



# Addressing Growing Water Needs in Providenciales, the Turks and Caicos Islands: The Bottled Water Conundrum and Future Infrastructure Recommendations

## Citation

Staley, Andrew Joseph. 2026. Addressing Growing Water Needs in Providenciales, the Turks and Caicos Islands: The Bottled Water Conundrum and Future Infrastructure Recommendations . Masters Thesis, Harvard University Division of Continuing Education.

## Link

<https://dash.harvard.edu/handle/1/42735599>

## Terms of use

This article was downloaded from Harvard University's DASH repository, and is made available under the terms and conditions applicable to Other Posted Material (LAA), as set forth at

<https://harvardwiki.atlassian.net/wiki/external/NGY5NDE4ZjgzNTc5NDQzMGIzZWZhMGFIOWI2M2EwYTg>

## Accessibility

<https://accessibility.huit.harvard.edu/digital-accessibility-policy>

## Share Your Story

The Harvard community has made this article openly available.  
Please share how this access benefits you. [Submit a story](#)

Addressing Growing Water Needs in Providenciales, the Turks and Caicos Islands: The Bottled  
Water Conundrum and Future Infrastructure Recommendations

Andrew Joseph Staley

A Thesis in the Field of Sustainability  
for the Degree of Master of Liberal Arts in Extension Studies

Harvard University

May 2026



## Abstract

Globally, four billion people experience severe water scarcity for at least one month every year (Mekonnen & Hoekstra, 2016). Coastal regions and islands are particularly at risk of threatened water resources as sea levels rise and precipitation patterns have become increasingly more erratic and unpredictable. Specifically, Caribbean nations are susceptible to water scarcity due to increases in tourism visitation, lack of governance, and failing water infrastructure. Small Island Developing States (SIDS) in the Caribbean have largely turned to ocean water desalination, which is both energetically expensive and environmentally damaging. Providenciales (Provo), the most populated of the Turks and Caicos Islands (TCI), relies entirely upon desalination for its drinking water. The production of desalinated water increases TCI's carbon footprint because the island relies on nearly 100% diesel-generated electricity.

As tourism on Provo continues to expand, Provo Water, the sole water utility on the island, will have to increase production. However, the company's water distribution system is inadequate and does not supply 24-hour access to in-home drinking water for local residents. Moving forward, Provo Water will be forced to prioritize either expanding production capacity or improving distribution infrastructure. Currently, a significant portion of desalinated water are utilized for non-potable uses within the tourism industry. Other Caribbean SIDS, and particularly tourism entities in these nations, have begun utilizing wastewater reuse for non-potable uses as a water conservation method.

I address two major questions in this research: (1) What are the economic and environmental costs and benefits associated with construction of additional desalination facilities on Provo and how would the integration of solar power for desalination affect water production and energy consumption on Provo? (2) How much are residents of Provo willing to pay as a monthly premium for improved access to piped water 24 hours a day, and are residents open to potable reuse of wastewater? My hypotheses are: Adding additional desalination capacity will significantly increase Provo's carbon footprint; construction of additional diesel-powered desalination capacity is less profitable than powering additional desalination solely with solar power; greater than 75% of surveyed residents will be willing to pay for 24-hour in-home access to potable water; and greater than 50% of surveyed residents will be willing to drink reused wastewater.

I utilized historical data, deployed surveys, and conducted interviews to make projections for financial costs of added desalination capacity. Data from Provo Water and existing solar desalination projects in the Caribbean helped estimate financial costs of improving distribution infrastructure and constructing solar-powered desalination plants.

The results of my study revealed that Provo residents were generally satisfied with their drinking water source, and that residents were, on average, not willing to try recycled wastewater. Additionally, only 60% of respondents were willing to pay more than \$25 dollars per month for in-home, uninterrupted access to piped drinking water. Results also revealed that the cost of implementing solar tied with desalination production may be prohibitive to incentivizing the development of such projects. The results of this research should inform future water production policy in Provo and aid in providing equitable access to drinking water for all Provo residents.

## Dedication

This thesis is dedicated to the Power, the Program, the People, and the Puppies  
who saved my life.

## Acknowledgments

I would like to extend my deepest gratitude to my Thesis Director, Linda Powers Tomasso, for her continuous guidance. Her expertise in navigating the IRB process, survey creation and distribution, and RStudio analysis was much needed in the completion of this project. I would also like to thank my Research Advisor, Mark Leighton for his guidance, specifically for his assistance in crafting my thesis proposal. Yuqian Zhang's suggestions regarding data analysis were much appreciated.

Special thanks to Jared Fulton of HAB Group for his information and project guidance, specifically regarding the future of Provo Water and project scope for a solar-powered desalination plant. Thanks also to Maxime Therrillion of Osmosun for his description of his company's solar-desalination service and his advice regarding project design.

I want to thank the religious community of Provo for assisting in the distribution of the survey. More broadly, I would like to thank the Provo community for their willingness to participate in the survey and for being genuinely interested in their water resources.

Lastly, thank you to my parents, Chip and Amy Staley, and my brother, Thomas Staley, for their unwavering love and support these past four years. I am not writing these words without them.

## Table of Contents

|                                                                                          |    |
|------------------------------------------------------------------------------------------|----|
| Dedication .....                                                                         | v  |
| Acknowledgments.....                                                                     | vi |
| List of Tables .....                                                                     | ix |
| List of Figures .....                                                                    | x  |
| Chapter I. Introduction.....                                                             | 1  |
| Research Significance and Objectives .....                                               | 4  |
| Background .....                                                                         | 5  |
| Desalination .....                                                                       | 7  |
| Wastewater Reuse .....                                                                   | 11 |
| Feasibility of Integrating Wastewater Reuse Technologies in the<br>Caribbean Region..... | 12 |
| Water Shortages and Distribution on Provo .....                                          | 14 |
| Research Questions, Hypotheses and Specific Aims.....                                    | 16 |
| Specific Aims.....                                                                       | 16 |
| Chapter II. Methods .....                                                                | 18 |
| Resident Survey .....                                                                    | 18 |
| Economic Modeling: Business-As-Usual Model vs. Solar-Desalination .....                  | 20 |
| Chapter III. Results .....                                                               | 22 |
| Survey Analysis .....                                                                    | 22 |
| Solar-Powered Desalination Plant vs. Business-As-Usual Modeling.....                     | 32 |

|                                                                              |    |
|------------------------------------------------------------------------------|----|
| Business As Usual Model and Payback Period .....                             | 32 |
| Solar-Powered Desalination Plant and Payback Period.....                     | 33 |
| Carbon Emissions Avoided.....                                                | 34 |
| Chapter IV. Discussion .....                                                 | 36 |
| Interpretation of Statistical Analyses .....                                 | 36 |
| Demographic Variables .....                                                  | 36 |
| Response Variables .....                                                     | 37 |
| Recommendations.....                                                         | 42 |
| Research Limitations .....                                                   | 45 |
| Conclusions.....                                                             | 46 |
| Appendix 1. Resident Survey .....                                            | 48 |
| Appendix 2. Business-As-Usual Calculations .....                             | 50 |
| Appendix 3. Solar-Powered Desalination Calculations.....                     | 52 |
| Appendix 4. Diesel-Powered Desalination with Carbon Emissions Costs.....     | 53 |
| Appendix 5 .Solar-Powered Desalination with 24-Hour Operating Capacity ..... | 54 |
| References.....                                                              | 55 |

## List of Tables

|                                                                                                                         |    |
|-------------------------------------------------------------------------------------------------------------------------|----|
| Table 1. Summary statistics for all survey questions, stratified by distribution method...                              | 23 |
| Table 2. P-values of demographic variables regressed individually against all 12 response variables. ....               | 29 |
| Table 3. P-values of all 12 response variables regressed individually against the remaining 11 response variables. .... | 31 |
| Table 4. Business-As-Usual calculations.....                                                                            | 50 |
| Table 5. Solar-powered desalination calculations .....                                                                  | 52 |
| Table 6. Diesel-powered desalination with carbon emissions costs .....                                                  | 53 |
| Table 7. Solar-powered desalination with 24-hr operating capacity .....                                                 | 54 |

## List of Figures

|                                                                         |    |
|-------------------------------------------------------------------------|----|
| Figure 1. Provo Water's (2025) distribution map for Providenciales..... | 15 |
| Figure 2. Categories of survey response variables.....                  | 22 |

## Chapter I

### Introduction

*“Water, the Hub of Life. Water is its matter and matrix, mother and medium. There is no life without water”.*

—Albert Szent-Györgi, Nobel Prize-winning physiologist

Small Island Developing States (SIDS) bear the brunt of the effects of climate change. SIDS are disproportionately exposed to hurricanes and other extreme weather events (including drought), which are increasing in frequency and intensity (UNDP, 2024). Changing precipitation patterns and severe droughts are particularly straining Caribbean water resources, with water demand outstripping supply (Nibbs, 2024). Rapid industrialization and urbanization are straining water supplies, as over 75% of the Caribbean’s population now lives in cities (Nibbs, 2024). Increases in tourism, coupled with massive losses of treated water through insufficient water infrastructure, have resulted in instances of water scarcity in every Caribbean nation at least once in the last five years (Nibbs, 2024). A study conducted by the Development Bank of Latin America and the Caribbean found that Caribbean countries lose half of their available water due to outdated infrastructure and inefficiencies (UNDP, 2024).

In response, island nations have increased reliance on desalination of plentiful sea water resources, although desalination is energetically and financially expensive (World Economic Forum, 2022). According to a Bloomberg study, 15,000 kWh is needed to produce one million gallons of freshwater using desalination (World Economic Forum,

2022). Assuming the average Caribbean resident consumes 100 gallons per day, these one million gallons will only supply 10,000 Caribbean residents with their daily water supply. Additionally, desalination processes produce brine, a potential ocean pollutant. However, the major environmental hazard posed by brine is excess salt. (Gies, 2019).

As water demand increases, these nations will have to choose whether to expand their desalination capacity or explore less energy-intensive alternatives. Wastewater recycling is a developing alternative water production method. Wastewater reuse requires a little over half the energy of desalination (8300 kWh) to produce the same volume of freshwater (World Economic Forum, 2022). It is important to consider that countries favoring desalination processes are usually energy producers, and therefore do not face the high fuel costs, plus import tax and transport costs, that SIDS do. While potable reuse of wastewater is less energy-intensive than desalination and does not carry the same environmental risks, there are drawbacks. One obstacle that must be considered is public perception surrounding drinking reused wastewater. Many people are understandably hesitant to drink water that is associated with human waste. This is called the “yuck” factor and has unfortunately led to the creation and popularizing of such derogatory phrases as “sewer-mining” and “toilet-to-tap” (Lund et al, 2019). This public perception could undermine any investment in potable reuse.

There are few studies evaluating the feasibility of implementing wastewater reuse or alternative freshwater resource technologies in arid island nations. As countless arid island nations and cities are forced to increase water production because of climate change and population and tourism increases, these decisions cannot be made blindly or

haphazardly. Decisions regarding which water production method to utilize have serious implications for environmental sustainability and ecosystem health.

This dilemma is illustrated by Providenciales (Provo), the most populous island in the British overseas territory, the Turks and Caicos Islands (TCI) located in the Northern Caribbean Sea. TCI supports a growing economy reliant on tourism and ecotourism. Currently, this arid island relies on desalination plants to supply clean drinking water to both its residents and its visitors. Provo Water is the sole water utility on Provo and utilizes only desalination for water production. The effluents of Provo's desalination plants (brine) is discharged directly into the ocean. Currently, Provo's electricity utility, Fortis TCI, generates electricity using only low-sulfur diesel fuel (Fortis TCI, 2024). Most desalination plants operate using highly polluting fossil fuels, although HAB Group, a leading TCI property developer and major investor in desalination plants on Provo, has begun several solar and electric fleet projects (HAB Group, 2024).

In addition, current water provisioning in Caribbean SIDS includes heavy use of bottled water, both in large dispensers and individual single-use plastic bottles. In addition to questions of drinking water provisioning, plastic waste management and bottled water imports pose sustainability risks for the greater Caribbean region. Few Caribbean nations have a comprehensive waste management plan. It is estimated that 54% of solid waste is disposed of in sanitary landfills, with the remaining waste being dumped illegally or entering the marine environment (Courtene-Jones et al., 2021). Additionally, in 2018 it was estimated that the Caribbean and Latin American region comprised 11% of global waste production and less than 5% of that waste was being recycled. It has also been estimated that roughly 12% of the waste stream in the region is

plastic (Courtene-Jones et al., 2021). Plastic bottled water containers contribute significantly to the plastic waste stream in the Caribbean and seriously damage vital marine ecosystems.

As seasonal populations continue to increase, the people of Provo will be forced to (consider ways to) increase water production (Rose, 2024). Decision makers in Provo and beyond must evaluate whether desalination is a sustainable, cost-effective solution to the drinking water problem, or if there are alternative water resource options that can be explored. For instance, is it feasible for Provo to diversify their water production technologies and eventually move away from such energetically expensive production methods like desalination? Can Provo Water utilize alternative energy sources to power future and existing water production methods? Provo must expand their freshwater infrastructure imminently, so analyses of various water resource technologies and their long-term financial feasibility is critical.

### Research Significance and Objectives

This research informs government officials and the people of arid island nations of key sustainability-related tradeoffs of alternative water production investments. Instead of blindly expanding water production technologies such as diesel-powered desalination, decision makers can use these results to compare these costs and benefits with those solar-powered water production through various sustainability lenses.

My research objectives were to:

- Determine the environmental, social, and economic costs and benefits associated with the expansion of desalination technologies on Provo

- Compare these costs and benefits with those associated with construction of a solar-powered desalination plant
- Determine Provo residents' willingness to pay for improved water services and willingness to drink reused wastewater by surveying communities
- Provide decision makers in Provo with the data to make informed decisions and ensure equitable access to drinking water for all residents

### Background

By 2030, 50% of the global population will suffer from water insecurity or water scarcity (Mycoo & Roopnarine, 2024). Coastal populations will experience disproportionately greater negative impacts of water scarcity. Sea level rise will increase salt quantities in groundwater supplies and growing freshwater demand in developing coastal areas will only compound saltwater intrusion (Mishra 2023). Among coastal regions, SIDS are most vulnerable to water insecurity. Water scarcity in SIDS is exacerbated by limited freshwater resources, particularly the lack of freshwater groundwater reserves (Mycoo & Roopnarine, 2024).

Climate change presents a serious threat to available freshwater resources in the Caribbean region, as annual rainfall continues to decrease (Roopnarine, et al., 2023). Additionally, a decrease in annual precipitation of 10-30% by 2080 is projected for the Caribbean region (Peters, 2015). Coupled with higher temperatures, significant reductions in wet season rainfall across the Caribbean are particularly problematic for freshwater flows and groundwater recharge (Cashman, 2014). These projections are alarming, especially given preexisting supply and demand gaps in many Caribbean

countries. Barbados is utilizing nearly 100% of available supply, St. Lucia had a water supply deficit of approximately 35%, and Nevis of 40% in 2013 (Cashman, 2014).

Changing population dynamics and increasing incomes have been identified as two of the primary drivers of water demand increase in the Caribbean (Cashman, 2014). Specifically, rising standards of living, changes in the age distribution of populations, and urbanization are increasing daily water consumption per capita (Cashman, 2014). Ironically, Caribbean populations are not rising – in fact, nations in the region are experiencing a net migration out of their countries (Cashman, 2014). Thus, individual habits and failing water infrastructure are driving up consumption of freshwater resources (Cashman, 2014).

Coral reef-driven tourism also increases water demand in the Caribbean. Spalding et al. (2018) estimated that reef-adjacent expenditure in the Caribbean was \$5.7 billion annually and drives 7.4 million tourist visits. Average annual tourism visitation in Providenciales is 660,000 visitors, spending \$473,000 per square kilometer of reef. Additionally, tourists use more water than residents. Per capita water use in the Caribbean tourism industry was estimated at between 1.5-2.5x the domestic use per capita in 2011 (Ceron et al., 2012). Tourism, however, is economically vital to the region, and contributes to an average of 40% of the gross domestic product across the region (Rasoolimanesh, et al., 2020). High water consumption in the tourism industry is linked to: “extensive landscaping, water parks, swimming pools, and golf courses” (Rasoolimanesh, et al., 2020, p. 1501).

SIDS encounter unique challenges in water provisioning. In other arid regions globally, fresh water can simply be pumped from elsewhere to provide adequate

resources for populations. SIDS have developed several water production innovations to overcome these challenges. Many SIDS rely at least partially on rainwater harvesting (RWH) and storage in above-ground cisterns for household supply (Roopnarine, et al., 2021). However, this method of water provisioning is largely unregulated and decentralized, and is, at its largest, community wide. Water procurement from aquifers and groundwater is becoming increasingly difficult and costly due to saltwater intrusion, improper land use, land degradation, water pollution from inadequate wastewater treatment (approximately 85% of Caribbean wastewater is untreated), industrial activities, and urban and agricultural runoff (Mycoo & Roopnarine, 2024). Thus, SIDS have come to rely heavily upon seawater desalination for drinking water.

## Desalination

Seawater desalination has been utilized as a potential solution for global water scarcity, with total global capacity reaching 97.2 million cubic meters per year in February 2020 (Eke, et al., 2020). The industry is expected to grow by 40% by 2030, surpassing 54 billion cubic meters per year in capacity (Salah & Mezher, 2021). The same study evaluated the energetic and environmental impacts of desalination reliance in the United Arab Emirates (UAE). In 2020, desalination in the UAE accounted for 12%-22% of total produced electricity. It is important to note that energy costs in the UAE are significantly lower than in Caribbean SIDS, potentially explaining the UAE's willingness to produce substantial electricity to power desalination plants. Desalination effluent also presents coastal pollution concerns, including alterations to seawater salinity from brine, introduction of toxic antifoulants and antiscalants, and thermal alterations. It is also

important to note that while the example of the UAE offers some usable insights, the UAE does not rely on reef tourism (as Caribbean SIDS do), which reduces the potential negative impacts of brine discharge into the coastal ecosystem.

Besides production impacts, there are also negative externalities associated with the desalination process that have not been broadly studied (Salah & Mezher, 2021). The effluents of desalination brine present environmental hazards. Typically, brine is discharged directly into the ocean. Brine may contain residues of cleaning chemicals, reaction byproducts, and heavy metals from equipment corrosion, all of which are detrimental to marine life (Gies, 2019). However, the major environmental hazard posed by brine is excess salt. In certain locations in the Arabian Gulf, Red Sea, and Mediterranean Sea, brine discharge has resulted in seas that are 25% saltier than natural levels. Excess salt decreases dissolved oxygen in the water, which suffocates marine life (Gies, 2019).

Sirota et al. (2024) examined the environmental impacts of brine discharge on benthic organisms including bacteria, seagrasses, coral, and polychaetes. Hypersaline brine caused a reduction in seagrass cover up to 40%, decreased leaf and shoot size, reduced growth rates by up to 26%, and reduced shoot abundance (Sirota et al., 2024). The study also found that most hard corals around a brine discharge area in the Red Sea, where salinity was 42‰ over the ambient, disappeared. Similarly, corals within several tens of meters from the discharge in the Arabian Gulf were extensively damaged or dead (Sirota et al., 2024). Finally, Sirota et al. (2024) also found that brine plumes may reduce nutrient fluxes from the sediment into the water column, significantly altering the marine biogeochemistry, resulting in cascading changes in food-web dynamics.

Kelagher et al. (2019) conducted a seven-year assessment of the responses of fish assemblages to hypersaline discharge from the Sydney Desalination Plant in Sydney, Australia. The researchers sampled reef fishes at two outlet sites and two nearby reference sites, as well as four reference sites that were located 2-8 kilometers from the outlet. Counterintuitively, “following the commencement of discharging, there was a 279% increase in the abundances of fish around the outlet, which included substantially greater abundances of pelagic and demersal fish, as well as fishes targeted by recreational and commercial fishers” (Kelagher et al., 2019, p. 739). Additionally, “Following cessation of discharge, abundances of fishes mostly returned to levels such that there was no longer a significant effect compared to the period prior to the commencement of the desalination plant’s operations” (Kelagher et al., 2019, p.740). These results suggest that although sudden increases in local ocean temperature may temporarily bolster fish populations, there is no long-term fish population benefit associated with desalination brine.

Past studies have leveraged economic modeling to analyze cost-effectiveness and financial competitiveness of desalination. Mohammadi et al. (2019) utilized levelized cost of water (LCOW) and net present value (NPV) to quantify the costs and benefits of desalination plants, using Kuwait as a case study. The study found that desalination can be very expensive, but “can be cost competitive in some environments, given an appropriate design and configuration. Design improvements that lead to cost reduction include combination with thermal power plants, employment of zero-marginal-cost renewable generation, and coordinated operation with the power system” (Mohammadi et al., 2019, p.1097). As shown in their modeling, coordinated scheduling of power

generation and water desalination can result in significant savings in dispatch cost with flexible water production rate.

However, Mohammadi et al.'s (2019) study was limited to economic factors and did not address various environmental or social factors. In the Caribbean, based on historical data, the estimated total cost of building a reverse osmosis (RO) desalination plant with a five million gallon per day (MGD) capacity was estimated as \$10-\$16 million (Herber, 2024).

Palatnik (2019) estimated the economic benefit of desalination gained by reducing water shortages that cause nationwide economic loss in Israel. The value of desalinated seawater by diminishing potable water shortages was estimated to be \$4 per cubic meter, which is significantly higher than its direct cost (Palatnik, 2019). The author employed the "Israeli Computable General Equilibrium (CGE) model, which estimates the benefit of desalination gained by reducing water shortages that cause an economic loss with impact on the entire Israeli economy" (Palatnik, 2019, n.p). CGE "assessed the impact of water shortages on key economic indicators, where shortage values are equivalent to the amounts of desalinated water" (Palatnik, 2019, n.p.). These indicators included the price of potable water, agricultural production, the price of agricultural products, and the GDP (Palatnik, 2019). Specifically, the study found that as desalination capacity increased, expected GDP loss because of water shortages declined (Palatnik, 2019). However, this study was limited to studying GDP loss as a result of water shortages and failed to address potential GDP loss due to brine discharge pollution in coral reefs. For example, effluent from desalination impacts the blue economy, especially jobs in the fisheries and tourism sectors (Salah & Mezher, 2021).

## Wastewater Reuse

Currently, the United States touts the highest number of wastewater reuse projects. As of 2017, 14 states had devised policies to regulate wastewater reuse, and three states had created policies to address direct potable reuse (Roopnarine et al., 2023). California provides a key example of the success of wastewater reuse implementation, as the state allows reclaimed water to be directly discharged to surface water reservoirs that are utilized for drinking water (Roopnarine et al., 2023). The most popularized potable recycling project in California is the Orange County Groundwater Replenishment System. The system supplies potable reused water for an estimated 850,000 California residents (Tortajada, 2020). The groundwater recharge system also protects the basin from seawater intrusion (Tortajada, 2020). The system produces 130 million gallons of water per day (OCWD, 2024).

Countries like Namibia and Singapore have integrated wastewater reuse as well, and Namibia has been utilizing this water resource for over 55 years to manage drought and scarcity (Akpan et al., 2020). Singapore's reclaimed water project, called NEWater, already accounts for 40% of daily consumption, and is predicted to increase by 15% in the next 40 years (Akpan et al., 2020). Israel has also demonstrated development of reclaimed wastewater technologies for irrigation and groundwater recharge (Roopnarine et al., 2023). Well-developed technologies for irrigation in the agricultural sector have been noted in Bahrain, where chlorine is used to treat wastewater, and Kuwait, Tunisia, and the UAE, where ultraviolet radiation is used for disinfection (Guerra-Rodriguez et al., 2020). Morocco utilizes maturation ponds, ozonation is utilized in Saudi Arabia, and

waste stabilization ponds and aerated lagoons have been proven effective in Jordan and Tunisia (Guerra-Rodriguez et al., 2020).

Globally, a handful of alternate technologies have been developed to reclaim and recycle wastewater, including: “rotational microscreens, vortex grit chambers, anaerobic, facultative and polishing lagoons, up-flow anaerobic sludge blanket reactors, anaerobic filters, piston anaerobic reactors, anaerobic baffled reactors, activated sludge, and sequencing batch reactors” (Roopnarine et al., 2023, p. 1164). However, Peters (2015) found that the most common technology existing in the Caribbean region was the sequencing batch reactor (SBR). The case of Singapore presents a comparable model for economic valuation of a wastewater reuse facility (PUB, 2024).

#### Feasibility of Integrating Wastewater Reuse Technologies in the Caribbean Region

Many countries that are considered small island developing states (SIDS) are increasingly developing wastewater reuse technologies to meet growing demand due to tourism. However, most current wastewater reuse in the region is limited to irrigation use. In Barbados, wastewater is solely used for landscaping purposes within the tourism industry (Jones et al., 2021). In Jamaica and St. Kitts and Nevis, wastewater is primarily reused for irrigating golf courses, and 39% of resorts in the Grenadines use treated wastewater for irrigating (Jones et al., 2021). Additionally, there are countless examples of Caribbean resorts utilizing small-scale wastewater reuse technology for irrigation to conserve water (Nottleson, 2023).

The government of Trinidad and Tobago provides a useful example of legislation and policies that remove barriers to creating centralized wastewater reuse plants. Priority 2 of the National Environment Policy aims to “encourage water conservation through

recycling and wastewater reuse programs and projects” (Roopnarine et al., 2023, p. 1168). Wastewater reuse standards were created in the country in 2022 through the Trinidad and Tobago Bureau of Standards, the Ministry of Public Utilities, and various government and non-government stakeholders (Roopnarine et al., 2023). In Barbados, there is national legislation that requires all hotels and resorts to install their own wastewater treatment plants to provide irrigation water for golf courses (Peters, 2015). The World Bank also published a manual in 2020 offering financing and legislative advice for developing centralized water reclamation infrastructure in the Caribbean (World Bank, 2020).

Future estimates for Caribbean countries forecast that “demand for water by hotels, cruise ships, and golf courses will be approximately one third of total demand” (Peters, 2015, p. 987). Much of this water demand is for non-potable uses – for instance, at the Sandals Resort in Trinidad and Tobago, 33% of all water consumed was for irrigation, and 4% was used for toilet flushing (Peters, 2015). Peters (2015) found that in the Barbados and Jamaica, the tourism industry accounted for 16% and 14% of total water use, respectively.

Public perception of wastewater reuse is critical for successful implementation, and there are often barriers to convincing residents that recycled wastewater is safe to drink. Peters and Goberdhan (2016) found that residents of Trinidad and Tobago were not comfortable with potable reuse of wastewater, only reuse for non-potable purposes. Perceptions of wastewater reuse were influenced by “public mistrust of the local water authority, lack of knowledge of the treatment process, and perceived health risks associated with using treated wastewater” (Peters & Goberdhan, 2016, p. 37). Thus,

although potable reuse of wastewater may be technically feasible, Caribbean residents are likely more inclined to support reuse for non-potable purposes.

#### Water Shortages and Distribution on Provo

Provo is becoming the tourist capital of the Caribbean due to its pristine beaches and exquisite marine ecosystems. In 2023, Provo welcomed well over 660,000 international tourists (over 10 times its resident population) via air travel, a 36% increase from 2019 (Tourism Analytics). Tourism is expected to increase on Provo as the concept of “last chance tourism” popularizes with the looming extinction of coral reefs. People are flocking to the Caribbean to catch a glimpse of a disappearing ecosystem.

Increased tourism will exacerbate already-existing water insecurity on Provo and threaten the viability of tourism as Provo’s major economic driver. Increased hurricane intensity, coupled with decreased precipitation predictability will subject the island to extreme drought and flood events and threaten water infrastructure (ECLAC, 2011; Nibbs, 2024)

Provo Water, one of Provo’s sole water utility, supplies in-home water throughout much of the island. However, there are significant low-income communities that are not connected to the water distribution system and are forced to travel to nearby grocery stores to obtain drinking water (Figure 1). Provo Water has intricately connected the Grace Bay and Leeward neighborhoods to potable water (central and eastern portion of the island). The water users in these areas are predominantly tourists and European/American seasonal residents. However, the western region of the island is noticeably unconnected. This area is predominantly populated by Turks Islanders.

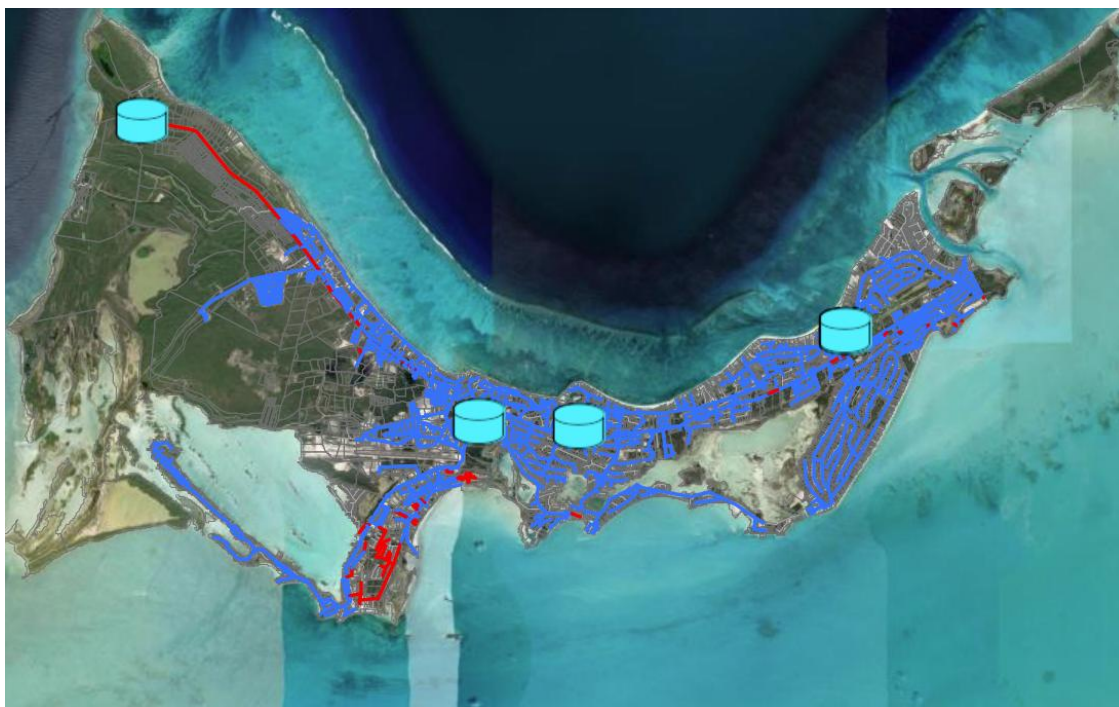


Figure 1. Provo Water's (2025) distribution map for Providenciales.

*Note. Inactive distribution lines (red), operational distribution lines (blue), and water storage infrastructure (light blue cylinders).*

Provo Water will soon be forced to increase water production capacity to meet increasing demand. However, the irrigation demands of the tourism industry may present Provo Water with an opportunity to reduce costs and utilize reused wastewater. Additionally, a more complete understanding of Provo residents' drinking water preferences and perceptions may provide guidance for Provo Water in planning a more sustainable water resource future. Specifically, are there identifiable variables—demographic or non-demographic—which influence individuals' preferences in water delivery and drinking water sourcing.

## Research Questions, Hypotheses and Specific Aims

The main research questions I evaluated and their associated hypotheses were:

- 1) What are the economic and social costs and benefits associated with construction of additional desalination facilities on Provo?
  - H1: The energy use costs and greenhouse gas pollution costs of constructing additional desalination facilities financially exceed any economic gains expected from additional water resources because:
    - H1a: Desalination's energy requirements significantly increase the TCI's carbon footprint.
- 2) How much are residents of Provo willing to pay as a monthly premium for improved access to piped water 24 hours a day, and are residents open to potable reuse of wastewater?
  - H2: Greater than 75% of residents will be willing to pay a monthly premium for in-home access to drinking water 24 hours a day.
  - H3: Greater than 50% of residents surveyed will be open to potable reuse of wastewater.

## Specific Aims

My specific aims for completing this research were to:

1. Conduct background research on explicit costs and benefits of wastewater reuse and ocean desalination technologies in the Caribbean region.
2. Interview contacts within the TCI government and Provo Water to inform the design of the research.

3. Create a survey and distribute it within underserved Provo communities to determine resident willingness to pay for improved water resources and willingness to use recycled wastewater.
4. Conduct financial modeling analysis of increased desalination capacity on Provo and feasibility analysis of implementing solar-powered desalination technology.

## Chapter II

### Methods

The aims of this study were to gain a more comprehensive understanding of Provo residents' attitudes and behaviors related to drinking water and water resources, to explore the possibilities of alternative drinking water resource production through wastewater recycling, and to model a potential future production method and compare it to a business-as-usual scenario.

#### Resident Survey

An 18-question survey was created and distributed to Provo residents over the age of 18 to better understand resident attitudes toward water resources (Appendix 1). The survey was submitted to the Harvard University IRB committee and approved before distribution began (IRB25-0403). The survey was designed to be completed in 5-10 minutes, with few barriers to entry. The dominant languages of Provo are English, Haitian Creole, and Spanish. Versions of the survey were available in both English and Haitian Creole. No version of the survey was available in Spanish due to the absence of an official translator. The Harvard Qualtrics survey engine was utilized to collect data, and the survey was made available digitally. Respondents could either use a shareable link or scan a QR code to take the survey. Initially, QR code posters were distributed throughout Provo in public places and oft-visited stores and institutions, such as grocery stores, water fill stations and churches. The survey was also distributed via religious

organizations, which are prevalent in Provo. The link was shared to church administrators and subsequently posted in a church weekly newsletter. The link was also shared with the local hospital in Provo. The link and QR code were also shared via email and WhatsApp to connections and acquaintances with family and friends living in Provo.

Additionally, in-person recruitment was conducted in Provo to actively encourage residents to take the survey. Eight survey recruitment sessions, all on Sundays, took place between May 2025 and December 2025. During the first trip to Provo, laminated QR code posters were posted in public places, specifically community bulletin boards in grocery stores and churches. Additionally, QR code posters were posted at water fill stations. In-person recruitment began on the second visit to Provo and occurred at various grocery stores and storefronts throughout multiple Provo neighborhoods to ensure that results were not preferential to any neighborhood or demographic. A total of 40 hours were spent in the field conducting in-person recruitment. Often, the survey had to be read aloud to ensure that the participant understood the question. It was advantageous to conduct the survey live and in-person. However, this method was time consuming and energetically demanding.

Simple linear regression and multiple regression analyses were conducted to further understand the relationships between demographic variables, non-demographic variables, drinking water preferences, and water delivery preferences. Survey responses were analyzed in RStudio 4.5.1 to uncover significant relationships between specific responses. Additionally, relationships between specific water provisioning responses were analyzed. All response variables were also regressed against each other to determine

if there were any significant statistical relationships between respondents' water preferences.

#### Economic Modeling: Business-As-Usual Model vs. Solar-Desalination

To inform modeling decisions, informal interviews were conducted with knowledgeable individuals intimately involved in both the Provo water resource landscape and renewable energy resources in the Caribbean. First, Jared Fulton, the Director of Operations at the Turks and Caicos Water Company was interviewed to gain a more complete understanding of the needs and plans of water resource institutions in Provo. Jared Fulton of HAB Group/Provo Water provided valuable data to use for reference. He also provided useful recommendations regarding projects that Provo Water would possibly entertain. Mr. Fulton detailed that battery backup in any solar-desalination pairing would not be utilized to power desalination operations during periods of no sunlight. Instead, battery backup would be used to ease the transition from solar power back to the grid when solar power is offline. The interruption to the grid if the entire load of the desalination plant would potentially be disastrous. Battery backup would gradually add the load requirements of the plant to the grid and drastically decrease the chance of blackouts. Mr. Fulton also expressed the interest of the water company in constructing a solar desalination plant to meet Provo's growing freshwater needs.

Additionally, Maxime Therrillion, head of business development at Osmosun, was interviewed to understand the mechanics and economics of solar-desalination projects. Osmosun is a French company that operates in 30 countries spread across four continents. The project of interest is situated in St. Kitts and Nevis. Osmosun constructed

a solar desalination system that has a capacity of 13.6 cubic meters of clean water produced per hour. Mr. Therrillion was consulted to determine if the Osmosun model could be utilized in Provo as water production capacity expands. It was determined that Osmosun was not able to support the growing demand of Provo. It is a company of interest for the future of Provo water production if the island shifts to more of a microgrid of water distribution.

To inform recommendations for the Provo government and water management, an economic and environmental model was developed to model two desalination options on Provo. The first option was a business-as-usual model to double desalination capacity, utilizing the same diesel fuel source as the existing desalination plant. The second option modeled was identical to the first, except utilizing solar power as a fuel source. Capital expenditure (capex) categories included the following: land acquisition, land preparation, intake infrastructure, outfall infrastructure, reverse osmosis technology, pumps and energy recovery devices, utilities connections, buildings and facilities, initial membrane stock and spare parts, engineering costs, procurement costs, and construction costs. Operational expenditure (opex) categories included the following: labor, insurance, administrative, maintenance and repairs, membrane and parts replacements, regulatory compliance monitoring, treatment chemicals, membrane cleaning, chemicals, and energy costs. Environmental costs were simplified to magnify the dependent environmental cost (emissions) and included brine effluent and emissions.

## Chapter III

### Results

The survey results are first presented, followed by the results of the economic modeling options.

#### Survey Analysis

Figure 2 illustrates the water preference response variables, color-coded by question category.

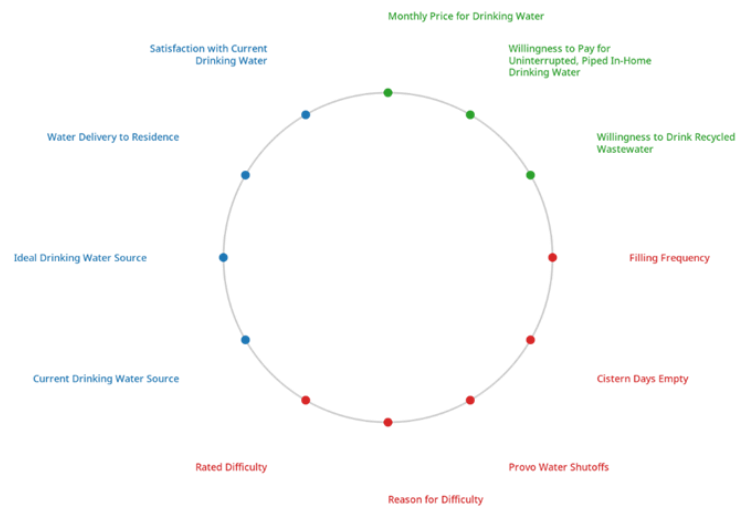


Figure 2. Categories of survey response variables.

*Note. Blue variables denote specific drinking water sources. Green variables denote financial/willingness-related variables. Red variables denote potential difficulties/complaints/inconveniences associated with water source preferences.*

The distribution of responses to the survey questions and relevant summary statistics are shown in Table 1. Demographic variables consisted of age, gender, nationality, residence, and household size. Although language spoken at home was also included in the survey, it was not included in analysis due to lack of variation. P-values indicate significance in the distribution of responses between the two survey methods.

Table 1. Summary statistics for all survey questions, stratified by distribution method.

| Variable                      | Resident Response   | Link Distribution (%) | QR Distribution (%) | P Value |
|-------------------------------|---------------------|-----------------------|---------------------|---------|
| Survey Language               | English             | 126 (99.2)            | 8 (100)             | 1.000   |
|                               | Creole              | 1 (0.8)               | 0 (0)               |         |
| Difficulty                    | Mean (0-10)         | 2.69                  | 4.12                | 0.110   |
| Reason for Difficulty         | Distance            | 14 (11.3)             | 2 (25.0)            | 0.694   |
|                               | Inconvenience       | 18 (14.5)             | 2 (25.0)            |         |
|                               | Not Difficult       | 73 (58.9)             | 4 (50.0)            |         |
| Current Drinking Water Source | Price               | 14 (11.3)             | 0 (0)               | 0.157   |
|                               | Weight              | 4 (3.2)               | 0 (0)               |         |
|                               | Weight and Distance | 1 (0.8)               | 0 (0)               |         |
|                               | Cistern             | 1 (0.8)               | 0 (0)               |         |
|                               | Leeward Water       | 2 (1.6)               | 0 (0)               |         |
|                               | Oasis               | 1 (0.8)               | 0 (0)               |         |
|                               | Other               | 4 (3.1)               | 1 (12.5)            |         |
|                               | Provo Water         | 50 (39.4)             | 6 (75.0)            |         |
|                               |                     |                       |                     |         |

| Variable                    | Resident Response                 | Link Distribution | QR Distribution | P Value |
|-----------------------------|-----------------------------------|-------------------|-----------------|---------|
|                             | Provo Water and Cistern           | 1 (0.8)           | 0 (0)           |         |
|                             | Rainwater                         | 1 (0.0)           | 1 (12.5)        |         |
|                             | Supermarket                       | 19 (15.0)         | 0 (0)           |         |
|                             | TC Crystal                        | 40 (31.5)         | 0 (0)           |         |
|                             | TC Crystal and Supermarket        | 6 (4.7)           | 0 (0)           |         |
|                             | Water Truck                       | 2 (1.6)           | 0 (0)           |         |
|                             | Current Price Paid Per Month      |                   |                 |         |
|                             | 1-25                              | 34 (28.6)         | 1 (50.0)        |         |
|                             | 26-50                             | 36 (30.3)         | 0 (0)           |         |
|                             | 51-100                            | 19 (16.0)         | 0 (0)           |         |
|                             | More Than 100                     | 30 (25.2)         | 1 (50.0)        |         |
| Current Water Delivery Mode | Cisterns with Water Delivery      | 6 (4.7)           | 1 (12.5)        | 0.077   |
|                             | Fill                              | 54 (42.5)         | 2 (25.0)        |         |
|                             | Piped in-home                     | 47 (37.0)         | 4 (50.0)        |         |
|                             | Provo Water                       | 1 (0.8)           | 0 (0)           |         |
|                             | Rainwater                         | 1 (0.8)           | 1 (12.5)        |         |
|                             | Supermarket                       | 18 (14.2)         | 0 (0)           |         |
|                             | Shutoffs per month                |                   |                 |         |
|                             | 0                                 | 54 (42.5)         | 4 (50.0)        | 0.453   |
|                             | 1-2                               | 42 (33.1)         | 1 (12.5)        |         |
|                             | 3 or more                         | 6 (4.7)           | 0 (0)           |         |
|                             | I am not connected to Provo Water | 25 (19.7)         | 3 (37.5)        |         |

| Variable                    | Resident Response          | Link Distribution | QR Distribution | P Value |
|-----------------------------|----------------------------|-------------------|-----------------|---------|
| Empty days before refill    | 0                          | 37 (30.1)         | 2 (25.0)        | 0.203   |
|                             | 1-2                        | 10 (8.1)          | 0 (0)           |         |
|                             | 3 or more                  | 2 (1.6)           | 1 (12.5)        |         |
|                             | I do not have a cistern    | 74 (60.2)         | 5 (62.5)        |         |
| Filling Frequency Per Month | 0                          | 6 (4.8)           | 0 (0)           | 0.394   |
|                             | 1-2                        | 22 (17.5)         | 0 (0)           |         |
|                             | 3 or more                  | 59 (46.8)         | 3 (42.9)        |         |
|                             | Does not use fill stations | 39 (31.0)         | 4 (57.1)        |         |
| Ideal Water Source          | Bottles Delivered          | 1 (0.8)           | 0 (0)           | <0.001  |
|                             | Cistern                    | 9 (7.6)           | 0 (0)           |         |
|                             | Piped directly to home     | 80 (67.2)         | 1 (50.0)        |         |
|                             | Rainwater Cistern          | 0 (0)             | 1 (50.0)        |         |
|                             | Refill Station             | 22 (18.5)         | 0 (0)           |         |
|                             | Supermarket                | 5 (4.2)           | 0 (0)           |         |
|                             | Well                       | 2 (1.7)           | 0 (0)           |         |
| Satisfaction                | Mean (0-10)                | 7.41              | 6.00            | 0.233   |
| Willingness to Pay (USD)    | 0-25                       | 47 (39.5)         | 0 (0)           | 0.039   |
|                             | 25-50                      | 16 (13.4)         | 0 (0)           |         |
|                             | 50-75                      | 27 (22.7)         | 1 (25.0)        |         |
|                             | 75-100                     | 11 (9.2)          | 0 (0)           |         |

| Variable                | Resident Response         | Link Distribution | QR Distribution | P Value |
|-------------------------|---------------------------|-------------------|-----------------|---------|
| Recycled Wastewater Age | 100-125                   | 9 (7.6)           | 2 (50.0)        |         |
|                         | 125+                      | 9 (7.6)           | 1 (25.0)        |         |
|                         | Mean (0-10)               | 2.12              | 0.60            | 0.252   |
|                         | 18-24                     | 28 (24.1)         | 1 (20.0)        | 0.191   |
|                         | 25-34                     | 25 (21.6)         | 0 (0)           |         |
|                         | 35-44                     | 21 (18.1)         | 3 (60.0)        |         |
|                         | 45-54                     | 20 (17.2)         | 0 (0)           |         |
|                         | 55-64                     | 12 (10.3)         | 0 (0)           |         |
|                         | 65+                       | 10 (8.6)          | 1 (20.0)        |         |
|                         |                           |                   |                 |         |
| Gender                  | Female                    | 74 (59.7)         | 1 (20.0)        | 0.004   |
|                         | Male                      | 47 (37.9)         | 3 (60.0)        |         |
|                         | Non-Binary / Third Gender | 2 (1.6)           | 0 (0)           |         |
|                         | Prefer Not to Say         | 1 (0.8)           | 1 (20.0)        |         |
| Nationality             | Bahamian                  | 5 (4.0)           | 0 (0)           | 0.014   |
|                         | Bahamian/TC Islander      | 1 (0.8)           | 0 (0)           |         |
|                         | British                   | 4 (3.2)           | 0 (0)           |         |
|                         | Cameroonian               | 1 (0.8)           | 0 (0)           |         |
|                         | Canadian                  | 1 (0.8)           | 1 (20.0)        |         |
|                         | Caribbean                 | 2 (1.6)           | 0 (0)           |         |
|                         | Dominican                 | 1 (0.8)           | 0 (0)           |         |

| Variable  | Resident Response         | Link Distribution | QR Distribution | P Value |
|-----------|---------------------------|-------------------|-----------------|---------|
| Residence | European                  | 1 (0.8)           | 0 (0)           | 0.110   |
|           | Filipino                  | 5 (4.0)           | 0 (0)           |         |
|           | Grenadian                 | 1 (0.8)           | 0 (0)           |         |
|           | Guyanese                  | 4 (3.2)           | 0 (0)           |         |
|           | Haitian                   | 18 (14.5)         | 0 (0)           |         |
|           | Indian                    | 2 (1.6)           | 0 (0)           |         |
|           | Indonesian                | 0 (0)             | 1 (20.0)        |         |
|           | Jamaican                  | 11 (8.9)          | 0 (0)           |         |
|           | Other                     | 5 (4.0)           | 0 (0)           |         |
|           | Trinidadian               | 1 (0.8)           | 0 (0)           |         |
|           | Turkish                   | 1 (0.8)           | 0 (0)           |         |
|           | Turks and Caicos Islander | 58 (46.8)         | 3 (60.0)        |         |
|           | TC Islander/Haitian       | 1 (0.8)           | 0 (0)           |         |
|           | Vincentian                | 1 (0.8)           | 0 (0)           |         |
|           | Blue Hills                | 30 (24.6)         | 0 (0)           |         |
|           | Blue Mountain             | 2 (1.6)           | 0 (0)           |         |
|           | Butterfield Drive         | 2 (1.6)           | 0 (0)           |         |
|           | Cooper                    | 1 (0.8)           | 0 (0)           |         |
|           | Discovery Bay             | 2 (1.6)           | 0 (0)           |         |
|           | Five Cays                 | 11 (9.0)          | 1 (20.0)        |         |

| Variable | Resident Response | Link Distribution | QR Distribution | P Value |
|----------|-------------------|-------------------|-----------------|---------|
|          | Flamingo Park     | 1 (0.8)           | 0 (0)           |         |
|          | Glass End         | 2 (1.6)           | 0 (0)           |         |
|          | Grace Bay         | 5 (4.1)           | 0 (0)           |         |
|          | Horseshoe Lane    | 1 (0.8)           | 0 (0)           |         |
|          | Juba Sound        | 6 (4.9)           | 0 (0)           |         |
|          | Kew Town          | 7 (5.7)           | 0 (0)           |         |
|          | Leeward           | 8 (6.6)           | 0 (0)           |         |
|          | Leeward Highway   | 1 (0.8)           | 0 (0)           |         |
|          | Leeward Palms     | 2 (1.6)           | 0 (0)           |         |
|          | Long Bay          | 14 (11.5)         | 3 (60.0)        |         |
|          | Other             | 4 (3.3)           | 0 (0)           |         |
|          | Paradise Road     | 1 (0.8)           | 0 (0)           |         |
|          | Ralph Close       | 1 (0.8)           | 0 (0)           |         |
|          | Richmond Hill     | 2 (1.6)           | 0 (0)           |         |
|          | South Dock        | 4 (3.3)           | 0 (0)           |         |
|          | Suzy Turn         | 1 (0.8)           | 0 (0)           |         |
|          | The Bight         | 6 (4.9)           | 0 (0)           |         |
|          | Thompson's Cove   | 2 (1.6)           | 1 (20.0)        |         |
|          | Turtle Cove       | 1 (0.8)           | 0 (0)           |         |
|          | Turtle Tail       | 1 (0.8)           | 0 (0)           |         |

|                |          |         |       |       |
|----------------|----------|---------|-------|-------|
|                | Venetian | 3 (2.5) | 0 (0) |       |
|                | Wheeland | 1 (0.8) | 0 (0) |       |
| Household Size | Mean     | 3.65    | 5.60  | 0.047 |

*Percentages of total respondents within each variable category in parentheses; P-values in 4th column.*

Demographic variables were first regressed against each response variable. Age and household size were the strongest predictors of response variables (Table 2).

Neighborhood of residence, gender, and nationality were poor predictors of all response variables. Respondent age was a strong predictor of drinking water source.

Table 2. P-values of demographic variables regressed individually against all 12 response variables.

| Variable     | Age             | Gender       | Nationality  | Residence | Household Size |
|--------------|-----------------|--------------|--------------|-----------|----------------|
| Difficulty   | 0.15            | 0.79         | 0.54         | 0.89      | 0.47           |
| Reason       | 0.94            | <b>0.088</b> | 0.52         | 0.68      | 0.14           |
| Source       | <b>0.0043**</b> | 0.96         | 0.48         | 0.84      | 0.76           |
| Price        | <b>0.012*</b>   | 0.17         | <b>0.066</b> | 0.51      | <b>0.041*</b>  |
| Delivery     | 0.16            | 0.77         | 0.62         | 0.64      | 0.13           |
| Shutoffs     | 0.28            | 0.34         | 0.16         | 0.25      | 0.83           |
| Empty        | 0.58            | 0.53         | 0.93         | 0.44      | 0.56           |
| Filling      | 0.37            | 0.47         | 0.65         | 0.96      | 0.23           |
| Frequency    |                 |              |              |           |                |
| Ideal Water  | 0.17            | 0.59         | 0.69         | 0.60      | 0.30           |
| Source       |                 |              |              |           |                |
| Satisfaction | <b>0.058</b>    | 0.63         | 0.49         | 0.92      | 0.40           |
| Willingness  | 0.17            | 0.42         | 0.20         | 0.51      | <b>0.083</b>   |
| to Pay       |                 |              |              |           |                |
| Recycled     | 0.36            | 0.18         | 0.39         | 0.40      | 0.75           |
| Wastewater   |                 |              |              |           |                |

*“\*” Denotes  $p < 0.05$ , indicating significance at the 5% level; “\*\*” Denotes  $p < 0.01$ ; “\*\*\*” denotes  $p < 0.001$ , A period mid-line indicates p-value between 0.05 and 0.099.*

All response variables were also regressed against each other to determine if there were any significant statistical relationships between respondents' water preferences. The strongest statistical relationship between response variables was between number of shutoffs per month and number of days respondents' cisterns were empty before being refilled by a water company (Table 3).

Table 3. P-values of all 12 response variables regressed individually against the remaining 11 response variables.

| Variable           | Difficulty      | Reason          | Source          | Price           | Delivery      | Shutoffs          | Empty             | Filling Frequency | Ideal Water   | Satisfaction    | Will-ing-ness   | Recycled |
|--------------------|-----------------|-----------------|-----------------|-----------------|---------------|-------------------|-------------------|-------------------|---------------|-----------------|-----------------|----------|
| Difficulty         | x               | <b>0.0022**</b> | <b>0.076·</b>   | 0.98            | 0.34          | 0.15              | 0.99              | 0.76              | 0.19          | <b>0.0028**</b> | 0.36            | 0.45     |
| Reason             | <b>0.0022**</b> | X               | 0.11            | 0.16            | 0.11          | 0.19              | <b>0.099·</b>     | <b>0.097·</b>     | 0.16          | 0.43            | 0.90            | 0.95     |
| Source             | <b>0.076·</b>   | 0.11            | X               | <b>0.035*</b>   | 0.23          | 0.38              | 0.66              | 0.69              | <b>0.013*</b> | <b>0.0084**</b> | 0.30            | 0.63     |
| Price              | 0.98            | 0.16            | <b>0.035*</b>   | x               | 0.16          | 0.61              | 0.30              | <b>0.058·</b>     | 0.11          | 0.75            | <b>0.0023**</b> | 0.82     |
| Delivery           | 0.34            | 0.11            | 0.23            | 0.16            | X             | 0.61              | <b>0.027*</b>     | 0.17              | 0.51          | <b>0.074·</b>   | 0.46            | 0.87     |
| Shutoffs           | 0.15            | 0.19            | 0.38            | 0.61            | 0.61          | X                 | <b>0.00024***</b> | <b>0.090·</b>     | 0.93          | <b>0.088·</b>   | 0.27            | 0.32     |
| Empty              | 0.99            | 0.099·          | 0.66            | 0.30            | <b>0.027*</b> | <b>0.00024***</b> | x                 | 0.45              | 0.82          | 0.79            | 0.72            | 0.70     |
| Filling Frequency  | 0.76            | <b>0.097·</b>   | 0.69            | <b>0.057·</b>   | 0.17          | <b>0.090·</b>     | 0.45              | X                 | 0.25          | 0.42            | 0.17            | 0.56     |
| Ideal Water        | 0.19            | 0.16            | <b>0.013*</b>   | 0.11            | 0.51          | 0.93              | 0.82              | 0.25              | X             | 0.98            | 0.47            | 0.95     |
| Satisfaction       | <b>0.0028**</b> | 0.43            | <b>0.0083**</b> | 0.75            | <b>0.074·</b> | <b>0.088·</b>     | 0.79              | 0.42              | 0.98          | X               | 0.31            | 0.31     |
| Willingness to Pay | 0.36            | 0.90            | 0.30            | <b>0.0023**</b> | 0.46          | 0.27              | 0.72              | 0.17              | 0.47          | 0.31            | X               | 0.47     |
| Recycled           | 0.45            | 0.95            | 0.63            | 0.82            | 0.87          | 0.32              | 0.70              | <b>0.077·</b>     | 0.56          | 0.72            | <b>0.0093**</b> | x        |

*“\*” Denotes  $p < 0.05$ , indicating significance at the 5% level; “\*\*” Denotes  $p < 0.01$ ; “\*\*\*” denotes  $p < 0.001$ , A period mid-line indicates p-value between 0.05 and 0.099.*

### Solar-Powered Desalination Plant vs. Business-As-Usual Modeling

For clarity and conciseness, I assumed that all other capital and operational expenses for any additional desalination capacity were equal for both a business-as-usual model and a solar-powered model. Thus, the only differences explored in the model were land acquisition, price of installing and operating solar, and energy costs from the grid. An acre of land in Provo costs approximately \$449,000 (VisitTCI). The existing desalination plant in Provo is 5.71 acres. Thus, the price for the land was \$2,563,790 for the business-as-usual model. However, in the solar model, land acquisition is affected by land required for solar installments.

### Business As Usual Model and Payback Period

Capex for a business-as-usual model desalination plant with four million gallons per day capacity was estimated at \$13 million (Herber 2024). This plant would cost \$1,312,162 annually for energy, assuming an electricity price of 44.4 cents per kWh, and total annual energy consumption of 2,955,319 kWh. Energy usage accounted for roughly 40% of total opex (Herber 2024). Thus, total operational expenses in a business-as-usual model were estimated to be \$3,280,404 annually (Appendix 2).

As Provo Water and Turks and Caicos Water Company did not disclose their annual revenue, the water utility on Dominica, Dominica Water and Sewerage Company Limited (DOWASCO) was used as a comparable benchmark to estimate annual revenue for Provo Water. It is the sole water utility in Dominica and a volume of six million cubic

meters in water billed in 2020 (Nils 2021). Similarly, Provo Water has a volume of 5.5 million cubic meters of water production annually. In 2020, DOWASCO had \$8 million in annual revenue (Nils 2021). This is equivalent to \$10,049,315 in 2025USD (U.S. Bureau of Labor Statistics, 2026).

Thus, the payback period for a business-as-usual model desalination plant was estimated to be two years. Net profit after 20 years of operation was projected to be over \$104 million (Appendix 2).

### Solar-Powered Desalination Plant and Payback Period

Provo Water has expressed interest in constructing a solar-powered desalination plant. The proposed solar array has a rated capacity of 2MW. The estimated total cost to construct was estimated as \$2,378,000 in 2021USD, or \$2,763,970 in 2025USD. The first year energy services fee was \$30,000 in 2021USD, or \$34,869 in 2025USD. The cost does not consider land acquisition cost for the solar array, which was estimated to occupy 5.25 acres. Land acquisition would be \$2,357,250 for just the solar array (Appendix 3). It is also important to consider that a solar-powered desalination plant would not operate at night or during periods of no sun. Thus, to match production of a business-as-usual model, the solar desalination plant would need to double daytime output. Thus, land needed to house the desalination plant would double (Appendix 3).

The battery energy storage system (BESS) proposed to Provo Water has a load capacity of 2MW and consists of a lithium-ion battery system. The price (not including siting, pad and conduit, and step-up transformers) of the BESS was quoted at \$1,444,937, plus a \$71,871 10-year warranty. This brings the total BESS to \$1,516,808. This quote

was generated in 2023, so accounting for inflation, the total in 2025USD was \$1,610,990. Operational costs are estimated as \$15,000 annually in 2023USD, or \$15,931 2025USD.

To summarize, the total CAPEX for the solar array would be \$11,859,790, comprised of:

- \$5,127,580 for 2x desalination land acquisition
- \$2,763,970 for solar array CAPEX
- \$2,357,250 for land acquisition of solar
- \$1,610,990 for BESS

Due to the necessity of doubling desalination capacity to eight million gallons per day to account for half time operation, capex would increase significantly. For simplicity here, capex was doubled from \$13 million to \$26 million. Thus, total capex for the solar array and the desalination plant was \$37,859,790 (Appendix 3).

Total OPEX was estimated at \$115,931 (plus cost inflation of 2.5% per annum) for solar array upkeep, plus non-energy operational expenses of 2x \$1,968,242 (operational expenses minus fuel costs for desalination), or \$3,936,484 (Appendix 3).

The payback period for a project with these costs and parameters was estimated as six years, four more than in the business-as-usual model. Net profit after 20 years of operation for Provo Water would be over \$80 million, approximately \$20 million less than the business-as-usual model (Appendix 3).

### Carbon Emissions Avoided

The relevant estimates to calculate annual CO<sub>2</sub> emissions from the desalination plant were:

- 2,955,319 kWh per year to produce four million gallons per day, assuming an intake salinity of 35,000 ppm, a recovery ratio of 45%, and pump efficiency of 90%.
- 0.105 gallons of diesel to produce 1kWh, so 310,308 gallons of diesel per year in business as usual.
- 22.38 lb of CO<sub>2</sub> per gallon of diesel burned.

Therefore, there were 6,944,704 lb of CO<sub>2</sub> per year associated with desalination processes in the business-as-usual model, just for the added capacity (or 3,472 tons).

Globally, carbon emission prices range from \$0.01-\$127 per ton of carbon (World Bank, 2020). However, the World Bank also estimates that only 3.2% of global emissions are priced above the recommended level (World Bank). Thus, the median of the range was used to calculate carbon emission prices: \$63.50 per ton of carbon emitted. Thus, annual emissions prices are \$220,494. When factored into the economic model, payback period remained at two years, and total profit after 20 years was projected to decrease to \$98,557,059 (Appendix 4).

## Chapter IV

### Discussion

I first review the survey responses and economic model results, then formulate cohesive, data-driven policy and water provisioning recommendations for Provo, and more broadly, for SIDS.

#### Interpretation of Statistical Analyses

The relationships among demographic variables and response variables are first discussed.

#### Demographic Variables

There was a strong statistically significant relationship between age and source of drinking water. A potential reason for this is age-based stereotypes regarding drinking water preferences.

There was also a statistically significant relationship between age and monthly drinking water price, perhaps because as residents age, family size tends to increase, thus increasing price of water per month. There was a weak positive correlation between age and satisfaction with current drinking water source. A potential reason for this relationship is that different age groups have different drinking water preferences, and younger generations prefer and value convenience more than older generations.

Gender and place of residence were poor predictors of any of the response variables. There was a weak correlation between gender and why residents find it difficult to obtain drinking water. A potential reason for this is differing gender roles and differing challenges faced by varying genders. Overall, this indicates that differing genders and neighborhoods of residence had similar drinking water preferences, pay similar monthly prices for drinking water, and are equally satisfied with their drinking water.

There was a weak correlation between nationality and price paid for drinking water, although nationality was a poor predictor of any of the remaining response variables.

There was a statistically significant relationship between household size and monthly price for drinking water. This is most likely because larger households pay more money per month for drinking water than smaller households. The weak statistic correlation between household size and willingness to pay for piped in-home, uninterrupted drinking water is likely because most respondents used their monthly price for drinking water as a benchmark and reference for estimating their willingness to pay.

### Response Variables

There was a strong statistically significant relationship between the rated difficulty in obtaining drinking water and reason why it is difficult to obtain drinking water. This may be because different reasons for difficulty affect the perceived difficulty.

There was a weak correlative relationship between rated difficulty in obtaining drinking water and current source of drinking water. Some drinking water sources are more difficult to obtain than others.

There was a strong statistically significant relationship between rated difficulty in obtaining drinking water and satisfaction with current drinking water source. This indicates that difficulty in obtaining drinking water is an important factor for residents when determining their overall satisfaction with their drinking water. There was a strong statistically significant relationship between reason for difficulty in obtaining drinking water and rated difficulty in obtaining drinking water.

There was a weak correlative relationship between reason for difficulty in obtaining drinking water and days per month residents' cisterns are empty before being refilled by a water company. This may reveal that empty cisterns are a prevalent reason for difficulty in obtaining drinking water. There was a weak correlative relationship between reason for difficulty in obtaining drinking water and filling frequency at local drinking water fill stations. This may reveal that the need to fill containers at water fill stations is an inconvenience and a major reason for difficulty in obtaining drinking water.

There was a weak correlative relationship between current drinking water source and rated difficulty in obtaining drinking water. There was a statistically significant relationship between current drinking water source and monthly price for drinking water, suggesting that differing sources of drinking water vary in price. There was a statistically significant relationship between current drinking water source and ideal drinking water source, suggesting that specific current drinking water sources are strong predictors of residents' preferred drinking water sources. There also was a strong statistically significant relationship between current drinking water source and satisfaction with current drinking water source, suggesting that satisfaction is dependent on current source.

There was a statistically significant relationship between monthly price for drinking water and source of drinking water, and a weak correlative relationship between monthly price for drinking water and monthly filling frequency at local drinking water fill stations, suggesting that more visits lead to higher monthly costs. There was a strong statistically significant relationship between monthly price for drinking water and willingness to pay for uninterrupted, in-home piped drinking water, suggesting that higher monthly costs for drinking water are linked to willingness to pay more for in-home drinking water service.

There was a statistically significant relationship between water delivery method to residence and days per month residents' cisterns are empty before being refilled by a water company, and a weak relationship between water delivery method to residence and satisfaction with current drinking water source, indicating that household water procurement method affects levels of satisfaction with drinking water.

There was a strong statistically significant relationship between monthly shutoffs for Provo Water customers and days per month residents' cisterns are empty before being refilled by a water company, suggesting a link between Provo Water service and water truck service. Perhaps place of residence determines level of water service. There was a weak correlative relationship between monthly shutoffs for Provo Water customers and filling frequency at local drinking water fill stations, suggesting that shutoffs may lead to more frequent visits to fill stations. There was a weak correlative relationship between monthly shutoffs for Provo Water customers and satisfaction with current drinking water source, indicating that more shutoffs lead to lower satisfaction with drinking water source.

There was a weak correlative relationship between days per month residents' cisterns are empty before being refilled by a water company and reason why it is difficult to obtain drinking water, suggesting that empty cisterns may be a predictor of difficulty in obtaining drinking water. There was a statistically significant relationship between days per month residents' cisterns are empty before being refilled by a water company and water delivery method to residence, indicating that residents that rely on water trucks for cistern refills experience more monthly empty cistern days.

There was a strong statistically significant relationship between days per month residents' cisterns are empty before being refilled by a water company and monthly shutoffs experienced by Provo Water customers.

There was a weak correlative relationship between filling frequency at local drinking water fill stations and reason why it is difficult to obtain drinking water. There was a weak correlative relationship between filling frequency at local drinking water fill stations and monthly price for drinking water. There were weak correlative relationships between filling frequency at local drinking water fill stations and monthly shutoffs experienced by Provo Water customers and with willingness to drink recycled wastewater, indicating that the more frequent residents have to fill containers at water filling stations, the more willing residents are to drink recycled wastewater.

There was a weak correlative relationship between willingness to drink recycled wastewater and filling frequency at local drinking water fill stations, but a strong statistically significant relationship between willingness to drink recycled wastewater and willingness to pay for uninterrupted, in-home piped drinking water.

There was a statistically significant relationship between ideal drinking water source and current drinking water source. This relationship indicates that residents' current drinking water source is a strong indicator of their ideal drinking water source. Perhaps residents who must visit fill stations and refill plastic bottles to source their drinking water have a strong desire for access to in-home piped drinking water. It seemed as if residents who source their drinking water from supermarkets (via bottled water) were quite content and wanted to stick with that sourcing option.

There was a strong statistically significant relationship between satisfaction with current drinking water source and rated difficulty in obtaining drinking water. This indicates that difficulty is a major consideration for residents when determining satisfaction with current drinking water source. This should be considered by Provo Water and other water entities when making new water provisioning and infrastructure plans. Barriers to obtaining drinking water (cost, distance, weight, etc.) should be removed by Provo Water to improve resident satisfaction. An easy way to do this is to provide uninterrupted, in-home piped drinking water for all residents.

There was a strong statistically significant relationship between satisfaction with current drinking water source and current drinking water source. This indicates that current source of drinking water is a strong predictor of resident satisfaction with current drinking water source. Thus, residents are likely not choosing a specific drinking water source because it is their first choice (or else satisfaction would not vary by source). Likely, residents choose their drinking water source because they think it is the only option, or they distrust what might be a more convenient option.

There were weak correlative relationship between satisfaction with current drinking water source and water delivery methods to residences, and with current drinking water source and monthly shutoffs for Provo Water customers. This indicates that increased shutoffs for Provo Water customers lowers overall satisfaction with drinking water source. Provo Water should prioritize limiting shutoffs for their residents and customers: this may lead to increased trust in tap water and less bottled water consumption.

There was a strong statistically significant relationship between willingness to pay for uninterrupted, in-home piped drinking water service and current monthly price for drinking water. This indicates that residents that pay higher prices for drinking water anyway are also willing to pay higher prices for piped drinking water service. There was a strong statistically significant relationship between willingness to pay for uninterrupted, in-home piped drinking water service and willingness to drink recycled wastewater, indicating that residents that are willing to pay more for improved water service are also more willing to drink recycled wastewater.

### Recommendations

Research results can provide Provo Water, and also the TCI government and infrastructure planners, with useful data and information regarding consumer choice and preferences regarding drinking water.

Mean willingness to drink recycled wastewater was 2.12 (out of 10). This result suggests that Provo Water would be wise to engage in public education campaigns regarding the safety of drinking recycled wastewater before investing in recycling technology.

Mean rated difficulty in acquiring drinking water was 2.69 (out of 10). This result indicates that Provo residents are actually quite satisfied with their current drinking water source. Additionally, mean satisfaction with current drinking water source was 7.41 (out of 10). This confirms that suspicion.

The majority of respondents stated that they pay \$26-\$50 per month for their drinking water, while the majority of respondents also stated they would pay \$0-\$25 for uninterrupted, in-home piped drinking water service per month. This indicates that in-home tap water is less of a valued asset to Provo residents than their current drinking water source.

Interestingly, over 42% of respondents indicated that they experience less than one shutoff per month as customers of Provo Water. This is much less than previously anticipated and perhaps indicates a misunderstanding of the question, as Provo Water restrictions are well documented, especially during the dry season and during the high tourism season.

The indicated ideal drinking water source for over 67% of respondents was tap water. However, it is important to note that most of the respondents that were surveyed in person anecdotally indicated that this would only be the case if they felt they could trust tap water. There remains skepticism regarding the safety of tap water as a potable source.

At the outset of this project, the hope was to model a wastewater reuse facility that could potentially increase Provo Water's potable capacity. Wastewater reuse technology is less energy-intensive than traditional reverse osmosis desalination and thus diversifying Provo Water's production means could help lower their carbon footprint. However, survey results indicated that Povo residents were not willing to try recycled

wastewater as a potable water source. On a scale of 0-10, with 10 being the highest willingness to drink recycled wastewater, the mean willingness of all survey respondents was 2.059. It is evident that there needs to be a public perception shift to promote the safety of drinking recycled wastewater before modeling the energy savings will become relevant. Interestingly, many survey respondents noted that they would be more willing to try drinking recycled wastewater if they could tour the facility and see the treatment processes for themselves. Perhaps engaging in a public education campaign advertising the cleanliness and rigorous treatment processes for recycled wastewater would improve overall resident willingness to explore using this resource.

Additionally, 56 respondents out of 135 selected Provo Water as their drinking water source (41.5%). This was an interesting and troublesome finding. An alarmingly large percentage of respondents obtained their drinking water from the supermarket (14.1%). 29.6% of respondents obtain their drinking water by bringing refillable containers to TC Crystal. However, in interviews with Provo Water representatives, it was revealed that TC Crystal simply utilizes Provo Water supply and runs that water through a freshwater reverse osmosis technology to lower the salinity levels further. Thus, realistically over 70% of respondents utilize some version of Provo Water for their drinking water. This finding has implications for the future of water resources in Provo. The representative I spoke with at Provo Water mentioned that there is not a massive incentive to run a public education campaign to promote the safety of drinking Provo Water from the tap, as even if residents do not trust the tap, Provo Water will likely still receive their business via TC Crystal. Thus, even if residents continue to use single-use plastics, Provo Water is receiving business. This revelation seemingly negates a potential

recommendation to invest considerable funds and educational effort in public awareness and education concerning the safety of drinking tap water.

### Research Limitations

I encountered a few noteworthy research limitations that possibly affected the results of this study. One limitation was that I could not reach as diverse a subset of the population that we hoped to. For instance, very few of the survey respondents utilized the Haitian Creole version of the survey, and because I was unable to produce a usable Spanish translation of the survey, we were unable to adequately survey the Hispanic population. Cultural norms may have also played a role as most of the respondents were women. As the survey was mostly distributed at grocery stores, there is a possibility that there were more women than men available to take the survey. Some demographic classes were therefore disproportionately sampled.

Another constraint of this study was the solar powered desalination plant that Provo Water is planning. Modeling templates for the new plant were contributed by Provo Water. However, representatives at Provo Water made it clear that in their plans for a solar powered desalination plant, they do not plan on implementing battery energy storage and so would not power operations during off-sun periods. The company only plans to utilize battery energy storage to aid in the transition from solar to the grid. Thus, they need to invest in double the desalination infrastructure, which increases capital expenditure drastically. This decision is the major reason why the solar powered desalination plant fails to compete financially with the diesel-powered desalination plant. If this capital cost of an added \$13 million were dropped, profit after 20 years and

payback period would be comparable to a business-as-usual scenario (\$94 million dollars; four years) (Appendix 5).

## Conclusions

There needs to be a complete shift in public perception to capitalize on renewable energy as a power source for desalinated drinking water. As it stands, residents do not trust tap water. Those that indicated they source their water from Provo Water (tap) either took the survey from a link or QR code, or likely misunderstood the question, because they would later contradict this statement and indicate that they fill bottles at fill stations or purchase plastic bottles at the supermarket. Perhaps more pressing is the demand for single-use water bottles. This study has revealed and highlighted Provo's massive reliance on the plastic water bottle industry. Adding insult to injury, the majority of these plastic bottled water products are imported, tacking on additional carbon emissions from shipping. Recycling programs in the TCI are largely underdeveloped and, in some cases, nonexistent, creating an end-of-life nightmare for these products. For an economy that relies on healthy coastal ecosystems to fuel tourism and sustain fisheries, additional plastic pollution is more than just a headache – it is a threat to livelihoods and ways of life for TC Islanders. Prioritizing a paradigm shift in drinking water preferences through public education and more reliable infrastructure will lead to more sustainable drinking water choices and less carbon-intensive water production.

Regarding recycled wastewater as a potential resource, there are non-potable uses for recycled wastewater that are currently being explored on Provo. In interviews with Provo Water, it was revealed that the golf course on the island utilizes greywater for irrigation. More widespread use of recycled wastewater for irrigation purposes will help

Provo reduce energy use and water use. Going forward, the TCI government and Provo Water should regulate, standardize, and require the use of recycled wastewater for all commercial irrigation purposes, especially within the tourism industry. Treatment of recycled wastewater for irrigation purposes may help to improve perception of its use in the public eye, and it is significantly cheaper to clean wastewater to irrigation standards, rather than drinking water standards.

## Appendix 1

### Resident Survey

#### Providenciales Water Supply

1. On a scale of 1-10 (1 - not difficult at all, 10 - extremely difficult) how difficult is it for you to get your water?

2. Why is it difficult to get your water?

- Distance
- Price
- Weight
- Inconvenience
- Other (please specify)

---

- It is not difficult to get my water

3. Where do you get your water?

- Provo Water
- Other (please specify)

---

4. How much do you currently pay for your monthly water supply (in \$)?

- 1-25
- 26-50
- 51-100
- More than 100

5. How is water delivered to your residence?

- Piped in-home
- Cisterns with water delivery
- Bring containers to local water filling stations
- Other (please specify)

---

6. If connected to Provo Water, how many times per month do you experience water restrictions or shutoffs?

- 0
- 1-2
- 3 or more
- I am not connected to Provo Water

7. If your residence utilizes a cistern, how many days per month is it empty before it is refilled by Provo Water?

- 0
- 1-2
- 3 or more
- I do not have a cistern

8. If your household fills its own water at local filling stations, how many times per month do you visit the filling station?
    - 0
    - 1-2
    - 3 or more
    - My household does not obtain water from local filling station
  9. In an ideal world, how would you get your water?
    - Piped directly into your home
    - Cistern with regular refills
    - Refilling bottles at a water station
    - Other (please specify) \_\_\_\_\_
  10. On a scale of 1 to 10 (1 - completely unsatisfied, 10 - completely satisfied) how satisfied are you with your current water source?
  11. If you were offered uninterrupted, in-home water supply, how much money would you be willing to pay per month (USD\$) (1-150)?
  12. How willing are you to drink recycled wastewater (0-Extremely Uncomfortable; 10-Extremely Comfortable)?
  13. What is your age (0-100)?
  14. What is your gender identity?
    - Male
    - Female
    - Non-binary / third gender
    - Prefer not to say
  15. What is your nationality?
    - Turks and Caicos Islander
    - Haitian
    - Dominican
    - Other (please specify)
- 
16. What neighborhood do you currently reside in?
    - Blue Hills
    - Five Cays
    - Leeward
    - Long Bay
    - Grace Bay
    - Frenchman's Creek
    - The Bight
    - Kew Town
    - Other (please specify) \_\_\_\_\_
  17. How many individuals reside in your home (1-10)?
  18. What language do you speak at home?
    - English
    - Spanish
    - Haitian Creole
    - Other (please specify)
-

## Appendix 2

### Business-As-Usual Calculations

Table 4. Business-As-Usual model calculations.

|                          |        | FPA rate | Total Rate | Avg. kWh Produced | Annual Projected Revenue | Annual maintenance, Insurance | Net cash inflow | 20 Year Depreciation | Net profit     | Accumulated Revenue | Cumulative cash flow | Cash ROI | Profit ROI |         | Revenue | Profit pre-dep'n | Profit post-dep'n |    |            |    |
|--------------------------|--------|----------|------------|-------------------|--------------------------|-------------------------------|-----------------|----------------------|----------------|---------------------|----------------------|----------|------------|---------|---------|------------------|-------------------|----|------------|----|
|                          |        |          |            |                   |                          |                               | 0.0%            |                      |                |                     |                      |          |            |         |         |                  |                   |    |            |    |
| Pilot Solar Project 2 MW |        |          |            |                   |                          |                               |                 |                      |                |                     |                      |          |            |         | 0.150   | \$ 805,000       | \$ 662,000        | 5% | \$ 519,000 | 4% |
| CAPEX                    | 0.0000 |          |            |                   |                          | \$ 8,333                      |                 | \$ 72,222            |                |                     |                      |          |            |         | 0.175   | \$ 940,000       | \$ 784,000        | 6% | \$ 654,000 | 5% |
| Land                     |        |          |            |                   |                          |                               |                 |                      |                |                     |                      |          |            |         | 0.200   | \$ 1,074,000     | \$ 920,000        | 7% | \$ 788,000 | 6% |
| Total Capex              | 0.0000 |          |            |                   |                          |                               |                 |                      |                |                     |                      |          |            |         |         |                  |                   |    |            |    |
| Cost inflation           | 2.5%   |          |            |                   |                          |                               |                 |                      |                |                     |                      |          |            |         |         |                  |                   |    |            |    |
| Const. Payback Yrs.      |        |          |            |                   |                          |                               |                 |                      |                |                     |                      |          |            |         |         |                  |                   |    |            |    |
| Forecast reduction       | 5%     |          |            |                   |                          |                               |                 |                      |                |                     |                      |          |            |         |         |                  |                   |    |            |    |
| ROI                      | 928%   |          |            |                   |                          |                               |                 |                      |                |                     |                      |          |            |         |         |                  |                   |    |            |    |
| Payback Yrs              | Yr 4   |          |            |                   |                          |                               |                 |                      |                |                     |                      |          |            |         |         |                  |                   |    |            |    |
| Years                    |        |          |            |                   |                          |                               |                 |                      |                |                     |                      |          |            |         |         |                  |                   |    |            |    |
| 0                        |        |          |            |                   | \$ 8,000,000             |                               | \$ (13,000,000) |                      |                |                     | \$ (13,000,000)      |          |            |         |         |                  |                   |    |            |    |
| 1                        | 0.0000 | 0.2000   | 5,500,000  |                   |                          |                               | \$ 6,768,911    | \$ 650,000           | \$ (6,231,089) | \$ 10,049,315       | \$ (6,231,089)       | 52%      | -48%       | 8000000 |         |                  |                   |    |            |    |
| 2                        | 0.0000 | 0.2000   | 5,486,250  |                   |                          |                               | \$ 6,686,901    | \$ 650,000           | \$ 455,812     | \$ 20,096,630       | \$ 455,812           | 51%      | 4%         |         |         |                  |                   |    |            |    |
| 3                        | 0.0000 | 0.2000   | 5,472,500  |                   |                          |                               | \$ 6,602,847    | \$ 650,000           | \$ 7,058,652   | \$ 30,147,945       | \$ 7,058,652         | 51%      | 54%        |         |         |                  |                   |    |            |    |
| 4                        | 0.0000 | 0.2000   | 5,458,750  |                   |                          |                               | \$ 6,516,679    | \$ 650,000           | \$ 13,575,331  | \$ 40,197,260       | \$ 13,575,331        | 50%      | 104%       |         |         |                  |                   |    |            |    |
| 5                        | 0.0000 | 0.2000   | 5,445,000  |                   |                          |                               | \$ 6,428,363    | \$ 650,000           | \$ 20,003,694  | \$ 50,246,575       | \$ 20,003,694        | 49%      | 154%       |         |         |                  |                   |    |            |    |
| 6                        | 0.0000 | 0.2000   | 5,431,250  |                   |                          |                               | \$ 6,337,839    | \$ 650,000           | \$ 26,341,533  | \$ 60,295,890       | \$ 26,341,533        | 49%      | 200%       |         |         |                  |                   |    |            |    |
| 7                        | 0.0000 | 0.2000   | 5,417,500  |                   |                          |                               | \$ 6,245,857    | \$ 650,000           | \$ 32,586,585  | \$ 70,345,205       | \$ 32,586,585        | 48%      | 251%       |         |         |                  |                   |    |            |    |
| 8                        | 0.0000 | 0.2000   | 5,403,750  |                   |                          |                               | \$ 6,149,943    | \$ 650,000           | \$ 38,736,530  | \$ 80,394,520       | \$ 38,736,530        | 47%      | 298%       |         |         |                  |                   |    |            |    |
| 9                        | 0.0000 | 0.2000   | 5,390,000  |                   |                          |                               | \$ 6,052,463    | \$ 650,000           | \$ 44,788,992  | \$ 90,443,835       | \$ 44,788,992        | 47%      | 345%       |         |         |                  |                   |    |            |    |
| 10                       | 0.0000 | 0.2000   | 5,376,250  |                   |                          |                               | \$ 5,953,540    | \$ 650,000           | \$ 50,741,532  |                     | \$ 50,741,532        | 46%      | 390%       |         |         |                  |                   |    |            |    |
| 11                       | 0.0000 | 0.2000   | 5,362,500  |                   |                          |                               | \$ 5,850,121    | \$ 650,000           | \$ 56,591,652  |                     | \$ 56,591,652        | 45%      | 435%       |         |         |                  |                   |    |            |    |
| 12                       | 0.0000 | 0.2000   | 5,348,750  |                   |                          |                               | \$ 5,745,141    | \$ 650,000           | \$ 62,336,793  |                     | \$ 62,336,793        | 44%      | 480%       |         |         |                  |                   |    |            |    |
| 13                       | 0.0000 | 0.2000   | 5,335,000  |                   |                          |                               | \$ 5,637,536    | \$ 650,000           | \$ 67,974,329  |                     | \$ 67,974,329        | 43%      | 523%       |         |         |                  |                   |    |            |    |
| 14                       | 0.0000 | 0.2000   | 5,321,250  |                   |                          |                               | \$ 5,527,242    | \$ 650,000           | \$ 73,501,571  |                     | \$ 73,501,571        | 43%      | 565%       |         |         |                  |                   |    |            |    |
| 15                       | 0.0000 | 0.2000   | 5,307,500  |                   |                          |                               | \$ 5,414,190    | \$ 650,000           | \$ 78,915,761  |                     | \$ 78,915,761        | 42%      | 607%       |         |         |                  |                   |    |            |    |
| 16                       | 0.0000 | 0.2000   | 5,293,750  |                   |                          |                               | \$ 5,298,312    | \$ 650,000           | \$ 84,214,073  |                     | \$ 84,214,073        | 41%      | 648%       |         |         |                  |                   |    |            |    |
| 17                       | 0.0000 | 0.2000   | 5,280,000  |                   |                          |                               | \$ 5,179,537    | \$ 650,000           | \$ 89,393,610  |                     | \$ 89,393,610        | 40%      | 688%       |         |         |                  |                   |    |            |    |
| 18                       | 0.0000 | 0.2000   | 5,266,250  |                   |                          |                               | \$ 5,067,792    | \$ 650,000           | \$ 94,451,402  |                     | \$ 94,451,402        | 39%      | 727%       |         |         |                  |                   |    |            |    |
| 19                       | 0.0000 | 0.2000   | 5,252,500  |                   |                          |                               | \$ 4,953,064    | \$ 650,000           | \$ 99,384,406  |                     | \$ 99,384,406        | 38%      | 764%       |         |         |                  |                   |    |            |    |
| 20                       | 0.0000 | 0.2000   | 5,238,750  |                   |                          |                               | \$ 4,835,097    | \$ 650,000           |                |                     | \$ 104,189,503       | 37%      | 801%       |         |         |                  |                   |    |            |    |

The variables in the columns of the BAU spreadsheet (and the subsequent appendices) are:

- PPA Rate: Rate that Provo Water will receive for every megawatt-hour (MWh) of energy generated by solar power (irrelevant in the business-as-usual calculations).
- Average kWh Produced: Energy produced by solar power per year
- Annual Projected Revenue: Annual revenue from solar energy sales and water sales
- Annual Maintenance: Cost of annual maintenance and operational upkeep and repair for solar and desalination technologies
- Insurance: Insurance costs for solar installations
- Net Cash Inflow: Annual cash inflow for sale of solar power, minus insurance and maintenance
- 20-Year Depreciation: Depreciation of solar assets over a 20-year project lifespan
- Net Profit: Projected Revenue minus maintenance and insurance, minus capital expenditures
- Accumulated Revenue: Additive revenue per year for solar sales and water sales
- Cumulative Cash Flow: Net cash inflow minus capital expenditures
- Cash ROI: Cash inflow divided by total capital expenditures
- Profit ROI: Net profit divided by total capital expenditures
- Profit Pre-Depreciation: Annual profit, not accounting for depreciation of assets
- Profit Post-Depreciation: Annual profit, accounting for depreciation of assets

## Appendix 3

### Solar-Powered Desalination Calculations

Table 5. Solar-powered desalination calculations.

| A                        | B     | C        | D          | E                 | F                        | G                  | H         | I               | J                  | K               | L                   | M                    | N        | O          | P | Q | R | S | T | U | V | W       | X               | Y                | Z  | AA         | A  |
|--------------------------|-------|----------|------------|-------------------|--------------------------|--------------------|-----------|-----------------|--------------------|-----------------|---------------------|----------------------|----------|------------|---|---|---|---|---|---|---|---------|-----------------|------------------|----|------------|----|
|                          |       | FEA rate | Total Rate | Avg. kWh Produced | Annual Projected Revenue | Annual maintenance | Insurance | Net cash inflow | 20 Yr Depreciation | Net profit      | Accumulated Revenue | Cumulative cash flow | Cash ROI | Profit ROI |   |   |   |   |   |   |   | Revenue | Profit pre-depr | Profit post-depr |    |            |    |
| Pilot Solar Project 2 MW |       |          |            |                   |                          |                    |           |                 | 1.0%               |                 |                     |                      |          |            |   |   |   |   |   |   |   |         |                 |                  |    |            |    |
| CAPEX                    | ***** |          |            |                   |                          |                    |           | \$ 8,333        | \$210,332          |                 |                     |                      |          |            |   |   |   |   |   |   |   | 0.150   | \$ 805,000      | \$ 662,000       | 2% | \$ 519,000 | 1% |
| Land                     | \$ -  |          |            |                   |                          |                    |           |                 |                    |                 |                     |                      |          |            |   |   |   |   |   |   |   | 0.175   | \$ 940,000      | \$ 784,000       | 2% | \$ 654,000 | 2% |
| Total Capex              | ***** |          |            |                   |                          |                    |           |                 |                    |                 |                     |                      |          |            |   |   |   |   |   |   |   | 0.200   | \$ 1,074,000    | \$ 920,000       | 2% | \$ 788,000 | 2% |
| Cost inflation           | 2.5%  |          |            |                   |                          |                    |           |                 |                    |                 |                     |                      |          |            |   |   |   |   |   |   |   |         |                 |                  |    |            |    |
| Const. Payback Yrs       |       |          |            |                   |                          |                    |           |                 |                    |                 |                     |                      |          |            |   |   |   |   |   |   |   |         |                 |                  |    |            |    |
| Forecast reduction       | 5%    |          |            |                   | *****                    |                    |           | *****           |                    |                 |                     |                      |          |            |   |   |   |   |   |   |   |         |                 |                  |    |            |    |
| ROI                      | 353%  |          |            |                   | *****                    |                    |           | *****           |                    |                 |                     |                      |          |            |   |   |   |   |   |   |   |         |                 |                  |    |            |    |
| Payback Yrs              | Yr 4  |          |            |                   |                          |                    |           |                 |                    |                 |                     |                      |          |            |   |   |   |   |   |   |   |         |                 |                  |    |            |    |
|                          |       |          |            |                   |                          |                    |           | \$ 115,001      |                    |                 |                     |                      |          |            |   |   |   |   |   |   |   |         |                 |                  |    |            |    |
| Years                    |       |          |            |                   |                          |                    |           |                 |                    |                 |                     |                      |          |            |   |   |   |   |   |   |   |         |                 |                  |    |            |    |
| 0                        |       |          |            |                   |                          |                    |           |                 | \$ (37,859,790)    |                 |                     | \$ (37,859,790)      |          |            |   |   |   |   |   |   |   |         |                 |                  |    |            |    |
| 1                        |       | 0.2000   | 0.2000     | 5,500,000         | *****                    | *****              | *****     | \$ 6,718,382    | *****              | \$ (30,762,890) | \$11,149,315        | \$ (37,859,790)      | 18%      | -81%       |   |   |   |   |   |   |   |         |                 |                  |    |            |    |
| 2                        |       | 0.2000   | 0.2000     | 5,486,250         | *****                    | *****              | *****     | \$ 6,614,742    | *****              | \$ (23,770,050) | \$22,295,880        | \$ (24,527,246)      | 17%      | -63%       |   |   |   |   |   |   |   |         |                 |                  |    |            |    |
| 3                        |       | 0.2000   | 0.2000     | 5,472,500         | *****                    | *****              | *****     | \$ 6,507,649    | *****              | \$ (16,883,804) | \$33,439,695        | \$ (18,019,598)      | 17%      | -45%       |   |   |   |   |   |   |   |         |                 |                  |    |            |    |
| 4                        |       | 0.2000   | 0.2000     | 5,458,750         | *****                    | *****              | *****     | \$ 6,398,459    | *****              | \$ (10,106,747) | \$44,580,760        | \$ (11,621,138)      | 17%      | -27%       |   |   |   |   |   |   |   |         |                 |                  |    |            |    |
| 5                        |       | 0.2000   | 0.2000     | 5,445,000         | *****                    | *****              | *****     | \$ 6,286,609    | *****              | \$ (3,441,540)  | \$55,719,075        | \$ (5,334,529)       | 17%      | -9%        |   |   |   |   |   |   |   |         |                 |                  |    |            |    |
| 6                        |       | 0.2000   | 0.2000     | 5,431,250         | *****                    | *****              | *****     | \$ 6,172,831    | *****              | \$ 3,109,090    | \$66,854,640        | \$ 837,502           | 16%      | 8%         |   |   |   |   |   |   |   |         |                 |                  |    |            |    |
| 7                        |       | 0.2000   | 0.2000     | 5,417,500         | *****                    | *****              | *****     | \$ 6,054,658    | *****              | \$ 9,542,346    | \$77,987,455        | \$ 6,892,161         | 16%      | 25%        |   |   |   |   |   |   |   |         |                 |                  |    |            |    |
| 8                        |       | 0.2000   | 0.2000     | 5,403,750         | *****                    | *****              | *****     | \$ 5,934,419    | *****              | \$ 15,855,363   | \$89,117,520        | \$ 12,826,580        | 16%      | 42%        |   |   |   |   |   |   |   |         |                 |                  |    |            |    |
| 9                        |       | 0.2000   | 0.2000     | 5,390,000         | *****                    | *****              | *****     | \$ 5,811,743    | *****              | \$ 22,045,204   | *****               | \$ 18,637,823        | 15%      | 58%        |   |   |   |   |   |   |   |         |                 |                  |    |            |    |
| 10                       |       | 0.2000   | 0.2000     | 5,376,250         | *****                    | *****              | *****     | \$ 5,685,056    | *****              | \$ 28,108,858   | *****               | \$ 24,322,879        | 15%      | 74%        |   |   |   |   |   |   |   |         |                 |                  |    |            |    |
| 11                       |       | 0.2000   | 0.2000     | 5,362,500         | *****                    | *****              | *****     | \$ 5,555,783    | *****              | \$ 34,043,239   | *****               | \$ 29,878,662        | 15%      | 90%        |   |   |   |   |   |   |   |         |                 |                  |    |            |    |
| 12                       |       | 0.2000   | 0.2000     | 5,348,750         | *****                    | *****              | *****     | \$ 5,423,247    | *****              | \$ 39,845,184   | *****               | \$ 35,302,009        | 14%      | 105%       |   |   |   |   |   |   |   |         |                 |                  |    |            |    |
| 13                       |       | 0.2000   | 0.2000     | 5,335,000         | *****                    | *****              | *****     | \$ 5,287,669    | *****              | \$ 45,511,452   | *****               | \$ 40,589,679        | 14%      | 120%       |   |   |   |   |   |   |   |         |                 |                  |    |            |    |
| 14                       |       | 0.2000   | 0.2000     | 5,321,250         | *****                    | *****              | *****     | \$ 5,148,668    | *****              | \$ 51,038,718   | *****               | \$ 45,738,347        | 14%      | 135%       |   |   |   |   |   |   |   |         |                 |                  |    |            |    |
| 15                       |       | 0.2000   | 0.2000     | 5,307,500         | *****                    | *****              | *****     | \$ 5,006,761    | *****              | \$ 56,423,576   | *****               | \$ 50,744,608        | 13%      | 149%       |   |   |   |   |   |   |   |         |                 |                  |    |            |    |
| 16                       |       | 0.2000   | 0.2000     | 5,293,750         | *****                    | *****              | *****     | \$ 4,860,762    | *****              | \$ 61,662,536   | *****               | \$ 55,604,970        | 13%      | 163%       |   |   |   |   |   |   |   |         |                 |                  |    |            |    |
| 17                       |       | 0.2000   | 0.2000     | 5,280,000         | *****                    | *****              | *****     | \$ 4,718,854    | *****              | \$ 66,752,018   | *****               | \$ 60,315,854        | 12%      | 176%       |   |   |   |   |   |   |   |         |                 |                  |    |            |    |
| 18                       |       | 0.2000   | 0.2000     | 5,266,250         | *****                    | *****              | *****     | \$ 4,571,738    | *****              | \$ 71,686,395   | *****               | \$ 64,873,592        | 12%      | 189%       |   |   |   |   |   |   |   |         |                 |                  |    |            |    |
| 19                       |       | 0.2000   | 0.2000     | 5,252,500         | *****                    | *****              | *****     | \$ 4,420,833    | *****              | \$ 76,467,785   | *****               | \$ 69,274,425        | 12%      | 202%       |   |   |   |   |   |   |   |         |                 |                  |    |            |    |
| 20                       |       | 0.2000   | 0.2000     | 5,238,750         | *****                    | *****              | *****     | \$ 4,268,073    | *****              | \$ 81,086,456   | *****               | \$ 73,514,498        | 11%      | 214%       |   |   |   |   |   |   |   |         |                 |                  |    |            |    |

## Appendix 4

### Diesel-Powered Desalination with Carbon Emissions Costs

Table 6. Diesel-powered desalination with carbon emissions costs.

| A                        | B     | C        | D          | E                 | F                        | G                  | H         | I               | J                    | K              | L                   | M                    | N        | O          | P       | Q | R | S | T | U | V | W       | X                 | Y                  | Z  | AA         | AB |
|--------------------------|-------|----------|------------|-------------------|--------------------------|--------------------|-----------|-----------------|----------------------|----------------|---------------------|----------------------|----------|------------|---------|---|---|---|---|---|---|---------|-------------------|--------------------|----|------------|----|
|                          |       | FPA rate | Total Rate | Avg. kWh Produced | Annual Projected Revenue | Annual maintenance | Insurance | Net cash inflow | 20 Year Depreciation | Net profit     | Accumulated Revenue | Cumulative cash flow | Cash ROI | Profit ROI |         |   |   |   |   |   |   | Revenue | Profit pre. dep'n | Profit post. dep'n |    |            |    |
|                          |       |          |            |                   |                          |                    |           | 0.0%            |                      |                |                     |                      |          |            |         |   |   |   |   |   |   |         |                   |                    |    |            |    |
| Pilot Solar Project 2 MW |       |          |            |                   |                          |                    |           |                 |                      |                |                     |                      |          |            |         |   |   |   |   |   |   | 0.150   | \$ 805,000        | \$ 662,000         | 5% | \$ 519,000 | 4% |
| CAPEX                    | ***** |          |            |                   |                          |                    |           | \$ 8,333        | \$ 72,222            |                |                     |                      |          |            |         |   |   |   |   |   |   | 0.175   | \$ 940,000        | \$ 784,000         | 6% | \$ 654,000 | 5% |
| Land                     | \$ -  |          |            |                   |                          |                    |           |                 |                      |                |                     |                      |          |            |         |   |   |   |   |   |   | 0.200   | \$ 1,074,000      | \$ 920,000         | 7% | \$ 788,000 | 6% |
| Total Capex              | ***** |          |            |                   |                          |                    |           |                 |                      |                |                     |                      |          |            |         |   |   |   |   |   |   |         |                   |                    |    |            |    |
| Cost inflation           | 2.5%  |          |            |                   | \$ 220,494               |                    |           |                 |                      |                |                     |                      |          |            |         |   |   |   |   |   |   |         |                   |                    |    |            |    |
| Cash. Payback Yrs.       |       |          |            |                   |                          |                    |           |                 |                      |                |                     |                      |          |            |         |   |   |   |   |   |   |         |                   |                    |    |            |    |
| Forecast reduction       | 5%    |          |            |                   |                          |                    |           |                 |                      |                |                     |                      |          |            |         |   |   |   |   |   |   |         |                   |                    |    |            |    |
| ROI                      | 928%  |          |            |                   |                          |                    |           |                 |                      |                |                     |                      |          |            |         |   |   |   |   |   |   |         |                   |                    |    |            |    |
| Payback Yrs              | Yr 4  |          |            |                   |                          |                    |           |                 |                      |                |                     |                      |          |            |         |   |   |   |   |   |   |         |                   |                    |    |            |    |
| Years                    |       |          |            |                   |                          |                    |           |                 |                      |                |                     |                      |          |            |         |   |   |   |   |   |   |         |                   |                    |    |            |    |
| 0                        |       |          |            |                   | \$ 8,000,000             |                    |           | \$ (13,000,000) |                      |                |                     | \$ (13,000,000)      |          |            |         |   |   |   |   |   |   |         |                   |                    |    |            |    |
| 1                        |       | 0.2000   | 0.2000     | 5,500,000         | *****                    | *****              | \$ -      | \$ 6,548,427    | \$ 650,000           | \$ (6,451,583) | \$ 10,040,315       | \$ (6,451,583)       | 50%      | -50%       | 8000000 |   |   |   |   |   |   |         |                   |                    |    |            |    |
| 2                        |       | 0.2000   | 0.2000     | 5,486,250         | *****                    | *****              | \$ -      | \$ 6,460,895    | \$ 650,000           | \$ 9,312       | \$ 20,098,030       | \$ 9,312             | 50%      | 0%         |         |   |   |   |   |   |   |         |                   |                    |    |            |    |
| 3                        |       | 0.2000   | 0.2000     | 5,472,500         | *****                    | *****              | \$ -      | \$ 6,373,184    | \$ 650,000           | \$ 6,380,496   | \$ 30,147,945       | \$ 6,380,496         | 40%      | 40%        |         |   |   |   |   |   |   |         |                   |                    |    |            |    |
| 4                        |       | 0.2000   | 0.2000     | 5,458,750         | *****                    | *****              | \$ -      | \$ 6,279,231    | \$ 650,000           | \$ 12,659,726  | \$ 40,197,200       | \$ 12,659,726        | 48%      | 97%        |         |   |   |   |   |   |   |         |                   |                    |    |            |    |
| 5                        |       | 0.2000   | 0.2000     | 5,445,000         | *****                    | *****              | \$ -      | \$ 6,184,979    | \$ 650,000           | \$ 18,844,705  | \$ 50,246,576       | \$ 18,844,705        | 48%      | 145%       |         |   |   |   |   |   |   |         |                   |                    |    |            |    |
| 6                        |       | 0.2000   | 0.2000     | 5,431,250         | *****                    | *****              | \$ -      | \$ 6,088,370    | \$ 650,000           | \$ 24,933,075  | \$ 60,295,890       | \$ 24,933,075        | 47%      | 192%       |         |   |   |   |   |   |   |         |                   |                    |    |            |    |
| 7                        |       | 0.2000   | 0.2000     | 5,417,500         | *****                    | *****              | \$ -      | \$ 5,989,147    | \$ 650,000           | \$ 30,922,422  | \$ 70,345,205       | \$ 30,922,422        | 46%      | 238%       |         |   |   |   |   |   |   |         |                   |                    |    |            |    |
| 8                        |       | 0.2000   | 0.2000     | 5,403,750         | *****                    | *****              | \$ -      | \$ 5,887,847    | \$ 650,000           | \$ 36,810,269  | \$ 80,394,520       | \$ 36,810,269        | 45%      | 283%       |         |   |   |   |   |   |   |         |                   |                    |    |            |    |
| 9                        |       | 0.2000   | 0.2000     | 5,390,000         | *****                    | *****              | \$ -      | \$ 5,783,811    | \$ 650,000           | \$ 42,594,080  | \$ 90,443,835       | \$ 42,594,080        | 44%      | 328%       |         |   |   |   |   |   |   |         |                   |                    |    |            |    |
| 10                       |       | 0.2000   | 0.2000     | 5,376,250         | *****                    | *****              | \$ -      | \$ 5,677,173    | \$ 650,000           | \$ 48,271,253  | *****               | \$ 48,271,253        | 44%      | 371%       |         |   |   |   |   |   |   |         |                   |                    |    |            |    |
| 11                       |       | 0.2000   | 0.2000     | 5,362,500         | *****                    | *****              | \$ -      | \$ 5,567,870    | \$ 650,000           | \$ 53,839,123  | *****               | \$ 53,839,123        | 43%      | 414%       |         |   |   |   |   |   |   |         |                   |                    |    |            |    |
| 12                       |       | 0.2000   | 0.2000     | 5,348,750         | *****                    | *****              | \$ -      | \$ 5,455,833    | \$ 650,000           | \$ 59,294,956  | *****               | \$ 59,294,956        | 42%      | 456%       |         |   |   |   |   |   |   |         |                   |                    |    |            |    |
| 13                       |       | 0.2000   | 0.2000     | 5,335,000         | *****                    | *****              | \$ -      | \$ 5,340,996    | \$ 650,000           | \$ 64,635,953  | *****               | \$ 64,635,953        | 41%      | 497%       |         |   |   |   |   |   |   |         |                   |                    |    |            |    |
| 14                       |       | 0.2000   | 0.2000     | 5,321,250         | *****                    | *****              | \$ -      | \$ 5,223,388    | \$ 650,000           | \$ 69,859,241  | *****               | \$ 69,859,241        | 40%      | 537%       |         |   |   |   |   |   |   |         |                   |                    |    |            |    |
| 15                       |       | 0.2000   | 0.2000     | 5,307,500         | *****                    | *****              | \$ -      | \$ 5,103,638    | \$ 650,000           | \$ 74,961,879  | *****               | \$ 74,961,879        | 39%      | 577%       |         |   |   |   |   |   |   |         |                   |                    |    |            |    |
| 16                       |       | 0.2000   | 0.2000     | 5,293,750         | *****                    | *****              | \$ -      | \$ 4,978,972    | \$ 650,000           | \$ 79,940,850  | *****               | \$ 79,940,850        | 38%      | 615%       |         |   |   |   |   |   |   |         |                   |                    |    |            |    |
| 17                       |       | 0.2000   | 0.2000     | 5,280,000         | *****                    | *****              | \$ -      | \$ 4,852,212    | \$ 650,000           | \$ 84,793,062  | *****               | \$ 84,793,062        | 37%      | 652%       |         |   |   |   |   |   |   |         |                   |                    |    |            |    |
| 18                       |       | 0.2000   | 0.2000     | 5,266,250         | *****                    | *****              | \$ -      | \$ 4,723,285    | \$ 650,000           | \$ 89,515,347  | *****               | \$ 89,515,347        | 36%      | 689%       |         |   |   |   |   |   |   |         |                   |                    |    |            |    |
| 19                       |       | 0.2000   | 0.2000     | 5,252,500         | *****                    | *****              | \$ -      | \$ 4,589,199    | \$ 650,000           | \$ 94,104,455  | *****               | \$ 94,104,455        | 35%      | 724%       |         |   |   |   |   |   |   |         |                   |                    |    |            |    |
| 20                       |       | 0.2000   | 0.2000     | 5,238,750         | *****                    | *****              | \$ -      | \$ 4,452,404    | \$ 650,000           | \$ 98,557,059  | *****               | \$ 98,557,059        | 34%      | 758%       |         |   |   |   |   |   |   |         |                   |                    |    |            |    |

## Appendix 5

### Solar-Powered Desalination with 24-Hour Operating Capacity

Table 7. Solar-powered desalination with 24-hr operating capacity.

|                          | A | B      | C        | D          | E                 | F                        | G                  | H         | I               | J                    | K          | L                   | M                    | N | O | P | Q | R | S        | T          | U | V | W       | X                | Y                 | Z  | AA         | AB |
|--------------------------|---|--------|----------|------------|-------------------|--------------------------|--------------------|-----------|-----------------|----------------------|------------|---------------------|----------------------|---|---|---|---|---|----------|------------|---|---|---------|------------------|-------------------|----|------------|----|
|                          |   |        | PPA rate | Total Rate | Aug. kWh Produced | Annual Projected Revenue | Annual maintenance | Insurance | Net cash inflow | 20 Year Depreciation | Net profit | Accumulated Revenue | Cumulative cash flow |   |   |   |   |   | Cash ROI | Profit ROI |   |   | Revenue | Profit pre dep'n | Profit post dep'n |    |            |    |
|                          |   |        |          |            |                   |                          |                    | 1.0%      |                 |                      |            |                     |                      |   |   |   |   |   |          |            |   |   |         |                  |                   |    |            |    |
| Pilot Solar Project 2 MW |   |        |          |            |                   |                          |                    |           |                 |                      |            |                     |                      |   |   |   |   |   |          |            |   |   | 0.150   | \$ 805,000       | \$ 662,000        | 3% | \$ 519,000 | 2% |
| CAPEX                    |   | 0.0000 | 0.0000   | 5,500,000  | 0.0000            | 0.0000                   | 0.0000             | 0.0000    | \$ 8,333        | \$138,110            |            |                     |                      |   |   |   |   |   |          |            |   |   | 0.175   | \$ 940,000       | \$ 784,000        | 3% | \$ 654,000 | 3% |
| Land                     |   | \$ -   |          |            |                   |                          |                    |           |                 |                      |            |                     |                      |   |   |   |   |   |          |            |   |   | 0.200   | \$1,074,000      | \$ 920,000        | 4% | \$ 788,000 | 3% |
| Total Capex              |   | 0.0000 | 0.0000   | 5,500,000  | 0.0000            | 0.0000                   | 0.0000             | 0.0000    |                 |                      |            |                     |                      |   |   |   |   |   |          |            |   |   |         |                  |                   |    |            |    |
| Cost inflation           |   | 2.5%   |          |            |                   |                          |                    |           |                 |                      |            |                     |                      |   |   |   |   |   |          |            |   |   |         |                  |                   |    |            |    |
| Comb. Payback Yrs.       |   |        |          |            |                   |                          |                    |           |                 |                      |            |                     |                      |   |   |   |   |   |          |            |   |   |         |                  |                   |    |            |    |
| Forecast reduction       |   | 5%     |          |            | 0.0000            |                          |                    |           |                 |                      |            |                     |                      |   |   |   |   |   |          |            |   |   |         |                  |                   |    |            |    |
| ROI                      |   | 537%   |          |            | 0.0000            |                          |                    |           | 0.0000          |                      |            |                     |                      |   |   |   |   |   |          |            |   |   |         |                  |                   |    |            |    |
| Payback Yrs.             |   | Yr 4   |          |            |                   |                          |                    |           |                 |                      |            |                     |                      |   |   |   |   |   |          |            |   |   |         |                  |                   |    |            |    |
| Years                    |   |        |          |            |                   |                          |                    |           |                 | \$ 115,931           |            |                     |                      |   |   |   |   |   |          |            |   |   |         |                  |                   |    |            |    |
| 0                        |   | 0.0000 | 0.0000   | 5,500,000  | 0.0000            | 0.0000                   | 0.0000             | 0.0000    | \$ 8,333        | \$138,110            |            |                     |                      |   |   |   |   |   |          |            |   |   |         |                  |                   |    |            |    |
| 1                        |   | 0.0000 | 0.0000   | 5,486,250  | 0.0000            | 0.0000                   | 0.0000             | 0.0000    | \$ 8,333        | \$138,110            |            |                     |                      |   |   |   |   |   |          |            |   |   |         |                  |                   |    |            |    |
| 2                        |   | 0.0000 | 0.0000   | 5,472,500  | 0.0000            | 0.0000                   | 0.0000             | 0.0000    | \$ 8,333        | \$138,110            |            |                     |                      |   |   |   |   |   |          |            |   |   |         |                  |                   |    |            |    |
| 3                        |   | 0.0000 | 0.0000   | 5,458,750  | 0.0000            | 0.0000                   | 0.0000             | 0.0000    | \$ 8,333        | \$138,110            |            |                     |                      |   |   |   |   |   |          |            |   |   |         |                  |                   |    |            |    |
| 4                        |   | 0.0000 | 0.0000   | 5,445,000  | 0.0000            | 0.0000                   | 0.0000             | 0.0000    | \$ 8,333        | \$138,110            |            |                     |                      |   |   |   |   |   |          |            |   |   |         |                  |                   |    |            |    |
| 5                        |   | 0.0000 | 0.0000   | 5,431,250  | 0.0000            | 0.0000                   | 0.0000             | 0.0000    | \$ 8,333        | \$138,110            |            |                     |                      |   |   |   |   |   |          |            |   |   |         |                  |                   |    |            |    |
| 6                        |   | 0.0000 | 0.0000   | 5,417,500  | 0.0000            | 0.0000                   | 0.0000             | 0.0000    | \$ 8,333        | \$138,110            |            |                     |                      |   |   |   |   |   |          |            |   |   |         |                  |                   |    |            |    |
| 7                        |   | 0.0000 | 0.0000   | 5,403,750  | 0.0000            | 0.0000                   | 0.0000             | 0.0000    | \$ 8,333        | \$138,110            |            |                     |                      |   |   |   |   |   |          |            |   |   |         |                  |                   |    |            |    |
| 8                        |   | 0.0000 | 0.0000   | 5,390,000  | 0.0000            | 0.0000                   | 0.0000             | 0.0000    | \$ 8,333        | \$138,110            |            |                     |                      |   |   |   |   |   |          |            |   |   |         |                  |                   |    |            |    |
| 9                        |   | 0.0000 | 0.0000   | 5,376,250  | 0.0000            | 0.0000                   | 0.0000             | 0.0000    | \$ 8,333        | \$138,110            |            |                     |                      |   |   |   |   |   |          |            |   |   |         |                  |                   |    |            |    |
| 10                       |   | 0.0000 | 0.0000   | 5,362,500  | 0.0000            | 0.0000                   | 0.0000             | 0.0000    | \$ 8,333        | \$138,110            |            |                     |                      |   |   |   |   |   |          |            |   |   |         |                  |                   |    |            |    |
| 11                       |   | 0.0000 | 0.0000   | 5,348,750  | 0.0000            | 0.0000                   | 0.0000             | 0.0000    | \$ 8,333        | \$138,110            |            |                     |                      |   |   |   |   |   |          |            |   |   |         |                  |                   |    |            |    |
| 12                       |   | 0.0000 | 0.0000   | 5,335,000  | 0.0000            | 0.0000                   | 0.0000             | 0.0000    | \$ 8,333        | \$138,110            |            |                     |                      |   |   |   |   |   |          |            |   |   |         |                  |                   |    |            |    |
| 13                       |   | 0.0000 | 0.0000   | 5,321,250  | 0.0000            | 0.0000                   | 0.0000             | 0.0000    | \$ 8,333        | \$138,110            |            |                     |                      |   |   |   |   |   |          |            |   |   |         |                  |                   |    |            |    |
| 14                       |   | 0.0000 | 0.0000   | 5,307,500  | 0.0000            | 0.0000                   | 0.0000             | 0.0000    | \$ 8,333        | \$138,110            |            |                     |                      |   |   |   |   |   |          |            |   |   |         |                  |                   |    |            |    |
| 15                       |   | 0.0000 | 0.0000   | 5,293,750  | 0.0000            | 0.0000                   | 0.0000             | 0.0000    | \$ 8,333        | \$138,110            |            |                     |                      |   |   |   |   |   |          |            |   |   |         |                  |                   |    |            |    |
| 16                       |   | 0.0000 | 0.0000   | 5,280,000  | 0.0000            | 0.0000                   | 0.0000             | 0.0000    | \$ 8,333        | \$138,110            |            |                     |                      |   |   |   |   |   |          |            |   |   |         |                  |                   |    |            |    |
| 17                       |   | 0.0000 | 0.0000   | 5,266,250  | 0.0000            | 0.0000                   | 0.0000             | 0.0000    | \$ 8,333        | \$138,110            |            |                     |                      |   |   |   |   |   |          |            |   |   |         |                  |                   |    |            |    |
| 18                       |   | 0.0000 | 0.0000   | 5,252,500  | 0.0000            | 0.0000                   | 0.0000             | 0.0000    | \$ 8,333        | \$138,110            |            |                     |                      |   |   |   |   |   |          |            |   |   |         |                  |                   |    |            |    |
| 19                       |   | 0.0000 | 0.0000   | 5,238,750  | 0.0000            | 0.0000                   | 0.0000             | 0.0000    | \$ 8,333        | \$138,110            |            |                     |                      |   |   |   |   |   |          |            |   |   |         |                  |                   |    |            |    |
| 20                       |   | 0.0000 | 0.0000   | 5,238,750  | 0.0000            | 0.0000                   | 0.0000             | 0.0000    | \$ 8,333        | \$138,110            |            |                     |                      |   |   |   |   |   |          |            |   |   |         |                  |                   |    |            |    |

## References

- Akpan, V.E., Omole, D.O. & Bassey, D.E. (2020). Assessing the public perceptions of treated wastewater reuse: opportunities and implications for urban communities in developing countries. *Heliyon*, 6(10), 1-21.
- Ahmed, M., & Anwar, R. (2012). An assessment of the environmental impact of brine disposal in marine environment. *International Journal of Modern Engineering Research (IJMER)*, 2(4), 2756-2761.  
<[https://www.researchgate.net/publication/270591145\\_An\\_Assessment\\_of\\_the\\_Environmental\\_Impact\\_of\\_Brine\\_Disposal\\_in\\_Marine\\_Environment](https://www.researchgate.net/publication/270591145_An_Assessment_of_the_Environmental_Impact_of_Brine_Disposal_in_Marine_Environment)>
- Cashman, A. (2014). Water security and services in the Caribbean. *Water*, 6(5), 1187-1203.
- Ceron, J.P., Peeters, P., & Hall, C.M. (2012). Tourism and water use: supply, demand, and security. An international review. *Tourism Management*, 33, 1-15.
- Courtene-Jones, W., et al. (2021). Source, sea and sink – A holistic approach to understanding plastic pollution in the Southern Caribbean. *The Science of the Total Environment*, 797(149098).
- Dalri-Cecato, L., Battistelli, A.A., Lapolli, F.R. (2020). CAPEX and OPEX evaluation of a membrane bioreactor aiming at water reuse. In: Leal Filho, W., de Andrade Guerra, J.B.S. (eds) *Water, Energy and Food Nexus in the Context of Strategies for Climate Change Mitigation. Climate Change Management*. Springer, Cham.
- Eke, J., et al. (2020). The global status of desalination. An assessment of current desalination technologies, plants and capacity. *Desalination*, 495(114633).
- Fortis TCI. (2024). *About FortisTCI - Power Company*.  
<<https://www.fortistci.com/about-fortis-tci>>
- Gies, E. (2019). Slaking the world's thirst with seawater dumps toxic brine in oceans. *Scientific American*. <<https://www.scientificamerican.com/article/slaking-the-worlds-thirst-with-seawater-dumps-toxic-brine-in-oceans/>>
- Guerra-Rodriguez, S. (2020). Towards the implementation of circular economy in the wastewater sector: challenges and opportunities. *Water*, 12(5), 1431.
- HAB Group. (2024). *Provo Water Company*. <<https://habgroup.com/portfolio-item/provo-water/>>
- Herber, G. (2024, January 7). *Plant Prices: The Costs of Constructing a Desalination Plant and Facility*. Medium. <<https://medium.com/@desalter/plant-prices-the-costs-of-constructing-a-desalination-facility-2c31f7fcb690>>

- Jones, E.R., et al. (2021). Country-level and gridded estimates of wastewater production, collection, treatment and reuse. *Earth System Science Data*, 13(2), 237-254.
- Kelaher, B.P., Clark, G.F., Johnston, E.L., & Coleman, M.A. (2019). Effect of desalination discharge on the abundance and diversity of reef fishes. *Environmental Science & Technology*, 54(2), 735-744.
- Lund, J., Lim, K., & Safford, H. (2019, January 20). *Improving Public Perception of Water Reuse*. California WaterBlog. <<https://californiawaterblog.com/2019/01/20/improving-public-perception-of-water-reuse/>>
- Mekonnen, M.M., & Hoekstra, A.Y. (2016). Four billion people facing severe water scarcity. *Science Advances*, 2(2).
- Mishra, R.K. (2023). Fresh water availability and its global challenge. *British Journal of Multidisciplinary and Advanced Studies*, 4(3), 1–78.
- Mohammadi, F., Sahraei-Ardakani, M., Al-Abdullah, Y., & Heydt, G.T. (2019). Cost-benefit analysis of desalination: a power market opportunity. *Electric Power Components and Systems*, 48(11), 1091-1101.
- Mycoo, M.A., & Roopnarine, R. (2024). Water resource sustainability: challenges, opportunities and research gaps in the English-speaking Caribbean Small Island Developing States. *PLOS Water*, 3(1), 1145-1160.
- Nibbs, F. (2024, May 14). Thirsty in paradise: Water crises are a growing problem across the Caribbean islands. *UMBC Magazine*. <<https://umbc.edu/stories/water-crises-across-the-caribbean-islands/>>
- Nottleson, E. (2023, December 5). How a St. Thomas resort optimizes wastewater reuse. *Veolia Water Technologies*. <<https://www.watertechnologies.com/blog/how-st-thomas-resort-optimizes-wastewater-reuse>>
- Orange County Water District (OCWD) (2024). *GWRS: Groundwater Replenishment System*. <<https://www.ocwd.com/gwrs/>>
- Palatnik, R.R. (2019). The economic value of seawater desalination—the case of Israel. In: Wittwer, G. (eds) *Economy-Wide Modeling of Water at Regional and Global Scales. Advances in Applied General Equilibrium Modeling*. Springer, Singapore.
- Peters, E.J. (2015). Wastewater reuse in the eastern Caribbean: a case study. *Water Management*, 12(3), 984-999.
- Peters E.J. & Goberdhan, L. (2016). Potential consumers' perception of treated wastewater reuse in Trinidad. *West Indian Journal of Engineering*, 38(2), 33–43. <<https://journals.sta.uwi.edu/ojs/index.php/wije/article/view/7706>>
- Petersen, K.L., et al. (2018). Impact of brine and antiscalants on reef-building corals in the Gulf of Aqaba – potential effects from desalination plants. *Water Research*, 144, 183-191.

- Provo Water (2025). *Water Distribution Map*. <https://provowater.com/pwc-water-distribution-map>
- PUB: Singapore's National Water Agency (2024, October 2). *NEWater*. Government of Singapore. <https://www.pub.gov.sg/Public/WaterLoop/OurWaterStory/NEWater>
- Rasoolimanesh, S. M., Ramakrishna, S., Hall, C. M., Esfandiar, K., & Seyfi, S. (2020). A systematic scoping review of sustainable tourism indicators in relation to the sustainable development goals. *Journal of Sustainable Tourism*, 31(7), 1497–1517.
- Roopnarine, R., et al. (2021). Capacity building in participatory approaches for hydro-climatic disaster risk management in the Caribbean. *International Journal of Disaster Risk Reduction*, 66(102592).
- Roopnarine, R., et al. (2023). Integrating wastewater reuse into water management schemes of Caribbean SIDS: A Trinidad and Tobago case study. *Water Policy*, 25(12), 1161-1174.
- Rose, O. (2024, April 12). Provo Water Company set to improve water distribution. *Turks and Caicos Weekly News*. <https://tcweeklynews.com/provo-water-company-set-to-improve-water-distribution-p13990-155.htm>
- Salah, L., & Mezher, T. (2021). Techno-economic analysis of sustainability and externality costs of water desalination production. *Renewable and Sustainable Energy Reviews*, 150(111465).
- Sirota, R., et al. (2024). Impacts of desalination brine discharge on benthic ecosystems. *Environmental Science & Technology*, 58, 5631-5645. <https://bpb-us-e1.wpmucdn.com/sites.ucsc.edu/dist/5/1050/files/2024/05/sirota-et-al-2024-impacts-of-desalination-brine-discharge-on-benthic-ecosystems.pdf>
- Spalding, M.D., et al. (2018, October 31). Estimating reef-adjacent tourism value in the Caribbean. *Ocean Wealth*. <https://oceanwealth.org/wp-content/uploads/2019/02/Reef-Adjacent-Tourism-Value-Caribbean-Study.pdf>
- Tortajada, C. (2020). Contributions of recycled wastewater to clean water and sanitation Sustainable Development Goals. *Clean Water*, 3(20), 33-45.
- Tourism Analytics (n.d.) Caribbean. <https://tourismanalytics.com/caribbean-statistics.html#>
- United Nations Development Programme (UNDP). (2024, April 30). *Small Island Developing States are on the Frontline of Climate Change – here's why*. <https://climatepromise.undp.org/news-and-stories/small-island-developing-states-are-frontlines-climate-change-heres-why>
- United Nations Economic Commission for Latin America and the Caribbean (ECLAC) (2011, October 22). *An Assessment of the Economic Impact of Climate Change on the Water Sector in The Turks and Caicos Islands*.

<<https://repositorio.cepal.org/server/api/core/bitstreams/49f32efb-8bf7-47f9-ab59-bc3acbd2729c/content>>

World Bank (2020, June 30). *Valuing Water, Enabling Change: Annual Report 2020* (English). Washington, D.C.: World Bank Group.  
<<http://documents.worldbank.org/curated/en/099113024053125486/P1811471cf96450b618b1a10baa61d28d5>>1

World Economic Forum (2022, December 16). The desalination process gives us freshwater – at a huge environmental cost. *World Economic Forum: Nature and Biodiversity*. <<https://www.weforum.org/stories/2022/12/desalination-process-freshwater-negative-environmental-cost>>