

# Food, Energy, Water (FEW) Nexus Analysis in the Panama Canal Watershed

*Individually Sponsored Residential Project  
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# Abstract

Food, Energy, and Water are components of a complex web of interdependencies (FEW Nexus). Using this Nexus concept as a lens, we investigated the environmental and social impacts of the Panama Canal Expansion. We mapped the relationships between water security, biodiversity, environmental awareness, sustainable agriculture, deforestation, economy, urbanization, and waste management as well as the connections between these issues, both directly and tangentially, to the broader FEW Nexus. This framework gives rise to the potential for future research.

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# Executive Summary

## Introduction

The Panama Canal Expansion Project, set to be completed in 2016, will effectively double the Canal's shipping capacity. In a national referendum on October 22, 2006, nearly 77% of Panamanian citizens voted to approve the expansion of the Canal. As one of Panama's primary economic engines, the expanded Canal will bring increased revenue from tariffs, since it will allow more, and larger, shipping vessels that the Canal could not previously accommodate. Though the Panama Canal Expansion Project undoubtedly has significant economic benefits, the social and ecological effects in the region remain unclear.

We examined the environmental and social impacts of the Expansion using a model known as the Food, Energy, and Water (FEW) Nexus. The FEW Nexus, or simply Nexus, is a human-centered synthesis of the interdependencies between food, energy, and water. The Nexus does not specify a method or mechanism, but rather it provides a model of understanding, a way of thinking about the relationships between food, energy, and water and their impacts on human lives. We have worked to further understand this concept, providing a framework for the continuation of Nexus analysis in Panama and elsewhere.

## Literature Review

The FEW Nexus provides an approach to the linkages between food, energy, and water that regards these concepts in a manner "integrated and addressed in tandem," so one might consider the Nexus a natural synthesis of those individual linkages. We have therefore considered sources which reference the Nexus directly as well as those which provide information regarding the individual components of the Nexus, as these components of interdependence among food, energy, and water cannot be separated from the Nexus concept as a whole. Our review also includes information about the cultural, historic, geographic, and economic contexts of the Canal Expansion, as different contexts will reflect the Nexus model in different ways.



## Methodology

The goal of this project was to develop a framework describing the Food, Energy, and Water Nexus relationships in the context of the Panama Canal Expansion Project that additionally provides a basis for future Nexus research. In order to accomplish this goal, we identified the following four objectives: 1) Acquire contacts through email and interviews and conduct additional background research; 2) Conduct interviews to gather information related to topics surrounding Food, Energy, and Water; 3) Analyze our findings and identify stakeholders; and 4) Build a framework describing our FEW Nexus research in Panama.

## Results

### **Water Security**

Panama faces issues concerning the amount, quality, and availability of drinkable water. In the past, Panamanians did not pay for water and therefore did not manage their use at all. This mindset has continued and contributes to Panama being the number one consumer of water per person in all of Central America. Panama's growth is only loosely planned, and therefore the aqueduct system continuously needs to be updated and expanded. Many of the pipes are old and leaking. Much of Panama's potable water comes from the Canal Watershed, specifically Lake Alajuela. Though Panama has enacted regulations to protect the Watershed, the regulations in place do not carry strong enough penalties to deter people from contaminating the water. Even with more strict regulations, there is going to be a need for more water due to the Canal Expansion and the growing population.

### **Environmental Awareness and Education**

For decades, activists around the world have struggled with the problem of raising awareness for environmental issues. In Panama, we spoke with many individuals representing a wide variety of interests; members of the Peace Corps and scientists from the Smithsonian Tropical Research Institute raised concerns about the level of public knowledge of environmental issues and discussed various efforts to increase public awareness of environmental topics that affect the area. However, there may be some factors that inhibit the dissemination of this information. Experiencing the benefits of the environment as a child is a key component to developing a sense of environmental awareness. If Panama continues to urbanize at the current rate, a smaller portion of the population will have access to the early formative influences that aid in the development of

that awareness, and it is possible that it will become more and more difficult to develop a sense of environmental awareness in the city context.

### **Biodiversity**

The benefits of biodiversity consist of three major components: an aesthetic beauty, a basis for pharmaceutical research, and a mechanism for carbon sequestration. Panama, with its high biodiversity, has many benefits such as attracting tourists which funnels billions of dollars into the Treasury's coffers each year. In addition to economic benefits arising from tourism, a high biodiversity also represents fertile ground for research into the applications of the biological structures found in the plant and animal species. Biodiversity also plays a key role in carbon sequestration, capturing carbon dioxide from the atmosphere. Deforestation threatens the biodiverse landscape, as biodiverse ecosystems on land exist primarily in heavily forested areas. In the oceans, the biodiversity resides heavily within the coral reefs, which may be threatened by increased traffic through the Caribbean Sea. Sustainable alternatives to agricultural production methods should be considered in order to conserve the biodiversity of the Panamanian isthmus.

### **Sustainable Agriculture**

Agriculture in Panama, at this moment in time, is simply not sustainable. Forests are being cut down for pastures, and these forests are eventually left barren after farmers move on to a new parcel of land. However, conserving the forests is not the solution to deforestation due to agriculture as it moves land off-limits does not help give jobs to workers in the rural areas of Panama. In order for agriculture to be sustainable, the methods employed need to move towards more sustainable processes. In Panama, there has been a long history of destructive farming techniques such as slash-and-burn. With new awareness programs arriving, ecologically conscious farming is on the rise. Even though our research and interviews have not pointed to any farmlands located directly in the Canal Watershed that will be affected by the construction and eventual operations associated with the Expansion, there is the social issue of workers are leaving agriculture to work in the city and there is now a deficit in farmhands.

**Deforestation**

Deforestation is an issue that has only risen further as the Panama Canal Expansion efforts progress. In order for the ACP to operate the necessary tasks for the Expansion, an area of land needed to be deforested. It is important that the forest around the Canal remains to reduce runoff and help filter the water. In many cases, regulations regarding the protection of national parks may be insufficiently enforced. Without proper enforcement, there is no preservation. Although preserving the national parks are important, it is also important to remember the need for farmland to feed the population and bring in a profit. The consideration of the economic benefit of deforestation must be weighed against the detrimental effects of removing trees from the area, whether to sell the wood or make space for pasture, farms, or city expansion.

**Economy**

Panama, like many countries worldwide, and particularly in Latin America, has a very uneven wealth distribution. This issue is apparent within the two major cities of Panama City and Colón. Areas such as the Free Zone in Colón and much of Panama City have flourished, while other parts of the cities have fallen to ruin. It is difficult to trace money from revenues to expenses because governments generally appropriate all expense from the combined sum of all revenues. The Canal currently brings in 1/12 of the annual revenue for the country, and the Expansion Project has the potential to increase that income even further.

**Urbanization**

Rapid urbanization in Panama has contributed to many issues with waste management and agriculture. With the expansion of the city, areas in the past that did not have issues with flooding now flood regularly due to poor drainage in the surrounding areas. The waste management system is expanding with the city but in some areas the infrastructure is minimal and waste is discharged into the rivers. Many of the immigrants into the city are younger members of rural communities who no longer wanted to work on their family farms and were attracted to the city by higher wages. Agriculture suffers from the youth leaving because there are no longer enough people to work the land and areas are now abandoned.

## **Waste Management**

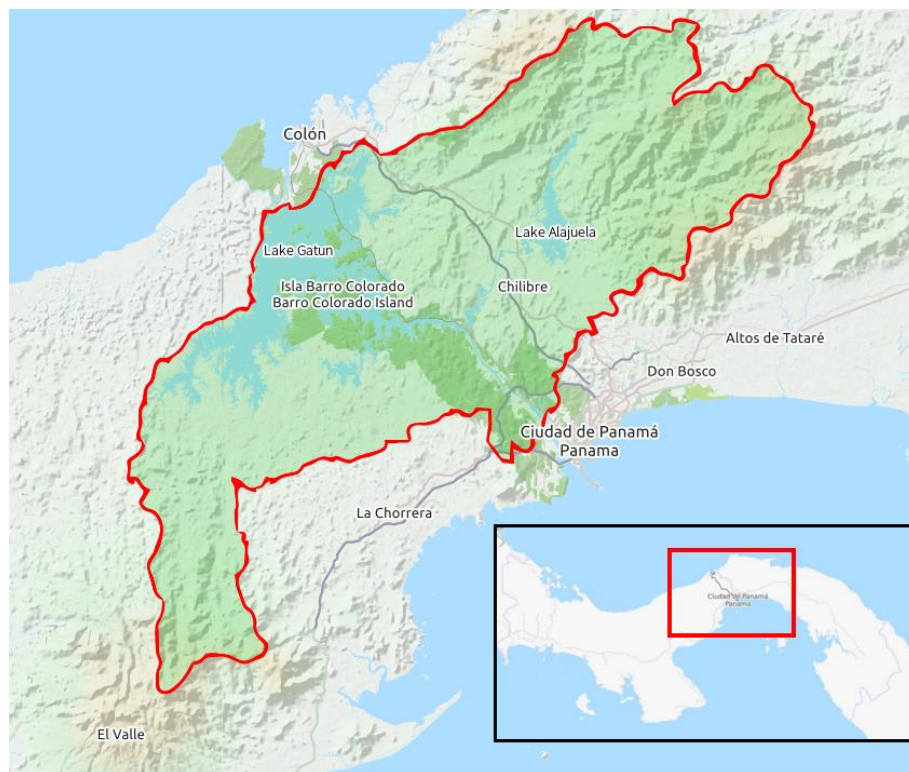
The main cause of waste issues in Panama is due to the urbanization of the city. Until recently, 100% of the waste in Panama City was discharged into the bay without any treatment. In 2010, a wastewater treatment plant was built in Tocumen for the city of Panama. At the moment it is serving only 30% of the city. However, due to inefficient water use, the plant reached water capacity in 2013 and is operating at reduced inefficiency from low waste concentrations. The population does not favor paying for waste services, as removal of human waste has historically been cost-free. The 37th President of Panama, Juan Carlos Varela Rodríguez, and CATHALAC came up with two separate waste management plans, known as 100/0, which would remove all trench latrines in Panama and replace them with conventional or compost toilets.

## **Conclusion**

As we conducted our research, we discovered that environmental and social impacts in Panama extend beyond the boundaries of the Canal Watershed. The Canal is part of the larger interconnected nexus that includes all of Panama. In this way, any work that is done in the Watershed will have a resonating effect across the country. In the event that future research teams from Worcester Polytechnic Institute, or elsewhere, wish to continue forward with the study of topics from this paper, we have enumerated some areas we feel have great potential to be expanded upon with more in-depth research.

# 1 - Introduction

Since the construction of the Panama Canal, cargo ships have saved about 12,500 km (7,870 miles) on trips from New York to San Francisco around Cape Horn, retaining 15 extra days of travel time (Panama Canal Museum, n.d.). In order to meet increasing demand, the Panama Canal Authority began a \$5.2 billion Expansion Project, estimated to be completed in early 2016 (ACP, 2015b). With the Expansion complete, ocean shippers may better utilize the Canal's travel-savings, and Panama will enjoy the economic rewards of increased tariffs. This Expansion will effectively double the Canal's capacity. As one of Panama's primary economic engines, the expanded Canal will bring increased revenue from tariffs, since it will allow more, and larger, shipping vessels that the Canal could not previously accommodate, or "Post-Panamax" vessels (ACP, 2015b). The Panama Canal Expansion project undoubtedly has significant economic benefits (A. Coates, STRI, personal communication, November 18, 2015). However, the social and ecological effects on the Panama Canal Watershed (Fig. 1), or simply the Canal Basin, and surrounding areas remain unclear.



*Figure 1 - Map of the Canal Watershed (© OpenStreetMap Contributors 2015)*

In a national referendum on October 22, 2006, nearly 77% of votes cast showed favor for the expansion of the Canal, ostensibly demonstrating a clear majority in favor of the Expansion (“The Panamanian Era: Canal Expansion,” 2006). However, the referendum has earned some skepticism due to its low 43% voter turnout, as *La Prensa* reported shortly after the passage of the referendum (Palm, 2006). To that end, our goal was to evaluate how the expansion project influenced the region by examining the effects in the broader context of its relationship to food, energy and water.

## 1.1 FEW Background

The Food, Energy, Water (FEW) Nexus, or simply Nexus, is a human-centered synthesis of the interdependencies between food, energy, and water. The Nexus does not specify a method or mechanism; rather, it provides a model of understanding the relationships between food, energy, and water and their impacts on human lives. The flexibility within the Nexus model makes it a powerful tool. The Stockholm Environment Institute (SEI) developed an innovative way of applying Nexus thinking by dividing the theory into three broader themes. Through *Governing the Nexus*, they examine the institutions already in place and provide alternatives that can help sustain natural resources. Through *Understanding the Nexus*, they create tools to analyze its different aspects. Lastly, through *Implementing the Nexus*, they work closely with stakeholders to discover functional methodologies and the feasibility of managing natural resources to a better extent (Huber-Lee & Kemp-Benedict 2015). In Panama, we have worked to further understand the Nexus, providing a framework that illustrates how the individual components are related to the Panama Canal Expansion Project.

## 1.2 Environmental History

The area of the Panama Canal Watershed sits at the center of one of the most biologically diverse areas in the entire world (Myers, Mittermeyer, Mittermeyer, Da Fonseca & Kent, 2000). Panama has a rich environmental history because of its unique location and position as an isthmus connecting North and South America. Upon its formation as a land bridge between the two continents that had been separated for over 70 million years, Panama became a path through which a great exchange of species occurred (NASA, 2003). The groups of species from the North and South American continents collided after Panama rose, leading to the rise of many new species

and the extinction of old ones (Condit *et. al*, 2001). This unique occurrence resulted in a significant biodiversity on a very small quantity of land and places Panama at the center of modern-day biological research studies

The Smithsonian Institute has taken a special interest in the wide variety of research locations available throughout the country and, over time, created the Smithsonian Tropical Research Institute with headquarters throughout Panama (Smithsonian Tropical Research Institute, n.d.). STRI credits the early pioneers of the Panama Railroad for producing some of the earliest recorded scientific data in Panama, providing opportunities to conduct research studies on over 150 years' worth of data. This aforementioned background makes Panama an ideal location to study the FEW Nexus because of the numerous environmental components which depend on one another and interact with the larger overarching themes of food, energy, and water.

## 2 - Literature Review

The concept of the Nexus derives its substance from prior research involving the interdependencies of food, energy, and water conducted before the popularization of the term “FEW Nexus.” It provides an approach to the linkages between food, energy, and water that regards these concepts in a manner “integrated and addressed in tandem” (Bizikova, *et al.*, 2013), so one might consider the Nexus a natural synthesis of those individual linkages. We have therefore considered sources which reference the Nexus directly as well as those which provide information regarding the individual components of the Nexus, as these components of interdependence among food, energy, and water cannot be separated from the Nexus concept as a whole. Our review also includes information about the cultural, historic, geographic, and economic contexts of the Canal Expansion, as different contexts will reflect the Nexus model in different ways (Ringler, *et al.*, 2013). We combined these research avenues to produce a Nexus research framework tailored to Panama.

### 2.1 - Site Description

Panama is an area rich in history, and in order to narrow our scope, we began our research focusing on the Panama Canal. The Panama Canal Watershed presented the most immediate and observable ecological response to development in the region, and has, in the past, provided several strong examples of changes attributable to Canal development (Heckadon, 1993). However, we found the impacts are not only localized to the Canal, but extend beyond the Canal Basin to all of Panama. An understanding of the history of environmental issues in Panama will provide some needed context to the discussion of current and ongoing environmental efforts.

#### 2.1.1 Environmental Political History

##### 2.1.1.1 Smithsonian Tropical Research Institute

When the construction of the original Panama Canal began in the early 1900s, surveyors and scientists started researching the area’s flora and fauna in order to control the spread of insect-transmitted diseases like malaria and yellow fever (Smithsonian Tropical Research Institute, n.d.). This early beginning of scientific documentation in the area has given researchers access to data such as rainfall amounts measured for over 100 years (S. Heckadon, STRI, personal communication, 27 November 2015). This early scientific investment in Panama also gave rise to



the Smithsonian Tropical Research Institute (STRI), which is now one of the world's preeminent tropical research authorities. According to the STRI History website, "Smithsonian scientists were asked to conduct a biological inventory of the new Canal Zone in 1910, and this survey was subsequently extended to include all of Panama," and this involvement subsequently contributed to the creation of one of the first biological reserves in the Americas at Barro Colorado Island. The Smithsonian Institution formally recognized this island research center as the STRI in 1966 when the first permanent staff scientists and fellowship programs were started to support aspiring tropical biologists (Smithsonian Tropical Research Institute, n.d.). The most complicated part of the STRI history, which has impacted how it is viewed within the country of Panama today, is the fact that it was formed within the Canal Zone under the jurisdiction of the United States. Over time, STRI formed a positive relationship with its host country of Panama, and eventually signed a treaty that allowed the organization to continue to function as an International Mission even after the Canal Zone was transferred to Panamanian control (Smithsonian Tropical Research Institute, n.d.). STRI researchers continue to provide large amounts of scientific data that give insight into the problems facing the tropics, particularly in Panama and the Canal Watershed.

#### 2.1.1.2 Canal Zone History

In 1980, the Panamanian Government created the National Renewable Resource (NRR) division in order to combat deforestation in Panama. Banks loaned money to companies and individuals to cut down the forests to produce pasture land for cattle resulting in 35,000 hectares (86,400 acres) of forest lost per year (Kaimowitz, 1996). The NRR was therefore tasked with observing the peasants entering the Watershed area getting loans from the bank to raise cattle (S. Heckadon, STRI, Personal Communication, 27 November 2015). These farmers, like many others in the world, would cut down the forest for pasture. However, these farmers did not predict the effects that this deforestation would have on the droughts in the region. Before the 1970s, the common belief was that no matter how bad the dry season was, rain would return in May and throughout the entire wet season. This belief changed following a severe drought during the El Niño years of 1982 and 1983. This extreme lack of water brought Panama to the verge of water rationing, and caused the Canal Commission to decrease the maximum draft of vessels allowed in the Canal in order to prevent large ships from contacting the lakebed on passage through Gatun Lake (S. Heckadon, STRI, Personal Communication, 27 November 2015). The necessary decrease in ship size meant that less cargo was going through the Canal and less money was being made

from tariffs. Further, the severity of the draught raised concerns about both the health of the people of Panama as well as the Canal's potential to operate in the future. These issues brought to light the need for more research into the rainfall patterns in Panama in hopes to prevent such a disaster from occurring in the future.

During this time period, power in the country was held by the National Police. The presidents during the 1970s and 1980s were puppets of Manuel Noriega, the general of the National Police (Infoplease Panama, 2015). The power held by the police ensured the rapid completion of any task they focused on due to the influence they had on the government. The Environmental Police (Policía Ecológica) division of the national force considered any threat to the Canal an issue of national security. The drought was considered a 'Level G4' security threat, which is the highest level that can be issued (S. Heckadon, STRI, Personal Communication, 27 November 2015). At this desperate time, the Ministry of Economic Planning authorized the creation of a task force to analyze and protect the Canal Watershed (S. Heckadon, STRI, Personal Communication, 27 November 2015). The ecological task force partnered with the Policía Ecológica and carried out a series of three workshops to deal with the issues surrounding the Canal Watershed area in Panama. The three workshops dealt with a variety of issues including the distribution of authority, and the identification of experts in watershed management (S. Heckadon, STRI, Personal Communication, 27 November 2015). These three workshops spanned two years and in the end gave recommendations to the President at the time.

The first workshop asked the question: who is working in the Canal Watershed, and on what? The focus was on discovering every environmental issue that had been present in Panama. The conclusion of this workshop was that there had previously been very little thought for the health of the Watershed. The number of issues that Panama was facing shocked many attendees.

“We were surprised by the magnitude of the problem: you name it, from contamination of the water, to deforestation, erosion, silting, mining, absolutely out of control urbanization, logging, other typical issues of development. We realized that the problem was much worse than we thought because nobody was in charge of the region, it was absolute chaos” (S. Heckadon, STRI, Personal Communication, 27 November 2015).

The second workshop dealt with understanding the distribution of authority in the Watershed. The list of people who had authority ranges from those operating the Canal to those who are going into

the Watershed and cutting down trees. Anyone who held a job involving the Watershed was invited to participate in this process (S. Heckadon, STRI, Personal Communication, 27 November 2015).

The final workshop focused on communicating with groups that had previous experience managing watersheds. The two major outside groups involved were representatives from the Tennessee Valley Authority in the US, and the Authority of Coco Valley River in Columbia. These groups shared their experiences managing their own watersheds and put the organizers of the workshop in contact with former students from their programs. They also sent some of their engineers to Panama to help with the preservation of the Canal Watershed (S. Heckadon, STRI, Personal Communication, 27 November 2015). These engineers helped explain the necessary actions to protect the Watershed.

The greatest suggestion that the task force made to the President was to protect the rest of the rainforest in Panama, and in 1985 a decree was signed creating the Chagres River National Park (S. Heckadon, STRI, Personal Communication, 27 November 2015). Even though the workshops helped create the national park, raise awareness, and document issues, no environmental work was possible due to political unrest from 1987 to 1989, the US invasion, and another drought.

In February 1988, General Noriega was convicted of drug trafficking by the US Justice Department and in December 1989, after the instatement of US economic sanctions, the Panamanian government named him “Maximum Leader for national liberation” and declared that the United States’ actions brought on a state of war (Shenon, 1988; Branigin 1989). The US invaded Panama that same month and captured General Noriega, severely damaging Panama City in the process. Over the years the Ministry of Agriculture had been borrowing money from USAID for funding to conservation and reforestation of the Canal Watershed. During the Noriega Crisis, this \$25 million was frozen. When the Canal was returned to Panamanian control, the people believed that the national parks belonged to everyone and therefore the trees were theirs, which resulted in large-scale deforestation again. Another El Niño hit, and the Watershed suffered because the trees that were crucial in delivering water to the Watershed were no longer there (S. Heckadon, STRI, Personal Communication, 27 November 2015). It was important for Panama to form their new government before any more conservation work was done.

Eventually the loan from the US was unfrozen and transformed into a donation to Panama. With some of the money, Panama founded the Natura Foundation (Fundación Natura), which

supports communities within the Canal Watershed and promotes biodiversity and sustainable use of natural resources (S. Heckadon, STRI, Personal Communication, 27 November 2015; Fundación Natura, 2015). Along with this foundation, Panama participated in the Food and Agriculture Organization of the United Nations' International Cooperative Framework for Sustainable Agriculture and Rural Development (Gale, 2007). In April 1991, 35 individuals came to Panama and gave \$6 million to the development of parks and environmental education (S. Heckadon, STRI, Personal Communication, 27 November 2015). Development in these two sectors helped with protecting the Watershed from more deforestation as well as alerting the public about the issues that Panama had been facing.

USAID put aside \$2 million of the original \$25 million donation to do an "in depth scientific study" on the Canal Watershed and in 2000 a document was released that estimated the net loss of forest in Panama had decreased to 30 hectares (74 acres) per year. However, the environment in Panama had degraded in other areas and in particular, the water quality had diminished more than anticipated. It was not possible to visually see the decrease in water quality brought on by poorer oxygen concentration and increased potassium content (S. Heckadon, STRI, Personal Communication, 27 November 2015). These reports provided quantifiable data showing the extent of environmental degradation in Panama and form the basis of our understanding of Panama's environmental issues.

### 2.1.2 Legal Framework of the Operation of the Canal

In order to understand the politics surrounding the Canal Expansion Project and regulation of the Canal Watershed area, it helps to have some understanding of the legal framework surrounding the Canal. The Panama Canal Authority (ACP) manages the "operation, administration, management, preservation, maintenance, and modernization of the Canal" (ACP, 2015c). The ACP obtains its objectives from a Board of Directors, composed of nine members appointed by the President of the Republic and confirmed by a majority of the National Assembly (Asamblea Nacional), one member appointed solely by the assembly, and a chairman appointed solely by the President of the Republic. These directors are government officials, and the chairman has the rank of Minister (among 17 other Ministers in the Cabinet Council). Once the directors set objectives for the Canal, the ACP is legally obligated to work towards those objectives. The day-to-day operations of the Canal Authority are controlled by an executive structure similar to a

typical corporation, and at the top sits the Administrator—for all purposes equivalent to a CEO (ACP, 2015c).

We spoke with Alberto Alemán Zubieta, Administrator of the Canal Authority from 1998 to 2012, who explained the operations and organization of the ACP. As a government organization, the ACP is similar to a government-owned corporation. However, the Canal Authority retains complete financial autonomy and patrimony over its holdings, including all of the land and facilities required to operate the Canal. In fact, the Panamanian Constitution guarantees the right of the Canal Authority to operate independently. The Canal Authority pays for all of its expenses using its own revenues from tariffs, and each year pays the entire surplus from its previous year's earnings to the National Treasury as "dividends." The National Assembly then spends that money as a component of their annual budget. Additionally, the Government assesses an immediate flat-rate tariff (by weight) on all cargo that passes through the Canal. However, the law forbids the Government from spending or making speculative investments based on the future earnings of the Canal (A. Alemán, personal communication, 2015; Law No. 19 of June 11, 1997, Panama Legislative Assembly). The ACP, charged with maintaining the Canal Watershed in order to ensure effective the operation of the Canal, has also taken the role of Environmental Protection authority in the Watershed region.

### 2.1.3 The ACP and the Environment

The ACP, in its role as caretaker of the Canal, has acknowledged its responsibility to care for the environment in and around the Canal Watershed area (ACP Environment, 2015a). In alignment with this responsibility, the ACP has released a report annually, since Panama acquired possession of the Canal in the year 2000, which includes a section on the environmental health of the region. In the report from 2014, the ACP cites deforestation, erosion, and decreased soil fertility as issues facing the Watershed area which support Dr. Heckadon's historic assessment of the impact of development on the region (ACP, 2015a; Heckadon, 1993).

In order to understand how the ACP handles environmental issues, we spoke with a team from the ACP's Environmental Division specifically focused on the Expansion Project. The team has identified many direct environmental impacts related to the construction of the third set of locks, and has taken steps to reduce the effects on the surrounding ecosystems and communities (L. Castañeda, ACP, personal communication, 2015). To give an example, among the issues

identified, the production of dust and vibrations, from both the operation of heavy machinery and blasting, raised concerns primarily for the health of the workers but also for the residential area of José Dominador Bazán, previously known as Fort Davis, near the Gatún expansion site. To monitor the levels of dust and vibrations, the team installed instruments for measuring concentrations of particulate matter and seismological activity in order to monitor the effects of the construction activities. Additionally, the ACP engaged in wildlife rescue and relocation efforts before clearing any forests to make room for the new locks and, pursuant to government regulation, replanted twice the amount of forest that they removed (L. Castañeda, ACP, personal communication, 2015). The ACP has similarly taken steps to mitigate a myriad of different additional environmental effects resulting from the Expansion Project's construction.

Some have lauded the ACP for both its comprehensive assessment and management of the environmental aspects of the project, as well as its transparency in dealing with the effects of construction. We spoke with Andrea Brusco from the United Nations Environmental Programme (UNEP) who characterized the environmental efforts of the ACP as follows:

“In terms of actually handling conflicts related to the Panama Canal...the UN played a primary role in mediation in other social environmental conflicts in parts of Panama with local and indigenous communities, but [the Canal Expansion Project] has a strong support from the population in general so there is no controversy about that and [UNEP] has not been involved in any mediation of environmental issues involving this project” (UNEP, personal communication, 30 November 2015).

While the ACP addressed the direct effects of the Expansion comprehensively, our interests led us to research less direct connections with an emphasis on social consequences rather than direct physical effects. In accordance with our own goals, we researched how the Canal, its Expansion, and environmental issues in Panama are interconnected and how they eventually connect to the overall topic of the Food, Energy, and Water Nexus.

## 2.2 The FEW Nexus

### 2.2.1 Beginnings of FEW

The concept of the FEW Nexus began when Tajikistan experienced a food-security crisis caused by a harsh winter, gas supply cuts, a locust invasion, and a drought that destroyed almost all of the crop production in the country. Matteo Fumagalli describes how the crisis of Tajikistan

as well as all of Central Asia has a chronic issue of food insecurity. Fumagalli believes that in order to solve the problem of food security, it had to be viewed from a larger perspective that included a nexus concept:

“To be sure, food security in Central Asia is not to be understood as a standalone challenge. The current food crisis in the region cannot be understood unless located in the broader nexus that encompasses food, water and, indeed, energy (gas and oil). It is only by understanding how the three dimensions of this nexus are entangled that a long-term, concerted and sustained strategy can be developed and applied” (Fumagalli, 2008).

Also in 2008, The “Handbook of Water and Energy Management in Food Processing” by Klemeš, Smith, Kim, and Kuk, was published, describing how the food industry is “a major consumer of both water and energy which therefore has the ultimate responsibility to ensure that both of these commodities are employed efficiently and sparingly” (Klemeš, *et al.*, 2008, p. xxvi). It is clear that this idea of interdependency developed from the desire to improve food security in certain parts of the world, but this “nexus” approach can be used for more than food security.

In November of 2011, the German government hosted a conference that officially introduced the concept of the FEW Nexus. In the 10 years leading up to a conference in Bonn, Germany, there was a large increase in the amount of reports written regarding food security in the world, such as the previously discussed Tajikistan crisis. At this first conference, two key objectives were created. First, to develop policy recommendations based on multi-stakeholder consultations a Nexus-modeled way of thinking, and second, to launch concrete initiatives to address the water, energy, and food security Nexus in a coherent and sustainable way.

The conference proceedings focused on three major case studies, featuring Myanmar, Zambia, and Colombia. Each site included a perspective on the pertinence and importance of FEW Nexus analysis, but only looked at the connections between one or two concepts at a time. In Myanmar, for example, the study focused on the effects of political and economic transitions restricting the food and water supply to the population (Hoff, 2011). The energy sector in Myanmar had many different options by which it could move forward and develop energy, but each option has its own repercussions that had to be evaluated. This study was the first to be published that focused heavily on the interdependence between food and water, between energy and water supply, and finally the involvement of politics and its ramifications. In the end, the case studies themselves

did not provide answers, but the conference combined information from each individual study to come up with and officially publish the combined concept of the FEW Nexus.

The proceedings also referred to a methodology that we used to inform our own approach. Referred to as the SEI Nexus toolkit, it highlights the interdependencies between the three areas of Food, Energy and Water and also provides some jumping off points for preliminary research (Hoff, 2011). The conference also presented three “action fields” of sustainable development to consider while conducting research using the toolkit:

- 1) “The social dimension: Accelerating Access, integrating the bottom of the pyramid”
- 2) “The economic dimension: Creating more with less”
- 3) “The ecologic dimension: Investing to sustain ecosystems services”

(Federal German Government, 2011)

Some may dispute the importance of the FEW Nexus, claiming that it merely names a concept that has existed for a very long time. However, the relative novelty of the FEW Nexus as compared with previous models lies in the fact that it considers the human-centered emphasis of the interdependencies between food, energy, and water. A report by the Stockholm Environment Institute states that the Nexus “formalizes these links and explicitly considers them, taking human aspirations as the starting point and placing stakeholders at the center of the process, rather than setting out from a traditional focus on allocation of natural resources” (Hoff, 2011). This concept shows the importance of clear communication with stakeholders. The proceedings stress the importance of enlarging the scope of all the individual researchers who come together to make decisions for governments past immediate concerns and discover the root causes and involve the entire community to make the necessary changes.

### 2.2.2 Nexus and the Environment

The FEW Nexus is a useful and relevant model that can be used to evaluate the environmental impact of the Panama Canal Expansion as well as all of Panama. Food production requires lands be cleared of forests, threatening the health of the forest as well as the biodiversity in the area. Water demands require damming rivers and flooding forests. Harmful chemicals from agriculture can seep into water supplies and cause health issues. Improper waste disposal contaminates the water in the rivers. Energy demands in the city have increased with the growing urban population. More energy production emits more carbon dioxide into the atmosphere. This



amount is reduced by using more ecofriendly energy sources such as wind power and hydropower. The case studies that we analyzed discussed the relationship of the FEW Nexus and the environment in Thailand and South Africa.

## 2.3 FEW Comparative Case Studies

### 2.3.1 *Energy, Water and Food Security Nexus in Thailand and the Transboundary Connections in the Mekong Region*

To better understand the success and failure of FEW assessments, we turned to analyzing case studies that used Nexus-related frameworks. One study took place in Thailand under the direction of the Stockholm Environment Institute’s Asia Centre. In this study, Chayanis Krittasudthacheewa of SEI’s Asia Centre developed recommendations for the Energy, Water, and Food Security Nexus in Thailand (2012). During her study, Krittasudthacheewa decided that diving into renewable resources and working from the angle of energy was the most efficient and impactful way to attack the concept of the Nexus in relation to Thailand. Specifically, there were two main components mentioned throughout the study—biofuels, or bioenergy crop expansion, which acts as the lens between energy and food, as well as hydropower development, which acts as the lens between energy and water (Krittasudthacheewa, et al., 2012). This “lens” concept is one we have adapted for our own research. As shown in Figure 2, we use each component of the Nexus as a lens through which to inspect the other components. For example, we analyzed sustainable agriculture, a food-related sub-component of the nexus, and asked “how does

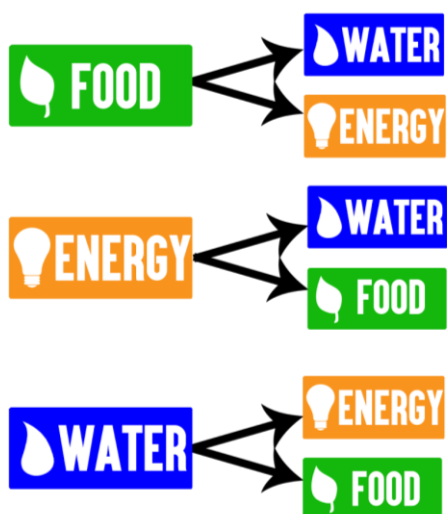


Figure 2- FEW Lenses

agriculture impact water and energy?” This approach to research allowed us to ensure that we looked at every sub-component of the Nexus from every possible angle in order to discover as many relationships and interdependencies as possible.

Throughout her research, Krittasudthacheewa not only enumerated the issues which she found pertinent to the Nexus research, but also explained how these issues play a significant role in impacting other aspects within Thailand (2012). The study explored the implications that biofuels and hydropower have across both water and food

security, the two remaining components within the Nexus, as well as the benefits that will arise from continued research and support in these areas. Krittasudthacheewa charted her progress and listed areas of research within two branches of a FEW triangle (i.e. on the side connecting food and energy the list contains biofuels, pump efficiency, energy for fertilizers, food supply chain, and transport) (2012). By using a power demand forecast, creating a renewable energy plan, and through an understanding of the regional power connection in the Mekong region, this case study was able to detail—with evidence—the significance of renewable energy sources such as hydropower in the area. The same argument holds true for her analysis of biofuels.

Overall, the research Krittasudthacheewa conducted in Thailand illustrates a key factor in our research: the criticality of connecting each possible direction we derive for understanding the Nexus back to the food, energy, water integration and how our stakeholders will benefit from our discoveries and recommendations. An area in which we will work to differ from this study is that there was not a strong emphasis on the stakeholders group, but an emphasis on numerical data collection. After reading this study, we are confident in that the FEW Nexus is a human-centered model and should be treated as such, and we feel this is a weakness from Krittasudthacheewa's work. Moreover, this study taught us that it is integral for us to be sure that we establish the main concerns, while laying groundwork for future research once ours has completed.

### *2.3.2 The Food Energy Water Nexus: Understanding South Africa's most Urgent Sustainability Challenge*

We also considered a case study regarding the World Wide Fund for Nature's (WWF) use of the Nexus to analyze biofuels and water management in South Africa. Making biofuels requires a considerable amount of land to grow the crops and water to produce the fuel. At the time, South Africa did not have enough arable land to grow the necessary crops. South Africa additionally suffered from a shortage of available water. 98% of the water in South Africa was already allocated for use in various sectors. Crop irrigation accounted for over 33% of the total allocated water (Gulati and Von Bormann, 2014). South Africa suffered additionally from high levels of water waste, so fresh water was considered a premium resource. Part of the case study's goal was to make the processes for irrigation more efficient as well as reduce wasted natural resources.

The study in South Africa was divided into four separate reports. The first provided an overview of the problems that South Africa faced and the need to overcome these problems and create a system that would be able to produce enough food for the country using the available

resources. This article provided a broad overview of food, energy, and water and how each interacts with one another in South Africa as well as the risks of maintaining the ecological status quo. For example, in the section “Complications in the Water System”, the author described the effects on energy and food if the South African water usage pattern did not change to the needed system (Gulati and Von Bormann, 2014). This initial paper provided a well-organized example of an introduction into the problems that a country may have. It provided implications of the pattern of food, energy, and water usage by describing possible outcomes of an unchanged system.

Along with the report, the WWF also produced a short video describing the problems that South Africa faces as well as the changes that needed to be made. In the video they used the slogan “Think Differently” to get the point across that changes needed to be made or else South Africa would not be able to accommodate its growing population (WWF, 2014). The video briefly explained the FEW Nexus and how each of the parts of the Nexus is dependent on the others. The video focused on food security issues in South Africa, much like the reports about the crisis in Tajikistan.

The other three articles of this study each investigated two parts of the FEW Nexus and the interdependencies between them. For example, looking at the Nexus through the water and energy lens in South Africa analyzed the water used in factories for the production of items such as milk and bread (Gulati, 2014b). The case study also included easy to follow diagrams and data that summarized all of the issues that South Africans are facing. Some of those apply in Panama, especially the analysis of the issue from a Nexus standpoint that illustrates the dependencies of each part of the Nexus on the other two, and a format that can be recycled for the different lenses as discussed in the previous case study. The video’s content was easy to understand and the visuals helped to follow along with the FEW Nexus. The use of visuals and non-technical language will allow more people to understand the changes that need to be made. However, we also identified negative aspects. The standout article, due to its difference in formatting, throws the reader off from the standard format that the study created, and our fear in using this format is that a reader would not retain some highly important information due to a formatting difficulty.

## 2.4 Summary

Food, energy, and water are connected and dependent on one another, and development undeniably alters those interdependencies. The Panama Canal Expansion project must therefore

affect the relationship between these three critical areas. The case studies have shown that involving the local government and population helps promote ongoing change which leads to direct benefits in return. Many governments and institutions across the globe have embraced the Nexus way of thinking. The social, economic, and ecologic background of the area play a role in the nature of how to conduct the research. Communication with various agencies and stakeholders provides a human-centered research approach that is beneficial to all affected parties.

The knowledge we have attained through our analysis of the case studies in Thailand and South Africa will assist us in creating a framework that can be applied to Panama. Krittasudthacheewa connected each individual aspect of the Nexus to each other, making sure to demonstrate why humans hold a stake in each connection she wrote about. Gulati called these interdependencies “lenses” to emphasize how examining one part of the Nexus consists of looking at the other two parts as well. We synthesized these many diverse techniques of analysis into a consistent, coherent methodology that ultimately benefits real lives.

## 3 - Methodology

The goal of this project was to develop a framework describing the Food, Energy, and Water Nexus relationships in the context of the Panama Canal Expansion Project that additionally provides a basis for future Nexus research. In order to accomplish this goal, we identified the following four objectives:

- Objective 1: Acquire contacts through email and interviews; conduct additional background research
- Objective 2: Conduct interviews to gather information related to topics surrounding Food, Energy, and Water
- Objective 3: Analyze our findings; identify stakeholders
- Objective 4: Build a framework and determine the potential for future FEW Nexus research in Panama

### 3.1 Objective 1 - Acquire Contacts

We used a variety of methods to acquire a diverse set of contacts. Initially, we contacted individuals referred to us by WPI faculty with relevant interests and experience. Additionally, we conducted Internet searches to find relevant organizations, some of which were able to provide not only information but also future contacts. This method of gathering contacts, known informally as “snowballing,” proved instrumental to our successful outreach. Fortunately, many of the individuals we initially contacted responded with candor and enthusiasm for our work and made themselves available to meet with us to discuss our mutual interests.

Our first contact with every individual was through an email. These emails briefly explained our purpose in Panama as a research team from the United States and also conveyed our desire to meet as soon as possible. We used a generic email template when reaching out to organizations, and expanded that template as necessary for some individuals depending on the information we were hoping to gain from them. The email template in both English and Spanish has been reproduced in Appendix A.

### 3.2 Objective 2 - Conduct Interviews

We reached out to a variety of individuals and groups while acquiring contacts, many of whom agreed to meet with us to further discuss our research. In order to not only understand facts, but also uncover the interviewees’ perceptions of the Canal Expansion and FEW related topics,

we set up these interviews to be relatively unstructured. As Berg and Lune stated in their chapter on the specifics of interviewing, *A Dramaturgical Look at Interviewing*, “Whereas highly structured interviews assume that the researchers and informants share a system of meaning, researchers undertaking loosely structured interviews typically seek to learn the nature of the informants’ meaning system itself” (Berg & Lune, 2012). Ultimately, we used a semi-structured strategy which began with some predetermined questions related to the interviewee’s interests and our project but also allowed the discussion to develop organically. With this strategy, we were able to frame the discussion at the outset to involve topics that we found interesting or relevant, but we also opened up the possibility of assimilating topics and information that the interviewee introduced into the discussion of their own volition. We hesitated to structure these discussions too rigidly around the concepts of the FEW Nexus and the Panama Canal, preferring instead to gather information on a wide array of topics and uncover the relationships between them.

These interviews also engaged a feedback loop in our process. Frequently, expert interviewees offered a narrow, but incisive perspective on the challenges facing their immediate area of expertise, and they often frequently referred us to colleagues with related opinions from a different perspective. These divergent perspectives provided additional layers of context and alternative points of view which allowed us to have a more comprehensive understanding of the topics. In this way, after conducting each interview we acquired not only additional contacts, but also an additional perspective on topics we had already considered. A complete table of the individuals we interviewed can be found in Appendix B.

It is important to note that this is where Objective 1 and Objective 2, described above, overlap. The purpose of these interviews was two-fold, whereas the research described in *Section 3.1* only had the singular goal of acquiring a contact. Through each interview we gained both a new understanding of a certain topic as well as potential for new contacts.

### 3.2.1 Data Management

This project gathered data including audio recordings and written notes from interviews. All recordings and notes were, in the short term, stored in password-protected cloud-storage, to which only the team had access. In the long-term, all files will be stored on WPI data storage arrays for a period of not less than five years. The necessary IRB paperwork detailing our intent to conduct the interviews is located in Appendix C. We maintained a list of contacts which included

the name, organization, and email address for each individual we contacted throughout the entire process, but have not reproduced the email addresses in this paper due to privacy concerns (Appendix B). This list was updated immediately upon any new interaction with any individual in our capacity as representatives of the project to show the state of all contacts at all times. Optimally, this information will be available indefinitely; however, the actual period will be not less than 5 years.

### 3.3 Objective 3 - Analyze Findings

Following the collection of information during our research phase, we analyzed our findings and identified both stakeholders and themes. We determined that the stakeholders would be anyone with the possibility to impact or be impacted by change in the region. Once a topic came up in our research and interviews multiple times, we noted these as recurrent themes and kept track of their recurrence to determine if they were dominant themes in our findings. We took to processing this information through a lens that allowed us to understand the connection of these ideas to how it impacts the Panamanian citizens. We also analyzed how each theme we discovered linked to each other. We spent time tying these concepts into three broader themes: food, energy, and water.

#### 3.3.1 Human-Centered Analysis

The FEW Nexus is a human-centric model for examining environmental topics Deforestation, urbanization, and waste management—all human-centered—are key parts of the environmental impacts in Panama. For example, Panama's rainforest is crucial in providing enough rainfall for the country. For our analysis, we decided to focus on the human impacts of environmental issues rather than the technical and mechanical processes, which bring about such issues. As we examined the FEW Nexus links in Panama, we considered these human impacts paramount. This is not to say that conservation and environmental stewardship are not important endeavors for their own sake. However, from our perspective, the FEW Nexus places humans, their livelihoods, and their aspirations first. In line with this goal, we developed a Framework that illustrates how the lives of real people might be affected by environmental problems.

### 3.4 Objective 4 - Build Framework

After conducting our analysis, we combined the data into a framework that clearly outlined the relationships and interdependencies we discovered through our research. The framework was created by condensing information gained through interviews, research, and site visits into a series of overarching themes and interconnected relationships. *Section 4.2* of this paper contains the framework. We determined how each theme fit into each aspect of the FEW Nexus. We then showed the links between the themes within the larger themes of food, energy, and water. The final component of this project includes multiple recommendations for future research which can expand upon the current framework by exploring each of the more complex relationships further and in more detail.



## 4 - Results

Many of our interviewees shared experiences, ideas, and concerns that fall within several common themes. Our interviews helped us to determine the stakeholders in Panama whose decisions can affect the environment. In this section, we discuss in detail each theme that we discovered throughout those discussions, and how these themes fit into the broader context of the FEW Nexus. Every theme we have discovered is connected either directly or through the FEW Nexus.

Individuals interested in further pursuit of FEW Nexus analysis in Panama will be able to reference our research and framework, paired with the recommendations for future research (*Section 5.2*). Understanding the FEW Nexus requires an integrated perspective, which is most easily understood when each aspect of the Nexus is broken down into the following themes that relate to the larger topics of Food, Energy, and Water (*Section 4.3*). Once more research is done regarding those themes, the interdependencies within the larger picture become more evident. In this paper we have presented the synthesis of those interdependencies as holistically as possible with the information we have obtained.

### 4.1 Stakeholders

Due to the human-centered nature of the Nexus, community dynamics and forces formed the center of our project. Through our research and interviews we discovered which entities hold a connection to environmental work in Panama, and from there we were able to identify a collection of stakeholders. The groups we identified ranged from local government officials, to agencies, to individual interests. The (non-exhaustive) list includes the National Science Foundation, which funds this research, and which has specifically allocated \$74 million to the development of the FEW Nexus (Innovations at the Nexus of Food, Energy, and Water Systems, 2014); STRI, which conducts environmental research in the region, many NGOs and foundations focused on improving environmental practices and raising awareness for environmental issues; the Panamanian government and the Canal Authority, who have an interest in protecting their environment and natural resources (ACP, 2015a); and the residents of the Canal Basin, who feel the immediate effects of the Canal Expansion (Heckadon, 1993). Within our stakeholder group, there is complexity within the strata that are represented. It is imperative to carefully assess the differing power and class levels by giving an equal voice to all who hold a stake in this research.

Local and global forces alike are involved when it comes to the Canal Expansion efforts, and as a result we considered the potential of having stakeholders in any area.

There are many stakeholders that are immediately invested in the Project, such as residents in the area of José Dominador Bazán near the Gatun Expansion site as well as the Expansion Project workers. Through our analysis we also determined many stakeholders that have an indirect connection to the Project. These groups of people do not appear to be connected to the expansion at first, but through the human-centered Nexus analysis we determined that they were also affected by the Expansion. For example, residence in certain neighborhoods with no history of flooding are now experiencing floods regularly due to the surrounding development blocking the drainage. Additionally, every interviewee we spoke with expressed how the Expansion has impacted their work, everything from sustainable agriculture to waste water treatment. In the end, there are likely many more stakeholders than we were able to consider in this analysis. The extended impacts and list of stakeholders affected by the Canal Expansion Project cannot be fully determined until well after the project is complete.

## 4.2 Themes and Findings

Through a combination of research and interviews we were able to gather information on a variety of environmental and social impacts throughout Panama and organize them into eight “themes.” Each section focuses on one theme and touches on how that theme is connected to other themes and the FEW Nexus. Also included in each section is a diagram that illustrates those connections. Each section’s central focus is in the center of the accompanying graphic with the themes that it directly connects to surrounding it in dark text. While each theme is undoubtedly connected to each other theme, some connections are more direct than others. The lighter text indicates a less-direct connection that is not discussed specifically, but can be traced tangentially through other sections.

### 4.2.1 Water Security

Our sources immediately began to relay concerns for the security of potable water. Panama faces issues concerning the amount, quality, and availability of drinkable water. The security of water contributes greatly to the health of Panamanian ecosystems as well as the population of Panama, specifically the population surrounding Panama City. The urban population's inefficient use of water resources and a lack of proper waste



disposal systems throughout Panama contribute to ongoing issues facing Panamanian water security. Panama City obtains its drinking water through a system of aqueducts that brings water from Lake Alajuela as well as a few smaller reservoirs to the city. The first aqueduct in Panama was constructed in 1905, but it wasn't until 1942 that larger aqueducts were created to serve Panama City and Colón (IDAAN, 2015). Since then, the aqueducts have been maintained and updated to fit the city's growth.

One critical aspect in the development of water distribution systems stems from continuing attitudes surrounding water services. In the early-to-mid 20<sup>th</sup> century, water security had not yet emerged as a pressing issue. It was not until the late 20<sup>th</sup> and early 21<sup>st</sup> century that summits and organizations which focused on water security were created (Global Water Partnership, 2012). In Panama, United States military bases such as Fort Clayton, now the City of Knowledge, had unregulated water meters in each building providing access to clean water free of charge. Similarly, in other parts of the country, water was not a restricted resource that required a subscription or substantial infrastructure to distribute. This high availability of water instilled the notion that water should be a free resource, and now even though the cost of delivering potable water has risen dramatically, the population resists increases in the price of water (G. Pulido, IDAAN, Personal Communication, 30 November 2015). IDAAN, the company in charge of the aqueducts and sewage treatment for all of Panama, struggles with this popular disposition. IDAAN spends roughly \$3 million each year to maintain the aqueducts (Fig. 3). The majority of the water is pumped from a station in Chilibre with other smaller stations to maintain water pressure. Without any payment from the population they will not be able to continue their operations. In order to



water pressure (G. Pulido, IDAAN, personal communication, 30 November 2015). The continuous need to update the water system results in an augmented amount of money spent. The charge for drinking water per month is also augmented due to inefficient water use.

The aqueduct system, in particular the pumping station(s), is under an excess amount of strain due to inefficient water use. Panama consumes the most water per person of any nation in Central America (Fig. 4). Individuals serviced by IDAAN consume an average of 355.76 liters (93 gallons) of water per person per day, roughly twice the average amount for Central America and 50 liters (13 gallons) per day more than the United States (The USGS Water Science School, 2015). Gonzalo Pulido, an assessor from the planning department at IDAAN, related his concerns for the inefficient use of water. “When you visit a family at random in Panama,” he said, “it is so common to find a faucet open... It costs so, so little, that they don’t care. We use the water in a very inefficient way” (G. Pulido, IDAAN, Personal Communication, 30 November 2015). Some consideration has been given to constructing another pumping station, or even flooding an additional reservoir, to keep up with growing demands and waste, but this new station may not be necessary if the water usage habits change to accommodate a more conservative pattern. A

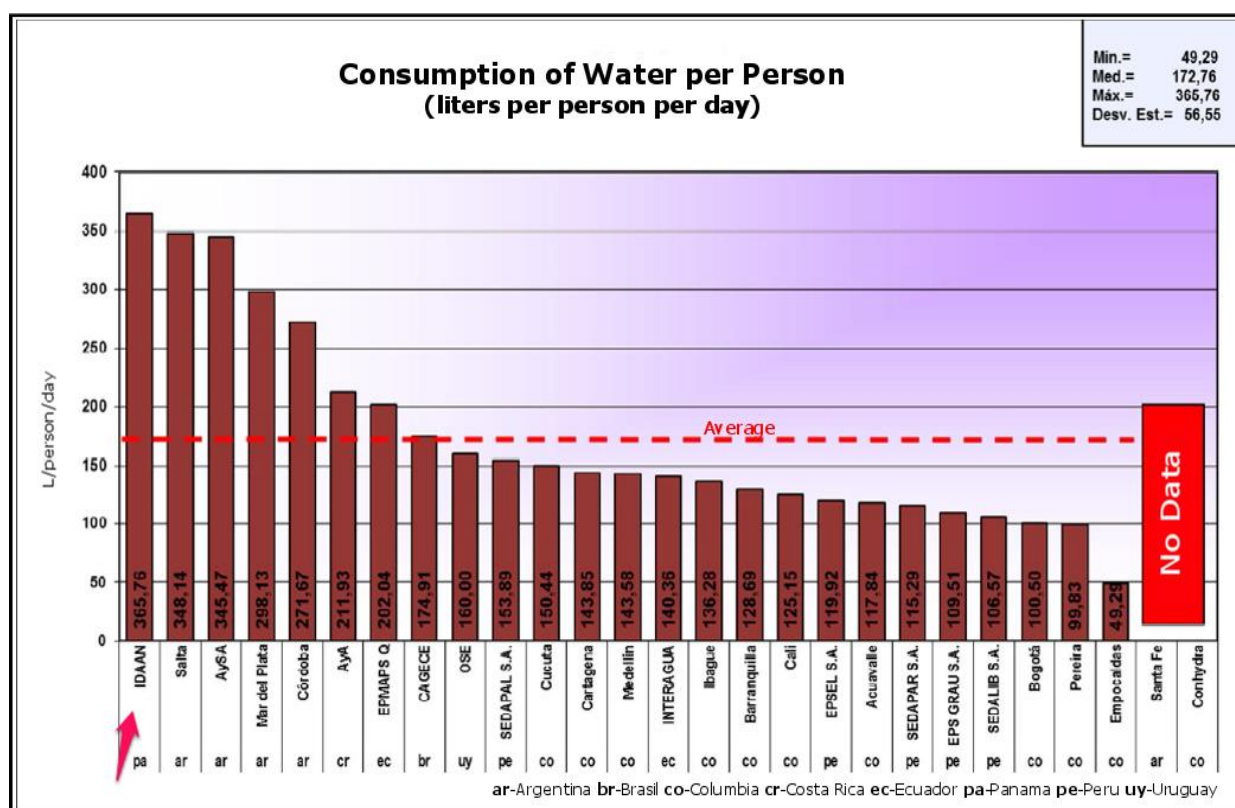


Figure 4 - Water consumption by distributor in Central and South America (© IDAAN 2015)

decrease in water losses from 50% to 20% may offset the need for a new station. Financially, a solution involving what Pulido calls “cultural change,” a change involving attitudes towards conservation practices, would be much cheaper than investing in expensive additional infrastructure (G. Pulido, IDAAN, Personal Communication, 30 November 2015). Deciding on the correct plan of action between the former and the latter requires more research into what would better suit the needs of the people of Panama City.

Much of this potable water comes from the Canal Watershed, specifically Lake Alajuela (see Fig. 1). Though Panama has enacted regulations to protect the Watershed, the regulations in place do not carry strong enough penalties to deter people from contaminating the water. The capacity of the government to enforce these regulations effectively may also be limited. The wages that the government pays patrol officers are low enough that logging companies can bribe them to look the other way (Z. Danon, CATHALAC, Personal Communication, 12 November 2015). However, this is not to say that there has been no effective attempt to regulate the area.

Various steps have been taken in order to protect the Canal Watershed. The Canal Expansion uses multiple sets of water saving basins (Appendix D) that use 193,500 m<sup>3</sup> (51 million gallons) per transit, 7% less than the current locks that use 208,000 m<sup>3</sup> (55 million gallons). Without these water saving basins, the new locks would have used 483,600 m<sup>3</sup> (128 million gallons) per transit (Quijano, 2014). The 60% raw amount saved relieves strain on the water supply to the Watershed and allows the possibility for more water to be used in different sectors. In order to prepare for the higher demand of water for the Canal, the Watershed has been expanded by 213,112 hectares (526,611 acres) to include the area of the Coclé del Norte, Caño Sucio, and Indio rivers that will deliver water to Lake Gatún (G. Pulido, IDAAN, Personal Communication, 30 November 2015). This plan, called the Panama Canal Watershed Expansion Plan (PCWE), included the construction of dams for each river, and hydropower systems on the Coclé del Norte and Indio rivers (Niesten and Reid, 2001). Figure 5 depicts the Traditional Watershed outlined in red with the additional Western Watershed outlined in black. This new source of water for the Canal will supply the necessary amount needed to maintain the water level of Lake Gatún concurrently with the widening and deepening of the Canal.



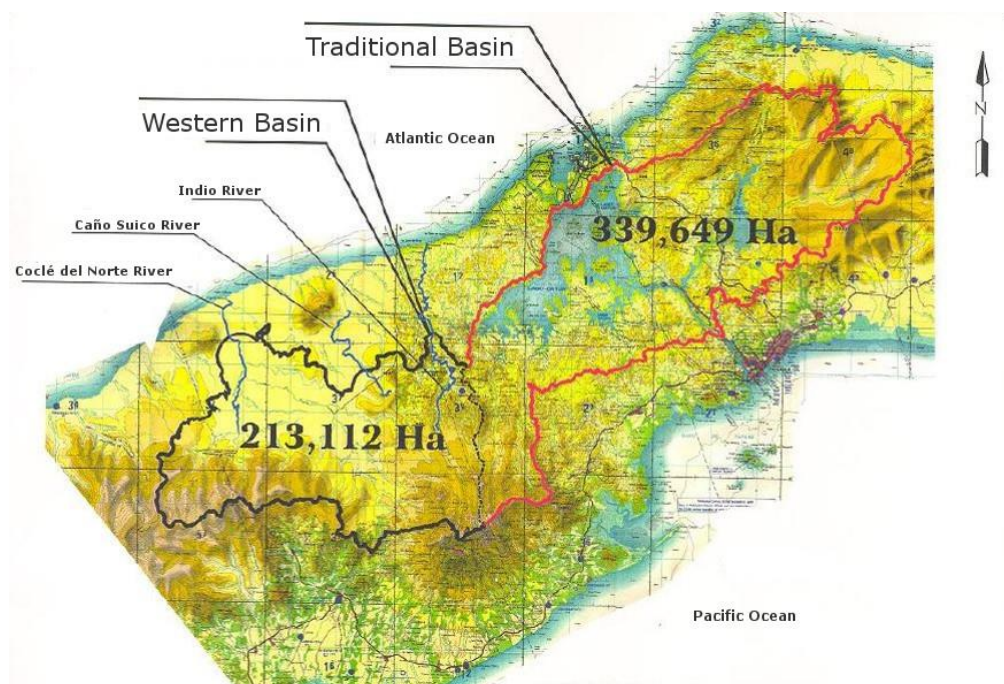
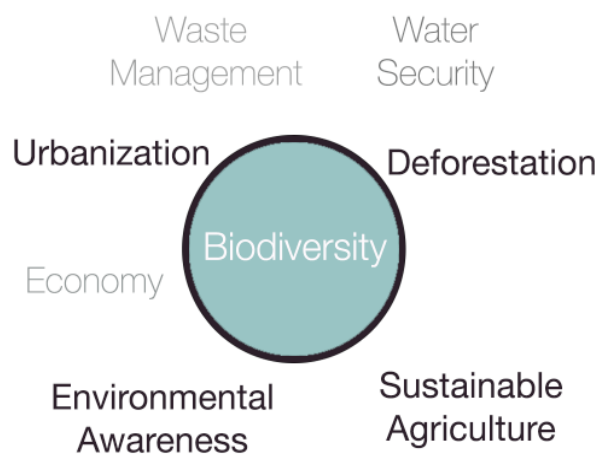


Figure 5 - Addition of the Western Basin to the Canal Watershed (IDAAN 2015)

Despite these efforts to combat contamination, the Chagres River continues to have issues due to dredging and quarries in the vicinity of the river. With the completion of the Canal Expansion and the continuous growth in urban population combined, there is going to be a greater need for water as well as water conservation. Even with the water saving basins, the Canal will be consuming more water than before, and may, in future years, need to be supplemented with water from additional watersheds. This is, however, likely a short term solution. Better water conservation is needed in order to ensure the continued operation of the expanded Canal and to meet the potable water needs of the city.

#### 4.2.2 Biodiversity

Due to its unique location as a land bridge between the continents of North America and South America, Panama enjoys a tremendous biodiversity arising from the Great American Interchange (*Biodiversity Museum Panama: Bridge of Life*, 2015). This high level of biodiversity impacts the country in various ways. Dr. Anthony Coates, a paleobiologist with STRI,



conducts research concerning the rise of the Panamanian Isthmus and the resulting biodiversity in the region. He described the benefits of biodiversity as consisting of three major components: an aesthetic beauty, a basis for pharmaceutical research, and a mechanism for carbon sequestration (A. Coates, STRI, personal communication, November 18, 2015). Moreover, biodiversity contributes to the effectiveness of an ecosystem, and in order to ensure that the ecosystem in Panama continues to provide its services to the population, the ecosystem must maintain its biodiversity. However, the biodiversity of the ecosystems in Panama is threatened by rapid population growth and the transformation of the landscapes due to deforestation brought on by this continuous increase in population size.

#### 4.2.2.1 Real Benefits of Biodiversity

Though at its surface, the aesthetic quality that biodiversity lends to an ecosystem may seem somewhat superficial, this beauty has important consequences for the economy. The beauty intrinsic to a high biodiversity both on land and in the oceans attracts tourists which funnel billions of dollars into Panamanian coffers each year, and this industry is growing extremely quickly. From January to September of 2015, visitors to Panama spent more than \$3 billion dollars on Panamanian goods and services (not including international transportation), representing an increase of more than 14% over the same time period in the previous year. (Autoridad de Turismo Panamá, 2015). The success of the tourism industry depends heavily on the continued maintenance of Panama's highly biodiverse ecosystems. The Convention on Biological Diversity summarizes the relationship between biodiversity and tourism as follows:

“Tourists are attracted by natural landscapes which harbour significant biodiversity. Tourists in coastal areas enjoy swimming in clean waters among the fish and coral reefs, and watching whales and seabirds. Others go on safaris to watch wildlife. All these activities require intact and healthy ecosystems. National parks rely on functioning ecosystems to provide visitors recreation, education, culture and fun” (Biodiversity and Tourism, 2010).

Certainly, Panama's biodiversity attracts thousands of tourists each year, and Panama's tourist industry will continue to grow so long as it protects this valuable asset.

In addition to the aforementioned economic benefits arising from tourism, a high biodiversity also represents fertile ground for research into the applications of the biological structures found in plant and animal species. In particular, pharmaceutical research benefits



heavily from increased biodiversity. Dr. Coates explains this relationship by equating biodiversity to diversity of genetic structures (A. Coates, STRI, personal communication, November 18, 2015). Pharmaceutical researchers study the medicinal effects of these structures to create cures for common diseases. Therefore, these researchers highly depend on the variety of genetic structures inherent to biodiverse areas. Indeed, 25% of modern Western medicines are derived from ingredients discovered within tropical rainforests; however, researchers have tested only 1% of arboreal rainforest species (Taylor, 2012). Every time a species disappears, a structure that may contain a cure or medicine also disappears. However, this genetic diversity benefits not only pharmaceutical research; scientists also study genetic structures to develop a wide variety of synthetic materials, for example the silk of the golden orb-weaver spider, which has mechanical properties similar to Kevlar (Foo & Kaplan, 2002). The loss of biodiversity threatens these developments, so it is in humanity's best interests to protect its species-rich landscapes.

Another benefit of biodiversity stems from its relationship with the forest ecosystems on land and the coral reefs in the oceans. As previously discussed, a flourishing ecosystem functions as a major mechanism for carbon sequestration. Intuitively, the amount of carbon these ecosystems can prevent from entering the atmosphere as CO<sub>2</sub> increases directly with the amount of forest life within the ecosystem. Due to a process known as “functional complementarity,” ecosystems with a higher biodiversity have more fully occupied niches, and are more functional and healthier (Benefits of Biodiversity to Humans, 2015). These forest ecosystems when fully developed help manage the water which flows over the land, preventing sedimentation and the transformation of the landscape (C. Jaramillo, STRI, personal communication, November 17, 2015). To take advantage of this natural benefit, the ACP protects a 16km (10 mile) wide strip of forest land around the Chagres River from the Pacific to the Atlantic, thereby also protecting the biodiversity within the surrounding forest ecosystems.

#### 4.2.2.2 Challenges Facing Biodiversity

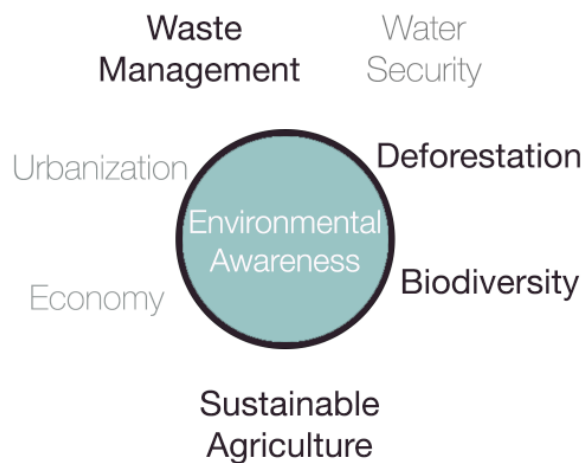
In order to protect these resources, some challenges which would diminish biodiversity in the surrounding ecosystems must be taken into consideration. Dr. Coates stated that the rapid growth in human population around the globe is a “real game changer in terms of global biodiversity” (A. Coates, STRI, personal communication, November 18, 2015). As human populations grow, strong correlations suggest that this increase in population is related to increased deforestation as more land goes to pasture and farming, presumably to feed more people. This

deforestation threatens the biodiverse landscape, as biodiverse ecosystems on land exist primarily in heavily forested areas. In the oceans, biodiversity resides heavily within the coral reefs, which may be threatened by increased traffic through the Caribbean Sea (Guzman, *et al.*, 2008). Coral reefs exist in a symbiotic relationship with the fish and other organisms living in the ocean, and it is unclear whether or not the increased level of traffic through the expanded Canal may have negative impacts on the health of the reefs.

The deforestation which threatens the biodiversity and the availability of natural forest resources is connected to the need for arable land. Large areas of forest are cut down to make room for pasture and farm land. Before we can discuss solutions, we need to discuss the current awareness of the issues, how awareness affects the ability to combat such issues, and what steps are being taken to increase awareness and environmental consciousness.

#### 4.2.3 Environmental Awareness

For decades, environmental activists around the world have struggled with the problem of raising awareness of pressing environmental issues. In Panama, we spoke with many individuals representing a wide variety of interests, such as members of the Peace Corps and affiliated scientists from the Smithsonian Tropical Research Institute, who raised concerns about the level of public knowledge of environmental



issues and discussed various efforts to increase public awareness of environmental topics which affect the area. However, there may be some factors which inhibit the dissemination of this information. Darién Montañez, a coordinator for Panama’s Biodiversity Museum (BioMuseo), described how humans’ natural preference for the comfort of insulated, low-resistance environments demands a unique approach to environmental awareness efforts. He joked that “people would rather live next to a shopping mall than next to mangroves” and further discussed that the conservationist agenda in Panama needs help gaining traction in order to be successful in the future (D. Montañez, BioMuseo, personal communication, 4 November 2015).

Mr. Montañez informed us that Dr. Anthony Coates played a key role in the development of the museum, which takes an interesting and alternative approach to the traditional concept of a museum. Visitors learn about Panama's immense biodiversity through a self-guided audio tour of exhibits that rely less on the presence of artifacts and more on an interesting presentation of the information. Mr. Montañez humorously went on to describe Panama as one of the "coldest countries in Latin America," referring to the prevalent use of air-conditioning to escape the intense tropical heat. However, he explained, the BioMuseo seeks to bring its visitors to a state of awareness of their surroundings. Its visitors must walk outside from the parking lot through a display of local flora to the building's open-air atrium, where they remain in contact with Panama's natural climate. Mr. Montañez describes the museum as a "non-traditional approach to education" because, unlike Panama's mid-twentieth-century classic museums, which rely on artifact displays, the BioMuseo attempts to "showcase research which would otherwise rarely permeate into the community." It also seeks to engage the visitors' curiosity, placing them in the middle of the information about the importance of the environment in Panama and allowing them to guide themselves. Ultimately, the BioMuseo strives to instill in all guests the desire to go out into the world and learn more about the natural environment. "The real museum is out there," Mr. Montañez told us. The true goal of the museum isn't to force people to learn in the building, but to bring the mindset of the visitors closer to their environment (D. Montañez, BioMuseo, personal communication, 4 November 2015). While the population's consciousness to the surrounding climate remains important, it may not be enough on its own to affect real change. Raising awareness of the issues surrounding the environment requires local scientists to study that environment and identify the issues in the first place.

Dr. Ira Rubinoff, a marine biologist and the former director of STRI from 1973–2007, had a lot to say about the environmental footprint of the Canal, but also spoke about what he saw as an imbalance between the resources allocated to the study of biodiversity in temperate climates compared to tropical climates, which house the most biodiverse areas of the planet;

"The tropics are exciting, it's where the biodiversity is and people don't realize that, but the wherewithal to study the biodiversity is in the temperate zone, and when you try to explain to them that you need to address that imbalance, it's very difficult" (I. Rubinoff, STRI, personal communication, 17 November, 2015).

He further described that in a state like California, a diverse area in a temperate climate, universities that consider themselves world-class locations to study biology and biodiversity invest in expensive and comprehensive technologies to conduct their research, whereas institutions in tropical locations with immense biodiversity such as Panama and Ecuador have not developed this research infrastructure to the same extent, as there is a lack of funding, resources, and interest to study the area (I. Rubinoff, STRI, personal communication, 17 November 2015). Therefore, a critical component of raising environmental awareness in Panama is attracting scientists, academics, and undergraduate student research teams to the tropics to conduct research and identify issues.

Once institutions and researchers conduct their studies and identify issues, the question becomes, how do governments, NGOs, and others affect real change based on these findings? As previously discussed, alternative approaches to education, such as the creatively-designed Biomuseo, may have an important role in raising awareness in an urban context. But, in the context of agriculture, many obstacles can inhibit the adoption of improved or environmentally friendly techniques. “Environmental Education in the 21<sup>st</sup> Century” discusses how significant life experiences, or formative influences, make up the basis of all understanding and how, in order to effectively educate a population on the best environmental practices, these formative influences must be taken into account (Palmer, 1998). Fernando Lopez, the director and founder of EcoFarms, an organization in Panama that promotes responsible environmental practices, spoke about the different challenges facing the adoption of these practices. Mr. Lopez told us about the challenges of creating a sustainable agriculture environment which he refers to as a “culture” of traditional farming. Many long-standing traditions conveyed from each generation to the next drive the dominant farming practices in Panama (F. Lopez, ECOFARMS, personal communication, 30 October 2015).

Seth Hopkins, Executive Director of the Batipa Field Research Institute, faced a similar problem with the “culture” in the region differing from the environmentally conscious methods he attempts to encourage (S. Hopkins, personal communication, 11 November 2015). What these activists refer to as “culture,” Palmer describes as a history of formative influences that frame the individual’s understanding of environmental topics (Palmer, 1998). However, according to Mr. Lopez, in recent years a more environmentally conscious culture has begun to emerge in some areas due in part to NGO’s and ecologists working to spread awareness of the environment (F.

Lopez, ECOFARMS, personal communication, 30 October 2015). Palmer states, though, that “the influence of environmental education is clearly not as dominant or successful as it ought to be...even where successful programs of environmental education do exist, their impact on long-term thinking and action is not as great as other significant experiences and formative influences in an individual’s life” (Palmer, 1998, p. 240). In “Emergent Environmentalism,” a study published in 1993, the authors show that outdoor experiences, particularly during early childhood, may be the single most important influence affecting people’s thinking in relation to the environment.

If Panama continues to urbanize at the current rate, a smaller portion of the population will have access to these kinds of early formative influences, and it is possible that it will become more and more difficult to develop a sense of environmental awareness in the city context (Palmer, 1993: Palmer & Suggate, 1996). Even in the rural context where agriculture dominates, access to early experience in the environment working towards the betterment of agricultural processes may be limited. Farmers’ needs and capacities for choice must form the basis for discourse on sustainable agriculture, and it is important not to view this problem as a two-sided conflict between the environment and the population. Rather, it is a symbiotic relationship with many interacting components.

#### 4.2.4 Sustainable Agriculture

Early in the interview process, many of our interviewees relayed their concerns for the sustainability of the agricultural practices in Panama. Nearly all cultivated or pasture land in Panama was originally covered by forest growth (Hanratty & Meditz, 1989, p. 152). However, the demand for arable land and pasture has resulted in widespread deforestation since the 1950s, particularly in the Dry Arc (*Arco Seco*) (Fig. 6), where many decades of farming and cattle

ranching have induced soil erosion and desertification, damaging the wildlife and making ranching difficult (McCarthy, 2013, p.126). In addition to the loss of forests, Panama, like many regions of the world, suffers from the ecological effects of both slash-and-burn agriculture and the use of



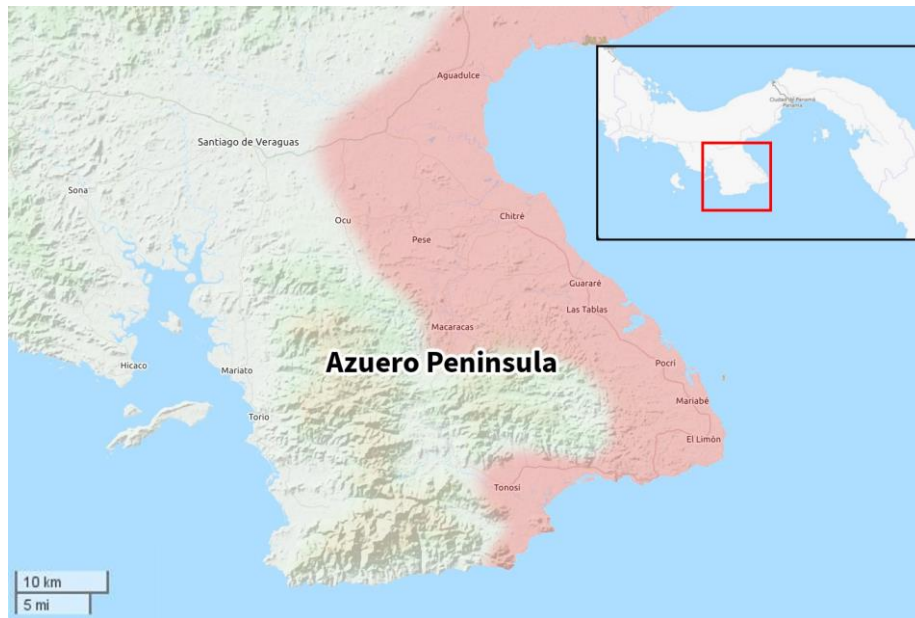


Figure 6 - Azuero Peninsula, Dry Arc Region (© OpenStreetMap Contributors)

pesticides, both of which have very long histories in Panamanian farming practices (Hanratty & Meditz, 1989, p. 153; *Pesticides In Panama: How Serious Are They?*, n.d.). The destructive nature of both of these techniques requires a continuous expansion of cultivated and pasture land, and further accelerates both the loss of forests (explained in detail in the following section) and the contamination of nearby water resources. Many of our sources expressed concerns that this agricultural methodology relies on an unsustainable model and suggested that some sustainable agriculture practices would mitigate the effects of agricultural practices on the environment.

One solution commonly offered to combat deforestation is forest conservation. The government has designated 2.4 million hectares (5.9 million acres), or about 32% of Panama's 7.5 million hectares (18.5 million acres) of land, as protected area (Arias García, n.d.). However, Fernando Lopez explained that, while important, conservation alone does not provide an ultimate solution. Conservationist principles, he reasoned, restrict access to arable land and do not ultimately empower farmers to meet their agricultural needs (F. Lopez, EcoFarms, personal communication, October 30, 2015). As such, regulatory authorities have to consider the concerns for the availability of farm-land and concerns for the conservation of forest land. This issue of availability becomes even more pressing when considering the frequency of subsistence farming in Panama. Subsistence farmers, or "smallholders," still make up a large portion of the agricultural labor force (Tschakert, *et al.*, 2007). As a net importer of food, Panama attributes only 3% of its GDP to agricultural activity. However, it accounts for about 17% of its labor force and for the use

of nearly 50% of its non-forested land (Central Intelligence Agency, 2015; Hanratty & Meditz, 1989, p. 153). In order for agricultural production to remain sufficient and sustain itself over an extended period of time, farmers should consider some sustainable alternative options.

In many parts of the world, “non-organic” Green Revolution agricultural methods have been met with pushback from environmental activists, and Panama is no exception (F. Lopez, EcoFarms, personal communication, October 30, 2015). With the introduction of environmental awareness programs, popular familiarity with ecologically friendly agricultural methods is increasing. However, the chief attraction of slash-and-burn agriculture is its low-cost. Other low-cost sustainable methods with many benefits over slash-and-burn such as Inga alley farming, a technique which involves the planting of nitrogen-fixing Inga trees, have been demonstrated to be effective in some cases even for smallholders (Sitler, 2013). However, these poorer smallholder farmers may not be in a position to change their methods without assistance. Petra Tschakert *et al.* raised this concern after studying the agricultural habits of an economically diverse indigenous population in Eastern Panama.

“Those individuals who most need the benefits from a new idea are usually the least likely to adopt, simply because they have limited capability to exercise choice... thus, they are also usually the last to be targeted by change agents, and they are effectively left behind” (Tschakert, *et al.*, 2007).

Sustainable solutions may be economically viable in the long term, even for smallholders, but many of these farmers are among the poorest class of citizens and simply cannot afford to wager a portion of their arable land on a payoff that could take years to materialize when they are used to subsisting on their day-to-day production.

Despite these widespread issues, farming within the Canal Watershed area is expected to continue without additional issues directly attributable to the operations of the expanded Canal, but urbanization of the area may be starving the agricultural industry—already struggling with a lack of high-quality land—of able workers. There are, however, initiatives to bring farming into urbanized areas. Nixa Gnaegi de Ríos, rector of the Oteima University of Technology (Universidad Tecnológica de Oteima), has worked to develop an urban farming initiative in Panama City. By nurturing these kinds of urban food security systems, she seeks to establish an area where individuals can grow their own food (N. Gnaegi de Ríos, personal communication, November 14,

2015). Urban farming reduces the pressure on rural food production and provides jobs for those without one.

To actualize a solution which encompasses all of the nuanced facets of agricultural production including, but certainly not limited to, those above, will be a long and difficult task for regulatory authorities, for NGOs, and most obviously for the farmers themselves. Any solution to the sustainability problems, however, must address deforestation. Current agricultural methods are heavily contributing to the loss of forests and to desertification, and there are many negative effects related to the loss of the forest cover. However, sustainable agriculture initiatives first have to empower farmers to make the sustainable choices in the first place.

#### 4.2.5 Deforestation

In an interview with Dr. Carlos Jaramillo of the Smithsonian Tropical Research Institute, we were told of the importance of forest regions in the Canal Watershed area. Carlos stated that without forests the Canal simply would not work. The bordering forest reduces the sediment runoff into the Canal, which means the Canal doesn't need to be dredged as often (C. Jaramillo, STRI, personal communication, 18 November 2015).

58% of Panama is covered by forest, and only 56% of that forest is under official protection to conserve the soil, water, and biodiversity. The deforestation rate in Panama is 0.1% annually from logging and the clearing of land for cash crops, pastures, and subsistence farming (Gray, 2008). The preservation of forests anywhere in the world is undoubtedly important, however in the Panama Canal Watershed this preservation is taken even more seriously to ensure proper operation of the Panama Canal.

Dr. Anthony Coates spoke of how national parks are lacking sufficient protection (A. Coates, STRI, personal communication, 18 November 2015). Without proper enforcement of the regulations, there is little preservation. However, Fernando Lopez, Director of EcoFarms discussed the ability of ecologically conscious organizations to mitigate deforestation. He said, “You cannot plant trees all around Panama because you have to think about food security as well,” (F. Lopez,





EcoFarms, personal communication, 30 October 2015). This also brings into consideration the issue of profit; farmers or landholders must consider what use will provide them with the most profit per area, which can be another issue altogether. The consideration of the economic benefit of deforestation must be weighed against the detrimental effects of removing trees from the area, whether to sell the wood or make space for pasture, farms, or city expansion.

Today, there is a one million hectare reforestation program in place to attempt to offset the many years of deforestation caused by inefficient farming. The program is run by the Ministry of Agriculture with the mission to “raise awareness to the Panamanian population on the importance of forests and echo [*sic*] systemic services that they offer us, in addition to reducing deforestation, recovering degraded areas, mitigate climate change and protect watersheds” (Alliance for the One Million Reforested Hectares, n.d.). It involves the planting of 40,000 seedlings across the country over the next 20 years by volunteers at the different planting sites (Alliance for the One Million Reforested Hectares, n.d.). This is the largest reforestation project in Panama, but it is not the only one.

Along with the Ministry of Agriculture's program, STRI created the Smart Reforestation and Agua Salud projects. The Smart Reforestation project focuses on maximizing the flow of good, such as food and lumber from landholders to consumers, while at the same time taking care of the environment. The project is broken down into two scales, the landscape scale and the local scale. The landscape scale focuses on promoting:

“Efficient yet practical land use planning [that] is needed so that different areas are appropriately allocated for reforestation, sustainable agriculture, urbanization, protected areas, and other land uses that optimize the different ecosystem services derived from the landscape mosaic” (Smithsonian Tropical Research Institute, 2015).

The local scale looks at the biodiversity in the region and decides on the proper trees to use for reforestation and agroforestry. The Agua Salud Project focuses on the goals that the Smart Reforestation project has created. The project “seeks to understand and quantify the ecological, social, and economic services provided by tropical forests in the Panama Canal Watershed” (Smithsonian Tropical Research Institute, 2015). A large part of the project focuses on reforestation in the Watershed that will eventually lead to a larger water supply. By growing the rainforest again, the Watershed area will have more water as well as more biodiversity and, as

mentioned in the beginning of this section, will secure the safety of the Canal and its economic benefits.

#### 4.2.6 Economy

The Panama Canal is a large component of Panama's economic success. Dr. Coates stated that "many people are ignorant to the benefits of the Canal for Panama" (A. Coates, STRI, personal communication, 18 November 2015). In the fiscal year 2014 the Republic of Panama reported about \$12 billion in gross revenues. Bringing in over \$1 billion in fiscal year 2014, the Panama Canal is one of the largest sources of income in the country (*2014*



*marcó récord en los ingresos*, 2015). Because of the way the government manages its budget, it is impossible to track which dollars specifically come from the Canal revenues and what they go to fund (A. Alemán, personal communication, 16 November 2015). Despite not being directly traceable through the budget, though, it can be determined that those billion dollars of Canal revenue are enough to fund programs such as the majority of the operating cost for the ministry of education, which was about \$1.4 billion in 2014, or the combined expenses of the Ministry of Public Works which were about \$1 billion (*2014 marcó récord en los ingresos*, 2015). The Canal has a large positive impact on the economy of Panama that, as Dr. Coates explained above, greatly outweighs possible negative environmental impacts of the Canal. However, the impact on Panama's economic equality remains in question.

According to the World Bank, Panama is one of the most unequal societies in the world. It has a GINI index of 51.9 (a lower index implies a more even distribution of wealth). Compared to its neighbors, Panama fares slightly better than Colombia (53.5), but worse than Costa Rica (48.6). Among all nations, it has the 18<sup>th</sup> highest GINI index among the countries rated by the World Bank (World Bank, 2011). This inequality manifests on the opposite side of the isthmus from Panama City, where Colón, the second largest city in Panama, stands in stark contrast. Colón was originally built in 1850 by Americans working on the Panama Railroad, and many of the buildings still

standing today were built over 100 years ago by these early pioneers of trans-isthmian travel. At one point, Colón was home to many of the wealthy of Panama. However, Colón is now in a state of disrepair. Randal Archibold, for the New York Times, writes:

"As Panama City grew and modernized in the post-World War II era, Colón's luster wore off. The reduction and ultimate closing of American military bases with the Canal's transfer to Panama in 1999 accelerated Colón's tailspin. Crime and poverty swelled, and middle-class strivers moved to the suburbs, Panama City, or abroad" (Archibold, 2013).

Though Colón contains one of Panama's other large sources of revenue, the Free Zone, the wealth gap between Colón and Panama City illustrates how sources of revenue do not always result in a better quality of life for the residents. Colón's Free Zone generates about \$100 million per year, but it is unclear where that money goes (Business Panama Group, 2015). Figure 7 shows how the city, once a beautiful and impressive display of architecture, is now falling apart directly over the heads of its current inhabitants.

Dr. Anthony Coates stated that, relative to the rest of the countries in Central America, Panama is extremely well developed socially and economically (A. Coates, STRI, personal communication, 18 November 2015). From within Panama City, this certainly seems to be true,



Figure 7 - The dilapidated state of many of Colón's buildings (© Meredith Kobut, for the New York Times)

as many areas appear to be thriving, full of skyscrapers and giant shopping malls, but the crumbling buildings of Colón seem to belong to another country altogether. Now that the Canal is managed from offices in Panama City, more jobs are being created in that area, and Colón has been left behind as a thing of the past. As previously addressed, the increase in jobs as well as sources of income for Panama City has led to enormous potential for development.

This wealth and development, even within the Panama City, is unevenly distributed. NPR's Tim Padgett addressed this issue in a segment titled "Panama's Canal Divides A Country Into Haves and Have-Nots." He discusses how Panama has run the Canal very effectively since its acquisition in 2000, treating it as a business meant to bring in revenue for the country. But it is also discussed that housing in Panama City is actually becoming more expensive as Canal revenues increase and the gap between the rich and poor is growing ever more rapidly (Padgett, 2014). How, then, might the Canal Expansion project affect this inequality?

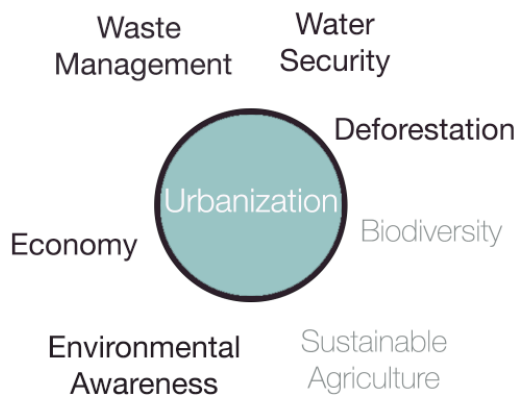
#### 4.2.6.1 Canal Expansion Project

A study in 2004 showed that infrastructure development, in general, actually *decreases* levels of economic inequality (Calderón & Servén, 2014). However, it is not clear how this benefit correlates with public access to the infrastructure. In the case of the Panama Canal, the average citizen does not make immediate use of the infrastructure, which is not the case for roads or bridges. In the near future, the expanded Canal has the potential to increase government revenues even further. Mr. Padgett states that the completed project should nearly double the income from the current Canal, which opens up many more possibilities for funding projects throughout the country (Padgett, 2014). In addition to bringing in more money, 30,000 temporary jobs have been created since the beginning of the Canal Expansion Project, which has further improved the economic situation in Panama City (ACP, 2015b). In 1989, unemployment was at an all-time high at 16.3%, which was reduced to about 14% by 2001, but decreased dramatically over the past 15 years to 2.5%, which likely was impacted by the jobs created by the Expansion Project (Panama Unemployment Rate, n.d.). These jobs will eventually no longer be required, however, and unemployment may again rise. As of 2014, about 40% of the country is still living in poverty, despite the high employment rate, but with the dramatic increase in revenue from the Canal there is the potential for the government to invest this revenue back into the country's development (Padgett, 2014). In the years following the completion of the Expansion Project, the government will have many decisions to make concerning funding and distribution of wealth throughout the

country. It cannot be determined how that wealth will be distributed, but as the revenue from the expanded Canal starts flowing in, the city will continue to grow.

#### 4.2.7 Urbanization

The population of Panama City and the surrounding area is increasing at a rapid rate (T. De Los Rios, Peace Corps, personal communication, 29 October 2015). The region is rapidly developing and new residences as well as more malls for shopping continue to arise. However, this rapid growth has caused various issues. During heavy rainfalls, areas that were not normally affected by flooding now experience



it regularly (C. Jaramillo, STRI, personal communication, 18 November 2015). Additionally as a result of this growth, one researcher claims that the oxygen levels in urban areas have decreased (S. Heckadon, STRI, personal communication, 27 November 2015). This theme of urbanization was dominant during our interviews with a number of different organizations. In particular, the expansion of the Panama Canal is driving a need for more individuals to work in urban settings, specifically in Panama City. The urban population in Panama was estimated to be 66.29% in 2014 with the Expansion efforts underway, compared to 41.25% in 1960 (Index Mundi, 2013). More people are moving to urban areas from the countryside, attracted to the opportunities afforded by city life.

One of our interviewees, Nixa Gnaegi de Ríos, explained how the urbanization of Panama City is harming agriculture in her Northern Panama province 320 km (200 miles) away. Once the Panama Canal Expansion Project began, upwards of 30,000 new jobs were created to ensure proper construction (ACP, 2006). Many individuals across Panama uprooted themselves, and sometimes also their families, from their rural communities to become a part of this project. They were offered better wages and better jobs. Many Panamanian citizens, excited to work on the center of Panama's national pride, welcomed this opportunity to work on the Canal. Ms. Gnaegi de Ríos explained how this migration has left abandoned land in the Chiriquí region, which portends harm for the future of her community (N. Gnaegi de Rios, personal communication, 14 November 2015).

Chiriquí and nearby areas rely on their youth to carry out agricultural work and continue to flourish within their native communities and cannot afford the loss of so many able workers.

One point that Ms. Gnaegi de Ríos wanted us consider was that a number of these people who are working on the Canal will likely no longer have the same job, or perhaps any job at all, once the Expansion efforts are completed. She asked the question, “then what?” The effect of these individuals moving from rural land spread across Panama to the confined city area causes urbanization to happen faster than Panama had planned for and in a smaller radius than expected (N. Gnaegi de Rios, personal communication, 14 November 2015). Additionally, many rural residents may be attracted to city life by its low-resistance environment. Darien Montañez discussed how natural habitats are highly accessible in the region, and the presence of nature is very immediate, however, the city is isolated from it. Mr. Montañez continued to speak of a time not so long ago when many urban conveniences such as commercial shopping malls had not yet developed. Now, the city is developing very rapidly, and many of Panama’s systems, such as waste management, were not designed to accommodate the rise of the population in the urban areas so quickly.

In an interview with representatives of CATHALAC, a water security and education organization, Zvia Danon, Education Manager, spoke about the effects of urban concentration. The high concentration of people is linked to high contamination in the water on the coast of Panama City. Ms. Danon went on to explain that the highland area produces better water than the Canal area does because there is a lack of urban concentration in the highlands. Water security is a strong issue that has risen from urbanization, and is a pressing matter in Panama’s current state of affairs. The representatives of CATHALAC, continued to describe how urban growth in Panama City has outstripped the region’s capability to manage the waste. All of this waste has caused Panama bay to become highly polluted with waste dumping into the rivers and streams. This can be seen by natives as well as tourists, and in popular areas such as Panama Viejo. Waste Management in Panama is an issue that will be discussed at length in the next section, however it is important to note that Panama’s rapid and loosely planned urban growth exacerbated the issues caused by its lack of a proper waste-management system.

#### 4.2.8 Waste Management

Waste management concerns are driven by economic, technical and social situations. Panama City is trying to combat a very large waste-management problem. Due to the high levels of rapid urbanization in the largest population centers in Panama and their water use habits, the amount of waste produced in the cities has risen drastically (CATHALAC, personal communication, 12 November 2015). Panama does not have a



comprehensive waste management plan for their largest urban areas. In 1956 the first plan was put in place to improve sewage management. This first sewage system has been continuously updated to adapt to the growing city. Even though the sewage system is expanding, it is still not able to keep up with the growth of the city. As a result, waste from Panama City ultimately finds its way to the Bay of Panama (G. Pulido, IDAAN, Personal Communication, 30 November 2015).

There is a strong correlation between the dense urban populations on the coast and the production of waste. Where there is less population, the amount of waste is significantly lower and the quality of water is much higher (CATHALAC, personal communication, 12 November 2015). One of the main contributors to this contamination is household wastes, or “residual water,” an issue which unfolds into a multi-faceted problem. (G. Pulido, IDAAN, Personal Communication, 30 November 2015). The main cause of concern regarding household waste comes from the rapid urbanization of Panama City. Unpredictable urban growth coupled with wasteful water use habits causes a number of issues in terms of waste management. The quality of the rivers and Panama Bay have improved in recent years, but Panama is years away from reducing these problems to the previous conditions in the 1940s.

The waste management process in particular has seen massive improvement since 2010. The state of the sewage system in Panama City until 2010 consisted of large pipes that collected wastewater from household and fed them into tributary rivers that lead directly to the ocean. As a result, 100% of the waste from Panama City was eventually discharged into Panama Bay (G. Pulido, IDAAN, Personal Communication, 30 November 2015). Despite this being an issue that involves the entire city’s population, the recognition of this problem has taken a long time.



CATHALAC personnel mentioned that this problem is contributed to partially by the “out of sight, out of mind” attitude that many residents have in regards to contaminated water. They also mention that because this problem does not affect the supply of drinking water that the public receives, some people believe that it is not their responsibility to worry about the waste they produce (CATHALAC, Personal Communication, 12 November 2015). With the growing population of Panama City, the problems with the existing infrastructure of the sewage system became more apparent, which sparked the need for a wastewater treatment plant and the start of IDAAN’s management of the waste water.

#### 4.2.8.1 Waste Water Treatment Plant

In 2010, IDAAN started the building of a sewage treatment plant in Tocumen that would treat all the wastewater in Panama City (Fig. 8), however, there are many issues with the system in place. This system is inefficient, as it requires the pumping of all of the city’s sewage 20 kilometers (12.5 miles) to the treatment plant (G. Pulido, IDAAN, Personal Communication, 30 November 2015). At the moment, the residual water treatment plant is designed to process  $2.2\text{m}^3/\text{sec}$  (581 gal/sec) of waste and expected this rate to be sufficient until 2015. However, the system reached capacity in 2013 and in 2015 the amount of waste entering the system has required the acceleration of construction plans originally set to be completed in 2020 to 2015. This expansion will double the capacity of the plant to  $4.4\text{m}^3/\text{sec}$  (1,162 gal/sec). There is also a second expansion plan set to be completed in 2025 that will bring the processing rate up to  $6.6\text{m}^3/\text{sec}$



*Figure 8 - Image of the Juan Diaz Wastewater Treatment Plant in Tocumen*



(1,743 gal/sec). One major reason that the plant reached capacity five years before previously thought is in part due to inefficient use of water. Even though the plant is operating at maximum water capacity, it is not operating at maximum efficiency, as the concentration of waste in the water is lower than the plant was designed to handle. Only 30% of the city is served at the moment and this issue will increase once more boroughs are attached to the system (A. Gutierrez. MINSA. Personal Communication, 4 December 2015).

More efficient use of water would solve both the issue of water capacity and inefficiency. The plant is also expensive to operate, costing \$13 million annually. The high operating costs of the treatment plant are paid partly by the population, but not enough at the moment to make the plant a good financial decision. The plant processes 190 million liters (50 million gallons) a year at \$0.24/m<sup>3</sup> (\$0.09/100 gallons). Each household only pays \$0.07/m<sup>3</sup> (\$0.02/100 gallons) of water used (G. Pulido, IDAAN, Personal Communication, 30 November 2015). This charge is lowest in all of Central and South America for sewage treatment for one of the most advanced and expensive systems (Fig. 9). The population, as Mr. Pulido described, naturally prefers that access to sewage treatment be free, and many argue that the government ought to provide this service for a free as a right. Before 2010, access to the sewage system was free of charge, so even a small payment request was met with much pushback (G. Pulido, IDAAN, Personal Communication, 30 November 2015). In order to ease the public into the mindset of paying for waste disposal and be responsible

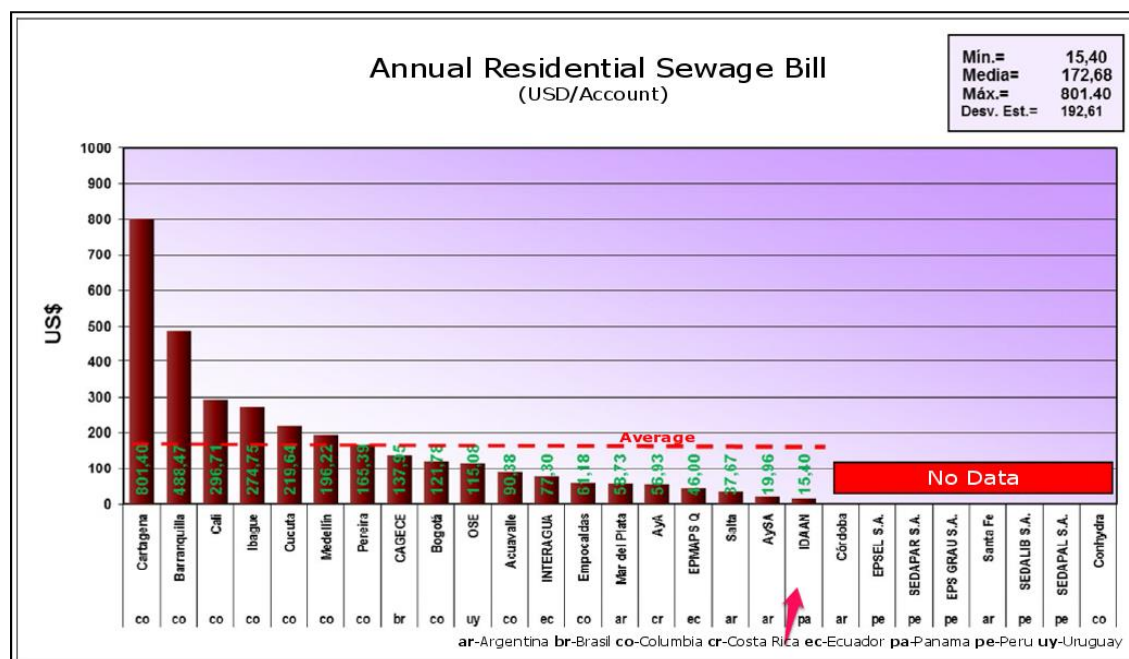


Figure 9 - Annual Residential Sewage Bill (© IDAAN 2015)

for their waste, IDAAN charges the partial cost of \$0.07/m<sup>3</sup> and expect to increase this amount slowly in the future. More financial information about the waste treatment plant is available (in Spanish) in Appendix E.

IDAAN currently only collects wastewater from homes and business connected to their pipeline. This pipeline transports the wastewater to the treatment plant. At this time, the plant does not collect storm water runoff—which allows the output of storms to wash any chemicals and contaminants from roads directly into the bay. To reduce the pollution of the bay, storm water pollution needs to be taken into account in treatment as well. In the upcoming year, IDAAN plans to expand and double the capacity of the plant in order to further reduce the effect of waste (G. Pulido, IDAAN, Personal Communication, 30 November 2015).

The sewage treatment plant processes the water in two out of three possible steps. The first step is the removal of large objects in the water. The second step is reducing the biological waste that consumes oxygen into the water. The IDAAN treatment plant is 90% efficient in removing the Biochemical Oxygen Demand (BOD) from the water. The third step, which Panama's plant does not apply, is to recycle the wastewater into drinking water. This process is extremely expensive and is only used by a few areas such as Orange County in California (Monks, 2015). It is unlikely that a process for converting residual waste into potable water would be an effective use of capital in Panama (G. Pulido, IDAAN, personal communication, 30 November 2015).

#### 4.2.8.2 The 100/0 Plan

As part of his campaign, the 37th President of Panama, Juan Carlos Varela Rodríguez, came up with the 100/0 plan, 100% of people with access to drinking water and zero trench latrines—still common in many parts of the world—preferring instead to replace them with flowing-water toilets (MINSa, 2015). This plan was very popular, and it was one of the main points of Varela's campaign. This may have contributed to his unpredicted victory with 40% of Panama's vote over his two other opponents (BBC, 2013). This plan was one of the reasons that the public so heavily supported the president. He brought to light how approximately 34% of the country was without access to potable water 24 hours a day, and about 31% of Panamanian households only had access to trench latrines for bathrooms (La Prensa, 2012). Examples of publicity for this 100/0 plan can be found in Appendix F.

The logistics of putting this plan into action, however, proved more difficult than expected. Replacing latrines with toilets increases the water consumption throughout the entire country by

adding water to a process that did not previously require it. Removing all the latrines will not leave a backup plan in case the new toilet system fails, and additionally leaves the possibility of the human waste leftover from the removed latrine to contaminate areas of a village. One perspective of the 100/0 plan is that there had not been enough consideration given regarding how it will affect each individual community. Modern developed bathrooms may not be the best choice in certain areas due to possible negative effects in some communities where water service may be unreliable (G. Pulido, IDAAN, personal communication, November 30, 2015). At this point, the elimination of the latrines is about 70% complete. For this plan to be effective, the populations of indigenous groups also need to be taken into consideration. The Kuna, Ngöbe-Buglé, and Embera communities are in their own areas that run under different systems (G. Pulido, IDAAN, Personal Communication, 30 November 2015). A concern will be if the completion of this plan will include the indigenous communities in the total percentage.

CATHALAC came up with a response to the proposed 100/0 plan that looked more in depth at the possible effects the plan would have on communities. Their argument against the President's plan is that his does not take into account possibilities for the plan to fail or address every situation on a case by case basis. Certain communities may have different needs and those needs are just as important as the next, even though they might not be the same. One of the facets of their proposed plan that attends to these different needs involves the use of compost toilets rather than conventional ones or latrines. This change would reduce the possibility of strain on the water intake and would provide a low-technology alternative for communities (G. Pulido, IDAAN, Personal Communication, 30 November 2015). The plan is quite extensive and provides many aspects of in depth consideration to environmental and social awareness. These suggestions have not been taken into account in the implementation of the government's 100/0 Plan (CATHALAC, 2013).

With these continued efforts for sanitation and water supply, the goal of the Panamanian government is to make it possible to swim in Panama Bay by 2020. Figures 10 and 11 show the visible contrast between the quality of the water in 2015 and 1940. This goal, at the moment, is put forth assuming that the waste management systems combating the pollution is operating at



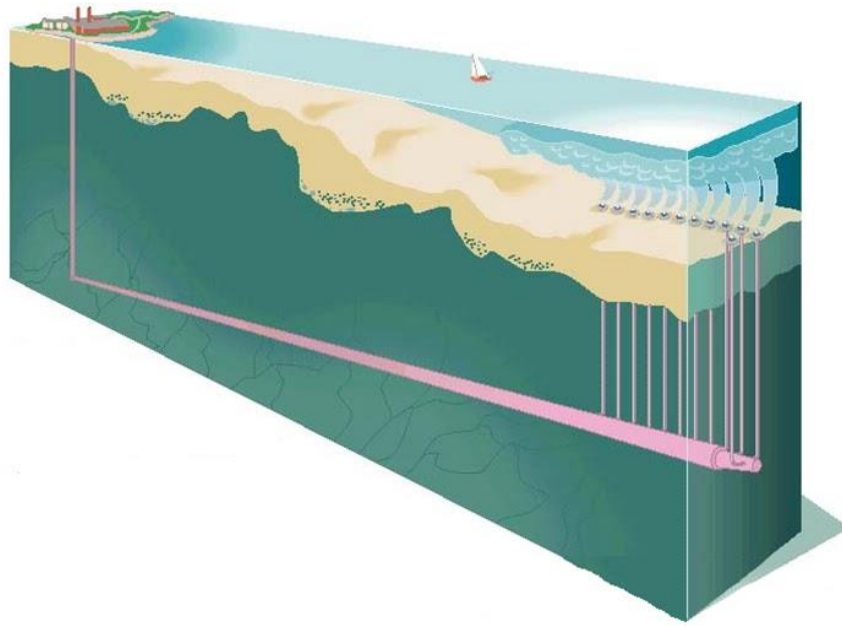
Figure 10 – Panama Bay 2015 (© NexTV Noticias, 2015)



Figure 11 - Panama Bay 1940 (© IDAAN, 2015)

100% and, at the moment, they are not. Another large contributor to the pollution in Panama Bay, however, is the runoff from storm water. The climate in Panama produces about  $2.3\text{m}^3$  of rain a year, and there is not a system in place to capture the runoff from the rain. It is important that this runoff water is taken into consideration when looking at the contamination of Panama Bay, because it contains harsh chemicals and oils from the roads, buildings, and trash. With this large amount of water that is free-flowing into the bay during rainstorms; a solution to this problem is still inconclusive (G. Pulido, IDAAN, Personal Communication, 30 November 2015). There are examples of how rainwater is collected and purified in rural areas of Panama, but these systems are not as prominent in Panama City, and not as feasible with the amount of contaminants.

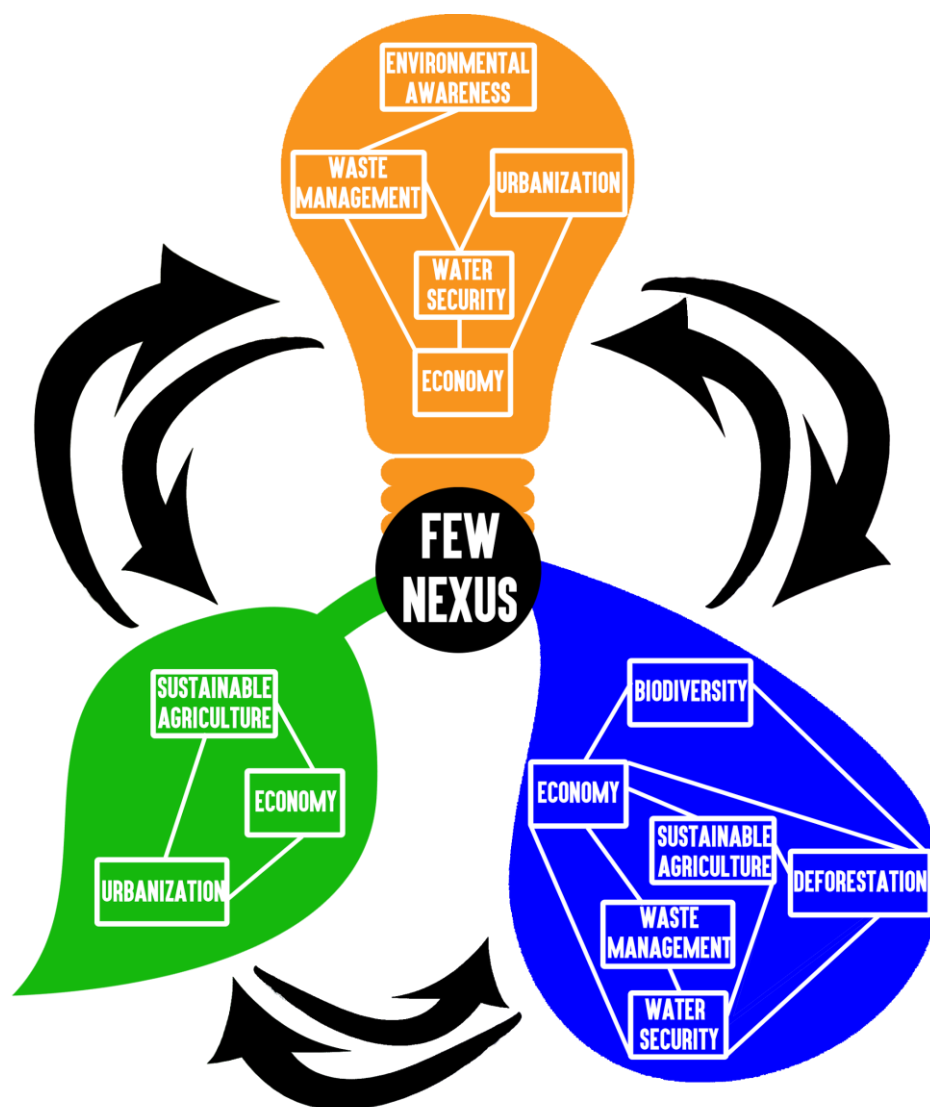
Panama would benefit highly from a more comprehensive waste management system. The system has improved, but in the future Panama's waste production will require a higher capacity system. There are talks of building a sub-marine outfall system that would carry the wastewater in pipes buried in the ocean out a calculated length and then release it into the ocean (Fig. 12) (G. Pulido, IDAAN, Personal Communication, 30 November 2015). This system is relatively inexpensive to build and maintain, and is utilized in many large coastal cities around the world including Sydney, Australia and the world's largest outfall system in Boston, Massachusetts, USA (Beder, 1992).



*Figure 12 - Schematic Diagram of Harbor Outfall System (© MixZon 2012)*

This system is not without flaws, in cases like Sydney, Australia, the outfall system has not completely removed the contamination and disease from the beaches and areas close to the coast. After its construction in the 1960s these issues have become more prevalent, to the point that proof was undeniably clear that releasing untreated waste into the ocean was affecting marine life, landscapes and the general health of the population. The solution to this issue was the more expensive choice, but the only one available to fix the problem. Sydney needed to construct a secondary water treatment plant, similar to what Panama has constructed now, so that the wastewater that is being released into the ocean has been through a level of purification (Beder, 1992).

### 4.3 FEW Framework Summary



*Figure 13 – Illustration of FEW Nexus Relationships*

Figure 13 is a visual representation of the interdependencies discussed throughout this chapter, organized by their connections with the three major components of the FEW Nexus. Each symbol is comprised of sub-sections that primarily connect with their corresponding topic of food, energy, or water. The connections illustrated above are supported through our research as the most prominent recurring topics. Our focus for this framework began with the environmental impacts of the Canal Expansion Project. Because of this initial focus, many of the beginning topics developed from water-related issues. We found that the impacts from the Expansion Project to be focused the Canal Watershed region, however, extended effects of these impacts rippled throughout the country, involving other components of the Nexus as well.

#### 4.3.1 Connection to the Canal

The ACP has been very effective in reducing the immediate effects of their work on the Expansion Project. However, by examining the expansion in a social context, we were able to identify some issues which may be indirectly related, or correlated, to the expansion of the Canal. To summarize the most salient points; the operation of the expanded Canal will require more energy and more water than ever before due to the increase in traffic, but the largest effect is revealed when we consider how the Canal and its Expansion Project may affect the rate of urban growth. The growing population in the Watershed will consume more water, putting more pressure on the water supply and the sewage system. While the Canal Expansion may bring economic benefits, it is unclear how it will affect the distribution of income in Panama. This money has the potential to go towards many improvements, such as advancements to waste management in Panama City, reforestation efforts, or restoring Colón, but ultimately this decision lies with the National Assembly. Overall, the effects of the Canal and Expansion project, while not always directly related, can be felt throughout the entire country.

## 5 - Conclusion and Recommendations

### 5.1 Conclusion

As we conducted our research, we discovered that environmental and social impacts in Panama cannot be confined to the Canal Watershed region as we had originally anticipated. The Canal is only part of the larger interconnected Nexus that includes all of Panama. Even though the FEW Nexus could be used to analyze the Canal Expansion, it would not have given a complete picture of the possible FEW Nexus of Panama to which our research had led. The Canal Watershed region remains the center of Panama and is in the public eye. Any work completed in the Watershed regarding the Nexus will have a resonating effect across the country.

It is important to continue research into the FEW Nexus in Panama as the country is not done developing and can either move rapidly towards a sustainable platform or lose the momentum that has been started. Panama has the proper organizations and infrastructure to continue advancing towards this goal. There are many upcoming decisions that have to be made, but the outcome of those will influence the course of the country.

### 5.2 Recommendations for Future Research

For further research, future teams should focus on these topics:

- I. *Development of realistic, efficient water usage techniques*  
Efficient water use can come from increased awareness, water efficient appliances, and sound infrastructure.
- II. *Methods to mitigate deforestation*  
Better agricultural practices will reduce deforestation for crops and pastures. More awareness about the importance of all the forest's functions in the ecosystem may increase uptake of these practices.
- III. *Cost/benefit analysis of utilizing hydroelectric power*  
Renewable energy techniques in today's society are becoming the norm, however, it is important to discover if the cost of developing this system will outweigh the future benefits.
- IV. *Threats posed by tourist traffic on natural biodiversity*  
Areas such as Bocas del Toro and Boquete, popular destinations of tourists, experience high traffic annually. There is potential for the natural biodiversity of the land to be affected accordingly.



V. *Waste management plan capable of adjusting to fit rise in population*

Due to the dramatic shift in recent years of Panama's urban population, it is important to have a plan in place for waste management which can be easily adjusted to accommodate this rise.

VI. *Government/NGO assistance with sustainable agriculture processes*

For safe and sustainable agricultural practices to become the norm in the region, or perhaps even practical for struggling subsistence farmers, involvement from Government/NGO's to create regulatory standards and support structures would be beneficial.

VII. *Effects of the Canal Expansion on wealth/income inequality*

While the Canal expansion undoubtedly increases gross revenues, it is not clear how these revenues eventually reach the ordinary citizen.

## Appendix A - Sample Emails

### English Sample Email:

Good afternoon,

My name is \_\_\_\_\_ and I am among five students from Worcester Polytechnic Institute in the USA working on a research project here in Panama. Our research has been funded by the National Science Foundation and involves the environment impacts of the Panama Canal Expansion Project. We would like to take an approach that looks at all angles of this project, focusing on how these environmental impacts, (focusing mainly on food, energy and water) can affect humans as well in this region.

We will be in the region through December 18, staying at La Ciudad Del Saber. We feel as though a conversation with a representative from your organization may be very valuable to us. Although we are here until mid- December, we are hoping to meet many of our contacts as soon as possible so that we can begin compiling our findings. That being said, we know it is the holiday season in Panama, and we are extremely flexible to make meeting convenient for you.

Thank you so much for your time, we are hoping to hear from you soon.  
Our email to reach all of us is panama-15-IQP@wpi.edu, and is CCed above.

Sincerely,

\_\_\_\_\_ (panama-15-iqp@wpi.edu)  
and the rest of the WPI FEW Nexus Team

### Spanish Sample Email:

Estimados Señores y Señoras,

Mi nombre es \_\_\_\_\_, y yo soy uno de un grupo de cinco estudiantes e investigadores de las ciencias sociales de Worcester Polytechnic Institute, una universidad en los Estados Unidos de América. Durante los próximos dos meses, estaremos aquí en Panamá. Mis colegas y yo estamos interesados en el medio ambiente y los problemas que han surgido en cuestión a los siguientes temas: agua, alimentos, y energía. En particular, nos interesa el Proyecto de la Expansión del Canal y como ha impactado el medio ambiente y a la población.

La agricultura toma gran parte de nuestros estudios, y estamos observando como el desarrollo del Canal influye en las actividades agrícolas. Creemos que ustedes y sus estudiantes puedan tener información sobre los impactos del Canal en la agricultura que nos ayudaría en nuestra investigación. Deseamos mejorar nuestro entendimiento de estos temas, entonces si alguien de ustedes quisiera hablar con nosotros, nos gustaría muchísimo.

Les agradecemos por cualquier información que nos puedan brindar.

Aviso: Español no es nuestra lengua materna. Posiblemente hay errores de traducción en este correo electrónico. Por favor, discúlpennos si los hay.

Sinceramente,

\_\_\_\_\_ (panama-15-iqp@wpi.edu)  
y el resto del equipo de Worcester Polytechnic Institute

## Appendix B - Contact Table

Below is a table with every individual or group we interviewed with throughout this research. The date expresses the day which an interview was held with said individual. The emails for each have been removed for privacy purposes, but will be stored for the next five years. We have also included one or two keywords indicating key points from each interaction.

<b>Date</b>	<b>Person</b>	<b>Company</b>	<b>Keyword 1</b>	<b>Keyword 2</b>
<b>10/29/2015</b>	Tess de los Rios	Peace Corps	Contacts	
<b>10/30/2015</b>	Fernando Lopez	EcoFarms	Sustainable Ag.	Land Mgmt.
<b>11/4/2015</b>	Darien Montañez	Biomuseo	Biodiversity	
<b>11/6/2015</b>	Rolando Armuelles	Ciudad del Saber	Contacts	
<b>11/11/2015</b>	Seth Hopkins	Alouatta sanctuary	Environment Sust.	
<b>11/12/2015</b>	Zvia Danon	CATHALAC	Water Security	Watershed
<b>11/13/2015</b>	Lorraine Metz	Peace Corps	Site Visits	
<b>11/14/2015</b>	Nixa Gnaegi de Ríos	Oteima	Society	Urban Gardens
<b>11/16/2015</b>	Alberto Aleman Zubieta	ABCO	Canal History	Expansion Politics
<b>11/17/2015</b>	Ira Rubinoff	STRI	Invasive Species	Biodiversity
<b>11/18/2015</b>	Carlos Jaramillo	STRI	Forest Impact	
<b>11/18/2015</b>	Arturo Dominici	RAMSAR/Creho	Eco Assess	Watershed Forest
<b>11/18/2015</b>	Anthony Coates	STRI	Biodiversity	Canal Benefits
<b>11/20/2015</b>	Luis Eduardo Castaneda Valdes	ACP Environment Team	Canal Exp. Impact	
<b>11/27/2015</b>	Stanley Heckadon	STRI	Environment Hist.	
<b>11/30/2015</b>	Gonzalo Pulido	IDAAN	Water Security	Waste Mgmt.
<b>11/30/2015</b>	Andrea Brusco	UNEP	Environmental Conflict	
<b>12/3/2015</b>	Alejandra Gutierrez	Ministry of Health/WWTP	Treatment Plant	

# Appendix C - IRB Paperwork

## WORCESTER POLYTECHNIC INSTITUTE

Worcester Polytechnic Institute IRB# 1  
HHS IRB # 00007374

**26 October 2015**  
**File:15-237**

**Re: IRB Application for Exemption #15-237 "FEW Nexus and the Panama Canal"**

Dear Prof. Sakulich,

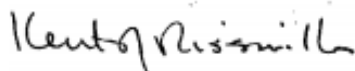
The WPI Institutional Review Committee (IRB) has reviewed the materials submitted in regards to the above mentioned study and has determined that this research is exempt from further IRB review and supervision under 45 CFR 46.101(b): (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation.

**This exemption covers any research and data collected under your protocol from 26 October 2015 until 25 October 2016**, unless terminated sooner (in writing) by yourself or the WPI IRB. Amendments or changes to the research that might alter this specific exemption must be submitted to the WPI IRB for review and may require a full IRB application in order for the research to continue.

Please contact the undersigned if you have any questions about the terms of this exemption.

Thank you for your cooperation with the WPI IRB.

Sincerely,



Kent Rissmiller  
WPI IRB Chair

## Appendix D - Explanation of Water-Saving Basins in Expanded Locks

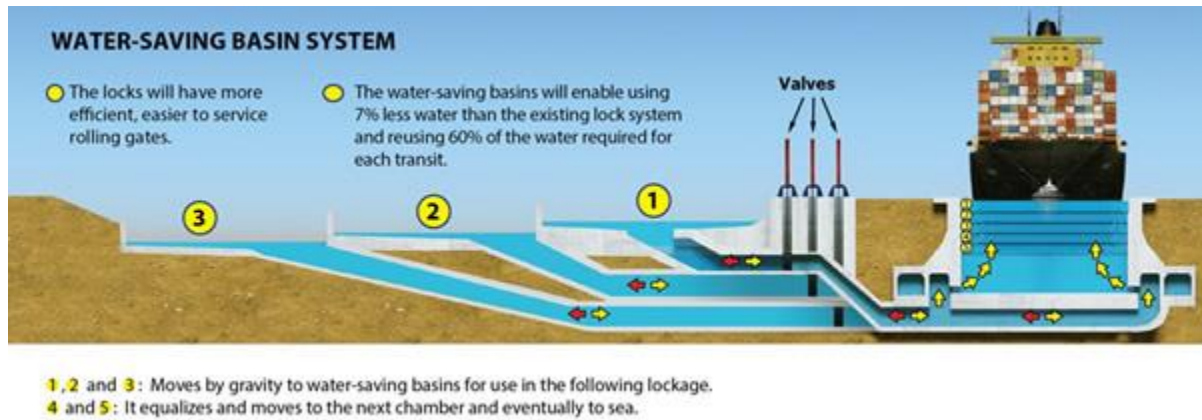


Figure A1 - Explanation of the Water-Saving Basins (© ACP)

The expanded locks use sets of three water-saving basins (Fig. 14) that operate based on gravity (thus, they require no pumping). When the operators lower the water level in the lock, they open the valves first into basin 1, then to basin 2, basin 3, and finally to sea level. Before any valve is opened, the previous valve is closed. When the operators raise the lock, the process is exactly reversed. By utilizing this water-saving system, each lock traversal discharges only the difference between the final water-level of basin 3 and sea-level, rather than an entire lock's volume from sea-level to lake-level.

## Appendix E - Waste Management Financial Information

In this appendix there are detailed breakdowns of data from the construction and implementation of the aqueduct system and collectors and receptors for the Juan Díaz Wastewater Treatment Plant. In some of the charts below, the plant is referred to as *Planta de Tratamiento de Aguas Residuales* or PTAR.

**Table 23. O&M Costs of Phase 1 - Treatment Plant and Pumping Stations**

**Tabla 23. Costos O&M Fase I – Planta Tratamiento y estaciones de bombeo** (Programa de Saneamiento de la Ciudad y Bahía de Panamá, 2015)

Concepto	Unidad (°)	Cantidad Anual (°)	P.U. US\$ sin (ITBM)	TOTAL medio anual
<b>ENERGÍA ELÉCTRICA</b>				
Estación de bombeo	Kwh	13,262,644	0.176	2,327,667.00
Planta de tratamiento	Kwh	16,745,113	0.181	3,025,041.00
Otros	Kwh			0.00
<b>Sub-total</b>				<b>5,352,708.00</b>
<b>QUÍMICOS</b>				
Estación de bombeo		Ver detalles en 5A		61,342.29
Planta de tratamiento		Ver detalles en 5B		1,849,655.72
Otros				
<b>Sub-total</b>				<b>1,910,998.01</b>
<b>CONSULTORÍA</b>				
Personal	mes	-	12	0.00
Viajes y Viáticos	mes	-	12	0.00
Costos Directos	mes	-	12	0.00
Costos Generales	mes	-	12	0.00
<b>Sub-total</b>				<b>0.00</b>
<b>PERSONAL</b>				
Estación de bombeo				
Encargado de la Estación de Bombeo	MES	Incluido en el personal de la PTAR		
Técnicos	MES	Incluido en el personal de la PTAR		
Obreros calificados	MES	Incluido en el personal de la PTAR		
Obreros no calificados	MES	Incluido en el personal de la PTAR		
Administrativos	MES	Incluido en el personal de la PTAR		
Planta de tratamiento				
Nivel gerencial	MES	23,253	12	279,032.00
Profesional senior	MES	69,081	12	828,970.00
Profesional junior	MES	6,140	12	73,680.00
Técnicos	MES	76,750	12	920,995.00
Obreros calificados	MES	9,087	12	109,046.00
Obreros no calificados	MES	24,560	12	294,718.00
Administrativos	MES	4,912	12	58,944.00
<b>Sub-total</b>				<b>2,565,385.00</b>
<b>MANEJO DE SÓLIDOS</b>				
Estación de bombeo	MES	365	23	8,395.00
Planta de tratamiento	MES	24,400	23	561,200.00
<b>Sub-total</b>				<b>569,595.00</b>
<b>VARIOS</b>				
Repuestos, suministros, materiales, seguros	MES			3,036,237.47
<b>Costo Total de Operación y Mantenimiento (Sin Electricidad)</b>				<b>8,082,215.47</b>

**Table 27. Cost of Wastewater Treatment of the first module of the PTAR (WWTP) PN-LI109**

**Tabla 27. Costo de Tratamiento de Agua Residual del Primer Módulo de la PTAR PN-L1109**  
(Programa de Saneamiento de la Ciudad y Bahía de Panamá, 2015)

Concepto	Costo Anual	Incidencia	Referencia
Costos de Energía	2.254.080,00	19,04%	(Nov 13 a Oct 14)
Costo de Insumos Químicos	1.770.000,00	14,95%	2014
Costo de Servicios Personales	2.360.000,00	19,94%	2014
Costos de disposición de lodos	643.600,00	5,44%	16,000 Tons
Costos de servicios de laboratorio externos	21.000,00	0,18%	2014
Pólizas y seguros	19.000,00	0,16%	2014
Mantenimiento de equipos de oficina	22.500,00	0,19%	2014
Mantenimientos locativos	138.500,00	1,17%	2014
Costos de mantenimiento de la maquinaria y equipos de operación	819.000,00	6,92%	2014
Servicios públicos	3.600,00	0,03%	2014
Vigilancia	175.000,00	1,48%	2014
Otros costos administrativos de la PTAR	655.160,00	5,53%	2014
Financiamiento y Utilidad	1.487.100,00	12,56%	
Ajuste de Precio	1.468.455,00	12,41%	(Dic 13 a Nov 14)
<b>Total Costo Anual de O y M Primer Módulo PTAR</b>	<b>11.836.995,00</b>	<b>100,00%</b>	
	<b>m3</b>	<b>\$/m3</b>	
Agua tratada en 1 año	49.766.400,00	0,24	(Nov 13 a Oct 14)



## Appendix F - The Official Advertisements for the 100/0 Plan or “Cien/Cero”



Figure A2 - 100/0 Plan Campaign Advertisement

These advertisements are the official propaganda for the Cien/Cero or 100/0 Plan enacted by Juan Carlos Varela. Pictured are two images: Figure 16 (below) describing the plan in detail, and Figure 15 (left) with an overview of the plan. (Amigos de Varela, 2013).

**100% AGUA POTABLE PARA TODOS LOS PANAMEÑOS**

Más de **1,000,000** de panameños se beneficiarán con acceso permanente al agua potable

Uno de los pilares del Plan Nacional de **JUAN CARLOS VARELA** es el programa **100/CERO**, que consiste en dotar al país del 100% de cobertura de agua potable, las 24 horas, todos los días de la semana y la eliminación de las letrinas o servicios de hueco a nivel nacional, reemplazándolas por baños higiénicos.

- Sólo el **66%** de los hogares panameños tienen agua potable las 24 horas del día.
- A más de **444 mil** personas les llega el agua menos de 7 horas al día.

**¿Cual es el impacto de la falta de agua potable en nuestra salud?**

- La falta de agua potable es una de las causas más importantes de mortalidad para niños menores de 5 años y es el mayor componente de enfermedades asociadas al ambiente.
- 88% de las enfermedades diarreicas son producto de problemas de acceso al agua potable y de servicios de saneamiento e higiene deficientes.
- Existen al menos 15 enfermedades asociadas a la falta de agua potable, servicios de saneamiento e higiene incluyendo: Dengue, cólera, malaria, amebiasis y conjuntivitis, entre otras.
- El acceso de la población al agua potable, saneamiento e higiene pueden reducir en un 80% estas enfermedades y muertes relacionadas.

**CERO LETRINAS A NIVEL NACIONAL**

Construiremos más de **300,000** baños a nivel nacional

**Datos Relevantes**

- 37% de los hogares panameños aún tienen letrinas o servicios de hueco.
- 25% de los habitantes que aún tienen letrinas viven en la provincia de Panamá.

**Viviendas a mejorar: 330,647**

**Costo Unitario aprox. B/. 2,000**

**Presupuesto estimado B/. 661,294,000**

**Modelo 1: Área Rural "Hacia Pozo Ciego"**

**Modelo 2: Área Rural "Hacia Pozo Ciego Interior"**

**Modelo 3: Área Urbana "Hacia domiciliaria"**

**CON TU APOYO, EN EL 2014 HAREMOS REALIDAD ESTA PROPUESTA!**

Figure A3 - 100/0 Plan Details



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