ABSTRACT

Title of Thesis:	THE RESILIENT ISLAND: REVITALIZING A BROKEN HOME
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Puerto Rico is known for its sandy shores, beautiful beaches, and green environment. Although it's marked as a great Caribbean vacation destination, Puerto Rico's prone to many natural disasters. The islands have seen earthquakes, tsunamis, wildfires, and more commonly hurricanes, tropical storms, and drought. The most recent and devastating disaster was Hurricane Maria in late 2017, which led to many deaths and much destruction. Although many historic sites have been preserved, some surrounding communities were destroyed. Since the hurricane, the residents of Puerto Rico are struggling to recover as the estimated damages are in the billions. As they rebuild, the islanders need to consider what can be done structurally, economically, and socially to prevent this from happening again. What type of resiliency is needed and what could help the islanders better prepare for environmental impacts?

THE RESILIENT ISLAND: REVITALIZING A BROKEN HOME

by

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Thesis submitted to the Faculty of the Graduate School of the
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Preface

Disaster struck Puerto Rico on September 6th, 2017, when Hurricane Irma, a category 5 hurricane, breached the islands. Communities had no time to recover as Hurricane Maria, an even bigger threat, reached land not more than two weeks later. These two disasters happening in quick succession led to a devastating death toll of 2,975 people and caused a total of $90 billion in damages. This had been the most devastating disaster to hit in over 100 years. The people of Puerto Rico are still recovering to this day and are trying to find solutions to creating community resiliency.

This thesis will focus primarily on what makes a community resilient and how to apply this to other Caribbean nations. Not all Caribbean islands face the same challenges and each one has its own identity. To assume that all islands are the same would be irrational. Additionally, this thesis will look at how a community can shift from being unconventional to very functional.

Throughout the recent years, there has been a shift in design and function toward creating communities that are more sustainable, durable, and resilient. While this shift can occur easily in more modern societies, those that lack the resources to do so will continue to struggle unless proper support can be given.

Dedication

I dedicate this thesis to the residents of Culebra, Puerto Rico. May this shed light on

all the hardships that they have been through over the years.

Acknowledgements

Thank you to my committee, Professor Ming Hu, Committee Member 2, Committee Member 3, Committee Member 4, and Committee Member 5 for supporting me and pushing me to be a better designer while also assisting me in providing the people of Puerto Rico with a voice.

Thank you to my thesis cohort for always being there by my side and providing me with drive, courage, and most importantly camaraderie.

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Figure 01: Christopher Columbus
(Source: Peter O'Connor)

History of Puerto Rico

Today, Puerto Rico is considered a destination vacation and is full of a large

historical background. But how did it become what it is today? Puerto Rico's rich

history dates back to the late 15th Century where the Island was formally known as

Boriken or Borinquen, otherwise known as "the great land of the valiant and noble

lord" or the "land of the great lords".[1] In 1493, Christopher Columbus (Figure 01)

had made several voyages across the Atlantic Ocean. Upon his travels, he discovered

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[1] Rivera, Magaly. n.d. "Puerto Rico's History." Welcome to Puerto Rico!
https://welcome.topuertorico.org/history.shtml.

the islands of Puerto Rico. The Taíno Indians, who resided on these islands, greeted Columbus and shared with him their knowledge of gold within the nearby rivers. The newcomers (who traveled with Columbus) renamed the island San Juan Bautista, for St. John the Baptist and renamed the town Puerto Rico (standing for "rich port"). These labels were eventually switched, changing the name of the island to Puerto Rico and the name of the town to San Juan.

Throughout the years, the islanders have dealt with a lot of reform, war, and environmental impact. Most notably was the Spanish colonization and the relationship Puerto Rico has with the Unites States. Back in 1508, the Spanish colonization began with Ponce de Leon leading an expedition to the island.[2] This colonization led to slavery on the island, the death of many Taino Indians, and many wars that caused both city damage and death. It wasn't until 1898 when the United Stated invaded Puerto Rico during the Spanish-American war. While not immediately after troops arrived on the islands, a peace treaty between Spain and America had been created and the Spanish Troops withdrew from Puerto Rico. About 20 years later, Puerto Ricans were made U.S. citizens under the Jones act.[3] Since this event, the Island has dealt with political reform and natural disasters that caused much damage and death to the various towns that reside on the islands.

Puerto Rico, at a glance, has a population of around 3.2 million and has an area of 3,515 square miles. Looking at its demographics reported by the census in 2019, 43.5% of the total population is in poverty and there are roughly 680,000 total

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[2] Rivera, Magaly. n.d. "Puerto Rico's History." Welcome to Puerto Rico! https://welcome.topuertorico.org/history.shtml.
[3] Posted: 2020. "Important Dates in Puerto Rican History." Teaching for Change. July 7. https://www.teachingforchange.org/important-dates-puerto-rican-history#.

employments. (census.gov) While it seems like there's a good amount of work, natural disasters such as Hurricane Maria can cause massive damage that affects the capabilities of the island's growth. Puerto Rico is also known for getting most of its revenue from tourism. With the hurricanes in 2017 and Covid-19 within the last two years, the Island is struggling to maintain a balanced economy.

History of Culebra, Puerto Rico

Figure 02: Islands of Puerto Rico
(Source: Library of Congress, Geography and Map Division.)

Culebra, also known as "Isla Chiquita" and "Ultima Virgen", is a sub-island on the east coast of Puerto Rico (Figure 02) and was founded in 1880 by Cayetano Escudero. To get back to the main island (San Juan), visitors must either take a ferry or a small aircraft to travel. In 1894, there were reports that found 519 residents in 5 separate communities: San Ildefonso, Flamenco, San Isidero, Playa Sardinas I y II,

3

and Frayle.[4] There were in total 84 houses built. In 1939, Culebra played host to the

United States Navy and was used as one of the primary gunneries and bombing

practice sites up until 1975.[5] Prior to the withdraw of its troops, the U.S. Navy was

trying to take over the island by removing the residents of Culebra and send them to

San Juan. Their intention was to ban the people from setting foot onto the island and

even "send the dead from their graves."[6] This became known as "Plan Dracula" and

was eventually cast away when the people of Culebra succeeded. While the Navy no

longer controls the island, some of the military equipment was left behind and can

still be found in multiple places as seen in Figure 03.

Figure 03: U.S. Navy Tank
(Source: Jami Dwyer)

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[4] Rivera, Magaly. n.d. "Puerto Rico's History." Welcome to Puerto Rico!
https://welcome.topuertorico.org/history.shtml.
[5] Rivera, Magaly. n.d. "Puerto Rico's History." Welcome to Puerto Rico!
https://welcome.topuertorico.org/history.shtml.
[6] Carrión, Ángel. 2015. "One Puerto Rican Island's 135-Year History of Struggle and Victory." Global
Voices. July 17. https://globalvoices.org/2015/07/17/one-puerto-rican-islands-135-year-history-of-
struggle-and-victory/.

Another piece of history that is still important to the culture to this day is the cultivation and preservation of wildlife. In 1909, President Theodore Roosevelt signed an executive order that designated portions of Culebra as wildlife reserve.[7] During that time, the U.S. Navy was responsible for managing both the island and the wildlife reserve. When the Navy departed in 1975, the lands had been given to the commonwealth of Puerto Rico and it wasn't until 1983 when on-site administration of the refuge was established.[8] Currently, around a quarter of the total landmass has been dedicated to the National Wildlife Refuge (see Figure 04). Some portions of the refuges are available for public access, but most areas are closed off to the public for safety issues.
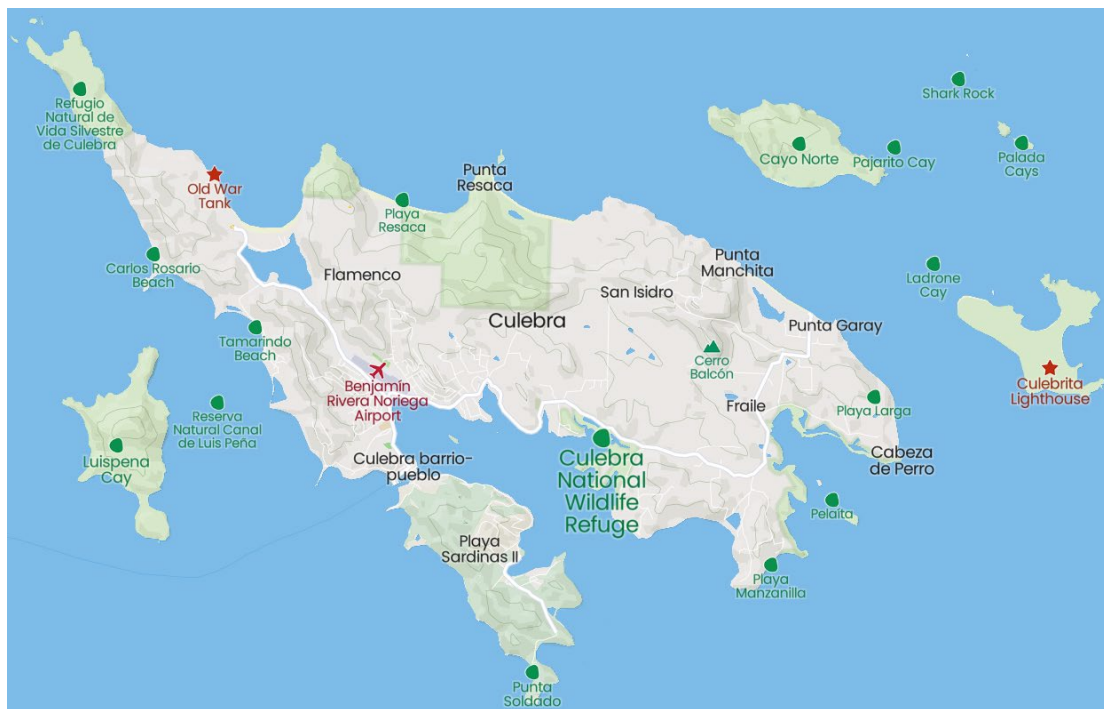
Figure 04: National Wildlife Refuge

[7] Silander, Susan, and Ana Román. n.d. "About the Refuge - Culebra - U.S. Fish and Wildlife Service." U.S. Fish & Wildlife Service. https://www.fws.gov/refuge/Culebra/about.html.
[8] "Culebra National Wildlife Refuge." 2020. Caribbean Birding Trail. January 19. https://www.caribbeanbirdingtrail.org/sites/puerto-rico/culebra-nwr/.

Narrowing in on the populous of Culebra, there is a total population of 1,714 people as listed on the 2019 census. Most of the islanders reside in the capital of Culebra, which is known as Dewey. Among this small population, 36.0% are in poverty and there are only 247 employment opportunities on this island.[9] While this island feels independent from San Juan, the islanders rely on the shipment and transportation of goods from its eastern ports. While there is no recent data, a population like this can be greatly affected by Covid-19 or other deadly diseases since it is secluded, has less than adequate conditions, and 15.6% of the population have no health insurance. After understanding the statistical data, it is clear that these islanders are in dire need of help. Without sufficient funding or proper materials, the locals face a continuous decrease in health and wellbeing and an increase in damage and poverty.

Current Conditions

To gauge the amount of support the island needs, it's current conditions must be explored. Since 2017, the islanders of Culebra are still trying to recover from the devastation that Hurricanes Irma and Maria brought. However, these storms are far from the start of the island's downfall. Puerto Rico has been subdued to tropical storms for as long as can be remembered, causing years of damage and destruction. What Hurricane Maria and Irma did was shed light on Puerto Rico's unsustainable

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[9] "U.S. Census Bureau Quickfacts: Culebra Municipio, Puerto Rico." 2021. https://www.census.gov/quickfacts/culebramunicipiopuertorico.

methods while causing mass damage and a huge death toll.[10] Some of the conditions majorly affected revolve around electricity, transportation, and farming.

Electricity is one of the most important resources for the lives of these islanders and when the Hurricanes hit in 2017, 40 percent of Puerto Rico's population were without access to electricity and running water. This caused the death toll to rise because there were many medical patients that awaited operations and were in need of refrigerated medicines. Both Hurricane Irma and Hurricane Maria paid a toll on how much electricity was displaced. Irma left Puerto Rico with one million people without Electricity and Culebra's municipalities were completely destroyed. Hurricane Maria was claimed to leave over 80 percent of the island's electrical cables in disarray causing hospitals to run on diesel generators.[11] While it has been 4 years since these devastating natural disasters hit the island's, the people are still struggling to restore their energy production and distribution efforts. This however leaves room for improvement because how it is restored will shape what recovery will be taken in Puerto Rico.

For the island of Culebra, transportation is the next important resource that has been damaged and is in need of reworking. As of now, there is one main mode of transportation to and from the main island and that is by ferry. Puerto Ricans that live on the island of Culebra use the ferry for doctors' appointments, work, school, and

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[10] Báez, Antonio Carmona. 2018. "It Takes a Hurricane. Puerto Ricos Yearning for Energy ..." July. https://www.tni.org/files/publication-downloads/it_takes_a_hurricane._puerto_ricos_yearning_for_energy_democracy.pdf.

[11] Báez, Antonio Carmona. 2018. "It Takes a Hurricane. Puerto Ricos Yearning for Energy ..." July. https://www.tni.org/files/publication-downloads/it_takes_a_hurricane._puerto_ricos_yearning_for_energy_democracy.pdf.

even groceries for when the island runs low on supplies.[12] Some of the locals

consider the ferry as their "highway." While the services by the Maritime

Transportation Authority of Puerto Rico have been lacking in maintenance,

scheduling, and accessibility, the natural disasters of Hurricane Irma and Maria made

it worse. What is important to note is that this mode of transportation is very crucial

for emergencies. Culebra has a clinic to treat emergencies, but the islanders need to

go the main island for more terminal cases.[13]

Another important condition is how farmers are responding to agricultural

setbacks since the Hurricanes in 2017. There was a study conducted 8 months after

Hurricane Maria hit that included responses of 405 farmers across Puerto Rico

covering discussion of any obstacles faced toward recovery after the natural disasters.

These farmers had identified that many of the obstacles faced related "to their

adaptive capacity (agricultural resources, economic resources, human resources,

institutions, material resources and technology, natural resources,

perception/cognition, political resources and social resources)".[14] As shown below,

table 01 gives a more comprehensive description for each determinant of adaptive

capacity.

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[12] Corujo, Cristina. 2021. "Maritime Transportation Issues Cause Outrage in Puerto Rico." ABC News. ABC News Network. April 2. https://abcnews.go.com/US/maritime-transportation-issues-outrage-puerto-rico/story?id=76768791.

[13] Corujo, Cristina. 2021. "Maritime Transportation Issues Cause Outrage in Puerto Rico." ABC News. ABC News Network. April 2. https://abcnews.go.com/US/maritime-transportation-issues-outrage-puerto-rico/story?id=76768791.

[14] Rodríguez-Cruz, Luis Alexis, Maya Moore, and Meredith T. Niles. n.d. "Puerto Rican Farmers' Obstacles toward Recovery and Adaptation Strategies after Hurricane Maria: A Mixed-Methods Approach to Understanding Adaptive Capacity." Frontiers. Frontiers. https://www.frontiersin.org/articles/10.3389/fsufs.2021.662918/full.

Determinant of adaptive capacity	Description
Agricultural resources	Resources available to carry out current or post-hazard agricultural production (e.g., seeds, agricultural inputs, agricultural machinery, etc.).
Economic resources	The economic, and financial resources (e.g., monetary) farmers have (e.g., earned income, savings, credit, pensions, transfers from the state, insurance, etc.), and that are available (e.g., monetary aids) for adaptation or recovery.
Human resources	The skills (e.g., training), knowledge (e.g., formal education), and awareness (e.g., of adaptation options, the nature and evolution of hazards), experience, ability to work, and good health (e.g., food secured) that enable farmers to pursue adaptive strategies before hazards, and afterwards for recovery.
Institutions	The availability of critical institutions that promote and support adaptive strategies amongst farmers, along with the way they operate and are structured (e.g., transparent decision-making, institutional requirement).
Material resources and technology	The infrastructure (e.g., transport, drainage systems, housing, utilities) and the production equipment and materials available for adaptation and recovery; along with technological systems (e.g., communication systems, protective structures) available for adaptation and recovery.
Natural resources	The resources present in the physical environment (e.g., raw materials, biodiversity) and/or the services they provide (e.g., pollination) that are useful for adaptation.
Perception/cognition	The different views of nature people have, perceptions of hazards (e.g., likelihood of occurrence and potential damages), perceived effectiveness of past adaptive actions, perceived alternatives and perceived capacity to undertake them or act upon hazard exposure.
Political resources	Power, right, development of political capabilities or claims farmers can make on the state, institutions, or those more powerful than they are (e.g., unions, lobbying, access to legislature, etc.).
Social resources	The social resources (e.g., informal-horizontal networks, social mobilization, collective actions, and relations of trust, reciprocity, and exchange) upon which farmers can draw for adaptation and recovery.

Language was modified to focus on farmers (e.g., instead of using the word people); "agricultural resources" was added, and "food security" was added to "human resources." Table content is from López-Marrero (2010).

Table 01: Determinants of adaptive capacity as delineated
(Source: López-Marrero and Yarnal)

These determinants are all suggesting that resources and institutional support are needed. However, this is just the qualitative analysis of the study. When looking at the quantitative results, many farms adopted new practices after Hurricane Maria. Table 02 below shows the many strategies that were adopted by local farmers. The study found that the farmers with higher education and total loss of their farms were more likely to report higher number of practices adopted.[15]

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[15] Rodríguez-Cruz, Luis Alexis, Maya Moore, and Meredith T. Niles. n.d. "Puerto Rican Farmers' Obstacles toward Recovery and Adaptation Strategies after Hurricane Maria: A Mixed-Methods Approach 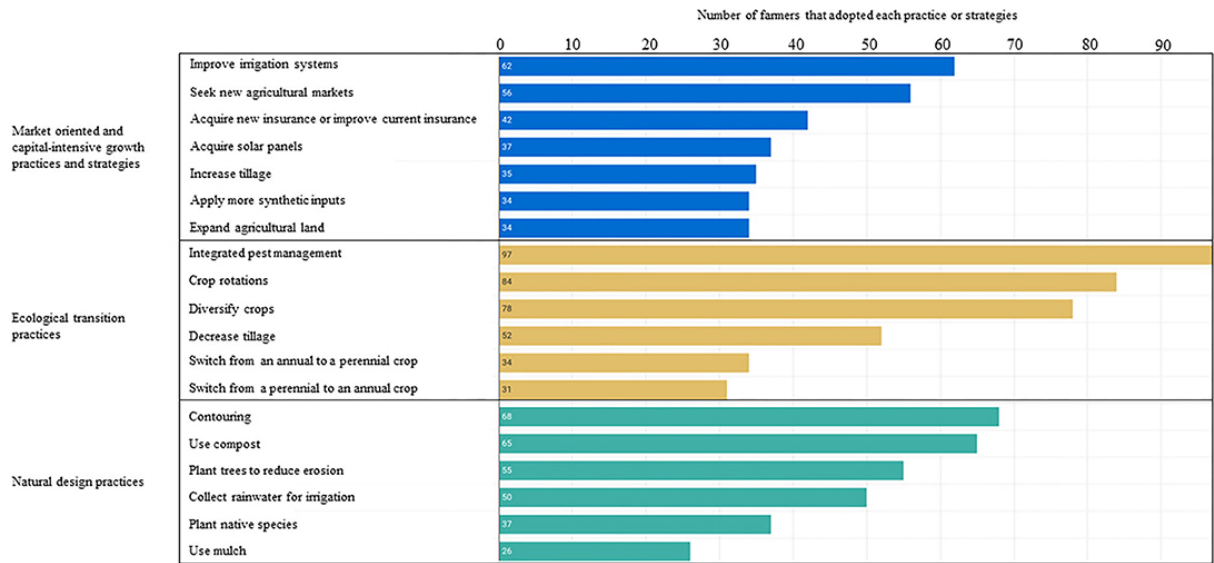to Understanding Adaptive Capacity." Frontiers. Frontiers. https://www.frontiersin.org/articles/10.3389/fsufs.2021.662918/full.

Number of farmers that adopted each practice or strategies

	Number of farmers
Market oriented and capital-intensive growth practices and strategies	
Improve irrigation systems	62
Seek new agricultural markets	56
Acquire new insurance or improve current insurance	42
Acquire solar panels	37
Increase tillage	35
Apply more synthetic inputs	34
Expand agricultural land	34
Ecological transition practices	
Integrated pest management	97
Crop rotations	84
Diversify crops	78
Decrease tillage	52
Switch from an annual to a perennial crop	34
Switch from a perennial to an annual crop	31
Natural design practices	
Contouring	68
Use compost	65
Plant trees to reduce erosion	55
Collect rainwater for irrigation	50
Plant native species	37
Use mulch	26

*Table 02: Farmers' reported actual adoption of adaptation practices and strategies
after Hurricane Maria
(Source: Rodríguez-Cruz)*

Overall, the current conditions of Culebra and Puerto Rico in general revolve around the recovery of infrastructural systems since the devastating natural disasters of Hurricane Irma and Hurricane Maria in 2017. While there is a lack of information and data pertaining to the current condition of Culebra this year, it can be assumed that the people of Puerto Rico are still struggling and are finding ways to recover socially, economically, and politically.

Chapter 2: Site Analysis

Regional Context

Culebra, Puerto Rico resides off to the east of the main island and is roughly 25 square miles. It's distance away from San Juan measures around 17 miles in length and has dimensions that are about 7 miles long and 3.5 miles wide. There are only two means of transport to get from one island to the other. The first is a ferry ride that takes roughly around an hour to move from one location to the next and the second is by taking a small aircraft that links the other islands of Puerto Rico (Vieques, Fajardo, and San Juan). Culebra, Puerto Rico, as seen in figure 05, is also 12 miles west of Saint Thomas and is 15 miles north of Vieques, Puerto Rico.[16]
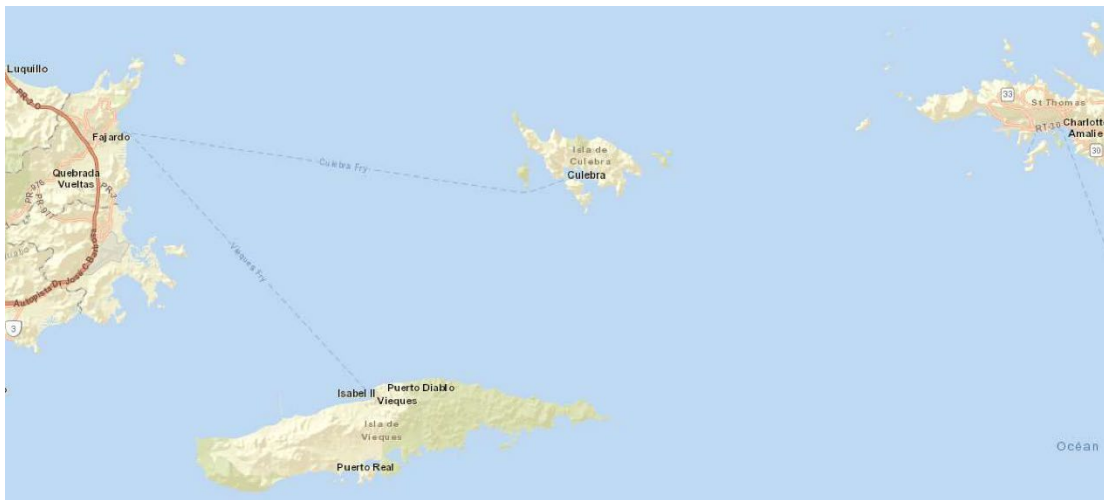
Figure 05 Culebra's Regional Context

(Source: GIS)

[16] Rivera, Magaly. 2021. "Culebra, Puerto Rico." Welcome to Puerto Rico! Accessed December 17. https://welcome.topuertorico.org/city/culebra.shtml.

Puerto Rico is known to have a tropical climate, which means that the islands will receives plenty of sun and rain throughout the year. Focusing on Culebra, the archipelago has an average annual temperature of 79.4 °F and has an average of 40.7 inches of annual rainfall.[17] The island deals with both drought and storms with February being the driest month and September having the most amount of precipitation. Hurricane Season in Culebra begins on June 10th and ends on November 30th.[18] See the table below that showcases the data for temperature and rainfall throughout the year.

	January	February	March	April	May	June	July	August	September	October	November	December
Avg. Temperature °C	25.2 °C	24.9 °C	24.9 °C	25.5 °C	26.2 °C	27.1 °C	27.3 °C	27.5 °C	27.6 °C	27.3 °C	26.6 °C	25.9 °C
(°F)	(77.3) °F	(76.8) °F	(76.9) °F	(77.9) °F	(79.2) °F	(80.7) °F	(81.1) °F	(81.6) °F	(81.7) °F	(81.2) °F	(79.9) °F	(78.6) °F
Min. Temperature °C (°F)	24.6 °C	24.3 °C	24.4 °C	24.8 °C	25.5 °C	26.3 °C	26.4 °C	26.6 °C	26.7 °C	26.4 °C	25.8 °C	25.2 °C
	(76.2) °F	(75.8) °F	(75.9) °F	(76.7) °F	(77.9) °F	(79.3) °F	(79.5) °F	(80) °F	(80) °F	(79.5) °F	(78.5) °F	(77.4) °F
Max. Temperature °C	25.7 °C	25.5 °C	25.5 °C	26.1 °C	26.9 °C	27.7 °C	27.9 °C	28.2 °C	28.3 °C	28 °C	27.3 °C	26.5 °C
(°F)	(78.3) °F	(77.8) °F	(77.9) °F	(79) °F	(80.4) °F	(81.8) °F	(82.2) °F	(82.8) °F	(83) °F	(82.5) °F	(81.2) °F	(79.7) °F
Precipitation / Rainfall	43	32	32	47	92	74	100	122	148	146	134	65
mm (in)	(1.7)	(1.3)	(1.3)	(1.9)	(3.6)	(2.9)	(3.9)	(4.8)	(5.8)	(5.7)	(5.3)	(2.6)
Humidity(%)	77%	76%	76%	78%	81%	81%	81%	81%	81%	81%	79%	77%
Rainy days (d)	10	8	8	9	12	12	14	16	15	15	14	12
avg. Sun hours (hours)	8.5	8.7	8.9	9.6	9.7	9.8	9.6	9.4	9.0	8.7	8.4	8.3

Table 03: Climate Chart
(Source: Climate-data)

[17] "Data.org." n.d. Climate. https://en.climate-data.org/north-america/united-states-of-america/puerto-rico/culebra-766576/.

[18] "Culebra Weather." 2021. Culebra Puerto Rico. February 17. http://culebrapuertorico.com/culebra-weather/#:~:text=Officially%20the%20hurricane%20season%20in,occur%20between%20August%20and%20November.
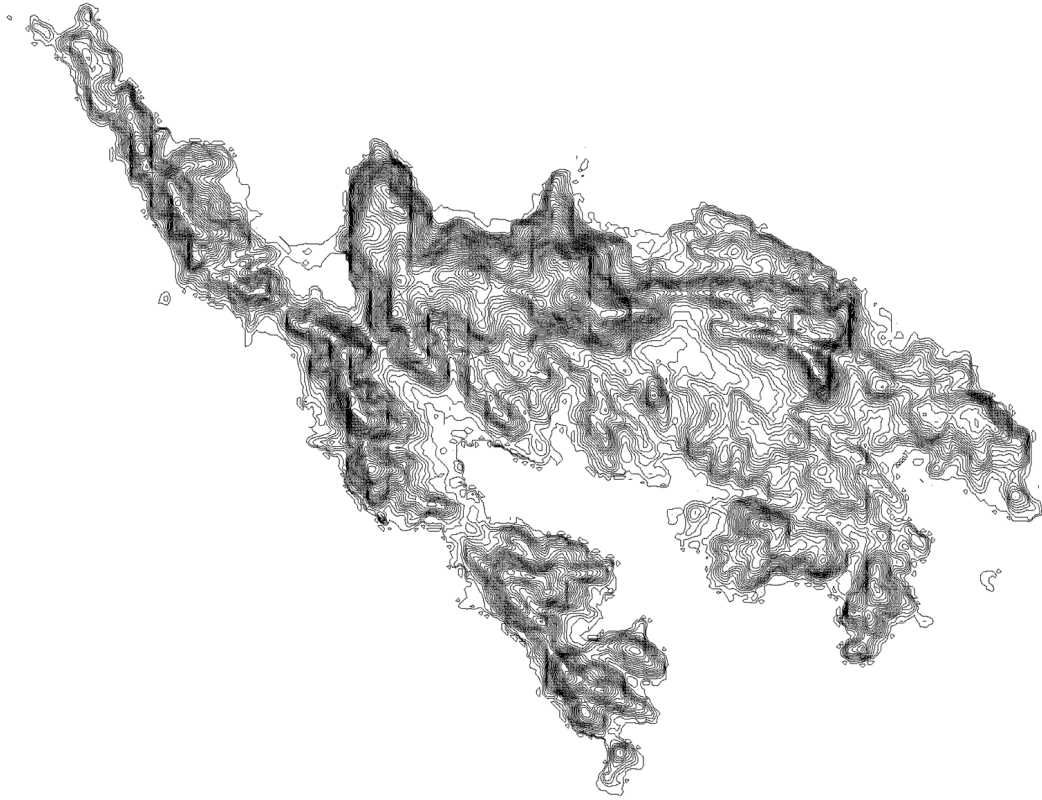
Figure 06: Topographic Map of Culebra
(Source: Author's Work)

As seen on figure 06, the island of Culebra is full of hill tops that slope toward

the edges of the island. It is also notable that most towns and buildings are located

toward the bottom of these slopes. This causes major concern of flooding after a

major storm, and it is also important to consider sea level rises for future design work

on this island.

Zoning and Building Parameters

When considering the future development of the island, there needs to be a

consideration for the existing zoning ordinances and its building parameters.

Culebra's zoning requirements are focused more on the agricultural and residential

building construction. Most of the island is zoned with R0-1C, R0-5C, and R0-25C, which represents agriculture construction. The C at the end of the district rating designation represents the word cuerda, which is equivalent to 0.971 acres of land. The number at the end is then multiplied and used to calculate the amount of acreage that is given for that location. As for residential construction, there are areas in which designates an R1 district rating or in other words intermediate residential. One other important zoning designation that is seen on the zoning map is PR, which represents the National Wildlife Refuge. (see figure 07).
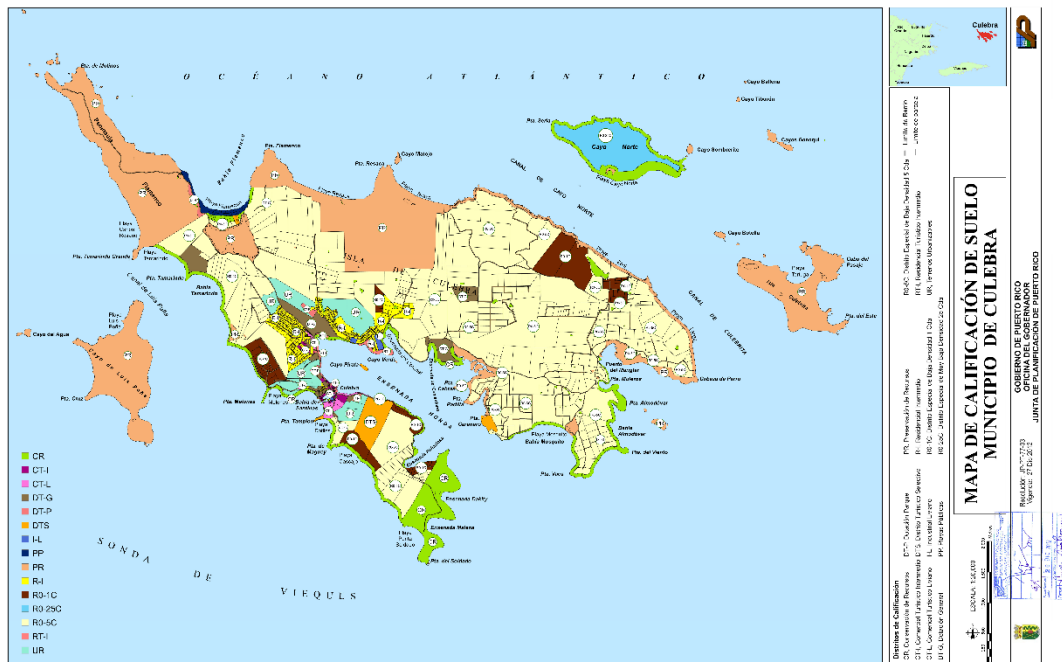
Figure 07: Zoning Map of Culebra
(Source: GIS)

These zoning districts and requirements affect and restrict the parameters of each specific building type. These parameters include maximum building height, minimum solar size, minimum width of plot, maximum occupancy area, gross area, and other related parameters such as a back yard, and side patios. Height is one of the top

parameters, which can change how a cityscape, or a townscape looks and feels. Going back to the three most common zoning districts, there is a small differentiation in building height. For obvious reasons, the PR zoning district has no height limit as it is a part of the National Wildlife Refuge. With intermediate residential (R-I), the maximum height is limited to 12 meters or roughly 39 feet. The agricultural district has a limited building height of 9 meters or roughly 29 feet.[19]

Historic Landmarks

On the island, there is one notable landmark that is often seen as a tourist spot. This landmark is the Culebra Historical Museum (Figure 08). This was constructed in 1905 and was once an ammunitions warehouse for the U.S. Navy. It is now used today for multiple exhibits that focus on the U.S. military, the sea turtle species, and the Taino Indians. Some of the displays include archaeological findings, historical maps, and photos of the military and life back in the 1880's.[20]

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[19] "REGLAMENTO CONJUNTO PARA LA EVALUACIÓN Y EXPEDICIÓN DE PERMISOS RELACIONADOS AL DESARROLLO Y USO DE TERRENOS." n.d.
[20] Rivera, Magaly. 2021. "Culebra, Puerto Rico." Welcome to Puerto Rico! Accessed December 17. https://welcome.topuertorico.org/city/culebra.shtml.

Figure 08: Culebra Museum
(Source: Charlie Peña)

<u>*Culebra in Comparison to Puerto Rico*</u>

While it is important to understand Culebra and its site analysis, this thesis focuses on the long-term effects and solutions for Puerto Rico. In theory, Culebra will become a prototype that has a solution that can be duplicated in different areas of the islands. To do so, it is imperative to view the comparisons of the archipelago to the overall development of Puerto Rico.

When looking at Culebra, it is enormously smaller in size and in population compared to Puerto Rico overall. As previously mentioned, Puerto Rico has an overall population of 3.2 million people with an area of roughly 3,515 square miles.

Culebra, on the other hand, has a population of 1,311 on an island that has roughly an area of 25 square miles. In comparison, Culebra has 0.04% of the amount of people that reside in Puerto Rico and is roughly 0.7% of the total land mass of its domain. While relatively small, the island can make for a good test site provided it shares the same variables as the rest of Puerto Rico. These variables should include the climate, any disasters that the islands can succumb to, and its generalized geology that would allow for similar construction to occur in different locations.

The climate for Puerto Rico is relatively the same all around with its climate being a tropical marine with an average temperature of 80 °F year-round and its average rainfall can vary between 29.32 inches and 171.09 inches depending on the topography and location on the island.[21] In comparison, Culebra's temperature is 0.6 °F off of the average and has a lower precipitation on the spectrum of annual rainfall. This also means that Culebra is likely to have the same environmental impacts as the main island, which would include tropical storms, hurricanes, and drought.

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[21] Rivera, Magaly. n.d. "Climate of Puerto Rico." Welcome to Puerto Rico!
https://welcome.topuertorico.org/reference/tempera.shtml.
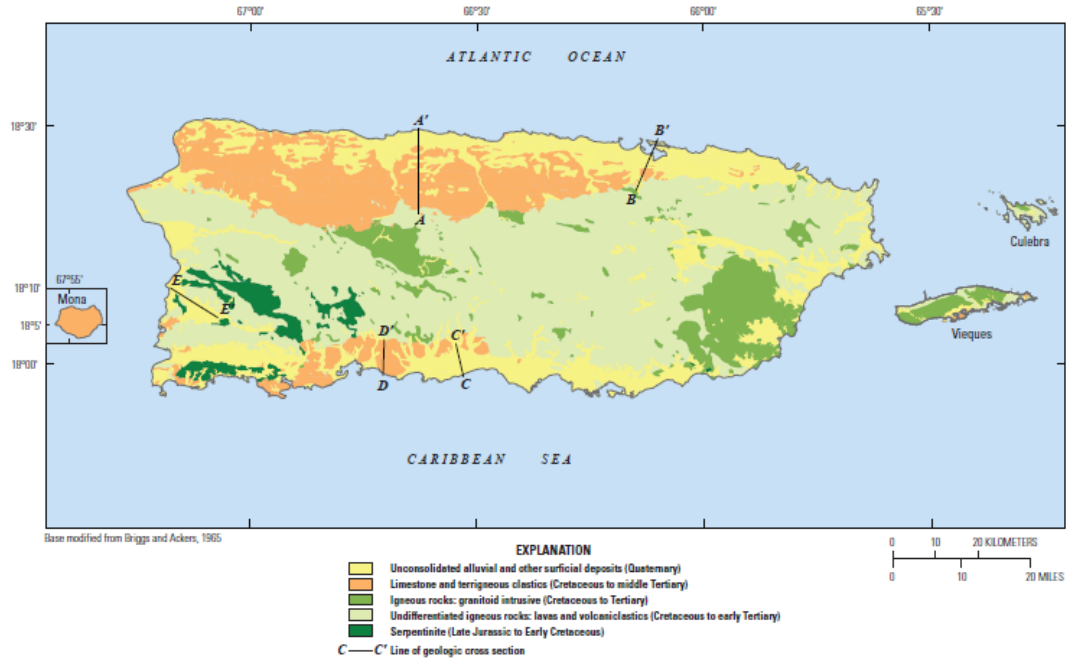
Figure 09: Generalized geology of Puerto Rico and the outlying islands
(Source: USGS)

Another important value that must be considered is the islands geology. Soil type affects the construction of a building and if the soil types vary drastically, then the prototype wouldn't be as useful as it could be. A comparison of soil types can be determined in figure 09 above. This diagram shows that Culebra mainly has undifferentiated igneous rocks and igneous rocks that can also be found in most of the main island of Puerto Rico.
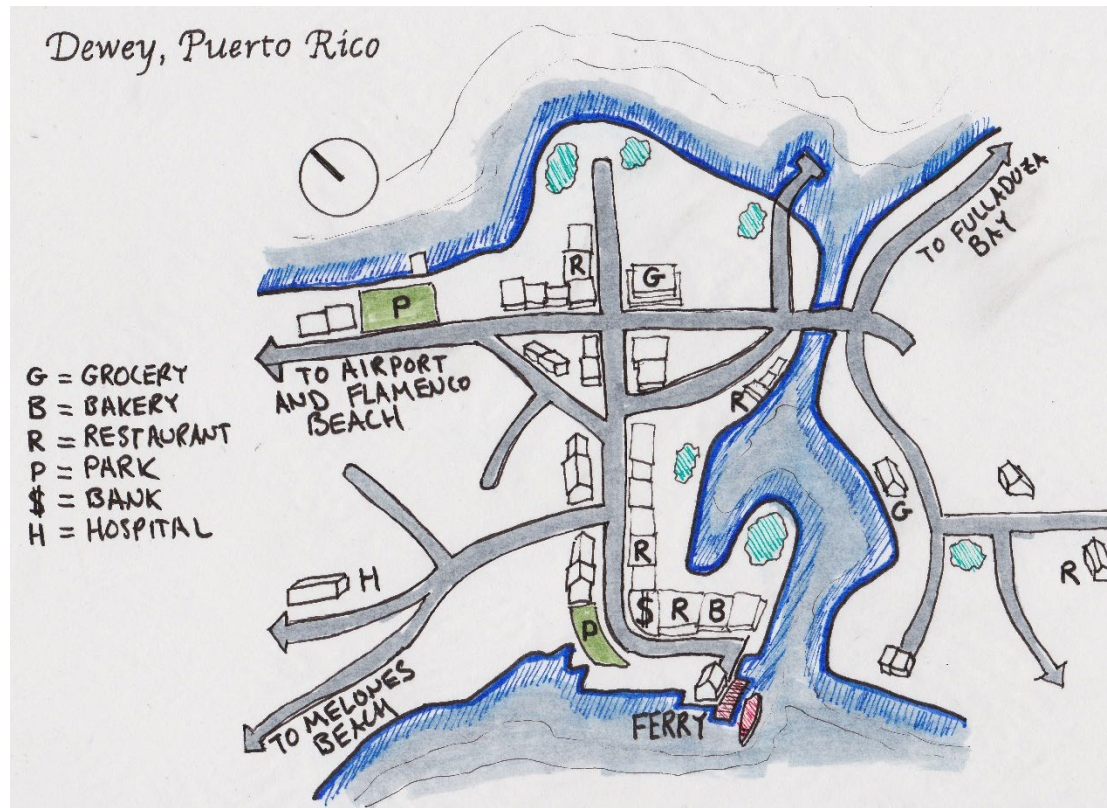
Figure 10: General Layout of Dewey
(Source: Author's Work)

Culebra, Puerto Rico is home to many small communities located around the island. To ensure that the prototype has the most engagement with its community, the town with the most active community will be used for this thesis. That town is known as Dewey and it is the capital of Culebra.[22] When entering the island by ferry, this is the first town that any visitor stumbles across. Dewey is very small, walkable, and has a variety of amenities found around the ferry terminal. See figure 10 above for a sketched layout of the town. These amenities include a couple of bakeries, a few

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[22] Rivera, Magaly. 2021. "Culebra, Puerto Rico." Welcome to Puerto Rico! Accessed December 17. https://welcome.topuertorico.org/city/culebra.shtml.

grocery stores, a full-service bank, a few restaurants, a gift shop, a US post office, and

an information center.[23] One other important existing programmatic element to note

is the park that is located at the north end of town. Aside from the amenities, this

seems to be the only communal area that the town incorporates.

[23] "Dewey Puerto Rico Isla Culebra Travel Guide." 2021. The Infinite Voyage: International Travel
& Living. January 3. http://www.infinitevoyage.net/2021/01/dewey-puerto-rico-isla-culebra-
travel.html.

Chapter 3: Environmental Impacts and Resiliency

Natural Disasters

Both natural and human based disasters affect thousands of people each year, leaving communities with loss of life or physical destruction. These disasters are usually unexpected, leaving families in disbelief. While some may bounce back, communities like Puerto Rico are in need of additional support to lead the people back to a road of recovery. But what exactly causes these disasters to happen and is there a way to prevent the likeliness of it happening again?

Diving further into the natural disasters that are affecting Culebra, Puerto Rico, what causes them to occur and why do they happen so frequently? Starting with hurricanes, it is understood that a hurricane can come together when warm water mixes with thunderstorm activity, low wind shear, and a pre-existing weather disturbance. As mentioned in chapter 2 of this document, Culebra is a tropical island meaning that it has a lot of annual rainfall and has other existing conditions that help create a hurricane. As for the issue of drought, there comes a time when the island has a dry season. One way to combat this is by collecting rainwater when the stormy season rolls around. The third most common disaster is tropical storms and unless there is a way to manipulate the site parameters, it will remain this way.

Most Devastating Disasters

As seen in the historical background, Puerto Rico has been hit by many natural disasters. There are three disasters that caused the most harm to the existing communities: Hurricane Hugo, Irma, and Maria. All three storms occurred within

thirty years of one another, two of which happening within two weeks of one another. But just how bad did each storm affect the exiting communities of Puerto Rico?

Hurricane Hugo had struck the northeast corner of Puerto Rico on September 18th, 1989. At the time, this was the strongest hurricane the residents had within a decade. Wind speeds in San Juan measured up to 100 mph and wind gusts elsewhere measured up to 140 mph. These insane winds "damaged nearly early 25% of homes on Puerto Rico, left approximately 75% of the island without power, and created 30-foot swells off the east coast."[24] The number of casualties added up to 95 total deaths; some resulted from drowning.

Around 28 years after Hurricane Hugo tore through the towns of Puerto Rico, two more hurricanes struck the island within weeks of each other; hurricane Irma and Maria. Hurricane Irma passed close to the main island on September 7th, 2017, which lead to widespread power outages, and water service interruptions for several days. The heavy rains and damaging winds from this hurricane weakened the already-fragile physical infrastructure and its natural systems. Less than two weeks later, Hurricane Maria directly hit Puerto Rico on September 20th. Its wind speeds were up to 155 mph and had been the most intense hurricane to hit Puerto Rico since 1928. The immediate aftermath of both hurricanes combined is devastating; see the figure down below for all the statistical data. The most devastating statistic of them all was that nearly 3,000 people lost their lives.

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[24] "Deaths Associated with Hurricane Hugo -- Puerto Rico." n.d. Centers for Disease Control and Prevention. Centers for Disease Control and Prevention. https://www.cdc.gov/mmwr/preview/mmwrhtml/00001476.htm.

100% of the power grid

95% of cellular sites

43% of wastewater treatment plants
were **inoperable**

More than **40,000** **landslides**

More than **97%** of roads were **impassable**

More than **95%** of Puerto Ricans
lacked drinking water

28% of federally qualified
health centers were damaged

90% of households
applied for assistance

Almost **3,000**
people lost their lives
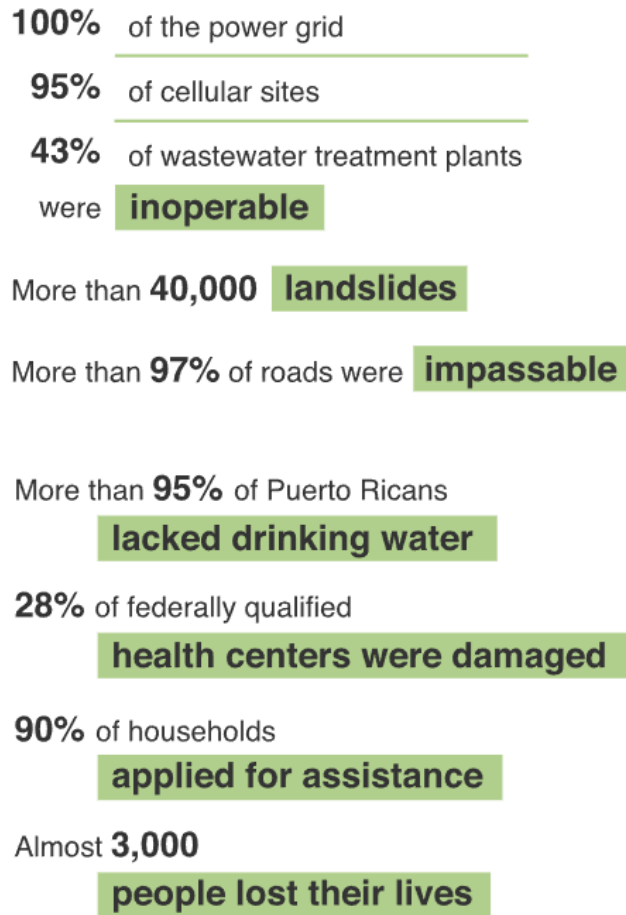
Figure 11: Hurricane Aftermath
(Source: Rand Corporation)

Post-Impact Solutions

The battle for civilization in Puerto Rico continued on after the Hurricanes hit

in 2017. Since then, the government of Puerto Rico has been developing a long-term

recovery plan to provide its citizens with relief. Additionally, there were other outside

organizations that also provided relief. The top support came from the Lift Puerto

Rico Impact Fund, Habitat for Humanity, and the Hurricane Maria Relief provided by

the company Direct Relief. These organizations and funding opportunities have allowed improvement in health care, housing, and employment.

As noted earlier in this chapter, Irma and Maria had intensified the existing challenges within the health and social services infrastructure that exist on the islands. To provide proper relief, the government of Puerto Rico used evidence based-assessment to create a long-term recovery plan. The development of this plan was supported by the Federal Emergency Management Agency, other federal agencies, and other local stakeholders. Additionally, the Homeland Security Operational Analysis Center (HSOAC) provided in-depth analysis that helped uncover the major issues that Puerto Rico struggles with. These issues revolve around social, governmental, fiscal, and economic policies and reforms. To combat them, there are a total of 31 courses of action that can be taken. Together, these actions present "an opportunity to build a more resilient health and social services infrastructure and regional health care networks to ensure reliable access to services, promote health and well-being, and more efficiently and effectively respond to public health crises and future disaster." HSOAC recommends that the health care system be strengthened, the workforce in healthcare be trained, there should be additional supportive services, healthy communities support healthy people, and an improved approach to preparedness.[25]

Other than the government, there are other organizations that have been supporting Puerto Rico since the Hurricanes hit on 2017. Direct Relief, a

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[25] Chandra, Anita, Terry Marsh, Jaime Madrigano, Molly M. Simmons, Mahshid Abir, Edward W. Chan, Jamie Ryan, Nupur Nanda, Michelle D. Ziegler, and Christopher Nelson. 2020. "Health and Social Services in Puerto Rico before and after Hurricane Maria." RAND Corporation. September 30. https://www.rand.org/pubs/research_reports/RR2603.html.

humanitarian aid organization, was one of the first to provide Puerto Rico with aid.

Starting right after Hurricane Maria's aftermath, Direct Relief gave $300,000 in cash

for community health centers to aid in recovery efforts on the islands. The

organization then donated another $50,000 to the Puerto Rico Primary Care

Association, which was given for 20-member nonprofit corporations and 62 clinical

sites in 53 municipalities that cared for nearly 350,000 patients annually. After both

Hurricane Irma and Hurricane Maria, the organization had continued to deliver

emergency health kits, hygiene kits, and medical backpacks. In December of 2017,

just months after the hurricane aftermath, Direct relief continued to provide Puerto

Rico with supplies and had provided the government with 79,465 pounds of items for

medical aid that was estimated to be around $20.6 million's worth of donated items.

With the help of nonprofit VOCES in 2018, Direct relief was the first

nongovernmental organization to provided vaccines to Puerto Rico after Hurricane

maria and provided more than 40,000 doses of the influenza vaccine.[26] This

organization is still committed to any on-going needs in Puerto Rico and can be a

huge asset to creating indefinite change.

Another organization that has played a major part in the redevelopment of

Puerto Rico is Habitat for Humanity. This global nonprofit organization assessed the

damages from the aftermath of Hurricane Irma and Maria and has been providing

shelter kits and solar kits to many affected families.[27] With the financial support of

AbbVie, a research-based pharmaceutical company, the organization has been able to

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[26] "Hurricane Maria Relief." 2021. Direct Relief. Direct Relief. September 16.
https://www.directrelief.org/emergency/hurricane-maria/.
[27] "Recovery and Rebuilding after Devastating Hurricanes in Puerto Rico." n.d. Habitat for Humanity.
https://www.habitat.org/our-work/disaster-response/hurricanes/hurricane-maria.

implement a program that focuses on home repairs, the security of land tenure, and the advocacy work and workforce development.[28] Figure 12 below shows the organizations estimated repairs reported in July of 2021 since Hurricane Maria struck in 2017. To provide the homeowners with the best possible solution, Habitat partners up with them, repairs or rebuilds their homes, and offers trainings to ensure safe repairs and building practices that will be more resilient to future storms.
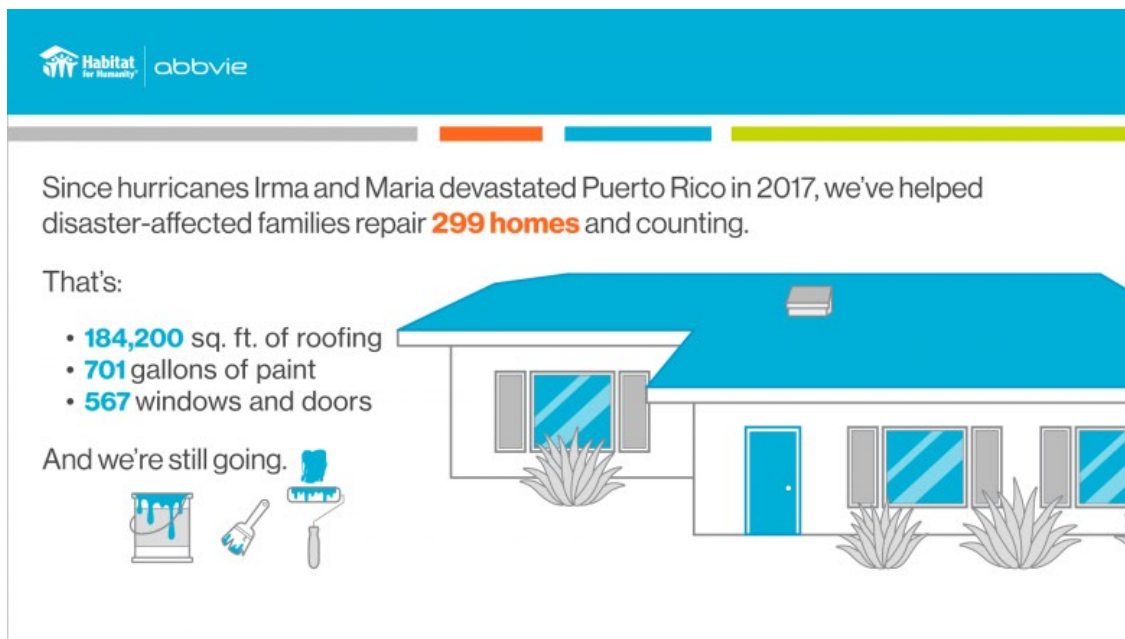
Figure 12: Complete Home repairs
(Source: Habitat for Humanity)

Originated by the Acrecent Financial Corporation, the Lift Puerto Rico Impact fund was created to help businesses post Hurricane Maria by saving jobs, stimulating employment, and stemming outward migration from the island.[29] Acrecent has provided small and medium sized enterprises in Puerto Rico with access to capital over the years and its customers provide much-needed services to the population of

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[28] "Recovery and Rebuilding after Devastating Hurricanes in Puerto Rico." n.d. Habitat for Humanity. https://www.habitat.org/our-work/disaster-response/hurricanes/hurricane-maria.
[29] "Lift Puerto Rico Impact Fund." n.d. Calvert. https://calvertimpactcapital.org/investing/partner/lift-puerto-rico-impact-fund.

the islands such as medical services, construction, education, and off-grid energy solutions.[30] Since the fund was launched in 2018, it has helped create/maintain over 16,700 jobs in Puerto Rico.

Altogether, these organizations and funds have provided the islanders with the necessary equipment and tools to help jumpstart their resiliency to future disasters. But how may this be maintained? One solution that will be further developed is having a community center that engages the community and provides its people with proper tools and education to continue making their habitats resilient. One other thing to consider is how resiliency is defined. Is it all social or are there other aspects to it? The next part of this chapter dives deeper into the different types of resiliencies and what type will this thesis focus primarily on.

Resiliency

To make something resilient, there must be a clear understanding of what the term means. In the eyes of psychologists, resilience is the "process of adapting well in the face of adversity, trauma, tragedy, threats, or significant sources of stress-such as family and relationship problems, serious health problems, or workplace and financial stressors."[31] Connecting this back to this thesis, the people of Puerto Rico have been dealing with lasting impacts from natural disasters and it is time to find ways for the islanders to become resilient to these environmental issues. There are three different

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[30] "Lift Puerto Rico Impact Fund." n.d. Calvert. https://calvertimpactcapital.org/investing/partner/lift-puerto-rico-impact-fund.
[31] "Building Your Resilience." 2012. American Psychological Association. American Psychological Association. January 1. https://www.apa.org/topics/resilience.

types of resiliencies: engineering resiliency, social resiliency, and ecological resiliency.

Engineering resilience looks more at the built environment and its designed systems and finds different adaptation methods when failure occurs. This is a more traditional definition of resiliency that "concentrates on stability near an equilibrium steady state, where resistance to disturbance and speed of return to the equilibrium are used to measure the property."[32] The focus of this resiliency is aimed toward the efficiency, constancy, and predictability of a designed system. Using this resiliency in Puerto Rico will provide the islanders with the understanding of how the structural systems are failing and can provide a series of solutions that could be taken to prevent this from happening.

Social resilience is the ability of a community to resist and hold out against traumas outside of its social infrastructure. These external traumas include social, economic, and political changes within a domain and environmental variability. As discussed early, these traumas include the environmental impacts that Puerto Rico has succumb to and any issues that stem from it.

Ecological resiliency focuses more on how much disturbance a system can take before it shifts into a different state. In other words, it is the "capacity of a system to absorb disturbance and reorganize while undergoing change so as to retain essentially the same function, structure, identity, and feedbacks."[33] What this

[32] Holling, C. S. n.d. "Engineering Resilience versus Ecological Resilience." National Academies Press: OpenBook. https://www.nap.edu/read/4919/chapter/4#33.

[33] Soroushmz. 2016. "#3 .Difference between Engineering, Ecological and Social-Ecological Resilience." Soroushmz. February 21. https://soroushmz.wordpress.com/2016/02/21/3-difference-between-engineering-ecological-and-social-ecological-resilience/.

resilience stresses are persistence, change, and unpredictability. Looking at Puerto

Rico, how much does it take for the updated systems to fail? In the terms of

environmental impacts, does one tropical storm make a huge setback or can it only be

seen with huge natural disasters like Hurricane Maria?

While each resiliency has its own focus, this thesis will mainly be based

around social resiliency. Many of Puerto Rico's problems revolve around social,

economic, and political upheaval and while the natural disasters have impacted the

island greatly, the revitalization of the islands won't work unless the social system is

stable.

Chapter 4: Community Resilience

Definition of Terminology

The term community resilience describes the ability of a community to prepare, adapt, withstand, and recover from a rapid disruption. This relates to activities such as disaster preparedness, which includes prevention, protection, mitigation, response, and recovery.[34] These are the key steps to resiliency. However, to build resiliency, a community must consult the six foundations that help support the shift. These six foundations include people, systems thinking, adaptability, transformability, sustainability, and courage.

The first and arguably the most important foundation are the people that reside within a community. Members of these communities have the power to evoke change and build upon what is already existing. Without people, community wouldn't exist. "What the community is now and what it will be in the future both result from decisions made by people interacting, negotiating, and working together."[35] Additionally, a community has its own identity that maintains core functions and structure. What resiliency is meant to do is deal with disruption while maintaining the identity of the community.

The second foundation, systems thinking, is essential to understanding the complex crises that are unfolding and what they mean for the community. There are

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[34] "National Preparedness Goal." n.d. FEMA.gov. https://www.fema.gov/emergency-managers/national-preparedness/goal.

[35] Lerch, Daniel. 2015. "Six Foundations for Building Community Resilience." November. http://www.postcarbon.org/wp-content/uploads/2015/11/Six-Foundations-for-Building-Community-Resilience.pdf.

many sub-systems that are found within a community that are connected or influenced by external factors including regional water supplies, national energy policy, and global climate change. These all impact the dynamics and relationships that exist because in ways one system is dependent on another. Systems thinking also helps a community to understand the complex E4 (environment, energy, economic, equity) crises that are found within their society. As a result, it helps community members see actions that play a role in what happens at a national and global scale.

The third foundation, adaptability, is how a community adapts to change. Adaptation has and always will be an ongoing process since the challenges a community faces are dynamic. Andrew Zolli, an author that wrote about resilience and why things bounce back, describes four things that are happening constantly in a resilient community. These four things are as follows: "building regenerative capacity, sensing emerging risks, responding to disruption, and learning and transforming." If resilience building can be ingrained in a community's culture, then it can evolve alongside the community. Resilience can become an issue if the resilience building qualities fail to adapt.

The fourth foundation, transformability, focuses on challenges that are too big to adapt and instead make transformative changes to a community. Communities generally adapt as the world around them changes. But, if the adaptation is too slow or constrained, those challenges can threaten the overall resilience.[36] This means that some part of the community's identity may need to change to a new state that could

[36] Lerch, Daniel. 2015. "Six Foundations for Building Community Resilience." November. http://www.postcarbon.org/wp-content/uploads/2015/11/Six-Foundations-for-Building-Community-Resilience.pdf.

be resilient under the new challenges. With anything, it is hard to achieve new and better results if the solution is to stick with old patterns. Additionally, there are three attributes that transformability depends on. The first is getting to acceptance. The transformation will not be successful if the people don't recognize the need for change and accept it. The second attribute is having options for transformational change. Similar to any design phase, any new idea requires room for development, testing, and experimentation. The third and last attribute is having capacity for transformational change. Capacity focusing more on who has the ability to make the transformative change at different scales (policymakers, elected officials, etc.).

The fifth foundation revolves around sustainability and how community resilience should serve both the present and future generations. Resiliency and sustainability are two concepts that are separate entities but complement each other. Resilience focuses on how socio-ecological systems work while sustainability engages with the complex relationship between humans and the natural world and the consequences on getting that relationship wrong.[37] Certain insights and analytical methods created in sustainable thinking will be valuable for dealing with the E4 crises in community resilience-building activities. These analytical tools focus on limits to growth, capital and services, safe operating spaces for humanity, and seven generations.

The sixth and last foundation, courage, expresses that a community and its individuals need this trait in order to confront challenging issues and take

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[37] Lerch, Daniel. 2015. "Six Foundations for Building Community Resilience." November. http://www.postcarbon.org/wp-content/uploads/2015/11/Six-Foundations-for-Building-Community-Resilience.pdf.

responsibility for their collective future.[38] Building community resilience is not an engineering problem that can be solved solely by knowledge and talent. It's a social project that involves hundreds, if not millions, of individuals and their most important relationships, hopes, and anxieties. Individuals must have the bravery to express their opinions and needs, putting themselves in a vulnerable position. Communities, too, require bravery to hold uncomfortable discussions, make large-scale investments and policy shifts, and risk sharing political and economic power.

Community resilience is connection between the community and its various systems. After looking at each individual foundation – people, systems thinking, adaptability, transformability, sustainability, and courage – it becomes clear as to how a resilient community can be created and shifted based on the challenges it faces. The people of Puerto Rico have, in some ways, been resilient to environmental impacts. Since the Hurricanes in 2017, the islanders have started to replace older systems with newer ones, and this should continue as time goes on.

Community Resilience to Disasters

The six foundations of disaster preparedness are a good start in making a community resilient to all kinds of disasters. But how else might a community build upon its resilience to disaster? The RAND Corporation, a nonprofit institution, has conducted a technical report about building community resilience to disasters. The document was originally based on assisting the survivors of Hurricane Katrina in

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[38] Lerch, Daniel. 2015. "Six Foundations for Building Community Resilience." November. http://www.postcarbon.org/wp-content/uploads/2015/11/Six-Foundations-for-Building-Community-Resilience.pdf.

2005. While it is not directly allocated to hurricane disaster, this is a useful tool and document that provides key information on what areas of a community should be focused around and can be used as a roadmap for communities to become more resilient. The key areas, otherwise known as levers, in creating a resilient community focused on disaster preparedness is around wellness, access, education, engagement, self-sufficiency, partnership. quality, efficiency, and future decisions.

Looking at each focus individually and looking at what actions could be taken can help determine what state Puerto Rico is in and how it's government may move forward.

Wellness, the first area of interest, focuses on the health of a community's members both before and after a disaster. The amount to which a health incident affects a community, and its resources is partly determined by community members' current wellness levels—their physical, behavioral, and social well-being at the time the incident happens.[39] Maintaining an overall degree of wellness can serve as a societal and individual resource for resiliency since collective well-being before a natural disaster might alter people's need for resources and the length of the recovery period. Communities that are already healthy are better equipped to handle the shock of a disaster and will require less medical assistance before, during, and after the event. Those who are less fortunate and have less resources will be less equipped to handle the shock of a disaster.

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[39] Chandra, Anita, Joie Acosta, Stefanie Stern, Lori Uscher-Pines, Malcom V. Williams, Douglas Yeung, Jeffrey Garnett, and Lisa S. Meredith. 2011. "Building Community Resilience to Disasters." https://www.rand.org/content/dam/rand/pubs/technical_reports/2011/RAND_TR915.pdf.

Creating a culture in which people understand the link between individual and community readiness and how to stay healthy in general is one method to enhance pre-incident preventive and population wellness. To do so, there are a few community activities that can be followed (see Table 04 below for more information on each activity). The first activity is to train the workforce on healthcare that is culturally sensitive and linguistically suitable. This is to remove any bias as some cultures perceive and respond to traumatic events differently. The second activity focuses around developing public health messages that provide information on how to live a healthy lifestyle and strengthen psychological wellness. These messages are designed to help prevent potential stressors that are needed to function and that are needed as a coping resource. The third activity is to conduct an annual assessment of any health vulnerabilities. Understanding any preexisting medical conditions can allow for pre-disaster resource allocation. The fourth activity is to ensure that the community has access to health services before and after the disaster hits. Preventive healthcare should be available on a regular basis to allow for better population wellness. The last activity that can be followed to enhance community wellness is to provide the population with timely and age-appropriate vaccinations.[40] The more people that are vaccinated, the lower the chances of any disease transmission within the population. As seen with Covid-19 in the past two years, disease causes disruption and can make production and adaptation slower.

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[40] Chandra, Anita, Joie Acosta, Stefanie Stern, Lori Uscher-Pines, Malcom V. Williams, Douglas Yeung, Jeffrey Garnett, and Lisa S. Meredith. 2011. "Building Community Resilience to Disasters." https://www.rand.org/content/dam/rand/pubs/technical_reports/2011/RAND_TR915.pdf.

Element	Description	Activities for State and Local Entities
1. Promote public understanding of health and wellness.	Community members understand how to prevent or mitigate the impact of health threats by maintaining health and wellness on an ongoing basis. As described in Figure 2.1, resilience rests on a foundation of community wellness, so communities must embrace a guiding orientation toward health promotion and overall well-being.	Train workforce on culturally competent and linguistically appropriate healthcare. Develop public health messaging to promote healthy lifestyles and bolster psychological wellness, particularly coping skills and resilience attitudes.
2. Ensure sufficient community health resources, along with the capability to leverage those resources to achieve desired outcomes.	Communities have appropriate resources to address physical and psychological health, and the functional needs of at-risk individuals. The ability to leverage these resources depends in part on knowledge about how to allocate them.	Conduct an annual assessment of population health vulnerabilities. Ensure pre–health incident access to health services and post–health incident continuity of care. Ensure that the population receives timely and age-appropriate vaccinations.

Table 04: Key Elements of Community Wellness

(Source: Rand Corporation)

Access, another area of interest within community resiliency, focuses on the communities' access to health and social resources and services. Simply put, areas with a lack of adequate resources and services tend to recover slowly. Accessing high-quality resources and services is an important part of community resilience, especially in vulnerable populations. To successfully maintain community access to health and social services, there are a few activities that can be done (see Table 05 below for more information on each activity). The first is to ensure that people who require long-term medical or health services after a disaster receive them. This requires a routine and coordination amongst the government. The second activity would be to identify any existing community assets that could play a role in preparedness through recovery.[41] During the reaction and recovery periods,

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[41] Chandra, Anita, Joie Acosta, Stefanie Stern, Lori Uscher-Pines, Malcom V. Williams, Douglas Yeung, Jeffrey Garnett, and Lisa S. Meredith. 2011. "Building Community Resilience to Disasters." https://www.rand.org/content/dam/rand/pubs/technical_reports/2011/RAND_TR915.pdf.

communities frequently have a variety of social and physical assets that local

governments may use creatively. Another activity that can be accomplished is

planning for long-term food, shelter, clothing, and medical needs of recovering low-

income populations. Appropriate planning for long-term disaster recovery aids in the

restoration of low-income people's health and livelihood. Like the last few activities,

providing "psychological first aid" or other behavioral interventions after disaster can

benefit the community. The last activity to be done is to bridge any cultural

differences to help increase understanding and cooperation with any public health

recommendations. Misunderstandings regarding the nature and availability of

recovery resources may result from cultural differences, as well as mistrust between

response agency staff and minorities.[42] In which case, it is best to collaborate as a

community on these public health recommendations.

Element	Description	Activities for State and Local Entities
1. Ensure continuity of healthcare and related social services.	Federal and state governments identify local NGOs with the capacity and capability to meet the health, behavioral health, and social service needs of constituents rapidly, effectively, and uniformly.	Ensure continuity of care for those needing long-term medical/health services post-disaster.
2. Facilitate transition to recovery planning.	Plans are developed to assess community needs for resources at the onset, during and after a health incident.	Identify existing community assets that can play a role in preparedness through recovery.
3. Provide health services and remove barriers to accessing them.	Rapid dissemination and implementation of services and interventions is critical. For example, traumatized disaster survivors may require psychological orientation to function and begin to recover in other ways. Cultural barriers may prevent some individuals from complying with public health recommendations.	Provide "psychological first aid" or other early psychological or behavioral health interventions after a disaster. Bridge cultural differences to increase understanding of and cooperation with public health recommendations.

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[42] Chandra, Anita, Joie Acosta, Stefanie Stern, Lori Uscher-Pines, Malcom V. Williams, Douglas Yeung, Jeffrey Garnett, and Lisa S. Meredith. 2011. "Building Community Resilience to Disasters." https://www.rand.org/content/dam/rand/pubs/technical_reports/2011/RAND_TR915.pdf.

Table 05: Key Elements of High-Quality Health, Behavioral Health, and Social

Resources and Service (Source: Rand Corporation)

Education, one of the more important areas of interest, focuses on providing a community with information before, during, and after a disaster about preparedness, risks, and resources. Community education is a continuous process in which members of the community learn about their roles, responsibilities, and expectations for individual preparedness, as well as how to work together with other members of the community to respond to and recover from a disaster. What community education also means is that individuals know where to go for aid for themselves and their neighbors, allowing the entire community to remain resilient in the event of a crisis.

To help provide this information, the government can work on implementing a few activities (see Table 06 below for more information on each activity). The first activity is to provide people with accurate information regarding potential health threats. This can help provide pre-disaster planning and stress the need of preventive care. The second activity that can be done is to develop and deliver messages that promote the knowledge of both individual and community health. Community members are more likely to adopt preparatory steps if communications are framed to stress the relationships between person and community. A similar activity that can take place is to create communication messages that discuss general principles and best practices in risk communication.[43] Effective risk communication helps communities adapt by giving accurate information about health concerns and raising

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[43] Chandra, Anita, Joie Acosta, Stefanie Stern, Lori Uscher-Pines, Malcom V. Williams, Douglas Yeung, Jeffrey Garnett, and Lisa S. Meredith. 2011. "Building Community Resilience to Disasters." https://www.rand.org/content/dam/rand/pubs/technical_reports/2011/RAND_TR915.pdf.

understanding about protective practices and support services. Another activity that could help with providing clear information is to consider health literacy, culture, trusted spokespersons/channels, preferred languages, and preferred, alternate, and accessible forms when tailoring information for at-risk individuals. By doing so, the information provided should be easily accessible and understandable to all demographics within a community.

While the last suggested activities promote strictly communication, there are other suggested activities that engage in training, educating, and developing an effective communication system. The first focuses on supporting and promoting social media among communities and organizations. When risk communication and other public health messages are provided through trustworthy, intelligible, and culturally relevant venues, they are most successful. The second activity is to continue to educate media organizations about their role in facilitating disaster response. During a crisis, the media may be an ally by informing the public about steps they can take to secure their safety and reduce the event's impact on their community. The third activity is to involve groups and organizations that represent at-risk individuals in the design and distribution of health-related information. When health-related risk communication messages are tailored to meet relevant cultural norms and originate from reliable sources, at-risk persons are more responsive.[44] The fourth activity focuses on training community partners and health advisors in proper risk communication techniques and use them as information distributors during a

[44] Chandra, Anita, Joie Acosta, Stefanie Stern, Lori Uscher-Pines, Malcom V. Williams, Douglas Yeung, Jeffrey Garnett, and Lisa S. Meredith. 2011. "Building Community Resilience to Disasters." https://www.rand.org/content/dam/rand/pubs/technical_reports/2011/RAND_TR915.pdf.

disaster. Resilient communities are those in which all parts of the population are likely to act on official messages, and the messaging can cause behavioral changes. As a result, it's critical that risk communication and public education tactics connect to the public health. Additionally, medical concerns build trust among community members, resulting in increased adherence to government recommendations. The last activity that engages in training, educating, and developing an effective communication system is to ensure that there is a functional communication infrastructure that has links to health professionals, medical providers, health officials, diverse publics, and volunteers. The flow of risk information to large segments of a community is facilitated by communications infrastructure, which improves awareness of recommended countermeasures and responses while also ensuring consistency of messaging.

The last major component to education is to build upon basic health literacy and ensure that the people have an awareness to their health issues. There are only two activities recommended by the RAND corporation. The first is to ensure that the community has information about health promotion and disease prevention. By providing information and creating initiatives, the population's overall health literacy will increase. The second activity is to strengthen both coping skills and psychological wellness by developing campaigns based on these messages. Individuals must have appropriate coping resources in order for a community to survive and recover from a tragedy.[45]

[45] Chandra, Anita, Joie Acosta, Stefanie Stern, Lori Uscher-Pines, Malcom V. Williams, Douglas Yeung, Jeffrey Garnett, and Lisa S. Meredith. 2011. "Building Community Resilience to Disasters." https://www.rand.org/content/dam/rand/pubs/technical_reports/2011/RAND_TR915.pdf.

Element	Description	Activities for State and Local Entities
1. Use effective risk communication to bolster community resilience by providing accurate information about health threats.	Communication strategies and content should acknowledge the individual and cultural beliefs and community norms that shape expectations of what is to be done before, during, and after event.	Communicate realistic recovery timeline/plan to set reasonable expectations, given likely post-event challenges. Develop and disseminate messages that improve understanding between individual and community health.
2. Work collectively to train and educate partner agencies and to have an effective and coordinated communication system or network.	Strong communication networks are critical for resilience. These networks should rely on diversity of mode and content as well as ability to link social networks effectively.	Support and promote the use of social media among communities and organizations. Proactively educate media organizations regarding their role in facilitating health incident response. Train community partners and lay health advisors in proper risk communication techniques.
3. Build basic health literacy and awareness of health issues.	The underlying literacy of the community, particularly health literacy, supports its ability to process messages, take action, and plan for recovery.	Promote healthy lifestyles by ensuring that the population has information about health promotion and disease prevention. Bolster coping skills and psychological wellness by developing public health campaigns focused on these messages.

Table 06: Key Elements of Community Education

(Source: Rand Corporation)

The fourth area of focus around creating community resilience toward disaster is engagement. Community resilience stems from the populations ability to utilize its own internal resources upon facing disaster while also returning to a state of self-sufficiency post-crisis. With engagement, communities become more resilient when all individuals participate in the decision making, planning, response, and recovery processes before, during, and after a disaster strikes. Engagement also tends to be very critical as it ensures accurate and timely situational awareness.[46] In addition,

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[46] Chandra, Anita, Joie Acosta, Stefanie Stern, Lori Uscher-Pines, Malcom V. Williams, Douglas Yeung, Jeffrey Garnett, and Lisa S. Meredith. 2011. "Building Community Resilience to Disasters." https://www.rand.org/content/dam/rand/pubs/technical_reports/2011/RAND_TR915.pdf.

community members should be engaged in the planning exercises for any health crisis and should craft professional and personal relationships among residents to allow for easier access to support. As recommended by the RAND corporation, there are activities that relate to community engagement (see Table 07 for more information on each activity).

To involve community members in the planning and decision making of issues that relate to response and recovery, there are a few activities that can be utilized. The first is to allow residents to be included in the creation of individual and community preparedness plans and strategies. To effectively include input and reflect the views of local community members while developing plans for health security in the areas of response and recovery, plans must effectively incorporate input and reflect the views of the local residents. The second activity is to identify where the at-risk individuals are located. Identifying the locations of at-risk persons with functional requirements helps planners to design effective strategies to address their needs, as well as aiding in the creation and translation of important preparedness and response actions for all at-risk individuals. A third activity that can be utilized is to engage community members in collective action to address an issue (i.e., service project). Experience in successfully tackling obstacles in a normal setting (day-to-day interactions when inhabitants jointly confront and resolve problems) can assist a community by preparing for large changes post-disaster and developing a collective sense of effectiveness among community members.[47] The last activity that can bring

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[47] Chandra, Anita, Joie Acosta, Stefanie Stern, Lori Uscher-Pines, Malcom V. Williams, Douglas Yeung, Jeffrey Garnett, and Lisa S. Meredith. 2011. "Building Community Resilience to Disasters." https://www.rand.org/content/dam/rand/pubs/technical_reports/2011/RAND_TR915.pdf.

community members into the planning and decision-making process is to develop best practices for the government's active participation in local emergency planning committees or other relevant entities with a role in health security. Many communities lack a clear vision of ideal solutions to improve the community's general resilience through increased organizational engagement, as well as to avoid, guard against, respond to, and recover from health catastrophes. In which case, developing the governments participation can bring a new level of engagement and organization within community involvement.

Much like involving members in the planning and decision making of issues that relate to response and recovery, members should also be included in the planning of exercises for disasters. There are two activities that will allow for more community engagement. The first is to involve the residents in planning for response to any disaster. It is important to know what existing social networks are available to promote situational awareness and emergency response plans before a crisis strikes. To do this, emergency planners must include members of the local community to discover what social networks exist and how to activate them during a crisis. The second activity is to create community exercise drills that focus on the needs of vulnerable populations. By practicing these drills, it will make for identifying at-risk individuals during an emergency a lot easier and will increase the trust and cooperation of those individuals during a disaster.[48]

[48] Chandra, Anita, Joie Acosta, Stefanie Stern, Lori Uscher-Pines, Malcom V. Williams, Douglas Yeung, Jeffrey Garnett, and Lisa S. Meredith. 2011. "Building Community Resilience to Disasters." https://www.rand.org/content/dam/rand/pubs/technical_reports/2011/RAND_TR915.pdf.

As previously mentioned, building connections, and creating social networks can allow for quicker and more efficient support. While many communities have existing networks, there are a few activities that can be used to help build upon these connections. The first is to encourage neighbors, friends, and family to seek help from local sources during non-emergency situations. Personal and professional relationships are built stronger, creating deeper social connections before any emergency occurs. This is important because communities that have multiple social connections can quickly gather resources for disaster response through its residents. Without these connections, the necessary equipment and supplies may take longer to get distributed by the government or other organizations. A second activity that can be followed is to establish a plan with social routines and community relationships after a disaster strikes. Interconnectivity—that is, the presence of strong horizontal and vertical ties amongst community residents—can be used to define a resilient community. There is evidence that the sense of community formed by these interactions, as well as the individual characteristics of the relationships, contribute to better disaster preparation.[49]

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[49] Chandra, Anita, Joie Acosta, Stefanie Stern, Lori Uscher-Pines, Malcom V. Williams, Douglas Yeung, Jeffrey Garnett, and Lisa S. Meredith. 2011. "Building Community Resilience to Disasters." https://www.rand.org/content/dam/rand/pubs/technical_reports/2011/RAND_TR915.pdf.

Element	Description	Activities for State and Local Entities
1. Involve community members in planning and decisionmaking on issues relating to response and recovery activities.	Local government and community organizations actively work to elicit input from local residents and include their feedback in development of plans. Actions or decisions taken reflect an appropriate level of consensus among the local population.	Engage residents in the development of preparedness plans at the individual and community level. Identify geographic concentrations of at-risk individuals. Build the capacity of social and volunteer organizations (i.e., NGOs) to engage citizens in collective action to address an issue or problem (e.g., a community development or service project).
2. Include community members in planning exercises for health incidents.	Residents of the community are encouraged to participate in appropriate exercises and are familiar with planned response and recovery activities.	Involve local community residents in response planning. Develop community exercises that focus on the needs of vulnerable populations.
3. Build connections among social networks and community organizations.	Response and recovery activities have a broader reach when social networks are utilized to promote greater sharing of information and resources. Connections among community organizations and local residents should be reinforced and utilized to quickly disseminate information and offer assistance to those who need it.	Encourage support from local sources for neighbors, friends, and family during nonemergent times. Develop a plan for establishing social routines and relationships in the community after disaster.

Table 07: Key Elements of Community Engagement

(Source: Rand Corporation)

The next area of focus that helps create a resilient community is through self-sufficiency. Self-sufficiency is a crucial component of community resilience, and it comprises enhancing people', groups', or institutions' capacity to become more self-reliant. Working toward self-sufficiency means that individuals should take responsibility for their own readiness and support the efforts of other members of the community.[50] To engage in increased self-sufficiency, there are activities that the RAND corporation recommends that relate to encouraging personal and community preparedness, encouraging civic responsibility, promoting effective and efficient

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[50] Chandra, Anita, Joie Acosta, Stefanie Stern, Lori Uscher-Pines, Malcom V. Williams, Douglas Yeung, Jeffrey Garnett, and Lisa S. Meredith. 2011. "Building Community Resilience to Disasters." https://www.rand.org/content/dam/rand/pubs/technical_reports/2011/RAND_TR915.pdf.

bystander responses, and fostering self and community reliance (see Table 08 for more information on each activity).

Encouraging personal and community preparedness is one way to increase self-sufficiency and can assist both an individual and a group of people by supporting the efforts of other community members. To help promote personal and community preparedness, there are four activities that are recommended. The first is to develop an individual or family plan that identifies a location to reconnect. After a tragedy, timely and effective reuniting of families helps to prevent poor mental health consequences and gives people control over their situation. The second activity is for community members to become knowledgeable on emergency preparation and spread educational materials obtained during trainings to members of the community and neighborhood associations. When the members of a community are given this material, they become more aware of where to seek the information and where evacuation routes are located. The third activity is to incentivize individual and community preparedness. This leads to additional encouragement for both personal and collective preparedness. The last activity that is recommended is to conduct research on the utility and composition of med kits and then spread that research to local jurisdictions to help inform individual preparedness. Resilient communities consist of members that are prepared for a temporary disruption. In which case, knowledge of this information can impact the governments messages that are sent to individuals. [51]

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[51] Chandra, Anita, Joie Acosta, Stefanie Stern, Lori Uscher-Pines, Malcom V. Williams, Douglas Yeung, Jeffrey Garnett, and Lisa S. Meredith. 2011. "Building Community Resilience to Disasters." https://www.rand.org/content/dam/rand/pubs/technical_reports/2011/RAND_TR915.pdf.

Self-sufficiency can be seen through encourages civic responsibility. What this means is that community members tend to support the actions and attitudes toward democratic governance and social participation. One key activity that can be implemented to push civic responsibility is to create and spread messages that promote civic responsibility in the aftermath of a disaster. By framing messages that emphasize the connection between individuals and community, community members will then in-turn be motivated to take preparedness measures.

Similar to civic responsibility, it's important for communities to promote effective bystander responses. During a disaster, the people may have to take it upon themselves to protect their own lives and the lives of other community members around them. Bystander responses is the first action taken until emergency responders arrive. One action that follows this responsibility is to create programs that will recognize individuals as "first responders" to assist others at the beginning of any disaster.

One other crucial part to self-sufficiency is to have activities that foster self and community reliance. Community members should take it upon themselves to function and take care of their health and well-being without external health for up to 72 hours after any incident. Two activities can be done to create personal and community reliance. The first is to ask for and provide any type of support between friends, family, neighbors, and other community members. This is because communities with greater social ties can gather needed resources more efficiently.[52]

[52] Chandra, Anita, Joie Acosta, Stefanie Stern, Lori Uscher-Pines, Malcom V. Williams, Douglas Yeung, Jeffrey Garnett, and Lisa S. Meredith. 2011. "Building Community Resilience to Disasters." https://www.rand.org/content/dam/rand/pubs/technical_reports/2011/RAND_TR915.pdf.

The second activity is to create a community "call to action" that places responsibility on individuals. This serves as an increase to resilience and mobilization.

Element	Description	Activities for State and Local Entities
1. Encourage personal and community preparedness.	Promote and support actions taken by individuals, households, and communities to gain knowledge about potential hazards, prevent adverse consequences, and implement appropriate incident response.	Develop individual/family plans that identify where reunification will take place. Become educated on emergency preparedness and disseminate educational materials received from trainings to community members and neighborhood associations. Incentivize individual and community preparedness.
2. Encourage civic responsibility.	Support actions and attitudes associated with democratic governance and social participation. In the context of national health security, civic responsibility includes actions such as participation in emergency planning and advocacy.	Develop and disseminate messages that foster a sense of civic responsibility in responding to a disaster (e.g., public benefits of vaccination). Emphasize positive messaging as opposed to the negative consequences of inaction.
3. Promote effective bystander responses.	Encourage productive actions to be taken by individuals to protect themselves and other community members during an incident. Bystander response requires that, until emergency responders arrive, communities are sufficiently healthy to sustain themselves and attend to their own health needs (including the need for psychological support), and can assist in addressing the needs of at-risk individuals.	Develop and promote programs that recognize the vital role citizens can and must play as "first responders" to help their own families and neighbors in the first hours to days of a major disaster.
4. Foster self- and community-reliance.	Encourage individuals and communities to assume responsibility for their health and well-being and the health and well-being of their neighbors, and communicate that they should expect to function without external assistance for up to 72 hours after an incident.	Ask for and provide informational, instrumental, and emotional support to/from neighbors, friends, and family. Emphasize a community "call to action" in which individual responsibility is stressed.

Table 08: Key Elements of Self-Sufficiency

(Source: Rand Corporation)

Partnership, another lever that helps create a resilient community, focuses on the development of strong partnerships that can be found within and between government and other organizations both internal and external.[53] A crucial part of

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[53] Chandra, Anita, Joie Acosta, Stefanie Stern, Lori Uscher-Pines, Malcom V. Williams, Douglas Yeung, Jeffrey Garnett, and Lisa S. Meredith. 2011. "Building Community Resilience to Disasters." https://www.rand.org/content/dam/rand/pubs/technical_reports/2011/RAND_TR915.pdf.

community resilience is building a community's capacity to avoid, endure, and ameliorate the stress of disaster. Because much of this capacity may now be spread throughout a loosely connected web of groups, networks, and organizations, creating strong relationships inside communities as well as across government and civil society is critical to community resilience. There are three critical elements that effective community partnership brings and that is the establishment of pre-event memorandums, partnership agreements and terms, and assessment of existing networks and social routines (see Table 09 for more information on each element and activity).

Establishing pre-event memorandums are made to promote formalized agreements between potential partners ahead of any disaster or catastrophic event and are supposed to delineate clear roles and responsibilities among them. With this focus in mind, there are seven activities that can relate to this element. The first activity is to form regional healthcare coalitions to make certain that health systems have the right amount of capacity during the response and recovery stages of a disaster. Building these coalitions can strengthen the coordination and communication of stakeholder across the region and they can aid in the mobilization of a larger pool of human and technical resources that may be used as critical assets during the disaster response phase. The second activity is to have local organizations and social networks create and distribute preparedness information and supplies.[54] Allowing local organizations to assist with disaster planning can engage new partners into health

[54] Chandra, Anita, Joie Acosta, Stefanie Stern, Lori Uscher-Pines, Malcom V. Williams, Douglas Yeung, Jeffrey Garnett, and Lisa S. Meredith. 2011. "Building Community Resilience to Disasters." https://www.rand.org/content/dam/rand/pubs/technical_reports/2011/RAND_TR915.pdf.

security and increase capacity. Additionally, faith-based groups can have strong ties

with the local community. The third activity is to establish partnerships with colleges

and other employers that could offer courses of other educational opportunities to

practitioners and volunteers. Any worker, volunteer or not, requires training in order

to be prepared for the challenges that lie ahead. The fourth activity is to develop

integrated situational awareness alongside private hospitals, libraries and other

industries involved in the planning efforts and then encourage the use of the systems

once they become available. This is meant to engage in effective coordination

between health sectors, especially since each stakeholder has a different combination

of skills, goals, responsibilities, and expectations. The fifth activity is to improve the

coordination of roles and responsibilities and strengthen the links and relationships

within the different levels of government. Similar to the last activity, this is meant to

coordinate roles within the government to improve communication, set funding

priorities, and identify agencies that can perform preparedness, response, and

recovery. The sixth activity is to get the state and local public health officials

involved in the planning at the regional level. Federal guidance can affect the level of

preparedness for the state and local governments. Since the information would be

directly coordinated with the local level, having local officials involved at the

regional level can strengthen awareness and emergency preparedness. The final

activity is to have systems and programs improve upon returning patients from

outside a community to their original community.[55] Disasters and other threats can

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[55] Chandra, Anita, Joie Acosta, Stefanie Stern, Lori Uscher-Pines, Malcom V. Williams, Douglas Yeung, Jeffrey Garnett, and Lisa S. Meredith. 2011. "Building Community Resilience to Disasters." https://www.rand.org/content/dam/rand/pubs/technical_reports/2011/RAND_TR915.pdf.

cause major disruption and local governments tend to struggle with returning patients to their original community. Furthermore, this activity will strengthen programs to repatriate medically vulnerable individuals.

Partnerships not only focus on memorandums, but they also focus on partnership agreements and terms. Generally speaking, organizations must try to ensure that partnerships are long-term and result in the formation of continuing working relationships. There are two activities that are recommended to maintain working relationships. The first is to collaborate with institutions that serve culturally diverse populations to attract a diverse workforce to professions connected to health security. This is to help ensure that the workforce is emotionally responsive to the communities it serves. The second activity is to develop guidelines for best practices in the health security workforce, including active government participation. This helps local communities understand how to better engage stakeholders in effective partnerships.

Expanding on effective partnerships, it is important to assess the existing networks and social routines that are found among community members and organizations. It is especially important to explore what effective ways these social tools can be accessed during a disaster. To do so, there are three activities that can be followed.[56] The first is to examine the location and strength of social networks, paying special attention to which community groups will act as lead agencies in communicating risk information and resources to constituents in preparation for

[56] Chandra, Anita, Joie Acosta, Stefanie Stern, Lori Uscher-Pines, Malcom V. Williams, Douglas Yeung, Jeffrey Garnett, and Lisa S. Meredith. 2011. "Building Community Resilience to Disasters." https://www.rand.org/content/dam/rand/pubs/technical_reports/2011/RAND_TR915.pdf.

reaction and recovery. Knowing who communicates with whom can help promote situational awareness and build coordinated emergency response plans before a crisis strikes. The second activity is for the local government to partner with non-government and private organizations to undertake vulnerability assessments prior to any event. Conducting pre-event risk assessments in collaboration with local community-based groups can be especially beneficial because the local government may lack the means and personnel to do it alone. The last activity is to gather, implement, and evaluate a suite of low-cost, easy-to-implement innovative practices that allow public health authorities to collect and analyze data important to national health security. [57]Systems that are used to share awareness information during a real-time disaster must be reliable and interoperable.

Element	Description	Activities for State and Local Entities
1. Establish pre-event memorandums of understanding that delineate clear roles and responsibilities among partners.	This helps to establish "ownership" of critical tasks among stakeholders and prevents redundancy and confusion among collaborating organizations during the response and recovery phases of a disaster.	Convene working committees composed of members from the public and private sectors. Identify outcomes and measures of community resilience, as well as local vulnerabilities.
2. When possible, partnership agreements should be supported by a dedicated workforce to implement agreed-upon activities.	Generally, organizations must work to ensure that partnerships are sustainable over time and result in the development of ongoing working relationships.	Identify strategies to build the capacity of NGOs as partners in health security.
3. Assess the extent of existing networks and social routines among community members and organizations, with attention to identifying strategies to reinforce them.	Organizations should also explore effective ways of activating social networks during a disaster.	Determine what social networks exist and how to activate them during a disaster. Conduct vulnerability assessments prior to health incidents.

Table 09: Key Elements of Effective Community Partnerships

(Source: Rand Corporation)

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[57] Chandra, Anita, Joie Acosta, Stefanie Stern, Lori Uscher-Pines, Malcom V. Williams, Douglas Yeung, Jeffrey Garnett, and Lisa S. Meredith. 2011. "Building Community Resilience to Disasters." https://www.rand.org/content/dam/rand/pubs/technical_reports/2011/RAND_TR915.pdf.

Quality, another essential component to creating a resilient community focuses on the collection, analysis, and utilization of data that reviews the progress on building community resilience. This particularly focuses on the previous key components of creating a resilient community and tackles the progress for each one. This is very vital for a community because if a community can't keep track of illness incidence, quality, and continuity of treatment throughout the response, its potential to recover rapidly is compromised. With quality comes three main elements: the continuity of monitoring the quality of care and long-term health effects after a disaster, conducting research and evaluation, and using monitoring, research, and evaluation data for continuous quality improvement (see Table 10 for more information on each element and activity).

Monitoring the quality of care and long-term health effects after a disaster can help uncover how prepared and resilient a community was. It also helps determine what the next steps in recovery will be. There are two activities that can be followed to monitor the quality of care. The first is to ensure that all disaster plans include common data elements to allow for the monitoring of health, behavioral health, and social services before, during, and after the impact and start developing tools that will assist the state and local recovery planning groups in integrating these elements into their disaster plans. This type of monitoring and evaluation is critical in ensuring that individuals receiving health services continue to receive that care. [58]The second activity is to improve upon the capacity of local communities to make better use of

[58] Chandra, Anita, Joie Acosta, Stefanie Stern, Lori Uscher-Pines, Malcom V. Williams, Douglas Yeung, Jeffrey Garnett, and Lisa S. Meredith. 2011. "Building Community Resilience to Disasters." https://www.rand.org/content/dam/rand/pubs/technical_reports/2011/RAND_TR915.pdf.

current data that revolves around health, behavioral health, and social services from FEMA and other state and local sources. This is important to communities who are planning for adequate physical and psychological healthcare because it helps mitigate the impacts of disaster.

The second element is to conduct research and evaluation. This is meant to help advance the science and practice that is associated with community resilience. Research and evaluation should fill in knowledge gaps, influence decision-making and resource allocation, and assist in determining staff performance and competency. There are two activities associated with this element of quality. The first is to gather representatives from both the national and local level to identify the key outcomes and measures for community resilience. This can lead to better planning around the unknowns of community resilience. The second activity is to conduct a pilot test with proposed community resilience metrics. Since there are no validated metrics of community resilience, a set of core metrics can help inform the systematic evaluation of community resilience.

The last element of quality focuses on using monitoring, research, and evaluation data for continuous quality improvement. Data can be used to inform plans, expectations, recovery, and future responses to disaster. Therefore, data collection plays an integral part in the creation of community resiliency. There are three activities that encourage this focus.[59] The first is to develop a centralized and accessible system to collect and communicate resilience and recovery-related lessons

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[59] Chandra, Anita, Joie Acosta, Stefanie Stern, Lori Uscher-Pines, Malcom V. Williams, Douglas Yeung, Jeffrey Garnett, and Lisa S. Meredith. 2011. "Building Community Resilience to Disasters." https://www.rand.org/content/dam/rand/pubs/technical_reports/2011/RAND_TR915.pdf.

learned from local communities, as well as supporting tools/supports and incentives to apply them. The ability to incorporate lessons learned back into practice as a part of quality improvement is an important component for resiliency. The second activity is to look over existing quality improvement programs and its tools and techniques. This will help gauge whether or not new tools and techniques need to be implemented. The final activity involves the distribution and incorporation of quality improvement trainings and tools into community resilience grant guidance and educational programs. This provides communities with appropriate support and can provide community members with important opportunities.

Element	Description	Activities for State and Local Entities
1. Monitor continuity/quality of care and long-term health effects before, during, and after a health incident.	This includes the regular monitoring of health indicators and health services.	Integrate core data elements relating to health, behavioral health, and social recovery into disaster plans. Partner with universities to identify local sources of data that could inform response and recovery planning and integrate them into a single database.
2. Regularly conduct research and evaluation to advance science and practice associated with community resilience.	Research and evaluation should address gaps in the evidence base, inform decisionmaking and resource allocation, and help determine staff performance and competency.	Regularly collect community resilience measures to determine baseline levels of community resilience and any improvement that occurs.
3. Use monitoring, research, and evaluation data for CQI.	Data can be used to inform plans, expectations for the length of a specific community's recovery period, and future response and recovery.	Share resilience and recovery-related lessons within and across communities. Utilize CQI programs, tools, and techniques to improve community resilience–building activities.

Table 10: Key Elements of Monitoring and Evaluating Progress in Building Community Resilience (Source: Rand Corporation)

One of the last levers that helps create community resiliency is efficiency.[60] This looks deeply into leveraging existing resources within a community and using

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[60] Chandra, Anita, Joie Acosta, Stefanie Stern, Lori Uscher-Pines, Malcom V. Williams, Douglas Yeung, Jeffrey Garnett, and Lisa S. Meredith. 2011. "Building Community Resilience to Disasters." https://www.rand.org/content/dam/rand/pubs/technical_reports/2011/RAND_TR915.pdf.

them to their maximum potential. There are some communities have limited resources and need to know how to effectively use them in a time of need. This component of community resiliency has two major elements that focus on defining the transition and funding processes for the response and recovery phases and developing monitoring systems that can determine where the assets are needed (see Table 11 for more information on each element and activity).

The first element of efficiency focuses defining the transition and funding processes for response and recovery. Overall, this looks at how funds are being distributed from the federal and state level to the local level. To increase efficiency, there are four recommended activities. The first is develop a national guide for transitioning into recovery planning within the initial phases of disaster response. This helps mitigate delays in reconstruction and can address the needs of physical and psychological health that haven't been met. The second activity focuses on providing non-government organizations with funding to include health security and to help further develop disaster plans. This resource helps restore the social routines that follow the disaster. The third activity is to create policies that focus on effective donation management and help guide the public on what should be donated and why. Post-disaster, many public organizations donate money, and it is important to have a management system that allocates resources to specific things (clothing or other equipment).[61] The fourth activity involves the continuation of the development and publication of materials that enhance preparedness for emergency response and its

[61] Chandra, Anita, Joie Acosta, Stefanie Stern, Lori Uscher-Pines, Malcom V. Williams, Douglas Yeung, Jeffrey Garnett, and Lisa S. Meredith. 2011. "Building Community Resilience to Disasters." https://www.rand.org/content/dam/rand/pubs/technical_reports/2011/RAND_TR915.pdf.

transition to health and social service recovery. This is especially important in the health and social service sectors to minimize service gaps that result in unmet physical and psychological health requirements, which can lead to major problems if left neglected.

The second element of efficiency focuses on developing monitoring systems that can determine where the assets are needed. While it is important to create a system that focuses on funding distribution, it is also important to for communities to upgrade and strengthen systems that locate local assets for effective response and quicker distribution of resources to where they are needed most. The only activity that is recommended for this is to develop plans that analyze a community's needs for resource allocation at the start of a crisis so that funding strategies may be activated promptly. This will allow for quicker response and increased recovery at the spots that have more needs than others. [62]

Element	Description	Activities for State and Local Entities
1. Clearly delineate transition and funding processes for response and recovery.	This includes procedures and funding plans for nongovernmental organizations, particularly in terms of how funds are distributed from federal and state government to local entities.	Develop national guidance for transition to recovery planning in the initial phases of any disaster response. Provide funding to NGOs to include health security as part of their effort to improve community resilience and to develop disaster plans. Develop policies for effective donation management.
2. Develop monitoring systems to determine where resources are needed.	This capability will allow communities to marshal resources appropriately to areas of community and not to expend assets unnecessarily.	Develop plans to assess community needs for resource allocation at the onset of an incident to activate funding plans quickly.

Table 11: Key Elements of Efficiency

[62] Chandra, Anita, Joie Acosta, Stefanie Stern, Lori Uscher-Pines, Malcom V. Williams, Douglas Yeung, Jeffrey Garnett, and Lisa S. Meredith. 2011. "Building Community Resilience to Disasters." https://www.rand.org/content/dam/rand/pubs/technical_reports/2011/RAND_TR915.pdf.

After communities have implemented the key components of this roadmap into their plans that focus on disaster preparedness, community members should plan to study and collect data on how well these new systems work. Since there is little evidence that supports a working community resilience, data collection and the continuation of monitoring will provide critical feedback on what works and what doesn't. The RAND corporation suggests that communities look at each individual lever, as shown in table 12, to study specific measurements and improve upon those areas within the community. While the existing research can identify ways to strengthen community resilience, it is important to further research as it will help fill gaps within the existing knowledge.[63]

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[63] Chandra, Anita, Joie Acosta, Stefanie Stern, Lori Uscher-Pines, Malcom V. Williams, Douglas Yeung, Jeffrey Garnett, and Lisa S. Meredith. 2011. "Building Community Resilience to Disasters." https://www.rand.org/content/dam/rand/pubs/technical_reports/2011/RAND_TR915.pdf.

Lever	Proposed Measurement Area
Wellness	Disability status
	Poverty level
	Health status of the population
Access	Health insurance coverage
	Availability of healthcare providers in medically underserved areas
Education	Level of health literacy in the population
	Communication vulnerability/non-English-speaking households
	Dissemination of risk information and subsequent uptake or use of information
Engagement	Identification of at-risk individuals through governmental and nongovernmental engagement
	Health department identification of at-risk population "hot spots"
	Health department identification of organizations that can serve at-risk population "hot spots"
	Social connectedness of general population for disaster response and recovery
	Voting behavior
Self-Sufficiency	Health department education with at-risk populations
	Public's ability to act upon official messages/vulnerability
	Level of citizen preparedness and sense of self-reliance
Partnership	Local Emergency Planning Committee (LEPC) composition
	Role of NGOs in community response and recovery plans
Quality	Time to new normalcy (post-incident)
	Community's ability to integrate lessons learned from previous incidents
Efficiency	Use of public health dollars for dual benefit (public health promotion activities and community resilience–building activities)

Table 12: Levers and Proposed Measurement Areas

(Source: Rand Corporation)

After understanding what makes a community more resilient before, during, and after a disaster, some of these strategies can be implemented into the communities of Puerto Rico. As seen in chapters one and two, Puerto Rico is known to have a financial, political, and social crisis both before and after Hurricane Maria hit in 2017. Based on the current community conditions, it can be said that the islanders lack both a social network and a lack of resources.[64] To improve upon these issues, the government should implement the levers introduced by the RAND

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[64] Chandra, Anita, Joie Acosta, Stefanie Stern, Lori Uscher-Pines, Malcom V. Williams, Douglas Yeung, Jeffrey Garnett, and Lisa S. Meredith. 2011. "Building Community Resilience to Disasters." https://www.rand.org/content/dam/rand/pubs/technical_reports/2011/RAND_TR915.pdf.

Corporation. More specifically, the government should impose a plan that looks into community wellness, access, education, engagement, and partnership.

Wellness and access are both focused on providing and maintaining good health within a community. Currently, the people in Culebra only have one clinic that can provide limited support. Additionally, 15.6% of the population have no health insurance, making access to resources even more scarce. By implementing activities such as providing the community with sufficient community health resources, it will increase the overall wellness of a community and would provide a deeper level of knowledge to its members.

As for education and engagement, they both focus on the identification of information regarding health, safety risks, and vulnerability. Educating individuals will allow people to become more self-aware and can train members of a community to engage with those members who are more at risk during a disaster. This then ties into partnership and how local organizations and community members can work together to provide resources to those in need. All in which makes the community more resilient.[65]

Additional Guidelines Provided by The U.S.

In 2016, the National Oceanic and Atmospheric Administration (NOAA) had led a series of federal agencies and organizations in the release of a U.S. climate resilience toolkit that allowed people to build upon community resiliency. This toolkit

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[65] Chandra, Anita, Joie Acosta, Stefanie Stern, Lori Uscher-Pines, Malcom V. Williams, Douglas Yeung, Jeffrey Garnett, and Lisa S. Meredith. 2011. "Building Community Resilience to Disasters." https://www.rand.org/content/dam/rand/pubs/technical_reports/2011/RAND_TR915.pdf.

was meant to focus on preparedness along with incorporating the "prevention, protection, mitigation, response, and/or recovery from natural or man-made hazards."[66] To provide citizens with an easy-to-read guideline, the National Institute of Standards and Technology (NIST) had released a guide that listed out a planning process for building community resilience. This guide, as seen in table 13 below, follows a sequence of six steps that allow communities to improve their resilience overtime at their own pace and with their own set goals. While following these steps can be crucial to creating community resilience, there are a few other things that should be noted. The first is that many disaster plans are not well integrated with other community plans such as capital budgetary plans. To make an integrated community-level resilience plan, it must include steps for disaster preparedness and recovery actions alongside other community plans. The second is that community must be defined. Each community has its own identity and has its own level of risk tolerance. This is important to identify when creating effective community resilience plans. The last thing to consider is how stakeholders are involved. Many of the effective community resilience programs to date have been headed by a community official who collaborates with a resilience team. What's important about these teams is that they collaborate with other public, non-profit, and private groups, which these groups then provide recommendations for the next steps in the plan.

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[66] "U.S. Climate Resilience Toolkit." n.d. Community Resilience | U.S. Climate Resilience Toolkit. https://toolkit.climate.gov/topics/built-environment/community-resilience.

Table 13: Six-Step Process To Planning For Community Resilience

(Source: NIST)

Various populations around the globe deal with different natural disasters every day. To understand how communities survive and thrive after these events can help provide insight as to how to pursue Puerto Rico's issues. The various precedents included below all come at different scales with different problems, but they all have one thing in common and that is a that they all have a resilient community.

Santa Cruz del Islote, Columbia

Figure 13: View of Santa Cruz del Islote
(Source: Uhkabu)

Santa Cruz del Islote, a 2.4-acre island that can be found near the coast of Columbia, has been around for nearly 150 years. The island plays host to around 1,200 inhabitants and its density is four times the amount of Manhattans. The island is as big as the size of one and a half soccer fields, meaning that everyone is always

within close proximity of one another. Although close proximity can be uncomfortable, it allows for a 0% crime rate. Additionally, the living conditions are far from modern, as the residents rely on a generator that provides only 5 hours of electricity per day. For those living in a modern city like Manhattan, these conditions would be unacceptable. However, those living on the island find it to be peaceful and calm.[67] But how does the city have enough resources to sustain itself?

The people living in Santa Cruz del Islote have a few ways for living sustainably. With limited resources, there is a great emphasis placed upon the people to make the most out of what they have. This requires a huge amount of sharing and cooperation between the residents. When it comes to food supply, the members of the community rely on fishing to sustain themselves. But recently, the seas have started to become overfished, and the locals have had to find different means of occupation off the island. Water on the island is also scarce, but the community's members ensure that their freshwater supply is well maintained. In other words, the islanders share the economy and join together to create a better quality of life.

One other important sustainable living quality is educating the island's future. Every action that takes place in Santa Cruz del Islote is another chance for the children to learn. While the islanders already know how to live sustainably, the teachers that educate the children hope to grow lessons about sustainability. (medium.com) By teaching outside of the island, the world population can grow to utilize less and focus more on showing care for the world and to others around them.

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[67] Adela. 2017. "Santa Cruz Del Islote: A Brand New Way of Living." Unusual Places. February 28. https://unusualplaces.org/santa-cruz-del-islote-a-brand-new-way-of-living/.

The important lesson that can come from this resilient community is that a population can make a lot from a lot less. Likewise, Puerto Rico is a community that has limited resources and fishes to sustain themselves. However, the one thing that the community is a well-connected social network like the community of Santa Cruz del Islote. In times of need, the people on the island help each other out and that is one thing that Puerto Ricans can incorporate into their everyday lives.

Lake Village of Ganvie, Benin

Figure 14: View of Structure on Wooden Stilts
(Source: Kulttuurinavigaattori)

Located around 25 kilometers away from the capital of Benin is the lake village of Ganvie. This village plays host to around 20,000 people and is known as the community on stilts.[68] Lake Nokoué, the main body of water, is what governs the community's organization. The built environment consists mainly of structures that

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[68] "The 'Venice' of Africa: Ganvie, Benin.: Hadithi Africa." 2019. Hadithi Africa | A Platform for the African Narrative. April 15. https://hadithi.africa/the-venice-of-africa-ganvie-benin/.

are built on wooden stilts and suspend above the lake. Everything in this community revolves around this body of water, from the transportation, to myths and history, to ancestral religions that are still practiced today.[69]

The village seems to live a sustainable life where most people make a living off of fishing. However, this village and others that reside in Benin are susceptible to erosion and flooding. How does this culture and community become resilient to these disasters? With erosion, residents in Benin have advanced technologies that can predict the movement of sand and use market gardening to strengthen the soil for when it becomes weak. These resources were shared with them through partnered stakeholders. Flooding poses more of an issue as increased rainfall has caused main bridges to become impassable. To tackle this issue, community members have been improving infrastructure by crafting new bridges to maintain the flow of traffic.[70]

If anything can be learned from this community, it is that partnership and community engagement have become a critical tool for the community to succeed. Comparatively, Puerto Rico has recently gained partnerships with non-government organizations within the U.S., which have provided resources that are helping the islanders recover from its most recent disaster in 2017. In comparison, both Benin and Puerto Rico deal with erosion and flooding but at different scales. However, the way they respond to flooding is very different. The people of Benin have been upgrading infrastructure and moving bridges up higher to allow for a continuity of

[69] Valin, Délani. 2019. "Water as Protector: Divinities of Vodoun in Benin." Culturally Modified. July 15. https://culturallymodified.org/water-as-protector-water-divinities-of-vodoun-in-benin/.
[70] Close, James. 2017. "In Benin, Can Resilient Investment Solutions Save a Battered Coast?" World Bank Blogs. August 14. https://blogs.worldbank.org/nasikiliza/in-benin-can-resilient-investment-solutions-save-a-battered-coast.

connection across the river plain. The communities in Puerto Rico tend to remain in the same location after a flood, which increases damage over time. It can be suggested that the infrastructure within the islands of Puerto Rico be shifted to higher ground to remove any risk of flooding.

Halong Bay Floating Village, Vietnam

Figure 15: View of Hang Floating Fishing Village
(Source: Michelle Maria)

Found along the Halong Bay off Vietnam's northeastern seacoast are floating villages. These villages are divided into four distinct residential areas with around a total count of 400 households totaling approximately 1,000 people. These residents have no land ownership and survive off the fish found within the bay. The people that reside in the community operate as a family and usually children as young as 5 years old learn how to properly cast fishing nets.

The greatest challenges that this community faces includes a lack of education, climate change, pollution, and the reduction of fish found within the bay. Sustainability with the current way of life is a huge concern because any slight change affects their ecosystem greatly.[71] Around 2012, Halong Bay's management decided that all residents should be moved onto land due to safety and environmental issues. While it became uncomfortable for the community's members to be away from the sea, it brought some advantages to the people. Focusing on the quality of life, it would bring better education to children and better the life standard for the local fisherman. It also helped protect the bay since floating villagers had caused much pollution within the bay.[72]

What can be learned from this precedent is that continuously reverting back to old solutions will cause more harm than finding new and innovative solutions. By pushing the people away from the water, the environment in and around the Halong bay had a better quality of life. As a lesson for Puerto Rico residents, moving away from something that is familiar can provide better results. In other words, the islanders should rethink the placement of their built environment based on the issues they are continuously having.

Grenada in the Caribbean

Grenada, located southeast of Puerto Rico, is a Caribbean island that is about two times the size of Washington D.C. This island nation has a population of around

[71] Nguyen, Linh Phuong. 2012. "An Overview of Ha Long Bay's Fishing Villages." World Monuments Fund. March 22. https://www.wmf.org/blog/overview-ha-long-bay%E2%80%99s-fishing-villages.
[72] Ngoc, Bich. 2017. "How Halong Bay Floating Village Has Changed since Locals Move to the Mainland?" July 25. https://www.nature.org.vn/en/2017/07/how-halong-bay-floating-village-has-changed-since-locals-move-to-the-mainland/.

100,000 people that reside within a land area of around 135 square miles. Similar to Puerto Rico, Grenada faces huge vulnerability to climate change. It has been affected by many hurricanes, including Hurricane Ivan in 2004 and Hurricane Emily in 2005. While it has taken a while for the island to recover, many community members benefited from post-hurricane job opportunities in the construction sector. (2009-2017.state) To help combat and recover from these natural disasters, the government partnered with other agencies to create a Strategic Program for Climate Resilience back in 2011. This provided Grenada with funding from international donors.[73]

As Puerto Rico's issues are tackled, Grenada can be utilized as an example on how to rebuild after a major disaster. Another benefit to Grenada's revival is that a Pilot Program for Climate Resilience was created to finance the Caribbean nations. Since Puerto Rico is a designated Caribbean Island, the government can gain funding from this program.

[73] "Strengthening Climate Resilience: The Case of Grenada: NDC Partnership." n.d. Accelerating Climate Action & NDC Implementation : NDC Partnership. https://ndcpartnership.org/case-study/strengthening-climate-resilience-case-grenada.

Chapter 5: Revitalizing Infrastructure

Defining Infrastructure

In the field of architecture, the word infrastructure can take on multiple meanings and roles. The dictionary definition of the word, however, is "the basic systems and services, such as transportation and power supplies, that a country or organization uses in order to work effectively".[74] Relatively speaking, the general terminology is what is perceived as making a community function. How this relates to community resiliency is that certain aspects and types of infrastructure need to be improved upon to provide the people with more impactful resources and conditions.

The longevity of a community is heavily reliant on the different types of infrastructure. National, regional, or local goals also depend on it to bridge connections between one location to another, allowing for goods and services to be provided across borders.[75] To make a community more resilient toward disasters could mean improving on certain types of infrastructure. These types may include transportation, water and wastewater, waste management, energy production and distribution, buildings, and recreation facilities.[76] Each individual type has its own sub-division of resources (see table 14 below for each sub-division).

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[74] "Infrastructure." n.d. INFRASTRUCTURE | Definition in the Cambridge English Dictionary. https://dictionary.cambridge.org/us/dictionary/english/infrastructure.

[75] Puentes, Robert. 2015. "Why Infrastructure Matters: Rotten Roads, Bum Economy." Brookings. Brookings. January 20. https://www.brookings.edu/opinions/why-infrastructure-matters-rotten-roads-bum-economy/#:~:text=The%20economy%20needs%20reliable%20infrastructure,transit%20can%20reduce%20greenhouse%20gases.

[76] Jamal, Haseeb. 2017. "Types of Infrastructure in Urban and Rural Areas." Types of Infrastructure | Infrastructure Examples | Categories of Infrastructure. May 1. https://www.aboutcivil.org/infrastructure-types.

Transportation
Ground transportation - roads, bridges, tunnels, railroads
Air transportation - airports, heliports, ground facilities, air-traffic control
Waterways and ports - inland waterways, shipping channels, terminals, dry docks, sea ports
Intermodal facilities - rail/airport terminals, truck/rail/port terminals
Mass transit - subways, bus transit, light rail, monorails, platforms/ stations
Pipelines - natural gas, crude oil

Water and Wastewater
Water supply - pumping stations, treatment plants, main water lines, wells, mechanical/electric equipment
Structures - dams, diversion, levees, tunnels, aqueducts
Agricultural water distribution - canals, rivers, weir, gates, dikes
Sewers - main sewer lines, septic tanks, treatment plants, storm water drains
Storm water drainage - roadside gutters and ditches, streams, levees

Waste Management
Solid waste - transport, landfills, treatment plants, recycling facilities
Hazardous waste - transport, storage facilities, treatment plants, security
Nuclear waste - transport, storage facilities, security

Energy Production and Distribution
Fossil fuel-based electric power production - gas-,oil and coal-fueled power generation
Electric power distribution grid networks - high-voltage power- transmission lines, substations, distribution systems, energy-control centers, service and maintenance facilities
Gas pipelines - gas production, pipeline, computer stations and control centers, storage tanks, service and maintenance facilities
Petroleum/oil production - pumping stations, oil/gas separation plants, roads
Petroleum/oil distribution - marine and ground tanker terminals, pipelines, pumping stations, maintenance facilities, storage tanks
Nuclear power stations - nuclear reactors, power-generation stations, nuclear-waste disposal facilities, emergency equipment and facilities
Renewable energy and non-fossil fuels - infrastructure for solar power, wind power, hydro-electric power, biofuels

Buildings
Public buildings - schools, hospitals, government offices, police stations, fire stations, postal offices, prison systems, parking structures
Other buildings and structures—public/residential/commercial/offices - public housing, structures, utilities, swimming pools, security, ground access, parking) Multipurpose and sports complexes (coliseums, amphitheaters, convention centers
Housing facilities - public, private
Industrial, manufacturing/warehouse, and supply chain facilities - private

Recreational Facilities
Parks and playgrounds - roads, parking areas, recreational facilities, office buildings, restrooms, ornamental fountains, swimming pools, picnic areas
Lake and water sports - roads, parking areas, picnic areas, marinas
Theme parks/casinos - access roads, buildings, restaurants, security facilities, structures) Hospitals and public health facilities (public, private

Table 14: Infrastructure Types

(Source: Author's Work)

Infrastructural Focus

The infrastructural focus of this thesis will be around transportation, energy production and distribution, buildings, and recreational facilities. As will be discussed in chapters 6 and 7, the shift toward updating these types is focused on the major

issues that the community of Culebra faces. With an emphasis on creating a resilient

community, infrastructure based on community engagement and resource allocation

will be majorly impacted.

Chapter 6: Design Approach

Values

Sociocultural values that can be found within the island of Culebra can reflect upon the traditions, habits, and patterns that the community engages in. Taking these values away would remove any identity that the island has. In which case, it is imperative that these values remain the same throughout the design process.

Culebra's main values revolve around preserving natural life and in-turn celebrating it. As mentioned in chapter 1, there was the establishment of the Culebra National Wildlife Refuge in 1909 and about 20% of the island is protected by the U.S. Fish and Wildlife service. This is something that the islanders highlight and continue to promote within their community. For people visiting the island, it is suggested to explore and engage with the wildlife habitats both in the water and above ground.

Post-disaster Problems

While maintaining the cultural and heritage values, the objective is to revitalize the community and create a more resilient island towards natural disaster. In particular, the major failures and issues post-disaster are to be improved upon so that the members of the community are better prepared for the next catastrophe. Relating back to different types of infrastructure, Culebra needs updated information, tools, and resources on transportation, energy production and distribution, buildings, and recreational facilities. Additionally, recognizing the various toolkits mentioned in chapter 4 will provide a guideline as to how a successful resilient community looks.

*Figure 16: Site Selection*
(Source: Author's Work)

Relating this back to the overall goal of this thesis, the selected context should reflect the overall population of Puerto Rico while also pinpointing the major failures that were developed post-disaster. Chapter 2 has already determined that the parameters of Culebra are relatively the same as most parts within the main island. In which case, the selected site should reflect where major community gathering takes place. There are four sites that show greater amounts of community activity (as shown in figure 16 above.) within the island. Out of all sites, Dewey is where most community activity occurs as it is both the capital and main transportation hub of the island.

When integrating new infrastructure into an existing urban fabric, it is important to understand where people could get displaced and what location would work best for community engagement. As seen in figure 17 below, some of the existing infrastructure will be submerged under water in 100 years. Since the FEMA 100-year flood plain is a bit outdated, figure 18 below shows an estimated 200-year flood plain. This is important to factor in because in about 200 years, most of the existing buildings will be submerged underwater.
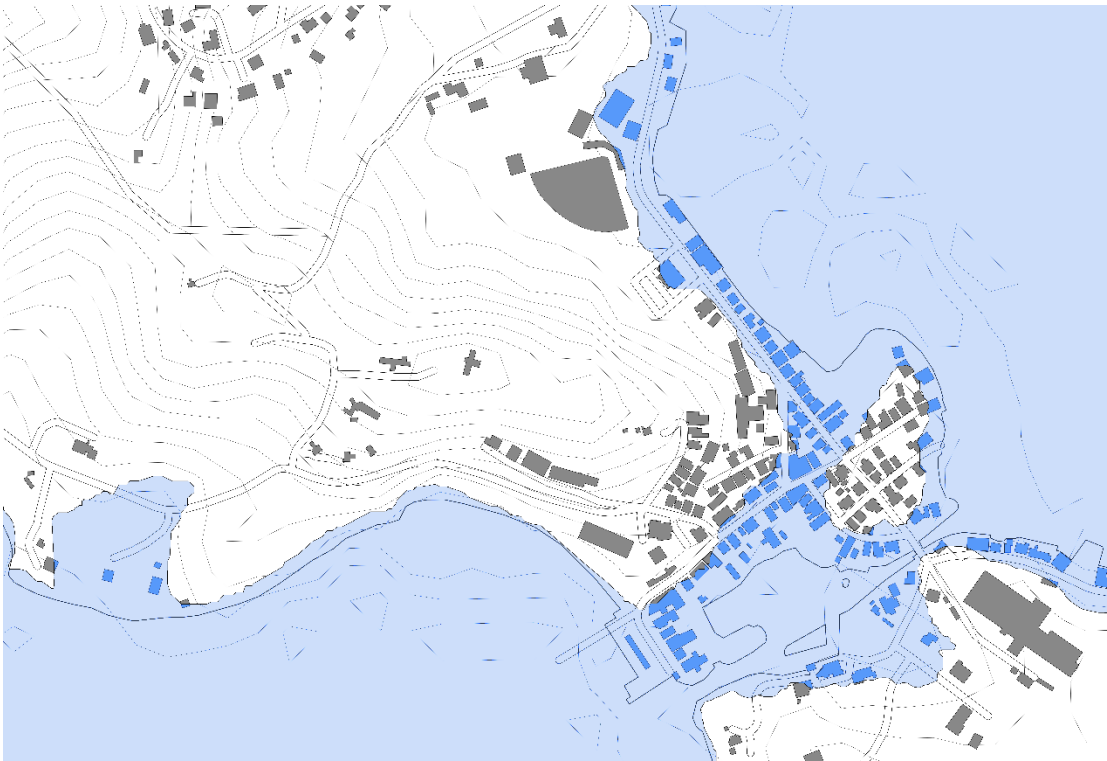
Figure 17: FEMA 100-year Flood Plain
(Source: Author's Work)
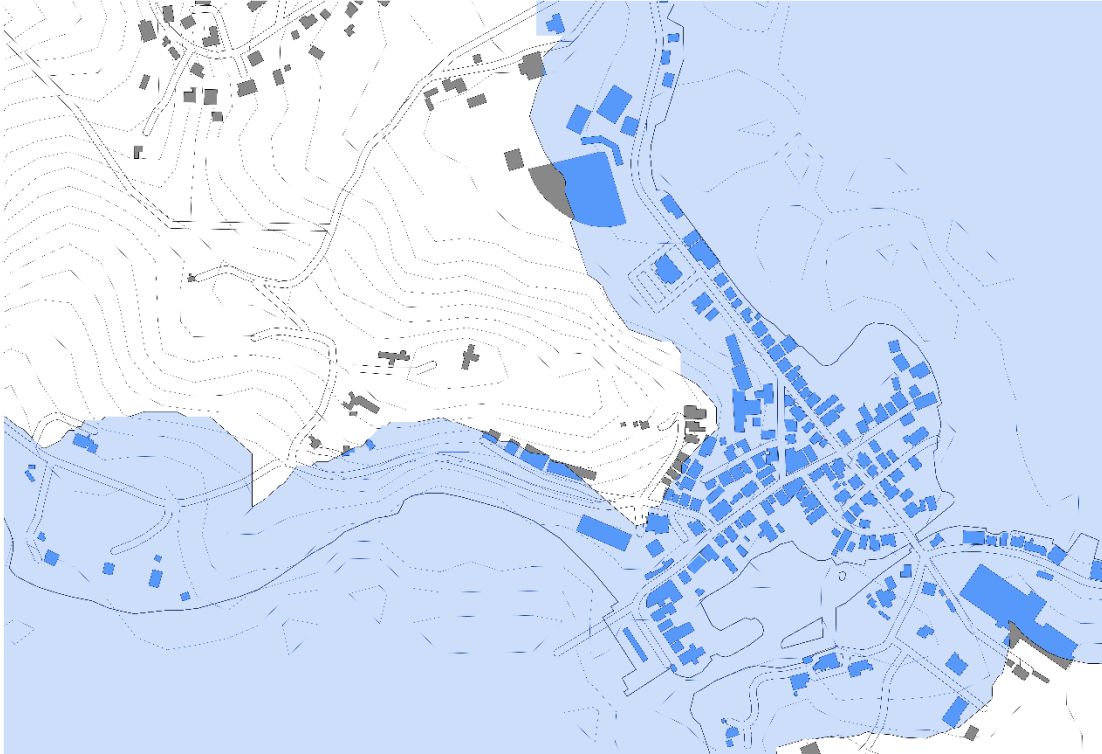
Figure 18: Estimated 200-year Flood Plain
(Source: Author's Work)

Additionally, when approaching the site, it is important to note the existing building

types and the walkability of the site. Figure 19 below shows the existing building

types and Figure 20 shows the walking radius around the center of the site. From both

figures, the site is shown as very walkable and has a separation between two

communities. The community in the north is residential heavy and the community in

the south is commercial heavy. Moving into the proposed design, it will be crucial to
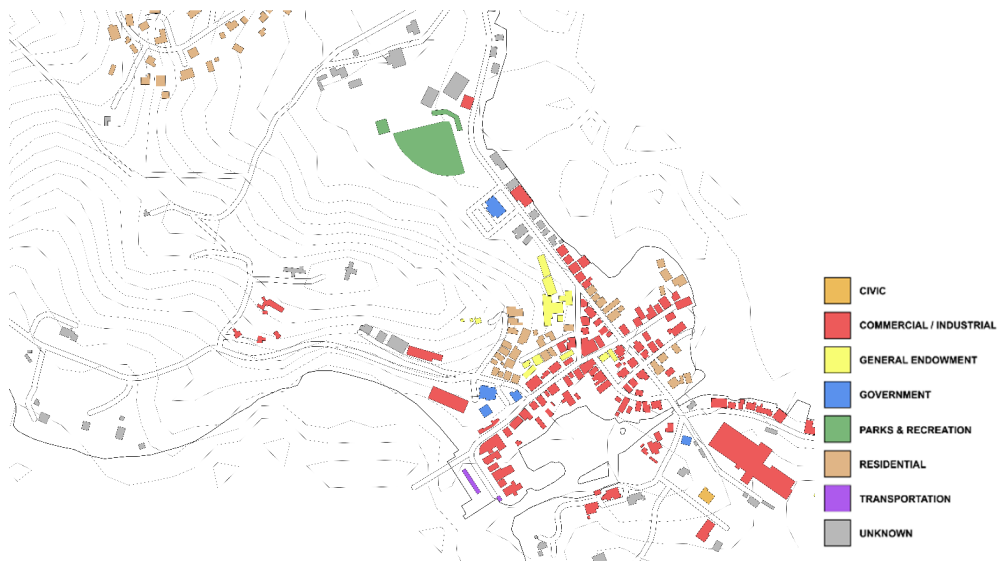
connect these communities.

CIVIC

COMMERCIAL / INDUSTRIAL

GENERAL ENDOWMENT

GOVERNMENT

PARKS & RECREATION

RESIDENTIAL

TRANSPORTATION

UNKNOWN

Figure 19: Building Types
(Source: Author's Work)
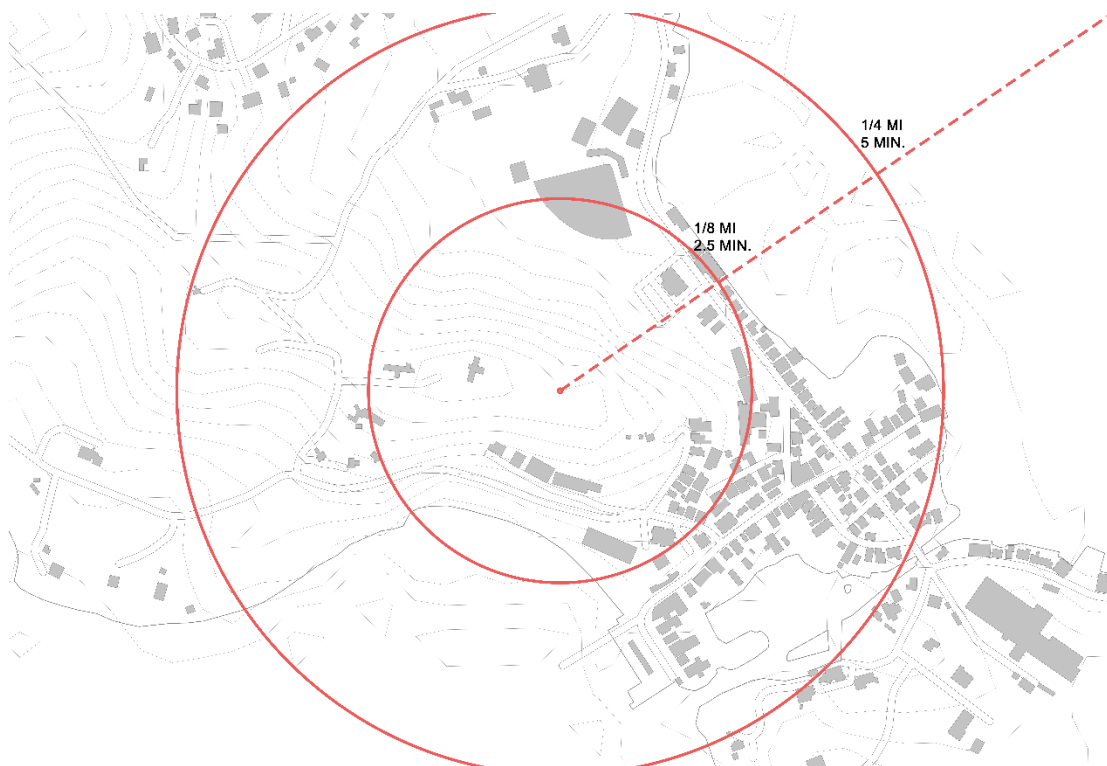

1/4 MI
5 MIN.

1/8 MI
2.5 MIN.

Figure 20: Site Walking Radius
(Source: Author's Work)

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One other crucial element to consider when approaching the site is to look at what was planned for the site and how previous planning can affect the new design. Culebra, Puerto Rico had plans that followed the planning of the main island. In other words, decades ago, the town of Dewey was planned to be developed in a grid like system. As seen in the previous figures, the buildings and roads started off with a linear grid but were never finished. To continue this development and to better acclimate the people to a system that they are familiar with, the design approach will take San Juan's grid and adjust it to fit the current site conditions (see Figure 21 below for grid delineation).
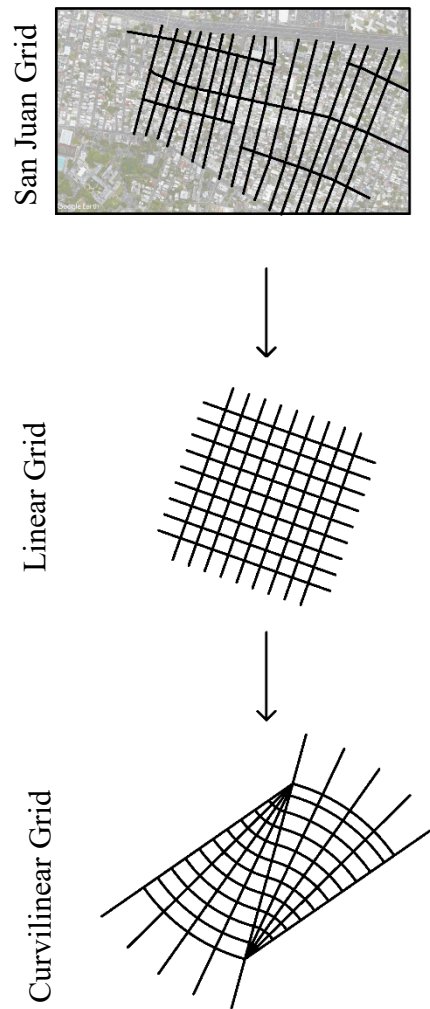
Figure 21: Grid Delineation
(Source: Author's Work)

As seen in figure 22 below, the curvilinear grid will be placed in between the two

existing communities. This, again, serves the purpose of connecting the old and the

new. The purpose of the curves is to blend in with the existing contours while

creating an organizational system for the new site. When looking at the figure, the

highlighted areas in red will be the location of the new infrastructure.
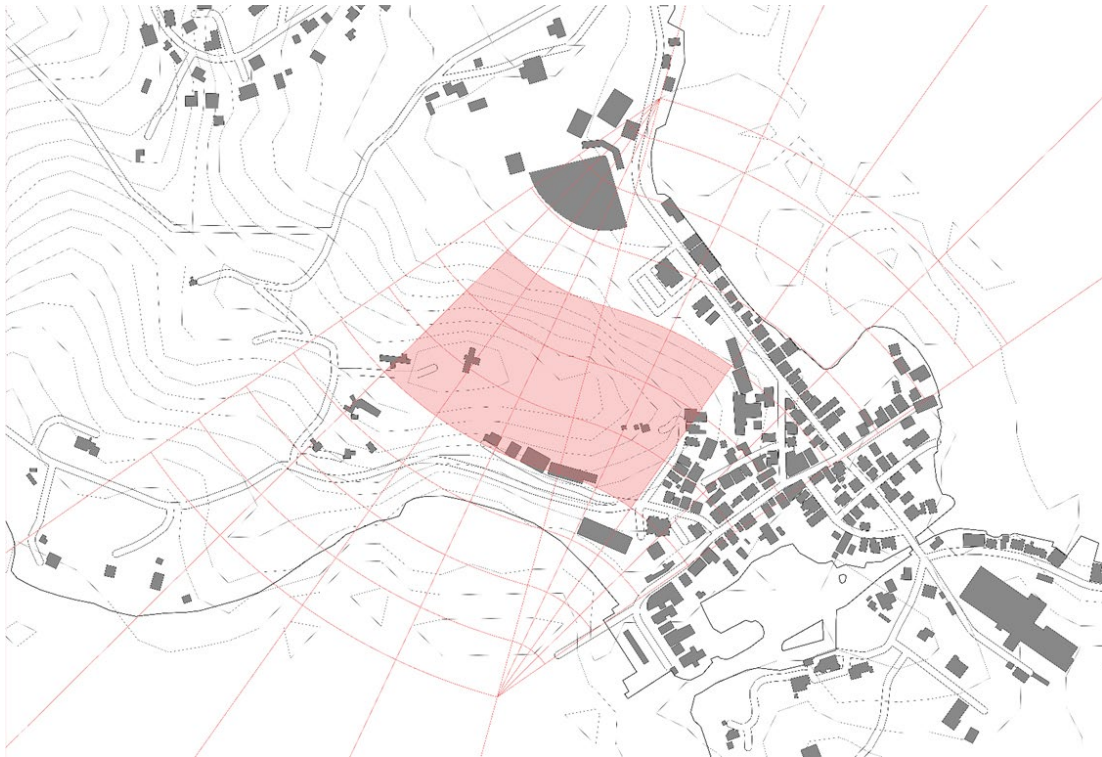
Figure 22: Overview of Grid on Site
(Source: Author's Work)

Chapter 7: Design Proposal

Community Center Within Existing Fabric

The community of Culebra seems to lack immediate resources that can provide access, education, community engagement, and partnership to its members. These components can typically be found within separate buildings in an existing urban fabric. Unfortunately, some of these resources are not found within the archipelago and are instead found at the main island. One building typology that could be incorporated into the urban layout is a community center.

Community centers, as included in the title, focuses on community engagement, and provides possible educational opportunities for its members. While

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community centers don't always have programmatic elements that provide access to resources, it can be an element that is incorporated into the design. Additionally, dividing a community centers program into separate buildings can produce partnership among the different areas of focus.

Relative Programmatic Elements

Typically, community centers are designed around community activity and are designed to include all relative programmatic elements in one building. But to ensure that the criteria is met, it would be best to match the necessary resource to a programmatic element that can then be placed within its own entity. Table 15 below provides an example of what the programmatic elements might look like that can relate to the much-needed resources. Starting with access, the community center could provide parents with a daycare center. This allows parents access to additional childcare services. The community center also implements an educational center that focuses on educational opportunities for the community. The event space, meeting space, performance space, and recreational space all promote community activity. This is where members within the community can both gather and create long lasting partnerships. By providing a community with these resources, it will be more likely to adapt and become more resilient over time.

Draft: Area take-off tabulation				
Building		Program Type	Space	Floor Area (sq. ft)
Building A:		Reception and B.O.H.	Front Desk	750
			Lounge	350
			Office A	400
			Office B	400
			Office C	400
			Storage Room	250
			Mechanical Equipment	250
			IT Equipment	150
			Total:	2,800
Building B:		Event Space	Multipurpose functional space	4,500
			Storage	500
			Functional Prep	315
			Total:	5,315
Building C:		Meeting Spaces	Meeting Room A	450
			Meeting Room B	450
			Meeting Room C	300
			Meeting Room D	300
			Storage Room	150
			Total:	1,650
Building D:		Restaurant/Café	Café	1,000
			Bathrooms	250
			Storage Room	200
			Total:	1,450
Building E:		Educational Center	Classroom A	1,200
			Classroom B	1,200
			Classroom C	1,200
			Gallery	500
			Library	3,000
			Workshop	200
			Green Room	150
			Storage Room	150
			Total:	7,600
Building F:		Performance Space	Auditorium	1,200
			Coat Room	300
			Storage Room	300
			Total:	1,800
Building G:		Daycare Center	Classroom A (4 and 5 yr olds = x15)	520
			Classroom B (Toddlers = x6)	270
			Classroom C (Infants = x10)	360
			Classroom D (2 yr olds = x8)	310
			Classroom E (3 yr olds = x10)	355
			Reception	200
			Kitchen	304
			Bathrooms	120
			ADA Bathrooms	120
			Office	130
			Total:	2,689
Outdoor Space A:		Outdoor/indoor Recreation	Green Space	2,500
			Sports Court	1,200
			Play Space	1,000
			Total:	4,700
			Total Square Footage:	28,004
			Gross Square Footage:	40,000
			Net Square Footage:	28,004
			Grossing Factor :	1.4

Table 15: Programmatic Elements

(Source: Author's Work)

To provide the people of Culebra with the best possible solution, it is important to gather information from the people that regards what their needs are before, during, and after a natural disaster hits. Tables 16, 17, 18, 19, and 20 show questions taken from a survey that gathered information regarding social and structural resiliency. These questions provided information on what should be built and what materials should be used and were asked to people that either lived in Puerto Rico, live in Puerto Rico, or have family members in Puerto Rico.

From a social standpoint, which of the following would you consider to be the main issue in Puerto Rico before, during, and after a disaster?
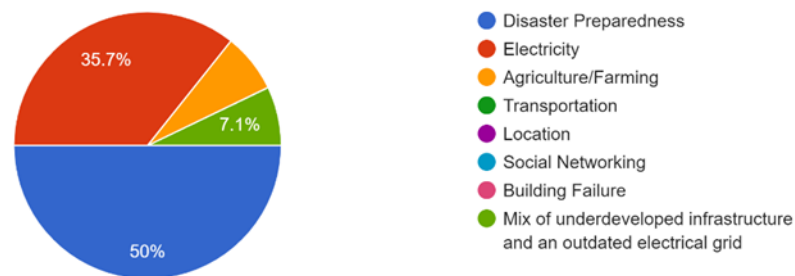
14 responses

- Disaster Preparedness
- Electricity
- Agriculture/Farming
- Transportation
- Location
- Social Networking
- Building Failure
- Mix of underdeveloped infrastructure and an outdated electrical grid

Table 16: Social Issues

(Source: Author's Work)

Post-disaster, what building material do you see being reused the most?
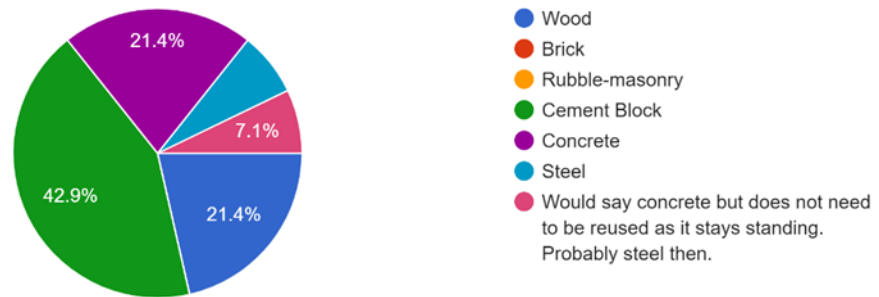
14 responses

Table 17: Reused Materials

(Source: Author's Work)

Which of the following would you consider to be the most useful building typology after a disaster hits?
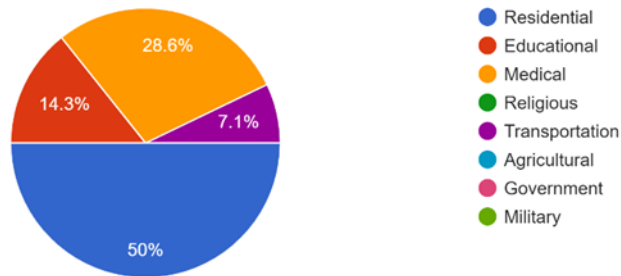
14 responses

Table 18: Building Types

(Source: Author's Work)

What would be most helpful after a disaster hits?

14 responses

Legend:
- Community Education (learning what resources are needed, how to rebuild...
- Community Engagement (involving community members in planning, help...
- Community Wellness (promote public understanding of health and wellness,...
- Community Partnerships (social networking, connection to outside org...
- Increased Communication (Providing t...
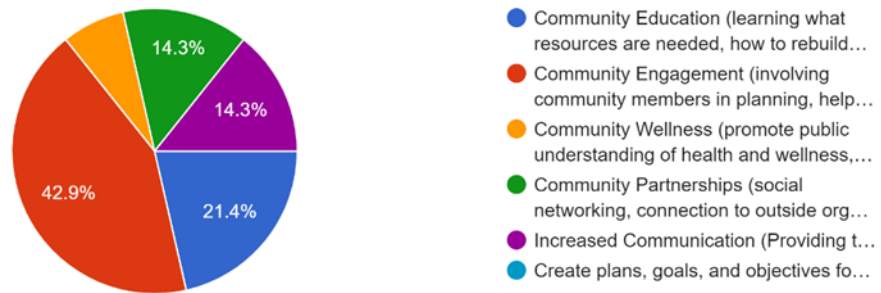- Create plans, goals, and objectives fo...

Table 19: Social Reform

(Source: Author's Work)

If you had to relocate from your existing home due to flooding, which part of the island would you move to?

14 responses

To a higher place
Atlantic side
High parts like mountains
Somewhere more inland. Towards the center of the island (Ex: San Juan)
To any area with mountains or hills. The main 2 reason for this decision is because waves causing floods in the cost and rushing rain water coming from the hills and mountains.
It might be tough for people to move on the fly, though I live in the states so I would not have a preference for this.
Resaca
A central area like Orocovis rather than a coastal town.

Table 20: Moving Locations

(Source: Author's Work)

After understanding what the people felt like they needed before, during, and after a natural disaster, the next thing to do was to create relevant programmatic

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buildings and create a plan that would place focus on what should be done first.

Tables 21 and 22 below show the program in a phasing system. Phase 1 focuses on

the community aspect and phase 2 focuses on housing. The reason for this order is to

create a stronger sense of community and build around it. It is also important to note

that people take refuge in big community buildings (such as schools) when a natural

disaster occurs because it is safer. In which case, the community buildings being built

first would allow for all existing communities to take shelter in the case of an
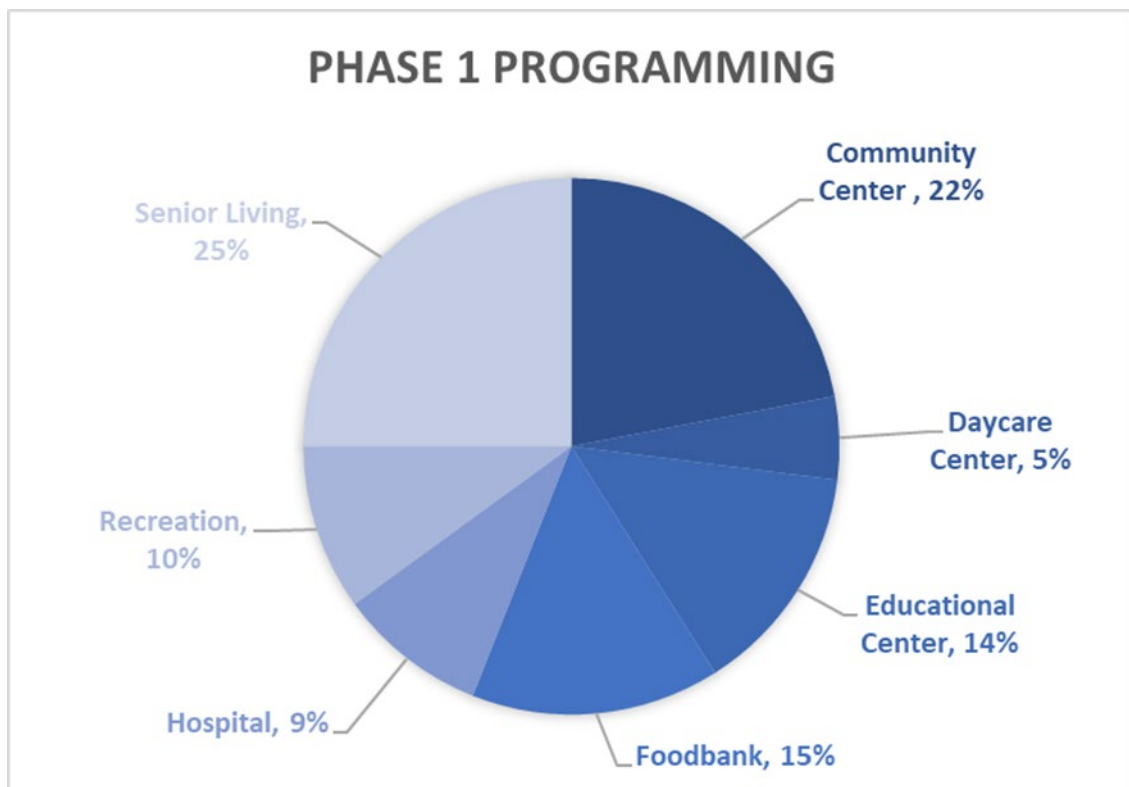
emergency.

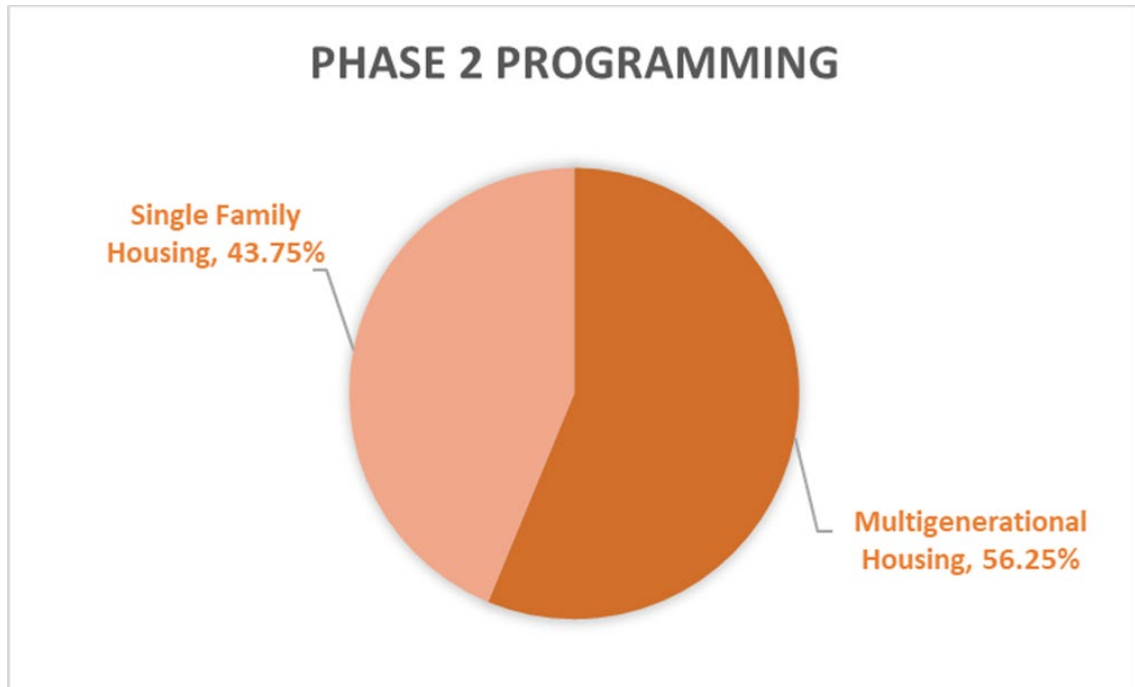*Table 21: Phase 1 Programming*

(Source: Author's Work)

Table 22: Phase 2 Programming

(Source: Author's Work)

After combining the ideas of site approach and the new programmatic

elements, figure 23 below shows the new site proposal. With the flood plain causing

issue to the existing community, the idea of the new site will be to place the new

infrastructure on the top of a hill and terrace down towards the water (see figures 24,

25, 26, 27, and 28 for views of the terracing). As mentioned in the previous

paragraph, the community buildings would be built first to allow for places of refuge.

In which case, the community buildings would be placed on the top of the hill and the

residential buildings would terrace down from them. This also creates a sense of scale

and promotes the community buildings from afar.

Figure 23: New Site Plan
(Source: Author's Work)

Figure 24: View of Terracing
(Source: Author's Work)

Figure 25: Aerial View of Site
(Source: Author's Work)

Figure 26: Connection Back to Ferry
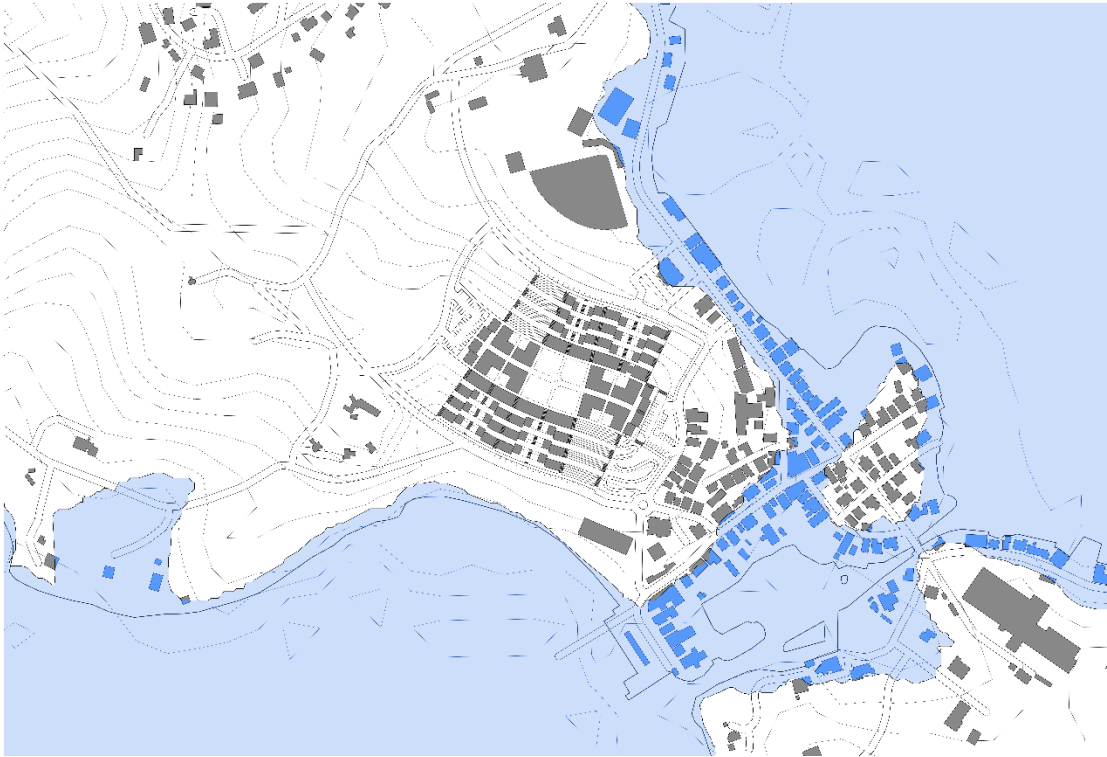*(Source: Author's Work)*

Figure 27: Typical Site Block
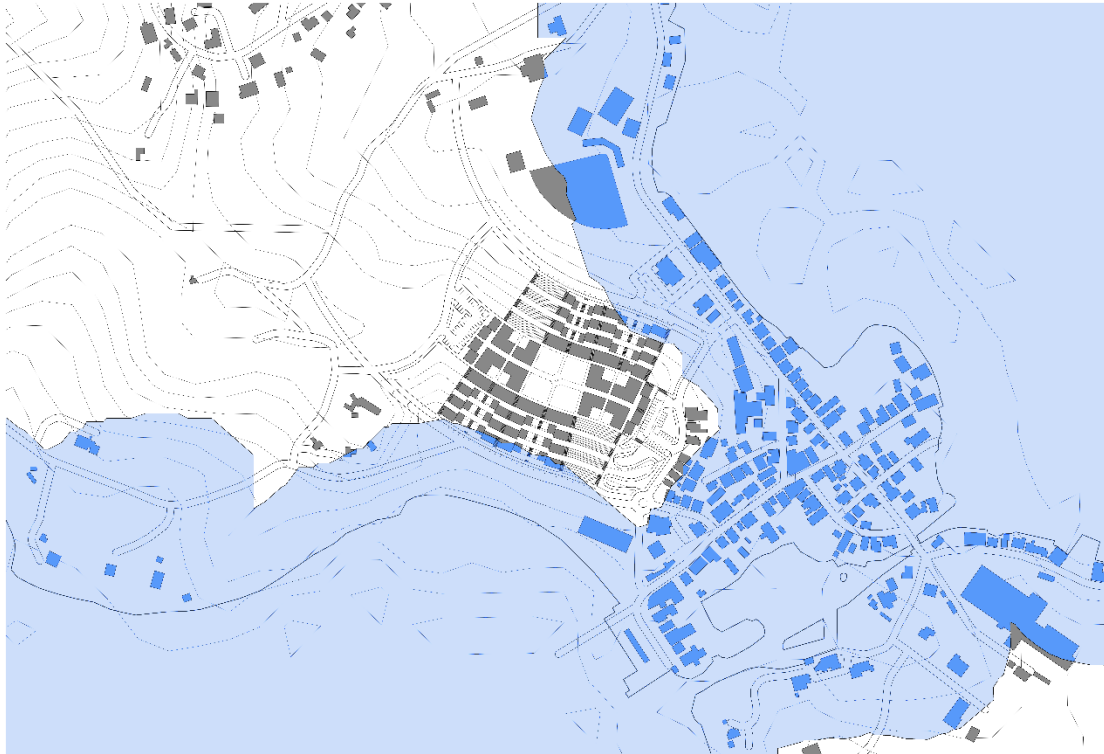*(Source: Author's Work)*

Figure 28: Typical Site Section
(Source: Author's Work)

Looking at the new site plan and relating it back to the site analysis, it remains as walkable and as central to the existing communities while also providing the people with an area in which they can relocate to once the buildings in the existing site get covered by water. Figures 29 and 30 show the new site in comparison to the flood plains. As shown, the site will be unaffected by the 100-year flood plain but will be minorly impacted with the estimated 200-year flood plain. When the 200-year

flood plain begins to affect the site, it can be assumed that new infrastructure would

have already been put into place.

Figure 29: New Site in Comparison to 100-year Flood Plain
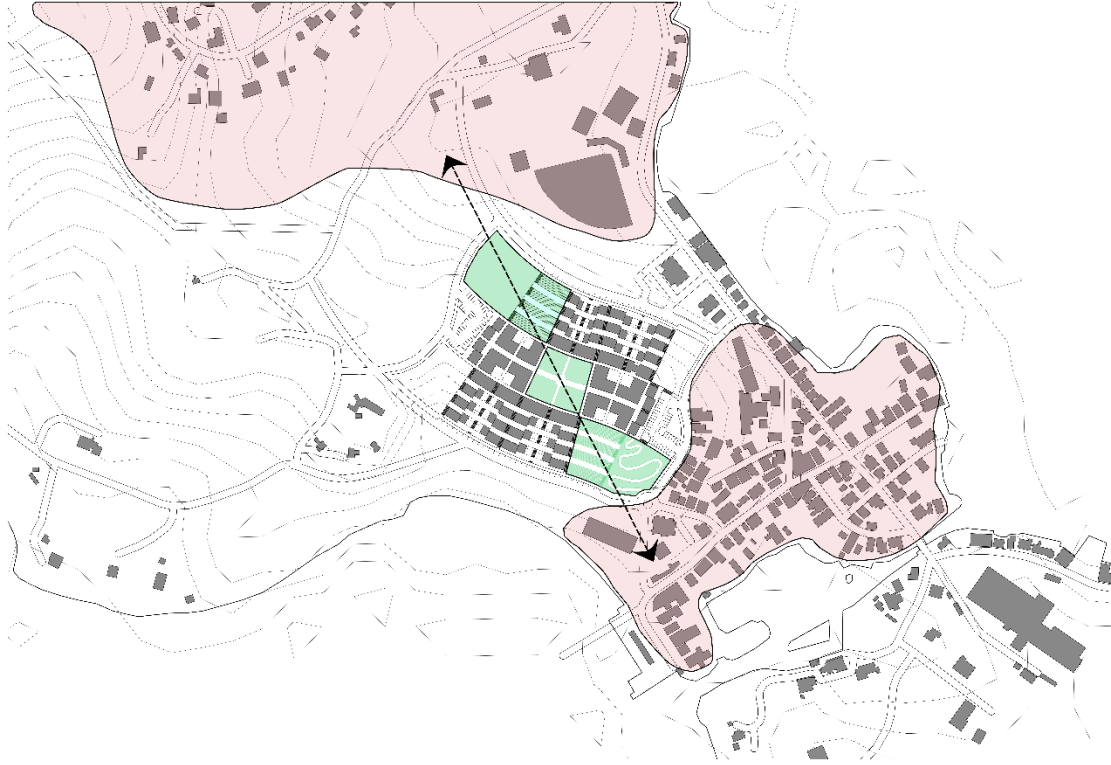*(Source: Author's Work)*

Figure 30: New Site in Comparison to 200-year Flood Plain
(Source: Author's Work)

Additionally, the new site connects to the existing sites in the north and south by using green spaces, Figure 31 below shows a simple diagram showing the connection. Within these green spaces are various stormwater management and renewable energy systems (figure 32 shows areas in which these systems lay). These systems include water collection cisterns, a solar farm, and constructed wetlands. The importance of these systems is to essentially provide the site with net zero energy and reusable potable water and grey water. This is also important because the islanders don't have access to freshwater resources and instead have to use the ocean water (salt-water) within their homes and businesses. To further analyze each system, it would be imperative to see what each system can provide.
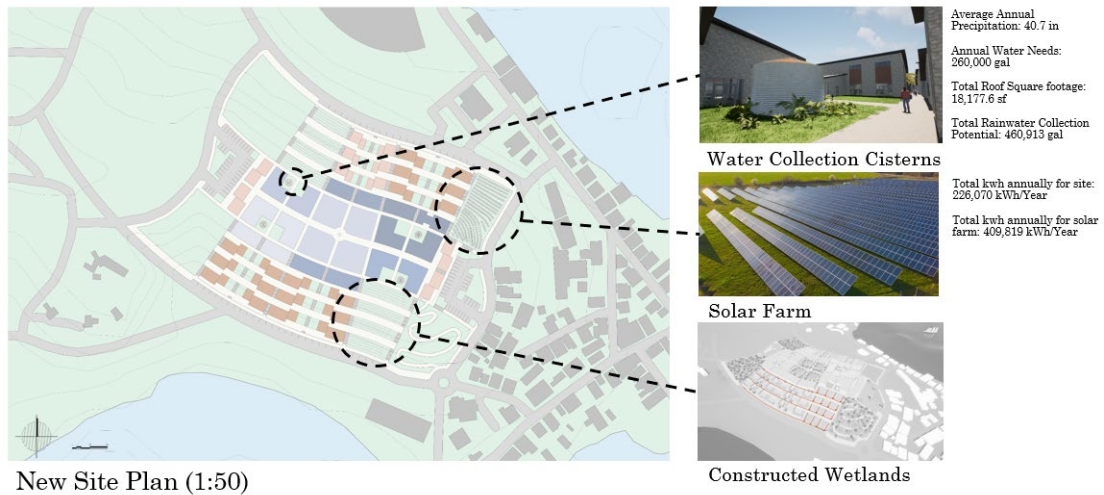
Starting with the cisterns and constructed wetlands, both of these systems are being proposed to collect rainwater and reuse it on site. As mentioned in previous sections, the site has an average annual precipitation of 40.7 inches. Using the community building as example, the annual water needs for this building is 260,000 gallons. With a total roof square footage of 18,177.6 sf, the total rainwater that can be collected annually is 460,913 gallons. That's almost double the size of what is needed, and this is just for one building. This data set goes to show that each building can be provided with the appropriate amount of grey water during natural disasters. As it sits, the plan is to provide the community buildings with cisterns and the terraced buildings with a constructed wetland.

The solar farm, while not entirely accurate to the site topography, can be used to provide the site with renewable energy. Using one corner of the site as a solar farm, it can produce an estimated 409,819 kWh/Year. In comparison, the new site uses roughly 226,070 kWh/year. This means that the site can go net zero while also providing existing buildings with green energy.

The last and main green space of the site is found at the center of the connection (see figure 33 for an image of the space). This space, while designed to be recreational, is a space that all community buildings are connected to. This allows for community connection within the newly designed community buildings.

Figure 31: Green Space Community Connection
(Source: Author's Work)

Average Annual
Precipitation: 40.7 in

Annual Water Needs:
260,000 gal

Total Roof Square footage:
18,177.6 sf

Total Rainwater Collection
Potential: 460,913 gal

Water Collection Cisterns

Total kwh annually for site:
226,070 kWh/Year

Total kwh annually for solar
farm: 409,819 kWh/Year

Solar Farm

Constructed Wetlands

New Site Plan (1:50)

Figure 32: Stormwater Management and Renewable Energy
(Source: Author's Work)

Figure 33: Public Green Space
(Source: Author's Work)

Moving deeper into the design proposal, not all programmatic elements could

be designed for. However, the building that was examined and designed was the

community center building. The reason of this building's selection was because it

encompasses the imposed idea of community engagement while also creating a study

for what the community buildings could be. Starting off, the community center had

specific program that was broken up into 4 components. These components were the

office spaces, the meeting spaces, the multi-functional spaces, and the auditorium. To

allow for natural light, daylight, and a better sense of scale regarding the existing

conditions, the building was segmented into four buildings (see figure 34 below for

floor plans of the building). Each of these components are spaces that provide

community engagement, which is what the people of Puerto Rico requested in the

survey. The meeting space (figure 35) provides an area of conversation between

professionals and community members. The office (figure 36) is the backbone of the

community. Whatever the community needs, the people there provide those needs.

The multifunctional space (figure 37) and the auditorium are both spaces in which

provide an events space to gather community members. This is crucial because

deeper community relationships and more education will give the people a better

understanding on how to handle a natural disaster both alone and together as one.

Figure 34: Community Center Ground Floor Plan
(Source: Author's Work)

Figure 35: Meeting Space
(Source: Author's Work)

Figure 36: Office Space
(Source: Author's Work)

Figure 37: Multi-functional Space
(Source: Author's Work)

Relating back to the survey taken, the materiality of the building is comprised

of reused material due to the site's scarce resources. Figure 38 showcases the

materials and structural components within the building. Each community building

will use Cement Block for the exterior walls with the addition of brick to highlight

areas of public space. The main structure of the building will be reinforced concrete

columns and beams with a wooden truss. Figure 39 shows how the concrete column

would be embedded into the walls of the building. Because natural disasters cause

buildings to structurally fail in the foundation, and roof systems, a tie-down strap will

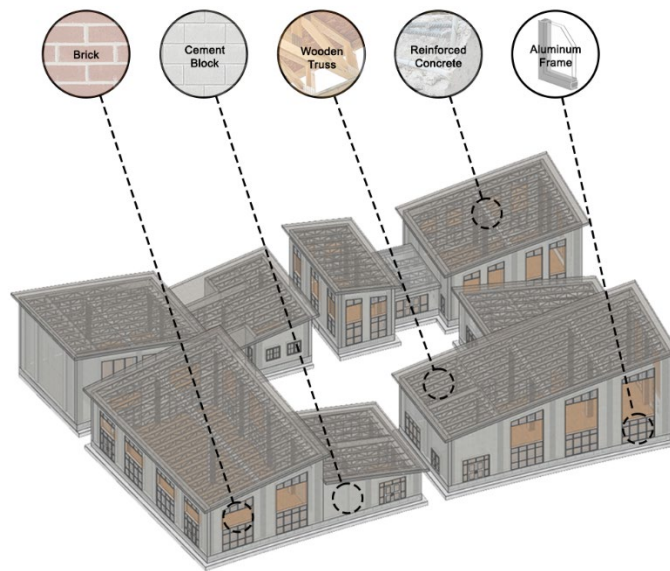be included in the foundation and roof systems (see figures 40 and 41 for wall

details).

Figure 38: Materiality Diagram
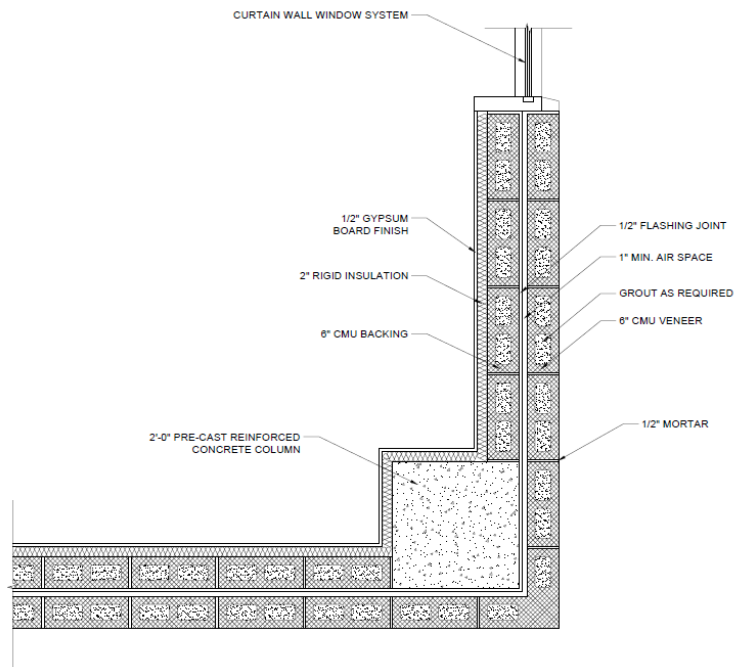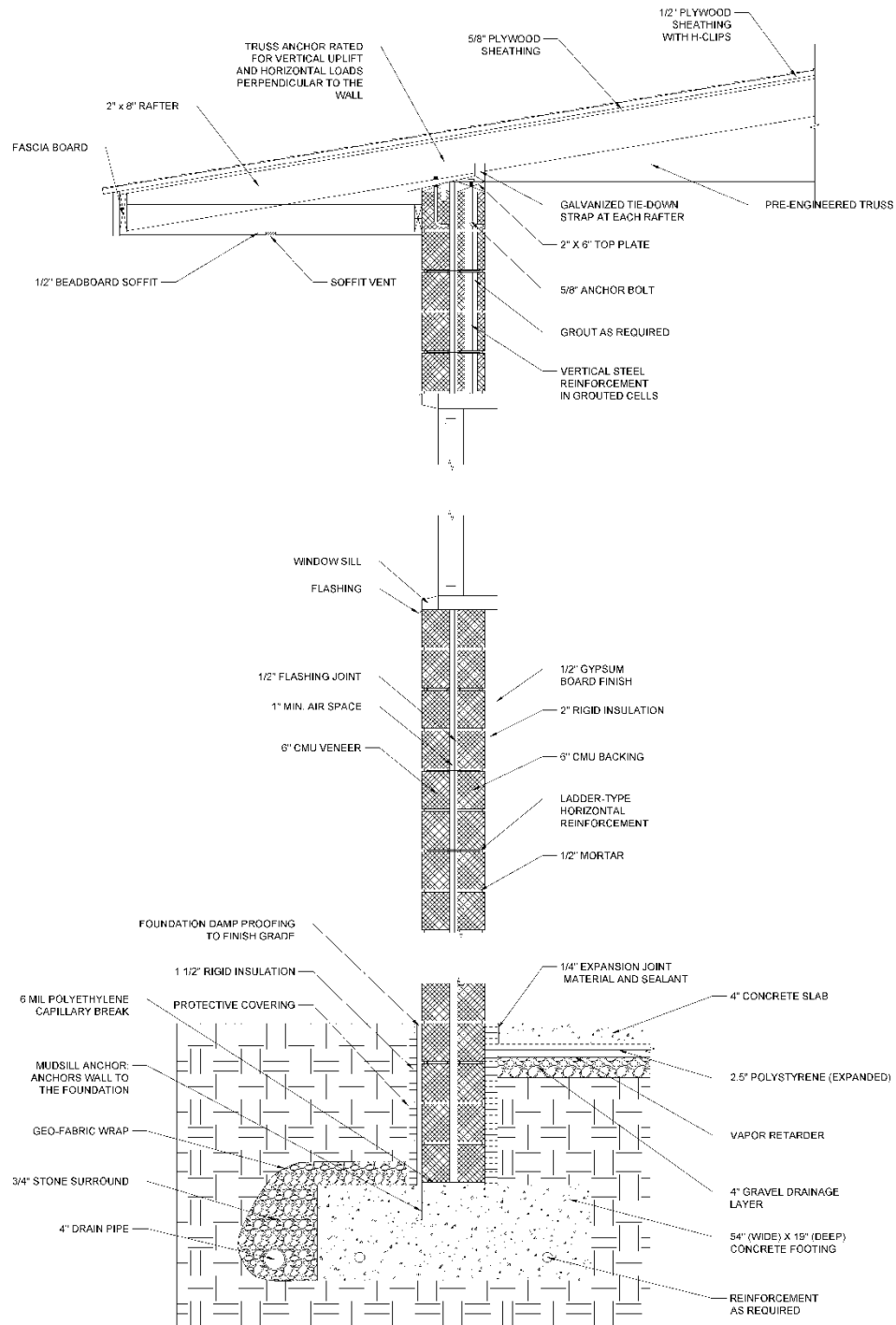*(Source: Author's Work)*

Figure 39: Plan Detail
(Source: Author's Work)

Figure 40: Wall Section Detail 01
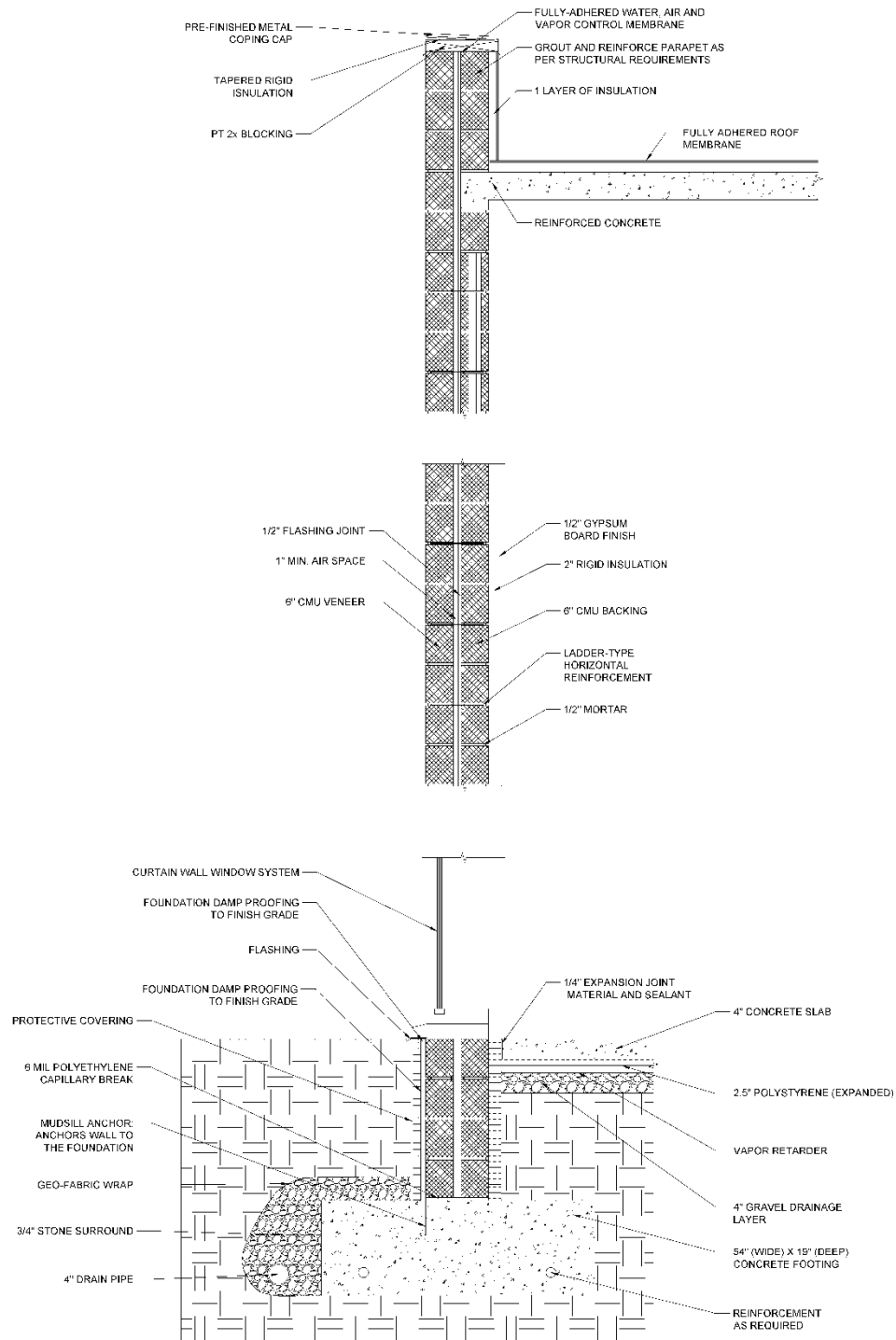*(Source: Author's Work)*

100

Figure 41: Wall Section Detail 02
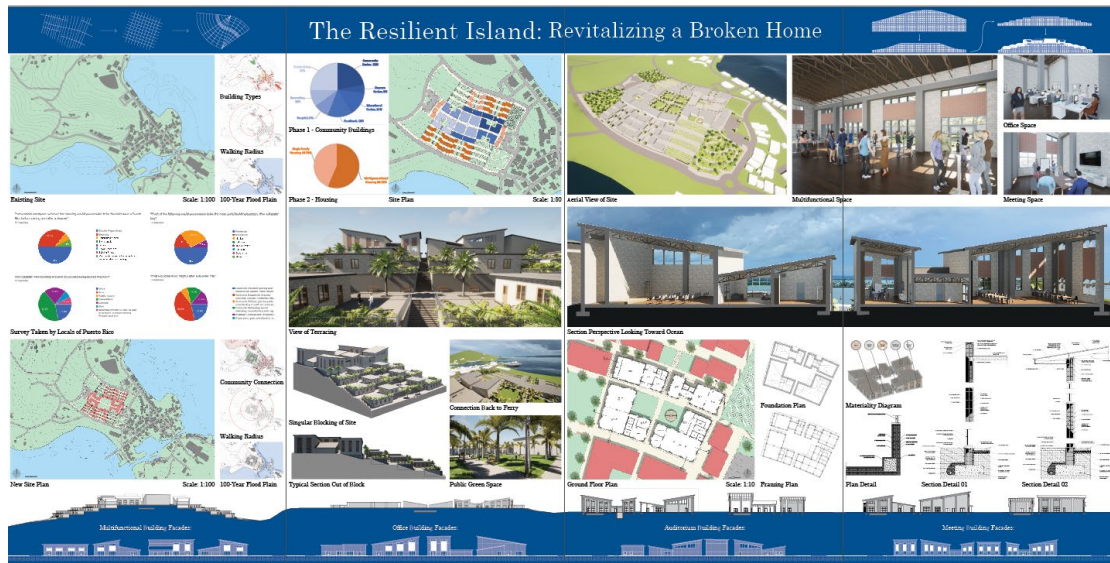*(Source: Author's Work)*

Looking at the building as a whole and comparing the ideas of resiliency to the design, there are clear moves that speak to resiliency (see figure 42 that shows all aspects of resiliency covered). The first is the social resilience. Using the programmatic spaces to define community engagement speaks strongly to a community's resilience. The second is the structural resilience which is easily seen with the details of the structure (from foundation to roof). The last one is the ecological resilience which are the systems that are in play. This is what makes the site and the design proposal an appropriate solution to natural disaster and how a community in Puerto Rico can thrive from this.

Figure 42: Building Section Perspective
(Source: Author's Work)

Site and Building Proposal Provided in Presentation Boards

The figure shown below provides a clear overall proposal of the new infrastructure, site, and building. Most of the images on these figures can be found in greater detail in the figures above.

Figure 42: Overall Design Proposal
(Source: Author's Work)

Chapter 8: Conclusion

Community resiliency can often be a difficult task without the proper support. The devastation that happened in Puerto Rico back in 2017 shows that disaster can strike when a community is most vulnerable. This thesis will provide the public with knowledge on how to take action and address those communities that are in dire need of assistance. By focusing on addressing community resiliency within a Caribbean Island, Culebra will serve as a model for disaster recovery in the future. Although this can't be entirely replicated to other communities in need, it can serve as an example on how to best address environmental impacts.

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