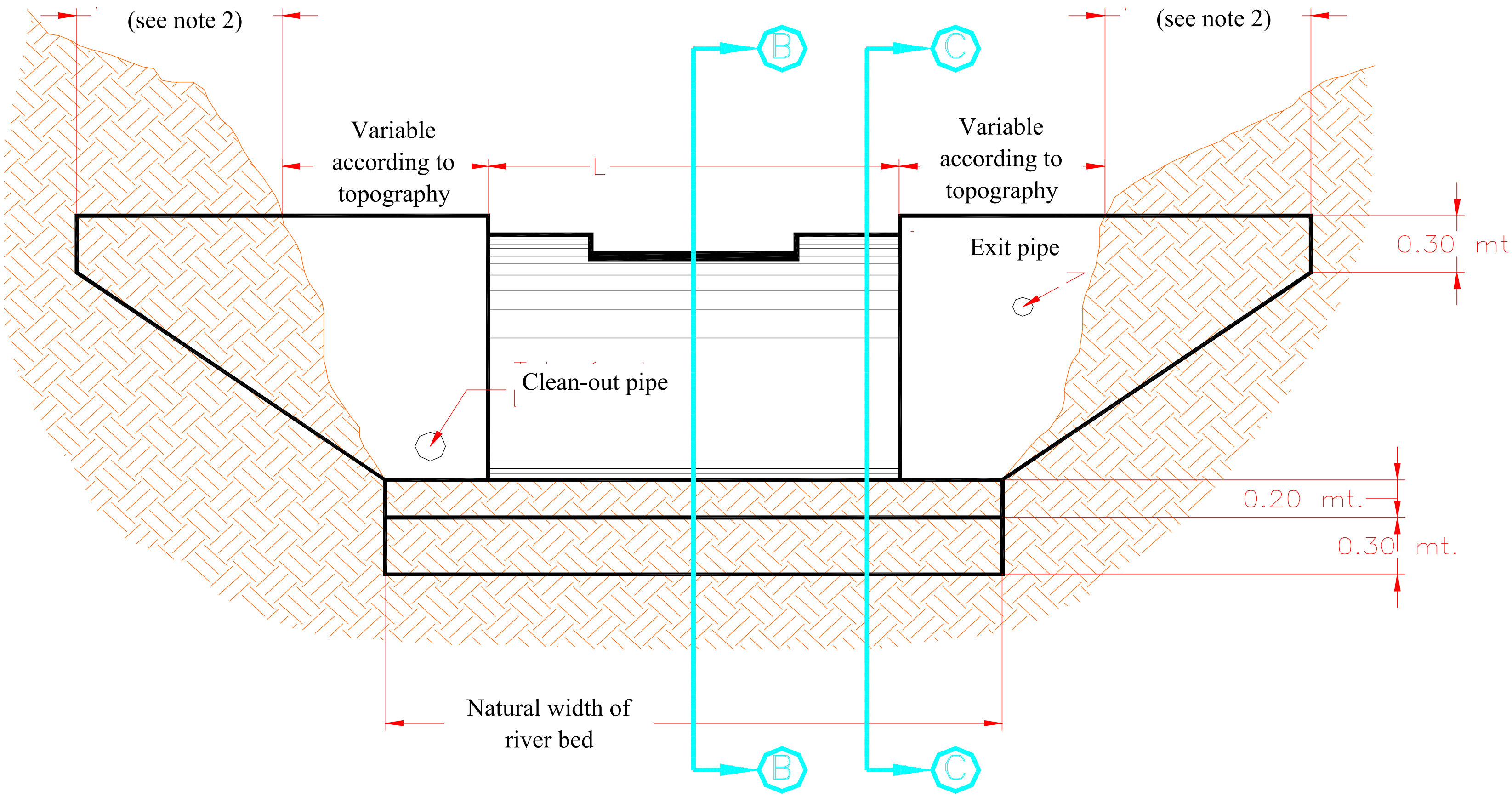
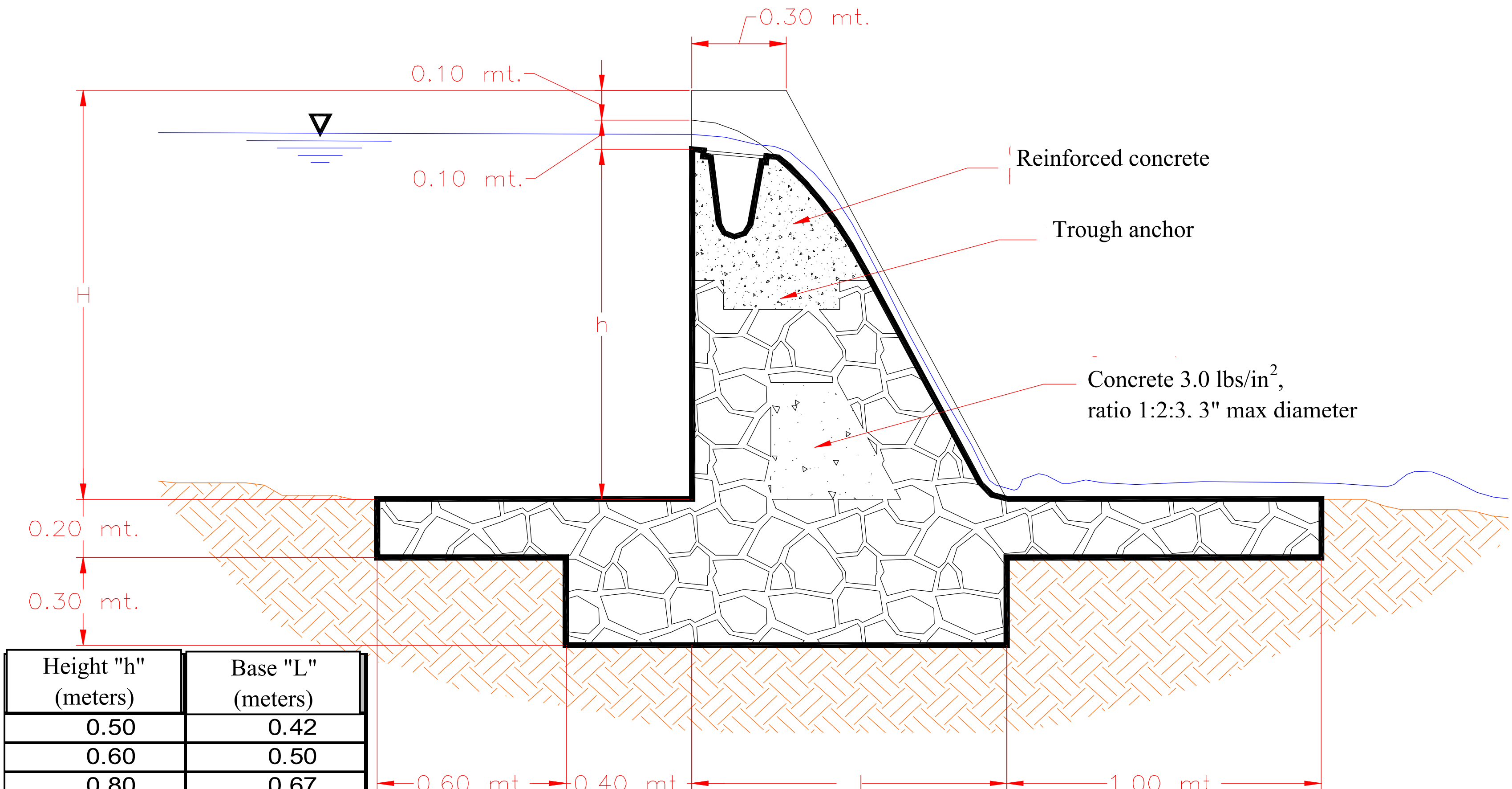


Figure B.2.3 Front view of dam with details on the locations of cross sections "B" and "C."

Adapted from: SANAA, Servicio Autónomo Nacional de Acueductos y Alcantarillos, "Normas de Diseño para Acueductos Rurales V.1.0," Tegucigalpa, Honduras, 1999.



Height "h" (meters)	Base "L" (meters)
0.50	0.42
0.60	0.50
0.80	0.67
1.00	0.83
1.20	1.00
1.30	1.05
1.50	1.25
1.80	1.80
2.00	1.86

Figure B.2.4 Profile view cross section "B" of dam with a table of height verses base dimensions for different size streams.

Adapted from: SANAA, Servicio Autónomo Nacional de Acueductos y Alcantarillos, "Normas de Diseño para Acueductos Rurales V.1.0," Tegucigalpa, Honduras, 1999.

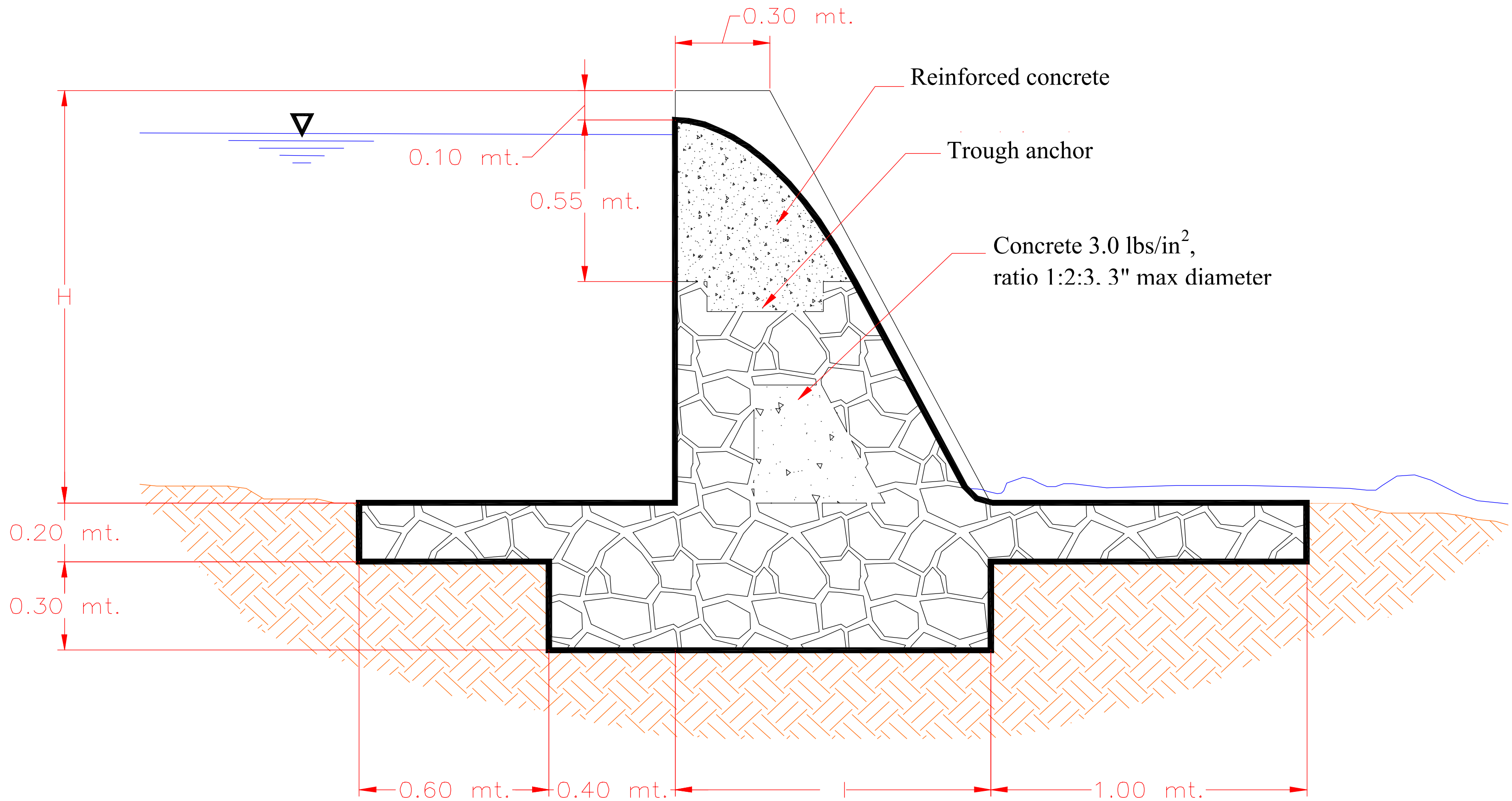
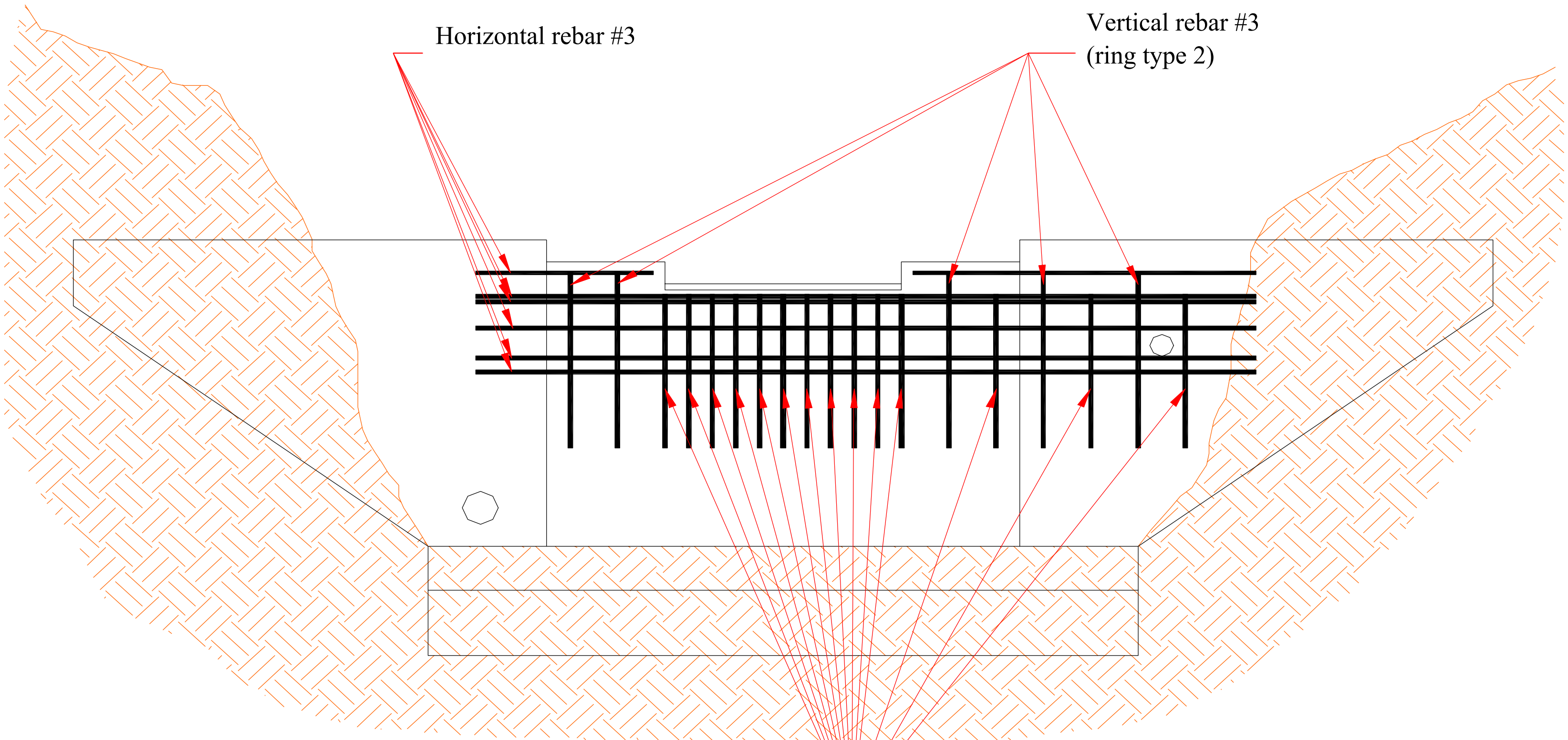


Figure B.2.5 Profile view cross section "C" of dam with details on outer dimensions.

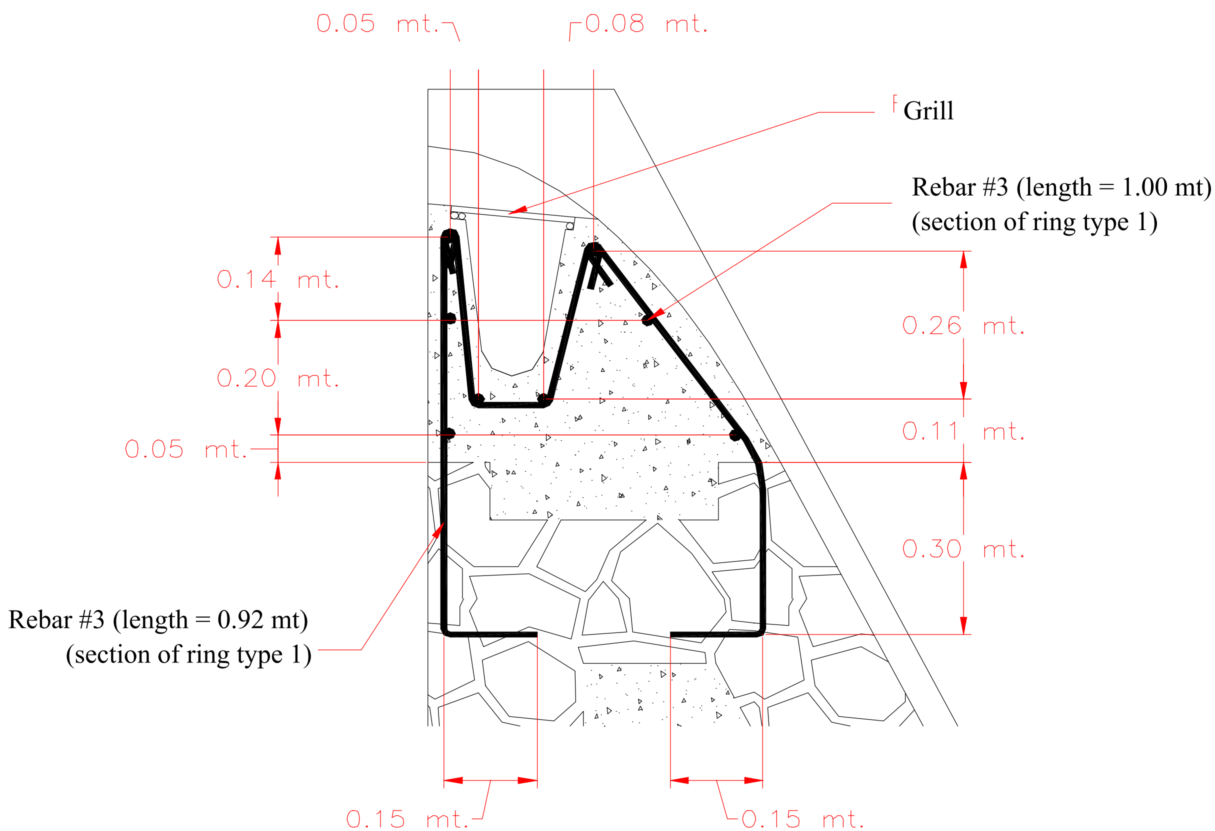
Adapted from: SANAA, Servicio Autónomo Nacional de Acueductos y Alcantarillos, "Normas de Diseño para Acueductos Rurales V.1.0," Tegucigalpa, Honduras, 1999.



Note 3: Horizontal rebar is placed every 30 cm. Ring type 1 rebar is placed every 10 cm below the trough. Outside the trough, ring types 1 and 2 are alternated every 20 cm.

Figure B.2.6 Front view of dam with details on arrangement of rebar.

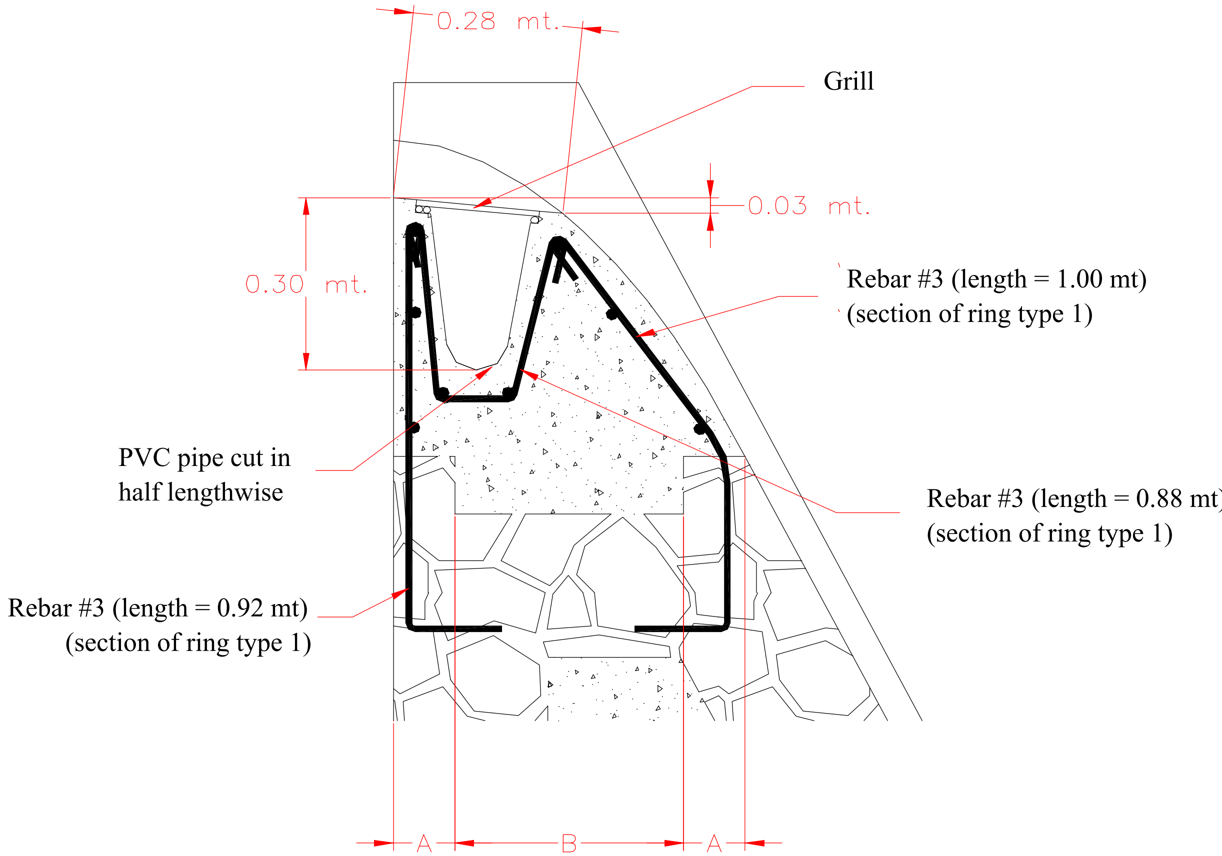
Adapted from: SANAA, Servicio Autónomo Nacional de Acueductos y Alcantarillos, "Normas de Diseño para Acueductos Rurales V.1.0," Tegucigalpa, Honduras, 1999.



Minimum rebar overlap is 2.5 cms

Figure B.2.7 Profile view cross section "A" of dam with details on trough and rebar arrangement.

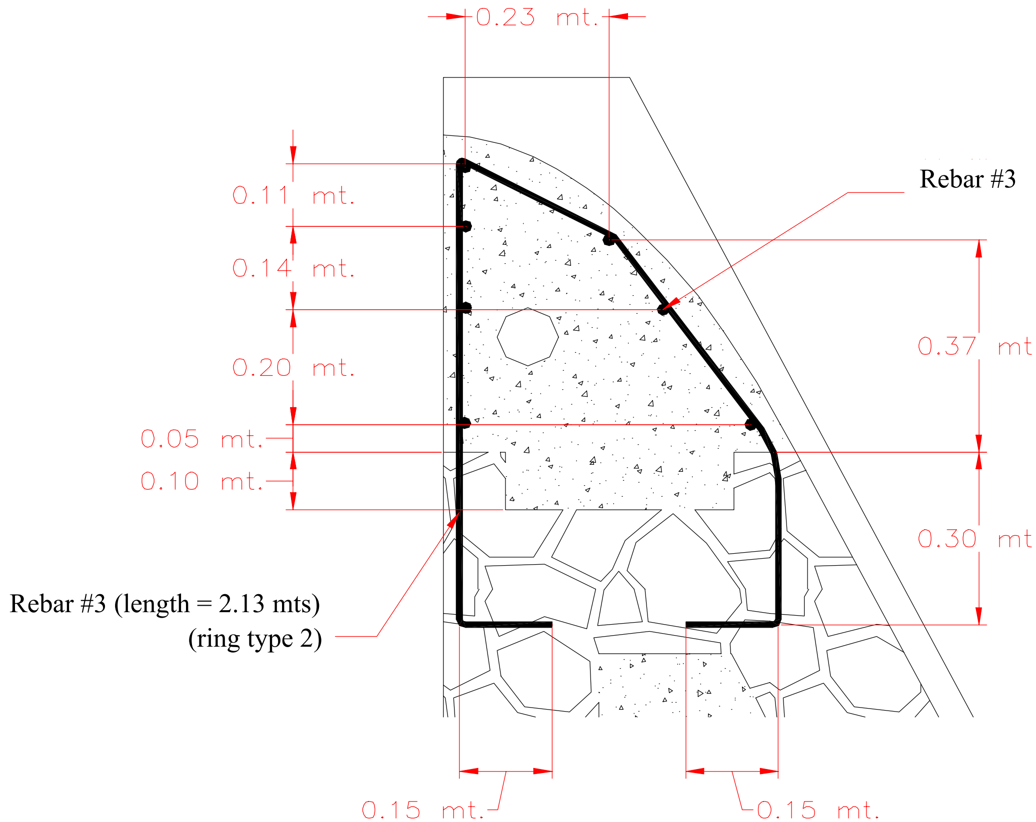
Adapted from: SANAA, Servicio Autónomo Nacional de Acueductos y Alcantarillos, "Normas de Diseño para Acueductos Rurales V.1.0," Tegucigalpa, Honduras, 1999.



Minimum rebar overlap is 2.50 cms

Figure B.2.8 Profile view cross section "B" of dam with details on trough and rebar arrangement.

Adapted from: SANAA, Servicio Autónomo Nacional de Acueductos y Alcantarillos, "Normas de Diseño para Acueductos Rurales V.1.0," Tegucigalpa, Honduras, 1999.



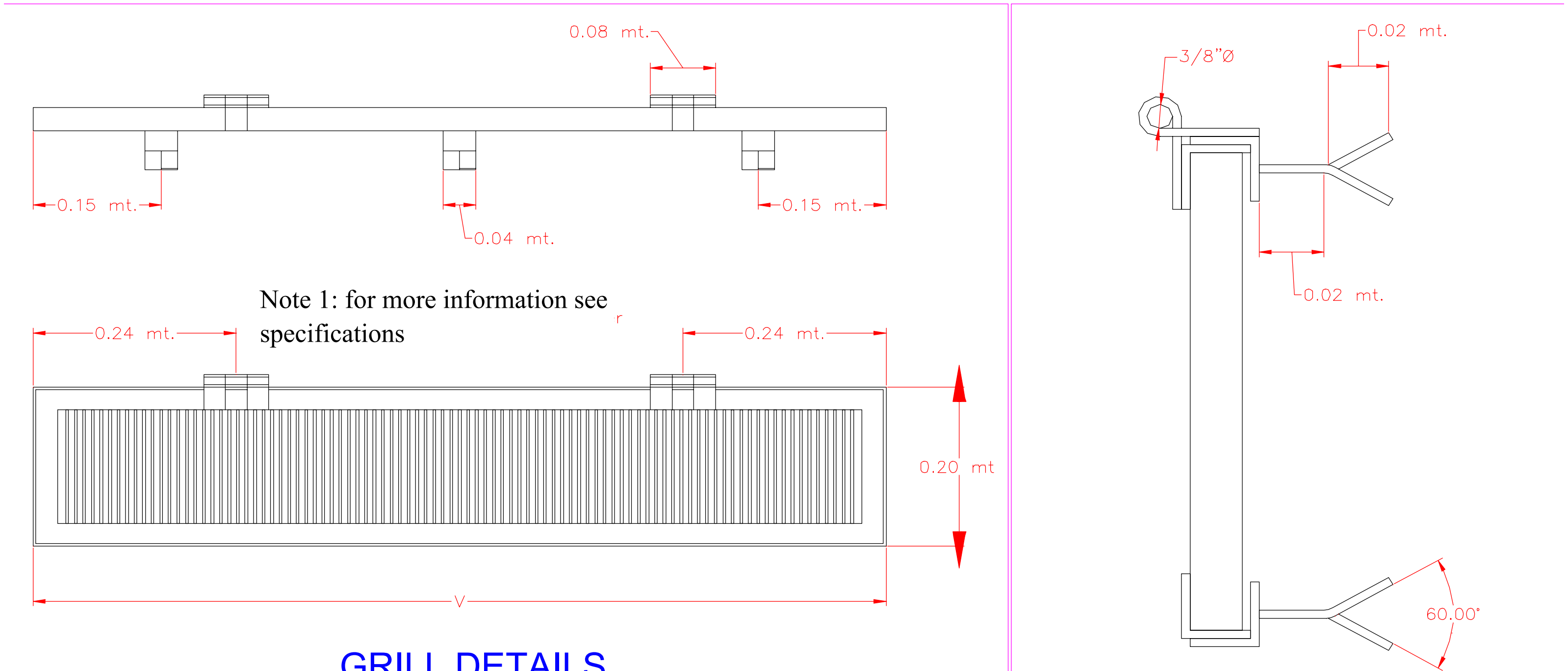
Minimum rebar overlap is 2.50 cms

Figure B.2.9 Profile view cross section "B" of dam with details on trough and rebar arrangement.

Adapted from: SANAA, Servicio Autónomo Nacional de Acueductos y Alcantarillos, "Normas de Diseño para Acueductos Rurales V.1.0," Tegucigalpa, Honduras, 1999.

TROUGH DIMENSIONS TABLE		
Caudal (gpm)	L (mts)	V (mts)
16 a 240	2.00	1.00
240 a 395	3.00	1.00
395 a 635	4.00	1.00

GENERAL DIMENSIONS TABLE (mts)									
H	0.70	0.80	1.00	1.20	1.40	1.50	1.70	2.00	2.20
h	0.50	0.60	0.80	1.00	1.20	1.30	1.50	1.80	2.00
I	0.42	0.50	0.67	0.83	1.00	1.08	1.25	1.50	1.66
A	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
B	0.21	0.26	0.34	0.39	0.43	0.44	0.46	0.49	0.50



GRILL DETAILS

Figure B.2.10 Grill details of dam with general and trough dimension tables.

Adapted from: SANAA, Servicio Autónomo Nacional de Acueductos y Alcantarillos, "Normas de Diseño para Acueductos Rurales V.1.0," Tegucigalpa, Honduras, 1999.

SPECIFICATIONS

1) Two types of concrete mixes are used. Concrete 3.0 lbs/in^2 has a volume ratio of 1:2:2 with a maximum aggragate size of 3/4." Concrete 3.0 lbs/in^2 has a volume ratio of 1:2:3 with a maximum aggragate size of 3."

2) All rebar used is grade 40 rebar.

3) Morter used in foundation has a volume ratio of 1:4, rock no smaller than 12."

4) A covering of rough sand and fine sand morter is be applied to the entire dam and also a cement paste layer to the middle overflow section.

5) Morter used to finish walls has a volume ratio of 1:4.

6) Leave 1 cm space between each bar on the grill.

7) All metal parts should be painted with anticorrosive paint.

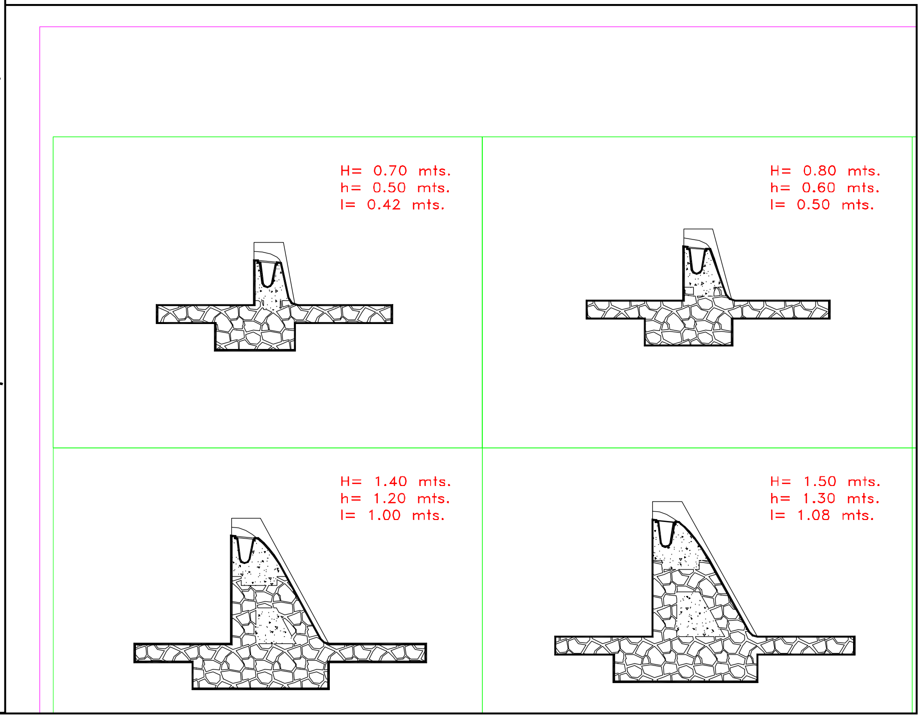


Figure B.2.11 Specifications for concrete mix and finish with typical dimensions for dams.

Adapted from: SANAA, Servicio Autónomo Nacional de Acueductos y Alcantarillos, "Normas de Diseño para Acueductos Rurales V.1.0," Tegucigalpa, Honduras, 1999.

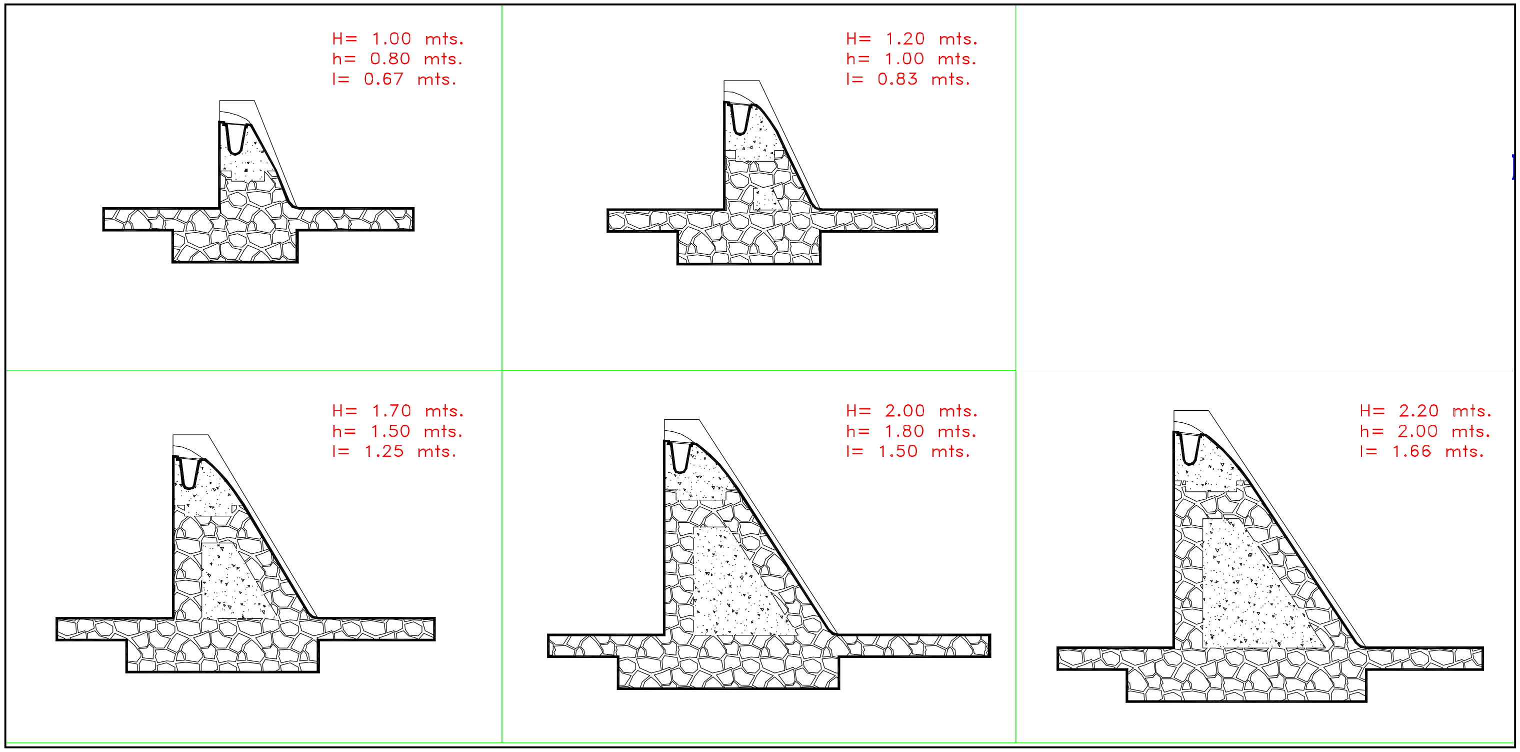


Figure B.2.12 Profile cross sections of typical dimensions for dams.

Adapted from: SANAA, Servicio Autónomo Nacional de Acueductos y Alcantarillos, "Normas de Diseño para Acueductos Rurales V.1.0," Tegucigalpa, Honduras, 1999.

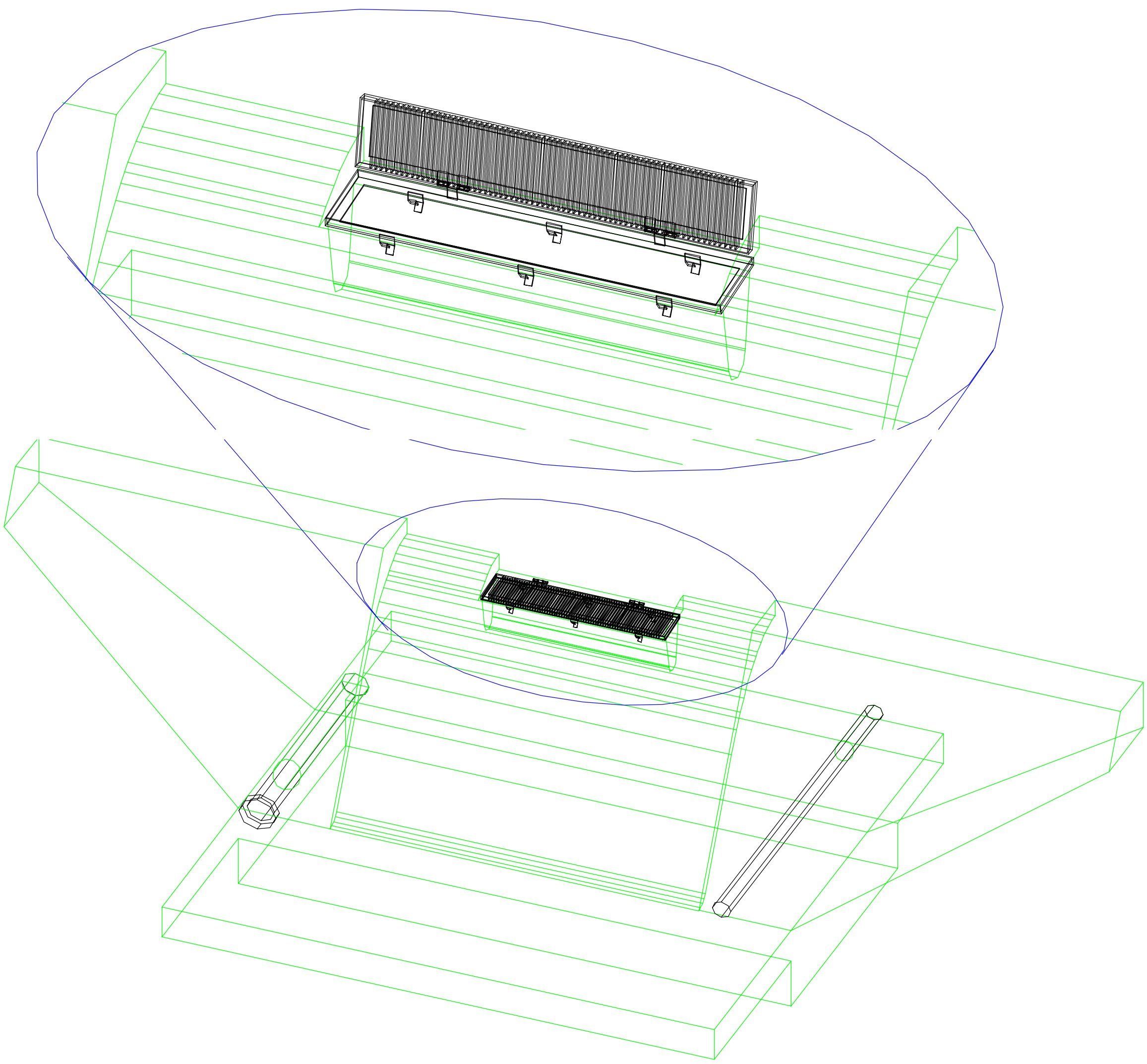


Figure B.2.13 Isometric view of dam highlighting location of grill.

Adapted from: SANAA, Servicio Autónomo Nacional de Acueductos y Alcantarillos, "Normas de Diseño para Acueductos Rurales V.1.0," Tegucigalpa, Honduras, 1999.

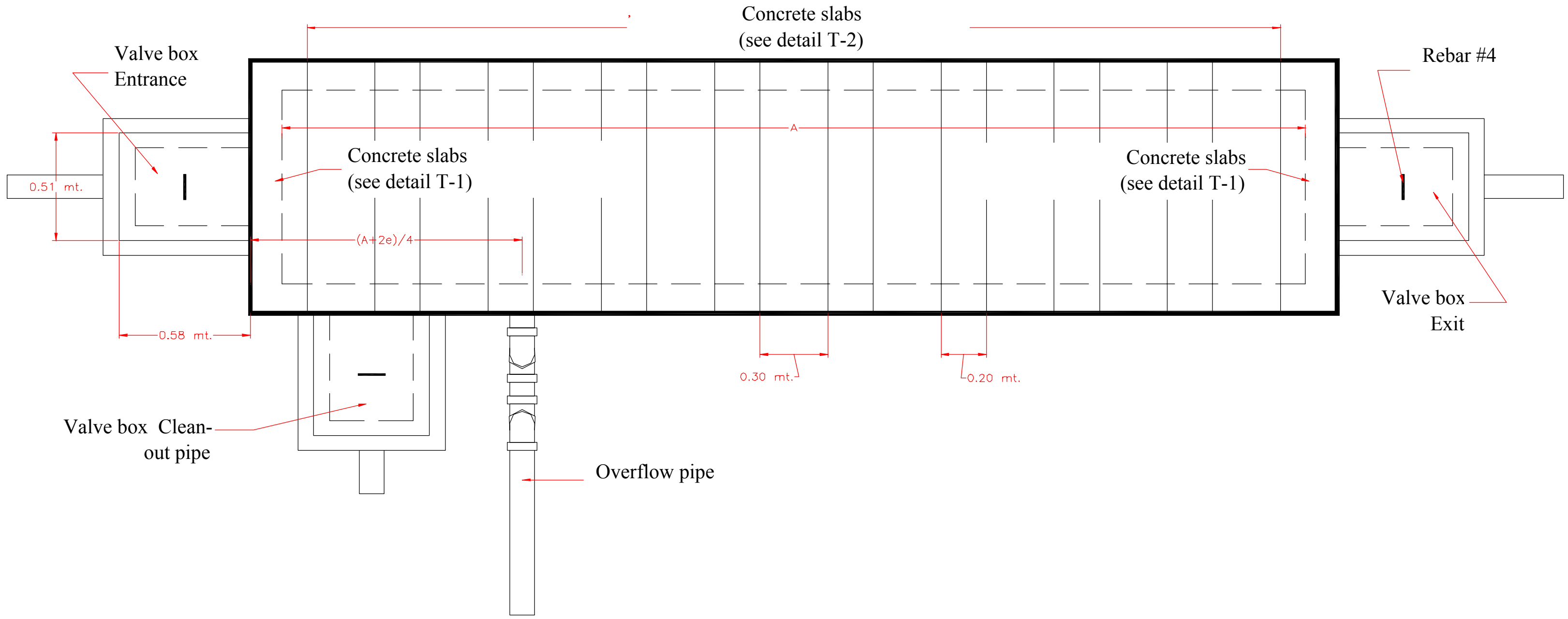


Figure B.3.1 Plan view of sedimentation tank with details on concrete slabs used to cover tank and valve boxes.

Adapted from: SANAA, Servicio Autónomo Nacional de Acueductos y Alcantarillos, "Normas de Diseño para Acueductos Rurales V.1.0," Tegucigalpa, Honduras, 1999.

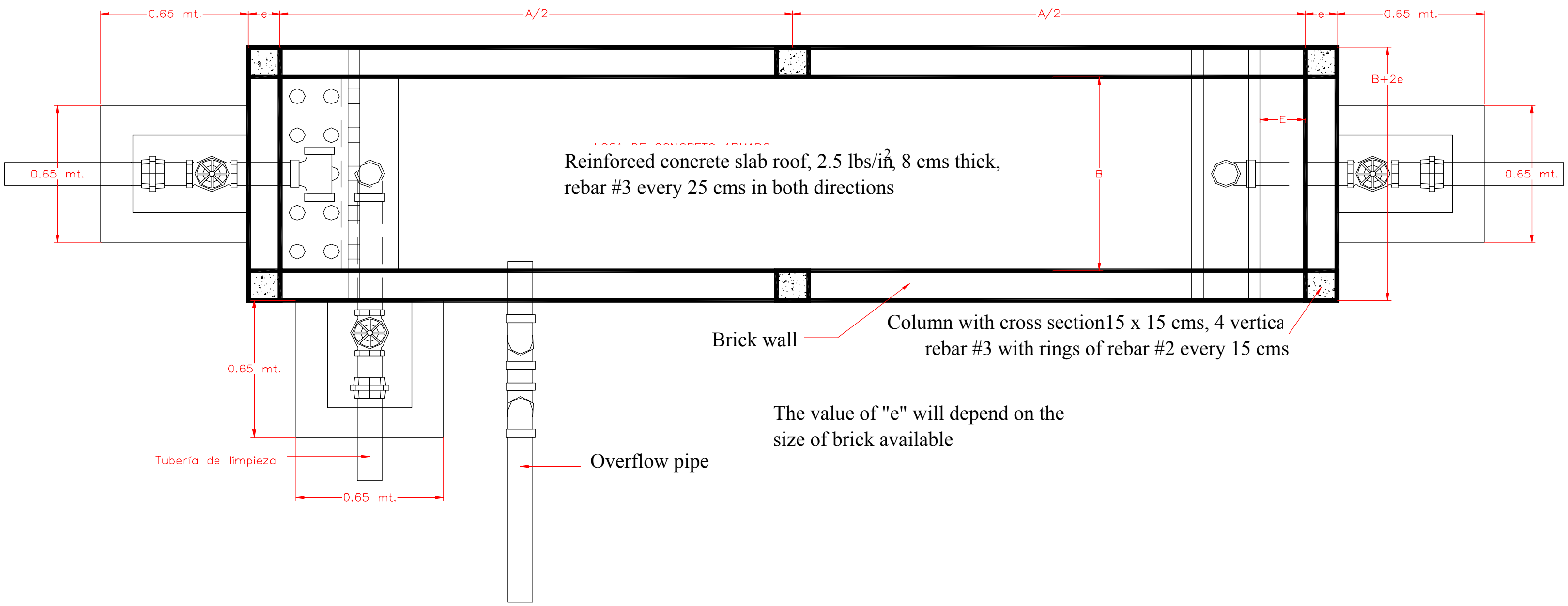


Figure B.3.2 Plan view cross section of sedimentation tank with details on outer dimensions.

Adapted from: SANAA, Servicio Autónomo Nacional de Acueductos y Alcantarillos, "Normas de Diseño para Acueductos Rurales V.1.0," Tegucigalpa, Honduras, 1999.

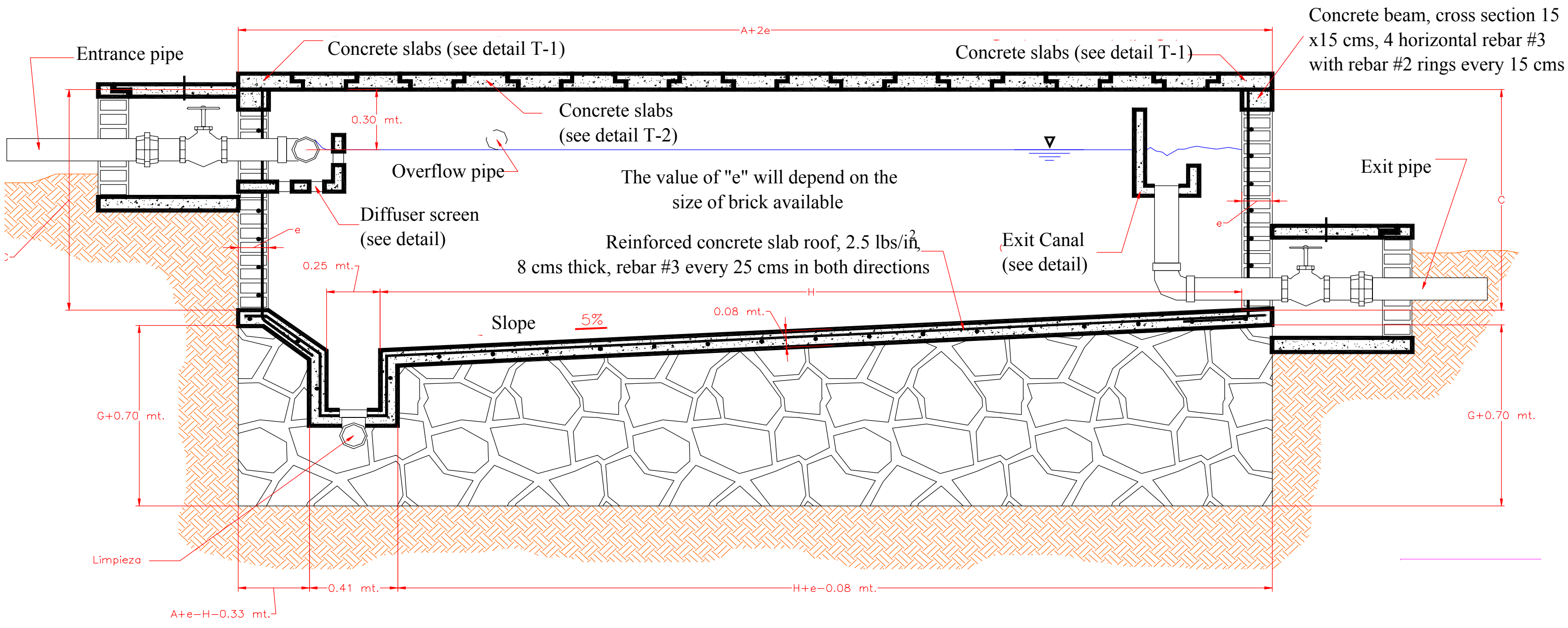


Figure B.3.3 Profile view cross section of sedimentation tank.

Adapted from: SANAA, Servicio Autónomo Nacional de Acueductos y Alcantarillos, "Normas de Diseño para Acueductos Rurales V.1.0," Tegucigalpa, Honduras, 1999.

SPECIFICATIONS

1) Concrete 2.5 lbs/in^2 has a volume ratio of 1:2:3 with a maximum aggragate size of 3/4." Concrete 4.0 lbs/in^2 has a volume ratio of 1:1½:1½ with a maximum aggragate size of 3/4."
2) All rebar used is grade 40 rebar.
3) All rebar overlaps are at least 30 cms. Hooks at ends of rebar are at least 15 cms long.
4) Morter used in foundation has a volume ratio of 1:4, rock no smaller than 12."
5) A layer of coarse sand morter and fine sand morter is applied to the entire structure and a layer of cement paste on the inside.
6) Morter used to finish walls has a volume ratio of 1:4.
7) The diffuser screen, exit canal, and concrete slabs used to cover valve boxes are made with concrete 4.0 lbs/in^2. Rebar #2 is placed every 10 cms in both directions.
8) Flooring of valve boxes is made with concrete 2.5 lbs/in^2, 7 cms thick.

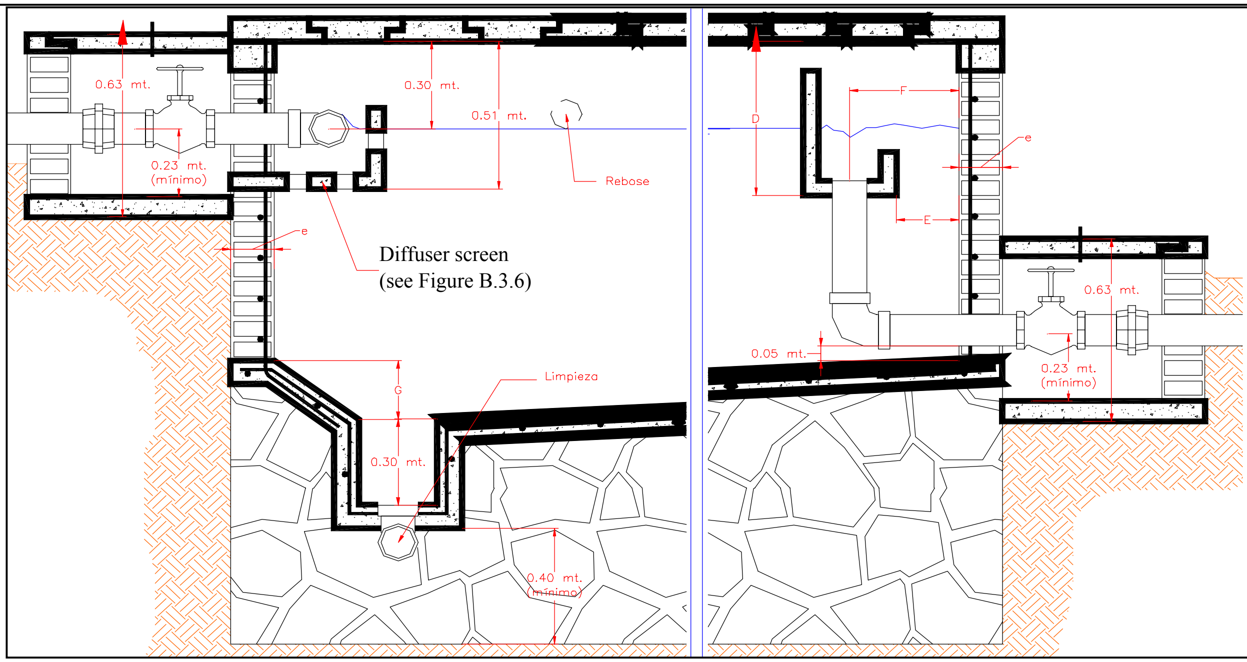


Figure B.3.4 Profile view cross section of sedimentation tank with details on entrance and exit and specifications for construction.

Adapted from: SANAA, Servicio Autónomo Nacional de Acueductos y Alcantarillos, "Normas de Diseño para Acueductos Rurales V.1.0," Tegucigalpa, Honduras, 1999.

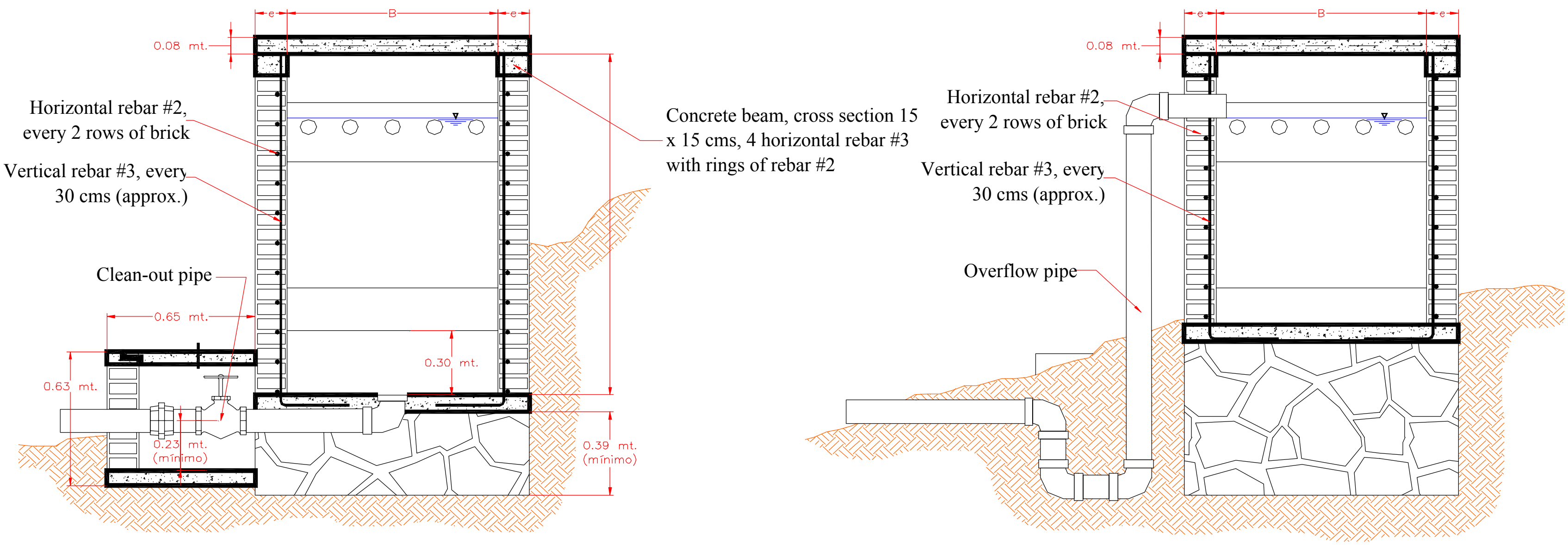
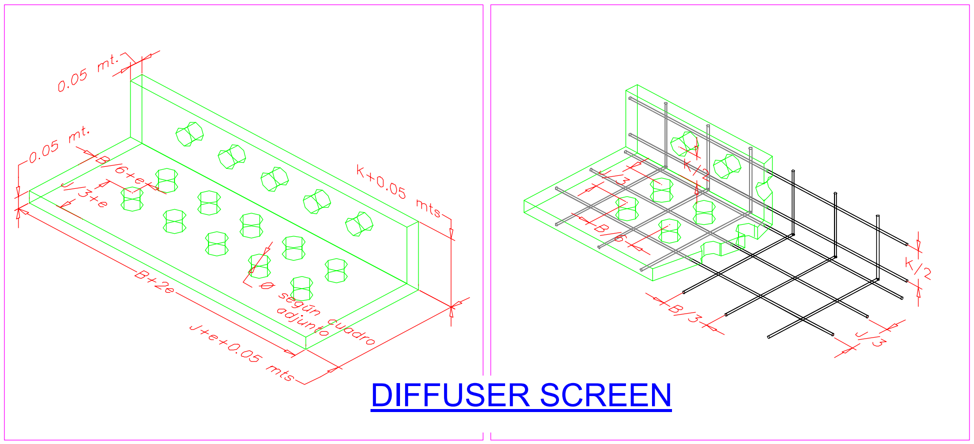
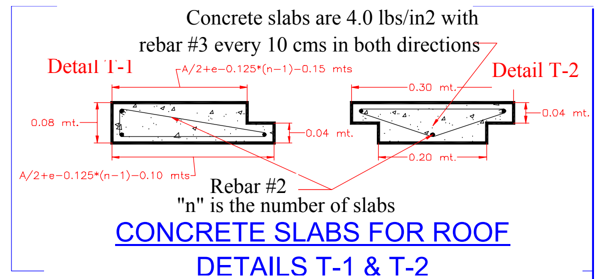


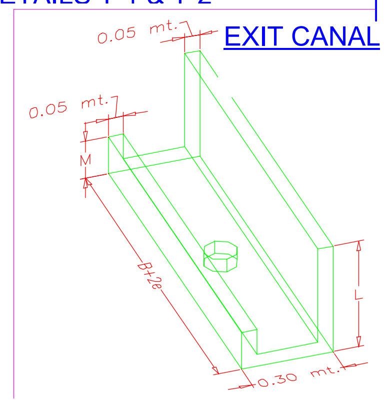
Figure B.3.5 Side view cross sections of sedimentation tank with details on overflow and clean-out pipes.

Adapted from: SANAA, Servicio Autónomo Nacional de Acueductos y Alcantarillos, "Normas de Diseño para Acueductos Rurales V.1.0," Tegucigalpa, Honduras, 1999.





Rebar for the exit canal is the same as the diffuser screen



GENERAL DATA SEDIMENTATION TANK																				
DESIGN FLOW	DIMENSIONS IN METERS														Ø Orifices (cms)		# Orifices		# Lines	
	A	B	C	D	E	F	G	H	I	J	K	L	M	T−1	T−2	Fondo	Lateral	Fondo	Lateral	Fondo	Lateral
47 gpm	3.02	0.50	0.75	0.43	0.12	0.27	0.12	2.42	1.17	0.25	0.18	0.35	0.10	2	11	5.00	5.00	10	–	2	–
79 gpm	3.52	0.70	0.85	0.48	0.15	0.30	0.15	2.92	1.49	0.30	0.18	0.37	0.10	2	13	5.00	5.00	10	2	2	1
99 gpm	4.02	0.70	1.05	0.50	0.20	0.35	0.17	3.42	1.52	0.30	0.23	0.40	0.12	2	15	6.00	6.00	10	5	2	1
158 gpm	4.52	0.90	1.10	0.53	0.20	0.35	0.20	4.00	1.60	0.30	0.23	0.43	0.15	2	17	7.00	7.00	10	5	2	1

Figure B.3.6 Isometric views of diffuser screen and exit canal, details T-1 and T-2 for concrete slabs used to cover tank and table of dimensions for different design flows.

Adapted from: SANAA, Servicio Autónomo Nacional de Acueductos y Alcantarillos, "Normas de Diseño para Acueductos Rurales V.1.0," Tegucigalpa, Honduras, 1999.

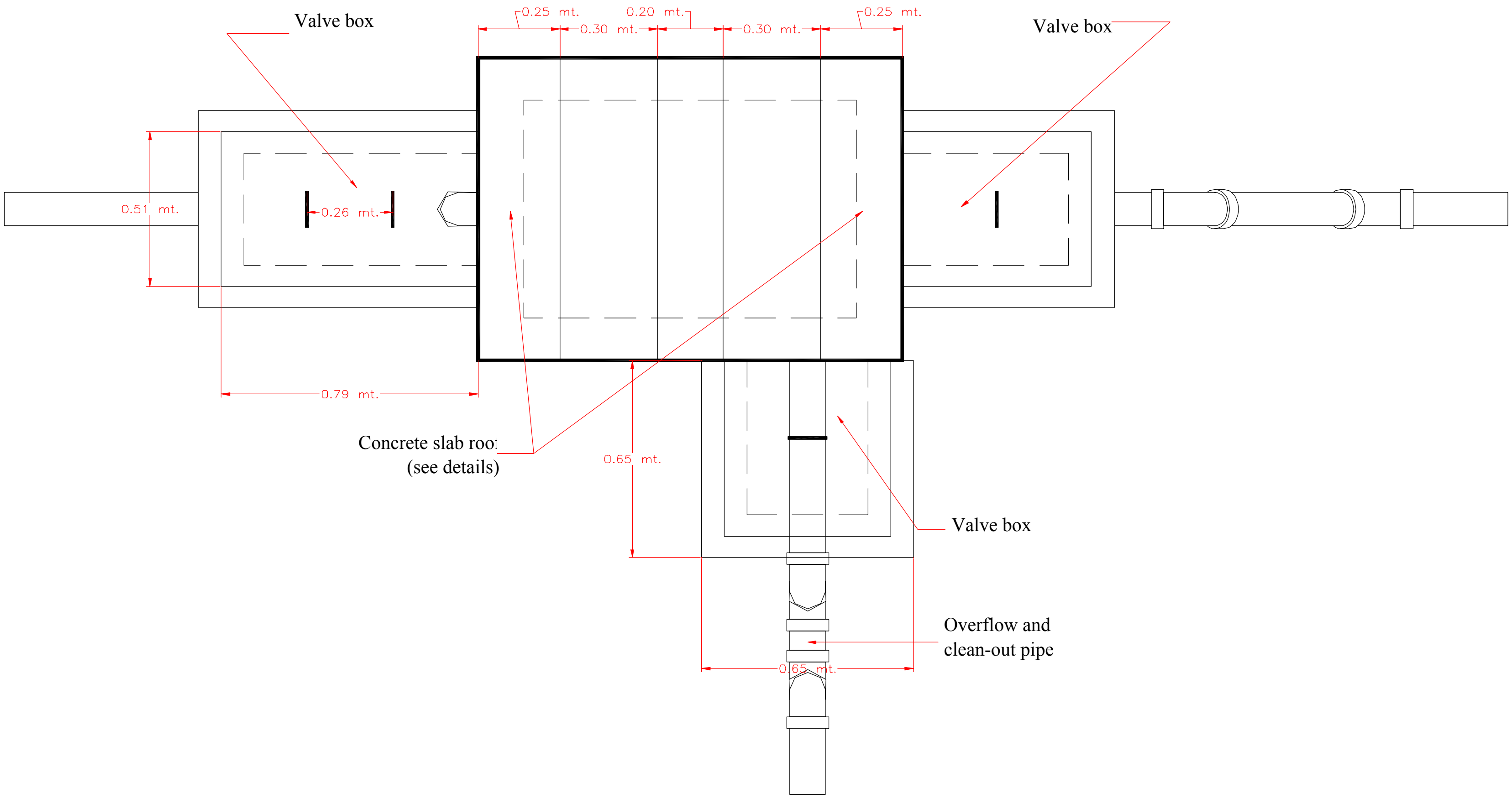


Figure B.4.1 Plan view of break pressure tank with details on concretes slabs used to cover tank and valve boxes.

Adapted from: SANAA, Servicio Autónomo Nacional de Acueductos y Alcantarillos, "Normas de Diseño para Acueductos Rurales V.1.0," Tegucigalpa, Honduras, 1999.

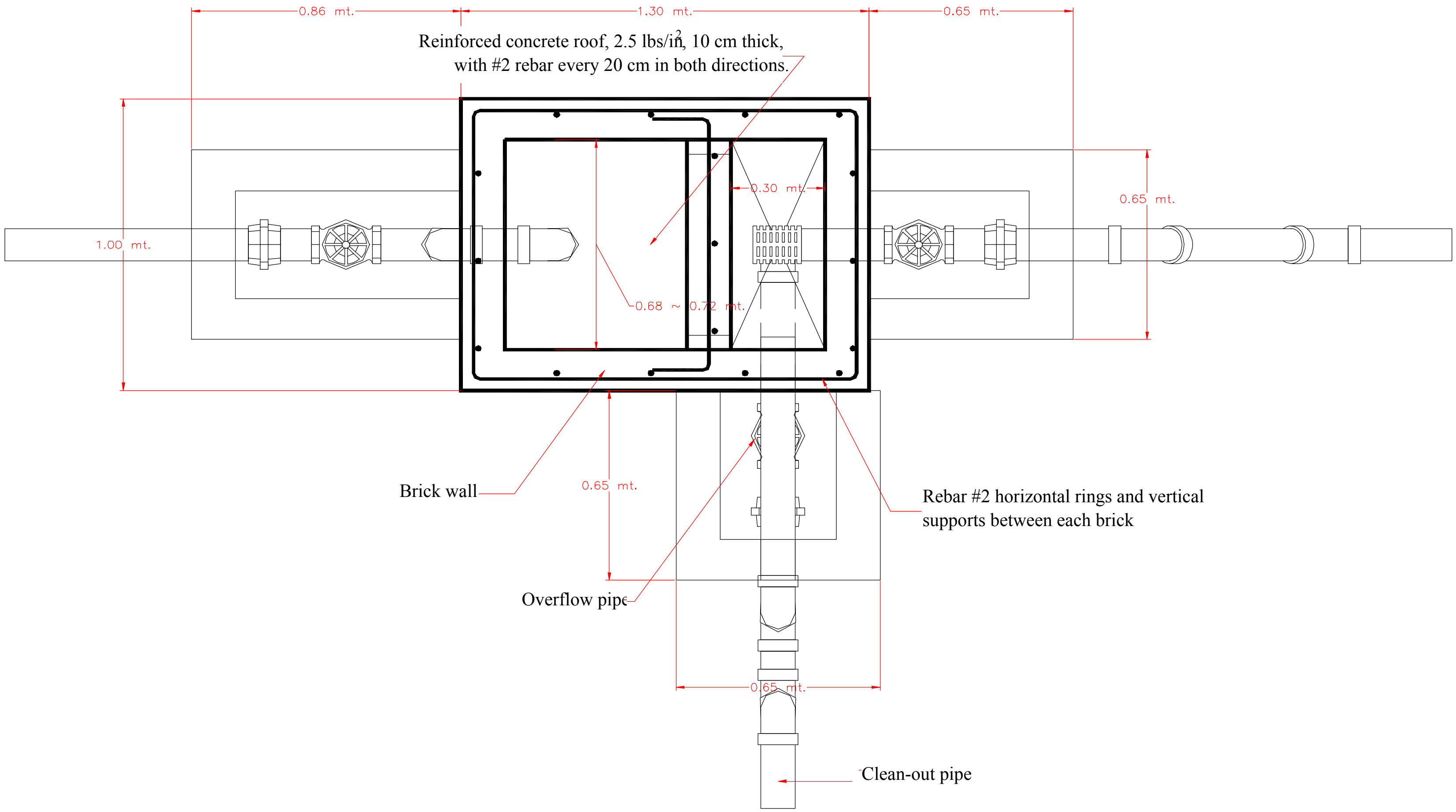


Figure B.4.2 Plan view cross section of break pressure tank with details on rebar arrangement.

Adapted from: SANAA, Servicio Autónomo Nacional de Acueductos y Alcantarillos, "Normas de Diseño para Acueductos Rurales V.1.0," Tegucigalpa, Honduras, 1999.

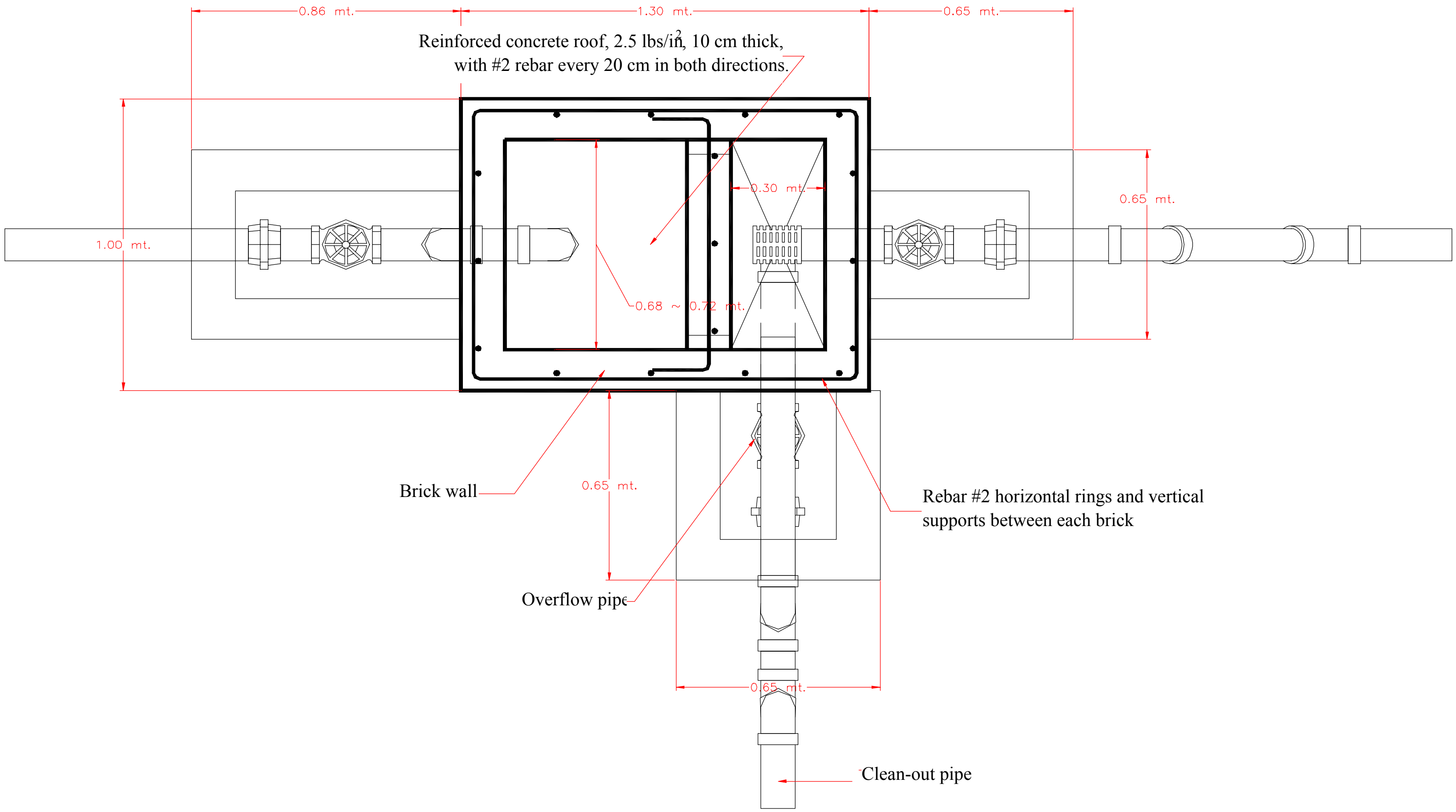


Figure B.4.2 Plan view cross section of break pressure tank with details on rebar arrangement.

Adapted from: SANAA, Servicio Autónomo Nacional de Acueductos y Alcantarillos, "Normas de Diseño para Acueductos Rurales V.1.0," Tegucigalpa, Honduras, 1999.

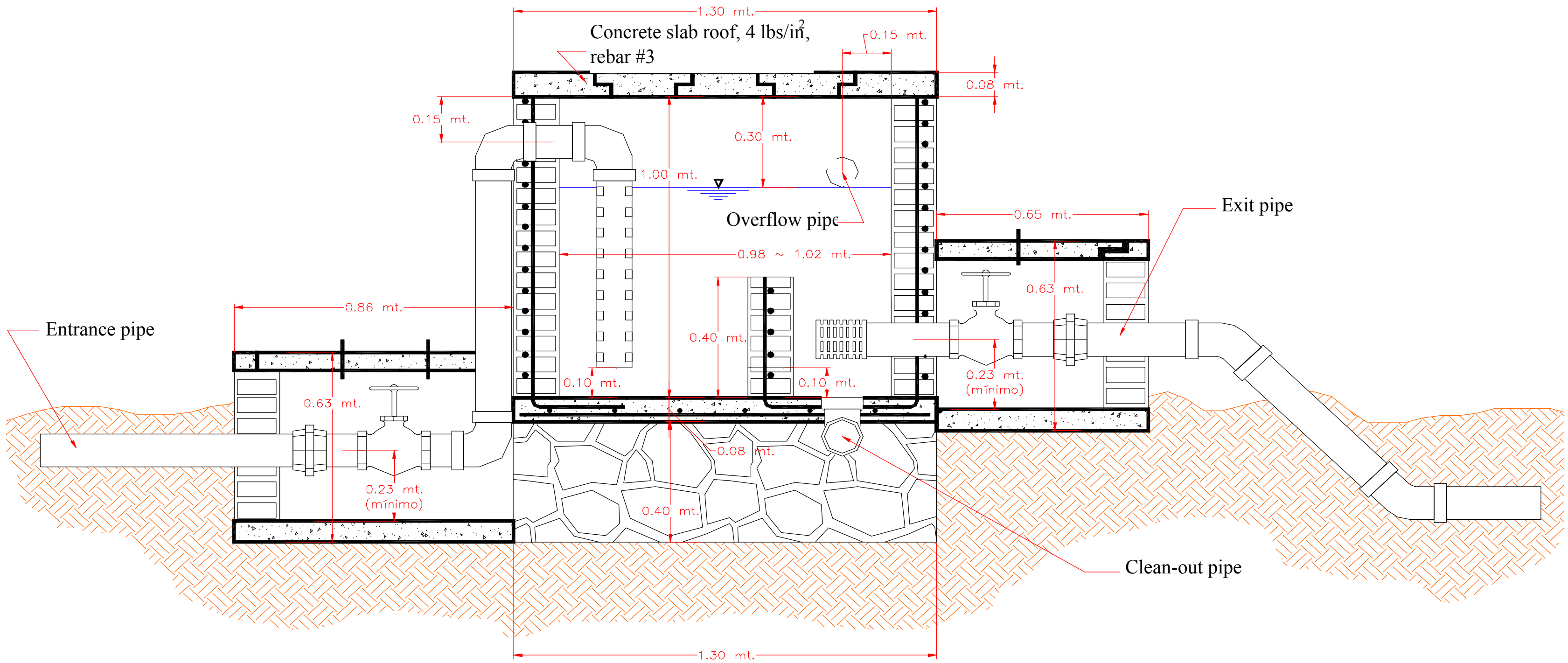
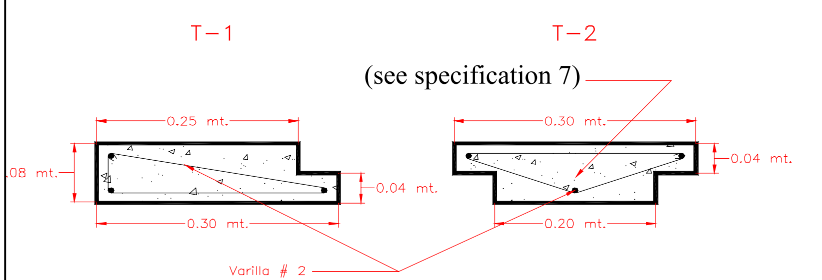


Figure B.4.3 Profile view cross section of break pressure tank with details on rebar arrangement and inner dimensions.

Adapted from: SANAA, Servicio Autónomo Nacional de Acueductos y Alcantarillos, "Normas de Diseño para Acueductos Rurales V.1.0," Tegucigalpa, Honduras, 1999.

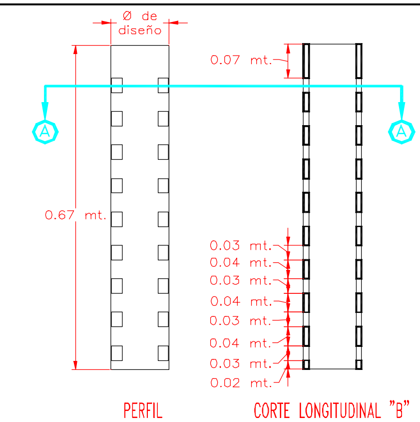
SPECIFICATIONS

1) Concrete 2.5 lbs/in^2 has a volume ratio of 1:2:3 with a maximum aggragate size of 3/4." Concrete 4.0 lbs/in^2 has a volume ratio of 1:1½:1½ with a maximum aggragate size of 3/4."
2) All rebar used is grade 40 rebar.
3) All rebar overlaps are at least 30 cms. Hooks at ends of rebar are at least 15 cms long.
4) Morter used in foundation has a volume ratio of 1:4, rock no smaller than 12."
5) A layer of coarse sand morter and fine sand morter is applied to the entire structure and a layer of cement paste on the inside.
6) Morter used to finish walls has a volume ratio of 1:4.
7) Concrete slabs used to cover valve boxes are made with concrete 4.0 lbs/in^2. Rebar #2 is placed every 10 cms in both directions.
8) Flooring of valve boxes is made with concrete 2.5 lbs/in2, 7 cms thick.



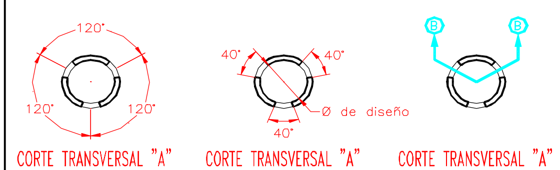
CONCRETE SLAB ROOF

PROFILE CROSS SECTION



ENTRANCE PVC PIPE

PROFILE CROSS SECTION



ENTRANCE PVC PIPE

PLAN CROSS SECTION

Figure B.4.5 Profile view cross section of concrete slabs used to cover tank, details on entrance PVC pipe and specifications for construction.

Adapted from: SANAA, Servicio Autónomo Nacional de Acueductos y Alcantarillos, "Normas de Diseño para Acueductos Rurales V.1.0," Tegucigalpa, Honduras, 1999.

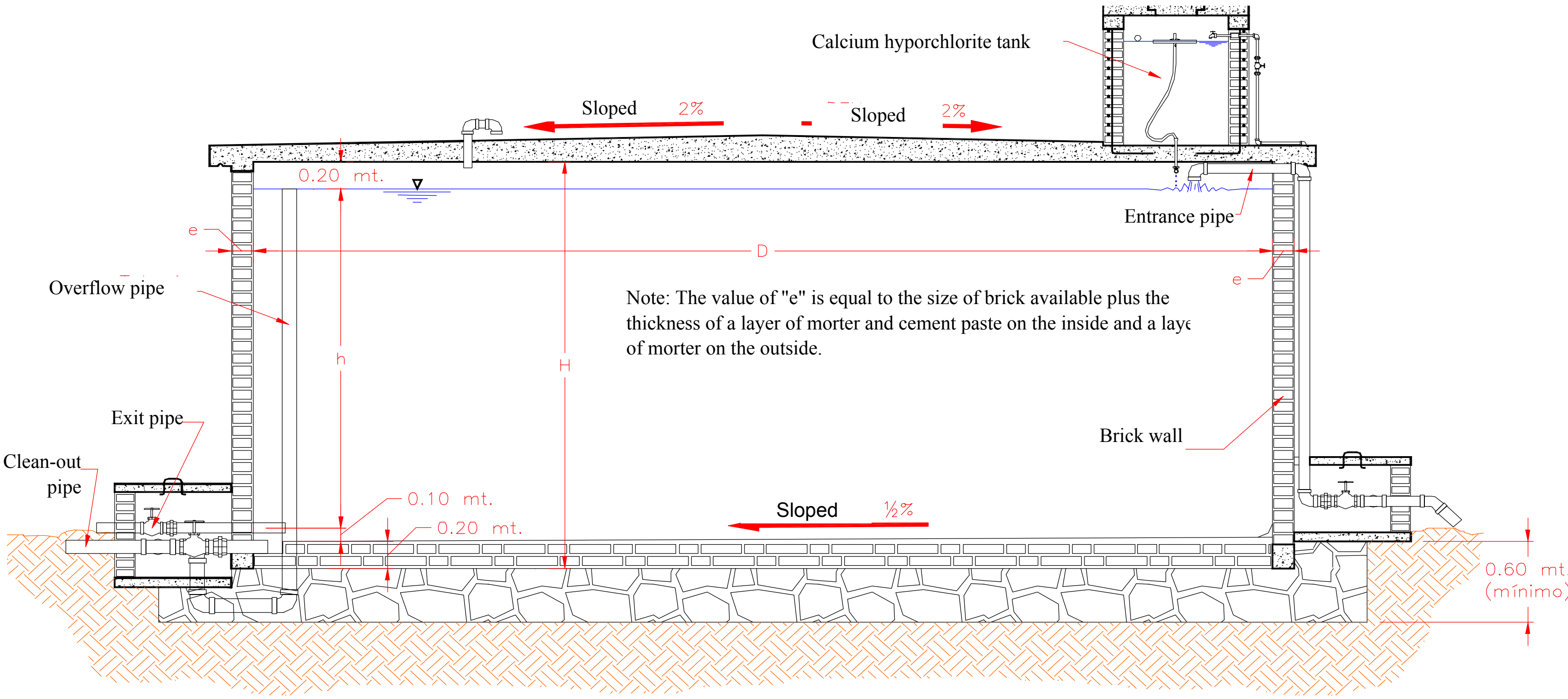


Figure B.5.1 Profile view cross section "A" of storage tank.

Adapted from: SANAA, Servicio Autónomo Nacional de Acueductos y Alcantarillos, "Normas de Diseño para Acueductos Rurales V.1.0," Tegucigalpa, Honduras, 1999.

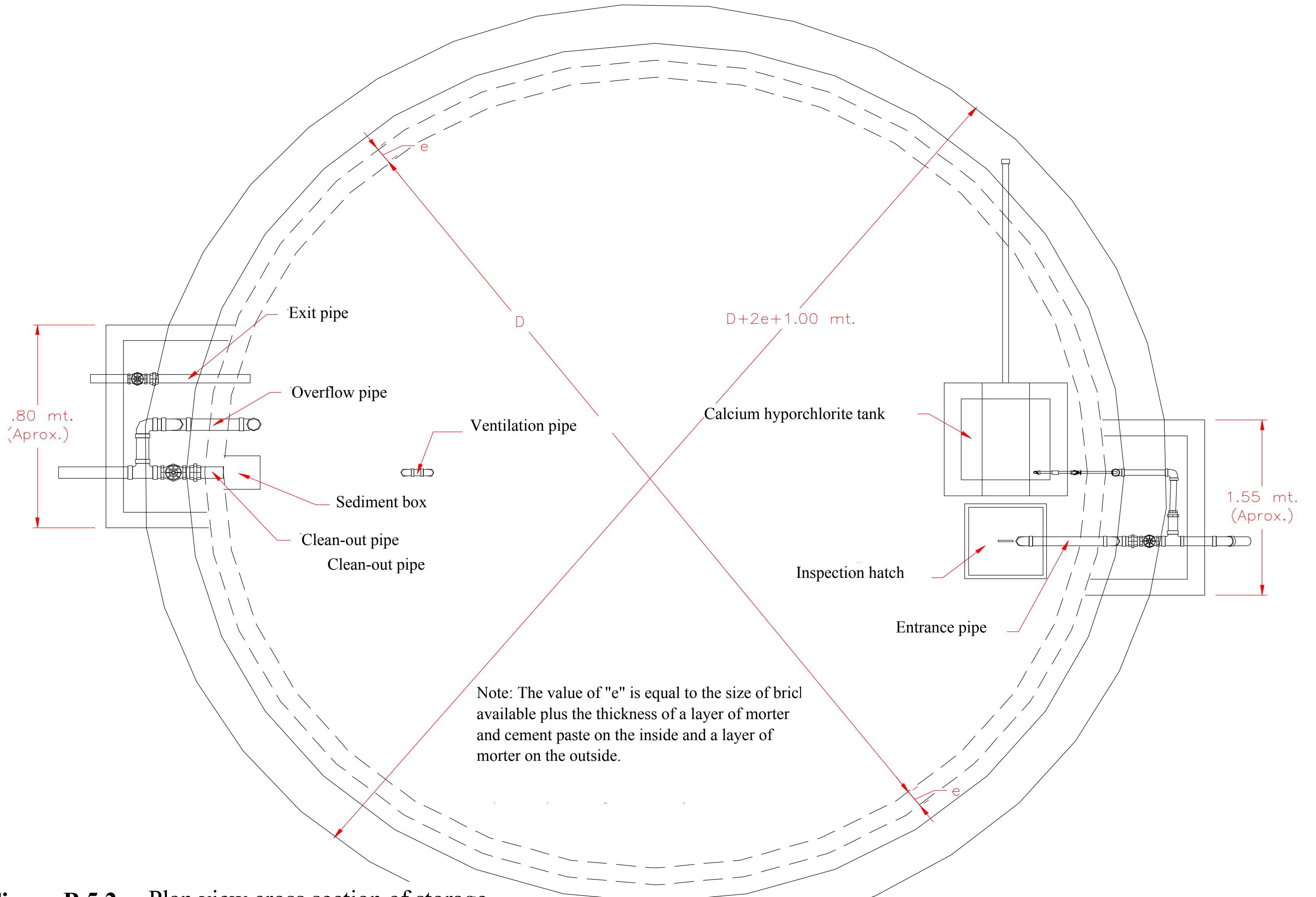


Figure B.5.2 Plan view cross section of storage tank with details on plumbing.

Adapted from: SANAA, Servicio Autónomo Nacional de Acueductos y Alcantarillos, "Normas de Diseño para Acueductos Rurales V.1.0," Tegucigalpa, Honduras, 1999.

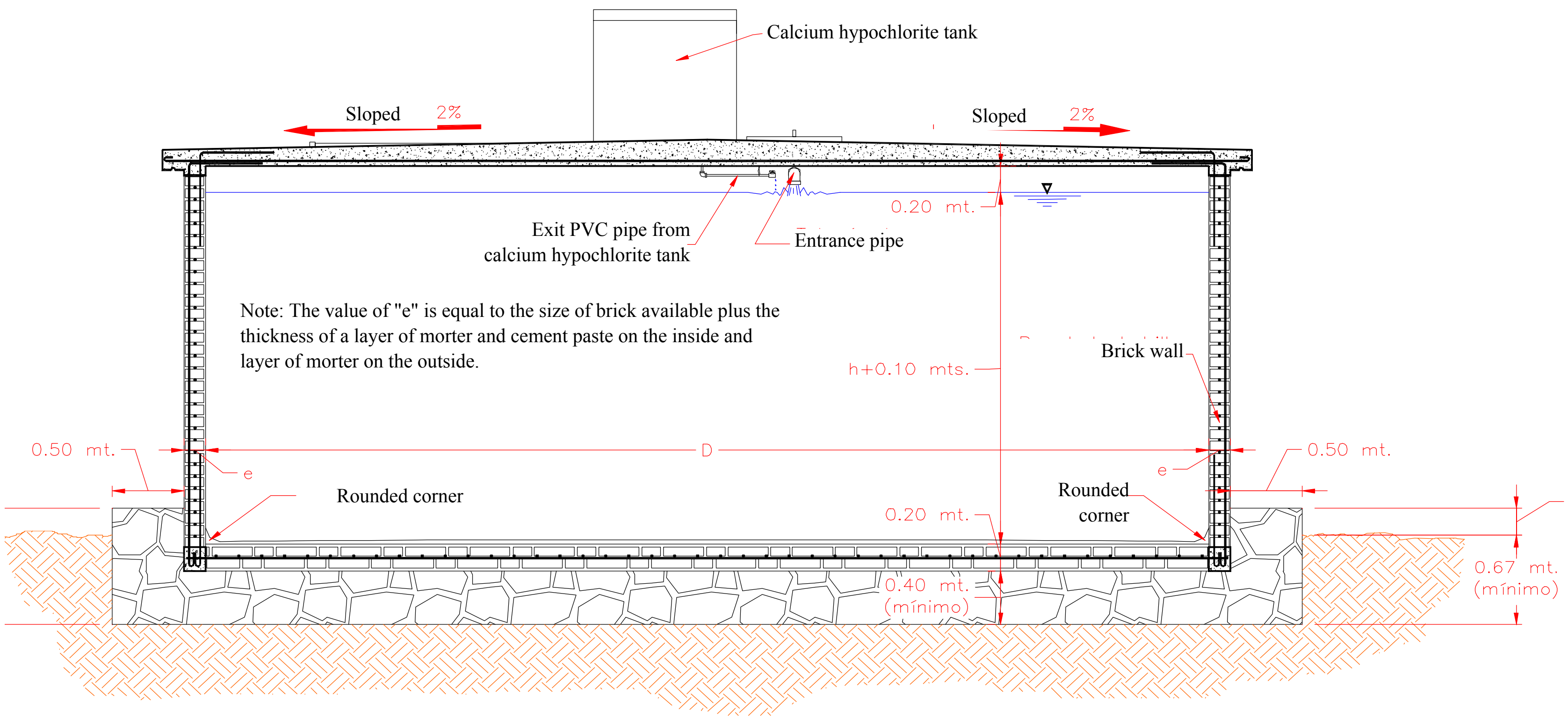


Figure B.5.3 Profile view cross section "B" of storage tank.

Adapted from: SANAA, Servicio Autónomo Nacional de Acueductos y Alcantarillos, "Normas de Diseño para Acueductos Rurales V.1.0," Tegucigalpa, Honduras, 1999.

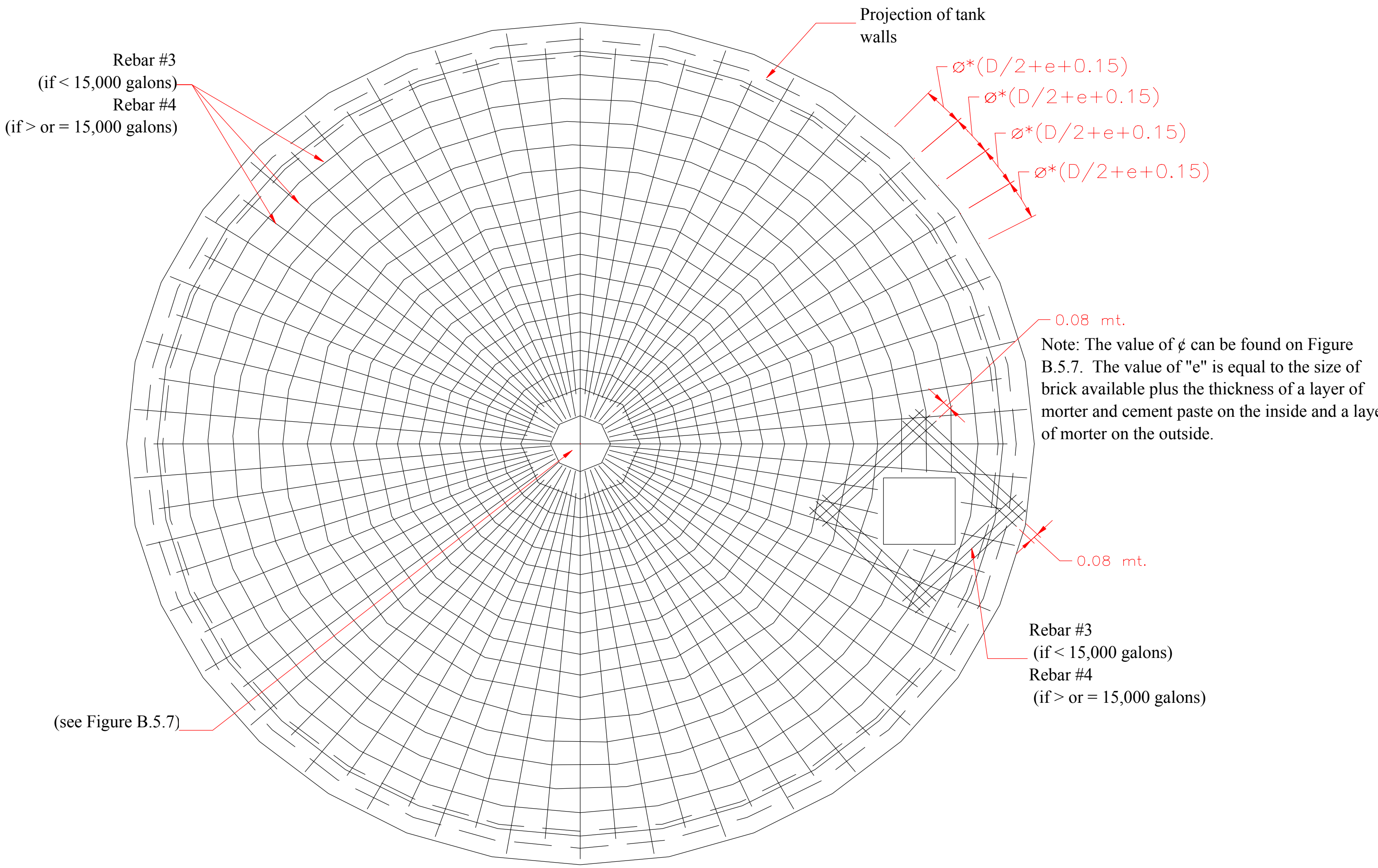
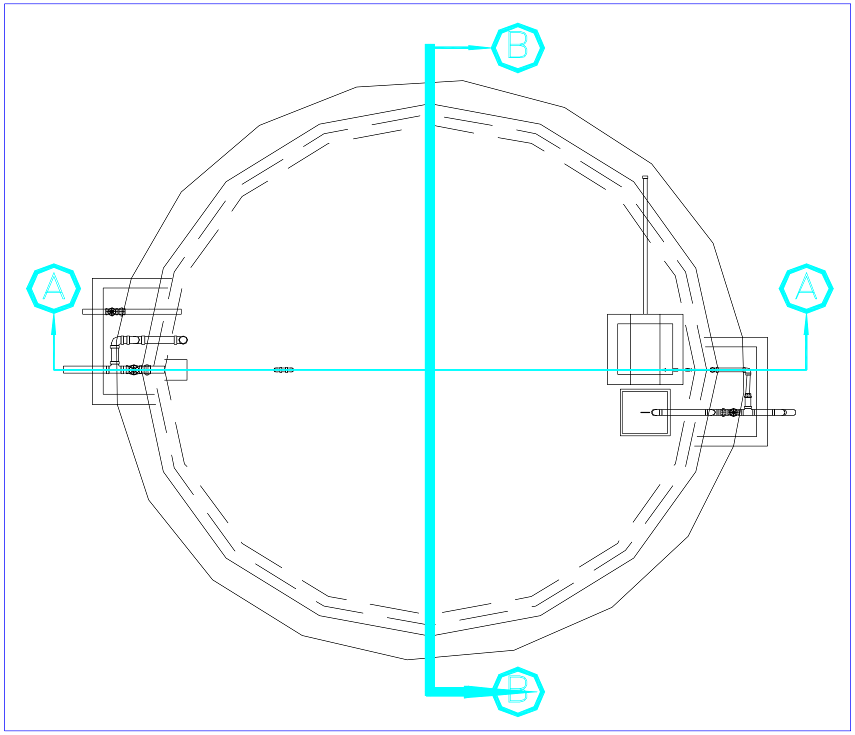
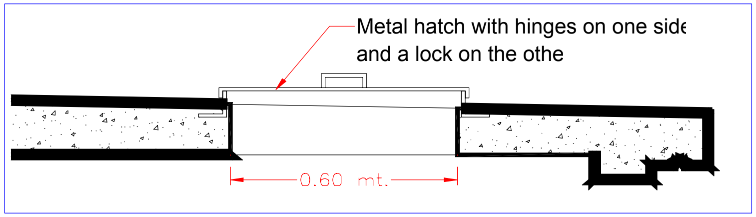


Figure B.5.4 Plan view of concrete roof on storage tank with rebar details.

Adapted from: SANAA, Servicio Autónomo Nacional de Acueductos y Alcantarillos, "Normas de Diseño para Acueductos Rurales V.1.0," Tegucigalpa, Honduras, 1999.

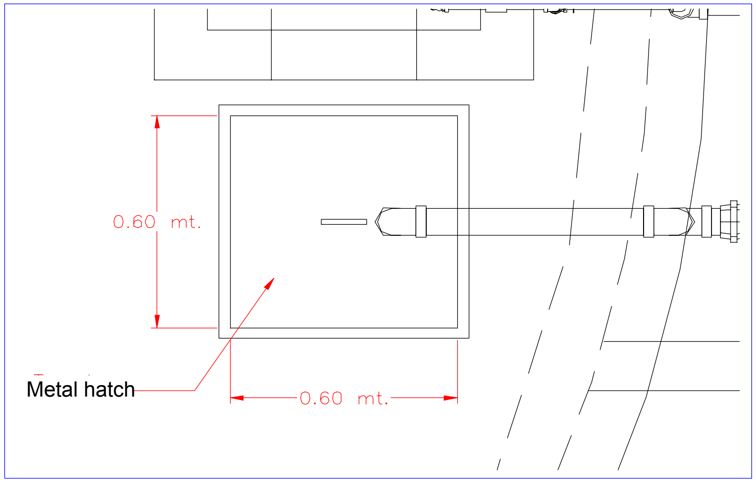


LOCATIONS OF CROSS SECTION DIVISIONS



ENTRANCE FOR INSPECTION

PROFILE CROSS SECTION



LOCATIONS OF CROSS SECTION DIVISIONS

PLAN CROSS SECTION

Figure B.5.5 Locations of cross section divisions of storage tank and details on inspection hatch.

Adapted from: SANAA, Servicio Autónomo Nacional de Acueductos y Alcantarillos, "Normas de Diseño para Acueductos Rurales V.1.0," Tegucigalpa, Honduras, 1999.

SPECIFICATIONS

1) Concrete 2.5 lbs/in^2 has a volume ratio of 1:2:3 with a maximum aggragate size of 3/4." Concrete 3.0 lbs/in^2 has a volume ratio of 1:2:2 with a maximum aggragate size of 3/4." Concrete 4.0 lbs/in^2 has a volume ratio of 1:1½:1½ with a maximum aggragate size of 3/4."

2) All rebar used is grade 40 rebar.

3) Morter used in foundation has a volume ratio of 1:4, rock no smaller than 12."

4) Concrete slabs used to cover valve boxes use a volume ratio of 1:1½:1½ and rebar #2 every 10 cms in both directions.

5) Morter used to finish walls has a volume ratio of 1:4.

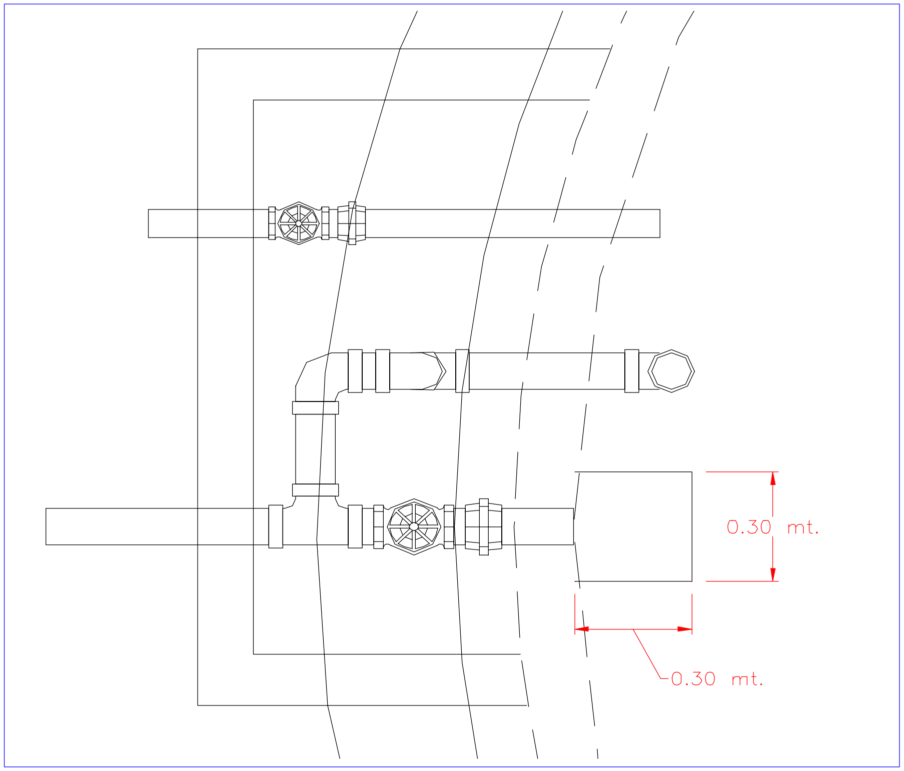
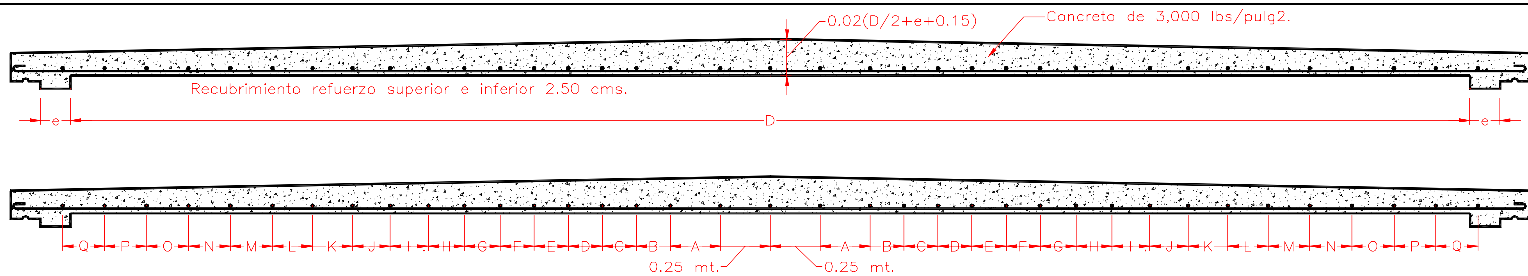
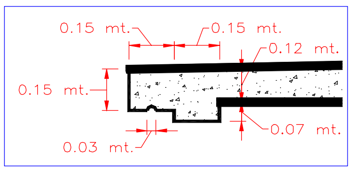


Figure B.5.6 Plan view cross section of storage tank pipe entrance and specifications for construction.

Adapted from: SANAA, Servicio Autónomo Nacional de Acueductos y Alcantarillos, "Normas de Diseño para Acueductos Rurales V.1.0," Tegucigalpa, Honduras, 1999.



CIRCULAR SPACING OF REBAR IN CONCRETE ROOF																	
Capacidad del tanque	DIMENSIONAMIENTO EN METROS																
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
5,000 galones	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.22	0.15	–	–	–	–	–	–	–	–
10,000 galones	0.17	0.17	0.18	0.18	0.19	0.19	0.20	0.20	0.20	0.20	0.20	0.07	0.15	–	–	–	–
15,000 galones	0.27	0.27	0.28	0.28	0.28	0.28	0.29	0.29	0.28	0.15	–	–	–	–	–	–	–
20,000 galones	0.20	0.20	0.20	0.20	0.21	0.21	0.22	0.22	0.23	0.23	0.23	0.23	0.23	0.15	0.15	–	–
25,000 galones	0.25	0.17	0.17	0.17	0.17	0.17	0.18	0.18	0.19	0.19	0.20	0.20	0.21	0.21	0.21	0.21	0.21



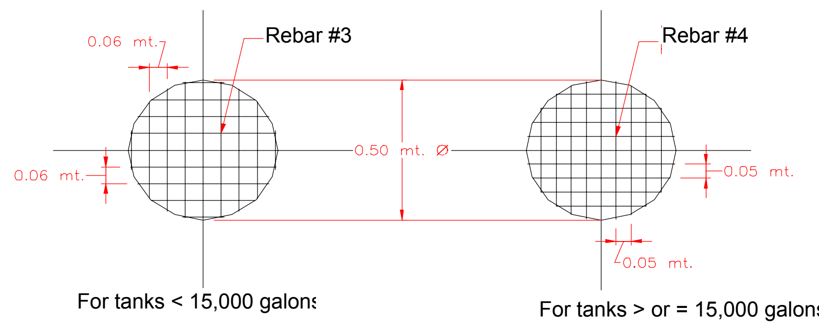
OVERHANG DETAILS

PROFILE CROSS SECTION

CONCRETE ROOF DETAILS

PROFILE CROSS SECTION

GENERAL DATA FOR STORAGE TANK				
Capacity of Tank	Dimensions in Meters			
	D	H	h	Ø (radianes)
5,000 galones	3.60	2.36	1.86	0.1653
10,000 galones	4.60	2.78	2.28	0.1164
15,000 galones	5.40	2.98	2.48	0.1309
20,000 galones	6.25	2.97	2.47	0.1013
25,000 galones	7.00	2.96	2.46	0.0806



REBAR AT CENTER OF TANK ROOF

PLAN VIEW

Figure B.5.7 Profile view cross section of concrete roof with dimension tables and rebar details.

Adapted from: SANAA, Servicio Autónomo Nacional de Acueductos y Alcantarillos, "Normas de Diseño para Acueductos Rurales V.1.0," Tegucigalpa, Honduras, 1999.

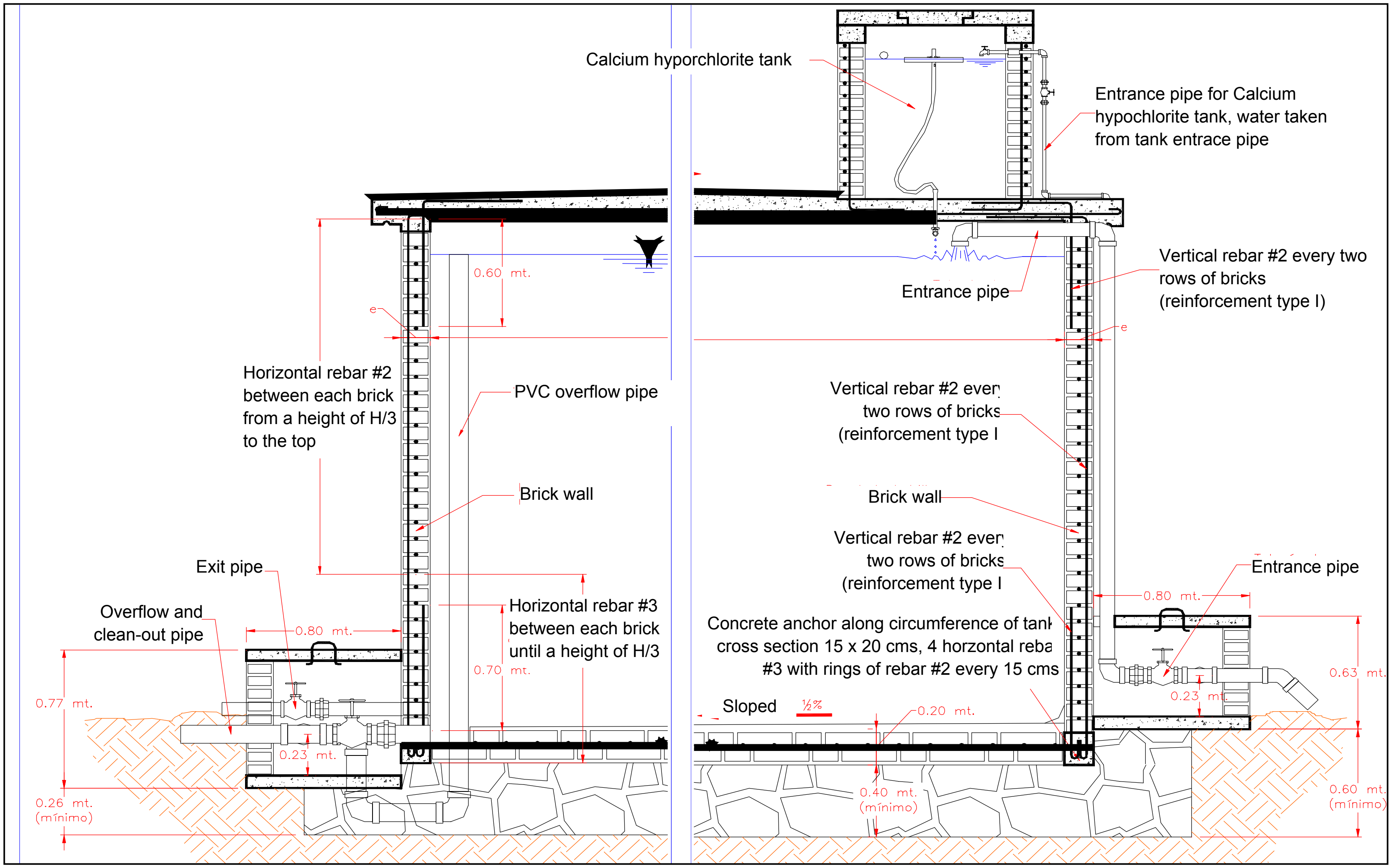
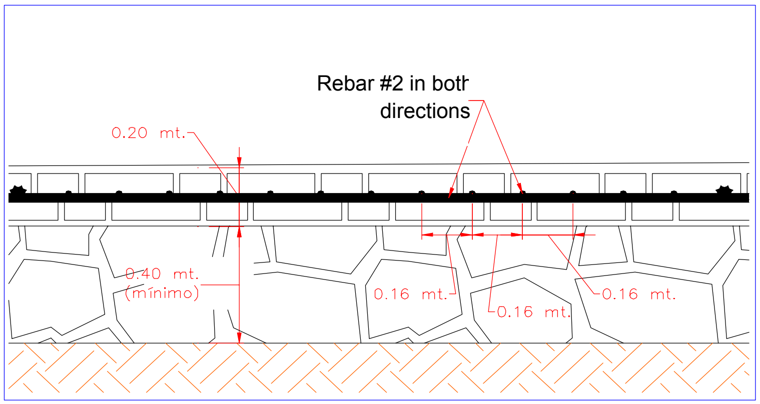
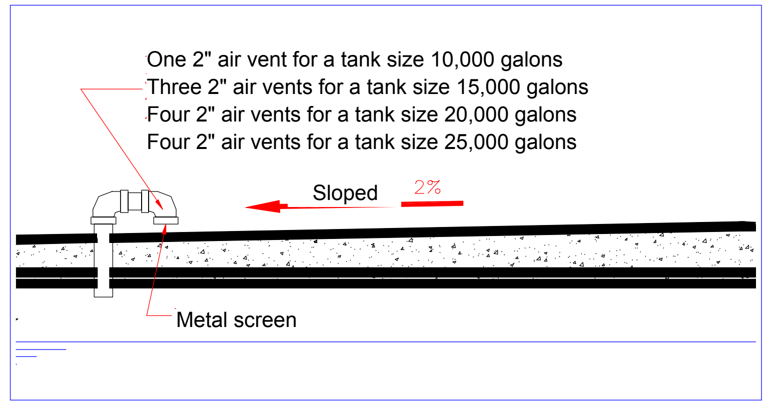


Figure B.5.8 Profile view cross section "B" of storage tankwith rebar details.

Adapted from: SANAA, Servicio Autónomo Nacional de Acueductos y Alcantarillos, "Normas de Diseño para Acueductos Rurales V.1.0," Tegucigalpa, Honduras, 1999.



BRICK FLOOR DETAILS
PROFILE CROSS SECTION



AIR VENT DETAILS
PROFILE CROSS SECTION

Figure B.5.9 Profile view cross section details of brick floor and air vent.

Adapted from: SANAA, Servicio Autónomo Nacional de Acueductos y Alcantarillos, "Normas de Diseño para Acueductos Rurales V.1.0," Tegucigalpa, Honduras, 1999.

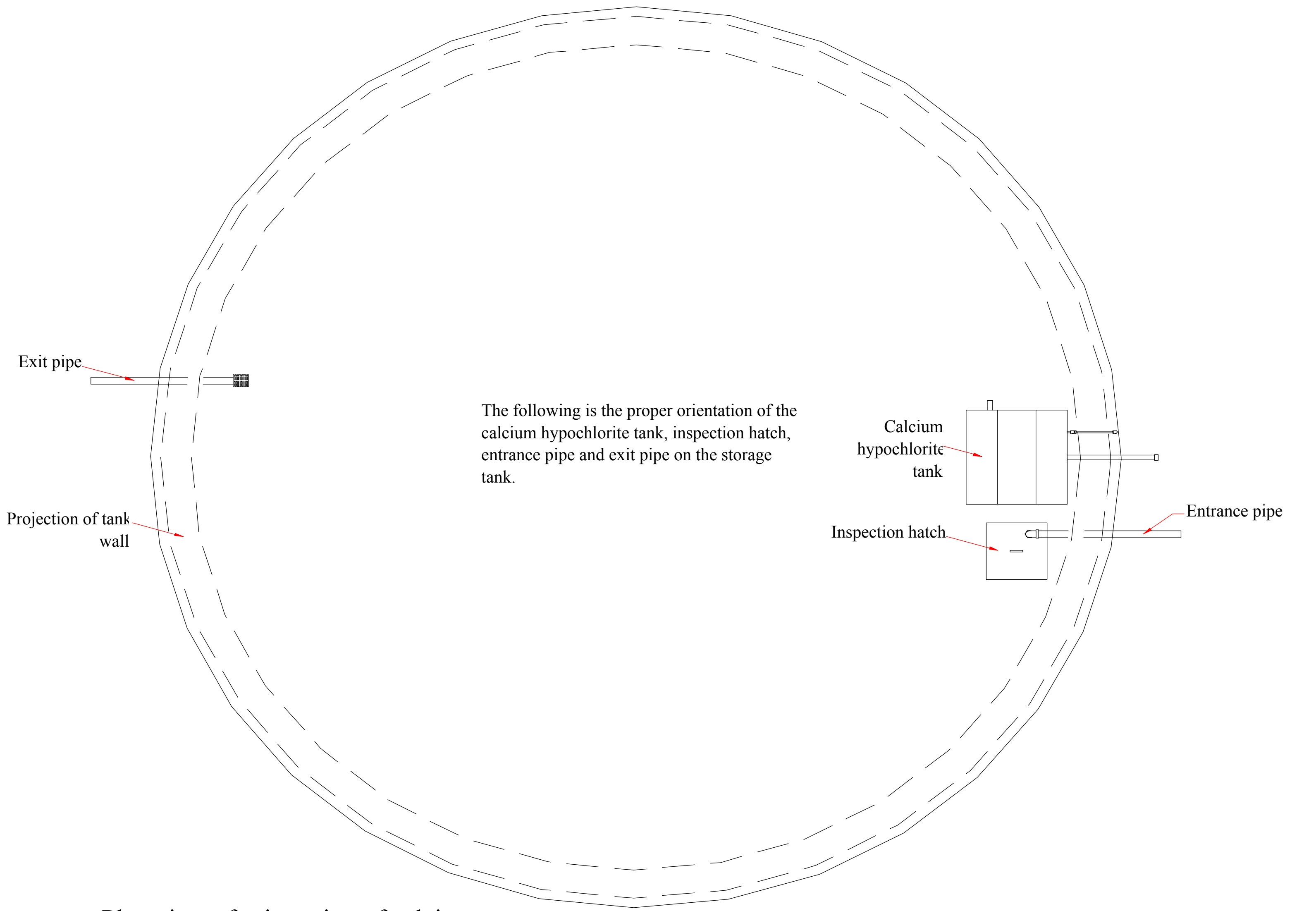
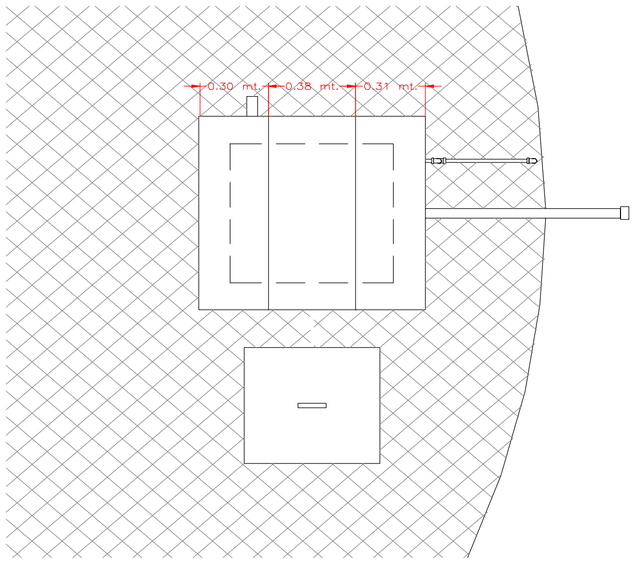


Figure B.6.1 Plan view of orientation of calcium hyperchlorite tank, inspection hatch and entrance and exit pipes.

Adapted from: SANAA, Servicio Autónomo Nacional de Acueductos y Alcantarillos, "Normas de Diseño para Acueductos Rurales V.1.0," Tegucigalpa, Honduras, 1999.



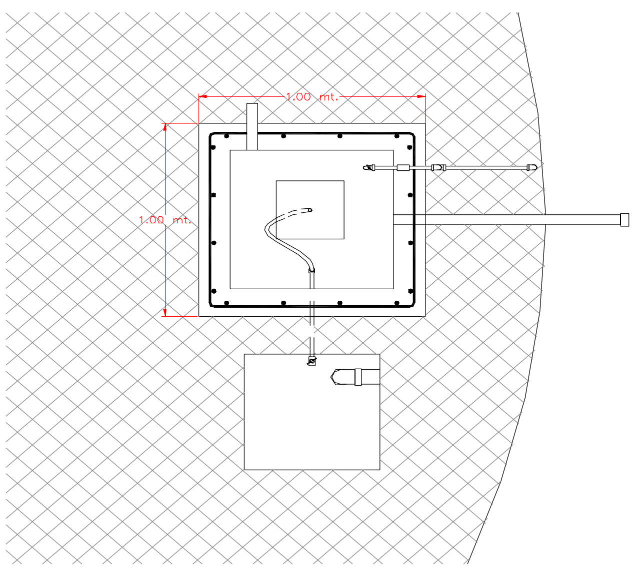
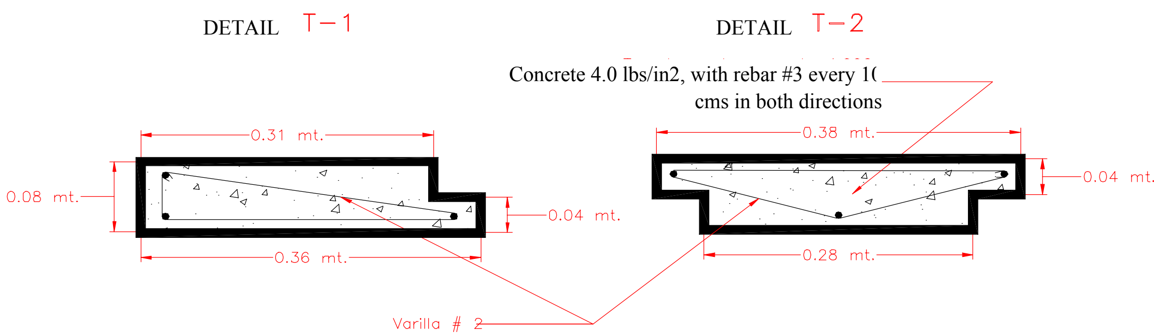


Figure B.6.2 Plan view and plan view cross section of calcium hyperchlorite tank.

Adapted from: SANAA, Servicio Autónomo Nacional de Acueductos y Alcantarillos, "Normas de Diseño para Acueductos Rurales V.1.0," Tegucigalpa, Honduras, 1999.



CONCRETE SLABS FOR ROOF

DETAILS T-1 & T-2

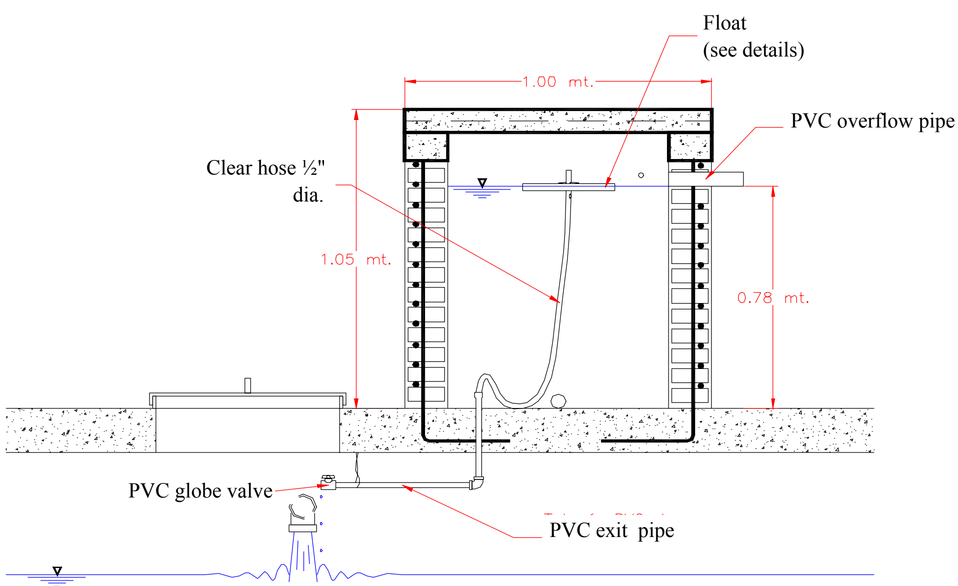
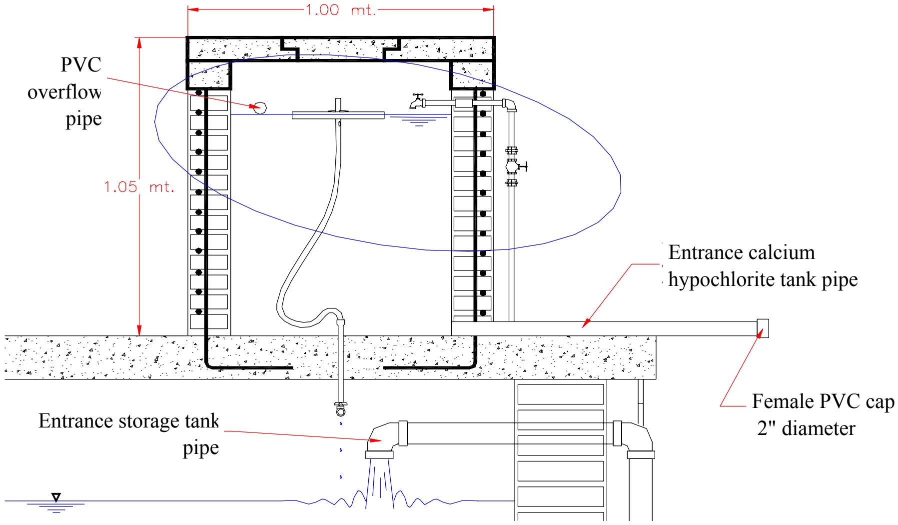


Figure B.6.3 Profile view cross section of calcium hyperchlorite tank with details on concrete slabs used to cover tank.

Adapted from: SANAA, Servicio Autónomo Nacional de Acueductos y Alcantarillos, "Normas de Diseño para Acueductos Rurales V.1.0," Tegucigalpa, Honduras, 1999.



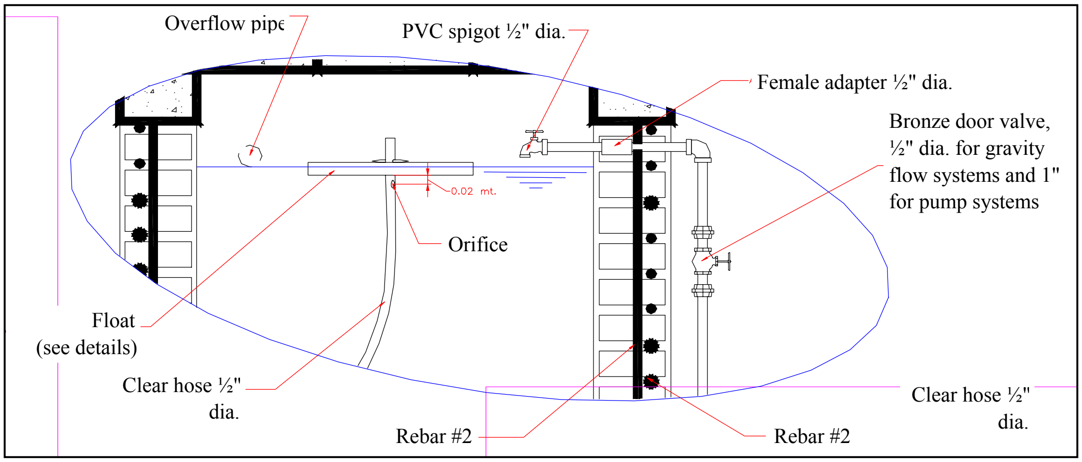
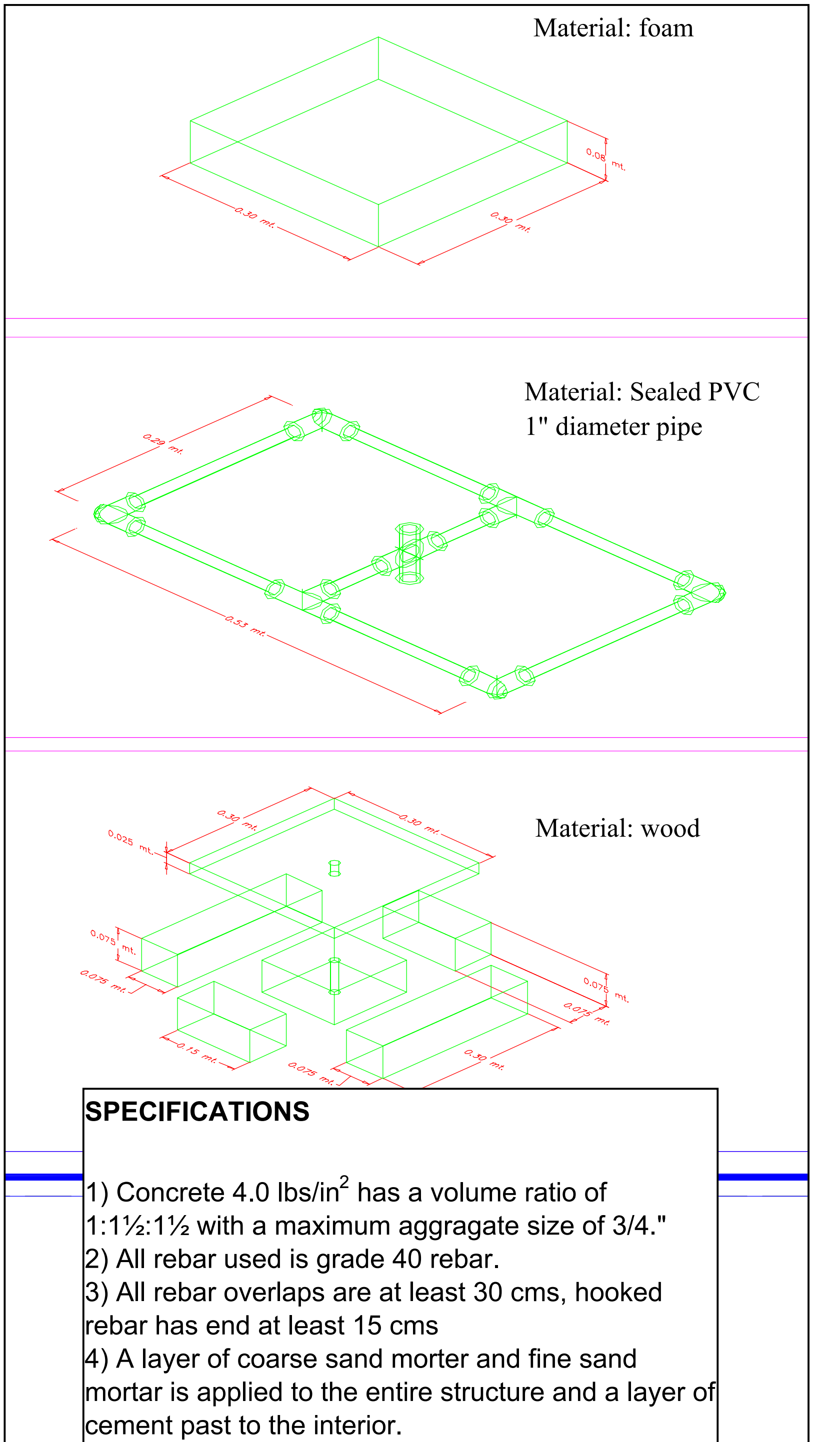


Figure B.6.4 Profile view cross section of calcium hyperchlorite tank with details on float used to control height of exit hose.

Adapted from: SANAA, Servicio Autónomo Nacional de Acueductos y Alcantarillos, "Normas de Diseño para Acueductos Rurales V.1.0," Tegucigalpa, Honduras, 1999.



SPECIFICATIONS

1) Concrete 4.0 lbs/in^2 has a volume ratio of 1:1½:1½ with a maximum aggragate size of 3/4."
2) All rebar used is grade 40 rebar.
3) All rebar overlaps are at least 30 cms, hooked rebar has end at least 15 cms
4) A layer of coarse sand morter and fine sand mortar is applied to the entire structure and a layer of cement past to the interior.
5) Morter used to finish walls has a volume ratio of 1:4.

Figure B.6.5 Isometric views of different types of floats and specifications for construction.

Adapted from: SANAA, Servicio Autónomo Nacional de Acueductos y Alcantarillos, "Normas de Diseño para Acueductos Rurales V.1.0," Tegucigalpa, Honduras, 1999.

APPENDIX C

The following documents are included in this report to give the engineer the information necessary to evaluate whether a water source is acceptable for potable use. Sections C.1-C.5 include drinking-water guidelines developed by the World Health Organization (WHO). SANAA requires that water for potable use be within these guidelines. Many of the water sources used in SANAA's projects contain fecal coliform bacteria. This is accepted if the community agrees to disinfect at the tank.

Section C.6 shows two typical water quality tests done in Honduras by government sponsored labs. Notice that not all the parameters tested are on the list of WHO guidelines. This is because some parameters are tested, not because they are harmful themselves, but because they are indicators that other more harmful substances could be present. These more harmful substances are usually more difficult to test for and therefore are not tested directly. In two of the example tests, abnormal levels of orthophosphate are found. High levels of phosphates can indicate the presence of fertilizers, phosphate based organic pesticides or human or animal waste. Because the high levels of orthophosphates could be for a number of reasons, it is the job of the engineer and the community to investigate which specific type of contamination is most likely the cause. This is done by looking for signs of contamination and talking to the people who own land inside the watershed. In some cases talking to watershed users is enough to solve the problem, but, more complicated contamination cases may require a large reforestation project or a fence to encircle the entire watershed.

The final Section, C.7 contains practical information by former Peace Corps volunteers on what types of water quality analysis have been tested in Honduras and how these results should be interpreted.

Table C.1 **Bacteriological quality of drinking-water**[a]

Organisms	Guideline value
All water intended for drinking	
E. coli or thermotolerant coliform bacteria[b,c]	Must not be detectable in any 100-ml sample
Treated water entering the distribution system	
E. coli or thermotolerant coliform bacteria[b]	Must not be detectable in any 100-ml sample
Total coliform bacteria	Must not be detectable in any 100-ml sample
Treated water in the distribution system	
E. coli or thermotolerant coliform bacteria[b]	Must not be detectable in any 100-ml sample
Total coliform bacteria	Must not be detectable in any 100-ml sample. In the case of large supplies, where sufficient samples are examined, must not be present in 95% of samples taken throughout any 12-month period

[a] Immediate investigative action must be taken if either *E. coli* or total coliform bacteria are detected. The minimal action in the case of total coliform bacteria is repeat sampling; if these bacteria are detected in the repeat sample, the cause must be determined by immediate further investigation.

[b] Although *E. coli* is the more precise indicator of faecal pollution, the count of thermotolerant coliform bacteria is an acceptable alternative. If necessary, proper confirmatory tests must be carried out. Total coliform bacteria are not acceptable indicators of the sanitary quality of rural water supplies, particularly in tropical areas where many bacteria of no sanitary significance occur in almost all untreated supplies.

[c] It is recognized that, in the great majority of rural water supplies in developing countries, fecal contamination is widespread. Under these conditions, the national surveillance agency should set medium-term targets for the progressive improvement of water supplies.

Source: World Health Organization, "Guidelines for drinking-water quality," 2nd ed. Vol. 2 "Health criteria and other supporting information," Geneva, 1996 (pp. 940-949) and Addendum to Vol. 2, Geneva, 1998 (pp. 281-183).

C.2 Chemicals of health significance in drinking-water

Table C.2.1 Inorganic constituents

	Guideline value (mg/litre)	Remarks
antimony	0.005 (P)[a]	
arsenic	0.01[b] (P)	For excess skin cancer risk of 6×10^{-4}
barium	0.7	
beryllium		NAD[c]
boron	0.5 (P)	
cadmium	0.003	
chromium	0.05 (P)	
copper	2 (P)	Based on acute gastrointestinal effects
cyanide	0.07	
fluoride	1.5	Climatic conditions, volume of water consumed, and intake from other sources should be considered when setting national standards
lead	0.01	It is recognized that not all water will meet the guideline value immediately; meanwhile, all other recommended measures to reduce the total exposure to lead should be implemented
manganese	0.5 (P)	ATO[d]
mercury (total)	0.001	
molybdenum	0.07	
nickel	0.02 (P)	
nitrate (as NO_3^-)	50 (acute)	
nitrite (as NO_2^-)	3 (acute) 0.2 (P) (chronic)	
selenium	0.01	

uranium	0.002 (P)	

[a] (P) — Provisional guideline value. This term is used for constituents for which there is some evidence of a potential hazard but where the available information on health effects is limited; or where an uncertainty factor greater than 1000 has been used in the derivation of the tolerable daily intake (TDI). Provisiona guideline values are also recommended: (1) for substances for which the calculated guideline value would be below the practical quantification level, or below the level that can be achieved through practical treatmen methods; or (2) where disinfection is likely to result in the guideline value being exceeded.

[b] For substances that are considered to be carcinogenic, the guideline value is the concentration in drinking water associated with an excess lifetime cancer risk of 10^{-5} (one additional cancer per 100 000 of the population ingesting drinking-water containing the substance at the guideline value for 70 years). Concentrations associated with estimated excess lifetime cancer risks of 10^{-4} and 10^{-6} can be calculated by multiplying and dividing, respectively, the guideline value by 10.

In cases in which the concentration associated with an excess lifetime cancer risk of 10^{-5} is not feasible as a result of inadequate analytical or treatment technology, a provisional guideline value is recommended at a practicable level and the estimated associated excess lifetime cancer risk presented.

It should be emphasized that the guideline values for carcinogenic substances have been computed fron hypothetical mathematical models that cannot be verified experimentally and that the values should be interpreted differently from TDI-based values because of the lack of precision of the models. At best, these values must be regarded as rough estimates of cancer risk. However, the models used are conservative and probably err on the side of caution. Moderate short-term exposure to levels exceeding the guideline value fo carcinogens does not significantly affect the risk.

[c] NAD — No adequate data to permit recommendation of a health-based guideline value.

[d] ATO — Concentrations of the substance at or below the health-based guideline value may affect the appearance, taste, or odor of the water

Table C.2.2 Organic constituents

	Guideline value (µg/litre)	Remarks
Chlorinated alkanes		
carbon tetrachloride	2	
dichloromethane	20	
1,1-dichloroethane		NAD
1,2-dichloroethane	30[b]	For excess risk of 10^{-5}
1,1,1-trichloroethane	2000 (P)	
Chlorinated ethenes		
vinyl chloride	5[b]	For excess risk of 10^{-5}
1,1-dichloroethene	30	
1,2-dichloroethene	50	
trichloroethene	70 (P)	
tetrachloroethene	40	
Aromatic hydrocarbons		
benzene	10[b]	For excess risk of 10^{-5}
toluene	700	ATO
xylenes	500	ATO
ethylbenzene	300	ATO
styrene	20	ATO

benzo[*a*]pyrene	0.7[b]	For excess risk of 10^{-5}
Chlorinated benzenes		
monochlorobenzene	300	ATO
1,2-dichlorobenzene	1000	ATO
1,3-dichlorobenzene		NAD
1,4-dichlorobenzene	300	ATO
trichlorobenzenes (total)	20	ATO
Miscellaneous		
di(2-ethylhexyl)adipate	80	
di(2-ethylhexyl)phthalate	8	
acrylamide	0.5[b]	For excess risk of 10^{-5}
epichlorohydrin	0.4 (P)	
hexachlorobutadiene	0.6	
edetic acid (EDTA)	600	Applies to the free acid
nitrilotriacetic acid	200	
dialkyltins		NAD
tributyltin oxide	2	
microcystin-LR	1 (P)	Applies to total microcystin-LR (free plus cell-bound)

[a] (P) — Provisional guideline value. This term is used for constituents for which there is some evidence of potential hazard but where the available information on health effects is limited; or where an uncertaint factor greater than 1000 has been used in the derivation of the tolerable daily intake (TDI). Provisiona guideline values are also recommended: (1) for substances for which the calculated guideline value would b below the practical quantification level, or below the level that can be achieved through practical treatmer methods; or (2) where disinfection is likely to result in the guideline value being exceeded.

[b] For substances that are considered to be carcinogenic, the guideline value is the concentration in drinking water associated with an excess lifetime cancer risk of 10^{-5} (one additional cancer per 100 000 of th population ingesting drinking-water containing the substance at the guideline value for 70 years)

Concentrations associated with estimated excess lifetime cancer risks of 10^{-4} and 10^{-6} can be calculated b multiplying and dividing, respectively, the guideline value by 10.

In cases in which the concentration associated with an excess lifetime cancer risk of 10^{-5} is not feasible as result of inadequate analytical or treatment technology, a provisional guideline value is recommended at practicable level and the estimated associated excess lifetime cancer risk presented.

It should be emphasized that the guideline values for carcinogenic substances have been computed fror hypothetical mathematical models that cannot be verified experimentally and that the values should b interpreted differently from TDI-based values because of the lack of precision of the models. At best, thes values must be regarded as rough estimates of cancer risk. However, the models used are conservative an probably err on the side of caution. Moderate short-term exposure to levels exceeding the guideline value fc carcinogens does not significantly affect the risk.

[c] NAD — No adequate data to permit recommendation of a health-based guideline value.

[d] ATO — Concentrations of the substance at or below the health-based guideline value may affect th appearance, taste, or odor of the water.

Table C.2.3 Pesticides

	Guideline value (μg/liter)	Remarks
alachlor	20[b]	For excess risk of 10^{-5}
aldicarb	10	
aldrin/dieldrin	0.03	
atrazine	2	
bentazone	300	
carbofuran	7	
chlordane	0.2	
chlorotoluron	30	
cyanazine	0.6	
DDT	2	
1,2-dibromo-3-chloropropane	1[b]	For excess risk of 10^{-5}
1,2-dibromoethane	0.4–15[b] (P)	For excess risk of 10^{-5}
2,4-dichlorophenoxyacetic acid (2,4-D)	30	
1,2-dichloropropane (1,2-DCP)	40 (P)	
1,3-dichloropropane		NAD
1,3-dichloropropene	20[b]	For excess risk of 10^{-5}
diquat	10 (P)	
heptachlor and heptachlor epoxide	0.03	

hexachlorobenzene	1[b]	For excess risk of 10^{-5}
isoproturon	9	
lindane	2	
MCPA	2	
methoxychlor	20	
metolachlor	10	
molinate	6	
pendimethalin	20	
pentachlorophenol	9[b] (P)	For excess risk of 10^{-5}
permethrin	20	
propanil	20	
pyridate	100	
simazine	2	
terbuthylazine (TBA)	7	
trifluralin	20	
Chlorophenoxy herbicides other than 2,4-D and MCPA		
2,4-DB	90	
dichlorprop	100	
fenoprop	9	
MCPB		NAD
mecoprop	10	
2,4,5-T	9	

[a] (P) — Provisional guideline value. This term is used for constituents for which there is some evidence of a potential hazard but where the available information on health effects is limited; or where an uncertainty factor greater than 1000 has been used in the derivation of the tolerable daily intake (TDI). Provisional guideline values are also recommended: (1) for substances for which the calculated guideline value would be below the practical quantification level, or below the level that can be achieved through practical treatment methods; or (2) where disinfection is likely to result in the guideline value being exceeded.

[b] For substances that are considered to be carcinogenic, the guideline value is the concentration in drinking-water associated with an excess lifetime cancer risk of 10^{-5} (one additional cancer per 100 000 of the population ingesting drinking-water containing the substance at the guideline value for 70 years). Concentrations associated with estimated excess lifetime cancer risks of 10^{-4} and 10^{-6} can be calculated by multiplying and dividing, respectively, the guideline value by 10.

In cases in which the concentration associated with an excess lifetime cancer risk of 10^{-5} is not feasible as a result of inadequate analytical or treatment technology, a provisional guideline value is recommended at a practicable level and the estimated associated excess lifetime cancer risk presented.

It should be emphasized that the guideline values for carcinogenic substances have been computed from hypothetical mathematical models that cannot be verified experimentally and that the values should be interpreted differently from TDI-based values because of the lack of precision of the models. At best, these values must be regarded as rough estimates of cancer risk. However, the models used are conservative and probably err on the side of caution. Moderate short-term exposure to levels exceeding the guideline value for carcinogens does not significantly affect the risk.

[c] NAD — No adequate data to permit recommendation of a health-based guideline value.

[d] ATO — Concentrations of the substance at or below the health-based guideline value may affect the appearance, taste, or odor of the water.

Table C.2.4 Disinfectants and disinfectant by-products

Disinfectants	**Guideline value (mg/liter)**	**Remarks**
monochloramine	3	
di- and trichloramine		NAD
chlorine	5	ATO. For effective disinfection there should be a residual concentration of free chlorine of =0.5 mg/litre after at least 30 minutes contact time at pH <8.0
chlorine dioxide		A guideline value has not been established because of the rapid breakdown of chlorine dioxide and because the chlorite guideline value is adequately protective for potential toxicity from chlorine dioxide

iodine		NAD
Disinfectant by-products	**Guideline value (μg/liter)**	**Remarks**
bromate	25^b (P)	For 7×10^{-5} excess risk
chlorate		NAD
chlorite	200 (P)	
Chlorophenols		
2-chlorophenol		NAD
2,4-dichlorophenol		NAD
2,4,6-trichlorophenol	200^b	For excess risk of 10^{-5}, ATO
formaldehyde	900	
MX		NAD
trihalomethanes		The sum of the ratio of the concentration of each to its respective guideline value should not exceed 1
bromoform	100	
dibromochloromethane	100	
bromodichloromethane	60^b	For excess risk of 10^{-5}
chloroform	200	
Chlorinated acetic acids		
monochloroacetic acid		NAD
dichloroacetic acid	50 (P)	
trichloroacetic acid	100 (P)	
chloral hydrate (trichloroacetaldehyde)	10 (P)	

chloroacetone		NAD
Halogenated acetonitriles		
dichloroacetonitrile	90 (P)	
dibromoacetonitrile	100 (P)	
bromochloroacetonitrile		NAD
trichloroacetonitrile	1 (P)	
cyanogen chloride (as CN)	70	
chloropicrin		NAD

[a] (P) — Provisional guideline value. This term is used for constituents for which there is some evidence of a potential hazard but where the available information on health effects is limited; or where an uncertainty factor greater than 1000 has been used in the derivation of the tolerable daily intake (TDI). Provisional guideline values are also recommended: (1) for substances for which the calculated guideline value would be below the practical quantification level, or below the level that can be achieved through practical treatment methods; or (2) where disinfection is likely to result in the guideline value being exceeded.

[b] For substances that are considered to be carcinogenic, the guideline value is the concentration in drinking-water associated with an excess lifetime cancer risk of 10^{-5} (one additional cancer per 100 000 of the population ingesting drinking-water containing the substance at the guideline value for 70 years). Concentrations associated with estimated excess lifetime cancer risks of 10^{-4} and 10^{-6} can be calculated by multiplying and dividing, respectively, the guideline value by 10.

In cases in which the concentration associated with an excess lifetime cancer risk of 10^{-5} is not feasible as a result of inadequate analytical or treatment technology, a provisional guideline value is recommended at a practicable level and the estimated associated excess lifetime cancer risk presented.

It should be emphasized that the guideline values for carcinogenic substances have been computed from hypothetical mathematical models that cannot be verified experimentally and that the values should be interpreted differently from TDI-based values because of the lack of precision of the models. At best, these values must be regarded as rough estimates of cancer risk. However, the models used are conservative and probably err on the side of caution. Moderate short-term exposure to levels exceeding the guideline value for carcinogens does not significantly affect the risk.

[c] NAD — No adequate data to permit recommendation of a health-based guideline value.

[d] ATO — Concentrations of the substance at or below the health-based guideline value may affect the appearance, taste, or odor of the water.

Table C.3 **Chemicals not of health significance at concentrations normally found in drinking-water**

Chemical	Remarks
asbestos	U
fluoranthene	U
glyphosate	U
silver	U
tin	U

U — It is unnecessary to recommend a health-based guideline value for these compounds because they are not hazardous to human health at concentrations normally found in drinking-water.

Table C.4 **Radioactive constituents of drinking-water** [1]

	Screening value (Bq/litre)	Remarks
gross alpha activity	0.1	
gross beta activity	1	

Source: World Health Organization, "Guidelines for drinking-water quality," 2nd ed. Vol. 2 "Health criteria and other supporting information," Geneva, 1996 (pp. 940-949) and Addendum to Vol. 2, Geneva, 1998 (pp. 281-183).

Table C.5 **Substances and parameters in drinking-water that may give rise to complaints from consumers**

	Levels likely to give rise to consumer complaints[a]	Reasons for consumer complaints
Physical parameters		
colour	15 TCU[b]	appearance
taste and odour	—	should be acceptable
temperature	—	should be acceptable
turbidity	5 NTU[c]	appearance; for effective terminal disinfection, median turbidity =1 NTU, single sample =5 NTU
Inorganic constituents		
aluminium	0.2 mg/l	depositions, discoloration
ammonia	1.5 mg/l	odour and taste
chloride	250 mg/l	taste, corrosion
copper	1 mg/l	staining of laundry and sanitary ware (health-based provisional guideline value 2 mg/litre)
hardness	—	high hardness: scale deposition, scum formation low hardness: possible corrosion
hydrogen sulfide	0.05 mg/l	odour and taste
iron	0.3 mg/l	staining of laundry and sanitary ware
manganese	0.1 mg/l	staining of laundry and sanitary ware (health-based guideline value 0.5 mg/litre)
dissolved oxygen	—	indirect effects
pH	—	low pH: corrosion high pH: taste, soapy feel preferably <8.0 for effective disinfection with chlorine
sodium	200 mg/l	taste
sulfate	250 mg/l	taste, corrosion

total dissolved solids	1000 mg/l	taste
zinc	3 mg/l	appearance, taste
Organic constituents		
toluene	24–170 µg/l	odour, taste (health-based guideline value 700 µg/l)
xylene	20–1800 µg/l	odour, taste (health-based guideline value 500 µg/l)
ethylbenzene	2–200 µg/l	odour, taste (health-based guideline value 300 µg/l)
styrene	4–2600 µg/l	odour, taste (health-based guideline value 20 µg/l)
monochlorobenzene	10–120 µg/l	odour, taste (health-based guideline value 300 µg/l)
1,2-dichlorobenzene	1–10 µg/l	odour, taste (health-based guideline value 1000 µg/l)
1,4-dichlorobenzene	0.3–30 µg/l	odour, taste (health-based guideline value 300 µg/l)
trichlorobenzenes (total)	5–50 µg/l	odour, taste (health-based guideline value 20 µg/l)
synthetic detergents	—	foaming, taste, odour
Disinfectants and disinfectant by-products		
chlorine	600–1000 µg/l	taste and odour (health-based guideline value 5 µg/l)
chlorophenols		
2-chlorophenol	0.1–10 µg/l	taste, odour
2,4-dichlorophenol	0.3–40 µg/l	taste, odour
2,4,6-trichlorophenol	2–300 µg/l	taste, odour (health-based guideline value 200 µg/l)

[a] The levels indicated are not precise numbers. Problems may occur at lower or higher values according to local circumstances. A range of taste and odour threshold concentrations is given for organic constituents.

[b] TCU, true color unit.

[c] NTU, nephelometric turbidity unit.

PROSAR

PROYECTO DE SANEAMIENTO
Y AGUA RURAL

SECRETARIA DE SALUD

REGION No. 3 AREA NO. 4

RESULTS FROM PHYSICAL AND CHEMICAL ANALYSIS

14/5/01

La alegria Trinidad

11:00 AM

Jose Arnold Mozoriegoz

Analista de Agua

0-10	ppm	0.02
0-2	ppm	0.06
0-5	ppm	0.02
0-10	ppm	18.8
0-1	ppm	0.006
6.5-8.5	ppm	4.6
0-50	ppm	0.00
0-1000	ppm	0.89
0-5	NTU	— 0 —

FIRMA

Table C.6.2 Sample biological water quality analysis done by the Honduran government institution, Sanitation and Rural Water Project (PROSAR).

PROSAR
PROYECTO DE SANEAMIENTO Y AGUA RURAL

SECRETARIA DE SALUD

REGION No. 3 AREA NO. 4

RESULTS FROM MICOBIOLOGICAL ANALYSIS

Date: 14/5/01
Community: La alegría Trinidad
Hour: 11:00 AM
Analysis done by: José Arnold Mazariegos F
Position: Analista de Agua

ANALYSIS	GUIDELINE VALUE	RESULT
Total Coliforms	0-UFC	Negativo
E Coli	0-UFC	Negativo

Observations: No microbiological contamination was found. It is still recommended that the community chlorinate their water.

FIRMA

Table C.6.3 Sample biological, chemical and physical water quality analysis done by the Honduran government institution, National Autonomous Service of Aqueducts and Sewer Systems (SANAA).

S A N A A

Barrio el Triangulo, La Entrada Copan. Tel. 661 - 3072

No.082

ecolector de muestra: JOSE ANTONIO PONCE (PRESIDENTE)	Fecha de muestra: 7 DE MAYO. de 2001
gencia: SANAA-USAID	Hora: 6.00 AM
ombre de fuente: MALCOTA	Municipio :TRINIDAD
omunidad: LA ANGOSTURA	Departamento: SANTA BARBARA

TYPE OF WATER SOURCE

	X

WATER SAMPLE SITE

Well		Network	
Dam	X	Cistern	
Storage Tank		Neighborhood	

BACTERIA ANALYSIS

Fecha : 07/05/2001 **Hora :10 AM**

Total Coliforms			Fecal Coliforms		
	ml filtrados	No. Col. Contadas		ml Filtrados	No. Col. Contadas
	100			100	

oliformes Totales / 100 ml: Positivo

Coliformes Fecales / 100 ml: Positivo

PHYSICAL ANALYSIS

Fecha :07/05/2001 **Hora : 8.00 PM**

	Units	Guidelines	Results
	°C	18 – 30	24
	NTU *	1 – 5	1.3
	µS / Cm	400	62.3
	·UC	15	0
	-	6.5 – 8.5	6.8
	Mg / l	1000	31
	Mg / l	400	43.32
	Mg / L	0.07	-
	Mg / l	0.50	-
	Mg / l	0.20	-
	Mg / l	0.10	2.75

PARAMETER	Units	Guidelines	Results
Nitrates	mg / l	50**	0.50
Nitrites	mg / l	0.005**	0.000
Chlorides	mg / l	250	-
Phosphates	Mg / l		-
Fluorides	mg / l	0.7 - 1.5	-
Sulfates	Mg / l	250	-
Sulfur	mg / l		0.01
Hardness	mg / l	400	35.64
Total Iron	mg / l	0.3	-
Ammonium Natr.	mg / l	0.5**	-
Residual Chlor.	mg / l	0.5 – 1.0	-

Modesto Andony
ANALISTA

PROGRAMA DE OPERACION Y MANTENIMIENTO DE ACUEDUCTOS RURALES SANAA-USAID LA ENTRADA, COPAN

Modesto Andony
REVISO

01:50 P.M.01:50 P.M.Norma nacional de calidad de agua, Valor Máximo Permitido (VMP), Gaceta 4 de Octubre de 1995)
* OPS recomiende entre 1 y 5 NTU para clorar el agua
** INFLUYE SOBRE LA SALUD 01:50 P.M.

C.7 Practical information on how to interpret water quality analysis.

This section was extracted from:
Peace Corps Honduras, "Training of Community Water Boards" (Tegucigulpa, Honduras: Peace Corps, 1990) no page numbers.

Water Testing (What is commonly tested and why?)

The principle goals of a water quality testing program are:

1. To determine if water quality standards for specific parameters are exceeded and if the resulting water quality poses a threat to human health.
2. To test for indicator parameters that can indicate particular causes (ex. sewage or animal waste, agricultural production, deforestation, erosion) of water quality problems in the watershed.
3. To investigate potential sources of contamination leading to solutions to the problem (ex. moving a water intake structure upstream of a joining stream that was found. By testing, to be the source of the contamination of a system).
4. To determine if a particular action to treat or improve water quality has been successful.

Due to limited resources and the current belief that the greatest risks to human health are: (1) water borne diseases; and (2) loss of water supply due to watershed degradation, typical water analysis has been limited to microbiological and some easily analyzed physical and chemical parameters. The following is a list of parameters routinely analyzed by several water quality labs in Honduras.

Table C.7.1 A list of common water quality parameters, measured in Honduras, that are compared to WHO guidelines and/or used as indicators of other contaminants.

Parameter	Tested to Compare to Water Quality Standards	Tested as an Indicator Parameter
A. Microbiological Parameters		
Fecal Coliforms	X	X
Total Coliforms	X	X
B. Physical Parameters		
Temperature		X
Turbidity	X	X
C. Chemical Parameters		
pH	X	X
Conductivity	X	X
Hardness	X	X
Nitrates	X	X
Nitrites		X
Ammonia		X
Phosphorus (Phosphate)		X
Iron	X	
Sulfates	X	X
Flourides	X	

Some chemical and microbiological parameters have specific water quality standards, and at the same time the results for these parameters can indicate if an activity (ex. sewage or animal waste, agricultural practices, deforestation) is the source of the problem. Similarly, there are some parameters tested, such as phosphate, where there is no standard, but the presence of this chemical in a water source might indicate a lot of agricultural runoff or animal waste is entering a stream.

The following is a brief discussion of several of the above listed parameters:

Microbiological Parameters

The isolation and determination of many pathogenic (disease-causing) organisms in water is very difficult because (a) many pathogenic organisms don't survive in water for a long time, and (b) if the pathogens are present usually they are in small numbers that can easily escape laboratory detection methods; furthermore, the techniques for isolation and identifying individual pathogens are costly and time consuming. For all these reasons, the detection of a group of "indicator organisms" is used to evaluate public health safety of a water source. The most commonly used indicator organism is the coliform bacteria group. The presence of these bacteria does not indicate a risk to the consumers of contracting any specific disease, bit rather indicates the risk of transmission of all types of water-borne diseases which could result from fecal contamination of the water source.

The technique most commonly used in Honduras to test for the presence of fecal contamination is the membrane-filter (MF) method. The MF method is based on passing a known volume of sample through a special filter, which, subsequently, is incubated on special media (food) under controlled conditions. Each individual bacterium caught on the filter will then grow into a colony of bacteria, which is visible to the naked eye. After incubation of 24 hours the number of bacteria on the filter is counted and reported as the number for a predetermined volume of the water sample tested (ex. number of bacterial colonies/100 ml).

Total Coliform Bacteria

The total coliform test detects the presence of any bacteria in the coliform group. Colform bacteria are characterized by the ability to ferment lactose between 35 and 37 degrees centigrade. This group includes bacteria originating in the feces of warm-blooded animals (fecal coliforms), as well as others that can originate in soil or vegetative matter. Coliform bacteria should not be found in supplies of treated water and are a good indication of the adequacy of disinfection or other treatment schemes. Positive results of this test should be interpreted as a measure of the opportunity for pathogens to be present in the water.

Fecal Coliform Bacteria

Fecal coliform bacteria are a subgroup of the coliform group, which are capable of fermenting lactose between 44 and 45 degrees centigrade. This group includes one type of bacteria, E. Coli, which originates specifically in the intestines of warm-blooded animals and is always present in large quantities in the feces of these animals and humans. To test specifically for E. Coli, is not practical due to complicated analytical methods. For this reason the presence of fecal coliform is considered presumptuous of fecal contamination.

The WHO guideline for total and fecal coliforms is set at 0 colonies per 100 millimeters of sample tested.

Physical Parameters

Turbidity

Turbidity can be associated with the cloudiness or murkiness of water. Turbidity in water is caused by suspended matter, such as clay, silt, decomposed organic matter and microscopic organisms. Turbidity is often a problem in streams and rivers in Honduras due to significant deforestation and watershed degradation resulting in landslides and erosion. High turbidity may also be associated with other contaminants, such as bacteria in water, because high turbidity is usually a result of human activity upstream in the watershed. Turbidity can also affect the ability to treat water. For example, to effectively chlorinate a highly turbid water a lot of chlorine will be needed because most of the chlorine combines with the suspended particles, making less available for killing bacteria. The range of turbidity varies greatly in streams and rivers of Honduras and is greatly influenced both by the condition of the watershed and the season, being higher in the rainy season.

Temperature

Temperature is important because of its affect on the solubility of oxygen in water. The colder the water the higher the oxygen content, which increases the stream's or lake's ability to support life. Temperature also affects the rate of breakdown of chemical or organic matter in the water. The higher the temperature the higher the rate of breakdown of chemical or organic matter in the water. In most water sources in Honduras the temperature is relatively constant, since the ambient air temperature does not change much. In terms of drinking water quality most temperatures encountered are at an acceptable level.

Chemical Parameters

pH

pH is a measure of the acidic activity of the water and is measured on a scale of 1 to 14, 1 being very acidic, 14 being alkaline or basic, and 7 being neutral. Most natural sources have pH values ranging from 6.4 to 8.5, all of which are within the neutral range and acceptable drinking water limits.

Conductivity

Conductivity is a measure of the ability of a substance, in this case water, to conduct an electric current. Conductivity is directly related to the amount of dissolved minerals (salts) in the water. Seawater has very high conductivity (normally about 50,000 μS/cm) whereas freshwater typically has a conductivity ranging from about 50 to 1500 μS/cm. The conductivity of natural waters depends primarily on the contact the water has with the soil or rock and mineral composition of the soil or geological material. Groundwater and springs will typically have higher conductivity than surface water because the water has been in contact with minerals typically for long distances and long periods of time. However, conductivity of superficial waters can be high if a waste discharge of sewage or agricultural runoff enter the water. Conductivity is a good measurement because it can be measured easily and rapidly in the field using a portable conductivity meter. It can also be used to compare water sources to see if they are possibly derived from the same parent source. (A conductivity difference of 20 μS/cm would generally indicate that the two sources sampled are not derived from the same source. The one with the higher conductivity could be contaminated.) Conductivity is also directly related to the total dissolved solids (TDS) in the water, and multiplying the conductivity by a conversion factor of 0.7 will give you an approximation of the TDS (mg/L) of the water.

Hardness

The concept of hardness in water quality is as old as science itself. The terms hard and soft water are contained in the writings of Hippocrates. The property of hardness has been associated with the effects observed in the use of soup or with the encrustation left on water pipes and in pots after boiling. Hard waters do not allow soap to form suds because the hardness of the water "consumes" the soap. Hardness is primarily derived by the calcium and magnesium in water and to a lesser degree carbonates. The following table provides an approximate classification of water hardness:

Table C.7.2 Hardness classifications based on mg/L of $CaCO_3$.

Hardness (mg/L $CaCO_3$)	Description
0-60	Soft
61-120	Moderately Hard
121-180	Hard
More than 180	Very Hard

Hardness of Honduran water is quite variable and is influenced greatly by the local geology. In the municipalities of El Negrito and Morazan, Yoro, water samples of several streams had very hard water in the range of 245 to 362 mg/L as $CaCO_3$, whereas, samples obtained between Tela and Ceiba in Brisas de America had hardness values of 25 mg/L as $CaCO_3$. The hard waters observed in Yoro are attributed to extensive limestone in the area. This has resulted in significant encrustation and reduced flows in several conduction lines of rural aqueducts.

The WHO guidelines for hardness are not based on the threat to human health but for esthetic and practical purposes (ex. problems with scaling). If very hard waters are encountered during an initial source investigation it is recommended that an alternative source of higher quality be used if available.

Nitrates, Nitrites and Ammonia Nitrogen

All three of these nitrogen compounds can be found in natural waters, although you would not expect to find concentrations of all three in the same sample because they exist generally under different chemical conditions. Usually, nitrogen enters the aquatic environment initially as ammonia in human and/or animal wastes or from ammonia-urea fertilizers. When the waste or fertilizer is in contact with the soil and oxygen, bacteria in the soil convert the ammonia first into nitrites and then into nitrates.

Ammonia is commonly found in streams or rivers where there exists a direct discharge of sewage or agricultural drainage or runoff. Sometimes in shallow hand-dug wells, ammonia is a problem. Ammonia is often present when a well is excavated in organic soils where vegetation is decaying (which might be the case when building a well in an old filled in wetland or sugar cane field) and the oxygen content of the water is very low. These waters tend to have strong odors and flavors and in general are undesirable to drink.

Since nitrates are derived from the conversion of ammonia by bacteria in the soil they are most commonly found in appreciable concentrations in ground waters. They are rarely found in high concentrations in streams or rivers. Nitrates in ground water can be an indication of contamination from a waste discharge on the surface from latrines, feedlots, agricultural production etc. For example, as wastewater from a pour flush latrine percolates through the soil the ammonia from the waste is converted to nitrates, and the nitrates, which are very stable, move down into the groundwater.

Excessive concentrations of nitrate in drinking water poses a health risk to infants. Concentrations of 10 mg/L or more, measured as nitrogen (or 45 mg/L as nitrates) can cause infant metahemoglobinemia (blue baby disease) in which nitrate displaces oxygen in the blood causing anemic conditions. Metahemoglobinemia is considered a temporary blood disease that can be fatal, especially if adequate medical facilities are not easily accessible. It is also suspected that high levels of nitrates might pose a health risk to pregnant women. The incidence of nitrates in the groundwater in Honduras has not been well investigated. Some shallow groundwater in the northern Sula Valley has high nitrates, probably associated with the intense agricultural practices in the area. If a potential or existing source has high nitrates it is strongly recommended that a different source be used. The treatment of nitrates is complicated and expensive.

Phosphorus

Phosphorus is a very common element and is abundant in soils, but concentrations present in natural waters are normally very low, less than a few tenths of a milligram per liter (.0.3 mg/L). Phosphorus found in surface waters is usually in the phosphate form. Phosphates in high concentrations (> 1.0 mg/L) may be derived from phosphate fertilizers, human and animal waste or from organic phosphate pesticides. Since phosphates tend to attach themselves onto soil, they are typically not very mobile, and usually are more of a problem when there is a lot of soil erosion. If high phosphates (>1.4 mg/L) are detected, the community should attempt to find their source and eliminate it if possible. High levels of phosphates are a good indicator that other more harmful contaminants may be entering the water.

Iron

Although iron is the second most abundant metal in the earth's crust, concentrations in water are generally very low. Low concentrations of iron in surface water occur because when iron is in the presence of oxygen, it usually will precipitate (form a solid) and settle out of the water. Usually the concentrations are less than a few micrograms per liter (0.01 to 0.05 mg/L). However, iron in water is often from geological materials and is directly related to the chemistry (such as pH) of the water.

Iron is an essential element in metabolism of animals and plants. If present in water in excessive amounts, however, it forms red solids that stain clothes, sinks or toilets, and can cause undesired tastes. The recommended WHO guideline for iron is 0.3 mg/L. This is for esthetic purposes, taste and staining.

Sulfates

Sulfates in natural waters are typically low, from 0.5 to 20 mg/L. They are usually derived from geological materials. Waters containing high concentrations often are in contact with geothermal springs. If the concentration of sulfate is very high (> 100 mg/L) and the pH is low (< 6.0) there is a good possibility that several other metals and toxic substances (ex. Arsenic) may be present. It is recommended that an alternative source be utilized. So far, high sulfates have not been seen in Honduras. However, there are several geothermal springs in Honduras, so caution should be taken if a potential source is located near a hot spring.

The WHO guideline for sulfates (400 mg/L) is based on esthetics, the poor taste of high sulfate levels in water, and not the potential threat it may pose.

Fluorides

The concentration of fluoride in most natural waters is less than 1 mg/L. The major source of fluorides in water is derived from local geological materials. High fluorides have been found in groundwater in contact with volcanic ash and thermal waters.

The WHO guideline for fluoride is set at 1.5 mg/L. This has been established because it was found that concentrations above this level might cause discoloration of tooth enamel (mottling) and tooth decay (caries). Although, at the same time it has been determined that waters that have fluoride between 0.7 to 1.2 mg/L have been beneficial to protect against tooth decay. It is recommended that waters containing fluoride above the stated standard not be used if another source is available. Treatment of fluorides is expensive and complicated.

Water Sampling Analysis

Water sampling is not something that should be done just once every few years. It should be done to make the best source selection, but also should be done on a regular basis (at least every 6 months) to monitor water quality and to detect changes that could threaten human health, or that could indicate degradation of the watershed. Similarly, more frequent water sampling/testing may be required in order to test the effectiveness of any type of treatment process being used. When conducting a water quality evaluation for a new potential source, samples should be collected during the rainy season to see if surface water runoff is affecting the water quality. Usually the worst water quality is found during the rainy season. For routine sampling of an existing system, samples should be collected a minimum of once during the wet season and once during the dry season.

APPENDIX D

Honduran Law Concerning Water Supply Projects and Strategies for Resolving Problems with Landowners

D.1 Honduran Law Concerning Water Supply Projects

THE CONSTITUTION OF THE REPUBLIC OF HONDURAS

Article 103: The state recognizes, encourages, and guarantees the existence of private property in its broadest concept of social function without limitations, except for cases where, for the motivation of need or public interest, the law says differently.

Article 104: The right to own property does not over ride the eminent authority of the state.

Article 106: Land can not be taken away from anyone without it being for public interest justified by the law, a resolution founded in the law or without justified indemnification.

CIVIL CODE

Article 807: A person who has the rights to a peace of land, also has the right to exercise the steps necessary to use the land.

Furthermore, a person that has the right to take out water from a source located on the property of another person, also has the right to travel to this water source, even though it may not be explicitly stated on the title.

Article 623: All rivers and all waters that flow for natural causes are national goods to be used by the public, except for streams that start and end within the same estate. These streams are considered to be owned by the land owner and can be passed on to future land owners.

MUNICIPAL LAWS

Article 14: The municipality is the organ of the government, and administration of the county and exists to improve the wellbeing of the habitants, promote development, protect the environment, and with the support of the constitution and other laws, achieve the following objectives:

1. Make sure the constitution and other laws are being inforced.
2. Seek out participation of the communities to solve problems within the county.
3. Improve the social and material wellbeing of the county by carrying out programs and public works and services.

LAWS OF THE GOVERNOR

Article 6: The governor of the Department is a representative of the Executive Branch in his jurisdiction.

Article 7: Attributes of a Departmental Governor are the following:

4. Know and resolve the resources of appeal of individuals against the municipality, complaints against civil servants, and conflicts between municipalities in the Department.

FORESTRY LAWS

Article 64: It is prohibited in the entire Republic to cut, damage, burn, or destroy trees and shrubs, and in general, the forest within 250 meters of all natural springs and in a belt of 150 meters on all sides of any permanent stream of river, or lake or pond, or drainage. When a water source is used for the public good, the Municipality, the Advisors District, en cooperation with Governors, and the National Armed Forces is responsible for protecting it in accordance with the regulations of the National Corporation of Forest Development.

Article 148: The protection of a water source is primarily the responsibility of its municipality.

D.2 Strategies for Resolving Problems with Landowners in Honduras

Strategy 1 Talk with landowner.

Send a group of community members to explain to the landowner the conditions the community is living in, the number of kids that will benefit from the project, and the objectives of the community to improve health conditions. Explain to the owner that the community will respect his or her property and pay for any damages that occur during construction of the water system. Show the owner a written document with this information that is signed by the board of directors of the community.

If the landowner still will not provide permission, ask the Mayor of the municipality to talk to the owner and send a letter outlining the importance of the project.

Strategy 2 Apply the law.

Provide a list of the laws of land ownership (Constitution, Civil Code, Forestry Laws and Laws of Municipalities and Governors Appendix IV) to the mayor and request that he or she find the community a lawyer to represent the case.

At the same time the community should visit Forestry Development Corporation of Honduras (COHDEFOR) and ask them to mark areas of the watershed that are protected by forestry laws.

Strategy 3 Talk to the Governor.

If the Mayor does not respond to the communities request, the community needs to contact the Governor, and request help in resolving the problem.

Strategy 4 Talk to the Ministry of Natural Resources.

Request help from the director of a farmers organization in Tegucigulpa, and coordinate a meeting with the Ministry of Natural Resources through the director.

APPENDIX E

Results of Work Done on Potable Water Projects in Honduras

Table E.1 A list of the communities I worked with between August 2000 until Febuary 2003, the wor that was done, and the status and limitations of each project when I left Honduras.

Community	Work done	Current Status	Current Limitations
La Guama y La Alegria, Trinidad	supervision - construction	finished project	none
El Volcán, Concepción Norte	supervision - construction	finished project	funds
El Diviso, San Francisco de Ojuera	topographic study design solicitation of funds supervision - construction	construction	transportation to water source
El Cielito, Santa Bárbara	estudio topográfico design solicitation of funds supervision - construction	construction	none
Monte Cristo, Trinidad	topographic study design	lack land permission	lack political and community support
Platanares, Chinda	topographic study design	lack funding	lack political and community support
La Sandillera, Santa Cruz - Yojoa	topographic study design supervision - construction	finished project	none
Montecillos 2, Santa Cruz-Yojoa	topographic study design	funded	none
Azacualpa, Zacapa	diagnostica plan de mejoramiento	lack funding	lack political and community support
La Angostura, Trinidad	topographic study design	lack land permission	lack political and community support
Gracias a Dios, Santa Bárbara	topographic study design	lack funding	lack political and community support
Brisas de Oro, Arada	topographic study design	abandoned project	lack community support
La Montañita, Ilama	topographic study design solicitation of funds	funded	none
Krique Las Rosas, Atlantida	topographic study design	lack funding	desinteres - municipalidad y vecinos
San José Colinas	diagnostic study improvement plan	funded	
Las Rosas, San Luis	topographic study design	lack funding	
Emilio Rapalo, San Luis	topographic study	not feasable	altitude of water source
Las Joyas, Trinidad	topographic study	not feasable	altitude of water source
Flor Blanca, Petoa	topographic study design	lack funding	lack of community organization
Petoa, Petoa	topographic study	lack funding	lack of community organization
	design		

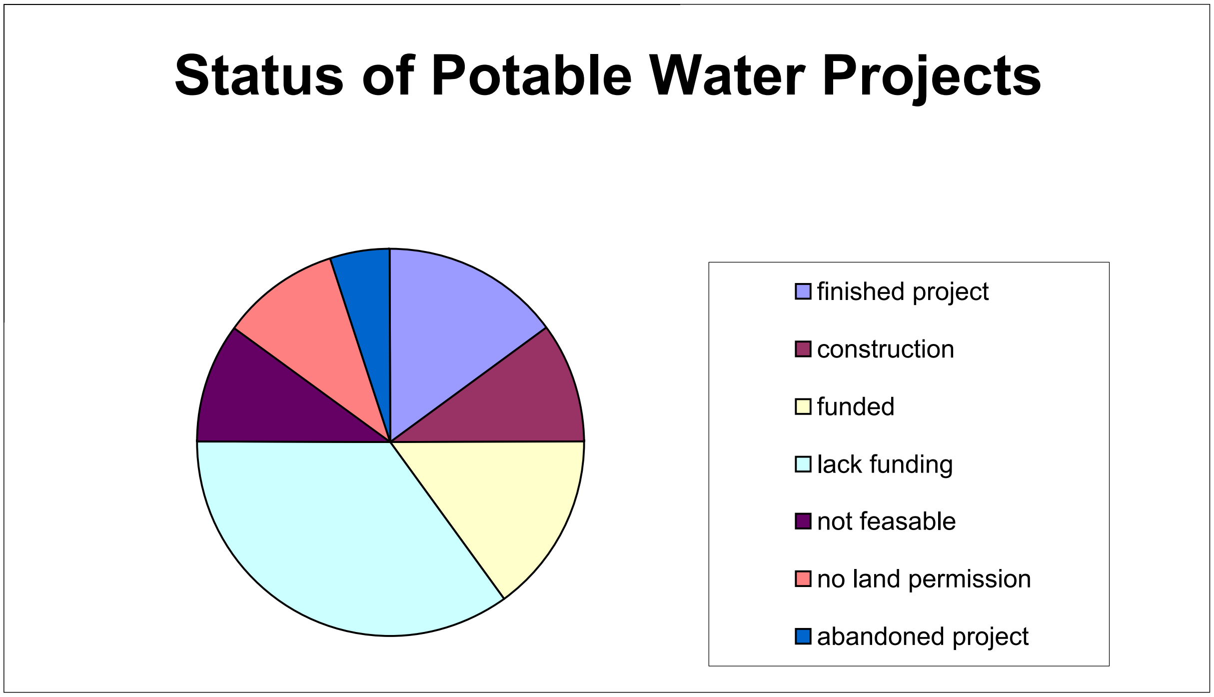


Figure E.1 A pie chart showing the status of the water projects I worked on after 2½ years as Peace Corps volunteer in Santa Barbara, Honduras.

APPENDIX F

The following design and proposal for the community of, La Colonia El Cielito, was done using the Excel program explained in chapter 3.3. It serves as an example of the various components that make up a design and proposal, and is helpful for following the description of how to use the Excel program. This same example can be found on the website: (http://www.cee.mtu.edu/peacecorps/resources.html)

The community of El Cielito is located in a coffee-growing region high up on the flanks of the Santa Bárabara Mountain. The geology of the area is considered to be very unstable. During hurricane Mitch in 1998 one family was killed when a landslide destroyed their house. Since the hurricane, government scientists have investigated the area and deemed it unsafe to live there. The area around El Cielito also serves as a watershed for many communities located in the valley below the mountain. This has motivated the Honduran government to relocate some of the houses and farms in order to protect the watershed from being contaminated by agricultural activities.

In the year 2000 the community was able to buy, with the help of the Municipality, a piece of land directly below El Cielito. They solicited my help to survey the new property and we subsequently divided it into 90, 14 meter by 14-meter lots. The new town was named La Colonia El Cielito and by the year 2002 16 families had moved and built houses there. The town of El Cielito has a water project, so many community members were reluctant to move down to the new property without easy access to potable water. In August of 2002 another Peace Corps volunteer and I elaborated a topographic study design and proposal. The proposal was accepted by the non-profit organization, Water For People based out of Boulder Colorado. Construction of the project began in October of 2002 and was finished in April 2003.

Topographic Study, Design and Proposal for the Community, La Colonia El Cielito

POPULAR CULTURAL ACTION OF HONDURAS

REGIÓN, SANTA BARBARA

Rural Aqueducts Program

La Colonia El Cielito, Santa Barbara, SANTA BARBARA

August of 2002

Eng. Nathan Reents
Tech. Gifford Laube
Santa Barbara, Santa Barbara
TeleFax: 643-21-29

GENERAL DATA

POTABLE WATER PROJECT

Community:	***La Colonia El Cielito***
Municipality:	***Santa Barbara***
Department:	***SANTA BARBARA***
Engineer:	***Eng. Nathan Reents***
Technician:	***Tech. Gifford Laube***
Date of Design:	***August of 2002***

GENERAL DATA OF PROJECT

Date of Topographic Study:	***August of 2002***	
Study Method:	***Abney Level***	
Water Source:	***El Cielito***	
Flow Measurement Method:	***Volumetric***	
Flow Measurement of Source:	***30***	**gpm**
Relative Altitude of Source:	***1000***	**m**
Tank Altitude:	***711.58***	**m**
Distance of Conduction Line:	***3.59***	**Km.**
Distance of Distribution Network:	***1.28***	**Km.**
Number of Houses:	***93***	**Houses**
Design Period:	**20**	**Years**
Growth Rate:	**3.5**	**Percentage**
Average Inhabitants Per House:	**6**	**Inhabitants / House**
Water Consumption:	**30**	**gppd (Gal./Person/Day)**
Actual Population:	**558**	**People**
Future Population, P_f:	**949**	**People (Design Population)**
Average Daily Consumption, ADC:	**19.8**	**gpm**
Maximum Daily Consumption, MDC:	**29.6**	**gpm (for design of conduction line)**
Maximum Hourly Consumption, MHC:	**44.5**	**gpm (for design of distribution network)**
Design Flow Per House:	**0.48**	**gpm (for design of distribution network)**
Volume of Tank:	**10,000**	**Galons**

TOPOGRAPHIC DATA - CONDUCTION LINE

TOPOGRAPHIC DATA - CONDUCTION LINE

La Colonia El Cielito, Santa Barbara, SANTA BARBARA

Technician: **Tech. Gifford Laube** Date of Topographic Study: **August of 2002**

Section Sta. - Sta.		Inclined Distance (m.)	Vert. Ang. Forward (deg. min.)	Vert. Ang. Back (deg. min.)	Compass (deg.)	Type of Tubing	Notes	Accum. Dist. (m)	Ave. Ang. (degrees)	Terrain Elev. (m)	Direction Ang.			Projec. E - W (m)	Projec. N -S (m)
														0.00	
							Spring Box	0.00		1,000.00				0.00	0.00
0 -	1	13.00	-17°20'	18°20'	70°	GI		13.00	-18.17	995.95	N	70°	E	11.61	4.22
1 -	2	8.00	-0°50'	1°40'	102°	GI	Follow Stream	21.00	-1.58	995.73	S	78°	E	19.43	2.56
2 -	3	7.50	-28°30'	29°00'	128°	GI	Follow Stream	28.50	-29.08	992.08	S	52°	E	24.59	-1.47
3 -	4	17.00	-30°50'	31°30'	124°	GI	Follow Stream	45.50	-31.50	983.20	S	56°	E	36.61	-9.58
4 -	5	20.00	-18°00'	18°30'	112°	PVC	Follow Stream	65.50	-18.25	976.93	S	68°	E	54.22	-16.69
5 -	6	25.00	-29°50'	30°20'	128°	PVC	Follow Stream	90.50	-30.42	964.28	S	52°	E	71.21	-29.97
6 -	7	21.00	-35°30'	35°50'	120°	PVC	Follow Stream	111.50	-35.67	952.03	S	60°	E	85.99	-38.50
7 -	8	27.00	-30°40'	30°50'	110°	PVC	Follow Stream	138.50	-30.75	938.23	S	70°	E	107.79	-46.43
8 -	9	25.30	-31°00'	31°10'	102°	PVC	Follow Stream	163.80	-31.08	925.17	S	78°	E	128.98	-50.94
9 -	10	9.50	-24°00'	24°00'	84°	GI	Old Spring Box	173.30	-24.00	921.30	N	84°	E	137.62	-50.03
10 -	11	21.60	-8°20'	9°00'	136°	GI		194.90	-9.00	917.92	S	44°	E	152.44	-65.38
11 -	12	28.00	-9°20'	10°00'	105°	GI		222.90	-10.00	913.06	S	75°	E	179.07	-72.51
12 -	13	14.20	-4°40'	5°50'	97°	GI		237.10	-5.58	911.68	S	83°	E	193.10	-74.24
13 -	14	23.00	-12°10'	14°00'	104°	GI	Stream	260.10	-13.08	906.47	S	76°	E	214.84	-79.66
14 -	15	30.60	-10°10'	10°50'	64°	GI	Follow Road	290.70	-10.50	900.90	N	64°	E	241.88	-66.47
15 -	16	30.60	-9°40'	10°20'	74°	GI	Follow Road	321.30	-10.33	895.41	N	74°	E	270.82	-58.17
16 -	17	30.60	1°50'	-1°00'	94°	GI	Follow Road	351.90	1.42	896.16	S	86°	E	301.33	-60.30
17 -	18	30.60	1°50'	-1°00'	103°	GI	Follow Road	382.50	1.42	896.92	S	77°	E	331.14	-67.18
18 -	19	30.60	-4°00'	5°00'	98°	GI	Follow Road	413.10	-4.83	894.34	S	82°	E	361.33	-71.43
19 -	20	30.60	0°50'	-0°30'	83°	GI	Follow Road	443.70	0.67	894.70	N	83°	E	391.70	-67.70
20 -	21	30.60	-7°50'	8°20'	72°	GI	Follow Road	474.30	-8.42	890.22	N	72°	E	420.49	-58.35
21 -	22	30.60	-10°30'	11°10'	94°	GI	Follow Road	504.90	-11.17	884.29	S	86°	E	450.44	-60.44
22 -	23	30.60	-10°10'	11°10'	90°	GI	Follow Road	535.50	-11.00	878.45	N	90°	E	480.48	-60.44
23 -	24	30.60	-15°30'	14°10'	68°	GI	Follow Road	566.10	-15.17	870.45	N	68°	E	507.86	-49.38
24 -	25	30.60	-11°00'	11°40'	80°	GI	Follow Road	596.70	-11.33	864.44	N	80°	E	537.41	-44.17
25 -	26	30.60	-11°00'	11°50'	108°	GI	Follow Road	627.30	-11.42	858.38	S	72°	E	565.93	-53.43
26 -	27	30.60	-7°30'	8°10'	108°	PVC	Follow Road	657.90	-8.17	854.03	S	72°	E	594.74	-62.79
27 -	28	30.60	-7°00'	7°50'	130°	PVC	Follow Road	688.50	-7.42	850.08	S	50°	E	617.99	-82.30
28 -	29	30.60	-10°00'	10°40'	114°	PVC	Follow Road	719.10	-10.33	844.59	S	66°	E	645.49	-94.54
29 -	30	30.60	-8°20'	9°10'	108°	PVC	Follow Road	749.70	-9.08	839.76	S	72°	E	674.22	-103.88
30 -	31	30.60	-10°00'	10°30'	100°	PVC	Follow Road	780.30	-10.25	834.32	S	80°	E	703.88	-109.11
31 -	32	30.60	-7°50'	8°30'	72°	PVC	Follow Road	810.90	-8.50	829.79	N	72°	E	732.66	-99.76
32 -	33	30.60	-7°00'	7°40'	82°	PVC	Follow Road	841.50	-7.33	825.89	N	82°	E	762.72	-95.53
33 -	34	30.60	-6°00'	7°00'	74°	PVC	Follow Road	872.10	-6.83	822.25	N	74°	E	791.92	-87.16
34 -	35	30.60	-12°10'	12°50'	72°	PVC	Follow Road	902.70	-12.50	815.62	N	72°	E	820.33	-77.93
35 -	36	30.60	-15°10'	13°50'	90°	PVC	Follow Road	933.30	-14.50	807.96	N	90°	E	849.96	-77.93
36 -	37	28.50	-12°10'	12°50'	56°	PVC	Follow Road	961.80	-12.50	801.79	N	56°	E	873.03	-62.37
37 -	38	20.40	-10°40'	11°30'	50°	PVC	Follow Road	982.20	-11.42	797.76	N	50°	E	888.34	-49.52
38 -	39	27.00	-16°20'	17°20'	64°	PVC	Follow Road	1,009.20	-17.17	789.79	N	64°	E	911.53	-38.21
39 -	40	19.40	-16°20'	17°00'	96°	PVC	Follow Road	1,028.60	-17.00	784.11	S	84°	E	929.98	-40.15
40 -	41	29.40	-16°10'	16°40'	74°	PVC	Follow Road	1,058.00	-16.42	775.81	N	74°	E	957.09	-32.37
41 -	42	21.50	-14°50'	15°00'	72°	PVC	Follow Road	1,079.50	-15.25	770.15	N	72°	E	976.82	-25.96
42 -	43	26.30	-3°20'	4°00'	76°	PVC	Coffee Fields	1,105.80	-4.00	768.32	N	76°	E	1,002.28	-19.62
43 -	44	12.50	1°10'	0°00'	68°	PVC	Coffee Fields	1,118.30	0.92	768.52	N	68°	E	1,013.86	-14.93
44 -	45	15.70	1°10'	-0°10'	54°	PVC	Coffee Fields	1,134.00	1.00	768.79	N	54°	E	1,026.56	-5.71
45 -	46	18.30	-2°40'	2°50'	48°	PVC	Coffee Fields	1,152.30	-2.75	767.91	N	48°	E	1,040.15	6.52
46 -	47	17.00	-1°20'	2°00'	50°	PVC	Follow Road	1,169.30	-2.00	767.32	N	50°	E	1,053.16	17.45
47 -	48	16.40	-3°00'	3°40'	48°	PVC	Follow Road	1,185.70	-3.33	766.36	N	48°	E	1,065.33	28.40
48 -	49	25.00	-3°20'	4°50'	52°	PVC	Follow Road	1,210.70	-4.42	764.44	N	52°	E	1,084.97	43.75
49 -	50	21.50	-10°20'	10°40'	58°	PVC		1,232.20	-10.50	760.52	N	58°	E	1,102.90	54.95
50 -	51	20.50	-14°30'	15°00'	68°	PVC		1,252.70	-15.08	755.19	N	68°	E	1,121.25	62.36
51 -	52	30.60	-18°40'	19°40'	74°	PVC		1,283.30	-19.50	744.97	N	74°	E	1,148.98	70.31
52 -	53	24.00	-21°50'	22°30'	90°	PVC		1,307.30	-22.50	735.79	N	90°	E	1,171.15	70.31
53 -	54	2.50	-18°50'	18°50'	90°	PVC		1,309.80	-18.83	734.98	N	90°	E	1,173.52	70.31
54 -	55	36.00	-22°00'	23°10'	90°	GI	Stream (cable)	1,345.80	-22.92	720.96	N	90°	E	1,206.68	70.31
55 -	56	29.00	-12°40'	13°30'	74°	PVC	Stream (cable)	1,374.80	-13.42	714.23	N	74°	E	1,233.79	78.09
56 -	57	30.60	-8°20'	9°00'	52°	PVC	Follow Road	1,405.40	-9.00	709.45	N	52°	E	1,257.61	96.70
57 -	58	30.60	0°00'	0°30'	74°	PVC	Follow Road	1,436.00	-0.25	709.31	N	74°	E	1,287.02	105.13
58 -	59	30.60	4°30'	-4°00'	70°	PVC	Storm Drain	1,466.60	4.25	711.58	N	70°	E	1,315.70	115.57
59 -	60	30.60	-1°40'	2°10'	54°	PVC		1,497.20	-2.25	710.38	N	54°	E	1,340.43	133.54
60 -	61	30.60	-5°10'	5°50'	48°	PVC		1,527.80	-5.50	707.45	N	48°	E	1,363.07	153.92
61 -	62	30.60	-6°00'	7°00'	48°	PVC		1,558.40	-6.83	703.81	N	48°	E	1,385.65	174.25
62 -	63	30.60	-11°50'	12°10'	64°	PVC		1,589.00	-12.33	697.27	N	64°	E	1,412.52	187.36
63 -	64	30.60	-9°40'	10°10'	66°	PVC		1,619.60	-10.25	691.83	N	66°	E	1,440.03	199.60
64 -	65	30.60	-7°20'	8°00'	75°	PVC		1,650.20	-8.00	687.57	N	75°	E	1,469.30	207.45
65 -	66	30.60	-3°30'	4°00'	64°	PVC		1,680.80	-4.08	685.39	N	64°	E	1,496.73	220.83
66 -	67	30.60	-4°00'	4°30'	58°	PVC		1,711.40	-4.25	683.12	N	58°	E	1,522.61	237.00
67 -	68	30.60	-9°40'	10°20'	64°	PVC		1,742.00	-10.33	677.63	N	64°	E	1,549.66	250.19
68 -	69	21.00	-8°50'	9°20'	52°	PVC		1,763.00	-9.42	674.20	N	52°	E	1,565.99	262.95
69 -	70	20.00	-8°50'	9°50'	50°	PVC		1,783.00	-9.00	671.07	N	50°	E	1,581.12	275.65
70 -	71	27.00	-5°10'	6°10'	64°	PVC		1,810.00	-6.00	668.24	N	64°	E	1,605.26	287.42
71 -	72	29.20	-5°10'	6°00'	72°	PVC		1,839.20	-5.92	665.23	N	72°	E	1,632.88	296.39
72 -	73	8.50	-1°40'	2°10'	80°	PVC		1,847.70	-2.25	664.90	N	80°	E	1,641.24	297.87

TOPOGRAPHIC DATA - CONDUCTION LINE

La Colonia El Cielito, Santa Barbara, SANTA BARBARA

Technician: **Tech. Gifford Laube** Date of Topographic Study: **August of 2002**

Section Sta. -	Sta.	Inclined Distance (m.)	Vert. Ang. Forward (deg. min.)	Vert. Ang. Back (deg. min.)	Compass (deg.)	Type of Tubing	Notes	Accum. Dist. (m)	Ave. Ang. (degrees)	Terrain Elev. (m)	Direction Ang.			Projec. E - W (m)	Projec. N -S (m)
														0.00	
73 -	74	12.70	-5°50'	7°00'	56°	PVC		1,860.40	-6.42	663.48	N	56°	E	1,651.71	304.93
74 -	75	8.20	-2°00'	2°00'	80°	PVC		1,868.60	-2.00	663.19	N	80°	E	1,659.78	306.35
75 -	76	13.90	-9°30'	10°00'	52°	PVC		1,882.50	-10.08	660.76	N	52°	E	1,670.56	314.77
76 -	77	17.50	-5°00'	5°50'	50°	PVC		1,900.00	-5.42	659.11	N	50°	E	1,683.91	325.97
77 -	78	11.10	-3°00'	3°40'	50°	PVC		1,911.10	-3.33	658.46	N	50°	E	1,692.40	333.10
78 -	79	12.70	1°50'	-1°10'	70°	PVC		1,923.80	1.50	658.80	N	70°	E	1,704.33	337.44
79 -	80	14.00	3°20'	-2°40'	73°	PVC		1,937.80	3.33	659.61	N	73°	E	1,717.69	341.52
80 -	81	18.60	5°40'	-5°10'	66°	PVC		1,956.40	5.42	661.37	N	66°	E	1,734.61	349.06
81 -	82	16.00	4°20'	-3°50'	60°	PVC		1,972.40	4.42	662.60	N	60°	E	1,748.42	357.03
82 -	83	11.50	5°30'	-5°00'	70°	PVC		1,983.90	5.25	663.65	N	70°	E	1,759.18	360.95
83 -	84	6.00	1°10'	-1°20'	36°	PVC		1,989.90	1.25	663.78	N	36°	E	1,762.71	365.80
84 -	85	14.70	4°50'	-4°00'	60°	PVC		2,004.60	4.42	664.91	N	60°	E	1,775.40	373.13
85 -	86	16.40	5°30'	-5°00'	48°	PVC		2,021.00	5.25	666.41	N	48°	E	1,787.54	384.06
86 -	87	10.00	-2°30'	3°00'	48°	PVC		2,031.00	-3.08	665.88	N	48°	E	1,794.96	390.74
87 -	88	13.00	-19°30'	20°10'	72°	PVC		2,044.00	-20.17	661.39	N	72°	E	1,806.57	394.51
88 -	89	15.00	-17°10'	17°30'	80°	PVC		2,059.00	-17.33	656.93	N	80°	E	1,820.67	397.00
89 -	90	10.00	-19°20'	20°00'	70°	PVC		2,069.00	-20.00	653.51	N	70°	E	1,829.50	400.21
90 -	91	17.00	-18°00'	18°00'	92°	PVC		2,086.00	-18.00	648.25	S	88°	E	1,845.66	399.65
91 -	92	22.00	-32°50'	33°10'	94°	PVC		2,108.00	-33.33	636.16	S	86°	E	1,863.99	398.36
92 -	93	23.30	-32°00'	32°10'	90°	PVC		2,131.30	-32.08	623.79	N	90°	E	1,883.73	398.36
93 -	94	21.00	-20°00'	20°00'	96°	PVC		2,152.30	-20.00	616.60	S	84°	E	1,903.36	396.30
94 -	95	25.00	-15°10'	16°00'	90°	PVC		2,177.30	-15.92	609.75	N	90°	E	1,927.40	396.30
95 -	96	30.60	-20°30'	21°10'	80°	PVC		2,207.90	-21.17	598.70	N	80°	E	1,955.50	401.26
96 -	97	30.60	-12°20'	12°50'	74°	PVC		2,238.50	-12.58	592.03	N	74°	E	1,984.21	409.49
97 -	98	13.00	-17°10'	18°10'	80°	PVC		2,251.50	-18.00	588.02	N	80°	E	1,996.39	411.63
98 -	99	15.60	-23°30'	24°00'	62°	PVC		2,267.10	-24.08	581.65	N	62°	E	2,008.96	418.32
99 -	100	22.40	-26°40'	27°40'	100°	PVC		2,289.50	-27.50	571.31	S	80°	E	2,028.53	414.87
100 -	101	30.60	-18°50'	19°10'	98°	PVC		2,320.10	-19.33	561.18	S	82°	E	2,057.12	410.85
101 -	102	18.00	-16°30'	17°10'	98°	PVC		2,338.10	-17.17	555.86	S	82°	E	2,074.15	408.46
102 -	103	25.00	-12°00'	12°40'	96°	PVC	Small Road	2,363.10	-12.33	550.52	S	84°	E	2,098.44	405.91
103 -	104	30.60	-6°40'	7°10'	112°	PVC		2,393.70	-7.25	546.66	S	68°	E	2,126.59	394.53
104 -	105	30.60	-6°00'	6°40'	100°	PVC		2,424.30	-6.33	543.29	S	80°	E	2,156.54	389.25
105 -	106	29.00	-12°00'	12°50'	90°	PVC		2,453.30	-12.42	537.05	N	90°	E	2,184.86	389.25
106 -	107	14.60	-10°20'	10°50'	72°	PVC		2,467.90	-10.58	534.37	N	72°	E	2,198.51	393.69
107 -	108	17.00	-9°50'	10°20'	94°	PVC		2,484.90	-10.42	531.30	S	86°	E	2,215.19	392.52
108 -	109	21.50	-2°00'	1°20'	94°	GI	Stream	2,506.40	-2.00	530.55	S	86°	E	2,236.62	391.02
109 -	110	22.00	19°00'	-18°50'	66°	PVC		2,528.40	19.25	537.80	N	66°	E	2,255.60	399.47
110 -	111	29.00	8°50'	-8°00'	42°	PVC		2,557.40	8.42	542.04	N	42°	E	2,274.79	420.79
111 -	112	17.00	-6°10'	7°00'	42°	PVC		2,574.40	-6.92	540.00	N	42°	E	2,286.08	433.33
112 -	113	30.60	-12°50'	13°30'	76°	PVC		2,605.00	-13.50	532.85	N	76°	E	2,314.96	440.53
113 -	114	30.60	-12°30'	13°30'	74°	GI	Road	2,635.60	-13.33	525.80	N	74°	E	2,343.58	448.74
114 -	115	22.20	16°10'	-14°30'	72°	PVC		2,657.80	15.33	531.67	N	72°	E	2,363.94	455.35
115 -	116	4.50	28°50'	-29°20'	70°	PVC		2,662.30	29.42	533.88	N	70°	E	2,367.62	456.69
116 -	117	10.70	25°00'	-25°00'	50°	PVC		2,673.00	25.00	538.40	N	50°	E	2,375.05	462.93
117 -	118	12.50	22°50'	-22°10'	51°	PVC		2,685.50	22.50	543.18	N	51°	E	2,384.03	470.19
118 -	119	10.00	14°00'	-16°00'	48°	PVC		2,695.50	15.00	545.77	N	48°	E	2,391.20	476.66
119 -	120	13.00	29°40'	-29°50'	65°	PVC		2,708.50	29.75	552.22	N	65°	E	2,401.43	481.43
120 -	121	16.00	18°30'	-18°00'	65°	PVC		2,724.50	18.25	557.23	N	65°	E	2,415.20	487.85
121 -	122	13.00	2°20'	-1°10'	72°	PVC		2,737.50	2.08	557.70	N	72°	E	2,427.56	491.86
122 -	123	17.00	-4°20'	4°50'	66°	PVC		2,754.50	-4.58	556.35	N	66°	E	2,443.04	498.76
123 -	124	15.00	-2°20'	2°30'	94°	PVC		2,769.50	-2.42	555.71	S	86°	E	2,457.99	497.71
124 -	125	11.00	14°50'	-14°50'	56°	PVC		2,780.50	14.83	558.53	N	56°	E	2,466.81	503.66
125 -	126	21.00	16°00'	-15°30'	37°	PVC		2,801.50	16.08	564.35	N	37°	E	2,478.95	519.77
126 -	127	9.00	16°20'	-15°50'	48°	PVC		2,810.50	16.42	566.89	N	48°	E	2,485.37	525.55
127 -	128	17.00	23°00'	-22°50'	60°	PVC		2,827.50	23.25	573.60	N	60°	E	2,498.89	533.36
128 -	129	20.00	0°40'	0°20'	114°	PVC		2,847.50	0.17	573.66	S	66°	E	2,517.16	525.22
129 -	130	28.70	-5°10'	6°00'	86°	PVC		2,876.20	-5.92	570.70	N	86°	E	2,545.64	527.22
130 -	131	13.40	-13°50'	14°20'	70°	PVC		2,889.60	-14.42	567.36	N	70°	E	2,557.84	531.65
131 -	132	12.00	-11°20'	11°50'	88°	GI		2,901.60	-11.58	564.96	N	88°	E	2,569.58	532.06
132 -	133	20.50	-12°30'	13°40'	68°	GI		2,922.10	-13.42	560.20	N	68°	E	2,588.07	539.53
133 -	134	21.40	-0°40'	1°00'	75°	GI		2,943.50	-1.17	559.76	N	75°	E	2,608.74	545.07
134 -	135	21.30	-0°50'	1°30'	68°	GI		2,964.80	-1.50	559.21	N	68°	E	2,628.48	553.05
135 -	136	11.00	-17°10'	17°40'	66°	GI		2,975.80	-17.42	555.91	N	66°	E	2,638.07	557.32
136 -	137	22.00	-12°00'	13°00'	98°	GI		2,997.80	-12.83	551.03	S	82°	E	2,659.31	554.33
137 -	138	12.00	-20°50'	20°40'	100°	GI		3,009.80	-20.75	546.77	S	80°	E	2,670.36	552.38
138 -	139	15.00	-2°00'	2°40'	96°	GI		3,024.80	-2.33	546.16	S	84°	E	2,685.27	550.82
139 -	140	7.00	-2°00'	2°20'	60°	GI		3,031.80	-2.17	545.90	N	60°	E	2,691.33	554.31
140 -	141	16.30	-23°50'	24°30'	88°	GI		3,048.10	-24.50	539.14	N	88°	E	2,706.15	554.83
141 -	142	14.50	-7°00'	7°20'	80°	GI		3,062.60	-7.17	537.33	N	80°	E	2,720.32	557.33
142 -	143	30.60	10°20'	-9°50'	81°	GI		3,093.20	10.42	542.86	N	81°	E	2,750.04	562.04
143 -	144	19.50	23°20'	-22°30'	74°	GI		3,112.70	23.25	550.56	N	74°	E	2,767.27	566.98
144 -	145	22.00	-4°00'	4°50'	62°	GI		3,134.70	-4.42	548.87	N	62°	E	2,786.63	577.27
145 -	146	9.00	-19°10'	20°20'	54°	GI		3,143.70	-20.08	545.78	N	54°	E	2,793.47	582.24
146 -	147	12.00	-24°00'	25°10'	92°	GI		3,155.70	-24.92	540.72	S	88°	E	2,804.35	581.86

TOPOGRAPHIC DATA - CONDUCTION LINE

La Colonia El Cielito, Santa Barbara, SANTA BARBARA

Technician: **Tech. Gifford Laube** Date of Topographic Study: **August of 2002**

Section Sta. - Sta.		Inclined Distance (m.)	Vert. Ang. Forward (deg. min.)	Vert. Ang. Back (deg. min.)	Compass (deg.)	Type of Tubing	Notes	Accum. Dist. (m)	Ave. Ang. (degrees)	Terrain Elev. (m)	Direction Ang.			Projec. E - W (m)	Projec. N -S (m)
														0.00	
147 -	148	24.00	-0°50'	1°40'	104°	GI		3,179.70	-1.58	540.06	S	76°	E	2,827.63	576.06
148 -	149	19.00	6°10'	-5°10'	87°	GI		3,198.70	6.00	542.04	N	87°	E	2,846.50	577.05
149 -	150	10.50	20°20'	-20°00'	78°	GI		3,209.20	20.17	545.66	N	78°	E	2,856.14	579.10
150 -	151	10.00	13°00'	-12°20'	98°	GI		3,219.20	13.00	547.91	S	82°	E	2,865.79	577.74
151 -	152	11.00	-15°10'	15°40'	120°	GI		3,230.20	-15.42	544.99	S	60°	E	2,874.97	572.44
152 -	153	22.00	-28°00'	28°10'	124°	PVC		3,252.20	-28.08	534.63	S	56°	E	2,891.06	561.58
153 -	154	30.60	-11°00'	11°50'	124°	PVC		3,282.80	-11.42	528.58	S	56°	E	2,915.93	544.81
154 -	155	14.00	-4°00'	3°30'	134°	PVC	Corn Field	3,296.80	-4.08	527.58	S	46°	E	2,925.97	535.11
155 -	156	30.60	0°00'	0°20'	148°	PVC	Corn Field	3,327.40	-0.17	527.49	S	32°	E	2,942.19	509.16
156 -	157	30.60	2°10'	-1°50'	137°	PVC	Corn Field	3,358.00	2.33	528.74	S	43°	E	2,963.04	486.80
157 -	158	19.50	-10°00'	10°30'	116°	PVC	Corn Field	3,377.50	-10.25	525.27	S	64°	E	2,980.29	478.39
158 -	159	30.60	-5°00'	5°20'	118°	PVC	Corn Field	3,408.10	-5.17	522.51	S	62°	E	3,007.19	464.08
159 -	160	18.00	-0°30'	0°40'	110°	PVC	Corn Field	3,426.10	-0.58	522.33	S	70°	E	3,024.11	457.93
160 -	161	19.40	-4°30'	5°50'	110°	PVC	Corn Field	3,445.50	-5.50	520.47	S	70°	E	3,042.25	451.32
161 -	162	22.00	-5°20'	6°00'	138°	PVC		3,467.50	-6.00	518.17	S	42°	E	3,056.89	435.06
162 -	163	14.00	-9°30'	9°50'	144°	PVC		3,481.50	-9.67	515.82	S	36°	E	3,065.01	423.90
163 -	164	30.60	-13°30'	14°00'	158°	PVC		3,512.10	-14.08	508.37	S	22°	E	3,076.13	396.38
164 -	165	17.00	-13°30'	14°10'	156°	PVC		3,529.10	-14.17	504.21	S	24°	E	3,082.83	381.32
165 -	166	17.00	-23°30'	24°10'	156°	PVC		3,546.10	-24.17	497.25	S	24°	E	3,089.14	367.15
166 -	167	19.00	-24°00'	24°40'	176°	PVC		3,565.10	-24.33	489.42	S	4°	E	3,090.35	349.88
167 -	168	12.00	-16°00'	16°50'	188°	PVC		3,577.10	-16.42	486.03	S	8°	W	3,088.74	338.48
168 -	169	12.20	-30°40'	31°50'	164°	PVC	**Tank**	3,589.30	-31.58	479.64	S	16°	E	3,091.61	328.49

HYDRAULIC DESIGN - CONDUCTION LINE

HYDRAULIC DESIGN - CONDUCTION LINE

La Colonia El Cielito, Santa Barbara, SANTA BARBARA

Engineer: **Eng. Nathan Reents** Date of Design: **August of 2002**

Section Sta - Sta	Incli. Dist. (m)	Accum. Dist. (m)	Terren. Elev. (m)	Flow MDC (gpm)	Diam. Rec. (in)	*Diam. Prop. (in)*	Coeffic. of Friction	Frict. Losses (m/sect.)	Piezo. Elev. (m)	Dynamic Head (m)	Static Head (m)	Vel. (m/s)	Type of Piping			*Notes*
		0.00	1,000.00						1,000.00							***Spring Box***
0 - 1	13.00	13.00	995.95	29.64	2.61	*1.50*	0.207	1.40	998.60	2.65	4.05	1.64	GI	SCH40	1.5"	
1 - 2	8.00	21.00	995.73	29.64	2.61	*1.50*	0.207	0.86	997.73	2.01	4.27	1.64	GI	SCH40	1.5"	
2 - 3	7.50	28.50	992.08	29.64	2.61	*1.50*	0.207	0.81	996.92	4.84	7.92	1.64	GI	SCH40	1.5"	
3 - 4	17.00	45.50	983.20	29.64	2.61	*1.50*	0.207	1.84	995.09	11.89	16.80	1.64	GI	SCH40	1.5"	
4 - 5	20.00	65.50	976.93	29.64	2.61	*1.50*	0.111	1.16	993.93	17.00	23.07	1.64	PVC	SDR26	1.5"	
5 - 6	25.00	90.50	964.28	29.64	2.61	*1.50*	0.111	1.45	992.48	28.21	35.72	1.64	PVC	SDR26	1.5"	
6 - 7	21.00	111.50	952.03	29.64	2.61	*1.00*	0.111	9.87	982.61	30.58	47.97	3.68	PVC	SDR26	1.0"	
7 - 8	27.00	138.50	938.23	29.64	2.61	*1.00*	0.111	12.69	969.92	31.69	61.77	3.68	PVC	SDR26	1.0"	
8 - 9	25.30	163.80	925.17	29.64	2.61	*1.00*	0.111	11.89	958.03	32.86	74.83	3.68	PVC	SDR26	1.0"	
9 - 10	9.50	173.30	921.30	29.64	2.61	*1.00*	0.207	8.33	949.70	28.40	78.70	3.68	GI	SCH40	1.0"	***Break Pressure Tank 1***
10 - 11	21.60	194.90	917.92	29.64	2.61	*2.00*	0.207	0.81	920.49	2.57	3.38	0.92	GI	SCH40	2.0"	
11 - 12	28.00	222.90	913.06	29.64	2.61	*2.00*	0.207	1.05	919.43	6.37	8.24	0.92	GI	SCH40	2.0"	
12 - 13	14.20	237.10	911.68	29.64	2.61	*2.00*	0.207	0.53	918.90	7.22	9.62	0.92	GI	SCH40	2.0"	
13 - 14	23.00	260.10	906.47	29.64	2.61	*2.00*	0.207	0.87	918.03	11.56	14.83	0.92	GI	SCH40	2.0"	
14 - 15	30.60	290.70	900.90	29.64	2.61	*2.00*	0.207	1.15	916.88	15.99	20.41	0.92	GI	SCH40	2.0"	
15 - 16	30.60	321.30	895.41	29.64	2.61	*2.00*	0.207	1.15	915.73	20.32	25.89	0.92	GI	SCH40	2.0"	
16 - 17	30.60	351.90	896.16	29.64	2.61	*2.00*	0.207	1.15	914.58	18.41	25.14	0.92	GI	SCH40	2.0"	
17 - 18	30.60	382.50	896.92	29.64	2.61	*2.00*	0.207	1.15	913.43	16.51	24.38	0.92	GI	SCH40	2.0"	
18 - 19	30.60	413.10	894.34	29.64	2.61	*2.00*	0.207	1.15	912.27	17.93	26.96	0.92	GI	SCH40	2.0"	
19 - 20	30.60	443.70	894.70	29.64	2.61	*2.00*	0.207	1.15	911.12	16.42	26.60	0.92	GI	SCH40	2.0"	
20 - 21	30.60	474.30	890.22	29.64	2.61	*2.00*	0.207	1.15	909.97	19.75	31.08	0.92	GI	SCH40	2.0"	
21 - 22	30.60	504.90	884.29	29.64	2.61	*2.00*	0.207	1.15	908.82	24.52	37.01	0.92	GI	SCH40	2.0"	
22 - 23	30.60	535.50	878.45	29.64	2.61	*1.50*	0.207	3.30	905.51	27.06	42.85	1.64	GI	SCH40	1.5"	
23 - 24	30.60	566.10	870.45	29.64	2.61	*1.50*	0.207	3.30	902.21	31.76	50.85	1.64	GI	SCH40	1.5"	
24 - 25	30.60	596.70	864.44	29.64	2.61	*1.50*	0.207	3.30	898.91	34.47	56.87	1.64	GI	SCH40	1.5"	
25 - 26	30.60	627.30	858.38	29.64	2.61	*1.50*	0.207	3.30	895.60	37.22	62.92	1.64	GI	SCH40	1.5"	***Break Pressure Tank 2***
26 - 27	30.60	657.90	854.03	29.64	2.61	*1.50*	0.111	1.77	856.61	2.58	4.35	1.64	PVC	SDR26	1.5"	
27 - 28	30.60	688.50	850.08	29.64	2.61	*1.50*	0.111	1.77	854.84	4.75	8.30	1.64	PVC	SDR26	1.5"	
28 - 29	30.60	719.10	844.59	29.64	2.61	*1.50*	0.111	1.77	853.06	8.47	13.79	1.64	PVC	SDR26	1.5"	
29 - 30	30.60	749.70	839.76	29.64	2.61	*1.50*	0.111	1.77	851.29	11.53	18.62	1.64	PVC	SDR26	1.5"	
30 - 31	30.60	780.30	834.32	29.64	2.61	*1.50*	0.111	1.77	849.52	15.20	24.06	1.64	PVC	SDR26	1.5"	
31 - 32	30.60	810.90	829.79	29.64	2.61	*1.50*	0.111	1.77	847.75	17.96	28.58	1.64	PVC	SDR26	1.5"	
32 - 33	30.60	841.50	825.89	29.64	2.61	*1.50*	0.111	1.77	845.98	20.09	32.49	1.64	PVC	SDR26	1.5"	
33 - 34	30.60	872.10	822.25	29.64	2.61	*1.50*	0.111	1.77	844.21	21.96	36.13	1.64	PVC	SDR26	1.5"	
34 - 35	30.60	902.70	815.62	29.64	2.61	*1.50*	0.111	1.77	842.43	26.81	42.75	1.64	PVC	SDR26	1.5"	
35 - 36	30.60	933.30	807.96	29.64	2.61	*1.50*	0.111	1.77	840.66	32.70	50.42	1.64	PVC	SDR26	1.5"	
36 - 37	28.50	961.80	801.79	29.64	2.61	*1.50*	0.111	1.65	839.01	37.22	56.58	1.64	PVC	SDR26	1.5"	
37 - 38	20.40	982.20	797.76	29.64	2.61	*1.50*	0.111	1.18	837.83	40.08	60.62	1.64	PVC	SDR26	1.5"	
38 - 39	27.00	1,009.20	789.79	29.64	2.61	*1.50*	0.111	1.56	836.27	46.48	68.59	1.64	PVC	SDR26	1.5"	
39 - 40	19.40	1,028.60	784.11	29.64	2.61	*1.50*	0.111	1.12	835.15	51.03	74.26	1.64	PVC	SDR26	1.5"	
40 - 41	29.40	1,058.00	775.81	29.64	2.61	*1.50*	0.111	1.70	833.44	57.64	82.57	1.64	PVC	SDR26	1.5"	
41 - 42	21.50	1,079.50	770.15	29.64	2.61	*1.50*	0.111	1.24	832.20	62.05	88.23	1.64	PVC	SDR26	1.5"	
42 - 43	26.30	1,105.80	768.32	29.64	2.61	*1.50*	0.111	1.52	830.68	62.36	90.06	1.64	PVC	SDR26	1.5"	
43 - 44	12.50	1,118.30	768.52	29.64	2.61	*1.50*	0.111	0.72	829.95	61.44	89.86	1.64	PVC	SDR26	1.5"	
44 - 45	15.70	1,134.00	768.79	29.64	2.61	*1.50*	0.111	0.91	829.04	60.25	89.59	1.64	PVC	SDR26	1.5"	
45 - 46	18.30	1,152.30	767.91	29.64	2.61	*1.50*	0.111	1.06	827.98	60.07	90.47	1.64	PVC	SDR26	1.5"	
46 - 47	17.00	1,169.30	767.32	29.64	2.61	*1.50*	0.111	0.98	827.00	59.68	91.06	1.64	PVC	SDR26	1.5"	
47 - 48	16.40	1,185.70	766.36	29.64	2.61	*1.00*	0.111	7.71	819.29	52.93	92.01	3.68	PVC	SDR26	1.0"	
48 - 49	25.00	1,210.70	764.44	29.64	2.61	*1.00*	0.111	11.75	807.54	43.10	93.94	3.68	PVC	SDR26	1.0"	***Break Pressure Tank 3***
49 - 50	21.50	1,232.20	760.52	29.64	2.61	*1.50*	0.111	1.24	763.20	2.67	3.92	1.64	PVC	SDR26	1.5"	
50 - 51	20.50	1,252.70	755.19	29.64	2.61	*1.50*	0.111	1.19	762.01	6.82	9.25	1.64	PVC	SDR26	1.5"	
51 - 52	30.60	1,283.30	744.97	29.64	2.61	*1.50*	0.111	1.77	760.24	15.26	19.47	1.64	PVC	SDR26	1.5"	
52 - 53	24.00	1,307.30	735.79	29.64	2.61	*1.50*	0.111	1.39	758.85	23.06	28.65	1.64	PVC	SDR26	1.5"	
53 - 54	2.50	1,309.80	734.98	29.64	2.61	*1.50*	0.111	0.14	758.70	23.72	29.46	1.64	PVC	SDR26	1.5"	
54 - 55	36.00	1,345.80	720.96	29.64	2.61	*1.50*	0.207	3.89	754.82	33.85	43.48	1.64	GI	SCH40	1.5"	
55 - 56	29.00	1,374.80	714.23	29.64	2.61	*1.50*	0.111	1.68	753.14	38.90	50.21	1.64	PVC	SDR26	1.5"	
56 - 57	30.60	1,405.40	709.45	29.64	2.61	*1.50*	0.111	1.77	751.37	41.92	54.99	1.64	PVC	SDR26	1.5"	
57 - 58	30.60	1,436.00	709.31	29.64	2.61	*1.50*	0.111	1.77	749.59	40.28	55.13	1.64	PVC	SDR26	1.5"	
58 - 59	30.60	1,466.60	711.58	29.64	2.61	*1.50*	0.111	1.77	747.82	36.24	52.86	1.64	PVC	SDR26	1.5"	
59 - 60	30.60	1,497.20	710.38	29.64	2.61	*1.50*	0.111	1.77	746.05	35.67	54.06	1.64	PVC	SDR26	1.5"	
60 - 61	30.60	1,527.80	707.45	29.64	2.61	*1.50*	0.111	1.77	744.28	36.83	56.99	1.64	PVC	SDR26	1.5"	
61 - 62	30.60	1,558.40	703.81	29.64	2.61	*1.50*	0.111	1.77	742.51	38.70	60.63	1.64	PVC	SDR26	1.5"	
62 - 63	30.60	1,589.00	697.27	29.64	2.61	*1.50*	0.111	1.77	740.74	43.47	67.17	1.64	PVC	SDR26	1.5"	
63 - 64	30.60	1,619.60	691.83	29.64	2.61	*1.50*	0.111	1.77	738.96	47.14	72.61	1.64	PVC	SDR26	1.5"	
64 - 65	30.60	1,650.20	687.57	29.64	2.61	*1.50*	0.111	1.77	737.19	49.63	76.87	1.64	PVC	SDR26	1.5"	
65 - 66	30.60	1,680.80	685.39	29.64	2.61	*1.50*	0.111	1.77	735.42	50.03	79.05	1.64	PVC	SDR26	1.5"	
66 - 67	30.60	1,711.40	683.12	29.64	2.61	*1.50*	0.111	1.77	733.65	50.53	81.32	1.64	PVC	SDR26	1.5"	
67 - 68	30.60	1,742.00	677.63	29.64	2.61	*1.50*	0.111	1.77	731.88	54.25	86.81	1.64	PVC	SDR26	1.5"	
68 - 69	21.00	1,763.00	674.20	29.64	2.61	*1.50*	0.111	1.22	730.66	56.47	90.24	1.64	PVC	SDR26	1.5"	

HYDRAULIC DESIGN - CONDUCTION LINE

La Colonia El Cielito, Santa Barbara, SANTA BARBARA

Engineer: **Eng. Nathan Reents** Date of Design: **August of 2002**

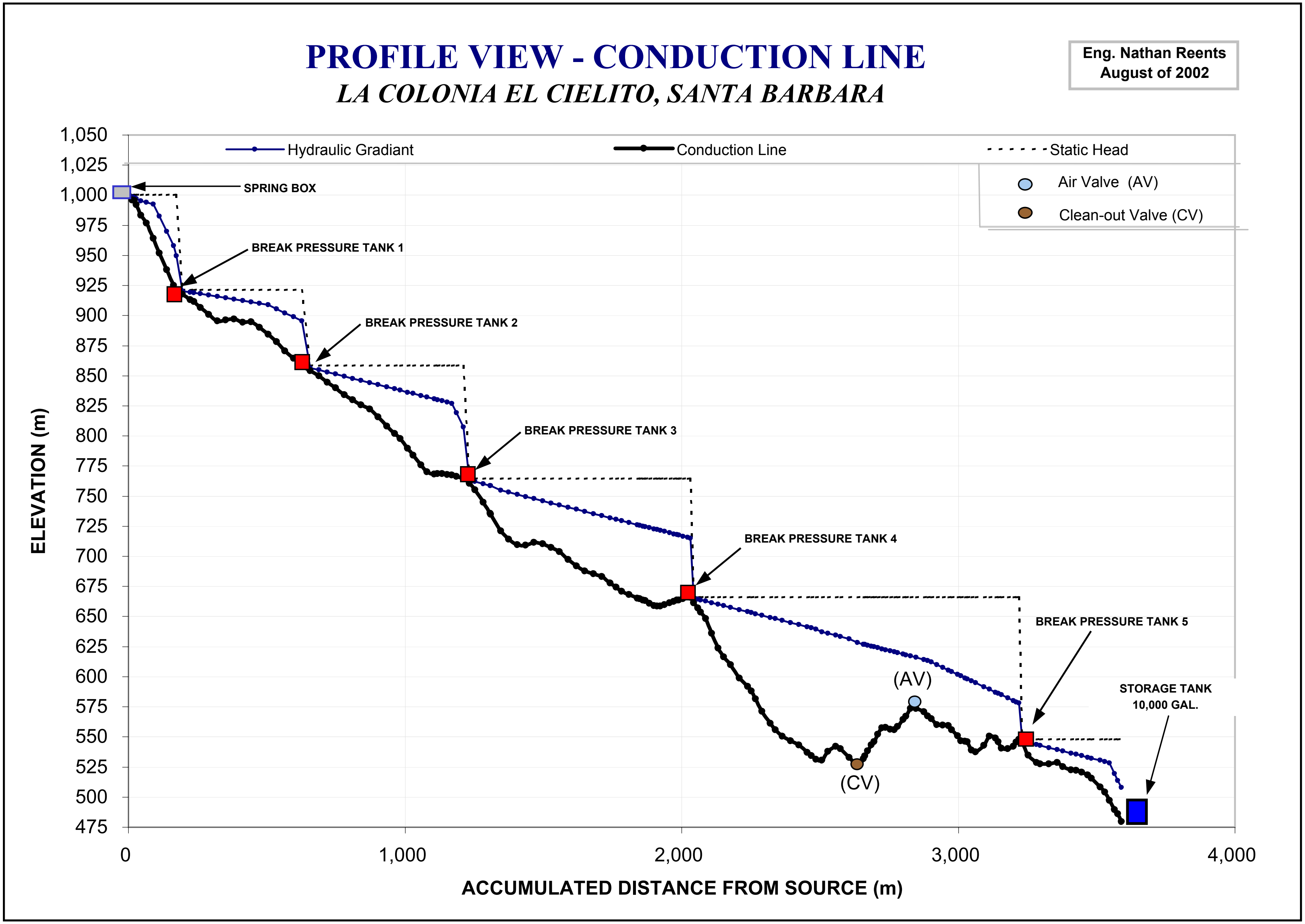
Section Sta - Sta	Incli. Dist. (m)	Accum. Dist. (m)	Terren. Elev. (m)	Flow MDC (gpm)	Diam. Rec. (in)	*Diam. Prop. (in)*	Coeffic. of Friction	Frict. Losses (m/sect.)	Piezo. Elev. (m)	Dynamic Head (m)	Static Head (m)	Vel. (m/s)	Type of Piping			*Notes*
69 - 70	20.00	1,783.00	671.07	29.64	2.61	*1.50*	0.111	1.16	729.50	58.44	93.37	1.64	PVC	SDR26	1.5"	
70 - 71	27.00	1,810.00	668.24	29.64	2.61	*1.50*	0.111	1.56	727.94	59.70	96.20	1.64	PVC	SDR26	1.5"	
71 - 72	29.20	1,839.20	665.23	29.64	2.61	*1.50*	0.111	1.69	726.25	61.02	99.21	1.64	PVC	SDR26	1.5"	
72 - 73	8.50	1,847.70	664.90	29.64	2.61	*1.50*	0.111	0.49	725.76	60.86	99.54	1.64	PVC	SDR26	1.5"	
73 - 74	12.70	1,860.40	663.48	29.64	2.61	*1.50*	0.111	0.74	725.02	61.54	100.96	1.64	PVC	SDR26	1.5"	
74 - 75	8.20	1,868.60	663.19	29.64	2.61	*1.50*	0.111	0.47	724.55	61.35	101.24	1.64	PVC	SDR26	1.5"	
75 - 76	13.90	1,882.50	660.76	29.64	2.61	*1.50*	0.111	0.80	723.74	62.98	103.68	1.64	PVC	SDR26	1.5"	
76 - 77	17.50	1,900.00	659.11	29.64	2.61	*1.50*	0.111	1.01	722.73	63.62	105.33	1.64	PVC	SDR26	1.5"	
77 - 78	11.10	1,911.10	658.46	29.64	2.61	*1.50*	0.111	0.64	722.09	63.62	105.98	1.64	PVC	SDR26	1.5"	
78 - 79	12.70	1,923.80	658.80	29.64	2.61	*1.50*	0.111	0.74	721.35	62.56	105.64	1.64	PVC	SDR26	1.5"	
79 - 80	14.00	1,937.80	659.61	29.64	2.61	*1.50*	0.111	0.81	720.54	60.93	104.83	1.64	PVC	SDR26	1.5"	
80 - 81	18.60	1,956.40	661.37	29.64	2.61	*1.50*	0.111	1.08	719.47	58.10	103.07	1.64	PVC	SDR26	1.5"	
81 - 82	16.00	1,972.40	662.60	29.64	2.61	*1.50*	0.111	0.93	718.54	55.94	101.84	1.64	PVC	SDR26	1.5"	
82 - 83	11.50	1,983.90	663.65	29.64	2.61	*1.50*	0.111	0.67	717.87	54.22	100.79	1.64	PVC	SDR26	1.5"	
83 - 84	6.00	1,989.90	663.78	29.64	2.61	*1.50*	0.111	0.35	717.53	53.74	100.66	1.64	PVC	SDR26	1.5"	
84 - 85	14.70	2,004.60	664.91	29.64	2.61	*1.50*	0.111	0.85	716.68	51.76	99.53	1.64	PVC	SDR26	1.5"	
85 - 86	16.40	2,021.00	666.41	29.64	2.61	*1.50*	0.111	0.95	715.73	49.31	98.03	1.64	PVC	SDR26	1.5"	
86 - 87	10.00	2,031.00	665.88	29.64	2.61	*1.50*	0.111	0.58	715.15	49.27	98.56	1.64	PVC	SDR26	1.5"	***Break Pressure Tank 4***
87 - 88	13.00	2,044.00	661.39	29.64	2.61	*1.50*	0.111	0.75	665.12	3.73	4.48	1.64	PVC	SDR26	1.5"	
88 - 89	15.00	2,059.00	656.93	29.64	2.61	*1.50*	0.111	0.87	664.26	7.33	8.95	1.64	PVC	SDR26	1.5"	
89 - 90	10.00	2,069.00	653.51	29.64	2.61	*1.50*	0.111	0.58	663.68	10.17	12.37	1.64	PVC	SDR26	1.5"	
90 - 91	17.00	2,086.00	648.25	29.64	2.61	*1.50*	0.111	0.98	662.69	14.44	17.62	1.64	PVC	SDR26	1.5"	
91 - 92	22.00	2,108.00	636.16	29.64	2.61	*1.50*	0.111	1.27	661.42	25.26	29.71	1.64	PVC	SDR26	1.5"	
92 - 93	23.30	2,131.30	623.79	29.64	2.61	*1.50*	0.111	1.35	660.07	36.28	42.09	1.64	PVC	SDR26	1.5"	
93 - 94	21.00	2,152.30	616.60	29.64	2.61	*1.50*	0.111	1.22	658.85	42.25	49.27	1.64	PVC	SDR26	1.5"	
94 - 95	25.00	2,177.30	609.75	29.64	2.61	*1.50*	0.111	1.45	657.41	47.66	56.13	1.64	PVC	SDR26	1.5"	
95 - 96	30.60	2,207.90	598.70	29.64	2.61	*1.50*	0.111	1.77	655.63	56.94	67.18	1.64	PVC	SDR26	1.5"	
96 - 97	30.60	2,238.50	592.03	29.64	2.61	*1.50*	0.111	1.77	653.86	61.83	73.84	1.64	PVC	SDR26	1.5"	
97 - 98	13.00	2,251.50	588.02	29.64	2.61	*1.50*	0.111	0.75	653.11	65.09	77.86	1.64	PVC	SDR26	1.5"	
98 - 99	15.60	2,267.10	581.65	29.64	2.61	*1.50*	0.111	0.90	652.21	70.56	84.23	1.64	PVC	SDR26	1.5"	
99 - 100	22.40	2,289.50	571.31	29.64	2.61	*1.50*	0.111	1.30	650.91	79.60	94.57	1.64	PVC	SDR26	1.5"	
100 - 101	30.60	2,320.10	561.18	29.64	2.61	*1.50*	0.111	1.77	649.14	87.96	104.70	1.64	PVC	SDR26	1.5"	
101 - 102	18.00	2,338.10	555.86	29.64	2.61	*1.50*	0.111	1.04	648.10	92.23	110.01	1.64	PVC	SDR21	1.5"	
102 - 103	25.00	2,363.10	550.52	29.64	2.61	*1.50*	0.111	1.45	646.65	96.13	115.35	1.64	PVC	SDR21	1.5"	
103 - 104	30.60	2,393.70	546.66	29.64	2.61	*1.50*	0.111	1.77	644.88	98.22	119.21	1.64	PVC	SDR21	1.5"	
104 - 105	30.60	2,424.30	543.29	29.64	2.61	*1.50*	0.111	1.77	643.11	99.82	122.59	1.64	PVC	SDR21	1.5"	
105 - 106	29.00	2,453.30	537.05	29.64	2.61	*1.50*	0.111	1.68	641.43	104.38	128.83	1.64	PVC	SDR21	1.5"	
106 - 107	14.60	2,467.90	534.37	29.64	2.61	*1.50*	0.111	0.85	640.58	106.21	131.51	1.64	PVC	SDR21	1.5"	
107 - 108	17.00	2,484.90	531.30	29.64	2.61	*1.50*	0.111	0.98	639.60	108.30	134.58	1.64	PVC	SDR21	1.5"	
108 - 109	21.50	2,506.40	530.55	29.64	2.61	*1.50*	0.207	2.32	637.28	106.73	135.33	1.64	GI	SCH40	1.5"	
109 - 110	22.00	2,528.40	537.80	29.64	2.61	*1.50*	0.111	1.27	636.00	98.21	128.08	1.64	PVC	SDR21	1.5"	
110 - 111	29.00	2,557.40	542.04	29.64	2.61	*1.50*	0.111	1.68	634.32	92.28	123.83	1.64	PVC	SDR21	1.5"	
111 - 112	17.00	2,574.40	540.00	29.64	2.61	*1.50*	0.111	0.98	633.34	93.34	125.88	1.64	PVC	SDR21	1.5"	
112 - 113	30.60	2,605.00	532.85	29.64	2.61	*1.50*	0.111	1.77	631.57	98.72	133.02	1.64	PVC	SDR21	1.5"	
113 - 114	30.60	2,635.60	525.80	29.64	2.61	*1.50*	0.207	3.30	628.27	102.47	140.08	1.64	GI	SCH40	1.5"	**Clean-out Valve**
114 - 115	22.20	2,657.80	531.67	29.64	2.61	*1.50*	0.111	1.29	626.98	95.31	134.21	1.64	PVC	SDR21	1.5"	
115 - 116	4.50	2,662.30	533.88	29.64	2.61	*1.50*	0.111	0.26	626.72	92.84	132.00	1.64	PVC	SDR21	1.5"	
116 - 117	10.70	2,673.00	538.40	29.64	2.61	*1.50*	0.111	0.62	626.10	87.70	127.48	1.64	PVC	SDR21	1.5"	
117 - 118	12.50	2,685.50	543.18	29.64	2.61	*1.50*	0.111	0.72	625.38	82.19	122.69	1.64	PVC	SDR21	1.5"	
118 - 119	10.00	2,695.50	545.77	29.64	2.61	*1.50*	0.111	0.58	624.80	79.03	120.11	1.64	PVC	SDR21	1.5"	
119 - 120	13.00	2,708.50	552.22	29.64	2.61	*1.50*	0.111	0.75	624.04	71.82	113.66	1.64	PVC	SDR21	1.5"	
120 - 121	16.00	2,724.50	557.23	29.64	2.61	*1.50*	0.111	0.93	623.12	65.89	108.64	1.64	PVC	SDR26	1.5"	
121 - 122	13.00	2,737.50	557.70	29.64	2.61	*1.50*	0.111	0.75	622.37	64.66	108.17	1.64	PVC	SDR26	1.5"	
122 - 123	17.00	2,754.50	556.35	29.64	2.61	*1.50*	0.111	0.98	621.38	65.04	109.53	1.64	PVC	SDR26	1.5"	
123 - 124	15.00	2,769.50	555.71	29.64	2.61	*1.50*	0.111	0.87	620.51	64.80	110.16	1.64	PVC	SDR26	1.5"	
124 - 125	11.00	2,780.50	558.53	29.64	2.61	*1.50*	0.111	0.64	619.88	61.35	107.35	1.64	PVC	SDR26	1.5"	
125 - 126	21.00	2,801.50	564.35	29.64	2.61	*1.50*	0.111	1.22	618.66	54.31	101.53	1.64	PVC	SDR26	1.5"	
126 - 127	9.00	2,810.50	566.89	29.64	2.61	*1.50*	0.111	0.52	618.14	51.25	98.99	1.64	PVC	SDR26	1.5"	
127 - 128	17.00	2,827.50	573.60	29.64	2.61	*1.50*	0.111	0.98	617.16	43.55	92.28	1.64	PVC	SDR26	1.5"	
128 - 129	20.00	2,847.50	573.66	29.64	2.61	*1.50*	0.111	1.16	616.00	42.34	92.22	1.64	PVC	SDR26	1.5"	**Air Valve**
129 - 130	28.70	2,876.20	570.70	29.64	2.61	*1.50*	0.111	1.66	614.34	43.64	95.18	1.64	PVC	SDR26	1.5"	
130 - 131	13.40	2,889.60	567.36	29.64	2.61	*1.50*	0.111	0.78	613.56	46.20	98.51	1.64	PVC	SDR26	1.5"	
131 - 132	12.00	2,901.60	564.96	29.64	2.61	*1.50*	0.207	1.30	612.26	47.31	100.92	1.64	GI	SCH40	1.5"	
132 - 133	20.50	2,922.10	560.20	29.64	2.61	*1.50*	0.207	2.21	610.05	49.85	105.68	1.64	GI	SCH40	1.5"	
133 - 134	21.40	2,943.50	559.76	29.64	2.61	*1.50*	0.207	2.31	607.74	47.98	106.11	1.64	GI	SCH40	1.5"	
134 - 135	21.30	2,964.80	559.21	29.64	2.61	*1.50*	0.207	2.30	605.44	46.24	106.67	1.64	GI	SCH40	1.5"	
135 - 136	11.00	2,975.80	555.91	29.64	2.61	*1.50*	0.207	1.19	604.25	48.34	109.96	1.64	GI	SCH40	1.5"	
136 - 137	22.00	2,997.80	551.03	29.64	2.61	*1.50*	0.207	2.38	601.88	50.85	114.85	1.64	GI	SCH40	1.5"	
137 - 138	12.00	3,009.80	546.77	29.64	2.61	*1.50*	0.207	1.30	600.58	53.81	119.10	1.64	GI	SCH40	1.5"	
138 - 139	15.00	3,024.80	546.16	29.64	2.61	*1.50*	0.207	1.62	598.96	52.80	119.71	1.64	GI	SCH40	1.5"	

HYDRAULIC DESIGN - CONDUCTION LINE

La Colonia El Cielito, Santa Barbara, SANTA BARBARA

Engineer: **Eng. Nathan Reents** Date of Design: **August of 2002**

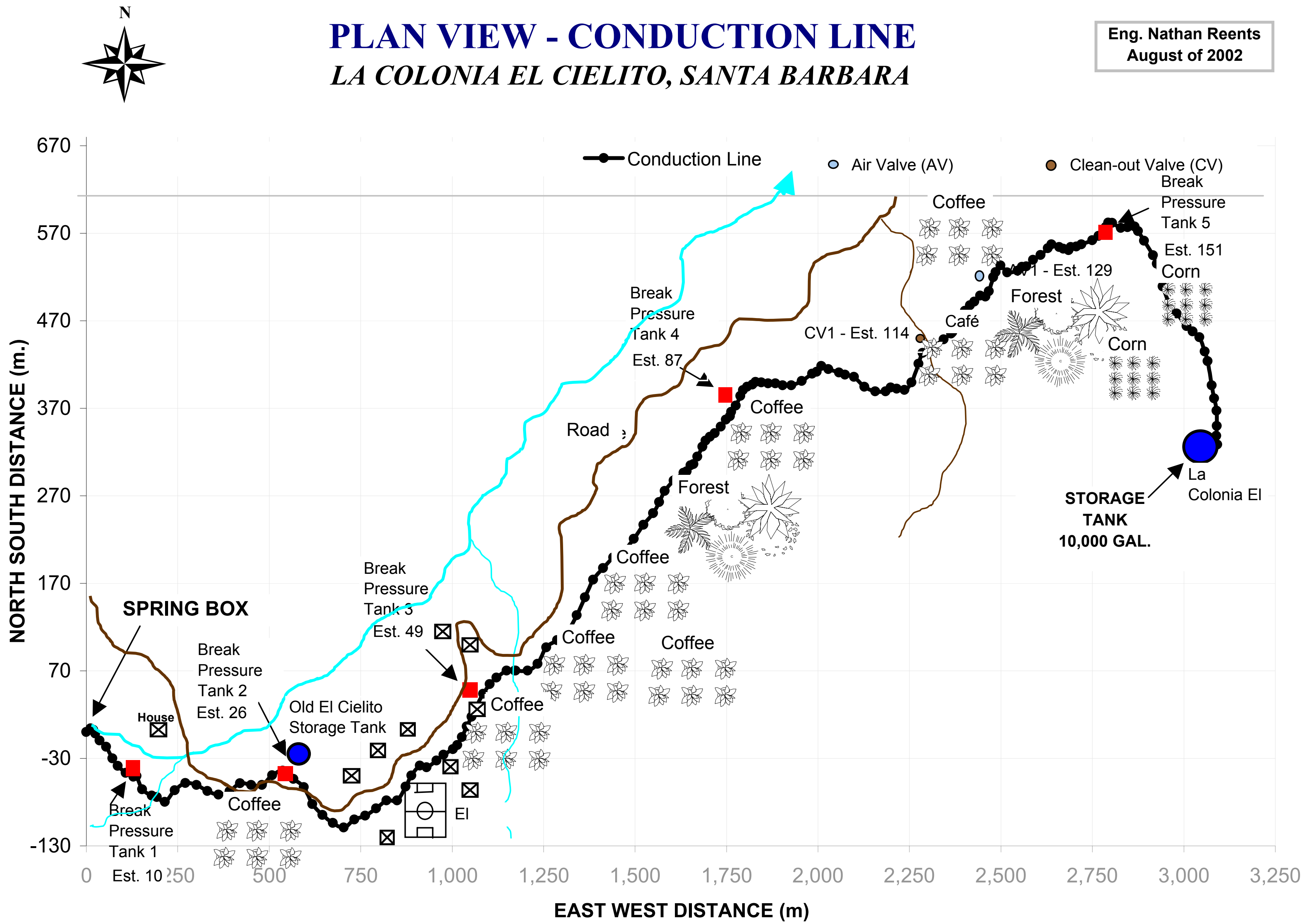
Section Sta -	Sta	Incli. Dist. (m)	Accum. Dist. (m)	Terren. Elev. (m)	Flow MDC (gpm)	Diam. Rec. (in)	*Diam. Prop. (in)*	Coeffic. of Friction	Frict. Losses (m/sect.)	Piezo. Elev. (m)	Dynamic Head (m)	Static Head (m)	Vel. (m/s)	Type of Piping			*Notes*
139 -	140	7.00	3,031.80	545.90	29.64	2.61	*1.50*	0.207	0.76	598.21	52.31	119.98	1.64	GI	SCH40	1.5"	
140 -	141	16.30	3,048.10	539.14	29.64	2.61	*1.50*	0.207	1.76	596.45	57.31	126.74	1.64	GI	SCH40	1.5"	
141 -	142	14.50	3,062.60	537.33	29.64	2.61	*1.50*	0.207	1.57	594.88	57.55	128.55	1.64	GI	SCH40	1.5"	
142 -	143	30.60	3,093.20	542.86	29.64	2.61	*1.50*	0.207	3.30	591.58	48.72	123.01	1.64	GI	SCH40	1.5"	
143 -	144	19.50	3,112.70	550.56	29.64	2.61	*1.50*	0.207	2.11	589.47	38.91	115.32	1.64	GI	SCH40	1.5"	
144 -	145	22.00	3,134.70	548.87	29.64	2.61	*1.50*	0.207	2.38	587.10	38.23	117.01	1.64	GI	SCH40	1.5"	
145 -	146	9.00	3,143.70	545.78	29.64	2.61	*1.50*	0.207	0.97	586.13	40.35	120.10	1.64	GI	SCH40	1.5"	
146 -	147	12.00	3,155.70	540.72	29.64	2.61	*1.50*	0.207	1.30	584.83	44.11	125.16	1.64	GI	SCH40	1.5"	
147 -	148	24.00	3,179.70	540.06	29.64	2.61	*1.50*	0.207	2.59	582.24	42.18	125.82	1.64	GI	SCH40	1.5"	
148 -	149	19.00	3,198.70	542.04	29.64	2.61	*1.50*	0.207	2.05	580.19	38.14	123.83	1.64	GI	SCH40	1.5"	
149 -	150	10.50	3,209.20	545.66	29.64	2.61	*1.50*	0.207	1.13	579.06	33.39	120.21	1.64	GI	SCH40	1.5"	
150 -	151	10.00	3,219.20	547.91	29.64	2.61	*1.50*	0.207	1.08	577.98	30.06	117.96	1.64	GI	SCH40	1.5"	**Break Pressure Tank 5**
151 -	152	11.00	3,230.20	544.99	29.64	2.61	*1.50*	0.207	1.19	546.73	1.74	2.92	1.64	GI	SCH40	1.5"	
152 -	153	22.00	3,252.20	534.63	29.64	2.61	*1.50*	0.111	1.27	545.45	10.82	13.28	1.64	PVC	SDR26	1.5"	
153 -	154	30.60	3,282.80	528.58	29.64	2.61	*1.50*	0.111	1.77	543.68	15.11	19.34	1.64	PVC	SDR26	1.5"	
154 -	155	14.00	3,296.80	527.58	29.64	2.61	*1.50*	0.111	0.81	542.87	15.29	20.33	1.64	PVC	SDR26	1.5"	
155 -	156	30.60	3,327.40	527.49	29.64	2.61	*1.50*	0.111	1.77	541.10	13.61	20.42	1.64	PVC	SDR26	1.5"	
156 -	157	30.60	3,358.00	528.74	29.64	2.61	*1.50*	0.111	1.77	539.33	10.59	19.18	1.64	PVC	SDR26	1.5"	
157 -	158	19.50	3,377.50	525.27	29.64	2.61	*1.50*	0.111	1.13	538.20	12.93	22.65	1.64	PVC	SDR26	1.5"	
158 -	159	30.60	3,408.10	522.51	29.64	2.61	*1.50*	0.111	1.77	536.43	13.92	25.40	1.64	PVC	SDR26	1.5"	
159 -	160	18.00	3,426.10	522.33	29.64	2.61	*1.50*	0.111	1.04	535.38	13.06	25.59	1.64	PVC	SDR26	1.5"	
160 -	161	19.40	3,445.50	520.47	29.64	2.61	*1.50*	0.111	1.12	534.26	13.79	27.45	1.64	PVC	SDR26	1.5"	
161 -	162	22.00	3,467.50	518.17	29.64	2.61	*1.50*	0.111	1.27	532.99	14.82	29.75	1.64	PVC	SDR26	1.5"	
162 -	163	14.00	3,481.50	515.82	29.64	2.61	*1.50*	0.111	0.81	532.18	16.36	32.10	1.64	PVC	SDR26	1.5"	
163 -	164	30.60	3,512.10	508.37	29.64	2.61	*1.50*	0.111	1.77	530.41	22.03	39.54	1.64	PVC	SDR26	1.5"	
164 -	165	17.00	3,529.10	504.21	29.64	2.61	*1.50*	0.111	0.98	529.42	25.21	43.70	1.64	PVC	SDR26	1.5"	
165 -	166	17.00	3,546.10	497.25	29.64	2.61	*1.50*	0.111	0.98	528.44	31.19	50.66	1.64	PVC	SDR26	1.5"	
166 -	167	19.00	3,565.10	489.42	29.64	2.61	*1.00*	0.111	8.93	519.51	30.08	58.49	3.68	PVC	SDR26	1.0"	
167 -	168	12.00	3,577.10	486.03	29.64	2.61	*1.00*	0.111	5.64	513.86	27.83	61.88	3.68	PVC	SDR26	1.0"	
168 -	169	12.20	3,589.30	479.64	29.64	2.61	*1.00*	0.111	5.73	508.13	28.49	68.27	3.68	PVC	SDR26	1.0"	**Tank**


PROFILE VIEW - CONDUCTION LINE
LA COLONIA EL CIELITO, SANTA BARBARA
Eng. Nathan Reents
August of 2002
Hydraulic Gradiant
Conduction Line
Static Head
Air Valve (AV)
Clean-out Valve (CV)
SPRING BOX
BREAK PRESSURE TANK 1
BREAK PRESSURE TANK 2
BREAK PRESSURE TANK 3
BREAK PRESSURE TANK 4
BREAK PRESSURE TANK 5
STORAGE TANK
10,000 GAL.
(AV)
(CV)
ELEVATION (m)
1,050
1,025
1,000
975
950
925
900
875
850
825
800
775
750
725
700
675
650
625
600
575
550
525
500
475
0
1,000
2,000
3,000
4,000
ACCUMULATED DISTANCE FROM SOURCE (m)

PLAN VIEW - CONDUCTION LINE

LA COLONIA EL CIELITO, SANTA BARBARA

Eng. Nathan Reents
August of 2002



TOPOGRAPHIC DATA - DISTRIBUTION NETWORK

TOPOGRAPHIC DATA - DISTRIBUTION NETWORK

La Colonia El Cielito, Santa Barbara, SANTA BARBARA

Technician: **Tech. Gifford Laube** Date of Topographic Study: **August of 2002**

Section Sta. -	Sta.	Inclined Distance (m.)	Vert. Ang. Forward (deg. min.)	Vert. Ang. Back (deg. min.)	Compass (deg.)	Type of Tubing	Houses per Section	Notes	Accum. Dist. (m)	Ave. Ang. (degrees)	Terrain Elev. (m)	Direction Ang.			Projec. E - W (m)	Projec. N -S (m)
169 -	0							*Tank*	0.00		479.64	N	770°	W	0.00	0.00
0 -	1	30.00	-34°20'	35°10'	94°	PVC	0		30.00	-35.08	462.40	S	86°	E	24.49	-1.71
1 -	2	30.00	-31°20'	32°20'	94°	PVC	0		60.00	-32.17	446.43	S	86°	E	49.82	-3.48
2 -	3	28.00	-20°30'	21°30'	98°	PVC	0		88.00	-21.33	436.24	S	82°	E	75.65	-7.11
3 -	4	9.00	-11°00'	12°50'	100°	GI	0		97.00	-12.25	434.33	S	80°	E	84.31	-8.64
4 -	5	21.00	-3°20'	4°00'	98°	PVC	2		118.00	-4.00	432.87	S	82°	E	105.06	-11.56
5 -	6	30.00	-5°00'	6°00'	98°	PVC	2		148.00	-5.83	429.82	S	82°	E	134.61	-15.71
6 -	7	12.00	-1°30'	2°30'	98°	PVC	2		160.00	-2.33	429.33	S	82°	E	146.48	-17.38
7 -	8	30.00	11°20'	-10°50'	104°	PVC	4		190.00	11.42	435.27	S	76°	E	175.02	-24.49
8 -	9	8.00	26°30'	-25°20'	104°	PVC	2		198.00	26.25	438.80	S	76°	E	181.98	-26.23
7 -	1c	17.00	10°20'	-9°50'	178°	PVC	0		177.00	10.42	432.40	S	2°	E	147.07	-34.09
1c	2c	30.00	10°50'	-10°10'	137°	PVC	2		207.00	10.50	437.87	S	43°	E	167.19	-55.66
2c	3c	30.00	12°50'	-11°50'	151°	PVC	2		237.00	12.00	444.11	S	29°	E	181.41	-81.33
7 -	1b	30.60	-6°10'	7°00'	10°	PVC	0		190.60	-6.92	425.64	N	10°	E	151.76	12.54
1b	2b	30.00	-7°30'	8°30'	10°	PVC	0		220.60	-8.33	421.29	N	10°	E	156.91	41.77
2b	3b	3.30	-6°00'	7°00'	10°	PVC	0		223.90	-6.83	420.90	N	10°	E	157.48	45.00
3b	4b	30.60	-6°40'	7°20'	10°	PVC	0		254.50	-7.33	417.00	N	10°	E	162.75	74.88
4b	5b	2.30	-7°00'	8°30'	10°	PVC	0		256.80	-8.08	416.67	N	10°	E	163.15	77.13
5b	6b	30.70	-5°00'	5°50'	10°	PVC	0		287.50	-5.42	413.77	N	10°	E	168.46	107.23
6b	7b	30.70	-3°30'	5°00'	10°	PVC	0		318.20	-4.25	411.50	N	10°	E	173.77	137.38
7b	8b	2.70	0°50'	0°30'	93°	PVC	0		320.90	0.17	411.51	S	87°	E	176.47	137.23
8b	9b	30.60	-4°30'	5°30'	77°	PVC	0		351.50	-5.33	408.66	N	77°	E	206.15	144.09
9b	10b	30.60	-4°50'	5°40'	77°	PVC	0		382.10	-5.58	405.69	N	77°	E	235.83	150.94
10b	1d	30.60	2°30'	-2°00'	94°	PVC	1		412.70	2.25	406.89	S	86°	E	266.33	148.81
1d	2d	24.00	20°30'	-19°50'	92°	PVC	2		436.70	20.50	415.29	S	88°	E	288.80	148.02
9b	1e	30.60	7°50'	-7°00'	94°	PVC	1		382.10	7.42	412.61	S	86°	E	236.43	141.97
1e	2e	19.00	27°50'	-27°00'	98°	PVC	4		401.10	27.42	421.36	S	82°	E	253.13	139.62
8b	1f	30.60	15°00'	-14°10'	95°	PVC	1		351.50	14.92	419.38	S	85°	E	205.92	134.66
1f	2f	11.00	24°00'	-23°30'	95°	PVC	3		362.50	24.08	423.87	S	85°	E	215.93	133.78
3 -	1a	13.30	-7°10'	7°40'	38°	PVC	0		101.30	-7.42	434.52	N	38°	E	83.77	3.28
1a	2a	21.00	-7°40'	8°10'	10°	PVC	0		122.30	-8.25	431.51	N	10°	E	87.38	23.75
2a	3a	30.60	-6°30'	7°20'	14°	PVC	0		152.90	-7.25	427.65	N	14°	E	94.72	53.20
3a	4a	30.60	-6°00'	6°20'	14°	PVC	0		183.50	-6.17	424.36	N	14°	E	102.08	82.72
4a	5a	2.50	-7°30'	5°10'	14°	PVC	0		186.00	-6.33	424.08	N	14°	E	102.68	85.13
5a	6a	28.00	-2°30'	3°00'	20°	PVC	0		214.00	-3.08	422.58	N	20°	E	112.25	111.40
6a	7a	5.00	-9°20'	8°00'	0°	PVC	0		219.00	-9.00	421.80	N	0°	E	112.25	116.34
6b	3g	30.60	2°00'	-1°40'	98°	PVC	4		318.10	2.17	414.93	S	82°	E	198.74	102.97
3g	4g	27.00	26°20'	-25°50'	86°	PVC	2		345.10	26.42	426.94	N	86°	E	222.86	104.66
6b	2G	2.30	-1°00'	0°00'	286°	PVC	2		289.80	-0.83	413.74	N	74°	W	166.25	107.86
2G	1G	30.60	3°30'	-3°00'	280°	PVC	2		320.40	3.25	415.48	N	80°	W	136.16	113.16
1G	7a	30.60	9°50'	-9°10'	280°	PVC	4		351.00	9.50	420.53	N	80°	W	106.44	118.41
5b	1h	30.60	3°50'	-3°10'	98°	PVC	4		287.40	3.50	418.54	S	82°	E	193.39	72.88
1h	2h	14.00	23°00'	-23°10'	102°	PVC	2		301.40	23.08	424.03	S	78°	E	205.99	70.20
5b	3H	30.60	4°00'	-3°00'	280°	PVC	4		287.40	3.83	418.72	N	80°	W	133.08	82.43
3H	5a	30.90	8°00'	-7°20'	288°	PVC	4		318.30	8.00	423.02	N	72°	W	103.98	91.88
5a	4h	21.00	24°00'	-23°50'	284°	PVC	4		207.00	24.25	432.71	N	76°	W	84.11	89.76
3a	1i	20.00	20°50'	-20°00'	284°	PVC	4		172.90	20.42	434.62	N	76°	W	76.54	57.73
3a	2l	29.00	-9°00'	9°10'	100°	PVC	4		181.90	-9.08	423.07	S	80°	E	122.92	48.23
2l	3l	30.60	-1°50'	2°20'	100°	PVC	4		212.50	-2.42	421.78	S	80°	E	153.03	42.92
3l	3b	4.60	-4°20'	3°50'	100°	PVC	0		217.10	-4.42	421.42	S	80°	E	157.55	42.12
3b	4i	30.60	9°10'	-6°50'	104°	PVC	2		254.50	8.33	425.34	S	76°	E	186.86	37.67
4i	5i	11.00	29°00'	-28°00'	90°	PVC	2		265.50	28.83	430.64	N	90°	E	196.50	37.67
1b	1j	30.60	12°20'	-12°00'	88°	PVC	3		221.20	12.17	432.09	N	88°	E	181.65	13.58
1j	2j	8.00	25°30'	-25°10'	88°	PVC	2		229.20	25.33	435.51	N	88°	E	188.88	13.83
1b	3J	30.60	2°40'	-1°20'	280°	PVC	4		221.20	2.33	426.89	N	80°	W	121.65	17.85
3J	4J	30.60	6°30'	-5°50'	288°	PVC	4		251.80	6.50	430.35	N	72°	W	92.73	27.24
4J	2a	4.20	14°40'	-15°00'	288°	PVC	0		256.00	15.17	431.45	N	72°	W	88.88	28.49
2a	5j	28.00	21°00'	-20°50'	265°	PVC	4		150.30	21.25	441.66	S	85°	W	61.38	21.47

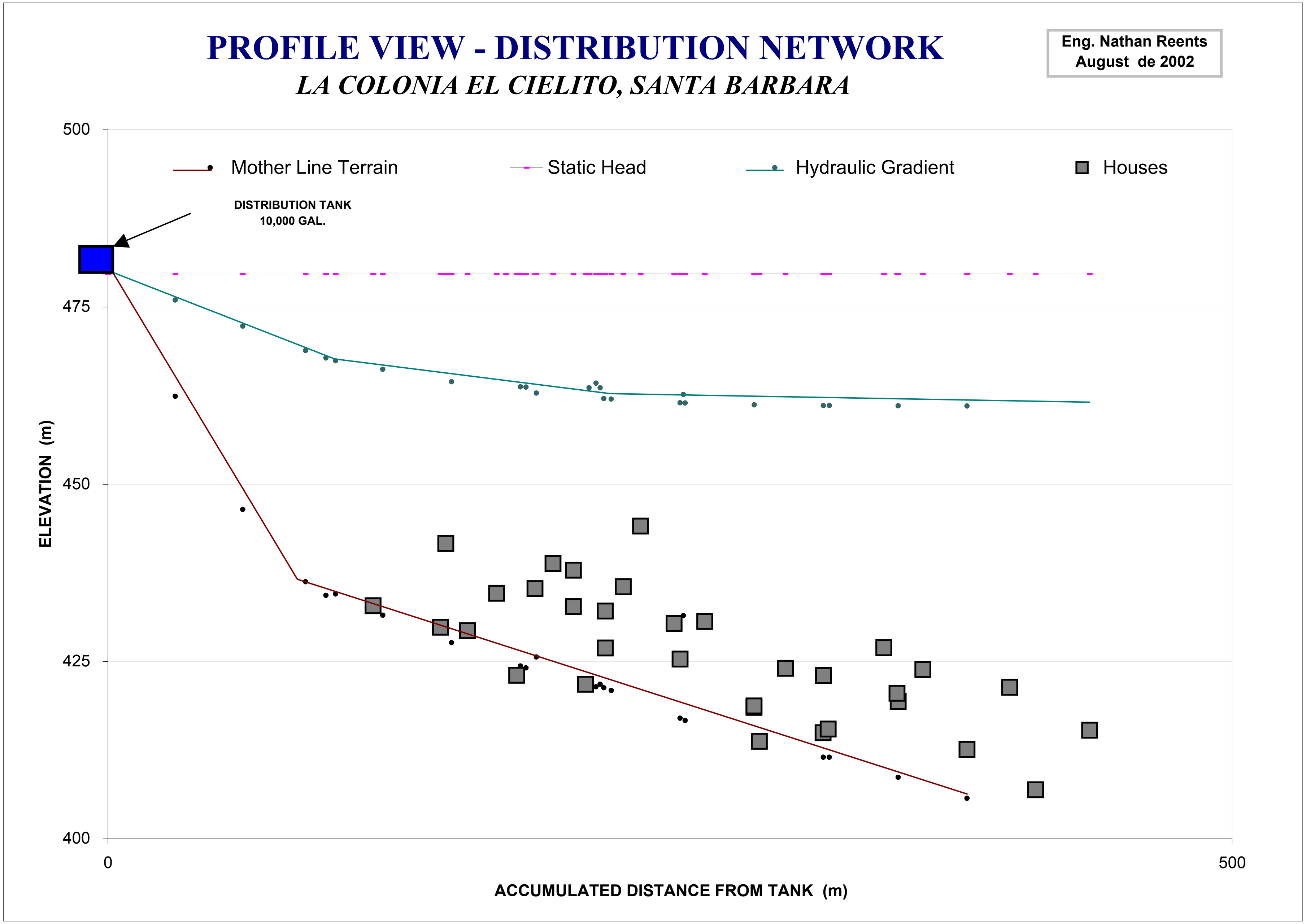
HYDRAULIC DESIGN - DISTRIBUTION NETWORK

HYDRAULIC DESIGN - DISTRIBUTION NETWORK

La Colonia El Cielito, Santa Barbara, SANTA BARBARA

Engineer: **Eng. Nathan Reents** Date of Design: **August of 2002**

Section Sta -	Sta	Incli. Dist. (m)	Acum. Dist. (m)	Terren. Elev. (m)	House per Sec.	Houses until end	Flow MHC (gpm)	Diam. Rec. (in)	Diam. Prop. (in)	Coeffic. of Friction	Frict. Losses (m/sect.)	Piezo. Elev. (m)	Dynamic Head (m)	Static Head (m)	Type of Piping			Notes
169 -	0		0.00	479.64								479.64						***Tanque***
0 -	1	30.00	30.00	462.40	0	*93*	44.47	3.04	*1.50*	0.11	3.68	475.96	13.56	17.24	**PVC**	**SDR26**	**1.5"**	
1 -	2	30.00	60.00	446.43	0	*93*	44.47	3.04	*1.50*	0.11	3.68	472.28	25.85	33.21	**PVC**	**SDR26**	**1.5"**	
2 -	3	28.00	88.00	436.24	0	*93*	44.47	3.04	*1.50*	0.11	3.43	468.85	32.61	43.40	**PVC**	**SDR26**	**1.5"**	
3 -	4	9.00	97.00	434.33	0	*65*	31.08	2.65	*1.50*	0.21	1.06	467.78	33.45	45.31	**GI**	**SCH40**	**1.5"**	
4 -	5	21.00	118.00	432.87	2	*65*	31.08	2.65	*1.50*	0.11	1.33	466.46	33.59	46.78	**PVC**	**SDR26**	**1.5"**	
5 -	6	30.00	148.00	429.82	2	*63*	30.12	2.62	*1.50*	0.11	1.79	464.67	34.85	49.82	**PVC**	**SDR26**	**1.5"**	
6 -	7	12.00	160.00	429.33	2	*61*	29.17	2.59	*1.50*	0.11	0.67	463.99	34.67	50.31	**PVC**	**SDR26**	**1.5"**	
7 -	8	30.00	190.00	435.27	4	*6*	2.87	1.07	*1.00*	0.11	0.19	463.81	28.54	44.37	**PVC**	**SDR26**	**1.0"**	
8 -	9	8.00	198.00	438.80	2	*2*	0.96	0.71	*1.00*	0.11	0.01	463.80	25.00	40.84	**PVC**	**SDR26**	**1.0"**	
7 -	1c	17.00	177.00	432.40	0	*4*	1.91	0.92	*1.00*	0.11	0.05	463.94	31.54	47.24	**PVC**	**SDR26**	**1.0"**	
1c	2c	30.00	207.00	437.87	2	*4*	1.91	0.92	*1.00*	0.11	0.09	463.86	25.99	41.77	**PVC**	**SDR26**	**1.0"**	
2c	3c	30.00	237.00	444.11	2	*2*	0.96	0.71	*1.00*	0.11	0.02	463.83	19.73	35.53	**PVC**	**SDR26**	**1.0"**	
7 -	1b	30.60	190.60	425.64	0	*49*	23.43	2.38	*1.50*	0.11	1.15	462.85	37.21	54.00	**PVC**	**SDR26**	**1.5"**	
1b	2b	30.00	220.60	421.29	0	*40*	19.13	2.21	*1.50*	0.11	0.77	462.08	40.78	58.35	**PVC**	**SDR26**	**1.5"**	
2b	3b	3.30	223.90	420.90	0	*40*	19.13	2.21	*1.50*	0.11	0.08	461.99	41.09	58.74	**PVC**	**SDR26**	**1.5"**	
3b	4b	30.60	254.50	417.00	0	*32*	15.30	2.03	*1.50*	0.11	0.52	461.47	44.48	62.64	**PVC**	**SDR26**	**1.5"**	
4b	5b	2.30	256.80	416.67	0	*32*	15.30	2.03	*1.50*	0.11	0.04	461.43	44.76	62.97	**PVC**	**SDR26**	**1.5"**	
5b	6b	30.70	287.50	413.77	0	*22*	10.52	1.76	*1.50*	0.11	0.26	461.17	47.40	65.87	**PVC**	**SDR26**	**1.5"**	
6b	7b	30.70	318.20	411.50	0	*12*	5.74	1.40	*1.50*	0.11	0.08	461.09	49.59	68.14	**PVC**	**SDR26**	**1.5"**	
7b	8b	2.70	320.90	411.51	0	*12*	5.74	1.40	*1.50*	0.11	0.01	461.08	49.57	68.13	**PVC**	**SDR26**	**1.5"**	
8b	9b	30.60	351.50	408.66	0	*8*	3.83	1.20	*1.50*	0.11	0.04	461.04	52.38	70.98	**PVC**	**SDR26**	**1.5"**	
9b	10b	30.60	382.10	405.69	0	*3*	1.43	0.82	*1.50*	0.11	0.01	461.03	55.35	73.95	**PVC**	**SDR26**	**1.5"**	
10b	1d	30.60	412.70	406.89	1	*3*	1.43	0.82	*1.00*	0.11	0.05	460.98	54.09	72.75	**PVC**	**SDR26**	**1.0"**	
1d	2d	24.00	436.70	415.29	2	*2*	0.96	0.71	*1.00*	0.11	0.02	460.96	45.67	64.35	**PVC**	**SDR26**	**1.0"**	
9b	1e	30.60	382.10	412.61	1	*5*	2.39	1.00	*1.00*	0.11	0.14	460.90	48.29	67.03	**PVC**	**SDR26**	**1.0"**	
1e	2e	19.00	401.10	421.36	4	*4*	1.91	0.92	*1.00*	0.11	0.06	460.85	39.49	58.28	**PVC**	**SDR26**	**1.0"**	
8b	1f	30.60	351.50	419.38	1	*4*	1.91	0.92	*1.00*	0.11	0.09	460.99	41.61	60.26	**PVC**	**SDR26**	**1.0"**	
1f	2f	11.00	362.50	423.87	3	*3*	1.43	0.82	*1.00*	0.11	0.02	460.97	37.10	55.77	**PVC**	**SDR26**	**1.0"**	
3 -	1a	13.30	101.30	434.52	0	*28*	13.39	1.93	*1.00*	0.11	1.43	467.41	32.89	45.12	**PVC**	**SDR26**	**1.0"**	
1a	2a	21.00	122.30	431.51	0	*20*	9.56	1.70	*1.00*	0.11	1.21	466.20	34.69	48.13	**PVC**	**SDR26**	**1.0"**	
2a	3a	30.60	152.90	427.65	0	*20*	9.56	1.70	*1.00*	0.11	1.77	464.43	36.78	51.99	**PVC**	**SDR26**	**1.0"**	
3a	4a	30.60	183.50	424.36	0	*12*	5.74	1.40	*1.00*	0.11	0.69	463.74	39.38	55.28	**PVC**	**SDR26**	**1.0"**	
4a	5a	2.50	186.00	424.08	0	*12*	5.74	1.40	*1.00*	0.11	0.06	463.68	39.60	55.56	**PVC**	**SDR26**	**1.0"**	
5a	6a	28.00	214.00	422.58	0	*4*	1.91	0.92	*1.00*	0.11	0.08	463.60	41.02	57.06	**PVC**	**SDR26**	**1.0"**	
6a	7a	5.00	219.00	421.80	0	*4*	1.91	0.92	*1.00*	0.11	0.01	463.59	41.79	57.84	**PVC**	**SDR26**	**1.0"**	
6b	3g	30.60	318.10	414.93	4	*6*	2.87	1.07	*1.00*	0.11	0.19	460.98	46.05	64.71	**PVC**	**SDR26**	**1.0"**	
3g	4g	27.00	345.10	426.94	2	*2*	0.96	0.71	*1.00*	0.11	0.02	460.96	34.02	52.70	**PVC**	**SDR26**	**1.0"**	
6b	2G	2.30	289.80	413.74	2	*2*	0.96	0.71	*1.00*	0.11	0.00	461.17	47.43	65.90	**PVC**	**SDR26**	**1.0"**	
2G	1G	30.60	320.40	415.48	2	*4*	1.91	0.92	*1.00*	0.11	0.09	461.08	45.60	64.16	**PVC**	**SDR26**	**1.0"**	
1G	7a	30.60	351.00	420.53	4	*4*	1.91	0.92	*1.00*	0.11	0.09	460.99	40.46	59.11	**PVC**	**SDR26**	**1.0"**	
5b	1h	30.60	287.40	418.54	4	*6*	2.87	1.07	*1.00*	0.11	0.19	461.24	42.70	61.10	**PVC**	**SDR26**	**1.0"**	
1h	2h	14.00	301.40	424.03	2	*2*	0.96	0.71	*1.00*	0.11	0.01	461.23	37.20	55.61	**PVC**	**SDR26**	**1.0"**	
5b	3H	30.60	287.40	418.72	4	*4*	1.91	0.92	*1.00*	0.11	0.09	461.34	42.62	60.92	**PVC**	**SDR26**	**1.0"**	
3H	5a	30.90	318.30	423.02	4	*4*	1.91	0.92	*1.00*	0.11	0.09	461.25	38.23	56.62	**PVC**	**SDR26**	**1.0"**	
5a	4h	21.00	207.00	432.71	4	*4*	1.91	0.92	*1.00*	0.11	0.06	463.62	30.91	46.93	**PVC**	**SDR26**	**1.0"**	
3a	1i	20.00	172.90	434.62	4	*4*	1.91	0.92	*1.00*	0.11	0.06	464.37	29.74	45.02	**PVC**	**SDR26**	**1.0"**	
3a	2l	29.00	181.90	423.07	4	*4*	1.91	0.92	*1.00*	0.11	0.09	464.34	41.27	56.57	**PVC**	**SDR26**	**1.0"**	
2l	3l	30.60	212.50	421.78	4	*4*	1.91	0.92	*1.00*	0.11	0.09	464.25	42.47	57.86	**PVC**	**SDR26**	**1.0"**	
3l	3b	4.60	217.10	421.42	0	*4*	1.91	0.92	*1.00*	0.11	0.01	464.24	42.81	58.22	**PVC**	**SDR26**	**1.0"**	
3b	4i	30.60	254.50	425.34	2	*4*	1.91	0.92	*1.00*	0.11	0.09	461.90	36.57	54.30	**PVC**	**SDR26**	**1.0"**	
4i	5i	11.00	265.50	430.64	2	*2*	0.96	0.71	*1.00*	0.11	0.01	461.89	31.25	49.00	**PVC**	**SDR26**	**1.0"**	
1b	1j	30.60	221.20	432.09	3	*5*	2.39	1.00	*1.00*	0.11	0.14	462.71	30.62	47.55	**PVC**	**SDR26**	**1.0"**	
1j	2j	8.00	229.20	435.51	2	*2*	0.96	0.71	*1.00*	0.11	0.01	462.71	27.19	44.13	**PVC**	**SDR26**	**1.0"**	
1b	3J	30.60	221.20	426.89	4	*4*	1.91	0.92	*1.00*	0.11	0.09	462.76	35.87	52.75	**PVC**	**SDR26**	**1.0"**	
3J	4J	30.60	251.80	430.35	4	*4*	1.91	0.92	*1.00*	0.11	0.09	462.67	32.32	49.29	**PVC**	**SDR26**	**1.0"**	
4J	2a	4.20	256.00	431.45	0	*4*	1.91	0.92	*1.00*	0.11	0.01	462.66	31.21	48.19	**PVC**	**SDR26**	**1.0"**	
2a	5j	28.00	150.30	441.66	4	*4*	1.91	0.92	*1.00*	0.11	0.08	466.11	24.46	37.98	**PVC**	**SDR26**	**1.0"**	

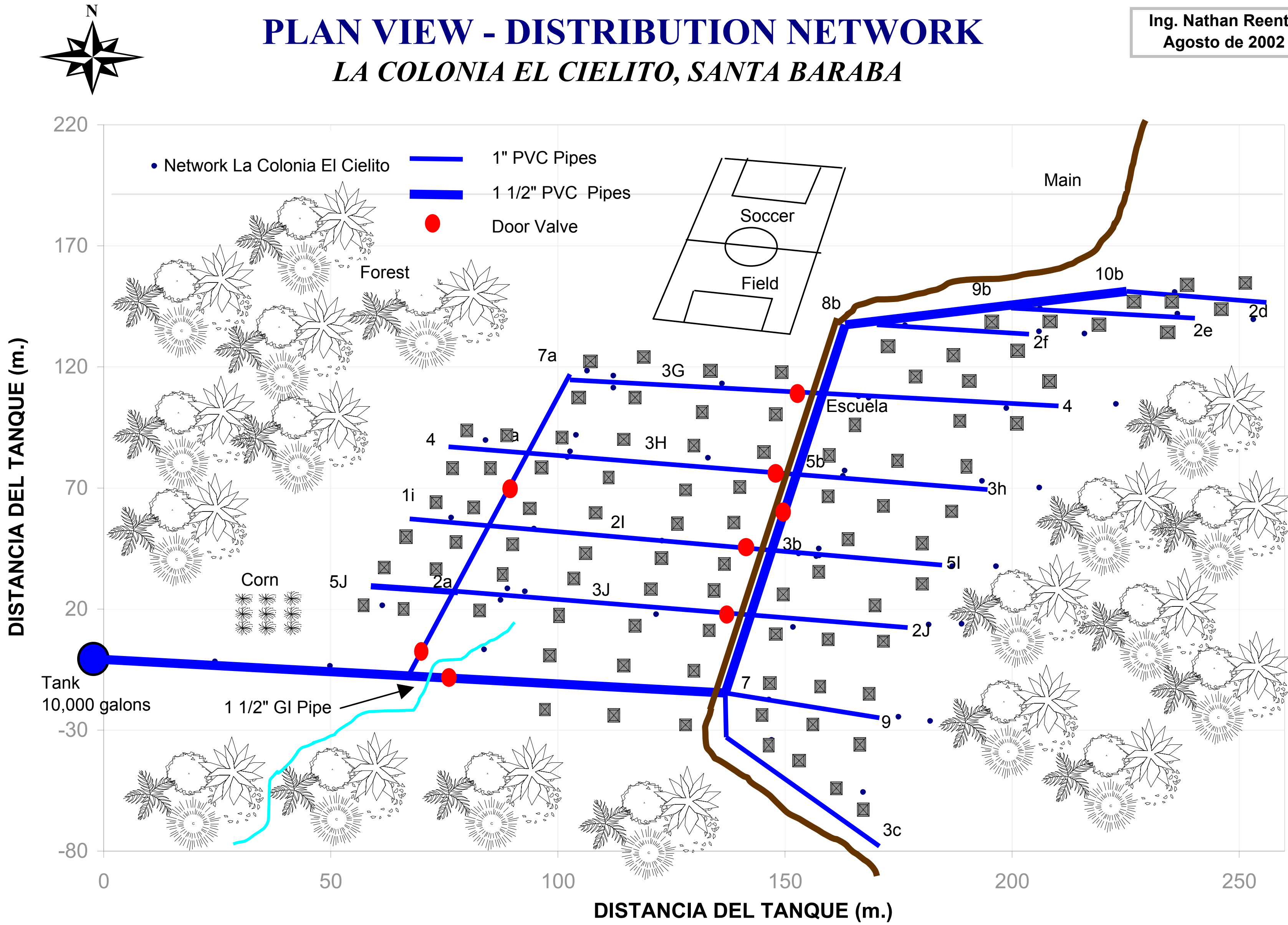


PROFILE VIEW - DISTRIBUTION NETWORK
LA COLONIA EL CIELITO, SANTA BARBARA
Eng. Nathan Reents
August de 2002
Mother Line Terrain
Static Head
Hydraulic Gradient
Houses
DISTRIBUTION TANK
10,000 GAL.
ELEVATION (m)
ACCUMULATED DISTANCE FROM TANK (m)
500
475
450
425
400
0
500

PLAN VIEW - DISTRIBUTION NETWORK

LA COLONIA EL CIELITO, SANTA BARABA

Ing. Nathan Reents
Agosto de 2002



MATERIALS LIST AND PROPOSAL

MATERIALES LIST - PROPOSAL

La Colonia El Cielito, Santa Barbara, SANTA BARBARA

Engineer: **Eng. Nathan Reents** **Date of Design:** **August of 2002**

Article Descripción	Quantity	Units	Unit Cost	Support WFP	Support Mayor	Support Comm.	Support Other	TOTAL Lempiras
Summery								
Spring Box								
MATERIALS =				5,713.92	700.00	0.00	0.00	6,413.92
NON-SKILLED LABOR =				0.00	0.00	1,200.00	0.00	1,200.00
SKILLED LABOR =				2,000.00	0.00	0.00	0.00	2,000.00
SPRING BOX TOTAL =				7,713.92	700.00	1,200.00	0.00	**9,613.92**
Conduction Line								
MATERIALS =				108,001.19	4,713.00	10.00	0.00	112,724.19
NON-SKILLED LABOR =				0.00	0.00	19,500.00	0.00	19,500.00
SKILLED LABOR =				8,818.50	0.00	0.00	0.00	8,818.50
CONDUCTION LINE TOTAL =				116,819.69	4,713.00	19,510.00	0.00	**141,042.69**
Storage Tank								
MATERIALS =				26,507.28	2,540.00	0.00	0.00	29,047.28
NON-SKILLED LABOR =				0.00	0.00	5,500.00	0.00	5,500.00
SKILLED LABOR =				7,500.00	0.00	0.00	0.00	7,500.00
STORAGE TANK TOTAL =				34,007.28	2,540.00	5,500.00	0.00	**42,047.28**
Distribution Network								
MATERIALS =				11,628.50	0.00	100.00	0.00	11,728.50
NON-SKILLED LABOR =				0.00	0.00	5,950.00	0.00	5,950.00
SKILLED LABOR =				1,308.00	0.00	0.00	0.00	1,308.00
DISTRIBUTION NETWORK TOTAL =				12,936.50	0.00	6,050.00	0.00	**18,986.50**
Domestic Connections and Latrines								
MATERIALS =				92,217.60	465.00	0.00	0.00	92,682.60
DOMESTIC CONNECTIONS AND LATRINES TOTAL =				92,217.60	465.00	0.00	0.00	**92,682.60**
GRAND TOTAL								
MATERIALS =				244,068.49	8,418.00	110.00	0.00	**252,596.49**
NON-SKILLED LABOR =				1,251.19	0.00	32,150.00	0.00	**33,401.19**
SKILLED LABOR =				19,756.86	0.00	0.00	0.00	**19,756.86**
GRAND TOTAL				**265,076.54**	**8,418.00**	**32,260.00**	**0.00**	**305,754.54**
SPRING BOX	1							
Intake structure for a natural spring with a sand filter								
Portland Cement	30.00	bolsa	64.73	1,941.96				1,941.96
Sand	4.00	m^3	+ 100		400.00			400.00
Gravel	1.00	m^3	+ 100		100.00			100.00
Rock	2.00	m^3	+ 100		200.00			200.00
Rebar Corrugated 1/4"x30	7.00	c/u	10.00	70.00				70.00
Rebar Corrugated 3/8"x30	12.00	c/u	28.00	336.00				336.00
Wood 1"x12"x10'	12.00	c/u	45.00	540.00				540.00
Wood 2"x4"x10'	12.00	c/u	32.00	384.00				384.00
Nails 2½"	4.00	libras	4.50	18.00				18.00
Wire	5.00	libras	5.00	25.00				25.00
Brick 3"x6"x11"	500.00	c/u	+ 1.55	775.00				775.00
Metal Hatch (24" x 24") with hinges	1.00	c/u	350.00	350.00				350.00
Accessories								

MATERIALES LIST - PROPOSAL

La Colonia El Cielito, Santa Barbara, SANTA BARBARA

Engineer: **Eng. Nathan Reents** **Date of Design:** **August of 2002**

Article Descripción	Quantity	Units	Unit Cost	Support WFP	Support Mayor	Support Comm.	Support Other	TOTAL Lempiras
Exit - Diameter =>		**2.0"**						
Bronze Door Valve 2" Diamete	1.00	c/u	190.00	190.00				190.00
Male Adapter PVC 2" Diameter	1.00	c/u	10.00	10.00				10.00
Elbow PVC 45 Degrees 2" Diameter	2.00	c/u	58.00	116.00				116.00
Pipe GI SCH40 2" Diameter	0.50	lance	300.00	150.00				150.00
Clean-out and Overflow		**2.0"**						
Bronze Door Valve 2" Diamete	1.00	c/u	190.00	190.00				190.00
Pipe GI SCH40 2" Diameter	1.00	lance	300.00	300.00				300.00
Elbow GI 90 Degrees 2" Diameter	5.00	c/u	27.99	139.96				139.96
Tee GI 2" Diameter	1.00	c/u	28.00	28.00				28.00
Universal Union GI 2" Diameter	2.00	c/u	75.00	150.00				150.00
Labor								
Non-skilled Labor	20	día	60.00			1,200.00		1,200.00
Skilled Labor	1	global	2,000.00	2,000.00				2,000.00
Materials Total =				5,713.92	700.00	0.00	0.00	6,413.92
Non-skilled Labor Total =				0.00	0.00	1,200.00	0.00	1,200.00
Skilled Labor Total =				2,000.00	0.00	0.00	0.00	2,000.00
SPRING BOX TOTAL =				7,713.92	700.00	1,200.00	0.00	**9,613.92**

MATERIALES LIST - PROPOSAL

La Colonia El Cielito, Santa Barbara, SANTA BARBARA

Engineer: **Eng. Nathan Reents** **Date of Design:** **August of 2002**

Article Descripción	Quantity	Units	Unit Cost	Support WFP	Support Mayor	Support Comm.	Support Other	TOTAL Lempiras
CONDUCTION LINE								
Piping								
GI								
Pipe GI SCH40 2" Diameter	61.00	lance	300.00	18,300.00				18,300.00
Pipe GI SCH40 1½" Diameter	110.00	lance	235.71	25,928.57				25,928.57
Pipe GI SCH40 1" Diameter	2.00	lance	142.99	285.98				285.98
Anchor								
Portland Cement	173.00	c/u	64.73	11,198.66				11,198.66
Sand	17.30	c/u	+ 100		1,730.00			1,730.00
Rock	25.95	c/u	+ 100		2,595.00			2,595.00
Rebar Corrugated 3/8"x30	9.00	lance	28.00	252.00				252.00
Accessories								
Universal Union GI 2" Diameter	13.00	c/u	75.00	975.00				975.00
Universal Union GI 1½" Diameter	22.00	c/u	45.00	990.00				990.00
Universal Union GI 1" Diameter	1.00	c/u	30.00	30.00				30.00
Paint Anticorrosive	0.20	galone	152.14	29.70				29.70
Teflon Tape	35.00	rollo	2.68	93.75				93.75
Labor								
Non-skilled Labor	1	global	4,325.00			4,325.00		4,325.00
Skilled Labor:	1	global	2,253.00	2,253.00				2,253.00
PVC								
Pipe PVC SDR26								
Pipe PVC SDR26 1½" Diameter	396.00	lance	60.00	23,760.00				23,760.00
Pipe PVC SDR26 1" Diameter	29.00	lance	34.00	986.00				986.00
Pipe PVC SDR21								
Pipe PVC SDR21 1½" Diameter	62.00	lance	97.50	6,045.00				6,045.00
Accessories								
Adhesive for PVC	3.21	galone	389.24	1,251.19				1,251.19
Sand Paper	20.00	pliego	6.52	130.36				130.36
Labor								
Labor No-calificado	1	global	12,175.00			12,175.00		12,175.00
Labor Calificado	1	global	3,565.50	3,565.50				3,565.50
Clean-out Valves	**1**							
Boxes								
Portland Cement	1.00	bolsa	64.73	64.73				64.73
Brick 3"x6"x11"	60.00	c/u	+ 1.55	93.00				93.00
Sand	0.10	m^3	+ 100			10.00		10.00
Rebar Corrugated 3/8"x30	1.00	lance	28.00		28.00			28.00
CV 1 - Diameter =>	**1**	**1½**						
Bronze Door Valve 1½" Diameter	1.00	c/u	120.00	120.00				120.00
Tee GI 1½" Diameter	1.00	c/u	20.00	20.00				20.00
Pipe GI SCH40 1½" Diameter	0.10	c/u	235.71	23.57				23.57
Air Valves	**1**							
Boxes								
Portland Cement	1.00	bolsa	64.73	64.73				64.73
Brick 3"x6"x11"	40.00	c/u	+ 1.55	62.00				62.00
Sand	0.10	m^3	+ 100	0.00	10.00			10.00
Rebar Corrugated 3/8"x30	1.00	lance	28.00	28.00				28.00
VA 1 - Diameter =>	**1**	**1½**						
Air Valve ½" Diameter	1.00	c/u	+ 700	700.00				700.00
Bronze Door Valve ½" Diameter	1.00	c/u	45.00	45.00				45.00
Tee GI 1½" Diameter	1.00	c/u	20.00	20.00				20.00
Bushing GI 1½" - ½" Diameter	1.00	c/u	+ 10	10.00				10.00

MATERIALES LIST - PROPOSAL

La Colonia El Cielito, Santa Barbara, SANTA BARBARA

Engineer: **Eng. Nathan Reents** **Date of Design:** **August of 2002**

Article Descripción	Quantity	Units	Unit Cost	Support WFP	Support Mayor	Support Comm.	Support Other	TOTAL Lempiras
Pipe GI SCH40 ½" Diameter	0.10	lance	70.54	7.05				7.05
Male Adapter PVC 1½" Diameter	2.00	c/u	6.04	12.09				12.09
Break Pressure Tanks - (1.3mx1mx	**5**							
Boxes								
Brick 3"x6"x11"	1,750.00	c/u	+ 1.55	2,712.50				2,712.50
Portland Cement	35.00	bolsa	64.73	2,265.63				2,265.63
Sand	3.50	m^3	+ 100		350.00			350.00
Wood 1"x12"x10'	40.00	c/u	45.00	1,800.00				1,800.00
Wood 2"x4"x10'	40.00	cu	32.00	1,280.00				1,280.00
Nails 2½"	1.60	libra	4.50	7.20				7.20
Rebar Corrugated 1/4"x30	25.00	lance	10.00	250.00				250.00
Rebar Corrugated 3/8"x30	50.00	lance	28.00	1,400.00				1,400.00
Break Pressure Tank 1 - Accessories	**1**							
Entrance - Diameter =>		**1.0"**						
Bronze Door Valve 1" Diameter	1.00	c/u	70.00	70.00				70.00
Male Adapter PVC 1" Diameter	1.00	c/u	2.70	2.70				2.70
Elbow GI 90 Degrees 1" Diameter	3.00	c/u	10.00	30.00				30.00
Pipe GI SCH40 1" Diameter	0.50	lance	142.99	71.50				71.50
Exit - Diameter =>		**2.0"**						
Bronze Door Valve 2" Diameter	1.00	c/u	190.00	190.00				190.00
Male Adapter PVC 2" Diameter	1.00	c/u	10.00	10.00				10.00
Elbow PVC 45 Degrees 2" Diameter	2.00	c/u	58.00	116.00				116.00
Pipe GI SCH40 2" Diameter	0.50	lance	300.00	150.00				150.00
Clean-out & Overflow		**2.0"**						
Bronze Door Valve 2" Diameter	1.00	c/u	190.00	190.00				190.00
Pipe GI SCH40 2" Diameter	1.00	lance	300.00	300.00				300.00
Elbow GI 90 Degrees 2" Diameter	5.00	c/u	27.99	139.96				139.96
Tee GI 2" Diameter	1.00	c/u	28.00	28.00				28.00
Universal Union GI 2" Diameter	2.00	c/u	75.00	150.00				150.00
Break Pressure Tanks 2,4,5 - Accessories	**3**							
Entrance - Diameter =>		**1½**						
Bronze Door Valve 1½" Diameter	3.00	c/u	120.00	360.00				360.00
Male Adapter PVC 1½" Diameter	3.00	c/u	6.04	18.13				18.13
Elbow GI 90 Degrees 1½" Diameter	9.00	c/u	22.00	198.00				198.00
Pipe GI SCH40 1½" Diameter	1.50	lance	235.71	353.57				353.57
Exit - Diameter =>		**1½**						
Bronze Door Valve 1½" Diameter	3.00	c/u	120.00	360.00				360.00
Male Adapter PVC 1½" Diameter	3.00	c/u	6.04	18.13				18.13
Elbow PVC 45 Degrees 1½" Diameter	6.00	c/u	+ 0	0.00				0.00
Pipe GI SCH40 1½" Diameter	1.50	lance	235.71	353.57				353.57
Clean-out & Overflow		**2.0"**						
Bronze Door Valve 2" Diameter	3.00	c/u	190.00	570.00				570.00
Pipe GI SCH40 2" Diameter	3.00	lance	300.00	900.00				900.00
Elbow GI 90 Degrees 2" Diameter	15.00	c/u	27.99	419.87				419.87
Tee GI 2" Diameter	3.00	c/u	28.00	84.00				84.00
Universal Union GI 2" Diameter	6.00	c/u	75.00	450.00				450.00
Break Pressure Tank 3 - Accessories	**1**							
Entrance - Diameter =>		**1.0"**						
Bronze Door Valve 1" Diameter	1.00	c/u	70.00	70.00				70.00
Male Adapter PVC 1" Diameter	1.00	c/u	2.70	2.70				2.70
Elbow GI 90 Degrees 1" Diameter	3.00	c/u	10.00	30.00				30.00
Pipe GI SCH40 1" Diameter	0.50	lance	142.99	71.50				71.50
Exit - Diameter =>		**1½**						
Bronze Door Valve 1½" Diameter	1.00	c/u	120.00	120.00				120.00
Male Adapter PVC 1½" Diameter	1.00	c/u	6.04	6.04				6.04
Elbow PVC 45 Degrees 1½" Diameter	2.00	c/u	+ 0	0.00				0.00
Pipe GI SCH40 1½" Diameter	0.50	lance	235.71	117.86				117.86
Clean-out & Overflow		**2.0"**						
Bronze Door Valve 2" Diameter	1.00	c/u	190.00	190.00				190.00
Pipe GI SCH40 2" Diameter	1.00	lance	300.00	300.00				300.00
Elbow GI 90 Degrees 2" Diameter	5.00	c/u	27.99	139.96				139.96
Tee GI 2" Diameter	1.00	c/u	28.00	28.00				28.00

MATERIALES LIST - PROPOSAL

La Colonia El Cielito, Santa Barbara, SANTA BARBARA

Engineer: **Eng. Nathan Reents** **Date of Design:** **August of 2002**

Article Descripción	Quantity	Units	Unit Cost	Support WFP	Support Mayor	Support Comm.	Support Other	TOTAL Lempiras
Universal Union GI 2" Diameter	2.00	c/u	75.00	150.00				150.00
Labor								
Non-skilled Labor	30	día	100.00			3,000.00		3,000.00
Skilled Labor	5	global	600.00	3,000.00				3,000.00
Materials Total =				108,001.19	4,713.00	10.00	0.00	112,724.19
Non-skilled Labor Total =				0.00	0.00	19,500.00	0.00	19,500.00
Skilled Labor Total =				8,818.50	0.00	0.00	0.00	8,818.50
CONDUCTION LINE TOTAL =				116,819.69	4,713.00	19,510.00	0.00	**141,042.69**

MATERIALES LIST - PROPOSAL

La Colonia El Cielito, Santa Barbara, SANTA BARBARA

Engineer: **Eng. Nathan Reents** **Date of Design:** **August of 2002**

Article Descripción	Quantity	Units	Unit Cost	Support WFP	Support Mayor	Support Comm.	Support Other	TOTAL Lempiras
STORAGE TANK	**10,000**	**GAL**						
Tank								
Brick 3"x6"x11"	2,600.00	c/u	+ 1.55	4,030.00				4,030.00
Portland Cement	160.00	bolsa	64.73	10,357.14				10,357.14
Sand	15.00	m^3	+ 100		1,500.00			1,500.00
Rock	10.00	m^3	+ 100		1,000.00			1,000.00
Plywood Sheet 3/16"x6	1.00	lamina	119.24	119.24				119.24
Rebar Corrugated 1/4"x30	80.00	lance	10.00	800.00				800.00
Rebar Corrugated 3/8"x30	90.00	lance	28.00	2,520.00				2,520.00
Rebar Corrugated 1/2"x30	0.00	lance	46.96	0.00				0.00
Wood 1"x12"x10'	65.00	c/u	45.00	2,925.00				2,925.00
Wood 2"x4"x10'	50.00	c/u	32.00	1,600.00				1,600.00
Wood Pleybo 1/8"x6"x6	4.00	c/u	28.00	112.00				112.00
Paint Sky Blue	3.00	galones	135.00	405.00				405.00
Wire	10.00	libra	5.00	50.00				50.00
Nails 2½"	15.00	libra	4.50	67.50				67.50
Accessories								
Entrance - Diameter =>		**1.0"**						
Bronze Door Valve 1" Diamete	1.00	c/u	70.00	70.00				70.00
Pipe GI SCH40 1" Diameter	1.00	lance	142.99	142.99				142.99
Male Adapter PVC 1" Diameter	1.00	c/u	2.70	2.70				2.70
Universal Union GI 1" Diameter	1.00	c/u	30.00	30.00				30.00
Elbow GI 90 Degrees 1" Diameter	3.00	c/u	10.00	30.00				30.00
Tee GI 1" Diameter	1.00	c/u	10.00	10.00				10.00
Exit - Diameter =>	**1**	**1½**						
Bronze Door Valve 1½" Diamete	1.00	c/u	120.00	120.00				120.00
Pipe GI SCH40 1½" Diameter	2.00	lance	235.71	471.43				471.43
Female Adapter PVC 1½" Diameter	1.00	c/u	6.00	6.00				6.00
Universal Union GI 1½" Diameter	2.00	c/u	45.00	90.00				90.00
Elbow GI 45 Degrees 1½" Diameter	2.00	c/u	22.00	44.00				44.00
Elbow GI 90 Degrees 1½" Diameter	2.00	c/u	22.00	44.00				44.00
Clean-out & Overflow - Diameter =>		**3.0"**						
Cap GI 3" Diameter	1.00	c/u	26.79	26.79				26.79
Pipe GI SCH40 3" Diameter	2.00	lance	579.46	1,158.93				1,158.93
Elbow GI 90 Degrees 3" Diameter	4.00	c/u	80.00	320.00				320.00
Calcium Hypochlorite Tank - 1m x 1m x 1m								
Box								
Brick 3"x6"x11"	165.00	c/u	+ 1.55	255.75				255.75
Portland Cement	4.00	bolsa	64.73	258.93				258.93
Sand	0.40	m^3	+ 100		40.00			40.00
Rebar Corrugated 1/4"x30	10.00	lance	10.00	100.00				100.00
Rebar Corrugated 3/8"x30	4.00	lance	28.00	112.00				112.00
Accessories								
Bronze Door Valve ½" Diamete	1.00	c/u	45.00	45.00				45.00
Ball Valve PVC ½" Diameter	1.00	c/u	32.54	32.54				32.54
Pipe GI SCH40 ½" Diameter	1.00	lance	70.54	70.54				70.54
Pipe PVC SDR26 ½" Diameter	1.00	lance	22.41	22.41				22.41
Elbow GI 90 Degrees ½" Diameter	4.00	c/u	4.00	16.00				16.00
Female Adapter PVC ½" Diameter	1.00	c/u	1.40	1.40				1.40
Universal Union GI ½" Diameter	2.00	c/u	20.00	40.00				40.00
Labor								
Non-skilled Labor	55	día	100.00			5,500.00		5,500.00
Skilled Labor	1	global	7,500.00	7,500.00				7,500.00
Materials Total =				26,507.28	2,540.00	0.00	0.00	29,047.28
Non-skilled Labor Total =				0.00	0.00	5,500.00	0.00	5,500.00
Skilled Labor Total =				7,500.00	0.00	0.00	0.00	7,500.00
TOTAL DE TANQUE DE DISTRIBUCION =				**34,007.28**	**2,540.00**	**5,500.00**	**0.00**	**42,047.28**

MATERIALES LIST - PROPOSAL

La Colonia El Cielito, Santa Barbara, SANTA BARBARA

Engineer: **Eng. Nathan Reents** **Date of Design:** **August of 2002**

Article Descripción	Quantity	Units	Unit Cost	Support WFP	Support Mayor	Support Comm.	Support Other	TOTAL Lempiras
DISTRIBUTION NETWORK								
Piping								
GI								
Pipe GI SCH40 1½" Diameter	4.00	lance	235.71	942.86				942.86
Anclajes								
Portland Cement	4.00	c/u	64.73	258.93				258.93
Sand	0.40	c/u	+ 100	0.00		40.00		40.00
Rock	0.60	c/u	+ 100	0.00		60.00		60.00
Rebar Corrugated 3/8"x30	1.00	lance	28.00	28.00				28.00
Accessories								
Universal Union GI 1½" Diameter	1.00	c/u	45.00	45.00				45.00
Teflon Tape	1.00	rollo	2.68	2.68				2.68
Labor								
Non-skilled Labor	1	global	100.00	0.00		100.00		100.00
Skilled Labor	1	global	48.00	48.00				48.00
PVC								
Pipe PVC SDR26 1½" Diameter	69.00	lance	60.00	4,140.00				4,140.00
Pipe PVC SDR26 1" Diameter	165.00	lance	34.00	5,610.00				5,610.00
Accessories								
Adhesive for PVC	1.38	galone	389.24	535.86				535.86
Sand Paper	10.00	pliego	6.52	65.18				65.18
Labor								
Non-skilled Labor	1	global	5,850.00	0.00		5,850.00		5,850.00
Skilled Labor	1	global	1,260.00	1,260.00				1,260.00
Materials Total =				11,628.50	0.00	100.00	0.00	11,728.50
Non-skilled Labor Total =				0.00	0.00	5,950.00	0.00	5,950.00
Skilled Labor Total =				1,308.00	0.00	0.00	0.00	1,308.00
DISTRIBUTION NETWORK TOTAL =				**12,936.50**	**0.00**	**6,050.00**	**0.00**	**18,986.50**

MATERIALES LIST - PROPOSAL

La Colonia El Cielito, Santa Barbara, SANTA BARBARA

Engineer: **Eng. Nathan Reents** **Date of Design:** **August of 2002**

Article Descripción	Quantity	Units	Unit Cost	Support WFP	Support Mayor	Support Comm.	Support Other	TOTAL Lempiras
DOMESTIC CONNECTIONS	93							
Box								
Portland Cement	46.50	bolsa	64.73	3,010.04				3,010.04
Sand	4.65	m^3	+ 100	0.00	465.00			465.00
Rebar Corrugated 3/8"x30	46.50	lance	28.00	1,302.00				1,302.00
Accessories								
Bronze Door Valve ½" Diamete	93.00	c/u	45.00	4,185.00				4,185.00
Spigot ½" Diameter	93.00	c/u	35.00	3,255.00				3,255.00
Pipe GI SCH40 ½" Diameter	93.00	lance	70.54	6,559.82				6,559.82
Pipe PVC SDR13.5 ½" Diameter	186.00	lance	30.00	5,580.00				5,580.00
Female Adapter PVC ½" Diameter	279.00	c/u	1.40	391.10				391.10
Reducer PVC 1" - ½" Diameter	93.00	c/u	5.00	465.00				465.00
Tee PVC 1" Diameter	93.00	c/u	12.59	1,170.80				1,170.80
Elbow GI 90 Degrees ½" Diameter	186.00	c/u	4.00	744.00				744.00
Universal Union GI ½" Diameter	93.00	c/u	20.00	1,860.00				1,860.00
Pipe GI SCH40 ½" Diameter	23.25	lance	70.54	1,639.96				1,639.96
Pipe GI SCH40 ½" Diameter	4.65	lance	70.54	327.99				327.99
Coupling GI ½" Diameter	93.00	c/u	4.00	372.00				372.00
LETRINES	93							
Portland Cement	186.00	bolsa	64.73	12,040.18				12,040.18
Rebar Corrugated 1/4"x30	139.50	lance	10.00	1,395.00				1,395.00
Toilet Stool	93.00	c/u	285.71	26,571.43				26,571.43
Pipe PVC SDR26 3" Diameter	33.48	lance	258.00	8,637.84				8,637.84
Zinc Sheet 28"x6'	186.00	c/u	68.04	12,654.64				12,654.64
Wire	11.16	libra	5.00	55.80				55.80
Materials Total =				92,217.60	465.00	0.00	0.00	92,682.60
DOMESTIC CONNECTIONS AND LATRINES TOTAL =				**92,217.60**	**465.00**	**0.00**	**0.00**	**92,682.60**

WORK ORDER

WORK ORDER

La Colonia El Cielito, Santa Barbara, SANTA BARBARA

Ingeniero: **Eng. Nathan Reents** **Date of Design:** **August of 2002**

Article Description	Quantity	Units	Unit Cost	Support WFP	Support Mayor	Support Comm.	Support Other	TOTAL Lempiras
Adhesive for PVC	4.59	galon	389.24	1787.0				1,787.05
Air Valve ½" Diameter	1.00	unit	+ 700	700.00				700.00
Ball Valve PVC ½" Diameter	1.00	unit	32.54	32.54				32.54
Brick 3"x6"x11"	5115.00	unit	+ 1.55	7,928.25				7,928.25
Bronze Door Valve ½" Diamete	95.00	unit	45.00	4,275.00				4,275.00
Bronze Door Valve 1" Diamete	3.00	unit	70.00	210.00				210.00
Bronze Door Valve 1½" Diamete	9.00	unit	120.00	1,080.00				1,080.00
Bronze Door Valve 2" Diamete	8.00	unit	190.00	1,520.00				1,520.00
Bushing GI 1½" - ½" Diameter	1.00	unit	+ 10	10.00				10.00
Cap GI 3" Diameter	1.00	unit	26.79	26.79				26.79
Coupling GI ½" Diameter	93.00	unit	4.00	372.00				372.00
Elbow GI 45 Degrees 1½" Diameter	2.00	unit	22.00	44.00				44.00
Elbow GI 90 Degrees ½" Diameter	190.00	unit	4.00	760.00				760.00
Elbow GI 90 Degrees 1" Diameter	9.00	unit	10.00	90.00				90.00
Elbow GI 90 Degrees 1½" Diameter	11.00	unit	22.00	242.00				242.00
Elbow GI 90 Degrees 2" Diameter	30.00	unit	27.99	839.73				839.73
Elbow GI 90 Degrees 3" Diameter	4.00	unit	80.00	320.00				320.00
Elbow PVC 45 Degrees 1½" Diameter	8.00	unit	+ 0	0.00				0.00
Elbow PVC 45 Degrees 2" Diameter	4.00	unit	58.00	232.00				232.00
Female Adapter PVC ½" Diameter	280.00	unit	1.401786	392.50				392.50
Female Adapter PVC 1½" Diameter	1.00	unit	6	6.00				6.00
Gravel	1.00	m^3	+ 100	0.00	100.00			100.00
Male Adapter PVC 1" Diameter	3.00	unit	2.696429	8.09				8.09
Male Adapter PVC 1½" Diameter	9.00	unit	6.044643	54.40				54.40
Male Adapter PVC 2" Diameter	2.00	unit	10	20.00				20.00
Metal Hatch (24" x 24") with hinges	1.00	unit	350	350.00				350.00
Nails 2½"	20.60	pound	4.50	92.70				92.70
Paint Anticorrosive	0.20	galon	152.14	29.70				29.70
Paint Sky Blue	3.00	galon	135.00	405.00				405.00
Pipe GI SCH40 ½" Diameter	122.00	lance	70.54	8,605.36				8,605.36
Pipe GI SCH40 1" Diameter	4.00	lance	142.99	571.96				571.96
Pipe GI SCH40 1½" Diameter	119.60	lance	235.71	28,191.43				28,191.43
Pipe GI SCH40 2" Diameter	68.00	lance	300.00	20,400.00				20,400.00
Pipe GI SCH40 3" Diameter	2.00	lance	579.46	1,158.93				1,158.93
Pipe PVC SDR13.5 ½" Diameter	186.00	lance	30.00	5,580.00				5,580.00
Pipe PVC SDR21 1½" Diameter	62.00	lance	97.50	6,045.00				6,045.00
Pipe PVC SDR26 ½" Diameter	1.00	lance	22.41	22.41				22.41
Pipe PVC SDR26 1" Diameter	194.00	lance	34.00	6,596.00				6,596.00
Pipe PVC SDR26 1½" Diameter	465.00	lance	60.00	27,900.00				27,900.00
Pipe PVC SDR26 3" Diameter	33.48	lance	258.00	8,637.84				8,637.84
Plywood Sheet 3/16"x6	1.00	sheet	119.24	119.24				119.24
Portland Cement	640.50	bag	64.73	41,460.94				41,460.94
Rebar Corrugated 1/4"x30	261.50	lance	10.00	2,615.00				2,615.00
Rebar Corrugated 3/8"x30	214.50	lance	28.00	6,006.00				6,006.00
Reducer PVC 1" - ½" Diameter	93.00	unit	5.00	465.00				465.00
Rock	38.55	m^3	+ 100	0.00	3,855.00			3,855.00
Sand	45.45	m^3	+ 100	0.00	4,545.00			4,545.00
Sand Paper	30.00	sheet	6.52	195.54				195.54
Spigot ½" Diameter	93.00	unit	35.00	3,255.00				3,255.00
Tee GI 1" Diameter	1.00	unit	10.00	10.00				10.00
Tee GI 1½" Diameter	2.00	unit	20.00	40.00				40.00
Tee GI 2" Diameter	6.00	unit	28.00	168.00				168.00
Tee PVC 1" Diameter	93.00	unit	12.59	1,170.80				1,170.80
Teflon Tape	36.00	roll	2.68	96.43				96.43
Toilet Stool	93.00	unit	285.71	26,571.43				26,571.43
Universal Union GI ½" Diameter	95.00	unit	20.00	1,900.00				1,900.00
Universal Union GI 1" Diameter	2.00	unit	30.00	60.00				60.00
Universal Union GI 1½" Diameter	25.00	unit	45.00	1,125.00				1,125.00
Universal Union GI 2" Diameter	25.00	unit	75.00	1,875.00				1,875.00
Wire	26.16	pound	5.00	130.80				130.80
Wood 1"x12"x10'	117.00	unit	45.00	5,265.00		5,265.00		10,530.00
Wood 2"x4"x10'	102.00	unit	32.00	3,264.00		3,264.00		6,528.00
Wood Pleybo 1/8"x6"x6	4.00	unit	28.00	0.00		112.00		112.00
Zinc Sheet 28"x6'	186.00	unit	68.04	12,654.64				12,654.64
MATERIALES GRAND TOTAL =				243,984.49	8,500.00	8,641.00	0.00	**261,125.49**