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Developing a Preservation Strategy for the Water Filtration System of the Antiguo Acueducto de San Juan

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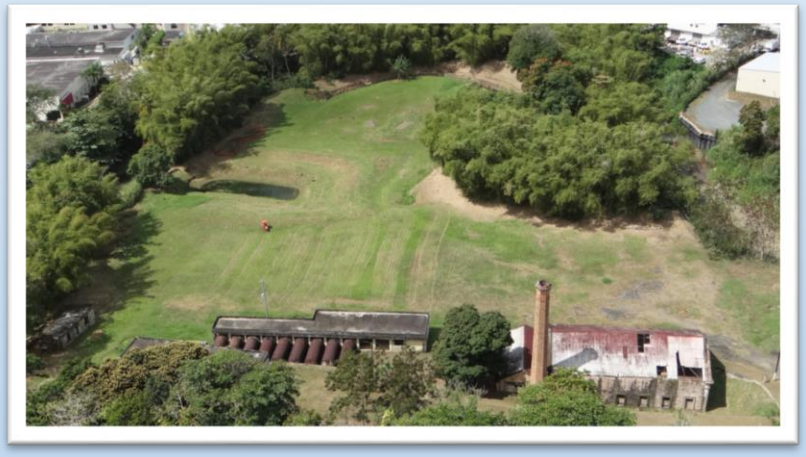

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Developing a Preservation Strategy for the Water Filtration System of the Antiguo Acueducto de San Juan

An Interactive Qualifying Project Report

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Executive Summary

The Antiguo Acueducto of San Juan is a site of historical and environmental importance to the Conservation Trust of Puerto Rico. The Trust acquired the Antiguo Acueducto in 2005. The Antiguo Acueducto has not been operational since the 1970's. The Trust plans to fully preserve this site and use it to educate visitors on the importance of historic preservation and water conservation. Our project goal was to develop a preservation plan for the mechanical water filtration facility at the Antiguo Acueducto.

The Trust is an organization that focuses on historic and ecological preservation in Puerto Rico. Its goal is to preserve one third of the island of Puerto Rico for the value that it will bring to the community and for tourism. The Trust caries out this mission by acquiring natural areas and historic sites to be protected. Part of the Trust's mission is to develop educational programs to garner general public support and awareness. The division of the Trust that works with environmental and historic preservation is called Para la Naturaleza. Throughout our time in Puerto Rico, we were working directly with representatives of Para la Naturaleza. By garnering public support and fostering awareness, Para la Naturaleza is planning to restore and preserve the Antiguo Acueducto as part of the Trust's plan to preserve a third of the island of Puerto Rico by 2033.

Methodology:

Our mission was to develop a plan to communicate to the visitors of the Antiguo Acueducto the principles of its mechanical water filters, its historic value, and the general importance of water conservation, in order to help preserve the site. This preservation strategy included developing a model of the mechanical water filtration system and creating educational exhibit designs of the Antiguo Acueducto. The results of this project were a functional physical model of the filtration system and sample educational exhibit designs. Afterwards, we made recommendations on how to implement and create the model of the mechanical water filtration system and the educational exhibit designs.

The objectives of this project were to:

1. To design a functional physical model of the mechanical water filtration system of the Antiguo Acueducto.

2. To design an educational exhibit that showcases the history and technology of the Antiguo Acueducto and communicates the importance of water conservation.

We evaluated the site of the Antiguo Acueducto to determine how the mechanical water filtration system worked. Additionally, we interviewed the engineers who have been working on the site since 2005. After understanding how the system worked, we created a computer-aided design (CAD) model and fluid simulations of a section of the mechanical water filtration system. The model we created helped us convey the function of the mechanical water filtration system to the Trust and any future visitors of the site.

In order to design the functioning physical model, we adapted the existing design into a smaller version. We used SolidWorks to model this smaller design and to determine the exact dimensions of the parts that would be needed to construct the model. In order to ensure our smaller filter would work, we conducted an exploratory experiment to determine what could be used for contaminants and filter media.

For the educational exhibit design creation, we visited other historic sites around Puerto Rico. We conducted interviews of the staff on the sites and evaluated their educational exhibits. Two of the sites that we visited are managed by the Trust, and our liaison, Elizabeth Padilla, organized tours of those sites for us. Through the interviews, tours, and exhibit evaluations we learned what kind of educational exhibits are typically found in Puerto Rico. The content we used for our exhibits includes information acquired from our background research of the project, provided to us by the Trust, and gained from the interviews we conducted. We asked for preliminary evaluations of our educational exhibit designs from the members of the Trust that we interacted with during various components of the project. We used their feedback to adjust and finalize the educational exhibit designs. Finally, we developed recommendations for the Trust on how to implement the CAD model and the educational exhibit designs and suggestions that we developed.

Results and Analysis:

In order to convey to the Trust how the mechanical water filters work, we created a SolidWorks model. This model shows the different states of operation of the mechanical water filtration system. Each state of the operation accurately reflects the state of each valve through

color. Our fluid simulations are included in these configurations and clearly show how water flows through the system. We then produced a plan for converting our SolidWorks design into a functioning physical model of the mechanical filters at the Antiguo Acueducto. This design is composed of a SolidWorks model, along with a description and recommendations on how the model can be constructed and run.

For our educational exhibit evaluations and interviews, we visited four sites: Castillo San Felipe del Morro, Castillo de San Cristóbal, Hacienda la Esperanza and Cabezas de San Juan. The first two sites are managed by the U.S. National Park Service, while the last two sites are owned and managed by the Trust. We interviewed park rangers at the U.S. National Park Service sites. At the sites managed by the Trust, we were given tours of the sites and interviewed interpreters. From the interviews we learned that each site has exhibits that help visitors easily navigate the site by their strategic placement. All the exhibits tell a continuous story related to the history of the site. The sites managed by the Trust tell multiple stories simultaneously such as the history of the site, the plants and animals found on the site, and importance of historic and environmental preservation.

Our exhibit evaluations revealed that all of the sites had all of their exhibits written in both English and Spanish. The exhibits at all of the sites also used a lot of bright colors and graphics to help draw the visitors' attention. Most of the exhibits contained a headline and subheadline as identified by Falk (1997). After the site visits, using exhibit evaluations from other historic sites, we came up with the exhibit display designs. Afterwards, we sent the designs and evaluation questions about the educational exhibit designs to the members of the Trust with whom we had worked in some capacity during the execution of our project. After gathering their feedback, we adjusted and finalized our educational exhibit designs.

In order to decide what physical material should be used for the exhibit displays, we identified three different companies that provide these types of materials. Integrating this information with our plans for the spatial layout of the displays, we identified a list of qualities that we suggest should be required from each of the exhibit materials. We then came up with a separate list of qualities that are not exactly necessary but can be useful. Using this list and the list of products and their descriptions from each company, we compared their qualities to our list of required qualities. These comparisons allowed us to make a final recommendation of what product would be best for the educational exhibits of the Antiguo Acueducto.

Recommendations and Conclusions:

Based on our results and analysis, we created various recommendations on how the Trust could utilize the physical model and our SolidWorks design of the existing system.

Our recommendations for the physical model focus on how the model could be constructed and operated. We include information on where parts could be acquired and pricing. We recommend an following our operational procedure that includes all of the operations of the system, and how to properly clean and maintain the system. We also discuss potential problems and how to address them.

For the educational exhibit designs, we recommend that the Trust to pilot-test them with a group of visitors before implementing them. The designs we created were reviewed by a few members of the Trust, but we were not able to gather feedback from potential visitors to the site. We recommend pilot-testing to potential visitors to see how they would react to the educational exhibits. This will give the Trust a chance to make appropriate final revisions to the exhibit designs according to visitor feedback before purchasing the final exhibits. We made recommendations for the type of material that should be used for the exhibit displays, and identified the Trust's best options for actually producing the displays

Our most important deliverables included the SolidWorks design of the physical model and the finalized educational exhibit designs. We hope that our results and recommendations are helpful to the Trust in moving forward with the preservation of the Antiguo Acueducto of San Juan.

1.0. Introduction

Is preservation important to society? Stipe (2003), an expert in design and landscape architecture, argued that not only artifacts, but also buildings, historic sites, and if possible, urban neighborhoods and rural landscapes should be preserved. If historic sites are not properly preserved, they will degrade. People have the opportunity to either preserve these sites that are part of their history and culture, or to replace them with new, contemporary architecture. Historical buildings can maintain their original use. Maintaining these buildings is not only feasible but also a strategy to preserve history. Afterwards, the restored buildings can be used as educational examples or even be made practical for use.

Puerto Rico is rich with history and historical sites. However, just like numerous places around the world, Puerto Rico faces many of the same problems associated with industrialization and expansion. The Conservation Trust of Puerto Rico (the Trust) is an organization that focuses on the preservation of the island. Its goals include preserving a third of the island for the value that it will bring to the community and for tourism. It provides diverse programming for visitors to help foster in them a sense of responsibility toward preserving natural and cultural assets and promoting a conservation culture. Throughout the years, the Trust has engaged tens of thousands of participants through nature immersion activities, volunteer programs and active conservation efforts. It has received numerous awards for its achievements in historical preservation and restoration (The Conservation Trust of Puerto Rico, 2014).

One of the projects the Trust is currently working on, and the subject of this project, is the Antiguo Acueducto de San Juan. The Antiguo Acueducto, which was built in the late 1890's, contains a water filtration system and is located near the botanical gardens of the University of Puerto Rico (UPR). Its construction was ordered by the Crown of Spain in the 1840's. It was built two miles up the Río Piedras from the San Juan water works, which was the primary source of drinking water at the time. The new site, with more advanced technology and cleaner water supply, was to provide improved drinking water to the citizens of San Juan.

Like many of the other sites in Puerto Rico, the Antiguo Acueducto is in need of restoration. It has been abandoned since the 1970's. Over the course of this time, the equipment has degraded and is no longer operational. With the industrialization of Puerto Rico, many

important historical sites have been neglected or replaced. The Trust is trying to inform people locally about its goals for the neglected site of the Antiguo Acueducto. Through this process it hopes to gain support for its efforts. If the necessary steps are not taken to restore and preserve the Antiguo Acueducto, there is a possibility that it may eventually be destroyed. It was our job to work and to collaborate with our sponsor on a portion of the repurposing of this historically important site.

Our project focused on preserving the mechanical water filtration system of the Antiguo Acueducto by demonstrating how it functioned. We evaluated the current condition of the mechanical water filtration system and the area surrounding it. Based on this assessment of the site, other site visits, and interviews with employees of the Trust, we designed educational exhibits that are able to showcase the history and purpose of the Antiguo Acueducto and its water filtration system. We were able to provide the Trust with a proposal for the preservation of the site and the educational exhibit installation. We also designed a working model of a section of the mechanical water filtration system for educational purposes.

2.0. Background

This chapter is meant to discuss and summarize some of the main topics related to the project. These topics include the importance of historical preservation, history of the Antiguo Acueducto, a description of the mechanical water filtration system, importance of water conservation, and background information on our sponsor: The Conservation Trust of Puerto Rico, also referred to as the Trust. The site that we worked on, the Antiguo Acueducto de San Juan, was built for the purpose of water filtration in Puerto Rico. As will be clarified further, the site encompasses more than just the water filtration section. The whole site includes multiple sections such as the dam, the water filtration system and a power house. In the following chapter and project we will be referring to the site as a whole by its title which is the Antiguo Acueducto.

2.1. Importance of Historic Preservation

Historic preservation seeks to conserve and protect historic buildings and sites. A key aspect of preservation is often restoring the site. This paper defines preservation as the maintaining of something in its current state. True preservation implies that the people who use the site not only understand its value but also actively work to maintain it. Preservation is an ongoing process and requires support throughout generations.

2.1.1. History of the Historic Preservation Movement

The question of whether to preserve historical sites has been a popular issue over the last century. As time has passed there has been a growing movement in support of preservation. This support is manifested in many ways, such as legislation, creation of local community organizations, and the strengthening of support of more global organizations.

Preservation and urban planning efforts in the United States date back to the 1800s. Early preservationists focused their efforts on saving prominent sites associated with the founding of the nation (Ryberg-Webster & Kinahan, 2013). The push for preservation came from the belief that historic sites and neighborhoods contribute to a city's sense of place, enhance quality of life and offer unique community character. In addition to cultural value, historic sites largely affect property values as well. Cities that have invested in preserving historic neighborhoods enjoy higher real estate prices. The historic preservation movement has gone through three general

stages: the focus on nationalism in the nineteenth century, architectural treasures in the early twentieth century and environmentalism in the late twentieth century (Ryberg-Webster & Kinahan, 2013).

While historic preservation in the U.S. has had support from citizens for over one hundred years, it is only more recently that it has gained the support of the government. Many legal battles have been fought with the government over preservation. One of the earliest examples of one such battle was *Berman v. Parker*. *Berman v. Parker* is a Supreme Court case involving eminent domain. Eminent domain is the taking of private land by the government for public use (Barros, 1954). Berman and his associates owned a department store in a dilapidated neighborhood in Washington DC. When the District of Columbia Redevelopment Act was passed in 1945, the department store was to be demolished as part of the plan set by the act. The area in which the store was located was blighted, and was considered unfit for human habitation. The Act's goal was to beautify the city by removing and redeveloping the area. Despite the poor condition of the neighborhood, the department store was a successful business and in good condition. Berman argued that even though the area was in poor condition, the city had no right to take possession of his store because it was not part of the blight. In the end, the Supreme Court ruled against Berman and the store was taken (Barros, 1954). Although the site had no historical significance, this case was an example of the unchecked power of eminent domain. It exemplifies the federal government's power over private property regardless of the value the property has to individuals or a community. This case, amongst others, began a movement to change the way that the federal government treated individual sites. (Ginsberg, 1971).

As the number of these cases of eminent domain began to grow, preservation campaigns started to appear across the country. One of these campaigns was the popular "Save Grand Central" movement (Brian & Landsberg, 2006). In 1963, Penn Central Transportation established a plan to build a skyscraper atop Grand Central Station (Collins, 1978). In 1963, there was backlash almost immediately to the plan and support to stop the construction grew quickly. Prominent people such as former First Lady Jackie Kennedy and famous architect Philip Johnson joined the fight and had a huge impact (Collins, 1978). Kennedy petitioned the mayor of New York at the time to appeal the decision to build the skyscraper. He did and the appeal was taken all the way to the Supreme Court. The Supreme Court decided that the station was a historical site and could not have the addition. A large part of this victory was due to the vast

amount of public interest which impressed the Court Justices at the time (Kaplan, 1998). The fervor and impact of Kennedy's support earned her a dedication of a part of Grand Central Station in her name so that her efforts to "Save Grand Central" would never be forgotten (Juva-Brown, 2014).

As a result of these cases, along with numerous others and the growth of the preservation movement in general, the United States Congress passed the National Historic Preservation Act in 1966. The goal of this act was to prevent destruction or mistreatment of historical sites by the federal government, as well as to help incentivize the preservation of these sites by private developers. The act created the National Registry of Historic Places and the State Historic Preservation Office (Ginsberg, 1971). By being a part of the Registry, sites receive several benefits (Brophy, 1996). First, they are designated as official historical sites and can be officially represented in that way. Second, after a site is put on the registry, it cannot be destroyed, renovated, or changed in any way using any federal funding without the permission of the Advisory Council of Historic Preservation, which oversees the Registry (Brophy, 1996). However, by being on the list, a site can be eligible to receive special funding for preservation. This funding comes from the Advisory Council of Historic Preservation. Funding can come from either the Council's funds, which are allotted to them every year, or from special grants that are created by the federal government. One such grant was the "Save America's Treasure" grant that was strictly provided to National Registry sites. The final benefit of being on the Registry is that private owners of a site can receive substantial tax breaks (Brophy, 1996). These include a general tax break for the upkeep and preservation of the site as well as a 20% investment tax credit on income-producing properties such as exhibits with paid entry. Generally tax breaks similar to these are designated for not-for-profit organizations. However, in the case of National Registry sites, the tax breaks apply to even for-profit sites. The aim of the registry is to encourage private ownership and investment in historic sites and at the same time to limit the power the federal government has to cause damage to or destroy these sites (Brophy, 1996).

The Advisory Council of Historic Preservation is the group that oversees the registry and the regulations regarding it. They are in charge of deciding what sites are placed on the registry as well as where any federal funding is directed. The council has 17 members including the Secretary of the Interior, the Secretary of Housing and Urban Development, the Secretary of

Commerce, the Administer of the General Services Administration, the Attorney General, the Chairman of the National Trust for Historic Preservation, and ten members appointed by the President of the United States. These final ten members are appointed from outside of the federal government. They are usually representatives from state and local governments that have an interest and experience in matters related to the council. This helps to bring in a more local view of these sites and to achieve the goal of having less interference by the federal government (National Preservation Act, 1966). The historic preservation movement in the U.S. has led to the creation of many preservation organizations. One such organization that came out of the movement was the National Trust for Historic Preservation (NTHP). It is a privately funded nonprofit organization that works to save America's historic places with the help of local preservation groups and preservation professionals (Goodman, 2012). Nationally historic preservation has continued to gain support. Membership in the National Trust for Historic Preservation grew from 330 people in 1950 to 230,000 in 1991. Since 1976, approximately 22,000 historic buildings have been preserved through federal income tax incentives. The National Register of Historic Places, which was started in 1967, now incorporates 800,000 historic properties. Every year, federal agencies survey six million acres of land for archeological resources and identify new sites (Baer, 1995).

The creation of historic districts has become a common way to preserve historic buildings and neighborhoods. It is a way to preserve a collective built heritage. According to the National Register of Historic Places, in the United States there are approximately 2,300 local historic districts that are created and administered by local governments and administrators (Heintzelman & Altieri, 2013). The National Trust for Historic Preservation considers that such local measures accomplish five things: they provide a municipal policy for the protection of historic properties, establish an objective for designating historic properties, protect the integrity of designated historic properties, authorize design guidelines for new development within historic districts and stabilize, protect and enhance declining neighborhoods. Historic designation and subsequent preservation provides a public good. It protects properties or buildings of historic significance that have a unique character or architecture that the public wishes to see preserved (Heintzelman & Altieri, 2013).

Experts in historic preservation have offered many reasons why it is important to preserve the past. For example, Stipe (2003), an Emeritus Professor of Design at North Carolina State University, offered seven main reasons why historical preservation is important. The first two reasons emphasize that we live in historic and architectural heritage, and our culture has been measurably affected by that history. The third reason is that we live in an age of communication and increasing cultural homogeneity, which makes it difficult to maintain individuality and personal identity. Fourth, historic sites and structures are related to past events, eras, movements and people that we honor and seek to understand. The preservation of these sites is a demonstration of our respect for the past, and is often motivated by impulses such as nostalgia and patriotism. Fifth, we preserve historical architecture and sites simply for their value as art. If we valued historical structures the same way we value other works of art, much unwanted destruction could be avoided. Sixth, the structures of our past make our cities and countryside more beautiful. The past is unique, beautiful, historically important and architecturally significant and cannot be easily replaced with contemporary structures of equal aesthetic value. The seventh, and the most important, reason is that preservation can be used to serve human and social purposes in our society. Preserved historical sites play a role in society by helping to teach future generations about their history and culture (Stipe, 2003).

Around the world, there are numerous organizations focusing on historical preservation. These organizations range from those that operate globally to preserve sites of international importance, to those that operate locally to preserve sites that are historically important to the regions in which they occur. The United Nations Educational, Scientific and Cultural Organization (UNESCO) is an example of a preservation organization that operates on the broadest geographic scale. It seeks to encourage the identification, protection and preservation of natural and cultural heritage everywhere around the world. It considers natural and cultural heritage to be of outstanding value to humanity. Its mission statement encourages international cooperation and local participation in the conservation of the world's cultural and natural heritage. A World Heritage Site is a place that is considered to be of special cultural or physical significance by UNESCO. The list of World Heritage Sites could include a forest, mountain, lake, island, desert, monument, building, complex, or city. The organization provides emergency assistance for any World Heritage sites in immediate danger, located anywhere around the world (Cane, 2008).

Local preservation organizations are maintainers and preservers of historic sites and neighborhoods. These organizations have the biggest impact when the following two conditions exist: clearly written guidelines for affected properties and active educational outreach to the real estate community (Gordon & Vaughan, 2012). A fully staffed local preservation organization can maintain these two conditions. One of the roles of a local historic preservation organization is to provide additional important information to the local community about the nature, and significance of the structures located in a historic site and district. It provides this additional information by expressing the importance of the local historic sites to the community. Local preservation organizations can lead to a national designation for a site, such as the National Register of Historic Places, a listing that which comes with tax benefits. A tax benefit that comes from a designation is a federal tax credit used for the rehabilitation and maintenance of the designated properties (Gordon, & Vaughan, 2012).

There are numerous national and local preservation organizations around the world. Some of the most prominent local and national preservation organizations in the United States include the National Park Service, the National Trust for Historic Preservation and the California Preservation Foundation (Office of Historic Resources, 2014). The National Park Service is a bureau of the Department of the Interior of the United States. Its main role is the supervision, management, and control of the national parks and monuments, which are under its department's jurisdiction (Cameron, & Jenks, 1922). The role of the National Trust for Historic Preservation is to help more local preservation organizations, individuals and government agencies around the United States. It was created with the intent to acquire and operate historic properties and sites. It is one of the main examples of preservation and restoration methods nationwide. The National Trust for Historic Preservation was created to be the practical demonstration of historic preservation (Thompson, 1966). The California Preservation Foundation is an example of a state-level preservation organization. It ensures that California's historic resources are identified and protected. Their goal is for historic resources to be celebrated for the valuable role they play in California's economy, environment, and quality of life (California Preservation Foundation, 2014). The organization we are currently working with, the Conservation Trust of Puerto Rico, is very similar to the preservation organizations listed above. It is the main organization working on historic preservation on the island of Puerto Rico.

2.2. The Conservation Trust of Puerto Rico

The Conservation Trust of Puerto Rico is a private, non-profit organization whose mission is to secure functional and healthy ecosystems in Puerto Rico (The Conservation Trust of Puerto Rico, 2014). The Trust carries out its mission by acquiring natural areas and historic sites to be protected. Among habitat and species restoration initiatives, they also work with the rehabilitation of historical landmarks. Part of the Trust's mission is to develop educational programs to garner general public support and awareness. Additionally, the Trust has implemented a plan to reverse the loss of natural areas in Puerto Rico which consists of three main goals: to have 33 percent of Puerto Rico's land to be protected by the year 2033, to provide diverse programs for visitors to help them foster a sense of responsibility towards their natural and cultural assets and to develop and support environmental policies that seek Puerto Rico's economic prosperity.

The Trust was founded in 1968 during a time when Puerto Rico's economy was going through a period of modernization and industrialization (The Conservation Trust of Puerto Rico, 2014). This placed a heavy burden on the island's natural environment, with urban sprawl and deforestation among other factors taking a toll on the natural resources. Throughout the years, the Trust has engaged thousands of participants through nature immersion activities, volunteer programs and active conservation efforts. It has received numerous awards and recognitions for its achievements with protecting and restoring nature and historical preservation and restoration along with its excellence in educational programming (The Conservation Trust of Puerto Rico, 2014).

As the main organization focused on environmental and historic preservation in Puerto Rico, the Trust has divided up the island into 5 distinct regions and labeled them according to their cardinal direction: Northern, San Juan-Central, Southern, Eastern and Western Region. Each region has a designated protected area as its operational headquarters.

An example of historical restoration in Puerto Rico is located in the San Juan-Central region and is actually the current home of the Conservation Trust of Puerto Rico. The site is called the Casa de Ramón Power y Giralt. It was named after a historically important naval captain who, in the early 19th century, advocated for parliamentary representation for Puerto Rico

in Spain. He was also the first Puerto Rican to sit on the court in Spain and one of the first of his people to refer to themselves as Puerto Rican (The Conservation Trust of Puerto Rico, 2014). The importance of the restoration of Casa de Ramón Power y Giralt is that it is the home of the largest organization in Puerto Rico in charge of preservation. In the spirit of Ramón Power and what he did for his country, it is the perfect place for this organization to be based. It is a microcosm of what the Trust stands for and symbolic of their mission. As well as serving as the Trust's headquarters, the house is also a museum about Ramón Power and his importance to the island (The Conservation Trust of Puerto Rico, 2014).

2.2.1. Para la Naturaleza

One of the focuses Para la Naturaleza, which is of a department of the Trust, is historical preservation on the island (The Conservation Trust of Puerto Rico, 2014). Some of the sites they have worked on restoring include Hacienda Buena Vista, Hacienda La Esperanza and Cabezas de San Juan.

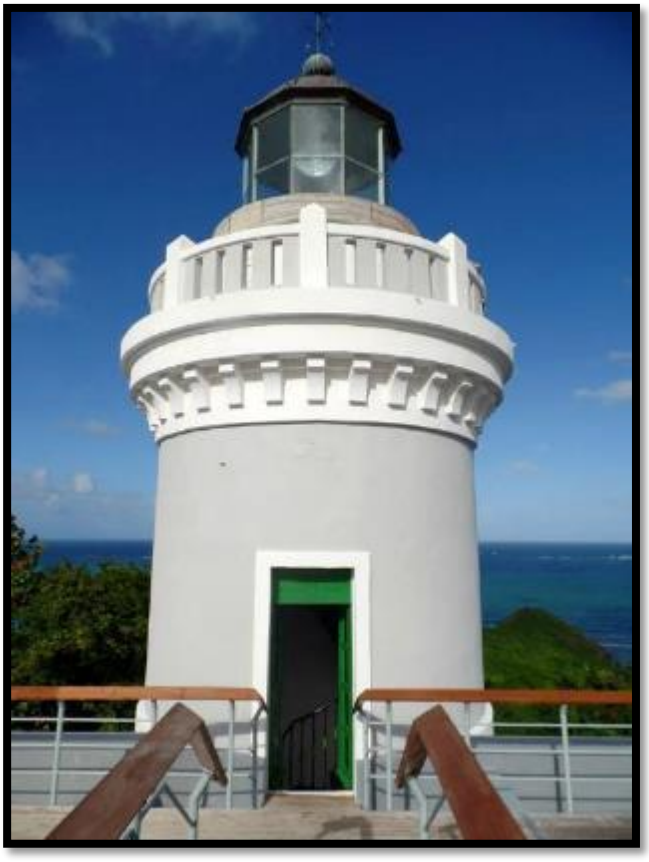


Figure 1. Lighthouse at Cabezas de San Juan.

In September 1987, Hacienda Buena Vista became the first site the Trust opened to visitors, and now has an estimated 40,000 visitors on a yearly basis. The Trust has designed interpretive walks and trails around the site for the educational and recreational use of the public. The American Society of Mechanical Engineers designated the hydraulic turbine at Hacienda Buena Vista as a historical monument in 1994 (The Conservation Trust of Puerto Rico, 2014).

Hacienda La Esperanza is a protected area in the municipality of Manatí, which is located in Puerto Rico's northern region (The Conservation Trust of Puerto Rico, 2014). Hacienda la Esperanza contains a diverse natural environment with ten different types of ecosystems, including four types of forests, three types of wetlands, two important river estuaries and vast alluvial plains. It also features a coastline that stretches over three kilometers. It was formerly one of the largest, most technologically advanced and successful sugarcane haciendas in Puerto Rico. Currently the site includes a refurbished Manor House and its original sugar mill constructed in 1861. All of this was restored by the Trust. They acquired the property in 1975 and it currently serves as an important ecological, historical and archeological research laboratory for history and biodiversity. The main goal guiding the programs of the location is to provide visitors with unique learning experiences that communicate the importance of ecological and historical conservation and to transform their beliefs into conservation actions within their own communities and beyond. Hacienda La Esperanza as well has interpretive walks through ecological trails which provides a diverse nature immersion experience (The Conservation Trust of Puerto Rico, 2014).

Figure 2. Manor at Hacienda la Esperanza.

The purpose of the restoration of the Hacienda la Esperanza was to raise awareness of preservation of the environment and historical sites. The site of the sugar mill, which was the focus of a previous WPI project, was gifted to the Conservation Trust of Puerto Rico and is part of their drive to preserve vast amounts of the island. As part of that project, the team informed the community about the site to help grow interest and support for the restoration. A representative of the Trust mentioned that they consider the project and site to be a success (E. Padilla, personal communication, September 16, 2014). Sugar is an underemphasized aspect of Puerto Rico's history and by emphasizing its importance through this restored site, it is possible to attract diverse groups of people (Bumila et al, 2013).

2.3. History of the Antiguo Acueducto

One of the projects that Para la Naturaleza is currently working on is the Antiguo Acueducto, which directly translates to the "Old Aqueduct". This site is located on the Río Piedras right within the Botanical Gardens.

Aqueducts, manmade conduits used for the transportation of water from one location to another, were originally designed, built, and used by the Ancient Greeks, Egyptians, and the Romans. The Romans in particular were considered to be the greatest aqueduct builders of the

ancient world, with their elaborate system that served the entire capital of the Roman Empire. The city originally depended on nearby resources for its water supply. However, as the surrounding city continued to grow, they needed to locate other sources to meet the cities new requirements. This is when they designed the aqueduct system. This particular conduit design achieves a regular and controlled water supply from a location with an abundant amount of water to another location that could not have received an adequate amount of water. This allows for the neighboring area to meet basic needs such as the irrigation of crops and drinking fountains. Aqueducts also allow the surrounding community to live farther away from sources of water and to utilize more land, which would otherwise have been unusable for agriculture (Martini, 1976).

Figure 3. Example of an aqueduct built by the Romans (Andrews, 2012).

The earliest aqueducts, built both above and underground, were first constructed by the Romans around 312 B.C., and were entirely of stone lined with mortar. The Romans eventually learned to make concrete and used that instead. Figure 3 above shows an example of one of the original aqueducts built by the Romans. Since the early Renaissance era, major advances in public water systems included the refinement of pumps and pipe materials, which were then used in the construction of future water systems such as aqueducts. The introduction of steam pumps and the development of pressurized systems during the 18th and 19th centuries was a major advancement for the aqueducts. Without the new steam pump systems, the free-flowing systems had to uphold certain gradients over the assorted terrain. This is because the water flowed by the

force of gravity alone. Once the steam pumps were introduced, the systems could be built following the contours of the land (Howatson, 2013).

The Antiguo Acueducto contains a water filtration system and is located within the grounds of the University of Puerto Rico (UPR) Botanical Gardens in the Río Piedras section of San Juan. The construction of the water system for the city of San Juan was ordered by the Crown of Spain and was completed between 1896 and 1900, although the official planning for it began in 1847. Engineer Juan Manuel Lombera proposed the initial design.

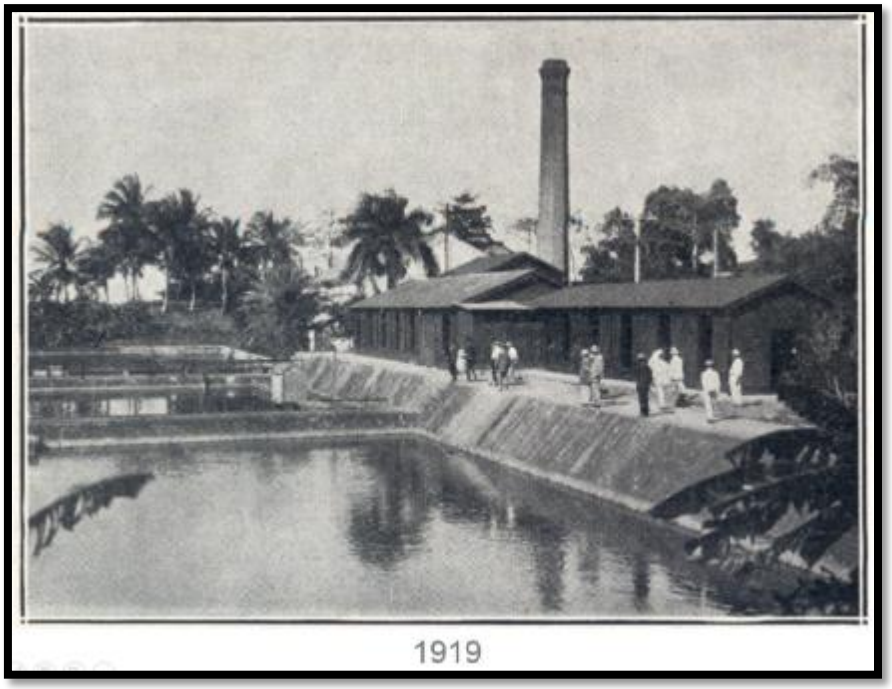


Figure 4. Picture of the site of the Antiguo Acueducto in 1919.

The site was acquired in 2005 by the Conservation Trust of Puerto Rico. It is part of the 29,000 acres of wildlife sanctuaries currently protected by the Trust, which marks the importance of urban planning and management of environmental resources in San Juan (Fideicomiso de Conservación de Puerto Rico et al., 2011). The particular site of the Antiguo Acueducto covers an area of 24 acres. Para la Naturaleza manages nine of them. The site of the Antiguo Acueducto includes a machine room, a house for employees and two open water tanks. Between 1917 and 1918, mechanical filters were designed and installed within the Antiguo Acueducto. After that it supplied water to the boot camp of the first Puerto Rican soldiers who participated in the First World War. The Antiguo Acueducto promoted the growth of the city along its main line and

through its branches to other neighborhoods throughout the city. Figure 5 below contains an image of the site of the Antiguo Acueducto after it has been acquired and cleared by the Trust.

Figure 5. Picture of the site of the Antiguo Acueducto after initial changes made by the Trust.

2.4. The World Water Crisis

One of the most vital resources to human life is water. Over the course of the last century, human water usage has increased at more than the twice the population growth rate. Due to the increases in both water usage and the human population, about one third of the world's population lives under moderate to high water stress, meaning that individuals experience limited access to water resources (UN, 1997).

The increasing strain of population growth and increased usage causes the shortage of clean usable water. Currently, 1.2 billion people do not have access to clean drinking water, nearly half of the world's population lacks proper water purification and 2.4 billion people have no access to basic sanitation facilities. The danger of not having clean water and basic sanitation facilities is vulnerability to disease. The majority of illnesses around the world are caused by contaminated water and lack of sewer treatment. Contaminated water causes disease such as cholera, dysentery, typhoid, trachoma and intestinal worm infections. These diseases are often life threatening to children under the age of five years old (Singh, 2008).

The scarcity of clean water limits economic and social development (Singh, 2008). Water is not only needed just for drinking. It is also used for many household purposes, agriculture, manufacturing goods, food processing, and power generation. Much of the world's water pollution is caused by industry, agriculture and other human activities. The world economy and, in particular, the economies of developing countries, feel the adverse effects of looming water scarcity, effects of environmental pollution and global warming on water availability. It is imperative that existing water resources are protected and advanced water treatment processes are invented and used to provide potable water. To achieve this goal, international agencies and the government need to take measures that include water management and conservation, the prevention of water supply degradation in lakes and rivers, rain water harvesting and desalination (Singh, 2008). Shown in Figure 6 below is an infographic of the world. It shows with percentages of the population in each country around the world with access to clean drinking water. While for some countries, clean drinking water is granted, there are countries in the world that consider it a luxury and have very limited access to it.

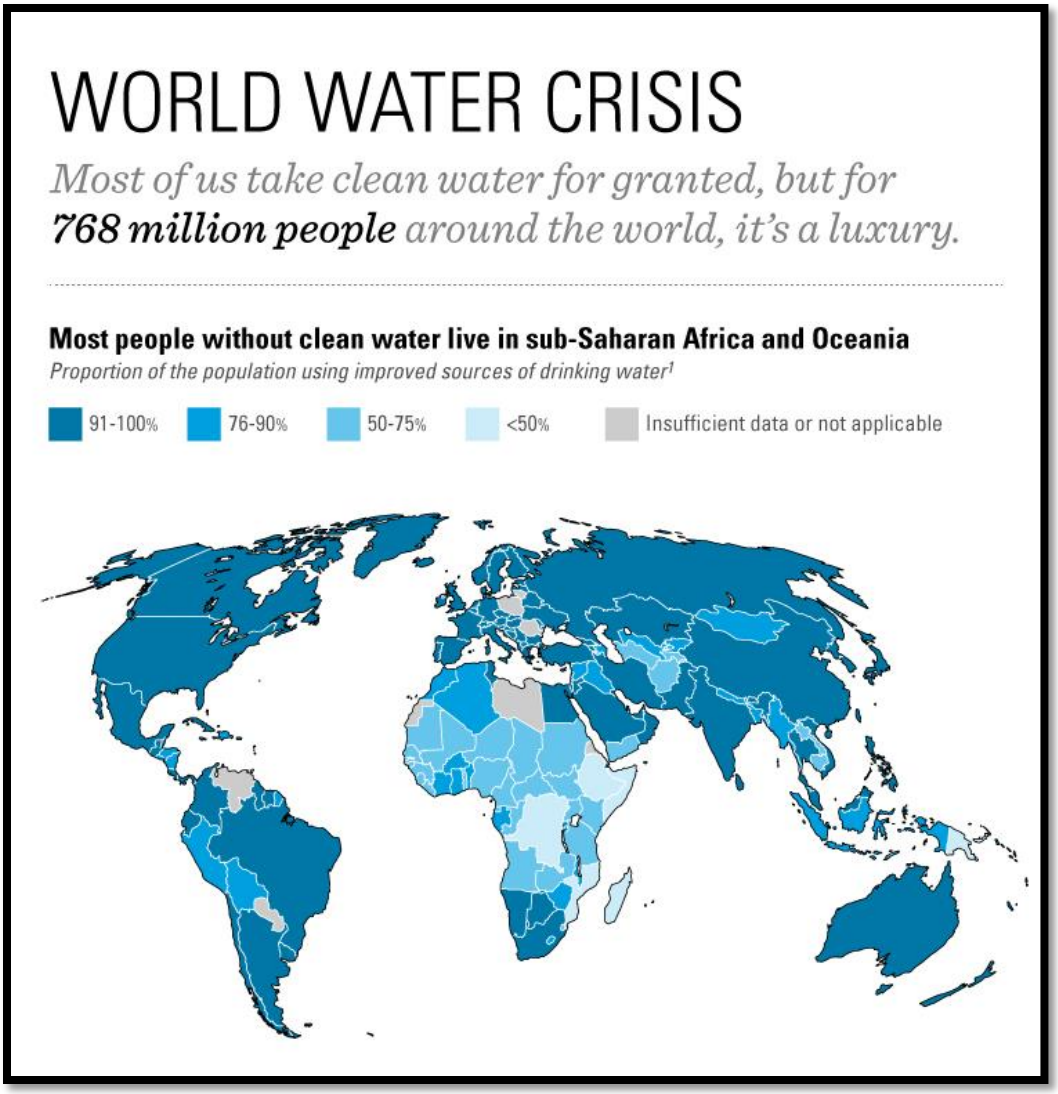


Figure 6. Infographic: World Water Crisis. The map shows the proportion of the population using improved sources of drinking water. (1) Improved sources of drinking water include public taps or standpipes, tube wells or boreholes, protected dug wells, protected springs, rainwater collection, or piped household water connection located inside the user's dwelling, plot or yard (UNICEF, 2014).

By using fewer resources, as well as using them more efficiently, a society can be more sustainable. Energy and water are two resources that are very different from other consumer goods. This is because they are necessary for life today and are supplied by large technical systems. For example, in areas of high population density, water is typically delivered through an urban water and sanitation system (Krantz, 2011). The system is a widespread pipe-bound network, which contains a centralized treatment and professionalized management. In Britain, these systems were originally developed in the second half of the 19th century. In most cases, the defining moments for their development were events such as a cholera epidemic or a

breakthrough in technology. The cause for a major increase in pace of the development of these systems in Britain was mostly in response to public health acts enacted in the late 19th century. One such act was the Public Health of 1848. It legislated the sanitary conditions of England and Wales. It is considered as one of the great milestones in the history of public health. The act established a General Board of Health, which was empowered to create local boards of health when petitioned to do so by at least one tenth of the tax payers in a district. The act also legislated the process to be triggered automatically when the national average mortality rate exceeded the rate of 23 out of 1000 over a period of seven years (Fee & Brown, 2005).

Beginning in the 1970s, in the United States, municipal wastewater treatment plants were established on a large scale. This was a result of the increase of uses of water other than drinking and cooking in the home. Currently in the US, household water is largely used for domestic and personal hygiene while a much smaller volume is used for cooking and drinking (Krantz, 2011). In a typical western-style household, 49.4% of the total water used goes to landscaping or other outdoor uses, with shower and bath following in second place at 13.8%. Cooking and drinking take 2% out of total water used. Showers and baths use approximately 49 liters of water per person per day and consume 30% of indoor water use. The biggest factor in urban water conservation is high storage, transmission and delivery loss rate of up to about 55% (Goosen & Shayya, 2000).

2.5. Basic Principles of Water Treatment

Clean water is important to any city. Without it, citizens could be exposed to disease and sickness from drinking contaminated water. Many pathogens, such as those that cause giardia and typhoid fever, can be transmitted through public water supplies (S.A.H.T., 2003). It is the responsibility of the city to remove these pathogens and provide clean water to its citizens (Hill, 1898). According to the S.A.H.T. (2003), “Access to safe drinking-water is essential to health, a basic human right and a component of effective policy for health protection”.

Water treatment technology advanced rapidly in the late 1800s (Fuertes, 1901). One driver was the rapid expansions of cities. The 1890 US census describes the growth of US cities as “amazing”, reporting that multiple cites quadrupled in size (Census Office, 1890). This created a great burden on the existing water supply systems, at a time when cholera and typhoid

were very real threats. At the turn of the century a new mechanical filter was developed. These new filters drastically improved efficiency, and allowed water treatment plants to be much smaller. They would also prove to be ideal for city of San Juan's new water treatment plant (Hill, 1898).

2.5.1. Water Filtration Specifics Related to the Antiguo Acueducto

In 1901, the primary source of water in Puerto Rico was the San Juan water works. While the quantity of water supplied was sufficient, the quality was not. The water was taken from the Río Piedras at a point that was very muddy. In addition, the river ran through densely inhabited areas which were used for cattle grazing. This caused the water to not only be murky, but also unsafe to drink. A new water supply was needed (S.A.H.T., 2003).

The new facility, now known as the Antiguo Acueducto de San Juan, was to be two miles up the river where the water was much cleaner. Here the water flowed through unused land that was ill suited for cattle grazing, so bacterial pollutants would be kept to a minimum. In addition, the river bed was rocky which made the water much clearer. This new site, along with more advanced technology, would provide ample, clean drinking water to the citizens of San Juan (Governor of Puerto Rico, 1901).

The Antiguo Acueducto de San Juan employed a treatment method now referred to as "conventional treatment" (Huben, 1991). This method uses chemical-aided sedimentation, as well as mechanical filters, to purify water. The Antiguo Acueducto draws water from the Río Piedras, which first flows to dousing chambers. Here a chemical called alum is added. This helps to bind small particles together to form flocci. As the water flows through the sedimentation beds, these flocci, which are denser than the water, drift to the bottom. The Antiguo Acueducto has five sedimentation tanks. They are large open topped tanks, not unlike swimming pools. Water flows slowly through each, causing any large contaminants to fall out of suspension, and remain in the tank.

Next the water is pumped into the mechanical filters. As mentioned previously, these filters were developed only a short time before the Antiguo Acueducto was built, and were still considered to be experimental at the time they went into use at the Antiguo Acueducto (Fuertes, 1901). The Antiguo Acueducto has nine high pressure sand filters. These work by forcing water

through sand, which traps the particulates too small to be caught by the sedimentation beds. This is the same principle that was used in previous filters, however, these filters operate at a much higher flow rate. As a result, this causes them to become fouled very quickly, sometimes in as little as 16 hours (Arnold, 1999). In previous filters, the sand would have to be removed, and new sand added. The innovation of the mechanical filter is that the sand can be quickly "washed", and returned back to use (Hill, 1898). This "backwashing" can take as little as 30 minutes and restores the filter to a clean condition (Murcray, 2006).

2.6. Current State of the Antiguo Acueducto

The Antiguo Acueducto currently faces the issue that it is no longer being utilized or maintained. Because of this, the Army Corps of Engineers submitted a new proposal for the construction of a canal through the area where the Antiguo Acueducto currently stands. In order for this not to occur, the Antiguo Acueducto needs to be restored. Unfortunately, there has been a halt to its restoration for the past ten years (Colon, 2012).

Starting in the 1970s the Antiguo Acueducto became obsolete and fell out of full working order. In the 1980s the Antiguo Acueducto stopped functioning as the main source of drinking water for San Juan (Fideicomiso de Conservación de Puerto Rico et al., 2011). Because of this the original reservoirs of the Antiguo Acueducto were filled and the Antiguo Acueducto itself was forgotten. The majority of the buildings within have broken or damaged roofs, along with no windows or doors. The settling tanks have been filled with soil but their stone walls are still visible. Many of the metal tanks and pipes have rusted, and many valves are beyond repair.

Due to the lack of maintenance and the extent of the deterioration, many of the components of the Antiguo Acueducto need to be fully replaced. The dam that diverts the water, which was originally built in the 1950s to augment the supply of the Antiguo Acueducto, has broken and crumbled. The fireplace and engine room of the Antiguo Acueducto are the only main sections still intact (E. Aponte, personal communication, November 4, 2014).

The Antiguo Acueducto's current state, and complex and undocumented past presents numerous complex challenges. These challenges include the extensiveness of disrepair and the lack of documentation of work done in the past 50 years. Not only should the Antiguo Acueducto be restored, but also other things should be improved upon such as site access and the

support of local organizations and businesses (Fideicomiso de Conservación de Puerto Rico et al., 2011). The definitive goal for the Conservation Trust of Puerto Rico is that the Antiguo Acueducto will eventually be fixed, maintained, and open to the public as an educational exhibit. The Trust is currently planning to raise $10 million for its restoration. In order to make this happen they plan on garnering the support of the local community.

2.7. Creating an Educational Exhibit

Exhibits are valuable tools for presenting information to viewers. Whether it is for a museum, an exposition, or a class project, exhibits provide a way to inform an audience about a subject and hopefully create an interest. This section focuses on the preparation and design of an educational exhibit.

Findings from a study about museum exhibition design suggest that when museums develop exhibits they should be clearly and explicitly designated for visitors (Falk, 1997). The study investigated an exhibition design assumption. The assumption was that visitors develop conceptual understanding of a science topic after utilizing a cluster of conceptually related exhibits that lacked explicit concept labeling. Two different clusters of exhibits were investigated. Both were assessed under two treatments: with and without explicit labeling that inform visitors of the intended conceptual messages. Under the first treatment, there was no explicit labeling that defined to the visitor the main concept the cluster was trying to communicate. This treatment represented the exhibit cluster that was at the time installed in the museum. In the second treatment, every label contained a "headline" and "subheadline". After surveying the visitors, it was concluded that the second treatment was more successful at conveying the information. The responses to questions about what the exhibit was trying to tell were more elaborate and accurate. The average amount of time the visitors spent looking at each exhibit ranged from 2 to 4 minutes. The study concluded that visitors can acquire both factual and conceptual information as a consequence of brief interactions. Factual information focused on the facts presented by each individual exhibit. Conceptual information was the main concept that the exhibit cluster was trying to convey. For example, in an exhibit focused on transportation, the conceptual information would focus on the main concepts about transportation while factual information would give data about transportation. The concept is what links the exhibit clusters together. The study reached this conclusion after evaluating a group of people

before and after each treatment. The amount of time spent at the exhibits, the responses to the surveys, race, age, and gender were the key aspects used for the evaluations. The learning should be facilitated by explicitly and repeatedly displaying the conceptual messages that are to be communicated. Labels should be provided at each exhibit element that contains a headline and a subheadline. The headline is a brief summary of the main message and the subheadline is a brief description of the headline of the individual exhibit element. According to the study, this appears to be a successful way to facilitate conceptual development. In order to facilitate conceptual development, exhibit elements within an exhibition should include reinforcing messages as often as possible. The reinforcing messages should be the headline and subheadline that keep reminding the visitor what the main topic is. The presence of consistent conceptual organizers on every exhibit element facilitates comprehension of the exhibit messages (Falk, 1997). Figure 7 below is an example of an educational exhibit that has a headline and subheadline. The headline is the main topic that the exhibit is going to focus on, which in the case of Figure 7 is "Powder Magazine". The subheadline is what informs the visitors which aspect of the main topic (headline) the exhibit is focusing on, which in the case of Figure 7 is "Lifeblood of the Artillery".

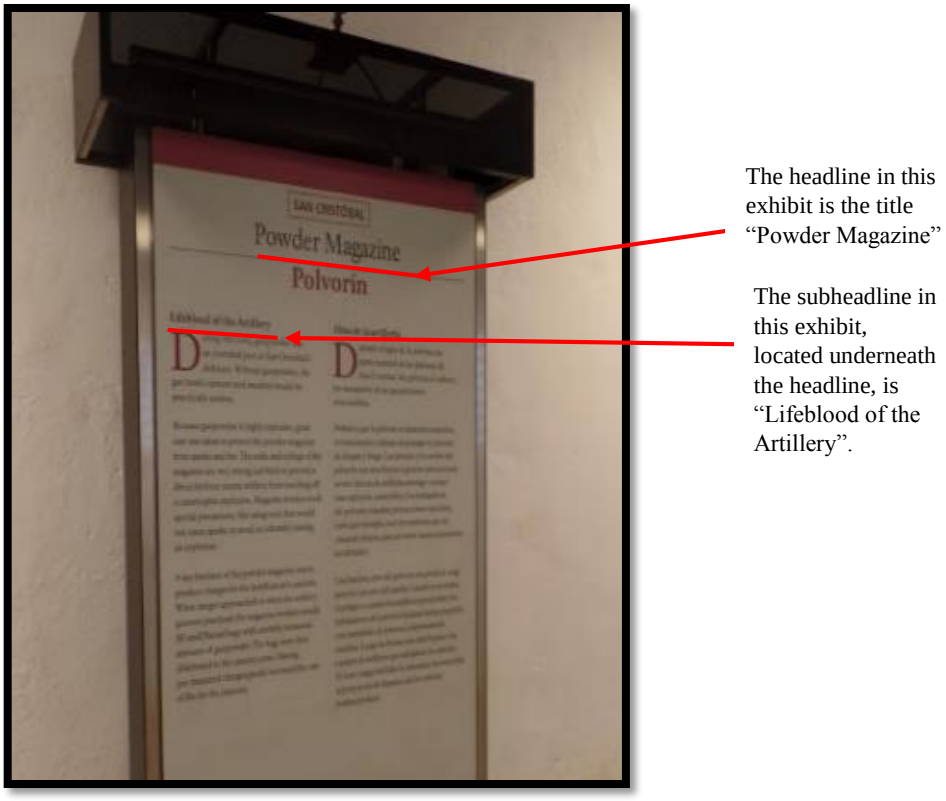


Figure 7. Educational exhibit example from Castillo de San Cristóbal.

According to Falk (1997), the main message of an exhibit is most effectively conveyed through a story. A story is used in order to engage an audience and to cultivate interest. It tells what the exhibit is about and why the audience should care (Boyd, 2011). The mode of presentation significantly influences the story (Schittich, 2012). The type of dramatization, the selected colors and materials, the lighting design, explanatory graphics, and the compilation of exhibits greatly influence how visitors comprehend an exhibition. A conceptual central theme is of particular importance because it helps contextualize or group objects according to their topic. This helps build a story and create suspense which captures the audience. The best option to tell the story depends not only on the particular situation and the subject but also on the purpose and function of the exhibition. For example, an exhibition on opera would call for a different concept than a museum for the automotive industry (Schittich, 2012). An example of a story being told by an educational exhibit is a project done by a group of students in Puerto Rico last year. The project was about a sugar mill located on the Hacienda la Esperanza site. The students created an exhibit and told the story of the mill as well as the history of sugar in Puerto Rico. Sugar is an

important component of the history of Puerto Rico. By linking the history of the sugar mill to the overall history of sugar production and slavery in Puerto Rico, the students created a story about the importance of the Hacienda la Esperanza site to Puerto Rico today. Representatives of their sponsoring organization, Para la Naturaleza, spoke highly of the project and considered it a success (E. Padilla, personal communication).

Figure 8. Sample design of educational exhibit from Hacienda la Esperanza (Bumila et al., 2013).

The students chose to write the story in the way that would reach the people and the Puerto Rican culture. Their final designs for the educational exhibits focused on the mill technology and the slavery in sugar mills, particularly in Hacienda la Esperanza. Figure 8 above presents one of the sample designs proposed by the students last year. The design has text in both English and Spanish. It also uses images to help communicate to the visitors the content presented in the exhibit. The topic this particular exhibit focuses on is the slavery in sugar mills because Hacienda la Esperanza used to have many slaves while it was operational. Exhibits like this one help people realize the importance of the mill and the complex history of sugar production in Puerto Rico (Bumila et al., 2013).

Another key component of a successful exhibition is the aesthetic design of displays. When design fails, people will react to it negatively, regardless of how beautiful or important the contents are (Dean, 1996). Designing exhibitions requires arranging the visual, spatial and material elements of an environment into a composition that visitors move through. Quality

exhibitions require a high degree of development and design. A well-founded knowledge of design basics can foster an organized approach to exhibition design. Six main elements for basic exhibit design can be identified: value, color, texture, balance, line, and shape. Value is the quality of lightness or darkness and is associated with visual weight characteristics. For designing purposes, values are important for emphasis and orientation. Color is perceived through the filter of perception and is ascribed meanings. Characteristics attributed to color relate to associations. Texture is the visual roughness or smoothness of a surface. Balance is defined as the quality of visual weight distribution. Line is the quality of linearity and gives a strong directional content to composition. Lastly, shape is the element of physical or spatial containment. Contrasting, joining, overlapping, and mixing shapes makes the composition more interesting visually. Experimenting with and observing the design elements helps produce the most useful designs (Dean, 1996).

2.7.1. Interactive Exhibits

When making decisions on the design of an exhibit, determining whether it should be interactive versus non-interactive is one important step. Interactive exhibits can be defined as a device in which the visitor's response to the exhibit produces some sort of change. Not only does the exhibit include mental interaction, but also it includes physical interaction as well. The interactive part of an exhibit can be as simple as pressing a button that lights up a specific area, or something as complex as a high-tech interactive computer system (Bitgood, 1991). Although more work and money may be needed for creating an interactive exhibition, it provides several benefits including increased interest in the topic and an increase in visitors. If interactive exhibits are well-designed, they can be highly effective and become quite popular.

There has already been research establishing that interactive exhibits attract and capture visitor attention for longer periods of time versus exhibits that are not interactive (Morrison et al, 1984). For example, a study was performed on visitors at the Reuben Fleet Science Center in San Diego, California to test the average time they spent at each exhibit. It was determined that the visitors spent nearly three times the 30 second average reported by museums with non-interactive exhibits (Sandifer, 1997).

Four main characteristics of interactive exhibits were recognized and observed by Sandifer (2003), a professor at Towson University. These four characteristics include technological novelty, user-centeredness, sensory stimulation, and open-endedness. Two of these characteristics, technological novelty and open-endedness, help to account for the change in the average visitor holding time. Both of these characteristics have positive correlations with the amount of time the visitors spend at the exhibits. Technological novelty is important because visitors tend to spend more of their time at exhibits with innovative phenomena, and this is due to the fact that novelty is a big factor in task engagement and intrinsic motivation. The visitors of a site also seem to take advantage of open-ended exhibit activities when given the chance to do so. If a visitor is given the opportunity to be involved with the exhibit, there is a larger chance that they will call over others to also perform whatever activities the exhibit provides (Sandifer, 2003).

There are five major pitfalls that may come into play when designing and utilizing an interactive exhibit (Allen & Gutwill, 2004). The first is that if there is more than one interactive feature involved, the display could become overwhelming. Some features that could possibly make an exhibit overwhelming include multiple elements, no priority to the elements, different possible combinations, no obvious area where the interactive phenomenon is occurring, and no priority in the label. The second drawback is that interactivity by more than one user at the same time can lead to interference. When people come to visit exhibits they typically come in groups. Because of this, having multiple interactive parts could be useful in keeping the majority of the group's attention at one time. In order for this to be successful the exhibit creators need to make sure that each element does not distract from the others. The third is that interactivity, even if by a single visitor, can disrupt whatever is being displayed. Most exhibits are created in order to display one large phenomenon. If an exhibit it created so that the visitor gets in to close they may not be able to see the overall picture of what the display is trying to teach. The fourth is that interactive features can make a critical phenomenon difficult to find. If there are too many interactive parts, it can make the main educational part difficult to locate and the visitor's will fail to see what the exhibit is trying to educate them on. Finally, the fifth is that a secondary interactive feature can shift visitors' attention from the primary one (Allen & Gutwill, 2004).

3.0. Methodology

This chapter focuses on the specific steps we took upon our arrival in Puerto Rico. Our mission was to develop a plan to communicate to the visitors of the Antiguo Acueducto the principles of its mechanical water filters, its historical value and the importance of water conservation.

Our methods chapter is framed around the objectives we established during our work in Puerto Rico. These objectives were: **to design a functional physical model of the mechanical water filtration system of the Antiguo Acueducto**, and present our recommendations to The Conservation Trust of Puerto Rico, and **to design an educational exhibit that showcases the history and technology of the Antiguo Acueducto and communicates the importance of water conservation**. Each of these objectives contains a set of tasks that specifically describes the actions that were required to achieve our mission. These steps allowed us to create a strategy that fit well within the greater plan of the Trust, and can be easily implemented by it. Some of our tasks included conducting interviews with various members of the Trust to gain further information about the Antiguo Acueducto. Table 1 below has a list of all the interviews we conducted about the Antiguo Acueducto.

Table 1. Interviews conducted about the Antiguo Acueducto

Interviews conducted about the Antiguo Acueducto			
Name	**Affiliation**	**Date**	**Purpose**
Elizabeth Padilla	Para la Naturaleza	10/27/2014	To gain a better understanding of the project and acquire documentation about the Antiguo Acueducto.
Elsie Aponte	Para la Naturaleza	11/04/2014	To learn more about the history and purpose of the Antiguo Acueducto. Gain an understanding of the vision of Para la Naturaleza for the site and educational exhibits.

Marcos Negrón	Autoridad de Acueductos y Alcantarillados	11/14/2014	Gain an understanding of how the water filtration system of the Antiguo Acueducto functioned when it was operational. Identify the focus of the project and possible educational exhibit options.
John Ice	Autoridad de Acueductos y Alcantarillados	11/14/2014	Gain an understanding of how the water filtration system of the Antiguo Acueducto functioned when it was operational. Identify the focus of the project and possible educational exhibit options.

3.1. Preservation plan

3.1.1. Initial assessment

The first task was to understand the way the water filtration system worked. We utilized multiple resources, including documents, the staff, and the site itself to accomplish this task. First we performed an initial observation of the site, with our liaison, Elizabeth Padilla. During this observation we disscussed the Trust's plans for the site.

(a)

(b)

Figure 9. Site of the Antiguo Acueducto. (a) Water filter tank that belongs to the site of the Antiguo Acueducto and was acquired later by Trust after being taken from the site. (b) Current condition of the mechanical water filtration system.

Afterwards, we had an informal meeting with Elsie Aponte, the site manager for the Antiguo Acueducto, on November 4th. The focus of the meeting was to receive more insight on what Para la Naturaleza would like to see from the site. During the meeting, Señora Aponte also provided us with the copies of original plans and technical documents. These documents helped clear up some of the confusion we had with our understanding of the operations and the structure

of the subterranean parts of the filter. However, some of these documents were outdated, and did not reflect the current state of the site, as they showed pipes that no longer existed. With the help of Señora Padilla, we then organized an interview with Marcos Negrón and John Ice, engineers who work for the Puerto Rico Aqueducts and Sewers Authority and are working with Para Naturaleza on the Antiguo Acuducto. This intereview took place on November 14th. Our interview questions for Señor Negrón and Señor Ice are shown in Table 2. After this interview, we were able to better understand the entirety of the system.

Table 2. Questions for Marcos Negrón

Questions for Marcos Negrón, engineer at the Puerto Rico Aqueducts and Sewers Authority
1. What is the function of the bypass line?*
2. When was the last time the water filtration system was used?
3. When was the last time the water filtration system was renovated?
4. Where can we find additional and more up to date diagrams?
5. Could you please explain how the water filtration system can be backwashed?

*The bypass line is a 20 inch diameter pipe that runs from the river under the facility but its function was unknown

Figure 10. Meeting Marcos Negrón and John Ice.

After this meeting and our initial observations we decided that we would make a model design of three of the mechanical water filters. We decided to create three of the tanks because in the interview with Señor Negrón and Señor Ice we learned that the filters run in groups of three and need each other in order to work properly. We chose to design a small physical model instead of restoring the actual filter for several reasons. The first reason was because Para la Naturaleza wanted to show how these filters worked and a model would be easier to use to express this. Especially if it was using a clear material. Another reason we chose the model option was because during our meeting with Señor Negrón and Señor Ice, they spoke to us about the damage to the system and the large number of potential problems that may occur if the filters are put back in operation. Some of the problems include the tanks rupturing due to erosion, rust, or other damage done to them in the past, the potential for having to deal with or alter undocumented additions or changes to the system that may be underground that we can not see because of the many iterations the entire compound has gone through, or the need to replace the existing, whether known or unknown, parts that are underground which would cost time and money or more importantly could require serious excavation damaging both the physical and historical integrity of the site.

Figure 11. Site of the Antiguo Acueducto. The current condition of the mechanical water filtration system.

In order to help us better understand the system and to communicate our design to Para la Naturaleza, we created a Computer Aided Design (CAD) model of the current system. Once we gained an understanding of the system from the documents and the site itself, we started working on the model. We started by making an initial SolidWorks model. Afterwards, we took detailed measurements and pictures of each part in order to create a detailed scaled model in SolidWorks, a CAD program that allowed us to make a 3D model of the system.

We created rough models of each part that had the same features, but lacked accurate dimensions. We combined these parts into an assembly that showed where each part went and what parts they were connected to. This rough model helped us keep the specifications of each part organized and served as a guide for the final SolidWorks assembly. Once the system had been laid out, we began taking detailed measurements and photographs of each part. These detailed measurements are shown on the part dimensions form. We used the part dimensions form shown in Appendix A to ensure that all measurements were well organized. For some of the more complex parts, such as the valves, we took multiple pictures. Later, we used these pictures as templates to form the parts in SolidWorks. In some cases, we were not able to directly measure the internal diameter of the pipe because two pipes were attached together. In these cases, we looked for other similar pipes with exposed ends. We used the measurements from those exposed pipes to estimate the diameter, or other missing measurements. Once all of the parts had been measured, we used the part dimension forms to edit the dimensions of each part in SolidWorks.

Once the model had been created we used SolidWorks Flow to simulate the flow of water through the system. While the primary objective of this was to generate images and videos to be used to explain how the system worked, to the best of our knowledge, the simulations do accurately reflect the flow of water in the system.

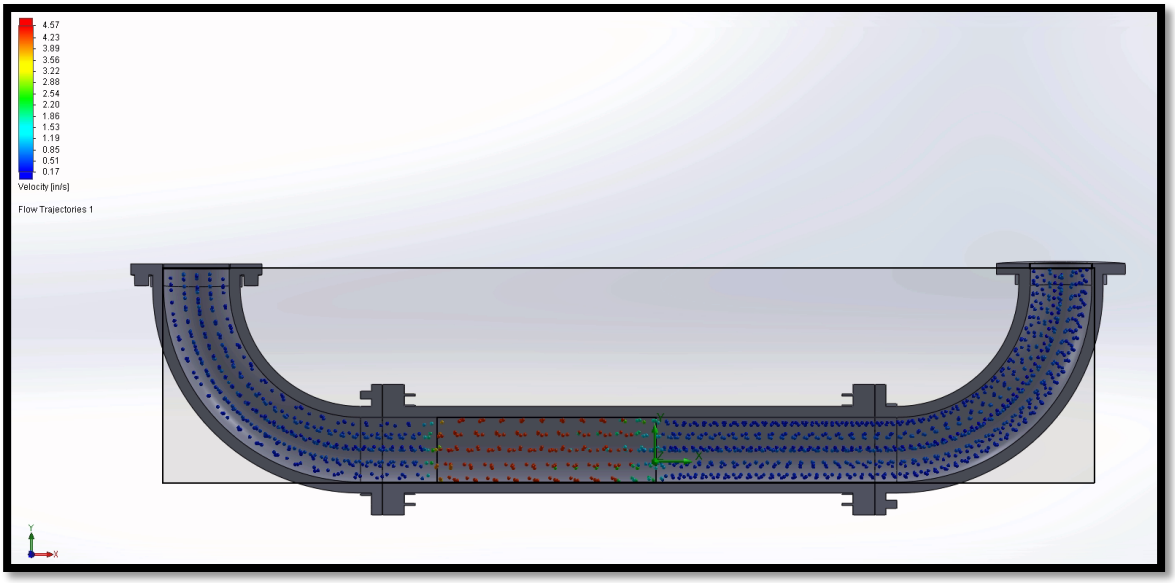


Figure 12. SolidWorks flow simulation. Cross-section of a pipe with water flowing through it. Color of the spheres indicates the velocity of the water.

Considering that using SolidWorks Flow can be a complicated and lengthy process we first performed a series of simplified studies to evaluate the feasibility and possible outcomes of a full simulation. The cross-section shown above in Figure 12, shows a pipe with a cylindrical filter with water flowing through it. The color of the spheres indicates the velocity of the water. Blue spheres are the slowest flow while red spheres indicate the highest velocity flow. The filter is located just to the left of the green origin. Our study clearly shows that the water flows faster through the filter, as it should.

Our initial studies indicated that SolidWorks Flow would be an appropriate tool to generate images and videos to explain how the system worked. With these initial studies complete, we moved on to more complex studies of the whole system. As the purpose of these studies was to generate graphics, and not accurate numbers or specific data, many of the features of Flow were not used, although some features were necessary. The filters depend on gravity to work properly so this was enabled. In addition, we created a porous medium to represent the filter media. We had to create a custom medium to best reflect the properties of the media used in the system. While the original system had multiple media, we simplified things by only using one medium in the simulation. Once the simulation was run, flow trajectories were added. These trajectories are created by SolidWorks and show how the fluid flows. We used arrow shaped

trajectory vectors to show the direction of flow. Different trajectories were created in order to color the arrows and represent the turbidity of the water.

Once the SolidWorks model was created, we loaded in the SolidWorks 2012 Flow Simulation add-in. Next we used the lid tool to seal all of the open pipes and created an enclosed fluid volume. This volume was confirmed through the use of the check geometry tool. This tool allowed us to confirm that all of the pipes and valves were attached properly and fluid could flow through them properly. Once the appropriate fluid volume was created, we started a new fluid simulation project for which we used a different configuration of the model for each of the states. These configurations are slightly different versions of the model; there is one that corresponds to each of the four states the system can be in, normal flow, and each of the backwash states. The appropriate parameters were specified in the general settings. Gravity was the only physical feature that was included. The incompressible water profile was used for the fluid, and the flow characteristics were set to laminar and turbulent flow, but cavitation was not enabled. \Wall conditions were left at the default of adiabatic walls with 0 micrometer roughness.

With the general settings in place we began setting up the boundary conditions. These parameters tell SolidWorks where and how fluid can flow in and out of the system. We created a volume inlet flow of .1 m^3/s on the internal face of the main influent line. This volume is an estimate we acquired from the interview with John Ice mentioned in Table 1. Additionally this number did not need to be accurate as no numerical data from this study would be used, and altering the volume flow, does not visibly alter the flow paths of the water. An environmental pressure boundary condition was added to the interior face of the lid of the main effluent pipe, as well as all of the drains.

Next the porous medium was created. As no appropriate option was available from the default templates, we modified the isotropic template to have a porosity of .3 that better reflected the filter medium used. We applied this medium to all of the filters in the tanks. With all of the parameters in place we were able to run the simulations for all of the configurations

3.1.2. Design of the physical model

Once we had gained a sufficient understanding of how the filtration system functioned and created a SolidWorks model of it, we began designing a smaller simplified system. The purpose of this system would be to demonstrate how the filters work, and help educate visitors

about water filtration. We would use SolidWorks to design the system, and SolidWorks Flow to ensure that the water would flow in the right direction.

First, we developed design parameters. The system had to function in the same manner as the original filters, and had to be able to remove contaminants from the water. In additon, the system had to be able to be backwashed in the same way as the larger filters. Both of these functions had to be able to be easily seen by visitors. The system had to fit inside of the filter house and leave room for visitors to gather around it and clearly see its functionality. Lastly, the system should have been low mainentence and not consume water.

The second step was to determine which aspects of the system were vital, and which were not needed. After the interview with John Ice, we determined that the flow controller and the filter to drain valve were not necessary. The flow controller restricts the water flow during a backwash, and helps prevent the filter media from being disturbed. This feature was not needed for our smaller model, as the total rate of flow would be much less. In additon, a smaller version of this complicated part is not easily available. The filter to drain valve is only needed to run clean water into the drain after a backwash. This feature was not needed as all water would be returned to a tank in the model. This part was omitted in order to reduce the size of the model and save costs.

With our design parameters set, and our simplifications made, we were ready to begin the design in SolidWorks. We started with the filter tank designs. These were based on the larger filter tanks, but scaled down to fit our size constraints and with different access holes. Next, the pipe gallery was modeled. This was also based on the original system, but smaller and simplified as mentioned previously. Finaly the table and reservoir were added.

Next we used SolidWorks Flow to assess our design. We used the same parameters as on the larger model, but scaled down the initial flow rate to reflect what would be provided with a smaller pump.

3.1.3. Model filter particulate experiment

With the decision to create a model of the mechanical filter instead of restoring the actual filter, we needed to determine what contaminant to use to demonstrate the function of our model filter. The reason we needed to determine a new contaminant was that our model is on a much smaller scale than the actual mechanical filter. The mechanical filters, when in operation,

contained around six feet of filter media but our model would have at the most 10 to 12 inches of filter media, meaning there would be less of it to catch impurities.

In order for us to make recommendations as to what particulate to use as our contaminant in our model, we chose to design and conduct an experiment. The experiment was designed to test what type of particulates are most easily filtered using sand and gravel. The experimental procedure we followed is presented below:

Preparation

A. Filter tube construction
    1. Take 1 1/2 ft. PVC pipe and apply PVC sealant to bottom end of the pipe.
    2. Cut mesh into circle with four in diameter
    3. Place mesh circle to end of the pipe with sealant applied to it
    4. Place cap on the side of the pipe with sealant applied
    5. Allow sealant to dry
    6. Cut mesh into circle with four in diameter
    7. Place mesh circle in screw cap
    8. Screw cap onto bottom of the pipe
    9. Pour in two in of gravel into the top end of the tube
    10. Pour four in of sand into top of pipe

Execution

A. Filtering of particulates through filter tube
    1. Remove hose fitting cap from bottom of the filter
    2. First prime filter with two full pint cups of clean uncontaminated water

Figure 13. Step 2 of experiment.

3. Collect two pints of water from bottom of the filter as the control before adding particulates
4. Mix in 1/4 pint of particulate into two pint cups of water

Figure 14. Step 4 of experiment.

5. Have one person hold filter above the bucket with clear cup under filter to catch filtered water

Figure 15. Step 5 of experiment.

6. Other person pours particulate/ water mixture into filter. (Be sure to do so slowly as to not over flow the filter so that all of the water and particulates reach filter)

Figure 16. Step 6 of experiment.

7. Collect two pint cups worth of water from filter until filter tube is empty of visible standing water
8. Take pictures of sample for documentation

B. Backwash the tube

1. Wait until water is fully drained from the tube

Figure 17. Step 1 for backwash part of the experiment.

2. Attach hose cap to the bottom of filter
3. Attach the hose that is connected to the water faucet to bottom end of the tube
4. Turn hose on low (as to not have too much pressure and push filter media from the top of the tube)

Figure 18. Step 4 for backwash part of the experiment.

5. Hold tube upright and allow water to flow back through the top of the pipe into the bucket until water appears to be clean for at least a minute

Figure 19. Step 5 for backwash part of the experiment.

6. When finished backwash, pour out filter media in a line

Figure 20. Step 6 for backwash part of the experiment.

7. Observe and take pictures of the filter media to see how much contaminant remains
8. Repeat three times

C. Repeat actions A and B with each of the different contaminants

This experiment was not made to simulate a test of our model design or the actual function of filter media used for usual water filtration. In place of actual filter media we used QuickCrete brand sand and gravel. The reason that it was not a problem using these materials in place of better filter media was because we were simply testing how well the particulates were filtered compared to each other. The reason we chose the do the two contaminants was that one is organic and closely relates to river water (potting soil) and the other is a plastic based hydrophobic material (glitter). This attribute of the potting soil was important because it imitated what would have run through the filters when they were in actual operation. The attributes of the glitter were important because it stays unmixed with the water, which we hoped would cause less penetration into the filter media.

3.1.4. Model part research

After understanding how our model of the mechanical water filter would work and creating the design in SolidWork, we moved on to finding potential suppliers for the pipes, valves, tanks, pumps, and filter media. Since the primary functions of the model include demonstrating to visitors how the different components of the filter actually work, we decided to use clear PVC and acrylic. These materials allow the visitors to see inside of the physical model.

When looking inside they would be able to see the different water flows as well as the contaminants and filter media interacting in the filter. These materials are durable but easy to work with. Unlike glass or other clear materials, they can easily be cut and connected. Clear PVC and acrylic are both forms of durable plastics often used in plumbing, fish tanks, and other water applications.

We also determined different pump options to use. We determined that the best type of pump to use was a sump pump. Sump pumps are designed to always be submerged in water, do not need to be primed, and are built to be durable enough to pump water and whatever particulates are in that water. Most pumps need to be primed before they are run, so water needs to be added into them before they are turned on.This is important because it is one less step of the everyday maintance of the model for whoever starts the model every morning. We searched several stores and online potential suppliers for these pumps. We determined about what size pump we were looking for by calculating the horsepower of the original mechanical filter and comparing that to its volume and then comparing that to the volume of the physical model we designed to determine the horsepower of the pump in our design. We also determined the size of the holding tank for the water. In order to determine this we used SolidWorks to calculate the volume of water that the model would need. Finally, we determined the filter media options. In order to find these media options we researched filter media providers online. When all of the data and prices were compiled, we created charts and recommendations on which parts we suggest for use.

3.2. Research and development of educational exhibit design

We began by conducting research that would help us identify appropriate content for the educational exhibit designs. In order to generate content for the exhibits we interviewed representatives of Para la Naturaleza and visited historic sites around Puerto Rico. Señora Padilla helped us schedule all of the meetings we needed with the employees of Para la Naturaleza. Each of these employees possesses their own expertise that would help us with the project. Señora Padilla also helped us organize trips to other historical sites located throughout Puerto Rico.

The first step for creating the exhibits was establishing the focus of the information it should convey to visitors. We met with multiple representatives from Para la Naturaleza to ensure that our focus fit well with what they would like to see presented in the exhibit. As shown

in Table 1 above, we met with Elsie Aponte. Señora Aponte provided us with a general overview of what Para la Naturaleza wanted to be represented in the exhibit: the history of the Antiguo Acueducto, its mechanical water filtration system and the importance of water conservation. With this better understanding of what Para la Naturaleza would like to see from the exhibit, we gathered information by reading through and analyzing all of the documents we had received to date. Señora Aponte provided us with digital documents of the original construction. These documents allowed us to map out how the system worked as a whole and to establish a better timeline of what occurred on the site and when. Our next step was to have Señora Padilla coordinate a meeting with Marcos Negrón. Using the information we obtained from Señora Aponte and Señor Negrón, we collected a better history of the Antiguo Acueducto. For technical information that was not contained in the documents provided to us by the Trust, we carried out extensive archival research to decide on content to include in our displays.

Using the information and research we compiled about the Antiguo Acueducto and water conservation, we generated the content of our educational exhibit. We acquired information about the Antiguo Acueducto through interviews presented in Table 1. For the content of the educational exhibit, we researched the importance and role of water in the world today and the key components of educational exhibit design. We used the information we researched for the background as the content for our exhibit. Our interview with Señora Aponte helped us determine the main topics to be included in the exhibit. We used pictures and various colors in the exhibits to communicate concepts easily. Our interviews helped us gain a better understanding of what story the site should tell. Señora Aponte suggested that the main focus should be on the importance and history of the Antiguo Acueducto. She also suggested that the role and importance of water in daily lives and how it ends up getting from its source to people's houses be a component of the story as well.

At the same time that we were working on the process of generating content, we began developing a floor plan. We developed a 2-D floor plan of the exhibit site to convey our idea of what the site will look like when the exhibit is installed. In order to proceed with the floor plan, we evaluated the space available in the water filtration building. We focused on the empty wall space because this will be where the exhibit panels will be placed. To create the floor plan, we used Microsoft Visio. It helped us create a basic floor plan, using measurements we took and

previous blueprints of the site, which indicated where each section of the exhibit would be. When viewing these plans, it would be easy for others to be able to visualize how the exhibit will be set up in the future. Using this floor plan and what we gathered from previous visits to the site, we decided on the best options for the placement of panels included within the exhibit. We made the exhibit panel designs in Microsoft Office PowerPoint. The panel design included text in Spanish and various images of the site of the Antiguo Acueducto over the years provided to us by the Trust.

Once we established the design layout, this defined the constraints of our exhibit designs. To create our designs, we focused on visiting historic sites around Puerto Rico. Our visits consisted of two components: evaluating the sites and interviewing the staff.

In-depth research of educational exhibit design helped us determine what to look for at the sites that we visited. We recorded our evaluations of exhibits using the form in Appendix B. This evaluation protocol was based on research into museum exhibition designs, considering specifically the research of Falk (1997) and Dean (1996). The factors we used to evaluate the exhibits include value, color, texture, balance, line and shape. A definition of each of these factors is provided in the evaluation form in Appendix B. All of these factors play an equally important role in creating an educational exhibit (Dean, 1996). Other than the exhibit evaluation factors, we also identified the headline and subheadline of each exhibit we evaluated, as defined in the background chapter. The headline and subheadline facilitate conceptual development of the exhibit (Falk, 1997). In the evaluations, we checked to see if each of the exhibits we evaluated had a clearly defined headline and subheadline that corresponded with the content. We all checked to see if the exhibit followed all the factors identified by Dean (1996). Some of the questions we asked for the factors we evaluated include the following: do the colors follow a theme? Is the exhibit balanced or is it too cluttered? Is the exhibit linear? We recorded our evaluations of each of the factors in the form presented in Appendix B. Our evaluations are included in the results sections of this report.

We organized trips to Fort San Felipe del Morro, Fort San Cristóbal, Hacienda La Esperanza and Cabezas de San Juan. We chose to visit the two forts because they are two of the top historical touristic attractions in Puerto Rico that attract numerous visitors every year. The first two sites that we visited, Castillo San Felipe del Morro and Castillo de San Cristóbal, compose the San Juan National Historic Site (NHS). The San Juan NHS also includes Castillo

San Juan de la Cruz, remainders of the fortress wall that surrounds Old San Juan, and the San Juan Gate. Both of the sites that we visited are managed by the same Grand Management Plan of the San Juan NHS (National Park Service, 2006). The sites have the similar educational exhibit designs and staff managing them. Hacienda La Esperanza is the site of a historic sugar mill. We chose to visit this site because it belongs to and was restored by the Conservation Trust of Puerto Rico. The last site we visited was Cabezas de San Juan. Like the previous site, it is restored and managed by the Conservation Trust of Puerto Rico. Table 3 provides a summary of information about each of the sites we visited.

Table 3. Historic sites visited

Historic Sites Visited					
Name	**Location**	**Technical Designation**	**Administrating Organization**	**Years in Operation as Historic Site**	**Number of Visitors at the Site in 2013**
Fort San Felipe del Morro	Old San Juan	National Historic Site	U.S. National Park Service	53	1,328,801
Fort San Cristóbal	Old San Juan	National Historic Site	U.S. National Park Service	53	
Hacienda La Esperanza	Manatí	Natural Reserve	The Conservation Trust of Puerto Rico	4	11,192
Cabezas de San Juan	Fajardo	National Reserve	The Conservation Trust of Puerto Rico	33	29,390

The second component we used to design the exhibit was interviews with staff members. Specifically, we interviewed the staff members that gave tours and presented the sites to the visitors. The staff members that present the site to the visitors have the most knowledge about how effective the exhibits at the site are and which aspects of the site captivate visitors the most.

For the U.S. National Historic Sites, we interviewed the park rangers who were running the site and giving guided tours to the visitors. At the sites of the Trust, we interviewed the interpreters that give detailed tours of the site. The interpreters are professionals who are part of the Trust and have been working at the sites that they guide at for years. We decided to conduct interviews with the staff of historic sites because some of the topics they are knowledgeable about include how each exhibit is constructed, why it is placed in specific locations, which factors were considered when designing the exhibit and how the audience responds to the exhibits at the site. Afterwards, we used the information obtained from our interviews and the evaluations of educational exhibits at the sites to create our educational exhibit for the Antiguo Acueducto. With each separate interview, we asked specific questions to see how our design can be improved upon. Appendix C provides the list of interview questions that we asked the staff members during our visits.

After the interviews and the site visits, we created our educational exhibit designs. In order to finalize them, we presented them to several members of the Trust. Presented in Appendix C as well is a list of interview questions that we asked the members of the Trust to evaluate our educational exhibit designs. Using the feedback that they provided us with, we adjusted the educational exhibit designs and finalized them. We interviewed all the members of the Trust that we have interacted with through are time here in Puerto Rico including the interpreters from both of the sites that we visited, Elsie Aponte, Elizabeth Padilla, Marcos Negrón, and John Ice.

To select what material we would like to use for our designs of the exhibit, we researched different companies that provide interpretive sign materials. We made sure that these companies provided materials for exhibits similar to the ones that will be placed within the site of the Antiguo Acueducto. Using this research and the websites of the companies, we developed a list of material features and capabilities that should be required for the exhibit displays of the Antiguo Acueducto. We then developed a separate list of optional features and capabilities that may also be desired from the material of the exhibit. We then used these two tables to compare to the characteristics of the available material options from each individual company. Using this comparison we developed a final suggestion on what material the Trust should use and from which company.

4.0. Results and Analysis

4.1. Initial assessment

After conducting an initial walk through, analyzing documents we gained access to, and conducting several interviews, we now have a full understanding of the site. Originally the site used settling tanks to filter the water from the Río Piedras. Water would flow in from the river through the weir. This weir or dam contained a sluice gate, which is designed to allow water to flow through the bottom of the dam.

Figure 21. The weir of the Antiguo Acueducto from around the year 1918. This image is from the Trust's archives.

From the weir's sluice gate, the water would flow into the valve house. The valve house is simply a small building where workers would control the amount of water that would flow into the system. Workers used several valves that controlled whether the water would continue on to be filtered or divert back into the river. All of the water that was sent to be filtered, is then sent to the settling tanks. The settling tanks were large pools that were designed to allow the water to

move very slowly through each one, giving the sediment in the water a chance to settle to the bottom of the tanks.

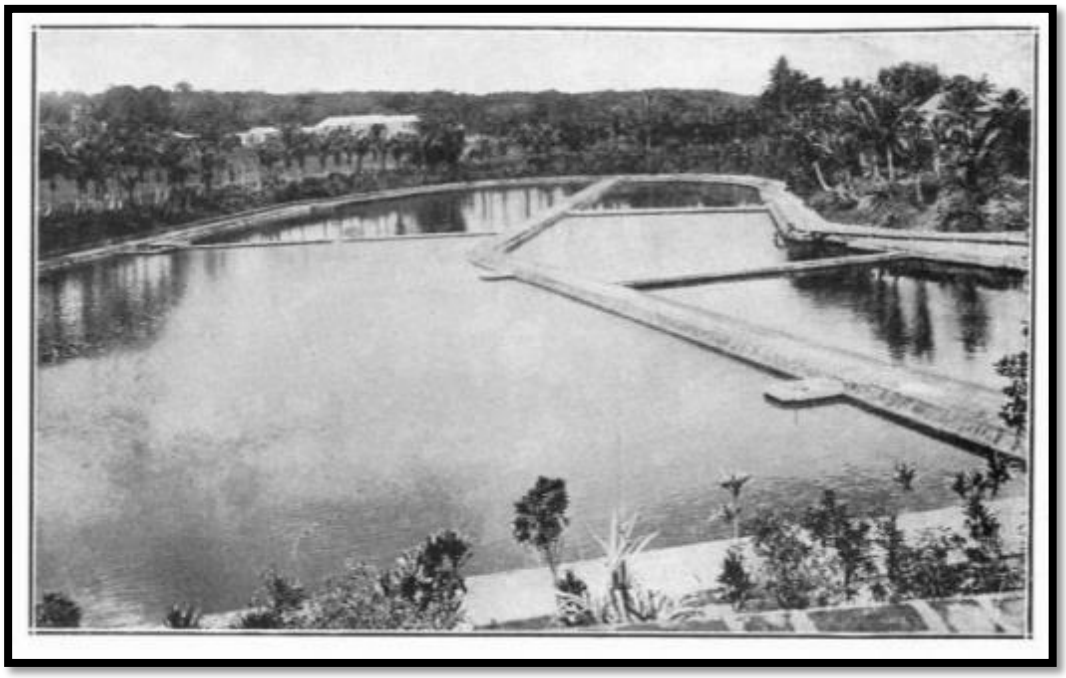


Figure 22. Picture of the settling tanks of the Antiguo Acueducto from before the introduction of the mechanical water filters in 1917. Taken from the archives of the Trust.

At the bottom of the tanks there were white ceramic spheres. These spheres ranged from about one half to four inches in diameter and acted as filters, allowing water to flow through them while catching the sediment as it passed by. The spheres were different sizes in order to catch a wider range of sediment. After the water traveled through all of the tanks, it ran into the pump house. At this time the pumps were run by steam engines. The pumps would then pump the water to a location on a nearby hill.

In 1917, the filtration system was updated with Roberts brand horizontal pressure filters, shown in Figure 23. These new mechanical filters allowed for an increase in filtration capacity and made the majority of the sediment tanks obsolete.

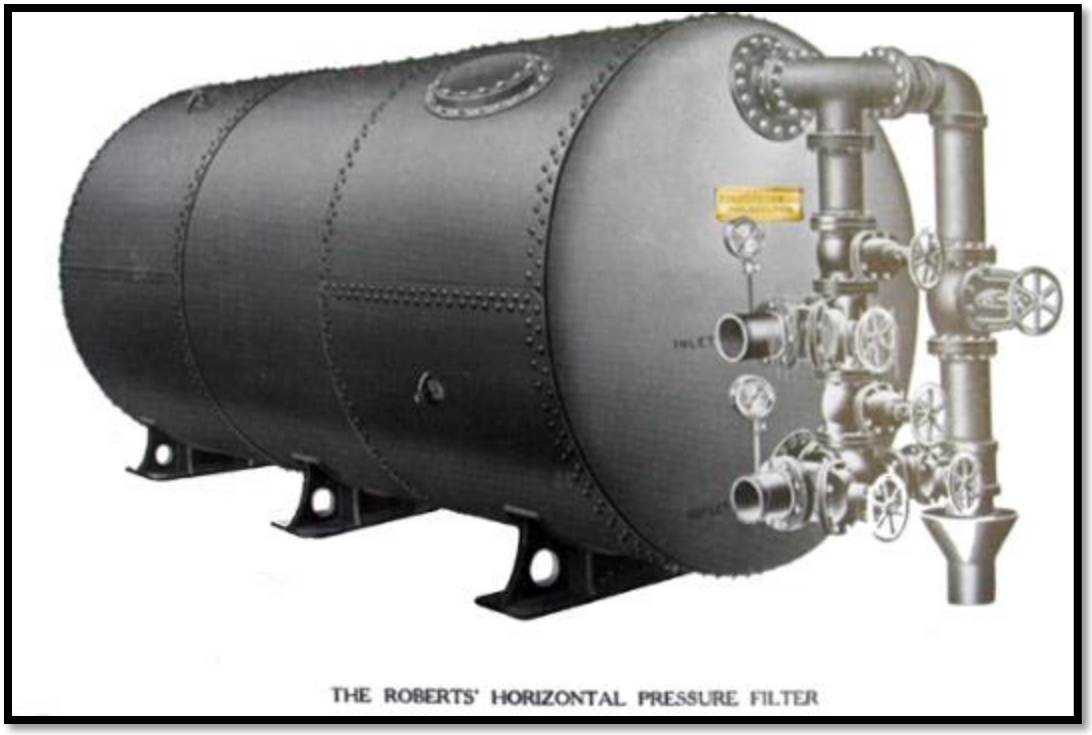


Figure 23. The Roberts' filter. Taken from the Trust's archives.

Now the water would flow from the weir to a sediment tank that added a coagulant to aid in the filtration process. A coagulant, in terms of water filtration, is a gelatinous chemical that adheres to dirt and sediment that is located in raw unfiltered water. Some of the coagulant containing the dirt would sink to the bottom of the sediment tanks because with the added coagulants, it is slightly denser than the water. The rest of the coagulant does not settle and continues with the raw water into the filter. The new mechanical filters that were installed worked using pressure and filter media. Raw water is pumped into the filter tanks through a pipe that runs parallel to the front top of the filters; this pipe is known as the influent pipe. The water is pushed into the influent pipe using four 150 horse power electric pumps. The influent pipe (Figure 24) is connected to the top of each of the filter tanks with individual pipes.

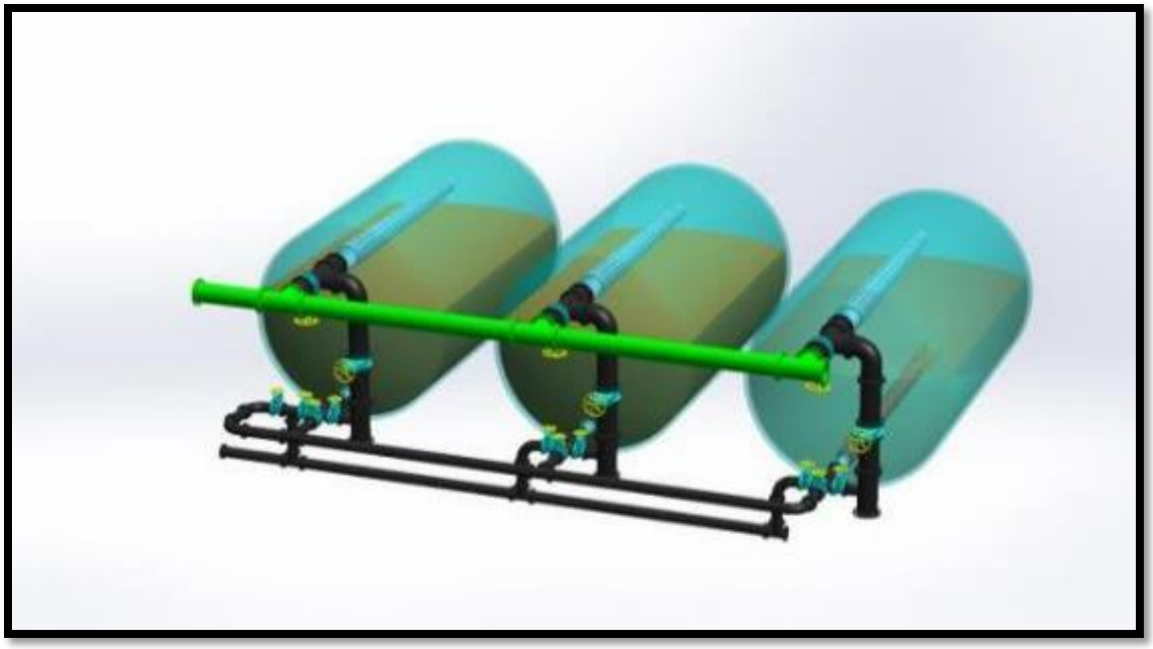


Figure 24. Influent pipe (shown in green) generated in SolidWorks.

The raw water flows into the top of the filter and enters the filter through a diffuser. A diffuser (Figure 25) is a tube that runs the length of the filter tank that has holes distributed throughout its length. The diffuser's purpose is to input water more evenly into the tank rather than just have one entry point.

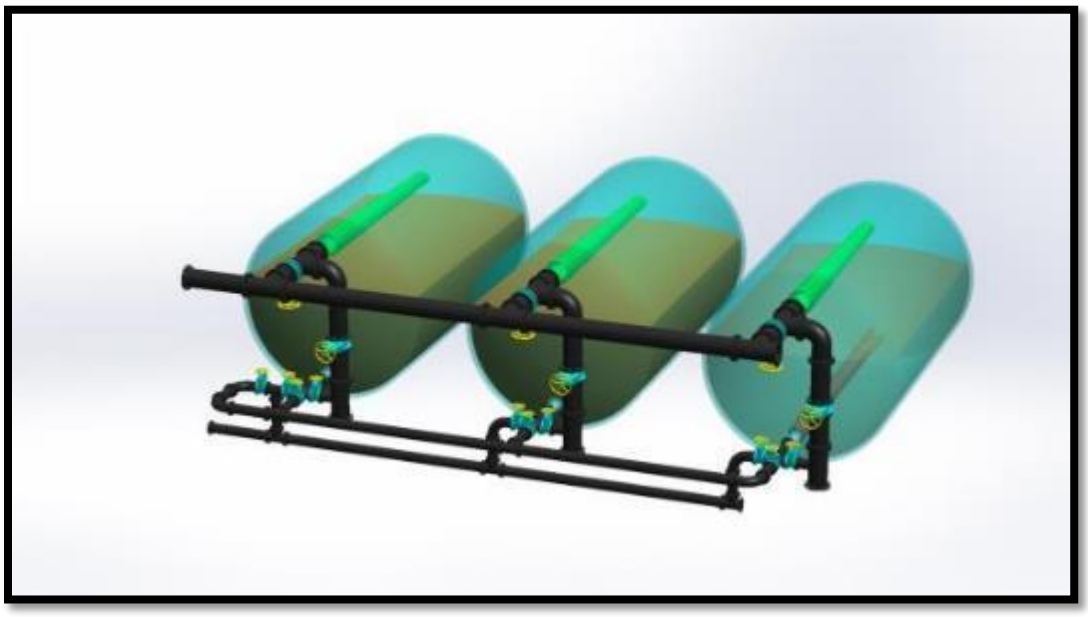


Figure 25. The diffuser tubes (shown in green) generated in SolidWorks.

The raw water is then pushed through the filter media inside the tanks. The filter tanks were full of three substances for their filter media: gravel on the bottom, topped by coarse sand, and finally, fine sand as the highest level. The fine sand's purpose was to do most of the filtering. Since the sand is tightly packed, when dirt tried to pass through it, most of the dirt would get caught up in the sand. The fineness of the sand allowed it to pack tighter, making it more likely to catch smaller particles that may be in the raw water. The function of the other two media, the coarse sand and gravel, was to keep the fine sand in place while the tank was under normal operation and being cleaned. The cleaning process is called backwash and is explained in more detail in the following paragraph. The remaining coagulant, which was saturated with the dirt and impurities, was then caught up in the fine sand and separated from the water. The water is pushed through the remaining media and exits the tank through another diffuser. The purpose of this diffuser is to prevent the filter media from escaping the tank but at the same time provides the surface area for the water to flow through a large opening. The now filtered water flowed out of the bottom of the tank to the effluent line.

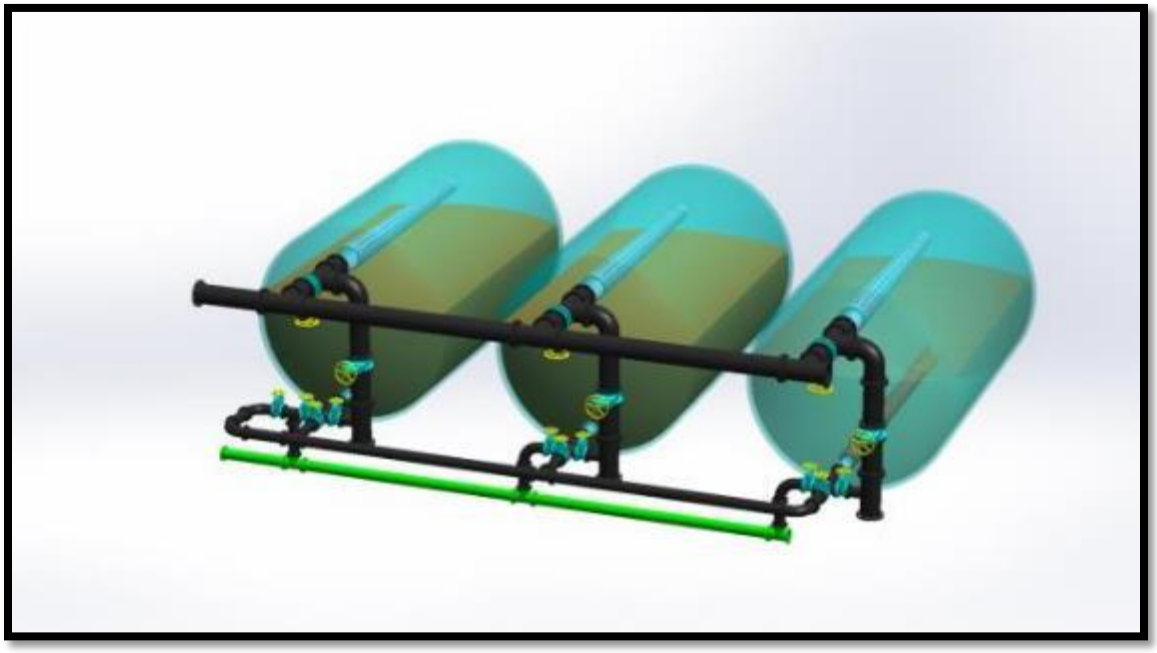


Figure 26. The effluent line generated in SolidWorks.

The effluent line (Figure 26) is the clean water output, which connects all of the mechanical filters to the pump house. In the pump house, the clean water was then pumped to a separate location so that it can be brought to the community for use.

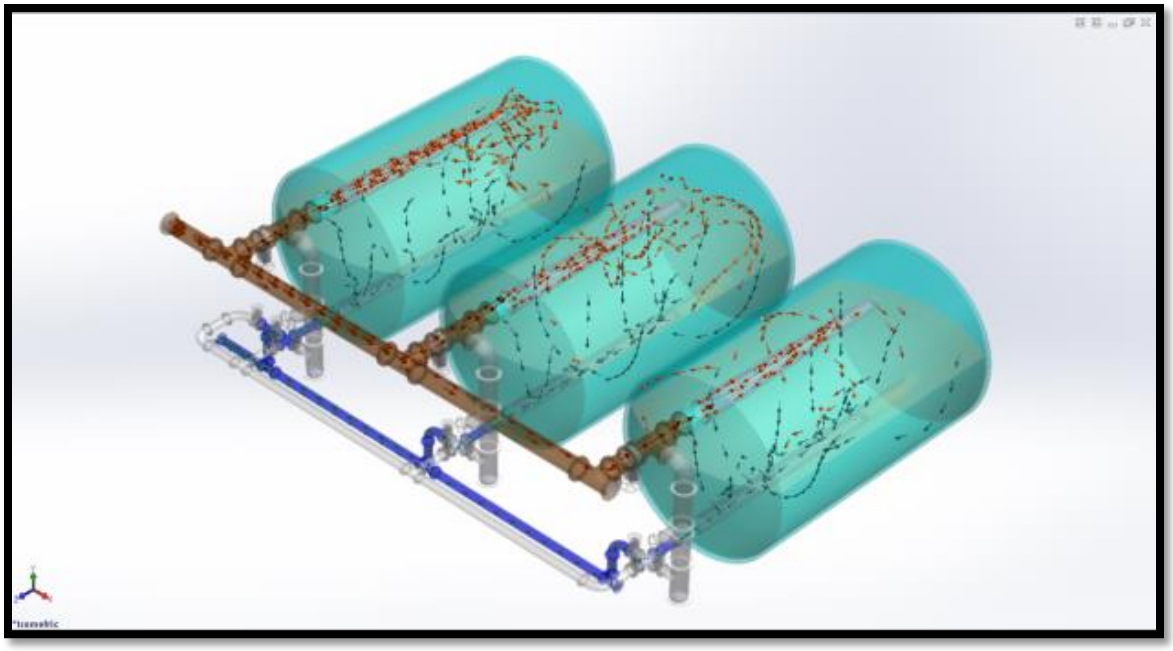


Figure 27. The normal flow generated in SolidWorks.

Figure 27 above depicts a group of three mechanical water filters working under normal operation. The arrows represent the flow of water through the filters. The different colors of the arrows are to express a difference in the water's turbidity. The water moving through the influent pipe is red, indicating that it is moving at a high velocity. As the water moves into the tanks, the colors of the arrows change through the spectrum from red to blue as it moves through the filter media and the velocity of the water decreases. As the water leaves the tanks and enters the effluent pipe, the arrows change back to red, indicating an increase in the water's velocity due to how narrow the pipe is. Also shown in this image is the direction of flow of the water. The arrows in the tank depict the varying directions of the water moving through the filter media.

The major advantage of these mechanical filters is their backwash feature. As stated above, the backwash is how the mechanical filters are cleaned. This process involves running clean water backwards through the system to remove debris that has become trapped in the filter. The filters at the Antiguo Acueducto are arranged in sets of three connected by pipes that are attached to their respective effluent line connections.

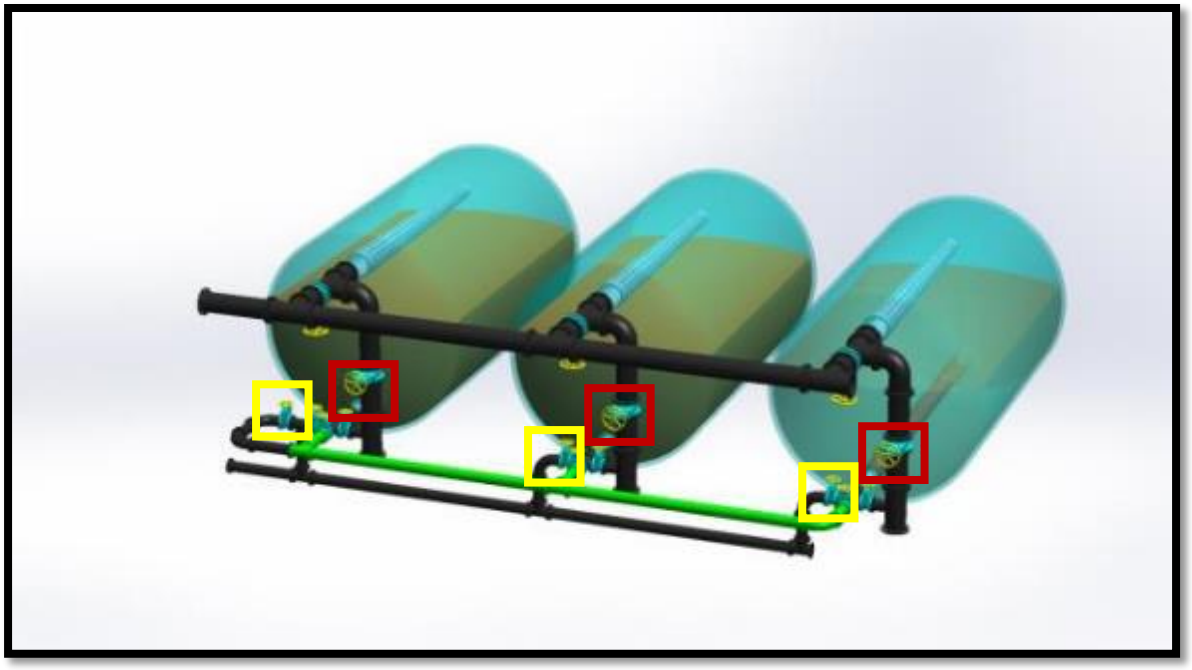


Figure 28. The effluent line connector pipe (shown in green) generated in SolidWorks.

During a backwash, the raw water input to the filter to be cleaned is closed. The water in the filter is allowed to drain out into the main effluent line. Next, one of the three valves connecting the top of the filter to a drain is opened (shown in red squares). All three valves that control the flow to the effluent lines are then closed (shown in yellow squares). The two filters not being cleaned run normally but since their effluent line valves are closed the water that is filtered through them flows through the effluent line connector pipe instead (Figure 28). Since the filter that is being cleaned is the only one that has no water flowing through it from the influent pipe, pressure pushes the water from the other two filters up through the bottom of the filter. The water is forced up through the filter media, and out the top into a drain through the backwash drain pipe (Figure 29).

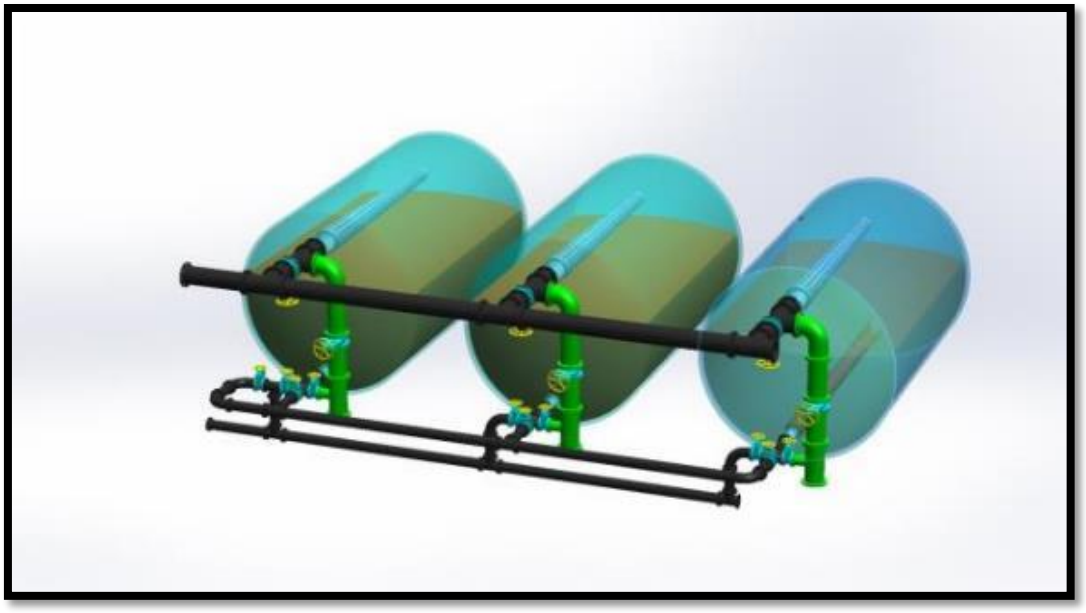


Figure 29. The backwash drain pipes generated in SolidWorks.

The gravel and coarse sand in the tank helps to distribute the water more evenly so that all of the fine sand has clean water running through it. This is because the gravel and coarse sand is less tightly packed than the fine sand, allowing more avenues for the sand to flow. The coarse sand is also an important buffer between the sand and the gravel so that the two do not start to combine because it is between the other two in particle size. During backwash operation, the gravel is left mostly unmoved at the bottom of the tank and the coarse sand is moderately agitated. The fine sand at the top of the tank is the medium that moves the most and is stirred up vigorously. This happens because even though the fine sand is more tightly packed, the individual particles are less heavy than the larger coarse sand particles and gravel chunks. The force of the water through the bottom of the tank during backwash is not strong enough to seriously mix the bottom two media. The operator then observes the backwashing water and waits until the water is clear before ending the backwash. The filters are returned to their original configuration and allowed to run. The recently backwashed filter's output is diverted to waste for 20 to 30 minutes while the filter media re-packs. The backwash is not perfect and the filter media becomes increasingly dirty over time. Therefore, the filter media needed to be replaced once every three years.

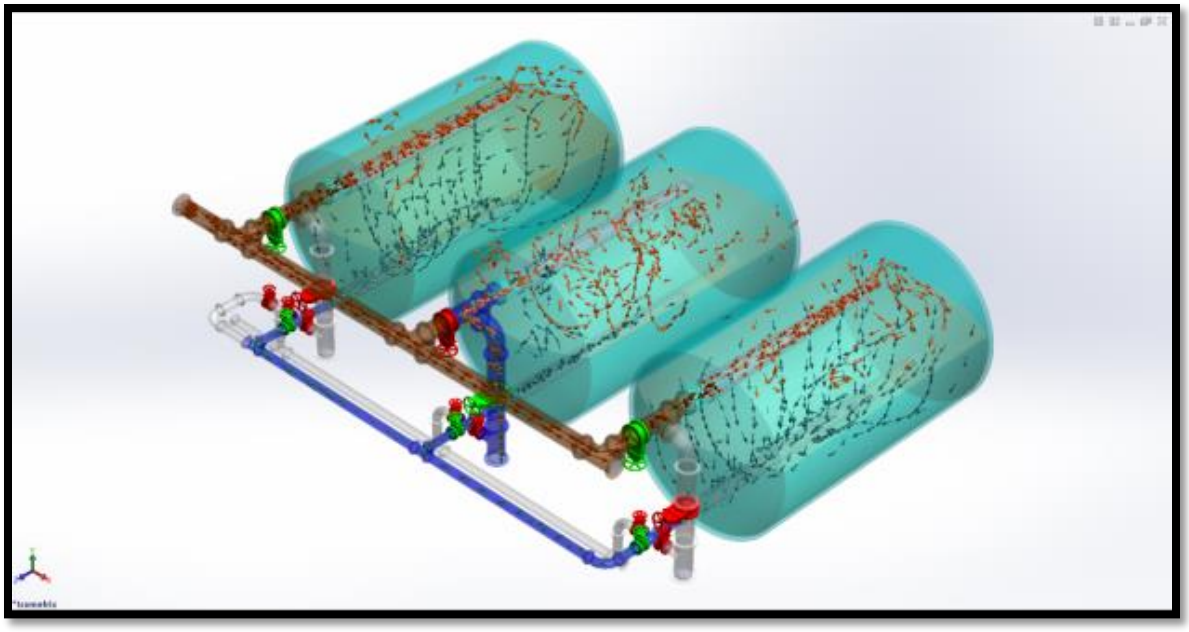


Figure 30. The backwash flow generated in SolidWorks.

Figure 30 above depicts a group of three mechanical filters while one is being backwashed. In this figure, the middle tank is being backwashed. The left and right tanks appear to be operating normally but the water from them flows into the effluent line connector pipe and into the middle tank. The pipes that have water flowing through them are highlighted in brown and blue and the pipes with no water flow are clear. The valves are color coded to which ones are open (green) and closed (red).

4.2. Design of physical model

Our design is a smaller simplified version of a set of three horizontal pressure filters. While some of the components of the larger system were omitted for the sake of simplicity, our system performs all of the major functions of the original system in the same way.

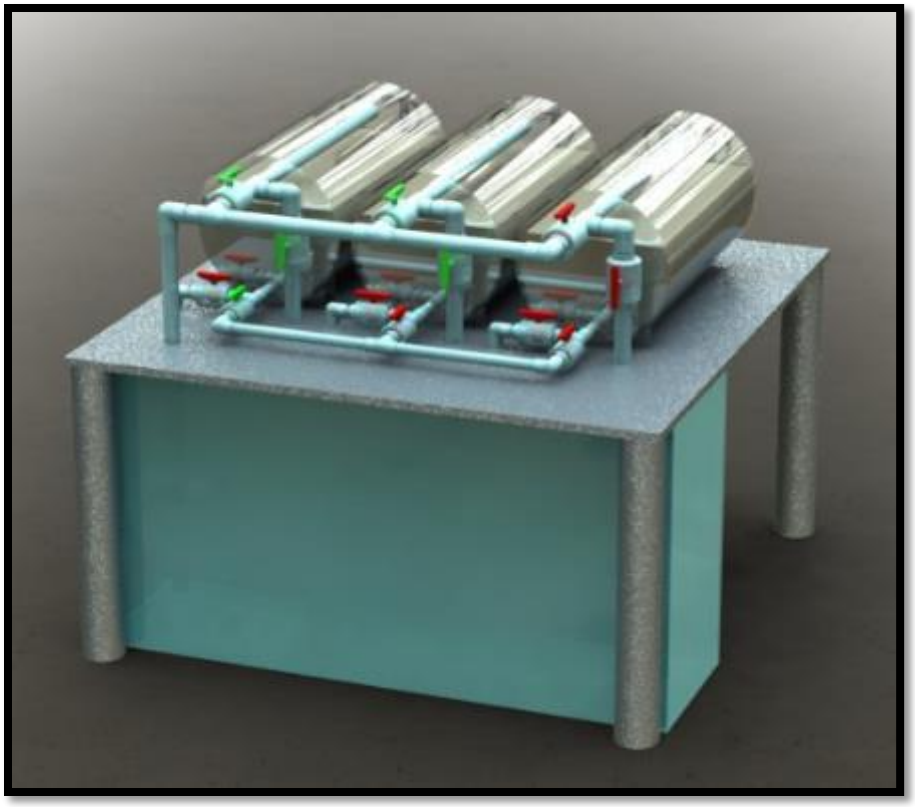


Figure 31. SolidWorks design of the physical model. All the materials used in this model above on the table are to be transparent.

Shown in Figure 31 above is the design of our model. Or model has three three-foot long clear acrylic tanks that mimic the filter tanks of the larger system. These tanks are connected to a system of clear PVC pipes. Both the tanks and pipes sit on a table that helps to conceal the reservoir and pump. These are concealed as they are not in the original system. The reservoir is a large holding tank that contains a sump pump.

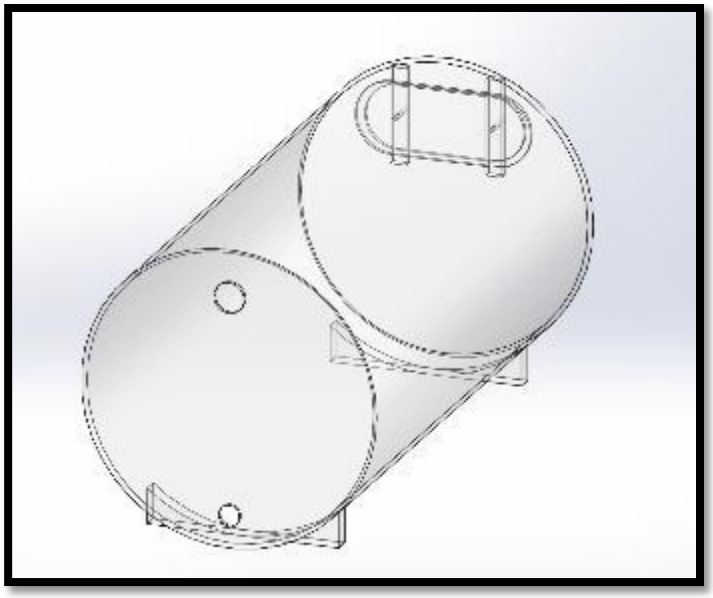


Figure 32. SolidWorks design of one of the tanks.

The tanks are made of thick clear acrylic and are effectively large hollow cylinders. They have small feet to hold them in place and secure the entire model to the table. On the backs of the tanks are openings sealed with plates. These openings allow the tanks to be filled with filter media, and for maintenance to be performed. The design of the seals mimics that of those found on the original Roberts filters. The openings are oblong so that the plate, which is larger than the opening, can be inserted inside the tank and fitted to the interior of the back wall. This means that as pressure increases inside the tank, the plate is forced against the wall, strengthening the seal. If the plate was attached to the outside of the tank, any pressure would force the plate away from the tank causing leaks.

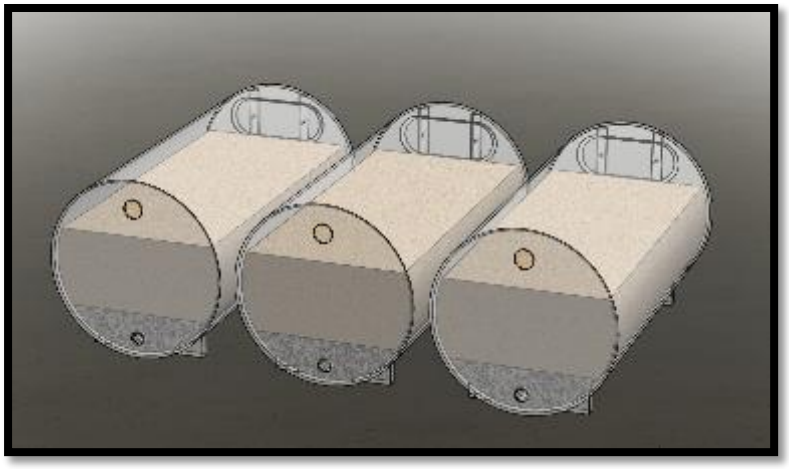


Figure 33. SolidWorks design of the tanks with the filter media.

The tanks hold filter media. This media is composed of a layer of sand, supported by a layer of gravel. As shown in our experiment, this should effectively filter out the contaminant. Ideally the sand and gravel can be material that is designed for water filtration systems, but most sand and gravel will work as well. This is further discussed in the recommendations section of this paper.

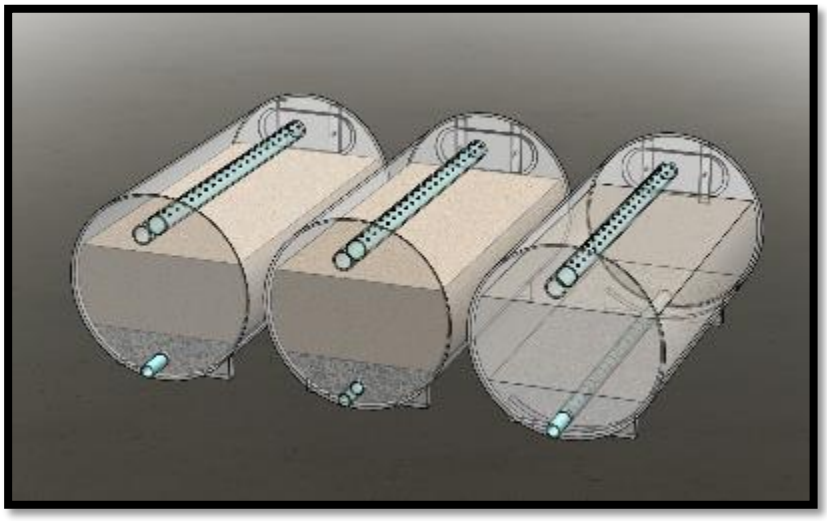


Figure 34. SolidWorks design of the tanks with the filter media and diffusers.

Inside the tanks are the diffusers. These are long clear PVC pipes that are capped on one end and have a series of holes in them. They allow water to flow into the tanks and help to distribute the water evenly across the filter media. This slows the water and prevents it from

disturbing the media. The bottom diffuser has a mesh around it that prevents any of the filter media from leaving the tank. The diffusers are attached outside the tanks to the rest of the pipes.

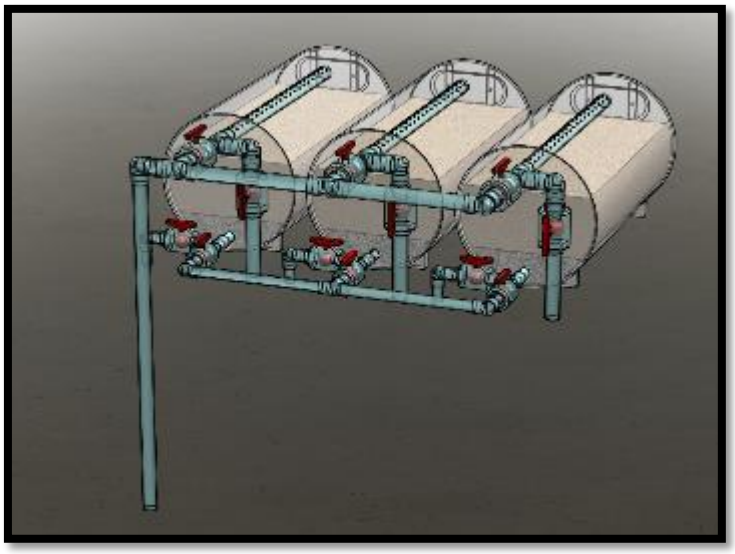


Figure 35. SolidWorks design of the tanks with the pipes attached. All exterior pipes make up the "pipe gallery".

The pipes outside the tanks compose the pipe gallery. These pipes and valves allow an operator to change the flow of the water through the system and perform the different functions of the system. Almost all of the pipes are analogous to those on the original system. The one exception is the pipe and valve connecting the effluent directly to the drain. This was omitted as it is not necessary for basic operation and the parts necessary to implement it are not available.

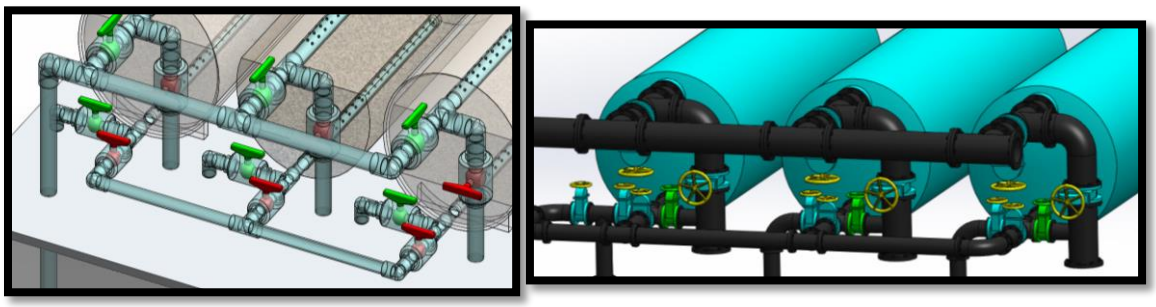


Figure 36. Closer look at the pipes and valves in the design of the physical model.

As shown in Figure 36 above, the pipes and valves are both made of clear PVC with a slight blue tint. This allows the water and contaminants to be seen. Ball valves were chosen for ease of operation and simplicity.

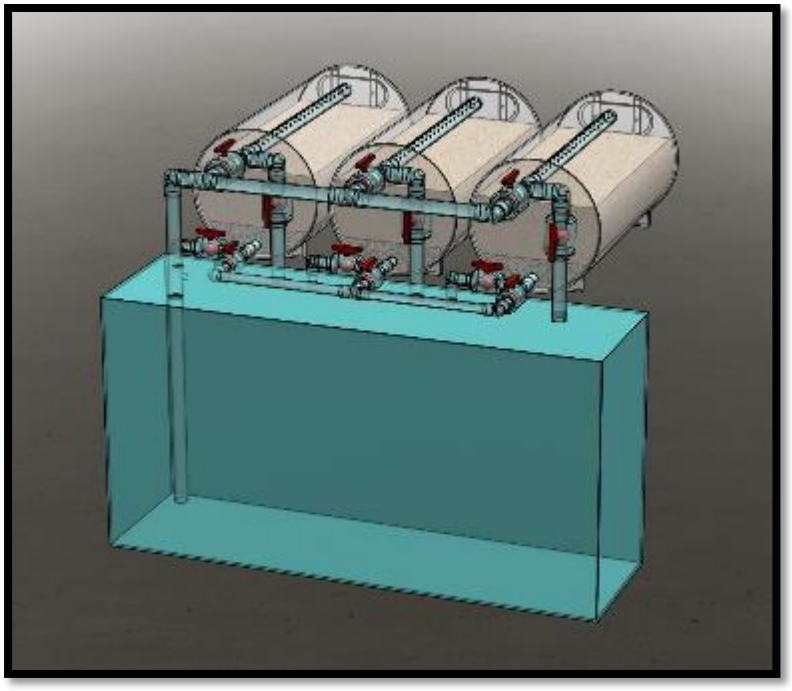


Figure 37. SolidWorks design of the filter tanks attached to the reservoir.

The reservoir is made of clear acrylic so that the water level and contaminants can be easily observed. This reservoir allows the water in the system to be recycled. It can also hold enough water to fill all the tanks and pipes. This insures that the system will not overflow if the pump is turned off. The pipes from the gallery enter the reservoir at the top. A lid covers the rest of the top to allow easy access while preventing any unwanted contaminants from entering the system. A sump pump is at the bottom of the tank and is connected to the influent riser. This pump is always submerged in water and is designed to run without getting clogged with debris so it can be run at any time.

An interpreter can easily operate the system. Each valve has a number and a chart described in the operation manual in Appendix H showing which to open or close for each operation. To demonstrate normal operation, the pump is turned on, and the valves are opened or closed according to the chart that describes normal functions. “Contaminated” water flows from the pump and into the filters. The contaminant becomes trapped in the filter, and the water flows through clean on the other side. The clean water flows back into the reservoir where it is mixed with the contaminant and then recycled. The system can be run like this until all of the contaminant is trapped in the filter. To remove the contaminant from the filter the system is

backwashed. Each filter is backwashed in turn. The operator turns off the pump and configures the valves according to the chart that describes backwash functions. The pump is then turned back on and clean water from the two filters not being backwashed flows backwards through the filter being backwashed. The water removes the contaminants from the filter and flows out of the drain back into the reservoir. This returns both the water and the contaminant to the reservoir so that they may both be reused. All of the operations are shown and described in Appendix H.

A primary design objective for our model was for the system to function both in the same way as the original system as much as possible and as an interactive educational exhibit. Our design accomplishes both of these objectives. The model can filter water in the same way as the larger system, and effectively removes the contaminant from the water. In addition this process can be observed and manipulated by the visitors at the site.

4.3. Model filter particulate experiment

We tested two contaminants in our water filtration experiment: glitter and potting soil. We show the results of our experiment in a series of images and analyze the outcomes by comparing the appearances of the separate trials we conducted.

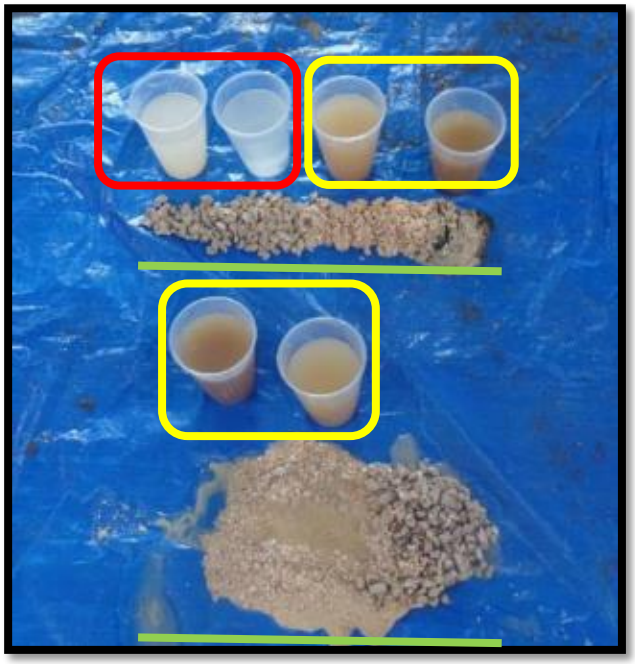


Figure 38. Results for potting soil filtration. Red rectangle represents the water out of the filter without contaminant added, yellow rectangles represent samples of water out of the filter after contaminant was added, green line underlines the filter media poured out after filtration and "backwash".

Figure 39. Results for glitter filtration Red rectangle represents the water out of the filter without contaminant added, yellow rectangles represent samples of water out of the filter after contaminant was added, green line underlines the filter media poured out after filtration and "backwash".

In Figures 38 and 39, the cups on the left in the red boxes are the first samples, which just contain the water that was run through the filter without the contaminants. The cups on the left, in the yellow boxes, are the second samples we took. They contain the water after it is run through the filter with the contaminant added. The samples in the yellow boxes show the water after it is mixed with the contaminant and put through the filter. We evaluated the function of our filter media by comparing the water put through the filter without contaminants added with the water put through the filter with the contaminant added to it. In Figure 38, the potting soil samples in the yellow boxes are much dirtier when compared with the samples in the red box. In Figure 39, the glitter sample in the yellow box has no real visible differences to the samples in the red box. In addition, we compared the samples in the yellow boxes between the tests of alternative contaminants. The water is much clearer in the glitter trial than both potting soil trials. Finally, we examined the filter media after we performed a backwash. In Figure 38 there are two filter media samples and in Figure 39 there is just one. There are two samples in Figure 38 because the first sample, which is located on the bottom of the figure, was an experimental error, which we explain later in the section. As can be seen in the two figures there is more glitter remaining in its filter media then there is potting soil in its filter media in the one trial that was successful. There are two reasons for this. First, the potting soil was filtered out less than the glitter, which is indicated by the quality of the effluent water (yellow boxes). The other reason is

when the filter was backwashed, more of the potting soil could have come out of the top of the test filter compared to the amount that came out during the glitter trial. Unfortunately, the data from the backwash trials was unable to be gathered because there was not a consistent or reliable way of collecting it. This was because the backwash water and contaminants would run down the sides of the filter, which made it difficult to collect it all.

Figure 40. Remaining filter media from first trial mentioned above as the error in our attempt to backwash.

Figure 41. The filter media lost in trial 1 while trying to backwash (media is at the bottom of an orange bucket).

The above two pictures are of the filter media in the first trial with potting soil. When we attempted to backwash the filter, the water was turned on too high. This resulted in the contaminant as well as part of the filter media to be pushed out of the filter. This data was gathered because the dark spots in Figure 41 indicate potting soil did get trapped in the filter as intended.

4.4. Model part research

We located several companies that would be available to provide us with the parts we would need. The parts and the companies that supply them are provided in Table 4 below.

Table 4. Part options and costs

Model Part Options and Costs						
Part type	**Part Dimensions**	**Material**	**Supplier**	**Price** (per unit)	**Phone**	**Email/ Web Site**
Tube x3*	1.5ft Diameter by 3ft. depth	Acrylic	Interstate Plastics	$1558.15	(888) 768-5759	Matt.s@interstateplastic.com https://www.interstateplastics.com
Sheet (x6)*	24 inch x24 inch	Acrylic	Interstate Plastics	$620.16	(888) 768-5759	Matt.s@interstateplastic.com https://www.interstateplastics.com
Tank x3	1.5 ft. diameter by 3 ft. depth	Cast Acrylic	Akrylix	TBD**	(800) 816-1732	quote@akrylix.com http://www.akrylix.com
Pipe	1 inch Diameter	Clear PVC	Alsco	$34.80 /10ft.	(888) 941-3030	sales@alscoind.com http://www.alscoplastics.com
Pipes	1 ½ inch	Clear	Alsco	$56.40/	(888)	sales@alscoind.com

	diameter	PVC		10ft	941-3030	http://www.alscoplastics.com
Ball valve	1 inch Diameter	Clear PVC	Alsco	$27.22/ ea.	(888) 941-3030	sales@alscoind.com http://www.alscoplastics.com
Ball valve	1 ½ inch diameter	Clear PVC	Alsco	$45.50/ ea.	(888) 941-3030	sales@alscoind.com http://www.alscoplastics.com
Tee pipe	1 inch Diameter	Clear PVC	Alsco	$15.17/ ea.	(888) 941-3030	sales@alscoind.com http://www.alscoplastics.com
Tee pipe	1 ½ inch diameter	Clear PVC	Alsco	$28.92/ ea.	(888) 941-3030	sales@alscoind.com http://www.alscoplastics.com
90° Elbow pipe	1 inch Diameter	Clear PVC	Alsco	$11.49/ ea.	(888) 941-3030	sales@alscoind.com http://www.alscoplastics.com
90° Elbow pipe	1 ½ inch diameter	Clear PVC	Alsco	$21.51/ ea.	(888) 941-3030	sales@alscoind.com http://www.alscoplastics.com
Pipe	1 inch Diameter	Clear PVC	USPC	$3.65/ft.	(800) 537-9724	usp@usplastic.com http://www.usplastic.com
Pipe	1 ½ inch diameter	Clear PVC	USPC	$5.95/ft	(800) 537-9724	usp@usplastic.com http://www.usplastic.com
90° Elbow pipe	1 inch Diameter	Clear PVC	USPC	$11.60/ ea.	(800) 537-9724	usp@usplastic.com http://www.usplastic.com
90° Elbow pipe	1 ½ inch diameter	Clear PVC	USPC	$21.64/ ea.	(800) 537-9724	usp@usplastic.com http://www.usplastic.com
Tee Pipe	1 inch Diameter	Clear PVC	USPC	$15.37/ ea.	(800) 537-9724	usp@usplastic.com http://www.usplastic.com
Tee Pipe	1 ½ inch diameter	Clear PVC	USPC	$28.96/ ea.	(800) 537-9724	usp@usplastic.com http://www.usplastic.com
Ball valve	1 inch Diameter	White PVC	USPC	$3.67/ ea.	(800) 537-9724	usp@usplastic.com http://www.usplastic.com
Ball valve	1 ½ inch diameter	White PVC	USPC	$6.02/ ea.	(800) 537-9724	usp@usplastic.com http://www.usplastic.com

*open ended tubes will need to cut out circles from sheet of acrylic to make into tanks

** Waiting for quote

***United States Plastic Corp.

The chart above shows the two companies we researched for the acrylic tanks and the two companies we researched for the PVC pipes that would serve as the pipes in the physical model. The two tank providers for the acrylic were Akrylix and Interstate Plastics. Akrylix is a custom acrylics producer that creates made to order acrylic and plastic product to your specifications. Interstate Plastics is a mass producer of acrylic and plastic and do less customized work. For the PVC pipes, the two companies were Alsco and United States Plastic Corp. These two companies are very similar in respects to the products that they sell. As for the clear PVC specifically that we looked into, they were very similar. The only differences were that Alsco clear PVC has a darker blue tint then United States Plastics' PVC pipes did. Also, United States Plastic Corp. did not sell clear PVC valves while Alsco did.

The parts listed in the chart are all parts and sizes that are needed to construct the filters. First, there will need to be three tanks. The model generated in SolidWorks determined the amount of each part. The amount of a one-inch pipe will be 13.5ft. The one-inch pipe will represent the pipes located on the bottom of the filter (effluent and effluent connectors). The amount of 1 ½ inch pipe is 19.41ft. These pipes will be used for the pipes at the top of the filter (the influent, diffusers, and the backwash drain pipes). The model also needs six one-inch valve and six 1 ½ inch valve. Finally the model needs four one-inch and four 1 ½ inch tee pipes and five one-inch and five 1 ½ inch 90° Elbow pipes.

The following Table 5 shows some options for the pumps the Trust could use in the model. We determined generally the strength of these pipes by calculating first the volumes of the actual and the model filter tanks, and then the ratio between the actual filters' volume to the horsepower of the pumps that were originally used to operate them. The dimensions are as follows: Mechanical filter has a radius (r) of 4 ft. and a length (D) of 25 ft. and the physical model has a radius of .75 ft. and length of 3 ft.

Volume equation	**Mechanical filter volume**	**Physical Model Volume**
$\pi r^2 H = V$	$\pi 4ft^2(25ft) = 1256ft^3$	$\pi .75ft^2(3ft) = 5.29ft^3$

The mechanical filters when in operation used one 150 horsepower (W) pump to each group of three filters. This means each tank takes 50 horsepower to operate. To identify the required horsepower to operate our model, we calculated a horsepower to volume ratio:

$$\frac{V_1}{V_2} = \frac{W_1}{W_2} \qquad \frac{1256}{5.29} = \frac{50}{x} \qquad x = .21$$

V_1= Volume of mechanical filter tank V_2= Volume of physical model tank W_1= Horsepower of the pump used by the mechanical filters W_2= the Horsepower of the pump for the model

We then used these calculations to estimate that the model system would require a pump with a strength of 0.6 horsepower or greater. The reason that we drew the comparison between volume and horsepower was that we were just comparing the amount of water the model would have to have run through it to be a proportional amount to the actual mechanical filter. It is important to have a pump with a high enough horsepower to ensure that it not only works under

normal operation but under backwash conditions as well. Normal flow can operate at a low pressure but the backwash requires higher pressure in order to ensure that the filter media is disturbed enough to so that the water can remove the contaminants from it. It is also important to ensure the pump is not too powerful because if it is the pump will drive faster water flow, requiring more frequent backwashes. This is not as important as a powerful enough pump because, for demonstrations, the system will be backwashed frequently anyway.

Table 5. Pump options

Pump Options					
Item type	Brand/ Model	Power	Supplier	Price	Email/Web site
Pump	Everbilt Professional Sump Pump	1 HP	Home Dept.	$249.00	http://www.homedepot.com
Pump	Wayne SEP8 - 2 HP Commercial Grade Cast Iron Sewage	2 HP	Sump Pumps Direct	$759.99	http://www.sumppumpsdirect.com/

4.5. Floor plan and exhibit placement

The educational exhibits should be strategically placed around the whole site to make it easier for visitors to guide themselves. Presented below in Figure 42 is a basic floor plan of the water filtration building of the Antiguo Acueducto. We designed the floor plan to determine in which parts of the building we would like to place the exhibits. We recommend not placing any exhibits in the narrower side of the building where most of the tanks are located in the interest of the limited space. There isn't sufficient space for a group of visitors to be able to view exhibits in that area without blocking other visitors from passing. The educational exhibit focusing on the mechanical water filtration system of the Antiguo Acueducto should be strategically placed right next to the mechanical water filtration system. Since the main attraction of the Antiguo Acueducto is the mechanical water filtration system, it should be the focus of the educational exhibit. To attract more visitors, we suggest that interactive components be added to the exhibit as well. Having two components provides visitors with the opportunity to either self-guide

themselves through the exhibit and interact with it, or listen to a tour guide and go through easy-to-read exhibits instead. The designs for the exhibits should be colorful and bright to attract the visitors' attention. A combination of technology and well-designed educational exhibits strategically placed throughout the site will reach visitors of various interests and age groups. Most importantly, the exhibits should be easy to read and understand and focus on reaching the visitors on a more personal level.

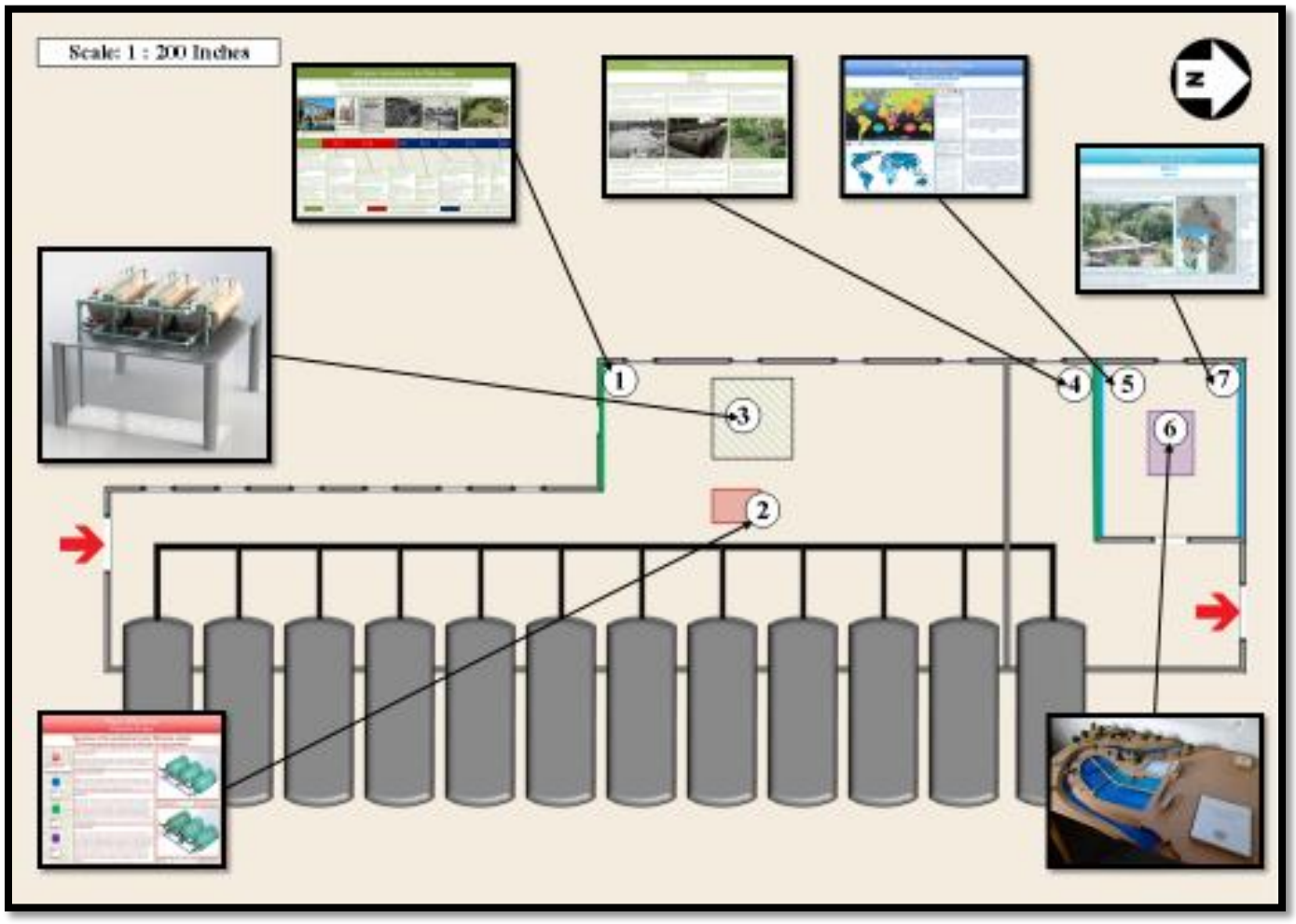


Figure 42. Floor plan of the water filtration building. Arrows show where each of the exhibits is to be located in the building. The numbers show the order in which the exhibits should be presented.

In the floor plan presented in Figure 42 above, there are numbers marking each of the suggested locations of the exhibits. All of the finalized exhibit designs can be found in Appendix G. Exhibit 1 (presented in Figure 52 (b) below) is going to be the timeline exhibit called "Antiguo Acueducto de San Juan". Exhibit 2 (presented in Figure 53 (b) below) is going to be

the water filtration standing interactive exhibit called “Water Filtration”. Exhibit 3 is going to be the physical model of the mechanical water filtration system. Exhibit 4 (presented in Figure 51 (b) below) is going to be the history exhibit also called “Antiguo Acueducto de San Juan”. Exhibit 5 (presented in Figure 54 (b) below) is going to be the facts and statistics exhibit of “The World Water Crisis”. Exhibit 6 is going to be the standing exhibit of the topographical map of the site of the Antiguo Acueducto. Finally, exhibit 7 (presented in Figure 55 (b) below) is going to be the effects of water pollution exhibit of “The World Water Crisis”. The numbers on the floor plan also correspond with our suggested order for the interpreters to show the exhibits to the visitors. The red arrows show the suggested direction for the tours to enter and exit.

4.6. Educational exhibit interviews and evaluations

This section presents the interview question responses we received by asking the questions presented in Appendix C. The interview group includes park rangers and interpreters from the historic sites of Castillo San Felipe del Morro, Castillo de San Cristóbal, Hacienda la Esperanza and Cabezas de San Juan.

The first site that we visited was Castillo San Felipe del Morro. The summary of the interview we conducted on the site is provided in Table 6 below. The responses listed in the right column are paraphrased responses reconstructed from our handwritten notes. Figure 43 below provides an example of an informational exhibit from El Morro with a drawing of a human. The person in the exhibit is designed to represent the certain time frame the information the exhibits inside the room are relaying. Exhibits similar to this one can be found all around the main plaza of El Morro to show visitors that the exhibits contain information from various time frames.

Table 6. Interview results for El Morro

Interview Results for El Morro	
Questions	**Responses**
Interviewee:	Jose Irizarry, Park Ranger at El Morro
Date Interviewed:	11/11/2014
1. How do you reach your audience? Social media? Interactive elements in your exhibit?	The park ranger told us that the site is designed to reach its audience by self-guided, strategically placed exhibits. These exhibits are placed around the whole site. Most of these strategically placed exhibits are very recent additions.

2. What specific aspects of your historical site attract visitors the most?	The massive walls of the El Morro fort are considered as the main thing that attract the visitors the most. The walls are the first things visitors see as they come into old San Juan from the side of the ocean.
3. What is the story your site is trying to tell?	The site is meant to tell the story of the Spaniards, why the fort was even built in the first place, and the importance of its location.
4. How has technology change affected your approaches?	The park ranger thought that compared to the modern technology available, the exhibits are more old-fashioned. In his opinion, some people just want to be able to talk to a guide, while others want to press buttons of an exhibit and just do their own thing.
5. How can visitors interact with the exhibits?	There is no technological interaction at the site. The park ranger thinks that colorful, bright, strategically placed around the site exhibits help visitors guide themselves. Informational exhibits have drawings of humans related to the time period of the information that they are conveying.*
6. What general feedback do you have about the educational exhibits at your site?	The staff of the site would prefer to have more technology and actually interactive exhibits. They consider interactive exhibits better because in their opinion they attract and interest people more. The site has a small staff of rangers that could talk to all the visitors, however, they do not think that all visitors would like a guided tour of the site.

Figure 43. Educational exhibit example from Castillo San Felipe del Morro.

The second site that we visited was Castillo de San Cristóbal. As well as the previous site, it is a U.S. National Historic Site and part of the San Juan NHS. The summary of the interview that we conducted on the site is provided in Table 7 below. Figure 44 below provides an example of an educational exhibit from San Cristóbal. The 4-sided exhibit presented in the figure is repeated in every room at the site. All of the exhibits at both of the sites site of El Morro and San Cristóbal are provided in both English and Spanish.

Table 7. Interview results for San Cristóbal

Interview Results for Castillo de San Cristóbal	
Questions	**Responses**
Interviewee:	Luis Domenech, Park Ranger at San Cristóbal
Date Interviewed:	11/17/2014
1. How do you reach your audience? Social media? Interactive elements in your exhibit?	The site has a high volume of tourists and the staff focuses on reaching people on a personal level. Visitors mainly reach to the staff.
2. What specific aspects of your historical site attract visitors the most?	The size of the fortress and the fact it took 250 years to build its lines of defense is considered to attract visitors the

	most.
3. What is the story your site is trying to tell?	The site is designed to tell the story of how Puerto Rico was tactically the most important location in the new world. It explains why it was so heavily fortified.
4. How has technology change affected your approaches?	Technology has not changed the approach of the site and staff much.
5. How can visitors interact with the exhibits?	The park ranger thinks that the visitors interact with the exhibits easily since they are easy to understand.
6. What general feedback do you have about the educational exhibits at your site?	In the opinion of the park ranger, the educational exhibits are great to understand how vital the location of the site was for the development of the new world.

Figure 44. Educational exhibit example from Castillo de San Cristóbal.

The third site that we visited was Hacienda la Esperanza. The site belongs to and is managed by the Trust. All of the visitors of the site are given tours by interpreters. We conducted an interview with one of these interpreters at the site. The summary of the interview is provided in Table 8 below.

Table 8. Interview results for Hacienda la Esperanza

Interview Results for Hacienda la Esperanza	
Questions	**Responses**
Interviewee:	Jose Nevarez, Environmental Interpreter at Hacienda la Esperanza
Date Interviewed:	11/20/2014
1. How do you reach your audience? Social media? Interactive elements in your exhibit?	The exhibits at the site can be moved around in the main house. Nothing is permanent and most exhibits involve interactive components. Social media is also used to reach out to the audience and invite them to explore the site.
2. What specific aspects of your historical site attract visitors the most?	The vast size of the site which 2286 acres, as well as its history. The history, topography and hydrology that shows the soul and essence of Hacienda la Esperanza. The interactive walking trails and beautiful views attract visitors as well.
3. What is the story your site is trying to tell?	The site is telling more than one story. From the history aspect it talks about the sugar making in Puerto Rico, the owner of the sugar plantation and slavery in Puerto Rico. How slavery was correlated with sugar making.
4. How has technology change affected your approaches?	Technology has provided more ways to reach the population and make it aware about the existence of the site.
5. How can visitors interact with the exhibits?	Most of the exhibits in the main house have interactive components and can be moved around. The interpreter thinks that Hacienda la Esperanza was basically used as a canvas to paint various stories. Visitors can see the shapes on the exhibits that are correlated to different aspects of the house. All of the exhibits are strategically placed around the house to immerse the visitors. All the symbols and pieces of the exhibits are connected.
6. What general feedback do you have about the educational exhibits at your site?	The interpreter informed us that to create an educational exhibit, every detail of the site, like location and history, should be considered. All the components make the exhibit. The exhibit should be tailored to all the aspects of the site and for storytelling and guiding.

The last site that we visited was Cabezas de San Juan (CSJ). This site also belongs to and is managed by the Trust. As with the previous site we visited managed by the Trust, interpreters

give visitors tours of the site. We conducted an interview with the interpreter that gave us a tour of the site. A summary of the interview is provided in Table 9 below.

Table 9. Interview results for Cabezas de San Juan

Interview Results for Cabezas de San Juan	
Questions	**Responses**
Interviewee:	Leonor Alicea, Environmental Interpreter at Cabezas de San Juan.
Date Interviewed:	11/21/2014
1. How do you reach your audience? Social media? Interactive elements in your exhibit?	The site is also managed by Trust. The interpreter told us that social media is used to reach the population and make it aware about the importance of the site. One of Puerto Rico's main bioluminescent bays is located on the site as well which attracts visitors. Exhibits in the lighthouse are interactive. The interpretive trails around the site allow for visitors to interact with nature.
2. What specific aspects of your historical site attract visitors the most?	The interpreter considers the view from the lighthouse, the bioluminescent bay, and the diverse plant and animal life.
3. What is the story your site is trying to tell?	The site is tailored to tell various stories depending on the audience visiting at the moment. It tells the story of conservation, the importance of the lighthouse and the story of the various species of plants and animals found on the site. The stories that the guides tell are tailored to the tour groups visiting.
4. How has technology change affected your approaches?	Technology provided more ways to reach the population and make it aware about the existence of the site.
5. How can visitors interact with the exhibits?	The lighthouse has interactive exhibits. There's a fish tank with some marine animals that the guide demonstrates and even lets visitors touch. There's a dark room in the lighthouse that has a bioluminescence interactive exhibit. The visitors can touch bags full of water with the bioluminescent plankton and see them glow in the dark.
6. What general feedback do you have about the educational exhibits at your site?	The interpreter told us that elements from the original lighthouse have been included in the current one. The interpreter shows the visitors the exhibits and how to interact with them. The interpreter emphasizes different aspects of the site depending on

	the visitor group.

We performed exhibit evaluations on six different displays during three separate site visits. The first site we visited consisted of the two military forts, San Cristóbal and El Morro, located on the coast of Old San Juan. The second site we visited was the site of a historic sugar mill, Hacienda la Esperanza, located in Manatí. And the third and final site we visited was to Cabezas de San Juan, a site containing a historic lighthouse located in Fajardo. For each exhibit evaluation we used a specific list of characteristics to analyze. These are shown in Appendix B Our exhibit evaluations for each display are shown in the tables below. Tables 10 and 11 have exhibit evaluations for San Cristóbal, Tables 12 and 13 have the exhibit evaluations for El Morro, Table 14 has the exhibit evaluation for Hacienda la Esperanza and finally, Table 15 has the evaluation for Cabezas de San Juan.

Table 10. Exhibit evaluation for San Cristóbal #1

Exhibit Evaluation: San Cristóbal #1

Date: November 10, 2014

Figure 45. Main Plaza exhibit at San Cristóbal.

Headline: The main purpose of this exhibit is to give an overview of the Castillo de San Cristóbal. It is a floor plan of the site.

Sub-headline: The floor plan is of the main plaza of the Castillo de San Cristóbal. It contains a legend that points out some of the main attractions of the area. Similar floor plans are located on each floor of the site

Key Element Evaluation	
Value: Quality of lightness or darkness used for emphasis and orientation	Bold text and dark colors are used for emphasis.
Color: Use of colors.	Dark blue and white are used to contrast one another. This use of contrasting colors really draws to eye to the exhibit. Rooms with exhibits are black for further contrast against the white and blue colors.
Texture: Visual roughness or smoothness of the surface.	The exhibit is mostly rough. Since it is a topographic map of the floor, the components of the map and legend are rough.
Balance: Quality of visual weight distribution.	The writing is spaced around the center, which is occupied by the map of the site. The legend is placed in the corner to not distract the visitors from the main focus: the map.
Line: Quality of linearity. Gives directional content to composition.	The floor plan itself is a 3-D topographic map with its components slightly raised on the standing exhibit.
Shape: Element of physical or spatial containment. The contrasting, joining, overlapping and mixing of shapes that helps create visual interest.	There aren't many shapes on this exhibit since it is mostly focused on the map. The components of the map and the legend are mostly simple rectangles.

Additional Comments: This exhibit does not feature many educational components. It simply acts as an informative map. The exhibit allows visitors to see how many rooms are located within the plaza and where exactly they are. The legend is helpful with the design of the exhibit because it uses symbols to represent where important items are located such as other exhibits.

Table 11. Exhibit evaluation for San Cristóbal #2

Exhibit Evaluation: San Cristóbal #2

Date: November 10, 2014

Figure 46. Hidden defenses exhibit from San Cristóbal.

Headline: The main purpose of this exhibit is to convey information about the defense system of the Castillo de San Cristóbal	
Sub-headline: This particular exhibit focuses on the hidden defenses of the fortress	
Key Element Evaluation	
Value: Quality of lightness or darkness used for emphasis and orientation	The exhibit uses contrast by going from dark to light from one side of the exhibit to the other. This makes the display more visually appealing because it is not a plain solid background. It fits in well with the darkness of the tunnel, which features lanterns lighting it along the way and stands directly in front of the exhibit.
Color: Use of colors.	Dark colors are alternated with white for maximum contrast. The colors of the exhibit match up with the physical tunnel directly ahead.
Texture: Visual roughness or smoothness of the surface.	The surface is smooth. There is no physical interactivity with the surface.
Balance: Quality of visual weight distribution.	The information text within the exhibit is equally distributed between both sides. The exhibit is not cluttered with text.
Line: Quality of linearity. Gives directional content to composition.	The exhibit is split into two parts with Spanish and English texts at the opposite corners. They are clearly separated by the picture in the center of the exhibit.
Shape: Element of physical or spatial containment. The contrasting, joining, overlapping and mixing of shapes that helps create visual interest.	The whole exhibit is created and written on a background image. The background image being the tunnel that the exhibit focuses on.
Additional Comments: The way the display uses the background image allows the viewers to immediately know what it is giving information on. The background image was of a dimly lit tunnel and if you were to look up from the display you would immediately be able to see the exact same tunnel. So, the placement of this display is important.	

Table 12. Exhibit evaluation for El Morro #1

Exhibit Evaluation: El Morro #1

Date: November 10, 2014

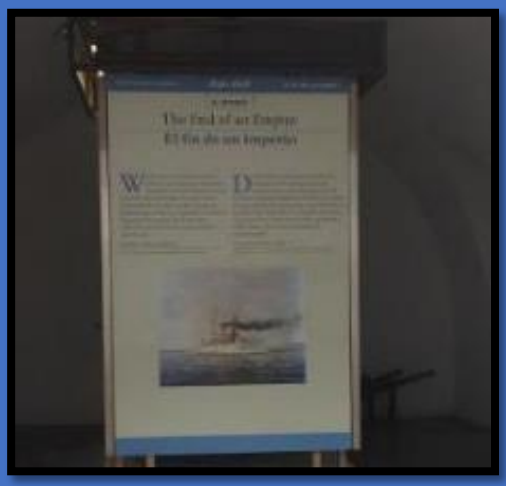


Figure 47. "The End of an Empire" exhibit from El Morro.

Headline: The main message of this particular exhibit located in El Morro is to educate visitors on the battalion soldiers stationed there. The title of the exhibit is "The End of an Empire"	
Sub-headline: This exhibit is smaller and focuses on one specific topic so it does not feature any sub-headlines.	
Key Element Evaluation	
Value: Quality of lightness or darkness used for emphasis and orientation	The section of this exhibit featuring text has a darker background. This emphasizes the text displaying the information on the soldiers. The title of the section is bold and bright and the text itself and the area surrounding it is of a darker color to highlight what that particular section is talking about.
Color: Use of colors.	A bright colorful drawing of a battalion soldier is used to draw the visitor's attention. The use of color allows the visitors to see for example what their uniforms looked like.
Texture: Visual roughness or smoothness of the surface.	This specific exhibit does not have any texture to it. It is a flat 2-D figure.
Balance: Quality of visual weight distribution.	The figure of the soldier itself is not exactly to scale but it is large enough to draw the eye and attention of the visitors.
Line: Quality of linearity. Gives directional content to composition.	The way the exhibit is designed allows the visitors to first view the image of the soldier, which is the important part, and then that figure draws their attention to the informational text to the right.
Shape: Element of physical or spatial containment. The contrasting, joining, overlapping and mixing of shapes that helps create visual interest.	The image of the soldier is slightly behind the rectangular text box to give it the look that he is standing behind it.
Additional Comments: This exhibit appears to be better for younger generations. Having a larger image of a soldier rather than a lot of informational text draws the younger crowd in.	

Table 13. Exhibit evaluation for El Morro #2

Exhibit Evaluation: El Morro #2

Date: November 10, 2014

Figure 48. "Three Flags" exhibit from El Morro.

Headline: This particular exhibit is located in El Morro. The main title of the exhibit is "Three Flags". Its main message is to educate the visitors on what each flag means and why they are there.	
Sub-headline: This is another smaller exhibit that focuses on one specific topic so it does not feature any sub-headlines.	
Key Element Evaluation	
Value: Quality of lightness or darkness used for emphasis and orientation	The exhibit has a lighter background to emphasize the darker text with all of the information.
Color: Use of colors.	The background and text colors are neutral in order to draw the attention to the colorful three images of the flags and the photo shows where the flags are located within the site.
Texture: Visual roughness or smoothness of the surface.	This specific exhibit does not have any texture to it. It is a flat 2-D figure.
Balance: Quality of visual weight distribution.	Both the text and the photos are equally distributed across the exhibit posters so it appears to be visually balanced. To the left is English text and to the right is Spanish text. In the middle is a larger photo. The images of the three flags are spread equally apart along the bottom.
Line: Quality of linearity. Gives directional content to composition.	The way the exhibit is designed allows the visitors to first view the exhibit. It then immediately draws the eye to the actual flags flying directly above.
Shape: Element of physical or spatial containment. The contrasting, joining, overlapping and mixing of shapes that helps create visual interest.	All of the images are rectangular and they overlap. The images of the flags appear to be in front of the overall image of the area.
Additional Comments: For this display, its placement is very important. The way it is positioned in front of the three flags allows the viewers to look at the display and the flags at the same time. Just from a quick glance they can immediately determine what the display is discussing.	

Table 14. Exhibit evaluation for Hacienda la Esperanza

Exhibit Evaluation: Hacienda la Esperanza

Date: November 20, 2014

Figure 49. Educational exhibit example from Hacienda la Esperanza.

Headline: This display has one main focus and that was on the timeline of all of the key components involved with Hacienda la Esperanza.	
Sub-headline: Some of the smaller sub topics include hydrology, flora, and the sugar mill.	
Key Element Evaluation	
Value: Quality of lightness or darkness used for emphasis and orientation	The display uses an array of different colors and shapes. Each timeline has a different color and ranges from darker to lighter colors for emphasis.
Color: Use of colors.	The display uses an array of colors such as greens, blues, red, orange and yellow. Each of these colors represents a different topic or element. The use of clear glass as the background really emphasizes the colored lines on the timeline.
Texture: Visual roughness or smoothness of the surface.	The display is completely flat and 2-D.
Balance: Quality of visual weight distribution.	The display is equally balanced from one side to the other.
Line: Quality of linearity. Gives directional content to composition.	The way the lines on the timeline flow and weave together show how each element is inter-reliant with one another.
Shape: Element of physical or spatial containment. The contrasting, joining, overlapping and mixing of shapes that helps create visual interest.	The lines within the timeline overlap. This overlapping does two things. It is visually appealing and it also shows how each topic works with one another.
Additional Comments: The exhibit does not feature any text directly on it besides the small headings of each timeline, however directly to the left of the display; there are pamphlets with more information. If you follow the lines from the left to the right, you first notice the pamphlets. These pamphlets correspond with the lines on the timeline by using the same colors so it appears as if they are the start of the lines on the timeline coming from around the corner. This allows the visitors to focus on one topic at a time if they would like to. Also this display is large, taking up an entire wall. This allows the visitors to immediately notice it when they walk into the main building of the sugar mill.	

Table 15. Exhibit evaluation for Cabezas de San Juan

Exhibit Evaluation: Cabezas de San Juan

Date: November 21, 2014

Figure 50. "Diagrama de Placas Tectonicas" exhibit from Cabezas de San Juan.

Headline: The main title of this display is "Diagrama de Placas Tectonicas" or "Diagram of Tectonic Plates." This exhibit acts as a topographic map.	
Sub-headline: This is another smaller exhibit that focuses on one specific topic so it does not feature any sub-headlines.	
Key Element Evaluation	
Value: Quality of lightness or darkness used for emphasis and orientation	The exhibit has a lighter background to emphasize the darker text with all of the information.
Color: Use of colors.	The background and text colors are neutral in order to draw the attention to the colorful three images of the flags and the photo shows where the flags are located within the site.
Texture: Visual roughness or smoothness of the surface.	This specific exhibit does not have any texture to it. It is a flat 2-D figure.
Balance: Quality of visual weight distribution.	Both the text and the photos are equally distributed across the exhibit posters so it appears to be visually balanced. To the left is English text and to the right is Spanish text. In the middle is a larger photo. The images of the three flags are spread equally apart along the bottom.
Line: Quality of linearity. Gives directional content to composition.	The way the exhibit is designed allows the visitors to first view the exhibit. It then immediately draws the eye to the actual flags flying directly above.
Shape: Element of physical or spatial containment. The contrasting, joining, overlapping and mixing of shapes that helps create visual interest.	All of the images are rectangular and they overlap. The images of the flags appear to be in front of the overall image of the area.
Additional Comments: For this display, its placement is very important. The way it is positioned in front of the three flags allows the viewers to look at the display and the flags at the same time. Just from a quick glance they can immediately determine what the display is discussing.	

4.7. Educational exhibit designs

The interviews we conducted with Señora Aponte, Señor Negrón and Señor Ice and visiting other historic sites managed by the Trust helped us we identify the main three themes for the educational exhibit of the Antiguo Acueducto. The three themes include an explanation of the function of the mechanical water filtration system, a history of the Antiguo Acueducto, and the importance of water. The mechanical water filtration system exhibit will contain one plaque with buttons, which provide the interactive component. Once one of the buttons is pressed, it should activate lights on a three-tank section of the water filtration system in front of the standing exhibit. The lights will show the visitors the direction of the water flow during each of the processes described on the plaque. The water filtration system interactive exhibit is going to be a standing exhibit located between the model of the water filtration system and the actual water filtration system.

Both the history of the Antiguo Acueducto and the importance of water exhibits each contain two plaques of information. We visited other important historical sites such as El Morro and Castillo de San Cristóbal, to determine how to emphasize the importance of the history of the Antiguo Acueducto. Finally, because Para la Naturaleza focuses on conservation, we decided our third main focus of the exhibit would be the importance of water and the world water crisis. We also recommend placing a standing exhibit of a topographic map of the site of the Antiguo Acueducto as part of the importance of water educational exhibit. The map can show how water is taken from the river, goes into the Antiguo Acueducto and is provided to people's homes after.

We then read through the background research that we did and took the content for each of the exhibits from it. To make the exhibits understandable for as many visitors as possible, we made them in both English and Spanish. This is following the same practice as all the exhibits at the sites that we visited. At each site, the exhibits were either in both English and Spanish or entirely in Spanish.

For our educational exhibit design research, the main sources we took into consideration while creating the exhibit designs were Falk (1997) and Dean (1996). Falk (1997) suggests the use of a headline and subheadline in an exhibit to facilitate its conceptual development. A headline and subheadline help the reader link the exhibits together and learn the story the exhibit

is trying to convey. Dean (1996) identifies the key factors of educational exhibit design. These factors as mentioned in the methodology include value, color, texture, balance, line, and shape. The exhibit evaluation form we created and used during our site visits determines the headline and subheadline of each exhibit and evaluates them on the factors Dean (1996) identified. Afterwards, we based our exhibit designs on the practices and factors Falk (1997) and Dean (1996) suggested.

Our background research, interviews and site visits helped us develop and finalize our preliminary exhibit designs. The documentation and history of the Antiguo Acueducto the members of the Trust provided us with were key to creating the preliminary designs. So were their suggestions for educational exhibit topics. The three main identified topics were history of the Antiguo Acueducto, function of the mechanical water filtration system and the importance of water. The main exhibit for the mechanical water filtration system is its actual physical model. The second exhibit for the mechanical water filtration system explains the operations of the system. This exhibit has been planned to be interactive and be integrated with a light system on the original water filtration system of the Antiguo Acueducto. The number of panels chosen for each topic was determined by the amount of information necessary to convey for each topic. All of the preliminary designs for the posters can be found in Appendix F. After we created our preliminary designs, we presented them to the members of the Trust and interviewed them with the questions presented in Appendix C. Presented below in Tables 16, 17 and 18 are their responses. On the left side of the tables are the questions and on the right side are the responses.

Table 16. Exhibit design interview responses of the interpreter from Hacienda la Esperanza

Interview Responses for Educational Exhibit Designs	
Questions	**Responses**
Interviewee:	Jose Nevarez, Interpreter at Hacienda la Esperanza
Date of Response:	**12/06/2014**
1. Could you please summarize what you learned from this exhibit?	The interpreter informed us that he learned a brief history of the development of aqueducts through the history. He also learned that the Antiguo Acueducto de San Juan is the first one of its kind in Puerto Rico. In his opinion, the History of the Antiguo Acueducto exhibit is very neat and gives a nice perspective of the

	development of the Antiguo Acueducto.
2. How do you think the content corresponds to the headline?	Overall, he thinks that the content relates to the headlines. He suggested including in the exhibits the purpose of the Antiguo Acueducto, why it was built, and what it is was used for.
3. How do you think the images, themes and colors were used?	The interpreter thought that the images and graphics that we used in the exhibits were nice and matched really well with the themes, and colors. He suggested adding some visual perspective to the timeline. In his opinion, people need to see dates and how far away in time these events occurred. He provided the timelines at the Hacienda La Esperanza. They have the dates and timescales visible to the public, which in his opinion help making references more easily.
4. What aspects of the exhibit did you like/dislike the most?	In the water filtration exhibit, he suggested to include a diagram or a drawing of how the system worked. Otherwise, he liked the images and colors in all of the exhibits.
5. How do you think the exhibit balanced pictures and content? Was it too cluttered?	He thought that the exhibit was well balanced.
6. What general feedback do you have about the exhibits you viewed?	He corrected the content about Para la Naturaleza and suggested that we include that there are more than 29,000 of land in more than 45 Natural Protected Areas protected by Para la Naturaleza.

Table 17. Exhibit design interview responses of the interpreter from Cabezas de San Juan

Interview Responses for Educational Exhibit Designs	
Questions	**Responses**
Interviewee:	Leonor Alicea, Interpreter at Cabezas de San Juan
Date of Response:	**12/06/2014**

1. Could you please summarize what you learned from this exhibit?	The interpreter said that she could learn that the San Juan Aqueduct was crucial for the economic and social development of the city and that the city doesn't need huge, expensive and complicated systems to have potable water.
2. How do you think the content corresponds to the headline?	In terms of the plates it selves, she thought that the headlines correspond to the content very well.
3. How do you think the images, themes and colors were used?	She thought the third slide needed to be more visual to help visitors understand how the water filtration system functioned.
4. What aspects of the exhibit did you like/dislike the most?	She liked the different colors, pictures and maps used in each of the exhibits. She liked the timeline arrangement, however, she would prefer to see it with less text.
5. How do you think the exhibit balanced pictures and content? Was it too cluttered?	She thought that the pictures and text balanced out well. For the aerial picture in the water crisis exhibit, she suggested using another picture with a close up on the city of San Juan along with the first one.
6. What general feedback do you have about the exhibits you viewed?	In general, she thought that the concept is good, content is excellent and the presentations grabs a person's attention.

Table 18. Exhibit design interview responses of the project manager of the Antiguo Acueducto

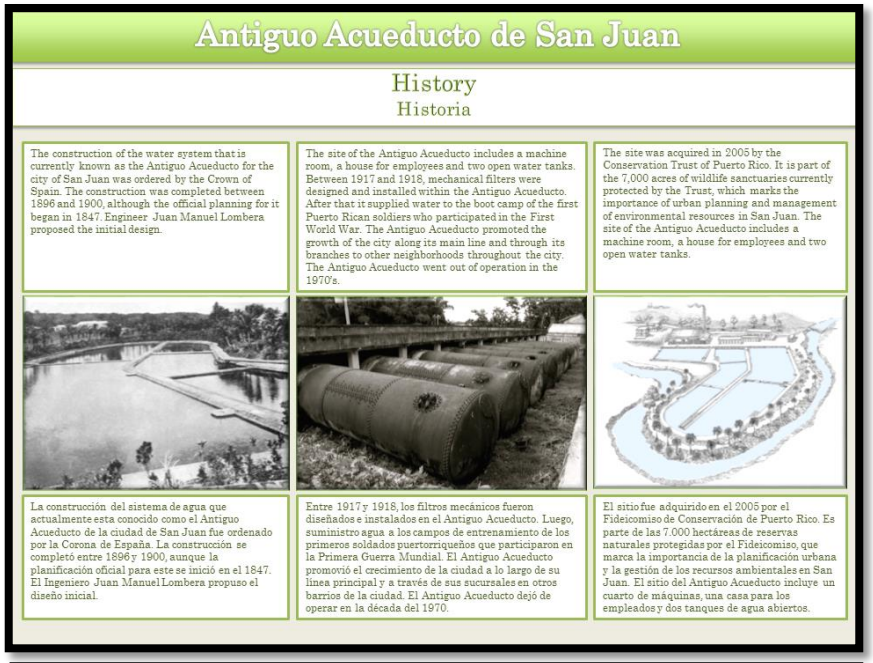
Interview Responses for Educational Exhibit Designs	
Questions	**Responses**
Interviewee:	Elsie Aponte, Project Manager of the Antiguo Acueducto
Date of Response:	**12/08/2014**
1. Could you please summarize what you learned from this exhibit?	In general, Señora Aponte considered the educational exhibits good. She suggested to review the Spanish words and definitions provided in the exhibits.

2. How do you think the content corresponds to the headline?	
3. How do you think the images, themes and colors were used?	For the images, she suggested providing a drawing or a sketch of the water filtration system for the visitors to be able to visualize how the water filtration system functions more easily.
4. What aspects of the exhibit did you like/dislike the most?	
5. How do you think the exhibit balanced pictures and content? Was it too cluttered?	
6. What general feedback do you have about the exhibits you viewed?	She also suggested to somehow visualize in the importance of water how water returns into the river at the end.

Using the feedback the members of the Trust gave us, we finalized our exhibit designs. Presented below in the Figures 51, 52, 53, 54 and 55 are both the preliminary and final designs for each of the educational exhibits that we created. Both the preliminary and final designs can be also found in Appendices F and G. The designs on the top are the preliminary (Appendix F) ones that we created and the designs on the bottom are the designs finalized (Appendix G) after all the feedback we received on them.

The poster size for each of the posters except the timeline is 40 inches in width and 30 inches in height. The poster size for the timeline is 48 inches in width and 30 inches in height. The font size for the main headline is 112, and the font size for the subheadline is 90 for the English text and 70 for the Spanish text. The font size for both languages in the text boxes is 35. The final designs of the educational exhibits that are of a higher resolution and larger size can be found separately in Appendix G. The floor plan presented in Figure 42 shows where each of the educational exhibits is to be located in the water filtration building.

(a)



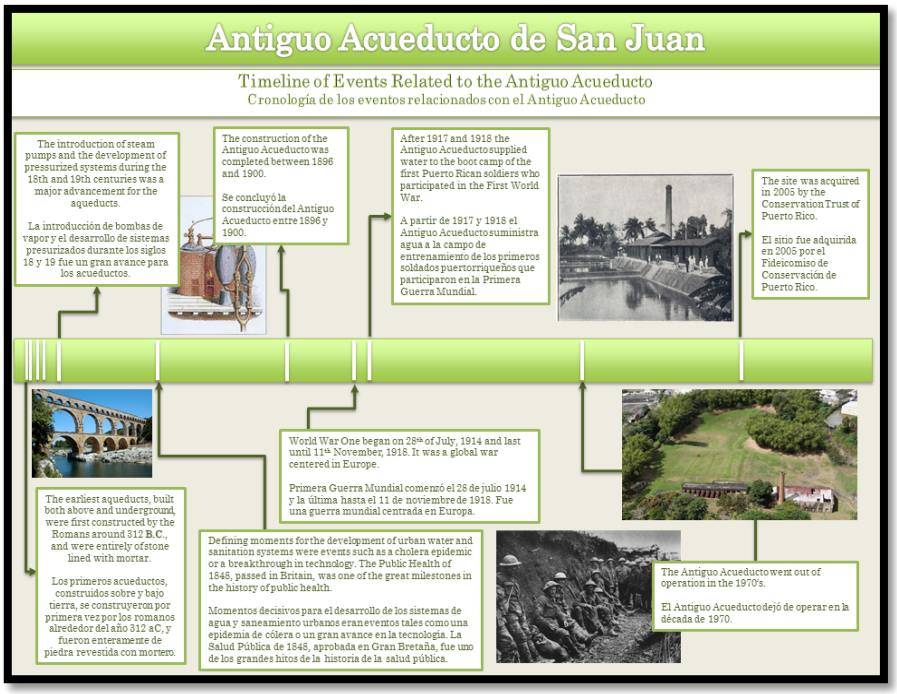
(b)

Figure 51. Preliminary and final exhibit design for the history of the Antiguo Acueducto. (a) Preliminary design of the history of the Antiguo Acueducto exhibit. (b) Finalized design of the history of the Antiguo Acueducto exhibit.

Figure 51 above shows the preliminary and final designs of the history exhibit of the Antiguo Acueducto. The original design had more text, which was all clumped together. As a result of the feedback we received from Jose Nevarez, who suggested that we add visual perspective to the exhibit we changed the colors. The original color scheme was too light so we made it a couple of shades darker. This helped the text stand out more. There was also a future drawing of the site of the Antiguo

Acueducto created by the Trust included in the preliminary design. Leonor Alicea, an interpreter at Cabezas de San Juan, suggested that we use an actual picture of the Antiguo Acueducto in its place instead, so our revised design reflects this change. The difference in colors can be clearly seen between Figure 51 (a) and Figure 51 (b).

(a)



(b)

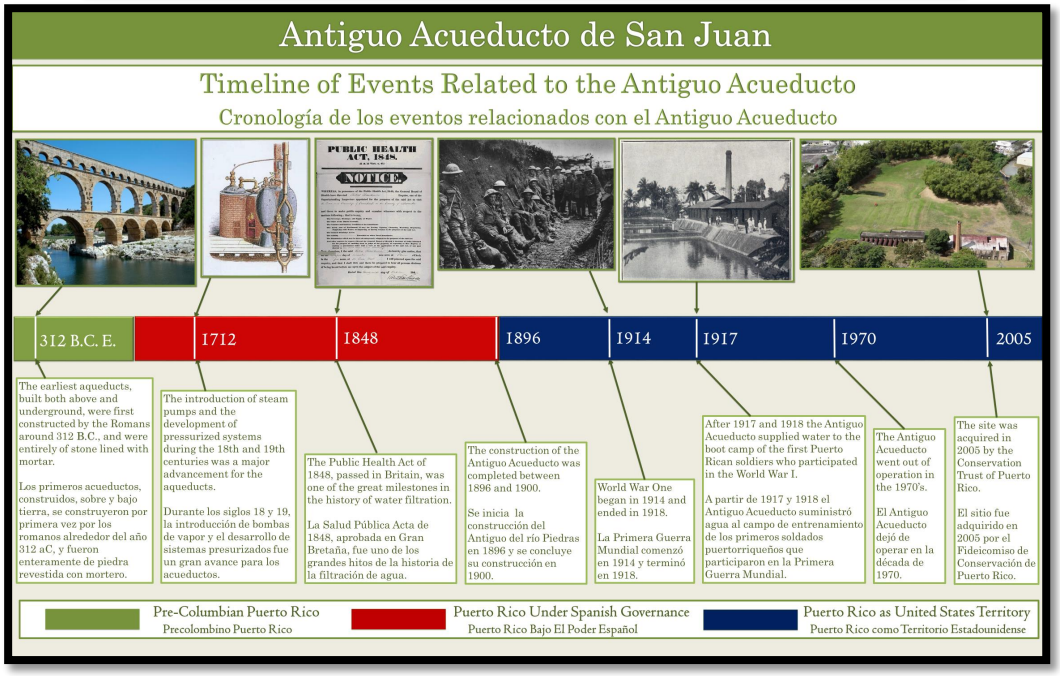
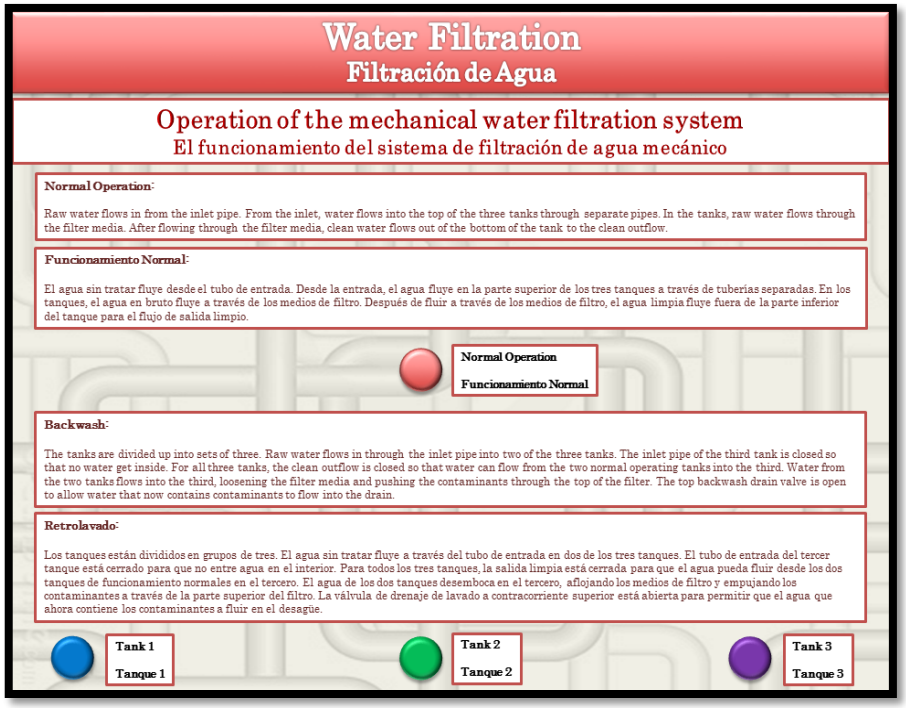


Figure 52. Preliminary and final designs for the timeline exhibit of the Antiguo Acueducto. (a) Preliminary design of the timeline. (b) Finalized design of the timeline.

Figure 52 above shows the preliminary and final designs of the timeline exhibit of the Antiguo Acueducto. The original design shown in Figure 52 (a), had more text than the current one. Since some of the information is repeated in the first history exhibit, we got rid of it. To make the exhibit more organized, we included all the pictures above the timeline and all the text below the timeline. The timeline is now divided up into three periods of Puerto Rico's history: pre-Columbian, under Spanish governance, and as United States Territory. As suggested by Jose Nevarez, interpreter at Hacienda la Esperanza, we also included the dates of all the events on the timeline. Another one of his suggestions was to make the timeline different colors depending on the time period. Each of Puerto Rico's three main time periods have been included in a different color on the timeline. As in the previous history exhibit shown in Figure 51, the colors have been darkened in this exhibit as well. We made the exhibit wider so that the events on the timeline could be better spaced out. The difference in the color and width in the final design presented in Figure 52 (b) can be noted compared to the preliminary design in Figure 52 (a).

(a)



(b)

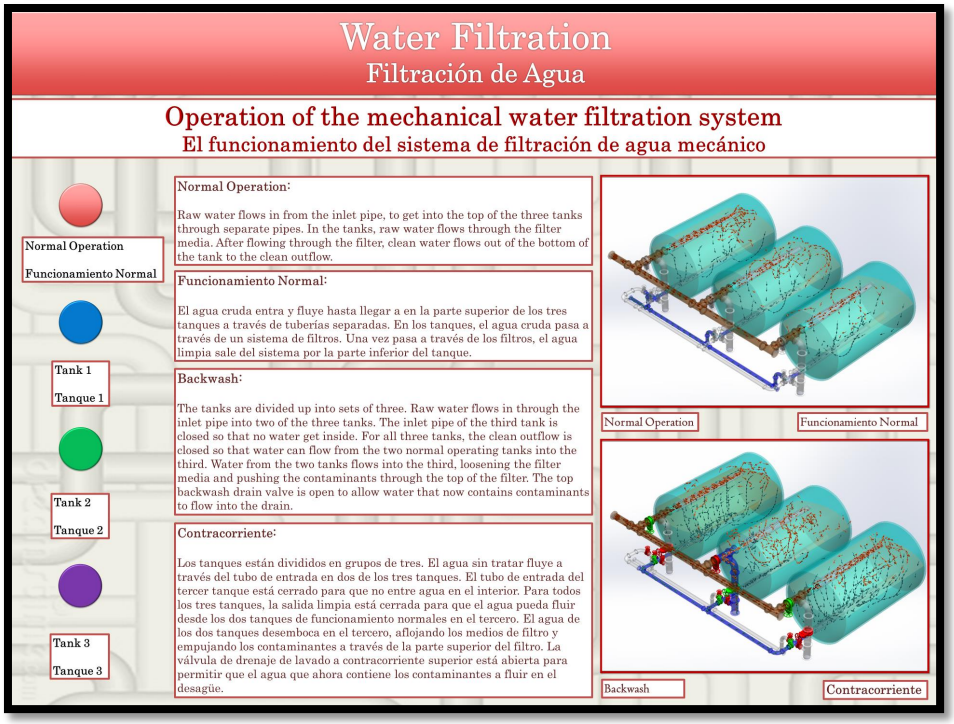
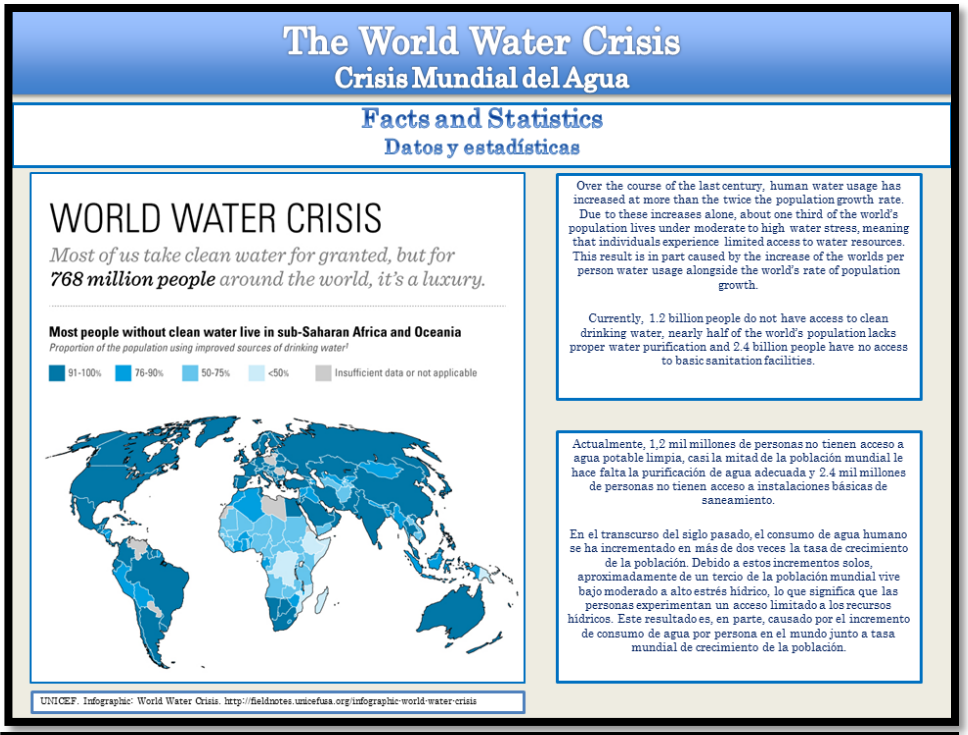


Figure 53. Preliminary and final designs of the function of the water filtration system exhibit. (a) Preliminary design of the water filtration exhibit. (b) Finalized design of the water filtration exhibit.

Displayed above in Figure 53 are the water filtration educational exhibit preliminary and finalized designs. The original design of the water filtration exhibit did not contain any images. All of the feedback we received suggested that we use images to help visitors understand the

water filtration processes. To reflect this feedback, our final design for this panel includes our SolidWorks drawings of the processes of the mechanical water filtration system. We also chose to align all the buttons on one side so that the visitors can follow the processes one after the other while reading the text next to them. The exhibit is meant to be interactive. The buttons are to be linked to a light system installed on three of the filter tanks of the original mechanical water filtration system of the Antiguo Acueducto located in front of the panel. When each of the buttons is pressed, they are to turn on the lights installed on the original mechanical water filtration system to show in which direction the water would have been flowing if the Antiguo Acueducto would have been still running. This exhibit is meant to be a standing interactive exhibit. It is number 2 on the floor plan presented in Figure 42 above. The difference between the finalized exhibit design, which has the buttons on the left in Figure 53 (b), can be seen compared to the preliminary design in Figure 53 (a).

(a)



(b)

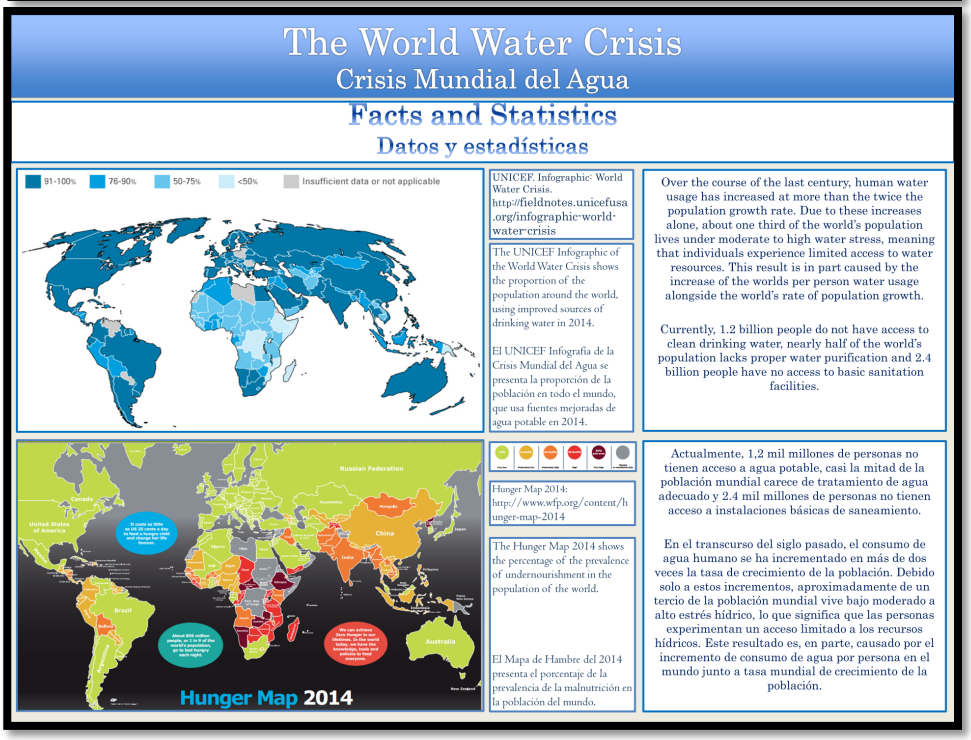
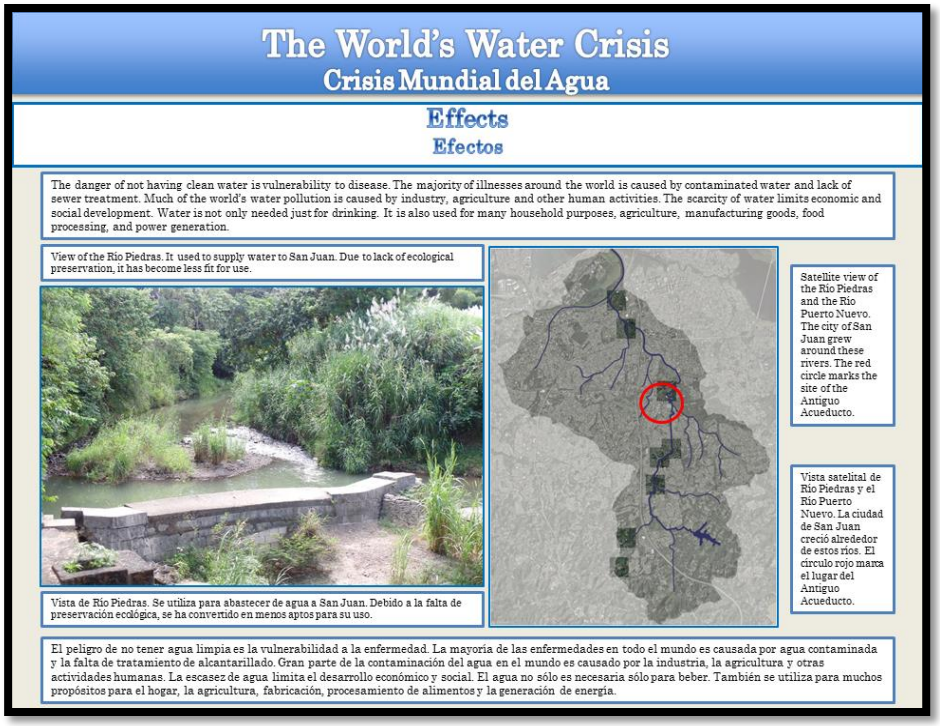


Figure 54. Preliminary and final designs for the importance of water facts exhibit. (a) Preliminary design of the importance of water facts exhibit. (b) Finalized design of the importance of water facts exhibit.

Presented in Figure 54 above is the importance of water exhibit focusing on facts and statistics. All of the feedback we received on this exhibit suggested that the members of the Trust

were in favor of the world water crisis image we included. The image shows by country the percentage of the population that has access to clean drinking water. To make the exhibit more interesting, we also included a world hunger map. We have included thinking questions for the interpreters to ask the visitors in the recommendations chapter below. These thinking questions will help visitors draw parallels between the water crisis and other major world problems and which countries are affected by them the most. Figure 54 (b) has the finalized exhibit design, including both the water crisis and hunger maps.

(a)



(b)

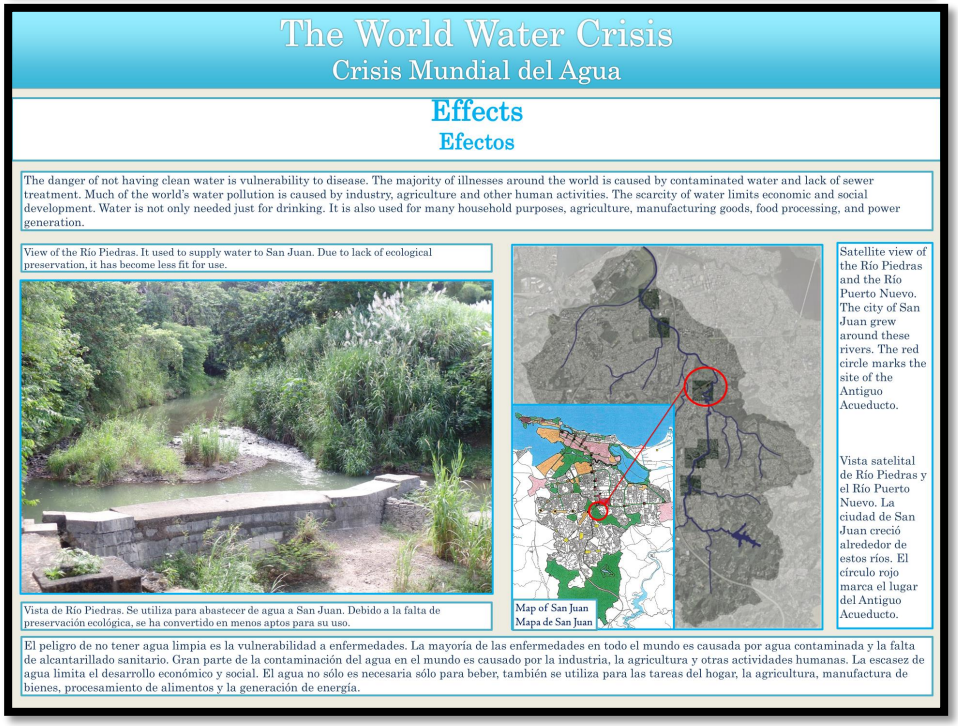


Figure 55. Preliminary and finalized designs for the importance of water effects exhibit. (a) Preliminary design for the importance of water effects exhibit. (b) Finalized design for the importance of water effects exhibit.

Figure 55 above contains the preliminary and finalized designs for the importance of water effects exhibit. As suggested by Leonor Alicea, we changed the colors between the two

exhibits about the importance of water. We did this to differentiate between them more easily and chose a slightly lighter blue color scheme for this exhibit. Another suggestion Leonor Alicea was to add another image to show visitors in which section of San Juan is the Antiguo Acueducto located. It would also help visitors see how the city grew along the river. Figure 55 (b) contains the finalized exhibit with the lighter blue color scheme in contrast to the preliminary design presented in Figure 55 (a).

4.8. Results for exhibit material research

After researching the different companies that provide interpretive sign materials and exploring the various features and capabilities of each, we developed a list of qualities that should be required for exhibit materials, as well as a list of desirable but optional qualities. We split these qualities into two separate groups using suggestions from the companies and keeping in mind the locations of our exhibit displays within the site of the Antiguo Acueducto. The required qualities are what will be necessary for the Antiguo Acueducto exhibits. We know that the exhibits need to be resistant to constant warm temperatures because Puerto Rico is consistently hot on a day-to-day basis. The quality and use of color of the display is important as well so good color and vibrancy is important. Use of color draws the eye of the visitors. Lots of pictures will be used for visual affect and to keep the visitors interest, so having good resolution will be essential. An image's resolution is how much detail the image holds. The higher the resolution, the better the quality of the images will be. Also, because the displays are simply mounted on the wall in the open it is imperative that they will not deteriorate if vandalized meaning they can easily be cleaned and if someone were to attempt to destroy it they would not be successful. This also attributes to the displays having a protective finish. The optional qualities are characteristics that are not particularly needed but can be beneficial. For example, because all of our exhibit displays are indoors, we do not necessarily need them to be resistant to moisture. They will be completely protected from the rain. This is also why UV resistance is an optional characteristic. We do not have to worry about UV rays because the exhibits will be protected from the sun. Also, it would be great if the exhibits are environmentally friendly, but that is not a necessary characteristic. Shatterproof and abrasion resistant are optional qualities as well because there will be staff there to keep an eye on the exhibit areas. There should be no

major issues that would lead to the exhibits shattering. Table 19 below shows these two lists of qualities.

Table 19. Required and optional qualities of exhibit materials

Required Qualities of Exhibit Materials
• Resistant to temperature • Full resolution • Good Color • Will not deteriorate if vandalized • Protective finish • At least a 10 year guarantee
Optional Qualities of Exhibit Materials
• Resistant to moisture (exhibit will be indoors) • Environmentally friendly • UV resistant • Shatterproof • Abrasion Resistant

The companies we found that provide interpretive display materials include EnviroSIGNS, Vacker Inc., and KVO Industries Inc. We chose these specific companies because they each provided materials for exhibits similar to ours. They are also three of the top competitors within their specialty. We used their product suggestions and descriptions to come up with the two lists in the table above. Table 20 below shows a list of the specific products each company provides. Along with the products is a list of characteristics each one has that match the ones named above.

Table 20. Supplier companies

Supplier Companies		
Company	**Product**	**Description**
Vacker Inc.	Imageloc	• Protective finish • Environmentally friendly • Good color and resolution • Resistant to moisture • 10 year warranty

	High Pressure Laminate-Embedded Phenolic Resin	• Durable • Will not fade in sun • 10 year warranty
EnviroSIGNS	DuraReader	Digital High Pressure Laminate (dHPL) phenolic interpretive sign panel • Environmentally friendly • Good color and resolution • UV Resistant • Resistant to temperature • Abrasion Resistant • Shatterproof • Will not delaminate or deteriorate • 10 Year Limited Warranty • Made in the US * Used by the National Park Service
	CompReader	• Environmentally friendly • UV resistant • Abrasion resistant
KVO Industries Inc.	High Pressure Laminate	• Does not peel or delaminate • UV resistant • 10 year guarantee
	Vitratek Porcelain Enamel	• Weather resistant • UV resistant • 25 year warranty • 12 week delivery

5.0. Recommendations and Conclusions

Presented below are the recommendations that we created based on our final results and analyses. These are suggestions for the Conservation Trust of Puerto Rico for both the physical model of the water filtration system and the exhibit displays.

5.1. Model Design Recommendations

After analyzing the data we gathered in our part research we decided on suggestions as to which parts to use. We recommend the use of the Akrylix custom acrylic tank for the filter tanks. We recommend this because the custom constructed tanks can be purchased with the several special features that the model design calls for in the tanks built in. These features include the two holes for the diffusers on the top and bottom of the tank as well as the maintenance hatch in the back. Unless the Trust has a person skilled in working with acrylics or a contractor they use frequently, we do not recommend the Interstate Plastic option. This is because it does not only require some assembly but needs the other modifications as stated above, which would be included in the custom option. The drawbacks of the Akrylix option is that it is custom, which means that it may end up being more expensive than the Interstate Plastic options. We have attempted to receive a quote from Akrylix but due to time constraints, we did not receive a price.

The parts supplier we recommend for the pipes and valves is Alsco. The difference in the actual products is not very large considering they are both schedule 40 clear PVC so that was not a factor. Alsco did have a couple of slight advantages over United States Plastic Corp. First Alsco's pipes had a stronger blue tint then the pipes available from United States Plastics Corp. We determined that the stronger tint would allow more of a visual contrast with the tank and water so that the filter process would be more visible. Second is that Alsco provided clear PVC valves and United States Plastics did not. Finally, Alsco's pipes were slightly cheaper.

For the pump we recommend the use of a 2 horsepower pump. We recommend this pump because it is important to make sure that the pump is strong enough to have the model function correctly. If the pump is too weak, then the backwash will not work as effectively because the filter media will not be able to spread out well enough to remove the contaminant from it. While a problem of the pump being too strong is that the filter media may be too agitated and affect the integrity of the layers of the filter media, a blow off valve or pressure release valve can be added

to the top of the pump to control the amount and velocity of the water entering the tanks. The reason our recommendation for the pump is not more exact is because the calculation to determine the optimal horsepower is highly complicated and we do not know all the variables, such as the filter media, to determine it.

The estimated cost of these recommended parts, including the pipes valves, and pump, will be $1,720.07. The price of the Akrylix tanks are unknown at this point simply because they did not have time to provide us a quote. The cost breakdown is in Table 21 below.

Table 21. Cost breakdown for part types

Part type	Number of part	Total cost
1 inch diameter pipe	13.5 ft.	$69.60
1 ½ inch diameter pipe	19.41 ft.	$112.80
1 inch diameter 90° elbow pipe	5	$57.45
1 ½ inch diameter 90° elbow pipe	5	$107.55
1 inch diameter tee pipe	4	$60.68
1 ½ inch diameter tee pipe	4	$115.68
1 inch diameter ball valve	6	$163.32
1 ½ inch diameter ball valve	6	$273.00
2 Horsepower pump	1	$759.99

While it is possible that the sand and gravel combination tested in the experiment would work in the system, it is recommended that the Trust contact Marcus Negrón or John Ice, engineers that both work for the Puerto Rico Aqueduct and Sewer Authority, to research and acquire more appropriate filter media. They both have experience in operating mechanical water

filters very similar to the ones we are attempting to replicate in our model. Once an acceptable media has been selected a suitable contaminant can be found.

These are some guidelines to follow when first setting up the physical model after it is constructed. First, fill the holding tank that is under the table with water. Fill until the water is 6 inches from the top of the tank. We recommend this because the amount of water will be enough to fill the filters and have enough water to have the contaminant still mixed in. The reason we do not recommend filling it all the way is that the water may over flow the tank when contaminants are added. After water is added into the holding tank, add the filter media. As stated earlier in these recommendations the exact filter media is yet to be determined but the setup of it is the same. First, open the maintenance hatch and pour the coarsest filter media in the amount decided and make sure to pour gently as to not damage the diffuser inside of the bottom of the filter tanks. Make sure that this filter medium is evenly dispersed and level across the tank. Next, add the next most coarse filter medium to the amount recommended. Continue this process until all of the desired media is added. Next, it is recommended to run the filters without the contaminant added. This is recommended so that the media can be packed and compressed. This is important because if contaminants are run through it before it is packed then the contaminants will mix with the media and may cause the filter media to become more clogged and make it more difficult to backwash it all out.

Once the filter is set up, the next important step is to determine the contaminant to use for the demonstration. In order to do this an experiment is recommended. The first step in the experiment is determining a potential test contaminant. From the results of the experiment that we conducted we found that glitter may be a viable option. With these results we could also recommend not using a substance like potting soil. Some things to keep in mind when selecting the potential contaminant are that they are not highly soluble in water, possibly a plastic material of some kind, and is large enough to be caught in the filters but small enough that they will not too quickly clog the filter media. Once the test contaminants are established, the next step is conducting the experiment. The two changing variables in the experiment will be the type of contaminant and the amount of the contaminant used in each trial. The data that should be recorded is the amount of time it takes for the filter media to be saturated with contaminant. “Saturated with contaminant” is a subjective term so there are a couple of options to measure

this. The first option is to film the filter while the experiment is running. Another option is to have an observer there who can determine when the filter media is "saturated". We recommend the video because it does not have to depend on just one person's opinion. Two things the experiment should compare are the amounts of contaminant used and the time it takes the filter media to become saturated with the contaminants. A detailed explanation of the exact procedure of the experiment is located in Appendix I.

The model will operate very specifically and need the interpreters to have the correct valves turned in order to have it operate correctly. The operation guidelines of the physical model for the interpreters can be found in Appendix H.

5.2. Educational Exhibit Recommendations

We recommend to the Trust that they pilot-test the exhibits with visitors before implementing them. This will enable the Trust to gain the opinion of the visitors on the educational exhibits. This way, they can learn how effective the exhibit designs are at communicating content and how well they facilitate learning. Although we had time to have some members of the Trust contribute their opinions, we did not have time during our stay in Puerto Rico to actually create the educational exhibits and pilot-test them on a group of visitors. Our finalized designs can be pilot-tested, adjusted and later implemented by the Trust to be used on the site.

In order to assist the Trust in this process, we developed a preliminary questionnaire and an outline of a strategy for the Trust to use during the pilot-testing. The questionnaire we developed is an adapted version of the questionnaire we used to gain feedback from the members of the Trust about our preliminary designs. Our original questionnaire turned out to be very informative and helpful with the feedback provided. Provided in the Table 22 below is the list of questions we suggest the Trust use during the pilot-testing of the educational exhibits. We recommend that the Trust present the questions to the visitors after a tour of the site given by one of the interpreters. The exhibits are designed to be explained by an interpreter.

Table 22. Interview questions for pilot-testing of the educational exhibit designs

Interview Questions for Pilot-Testing of Educational Exhibit Designs
1. Could you please summarize what you learned from this exhibit?

2. How do you think the content corresponds to the headline?
3. Do you think the images, themes and colors corresponded to the content? How?
4. Where there any aspects of the exhibit that left you confused? Lacked content?
5. How do you think the exhibit balanced pictures and content? Was it too cluttered?
6. What general feedback do you have about the exhibits you viewed?

The Trust notified us that the site of the Antiguo Acueducto, similar to all of its other sites, is going to have interpreters to give tours for all the visitors. We provide the following suggestions to the Trust for the interpreters to incorporate in their tours.

When presenting an educational exhibit poster, we suggest that the interpreter ask a thinking question to the audience. This thinking question will help the visitors understand the concept of each of the educational exhibits better and facilitate learning more successfully. Provided in the Table 23 below is the list of thinking questions we suggest for each of the educational exhibit posters. On the left side of the table is the exhibit main title and subheadline and on the right side is a sample thinking question for each of the exhibit plaques.

Table 23. Thinking questions for each plaque of the educational exhibits

Thinking Questions for Educational Exhibits	
Exhibit Title	**Question**
Antiguo Acueducto de San Juan History	In your opinion, what factors contributed to the fact that the Antiguo Acueducto of San Juan stopped operations in the 1970's?
Antiguo Acueducto de San Juan Timeline of Events Related to the Antiguo Acueducto	Why do you think the Public Health Act of 1848 was so important to the history of water filtration?
Water Filtration Operation of the mechanical water filtration system	What do you think would happen to the water if the filtration tanks were not regularly backwashed?

The World Water Crisis Facts and Statistics	What similarities do you see between the World Water Crisis Map and the Hunger Map?
The World Water Crisis Effects	Do you think going through the middle of a city makes a river polluted? If so, why?

We suggest that the interpreters guide the tour following the order of the exhibits presented in the floor plan in Figure 42. A summary of our recommended guidelines for the interpreters can be found in Table 24 below. This way they can start with a timeline of events related to the Antiguo Acueducto to give the visitors some background information before going into the interactive water filtration exhibit. This particular exhibit features buttons on the left side. We recommend that those buttons correlate with a lighting system installed on the existing water filtration system. The lights will light up in the direction of the flow of the water. This will allow the visitor to see the flow of both the normal operation and the backwash operation. The interactive water filtration exhibit will help the visitors understand the processes of the water filtration system better before they move on to the physical model. Mainly, the interpreter will operate the physical model, however, it is designed to allow visitors to interact with it as well. After presenting the physical model and the water filtration operations to the visitors, the interpreter can go back to talking about the history of the Antiguo Acueducto, this time providing the details about what its role and purpose used to be. The final stop is the room with the exhibits focusing on the importance of water. The interpreter can begin by talking about the main facts and statistics related to water in the world today. After that, the interpreter can show the visitors the standing exhibit of the Antiguo Acueducto. The exhibit will demonstrate how water is taken from a river, filtered, and delivered to people's homes after. In the Antiguo Acueducto standing exhibit, we recommend that the Trust include a model of the site of the Antiguo Acueducto. The space that we allocated for this exhibit is marked on the floor plan presented in Figure 42 by a purple rectangle under number 6. We found a model of the site that they could use in the exhibit in the office of the Trust located at the site of the Antiguo Acueducto.

Figure 56. Model of the Antiguo Acueducto. We suggest a model similar to this one to be used as part of the importance of water educational exhibit.

To have the exhibit demonstrate more clearly how water is taken from a water source, processed and delivered to people's homes, we suggest that the Trust enhance the model of the site presented in Figure 56. On the side of the source of the river, they could include more vegetation in the form of trees to show the importance of nature in having clean water. On the other side of the model, after the water is shown to go through the Antiguo Acueducto, we recommend that the Trust include a pipe on the model to show the water leaving from the site and add a model of a house to which the pipe with the water is supposed to be going to. This way visitors can see how the water is taken from a water source in the environment, processed at a water filtration facility and brought to their homes. The red circle on the picture shows where the extra trees and vegetation should be added to the map. The yellow circle shows where the pipe and the house should be added.

The final exhibit will talk about the effects of water pollution and how the rivers people take water out of are becoming contaminated. It includes a current picture of the Río Piedras, which is polluted and does not look fit for providing drinking water. The exhibit puts everything

into perspective because people will actually realize that the water in that river used to be delivered to their homes less than half a century ago. We recommend that the Trust follow this order while presenting the exhibits. All the exhibits are located in the larger part of the water filtration building so that the visitors have plenty of space to survey the educational exhibits and mechanical water filtration system without feeling uncomfortable. The Table 24 below corresponds to the floor plan presented in Figure 42 earlier. In the left column of the table is the number of each exhibit on the floor plan and on the right column is a summary of each exhibit along with a suggested thinking question.

Table 24. Summary of educational exhibit guidelines for interpreters

Summary of Educational Exhibit Guidelines for Interpreters	
Exhibit number on floor plan	**Suggested guidelines and thinking questions for the exhibit**
1	Antiguo Acueducto de San Juan timeline educational exhibit. This exhibit describes the events related to aqueducts and water filtration systems worldwide before focusing on the Antiguo Acueducto. Suggested thinking question for the exhibit: Why do you think the Public Health Act of 1848 was so important to the history of water filtration?
2	Water filtration system standing interactive exhibit. Interpreter can demonstrate each operation of the water filtration system by pressing the buttons on the left side of the text. The text describes each of the operations the mechanical water filtration system of the Antiguo Acueducto used to perform. The buttons will be linked to lights on the water filtration system. The lights will light up to demonstrate the direction of the flow of water in each of the operations. The order of the buttons to be followed is from the top to bottom. Suggested thinking question for the exhibit: What do you think would happen to the water if the filtration tanks were not regularly backwashed?
3	Physical model of the mechanical water filtration system. Guidelines for operating this model can be found in Appendix H.
4	Antiguo Acueducto de San Juan history exhibit. This exhibit goes more in depth about the history of the Antiguo Acueducto. Suggested thinking question for the exhibit: In your opinion, because of what reasons did the Antiguo Acueducto of San Juan go out of operation in the 1970's?
5	The world water crisis facts and statistics exhibit. This exhibit focuses on the lack of water worldwide. It also contains a map showing hunger statistics worldwide. This is for the visitors to

	draw parallels between the lack of water and food and their causes. Suggested thinking question for the exhibit: What similarities do you see between the World Water Crisis Map and the Hunger Map?
6	The Antiguo Acueducto site standing exhibit. This exhibit is to contain more trees around the river to depict the importance of nature, a pipe running from the river to the Antiguo Acueducto and leaving it, and the pipe connecting the Antiguo Acueducto to a house away from the site. The purpose of this exhibit is to demonstrate how water is taken from nature, filtered and delivered to people's houses.
7	The final exhibit, the world water crisis effects exhibit. This exhibit focuses on the effects of polluting the water. It mostly concentrates on San Juan the Río Piedras. It shows how the city grew around the river. Suggested thinking question for the exhibit: Do you think going through the middle of a city makes a river polluted? If so, why?

After analyzing multiple exhibits from different historically important sites, we've compiled a list of recommendations for the Antiguo Acueducto's display designs. First, the displays should not only include a major heading, but smaller subheadings as well. The major heading should give a general overview of what information the specific display is conveying to the public. For example, one of the main headings could be "El Antiguo Acueducto." With one quick glance the visitors will know what the overall exhibit will be about. Then, for a subheading it could be "History." Because the subheading is beneath the larger main heading, the visitors will automatically be able to assume that the following information will be discussing the history of the Antiguo Acueducto. Next, while choosing a design, you should take into account the characteristics listed in the evaluation form in Appendix B. As mentioned previously, the way these characteristics are interpreted within a display can really attract the attention and the interest of the visitors.

After doing extensive research on the different possible options for the interpretive displays for the Antiguo Acueducto, we were able to determine what would be the best option for the Trust to use. DuraReader from EnviroSIGNS seems to be the best possible option to use for our exhibit displays. This product has all of the qualities specified in the list of necessary characteristics plus some of the qualities that are optional. For example, the Trust values the environment and this particular material is environmentally friendly. Compared to the other

materials it seems to be the best option. When produced, it has good color and full resolution, which will be great for the use of pictures. It is also resistant to moisture and different temperatures. If vandalized, it will not deteriorate. The other materials have a few similar qualities but do not have all of the necessary qualities like the DuraReader. This is why our final recommendation will be to use the DuraReader from EnviroSIGNS.

5.3. Conclusion for recommendations

In conclusion, presented above are the recommendations our team came up with for the Trust to preserve the site of the Antiguo Acueducto. Our recommendations are aimed to help the Trust preserve the Antiguo Acueducto for educational purposes. To do so, we recommend that the Trust create a physical model of the mechanical water filtration system for demonstrative purposes. We also recommend to the Trust to install educational exhibit posters throughout the water filtration building at the site of the Antiguo Acueducto along with a model of the site. These exhibits will inform the visitors about the history and function of the mechanical water filtration system of the Antiguo Acueducto, along with the importance of water. We hope that our recommendations will help guide the Trust in achieving its preservation goal.

References

Allen, S. and Gutwill, J. (2004). Designing with Multiple Interactives: Five Common Pitfalls. *Curator: The Museum Journal*, 47: 199–212.

Andrews, E. (2012, November 20). 10 Innovations That Built Ancient Rome. Retrieved December 2, 2014, from http://www.history.com/news/history-lists/10-innovations-that-built-ancient-rome

Anonymous. (2014, September 24). Al Rescate del Antiguo Acueducto del Río Piedras. Retrieved November 3, 2014, from http://aldia.microjuris.com/2014/09/24/al-rescate-del-antiguo-acueducto-del-rio-piedras/

Arnold, J., & Schnieders, J. (1999). Filter media cleaning of a rapid flow sand filter for a surface water plant. *Water Engineering & Management, 146*(4), 28-28.

Baer, W. (1995). When Old Buildings Ripen for Historic Preservation: A Predictive Approach to Planning. *Journal of the American Planning Association*, 61(1), 82-94

Barros, D. Benjamin. "Berman v. Parker, 348 U.S. 26 (1954)." *Encyclopedia of the Supreme Court of the United States*. Ed. David S. Tanenhaus. Vol. 1. Detroit: Macmillan Reference USA, 2008. 140-142. U.S. History in Context. Web. 28 Oct. 2014.

Bitgood, S. (1991). Suggested guidelines for designing interactive exhibits.*Visitor Behavior*, 6(4), 4-11.

Boyd, R. (2011). Sin in the sagebrush: creating an exhibit for the high desert museum. Oregon Historical Quarterly.

Brian, E., & Landsberg, K. (2006). National Historic Preservation Act (1966). In *Major Acts of Congress* (Macmillan Reference USA, 2004 ed., Vol. 3, pp. 25-27). New York: Cengage Learning.

Brophy, Alfred L. "National Historic Preservation Act (1966)." *Major Acts of Congress*. Ed. Brian K. Landsberg. Vol. 3. New York: Macmillan Reference USA, 2004. 25-27. U.S. History in Context. Web. 28 Oct. 2014.

Bumila, K., Gifford, M., Lovett, Z., & Portera, A. (2013). Puerto Rican Sugar Mill Restoration: Worcester Polytechnic Institute.

CAGW releases spending cut alert: DOI's 'save america's treasures' program. (2011). *Manufacturing Close - Up*, Retrieved from

http://ezproxy.wpi.edu/login?url=http://search.proquest.com/docview/853957222?accountid=2912

California Preservation Foundation. (2014). Mission: What We Do. Retrieved November 13, 2014, from http://www.californiapreservation.org/mission.html

Cameron, & Jenks. (1922). Chapter 1: History. In *The National Park Service: Its history, activities and organization* (pp. 1-2). New York: D. Appleton and Company.

Cane, P. (2008). *The new Oxford companion to law*. Oxford, England: Oxford University Press.

Collins, N. (1978, April 17). Riding the Rails for Grand Central; Jacqueline Onassis, Supporting the Station's 'Landmark' Status. *The Washington Post*.

Colon, N. (2012, December 10). Rio Puerto Nuevo. Retrieved October 31, 2014, from http://www.saj.usace.army.mil/Portals/44/docs/review_plans/Rio Puerto Nuevo RP and Approval Memo.pdf

Conservation Trust of Puerto Rico. (2014, January 1). Retrieved December 11, 2014, from http://www.fideicomiso.org/natural-areas/

De Moel, P.J., Verberk, J.Q.J.C., and Van Dijk, J.C., Drinking Water: Principles and Practices. Singapore, SGP: World Scientific & Imperial College Press, 2006. ProQuest ebrary. Web. 30 October 2014.

Dean, D. K. (1996). Museum Exhibition. London, GBR: Routledge.

Falk, J. (1997). Testing a museum exhibition design assumption: Effect of explicit labeling of exhibit clusters on visitor concept development. Science Education, 81, 679-687.

Fee, E., & Brown, T. M. (2005). The Public Health Act of 1848. *Bulletin of the World Health Organization*, *83*(11), 866–867.

Fideicomiso de Conservación de Puerto Rico, Massachusetts Institute of Technology, & Universidad de Puerto Rico (2011). El futuro del Río Piedras.

Filter Operations Field Guide. Denver, CO, USA: American Water Works Association, 2006. ProQuest ebrary. Web. 30 October 2014.

Ginsberg, B. (1971). Berman v. Parker: Congress, the Court, & the Public Purpose. *Polity*, 4(1), 48-75.

Goosen, M. A., & Shayya, W. H. (2000). *Water Management, Purification & Conservation in Arid Climates*. Lancaster, Pa: Technomic Pub. Co.

Gordon, D., PhD., & Vaughan, R., PhD. (2012). The value added properties of local historical

preservation districts. *Journal of Applied Business Research*, 28(2), 277-282.

Hill, J. W. (1898). *The purification of public water supplies*. New York: D. Van Nostrand Company.

Howatson, M. C. (Ed.). (2013). The Oxford companion to classical literature. Oxford University Press.

Infographic: World Water Crisis - UNICEF USA Blog. (2014, January 1). Retrieved December 3, 2014, from http://fieldnotes.unicefusa.org/infographic-world-water-crisis

Juva-Brown, T. (2014, April 8). 100 years later, still a grand sight. *The Journal News, USA Today.*

Kaplan, F. (1998, Oct 01). The grand goes back into grand central as honorees gather, an absent advocate: Jacqueline Onassis. *Boston Globe.* Retrieved from http://ezproxy.wpi.edu/login?url=http://search.proquest.com/docview/405251193?accountid=29120

Koran, J.J. Jr., Morrison, L., Lehman, J.R., Koran, M.L., & Gandara, L. (1984). Attention and curiosity in museums. *Journal of Research in Science Teaching*, 21, 357–363.

Krantz, H. (2011). Water Systems Meeting Everyday Life: A Conceptual Model of Household Use of Urban Water and Sanitation Systems. Public Works Management & Policy, 17(1), 103-119. Retrieved November 6, 2014, from http://pwm.sagepub.com.ezproxy.wpi.edu/content/17/1/103.full.pdf html

Lopez, D., Vlamakis, H., & Kolter, R. (2010). Biofilms. *Cold Spring Harbor Perspective in Biology, 2*(7).

Martini, P. (1976). A Review of the History of the Aqueducts of Rome. *American Water Works Association, 68*(11), 560-567.

McCyost, M. H. (1920). Water Purification in War. Petroleum & Water History. Quartermaster Service News.

National Park Service. (2006, September 1). San Juan National Historic Site Long-Range Interpretive Plan. Retrieved December 9, 2014, from http://www.nps.gov/saju/parkmgmt/upload/saju-lrip-2006.pdf

National Preservation Act 1966. Public Law 89-665; 16 U.S.C. 470.

Office of Historic Resources. (2014). Preservation Related Websites. Retrieved November 13, 2014, from http://www.preservation.lacity.org/resources/preservation-related-websites

Permutit Company. (1949). *Water conditioning handbook*. New York: The Permutit Company.

Sandifer, C. (1997). Time-based behaviors at an interactive science museum: Exploring the differences between weekday/weekend and family/nonfamily visitors. *Science Education*, 81, 689 – 701.

Sandifer, C. (2003), Technological novelty and open-endedness: Two characteristics of interactive exhibits that contribute to the holding of visitor attention in a science museum. *Journal of Research in Science Teaching*, 40: 121–137.

Schittich, C. (2012). *Birkhäuser Generalstandingorder: In Detail Exhibitions and Displays: Museum Design Concepts Brand Presentation Trade Show Design*. Basel, CHE: Birkhäuser.

Singh, R. (2008). Worldwide water crisis. Journal of Membrane Science, 313(1-2), 353-354. Retrieved November 6, 2014, from http://www.sciencedirect.com.ezproxy.wpi.edu/science/article/pii/S0376738808000628

Stipe, R. E. (2003). *Richer Heritage: Historic Preservation in the Twenty-First Century*. Chapel Hill, NC, USA: University of North Carolina Press.

Thompson, G. (1966). The National Trust for Historic Preservation in the United States. *The Wisconsin Magazine of History*, 49(2), 152-160.

Tyler, N. (2000). *Historic Preservation: An Introduction to its History, Principles, and Practice*. New York: W.W. Norton.

UN. (1997, February 4). Comprehensive assessment of the freshwater resources of the world. Retrieved November 7, 2014, from http://www.un.org/esa/documents/ecosoc/cn17/1997/ecn171997-9.htm

United States. Census office. (189297). *[Census reports] Eleventh census: 1890*. Washington: Govt. print off.

Water, S. A. H. T. (2003). Guidelines for Drinking-water Quality, Volume 1: Recommendations (3rd Edition). Albany, NY, USA: World Health Organization. Retrieved from http://www.ebrary.com

Appendix A: Part Dimensions Form

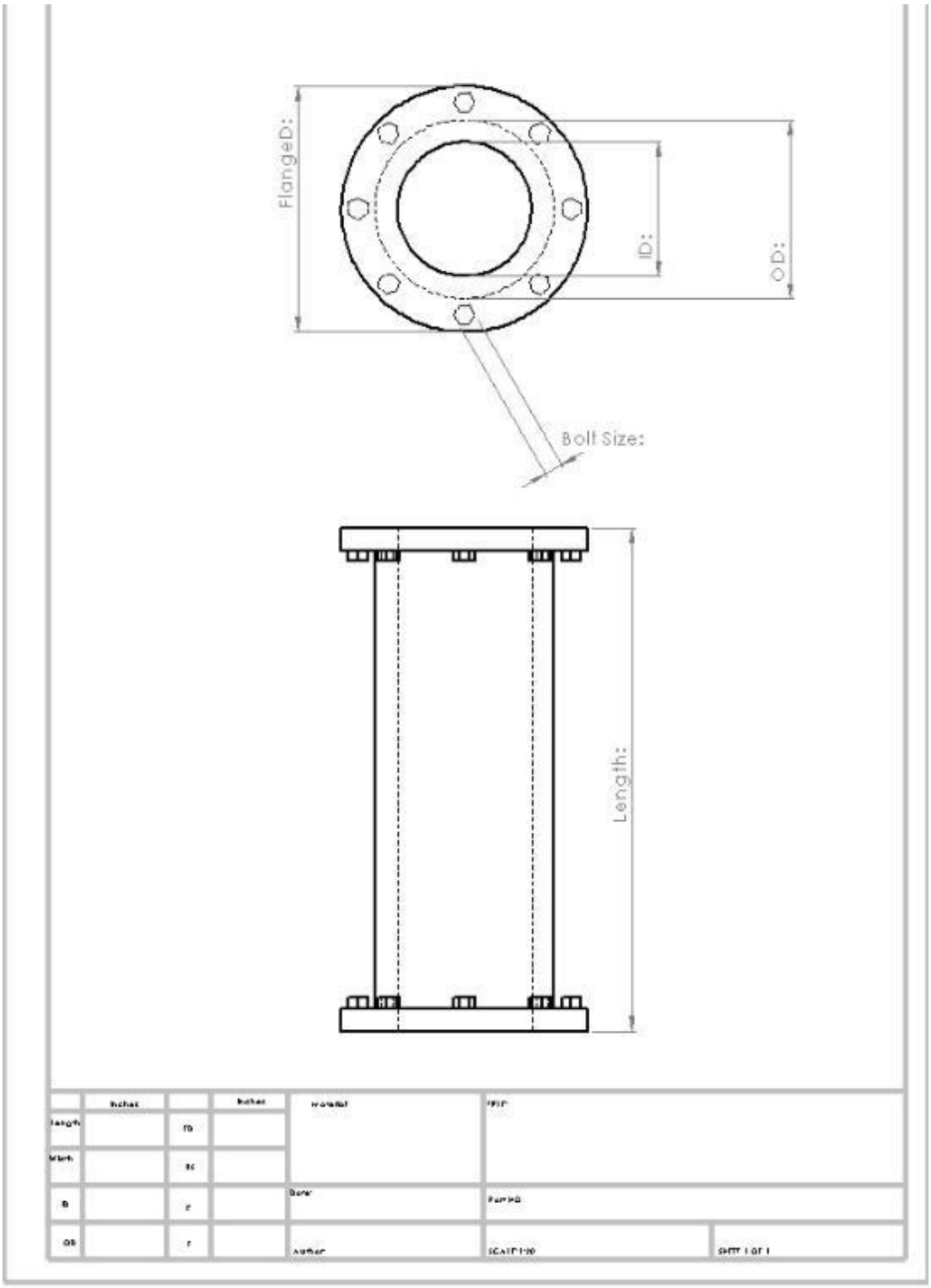


Figure 57. Part dimensions form.

Appendix B: Exhibit Evaluation

We created the exhibit evaluation form based on our sources used for the background chapter. The sources we used are from Falk (1997) and Dean (1996). The headline and subheadline concept were introduced by Falk (1997) and Dean (1996) introduces the key elements of educational exhibits.

Table 25. Exhibit evaluation form

Exhibit Evaluation **Date:**	
Headline:	
Sub-headline:	
Key Element Evaluation	
Value: Quality of lightness or darkness used for emphasis and orientation	
Color: Meaning ascribed to the colors. Associations and characteristics of the color.	
Texture: Visual roughness or smoothness of the surface.	
Balance: Quality of visual weight distribution.	
Line: Quality of linearity. Gives directional content to composition.	
Shape: Element of physical or spatial containment. The contrasting, joining, overlapping and mixing of shapes that helps create visual interest.	
Additional Comments:	

Appendix C: Interview Questions

Table 26. Interview questions for site visits

Interview Questions for Site Visits
1. How do you reach your audience? Social media? Interactive elements in your exhibit?
2. What specific aspects of your historical site attract visitors the most?
3. What is the story your site is trying to tell?
4. How has technology change affected your approaches?
5. How can visitors interact with the exhibits?
6. What general feedback do you have about the educational exhibits at your site?

Table 27. Interview questions for educational exhibit designs

Interview Questions for Educational Exhibit Designs
7. Could you please summarize what you learned from this exhibit?
8. How do you think the content corresponds to the headline?
9. How do you think the images, themes and colors were used?
10. What aspects of the exhibit did you like/dislike the most?
11. How do you think the exhibit balanced pictures and content? Was it too cluttered?
12. What general feedback do you have about the exhibits you viewed?

Appendix D: Testing the Filterability of Certain Particulates through a Sand Filter

Goals

- To determine what particulates are most thoroughly filtered out by sand and the other media.

Materials

- 2 ft. of 4 in diameter PVC pipe
- PVC pipe caps with threading
- Screw caps for the fittings with garden hose fittings
- mesh
- Sand
- Gravel
- PVC sealant
- Garden hoses
- Particulates (potting soil and glitter)
- 5 gallon paint buckets
- Stir stick
- Funnel
- Clear pint cups
- Measuring cup

Preparation

A. Filter tube construction
    1. Take 1 1/2 ft. PVC pipe and apply PVC sealant to bottom end of the pipe.
    2. Cut mesh into circle with 4 in diameter
    3. Place mesh circle to end of the pipe with sealant applied to it
    4. Place cap on the side of the pipe with sealant applied
    5. Allow sealant to dry
    6. Cut mesh into circle with 4 in diameter
    7. Place mesh circle in screw cap
    8. Screw cap onto bottom of the pipe
    9. Pour in 2 in of gravel into the top end of the tube
    10. Pour 4 in of sand into top of pipe

Execution

A. Filtering of particulates through filter tube
    1. Remove hose fitting cap from bottom of the filter
    2. First prime filter with 2 full pint cups of clean uncontaminated water
    3. Collect two pints of water from bottom of the filter as the control before adding particulates
    4. Mix in 1/4 pint of particulate into 2 pint cups of water
    5. Have one person hold filter above the bucket with clear cup under filter to catch filtered water
    6. Other person pours particulate/ water mixture into filter. (be sure to do so slowly as to not over flow the filter so that all of the water and particulates reach filter)
    7. Collect two pint cups worth of water from filter till filter tube is empty of visible standing water
    8. Take pictures of sample for documentation

A. Backwash the tube
    1. Wait till water is fully drained and from the tube
    2. Attach hose cap to the bottom of filter
    3. Attach the hose that is connected to the water facet to bottom end of the tube
    4. Turn hose on low (as to not have too much pressure and push filter media from the top of the tube)
    5. Hold tube upright and allow water to flow back through the top of the pipe into the bucket till water appears to be clean for at least a minute
    6. When finished backwash, pour out filter media in a line
    7. Observe and take pictures of the filter media to see how much contaminant remains
    8. Repeat three times

B. Repeat actions A and B with each of the different contaminant

Appendix E: Email Question Responses about Educational Exhibit Designs

1) **Jose Nevarez**: Interpreter from Hacienda la Esperanza

Comments:

- First, I have to tell that I learned a brief history of the development of aqueducts trough history, and that the Antiguo Acueducto de San Juan is the first one of its kind in Puerto Rico. The first slide of the presentation is very neat and gives a nice perspective of the development of the Antiguo Acueducto.
- I think that, overall, the content relates to the headlines. But, you need to add a slide in which you can explain to the visitors the purpose of the Antiguo Acueducto, and why it was built and used for.
- The images and graphics that you used were nice and matched really well with the themes, and colors. Having said that, I think you need to add some visual perspective of the timescale in the second slide. People need to see dates and how far away in time this events occurred. Remember the timelines here at the Hacienda La Esperanza, they have the dates and timescales visible to the public, so they can make reference more easily.
- Overall, I pretty sure I liked all the slides, in means of content and images. But, in the third slide, the one about water filtration, you need to include a diagram, drawing or something more visual, so visitors can understand the process you're making reference to. For me, it was difficult to imagine the water filtration process.
- From my perspective, I believe that the exhibition is balanced. Nice work managing the images and the text.
- In the first slide you talked about the land that is been protected by Para la Naturaleza right now and you said 7,000 acres, but in reality they're more than 29,000 acres of land in more than 45 Natural Protected Areas.

2) **Leonor Alicea**: Interpreter from Cabezas de San Juan

Comments:

- Let's begin with your questions. From this exhibit I can learn that the San Juan Aqueduct was crucial for the economic and social development of the city and we don't need huge, expensive and complicated systems to have potable water. In terms of the plates it selves, the headlines correspond to the content very well.
- I saw that the content of the first and second slide are the same, are they going to be in different areas? I prefer the timeline design with some changes because is too crowded, less text more pictures, the content is good, just try to make it shorter.
- The third slide needs to be more visual. Was very hard for me to "see" the process from the text to understand it. I suggest to do it as a flow chart.
- The pictures are excellent, I like the different colours for the different aspects of the exhibit. I like the timeline and boxes arrangement but with less text. The last two slides are good I do like the world map a lot, maybe different colours rather than the same one. I don't know if there are a closer aerial picture to appreciate urban development, could be two or three pictures to see the changes in land use over the time.

3) **Elizabeth Padilla**: Our liaison at the Trust

Elizabeth's comments were added straight to the exhibit designs. Added below, are the comments taken from the exhibit designs.

Comments:

- Can you use here a picture than a draw? That help to keep the same type of imagine in the exhibits.
- The Slide 1 & 2 has same information. Suggestion: you can use the 1rs slide to keep only basic information of history of the Acueducto. Then in 2nd slide keep facts/history.
- The dots, are "push buttons"? The colors dots, are "push buttons"? That show more information or illustrate the flow of the water through the filters?

4) **Elsie Aponte**: Project Manager for the Antiguo Acueducto.

Comments:

- Review the Spanish words and definitions, and sentences out of margins.

- In terms of machinery explanations and directions, I would like to see something more interactive, nowadays there are programs that provide those actions in case the presentation will be computadorized, or if not, a sketch or a design created in Photoshop or adobe illustrator could help, using a real photograph of the machinery and working on a graphic silluet or other ... I'am just thinking in those persons that are not technical or technological friendly...?!
- I didn't see pretty well the waters going back to the river...?! (Thinking in visual people).

Appendix F: Educational Exhibit Preliminary Designs

Antiguo Acueducto de San Juan

History
Historia

The construction of the water system that is currently known as the Antiguo Acueducto for the city of San Juan was ordered by the Crown of Spain. The construction was completed between 1896 and 1900, although the official planning for it began in 1847. Engineer Juan Manuel Lombera proposed the initial design.

The site of the Antiguo Acueducto includes a machine room, a house for employees and two open water tanks. Between 1917 and 1918, mechanical filters were designed and installed within the Antiguo Acueducto. After that it supplied water to the boot camp of the first Puerto Rican soldiers who participated in the First World War. The Antiguo Acueducto promoted the growth of the city along its main line and through its branches to other neighborhoods throughout the city. The Antiguo Acueducto went out of operation in the 1970's.

The site was acquired in 2005 by the Conservation Trust of Puerto Rico. It is part of the 7,000 acres of wildlife sanctuaries currently protected by the Trust, which marks the importance of urban planning and management of environmental resources in San Juan. The site of the Antiguo Acueducto includes a machine room, a house for employees and two open water tanks.

La construcción del sistema de agua que actualmente esta conocido como el Antiguo Acueducto de la ciudad de San Juan fue ordenado por la Corona de España. La construcción se completó entre 1896 y 1900, aunque la planificación oficial para este se inició en el 1847. El Ingeniero Juan Manuel Lombera propuso el diseño inicial.

Entre 1917 y 1918, los filtros mecánicos fueron diseñados e instalados en el Antiguo Acueducto. Luego, suministro agua a los campos de entrenamiento de los primeros soldados puertorriqueños que participaron en la Primera Guerra Mundial. El Antiguo Acueducto promovió el crecimiento de la ciudad a lo largo de su línea principal y a través de sus sucursales en otros barrios de la ciudad. El Antiguo Acueducto dejó de operar en la década del 1970.

El sitio fue adquirido en el 2005 por el Fideicomiso de Conservación de Puerto Rico. Es parte de las 7.000 hectáreas de reservas naturales protegidas por el Fideicomiso, que marca la importancia de la planificación urbana y la gestión de los recursos ambientales en San Juan. El sitio del Antiguo Acueducto incluye un cuarto de máquinas, una casa para los empleados y dos tanques de agua abiertos.

Antiguo Acueducto de San Juan

Timeline of Events Related to the Antiguo Acueducto
Cronología de los eventos relacionados con el Antiguo Acueducto

The introduction of steam pumps and the development of pressurized systems during the 18th and 19th centuries was a major advancement for the aqueducts.

La introducción de bombas de vapor y el desarrollo de sistemas presurizados durante los siglos 18 y 19 fue un gran avance para los acueductos.

The construction of the Antiguo Acueducto was completed between 1896 and 1900.

Se concluyó la construcción del Antiguo Acueducto entre 1896 y 1900.

After 1917 and 1918 the Antiguo Acueducto supplied water to the boot camp of the first Puerto Rican soldiers who participated in the First World War.

A partir de 1917 y 1918 el Antiguo Acueducto suministra agua a la campo de entrenamiento de los primeros soldados puertorriqueños que participaron en la Primera Guerra Mundial.

The site was acquired in 2005 by the Conservation Trust of Puerto Rico.

El sitio fue adquirida en 2005 por el Fideicomiso de Conservación de Puerto Rico.

The earliest aqueducts, built both above and underground, were first constructed by the Romans around 312 B.C., and were entirely of stone lined with mortar.

Los primeros acueductos, construidos sobre y bajo tierra, se construyeron por primera vez por los romanos alrededor del año 312 aC, y fueron enteramente de piedra revestida con mortero.

World War One began on 28th of July, 1914 and last until 11th November, 1918. It was a global war centered in Europe.

Primera Guerra Mundial comenzó el 28 de julio 1914 y la última hasta el 11 de noviembre de 1918. Fue una guerra mundial centrada en Europa.

Defining moments for the development of urban water and sanitation systems were events such as a cholera epidemic or a breakthrough in technology. The Public Health of 1848, passed in Britain, was one of the great milestones in the history of public health.

Momentos decisivos para el desarrollo de los sistemas de agua y saneamiento urbanos eran eventos tales como una epidemia de cólera o un gran avance en la tecnología. La Salud Pública de 1848, aprobada en Gran Bretaña, fue uno de los grandes hitos de la historia de la salud pública.

The Antiguo Acueducto went out of operation in the 1970's.

El Antiguo Acueducto dejó de operar en la década de 1970.

Water Filtration
Filtración de Agua

Operation of the mechanical water filtration system
El funcionamiento del sistema de filtración de agua mecánico

Normal Operation:

Raw water flows in from the inlet pipe. From the inlet, water flows into the top of the three tanks through separate pipes. In the tanks, raw water flows through the filter media. After flowing through the filter media, clean water flows out of the bottom of the tank to the clean outflow.

Funcionamiento Normal:

El agua sin tratar fluye desde el tubo de entrada. Desde la entrada, el agua fluye en la parte superior de los tres tanques a través de tuberías separadas. En los tanques, el agua en bruto fluye a través de los medios de filtro. Después de fluir a través de los medios de filtro, el agua limpia fluye fuera de la parte inferior del tanque para el flujo de salida limpio.

Normal Operation

Funcionamiento Normal

Backwash:

The tanks are divided up into sets of three. Raw water flows in through the inlet pipe into two of the three tanks. The inlet pipe of the third tank is closed so that no water get inside. For all three tanks, the clean outflow is closed so that water can flow from the two normal operating tanks into the third. Water from the two tanks flows into the third, loosening the filter media and pushing the contaminants through the top of the filter. The top backwash drain valve is open to allow water that now contains contaminants to flow into the drain.

Retrolavado:

Los tanques están divididos en grupos de tres. El agua sin tratar fluye a través del tubo de entrada en dos de los tres tanques. El tubo de entrada del tercer tanque está cerrado para que no entre agua en el interior. Para todos los tres tanques, la salida limpia está cerrada para que el agua pueda fluir desde los dos tanques de funcionamiento normales en el tercero. El agua de los dos tanques desemboca en el tercero, aflojando los medios de filtro y empujando los contaminantes a través de la parte superior del filtro. La válvula de drenaje de lavado a contracorriente superior está abierta para permitir que el agua que ahora contiene los contaminantes a fluir en el desagüe.

Tank 1

Tanque 1

Tank 2

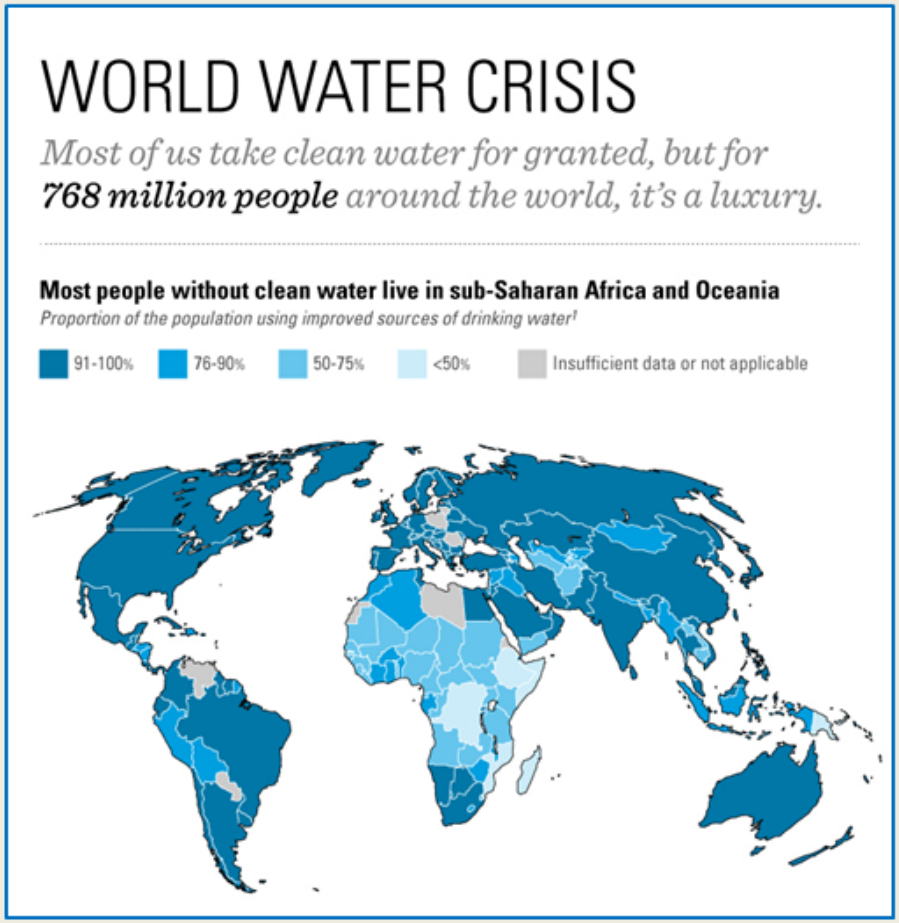
Tanque 2

Tank 3

Tanque 3

The World Water Crisis
Crisis Mundial del Agua

Facts and Statistics
Datos y estadísticas



UNICEF. Infographic: World Water Crisis. http://fieldnotes.unicefusa.org/infographic-world-water-crisis

Over the course of the last century, human water usage has increased at more than the twice the population growth rate. Due to these increases alone, about one third of the world's population lives under moderate to high water stress, meaning that individuals experience limited access to water resources. This result is in part caused by the increase of the worlds per person water usage alongside the world's rate of population growth.

Currently, 1.2 billion people do not have access to clean drinking water, nearly half of the world's population lacks proper water purification and 2.4 billion people have no access to basic sanitation facilities.

Actualmente, 1,2 mil millones de personas no tienen acceso a agua potable limpia, casi la mitad de la población mundial le hace falta la purificación de agua adecuada y 2.4 mil millones de personas no tienen acceso a instalaciones básicas de saneamiento.

En el transcurso del siglo pasado, el consumo de agua humano se ha incrementado en más de dos veces la tasa de crecimiento de la población. Debido a estos incrementos solos, aproximadamente de un tercio de la población mundial vive bajo moderado a alto estrés hídrico, lo que significa que las personas experimentan un acceso limitado a los recursos hídricos. Este resultado es, en parte, causado por el incremento de consumo de agua por persona en el mundo junto a tasa mundial de crecimiento de la población.

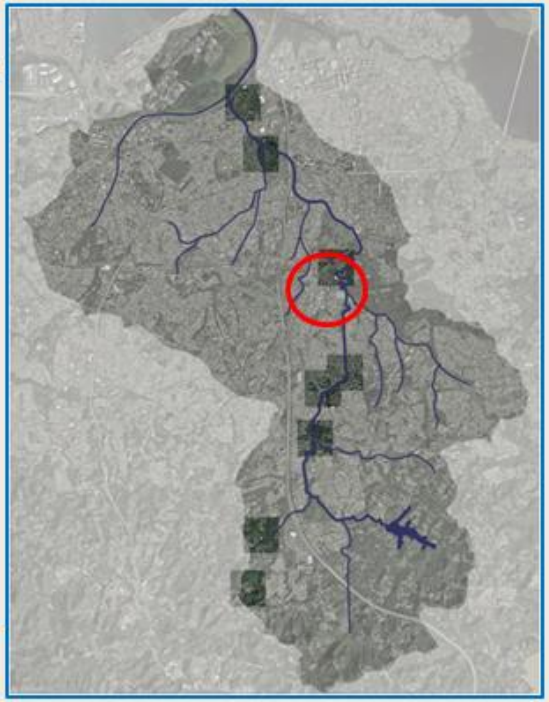
The World's Water Crisis
Crisis Mundial del Agua

Effects
Efectos

The danger of not having clean water is vulnerability to disease. The majority of illnesses around the world is caused by contaminated water and lack of sewer treatment. Much of the world's water pollution is caused by industry, agriculture and other human activities. The scarcity of water limits economic and social development. Water is not only needed just for drinking. It is also used for many household purposes, agriculture, manufacturing goods, food processing, and power generation.

View of the Río Piedras. It used to supply water to San Juan. Due to lack of ecological preservation, it has become less fit for use.

Vista de Río Piedras. Se utiliza para abastecer de agua a San Juan. Debido a la falta de preservación ecológica, se ha convertido en menos aptos para su uso.

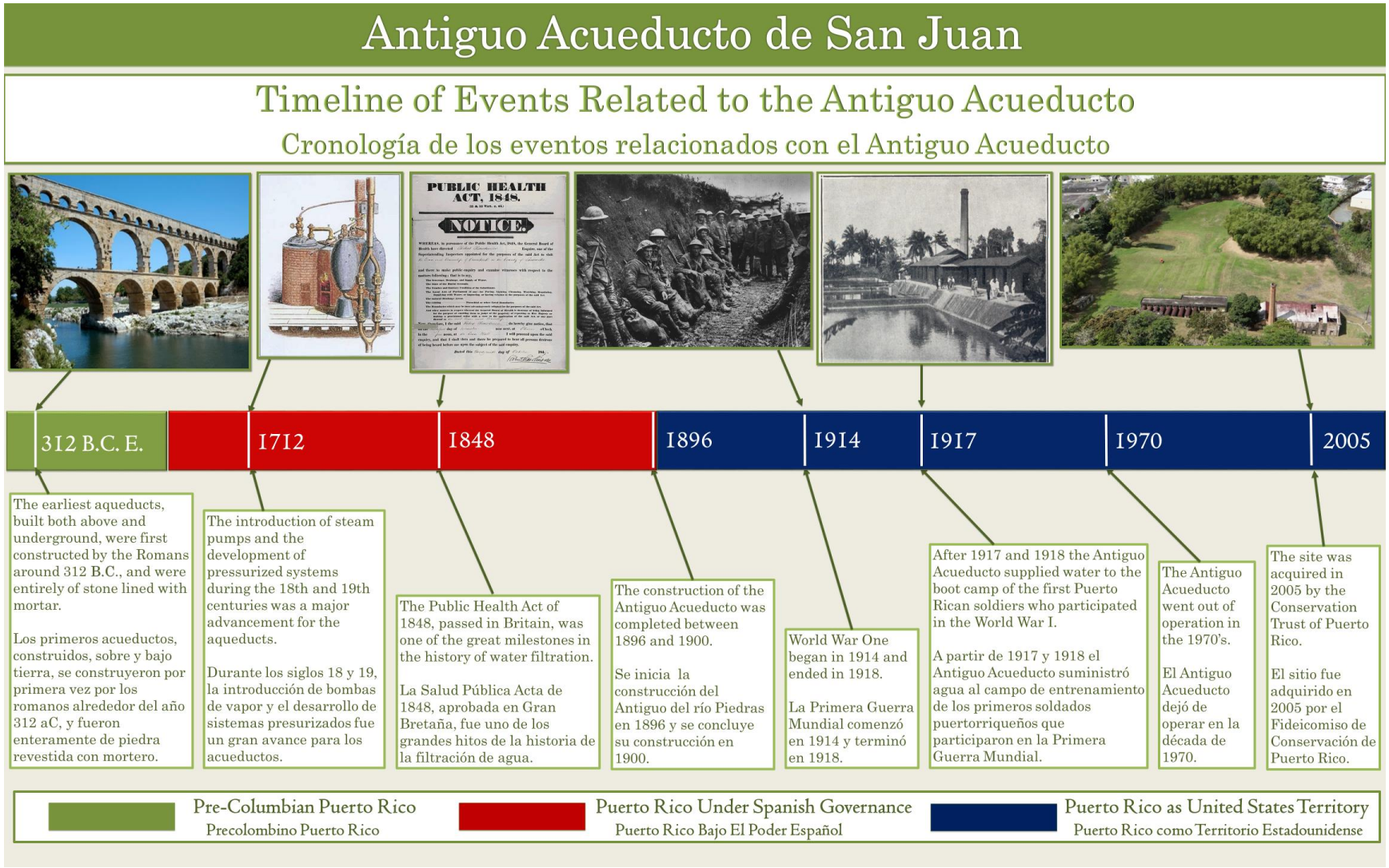


Satellite view of the Río Piedras and the Río Puerto Nuevo. The city of San Juan grew around these rivers. The red circle marks the site of the Antiguo Acueducto.

Vista satelital de Río Piedras y el Río Puerto Nuevo. La ciudad de San Juan creció alrededor de estos ríos. El círculo rojo marca el lugar del Antiguo Acueducto.

El peligro de no tener agua limpia es la vulnerabilidad a la enfermedad. La mayoría de las enfermedades en todo el mundo es causada por agua contaminada y la falta de tratamiento de alcantarillado. Gran parte de la contaminación del agua en el mundo es causado por la industria, la agricultura y otras actividades humanas. La escasez de agua limita el desarrollo económico y social. El agua no sólo es necesaria sólo para beber. También se utiliza para muchos propósitos para el hogar, la agricultura, fabricación, procesamiento de alimentos y la generación de energía.

Appendix G: Educational Exhibit Final Designs



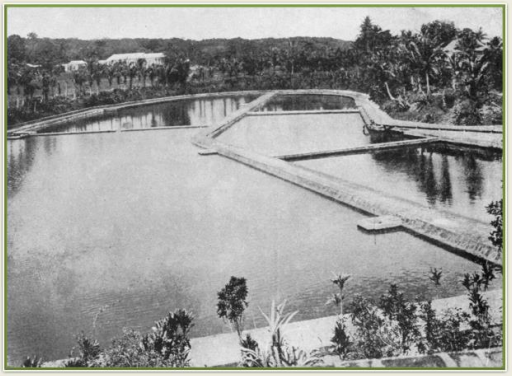
Antiguo Acueducto de San Juan

History
Historia

- In 1901, the primary source of water in Puerto Rico was the San Juan water works. The water was taken from the Río Piedras at a point that was very muddy.
- The new facility, now known as the Antiguo Acueducto de San Juan, was to be two miles up the river where the water was much cleaner. Its construction was ordered by the Crown of Spain.
- The official planning for it began in 1847. Engineer Juan Manuel Lombera proposed the initial design.

- Between 1917 and 1918, mechanical filters were designed and installed within the Antiguo Acueducto.
- The Antiguo Acueducto promoted the growth of the city along its main line and through its branches to other neighborhoods throughout the city.
- The Antiguo Acueducto went out of operation in the 1970's.

- The site was acquired in 2005 by the Conservation Trust of Puerto Rico.
- It is part of the 29.000 acres of land and 45 wildlife sanctuaries currently protected by the Trust, which marks the importance of urban planning and management of environmental resources in San Juan.
- The site of the Antiguo Acueducto includes a machine room, a house for employees and two open water tanks.



- En 1901, las principales fuentes de agua en Puerto Rico fueron las obras de agua de San Juan. El agua se toma de Río Piedras en un punto que era muy fangoso.
- La construcción del Antiguo Acueducto fue ordenado por la Corona de España.
- El Ingeniero Juan Manuel Lombera propuso el diseño inicial. La planificación oficial para este desarrollo comenzó en el 1847.

- Entre 1917 y 1918, los filtros mecánicos fueron diseñados e instalados en el Antiguo Acueducto.
- El Antiguo Acueducto promovió el crecimiento de la ciudad a lo largo de su línea principal y a través de sus estaciones en otros barrios de la ciudad.
- El Antiguo Acueducto dejó de operar en la década del 1970.

- El sitio fue adquirido en el 2005 por el Fideicomiso de Conservación de Puerto Rico.
- Es parte de las 29,000 hectáreas de terreno y 45 áreas naturales protegidas por el Fideicomiso. Este proyecto demuestra la importancia de la planificación urbana y la gestión de los recursos ambientales en San Juan.
- El sitio del Antiguo Acueducto incluye un cuarto de máquinas, una casa para los empleados y dos tanques de agua abiertos.

Water Filtration
Filtración de Agua

Operation of the mechanical water filtration system
El funcionamiento del sistema de filtración de agua mecánico

Normal Operation

Funcionamiento Normal

Tank 1

Tanque 1

Tank 2

Tanque 2

Tank 3

Tanque 3

Normal Operation:

Raw water flows in from the inlet pipe, to get into the top of the three tanks through separate pipes. In the tanks, raw water flows through the filter media. After flowing through the filter, clean water flows out of the bottom of the tank to the clean outflow.

Funcionamiento Normal:

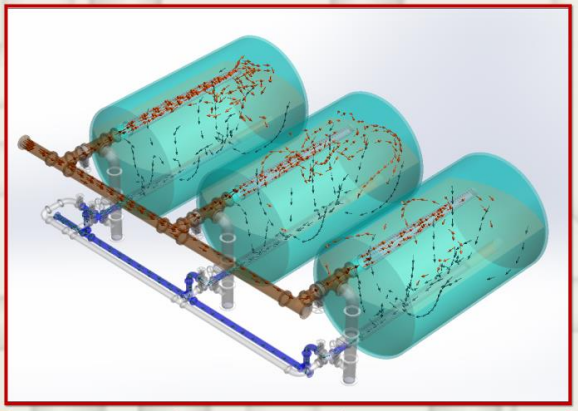
El agua cruda entra y fluye hasta llegar a en la parte superior de los tres tanques a través de tuberías separadas. En los tanques, el agua cruda pasa a través de un sistema de filtros. Una vez pasa a través de los filtros, el agua limpia sale del sistema por la parte inferior del tanque.

Backwash:

The tanks are divided up into sets of three. Raw water flows in through the inlet pipe into two of the three tanks. The inlet pipe of the third tank is closed so that no water get inside. For all three tanks, the clean outflow is closed so that water can flow from the two normal operating tanks into the third. Water from the two tanks flows into the third, loosening the filter media and pushing the contaminants through the top of the filter. The top backwash drain valve is open to allow water that now contains contaminants to flow into the drain.

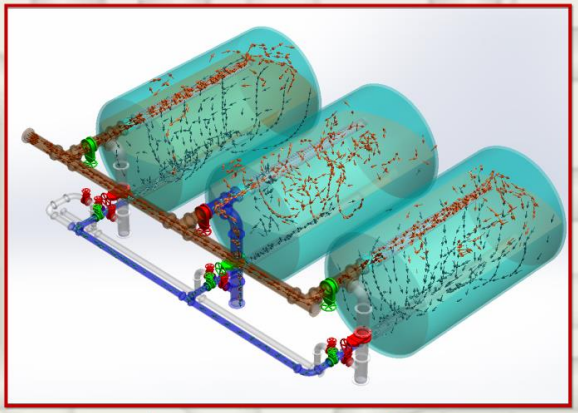
Contracorriente:

Los tanques están divididos en grupos de tres. El agua sin tratar fluye a través del tubo de entrada en dos de los tres tanques. El tubo de entrada del tercer tanque está cerrado para que no entre agua en el interior. Para todos los tres tanques, la salida limpia está cerrada para que el agua pueda fluir desde los dos tanques de funcionamiento normales en el tercero. El agua de los dos tanques desemboca en el tercero, aflojando los medios de filtro y empujando los contaminantes a través de la parte superior del filtro. La válvula de drenaje de lavado a contracorriente superior está abierta para permitir que el agua que ahora contiene los contaminantes a fluir en el desagüe.



Normal Operation

Funcionamiento Normal



Backwash

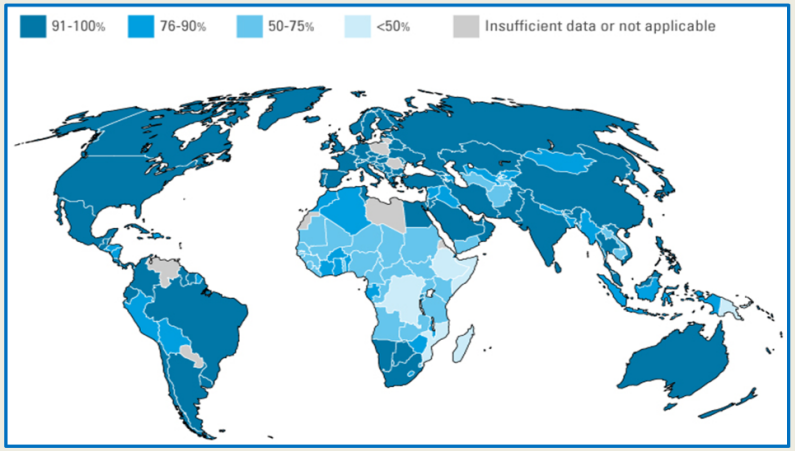
Contracorriente

The World Water Crisis

Crisis Mundial del Agua

Facts and Statistics

Datos y estadísticas



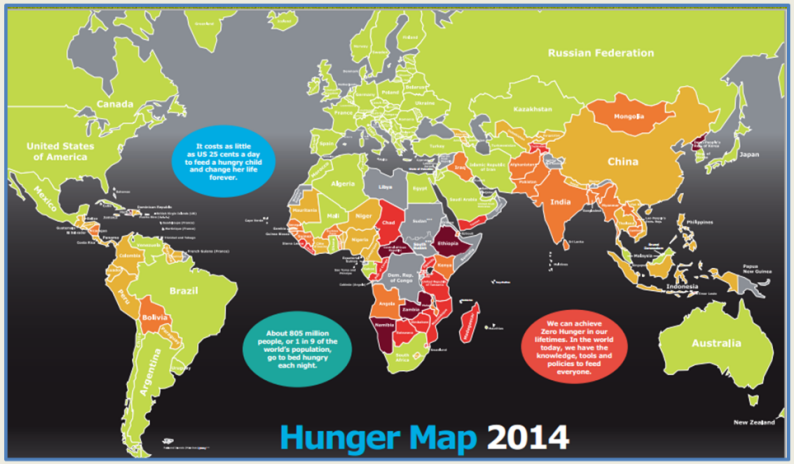
UNICEF. Infographic: World Water Crisis. http://fieldnotes.unicefusa.org/infographic-world-water-crisis

The UNICEF Infographic of the World Water Crisis shows the proportion of the population around the world, using improved sources of drinking water in 2014.

El UNICEF Infografía de la Crisis Mundial del Agua se presenta la proporción de la población en todo el mundo, que usa fuentes mejoradas de agua potable en 2014.

Over the course of the last century, human water usage has increased at more than the twice the population growth rate. Due to these increases alone, about one third of the world's population lives under moderate to high water stress, meaning that individuals experience limited access to water resources. This result is in part caused by the increase of the worlds per person water usage alongside the world's rate of population growth.

Currently, 1.2 billion people do not have access to clean drinking water, nearly half of the world's population lacks proper water purification and 2.4 billion people have no access to basic sanitation facilities.



Hunger Map 2014: http://www.wfp.org/content/hunger-map-2014

The Hunger Map 2014 shows the percentage of the prevalence of undernourishment in the population of the world.

El Mapa de Hambre del 2014 presenta el porcentaje de la prevalencia de la malnutrición en la población del mundo.

Actualmente, 1,2 mil millones de personas no tienen acceso a agua potable, casi la mitad de la población mundial carece de tratamiento de agua adecuado y 2.4 mil millones de personas no tienen acceso a instalaciones básicas de saneamiento.

En el transcurso del siglo pasado, el consumo de agua humano se ha incrementado en más de dos veces la tasa de crecimiento de la población. Debido solo a estos incrementos, aproximadamente de un tercio de la población mundial vive bajo moderado a alto estrés hídrico, lo que significa que las personas experimentan un acceso limitado a los recursos hídricos. Este resultado es, en parte, causado por el incremento de consumo de agua por persona en el mundo junto a tasa mundial de crecimiento de la población.

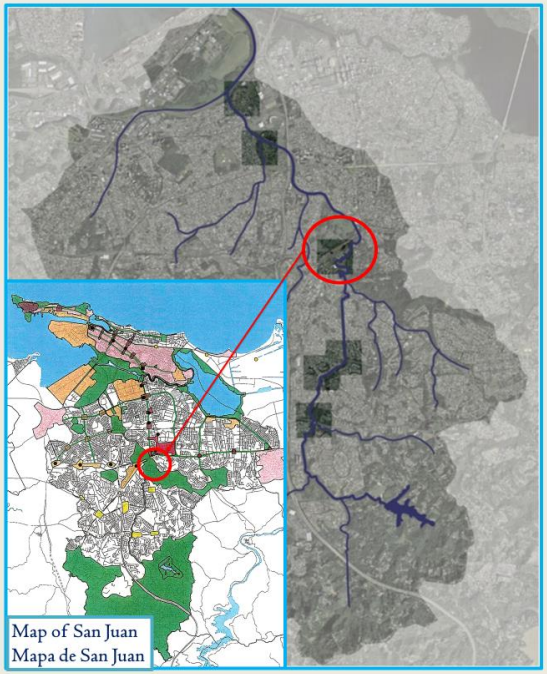
The World Water Crisis
Crisis Mundial del Agua

Effects
Efectos

The danger of not having clean water is vulnerability to disease. The majority of illnesses around the world is caused by contaminated water and lack of sewer treatment. Much of the world's water pollution is caused by industry, agriculture and other human activities. The scarcity of water limits economic and social development. Water is not only needed just for drinking. It is also used for many household purposes, agriculture, manufacturing goods, food processing, and power generation.

View of the Río Piedras. It used to supply water to San Juan. Due to lack of ecological preservation, it has become less fit for use.

Vista de Río Piedras. Se utiliza para abastecer de agua a San Juan. Debido a la falta de preservación ecológica, se ha convertido en menos aptos para su uso.



Map of San Juan
Mapa de San Juan

Satellite view of the Río Piedras and the Río Puerto Nuevo. The city of San Juan grew around these rivers. The red circle marks the site of the Antiguo Acueducto.

Vista satelital de Río Piedras y el Río Puerto Nuevo. La ciudad de San Juan creció alrededor de estos ríos. El círculo rojo marca el lugar del Antiguo Acueducto.

El peligro de no tener agua limpia es la vulnerabilidad a enfermedades. La mayoría de las enfermedades en todo el mundo es causada por agua contaminada y la falta de alcantarillado sanitario. Gran parte de la contaminación del agua en el mundo es causado por la industria, la agricultura y otras actividades humanas. La escasez de agua limita el desarrollo económico y social. El agua no sólo es necesaria sólo para beber, también se utiliza para las tareas del hogar, la agricultura, manufactura de bienes, procesamiento de alimentos y la generación de energía.

Appendix H: Physical Model Operation Guidelines for the Interpreters

General guidelines:

The model is designed to be rugged but not indestructible. It is unlikely that any mechanical failures will occur during operation, but some actions may increase the likelihood. This section outlines things that interpreters should be aware of when demonstrating the system. The first thing to note is that with the proper sump pump installed there is no way to damage the system simply by turning the valves. Interpreters should feel free to allow visitors to experiment with different valve configurations. Keep in mind that anyone who has trouble reaching a valve my attempt to climb on the system which may cause a failure. The tanks and reservoir are made of acrylic which will shatter under stress and my cause flooding and electrical shorts. For this reason it may be better to have small children suggest valves rather than turning them themselves.

Operation:

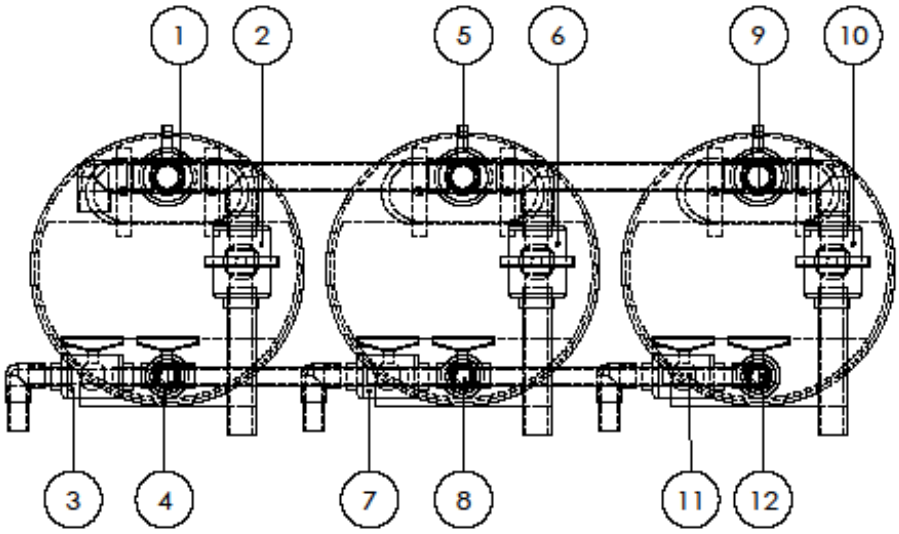
Operation of the system is quite simple; once the pump has been turned on the 12 valves are configured to change between the four configurations: Normal operation, Backwash 1, Backwash 2, and Backwash 3. A diagram and chart on the next page indicates the state of each valve for each configuration.

Normal operation:

In this state dirty water is pumped from the reservoir through the filters and back into the tank. The operator should be able to clearly see the dirty water flowing into the filters. Here the contaminant is removed. The contaminant should form a layer on top of the filter media; it should not penetrate the media more than 2 inches. The clean water should then flow out of the filter and back under the table. The water should be obviously cleaner. Normal operation will cause a buildup of contaminants on the filter media, this can be removed through the backwashing process.

Backwashing:

All of the backwashing states are the same except which filters are the clean water supplies and which is the backwash filter. During this state dirty water is pumped into the top two clean water supply filters, cleaned and then flows into the bottom of the backwash filter. The water should flow up through the media, visibly expanding it. The water should lift the contaminants out of the media and carry them out into the drain, and back into the reservoir. The backwashing operation can be stopped at any time, but the operator should wait until all the contaminants have been removed from the filter in order to best demonstrate proper procedure. Once the backwash is complete the filter can be returned to normal operation.



Valve	Normal Flow	Backwash 1	Backwash 2	Backwash3
1	Open	Closed	Open	Open
2	Closed	Open	Closed	Closed
3	Open	Closed	Closed	Closed
4	Closed	Open	Open	Open
5	Open	Open	Closed	Open
6	Closed	Closed	Open	Closed
7	Open	Closed	Closed	Closed
8	Closed	Open	Open	Open
9	Open	Open	Open	Closed
10	Closed	Closed	Closed	Open
11	Open	Closed	Closed	Closed
12	Closed	Open	Open	Open

Maintenance:

Because of the closed nature of the system little maintenance should be required. However in the event maintenance is necessary there are some things to keep in mind.

Organics:

As the system is full of water, it is possible that organic material forms. This can cause degradation of the filter media or a visible buildup. Chlorine can be added to the water to remove any organisms. In the event of a large buildup, the water should be drained, and the system flushed with soapy water.

Low water level:

Water will naturally evaporate out of the system, and will need to be replaced. To do so, first check the system for leaks. Then ensure that pump is off and open all the valves. Allow all the water to drain out of the filters and into the reservoir. It may take up to an hour for all the water to drain from the media. If not all the water has drained from the filters and pipes, filling the reservoir may cause the system to overflow. Once all the water has drained into the reservoir, fill the reservoir until the water level is 6 inches below the top.

Contaminated Media:

If the contaminant becomes stuck in the media, and cannot be backwashed, the media will need to be replaced or removed from the tank and washed manually. If this happens frequently, more than once a year, a new contaminant may need to be selected. Remove the service plate in the rear of the tank and remove the media. Try to avoid using sharp implements that may scratch or shatter the tank. A shop-vac can be used remove the media if it is to be thrown away.

Trouble shooting:

Problem:	Possible solutions:
Dirty water is not viably dirty.	• Contaminant may have settled in reservoir. Check reservoir and manually agitate if necessary. • Contaminant has built up in the filters. Backwash the system.

Output of filter is dirty.	• Incorrect filter media or contaminant. See contaminant selection guide. • Loss of filter media. Check to ensure that the media is at the right height, if not add additional media.

Appendix I: Experiment to Test for the Best Contaminants to Use in the Physical Model

Goals

- To determine what particulates work best as the contaminant in the physical model of the mechanical filters

Materials

- Fully assembled model with filter media added
- Pump attached to the model
- Holding tank full of water
- Assorted test contaminants

Procedure

1. Add filter media and water to the filter tanks as outlined in Appendix H
2. Add 1 cup of contaminant and record on camera
3. Continue adding more contaminants at 1 cup intervals till the filter media is visible saturated in all three tanks
4. Remove all filter media, contaminant, and water from the system as said in Appendix H
5. Replace water and filter media in Appendix H
6. Repeat above with all other test contaminants
7. Observe the videos of experiments and determine the amount and type of contaminant that would be ideal for visibility of the function of the filter.