2019 REPORT CARD FOR PUERTO RICO'S INFRASTRUCTURE

American Society of Civil Engineers Puerto Rico Section

INFRASTRUCTUREREPORTCARD.ORG/PUERTO-RICO

ASCE
AMERICAN SOCIETY OF CIVIL ENGINEERS

INTRODUCTION

Infrastructure is central to quality of life and economic development. Households receive a wide range of goods and services thanks to infrastructure, including fresh fruit and vegetables, water, electronics, and textile goods. Meanwhile, infrastructure can reduce fixed costs of production for businesses, especially costs associated with transportation, which tend to be a determinant of business location. Simply put, infrastructure matters to people and businesses all around.

Puerto Rico is no exception. The quality of infrastructure is essential in the daily lives of the people of Puerto Rico, and this was all too evident when Hurricanes Maria and Irma devastated the island in 2017. Two years removed from the storms, rebuilding our infrastructure remains a work in progress. Unfortunately, constant failures in the energy system, prevalent poor conditions in the road network, and notable deferred maintenance across public buildings impact daily functions, mobility and productivity. They serve as vivid reminders of the need to increase investment in infrastructure, employ better maintenance practices, and develop smarter policy.

The American Society of Civil Engineers (ASCE), founded in 1852, is the oldest national professional engineering society in the United States. ASCE represents more than 150,000 members of the civil engineering profession in 177 countries. The Puerto Rico Section is commemorating its 90th anniversary with the release of the first Report Card for Puerto Rico's Infrastructure. The ASCE Puerto Rico Section has devoted significant personal time in the development of the Infrastructure Report Card, in hopes of encouraging smart rebuilding efforts, influencing sound infrastructure policy, keeping the island competitive, and improving Puerto Ricans quality of life.

Contained in this report card is an analysis of eight categories of infrastructure: bridges, dams, drinking water, energy, ports, roads, solid waste, and wastewater. However, there are other built networks in Puerto Rico that are vitally important to public safety and wellbeing that aren't included in this report. For example, school facilities were critical to the recovery efforts following the 2017 hurricanes, and many of these buildings need rehabilitation. Coastal infrastructure serves to safeguard Puerto Rico from storms and sea level rise, as well as protect the environment and foster economic longevity. There are other areas of significant concern not covered by this report card, including land use planning and a lack of access to affordable housing. These challenges are critically important but are outside the scope of this ASCE Infrastructure Report Card.

The *2019 ASCE Report Card for Puerto Rico's Infrastructure* is a simple tool to help residents, businesses, and policymakers understand the state of the island's infrastructure and consider solutions to raise the grades. This information is intended to move the conversation forward about how to rebuild Puerto Rico and improve our economy and quality of life.

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GRADING CRITERIA

The Report Card Sections are based on the following eight criteria:

CAPACITY Does the infrastructure's capacity meet current and future demands?

CONDITION What is the infrastructure's existing and near-future physical condition?

FUNDING What is the current level of funding from all levels of government for the infrastructure category as compared to the estimated funding need?

FUTURE NEED What is the cost to improve the infrastructure? Will future funding prospects address the need?

OPERATION AND MAINTENANCE What is the owners' ability to operate and maintain the infrastructure properly? Is the infrastructure in compliance with government regulations?

PUBLIC SAFETY To what extent is the public's safety jeopardized by the condition of the infrastructure and what could be the consequences of failure?

RESILIENCE What is the infrastructure system's capability to prevent or protect against significant multi-hazard threats and incidents? How able is it to quickly recover and reconstitute critical services with minimum consequences for public safety and health, the economy, and national security?

INNOVATION What new and innovative techniques, materials, technologies, and delivery methods are being implemented to improve the infrastructure?

GRADING SCALE

EXCEPTIONAL: FIT FOR THE FUTURE

The infrastructure in the system or network is generally in excellent condition, typically new or recently rehabilitated, and meets capacity needs for the future. A few elements show signs of general deterioration that require attention. Facilities meet modern standards for functionality and resilient to withstand most disasters and severe weather events.

GOOD: ADEQUATE FOR NOW

The infrastructure in the system or network is in good to excellent condition; some elements show signs of general deterioration that require attention. A few elements exhibit significant deficiencies. Safe and reliable with minimal capacity issues and minimal risk.

MEDIOCRE: REQUIRES ATTENTION

The infrastructure in the system or network is in fair to good condition; it shows general signs of deterioration and requires attention. Some elements exhibit significant deficiencies in conditions and functionality, with increasing vulnerability to risk.

POOR: AT RISK

The infrastructure is in poor to fair condition and mostly below standard, with many elements approaching the end of their service life. A large portion of the system exhibits significant deterioration. Condition and capacity are of significant concern with strong risk of failure.

FAILING/CRITICAL: UNFIT FOR PURPOSE

The infrastructure in the system is in unacceptable condition with widespread advanced signs of deterioration. Many of the components of the system exhibit signs of imminent failure.

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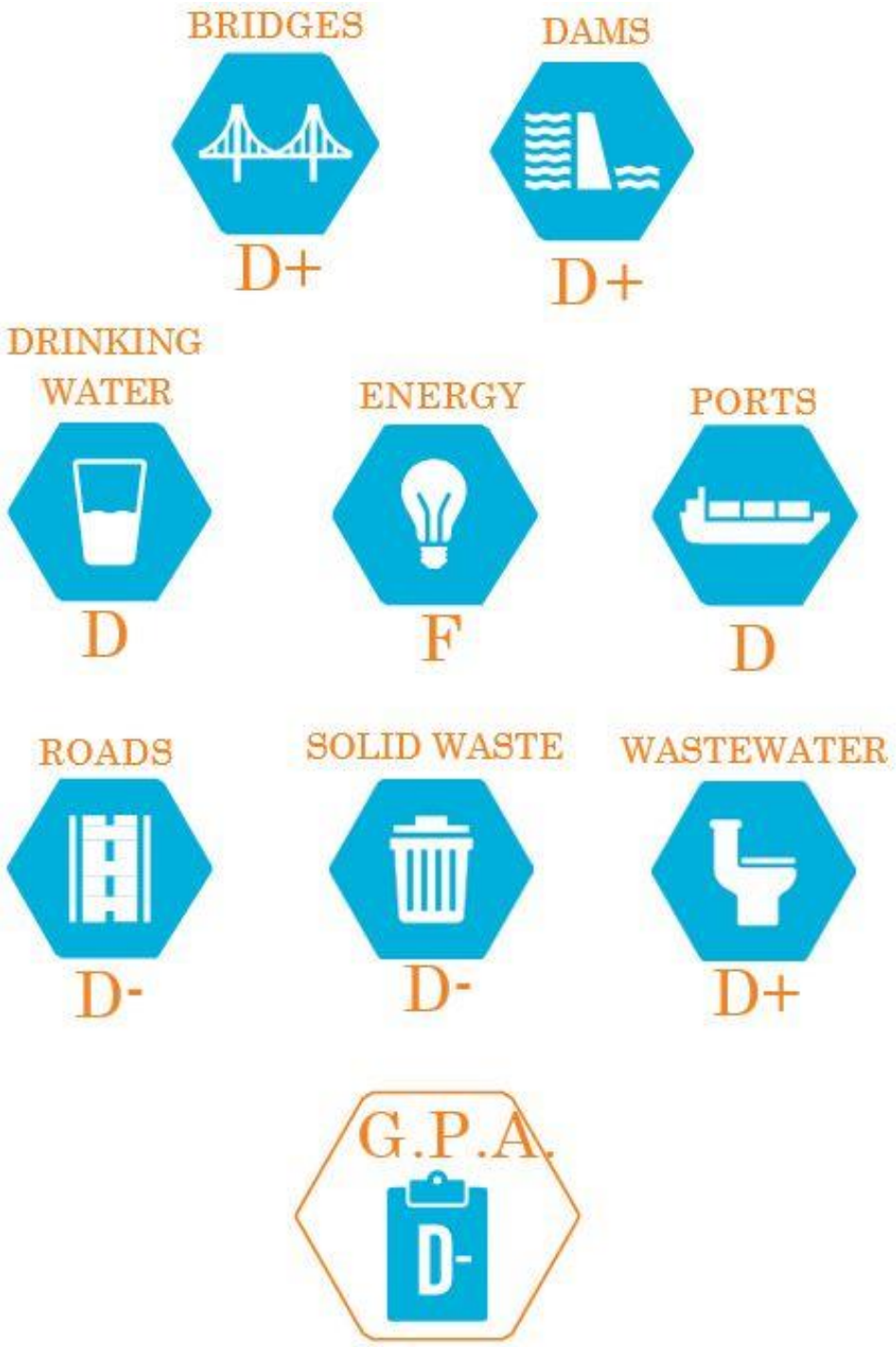


SOLUTIONS TO RAISE THE GRADE

Increase the resiliency of Puerto Rico's infrastructure. Our future depends on the ability of our infrastructure to not only protect us against increasingly severe storms, but to facilitate timely emergency management, response, and recovery efforts after a major event. The resiliency of all our networks can be improved by requiring the Central Government and municipalities build to ASCE 7 standards, incorporating lifecycle cost analysis into projects, and by maintaining our existing assets. Taking these actions will extend the useful life of our assets and decrease costs in the long-term.

Establish a Puerto Rico Infrastructure Plan with a wide variety of stakeholders and experts in the field. Infrastructure development is a long-term endeavor with significant impacts on economic growth and competitiveness. Puerto Rico should formulate a general Infrastructure Plan with clear priorities and strategies to achieve them. This plan should be approved by the Legislative Assembly but be developed with limited political interference. In the international area, the Caribbean region has some successful examples of a similar approach. For instance, in 2012 the Dominican Republic adopted their National Development Strategy 2030, which is a long-term plan for development that was enacted into law to ensure continuity in its implementation. The National Development Plan 2030 for Dominican Republic has clear infrastructure goals and indicators.

Puerto Rico's infrastructure systems need comprehensive and consistent maintenance programs and databases. A lack of programmed funding for the comprehensive maintenance of our existing roads, bridges, energy, dams and other critical networks has severely impacted the lifespan of these assets. Developing comprehensive asset management databases is a critical first step, as these databases can help determine total funding and maintenance needs. Looking ahead, infrastructure planning, designing, and constructing should consider the total cost of operating an asset over its lifespan. Resiliency and sustainability must be factors in determining lifecycle costs. Lessons learned, unique Puerto Rico characteristics, and climate change should also be considered.

Improve and increase the technical expertise at agencies that own and operate infrastructure so that they can complete regulatory requirements. Many of Puerto Rico's agencies have too few technical experts to operate the infrastructure in accordance with regulations and customer expectations. Additionally, institutional knowledge is not codified in the agency, but instead may be lost when individuals retire or resign. We need to improve the continuity of the workforce training to operate and maintain our roads, solid waste, drinking and wastewater infrastructure.

Increase drinking water infrastructure's capacity and delivery. An estimated 40 to 60% of storage capacity in water reservoirs is lost due to sedimentation build up. Additionally, an estimated 58% of non-revenue water is lost as a result of leaky pipes, tank overflows, and other issues. As a result, residents are subjected to water rationing nearly every year, despite significant annual rainfall. To fix this, we need sediment management in reservoirs to restore capacity, improved metering of treated water, better data collection to determine the condition of pipelines and a more regular line renewal and replacement program. Additionally, new funding and financing should be secured from all levels of government.

Solid waste infrastructure needs immediate action and significant funding. Landfills on Puerto Rico are often lacking an updated permit or are unregulated, resulting in non-compliance with Environmental Protection Agency standards. Capacity is also a major challenge, exacerbated by the debris from the 2017 hurricane season. Looking ahead, policymakers must close open dumps, expand landfills in compliance, monitor closed landfills, increase staff at the Department of Natural and Environmental Resources, and promote recycling and composting.

The Central Government and municipalities must develop and implement a plan to rehabilitate, reconstruct, and maintain roads to the highest standards. Most roads in Puerto Rico are owned by municipalities, which often lack sufficient funding, robust data, and the in-house expertise or technical experts to build, rebuild and maintain roads to acceptable standards.

Economic Analysis

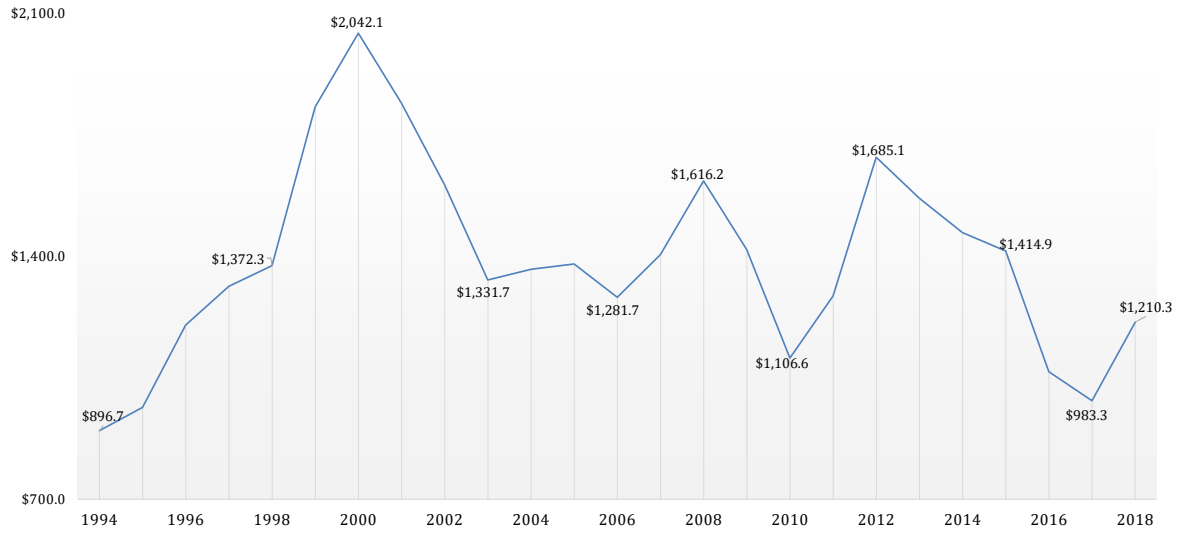
TRENDS IN INFRASTRUCTURE INVESTMENT IN PUERTO RICO

This section of the ASCE Report Card provides an overview of current infrastructure conditions in Puerto Rico and levels of investment across the infrastructure sectors.

According to the Construction Industry Selected Statistics Report, total investment in infrastructure has been trending down since fiscal year 2000.

In fiscal year 2000, the value of construction in infrastructure reached a peak of $2.04 billion. Subsequent years reveal a downtrend to a low of $983.3 million and $1,210.3 million in fiscal years 2017 and 2018, respectively. These are declines of over 40% with respect to fiscal year 2000. The graph below shows the trend in infrastructure investment for the last twenty-four (24) fiscal years in Puerto Rico.

Trend in Investment in Infrastructure



Fiscal Years, $ in millions.

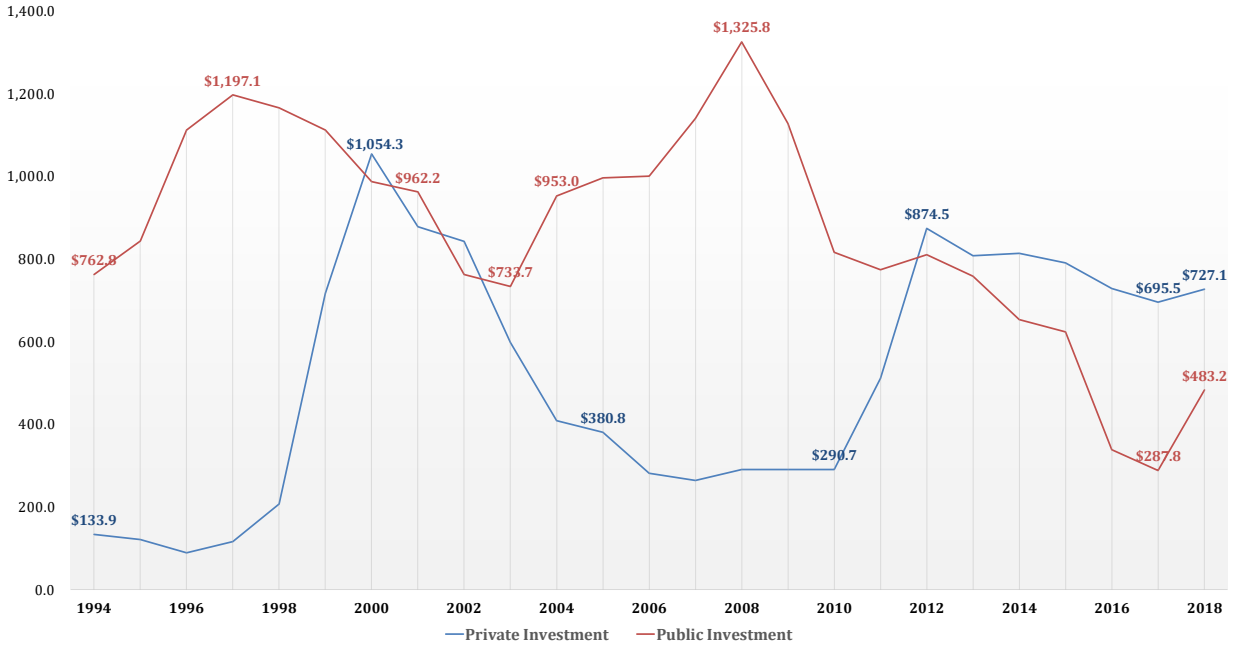
To put matters into context, it is important to understand the level of investment in and around fiscal year 2000. The majority of investment of Puerto Rico's first energy cogeneration plant occurred in fiscal year 2000, which coincided with other significant investments by the private sector. Simultaneously, public investment remained at healthy levels in different infrastructure installations.

Eighteen years later, the scenario was a much different one. In fiscal year 2018, total value of construction in infrastructure had dropped 41% compared to fiscal year 2000. A clearer picture can be obtained by analyzing total investment into public and private investment. In fiscal year 2018, the value of private and public construction activity into infrastructure was down 31% and 51% compared to the level in fiscal year 2000, respectively. The data show that public investment, in particular, has been in a steep decline since fiscal year 2008. Meanwhile, private investment in infrastructure remained low for most of the first decade of 2000s, and it was not until fiscal year 2010 that it experienced a notable increase.

In general terms, public investment played a dominant role between fiscal years 2003 to 2008, while private investment slumped to meager levels. After reaching a peak in 2008, public investment has constantly declined while private investment took a boost between fiscal year 2010 and 2012. This trend appears consistent with certain policy and economic fundamental shifts in Puerto Rico. Fiscal year 2008 marked the beginning of the Great Recession. Fiscal

constraints in Puerto Rico became more evident, which led to a decline in public investment, and forced a more systematic effort to encourage private investment to compensate for the inability of government to allocate funding and financing into infrastructure including capital improvements.

Trend in Public and Private Investment in Infrastructure



Fiscal Years, $ in millions.

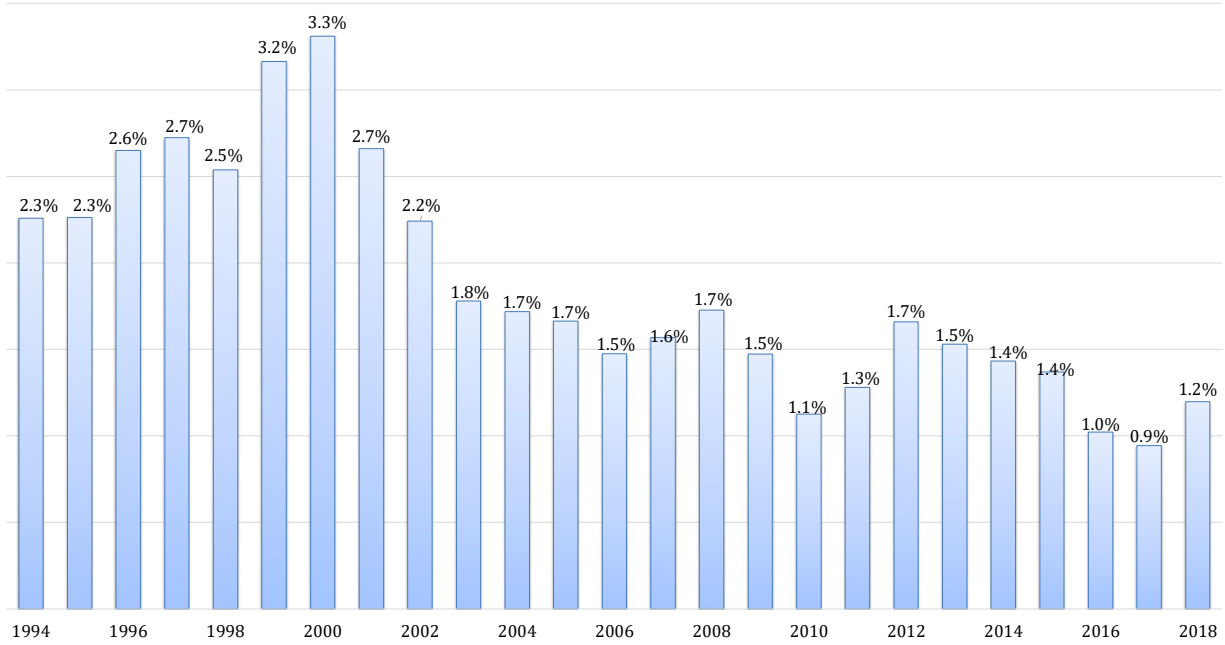
The trend based on data from fiscal years 2000 to 2018 reveal certain key lessons about infrastructure investment in Puerto Rico. First, fiscal year 2000 marked the end of a brief period of boosted public and private investment in Puerto Rico's infrastructure. Subsequently, between 2002 and 2011, the share of private investment declined dramatically, and only since 2018 has there been a slight jump in private expenditures. Finally, since 2008, public investment has dragged the entire level of infrastructure investment in Puerto Rico to historic lows. In short, investment in infrastructure from both public and private sources have lagged since 2000.

INFRASTRUCTURE INVESTMENT GAP

ASCE asks that investment in infrastructure constitute 3.5% of Gross Domestic Product ("GDP"). This benchmark is consistent with internationally accepted rule of thumb that at least 3% of GDP should be devoted to infrastructure investment in advanced economies in order to keep infrastructure updated.

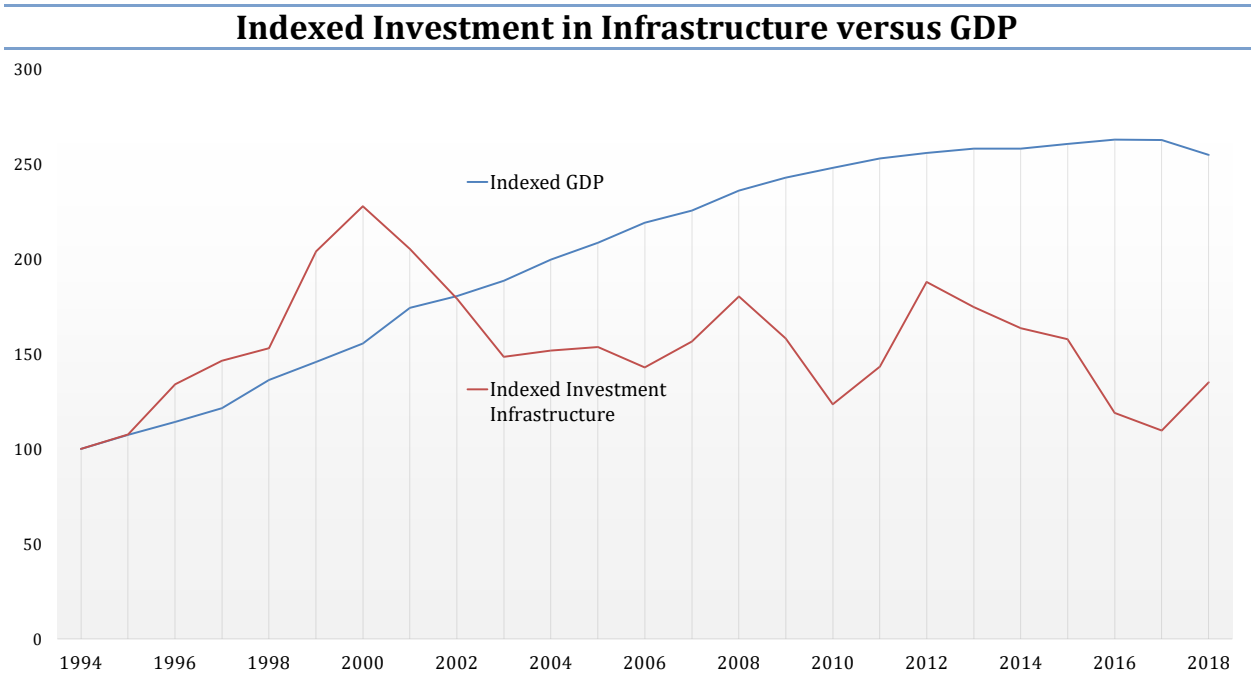
On average, federal, state and local governments in the U.S. spent 2.4% of GDP on infrastructure investment, below the recommended threshold. However, investment in infrastructure only amounted to 1.2% of GDP Puerto Rico in fiscal year 2018. In fact, significant divestment in infrastructure has occurred for a prolonged period of time. On average, Puerto Rico has experienced a level of investment in infrastructure of just 1.5% of GDP from fiscal year 2001 to 2018. Fiscal year 2018, contains the month of September 2017, when Puerto Rico was hit by Hurricane Maria, the most devastating hurricane in recent history in Puerto Rico. Thus, the data in these series only includes a small portion of post-Hurricane Maria recovery spending. The last time investment in infrastructure reached the 3% GDP mark, was in fiscal year 2000, when Puerto Rico recorded a level of investment equivalent to 3.3% of GDP. The graph below shows the trend in investment level as a percentage of GDP.

Investment in Infrastructure as a Percentage of Puerto Rico's GDP



Based on the ASCE's benchmark and the data above, it is reasonable to estimate that Puerto Rico faces an infrastructure investment gap that ranges from 1.3% to 2.3% of GDP. In other words, on average, Puerto Rico needs to increase infrastructure investment by $1.3 to $2.3 billion annually in order to reach a desired range of 2.5%-3.5% of GDP. Sustained, robust investment in infrastructure will allow Puerto Rico to address pressing needs across infrastructure sectors.

Furthermore, increased level of investment in infrastructure will provide support for economic growth. The existing levels of infrastructure investment are not associated with an expanding economy. The graph below portrays a graphical relationship between infrastructure investment and the evolution of GDP.



CONCLUSION

Modern infrastructure is critical for quality of life, productivity and economic development in general. Puerto Rico's level of infrastructure investment has been declining constantly since fiscal year 2000. Although the downtrend can have various explanations, the constraints in public finances and credit have had the largest dragging effect on infrastructure investment. However, a policy of encouraging complementary roles between public and private infrastructure investment can lead to increases in infrastructure in a sustainable manner. Puerto Rico faces a notable infrastructure investment gap that can be mitigated by raising the level of attention and enacting policies that gives infrastructure a renewed sense of priority in the public debate.

RESOURCES

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2. Puerto Rico Planning Board, Selected Statistics of the Construction Industry, Table 1, 1994-2018p. Data series constructed by the authors to reflect the adopted definition of infrastructure.
3. Puerto Rico Planning Board, Statistical Appendix 1994 – 2018p and Selected Statistics for the Construction Industry 1994-2018p.
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Bridges D+

EXECUTIVE SUMMARY

According to the Federal Highway Administration, there are 2,325 bridges in Puerto Rico. Of those bridges, 11.7 percent are in poor condition, and approximately 69 percent are in fair condition. Only 19 percent of Puerto Rico's bridges are in good condition. Additionally, Puerto Rico is home to four of the nation's top 250 most travelled structurally deficient bridges, with two in the top 10. Hurricanes Irma and Maria further exacerbated the precarious fiscal situation of Puerto Rico's highway agency. The Puerto Rico Highways & Transportation Authority and other bridge owners were forced to reassign regular maintenance funding to asset recovery due to widespread damage. Furthermore, planned capital improvement projects were put on hold to allow agencies to prioritize emergency repairs to bring damaged infrastructure back online. Looking forward, a robust maintenance program must be established and funded that prioritizes improving resilience and rehabilitating aging bridges.

CONDITION & CAPACITY

Bridge facilities are owned and serviced by state, municipal/county highway agencies as well as the state toll authority. Table 1 shows the breakdown of bridge ownership in Puerto Rico.

Bridge Owner	Frequency	Percentage (%)
Municipal/County	374	16
State Highway Agency	1,632	70
State Toll Authority	312	13.4
Other (Private Owners)	16	0.7

Table 1 Bridge Ownership in Puerto Rico (Source: Adapted from PRHTA)

The National Bridge Inspection Standards (NBIS) requires bridge inspections at a minimum of every two years. Puerto Rico completes bridge inspections in compliance with NBIS, but some structures may be inspected more frequently (e.g., 6, 12 or 24 months) depending on the bridge's condition.

The National Bridge Inventory (NBI) of 2018 classifies bridges as in good, fair or poor condition. Bridges in good condition present minor to no problems, while bridges in fair condition can show some minor deterioration, cracking, scour or spelling. Bridges in poor condition show signs of advance deterioration, spelling or scour. In Puerto Rico 19 percent of the bridges and culverts in Puerto Rico were classified in good condition, 69 percent were classified in fair condition, and 11.7 percent were classified in poor condition.

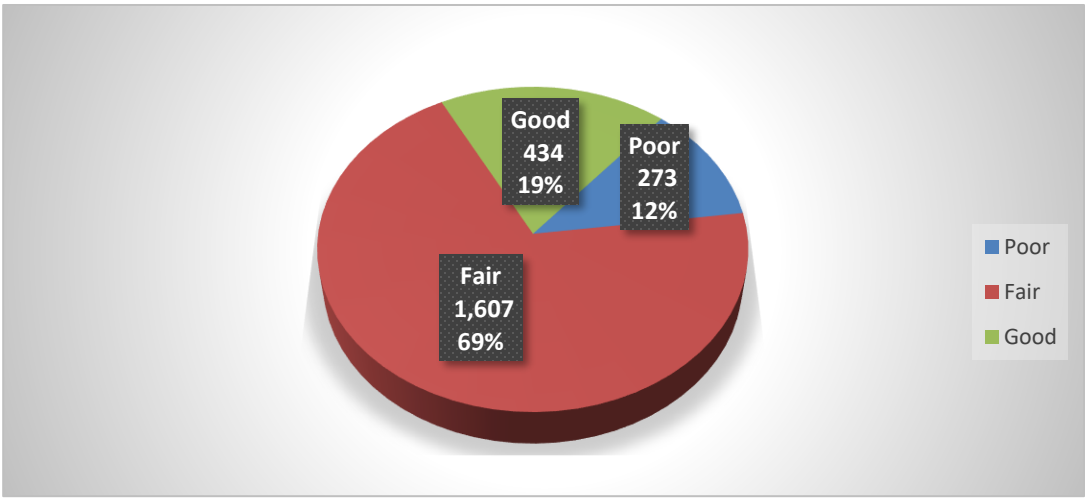

Figure 2 Bridge Conditions Rating (Source: NBI-PRHTA, 2018)

Structurally deficient bridges are bridges that require significant maintenance, rehabilitation, or replacement. These bridges must be inspected at least every year since critical load-carrying elements were found to be in poor condition due to deterioration or damage. Approximately 11.7 percent were considered structurally deficient, a classification that roughly equates to "poor." In addition, Puerto Rico is home to four of the nation's top 250 most travelled yet structurally deficient bridges, with two being among the top 10. A structurally deficient bridge does not mean its unsafe, but that the capabilities of the structure are limited, and must be monitored. The designation has a financial impact for the overseeing agency.

Age can also be an indicator of bridge condition, although bridge lifespans can be extended through regular maintenance. The average age of Puerto Rico's bridges is 45 years old – slightly older than the U.S average bridge age of 43 years, per ASCE's 2017 Infrastructure Report Card. Most of the country's bridges were designed for a lifespan of 50 years, so an increasing number of bridges will soon need major rehabilitation or retirement. Currently, 37 percent of the bridges in Puerto Rico have reached a service life of 50 or more years, and 21 percent of the bridges have reached a service life between 40 and 49 years. Bridges of this era often reach the end of their service lives at 50 years of age, especially when regular repair and maintenance does not occur. By 2030 at least 1,400 bridges will be 50 years or older, representing approximately 60 percent of Puerto Rico's bridge inventory.

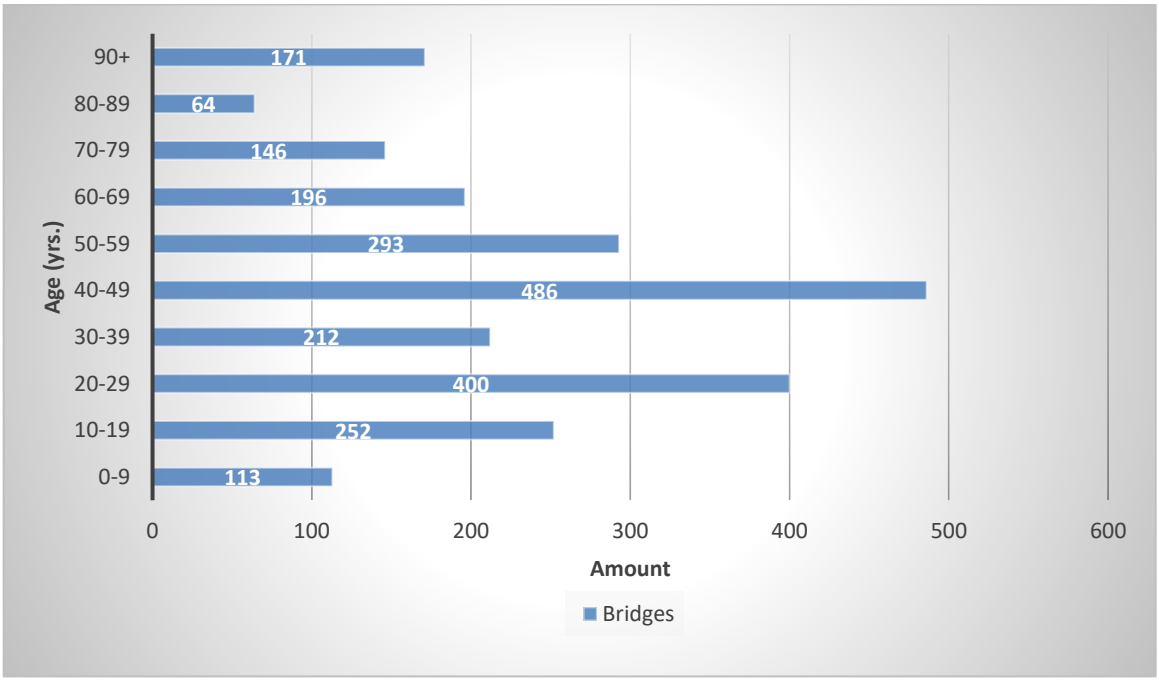

Figure 2 – *Service* Life Distribution of Bridges in Puerto Rico (Source: PRHTA)

In addition to nearing or surpassing their service lives, bridge conditions are worsening due to the exposure of high loads, poor maintenance, and scour. Under Puerto Rican law, trucks can weigh up to 110,000 pounds, compared with U.S. mainland regulations, which generally allow for up to 80,000lb trucks. High loads may result in more damage to bridges and roadways, which increases the amount of funding needed to perform routine operation and maintenance.

Additionally, many of Puerto Rico's bridges have problems of exposed foundations due to scour. Scour is the result of forceful flow of water in a watercourse over the foundations of a bridge that removes the soil or rock around and underneath the foundation. Heavy rains during Hurricanes Irma and Maria in 2017 resulted in increased scour around many bridge foundations. Overall, scour and structural deficiencies are two problems with bridges that PRHTA needs proper funding to address immediately.

OPERATION AND MAINTENANCE

With the exception of the 123 bridges operated and managed by the private company Metropistas, operation and maintenance (O&M) of bridges is generally managed by the state government or municipalities. In past years prior to Hurricane Irma and Maria, the transportation infrastructure plan prioritized bridges in critical condition using the following criteria: presence on the NHS list, traffic volume, status as fracture critical, and sole provider of access to a region.

O&M of bridges in Puerto Rico has been greatly hampered by the economic distress, a lack of personnel, and inadequate access to technology at the managing agencies. Hurricanes Irma and Maria further exacerbated the situation as agencies were forced to reassign regular maintenance funding to asset recovery due to widespread damage. Furthermore, planned capital improvements projects were put on hold to allow agencies to prioritize emergency repairs to bring damaged infrastructure back online.

PRHTA has a standard operation procedure for bridge project prioritization, a systematic preventive maintenance protocol for bridges, and it has a bridge preventive maintenance selection toolkit and checklist. However, in past years, the annual budget allocation for bridge work was $17 million, while the cost to replace one square meter of bridge is approximately $3,150. PRHTA was only able to address 0.26 percent of the area of Puerto Rico's bridges, forcing them to place bridges on the Critical Bridge List. However, PRHTA has just recently received a substantial bridge budget increase and is pursuing an aggressive bridge program based upon life cycle strategies.

FUNDING AND FUTURE NEED

A significant number of Puerto Rico's bridges have aged past their design life, and many additional bridges are now approaching the end of their service lives. As a result, robust funding is needed for bridge replacement, preservation, and rehabilitation. The 10-year condition targets is to have at least 10 percent of NHS bridges in good condition and no more than 10 percent of NHS bridges in poor condition. Currently, 18.5% NHS bridges are in good condition, however, bridge preservation and rehabilitation is important to maintain and increase the bridges in good condition.

Based on a proposed $738 million dollar investment from 2019 to 2028, PRHTA may achieve condition targets near the end of the 10-year asset management plan period. However, there are risk considering the proposed plan that may alter the expected results. The proposed plan does not account for continued inflation over the 10-year period, nor interruption of funding allocated for the bridge program. The long-term commitment of bridge preservation, rehabilitation and reconstruction projects are essential to achieving the desired results.

Funding is provided by both the federal government and the central government. Puerto Rico increased revenue for transportation as part of a 2015 law known as "*Crudita.*" The "*Crudita*" raised the import tariff on a barrel of oil from $9.25 to $15.50, which went into effect on March 15, 2015. With this, the Puerto Rico government aims to collect about $185 million in taxes that would allow it to subsidize the PRHTA and stabilize its finances. One of the purposes of this law is to financially assist PRHTA while also reducing its debt.

Federal funds are a critical financial resource for Puerto Rico. These funds are channeled to Puerto Rico through the Federal Highway Administration (FHWA) for highway projects and through the Federal Transit Administration (FTA) for mass transit projects. The federal government's share of a project is 80 percent, or up to 90 percent if the project is part of the interstate system.

In 2015, the federal government passed the Fixing America's Surface Transportation (FAST) Act, authorizing $305 billion for surface transportation infrastructure through September 2020 nationwide. Through this bill, the Federal Highway Administration (FHWA) and the Federal Transit Agency (FTA) provide PRHTA with $158.8 million per year for NHS roadways. Non-NHS roadways can receive federal funding from Surface Transportation Block Grant or Federal Emergency Management Agency in emergency cases.

Determining Puerto Rico's funding plan can be complicated for reasons that include:

1. Puerto Rico is a nonincorporated territory. This means federal funding is determined by a different formula than the states. It is worthwhile to investigate the differences and benefits between these formulas.
2. In Puerto Rico, transportation-related taxes and fees are not constitutionally dedicated to transportation purposes. Moreover, this revenue stream is sometimes redirected to other pressing situations not related to transportation.
3. On-going and proposed projects of PRHTA are financially based on toll credits from the federal government or emergency relief funding. State government provides a minor part of the budget allocated.

RESILIENCY AND INNOVATION

Bridges fared much better than other components of Puerto Rico's infrastructure systems during Hurricanes Irma and Maria. In general, bridges on the island withstood the wind forces of both hurricanes, and major problems were instead caused by high waters and debris accumulation.

Moving forward, it is important to learn from the experience of Hurricane María while also considering other natural disasters such as tsunamis and earthquakes. New designs should incorporate consideration of increasing frequency and severity of natural disasters, sea level rise, and the side effects of extreme weather such as scour and impacts of debris to infrastructure in their designs.

Another challenge to bridges relates to truck weights. Puerto Rico has one of the highest truck loads permitted in the United States and constant load pressures on bridges cause fatigue to structural elements. Consideration of the higher weight allowance must be accounted for when designing new bridges, maintaining established structures, and planning or developing routes that incorporate heavy truck loads.

Puerto Rico must also develop life cycle approaches that accounts for bridge rehabilitation and renovation maintenance programs to extend the service life of bridges. Having a long-term commitment to robust maintenance programs, leading-edge materials, techniques, designs, and infrastructure management databases can extend the useful life of bridges while lowering the long-term costs. Committing to fund the maintenance programs and adopt complete life cycle approach should be a priority.

RECOMMENDATIONS

Based on the current condition of the bridge infrastructure in Puerto Rico, and the importance of upgrading the system to improve safety to all road users, the following recommendations are made:

1. Adequate funding is needed to implement preventive maintenance programs immediately and stop further bridge deterioration.
2. Provide adequate funding to implement bridge replacement and rehabilitation immediately. Puerto Rico's TAMP plan proposes a $738 million dollars investment over 10 years, assuming post hurricane Maria inflation will not continue.
3. Enhance and maximize the use of federal funds.

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DAMS

D+

SUMMARY

Puerto Rico's 37 dams maintain water levels in reservoirs and streams for a variety of purposes, including recreation, flood control, potable water storage, and hydropower. Ninety-seven percent of Puerto Rico's dams are high-hazard potential, meaning failure would likely result in a loss of life. Island-wide, all the high-hazard potential dams have emergency action plans (EAP) in place, although only 35 percent were exercised – i.e. tested – in the past five years. While 81 percent of dams in Puerto Rico are reported to be in satisfactory condition, the state dam safety office lacks the funding to do comprehensive seismic and hydraulic studies and other analysis that is needed to more thoroughly determine the current conditions, risks, and necessary retrofits of the dams. Additionally, dams owners require funding to perform retrofits deemed necessary if discovered during those inspections. Meanwhile, sedimentation poses a long-term threat and impacts the ability of dams to store enough water to serve residents during dry seasons. Several of the most important water supply reservoirs have lost between 30 percent and 60 percent of their capacity due to sedimentation. With a large number of dams aged 50 years or more and predicted increases in flooding, additional funding is required to mitigate the risk of dam failure, especially for dams within the North Coast water supply network.

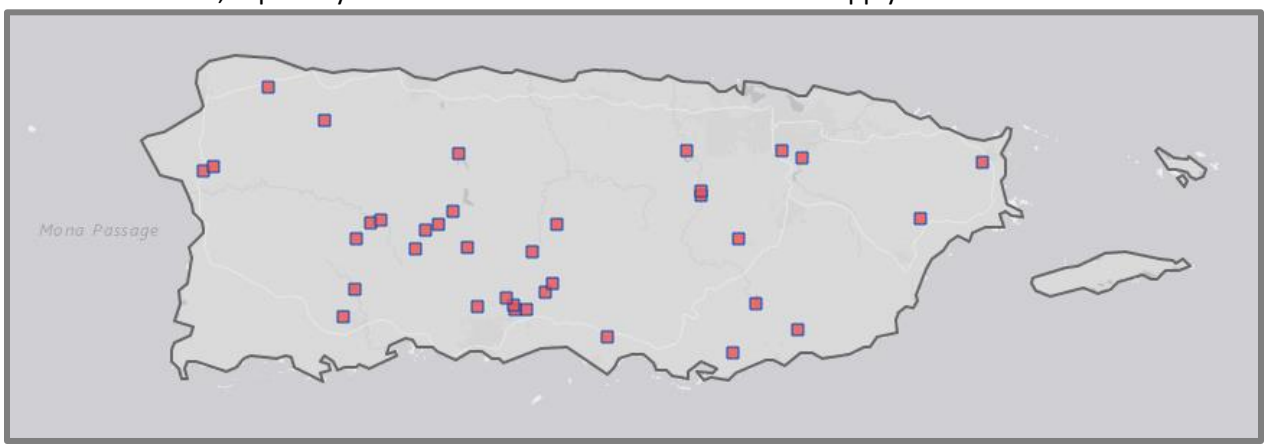

Figure 3: *Puerto Rico High-Hazard Potential Dams*

BACKGROUND

There are 37 dams of various sizes in Puerto Rico; 36 across rivers of the interior mountain region and one located on the east coast of the island (Figure 1). The dams provide services such as flood control, hydropower, and reservoirs for agricultural irrigation, recreation, and potable water. Just 11 dams contain approximately 67 percent of the drinking water sources for the Puerto Rico Aqueduct and Sewer Authority (PRASA). The average age of dams is 66 years old. Seven are sediment-filled and without maintenance and no longer fulfill their intended design.

Most dams are owned and operated by state-owned utilities, the P.R. Electric Power Authority (PREPA), the P.R. Aqueduct and Sewer Authority (PRASA), or state and local governments (Figure 2). The Dam and Reservoir Safety Inspection and Regulation Unit, a division within PREPA, is required to inspect each dam at least once every three years to identify structural and maintenance problems and needs. Their constructed capacity was 375,410 acre-feet, which has been reduced to 287,983 acre-feet due to sedimentation (about a 23 percent reduction).

Of the state-regulated dams, 36 are high-hazard potential (97 percent). A high-hazard potential classification indicates that dam failure or misoperation would likely result in loss of life and significant economic damages. The remining dam (Icacos) is classified as low-hazard potential, meaning a failure or mis-operation results in no probable loss of human life and low economic and/or environmental losses.

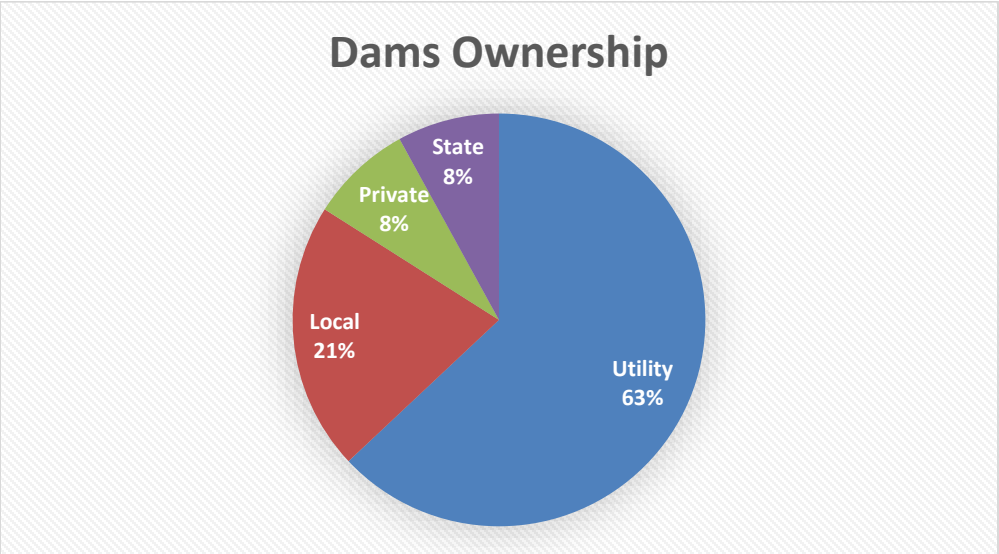

Figure 4: Puerto Rico's Dams Ownership

CAPACITY

Reservoirs contained by Puerto Rico's dams along rivers, streams and wells supply approximately 580 million gallons per day (mgd) of the raw water used by PRASA, which constitutes 67 percent of the island's drinking water. Reservoirs also provide approximately 40 mgd of water for agricultural irrigation in the northern and southern coastal valleys. In addition, they provide water to generate approximately 1.8 percent of the electric power produced by PREPA and support flood control in the Portugués, Cerrillos, Ajies and Dagüey basins.

The accumulation of sediments in reservoirs has reduced the storage capacity of all dams. Capacity has been reduced by more than 50 percent at the Dos Bocas, Loco, Loiza and Lucchetti dams. The baseline total capacity was approximately 375,410 acre-feet but was reduced to 287,983 acre-feet before Hurricane Maria. This represents a 23.3 percent decrease and a rate of sedimentation of 4.7 acre-feet per year at the El Guineo Dam to 277 acre-feet per year at the Dos Bocas Dam. High sedimentation rates occur in the north and east basins of the island where the rainfall is high, and the basins are more developed.

If the current sedimentation rate continues, the dams' life expectancies will be jeopardized. Consequently, this will affect their ability to generate hydroelectric power and store drinking water. This is the case for the Dos Bocas reservoir, whose capacity (pre-María) was reduced by more than 60 percent due to sedimentation. Furthermore, given its current sedimentation rate, life expectancy of the Dos Bocas reservoir is less than 35 years. The Dos Bocas reservoir, along with Caonillas and four others, is a part of the North Coast Superaqueduct which supplies more than 50 mgd drinking water to approximately 600,000 residents in the region. Other dams with low life expectancy include Loco, Loiza and Lucchetti with fewer than 15, 45 and 50 years, respectively.

Because a dam's hydroelectric generation performance is directly related to the dam capacity, the sedimentation of the dams affects electric generation. The installed hydroelectric energy generation capacity for the dams is 101.2 megawatts (MW). However, generation capacity has been reduced to 35 MW. Damage from hurricane María accounts for 31 MW of this reduction with the remainder attributed to lack of maintenance.

CONDITION

The National Inventory of Dams (NID) lists 36 state regulated dams in Puerto Rico. The majority, 24, are owned by state controlled public utilities (PREPA or PRASA). Additionally, eight are owned by the local government, one by the state and three are privately owned. The final dam in Puerto Rico is small enough that it is not listed in the NID.

All of the state regulated dams are of high-hazard potential, the Dam Safety Performance Report states that 29 are in satisfactory condition, four are in fair condition, two are in poor condition, and one is not rated. However, the Dam Safety Performance Report is based on state-provided information. Currently, dam conditions are being assessed through visual inspections. Due to budget constraints, the Dam Safety Inspection is limited in its ability to perform a diversity of studies such as seismic, hydraulic, stability, risk assessments, among other that are required to fully understand the current conditions to thoroughly determine their risks and necessary retrofits of the dams.

It is important to perform thorough analysis in timely manner to the dams, especially dams that are at least 50 years old (Figure 3). It's likely that some old dams were built without the seismic risk countermeasures, thus requiring more resources for thorough analysis in timely manner and retrofitting budget. However, in instances in which studies are conducted, they could take years also due to limited the budget.

OPERATION AND MAINTENANCE

On July 15, 1986, Law 133 was amended to require all dams be fully inspected at least once every three years. The inspections are carried out by the Dam and Reservoir Safety Inspection and Regulation Unit of PREPA. While the publicly-available 2019 NID reports that 10 inspections are out of date, NID information can take month to recollect and aggregate. For this reason, it's possible that most or all dam inspections are up to date.

The maintenance and operation of the dams in Puerto Rico is risk-based. This means that the priority for repair is given to structures that pose the greatest risk. However, a comprehensive assessment program is needed to focus on identifying deficiencies and prioritizing the repairs and mitigation measures.

Most of the dams have one operator during regular business hours (7:30AM-4:30PM). For dams primarily used for hydroelectricity, the operator is located in the hydrogeneration plant and makes visits as necessary. Because some of the operators are nearing retirement age, it would be beneficial to create a knowledge retention program to seamlessly train, and transfer experience and knowledge, to future operators.

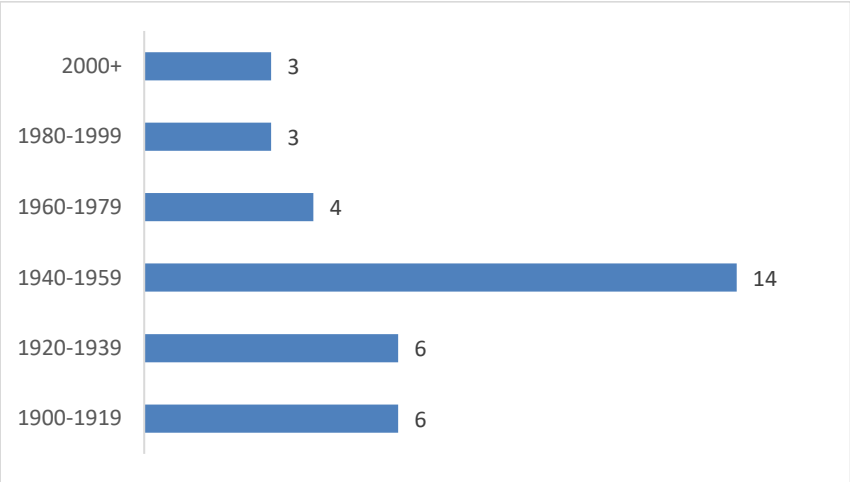

Figure 5: Dams by Completion Date (from NID)

PUBLIC SAFETY

Dam failure threatens public safety and poses millions of dollars in economic loss via property damages. Failure is not limited to damage to the dam itself, but also impacts infrastructure systems, such as roads, bridges, and water systems. While no dam has ever failed, from 1985 to 2017, there were three notable dam incidents, one of them causing loss of life and heavy damage.

Puerto Rico Law 133 was amended to require all dams be fully inspected at least once every three years. These inspections are carried out by the Dam and Reservoir Safety Inspection and Regulation Unit of PREPA. Dam safety inspections are the primary tool for avoiding accidents. However, for at least 10 of the dams registered in the 2019 NID, the last inspection date is more than three years old. As previously mentioned, the information reflected in the NID may take months to update, so inspection numbers may be out of date.

Once an emergency situation becomes imminent, such as a dam failure or uncontrolled release, Emergency Action Plans (EAPs) are put into action. Each dam has an EAP to standardizes procedures in case of a breach or failure and includes lists of agencies to alert, together with and flood inundation maps informing emergency personnel of at-risk areas that may require evacuation. After an EAP has been developed, it must be exercised by practicing the procedure, and it requires regular updating.

All 36 high hazard dams in Puerto Rico have an EAP. However, according to the 2019 Dam Safety Performance Report for Puerto Rico, only 35 percent of EAPs have been exercised in the past five years. After Hurricane María, an EAP was executed for the Guajataca Dam.

Currently, Puerto Rico has legislation to formalize methods for dam inventory, hazard classification, inspection, design, and condition assessment. Removal of obsolete and decaying dams that do not meet dam safety standards is not considered in this legislation. Therefore, the state needs additional resources to increase staffing levels in the PREPA and PRASA to properly assess and manage dams.

FUNDING & FUTURE NEED

Investment is needed to rehabilitate deficient dams and to improve the effectiveness of dam safety policies and regulatory programs. Occasional upgrades or rehabilitation to dams are necessary due to deterioration, evolving technical standards, technical improvements, progress in weather forecasting, increases in downstream population, and changes in land use.

According to the Puerto Rico Dam Safety program, the total state dam safety budget for 2018 was $230,686. This is equivalent to $6,234 per regulated high-hazard potential dam, which is higher than the national average of approximately $4,000. However, Puerto Rico's dam safety staff consists of five full time equivalents (FTE) - equivalent to seven state regulated high hazard dams per FTE, which is below the national average of 30 high-hazard potential dams per FTE for state inspected dams. The Puerto Rico Dam Safety program is well above the national average in terms of budget and staffing per dam, but regular inspections are not necessarily being completed and dam owners have very limited budgets for maintenance and repair.

However, more funding is needed to address the existing sedimentation of dams, especially those critical to supplying the island's drinking water, an especially important role during droughts and dry seasons. As an example, an annual dredging program to mitigate the sedimentation issues for up to 20 years could cost $15 million per dam that provides drinking water. However, immediate costs for dredging Carraizo, La Plata and Caonillas reservoirs, is approximately $250 million combined. The cost of temporary repairs to the Guajataca dam caused by damages from Hurricane María is $80 million.

Increased funding is required to properly assess all dams. Many dams need a comprehensive assessment, which includes hydrologic and hydraulic studies, seismic risk, and structural stability, among other factors, to fully determine the extent of their risk. It is estimated that implementing a solution to address identified deficiencies, which can include redesign, could cost up to $1 million per dam.

RESILIENCE AND INNOVATION

A resilient system recovers rapidly from challenges imposed by physical and economic factors, like hurricanes and droughts. Since a major use for dams is water supply and droughts are continuously getting worse, it is imperative dams be resilient. The water supply in the north and eastern regions is severely impacted by the droughts. For example, in 2015, a drought forced hundreds of thousands of users in these regions to be limited to two days of water service per week.

Most dams were constructed before the 1960s. For these structures to be resilient, they must be assessed, upgraded, and retrofitted. Furthermore, it is likely that Puerto Rico's dams are not designed for seismic loads. Thus, a comprehensive study and subsequent corrective measures must be undertaken.

Sedimentation creates capacity and lifespan challenges to local drinking water supplies. Although dredging reservoirs could help increase their capacity, it will not permanently solve the problem. Additional cost-effective and long-term mitigation measures must be implemented. One solution is the reconnection of diversions could increase the yield to the superaqueduct, assist with the north coast water supply, and minimize future sedimentation.

Another proposed measure is the implementation of a yearly dredging plan to remove sediment at a rate greater than the sedimentation rate. This practice would reduce overuse of surface and ground water, including the drawdown from reservoirs during dry seasons.

Another possible solution to problems such as sediment transportation, water capacity, hydroelectric generation, and others, is to evaluate and model the installation of a hydraulic barrier system. The installation of these barriers in strategic locations reduce the flow of sediment trapping it before reaching the dams. The sediment is then removed periodically by mechanical means. This tactic could help reduce the sedimentation rate of the reservoirs.

There are multiple solutions for current infrastructure challenges. The formation of a committee consisting of the Corps of Engineers, the Bureau of Reclamation along with the owners (PREPA, PRASA, Natural Resources Department and the Puerto Rico Government), and experts could help provide technical assistance for dams infrastructure. Using this multiagency taskforce to implement resilient, innovating and sustainable solutions could be the key to improving the overall grade. Moreover, the technical assist that can provide federal agencies may alleviate economic burden in local agencies/staff.

Figure 6: Guajataca Dam (photo by US Army Corps of Engineers)

RECOMMENDATIONS

1. A committee consisting of the Corps of Engineers, the Bureau of Reclamation along with the owners (PREPA, PRASA, Natural Resources Department and the Puerto Rico Government) should be formed to implement strategy plans, provide technical expertise, and assist with the rehabilitation of the dams.
2. Increase the funding associated with operations and maintenance, rehabilitation, and the implementation of the mitigation measures. Explore innovative solutions that increase capacity and lifespan with long term and cost-effective mitigation measures that do not rely in dredging alone.
3. Increase the resiliency of the dams with proper management, operation, and inspection along with frequent EAP testing (rehearsals).
4. Increase funding for comprehensive studies to fully assess the current condition.
5. Create a knowledge retention program to seamlessly train, and transfer experience and knowledge, to future employees. This pathway program will help conserve best practices and lessons learned through the years.
6. Rehabilitate, maintain and maximize the use of hydropower resources in the system.

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Drinking Water D

EXECUTIVE SUMMARY

Public water systems serve approximately 96 percent of Puerto Rico's 3.3 million residents, with the remainder served by rural and remote small community-operated systems. Puerto Rico Aqueduct and Sewer Authority (PRASA) owns and operates much of the complex infrastructure network and faces significant challenges. Approximately 59 percent of treated water ends up as non-revenue water loss, meaning the utility is providing it to customers at no charge through various mechanisms such as inaccurate meters, unauthorized water consumption, or water main leaks. It should be noted PRASA has improved its non-revenue water loss rate, which stood at 62 percent five years ago. While water quality continues to improve as new processes are implemented in response to stricter regulations and public expectations, hurricanes have aggravated an already difficult fiscal and operational situation for both PRASA and non-PRASA systems. PRASA will undertake a $2 billion capital improvement program over the next five years, with one-third of funding allocated to repair damage and a significant amount set aside for resiliency.

INTRODUCTION

The main provider of water in Puerto Rico is PRASA, a government corporation. PRASA is a complex utility with 4,654 employees that serves 1.24 million customers. The utility operates 114 filtration plants with 143 intakes, eight dams, 1,607 tanks, 1,766 water pumping stations, 233 water wells, and approximately 1,500 miles of water pipelines. These systems work together to deliver water to homes, business, and fire hydrants, without interruptions, that meets U.S. Environmental Protection Agency (EPA) public health standards.

PRASA's mission became exponentially more difficult after Hurricanes Irma and Maria devastated the island in September 2017, causing massive flooding, overwhelming water treatment plants, and depriving hundreds of thousands of residents of safe drinking water for weeks, or sometimes even months.

Hurricanes Irma and Maria's impact on PRASA's fiscal condition can be summarized as:

- Revenue reduction: $ 271 million
- Incremental expenses: $ 396 million
- Capital Investment Program for damage repair: $ 461 million

PRASA has significant capital needs, especially in the aftermath of the hurricanes. Funding needs include the development of new water supply projects, improvements to the water filtration plants, expansion of the distribution systems, operation and maintenance, and process improvements for the water treatment plants to meet new water quality regulations. Much of the water infrastructure is well into or beyond its expected service life. Responsible management of these assets is crucial to maintaining an acceptable level of service.

Currently, there are at least 250+ non-PRASA system which receive some funding from the PRASA client fees for compliance purposes. Rural and remote communities face significant challenges in terms of funding system improvements and securing recovery funds from the U.S. federal government. Many of these entities are not legally incorporated and some lack internet access – both necessities in order to qualify for and apply for recovery funding.

CONDITION

The condition of Puerto Rico's drinking water infrastructure can be judged based on the age and functionality of plant equipment, as well as the rate of water main leaks and pipe breaks. During the year 2018, 65,697 leaks and breaks were reported, for an average of 4.38 leaks or breaks per mile of installed line. In general, PRASA's system's condition has improved. However, significant challenges remain, and the system is rapidly aging.

For example, one challenge PRASA faces is non-revenue water loss. The main causes for non-revenue water loss are inaccurate meters, unauthorized water consumption, water consumption estimation, incomplete and non-precise database, lack of proactive collections, leaks throughout the system, water tanks overflow, excessive water pressure, poor O&M practices, lack of adequate leaks controls, and aged underground infrastructure.

The EPA reported in 2013 that average water loss in the U.S. is 16 percent. Unfortunately, non-revenue rates in Puerto Rico are approximately 59 percent, far above the U.S. average. It should be noted that PRASA is making progress in this area – its non-revenue water loss rate is down from 62 percent from five years ago.

PRASA's 2014 Strategic Plan required annual water loss audit reporting to better develop a comprehensive water supply and water conservation program. The goal was to allow Puerto Rico to efficiently meet water demands while reducing water waste. Every gallon of water lost or wasted due to system inefficiencies comes at increasing cost to communities and natural environments, especially in areas where demand may exceed supply. Leak detection, meter calibration, pipe condition assessment, sectorization, and surveys of interconnections are just a few of the tools available to reduce water loss. Reducing PRASA's non-revenue water would help lessen capacity and supply challenges significantly, mitigating the need for expansion in many areas.

CAPACITY AND FUTURE NEED

As of 2017, municipal and industrial water use totals in Puerto Rico averaged 507 million gallons per day (MGD). While overall water usage is declining, some water sources are overused. For example, the southern aquifers provide water to about 200,000 people, but drought and excessive water extraction severely reduce the available levels of supply. The same is true of several of the main reservoirs during the drought season.

While the public is sensitive to water service issues, it is generally known that Puerto Rico's water system has the ability to meet current demands. Based on formalized water planning, the utility has suitable baseline data for developing future supply and system capacity plans. The current status of these plans aligns with the reduction in demand due to decreasing population.

OPERATION & MAINTENANCE

Reactive maintenance of public water systems occurs too frequently and could be avoided with better asset management programs that rehabilitate and replace infrastructure before failures occur. PRASA has initiated the development of formal asset management tools. Inventories of existing infrastructure, including condition assessment, are the first component necessary for an effective asset management program.

PRASA serves approximately 100 customers per mile of pipe, compared with the U.S. average of 150 to 200 customers. A low-density population challenges a drinking water utility because operation and maintenance needs are significant and a smaller customer base impacts PRASA's ability to help pay. Additionally, PRASA must contend with significant elevation changes, which contributes to the utility's large and complex infrastructure network.

PUBLIC HEALTH & SAFETY

Puerto Rico's residents deservedly expect their water to be free of harmful contaminants, objectionable tastes, and odors. By strictly following standards set by US EPA, the Puerto Rico Department of Health (PRDOH) regulates all public water on the island. Compliance with water regulations in Puerto Rico is very high, with over 95% percent of public water systems operating without health-based water quality violations.

Although compliance rates are very high, the ability to meet regulations is always dependent on the responsible operation and maintenance of public water systems. Public health and safety has been threatened by catastrophic failures of large

water infrastructure like dams and treatment plants, as was observed from hurricanes Irma and Maria. Through better management and long-term planning, these risks can and are being diminished.

PRASA is focused on the provision of safe drinking water to safeguard the island's public health and its environment. Following the Safe Drinking Water Act, the Capital Improvement Program's main goal has been to maintain water quality and assure health and environmental compliance. Around $1 billion of PRASA's 6-year CIP is focused on compliance and the improvement of water quality and reliability. These projects include the improvement of filtration plant's processes as well as transmission and distribution pipelines.

As agreed in the 2015 Consent Decree with the EPA, PRASA's prioritization system established the Regulatory Compliance (water quality) category as the primary and most important consideration for project scoring. Furthermore, $551 million in Renewal and Replacement FY2018 – FY2024 CIP is expected to be partially allocated for unforeseen infrastructure repairs and additional water quality / non-mandatory compliance issues that may arise to ensure safeguarding health and the environment.

FUNDING

Water utility rates are expected to provide nearly all the funding for operation, maintenance and expansion of water systems. For any utility to be sustainable, rates must consider full life-cycle costs for services, rehabilitation of existing assets and construction of new assets, in addition to debt service and other indirect costs.

From 1994 to 2005, mainly due to the lack of financial resources to cover its operation costs, PRASA depended on central government allocations, which were insufficient to meet all needs. This situation affected the agency's CIP, ultimately resulting in non-compliance with federal and local environmental regulations. Treatment plants were fined, and new project endorsements were held back.

Starting in 2006, new agreements with the regulatory agencies were signed, minimizing uncertainties in the compliance processes and the payment of fines. However, as a consequence, new extraordinary compliance costs arrived:

- $ 3.4 billion over 15 years for compliance and capital improvements projects.
- $70 million annually for the operation of the Environmental Compliance Department and the Integrated Maintenance Program.

The American Water Works Association (AWWA), the U.S. Conference of Mayors (USCM), and the Water Environmental Federation (WEF) have jointly established that environmental compliance is the main cause of rising water rates, due to the investments needed to maintain compliance.

A short-term solution was implemented by PRASA based on an up-to-date rate study by a qualified financial consultant. In 2015, Raftelis Financial Consultants, Inc. recommended increasing PRASA water service rates by 2.5 percent annually for the next 10 years as a way to address actual and increasing operating costs with the availability of funds. The water rate depends on the amount consumed, with the minimum drinking water rate starting at $1.36 per cubic meter, with a maximum tariff of $3.58 per cubic meter PRASA rates are tiered to encourage water conservation and includes minimum charges to cover costs that are not affected by demand. Increased rates in addition to operational and organizational changes to reduce costs should eventually place the agency in condition to access the financial market.

PRASA funding also includes federal programs like the Community Development Block Grant Program, the Environmental Protection Agency (EPA) Drinking Water State Revolving Loan Fund, and USDA Rural Development Programs. Many of these funds or financing are received directly by either the municipalities or the Central Government that also develop water infrastructure in coordination with and using the standards set by PRASA.

A new fiscal plan for a six-year period starting in FY2018 outlines cash management levels that PRASA will use to improve its liquidity. The plan anticipates PRASA will increase revenues while reducing expenses, work with insurance agencies and the federal government to secure disaster funding, increase collection (particularly from government entities), and reduce non-reimbursable maintenance expenses. PRASA will also negotiate a restructuring of its debt obligations to improve its cash position.

PRASA will undertake a $2 billion CIP over the next five years, with one third allocated to repair damage and a significant amount set aside for resiliency. This CIP also includes compliance and repair projects designed to improve drinking water quality as well as to prevent leakage throughout PRASA's distribution networks.

To achieve long-term financial sustainability, improve water quality, and increase resiliency, the new fiscal plan requires PRASA to invest $303 million to reduce commercial and physical non-revenue water losses; invest up to $3.4 billion in hazard mitigation, safety, water availability, redundancy, management of critical assets and simplify and consolidate its infrastructure; spend $2 billion to increase automation of water treatment plant operations and water quality; and provide $100 million to adopt distributed solar generation and hydroelectric power generation.

RESILIENCE

Hurricanes Irma and Maria resulted in heavy damage to parts of Puerto Rico's drinking water infrastructure network. Portions of existing systems must be repaired and rebuilt and doing so should require rethinking how to build those systems to withstand stronger and more frequent hurricanes in the future.

Water rationing during the drought season is also a nearly annual concern for the island, despite heavy rainfall during the wet season. Some of the primary raw water source for PRASA water treatment plants are reservoirs maintained by eight dams owned and operated by PRASA. Another 18 dams are owned by the Electric Power Authority and are used for hydroelectric energy production, agricultural irrigation, and raw water supply for PRASA's plants. Almost all the dams have lost considerable storage capacity, 40 to 60 percent, due to sedimentation and poor operation and maintenance. The water shortage problem is exasperated by an over-extraction from deep wells, especially in the southern region, and the economically motivated closure of others.

Water systems in Puerto Rico are further challenged by the lack of qualified workers. PRASA will need to grow their own qualified candidates or market the utility to attract qualified personnel and technicians. The utility is challenged by an exodus of skilled workers from Puerto Rico to the U.S. mainland and other places with better working conditions. The water resources discipline is becoming increasingly complex and technical qualifications should be reflected in recruitment and training programs. The body of knowledge is essential to keep pace with the needs of the system and the public it serves.

Higher levels of raw and processed water storage, and evaluation of additional and alternative sources of water supply are part of PRASA's Strategic Plan due in 2024. Accordingly, redundancy and reliability achieved by the interconnection of adjacent water systems should be scheduled in a capital program and implemented.

RECOMMENDATIONS

- Improve underground water management to stabilize and control wells' firm yield and aquifer storage and recovery, especially in the southern region.
- Improve conjunctive use of surface and ground water. Specifically, improve hydrographic basin management to control erosion and reduce sedimentation into the dams. Strategic management and water supply source protection will improve quality. Watershed protection plans are needed to lessen potential impacts to source water and reservoirs and reduce costs of drinking water treatment.

- Restore storage capacity of water supply reservoirs: Puerto Rico has a high grade of rain and runoff. Some of the main raw water reservoirs have lost significant capacity due to sedimentation. Sedimentation management such as dredging, sluicing, etc. programs/projects are urgently needed to restore the existing capacity. Construction and/or expansion of reservoirs and/or water storage tanks should be programmed to retain greater amounts of runoff water for use during the drought season. Reservoirs in the east-central and western areas of the island were proposed many years ago without an effective effort to construct them.
- Reduce Unaccounted Water: PRASA estimates that 58 percent of the processed water is not accounted for. About 42 percent is considered lost through leaks in pipes, tank overflow, etc. A rehabilitation and replacement program should be a major consideration to control these losses. Also, system sectorization projects should be expanded and continued to effectively reduce these losses. Furthermore, improve meters in treatment plants and wells to account for real raw water intake and treated water distribution.
- Install emergency electric energy generators at all water pumping stations, wells, and filtration plants. Besides that, evaluate the options to have alternative energy source from PREPA.
- Actualize and maintain updated infrastructure records to improve operation of the systems and reduce service interruptions. This includes a program to uncover the thousands of lost house water meters.
- Workforce development: training courses on advanced technology and tools will be necessary to keep pace with stricter regulatory requirements, replace a much-reduced workforce, and attract a limited recruitment pool. Position descriptions and qualifications should reflect the increasing technical complexities of the field.

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Energy

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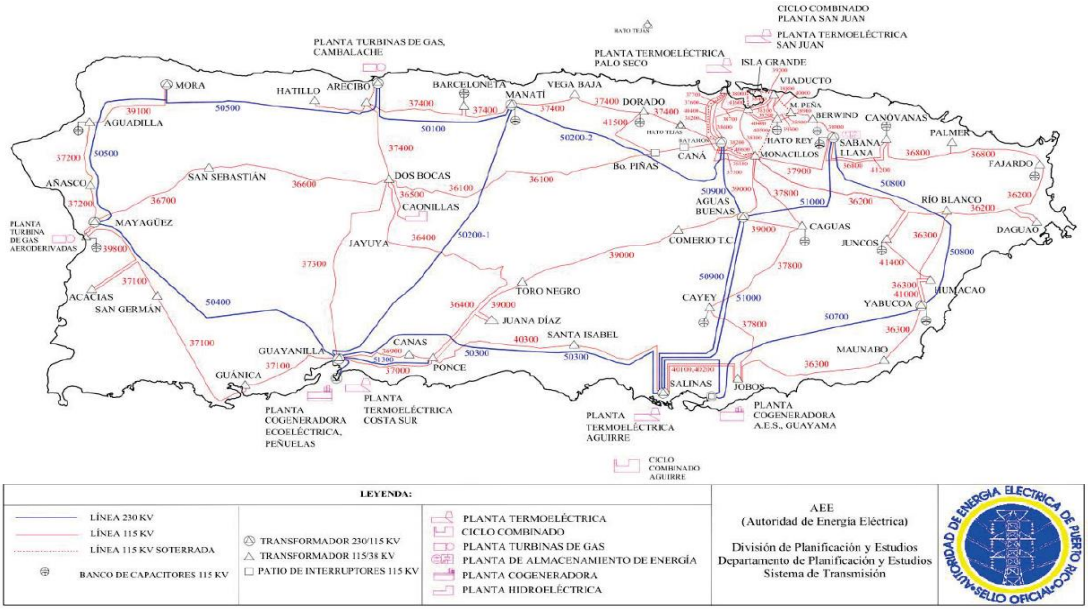

EXECUTIVE SUMMARY

Leading up to Hurricanes Irma and Maria in 2017, Puerto Rico's energy infrastructure was in poor condition. The island also lacked source diversity; approximately 98 percent of electricity was generated by fossil fuels. Still, average electricity prices exceeded $0.19/kWh, roughly double U.S. rates. After Hurricane Maria devastated the energy grid and contributed to the second-longest blackout in recorded history, authorities focused their efforts on the short-term goal of restoring power as quickly as possible. However, the long-term need for developing a resilient and sustainable energy grid was overlooked. Today's network is fragile, blackouts are frequent, and prices have continued to increase. Even modest wind events have the potential to render the current energy grid inoperable and Puerto Rico Electric Power Authority lacks access to the capital needed to improve grid condition, capacity, and resiliency, making federal support imperative.

ASCE supports recent findings from the U.S. GAO that any grid investment needs to be accompanied by policy, guidance, and regulations that yield grid resilience consistent with consensus industry standards. To facilitate smart building, ASCE has published a series of codes and standards for grid design and construction to better enable Puerto Rico's energy infrastructure to withstand future storms and other stresses. It is imperative that lifecycle cost methods, redundant power supplies and communications channels, and quality controls be included in decision-making and implementation to lessen the impacts of future storms. Proven renewable energy and advanced "smart grid" technologies must also be included.

INTRODUCTION

Puerto Rico's Energy Infrastructure grade of an "F" was driven by poor existing conditions, insufficient capacity and redundancy, inadequate restoration following 2017 hurricanes, poor maintenance and investment strategies, and a need for system-wide improvements. The lack of a reliable energy infrastructure today is greatly impacting human life and commerce, contributing to continued economic hardship and ever-growing financial crisis.

It is important to understand the geography and topography of the Caribbean island to see that Puerto Rico has one of the most complex energy distribution systems in the United States and its Territories. Most of Puerto Rico's energy is produced by the Puerto Rico Electric Power Authority (PREPA). PREPA serves near 1.5 million customers.

Electrical grids carry power from the south to the northern metropolitan areas. A lack of maintenance along the transmission and distribution lines and a failure to build to appropriate standards contributes to system-wide collapses during heavy wind events. During hurricanes Irma and Maria in 2017, the energy network failed, and Puerto Rico residents experienced the longest blackout in the U.S. history, lasting nearly a year. While power has been restored, the grid continues to be unreliable and vulnerable to even minor storms.

CAPACITY & CONDITION

Most of Puerto Rico's energy is produced by the Puerto Rico Electric Power Authority (PREPA) and generated in four main power plants: Costa Sur, Complejo Aguirre, San Juan and Palo Seco. In addition to PREPA, Puerto Rico also utilizes energy produced by a few private companies that sell to PREPA.

The transmission system consists of 2,478 miles of 230KV / 115KV transmission lines and 38KV sub-transmission lines connected, with 48 transmission centers. The system includes 38 kV, 13 kV, 8 kV and 4kV distribution lines totaling approximately 31,446 air miles and 1,723 underground miles; part of this system is made up of 293 substations and 27 technical offices.

Most of PREPA power plants are over 40 years old. However, old machinery and instruments are not always synonymous with inefficiency. Equipment can sometimes be combined with others to improve service. For example, a few PREPA power generation plants were converted to natural gas and combined cycle systems were integrated.

Electrical grids carry power from the south to northern metropolitan areas, which are home to most of the island's residents. High dependency on big electrical grids brings concern about service reliability and overall delivery of power.

In September 2017, Hurricane Maria made landfall at Yabucoa as a Category 4, but the National Hurricane Center recognized that in some high places, Category 5 winds could have been felt. Consequently, much of Puerto Rico's electric grid was destroyed, so that even undamaged generators could not supply power. Electricity generation dropped by 60 percent in the fourth quarter of 2017 when compared to the same period in 2016. Prior to Hurricane Maria, the existing grid was in disrepair and experienced frequent outages, but due to the 2017 atmospheric events, the electric grid reached the point of total failure.

Following Hurricane Maria, Puerto Rican authorities focused their efforts on the short-term goal of restoring power as quickly as possible. However, as a result, the long-term need for developing and distributing resilient and sustainable energy sources was overlooked.

SOURCES OF ENERGY

Imported oil and gas are the backbone of Puerto Rico's economy. Puerto Rico produces energy using petroleum, 47 percent; natural gas, 34 percent; coal, 17 percent; and renewable, 2 percent. The demand for imported energy reinforces Puerto Rico's need for resilient seaports and airports. Contrary to direct distribution of natural gas to users, Puerto Rico's

power plants convert natural gas into electricity, which is then distributed to citizens. This approach avoids the economic and environmental consequences related to pipe cracking. However, without natural gas distribution lines, our population's dependence on the grid as the only source of energy is more pronounced.

In the near term, oil and gas continue to be vital to Puerto Rico's economy, so it is imperative to invest in related facilities, implement routine maintenance checks, as well as make improvements based on the age of the power plants. Without adequate energy infrastructure investment, Puerto Ricans will continue to see energy-related problems impact their daily lives, driving down productivity and morale.

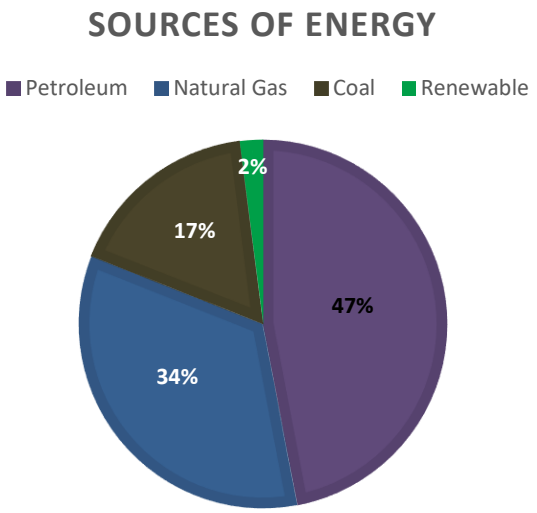

Figure 7. PREPA's

FUNDING

In August of 2017, Puerto Rican officials estimated that $1.6 billion was needed in overall infrastructure investment to meet the economic goals needed to prevent bankruptcy. A month later, Hurricane Maria's impact increased the funding required to improve the infrastructure. PREPA proposed a $20 billion plan to renovate the energy grid on the island, however, the total amount could be lower. Thus far, funding has been provided to restore electricity access, but the resulting grid is fragile, and blackouts are frequent.

The principal funding for PREPA is rates paid by users, including residences, the manufacturing sector, pharmaceutical and medical devices companies, hotels, and retail, among others.

Due to the elimination of Section 936, a law that gave U.S. corporations some tax advantages if they based some part of their company operations in Puerto Rico, hundreds of industries closed, and energy consumption decreased. This resulted in reduced income for PREPA. As the economy deteriorated, population declined, and disruptive technologies emerged, demand for electricity dropped by 18 percent from 2007 to 2017. On July 2, 2017, the Financial Oversight and Management Board (PROMESA) filed a petition seeking bankruptcy protection for PREPA and establishing an in-court process for restructuring debt that is modeled after the process under chapter 9 of the U.S. Bankruptcy code.

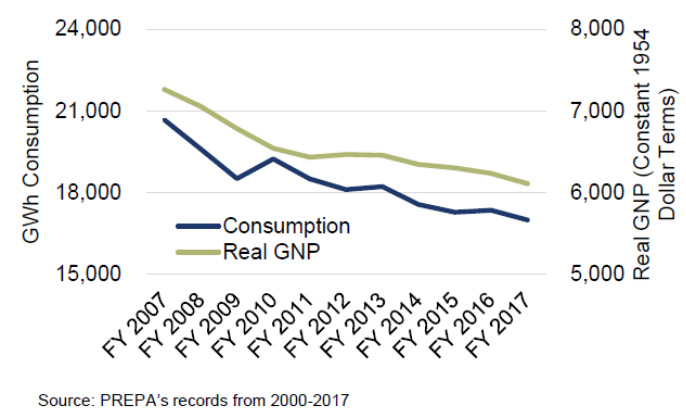

Figure 8. Consumption Through Years

In May 2019, a deal was reached between PREPA and the Financial Oversite and Management Board (FOMB) of Puerto Rico to settle approximately $8 billion in legacy debt. Under the deal, rates per kWh will increase annually and the new revenue will be used to pay off debts. The agreement further stipulates that residents and customers generating their own electricity through solar panels will still pay an annual fee towards paying down PREPA's debt. The deal has been criticized for putting a significant financial burden on residents; Puerto Ricans already pay 22 centers per kWh of electricity, compared to 12 cents on average nationally. This deal would raise electric prices to 32 cents per kWh. Due to the increased rate of the kWh, the Consumer Price Index (CPI) could increase by 1.22% - 2.47%. Additionally, new revenue would go towards paying down old debt, rather than investing in a resilient and sustainable future network.

FUTURE NEED

Besides paying down PREPA's debt, significant funding is needed to strengthen the grid against future storms, add generation capacity, and rebuild and upgrade transmission and distribution lines. However, the timing of expenditures and disbursements from the Government of Puerto Rico is still uncertain an initial disbursement of $2 billion was approved with 100 percent FEMA cost-share. Puerto Rico is requesting a cost-share adjustment for future FEMA's program amounts under the Stafford Act, but even with these adjustments, projects will still require a 10 percent cost-share match from PREPA. Puerto Rico is seeking Community Development Block Grant-Disaster Recovery (CDBG-DR) funding to cover the cost-share match requirements of Stafford Act programs. It is worth noting that historically, either FEMA or Congress has authorized a 100 percent federal cost-share for large and catastrophic disasters such as Hurricane Andrew in Florida and Hurricane Katrina in Louisiana and Mississippi.

Figure 9. Hurricane Maria Damages Year 2017

Moving forward, there is legislation to privatize PREPA. The effects of this legislation are generally unknown and only will reveal themselves as PREPA assets are sold to private companies.

PUBLIC SAFETY

Following Hurricane Maria, Puerto Rico experienced the longest blackout in American history and the second-longest blackout across the world. The failure of the electric grid meant residents were unable to use medical equipment. The

energy network's failure difficulted aid response and recovery efforts after the storm and caused public safety concerns for months.

RESILIENCE

Given its location and susceptibility to natural hazards, Puerto Rico's infrastructure must be more resilient than a majority of mainland America's. The need for more resilient infrastructure, coupled with bankruptcy, has led to current infrastructure that fails to meet citizens' demands. Due to time constraints and insufficient funding, Puerto Rican officials focus on short-term restoration without the ability to ensure long-term sustainability. Adopting the ASCE 7 codes and standards could help the energy grid become more resilient to future storms. ASCE 7 is the means for determining, soil, flood, tsunami, snow, rain, atmospheric ice, earthquake, and wind loads, and their combinations for general structural design. These codes and standards are critical to ensuring infrastructure remains functional and able to facilitate emergency response and recovery after a major storm event.

INNOVATION

There were attempts prior to Maria to focus on renewable energy, but that has since halted. There has been attention since Maria to microgrids and Puerto Rican officials have contracted out the installation of microgrids in certain places. The idea of incorporating microgrid systems is that in the event of a new emergency such as that caused by Hurricane Maria, each micro-network works independently. Tesla has helped install microgrids into small communities. While there is a role for microgrids on the island, especially for rural villages to ensure electrical autonomy to help avoid large-scale blackouts, professionals from the energy sector can't guarantee that microgrids can solve Puerto Rico's energy problems.

Two wind farms supplied 41 percent of Puerto Rico's renewable generation in the fiscal year ending June 30, 2017. One of them, the 95-megawatt Santa Isabel facility, is the largest wind farm in the Caribbean. Both wind farms were heavily destroyed by hurricanes Irma and Maria.

RECOMMENDATIONS:

- Adopt consensus industry standards with at least a 160-mph design wind speed such as those produced by ASCE to enhance complete energy system resilience to storms, harden existing infrastructure that is re-usable (e.g., the newer gas-fired generating plants), and implement a design/construction plan that includes necessary controls to yield long-term resilience;
- Utilize smart grid technologies, redundant power delivery, and hardened communications to ensure that future storm recovery is timely and with minimal disruption to critical facilities such as police/fire stations and hospitals (considering redundancy offered by local microgrids);
- Increase use of readily available solar and wind generation to reduce carbon emissions and provide a diverse backbone of power generation resources;
- Establish a transparent and auditable plan/timeline for energy infrastructure investment that allows third-party verification that lifecycle benefits and long-term resiliency are achieved.

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Ports D

EXCUTIVE SUMMARY

Puerto Rico—an island in the Caribbean—is highly dependent on maritime transportation to import most of its supplies. This makes ports infrastructure critical. Ninety-eight percent of the island's electricity comes from imported petroleum, natural gas, and coal. Approximately 80 percent of the island's food is currently imported. Ports also play an important role in the tourism industry; FY2018 closed with a total of approximately 1.2 million cruise ship visitors and an approximate contribution of $152 million to the economy. The importance of ports was especially noticeable after Hurricane Maria hit the island in September 2017, since they played a critical role in the delivery of first aid supplies. Puerto Rico's already fragile ports infrastructure suffered severe damage as a result of the hurricane. The estimated cost to repair all ports throughout the island is over $750 million. However, the capital improvement program for FY2020-2024 provides just over $2 million in investments.

INTRODUCTION

The Puerto Rico Ports Authority (PRPA) is one of the main government agencies responsible for supporting the island's economy. The agency is tasked with the administration of multiple ports and airports which handle a large number of passengers and cargo. The table below shows the main ports for which the PRPA is responsible:

Port	Main Use
San Juan Piers 1, 3 & 4	Cruise ships
San Juan Pan American Piers 1 & 2	Cruise ships
San Juan Pier 10	Goods and materials export
San Juan Piers 11-14	Construction materials shipments
San Juan Navy Frontier Pier	Cruise ships, car-carriers, mega yachts
Isla Grande Port	Container shipments
San Juan Pier 15-16	Container shipments, car shipments
Puerto Nuevo Army Terminal Pier	Container shipments
Puerto Nuevo Piers A-H, J-O	Container shipments (fuel, food, wood, etc.)
Arecibo Port	Fuel shipments
Yabucoa Port	Fuel shipments
Guayama Port	Fuel shipments
Guánica Port	Fertilizer material shipments
Guayanilla Port	Chemicals, asphalt, propane gas, and fuel shipments

Table 1: PRPA's Main Ports

CAPACITY

Most of the cruise ship industry is concentrated in San Juan, since Old San Juan is its main tourist attraction. The ports that are currently operating as homeports or port of call for cruise ships in San Juan Bay are Piers 1, 3, 4, and Pan-American Piers 1 and 2. The term "home port" refers to the port where a cruise ship begins and ends its voyage, while a "port of call" refers to a port where a cruise ship docks in the course of its voyage to load or unload passengers or cargo. The table below shows the average calls per year from 2013-2017 for these ports:

Piers	Current Use	Homeport	Port of Call
Pier 1	Port of Call/Homeport	20	25
Pier 3	Port of Call	0	123
Pier 4	Port of Call/Homeport	59	153
Pan American Piers	Home Port	106	2

Table 2: Average Cruise Ship Calls Per Year

As shown in the table above, these ports handle a high volume of cruise ships each year and it is essential to the island's tourism industry that port infrastructure remain in good operating condition.

Puerto Rico is also highly dependent on maritime transportation to import goods that are essential to its population. The island mainly imports chemicals, oil, food, electrical appliances, machinery and equipment, transport vehicles, and plastics. Approximately 80% of the island's food is currently imported. San Juan handles a high amount of cargo each year which is mostly received through the Puerto Nuevo ports. The table below shows the number of ships, trips, and containers received through San Juan:

Cargo Maritime Traffic – San Juan Ports			
Fiscal Year	**Number of Ships**	**Trips**	**Number of Containers**
2017	164	2,861	1,319,572
2018	254	3,513	1,290,158
2019 (through April 2019)	144	2,593	1,200,196
Total	562	8,967	3,809,926

Table 3: Cargo Maritime Traffic in San Juan

The energy sector is also highly dependent on fuel imports. About three-fourths of the energy used in Puerto Rico comes from petroleum products, which are all imported, principally through the ports of San Juan, Guayanilla, and Ponce. For FY2017, petroleum supplied just under half of the island's electricity, while natural gas supplied nearly one-third, coal about one-sixth, and renewables about 2.4%. The table below shows the number of fuel ships received in Puerto Rico from FY2015-2019:

Fuel Ship Traffic – Puerto Rico Ports	
Fiscal Year	**Number of Ships**
2015	199
2016	245
2017	212
2018	257
2019	216
Total	1,129

Table 4: Fuel Ship Maritime Traffic in Puerto Rico

This data shows the important role that maritime transportation plays in Puerto Rico. It is essential to the island's economy that ports that are capable of receiving a high number of ships each year remain in good operating condition.

FUNDING AND FUTURE NEED

After Hurricane Maria, Puerto Rico's already fragile ports infrastructure suffered severe damage. After the hurricane, PRPA engaged independent professional services to perform an assessment of the infrastructure's condition and to develop cost estimates for repairs at multiple cruise ship ports in San Juan. The results of the assessment show an estimated cost of over $290 million to repair the cruise ship piers, which include Piers 1, 3, 4, 11-14, and Pan American 1 and 2. The scope of the repairs includes pier structural repairs, wharf & utilities repairs, mechanical works, and electrical works, among others. As evident by their yearly capacity, Piers 4 and Pan-American 1 and 2 are essential to PRPA and the estimated repair costs of each pier is over $136 million for Pier 4, and over $28 million for Pan-American 1 and 2.

Currently, the PRPA is capable of docking a maximum of eight cruise ships at a time in the San Juan Bay. Piers 11-14 are currently not being used for cruise ships due to their poor infrastructure condition. An estimated investment of over $70 million is necessary to repair these piers and bring them back to operating conditions. Allocating the necessary funds to rehabilitate these piers will enable PRPA to increase their cruise ship capacity in the San Juan Bay since these piers are capable of berthing two additional vessels.

In addition to the assessment performed for the cruise ship ports in San Juan, a condition assessment was also performed in 2018 by the private sector for all other ports currently administered by the PRPA, including municipal-owned facilities in Mayaguez and Ponce. The results of the assessment, which does not differentiate between post-Maria damage and regular deferred maintenance, estimated costs of up to $345 million to repair all ports. Most of these ports are essential since they handle a large number of imported goods as well as providing better access points to municipalities throughout the island in the event of a natural disaster. The PRPA currently has a capital improvement program for FY2020-2024 with a total investment of just over $1 million. When compared to the estimated costs to repair all ports provided in the previously mentioned condition assessment, it is evident that the PRPA is in need of more funding in order to make the necessary repair to all ports.

Another agency that manages port facilities is the Puerto Rico Maritime Transport Authority (PRMTA). This agency is responsible for providing maritime transportation services from San Juan to Cataño, and from Ceiba to the island-municipalities of Vieques and Culebra. Maintaining PRMTA ports in good operating condition is crucial since ferry transportation is the main service used to transport passengers and cargo to and from the island-municipalities. A condition assessment was performed in 2018 for piers that belong to the PRMTA and an estimated repair cost totaled $53 million. The piers and facilities included in the aforementioned repair cost are Pier 2 in San Juan, Mosquito Pier in Vieques, the operations building and Pier 2 in Ceiba, and PRMTA's maintenance facility in Isla Grande. The PRMTA currently has a capital improvement program for FY2020-2024 with a total investment of over $1.3 million.

Figure 1: San Juan Bay Channels

Funding is also required in order to perform the required dredging of San Juan Bay. Dredging is required to maintain the necessary depth in the San Juan bay channels (illustrated in Figure 1) and is key for vessel access to the piers. Due to increasing vessel sizes, existing cruise vessel operators experience increased in-port maneuvering costs due to channel and turning basin width and depth constraints. In August 2017, the U.S. Army Corps of Engineers (USACE) prepared an integrated feasibility and environmental study for the widening and deepening of the navigation channels and turning areas. On August 18, 2018, USACE recommended the final program to Congress. The program will allow larger vessels to enter the port and increase overall safety. The total cost for the program is estimated around $553 million out of which approximately $54 million is related to dredging works. Construction is expected to begin by 2022. USACE is also currently finalizing plans to perform dredging in the Mayaguez harbor, Arecibo harbor and Rio Puerto Nuevo.

PUBLIC SAFETY AND RESILIENCE

It is evident that Hurricane Maria caused significant damage to the port's infrastructure in Puerto Rico. In addition to permanent repairs, recovery efforts should also focus on mitigation and resiliency. In the event of a future natural disaster, it is imperative that Puerto Rico's ports remain operational since they serve as an important access point. Improving the resiliency of coastal structures typically involves the principal tasks of raising the elevation of their critical components (e.g. finished, mechanical/electrical infrastructure, floor elevation of buildings, etc.) above the flood zone to avoid flood hazards and potential sea level rise. Since most of these piers have outdated structures, it is essential that the proper investment is allocated to bring their structures up to ASCE recommended codes. Furthermore, funding is necessary for projects that enhance resiliency to help create effective disaster implementation plans and exercises for restoring normal operations.

RECOMMENDATIONS

- Repair and rehabilitate Piers 11-14 in order to increase San Juan Bay's capacity for cruise ships.
- Invest in resiliency improvements for critical piers throughout the island.
- Invest and develop Ponce's port to increase tourism in the municipality and southern region.

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ROADS D-

SUMMARY

Puerto Rico has struggled in recent years to adequately maintain its roadway network, in part because of a reduction in personnel and partially due to a lack of dedicated funding for road preservation and maintenance. The lack of a data-driven asset management plan also hurts long-term road management policies and projects. Additionally, the island allows much heavier trucks on its roadways than much of the mainland U.S, which leads to quicker degradation of pavement and bridges. Making matters worse, often Puerto Rico's local municipal roads are built without the necessary supervision or quality control standards, which lead to early pavement failure. Pavement maintenance and resurfacing activities on local municipal roads could be substantially improved by promoting quality control standards and providing appropriate project supervision and management. Puerto Rico is currently restructuring its debt through Title III protections under PROMESA, which has allowed the Puerto Rico Highway and Transportation Authority (PRHTA) to direct its resources to improvement projects on state roads. However, in order to maintain its assets in a state of good repair and continue normal operations, PRHTA estimates that it will need $3.1 billion of capital expenditures from FY18 to FY23. Additionally, funding from the federal government and a more strategic approach to maintenance is necessary in the near-term.

CAPACITY

The Puerto Rico road network is divided into different classifications, including the National Highway System (NHS), state highways, and municipal roads.

The Puerto Rico Highway and Transportation Authority (PRHTA) submitted the Highway Performance Monitoring System (HPMS) report for year 2017.The HPMS report states that Puerto Rico has a total of 18,358 road miles. State highways make up 5,078 miles (27.66%) of the road network, while the NHS is limited to 781 miles (only 4.26% of the network). Most of the highway network is composed of municipal roads.

Quick Facts:			
Classification	Length(miles)	State highways make up 27.66% of the network; state highways are divided into 31% rural and 69% urban.	**The total Puerto Rico highway network is divided into: 17.38% rural 82.62% urban**
NHS-Interstate	284.6		
NHS-Non-Intersate	496.62		
Non-NHS	4,296.96		
Municipal System	13,280.02		
Total	18,358.20		

Table 1 Quick Facts about PR road network

As stated in the 2019-2023 Strategic Highway Safety Plan (SHSP), "The Puerto Rico Department of Transportation and Public Works' (PRDTPW) data indicates that Puerto Rico has approximately 2.8 million registered vehicles and 2.1 million licensed drivers".

Based on Federal Highway Administration (FHWA) data, "The Selected Measures for Identifying Peer States 2016", the Annual Vehicle Miles of Travelled (AVMT) is 14,564 million miles. Decreasing Annual Vehicle Miles Travelled (AVMT) per capita can directly improve air quality and the overall health of population, among others. Furthermore, decreasing AVMT can positively impact the capacity of the roadway network in Puerto Rico.

Puerto Rico ranks fourth in population density in the U.S. and its territories in 2018. On average, in 2017 San Juan commuters lost 58 hours due to car traffic and congestions with a cost (based on travel time delay and excess fuel consumption) of $1,166, as per the 2019 Urban Mobility Report. Comparatively, San Jose, CA and Austin, TX, lost 81 hours ($1,500 worth) and 66 hours ($1,270 worth), respectively.

Congestion issues observed on the island are caused by different factors which include, but not limited to:

- High demand for different services such as medical, governmental, private industries, and other services that are concentrated in the metropolitan area
- Closed roads due to external factors, such as constructions, post storms effects and natural wear, among others
- Flooding due to flash flooding, in combination with lack of maintenance and/or poorly design drainage.

Figure 1 Puerto Rico Road Network. Source: Puerto Rico Transportation Assets Management Plan (TAMP)

CONDITION

Puerto Rico's highway system construction began in the 1860's and state highways have been adapted to industry standards over the years when improvements or construction projects are carried out. Although the highway system has been adapted to latter specifications, the network is continuously degrading due to lack of effective maintenance programs. Moreover, tropical weather conditions (flooding, rain, hurricane, etc) experienced throughout the island intensify the degradation of the infrastructure. As Puerto Rico's roadway system reaches the end of its lifespan, much of it needs to be replaced or undergo significant resurfacing, restoration and rehabilitation to extend its service life.

It is pertinent to highlight that municipalities, which oversee the condition of municipal roads, are not required by law to comply with federal and/or PRHTA standards, unless the projects are federally funded. Pavement maintenance and resurfacing activities on local municipal roads could be substantially improved by promoting quality control standards and providing appropriate project supervision and management.

PAVEMENT

Much of the technical information provided in this section comes from the Transportation Asset Management Plan (TAMP), which examines the condition of National Highway System and State Highway pavements, excluding the municipal roads. The *Sec. 515.7 of Federal Highway Administration (FHWA) regulations for further explanation of TAMP.*

In table 2, the pavement condition rating according to functional classification is presented. This data is from 2017, prior Hurricane Irma and Maria impacting Puerto Rico. The current state of the pavement may have changed due to the 2017 hurricanes and the reconstruction efforts.

System		Interstate		NHS Non-Interstate		Non-NHS		Total	
Condition		Lane Miles	%	Lane Miles	Percent of Total	Lane Miles	Percent of Total	Lane Miles	Percent of Total
Good		138.85	10.8%	38.14	2.2%	20.12	0.2%	197.10	1.8%
Fair	Fair to Good (F1)	319.29	24.8%	131.38	7.5%	257.36	3.1%	708.02	6.3%
	Fair-Fair (F2)	369.73	28.7%	735.77	42.3%	446.99	5.4%	1,552.48	13.8%
	Fair to Poor (F3)	244.97	19.0%	308.28	17.7%	129.74	1.6%	682.99	6.1%
Poor		170.17	13.2%	156.45	9.0%	72.83	0.9%	399.45	3.5%
Incomplete		0.00	0.0%	286.39	16.5%	193.40	2.4%	479.79	4.3%
Not Measured		45.30	3.5%	84.15	4.8%	7,103.47	86.4%	7,232.92	64.3%
Roads Total		**1,288.31**	**100.0%**	**1,740.54**	**100.0%**	**8,223.91**	**100.0%**	**11,252.76**	**100.0%**

Information is from PRHTA 2017 Data.

Table 2 Source: 2019 PR-TAMP

It is important to note that 64% of the total road system of Puerto Rico (primarily the roadways owned and maintained by the municipalities) has not been assessed. Moreover, the lack of a data-driven asset management plan also hurts long-term road management policies and projects. Per the TAMP, the Annual Average Daily Traffic (AADT) is:

Average AADT	System	
Functional Class	***NHS***	***Non-NHS***
COLLECTOR	N/A	5,698
FREEWAY & EXPRESSWAY	45,748	N/A
INTERSTATE	56,892	N/A
LOCAL	N/A	1,097
MAJOR COLLECTOR	N/A	2,048
MINOR ARTERIAL	20,800	9,629
MINOR COLLECTOR	N/A	1,808
PRINCIPAL ARTERIAL	22,871	N/A
SMALL URBAN COLLECTOR	N/A	3,647
SMALL URBAN INTERSTATE	36,400	N/A
SMALL URBAN LOCAL	N/A	979
SMALL URBAN MINOR ARTERIAL	N/A	8,561
SMALL URBAN PRINCIPAL ARTERIAL	7,962	N/A

From HPMS Table, Average AADT 2017

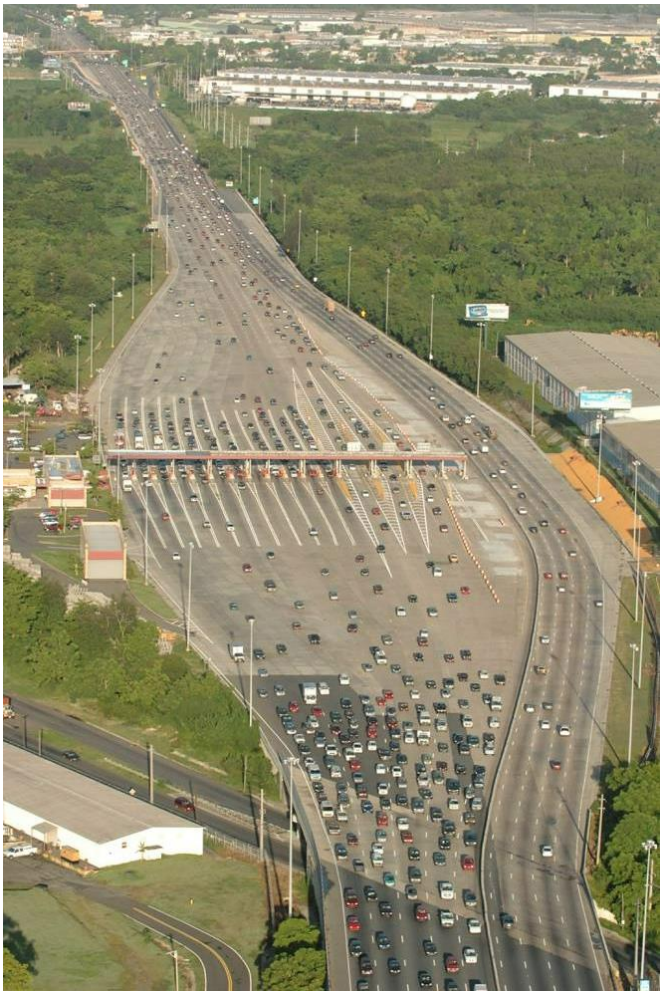
The major causes of pavement failure in Puerto Rico includes, but is not limited to, overweight trucks, fatigue-related damage, rutting, moisture induced damage/drainage, lack of preventive maintenance, utility roadwork and/or system issues, or quality control.

HEAVY VEHICLES

Puerto Rico truck size and weight regulations establish a maximum gross vehicle height (GWV) road vehicle weight of 110,000lbs trucks on its roadways. This load restriction is codified in Law 22- Motor Vehicle Law of Puerto Rico of 2001, as amended. The combination of heavier trucks and lack of adequate pavement maintenance practices can accelerate deterioration and reduce the service life of a roadway. Most truck size and weight regulation in the U.S. require trucks to weigh 80,000 lbs or less. Compounding the deterioration is the fact that there is only one permanent weighing station on the island. A study published in 2005 in the Latin American and Caribbean Consortium of Engineering Institutions (LACCEI) indicates that more than 55% of the heavy vehicles that used the freeway did not enter the permanent weighing station as stipulated by the law. Temporary portable weighing stations are used through the island; however, there is not enough human resources to coordinate an effective island-wide truck monitoring program. Furthermore, without adequate coordination with law enforcement, the truck weight monitoring program cannot be performed. Similar problems associated with lack of effective law enforcement are observed at the permanent weighting station.

SIDEWALKS

Adequate sidewalks are essential elements in urban areas, providing safety and accessibility for the pedestrian populations. In many locations in Puerto Rico, sidewalk discontinuity, hydrants, signs, utility poles, and more, obstruct the sidewalks and/or ramps for pedestrian use. This creates safety risks. The average percentage of pedestrian' fatalities account for 32% of total annual traffic fatalities in Puerto Rico (1997-2018), compared to 15% nationally, per FWHA. Estimates show that one out of five citizen in Puerto Rico are 60 years or older. Looking forward, sidewalks compliant with ADA requirements will continue to play an essential role in fostering mobility for our handicapped and aging population.



LIGHTING

The condition of lighting is of great importance, since 57.6% of fatal crashes between 2014 and 2016 occurred at night. The lighting system was strongly impacted by the passage of Hurricanes Irma and María in 2017.

INTERSECTIONS

In recent years there has been initiatives to create a robust database of Puerto Rico's intersections control equipment (such as signals, sensors, controller sized lights with specific equipment, etc.), exit/entrance ramps and more. Currently this database is incomplete. Missing information may include the specific type of control equipment of the intersections, including state and municipal highways. Per the TAMP, the network includes approximately 1,258 signalized intersections on state highways, but the total amount of intersections statewide could be more. Also, the passage of Hurricane Irma and Maria in 2017 contributed significantly to the number of traffic lights in Puerto Rico that are out of service.

OPERATION & MAINTENANCE

Puerto Rico has struggled in past years to adequately maintain its roadway network, in part because of a reduction in personnel and partially due to a lack of dedicated funding for road preservation and maintenance. The lack of a data-driven asset management plan also limits long-term road management policies and projects. Because of Puerto Rico's high density of roads per square mile, the asset priority should be on the operation and maintenance of existing infrastructure rather than new construction.

Due to the oversight of the Fiscal Control Board, PRHTA has filed for Title III protections under PROMESA, which has allowed the HTA to direct resources to improvement projects on state roads. Most projects have been executed by private companies and through associated contracts, due to the limitations in recent years of personnel and equipment. The principal projects currently funded by PRHTA are:

"Abriendo camino" Program

- ***High Quality Asphalt Repair Program (PEMAC, Spanish acronym)*** – The objective of this program is to improve deteriorated road infrastructure, specifically the condition of the primary, secondary and tertiary roads' pavements. This project began in 2018 and is expected to be completed by 2019 but depends on the allocation of

state funds for its continuity. In 2019, the total allocation is approximately $70 million for the complete project. The PEMAC is not related to a long-term maintenance plan.

- ***State Highway Modernization Program (PEMOC, Spanish acronym)*** – The program's objective is to rehabilitate more than 11,184 miles of roads in two years through the use of state and federals funds on innovative techniques, equipment and materials. Such approaches include Warm-Mix Asphalt (WMA) and sealing of cracks, among others.

Accelerated Program – This program began in 2017 (before Hurricane Irma and Maria) and has been carried out in several distinct phases. The program consists of the following: pavement improvements (rehabilitation or reconstruction), safety improvements on the roadside, signage and pavement marking, and preservation of four bridges. The projects carried out represent an estimated $298 million in federal and state funds for a total of 34 projects. Funds are designated for: $171 million in paving, $104 million in safety, and $23 million earmarked for special projects with the same direction. The PRHTA has invested approximately $7 million in state funds to design and is planning to begin a new phase.

The maintenance of municipal roads depends on the collaboration, coordination, personnel, and equipment from each of the 78 municipalities. However, not all locations may have the equipment, enough technical expertise and/or personnel, or capital necessary to carry out the required work. Furthermore, mutually beneficial collaborations between municipalities may help to fill those gaps.

FUNDING

The operations and maintenance of Puerto Rico's state transportation system is the responsibility of the PRHTA and the Puerto Rico Department of Transportation and Public Works (PR-DTPW). The municipal road system is not under the jurisdiction of PRHTA or PRDTPW.

The funding for road projects varies depending upon their classification. The NHS or otherwise identified as federal highways receive federal funding. State and municipal roads are funded by the PR central government or the municipalities.

PRHTA road projects are primarily supported by federal funds to match local funds. PRHTA receives about $158.8 million per year from FTA and FHWA, according to PRHTA Fiscal Plan. Non-NHS roadways can receive federal funding from Surface Transportation Block Grant or Federal Emergency Management Agency in emergency cases.

PRHTA relies on a large surplus of toll credits to meet the non-federal share of FHWA grant funded projects, allowing the Authority to continue developing infrastructure despite cash limitations associated with retention of revenue and Title III status.

Puerto Rico increased revenue for transportation as part of a 2015 law known as "*Crudita.*" The "Crudita" raised the import tariff on a barrel of oil from $9.25 to $15.50, which went into effect on March 15, 2015. With this, the Puerto Rico government aims to collect about $185 million in taxes that would allow it to subsidize the PRHTA and stabilize its finances. One of the purposes of this law is to financially assist PRHTA while also reducing its debt.

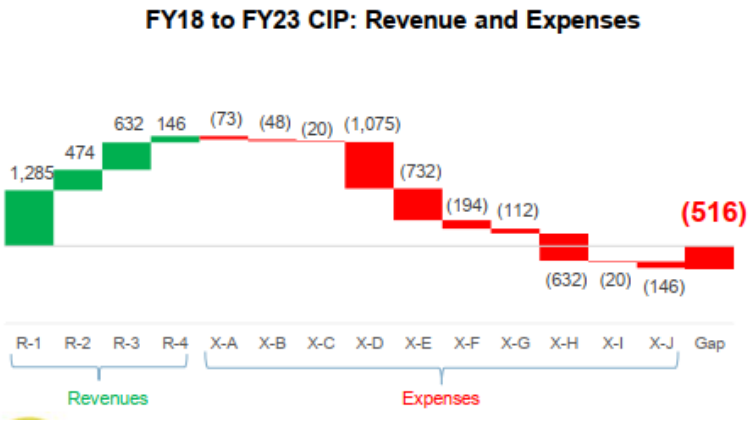
It should be noted that the infrastructure owned by PRHTA was severely impacted by Hurricane Maria. Specifically, PRHTA estimates that Maria caused $71 million in direct losses to the agency, excluding damage to the highway network which was estimated at $652 million.

FUTURE NEED

Per the PRHTA fiscal plan, in the near-term, the estimated funding need is $3.1 billion of capital expenditures from FY18 to FY23 to maintain assets in a state of good repair and continue normal operations. According to the Capital Improvement Plan, this includes:

- $2.25 billion for highway-related CIP,
- $652 million for Maria-related emergency repair, and
- $146 million for HTA's transit-related CIP.

During the same 6-year period, HTA's CIP expenses exceed capital revenues by $516 million. This gap will need to be funded by operating revenues or allocations from Central Government (FY18 to FY23).



Abr.	Revenue Category
R-1	FHWA Funds
R-2	State Funds Earmarked for CapEx
R-3	Federal Emergency Revenues
R-4	FTA Funds

Abr.	Expense Category
X-A	Construction Local
X-B	Design
X-C	ROW
X-D	FHWA Construction Spend Projects[1]
X-E	Non-Federal Construction Projects
X-F	FHWA Construction Soft Costs
X-G	Non-Federal Construction Soft Costs
X-H	Federal Emergency Repair Program
X-I	Local Emergency Repair Program
X-J	Transit CIP

Figure 10 Revenues and Expensed divided by category

PUBLIC SAFETY

Puerto Rico has approved the Strategic Highway Safety Plan (SHSP) 2019-2023. The purpose of the SHSP is to focus the efforts of the safety stakeholders by prioritizing strategies to keep a safe highway system for all users. Between 2007 and 2013, before the development and implementation of the first Puerto Rico SHSP, Puerto Rico reported more than 200,000 traffic crashes per year, resulting in more than 360 fatalities and 5,200 people who were seriously injured. During the implementation of the SHSP 2014-2018, the number of traffic fatalities and serious injuries decreased by 20.72% and 36.93%, respectively. However, pedestrian traffic fatalities remain a significant concern.

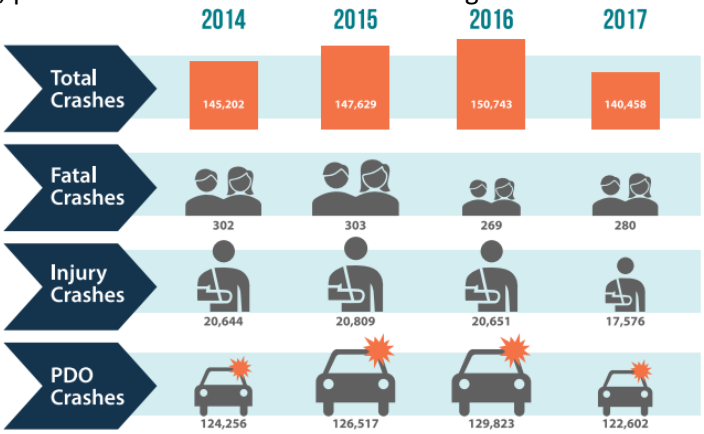


Figure 11. Total crashes by crash type, 2014-2017. Source: Puerto Rico Strategic Highway Safety Plan 2019-2023

RESILIENCE & INNOVATION

A resilient transportation system is defined as one that has the capabilities to prevent or protect against hazard threats and/or incidents. Moreover, a resilient system should withstand and recover critical services with minimal damage to public safety and health. Furthermore, a resilient, innovative, and sustainable transportation system should also be capable of reducing congestion through different measures, resist daily loads, withstand climate conditions, and more.

Due to hurricane Irma and Maria rainfall and winds, landslides occurred in Puerto Rico. As a result, vehicular routes where affected on a long-term basis. FHWA funded the "Landslide and Road Damage Evaluation and Repair Recommendations Program," intended to analyze and provide resilient solutions for fixing landslides as well as reestablishing affected routes.

Currently, Puerto Rico's transportation network faces different challenges. Improving state and municipal construction and maintenance parameters could improve the road network's condition. For example, pavement conditions could be improved through warm mix techniques, micro surfacing, and High Friction Surface Treatment to reduce public safety threats.

It should be noted that PRHTA is incorporating innovation to improve highway safety. For example, PRHTA has incorporated rumble strip countermeasures in several projects. This is used as a safety measure to address lane departure issues. In addition, Puerto Rico has adopted FHWA's Every Day Count (EDC) initiatives. PRHTA is currently working with the Safe Transportation for Every Pedestrian (STEP) initiative of EDC-5 to improve road safety for pedestrians through SHSP. Other potential innovation are evaluated through the State Transportation Innovation Council (STIC).

Another innovation incorporated to improve the public safety in highways is the Traffic Incident Management (TIM) Program. The Puerto Rico Department of Transportation and Public Works (PRDTPW) developed the TIM in 2014 as part of the Intelligent Transportation Systems (ITS) project for the San Juan Metropolitan Area (SJMA). The TIM Program consists of a planned and coordinated multi-disciplinary effort to detect, respond, and clear traffic incidents as fast and safely as possible to avoid secondary incidents. Effective TIM improves traffic operations and enhances safety for all road users, especially emergency responders and people involved in traffic crashes. In addition, the TIM program is a key element during massive evacuations caused by natural disasters or any other event.

The resiliency of Puerto Rico's road network has a direct effect on freight and employee movement, and the island's ability to attract and retain businesses, and boost tourism, economic development, public safety, and more. Assessing the challenges with better planning, resilient, innovative, and sustainable solutions should be a short- and long-term goal.

RECOMMENDATIONS TO RAISE THE GRADE

The recommendations to raise the grade are presented on following areas.

General:

- Encourage collection, dissemination, and processing of real-time data for day-to-day benefits and long-term planning. Future planning and projects must be based on good quality data, both from the state agencies and municipalities.
- Improve highway safety and reduce accidents/fatalities: provision of real-time information on maintenance and construction activities to the public and other agencies. Currently there is no database for the crashes that occurred in work zones. Improve management of roadway closures (i.e., work zones) and alert drivers to approaching roadway hazards. Finally, continue with the implementation of the SHSP, as it guarantees continuity in the coordination of integrated efforts for the benefit of highway safety in Puerto Rico for the coming years. In this way, better results can be obtained based on the best available data.
- Reduce congestion by relocating government agencies or offices out of congested zones in order to reduce traffic jams and VMT; improving public transportation systems, and providing real-time data for congestions, traffic jams, construction, maintenance and/or accidents occurring in the road network throughout and internet service, webpage or phone application.

- Improving the public transportation system and zoning could help minimize the amount of congestions in the road network. Implementing fast construction and accident mitigation procedures could also help minimize the congestion.
- Promote the establishment of collaborative agreements with local universities to develop research projects that could lead to the evaluation of innovative materials and equipment, to establish effective data collection practices and to improve data analysis capabilities to the HTA to improve road management policies and preservation activities.

Municipalities:

- Develop quality control procedures like those adopted by PRHTA. PRHTA has been performing quality control and quality assurance testing to verify the asphalt mixes on roadway projects. However, is possible that municipalities are not conducting enough quality control/ quality assurance procedures nor supervising the pavement construction job. Provide support to municipalities with technical experts, inspections, and design guides. PRHTA could also develop a cost-effective design for municipalities that meet certain parameters to improve the durability of the pavement.
  Build capacity throughout municipalities in proposal-writing for federal funding for future projects.
- Develop programmatic agreements and/or memorandum of understanding (MOU) between municipalities to share resources and/or equipment in order to carry out projects efficiently with a reduction in investment costs.

Intersections and traffic management:

- Create a detailed inventory of existing traffic control systems. Keeping up to date with updated, reliable, and available information can help improve the traffic control systems, reduce congestions and reduce emergency vehicle delays by monitoring the intersections and systems.

Pavement and Markings:

- Consider the use of different type of pavement materials, such as reclaimed rubber from (tires), recycled asphalt pavement, and using a higher temperature for the binding grade. Incorporating these solutions may help solve economical, structural and environmental problems. A researching throughout the local universities may help evaluate more solutions for existing problems, as well as incorporating innovations and developing the future professionals of the island.
- Addressing the drainage systems in the highway network is a key factor to maintain good pavement conditions. It is well known that the combination of moisture and heavy truck traffic are the primary sources of premature deterioration of HMA pavement. Puerto Rico highway network drainage infrastructure may be unfit for its purpose, lacking a drainage system and/or the roads that have a drainage system that don't receive proper maintenance.
- Establish an effective and systemic pavement preventive program. The lack of pavement maintenance has been a major issue affecting ride quality in Puerto Rico. Funding for maintenance problems should be allocated in order to extend the pavement ride quality. Maintenance programs and pavement patching should be done with the state-of-the-art procedures and higher standards applicable.
- Improve interagency communication and collaboration. Unregulated pavement utility cuts can compromise the entire pavement condition, as well as the safety of road users on work zone areas. Agencies should collaborate and have better communications in order to improve the short- and long-term service life of the pavements infrastructure by reducing the amount of unregulated pavement utility cuts. Moreover, agencies can coordinate their work in order to reduce the amount of pavement utility cuts needed by addressing the needs of multiple agencies before repaving the roads to optimal quality.

Heavy Vehicles:

- Freight network extension - The planning factors of Long-Range Transportation Plan (LRTP) 2045 include the priority of increasing accessibility and mobility of freight, but planning should also take in consideration the existing load design conditions of the routes. Otherwise, the omission of freight network extension will accelerate the deterioration of the existing highway infrastructure.
- Do an assessment of the National Highway Freight Network (NHFN) of Puerto Rico in terms of resiliency and availability after possible natural disasters. Having a resilient NHFN may improve disaster relief.

- Due to the redundant highway system of Puerto Rico, trucks can reroute to by-pass permanent or temporary weighting stations. Better law enforcement can improve road conditions by reducing the amount of trucks with overload bypassing the weighting stations.
- Consider increasing the number of axles when carrying very heavy loads. Very heavy loads will accelerate of the degradation of the highway and bridges infrastructure.
- Conduct a study to evaluate the economic impact of heavy truck weights (GVW = 110,000) of future maintenance cost in highways and bridges.

APPENDIX

HTA Infrastructure agenda according Fiscal Plan

HTA has established an infrastructure agenda to maximize federal funds obligated from FHWA and FTA and improve economic growth. Puerto Rico has a six-year Capital Improvement Plan (CIP). The six-year CIP is comprised of the 2017-2020 Statewide Transportation Improvement Plan (STIP) which are planned projects, active projects not included in the STIP, and projections beyond the STIP to maintain the system in a state of good repair.

- Strategy:
  - Focus CIP on maintaining the existing highways asset in an adequate operating condition
  - Engage expedited design services to accelerate preliminary designs and obligate funds – Increase project supervision through additional qualified resources
- Focus:
  - Planned projects for the next six years will mainly focus on:
    - Highway Safety Projects
    - Improvement of existing transportation infrastructure, including pavement reconstruction and preservation; bridge repairs and preservation; and the upgrade of traffic signals.
    - Congestion Mitigation
    - For the Transit Asset, the CIP will focus on the replacement and upgrades of buses and the TU train system
- Funds:
  - Obligate as much Federal Funds as possible to support economic growth
  - Current federal match is 80.25% of project costs for eligible projects, with the state matching 19.75% (exception: 100% for emergency relief).
  - Currently, HTA uses toll credits to cover the spend requirements of the state match.
- Projects and Execution:
  - The current CIP has been developed to maximize the deployment of already assigned federal funding on existing projects and optimize the use of future funding by prioritizing infrastructure needs in order to keep the road network in a safe operating condition.
  - As part of a Memorandum of Understanding (MOU) between the HTA and the FHWA, HTA is undergoing a transformation geared at revamping its project and program delivery capabilities to eliminate its project backlog. HTA feels confident that it will be able to deliver the described CIP in this fiscal plan, once this transformation is completed.
  - HTA has included in the fiscal plan a CIP for the Transit Assets at $5M per year to ensure availability of funds to overhaul any bus units and train system components in disrepair

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Solid Waste D-

EXECUTIVE SUMMARY

Puerto Rico's solid waste infrastructure is under significant strain. Post-closure activities at the 30 landfills that were closed in the 1990s are not taking place. Meanwhile, of the 29 solid waste facilities currently in operation, only 11 are compliant with federal standards. Insufficient operation practices, management, and inspection of both open and closed municipal solid waste facilities often leads to improper waste compaction and ineffective leachate and stormwater management. Consequently, this contributes to the presence of vectors at landfills, such as mosquitos, rats, and seasonal pests, which can potentially aid the spread of zika, chikungunya, and other diseases. Capacity at existing landfills is also an urgent concern, especially after Hurricanes Irma and Maria produced approximately 2.5 million tons of debris, or 2.5 to 3 years' worth of solid waste that was then disposed of at landfills. The U.S. Environmental Protection Agency found in 2018 that there is less than five years of remaining capacity at active landfills across the island. Meanwhile, Puerto Rico residents on average dispose of 5.56 pounds of solid waste per person, each day, compared with the 4.4 pounds per person a day in the mainland U.S. Recycling rates on the island are low, with approximately 9 to 14 percent of solid waste diverted.

BACKGROUND

For decades, Puerto Rico has been challenged by inadequate solid waste infrastructure. During the 1990s, the EPA advocated for the immediate closure of 29 of the 61 landfills identified in Puerto Rico. The goal was to increase compliance with environmental and safety regulations at the 32 landfills left, and in arrangement with the Puerto Rico Solid Waste Reduction and Recycling Act of 1992, increase recycling rates up to 35 percent. However, almost 30 years later, Puerto Rico is still struggling with a weak solid waste and recycling infrastructure. Moreover, the island's recycling rate is not well defined, with estimates of diversion somewhere between 9 percent and 14 percent in the best-case scenario.

Consumption habits, population density, geographical circumstances of the island, and the shortage of appropriate facilities for disposal are still some of today's challenges. The lack of dedicated funding and a multi-sector recycling educational program, inaccurate official information on generation rates, and other environmental issues lead to a substandard solid waste management state program which presents a risk to public safety and environmental health concerns.

As a result, Puerto Rico's communities are affected by the mishandling of special waste, a failure to collect and dispose generated leachates, and impacted groundwater resources. Several open dump landfill cells are under consent decree and compliance orders, as they were covered under a grandfathering clause included in the EPA regulations.

The last time that Puerto Rico conducted a solid waste characterization study was in 2003 at the 31 landfills and 2 transfer stations operating in Puerto Rico that year. The results of that study are presented in Figure 1. Between year 2003 and present day, waste generation and management has changed considerably, thus creating a need for an updated waste characterization study to identify solid waste disposal location needs, as well as commercial and industrial waste generation rates.

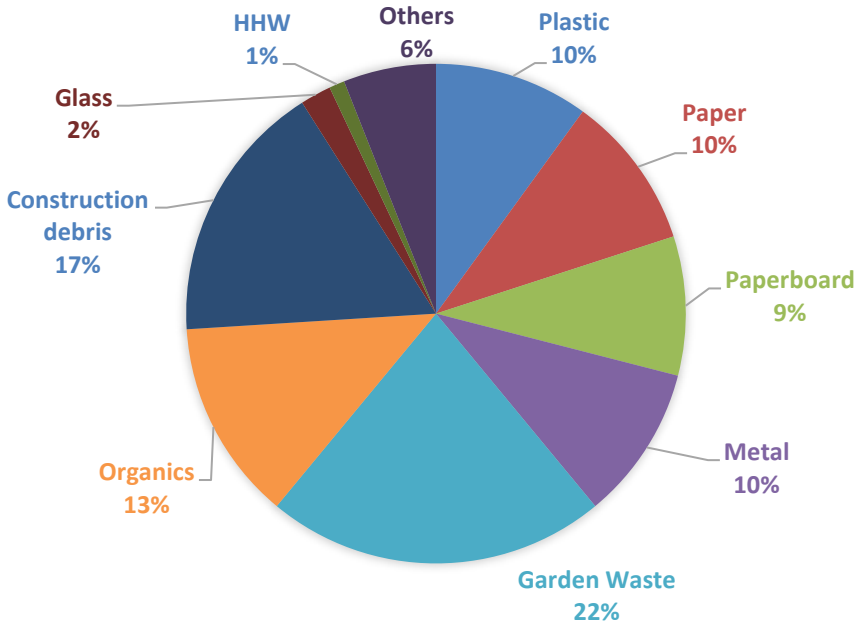

Figure 1: PR Solid Waste Characterization (2003) components percentage combined by weight

CONDITION & CAPACITY

In 2017, landfills received a large volume of debris from Hurricanes Irma and Maria, particularly in the form of unrecyclable construction and demolition debris and vegetative debris. Information provided by the landfills' operators and the US Army Corps of Engineers (USACE) showed that approximately 2 million tons of debris were collected and processed after Hurricane Maria, which translates into more than 2.5 years' worth of solid waste produced in Puerto Rico. Most of the debris was collected by USACE and disposed at active landfills, straining the limited capacity at these facilities.

At the request of Puerto Rico Department of Natural and Environmental Resources (PRDNER), EPA in cooperation with private consultants, conducted a Landfill Assessment Project in 2018 to determine the overall condition and capacity of the 29 landfills in operation. The Landfill Assessment Project is still under review and has not been made public. However, some of the finding were revealed by officials during a public hearing at the Puerto Rico House of Representatives. Officials reported that 67% of the existing landfills will close between 2022 and 2025[1]. Furthermore, the remaining lifespan of the active landfills is not more than 4 years[2]. These findings represent additional challenges to the regulation agencies already tasked with the urgent need to implement a comprehensive solid waste management strategy that is environmentally safe and cost-effective.

OPERATION & MAINTENANCE

The operation and maintenance of Puerto Rico's landfills is the joint responsibility of municipalities and the private sector. Most of the landfills are owned by the municipalities (only two landfills are privately owned). Thirteen out of the 29 active landfills are also operated by the municipalities. Unfortunately, most of the Puerto Rico's municipalities are under severe economic duress and cannot provide efficient operation and maintenance to achieve compliance with federal standards. For example, municipality-owned and operated landfills often lack monitoring systems that check groundwater contamination and/or landfill gas, or their facilities may include inappropriate stormwater runoff collection systems or unstable slopes. These landfills may also lack necessary solid waste daily cover up. Some municipalities lack the personnel

[1] Agencia EFE, El Nuevo Dia, July 8, 2019
[2] Agencia EFE, US Edition, September 19, 2018

with the technical knowledge and capacity to operate a landfill. Of the 29 landfills operating in Puerto Rico, only 11 are compliant with EPA standards, while the remaining 18 are not.

FUNDING & FUTURE NEED

The average collection fee for open dumps and compliant landfills in Puerto Rico averages $19 and $28 per ton, respectively. Comparatively, the U.S. national mean annual tipping fees were $50.59 per ton in 2014, per ASCE's 2017 Infrastructure Report Card. The continued operation and maintenance of landfills and recycling facilities in the U.S. is self-funded through trash collection fees; Puerto Rico could consider raising the tipping fees in order to bring facilities to compliance.

There are significant costs associated with improving solid waste infrastructure in Puerto Rico, including better operation and maintenance, closure and post-closure costs to bring facilities back into compliance, and costs associated with developing new landfills.

Closure costs in Puerto Rico are higher than normal, because most of the landfills in Puerto Rico do not comply with the EPA regulations, meaning they are technically open dumps and more expensive to close due to remediation action needed. A recent estimate showed closure costs of approximately $300,000 per acre. Thus, the current amount of investment needed to close the open dump sites of Florida, Isabela, Juncos, Lajas, Moca, Cayey, Arroyo, Toa Baja and Vega Baja landfills is estimated at approximately $85 million dollars. Additionally, landfill closing processes requires 30 years of post-closure maintenance that can be divided in two different phases. Puerto Rico's landfills will need $15 million dollars for the first 20 years of post-closure maintenance, or Phase 1. Phase 2 consists in the remaining 10 years of post-closure maintenance, where the post closure cost can be less expensive. Phase 2 cost-analysis can vary between landfills.

New landfills will be needed in the near future. With a cost of $115,000 per acre to open a new landfill cell in existing facilities, a recent estimate suggests a minimum of $11.5 million dollars is needed to open new compliant MSW sites in Puerto Rico. This conservative and simple assumption is based on landfill feasibility and geographical locations, but the total amount of funding needed for new landfills or new compliant cells in existing facilities could be much more.

Due to the Puerto Rico Oversight, Management, and Economic Stability Act (PROMESA) and the fiscal crisis, the funding available for solid waste management is very limited. Municipalities rely on the central government, public private partnerships, or federal grants to pay for solid waste infrastructure, but such arrangements are inadequate to meet the true needs of the sector.

The recycling system in Puerto Rico also needs a new strategy. To maintain its cost-effectiveness, the recycling system needs enough material to produce a consistent amount of revenue. Recycling partnerships should be created by regional initiatives that include partnerships between different municipalities and private companies. Additionally, composting should be an option for agencies and municipalities that typically dispose of vegetative waste. Incentives and legal measures requiring regional composting may be beneficial in multiple ways by reducing the amount of waste received in landfills and creating positive economic opportunities.

The most important need is a uniform public policy providing interagency coordination based on best engineering practices, accurate information, identification of hidden operation costs of non-compliance landfills, the cost of not recycling and real hauling costs. This new public policy should provide a feasible financial model adding transparency to current waste management expenses, promote technology and infrastructure investment and centralization of services.

PUBLIC SAFETY

In the 1990s, the EPA encouraged the immediate closure of at least 30 of the more than 60 landfills in Puerto Rico. Due to the rush to close these landfills, two important things happened:

1. There was a lack of information and monitoring procedures for the landfills that closed in the 1990s, which may result in previously unknown hazards to the environment.

2. Of the 29 landfills in operation today, 18 do not comply with USEPA standards and often lack proper operation management, for example:
    a. Inappropriate stormwater runoff collection systems may spread the leachate through the landfill and nearby properties. In image 1, leachate drains and flows through the surrounding areas, affecting animals, ecosystem, and human life.
    b. Unstable slope in landfills is an active hazard to landfill employees, surrounding communities, transportation industries, as well a threat to critical environments nearby the landfill sites.

Image 1 Leachate overflow into nearby wetland

Puerto Rico possess a vast underground water network of aquifers and wells. Such groundwater systems are a significant part of the environment, supporting wildlife, and supplying clean water to several communities. Potential contamination to our groundwater from landfills that were improperly closed, inadequately inspected, and/or are currently operating out of compliance with EPA is a public health concern.

It is estimated that Puerto Ricans dispose of 4.7 million tires each year. It is worth highlighting the danger posed by the excessive accumulation of tires for the spread of pests and diseases. Additionally, there are other potential risks to public safety and the environment, such as fires, explosions, spills, discharges of material with objectionable odors, and attraction of vectors. Vectors may include mosquitoes, rats, seasonal pests, and more.

RESILIENCE

The solid waste system in Puerto Rico is not resilient, nor sustainable. Post Hurricane María, research and EPA field work found slope erosion damage, exposed garbage in slopes, and non-functional and broken leachate collection systems. Furthermore, due to the lack of planning, communication and information, much of the debris with recycling or composting possibilities ended in the landfills. Two years after Hurricane Maria devastated Puerto Rico, there is vast amount of waste still waiting to be separated and disposed in the landfills. Another major hurricane poses a severe risk to the solid waste sector in Puerto Rico; existing landfills have less than five years of lifespan under normal conditions.

Although addressing the current capacity issue is a priority, stakeholders should plan for the long-term as well. Considerations of sea level rise, hurricane direct impacts, hurricane debris, tsunamis, and earthquakes must be part of the long-term planning efforts.

INNOVATION

Innovation is much needed in Puerto Rico's solid waste industry. Puerto Rico's solid waste infrastructure faces multiple challenges, but addressing limited space, high costs, poor recycling, and creating solutions for used tires should be a priority. There can be an economic opportunity in generating funds from recycling, composting, and harvesting methane gas from the landfills. Developing a strategy to resource recovery and/or recycle should be a goal. Presently, the only sustainable solid waste management practice in consideration is the use of landfill gas for electricity purposes. Sustainable solid waste management practices, including source reduction, should be pursed through public policy development.

RECOMMENDATIONS TO RAISE THE GRADE

- The Puerto Rico Department of Natural and Environmental Resources needs adequate funding and training to close open dumps and expand compliant landfills. In general, Puerto Rico needs to increase the number of landfills in compliance with EPA regulations, including groundwater monitoring requirements, leachate collection and removal, composite liner requirements, and more. These actions require a purposeful focus on, and prioritization of, solid waste infrastructure by decision-makers at all levels of government.
- Create a uniform solid waste management public policy which provides for continuous compliance assistance, innovative waste management projects and alternative financial methods, create statewide public education programs to encourage recycling and composting. Develop regional partnership with municipalities and the private sector in order to made recycling more profitable.
- Perform a new study of waste characterization. Analyze where the waste comes from (residential, commercial and industrial) and develop programs for more strategic solid waste management.
- Future solid waste system designers and regulators should take in consideration the natural hazards that may occur in Puerto Rico. Stakeholders should consider developing a resilient and innovative solid waste Infrastructure.

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Wastewater D+

EXECUTIVE SUMMARY

Puerto Rico's residents and businesses largely depend on the Puerto Rico Aqueduct and Sewer Authority (PRASA) to provide wastewater collection services. PRASA owns and operates 51 wastewater treatment plants, 5,300 miles of sewer lines, and 824 wastewater pumping stations. While PRASA has implemented new processes in response to two Consent Decree Agreements with the Environmental Protection Agency, the agency still faces significant fiscal and operational challenges, especially in the aftermath of Hurricanes Irma and Maria. The island population has declined by 14 percent since 2010, leaving fewer rate payers to fund necessary projects. The declining rate payer base, combined with a lack of access to financing, perpetuates challenges associated with funding PRASA's capital investment program. A total of $551 million is needed for renewal and replacement over the next six years to update aging PRASA infrastructure. A recent restructuring of approximately $1 billion debt is expected to provide payment savings of $440 million over five years; that funding will be provided to the stalled capital improvements program.

INTRODUCTION

The PRASA, a government corporation, is the only wastewater utility in Puerto Rico and serves approximately the 59% of the 3.3 million residents of the island. with the remainder of the population served by septic tanks. PRASA's responsibilities include the approval and construction of wastewater infrastructure as well as the oversight of wastewater collection and treatment processes.

Although wastewater infrastructure is often out of sight and out of mind for the average citizen, the collection and treatment systems are just as important as other more visible engineered structures. However, from 1994 to 2005, many of Puerto Rico's wastewater treatment plants lacked capacity and/or adequate treatment and were fined by the U.S. District Court. As a result, PRASA paid millions of dollars in fines and funded necessary remedies. Because the focus was on bringing existing systems up to standards, PRASA was unable to approve additional sewer connections and new construction projects. In 2015, a new consent decree was signed with EPA aimed at further improving the system.

CONDITION

PRASA's 51 wastewater treatment plants process about 220 million gallons a day (mgd) of wastewater. Wastewater is conveyed through 5,300 miles of sewer lines and 824 wastewater pumping stations. Most of the treated wastewater receives secondary treatment and then is disposed in the ocean or rivers. About 116 mgd is reused as agricultural irrigation and aquifer recharge.

The lifespan of collection systems is affected by age, type of pipe material, soil conditions and the chemistry of the wastewater. Pipes can break, crack, disintegrate, become disjointed or clogged. Other elements like pump stations and manholes are also subject to stress from wastewater flows. The age and resulting condition of wastewater infrastructure typically manifests itself in failures consisting of breakdowns of plant equipment and wastewater collection system clogs and overflows. A total of 27,729 clogs and overflows were reported during the year 2018, for an average of 5.23 per mile of installed lines. The current rate of failures in Puerto Rico's wastewater infrastructure indicates that the condition of systems has improved and is relatively good. However, this is likely to change rapidly as systems reach the end of their service lives.

Inadequate uses of the collection system impacts its performance. Incorrect uses include oil and grease discharges from houses and restaurants, makeshift connections for rainwater from roofs, and deposition of trash and debris in manholes. These incorrect uses impact the performance of the collection system. PRASA has recently adopted new regulations to control grease discharges, particularly from businesses. However, continued public education and stricter enforcement is required.

PRASA has also been emphasizing tracking and assessing the condition of pipes, wastewater plants, pumping stations and other components of its wastewater systems. Formal asset management programs have been put in place over the past few years, mostly at larger PRASA facilities. In general, asset management is essential for responsible utility stewardship. Only by understanding the risks associated with various assets can owners decide how to re-invest their limited funding and bring the most value to the utility.

In Puerto Rico, sanitary and storm sewers are mostly separated. Throughout the 2000s, PRASA aggressively removed connections between the two systems, thereby reducing combined sewer overflows into receiving waterways. Additionally, around 500 miles of sanitary sewer lines have been rehabilitated over the last decade. Unfortunately, the rate of additional sewer upgrades slowed due to the economic downturn and the related decrease in revenues.

CAPACITY

In general, Puerto Rico's wastewater systems have adequate capacity to serve the existing population. Notably, PRASA has improved their use of hydraulic modelling to predict capacity issues. To date, approximately 60% of the wastewater system has been computer analysed.

Although PRASA has been actively working to improve wastewater infrastructure, regional plants and its associated main collection lines – approximately 15 percent of the total lines – are estimated to be over capacity. Looking ahead, PRASA requires $500 million for wastewater compliance, reliable and resiliency projects, according to the agency's six-year Capital Improvement Plan (CIP). That funding will be focused on improvements to wastewater treatment processes as well as to main sewers and collection systems to improve capacity and accommodate future growth.

In the system at-large, capacity becomes a problem when infiltration and inflow (I&I) occurs. I&I is a problem for aging and poorly maintained systems. When I&I occurs, groundwater or stormwater enters into a dedicated sanitary or wastewater sewer system, potentially overwhelming the system past its capacity. Fortunately, PRASA's capacity certifications have helped the collection system avoid exceedances from the connection of new developments.

About 41 percent of Puerto Rico's population, mostly in rural areas, depend on septic tanks to treat and dispose their wastewater. Without these systems in place, wastewater can become a source of groundwater and surface water contamination. There are more than 540,000 septic systems, although records are incomplete. Septic systems will remain a viable wastewater management option in Puerto Rico given the limited extension of the PRASA's wastewater collection system. It is important to ensure that the septic systems are designed, constructed, and maintained properly. Currently there is little to none oversight of the septic systems, besides the Environmental Quality Board (EQB) guidelines and permits. Public education and regulation enforcement by EQB and EPA are an essential element of this effort.

OPERATION & MAINTENANCE

The active consent decree with EPA requires that PRASA emphasize their Capacity, Management, Operation and Maintenance (CMOM) program guidelines to provide an increased focus on system planning and are complimentary to asset management programs. Under the CMOM approach, a Computerized Maintenance Management System (CMMS) is essential to schedule and track maintenance activities. CMMS allows asset-by-asset tracking of maintenance, and work orders so that the frequency of preventive maintenance can be increased or decreased based on data-driven results. Using these tools, PRASA is beginning to better manage its wastewater system operation and maintenance. However, usage of this system is inconsistent.

However, PRASA lacks sufficient funding for capital-intensive infrastructure repair and replacement. As a result, leaks, overflows, and breaks are higher than national averages. PRASA estimates the need of $551 million for renewal and replacement for the next six years, according to the CIP, to update its aging infrastructure.

Finally, workforce attrition is an important concern as experienced personnel with valuable institutional knowledge leave the utility. PRASA has reduced its personnel from over 6,000 10 years ago to 4,900 today, which is a sufficient staff for performing technically necessary duties. The need for operators, maintenance staff, electronics specialists, engineers, geologists, laboratory analysts, and other technical staff will increase to meet future wastewater demands and changes.

PUBLIC HEALTH & SAFETY

PRASA must comply with EPA, Department of Health (DOH), and the EQB rules and regulations. Compliance with wastewater regulations in Puerto Rico is very high, with over 92 percent of public wastewater systems operating without health-based water quality violations. While PRASA is generally compliant, 41 percent of the population relies on septic tanks, mean the dependence of 41% of the population on septic tanks may be a threat to public health and the environment.

Public health and safety have been threatened recently by catastrophic failures of large wastewater treatment plants due to Hurricanes Irma and Maria. Through better management and long-term planning framework that incorporates aspects of resilience, these risks can be reduced.

The 2015 Consent Decree with the EPA requires PRASA to focus on projects that improve reliability in order to attain 98 percent compliance with the National Pollutant Discharge Elimination System (NPDES) permits for each treatment facility. PRASA's Prioritization System, as also agreed to in the 2015 Consent Decree, establishes the Regulatory Compliance category as the primary and most important consideration for ranking of future projects.

FUNDING AND FUTURE NEED

Water utility rates (including wastewater collection service) are expected to provide nearly all of the funds for operation, maintenance, and expansion of water and wastewater systems. For any utility to be sustainable, rates must consider full life-cycle costs for services, rehabilitation of existing assets and construction of new assets, resiliency measures, plus debt service and other indirect costs.

During the period from 1994 to 2005, mainly due to the lack of sufficient funding to cover its operation costs, PRASA depended on the Puerto Rican central government's allocations, which were insufficient. This impacted the agency's Capital Improvement Program, leading to instances of non-compliance with federal and local environmental regulations. Wastewater treatment plants were fined by a federal court, new projects endorsements were restrained, and millions of dollars of fines were paid.

Beginning in 2006, new agreements with the regulatory agencies were signed minimizing uncertainties in the compliance processes and the payment of fines. However, as a consequence, new extraordinary compliance costs arrived:

- At least $ 350 million over 15 years for compliance and capital improvements projects.
- $70 million annually for the operation of the Environmental Compliance Department and the Integrated Maintenance Program.

In 2015, PRASA and EPA signed a new Consent Decree establishing issues to be addressed and requiring projects and a general plan to be executed. The agreement also permitted PRASA to extend compliance dates to avoid new penalties.

In 2017, Hurricanes Irma and Maria devastated the island. They created significant challenges for PRASA. The impact on the agency's fiscal condition can be summarized as:

- Revenue reduction: $271 million
- Incremental expenses: $396 million
- Capital Investment Program funding for repairs to the wastewater system: $308 million

PRASA rates are tiered to encourage water conservation and include minimum charges to cover costs that are not affected by demand. In 2018, PRASA issued a special increase in water service rates of 2.5 percent annually for the next five years to address with recovery costs due to the hurricanes. This measure was coupled with operational and organizational changes to reduce costs and move the agency into a better financial condition.

PRASA funding also includes federal programs like the Community Development Block Grant Program, the Environmental Protection Agency Revolving Fund loans, and USDA Rural Development Programs. Some funds are also received directly by municipalities in coordination with and using the standards set by PRASA.

A new fiscal plan, for a six-year period starting in FY2018, outlines cash management levels that PRASA will use to improve its liquidity, including by increasing revenues while reducing expenses, working with its insurance agencies and the federal government to secure disaster funding, increasing collection (particularly from government entities), and reducing non-reimbursable maintenance expenses. PRASA will undertake a $2 billion Capital Investment Program (CIP) over the next six years, with about $254 million of that allocated to damage repair of wastewater systems and resiliency. This CIP also includes $328 million for compliance projects as well to prevent leakage within PRASA's collection networks.

RESILIENCE

PRASA is projecting $1.3 billion in investments to improve the resiliency of its system to better withstand future hurricanes. The main focus for resiliency is hazard mitigation, safety, treated wastewater quality, redundancy, robust infrastructure, energy independence, management of critical assets, simplification and consolidation of its infrastructure, increase automation of treatment plants operation, and adopt distributed solar generation and hydroelectric power generation. The results from this vision and a robust resiliency program is intended to break the cycle of PRASA's infrastructure and systems risk and vulnerability.

RECOMMENDATIONS

- The wastewater discipline is becoming increasingly complex and advanced technical qualifications should be reflected in recruitment and training programs. A qualified and trained workforce is essential to keep pace with the needs of the system and the public it serves. Caution should be observed to avoid that economies undermine the required institutional knowledge and experience, as it has been the situation in other government agencies.
- Prioritize the implementation of sewer line replacement and renovation programs.
- Improve inspection and enforcement of grease traps in food preparation businesses.
- Explore the possibilities to reuse treated wastewater for irrigation purposes and aquifer recharge.
- Coordinate needs with municipalities and other community organizations for the implementation of sewer improvement projects.
- Improve the detection and repair of infiltration and exfiltration to or from wastewater mains to prevent overflows and environment contamination.
- Consider the use of alternate energy systems in wastewater treatment facilities to reduce the dependence on the electrical service being PR one the US jurisdictions with higher energy cost.

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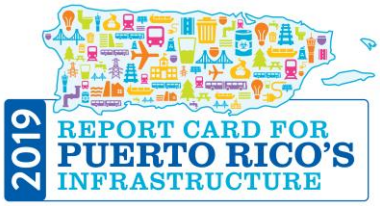

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