An Attempt to Optimize IDAAN's Water Treatment Plant Process

Presented by

Flint Eller
William Kennedy
Zachary Manfredi
Benjamin Wheet

Advised by

Prof. Grant Burrier
Prof. James Chiarelli

13 October 2022

IDAAN

WPI

An Attempt to Optimize IDAAN's Water Treatment Plant Process

An Interactive Qualifying Project
Submitted to the Faculty of
WORCESTER POLYTECHNIC INSTITUTE
completed at the
Panama City Project Center
in partial fulfillment of the requirements for the
Degree of Bachelor of Science

Presented by:

Flint Eller
(Mechanical Engineering)
William Kennedy
(Mechanical Engineering)
Zachary Manfredi
(Chemical Engineering)
Benjamin Wheet
(Electrical & Computer Engineering)

Date:

13 October 2022

Submitted to:

Professor James Chiarelli
Professor Grant Burrier
Professor Aaron Sakulich

This report represents the work of one or more WPI undergraduate students submitted to the faculty as evidence of completion of a degree requirement.
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Abstract

Water treatment plants in Panama lack centralized data analytics and chemical processes. Our team worked with Panama's national water authority, IDAAN, to help optimize these processes by collecting data to analyze trends between chemical usage and offer recommendations to improve the treatment of crude water into potable water. Despite repeated attempts to communicate with our sponsor and agency officials, including multiple visits to agency offices, we never received the necessary data to complete our analysis or the project. Our reflection on the experience taught us how to adapt to changes in the real world.

ACKNOWLEDGMENTS

We would first like to thank all IDAAN personnel that supported us throughout our IQP journey. Specifically, we would like to thank the superintendent of the Chilibre Plant, Javier Sanchez, and the Chilibre lab director, Ana, who guided us throughout the water treatment process at the plant. We would also like to thank the Subdirector of IDAAN, Luz Amalia Gonzales; Luiz Navarro; Jasmara Jaramillo; and Joaquin Degracia for their support of our IQP project.

We would also like to extend our gratitude to our IQP advisors: Professor Grant Burrier and Professor Jim Chiarelli. Professor Grant Burrier provided crucial help in meetings with IDAAN as a critical intermediary. Both professors aided in overseeing our project and supplied valuable criticism and guidance in the crafting of our report.

Figure 1. Our IQP group at an Emberá Village (photo from Prof. Burrier)

EXECUTIVE SUMMARY

Introduction

IDAAN, or the National Institute of Aqueducts and Sewers, is responsible for the production and distribution of potable water in Panama. IDAAN's mission statement is "to improve the level of health of the community, well-being and progress of the country through the provision of drinking water services, and the collection and disposal of wastewater, ensuring the conservation of the environment, with a view to reaching optimum levels of productivity and efficiency" (*Misión y Visión de IDAAN*, 2021). Despite IDAAN's leading role in providing access to drinking water, complicating issues within the institution remain. Each water treatment plant uses a different formula to achieve potable water due to the varied crude water going into each plant. This results in different amounts of chemicals being used at the different plants. This varied crude water going into each plant de-standardizes IDAAN's water treatment process and isolates the different plants run and operated by IDAAN. Due to these isolations, water quality data is not shared among all plants, effectively shutting plants off from efficiently helping or learning from each other. According to one employee at a water treatment plant run by IDAAN that we visited, it is difficult for engineers sent by other plants to provide help in a reasonable and efficient amount of time.

Our project consisted of comparing water quality data from three different potable water plants in terms of process, cost, and results to help optimize IDAAN's water treatment process. The analysis of chemical and water quality values given to us by IDAAN engineers were to have been performed using the software programs Stata and Microsoft Power BI. We hoped to help IDAAN optimize their water treatment regimen to create a more efficient process in the production and distribution of potable water.

Methods

The first objective involved going to a water treatment facility and interviewing IDAAN personnel about plant process and infrastructure. Our team met with the superintendent of the Chilibre water treatment plant to gather information and tour the plant. During the tour, we were shown each step of the water treatment process. We also spoke with the manager of the lab at the water plant to observe how water is tested for diseases and how the lab finds the optimal chemical mixtures for water treatment. In-person interviews were a reliable and detailed method of obtaining complex information on the water treatment process and would have been valuable in completing the next stage of our project.

The next objective involved the analysis of water treatment data according to several metrics defined by IDAAN personnel. The metrics by which we were to analyze the data can be split into 3 categories: input water characteristics, the chemical process in the water treatment plants, and the output characteristics of the water, after going through the water treatment process. The input water characteristics include the pH, turbidity, and chlorine of the water going into the plant for treatment. The chemicals added to the water include aluminum sulfate, cationic polymers, calcium hypochlorite, liquid chlorine, activated carbon, and hydrated lime. The output characteristics we would analyze included the pH, turbidity, and chlorine levels of the treated water. IDAAN also included the cost of the chemicals, in the hopes of finding the most cost-efficient solution available.

Data analysis would have been completed using software applications like Stata and Microsoft Power BI. The customizability and greater functionality of Stata allows for the much more complex customization of data filtering and comparison methods. However, we were unable to receive the bulk of our data in time to complete complex tests that would have been proven useful to IDAAN. Instead, we only received the independent variables needed to complete the analysis. The limited amount of time also left us with little time to experiment with the coding language of Stata. In this case, we turned to Microsoft Power BI, a user-friendly data analysis program provided by Microsoft. Microsoft Power BI is software that can function as a low code, high abstract software and allows for effective and quick data analysis.

The third and fourth objectives involved the creation of a report and presentation that could be read by IDAAN personnel. We planned to use Stata and Power BI outputs to create T-tests, correlation matrices, cost-benefit analysis, and data visualizations to develop an understanding of key action items and cohesively produce concise data reports outlining improvements and recommendations for plant synergy. The goal was to visualize our findings about important trends found in the water quality data. The report would be given to IDAAN along with a presentation of our findings to the different participating water treatment plant supervisors.

Final Considerations

Due to numerous setbacks, we were unable to complete our project in the time allocated. Although our project may be incomplete, we reflected on our experience, and we still generated several important takeaways from our time in Panama. There are significant factors that played a role in the downfall of our project. First and foremost, we were unable to receive all necessary data in time from IDAAN to achieve our project goals. The items listed below, however, are not intended to be a full list of all factors at play affecting our IQP project. Instead, they are merely a representation of the most prominent factors our group felt was noteworthy.

Factors Impeding Project Success

1. Absence of a Sponsor
2. Lack of Project Direction
3. Slow Movement of Information from IDAAN

Recommended Habits for Other Groups

1. Establishment of Constant, Meaningful Contact with Sponsor
2. Clear and effective communication with advisors
3. Documentation of Meetings

As said above, there were many factors that impeded the success of our project. But one of the biggest upsets to this project was the departure of our intermediary sponsor, Rick Montanari at Footprint Possibilities. Rick had to leave the country and halt advising on our project only a few days before we arrived in Panama. His expertise would have been invaluable in effective communication and planning with the IDAAN bureaucracy. Without Rick's help we were forced to start a dialog with IDAAN from scratch and all on our own. The delayed communication only strengthened the lack of project direction our group faced during our IQP in Panama.

Throughout the entire IQP process, our project changed focus 3 times, totaling 4 different project deliverables. Our group took time readjusting to our new goals only to see new project proposals surface, resulting in inconsistencies that severely hindered the ability of our group when attempting to complete the IQP project. Through each change in project focus, our group became increasingly confused about IDAAN's expectations. Additionally, we lost valuable time. At the time of our last project change, we were nearly halfway through our IQP. Even if we received the necessary data from IDAAN, we would have had very little time to analyze the data properly.

Like any national bureaucracy or public agency, IDAAN struggles to quickly process information, as our project illustrated. For instance, when it came to receiving the information we needed, our group was required to attend multiple meetings drafting contractual information which would later be signed by our advisor. It was assumed that after this meeting, all the data we needed could be handed over to us. However, we received only a fraction of the data we were promised. For the remainder of the data, our advisor was required to go in a second time to sign a second contract. We later learned that for the last couple weeks of our trip, this second contract was waiting for approval from the head of IDAAN water. With no central repository or system to deal with all the data at once, we were forced to deal with each department separately. We hope that future groups learn from our experience with IDAAN by approaching every interaction with urgency and persistence.

Just as past IQPs have helped us, we want to aid future IQPs in providing critical insights into IDAAN and Panama. We have made recommendations based on what our group felt were the most important aspects for future IQP groups to take away from our experience. Firstly, we recommend establishing early and clear communication with sponsors. This early communication would prove critical in working out the details and issues, removing many possibilities of miscommunication in an IQP project. Secondly, we recommend that IQP groups be transparent with your advisor. Clear and constant communication with our advisor allowed them to effectively assist our group with readjusting each time a new project goal came up. Finally, we highly recommend that every IQP group documents every step of their work to track any developments, feedback, and opportunities to look back on in the future. Our group's extensive documentation allowed us to reflect on our IQP experience and the process that lead us to each point.

Overall Takeaway

Our IQP had its fair share of complications. The absence of our original sponsor, the ill-defined nature of our project, and the sluggish movement of a bureaucratic government agency culminated in an IQP project which never came to fruition. Obviously, we had not expected our IQP to turn out the way it did, however we persevered and tried our best to develop a cohesive, successful project under the circumstances. Our reflections reveal the positives of our experience. They demonstrate our desire to extract wisdom from this experience and share it with others. Through the uncertainty that plagued our project, we remained determined and focused. All in all, we leave this IQP enlightened. IDAAN is a national organization tasked with providing water to Panama; we are a group of college students tasked with graduating. The priorities of our group are miniscule compared to the challenges the organization of IDAAN currently faces. There exists an entire world beyond ours with complexities that we can only hope to comprehend. We are less disappointed than we are grateful to have experienced such a unique IQP. And so, in the words of our advisor, Professor Grant Burrier, we will go forth and be merry, and remain hopeful for the future.

Authorship

FE = Flint Eller	WK = William Kennedy	ZM = Zachary Manfredi	BW = Benjamin Wheet

Section	Author(s) (In order of contribution)	Editor(s)
Title Page	ZM	ZM
Abstract	ZM, WK	FE, WK
Acknowledgments	BW	ZM
Executive Summary	BW	FE, WK
Table of Contents	ZM	ZM
Figures	ZM	ZM
Tables	ZM	ZM
Introduction	WK, ZM, FE	FE, ZM
Background	WK, ZM	ZM
2.1	WK, ZM	ZM
2.2.1	ZM	ZM, FE
2.1.2	FE, WK	ZM
2.2	WK	ZM
2.2.1	ZM, WK	ZM
2.2.2	ZM, FE, BW	ZM, WK

2.2.3	BW, ZM, WK	ZM
2.3.4	BW, ZM, WK	ZM, FE
2.3	All	ZM, WK
2.4	FE, BW, WK	ZM
Methodology	ZM, WK, FE	ZM
3.1	FE, WK	ZM, FE
3.2	WK, ZM	ZM
3.3	WK, ZM	ZM, FE
3.4	FE	WK
Final Considerations	ZM, BW, WK	WK, ZM
4.1	ZM	ZM
4.1.1	ZM, FE	ZM
4.1.2	ZM, BW	ZM, FE
4.1.3	WK	ZM
4.2	FE, WK	ZM, FE
4.2.1	BW	ZM, WK
4.2.2	BW, WK	ZM, FE
4.2.3	ZM, BW	ZM
4.3	ZM	ZM

Table of Contents

FIGURES

TABLE

Chapter 1 | Introduction

Twelve years ago, the United Nations General Assembly formally recognized access to clean drinking water and sanitation as a human right, one which is "essential for the full enjoyment of life and all human rights" (Resolution adopted by the General Assembly on 28 July 2010). With this formal recognition, the United Nations (UN) opened a door of opportunity to securing global support for universal water access. For this right to be sufficiently met, the water must be: free from foreign contaminants; of acceptable appearance, smell, and taste; within one kilometer of one's home and a collection time under 30 minutes; and affordable (*Water for Life*, 2014).

Water access has become a critical element of Panama's political discussion. While Article 110 of Panama's constitution declares that it is the state's responsibility to develop availability for drinking water, the government's attempts to expand and modernize the water infrastructure have been both successful and unsuccessful (*Constitución política de la República de Panamá*, 2016). While the national leadership strives to better aid in the development of the nation through supporting the needs of its people, currently Panama lacks the critical infrastructure required to maximize its production of potable water. And due to the rapidly growing population, a larger potable water supply is needed to support the health of the populous.

Preserving the potability of water is the most important element of providing water to an urban population. To produce potable water, many treatment processes are used to both filter and chemically sterilize water. In the sterilization aspect of water production, a variety of chemicals are used. These chemicals are used in regulated amounts to balance both chemical exposure and biological purity. Regulation of these chemicals is important in maintaining a reasonable cost and proper purification results (Ana, personal communication, September 16, 2022).

In Panama, the national water provider, IDAAN, serves 70% of the population with drinking water (*Plan nacional de seguridad hídrica*, 2016). Each water processing facility uses varied treatment formulae to achieve potable water due to different incoming crude water quality, resulting in each plant's process requiring different amounts of each chemical. The current season (wet/dry) also vastly changes the characteristics of incoming crude water as well (J. J. J. Guzmán, personal communication, September 15, 2022). These input variables make directly comparing plant's chemical use quite difficult. This lack of standardization causes different plants to run with different levels of efficiency, even though they are run by the same organization (C. Gomez, personal communication, September 22, 2022).

Recently, IDAAN started sharing some information between plants. They compiled a centralized list of the equipment and volume capacity of each plant, which they were able to share with us. This list made it very easy to compare the capability of each plant and helped them see differences in effectiveness and ability to provide service. However, since they lack a centralized system of data for water treatment plants, it is difficult for IDAAN to directly compare plants in their performance in improving water quality. Additionally, the engineers at one plant told us that if a plant is studying a problem, they will sometimes send engineers over from a different plant to look at the problem. Without knowing the context of their plant's water supply or their water quality data, however, they find it difficult to provide meaningful help in a reasonable amount of time (Ana, personal communication, September 16, 2022). IDAAN also struggles to identify which plants are losing the most of their valuable and scarce funding.

Our goal in aiding IDAAN is to help compare water quality data from three different potable water plants in terms of process, chemicals used, and results. We hope to help optimize IDAAN's water treatment plants through the analysis of these critical values. Software analysis of critical chemical and water quality values should allow for optimization of efficiency in how IDAAN utilizes its chemicals. Through adding optimized efficiency to chemical use, we expect to save IDAAN chemical supplies for its water processing treatment. With a higher production volume at a lower cost, IDAAN will be able to provide more potable water and devote more resources to increasing access.

Chapter 2 | Background

2.1 | The Global Water Problem

Water access is an issue of immense global importance. The development of water-based infrastructure throughout the developing and the developed world has been a premiere goal of many international organizations including the United Nations (UN). Over the beginning of the 21st century, these organizations have made great strides in improving and adapting water infrastructure to better support developing communities. Water processing is a key element of any nation's potable water processing capability. Its expansion is a critical point of change for any nation wishing to increase its ability to produce drinkable water for its population. As a result, drinking water access for the global population has increased by 107 million people from 2015 to 2020. However, as of 2020, 26% of the world's population still lacked safely managed drinking water services, translating to two billion people without access to such services (*Update 2021: SDG 6*, 2021). It is the aspiration of many groups and organizations to help develop this infrastructure on a global scale and provide safe potable water across the world.

2.1.1 | United Nations Sustainable Development Goals

Hayman & Mihelcic (2016) write about the results of improved water sources, detailing benefits such as "positive increases in time for education (as opposed to using that time fetching water from distance sources) [,] income generation, maternal health, child care, and food security" (Hayman & Mihelcic, 2016). It is therefore no question why potable water access is one of the UN's top concerns as a pivotal point of global development. For instance, Target 6.1 of the UN's 2030 Agenda for Sustainable Development specifically addresses access to drinking water, stating as their goal: “to achieve universal and equitable access to safe and affordable drinking water for all” by the year 2030 (*Update 2021: SDG 6*, 2021; *2030 Agenda for Sustainable Development*, 2015). While some progress has been made to reach this goal, an UN-Water report update on recent data bluntly stated that “The world is not on track to achieve SDG 6” (*Update 2021: SDG 6*, 2021). From 2015 to 2020, the estimated proportion of the global population meeting Target 6.1 only increased by 4%, (from 70% to 74%) leaving 26% or over two billion people without easily accessible safe drinking water (*Update 2021: SDG 6*, 2021). With only eight more years until 2030, the world still has a long way to go to achieve these goals.

The UN does, however, make concerted efforts to ensure equity in support of achieving SDG 6 through special provisions for developing countries. Their official development assistance (ODA) provides money in the form of grants and loans to a country’s spending plan. The ODA disbursements to countries specifically intended for drinking water and sanitation purposes totaled $8.8 billion in 2019, with different regions receiving varying amounts (*Update 2021: SDG 6*, 2021). By providing the developing world with enticing water development loans, the UN and other global NGOs incentivize developments of clean, stable drinking water, and economic enhancement.

2.1.2 | URUGUAY AS A MODEL COUNTRY FOR WATER ACCESS

As an exemplary model for public water production, Uruguay has developed a robust water infrastructure for use by its citizens. They have been so successful, 98% of the population has access to a continuous water supply, including most rural citizens. Additionally, they have not had any epidemics spread through the water supply (*Compact and Transportable Water*

Treatment Plant, 2022). In 1991 there was a cholera outbreak that affected almost every country in South America. Uruguay was the only non-island nation not to be affected, this was thanks to their excellent water production and distribution system (Guthmann, 1995). There are a couple of reasons why they have had so much success The National Administration of State Sanitary Works (OSE) is the main provider of potable water and sanitation services in Uruguay. Originally, they were a private company under a different name but was later acquired and nationalized by the Uruguayan Government (*Historia de OSE*, 2022). This transition meant there was rapid growth at the beginning and then leadership that solely held the Uruguay's interests at heart when it became a countrywide enterprise. Another reason for OSE's success in Uruguay is their model of potable water treatment plant called UPA (pictured below in **Figure 2**) (Unknown, 2021).

Figure 2. A water treatment unit (UPA) in Arbolito, Uruguay.

Note. From *Prosperan gestiones de la intendencia y Arachania tendrá agua potable* [Photograph], by Unknown, 2021, (https://www.gub.uy/intendencia-cerro-largo/comunicacion/noticias/prosperan-gestiones-intendencia-arachania-tendra-agua-potable)

This model was developed by engineers at OSE in conjunction with the Uruguayan Army. This model has helped increase water output in the interior of the country by 52% (*Compact and Transportable Water Treatment Plant*, 2022). OSE created a plant perfect for use in developing countries for the following reasons:

- The UPA is extremely compact, about the size of a shipping container.
- It can be broken down into easily transportable parts so it can quickly be moved to where it is needed.
- The model can be set up much faster and in far more remote locations than a traditional plant.
- It is also very effective at treating extremely dirty water (*OSE garantizó la continuidad*, 2012)
- Depending on the UPA type, the output ranges from 20 cubic meters per hour to 250 cubic meters per hour, which is enough to supply a small town.

Uruguay has between one and fourteen UPA models in every province to assist plants that are struggling to keep up with demand (*Unidad Potabilizadora*, 2022). Each machine costs between $130,000 and $155,000, and Uruguay sees this as a great business opportunity. They sold 40 models to Ecuador in 2012 and are happy to sell more all across South America (*OSE garantizó la continuidad*, 2012). The UPA has been a critical part of Uruguay's ability to provide excellent water service to its citizens.

While Panama could learn from these elements to better provide water to its people, there are other factors that make it much easier for Uruguay to do so than for Panama. Uruguay's high GDP, low level of wealth inequality, and low levels of corruption in government give the factors mentioned above much more of an impact on providing clean water (*The World Bank in Uruguay*, 2022).

The lack of these factors is a big part of why there is less clean water continuously distributed in Panama. With fewer resources and more challenges, IDAAN will have to work harder to achieve the same result.

The global focus on water quality, as well as its importance in the development of economic success makes potable water access a necessity for any nation wishing to develop economically. Uruguay, a leader in this field, can act as a prime example for any nation wishing to expand their water processing and distribution abilities. While both Panama and Uruguay have nationalized water distribution services, Panama does not provide water as effectively as Uruguay. Technology may be the key difference between service in Uruguay and service in Panama. The UPA model helps Uruguay tremendously while there is room for advancement in Panama. Technological research and physical infrastructure are specific areas in which Panama can learn from Uruguay.

2.2 | Water in Panama

Panama is an isthmus located in one of the densest freshwater locations on earth. An extraordinary volume of rainfall combined with a vast network of lakes, streams, and rivers provides Panama with an extensive storage network for fresh water. This network of freshwater tributaries is used to fuel an extensive network of public water purification facilities which provide an essential resource to the citizens of Panama. Despite the overwhelming supply of fresh water in the country, some locations still do not have access to running water in their homes. In many locations, locals rely on a system of water tanks, and water trucks for their daily requirement of drinking water. To produce the drinking water, a complex purification process is required. The process utilizes many specific chemicals such as chlorine, and processes such as flocculation to remove impurities from the water. All these systems and processes are essential in supplying fresh, clean drinking water to numerous citizens, and their expansion and maintenance will be a key element of future Panamanian infrastructure.

2.2.1 | PANAMA'S WATER DISTRIBUTION

Panama receives an immense amount of water as rainfall each year. The rainfall, combined with the vast network of mountainous freshwater lakes and streams provides Panama with an extensive system of natural freshwater storage. Over the past decade, Panama has experienced a significant increase in population and has become the wealthiest nation in Central America. (*Panama - Metro Water*, 2010). Panama's population growth in 2021 was 1.54%, the third highest in Latin America behind Belize (1.82%) and Honduras (1.59%) (*Population Growth in Panama*, 2021). Even with the vast reservoirs of fresh water within its borders, Panama cannot process enough volume to produce potable water for its ever-growing population. Availability of fresh drinking water is becoming an issue of prime interest for Panamanian citizens and its politicians. Over the coming decades, Panama hopes to increase its water processing capacity to better suit the needs of its expanding population.

Panama provides access to some form of drinking water storage to over 92% of its citizens. These water sources include water basins, water treatment plants, and rural aqueducts (Anguizola, 2022; Larsen, 2019). Furthermore, the Water Poverty Index (WPI), which reflects the "measures of resources, access, capacity, use, and environment, [and linking] household welfare with water availability," ranks Panama 25th out of 147 other countries surveyed (Larsen, 2019).

Within the 21 Latin American countries that have recorded WPIs, Panama ranks 7th, Guyana ranking highest (5th overall) followed by Suriname (6th overall) and Chile (16th overall). By these metrics, Panama appears to be a leading country in general water access for its citizens (*Plan nacional de seguridad hídrica*, 2016).

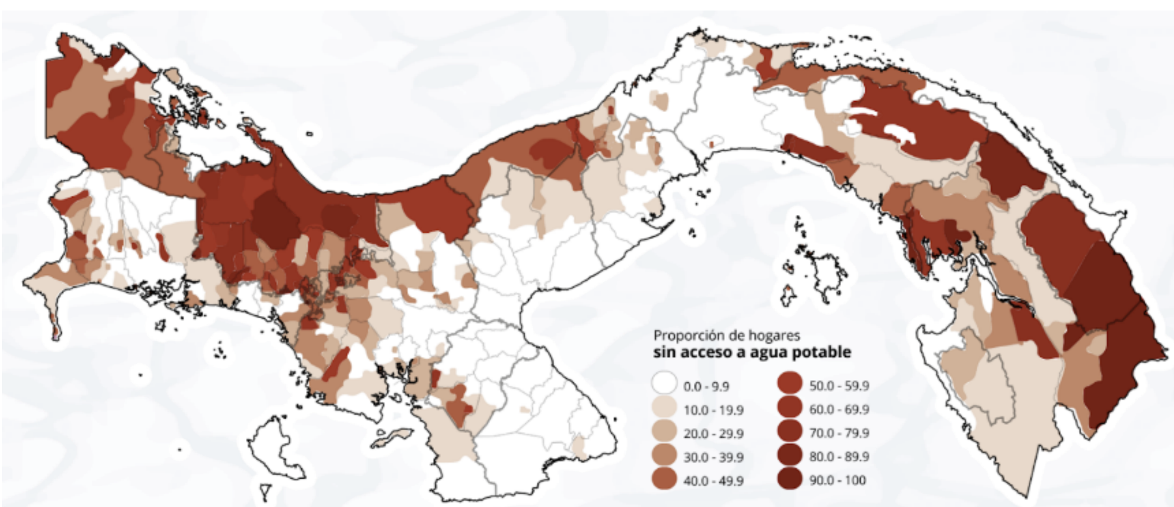
All Latin American countries have abundant sources of water, accounting for 32% of the world's internal renewable water resources (Bertoméu-Sánchez & Serebrisky, 2018). Panama alone receives 230 billion m^3 of freshwater by rainfall, of which 119.5 billion m^3 is distributed through a network of mountain streams (*Plan nacional de seguridad hídrica*, 2016). Approximately 25% of the freshwater is collected by various water basins, wells, and man-made reservoirs while the rest flows back into the Pacific and Atlantic Oceans. The biggest water reservoirs are Lake Gatún (volume of 769 million m^3) and Lake Alajuela (volume of 643 million m^3), which both serve as a major freshwater hub for over half of Panama's drinking water, as well as water for the Panama Canal locks, industry, and hydroelectric energy. (Larsen, 2019; *Plan nacional de seguridad hídrica*, 2016).

Figure 3. Lake Gatun in Chilibre, Panamá (own photo)

2.2.2 | ISSUES WITH ACCESS AND QUALITY

Despite Panama's mass abundance of water, there still exist issues with water provisions, namely access for rural communities and the quality of the water provided for citizens. Latin American countries average at about 84% access for rural communities, one percent higher than that of the average for other developing countries. Panama specifically averages around 79% water access in rural communities, falling short for both Latin America and global developing countries (Bertoméu-Sánchez & Serebrisky, 2018). The lowest percentages of water access fall in these rural areas, where access is as low as 28% ("Panama - Urban Waters Panama," 2015). The map below (**Figure 4**) illustrates the areas of Panama lacking water access (Unknown, 2016b).

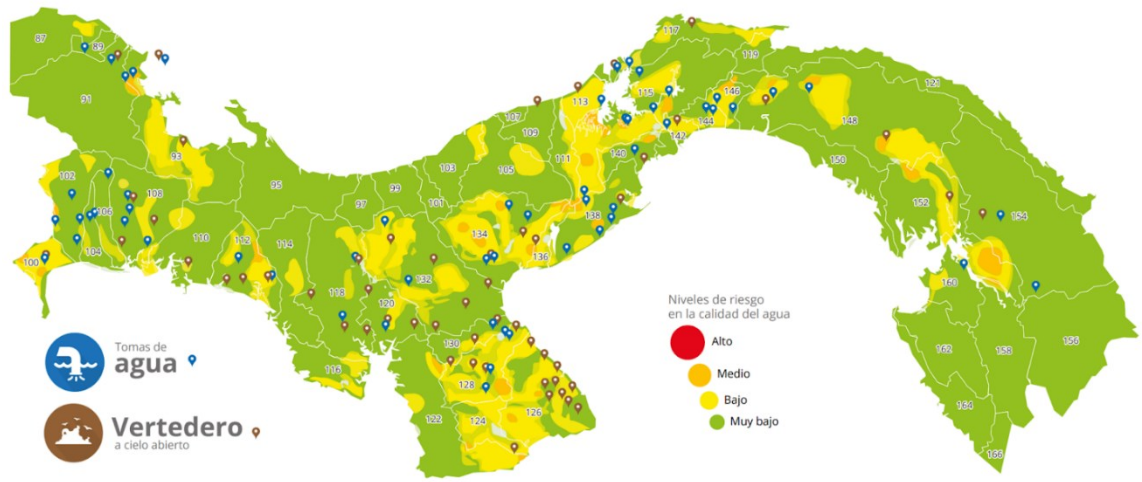
Figure 4. Proportion of houses in Panama without access to drinking water



Note. From *Plan nacional de seguridad hídrica* [Digital Image], by Unknown, 2016, (https://www.undp.org/es/panama/publications/plan-nacional-de-seguridad-h%C3%ADdrica-2015-2050-agua-para-todos)

Even in areas where water access is abundant, water quality still does not necessarily meet top standards. Water samples taken around Panama by MiAmbiente, a governing entity under the Panamanian government, showed only 78% of the samples as "good quality," with 5% as "average quality" and 17% "excellent quality" (Larsen, 2019). The water may be drinkable, but it is not optimal. Water quality is affected by a myriad of factors, including pollution from road water runoff, acidification of rainwater, and, specifically for Panama, pollution from garbage dumps. Open air garbage dumps have, in some areas, significantly affected groundwater quality through runoff. The distributed effects of these open air dumps can be seen in **Figure 5** below. (*Plan nacional de seguridad hídrica*, 2016; Unknown, 2016a).

Figure 5. Panama's different water quality risk levels based on proximity to garbage dumps and water sheds



Note. From *Plan nacional de seguridad hídrica* [Digital Image], by Unknown, 2016, (https://www.undp.org/es/panama/publications/plan-nacional-de-seguridad-h%C3%ADdrica-2015-2050-agua-para-todos)

Torrente-Velásquez et al. (2020) studied a case of open-air garbage dumps in Cerro Patacón, Panama. The landfill in question is about 50 meters from the nearest community and directly adjacent to a national park. The problem was that the waterproofing system of the landfill in Cerro Patacón has not been improved to keep up with the massive amounts of rainfall in Panama. Sludge from the landfill has been known to flow into a nearby stream, which in turn flows into a nearby river that supplies some communities with water. The article found that sludge and leachate accumulation in the water sources was well above water quality control parameters set by the Panamanian government, with metals such as cadmium, lead, and nitrate among other metals as being found in the groundwater and surface water (Torrente-Velásquez et al., 2020). Of 10 watersheds and 95 rivers tested in Panama, the World Bank says "34 percent are classified as contaminated or slightly contaminated" (*Panama - Locking in Success*, 2015).

Obviously, placing landfills without proper protection so close to water sources, both groundwater and surface water, poses a danger to the people living in the area. Even looking away from water pollution by leachate, this landfill is predicted to release almost half of the methane pollution generated by Panama this year. According to the United States Environmental Protection Agency, methane gas is 20 times more potent than carbon dioxide (US EPA, 2022). Uncontrolled open air garbage dumps like the one in Cerro Patacón hold a major environmental and societal impact on the communities and nature surrounding it. Gaining a better understanding and better control of these landfills is key to the improvement of quality life and water sources in Panama (Torrente-Velásquez et al., 2020).

2.2.3 | HEALTH EFFECTS OF CONSUMING UNTREATED WATER

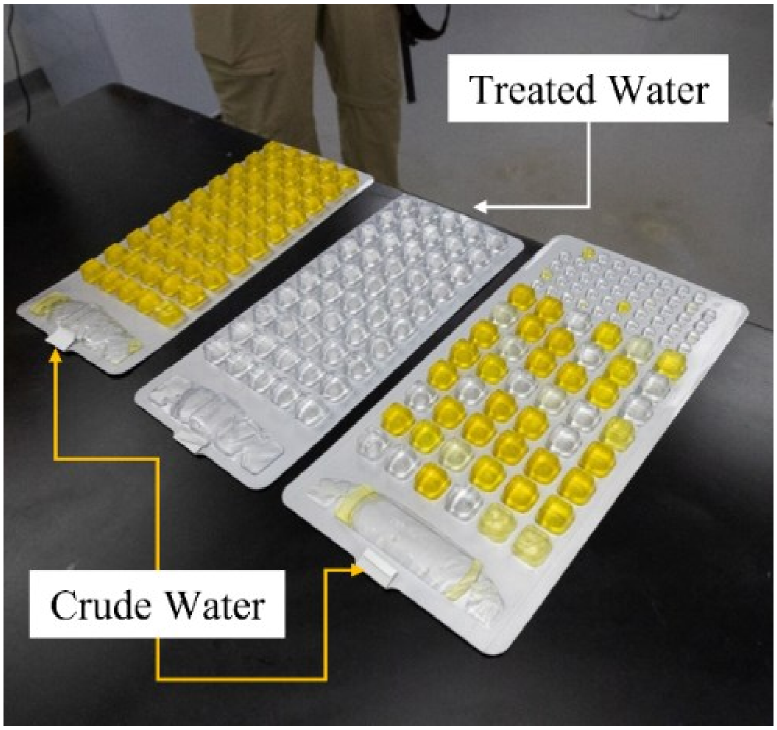
The water treatment process is an essential element of developing safe drinkable municipal water distribution. Consumption of untreated water can lead to serious health risks or even death. The Panamanian constitution outlines the health aspects of having a stable clean water source as it is essential in maintaining a healthy population. Untreated water such as that found in the natural lakes and tributaries of Panama can contain cholera, dysentery, hepatitis, typhoid fever, and polio. Globally, over 2 billion people are drinking water which could have been contaminated by feces, with contaminated water causing over 400,000 deaths per year. For those that do not perish, 771 million people lack basic drinking water services and must find their water from other sources, like unprotected wells, springs, and untreated surface water from lakes, ponds, rivers, and streams (WHO, 2022). These figures are why distribution of treated water is one of the most essential elements in preserving a healthy population.

There are two types of untreated and unhealthy water named by the United States Environmental Protection Agency: chemically affected water, or when too many chemicals are added to the water, and bacterially infected water. Chemically affected unhealthy water typically affects the organs of your body and causes organ damage. They might cause skin discoloration or damage the reproductive or developmental systems in your body (US EPA, 2021).

Water plants in Panama have a system for situations when too many chemicals have been added to the water at treatment plants. If too many chemicals are added, the plants will increase the amount of backwashing done during the treatment process. This process would take about 2 hours to effectively backwash all the chemically affected water. One preemptive measure taken at the plant is what they call the Jar Test. Essentially, this test is where they figure out the best chemical mixtures and amount of chemicals to add to the water during the treatment process (Ana, personal communication, September 16, 2022). Bacterially mixed water can add many more diseases to unhealthy water consumption. Some examples of diseases one can catch when drinking untreated water include typhoid fever, cholera, hepatitis, dysentery, *E. coli*, and polio (WHO, 2022). Symptoms and effects of these diseases include stomach pain, vomiting, diarrhea, headache, fever, and kidney failure (US EPA, 2021). The consequences of these diseases give clear concern as to why water treatment is crucial to public health.

Two specific parasites were found in Panama's raw water sources in 2018: *Cryptosporidium* and *Giardia* ("Panama - Urban Waters Panama," 2015). Consumption of these parasites can lead to the disease's cryptosporidiosis and giardiasis, respectively (*Cryptosporidium*, 2021; *Giardia*, 2021). Symptoms of cryptosporidiosis include watery diarrhea, stomach cramps or pain, dehydration, nausea, vomiting, fever, or weight loss (*Cryptosporidium*, 2021). Some symptoms of giardia include diarrhea, stomach cramps, upset stomach or nausea, vomiting, and dehydration (*Giardia*, 2021).

Figure 6. Coliform test results for crude water and treated water samples at IDAAN (own photo)



Diseases and parasites in drinking water pose a serious threat to the health of a population, and their prevention is an important step in promoting population health. Biologists and chemists in IDAAN's water treatment plants take samples of treated water and check for the presence of other bacteria like coliform and *E. coli*. Tests for coliform and *E. coli* are administered using colored culture cells (see **Figure 6** above). Tests are also used to detect the presence of algae and other water toxins.

These tests help to ensure purity, these tests are taken from the water source at intervals (Ana, personal communication, September 16, 2022). The presence of these and more toxins in raw drinking water highlights the necessity of safe, potable water access in Panama. Having safe, well-funded, and effective water plants can prevent countless people from sickness and suffering.

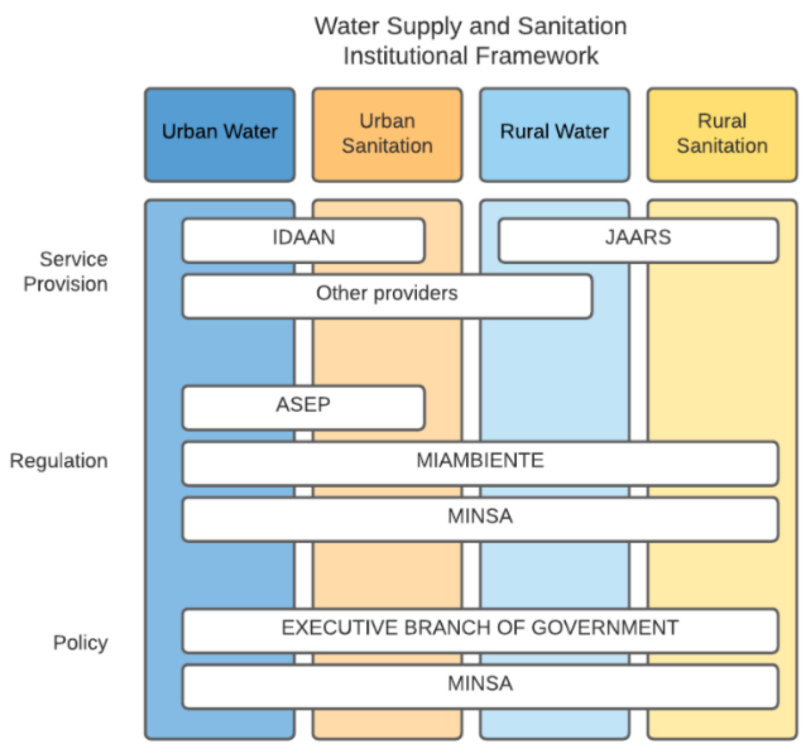
2.3 | PANAMA'S GOVERNMENT AND IDAAN

Article 110 of the Panamanian constitution states that every Panamanian is entitled to a fresh clean drinking water supply. Because of this, the national government of Panama is required to provide its citizens with a steady supply of drinking water. Although they are required to provide this resource, in many cases, the requirement is not met. To accomplish this national goal, the government established the national water authority IDAAN (Instituto de Acueductos y Alcantarillados Nacionales) to oversee the production, maintenance, and distribution of potable water systems and sanitation. IDAAN reports directly to the Panamanian Ministry for Health and provides information on the quality of water in Panama. In many situations, IDAAN lacks the funding and personnel to properly maintain and expand its water supply capabilities in Panama. Because of this, many Panamanians lack access to drinking water. As the Panamanian population grows, these conditions become more and more of a strain on IDAAN and its potable water network. Recently, Panamanian politicians have used the potable water conditions as a political argument for their campaign. For example, President Ricardo Martinelli instituted a plan for large scale improvement to the water processing network in Panama. Through the past decades, water treatment and distribution has been an essential piece of Panamanian political discussion. Through its constitution, the Panamanian government is liked to water, as water access is one of the most important and frequently discussed political arguments in Panama.

2.3.1 | INSTITUTIONAL FRAMEWORK

The national government of Panama is constitutionally bound to provide its citizens with a steady and robust supply of potable water. Article 110 of the Political Constitution of Panama outlines that, to combat illness from sanitation issues, the Panamanian government is obliged to develop the ability for its people to receive potable water (*Constitución política de la República de Panamá*, 2016). The Dutch model is often considered when looking at effective water treatment and distribution. However, according to a Dutch report, the number of organizations with overlapping responsibilities make the water sector in Panama inefficient (*Water Sector in Panama*, 2018).

Figure 7. Panama's water supply and sanitation institutional framework



Note. From *Panama water sector study 2022* [Digital Image], by van Vliet, 2022, (https://www.netherlandswaterpartnership.com/panama-water-sector-study-2022)

Figure 7 (above) shows all the organizations in Panama working on water and their shared responsibilities (van Vliet, 2022). All the organizations are of different sizes with different resources and different amounts of funding, which creates an almost competitive environment. For example, there is a massive difference of water quality between the Panama Canal Watershed (PCW) and watersheds in the rest of the country. According to the World Bank, water quality in PCW is ranked good to excellent (*Panama - Locking in Success*, 2015). The Panama Canal Water Authority (ACP) oversees the watershed that feeds the Canal. The ACP is financially and bureaucratically autonomous, meaning they are more efficient and have much more funding because of the massive amount of revenue the canal brings in each year (Larsen, 2019). With substantial maneuverability and funding, the ACP takes on huge projects such as monitoring systems and land-use studies (*Panama - Locking in Success*, 2015). On the other hand, the National Authority of Environment (ANAM), the Ministry of Health (MINSA), and the national water authority (IDAAN) are responsible for the remaining water in the country and have much more limited resources available in comparison to the area for which they are responsible. Without resources for projects like the ACP, watershed quality is not nearly as good in the rest of the country (*Panama - Locking in Success*, 2015, p. 88). Institutional disorganization in organizations such as IDAAN make high quality water distribution a very difficult task especially when compounded with other factors.

2.3.2 | PRESIDENTIAL SUPPORT OF WATER

For the past decade Panama's presidents have been in support of increasing water access for Panamanians through implementation of different legislative plans. President Ricardo Martinelli (2009-2014), for example, implemented a $13.6 billion strategic plan in 2010 to support and improve upon IDAAN and its infrastructure. This plan would include improving access to basic water services to increase access to water to above 90 percent of Panamanians living in specific Metropolitan areas (*Panama - Metro Water*, 2010).

The succeeding president, Juan Carlos Varela (2014-2019), also presented an ambitious plan in 2017 outlining the current state of water in Panama and the goals they planned to achieve toward improving water. This report, named the *National Plan for Water Security: Water for All*, aimed to primarily achieve the United Nations Sustainable Development Goal 6 and to be one of the first countries to implement their own official plan. They aimed to achieve the listed goals with a timeline from 2015-2050. The plan was significant in providing the public with an objective outlook of water access in specific communities and statistics that they planned to fix (*Plan nacional de seguridad hídrica*, 2016).

A major outcome of Varela's report was the creation of the National Water Council (CONAGUA). The council itself is composed of different administrators and directors relevant to the water sector, including the director of IDAAN and the secretary of the Office of the Environment. CONAGUA's primary job is to coordinate and guarantee the development and implementation of the goals outlined in the plan through evaluating and collecting data around Panama. The Panamanian government planned to invest nearly $10 billion into 560 projects related to water treatment and access. (*Plan nacional de seguridad hídrica*, 2016). Supplying over 70% of Panama's total water, IDAAN plays a key role in carrying out the goals laid out in the plan as well. Of the total $10 billion, $3.8 billion was allocated toward IDAAN projects such as constructing and renovating aqueducts and sewage systems across Panama. (*Plan nacional de seguridad hídrica*, 2016).

The current president, Laurentino Cortizo (2019-Present), continues the focus on improving IDAAN to, in turn, improve access to water and sanitation. His administration has also made significant investments in IDAAN regarding improvements in service and repairing leaks, water treatment plants, underground water systems, storage tanks, pumping stations, and drinking water networks. They plan on investing in IDAAN's human resources and training systems to incorporate suitable professionals and workforce (Vergara, 2018).

2.3.3 | PANAMA'S NATIONAL WATER AUTHORITY, IDAAN

IDAAN, or the Institute of National Aqueducts and Sewers is the national organization responsible for the production and distribution of potable water and sanitation resources in Panama. The mission statement of IDAAN is

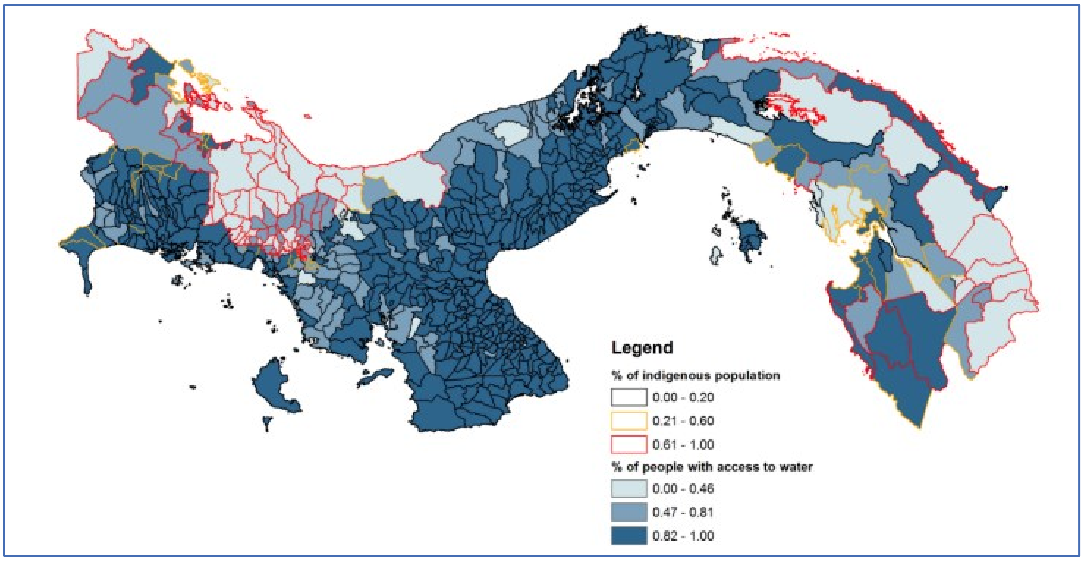
> *to improve the level of health of the community, well-being and progress of the country through the provision of drinking water services, and the collection and disposal of wastewater, ensuring the conservation of the environment, with a view to reaching optimum levels of productivity and efficiency*
>
> (Misión y Visión de IDAAN, 2021).

Their mission outlines their obligation to provide water through the means of improving the health of the Panamanian populous. IDAAN's water production is directly overseen by the Panamanian Ministry of Health. The ministry helps to track water quality across all processes of IDAANs production and ensure quality of water and sanitation to the Panamanian people. As of 2022, IDAAN is responsible for maintaining 59 water treatment plants, over 124 aqueduct systems, and services nearly 3.5 million Panamanians (*Informe Ejecutivo*, 2022; "Panama - Urban Waters Panama," 2015; *Plataforma Sig IDAAN*, 2022). The services provided by IDAAN help to ensure the quality of water and health to the Panamanian people.

2.3.4 | LACK OF IDAAN ABILITY AND SUPPORT

Despite IDAAN's leading role to fulfill Panamanians' right to drinking water, a distinct disparity in water access between rural and urban environments remains. Approximately 5% of the population currently relies on water trucks and tanks to access water in their communities. The map below (**Figure 8**) shows the relationship between lack of water access and population of indigenous peoples (Unknown, 2015). While all of Panama's urban environments are provided water through direct water plant connections, communities with non-continuous water supply also need water tanks installed in their neighborhoods to store water. These water trucking services are expensive to IDAAN and, due to their lack of enforcing billing practices, IDAAN provides low levels of services to these areas and continues to loses money (*Panama - Metro Water*, 2010). The cost of IDAAN services has also remained stagnant for over 40 years, leaving IDAAN with less money to spend on expansion and improving its infrastructure (Larsen, 2019).

Figure 8. Access to running water in the dwelling by concentrations of indigenous peoples



Note. From *Panama – Locking in success* [Digital Image], by Unknown, 2015, (https://documentos.bancomundial.org/es/publication/documents-reports/documentdetail/180611468100727814/Panama-Locking-in-success-a-systematic-country-diagnostic)

As a side effect of rapid governmental expansion over the past two decades, many other places in the Panamanian government lack staff and funding (*Panama - MAPAS*, 2014). Due to the lack of personnel oversight, the execution of many development plans such as the National Plan for Water Security has paused (*Plan nacional de seguridad hídrica*, 2016). The halted development of these national plans for progress cripples institutions such as IDAAN in their ability to expand and adapt to the growing needs of Panama.

In the past two years, the Cortizo administration has allegedly given little instruction toward the CONAGUA general secretary on what specifically he ought to do. Guillermo Torres, in an interview with the Panamanian newspaper *La Estrella de Panamá* explained that CONAGUA lacks the staff necessary to take water quality reports in the field, thus halting any sort of progress on how the goals of the *Plan Nacional* are progressing. This issue directly affects IDAAN's ability to monitor the progress on its projects since they lack an updated, centralized system outlining water demands in different regions of Panama. All they can do is continue to expand water treatment plants and put more pressure on the interoceanic highway with little to no idea on how water access is changing overall (Coriat, 2022).

2.4 | Water Treatment Plants in Panama

Globally, water is one of if not the most essential human resources. When the United States broke ground on the Panama Canal in 1904, It became clear that a concise plan for the production and distribution of potable water was necessary. During the construction of the canal, a steady reliable source of fresh water was necessary to sustain the needs of both the canal workers and nearby cities. The first cities to develop around the construction of the Panama Canal were Panama City and Colon, each on opposite sides of the isthmus. This new water production infrastructure would be required to efficiently sustain the needs of over 50,000 laborers for the 10 years expected to be required for the canal's construction.

The first plants constructed in Panama were the Mount Hope production facility constructed in 1914, and the Miraflores Treatment plant, constructed in 1915. These plants were designed to support the growing needs of the canal workers, while providing a stable supply of potable water to the major urban areas of Panama. As demand grew, Panama and IDAAN were required to expand water production capacity. In 1974 the Chilibre water processing plant was constructed, and eventually expanded to double its original size in 2008. The Chilibre plant was designed to support the potable water needs of the Panama City urban area and provide water for the growing Panamanian population. Over the past decade, water production needs have expanded, straining the capacity of the Chilibre plant and other IDAAN production facilities (Meneses et al., 2018).

Figure 9. Water treatment plant distribution in Panama

Note. From *Plataforma sig IDAAN* [Digital Image], 2022, (https://sig-idaan.hub.arcgis.com/)

The Chilibre Plant is by far the largest plant in Panama, servicing over a quarter of the population. Currently there are 59 active potable water plants around Panama, as shown above in **Figure 9** (*Plataforma Sig IDAAN*, 2022; Unknown, 2022).

Some plants have specialized systems to manage unique intake water quality, such as the Miraflores Plant. During the construction of the Panama Canal, Alajuela Lake was created by flooding the central part of the Panamanian rainforest. An aeration system was required for the Miraflores Plant to eliminate high amounts of iron as well as to resolve the odor from decomposing plant matter (Meneses et al., 2018). While some systems are unique, many of the processes and chemicals used are very similar between plants. This process has five steps: disinfection, coagulation, flocculation, sedimentation, and filtration. The graphic below (**Figure 10**) outlines six main steps of the Chilibre Plant, where the first step sources water from Lake Alajuela.

Figure 10. The six main steps of the Chilibre plant water treatment process (own photos)

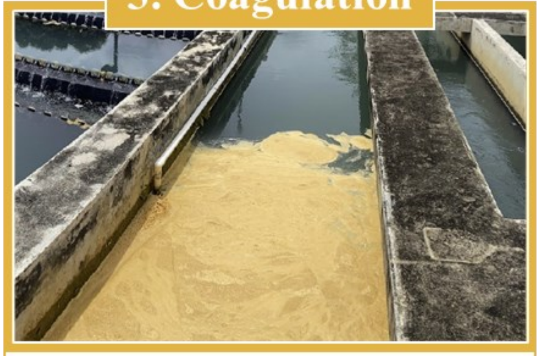
1. Water Intake

Crude water from Lake Alajuela is pumped into the water treatment facility by two large pipes. The pump station contains five working pumps.

2. Pre-Disinfection

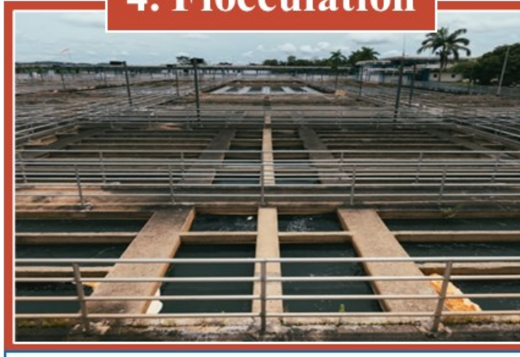
Chlorine is used as a general disinfectant and mixed into the crude water to eliminate any present microorganisms like coliforms and/or *E. coli*.

3. Coagulation



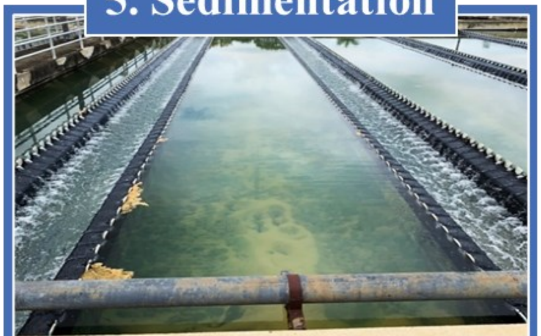
Aluminum sulfate ($Al_2(SO_3)_3$), also called *alum*, is added and binds to negatively charged particles in the crude water, like dirt and organic matter.

4. Flocculation



Flocculant 8, a cationic polymer, is injected to help the coagulated particles combine as the water is mixed to aggregate clumps into larger particles.

5. Sedimentation



Particles combined with *alum* and *Flocculant 8* sink to the bottom of the tank, while mostly clean water is skimmed off the top.

6. Filtration

Rapid sand filters composed of sand and anthracite (high quality, hard coal with lots of trapped carbon) remove suspended and dissolved particles.

7. Distribution

IDAAN provides the treated drinkable water to its over 3.3 million customers across Panamá (*Informe Ejecutivo, 2022*).

In looking at costs associated with running one of these potable water plants, we went to Chilibre to talk to Javier Sanchez, a chemical engineer and superintendent that has been running day-to-day operations for 28 years at the Chilibre Plant. The first place we went was the water intake facility. Lake Alajuela serves as the source for the Chilibre Plant. The lake maintains its water level from rainfall, the Chagres River, and the Canal. Five 1,750 horsepower pumps transfer the crude water up from the lake and into the next stage of the plant (see **Figure 11**).

Figure 11. An intake pump inside the Lake Alajuela pump station (own photo)

We were surprised to learn that 70% of the cost to treat the water comes from just running these electric pumps. IDAAN is one of the biggest energy consumers in the country (J. Sanchez, personal communication, September 16, 2022). The Chilibre Plant currently uses some hydroelectric power generated at its water source to power the intake pumps. Using hydropower is a much more efficient method than traditional non-renewable power lines. IDAAN is looking into using more hydroelectric power to run these pumps as it would be the best way to reduce costs as well as carbon emissions. While some plants like the Chilibre and the Miraflores are required by the government to inject fluoride to aid tooth health, the Chilibre Plant's equipment for this is broken, and with a lack of funding, they simply do not have the ability to do so.

Chapter 3 | Original Methodology

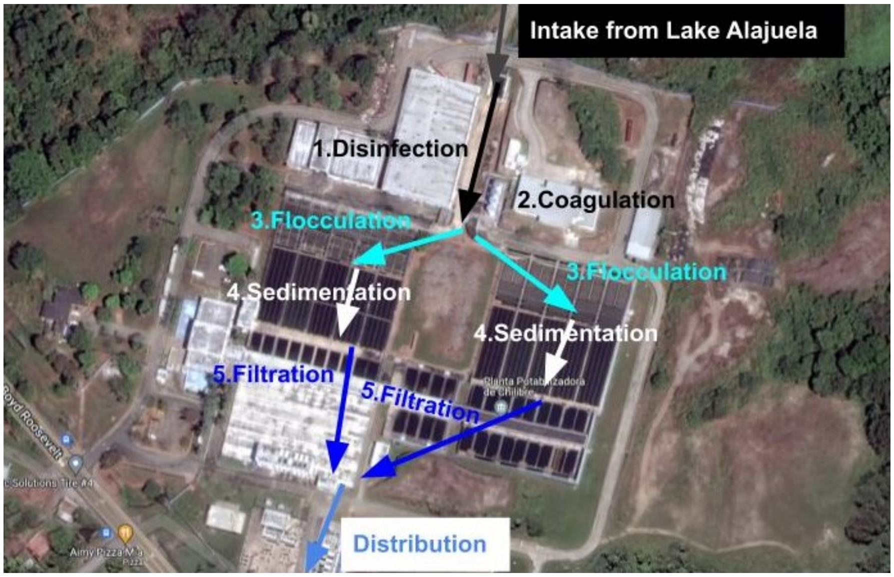
The goal of our project was to optimize IDAAN's water treatment process by first gathering information on IDAAN in general through informal interview, analyzing water quality data from different water treatment plants, generating a report based on the analysis, and then explaining the findings to IDAAN administration.

In planning to achieve this goal, we developed the following research objectives:

1. Interview IDAAN personnel regarding the water plant infrastructure
2. Analyze data from IDAAN using statistical methods
3. Generate a report based on our analysis
4. Present what our findings mean for each plant involved

3.1 | Determine the State of IDAAN's Water Plant Infrastructure

Figure 12. Bird's eye view of the stages of water treatment at the Chilibre plant



When our team set out to learn about Panama's current water supply infrastructure, we aimed to answer the question: what can we learn about the current water infrastructure to help contextualize the next steps of the project goal? Online research was our first method of data gathering. We were able to find information on the Miraflores Water Plant, just outside Panama City. Upon initial research, resources were found which highlighted procedures used at the Miraflores processing plant to purify water. This knowledge about plant processing techniques and equipment used provided insight into how public water is processed in Panama. The data from the Miraflores Plant also allowed us insight into the water intake qualities of Panamanian tributaries. From this remedial knowledge, we concluded that to fully understand the scope of our project, it would be necessary to visit an IDAAN water processing facility. Visiting the plant would provide our team with a higher level in knowledge on the water processing systems and distribution networks in Panama.

Our contact at the plant was Dr. Javier Sanchez, an IDAAN engineer with 28 years of experience at the Chilibre water facility. Javier is the Superintendent of the Chilibre plant and guided us on our task to understand the process of water purification in Panama. On a tour through the plant, Javier brought us through all key elements of plant processes like water induction, flocculation, and water quality testing. This tour, and subsequent interview with Dr. Sanchez was instrumental in our understanding of plant dynamics and the different issues water production in Panama may face. From our in-depth tour of the plant, issues such as an aging water infrastructure, and overuse in urban areas were highlighted. One key issue of the overproduction of potable water is the restriction in testing ability. Due to the higher than designed flow rate, the water engineers cannot adequately test every “batch” of water which passes through the plant. Chemical use is also a strained element in water production. With a higher production volume of water, chemical use must be increased to meet the demand of properly sterilized water. With an analysis system in place, the use of chemicals could be more properly regulated and optimized to exactly fit the needs of the plant’s raw water, while simultaneously creating a lower cost of chemicals.

An essential element of gathering varied data on sources regarding water supply in Panama was the internet. We were able to search millions of papers for exactly what we needed, without spending too much time or resources. Data on specific water plants in Panama and the organizations behind them bolstered both our report and our understanding of the topic at hand. One challenge, however, of gathering data from the internet is the sheer volume of material available makes the exact information like a virtual needle in a haystack. Even with advanced search features some time had to be spent just wading through information that was not useful to us. The knowledge gained from the plant visit and engineer interviews was essential in helping our team develop a good understanding of variables in the water production environment. This understanding allowed for a more focused and developed set of metrics and key datapoints to use in the creation of analytical methods. Developing methods to filter and compare targeted areas of data sets will allow for a more tailored precise system for data analysis.

We met our goal of gathering high-quality data on Panama's water infrastructure by using a combination of online and in-person resources. The combination of these methods gave us the most complete picture of our topic because where each one falls short, the other excels. With substantial research we moved forward to the next research objective.

3.2 | Analysis of Water Treatment Plant Data

We planned to use a program called STATA to create various statistical analysis charts for visual comparison. Stata allows for an advanced set of data processing criteria to be applied to a multitude of datasets. Customizability within Stata allows for immense customization of data filtering and comparison methods. Using these custom methods, we can contrast the large, chronologically organized data sets between the three processing facilities.

The data we would receive from IDAAN was segmented between three distinct sections of the water treatment process: input water characteristics, chemical processes, and the output water characteristics. **Table 1.** below lists the variables obtained from each section of data.

Section of Process	Input Water	Chemical Treatment	Output Water
Data Variables	• Turbidity • Chlorine • pH level	• Aluminum sulfate • Cationic polymer • Calcium hypochlorite • Liquid chlorine • Activated carbon • Hydrated lime	• Turbidity • Chlorine • pH level

Table 1. Expected data variables from IDAAN water quality data

After individual analysis of plant inputs and outputs, comparisons can be drawn between output quality and efficient chemical use. Comparing the chemical use of different plants can also help in the understanding of which water processing facilities are using their chemicals in a more cost effective and efficient way. Through a more developed understanding of the relationships between chemicals, outputs, and how they are affected by input quality, revealed trends can be used to create essential visual elements for the expression of a comprehensive data report.

3.3 | Organize Findings into a Comprehensive Report

Using the data visualizations created from Stata and/or PowerBI, we can compare key markers for efficiency between the plants. Understanding the relationships between input quality and chemical use through data visualizations would be essential in developing understanding of how chemical use can be compared between the plants. Since the raw water entering each plant contains differing levels of impurities and biotics, the chemical use would not be the same, even in optimized conditions. Understanding and developing models of the interactions between impurities and chemical use would allow us to understand an optimal level of chemical use for each plant based off the most efficient chemical users. Creating visualizations of chemical use would allow for comparisons between the individual units of water pollution and the chemicals required to process them. The end goal of the project being the concise expression of cumulative chemical use, creation of effective visuals is the most important aspect of the data organization process.

3.4 | Communicate our Report Findings through a Presentation

Once the report and analysis were completed, our team would have created a PowerPoint presentation highlighting all critical information and present it to each of the different water treatment plants where data was collected from. The goal of the presentation would be to explain how our analysis and findings affected each plant and to make recommendations based on those findings and the data provided. This would include any trends found during the analysis in relation to the relationship between input quality, the chemicals used, and output quality of the water as described above. In theory, the trends and recommendations found during our analysis would be handed over to the water treatment plants, where the plants would then be able to use said suggestions to improve upon the existing treatment process and standardization currently in place by IDAAN.

Chapter 4 | Final Considerations

Due to various reasons that we will discuss, we were unable to complete our project goals as outlined in the Methodology. Our team developed several invaluable lessons from our time spent in Panama, despite not having begun a formal project. There are significant factors that played a role in the downfall of our project. Fortunately, we kept in mind the functions we maintained during IQP that led to our ability to reflect on this experience.

The issues and recommendations that we identified are as follows:

Impeding Factors to our Project's Success

1. Absence of a Sponsor
2. Lack of project direction
3. Slow movement of information

Recommended Habits for Future Groups

1. Establishment of constant, meaningful contact with sponsor
2. Clear and effective communication with advisors
3. Documentation of meetings

These lists are not exhaustive for *all* impeding factors, variables, and recommended habits we maintained during IQP. Nonetheless, these elements proved to be most essential in framing the situation that occurred regarding our project. Through the expression of these key items, we hope to effectively communicate the factors that impeded our progress and provide critical analysis of what could have been done to better serve the project.

4.1 | Impeding Factors to our Project's Success

In most cases, the impeding factors that affected our ability to carry out this project were out of our control. Since our project was situated in Panama, most conversation was conducted in Spanish. This circumstance meant a language barrier between our non-native Spanish-speaking group members and the personnel we spoke with existed. Without our liaison Rick Montanari to help us set up meetings or translate, the task of translation unintentionally led to reliance on our advisor to talk for us. Additionally, from ID2050 in April up until IQP in mid-September we experienced changes to our project that prevented us from developing any meaningful product over the time that we were in Panama. This lack of project direction led our group to disillusionment and general confusion about what we ought to do with our time. When attempting to establish the scope of our projects, we often encountered slow movement of information from IDAAN. As a result, we arrived toward the end of IQP without the material needed to complete our project.

4.1.1 | ABSENCE OF A SPONSOR

To help our team with the intricacies of working with a bureaucratic agency, our original sponsor Footprint Possibilities was supposed to be in Panama with us. Footprint Possibilities is a nonprofit organization that aims to connect capable, hardworking people with communities and organizations that could use their help abroad. Rick Montanari, the vice president of the organization, was supposed to be our main connection to IDAAN. Rick has successfully set up projects and helped students communicate with IDAAN for years. He would have been an excellent resource in ensuring our project ran smoothly and had the resources it needed. Unfortunately, Rick was forced to leave Panama just a few days before we arrived and therefore could not assist us throughout the project. This considerable change happening right as our project was starting was a major upset to our resources. Without Rick we were forced to start a discourse with IDAAN from scratch and on our own, leading to miscommunication and loss of time.

Serving as interim translator for our project, Professor Grant Burrier played a key role in filling in the gaps left by Rick Montanari. We are wholeheartedly grateful to him for his close involvement and assistance in our meetings and for facilitating fluent conversation. Without his help in easing the difficulty of the language barrier, our progress in this project would not have been possible. We *do,* however, intend on highlighting the inherent difficulties of having an IQP abroad with a foreign language. When it came to breaking down the specifics of our project's deliverables, there always seemed to be missing information that prevented us from fully understanding what exactly we had to accomplish. Follow-up questions were often simple due to lacking context of the entire conversation and meeting minutes were only snippets of understood words and sentences. As such, we were limited in what we could and could not discuss during these meetings and the information we obtained from them.

The job of translation during these meetings was not Professor Burrier's main responsibility—he chose to take on that task. In the past, Rick has taken the role of translator for other groups working with IDAAN and has had success in communicating on behalf of those groups. His departure from Panama was out of his control so we do not seek to blame him, but spotlight that working without his assistance proved difficult and ultimately unsuccessful.

4.1.2 | LACK OF PROJECT DIRECTION

The lack of project direction throughout the whole IQP process prevented our group from developing a completed project in the time we had in Panama. Our project changed a total of three times from the start of ID2050, severely hindering the ability of the group when attempting to complete the project (see **Appendix A**). Our original project dealt with digitizing IDAAN's physical construction plans and creating a database to store them. This project was changed halfway through ID2050 when our sponsor Rick Montanari let us know that IDAAN had already created this database. He then gave us five other options to choose from for our project. We chose a project involving creating a database and complementary app for engineers taking water quality tests in the field. Over the summer we began preliminary research on Microsoft Access and PowerApps as the platform for our database and app.

This second project stuck through until we arrived in Panama. However, in our first meeting with IDAAN (9/1) the engineers informed our group that this project was no longer needed. They told us that their workers do not take water quality tests in the field often enough to constitute an entire project. Surprised with this second change, we struggled to find any need that they could have solved by a project. We also did not have Professor Burrier to help facilitate smooth communication during this meeting which meant all communication fell to one group member. Over the course of this three-hour meeting, we finally came up with a new project idea. They explained that at IDAAN's water treatment plants, workers use physical forms to record water quality tests throughout each stage of the potabilization process. The issue we could solve is to centralize the data collected into a single Microsoft Access database, and that instead of inputting data manually online post-recording, they could utilize a mobile app to record data directly into the database.

We worked on this new water plant data entry project for exactly two weeks (9/1-9/15). At the end of this period, we had another meeting with IDAAN's subdirector (9/15) to gain further insight on how IDAAN could use this new project. Unfortunately, at the very start of this meeting the subdirector stated that there were more pertinent issues that we could solve instead. She then changed our project to analysis and optimization of chemical use by three water treatment plants. We received data eight days after this meeting (9/23), leaving only three weeks until the end of IQP. Only a third of the data sent to us was usable, while the rest was historical data outside the scope of our project.

Throughout each change to our project, our group became increasingly confused about what IDAAN wanted us to do. We lost valuable time with each change and could only put most of our efforts into improving the background of this report. At the time of the last project change, we had half of the time originally allocated to our group to complete an IQP. Thus, it was expected for both our sponsor and our group to reduce the project to a size that could be completed in a shortened timespan. Even if we did acquire all the data in time, we would have had only about two weeks to both write the rest of our IQP report and work on analyzing the data. The culmination of these various changes served to make our group frustrated with spending time in Panama without any solid task to work on for IDAAN.

4.1.3 | SLOW MOVEMENT OF INFORMATION

Like any nationalized bureaucracy, IDAAN struggles with its ability to quickly process contracts and information. This inefficiency is a side effect of how a company of IDAAN's size deals with approvals of official documents. IDAAN requires a significant number of statistics and information about each source it releases its public data to. In the case of our specific project, we required key plant data about water quality and chemicals used to process drinking water. To receive this information, the students in the group were required to sit in on a meeting drafting contractual information which would later be signed by a faculty member from the university. After these requirements were met, it was the assumption that all necessary data and information could be transferred by email to us, the project team for processing and analysis.

IDAAN employs a massive number of individuals whose jobs are to deal with clerical and bureaucratic work. Our documents were required to traverse this lengthy and monotonous labyrinth through the inner workings of the IDAAN bureaucracy before they could be signed and released to us. As it turns out, one of the main hold-ups in our project was the approval of the head of IDAAN water. This specific employee is responsible for a large amount of information review, and document signing within the company. As a result of this, all major documents must be approved and signed by one person at the top of the hierarchy. This process causes significant delays in the delivery and processing of critical information as it all needs to be filtered through one specific individual. An inability for unilateral decision making within the company leads to a slow pace of progress, and any changes made to a project must be processed through a game of telephone all the way back through an always changing labyrinth of government policy.

Future groups may learn from our experience with IDAAN, by understanding the necessity of approaching every interaction with urgency and providing persistence to sponsors within IDAAN. Seven weeks to complete an IQP project is not a lengthy amount of time, and because of this, one must take full advantage of every second. Receiving responses from IDAAN on any topic takes a longer than expected amount of time and can lead to project delays if not properly negotiated before entering the project site.

With any sponsor like IDAAN it is important to have all project expectations and guidelines set in stone before arrival. ID2050 is the optimal time to plan and make proper preparations for the coming term. With this done in ID2050, the seven IQP weeks can be used to their full extent to develop the best proper project, and do the best,

4.2 | Recommended Habits for Future IQP Groups

Among the first research we conducted regarding our project was that of past IDAAN IQPs. A selection of these projects provided invaluable information on how to properly develop information and provided critical insight into what kind of a process and deliverable was required while working with IDAAN. These projects were extremely useful in helping us make decisions for the future of our project. Just as past IQPs have helped us, we want to continue to aid future IQPs in providing critical insight into IDAAN and Panama. We have made recommendations on what we have found are the most important critical aspects for future IQPs to take away from our experience.

Additionally, we believe we have more to offer than many other IQPs due to our project not becoming entirely successful. We hope to provide critical insights into the inner workings of government bureaucracy and IDAAN. We have broken this subject down into three distinct and essential elements to aid in IQP functionality and success. While each of these elements may seem self-explanatory, we believe that their utility provides essential information to the functioning of future IQP teams.

4.2.1 | ESTABLISHMENT OF CONSTANT, MEANINGFUL CONTACT WITH SPONSOR

Clear and efficient communication with our sponsors would have proven critical in a completed IQP project. We quickly established contact with our intermediary sponsor in ID2050, Rick Montanari of Footprint Possibilities. During the ID2050 process, Mr. Montanari did not have consistent contact with IDAAN, and delayed many aspects of our project's early development. Months later, after very little contact or communication Mr. Montanari had to leave Panama before our group arrived in August. His departure left us with no bilingual sponsor, or intermediary for the completion of our project. Therefore, we had the challenge of establishing first contact with our new sponsor from Footprint Possibilities, along with establishing contact with the sources at IDAAN upon arriving in Panama.

Our new Footprint Possibilities sponsor did not speak English and did not have an extensive working relationship with IDAAN. This setback contributed to the difficulties mentioned with our project, including the lack of communication and direction. We recommend that any IQP group in Panama establish contact with sponsors, along with the company the sponsors are working with, if necessary. The early establishment of communication with the sponsors would prove critical in working out the details and issues, removing many possibilities of miscommunication in an IQP project. It is also important to attain multiple working relationships for the progress of your project within ID2050, which can be expanded, if necessary, throughout the completion of the IQP.

4.2.2 | CLEAR AND EFFECTIVE COMMUNICATION WITH ADVISORS

Maintaining clear and transparent advisor communication was essential in nurturing project efficiency. Advisors provide critical insights through their experiences in previous project centers, and can help IQP teams to communicate, and achieve better results with their sponsors. Because our IQP project shifted focus more than once, our advisors were heavily involved in our project to try and push our group in the right direction. It was clear and constant communication with our advisors that allowed us to get a heading whenever our project shifted focus. They helped our group navigate the bureaucracy of IDAAN which allowed us to get as far as we did in our project. We recommend that any IQP group establish early, clear, and constant communication with their advisors, especially if they sense that there could be limitations presented with their IQP project or the direction their project is heading.

4.2.3 | DOCUMENTATION OF MEETINGS

Throughout every step of the IQP process, there exists documentation of the information shared between our group and whomever we spoke with. Our copious notetaking of all our meetings and interactions with our advisors and IDAAN personnel has now helped us to easily read each document and reflect on the process that led us to this point. In other words, having this information to look back on proved useful for painting the whole picture of how our project transformed various times throughout our IQP experience. These records were especially important because our project changed so completely and so often.

We used various programs to keep track of our meetings and meeting information. The primary program used for meeting agendas and minutes was Google Docs. With ease of sharing and editing access, Google Docs allowed our team to seamlessly add notes simultaneously to the agenda and minutes during meetings. In some interactions with lots of information, like the visit to the Chilibre plant, we were able to record our conversations with the Voice Memos app on iPhone and then have a program called Descript assist in transcribing words. WhatsApp was the primary program used for communication, with emails being used as a more formal form of contact. Through all these media, we had records of what we had discussed with everyone involved in our project. We have a compiled list of all our meetings in **Appendix B**. We highly recommend that every IQP team documents every step of their work to track any developments, feedback, and opportunities to look back on in the future.

4.3 | Overall Takeaway

As we discussed in Sections 4.1 and 4.2, our IQP has had its fair share of complications. The struggle of communicating in a foreign country without skilled assistance, the ill-defined nature of our project, and the sluggish movement of a bureaucratic government agency amounted to an IQP project which never came to fruition. Our group tirelessly sought to find an objective that we could accomplish during our time in Panama, but at the end we could only accept that our project became a reflection on the process we went through.

Our reflections revealed the positives of our experience. We learned the importance of communicating with the sponsor directly to facilitate immediate sharing of information. Although our sponsor was sluggish in responding, we still established that line of communication early on. We kept our advisors well-informed on every update and concern that we had regarding our project, allowing them to stay connected with us as we struggled to create cohesive opportunities from our time with IDAAN. Encompassing both points was the documentation of our interactions, which allowed us to reflect in retrospect on the challenges we experienced and the lessons we learned. Obviously, we had not expected our IQP to turn out the way it did, but we still tried our best to make a positive experience from our struggles. Our reflections demonstrate our desire to extract strategies and wisdom from this experience and share it with others in the future. Through the turmoil and uncertainty that plagued our desire for a project, we remained focused (with the heavy assistance and guidance of our advisors).

We greatly cherish the time that we spent in Panama. We had the opportunity to meet engineer Dr. Javier Sanchez who accompanied us throughout our tour of the plant and answered any question we gave to him. When asked what his job means to him, Sanchez told us,

> *… [this job] has a significant meaning because if you just realize that* ***all the water*** *that we produce has a* ***direct and instantly impact on people****…we [take] for granted that we will have water at home but with that water you can do a lot of things…****hospitals****…****depend on the water supply****. So, for me it's a very significant activity because we are* ***impacting positively on the people in Panama City*** (J. Sanchez, personal communication, September 16, 2022).

Rather than reflect on his own specific tasks, Sanchez focused his response on those who benefit from what the Chilibre plant offers. His selfless testament helped us to realize that our lack of a project was not the focus of this experience.

Figure 13. IDAAN Engineer Javier Sanchez (photo from Prof. Burrier)

IDAAN consists of over two dozen departments, responsible for bringing drinking water to over 3.5 million people across Panama through management of 59 different water treatment plants (*Informe Ejecutivo*, 2022; *Plataforma Sig IDAAN*, 2022; Unknown, 2020). Their primary responsibility is to provide water to Panama, which involves a lot of moving parts. Our team, as far as the whole of IDAAN is concerned, was likely very low on the list of priorities.

After all, IDAAN is a national organization tasked with providing water to Panama; we are a group of college students tasked with graduating. Through our trials and tribulations, we often focused on the plight of being in a project-less IQP. We now understand that our priorities pale when compared to those of IDAAN. Do we wish we had the opportunity to offer them results that could help them carry out this vast responsibility? Of course, we do. However, we realize that it is neither their responsibility nor obligation to provide a project, but to help people live better lives.

All in all, we leave this IQP enlightened. There exists an entire world beyond that of ours with complexities that we can only hope to comprehend. We had the fortunate chance to catch a glimpse of that world, including those who aim to better it. We are less disappointed than we are grateful to have experienced such a unique IQP. And so, in the words of our advisor Grant Burrier, we will go forth and be merry, and remain hopeful for the future.

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Appendix A | Graphic Timeline of Project Changes

Appendix B | Description of Meetings

ID2050

PQP Meeting 1

Thursday April 7 (1300)

- We met with Professor Chiarelli and Professor Burrier
- General meeting role discussion (Facilitator, etc.)
- We needed to talk to Rick Montanari at Footprint Possibilities

Rick Meeting 1

Thursday April 7 (1500)

- Met with Rick about our As-Built Drawing Register (ADR) project
- Rick was communicating with IDAAN about how task breakdown works
- Rick working on getting digitized drawings for us

Rick Email Update 1

Thursday April 14 (1208)

- He told us IDAAN cannot support us with the ADR
- They already have the software, but it was not available to outside agencies like us to use
- We needed to discuss other project ideas

PQP Meeting 2

Thursday April 14 (1300)

- Met with Professor Chiarelli and Professor Burrier about our last communication with Rick
- We needed to contact Sakulich because IDAAN couldn't support us with our current project
- Had 5 different projects to choose from:
    - Dashboard for monitoring media and social networks.
    - Geolocation system and response to complaints on social networks, Twitter, Instagram and WhatsApp.
    - Captive portal for visitors in the institution; 'Register via Smartphone, Monitor, Call for Appointment, Update Waiting List.' A virtual visitors reception (VVR) App.
    - Database for the registration and automation of water quality measurement tasks. This would be an IDAAN wide database to track tasks, projects, assignments, and status.
    - Asset management system that allows asset traceability. Like a BIM

Project Goal:

Undetermined.

Rick Meeting 2

Thursday April 14 (1500)

- We met with Rick to talk about the scope of our new project
- **Project Change 1:** We picked the water quality database as our new project since it was the most like the as-built drawing database that we had originally
- Had to do with making a water quality management database and application
- Tasked with working on a Microsoft Database

PQP Meeting 3

Thursday April 21 (1300)

- Meeting with Professor Chiarelli and Professor Burrier regarding the details of our new project
- We needed to get concrete directions from Rick
- Needed clarification from Rick from IDAAN about our new project
- Passively looking into Microsoft Access
  - Discussed that the database would be built while we're in Panama
  - Chose Access for sake of usability of IDAAN personnel (hoping that they use Microsoft)

Project Goal:

To create an IDAAN-wide database for the registration and automation of water quality measurement tasks, which would include tracking tasks, projects, assignments, and project status.

Rick Meeting 3

Thursday April 21 (1500)

- We met with Rick about more details for our project
  - Brought up idea of field-verification with smartphone while engineers are in the field
  - Stressing the importance of using images to identify leaks/any issues with the location to which they were sent
- Waiting for a solid scope of what to do
- Discussed the possibility of going out with a water quality engineer to see how they collect data
- We needed to develop a list of things that IDAAN had to provide for the database and app to work properly
  - Tasked with figuring out the constraints of using the database and app during summer

Rick Email Update 2

Friday April 22 (1705)

- IDAAN gave us a preliminary scope of work
- Additional functionality was included in his correspondence, including PowerApps smartphone implementation

Rick Email Update 3
Wednesday April 27 (1619)

- Rick told us he couldn't come to our scheduled meeting for Thursday April 28
- We were tasked with developing a proposal plan for IDAAN

PQP Meeting 4
Thursday April 28 (1300)

- Meeting with Professor Chiarelli and Professor Burrier to discuss our new project
- Our group changed from Drawings to Water Quality
- Project goal changed toward smart-phone accessible database

Project Goal:
Build a smartphone accessible database of water test data that can create reports for IDAAN.

Rick Email Update 4
Monday May 2 (1831)

- Rick told us he couldn't come to our sponsor presentations before we even presented them
- Sent us a final timeline from IDAAN regarding our project

Rick Email Update 5
Thursday August 18 (1059)

- Rick told us he couldn't come to Panama when we were there because his "contracts would not be extended"
- Scheduled to leave Panama on Sunday August 21
- "Not to worry. Val Guerrero our Supervisor is here [in Panama] …He will be with you the entire time. So you will be well taken care of."

IQP

Val Email Correspondence 1
Monday August 29

- 0927 first email to Val stating that we are in Panama
- 1001 Val tells us our meeting will be in CdS IDAAN office

Advisor Meeting 1
Monday August 29 (930)

- Meeting with Professor Chiarelli and Professor Burrier
- Professor Burrier told us we have a "sexy project" and that we need to sell the importance of it
- Creating a list of agenda items/questions we want to tackle for meetings with Val

Project Goal:
To create an IDAAN-wide database for the registration and automation of water quality measurement tasks, which would include tracking tasks, projects, assignments, and project status.

Val Email Correspondence 2

Tuesday August 30

- 1327 We sent a list of questions for the scheduled 9/1 meeting
- 1438 He gave us his number
- 1502 He confirmed the meeting for 2pm in IDAAN's CdS office
- 1548 confirmed our meeting would be with the Water Quality department with Jasmara Jaramillo and Edwin Moreno

Val Email Correspondence 3

Wednesday August 31

- 1213 Requesting confirmation of the IDAAN office location on Calle Anton
  - Gave him our phone numbers for WhatsApp communication
- 1216 He kind of said yes to the location (confusing)
  - "Y si mañana el grupo de calidad del agua es a las dos en la ciudad del saber."

IDAAN Meeting 1

Thursday Sept. 1

- We met with IDAAN engineers at Corozal to discuss our project for the first time
- We explained to them our idea for an app to record data in the field
- They told us they don't have enough volume of reports to have a need for such an app
- **Project Change 2:** They explained an app where data could be recorded by the workers at the production plants and then it would be compiled in a database
- Set up WhatsApp group with Jasmara and Edwin

Advisor Meeting 2

Monday Sept. 5 (930)

- Met with Professor Chiarelli and Professor Burrier
- Planning a meeting with the IT (Information Technology) guy about Power Apps at 1030
- We discussed the possibility of Chilibre Plant visit with Professor Burrier
- Talked about keeping close contact with Valmy, but a little confusing because he left early during our IDAAN meeting

Project Goal:

To create a water quality report database using Microsoft Dataverse for the Chilibre Potabilization plant, along with a compatible app in MS PowerApps for data entry and MS Power BI application for data analysis.

WPI ITS Meeting

Monday Sept. 5 (1030)

- Chris, the IT guy, told us that if we wanted to build a respectable app that we wouldn't make it in PowerApps
- Was very vague about what WPI used for their database storage and such
- Kind of a useless meeting

IDAAN Meeting 2

Friday Sept. 9

- Met with Edwin Moreno at Corozal (Professor Burrier, Val, and that other footprint guy attended)
- We planned to visit the Chilibre plant to see the whole process (goal was to go Wednesday)
- We also planned to meet the IT specialists and heads of departments to discuss projects (goal was Tuesday/Wednesday of the next week)
- Tasked with preparing *another* list of questions for the future meeting with the technology director, plant chief, and lab director
- At this point we had concerns about the feasibility of this project in terms of technology and more importantly in terms of the actual goal. We had no real problem we were trying to solve.

Advisor Meeting 3

Monday Sept. 12

- Met with Professor Chiarelli and Professor Burrier
- Tell them how we, at the very least, should be able to make the database
- The heart of our project is located on water treatment plants
- Still planned on Chilibre plant visit on Wednesday Sept 14

Project Goal:

To create a water quality report database using Microsoft Dataverse for the Chilibre Potabilization plant, along with a compatible app in MS PowerApps for data entry and MS Power BI application for data analysis.

IDAAN Meeting 3

Thursday Sept. 15

- Met with Burrier, Jasmara, Edwin, and IDAAN subdirector Luz Amalia Gonzalez
- The subdirector told us one of their problems is that all the plants are very disconnected
  - It would be interesting to see how efficiently three plants (Chilibre, Trapechito, Chitre)
- **Project Change 3:** We could compare how different plants use water treatment chemicals and use that analysis to inform the rest of the plants

IDAAN Chilibre Plant Visit

Friday Sept. 16

- Hung out with Javier Sanchez all day
  - Saw the open-air water treatment process
- Ana showed us around the bio lab and how they test for coliform and *E. coli*
- Learned lots of information regarding IDAAN's relationship with the government

Advisor Meeting 4

Monday Sept. 19 (930)

- Met with Professor Chiarelli and Professor Burrier
- Talked about our meeting with the subdirector
- Getting to work on our methods section but only working on our lit review

Project Goal:

Compare and contrast water quality data from three different potable water plants in terms of process, cost, and results, to help optimize IDAAN's water treatment process.

WPI ITS Email Correspondence

Monday Sept. 19 (1738)

- Requested access for Stata and PowerBI

Tuesday Sept. 20

- 855: Were told about two terminal servers with Stata (*turned out to be incorrect addresses*)
  - We could get access to PowerBI, just needed Professor Burrier approval
- 1023: Professor Burrier gave approval for us to get PowerBI
- 1128: Told ITS that we couldn't find Stata on either of the server addresses they gave us
- 1600: ITS told us the correct STATA server addresses

IDAAN Meeting 4

Thursday Sept. 22

- We met at IDAAN Vía Brasil with *Boss of Water Quality* Luis Navarro, *Technology subdirector* Carlos Gomez, *Project Manager of the Technology Dept.* Giuseppe Lagerutta, and *Data Administrator* Josue Manzo
- We (Professor Burrier and Edwin) explained our project to them
- We stressed the time sensitive nature of this project, so they made plans to get us the data on Friday 9/23
- They clarified the specifics of our project
  - They would give us data from the past 2 years
  - We would compare different chemical amounts at three different plants between both crude water data and traded water data
  - Involved working with the Planning Department for the chemical use and water quality for the crude and treated water specifications
- Set up a meeting at 9 at via Brasil with the Planning Department

Project Goal:

Compare and contrast water quality data from three different potable water plants in terms of process, cost, and results, to help optimize IDAAN's water treatment process.

IDAAN Meeting 5

Friday Sept. 23

- Met at IDAAN Vía Brasil with Edwin, Professor Burrier, Luis Navarro, Joaquin Degracia
- Discussed confidentiality agreement - Professor Burrier signed a form
- Met the people in the Planning department that has all the plant data
- We planned to get the treated water data from them
- And to get the crude water data from our original contact

IDAAN Data Acquired

Friday Sept. 23

1. We were given a link to three Excel files containing historical water quality data

Advisor Meeting 5

Monday Sept. 26

2. Met with Professor Chiarelli and Professor Burrier
3. We got *some* data from IDAAN on Friday Sept. 23
   - All the water quality data was not in the correct period (1999-2002, 2013-2017 instead of 2019-2022)
4. Discussed how we still lack the correct data
   - Professor Burrier contacted Luis Navarro about getting the water quality data
   - We contacted Edwin too

Project Goal:

Compare and contrast water quality data from three different potable water plants in terms of process, cost, and results, to help optimize IDAAN's water treatment process.

Advisor Meeting 6

Tuesday October 4

5. Met with Professor Chiarelli and Professor Burrier
6. We discussed how we *still* don't have the data that we need
7. Grant had to sign another confidentiality form last week and it still sits on the IDAAN director's desk for approval
8. All we can do is diplomatically reflect on what we took away from our IQP, despite never being able to complete our project

Project Goal:

Identify main takeaways from our IQP experience in Panama and with IDAAN.